Bit Bang

Rays to the Future

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Foreword

Bit Bang – Rays to the Future is a post-graduate cross-disciplinary course on the broad long-term impacts of information and communications technologies on lifestyles, society and businesses. It includes 22 students selected from three units making the upcoming Aalto University: Helsinki University of Technology (TKK), Helsinki School of Economics (HSE) and University of Art and Design Helsinki (UIAH).

Bit Bang is a part of the MIDE (Multidisciplinary Institute of Digitalisation and Energy) research program, which the Helsinki University of Technology has started as part of its 100 years celebration of university level education and research. Professor Yrjö Neuvo, MIDE program leader, Nokia's former Chief Technology Officer, is the force behind this course.

During the 2008–2009 semester the students in Bit Bang produced roadmaps describing the development and impacts of digitalisation. During the fall semester the course focused on four interesting technology trends until 2025: processors and memories, telecommunication and networks, printable electronics, and carbon nanostructures.

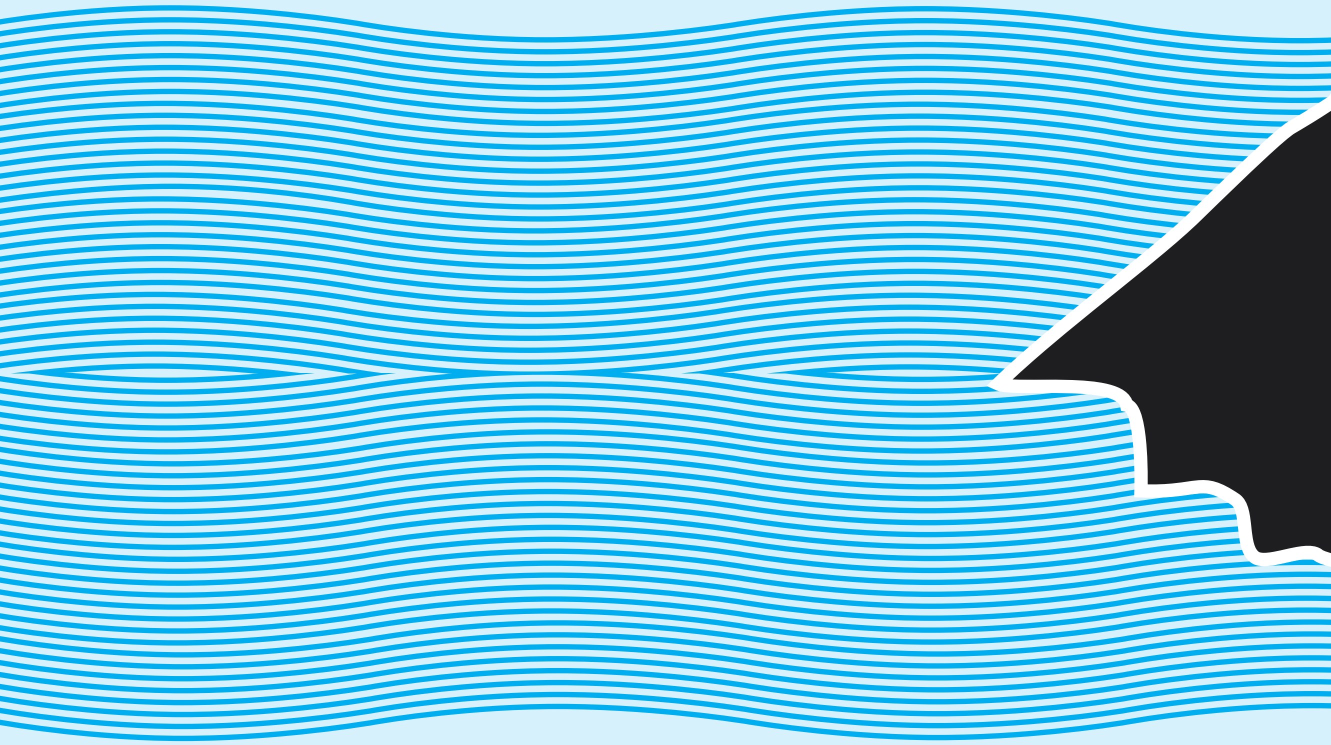
The course started with introductory lectures on the fundamentals of computing and communication by professor David Messerschmitt from UC Berkeley. The textbook for the fall semester (Wireless Foresight – Scenarios of the Mobile World in 2015) provided the systematic tools for scenario building. The Bit Bang course had a number of guest lecturers presenting a variety of topics, from the development of Nokia's first smart phone the Communicator to a discussion on the meaning of robots in the future as a part of everyday life. The fall semester gave the students a broad background and tools to foster a better understanding of the speed and impact of technological development.

The spring semester focused on the impacts of technology trends on a broader scale, in the society and in people's lifestyles as well as in business. The spring topics were globalisation, the future of living, the future of media and intelligent machines. In addition to the lectures, textbooks and group works, the Bit Bang group made a study tour to the UCB and Stanford Universities and a number of high-technology companies in Silicon Valley.

Passing the Bit Bang course required active attendance to the lectures and seminars as well as writing this joint publication based on the fall and spring group works. The texts have been written by doctoral students and are presenting their views. We do not take responsibility about the contents. The book is published in co-operation with Sitra, the Finnish Innovation Fund. We want to give our special thanks to Annika Artimo for her devotion and hands on support from the beginning to the very end of this ambitious project.

We warmly wish you all to have nice and eye opening moments with this book!

Yrjö Neuvo ***Sami Ylönen***



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Bit Bang

1.1 The Digital Evolution – From Impossible to Spectacular

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1 *The Information Technology Revolution*

Over the past 60 years information technology has become an integral part of our world. Computers have changed from being a rarity to a commodity. Our daily life is so influenced by information technology that it has become almost impossible to imagine a world without it. The speed with which this transition has taken place is hard to comprehend. But still the development is accelerating. And it is quite likely that the changes that lie ahead are going to be much bigger than anything seen so far. In order to understand the magnitude of the transition we are witnessing it is helpful to look back – way back.

1.1 A Brief History of Information Technology

In the beginning the earth was empty and void. But around 4 billion years ago there was a sudden decrease of entropy and life emerged. From a combination of proteins and nucleic acids self-replicating biological systems evolved. These organisms diversified and grew in numbers. They developed sensors to probe their environment and nervous systems to make sense of these inputs. Organisms grew more complex and so did their brains. Information could not only be found in their bodies but was also increasingly present in their behavior. Animals living in groups learn from observation or by communicating with each other. Over the millennia of years species were created and species went extinct but, the amount of information on earth slowly grew. Then something remarkable happened around 40,000 years ago: man developed language, a much more sophisticated version of communication. Language is essentially an information compression technique that allows sharing large amounts of knowledge between individuals and makes it possible for the shared information to survive its host. Nevertheless information was still bound to biological systems.

About 5,000 years ago the invention of writing changed the rules of the game dramatically. The abstraction of language into writing, with its digital nature and information compression capability, made it possible to store large amounts of information outside the human brain.[1] This made information something that is not bound to a certain person, geographic location, or specific time. Nevertheless, the process was in the beginning cumbersome, expensive, and error prone. Clay tablets with cuneiform writing were easily dropped and broken, moving an obelisk needed hundreds of slaves, papyrus libraries burned down, and short sighted monks did not copy manuscripts reliably. Only when Gutenberg invented the printing press in the year 1439, did things begin to speed up. The amount of stored knowledge started to increase dramatically. Mass reproduction made it cheaper to spread knowledge and created redundancy against information loss. Still reading had to be done by people.

At the same time, machines were aiding human labor in various other parts of life. Water and steam replaced animal and human muscle power. It only took a while until people found out how to use mechanical device, to create clocks and simple calculators. Over the years these concepts were refined. Mechanically readable storage systems were constructed. They could save numbers or be used to play music. With the development of electricity and electronics new concepts were tried. Meanwhile there was also great progress on the theory side. At the beginning of the 20th century it could be shown that certain types of machines are universal problem solvers. In 1943 Konrad Zuse[2] built the first of these computers. Although it was not too obvious in these first simple machines, suddenly information was completely free of the biological bottleneck. This ability to use machines to create, process, store, and transmit information much faster and more reliably than humans marks the beginning of the digital revolution; the Bit Bang.

1.2 The Digital Revolution

Since the 1940s this digital revolution has brought a plethora of changes. Individuals, lives have been transformed, industries and economies created and destroyed, and societies have been struggling to keep pace. But the item that changed the most was the computer itself. Their technology core developed from early relays, to vacuum

1 Arguably rock paintings or monuments had already been used to convey information for a much longer time. However, they were not a very efficient means of preserving larger amounts of information.

2 Jürgen Alex, Hermann Flessner, Wilhelm Mons, Horst Zuse: Konrad Zuse: Der Vater des Computers. Parzeller, Fulda 2000, ISBN 3-7900-0317-4

tubes, to transistors, to integrated circuits. They were shrunk from building filling machines to gadgets that fit in a pocket. Meanwhile their power increased thousands of times. Processing that was once only available to governments, operated by highly trained specialists, can now be found in children's toys. Computers have become abundant - a commodity.

How could all this happen so quickly? Why did this digital revolution change our society so fast in only 60 years? The simple answer is exponential growth. Moore's law describes the core property of this development. It states the trend that the number of transistors that can be placed inexpensively on a chip doubles roughly every two years.[3] So far exponential growth like this has been a characteristic only of biological systems. Even though there has also been exponential growth in technology in the past it has always been either a short-term effect or was linked to the population growth. In contrast, the growth we are witnessing in information technology has outpaced any other development.

The earlier detour into information history points out two reasons why the development since the 1950s has been so fast. The obvious reason is the removal of the biological bottleneck. Computers can process most kinds of information almost infinitely faster than humans. They are much more precise and less likely to forget. They are not limited by a short attention span nor do they need breaks for food and sleep. They are also much more efficient in sharing information among each other. Their total storage capacity will soon surpass the combined memory of all humans that ever lived. And while humans need to spend years to acquire knowledge, things that are known to one computer can be "taught" to any other computer in an instant. The second, more implicit reason is the feedback mechanism of the development. It accelerates progress since a new invention can benefit from all previous inventions. This also means an invention cannot be looked at as an isolated event. It benefits from its surrounding and it acts back on its surrounding. This happens in a biological ecosystem, but also in technology, only much faster. Developments in one field can suddenly be used to improve progress in another field. Faster machines help to design and build even faster machines.

1.3 Information Technology in 2025

The exponential nature of the digital revolution makes it hard to predict the future. It simply seems not to be an intuitive concept for our brains to grasp. However, there is one thing we know for sure about exponential growth: it is unsustainable. In a finite universe with finite resources exponential growth is bound to reach resource limits rather sooner than later. The question thus is not "will Moore's law continue" but

3 Almost all other properties of digital electronics have been observed to follow similar laws. Most notably the decline in storage cost per unit of information has sped up several times during the past decades. Currently the amount of non-volatile memory that can be purchased at a given cost doubles every 12 months.

rather "when will it stop". This is as hard a question to answer. It turns out that we cannot look at isolated topics like miniaturization but instead have to take a holistic approach. If it was only about miniaturization it would be easy to extrapolate when it would, continuing with the current pace, reach the quantum limit. But there are other ways, new technologies and architectures, for increasing computing power or storage capacity. This means we need to look at the whole ecosystem that has been created and which has fostered the development so far. We need to extract the driving forces that the different players in the ecosystem exert on each other. While technology is the enabler of the digital revolution it is these driving forces that have been pushing the development.

The world today is not homogenous and we do not believe that the world will be in 2025. There will be the experimental and high tech world that governments, the military, corporations, and scientist will have access to. There will be a technology main stream that middle class people in the developed world are experiencing every day. And there will be life in areas where the technological development has been slower for the masses but where stark contrasts between the technological have and have-nots exist. In order to account for this diversity we will not present a single vision of the future. Instead we will show how we use the driving forces to identify core technologies that will define our life in the year 2025. These key technologies are then highlighted in visions of everyday life located in the three different scenarios. There is another way to look at the scenarios: slower or faster growth, Moore's law continuing, slowing down, or speeding up.

The chapter is organized as follows. We present the state of the art in processor and memory technology in the context of its historic development over the past 60 years. Then we take an in-depth look on the driving forces that have governed this process and discuss their influence on the future development. After that we present six core technologies that we believe will shape the world in 2025. Short stories describing these technologies in everyday situations will conclude the chapter.

2 State of the Art

Before stepping in the future it is worthwhile to look back at the history and the current state of the art in memory and processors. This will give the reader a perspective to look into the future; when one sees the almost miraculous advancement in processors and memories in the past it might be easier to accept the future we are painting in this chapter.

2.1 Processor

The processor, or Central Processing Unit (CPU) in most conditions, is the brain of the computer. It reads instructions from the software and tells the computer what to do and how to do it. Accelerated by the fast development of semiconductor industry and popularization of the highly integrated circuit (IC), processing speed has seen an exponential growth during the late 20th and early 21st centuries. Both the miniaturization and standardization of CPUs have brought great changes to people's everyday life. Modern processors, often known as microprocessors, can be found in nearly every electronic device from automobiles to cell phones to children's toys.

Since the term "CPU" (Weik, 1961a) is generally defined as a software (computer program) execution device, the earliest devices that could rightly be called CPUs came with the advent of the stored-program computer. Konrad Zuse's Z3 (Zuse, 1993) was the world's first working programmable, fully automatic computing machine. It was completed in 1941. The purpose was to perform statistical analysis of wing flutter in aircraft design for the Nazi government's German Aircraft Research Institute. After the war, von Neumann presented his vacuum tube based computer ENIAC (Weik, 1961b), which stands for Electronic Numerical Integrator And Computer. It was a stored-program computer completed in 1946, but usually considered as the first general-purpose computer electronic computer. It was designed to perform a certain number of instructions (or operations) of various types. These instructions could be combined to create useful programs, which could be stored in high-speed computer memory. Therefore the program, or software, that ENIAC ran could be changed simply by changing the contents of the computer's memory. Being digital devices, all CPUs need to deal with discrete states and therefore require some kind of switching elements to differentiate between and change these states. Before the commercial acceptance of the transistor, electrical relays (Magie, 1931) and vacuum tubes (Spangenberg, 1948) were commonly used as switching elements. However, both of them suffered unreliable problems for various reasons. For example, the electrical relays require additional hardware to cope with contact bounce, which causes the misinterpretation of on-off pulses in some analogue and logic circuits. While vacuum tubes do not suffer from contact bounce, they must heat up before becoming fully operational and eventually stop functioning altogether. The clock rate of these relay-based and tube-based CPUs ranged from 100 KHz to 4 MHz at this time, largely limited by the speed of the switching devices they were built with.

During the 1950s and 1960s, the transistor (Lilienfeld, 1925) was introduced to improve CPU design by replacing the electrical relays and vacuum tubes. Moreover, the integrated circuit allowed a large number of transistors to be manufactured on a single semiconductor-based die, or "chip." Aside from facilitating increased reliability and lower power consumption, transistors also allowed CPUs to operate at much higher speeds because of the short switching time of a transistor in comparison to a relay or tube. CPU clock rates in the tens of megahertz were obtained during this period. One representative at this time was System/360 computer architecture introduced by IBM in 1964.

The introduction of the microprocessor (Osborne, 1980) in the 1970s significantly affected the design and implementation of CPUs. A microprocessor generally means a CPU on a single silicon chip, which costs much less than traditional general-purpose CPUs. Since the introduction of the first microprocessor Intel 4004 in 1971 (Faggin et al, 1996), this class of CPUs has almost completely overtaken all other central processing unit implementation methods. Mainframe and minicomputer manufacturers of the time launched proprietary IC development programs to upgrade their older computer architectures, and eventually produced instruction set microprocessors that were backward compatible with their older hardware and software. Combined with the advent and eventual vast success of the now ubiquitous personal computer, the term "CPU" is now applied almost exclusively to microprocessors. Actually one can find it in almost any modern electronic devices such as cell phones and PDAs etc.

Today, multiprocessing gains in popularity. Multiprocessing is the use of two or more central processing units (CPUs) within a single computer system (Alienware). The term also refers to the ability of a system to support more than one processor and/or the ability to allocate tasks between them. One example is Intel's multi-core processor (Alienware).

Systems that treat all CPUs equally are called symmetric multiprocessing (SMP) systems. SMP involves a multiprocessor computer-architecture where two or more identical processors can connect to a single shared main memory. SMP is commonly used in the modern computing world, and when people refer to "multi core" or "multi processing" they are most commonly referring to SMP. In case of multi-core processors, the SMP architecture applies to the cores, treating them as separate processors.

Compared to SMP, an asymmetric multiprocessing (ASMP) system assigns certain tasks only to certain processors. In particular, only one processor may be responsible for fielding all of the interrupts in the system or perhaps even performing all of the Input/Output (I/O) in the system. This makes the design of the I/O system much simpler, although it tends to limit the ultimate performance of the system. Graphics cards, physics cards and cryptographic accelerators, which are subordinate to a CPU in modern computers, can be considered a form of asymmetric multiprocessing.

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2.2 Memory

Basically there are two categories of memory of devices: volatile and persistent (Stallings, 2006). Volatile memory is comparable to the short-term memory of the human brain. Volatile memory can store a small amount of information for immediate processing. When processing ends or power is switched off, volatile memory will lose its data. Persistent memory is for storing data for longer period of time that needs to be retained when a device is powered off. With current technology volatile memory is extremely fast and small compared to persistent memory.

When a computer is processing data, it has to be kept in a memory that is almost as fast as the processor. However, increasing the size or the speed also increases the price of the memory. This is the main reason for having only a rather small but very fast memory nearby the processor while bigger and the slower memory is used for storing the results of computations.

Computers have several types of memory. In volatile category they can be listed from the fastest to lowest (see the manufacturers' websites, Intel, 2008; Nokia, 2008):

- Registers are the fastest memory inside computer. Registers are located inside the processor for storing only about hundred integers. Reading and writing take less than one tenth of a nanosecond.
- Processor caches, between the main memory and the processor, are sized less than 2 megabytes. The speed of reading and writing ranges from one to fifteen nanoseconds.
- Main memory in computers, working memory of a computer, normal sizes ranges from 1–8 gigabytes and the access time is about 100 ns.

Persistent memory is for storing data for a longer period of time, for example, all the files in a computer, such as contact information in mobile phones and music in portable music players. Hard disks have been the main non-volatile storage for computers in past decades and flash memory for most portable devices. The differences between hard disks and flash memory are that hard disks are cheaper and can contain more data, yet they have moving parts and thus are more fragile. However, flash memory size is growing while the price is dropping. In the near future it might replace hard disks as the default non-volatile memory.

There are also other types of non-volatile memory for storing data for a long period of time. They are needed, for example, when companies have to make backups of all their information. The price to store such a large amount of data to hard disks might be too great. Therefore magnetic tapes are used for storing memory that does not need to be accessed often but which needs to be kept safe.

Yet another important category of persistent memory consists of CD-, DVD- and Blue-ray-discs. The main reason for these types of memory is the easy and cheap distribution of the media. It has been the easiest and cheapest way to distribute music and software on CDs in the last decade. DVD and Blue-ray are used for movies and software. Yet there is already an ongoing process to distribute all the content through the Internet. (See more about this in the Section FUTURE INTERNET.)

IBM introduced the first hard disk in 1956 (IBM, 2005). The first hard disk had a capacity of 5 MB. After the first hard disk the size of the hard disks has grown exponentially as seen in figure. Moore's law is also applicable for memory capacity.

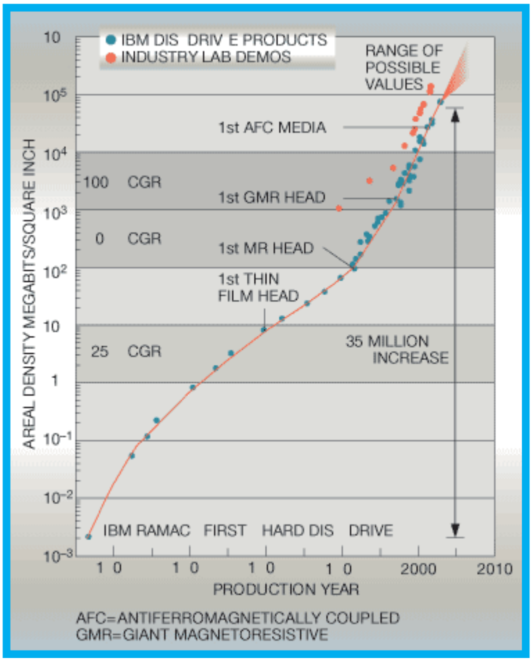

Figure 1. Hard disk drive areal density trend Image from IBM (Grochowski et al. 2005).

To grasp the average size of memory in 2008 we have listed here some common sizes of several types of memories. These memory types and sizes are common in the European market:

- Hard drives, 100GB–4TB, where 500GB is the most common in home computers.
- CD, DVD, Blueray, 640MB, 4GB, 25GB, and double with dual layer disks
- memory cards, flash, etc, 512MB–8GB

The important aspect of persistent memory size is the data that is stored in memory. The common file types and typical sizes of these files are:

- text document: 100kb–1MB
- pdfs: 1–10MB
- images: 50KB–10MB (from web images to raw digital photography)

- software: 50MB–5GB, browser might take 50 and office 5GB, games take typically 1–2GB
- videos: 700MB–20GB per film, 700MB with high encoding and 20GB with high definition blue ray movies
- music: 5MB–20MB per song, 5MB is typical mp3 and 20MB is typical lossless encoding
- The whole English Wikipedia is less than 1GB
- The capacity of a human being's functional memory is estimated to be 1.25 terabytes by futurist Raymond Kurzweil in The Singularity Is Near.

By comparing these two lists above one can see that it is easy to store a whole dictionary, music for weeks and every Hollywood-movie of the year in a single hard drive. And there are hard drives in computers, music players and even inside televisions.

At the same time with the processor and memory development there are also huge advances in sensor development. A sensor is a device that measures a physical quantity and converts it into a signal that can be read by an observer or by an instrument (Wikipedia, 6). Sensors are typically low-cost, low power, small devices equipped with limited sensing, data processing and communicating capabilities. Sensors are becoming smaller, cheaper, and more powerful, and they are used in many different types of equipment.[4]

The increase of sensors used in different products opens huge opportunities for a wide variety of applications. Sensors could be and already are embedded in to the vast part of our everyday products, like home equipment, cars, aircraft, medicines, manufactured products and robotics. Technological development will likely allow more and more sensors to be manufactured on a smaller scale as microsensors using MEMS (Microelectromechanical systems) technology. In most cases, a microsensor reaches a significantly higher speed and sensitivity compared to a macroscopic (measurable and observable by the naked eye) approach (Wikipedia, 6). In the future, sensors could be the key enabling technology in e.g. the field of health care, robotics and military applications.

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4 http://www.mdpi.com/journal/sensors/special_issues/wireless-sensor-technologies

3 *Driving Forces and Constraints*

There are a lot of factors affecting the development of computers including processors, memory and software. However, it seems that technology is not a limiting factor at least in the future: Computer technology will be developed to a level such that everything, which is really wanted, is possible to realize. Therefore the question will be: What we want to produce, and in whose interest would that be? In this chapter these factors are called driving forces and they have been divided into three parts, individual, industry and society. These are surrounded by harsh reality as presented in the Figure below.

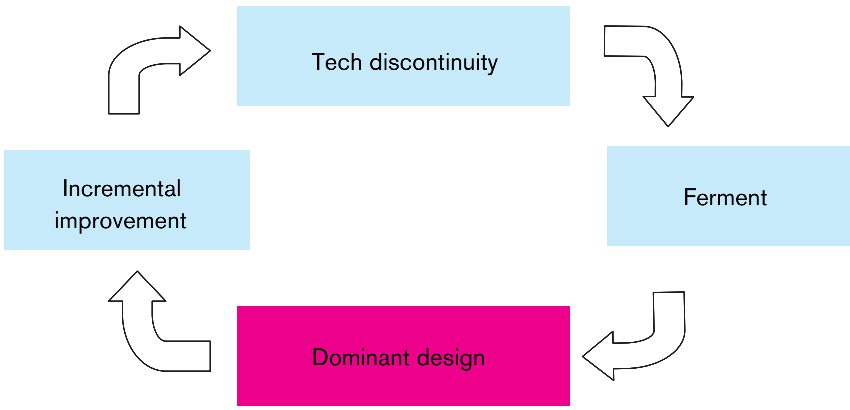

Figure 2. Driving Forces.

3.1 Individual

People are individuals who have their own will and needs. Even if some individuals have more power and their opinions and messages get more publicity, every person has the possibility to influence the development of markets with his or her behavior e.g. by selecting the products he or she is going to buy. Some individuals use their power, and many developments even in the computer industry were originally based on the inventions of particular individuals, such as Bill Gates, Linus Torvalds and Steve Jobs.

When considering the individual needs related to personal computers and their capacities, it is computer memory that has been the constraint for many applications in the past 40 years. However, it seems that there is a limit to the need for more memory. In the '90s, images, music and videos were the biggest files inside computers. It still seems that after ten years the video, image and music files are the things people use the most. Yet the size of those file formats have remained the same if not gotten smaller due to the better encoding.

This leaves us with the question of how much one can and needs to store in a personal computer. Typical sizes of documents have remained almost the same throughout the years; only the amount of documents has risen fast. Yet, one can store over 100 gigabytes in an iPod, a common portable music player of 2008. With this capacity the player can contain over 30,000 songs, 150 hours of video or 25,000 photos. For a music player the capacity is more than enough, when one song costs almost one euro from the official music shop, filling the device with legally purchased content this way seems to be impossible.

The same seems to be true also for personal computers. Common hard disk capacity is one terabyte, meaning that the disk can contain one thousand billion characters of data. The price of such a hard disk is about one day's salary for the average worker in Europe. In one terabyte it is possible to store 2,000 hours of good quality video encoded in MPEG4. Video is a good measurement for storing data; video seems to be the largest type of media people are storing. This means one can have 100 movies stored inside one's own computer. Therefore, capacity may not be the limit anymore.

Moore's law is applicable to memory as well. When considering that memory capacity grows exponentially, doubling every 18 months, memory would have over 2,000 times more capacity in 2025. What could one do with 2 petabytes of storage? It is really hard to imagine, when considering that the whole English wikipedia is less than 1 gigabyte and according to the famous futurologist Ray Kurzweil the human brain can store approximately 1.25 terabytes of data (Kurzweil, 2005).

Another interesting aspect when considering the needs of an individual user and the capacities of processors and memory are the user interfaces of technological devices and gadgets.

For today's technology it has been distinctive that the control mechanism in user interface design has usually been in the computer-to-user direction rather than a user-to-computer direction. The dialogues are typically one-sided with the bandwidth from the device to the user far greater than that from the user to device [2]. Today there are several principal types of output mechanisms from the user to the computer:

- Hand – discrete input (keyboards)
- Hand – continuous input (mouse, Wii-mote)
- Other body movements (foot, head position, eye movement)
- Voice (speech)
- Virtual reality inputs (magnetic tracker to sense a head position)

In the future, it is likely that the desktop computer we now know will be an artifact of the past. Future computers will be either larger or smaller than today's devices. If computers are smaller than today's devices, the development of different and more effective and sophisticated input mechanisms will be required. Also smaller size devices allow users to be engaged to other tasks simultaneously. That also causes different requirements to the user interface. The user interface must be unobtrusive and it must tolerate interference. At the same time, with miniaturization, the most effective computers may be getting bigger. In these computers the displays may be large, even wall size and the user can move around it and use different kinds of input means. On the other hand, the most powerful computers can be operated by cockpit, like the user interface where the user is actually inside the user interface. In virtual reality and computer games the user interfaces are becoming more like interacting with the real world. The input actions are more and more like they are in the real world. The user interfaces are trying to reduce the gap between the user's intentions and the actions needed to input them in to the device.

According to the Schneidermann [3] direct manipulation interfaces (where users input by pointing, grabbing, and moving objects in space) have enjoyed great success, particularly with new users. The reason for that is because they draw on analogies to existing human skills

Another totally different way of development of the user interface is a non command based dialogue, where the user does not issue a specific command, but the computer passively observes and monitors the user and provides appropriate responses. The user does not issue a specific command. This type of user interface will also have a significant effect on user interface software.

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3.2 Industry

Even if researchers, designers and other individuals do the actual development and manufacturing of new products, only the companies that have enough resources to connect individual experts together to manufacture the products will be able to sell them to the customers. Companies of the same branch form an industry. Today there are several big companies in the computer industry that are almost in an oligopoly situation in their markets. Examples of these companies are Intel, Microsoft, Nokia, Apple, Google and Yahoo. These companies have huge market power, which they can use to focus product development towards in the direction they want. They also have big influence on legislation and relationships between societies in many countries, because they work in a similar way as huge employees, tax payers, "knowledge warehouses" and product suppliers and because the companies are able to quite move smoothly to another country. Therefore politicians are tied to these companies in many countries, and industry can use this power by forcing societies to arrange an industrially friendly environment [1].

[1] http://en.wikipedia.org/wiki/Multinational_corporation#International_power

To be able to predict the future development of computers, we must know some basic theories related to innovations and product development. The rest of the industry chapter will focus on recent developments in the computers industry.

3.3 Theories of Innovation and Product Development

Product/Industry Life Cycle

As mentioned in the earlier chapters, exponential growth cannot continue forever. Moore's law will stop and the industry of silicon based single processor computers will mature. The whole IT industry is based on technological innovations and like other industries it is forming an S-shaped life cycle. The Product/industry life cycle model can help analyzing industry maturity stages.

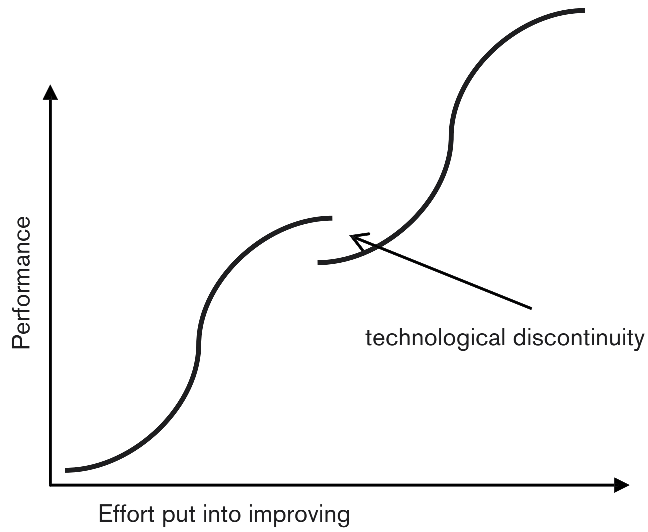

Figure 3. S-curves

Technological Discontinuities and Dominant Designs

In industry life cycles there are four stages: introduction, growth, maturity, and decline. For the S-curve to have practical significance there must be technological change coming. (One competitor is nearing its limits while others are exploring alternative techs with higher limits). The periods of change from one group of products or processes to another are called technological discontinuities. These technological discontinuities are rare, unpredictable innovations which advance a relevant tech frontier (moves forward the state of the art) by an order-of-magnitude and which involve fundamentally different product or process design (represents a new way of making something or new fundamental product architecture). One typical thing in technological discontinuities is that as these attacks are launched, they are often unnoticed by the market leader, hidden from view by conventional economic analysis.

After a technological discontinuity there is an era of ferment. The introduction of a radical advance increases variation in a product class. A revolutionary innovation is crude and experimental when introduced, but it ushers in an era of experimentation as organizations struggle to absorb (or destroy) the innovative tech. Two distinct selection processes characterize this era of ferment: competition between technical regimes and competition within the new technical regime. The era of ferment following a competence-destroying discontinuity that is longer than the era of ferment following a competence-enhancing discontinuity.

Eventually some technologies win and some lose. The winning technologies are called dominant designs. Dominant design may be embodied in a single product configuration, the system architecture of a family of products, or the process by which products or services are provided. In the case of mobile phones e.g. GSM technology was one of the dominant designs. During the competition small events may have a large impact on final outcomes in tech cycles– e.g. timing. In the tech market often exhibits extreme path dependency, enabling random or idiosyncratic events to have dramatic effects on tech success or failure.

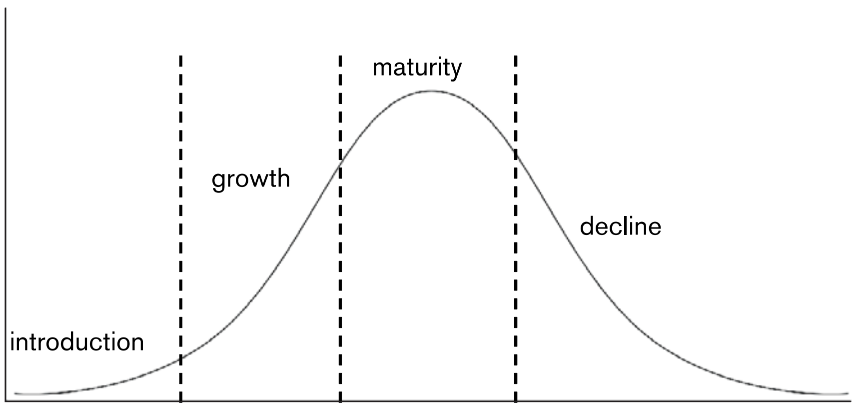

Figure 4. Cyclical model of technological change

One conclusion is that during technological discontinuities, attackers, rather than defenders, have the economic advantage. Although they often lack the scale associated with low costs, they also do not have the psychological and economic conflicts that slow, or prevent, them from capturing new opportunities.

3.4 The Disruptive and Sustaining Innovations

Another viewpoint in the development of technology and innovations is disruptive innovation theory. When an industry and technologies mature, the products and services get better and better. At the same time the performance customers can use also gets better. The existing products are improved on dimensions that customers value. Companies already in the market tend to concentrate on sustaining innovation, where they improve existing products using the asset they already have.

At this time the performance of the product or technology can become too good and hence overpriced relative to the value existing customers can use – the over estimation of consuming customers. In that kind of situation there is room for disruptive innovations.

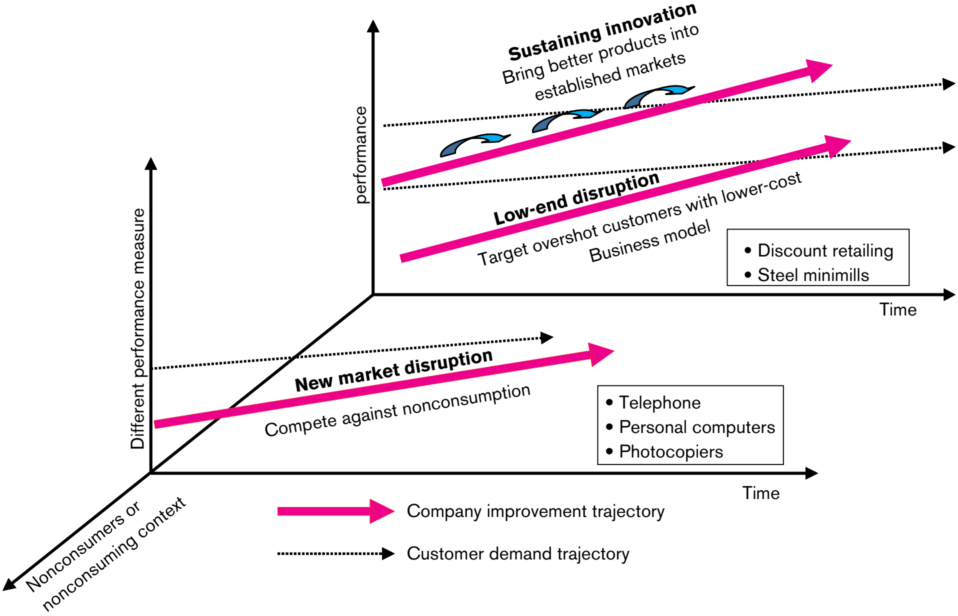

Figure 5. Different types of disruptive innovations

There are three types of innovations. First there are sustaining innovations which are improvements to existing products on dimensions historically valued by customers (faster computers, smaller cellular phones, etc.)

Then there are disruptive innovations that introduce a new value proposition. They either create new markets or reshape existing markets. Low-end disruptive innovations can occur when existing products or services are too good and hence overpriced relative to the value existing customers can use. A company can offer existing customers a low-priced, relatively straightforward product.

In the pc-market this is already happening. At the same time manufacturers are developing more and more powerful computers there are mini laptops. These small laptops are ideal to carry and battery life is rather long. On the other hand, their processors are not state of the art technology, but still, these minicomputers are good enough for web surfing.

The third type of innovation is new-market disruptive innovations. They can occur when characteristics of existing products limit the number of potential consumers or force consumption to take place in inconvenient, centralized settings. A company can make it easier for people to do something that historically required deep expertise or great wealth (Apple computer, Kodak camera, eBay, Sony transistor radio).

In the case of processors a disruptive innovation could be the use of the different kind of sensors such as RFID tags. Sensors can be used in some instances instead of computer. More of sensors and RFID tags are discussed in printable electronics chapter.

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3.5 Software and Operating System

The development of processors and memory has had several economic impacts. As the amount of memory is no longer the biggest constraint economically anymore, it has had the following impact: (i) more information is stored, and (ii) it is unattractive to use energy to package information for a smaller space. However, even if the cost of hardware is decreasing all the time, the cost of the software is not. Therefore in new technology investments, software development and other work has become the biggest cost factor for new technology adoption projects.

At the same time as new "super" processors and computers are developed, the prices of simple processors and memory have dropped to a tiny level. Therefore, for example, cars and apparel have had several processors for a long time. The decreasing prices offer more possibilities for attaching processors and memory in places, where they have not been used before. One possibility is that is almost every manufactured or sold product would have memory in a form of an RFID tag (For more see Printed Electronics chapter 1.3).

The introduction of the new technological solutions today is increasingly application-driven. From a systems viewpoint, in-house chip designs are replaced by system on chip (SOC) and system in package (SIP) designs incorporating building blocks from multiple sources. Examples of high-performance SOC designs include processors for mobile telephony and stationary high-end gaming (ITRS 2007).

However, the semiconductor industry is not the only platform on which processors and memory thrive, since the software industry contributes as well. One of the important drivers for buying increasingly powerful computing equipment has been that new versions of operating system and application software have typically demanded more processing power. Today processing power is increasingly determined by software that compiles computer programs into machine code rather than merely studying the characteristics of the chip itself. The MIPS ratings, or Million Instructions Per Second, for example, have become quite irrelevant for measuring processing power (see Ilkka Tuomi 2002).

Nevertheless, Moore's Law cannot surpass the ultimate limits. Gordon Moore stated in an interview that the law couldn't be sustained indefinitely: "It can't continue forever. The nature of exponentials is that you push them out and eventually disaster happens" and noted that transistors would eventually reach the limits of miniaturization at atomic levels"

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The game industry is about 10 billion dollars in the USA alone. 63% of the US population plays video games. One survey estimates that 72 percent of the European population plays video games. So video games are mainstream entertainment throughout the world. (see [1] and [2] for details)

Common knowledge is that games are the only software that really needs a faster processor; both for the computer CPU and graphics card GPU. Currently the most powerful machine one can buy from the market is actually PlayStation 3. Scientists are using the PS3 as supercomputers for research [3].

Therefore, it is obvious that if the people are buying new games, they need the hardware to play the games. A question arises: Why do the new games need faster processors (and actually games also need more and more memory, but volatile and non-volatile)? Old game programmers criticize the industry that they are just making better graphics and more real physics, but the concept of the games is the same as in the 80's. Anyhow, better graphics, physics, AI and other features need more processing power and memory, and there seems to be no end for this need.

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[2] http://arstechnica.com/news.ars/post/20071212-report-63-percent-of-us-population-now-plays-video-games.html

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3.6 Society

Even if industries and individuals do the actual development of products, the society is the environment, where the work is done. In addition to offering the basic requirements for the operation of companies by offering infrastructure, education for the potential work force, proper financial environment, security towards outside threats such as criminals, society also defines the direction of the behavior of companies by focusing financial support, by enacting laws and by defining the freedom of society in terms of media freedom and level of corruption. In a wider context society is a collection of individuals' ways of thinking which can be seen as an attitude towards selected companies and as a movements towards direction for more environmentally friendly behavior.

3.7 The Industry of Delay

So far it has been possible to predict the development of transistors and processors by Moore's law. The technological and scientific barriers to Moore's law have not yet become topical. However, the same cannot be said of the legal barriers to the technological development. "The industry of delay" [1] has not been able to adapt itself to technological changes. As examples of this one could mention frequent patent wars in the field of processors and memory or the polarized situation in the field of copyright between the content industry, device manufacturers and consumers.

Copyright law. The exponential growth in possibilities of processing and storing information has prepared the way for exponential growth in the use of copyrighted content. It seems to be impossible for a consumer to fill the devices by legal means. Enforcing copyrights in the evolving technological environment is challenging. It is clear that the gridlock of peer-to-peer copyrights will be solved in the near future. The solution is going to have wide impact on the content and device manufacturer ecosystem. Finally, it is a question of intellectual property related market power. One scenario could be that after heavy lobbing the content industry will be given the power to share the market and dictate the terms by which other industries are able to participate. However, the market is not shared merely between the content and device industry, but also the digital evolution has empowered the consumers as an active market actor who have their say in the game. Consumers in the digital environment are not simple users of copyrighted works, but they also are active players who generate content themselves. Traditional copyright association driven licensing models are not well suited for the digital revolution. Those lawyer driven models have faced competition in the form of Creative Commons[4], for instance. Creative Commons provides for authors, scientists, artists, and educators tools by which they can offer their works with less restrictive terms. Similarly, the Free Software Foundation[5] can be seen as a counterforce for the inflexible, restrictive licensing terms used in the software industry. In addition, Open Source Initiative[6], which is a more company driven organization, has been established to rise to the challenges faced by the digital revolution. In fact, those models use copyright to provide for openness and flexibility. Indeed, they can be seen as products of legal evolution.

Patent law. One of the leading ideas behind the patent system is to provide incentives for research and development (R&D). However, extensive patent thickets may cause inappropriate obstacles to innovation. Moreover, the spread of technology does not always work in the information technology field. The commitment to open standards is currently one of the trends in the software industry. At the same time companies make efforts to achieve strong technology and market power. Competition

4 http://creativecommons.org/
5 http://www.fsf.org/
6 http://www.opensource.org/

law is a way to tackle problems related to the side effects of patents. Nevertheless it is not always a very effective method to solve problems. The development of alternative dispute resolution mechanisms plays on important role in the future. The role of patents is also crucial in the geopolitical game [2]. "The power comes not just from bits, but from being able to do things with the bits" [3]. There is an ongoing debate on the global fairness of the patent system. The patent system has been alleged to serve only the benefits of developed countries at the expense of developing countries. It is clear that the developing vs. developed countries dichotomy has to be solved. Finally, it is, again, a question of power. This time geopolitical power, we will demonstrate later in the scenario part how future applications are used in high end, mainstream, and the third world. Radical patent related scenarios could be as follows, for example: processor and memory manufacturers stop R&D and concentrate on making money from existing patent portfolios, the evaluation of the value of a patent turns out to be impossible.

*Defects liability and data protection/privacy law*s. Moreover policies concerning defects liability and privacy laws have a direct impact on the development of processors, memory and different applications. The regulation of storage of information is an important question when it comes to virtual worlds. International harmonization measures are needed to secure the development of cross-border virtual worlds. Data protection rules might also influence the location of information storage and structure of applications (e.g. centralized or local memory?). Regulators also have to decide which kind of protection citizens need when it comes to sensors. It has to be decided whether it is possible to give up privacy rights in contracts or whether some kind of mandatory privacy rules should be enacted. A radical scenario related to defects liability and privacy law could be that class actions and liability issues would prevent the further development of memories and processors.

Finally, the industry of delay is most likely forced to commit on the legal status of robots. For example, following question might come up: What is the legal status of robots? Do they have human rights? Who is liable if a robot causes some harm - the developer, the owner or the robot itself? If a robot has a malfunction could it be regarded as on sick-leave (and get paid for that)? If a robot causes some harm to another robot, what happens? Is the situation somehow different if a robot causes some harm to a human? Is the relationship between a robot and a developer/owner similar to that of slave and dominus in Rome?

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[3] Abelson Hal, Ledeen Ken, Lewis Harry: Blown to Bits – Your Life, Liberty, and Happiness After the Digital Explosion

3.8 Economics

Computers have had three kind of effects on the economy growth: (1) Manufacturing equipment, (2) using equipment, and (3) reorganizing work by using computers [1].

In most developed countries the effect of using equipment is nowadays bigger than equipment manufacturing. In some countries with large telecommunications and electronics industries, such as in Finland, equipment manufacturing still has a bigger role than using equipment. However, the effect of reorganizing work by using computers is so tiny that it cannot yet be seen from statistics. Nevertheless, it is predicted that in the long run the telecommunication industry has same future as many other industries during the past decades. The factories are gradually moving to the countries with lower manufacturing cost. So the manufacturing does not bring growth for the economy of developed countries for very long. Reorganizing work by using computers has the greatest potential, just as the discovery of electricity made it possible to build assembly lines. However, it takes one to two generations to adopt new technology in a way that reorganizing work is possible [1].

Even if the development of computers and the Internet has introduced new business models and areas, the problem in this so called "new economy" is that it has concentrated on increasing the efficiency of the "old economy". E-traveling reservation systems, for example, have become a big business. They have totally changed the traveling agency business and decreased the size and profits of the traditional travel agency industry. Still this development has had a bigger influence on other industries such as the air traffic industry, which is suffering from decreased profits, when their customers search the cheapest flights from the Internet. Therefore the lack of new business models, which would bring totally new economic growth, has been introduced as an explanation for the slow development of economic growth generated by reorganizing work by using computers [2].

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3.9 Reality

We have seen that the driving forces behind the development of computers originate in the demands and needs of individuals, industry and society. However, these driving forces are governed and limited by fundamental realities. The causes for these boundaries are fundamental limits of physiology, ecology, and the basic laws of physics.

First of all, humans have physiological limits that are quite obvious: 2 hands, 2 eyes, 2 ears and so on. And even if medical science had developed rapidly by giving possibilities to return at least to some extent destroyed senses such as hearing and eyesight, humans have only a limited capacity to receive information. Even healthy eyes can distinguish only 20 pictures per second. Even if new computers offer new interfaces that use our less used senses or several senses together, our brains have limited ability to handle information, as the size of the human brains has not increased much for the past few hundred or thousand years.

Our globe also restricts development. There are only finite natural resources such as oil, metals, etc. Also the availability of energy is a constraint. And even if new power plants are built and new sources of energy found, global warming menaces living creatures.

The rapid development of processors and memory has also brought the problem of e-waste. As the price of the new electronic devices decreases rapidly, the devices are designed to be cheap and non-durable, leading to a short product life cycle. Only recently have different organizations have realized the problems of e-waste: The products have a variety of hazardous materials and a surprisingly large amount of the waste is transported to the poor countries, where some valuable metals are separated from the products. However most of the waste ends up in nature to harm the environment and human health. Recently many organizations such as Greenpeace have pointed out this problem and demanded more durable equipment [1, 2].

Power consumption becomes a more important issue in processor development and especially in utilization. Even if virtual databases seem to be more environmental friendly, because there is no need to print a document, even virtual information is stored somewhere and searches from databases also require energy.

The recycling of computers is also an important issue. One metric ton of electronic scrap from used computers contains more gold than can be extracted from 17 tons of gold ore [3]. Also, the re-use of computers becomes more and more attractive, because slightly used computers are, in many cases, still operative and increasing consciousness of e-waste problems may increase the costs of damaging the product. However, high-tech companies that require the latest computers do not want to give their slightly used computers to schools, because there are very advanced technologies required to retrieve deleted hard disk information; Thus, there is a risk that someone will later get the information remaining in the computer.

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Then there are laws of physics. The speed of the light poses an ultimate limit to size and clock rate of processors. Researchers have been able to build increasingly smaller transistors, but the size of atoms is probably the ultimate limit for the shrinking of components. Also charge quantization poses some limits, because the electricity current consists of electrons. Therefore one electron is the smallest unit of energy that can be used in an electronic component.

Last but not least humans also pose challenges for technology development. The development of automobiles, elevators and other machines has decreased the human's need to use his muscles for movement and carrying. Modern computers have decreased the human's need to do mental calculation and memorizing. Therefore, many individuals mayw encounter problems caused by an unbalanced use of body and brains. The opposite problem especially for highly educated people, is that in knowledge intensive work human brains are loaded heavily. If continuous technology development together with transition of working life and habits shapes our environment by making it full of stimuli all the time we are awake, brains may rapidly become overloaded. This kind of stress causes sleeping and attention problems, and can finally lead to severe health problems. [More reading e.g.: Jones, F; Burke, R and Westman, M (ed.) Work-Life Balance: A Psychological Perspective. Taylor and Francis, 2006]

4 The World in 2025

Now we have seen the trends that are taking us to the future. In this chapter we show the applications that are likely to be mega trends in 2025 due to processors and memory advancement. We also present six mini stories to show the impact of these applications on the world in different areas. These mini stories are visions or snapshots of the future we are predicting.

4.1 Virtual and Enhanced Realities

Virtual reality (VR) can be described as a technology allowing a user to interact with a real or imagined computer-simulated environment. Such concepts as simulation, interaction, artificiality, immersion, telepresence, full-body immersion and network communication belong to the metaphysics of virtual reality. Currently the virtual realities are mostly visual experiences displayed by means of computer screens or e.g. stereoscopic displays. However, some simulations contain also speakers and headphones. In VR games the simulated environment can be totally different from the real world whereas in pilot or military training the environment is similar to the real world [1][2]. Virtual realities are also widely used for therapeutic uses [3][4].

The lack of sufficient processing power is currently one of the major obstacles to the development of virtual realities. Other technical limitations are image resolution and communication bandwidth [1]. Virtual realities can be seen as driving forces for development of processors and memory.

We live in a world of limited resources. The cost of energy is one of the driving forces influencing the demand for virtual realities. As the price of kerosene increases, traveling will most likely happen partly in virtual worlds. An example of a travel-related application is presented later in our Dubai miniscenario. Second, the continually increasing requirement for effectiveness can be seen as a driving force for virtual realities as virtual realities are likely to foster productivity by allowing multi-tasking options.

The Pew Internet and American Life Project interviewed over 700 technology experts to find out potential virtual world trends for 2020. Most of the respondents were concerned about the addiction problems virtual worlds are likely to cause [5]. Increased processing power makes it possible to create sophisticated and compelling virtual worlds. In addition to the positive effects of namely virtual traveling, related environment friendliness, and an increase in human productivity, society has to be prepared to take care of users absorbed in fantasy worlds. Let see if the therapeutic uses of virtual worlds can also been used for addiction problems. It also remains to be seen whether enhanced reality is finally the predominant technology in 2025.

Finally, it should be interesting to know the market structure of future virtual worlds. Do users prefer a number of different virtual worlds or will there be just one virtual world divided into different parts? Some data protection issues have to be solved so that it is possible to process and store information effectively.

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4.2 Artificial Intelligence and Robotics

Artificial Intelligence (AI) is the study and design of intelligent machines, which is a system that perceives its environment and takes actions to maximize its chances of success. The field was founded in the 1950s on the claim that intelligence, a central property of human beings, can be so precisely described that it can be simulated by a machine or even copied into hardware and software (McCarthy et al. 1955). Since then, scientists have begun to build AI machines based on recent discoveries in neurology, information theory, cybernetics and above all, the invention of the digital computer. In the 90s and early 21st century AI achieved its greatest successes, albeit somewhat behind the scenes. Artificial intelligence was adopted throughout the technology industry, providing the heavy lifting for logistics, data mining, medical diagnosis and many other areas (Kurzweil, 2005).

The success of AI research today results from several factors, among which are the incredible power of processors and memory and a greater emphasis on solving specific subproblems. The central problems of AI include such traits as reasoning, knowledge, planning, learning, communication, perception and the ability to move and manipulate objects (Luger&Stubblefield, 2004). However, these subfields often failed to communicate with each other, a long-term goal for the AI research is to integrate the above fields and achieve general intelligence, or strong AI (Kurzweil, 2005). How intelligent can machines be? Is there an essential difference between human intelligence and artificial intelligence? It can be an artificial network that has the ability to learn, reason and reason based on current knowledge like human beings, or will it be a service robot with emotion and social skills in addition to motion and manipulation? These trends are reflected within our mini stories for the world in 2025.

One way of predicting the future of artificial intelligences is to consider Turing's test. Alan Turing had ideas on how to define intelligence or even self-awareness. The test is done by having human talk with test subjects. The connection is made through textual messages. The humans have to guess which of the test subjects were human and which were artificial intelligence.

If the majority of the humans cannot distinguish artificial intelligence from an actual human, then the artificial intelligence has passed the Turing's test. No artificial intelligence has yet passed the Turing's test, as of 2008. However, the latest results suggest that the first successful passing of the Turing's AI test will occur in the near future.

When it is common for artificial intelligence to pass the Turing's test there will be a new kind of user interface and new interaction between computers and humans. Much of the current labor in the western world is service from human to human. Many of these services can and will be replaced by much cheaper and more efficient artificial intelligences.

A robot is a mechanical device that can intelligently interact in the real world. Now, in 2008, most of the robots are for industry use inside factories. These robots can usually perform only one simple task. In science fiction the robots have been seen as a humanoid slave like work force for the future. In science fiction robots do all the physical labor such as constructing buildings, cleaning houses and driving cars. The problem for current general robotics is to navigate in a complex and changing environment. However companies like Honda already have prototypes of humanoid robots that are able to understand and move in the human environment. The problem still lies in intelligent action. Even a simple task like cleaning the house might still be too challenging for these prototypes [4].

Honda has predicted that the company will sell as many robots as cars in 2020. Also South Korea has a plan to have one robot in every home. These robots are seen as chambermaids, taking care of the elders and thus reducing the time people use for household chores. Self-driving cars can be regarded as robots as well. In The DARPA Urban Challenge 2007 six robotic cars were already able to pass the urban environment race without any mistakes [5]. It seems that technology is almost ready and the main limiting factors are society and laws. In 2025 the robot driven car might be a common sight on roads.

Robotics might also boost industrial production: Futurologist Ray Kurzweil predicts that robotics might lead to as huge an impact on the world economy as industrialization in 18th and 19th centuries but in matter of decades [6]. The first signs of this new robotics automation should already be visible before 2025. The official US report [7] predicts that service robotics in 2025 is going to be one of the main disruptive technologies. This means that robots will replace humans in various costly occupations, especially those that need much human labor.

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4.3 3D Printing

3D printing is a unique form of printing that is related to traditional rapid prototyping technology. A three dimensional object is created by layering and connecting successive cross sections of material. 3D printers are generally faster, more affordable and easier to use than other additive fabrication technologies. While prototyping dominates current uses, 3D printing offers tremendous potential for retail consumer uses [1] [2].

3D printing technology is currently being studied by biotechnology firms and academia for possible use in tissue engineering applications where organs and body parts are built using ink-jet techniques. Layers of living cells are deposited onto a gel medium and slowly built up to form three-dimensional structures. Several terms have been used to refer to this field of research: Organ printing, bio-printing, and computer-aided tissue engineering among others [3].

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4.4 Universal User Interfaces:

Computer software is sold for its functionality. Users demand new functions and developers try to sell more features. Currently users and developers of computer software face the same problem: increasing complexity. The challenge is to create a user interface that allows easy access to all the functionallity without getting in the user's way. This is further complicated by miniaturization and mobilization of devices. Although new interface technologies like touch screens, handwriting, and voice recognition are becoming more common we are still far from the ideal of natural human machine interaction.

How can we predict where the trends for user interfaces will lead us? There is only one thing not likely to change significantly in the next 25 years: human physiology. In a competitive environment the best-adapted device wins market share, the best-adapted means thus the best adapted to human capabilities. This means there is a trend toward more human-like interaction. The core problem is that current human computer interaction almost always is a low-level interaction. This is in stark contrast to human interaction where communication often has to be highly abstract. In other words, we can tell another human simply what to do while for a computer we also have to explain precisely how to do it.

In 2025 the interaction between technology and humans will have changed significantly. One radical example for these new interface technologies is the deamon[1]: a daemon is like a guardian angle, good friend, teacher, pet, alter ego, and genie in a bottle that follows its owner everywhere. Deamons know virtually everything, to some extent, they can even predict the future. A daemon can take any shape or even make itself invisible. It obeys its owner's every command and relays them to "lesser creatures"; like doors, elevators, pets robots, or cars.

Even though this idea might sound far fetched at a first look its realization requires only some incremental development. In fact building the required hardware is entirely feasible already today. In a simple version it could be based on a 2009 smart phone. These devices are connected wirelessly to cloud storage and computation resources and are also equipped with local storage and processing capabilities. They already come with a wide range of sensors, e.g. microphone, camera, gps, thermometer, accelerometer, etc. And they have a broad range of radio communication interfaces as well as acoustic and optical outputs. Such a device can act as an intermediary between the user and all other computerized technology. In order for such a device o work as a daemon only natural language understanding and augmented reality output need to be improved.

[1] Named in reference to deamons in the novel "The golden compass" by Philip Pullman (Published by Alfred A. Knopf, Distributed by Random House, 1996).

5 Mini Stories

5.1 Abu Dhabi – Enhanced Reality

Abdul Al-Saleem works as a human resource manager in XZ, the biggest software company in the United Arab Emirates. His job is to get capable workers for XZ. Attracting ambitious people for the United Arab Emirates is nowadays relatively easy, because the country can offer the salaries and working resources that most other countries can only dream of. In the beginning of the century Abu Dhabi invested its oil money heavily to get investors and tourists to visit this small country situated at the Persian Gulf by building artificial islands, the world's biggest and the highest quality hotels, hiring talented workers such as professors, athletes and top managers around the world, borrowing works of art from the world's best museums and supporting financial institutions and other companies by buying their shares during the recession.

Today two promising programmers from South Africa are coming to the country and Al-Saleem is going to present XZ to them. He already got a message from his email that the programmers have come to the airport and passed through customs, because when people entering the country arrive at its border, they are recognized in many ways and the government searches its own and Interpol's database in case the incoming people are recognized as "not-welcome."

XZ started by hiring the most talented programmers to create a virtual university for Dubai. The purpose of the university was to provide local students virtual lectures from the best teachers and professors around the world by developing teleconference technology. The next step was to provide possibilities for students to make virtual excursions around the world by wearing helmet and clothes, which made it possible to see and touch different things. The technology was used in medical studies, where the students were able to do virtual surgical operations.

But today, Al-Saleem is going to present something more advanced, where equipment such as helmets, glasses or clothes are not needed anymore: XZ's "Virtual Travel" holiday resort. Last year the company built an artificial copy of Venice for the big industrial hall situated in a desert 40 kilometers south of Abu Dhabi. The copy of Venice was built by combining some authentic pieces of the city with the artificial reality. XZ has hired real Venetian gondoliers, Italian chefs, and also borrowed some pieces of art from Venetian museums to ensure that the visitor gets a real touch of Venice. The main tourist attractions of Venice in XZ's hall are also a combination of authentic and artificial reality, e.g. the pavement and the ground floor of buildings are made from similar stone as their paragons in Venice, but the upper floors, roofs, birds, and sky are only virtual holograms that cannot be distinguished from reality. The hall is divided in several parts and each part represents one island of Venice. The distance between these parts is quite short in the hall, but the tourist feels them as long as they are in reality, because the "boat" or "gondola" actually moves slower than the passenger feels. Also the smells, zephyrs, sunshine and temperature are controlled automatically and are similar to Venice regardless of storms, rainfalls and other real life events that prohibit a tourist from fully enjoying his trip.

The new programmers are going to participate in the creation of another similar artificial attraction, the “African safari”. The dream of XZ is to create a virtual safari, where tourists can drive jeeps in the savanna and shoot or photograph wild animals without hurting endangered species and encountering the normal risks of wandering among the animals.

5.2 Finland – Students’ Life

Teppo is assistant teacher in Biotechnology department of Aalto University. The biotechnology sector has been growing tremendously for the last several years. Also new application areas have arisen, for example the Teppo’s field which focuses on chips integrated to nerves. Intel has presented a new processor technology that one can grow together with a nerve system. Then, sample human brains and digital systems can communicate through this biolink.

With this biolink technology a human can already fix and replace parts of the body. For example, the eye can be replaced by an artificial eye that work similarly to normal human eyes. Teppo’s own research is about sensors that surpass human abilities like infrared vision. A company already exists that sells artificial body parts for increasing the normal human system. Yet the problem lies in expensive and risky operations to the customer. The most advanced area in the field tries to boost the function of the human brain itself. Teppo expects to see technology that improves human memory and processing capabilities. There is already a shift in that people do not to remember lists of what to do, but they have special artificial assistants that keep record of their schedule and usually this artificial system beats humans both in accuracy and guessing what should be done next. This causes handwriting skills to degrade.

Teppo’s main task as an assistant teacher is to adjust and manipulate the teaching material his professor had made for the courses and, of course, answering messages from the students.

The artificial Internet site that generates exercises and checks student feedback has replaced exercise groups. However, this system still needs a teacher, or actually an assistant like Teppo, to select and adjust the exercises made by the artificial intelligence.

Teppo’s job as a teacher is not really time consuming. Both the exercises and grading is done by a sophisticated system. Teppo’s responsibility is to add new study modules to the system and also check and modify the details of what the artificial intelligence system creates. Also, if there is a question from a student that the system cannot answer, it’s Teppo who is going to step in.

Normal studying can be done at home or at school with an Internet terminal and personal access to the school system. Yet, because of freedom in the university, students do not have to follow the schedule. Because no system can enforce people to study, the assistant teacher meets students to give them a gentle push toward more active studying.

5.3 Japan – Robotics for Elders

Hiroshi Nakai is a 38-year-old industrial designer living in Kyoto Japan. He graduated from Kyoto Institute of Technology fifteen years ago and he has been working in Nanda Co, a big Japanese ICT Company ever since. During his working career he has been in several positions. Nowadays he works as a senior designer in Nanda's product development division. Hiroshi is responsible for the design development of the Nandas's flagship product - Mopet. Mopet is a robot pet that can be programmed for different tasks. For the children Mopet can be a smart toy that can help a child to speak or solve simple tasks like opening and using a media center or other smart devices. It can also be an artificial nanny. When acting as a nanny the Mopet monitors a child's behavior and acts so that when there is even the small possibility of something bad happening, Mopet either tells the child to stop doing it or it also contacts the parents at the same time. In Mopet there are several cameras and different kinds of connections to home appliances. It can, for example, switch the lights on/off and send real time video to several places simultaneously.

Because of the aging population and decreasing birthrate in Japan there is a need for different kinds of solutions in taking care of older people. Hiroshi is also facing this same problem. He is taking care of his parents who are already retired. His mother is quite well although she has some difficulties in walking, but his father is suffering from Alzheimers. Although his father's disease is serious and he needs some kind of attention all the time, he is still living in their old home. In Japan there are several service providers who offer different kinds of home help services. Some of the services are based on human contact. In these kinds of services there is a person who is present either in reality as a housekeeper/nurse or virtually as a duty officer in a service central which is placed near customers so that when an emergency situation occurs, the duty officer can quickly come up to customers. Some of these services are built on new technological solutions like intelligent clothes or different sensors placed in the apartment and/or wearable devices like watches. With these sensors the physical wellbeing and location (if he/she at home) of the customer can be monitored, but there is no information about customers mental wellbeing. Because of father's condition Hiroshi and his parents have made a contract with a service provider, who has an intelligent home service. Their house is equipped with multiple sensors and cameras and Hiroshi is able to receive, for example, real time video from his parents' house to his hand held device. Although the system works well, Hiroshi has given one Mopet to his parents and also connected it to the system. The service system was not originally designed to work with this robot pet, but the system's interface allows users to connect different devices to it. Now the system works also out of the house and his father can go out with the Mopet and there is no fear of him getting lost because the pet can take him home where ever he is.

Today Hiroshi is working as always in his office and he gets a message on his phone that his father has left his home unattended, but Mopet has joined him. Mopet sends a message to Hiroshi that his father has taken his medication and they are heading to an old temple area in Kyoto. Hiroshi opens the voice and video connection to his father and asks where they are going. They talk some time about the father's plans and agree that Hiroshi will join them for dinner in the evening. During the conversation Hiroshi is also receiving some medical data on his father's condition so that he can be sure that everything is all right. The Mopet guides the old man to a tour through old Kyoto and tells stories about the temples and the parks. At the end of the afternoon when it is time to take his medication, the Mopet guides him back home where Hiroshi's wife is preparing the family dinner. When they arrive the Mopet connects itself to a recharger and simultaneously uploads all the information (videos, route, medical data etc.) to the system for later use.

5.4 China – People's Processor

My name is Ai Yuan. I am working as a sales manager in ChinaCore, one of the biggest PC chip manufacturing companies in China. It has been over a decade since China held its first Beijing 2008 Olympic games. Within the past years China has envisaged a steady economic growth largely due to its efficient domestic reform strategies and moderate foreign policies. As shown earlier in the 21st century, the world economy cannot be carried alone by America's one-engined plane. Today the emerging Asian economies, especially China and India, have accounted for nearly half of the global GDP growth. Thanks to effective industrial reform oriented by the ICT industry, the Chinese government has funded and administered the 863 program (launched in the 3rd month in 1986), which is intended to stimulate the development of advanced technologies in a wide range of fields for the purpose of rendering China independent of financial obligations for foreign technologies. A key successful product resulting from the 863 programs is the Loongson chip, which is the first general-purpose CPU jointly developed at the Institute of Computing Technology and the Chinese Academy of Sciences in the year 2002. Since then, several state-owned companies have been established continue further research and development for improving CPU performance in order to compete with other foreign CPU giants.

Another important issue considered by government was to put the general CPUs into mass production and sell them worldwide, because earlier produced CPUs lacked both sufficient and efficient global marketing chains. ChinaCore, with its headquarters located in Beijing, P.R. China, is among one of the state-owned companies for such a purpose. My job here needs to coordinate between different agencies and companies both at home and abroad and for the most important, to ship our PC chips outside of China.

Today is a very important day for me and my college Wang, the chief technical engineer from our company's R&D department. We are now at the release conference organized after the 10th ICT Products Exhibition Show in Beijing, where the final evaluation results on the performances among all four PC chip companies are soon to be announced. The winner will win a big contract with an African country government, aiming at helping them with mass-producing mini PCs for their school children. Although Wang and I try to be calm as usual, we know that this time cannot be compared as before. Our rivals are all highly international chip companies, based in the America, Japan and France respectively. Clearly, they have very strong R&D teams and share nearly two thirds of the global CPU markets. However, we have built our own confidence. With the resources provided by Chinese Academy of Sciences, our company succeeded in designing our first general-purpose CPU processor, ChinaCore 1 in 2010. It was a 4 core 64-bit CPU running at 1.2GHz frequency with max 10W power consumption, together with full IP rights. Three years later, we managed to raise the frequency up to 2GHz and settled up our domestic sales chains in 10 major cities and expanded up into 26 major cities within China last year. The latest version of our CPU product for this competition, ChinaCore Max runs 4 times faster than the previous one. It is more stable especially in multimedia broadcasting and streaming with a good compatibility with various operating systems. What's more, we own all intellectual property rights.

"Hey Yuan, Did you see that? We were just chosen for the job!" shouted Wang. I hardly believed my eyes and then quickly glanced at the final evaluation results. Though ChinaCore Max clock frequency is still 10 percent lower than the models from other competitors, the results show that our model consumes less power and costs much less than others. Moreover, what they really appreciated, as the African representative stated, is that we have provided them with our own Red Flag Linux operating system that has been enhanced to support their local African language. Yes, we made the chip! It is a milestone for our company ChinaCore and also for China's ICT industry. All the work that we have done these years is worthwhile at this moment since this is our first step abroad. Now before we start preparing for the more challenging work tomorrow, I just can't wait to go back to my family and give them a big hug!

5.5 Indonesia – Ecoterrorism

John, an American college dropout is heading for the jungle of Indonesia helping a local environmental group to protest seabed mining. The sediments raised by offshore mining have destroyed the fishing areas of local communities. The protesters are planning to disrupt the mining operation to raise international awareness. In turn the government in Jakarta has declared them a terrorist group. The exploitation site is close to the shore in the strait of Malacca. There is a strong military presence in the area. The oil platforms and harbors are protected by private global security companies

(Brownwater). In addition to mercenaries they rely heavily on unmanned patrol and reconnaissance vehicles. There are seaborne surveillance platforms that are equipped with quadrocopter drones.

There have been protests against the pollution for years but the corrupt local government keeps backing the mining. Environment activist networks have, however, come up with a plan to stop them. A few weeks ago one of the robotic maintenance robots had malfunctioned and stranded. It was found and deconstructed by local activists. Since the whole process was documented online it took only a few days for a group of European university students to discover the Archilles heel: the maintenance submarines, without which the mining would have to be stopped in only days, were using an old fashioned communication chipset. The cryptography algorithm for the handshake protocol had been faultily implemented. The error was reported a few months earlier by American security researchers that had used a focused ion beam reverse engineering microscope to dissect the silicon chip. This security flaw would allow the take over of the robots, given that one could get close enough to them. No problem, if one could only get a small submersible to Indonesia - or build one there.

The problem is that there is no direct electronic communication with the local activists possible. Even though their jungle camps are well equipped with computers and electricity they cannot use radio communication without giving away their position. They even had to stop using their satellite uplink since Brownwater started to fly surveillance drones over the area. This is where John comes into the game: he is on a tourist trip to Indonesia. The blueprints for a fish robot and the software to hijack the maintenance submarines are securely and inconspicuously stored on the data cube of his video camera. The submersible itself, a modified version of an open source aquarium toy, will be assembled on site. The mechanical parts can be made using an old 3d printer with the model data on the storage chip. The electronic components will be made off reprogrammed scrap parts. But those details were not John's concern. After dropping of the camera he enjoyed two weeks of beach holiday before flying home. His hotel and flight tickets were paid for by greenwarriors.com where he found the ad promising a free holiday. Only a short news trailer would catch his attention weeks later: "The stock prize of Undersea Mining Inc. took a dive today after a company spokesperson announced that one of their biggest exploitations will be standing still for 6 month after the loss of its mining robots due to a technical failure."

5.6 Nigeria – Electronics Recycling

Umaru works as a security guard at the Processor Recycling Institute in Lagos, Nigeria. Today is an important day as the Economic and Financial Crimes Commission agent is going to evaluate the production plants and administration of the institute. In the last site visit the agent was concerned about the funding of the Institute due to the fact that some of the investors had given funding anonymously. This is against the new regulation on Good Governance. Bearing in mind the high unemployment rate, Umaru is concerned about his job. Umaru doesn't want to be out of work again. His last unemployment period lasted about two years. During that time Umaru sustained his family by selling 'pirate clone wifi music processor and memory combination devices powered by solar energy' to the tourists out in the new virtual hotels. Umaru was almost forced to join the army again. The army, however, is for him the last option.

Before work Umaru escorts his oldest daughter Amina to the school. Amina is one of the lucky ones, who was selected from her ethnic group to the One Laptop Per Child School. Amina is very proud of her laptop, which is filled with educational programs and games. By means of those games Amina is able to teach a group of younger kids who didn't fit into the school, but take an exam once a month based on the information given by Amina. This belongs to the program. In addition to its educational content, Amina's laptop is filled with the music from the famous Nigerian musicians and films provided by Nollywood, i.e. the Nigerian film industry. A Nigerian media tycoon contributed the tax kind levies to the memory of the laptops. The levy covers all Nigerian music and films. Amina and her friends are not at all interested in European or American content. Like almost all the other kids, during her free time Amina participates in hip hop groups led by the Nigerian artists. She is especially keen on writing lyrics for the songs. Not surprisingly, Nigerian music and films are becoming a remarkable export product.

Having determined that his daughter is safely at school, Umaru heads for the Processor Recycling Institute. As the first task Umaru guards a group of Chinese journalists who are going to write an article about the Institute. Umaru has heard the introduction to the Institute dozens of times, but he still listens carefully. The guide explains: "The second-hand processor hardware is imported from Europe. The Processor Recycling Institute is mainly funded by the waste charges paid by the European companies importing the second-hand processors. We have two R&D and production lines. On the first line our mission is to develop an industry standard hardware processor and then continue development further on the software side. Along those lines the functional parts of the recycled processors are scrapped and the development goes back to the drawing board. On the second line the mechanical processors are basically taken as they are and new functionalities are programmed into the devices. To be more precise, the intended application of mobile phones is converted into toys, educational games, text reading for illiterates, technical instruments for disabled persons, and parts of alarm systems. Currently we are collaborating with two media companies to convert mobile phones into platforms for news feed services that are replacing the traditional newspaper format. Some of the most efficient processors from the year 2020 are used to build new distance learning systems and archives necessary for libraries and storage of biodiversity information. One application already in the production line is an electric generator, which is used to convert solar energy into the electricity. Currently the biggest problems we face are the patents we necessarily infringe on in the development." Umaru sighs, more problems heave into sight. Nevertheless, it is time to pick up the Economic and Financial Crimes Commission agent.

6 Conclusion

"Change is the only certainty in an uncertain world. These changes can be either radical discontinuities or gradual shifts in context – either way, they will force a reaction. In the face of constant change, there is a choice between reacting to circumstances and proactively planning for possible future outcomes."[7] Between this year and year 2025 a lot will happen and almost everything imaginable is possible. Although it is possible that Moore's law will stop even before the year 2025 and silicon based technologies will reach their peak, the ICT industry will likely grow exponentially.

During the years to come the sensor technologies will develop radically because there is huge need and there are no major technical obstacles to prevent it. Automation of all kinds will expand and especially robotics will finally make their breakthrough and robots with artificial intelligence will be used in in the services market and in intelligent home applications.

Also virtual and enhanced reality will change the lives of people. Those realities will be used both for the business and enjoyment. Because of all this development the ordinary life of people will be easier, but same time more complicated. With the help of new technologies the distinction between work and leisure will be even more mixed than today.

In the future, growing energy consumption will cause some problems. It is estimated that today computers and mobile devices already consume 10% of the total energy consumption and it is increasing.

The scenarios in this chapter are not predictions of the future, but by testing strategic options and using the scenarios as a tool to map possible futures, decision makers can structure their decisions and guide their thinking about the future.

7 Scenarios for the future – How might IP regimes evolve by 2025? - What global legitimacy might such regimes have?, available at: http://documents.epo.org/projects/babylon/eponet.nsf/0/63A726D28B589B5BC12572DB00597683/$File/EPO_scenarios_bookmarked.pdf

1.2 Life Unwired – The Future of Telecommunication and Networks

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Abstract

Development in telecommunication and network technologies is facilitating novel services independent of our physical location. Increased mobility is one of the most significant changes in the telecommunication practices of ordinary people. The future of telecommunication involves not only new network architectures and protocols, but also advanced mobile devices, diversified services and enhanced energy awareness. This chapter discusses the state of the art and future trends in telecommunication and networks. The discussion is based on a scenario, which envisages how the field could look in the year 2025.

1 Introduction

For centuries humankind has used couriers, smoke signals and talking drums for long distance communication. It then witnessed the advent of electricity leading to the telegraph and the subsequent technologies of real-time telecommunication. Now we are facing the age of digital transmission systems that enable mobile telecommunication all around the world.

In the last few decades, fiber optics and modern telecommunication techniques have enabled extremely fast and cheap data transmission. Distance as a factor has been largely eliminated from mediated communication. In addition to advances in telecommunication networks, we have also witnessed the convergence of telecommunication devices. Previously most personal electronic devices did not contain an embedded functionality for telecommunication. For instance, cameras could be used to capture photographs, but not to transmit them. The recent trend in telecommunication is increasing mobility. Different devices are deployed with built-in functionality for network connectivity and the users are online all the time independent of their location. Wired connections are no longer required in order to communicate remotely with others or to access the Internet. Telecommunication will be universal, and not restricted to a place, distinct device, or network. In the near future, sensors with radio transmitters will be placed in different types of objects in the users' environment that monitor the activities, the state and the well-being of the users, and can communicate that information forward for services to consume.

In this chapter, we intend to look ahead into the trends of telecommunication and networks. The article is based on a scenario describing how telecommunication practices might evolve from the present to 2025. The scenario includes concrete examples, reflecting the telecommunication systems of 2025, and the utilization of these systems, in terms of possible services that could be built on them. After presenting the scenario we continue our discussion by examining wireless networks, their development in the coming years, and especially the aspects of seamless mobility and ad-hoc networks. Then we turn to reviewing telecommunication devices, in particular the personal communication device (PCD), which we presume to be in the core of people's everyday communication practices in the year 2025. Further, we examine software and services, focusing especially on ambient intelligence; electronic environments that are sensitive and responsive to the presence of people. In the context of ambient intelligence we discuss software technology, and business and information services. Finally, we present a review of energy consumption and power sources of future telecommunication devices and networks.

2 Scenario

To illustrate the technological road map for future networks, devices and services, we have created a scenario. The scenario is not intended as a prediction but as a vision painted to show possible future development trends, and as a source of inspiration for future innovation.

2.1 A Rainy Day in Helsinki 2025

I just turned off the alarm clock by raising my hands in the air and continued sleeping. It started ringing again after just five minutes because a sensor attached to the bed was still transferring messages to the clock since there was no significant change in the weight on the bed. I finally got out of the bed because, believe me, that clock would not to stop ringing if I did not get up. I was not in a very good mood, because I had to stay up late to complete an article. This was also indicated by the health monitoring system that recommended that I eat some fresh fruit for breakfast to balance my blood sugar levels.

My wife had got up earlier, as I could smell the strong aroma of coffee from downstairs. The coffee machine is programmed to be activated when the weight on the bed reduces. This triggers the activator to send a wireless message to the coffee machine. However, according to my personal smart-home profile this will not happen before 7 a.m. I went downstairs, grabbed a cup of coffee and a sandwich. According to the bus time schedule on the personalized electronic paper display, I had less than ten minutes to go. Fortunately it's only a short walking distance to the bus station from our house. At the same time, I quickly went through my health monitoring information and newspaper headlines from the display. I always tell myself, ”I like this house”, because all the telecommunication networks are now wireless and everything is seamlessly controlled. Additionally, we have installed a wireless energy transfer system (WET) to power sensors in the house.

I took my bag and activated the home security system from my personal communication device (PCD) after leaving the house (my wife had already left for work). This command automatically turns off the energy transfer system, the power from stand-by-devices, WLAN device and activates a burglar-free-mode in the house. The PCD functions as my phone, laptop, wallet, keys, and is used practically for all electronic transactions through the network. The PCD also requires minimum energy for it to be operated and can be powered both by my body heat, my movement, and wireless electricity. Thanks to technological breakthroughs in energy research, I rarely have to re-charge it.

A voice command told me to walk faster, even though according to information on the location of the bus as detected by the PCD, it would be late approximately five minutes. The mobile device knew this because it detected immediately that I was walking toward the bus station and combined this information with my information profile to allow for an effective personalized service based on spatial, temporal, and activity data. I had to wait for three minutes before the bus came.

I stepped into the bus and my PCD immediately switched to the secured WLAN system on the bus. The payment system in the bus detected that I had only one trip left in my prepaid period. It recommended purchasing 40 more trips according to my past travel history. I sent an activation code to the e-wallet to purchase the bus ticket. I was instantly informed that the transaction went through successfully and that the e-wallet had propagated the information to my personal profile.

It is very comfortable to use the PCD as different applications assist me in many daily decisions and adapt to my current contexts in time, space and mood. Actually, I never get irritated by the recommendations that give me useful information about my future consumption needs.

I did not need to ring a bell to stop the bus. The bus system registered my presence and predicted where I will get off. I was informed how much time I have left for the journey and also, a request to confirm the predicted stop where I will get off. I said yes and requested to be informed five minutes before the bus arrives at the Aalto University stop.

I settled down comfortably in my seat for the ride, removed my ear device (ED), and unfolded my electronic paper display-keyboard to work on my article. It immediately established a connection to the PCD using my personal network. My wife prefers the optical-ED, recommended for individuals wearing glasses, because it can be attached directly to the eyepiece, which acts as an amplified display and a touch screen keyboard. I often laugh at her in the bus when she sometimes sits beside me and touches the air in front of her glasses. She uses the optical-ED also as a laptop. She only needs to put the optical-ED on the table in her office or at a meeting to activate the display and keyboard. The keyboard is projected onto the table surface, and the display in the space immediately above the optical-ED. The device can also be activated and operated in touch-screen mode.

I worked fervently to finish the article before I got to work while also at the same time listening to music from a personalized music station that offers mass customized music services to my taste. I had scheduled a meeting using a social networking service at ten o'clock in the morning and received a voice-alert over the music. I was very much absorbed in my work when suddenly the PCD informed me of my stop in five minutes. I wrapped up my work and got off the bus.

I walked quickly to my office while my PCD registered me as present. I went to my office as I still had time before the meeting, talked with my wife who was also at work, and did some work before going to the meeting. I went to the meeting where I invoked my PCD and it automatically synchronized with the presentation devices in the meeting room. Suddenly, I saw my colleague Pekka sitting in a chair beside me, and he looked so real. But I was not to be fooled this time, as I knew that he was abroad. Pekka is always trying to play tricks on us, and he never announces that he will not be physically present at a meeting. He always activates static-virtual-presence on his mobile device and sits wherever he is and laughs at people trying to have a conversation with him. He always does that for a few minutes before activating dynamic-virtual-presence whereby there is real and full interaction. I presented my article together with others and the necessary materials were automatically stored on data storage. It was raining very hard outside so we decided to order lunch after the meeting to avoid walking in the rain. I was clearly informed and advised to take an umbrella in the morning by my PCD, but I had refused. We ordered pizza, although the health monitor suggested not doing so.

I went back to my office after lunch to continue working. Late in the afternoon, on my way home from work, I received a message from my shopping assistant that my wife had already gone to the grocery store and bought almost everything from our virtual shopping list. My PCD also informed me that she had picked up the kids from the day-care center and was on her way home. In the evening at home, we decided to watch a nice 3D movie after putting the kids to bed.

It was a quiet and pleasant day except for the rain, which had no intention of stopping. I was hoping earlier it would stop before I left from work. I was quite wet by the time I got home; as I said, I was stubborn enough to ignore the warnings from my PCD, which indicated that it would be a rainy day.

2.2 Technical Implications of the Scenario

From the scenario we formulate a number of technical implications about the technological developments, which will lead to the structure of telecommunication and subsequent networks in the year 2025. Assuming the delineated pattern becomes a reality in 2025 it means that there would have been significant breakthroughs in emerging technologies. The technical implications can be summarized as below.

1. Trend toward seamless wireless connectivity. Wireless communication has been progressing quickly and has transformed the entire telecommunications industry. With the switch of dominant access modes from wired to wireless ones, there exist challenges to wireless access networks for providing the same experience as when using wired networks (for example, seamless connectivity across different networks, and high-speed data rate while moving).
2. Trend toward media convergence and miniaturized mobile devices. The personal mobile communication device is evolving into a multi-functional device that utilizes the convergent media content originating from diverse devices.
3. Trend toward ambient intelligence and pervasive computing services. Future personal communication practices integrate interpersonal communication capabilities with the Internet and sensor networks in order to enable novel services.
4. Trend toward energy-efficient communication devices and networks. The energy-efficient communication system includes novel software architecture, network protocols, low-power hardware, and innovative power sources.

In the following sections, we will discuss the above trends and their technological implications. We start by fore-sighting future networks, then focus on personal communication devices, and finally discuss potential future services and energy efficiency of the devices and networks.

3 Wireless Networks

My PCD switched to the secured WLAN system on the bus. The paper display-keyboard immediately established a connection to the PCD using my personal network.

Wireless networks have experienced exponential growth over the last decade, and are supplanting wired access networks, coupled with the proliferation of laptops, mobile phones, PDAs, GPS terminals, sensors and other mobile devices. Future access networks will be made up of heterogeneous wireless networks, and the selection of access mode will depend on the context in terms of transmission distance, data rates, mobility performance, and the network interfaces available on devices. Though the wireless access networks transfer information via radio frequency, microwave, infrared light and line of sight, the backbone networks will use fiber optics as the transmission medium to gain a higher data rate, even over 100 Gbps. In addition, Internet addressing mediated communication architecture (all-IP) will be adopted to enable seamless interconnections such as the convergence of wired and wireless networks, as well as to act as a service platform for voice, data and Internet.

3.1 Current Networks

In terms of transmission range, as shown in Figure 1, wireless networks can be categorized into four groups, namely, wireless wide area networks (WWAN), wireless metropolitan area networks (WMAN), wireless local area networks (WLAN), and wireless personal area networks (WPAN).

Cellular networks often refer to cellular mobile phone networks, which are by far the most popular WWAN having over 3 billion users worldwide. Current cellular networks are based on digital radio communication, with the first commercial system deployed in the early 1990s. As shown in Figure 2, digital network technologies have evolved from GSM and CDMA, which are often called the second-generation (2G) cellular technologies. The evolved versions of 2G technology expanded the service range from voice service to narrow-band data services such as email, Internet access, and SMS. From 2001, some network operators started building networks using third-generation (3G) technologies. Compared to 2G, 3G technologies are expected to provide higher transmission rates, such as 2Mbit/s for stationary or walking users, and 348kbit/s in a moving vehicle [39], which will enable rich data applications like

VoIP, video conferencing, and file transfer. By June 2008, there were more than 750 million 3G subscriptions globally, and the beyond-3G technologies like LTE are supposed to be deployed from late 2009 onward. [Glodsmith2005]

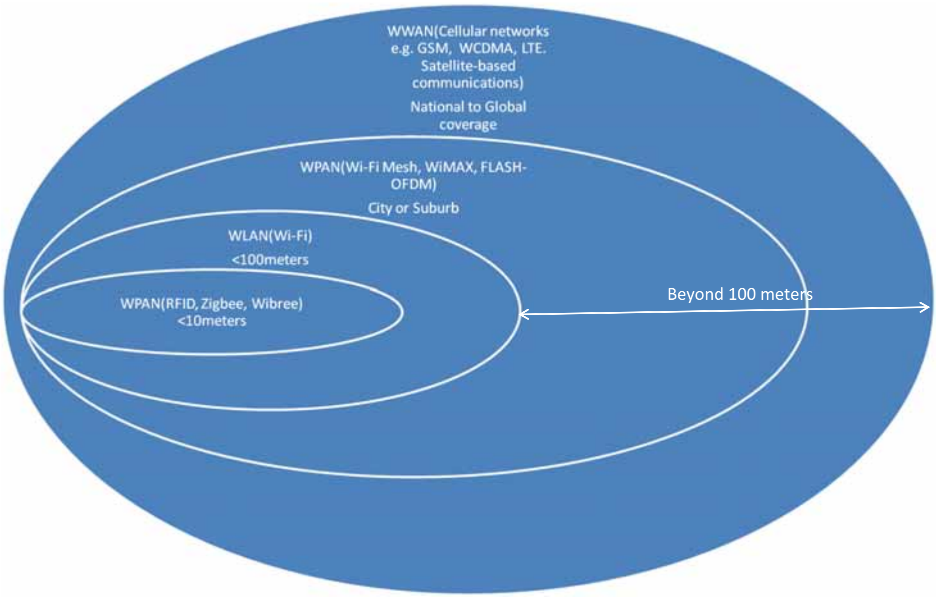

Figure 1. Classification of wireless networks in terms of transmission range

Satellite-based Networks provide global coverage of transmission even in areas without cellular signals. However, due to relatively higher cost and lower performance such as high latency, they are often used as complements to cellular networks, for example, in communication in remote areas, which are impractical to be connected to wired networks or cellular networks.

WLAN,with Wi-Fi as its trademark, is a wireless network that enables communication between devices in a limited area. In practice, WLAN has become synonymous with IEEE 802.11, a family of standards implementing wireless communication using similar over-the-air modulation techniques. IEEE 802.11 WLANs have been widely deployed in short-range communication environments such as homes, cafes, airports, hospitals and campuses, owing to their ease of installation and low cost. In addition to network access, they can be used for indoor positioning services. The most popular WLAN technologies of today, based on 802.11b and 802.11g protocols can offer down-link data rate up to 54Mbps within a range of 38 meters indoors or 140 meters outdoors. Proposed 802.11n standard WLAN will be able to achieve data rates as high as 600Mbps.

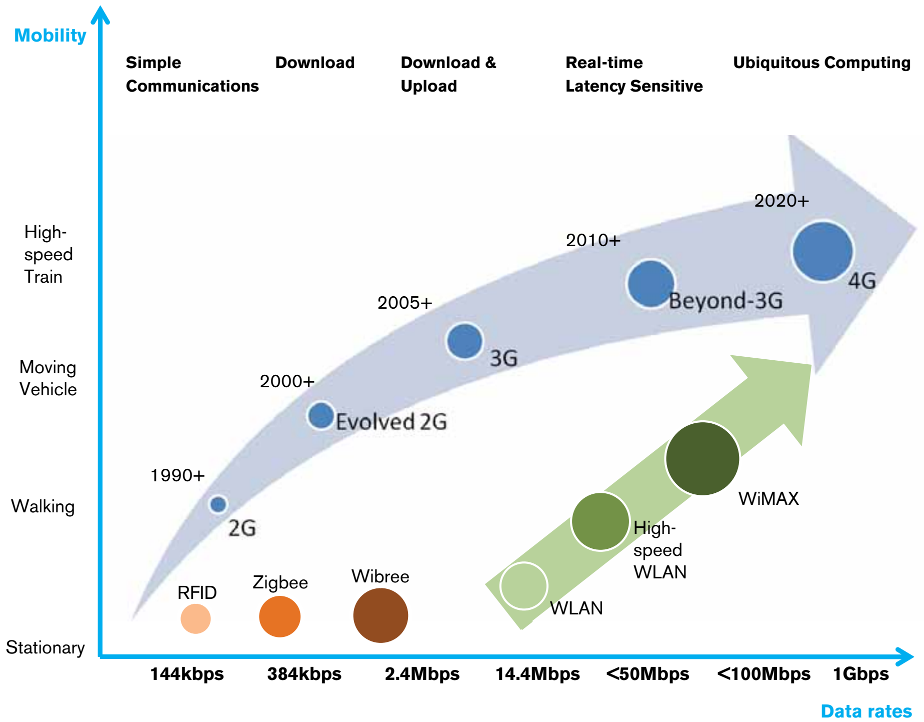

Figure 2. Roadmap of wireless networks towards year 2025.

WMAN provides connectivity among several WLANs. Current WMAN technologies include Wi-Fi mesh, (fixed) WiMAX and Flash-OFDM. Wi-Fi mesh evolves from traditional WLAN. In a Wi-Fi mesh network, each mesh node, such as Wi-Fi hot spot, communicates with each other wirelessly. Similarly, WiMAX connects Wi-Fi hot spots and other terminals to the Internet, while using a different mechanism from Wi-Fi. In theory, WiMAX can reach a peak data rate of up to 70 Mbps over a distance of 50km. Flash-OFDM is a WMAN technology optimized for IP data at all layers, and it can be seen as a rival to WiMAX technologies.

WPAN interconnects devices within a relatively short range from about 1 to 100 meters. Different WPAN technologies, such as Wibree, Zigbee, and RFID, have been adopted for different applications. For example, both Wibree and Zigbee are designed for low power, low data rate transmission on mobile phones, PDAs, laptops, cameras, printers, headsets, watches, heart monitors, and sensor networks. Furthermore, Wibree can co-exist with Bluetooth devices and is more power efficient, while Zigbee supports longer transmission range and mesh topology. In addition, RFID, an automatic identification method using radio waves, is used in logistics, such as goods tracking in supermarkets, and as electronic tickets and electronic keys.

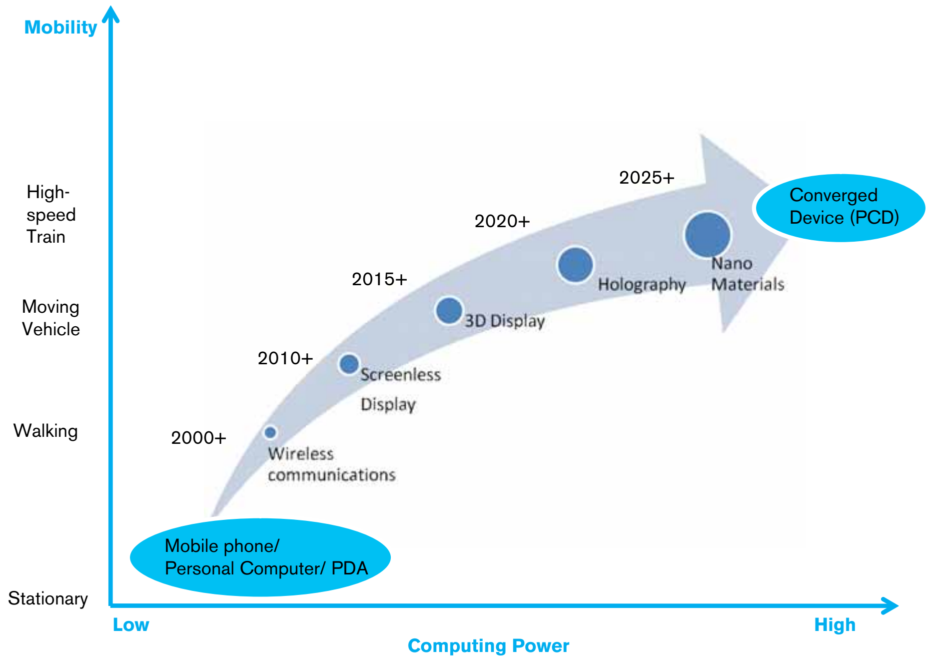

Figure 3. Evolution of PCD.

4 Devices

I only need to take with me my miniature PCD, which includes an electronic paper display-keyboard. It functions as my phone, laptop, wallet, keys, and is used practically for all electronic transactions through the network.

4.1 Personal Communication Device

For decades the progress of enhanced micro-electronics (size reduction, speed enhancement, increased capacity) has been the driving force behind the technological revolution we have witnessed [35]. In today's society media users are increasingly adopting technologies that combine a range of media applications into one device. The development of mobile phones has narrowed the gap between mobile communication devices and personal computers. As illustrated in Figure 3, at some point in the near future, this thin gap will be totally eradicated by personal communication devices (PCDs). The focal aspects regarding the development of PCDs are media convergence, miniaturization, and screenless displays.

The PCD can be situated on the evolutionary continuum of the mobile phone, as the mobile phone is developing gradually into a general media and communication device. However, it is questionable if the PCD can be called a phone anymore.

It will not be an apparatus oriented solely, and in most cases not even primarily, for voice communication. The PCD is rather a small computer capable of enabling a multitude of communicative (as well as non-communicative) activities. The PCD will operate in a ubiquitous and pervasive communication environment, offering constant connection to other people and information. Most importantly, it is used primarily for personal communication. Thus, we have coined it the personal communication device. Mobility as an attribute for the device would be trivial, as most communication devices in the year 2025 will be mobile and wireless.

In order to grasp the communicative essence of the PCD it is important to review the evolution of the mobile phone. In general, the development of mobile phone communication is characterized by progress from interpersonal voice transmission to more broad media consumption and content production. The mobile phone also serves increasingly as a device that connects the user to the Internet. As a consequence, its use is not motivated only by human interaction. It can be presumed that for the PCD in 2025, the main mode of use will not be interpersonal communication, but it will rather communicate independent of the user with the environment and different data services, engaging in machine-to-machine communication.

Most PCDs are thin clients, as the majority of the information and software used will be placed in a remote repository ('the cloud'), which is located on servers in data centers, and is accessible via the Internet. Cloud computing will allow mobile devices to act as people's primary computers, enabling them to seamlessly access their personal information, regardless of the place they are in, or the communication device they are using. A contradicting view is that, as memory will be cheap and ample, the PCD itself can also be used to store vast amounts of information. The cloud in this case would be primarily intended for ubiquitous distribution and sharing of information rather than data storage and processing.

The design philosophy for the PCD can be labelled as the 'Swiss Army knife' approach: cram as much functionality as possible into a single device [34]. The PCD is a mobile digital machine, which can substitute for most of its simpler predecessors. It is a medium that can be used for various communication needs. Thus, an important aspect in regard to the PCD is media convergence. Media convergence can be defined as the integration, merging, and unification of media systems, media devices and media forms. The force behind progress in media convergence in the last decades has been mainly digital technology.

The PCD is an emblem of the convergence of communication devices, but in addition to device-level convergence, the PCD also represents the convergence of communication systems [28], mainly between networks and the Internet. For the end-user, this convergence of communication systems is rather invisible on the network interfaces level, as the PCD can access and transit seamlessly between different telecommunication networks. In general, the PCD acts as the hub of media convergence; it is a computer, a mobile phone, a remote control, an Internet terminal, a receiver of broadcasting contents, among many other uses and functions. At the same time it is important to pay attention to usability issues, as the Swiss Army media knife should not be overly complicated to use.

Divergence is a contradictory, yet concurrent, course of development with convergence. It is exemplified, for instance, by the multitude of different devices and detached services. Although being a converged device, the PCD exhibits also divergence, at least on the device-level. The handheld PCD can be accompanied with several diverged and separate accessories, such as an ear device (ED), or a foldable screen and keyboard.

4.2 Miniaturization

The trend of the PCD seems to be toward a simpler, smaller, media converged, and at the same time a diverged device. The major technical challenges, which will be encountered, can be attributed to four key parameters: volume, weight, power consumption and the number of components [29]. Tolles and Rath [23] predicts the trend toward miniaturization of communication devices will meet a technological barrier within the next 10 to 15 years without new principles, materials, and phenomena. Likewise, Weibel [41], argues that the trend toward smaller communicating devices will possibly stop as it will be too hard to view, for instance, graphics from miniature screens. Text messaging from cell phones will become very difficult if the buttons are too small. But, as existing technologies are maturing, new technologies are emerging. Thus these arguments may be disputed in the wake of tremendous breakthroughs in emerging technologies [17]. For instance, nanotechnology is entering commercial use. Nano-materials have shown great promise for applications in flexible electronics. A mechanically flexible circuit for paper-like displays and heterogeneously integrated electronics for communication has been achieved by a combination of electronic printing and semiconductor nano-materials [16, 9].

4.3 Screenless Displays

When it comes to device functionality, a small device does have its limitations. One of these limitations is the output display from the usability and human-factor point of view [41]. One of the major changes that will be seen in future mobile devices (for instance in the PCD) is how the device delivers its output to the user. Graphic displays of mobile communication devices are steadily increasing in resolution with recent advances in the development of organic materials to conduct electricity and emit light. Full-color displays of Organic light-emitting devices (OLEDs) will eventually replace liquid-crystal displays (LCDs) for use [Bardsley´s 2004]. Most of tomorrow's mobile devices will be screenless. Screenless display (SD) is one potential solution to provide larger display on the PCD. An SD is a system for showing visual information without a screen (for instance screenless mobile phones) Screenless communicating systems can be divided into Visual Image and Retinal Direct solutions.

Visual Image SD includes any screenless image that the eye can perceive. The most common example is a hologram [22]. A new communication technology is being developed that will allow people to interact inside a simulated environment even if they are thousands of miles apart. Tele-immersion is aimed to enable users in geographically dispersed sites to collaborate in real time in a shared simulated environment as if they were in the same physical space [33]. Tele-immersion differs from virtual reality in the sense that it only creates a 3-D environment that one can see but not interact with [26].

Virtual Retinal Display (VRD) is another rapidly emerging display technology. VRD is a technology that draws a television-like display directly onto the retina of the eye. The user sees what appears to be a conventional display floating in space in front of her. By using VRD technology it is possible to build a display, which is small, light, and consumes less power [19]. The device will also be capable of see-through display mode and with brightness sufficient for outdoor use. VRD-display technology integrated into the PCD will allow users to view images and files as if on a full-size desktop monitor.

5 Future Services

A voice command told me to walk faster even though according to information on the location of the bus as detected by the PCD, it would be late approximately 5 minutes. The mobile device knew this because it detected immediately when I was walking toward the bus station and combined this information with my information profile to allow for an effective personalized service based on spatial, temporal, and activity data.

Wireless access to the Internet is enabling a breakthrough as a content mediator in addition to being a connectivity enabler. In the near future, technologies are expected to merge computing, telecommunication, and ad-hoc sensor networks into a single digital stream carried on the same network enabled by high-speed data transfer, seamless mobility and all-IP architectures.

Technologies that enable such services are often listed under ambient intelligence [1, 31]. The concept refers to a trend in which mobile services integrate with the surroundings. This can occur in variety of applications such as context-sensitive recommendation services, intelligent health monitoring or even telepresence, which allows persons to feel as if they were present in a distant location.

5.1 Toward Ambient Intelligence

It is predicted that by 2015, wirelessly networked sensors in different everyday objects will form a new World Wide Web, the Internet of Things. But this will only be of value if the stack of terabytes of data it generates can be collected, analyzed and interpreted [25]. It is important that the user receive only information that is of relevance. Fortunately, future technologies enable the development of smart systems that will be aware of who you are and who is around you, what you need, where you are, with which kind of devices you are equipped with, and in what condition or mood you are [6]. We have selected the six most significant trends of and challenges for ambient intelligence, each of which provides opportunities for novel services, namely, social spaces, information interoperability, location information, temporal information, device information, and situational information.

Social spaces Mobile devices are unique in the sense that they carry digital identifiers of the users. In addition, the devices contain information about other people that the owners of the devices know. Today this is in the form of a phone book, social networking sites or e-mail address lists that in fact formulate a huge social network. In the future, the devices can formulate ad-hoc networks and sense the other devices around. This enables the services to infer who and with whom the user is at any given time.

Information interoperability The number of services and separate pieces of information in the Internet together with the information recorded of the actions that people perform in their environments form a huge information storage, but also a heterogeneous information integration problem. This is because the information originating from various sources, such as human created content and sensor-collected data, is difficult to interpret by machines that are not designed for exactly those tasks. This means that, for example, information originating from home media servers cannot be used by mobile devices, or information from health sensors cannot be used by web applications. This is often referred to as a problem of interoperability. Solutions to this problem enable the services to be aware of what kind of information the user is accessing, and enables the machines to further process the information independently of the original information sources.

Location information Mobile communication enhances services by enabling them to be available anywhere, but also precisely where they are desired. The technologies enable mobile devices to inform users immediately about particular events based on their location. They also enable the delivery of location sensitive information whose value depends on only the location dimension, such as maps or route planners. [38]

Temporal information Calendars and personal reminder services are examples of existing temporally aware services. Typically the existing services use only temporal information, but are not very inventive in combining it with other information. Temporally aware information provides only one dimension, but an extremely important one, namely services personalized by time. For example, product information or comparisons might be essential services only based on other profile dimensions of the user, but they are highly dependent on the time that they are presented to the user. It is only feasible to recommend buying prepaid credit for bus transportation if the service is aware that the buyer is going to travel on a bus soon in the future.

Device information Services should be adapted to the environment of their users. Adaptability is possible along various dimensions including the type of the device in use and the currently available communication bandwidth [38]. Furthermore, customization is a key issue in using mobile devices because of the possible limitations of the user interface caused by the display size or usage situation.

Situational information answers the question 'in what condition'? The mobile user may consume the services in numerous situations, e.g. while engaged in another activity, like travelling, waiting at a bus stop or being in a certain physical or mental condition, such as tired or nervous.

Gathering these pieces of information together by utilizing the Internet that we know today is not possible. However, the future Internet is predicted to take ubiquitous computing one step further by realizing environments that are sensitive and responsive to the presence of people through sensor, social and ad-hoc networks, and is able to analyze this information with intelligent software systems.

5.2 Technological Enablers

Software technology is being further developed to support ambient intelligent services in terms of data transfer protocols, sensors, customization, and the intelligent information mediation.

Data transfer protocols Multimedia data traffic will keep increasing in the coming years since IP-based services such as VoIP, file sharing and video streaming are becoming popular in 3G/4G cellular networks. IP-based network and routing technology is therefore expected to be capable of transporting large volumes of multimedia traffic. In addition, broad- and multicasting [21] offers means to disseminate information to a large number of users inside a specific geographical region using limited bandwidth. It can be used to deliver information to users with common subscriptions for contents such as weather information, advertising or TV programs.

Sensors Future environments will be saturated with sensors [42] that measure, for example, physical quantity and activity, acoustics, motion, optics, chemical or biological properties or even mimic human senses. Myriad sensors already exist in various applications such as GPS receivers embedded in mobile phones, and biological sensors for monitoring heart rate. There are more advanced sensor technologies under development, for example, acceleration based positioning sensors or Wi-Fi based tracking for positioning services, bio-sensors, which mimic human senses (e.g. the electronic nose), proximity sensors and the sensors embedded into RFID tags.

Customization While once content and services mainly originated from professionally controlled sources, we are now moving toward a digital age where an increasing amount of information about the users and their social networks, actions and environment surroundings are available automatically. This enables highly advanced personalization that can occur at the content or network level. For example, a user can order digital content such as a customized newspaper, and receive information and recommendations that depend on context like location, time, personal profile and mood. In addition to content, the network traffic requirements could be customized [2]. For instance, when users are using teleconference or telepresence applications, bandwidth could be dynamically allocated by temporarily renting bandwidth from TV spectrum or other users.

Intelligent information mediation As increasing amount of information sources will be involved in future services, mediation and interpretation among them becomes a big challenge [40]. For example, advertising service may require consumer's profiles including preferences, location, social space, and current situations. All these information sources must be reachable and accessible. Overlay networks have been proposed to enable this over the Internet [4]. Moreover, semantic web [8] is a potential solution, which enables devices to interpret the information [15], and further enables services such as high precision search and recommendation [13]. Technologies such as event driven computing, text mining and natural language understanding, and real-time image and speech recognition will also play key roles in future information mediation. Therefore, combining content from several sources will be a crucial part of the business model, which considers aggregated content as the King.

5.3 Business Models for Future Services

Service systems [24] often refer to value-creation networks composed of people, technology, and organizations. The systems output digital information goods in different forms such as news, product comparison, travel information, electronic banking, financial services, digital games, music, and virtual goods. [20] In practice, the development of these services has resulted in an easier choice process, and higher competition, benefiting customers not only in price but also in comfort of use and transparency of offerings. When making choices, buyers pay more attention to the marginal cost of gathering information, as well as the marginal return, which could be gained after acquiring more information. [37]This marginal cost is called a search cost, which depends on the availability of information. However, consumers are not perfectly informed about available options in current service systems. To address this problem, one objective is to decrease the burden of the search process so that individuals can concentrate on the choice process. We see three main models supporting reduction of the search cost.

Audience or customer's attention economy In longer term, customer loyalty is maintained by providing them information that is credible and of high quality [14]. In intelligent ambient systems, the abundance of information and choice alternatives leads to a situation in which companies compete for consumer context (need, time, place) to provide accurate information as close to the decisive moment as possible. Therefore, the importance of managing and delivering correct information about different choice alternatives and reducing choice alternatives is one of the highest priorities for successful companies. Most high technology related innovation adoption being hardware, software, services, or a combination of them is dependent on an efficient communication process [32]. Empirical evidence from industries such as mobile phones suggest that the greater network effects of new technology leads to higher demand and economies of scale, which decrease hardware production costs. Consequently, these effects make new technology products more acquirable for wide masses with lower purchasing power.

High access-low entry cost based on a loss leadership model The *Economy of The Long Tail* is based on an idea in which selling *less is more* [5]. In practice, online delivery channels enable small producers (users, small enterprises) and not widely known brands to offer their information goods and services efficiently and profitably without high fixed costs compared to physical retail delivery channels. The success of digital goods and services of this type is dependent not only on easy availability but on awareness of positive user recommendation [11]. As a consequence, the increasing amount of specialized services enable mass customization in which many consumers may configure their service feed in many different ways based on their personal preferences.

Self-provision or very low cost information production Future revenues, coming from physical goods (devices) and information goods (applications and services) are more rarely sold separately to customers. Therefore, the perceived sum of these two offerings together has to be perceived higher than buying them separately. Traditionally, the selling of physical goods has been easier to adapt to consumers than information goods. Information goods suffer from the fact that they are relatively expensive to produce whereas cheap and easy to copy. Typical examples are digital music, games, and movies. Future success companies, instead of investing in copy protection and other regulatory measures, create business models that adapt by increasing the added value of their services. This all is done in a way in which consumers are interested in paying for them directly or indirectly through advertising. Great examples of a functional mechanism of this type are the monthly-fee based multi-player games. Furthermore, this provides an opportunity for a micro-market economy, such as, self-provision where very large user communities produce information for free or for a very low cost. Still, it is good to keep in mind that everything comes with an expense and there will be no ”free lunch” for consumers in the future, either.

6 Energy Consumption and Power Sources

The PCD requires minimum energy and can be powered by my body heat, my movement, or wireless electricity.

Batteries including lithium-ion (Li-on) and Lithium-polymer rechargeable battery systems have been successfully powering existing mobile devices [10, 3]. However, it has been and continues to be a challenge as batteries still present the most lagging technology and most frequent source of user frustration [12].This situation will become more critical as mobile phones and laptop computers merge to provide users with broadband wireless and multi-functional portable computing capability. Unfortunately, battery technology is unlikely to keep pace with these growing power demands. Higher energy density, higher specific energy or longer operational time between recharges of batteries will be a top requirement for consumers of the PCD device in addition to safety and environmental factors.Cutting the final cord of mobile devices has always been an attractive proposition for mobility. Losing the weight associated with batteries and battery packs is another engineering goal still on the drawing boards. For instance, replacing batteries with fuel cells is one of a series of alternative energy innovations to power mobile devices [30]. Energy harvesting is an innovation, which is attractive as inexhaustible replacements for batteries in low power electronic wireless devices. Energy harvesting (other names; Power harvesting, energy scavenging) is the process by which energy is captured from sources such as solar power, thermal energy, wind energy, salinity gradients, kinetic energy, and then stored [36]. Different techniques exist for harvesting power to augment or replace batteries in mobile and low-power electronics. Energy harvesting has grown from long-established concepts into devices aimed at powering ubiquitously deployed sensor networks. Systems can scavenge power from human activity or derive energy from ambient heat, light, radio, or vibrations [27].

7 Conclusions

In the scenario and the thematic sections we have presented various aspects of the evolution of telecommunication and networks. The core of the discussion has been digital convergence, in which computing, telecommunications, broadcasting, and ad-hoc sensor networks all merge into a single digital stream. This is manifested in seamless network connectivity when moving across networks. The users access the networks via miniaturized, yet converged, high-speed portable devices that consume less energy than today. Challenges facing the materialization of the future scenario are that – even if all the presented technologies could be available for wide use in 2025– it is uncertain, how fast the general audience will adopt these technologies. Because of this more culturally oriented challenge it is important to take into account the fact that technological innovations such as new applications and devices in the field of telecommunication media do not enter a cultural and communicational void. The communicative habits of the users are often quite persistent, and novel devices do not necessarily always conform easily to these conventions and practices. For example, if the personal communication device (PCD) introduced in this chapter is an evolution of the mobile phone, the cultural form of telephone communication will affect the practices and conventions of PCD use. The cultural form of a phone is predominantly in producing and communicating, rather than one-way receiving, which then has to be taken into account when considering the actual uses of the PCD. In this sense, the state of the art (mobile phone) determines the road map toward future (PCD), not just in relation to technology, but also to the cultural conventions relating to everyday communication. There are a multitude of other challenges as well. First, a low level of standardization of underlying technologies can threaten the evolution of interconnected devices. In practice, seamless mobility might be menaced by poor interoperability between different networks and devices. Second, there may emerge various challenges related to transfer capacity. The network data transfer capacity probably does not increase together with the ever-increasing amount of users with high-speed mobile devices. This may lead to lower experienced data transfer rates for each individual user. Third, the increasing environmental awareness and the lack of efficient power sources will force the redesign of the technologies. Therefore, the development of sensors, PCDs and other devices relies on the advancement of many other engineering fields such as energy related innovations. Furthermore, the costs of new technologies and services can also prevent their mass adoption. The currently ongoing economic turmoil will probably affect the adoption rate of new technology innovations. However, this does not necessarily mean that innovations adoption will become slower. In the essence of technology adoption the real value of new products and services will be in increasing not only the efficiency of work or leisure but also the general well-being of people. Actually, for many industries such as information and telecommunication technology this can be the beginning of a new era of great opportunities and new innovations.

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Glossary

1xRTT	Single-Carrier Radio Transmission Technology
AAA	Authentication, Authorization, Accounting
CDMA	Code Division Multiple Access
EDGE	Enhanced Data Rates for GSM Evolution
EV-DO	Evolution-Data Optimized
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
HIP	Host Identity Protocol
HSPA	High Speed Packet Access
ICT	Information and Communication Technology
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
MIT	Massachusetts Institute of Technology
OFDM	Orthogonal frequency-division multiple
QoS	Quality of Service
RFID	Radio-frequency Identification
TD-SCDMA	Time Division-Synchronous Code Division Multiple Access
TI	Texas instruments
UMB	Ultra Mobile Broadband
UMTS	Universal Mobile Telecommunication System
UWB	Ultra-Wideband
WCDMA	Wideband Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WMAN	Wireless Metropolitan Area Network
WPAN	Wireless Personal Area Network
WWAN	Wireless Wide Area Network

6 http://mide.tkk.fi/en/BitBang

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1.3 Printed Electronics, Now and Future

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Abstract

The purpose of this paper is to study the development of printed electronics and the impact of digitalization on it. At first, several common printing techniques as well as the materials relating to printed electronics are explained from the standpoint of the technology. In addition, the state-of-the-art applications of printed electronics are introduced in brief. Finally, the possible development and changes of both technologies and applications of printed electronics in the future to the year 2025 are predicted by means of a roadmap and a scenario.

Glossary

Circuit: A circuit is a closed path formed by an interconnection of electronic and electrical components through which electric current can flow. These components include voltage sources, current sources, resistors, inductors, capacitors, diodes, transistors, and switches so on.

Computation: From the standpoint of technology, computation refers generally to any kind of systematic information processing that is typically performed digitally with electronic devices.
adjust and react to changes in the environment.

Diode: A diode is a specialized electronic component with two electrodes called an anode and a cathode. Most diodes are made of semiconductor materials e.g. silicon, germanium or selenium. Its fundamental property is a tendency to conduct electric current in only one direction.

Display: A display is an output device for presenting information for visual or tactile reception. It can be based on various technologies, e.g. cathode ray tubes (CRTs), plasma cells, liquid crystals, and light-emitting diodes (LEDs).

Electronic paper (e-paper): E-paper is a display technology designed to mimic the appearance and usability of a traditional paper for presenting information. It can provide additional functions, e.g. interactivity and updatability, also physical flexibility.

Electronics: Electronics refers to the flow of charges (moving electrons) through nonmetal conductors, mainly semiconductors.

Hybrid media: Traditionally, hybrid media are the storage that supports various data formats. Recently, they refer to emerging forms of multimedia taking inspiration from the convergence of printed and digital media and typically offering some kinds of additional functions to traditional mainstream media service.

Ink: Ink is a liquid containing pigments, dyes and solvents, which is used in a printing process for adding thin, partially pervasive material layers on a surface. Typically, ink layers are appended in specific shapes and after a period of drying they are solid and enduring.

Nanotechnology: Nanotechnology is based on controlling chemical and physical properties of matter on an atomic and molecular scale, and thus dealing with structures of the size 100 nm or smaller. It is strongly focused on developing new types of enhanced materials. Nano- is an SI prefix indicating a value of 10.

Organic light-emitting diode (OLED): An OLED is a diode which can emit light from an electroluminescent layer that is composed of organic, e.g. carbon-based, compounds placed on a polymer substance. OLEDs are also known as light-emitting polymers (LEP).

Photovoltaic cell (PV cell): A PV cell is a device that can generate electricity from solar energy by the photovoltaic effect, also termed the Hertz effect. In this effect, electrons are emitted from matter due to electromagnetic radiation.

Polymer: A polymer is a large molecule consisting of repeating structural units (monomers) typically combined so that pairs of electrons are shared between atoms (covalent bonds). A polymer, at least in principle, consists of an unbounded number of monomers.

Printed electronics (PE): Printed electronics defines the printing of circuits which include various components, e.g. transistors, diodes, antennas, etc., with conductive ink on the surface of paper, cardboard or plastic, etc. Usually, the ink and surfaces to be printed can largely vary to provide tailored functions.

Printing: Traditionally, printing is a process of reproducing text and images with ink on paper. More generally, it is a process of adhering one or more material layers on a surface.

Radio frequency identification (RFID): RFID is an automatic identification method based on storing and retrieving data remotely from mobile tags by using radio waves. Most RFID tags contain an integrated circuit and an antenna, and possibly a battery.

Roll-to-roll printing (R2R printing): R2R printing is a kind of rotary printing technique that allows target material surface to move constantly during the printing process thus increasing cost-efficiency. Traditionally, it is used in printing newspapers, and more recently, is applied to printing flexible displays.

Semiconductor: A semiconductor is a solid material which has electric conductivity between those of a conductor and a dielectric. Traditionally, silicon has been considered as an exceptionally favorable material to produce semiconductors. Now, printed semiconductors are developing more rapidly than silicon semiconductors, as shown in Fig. 1.

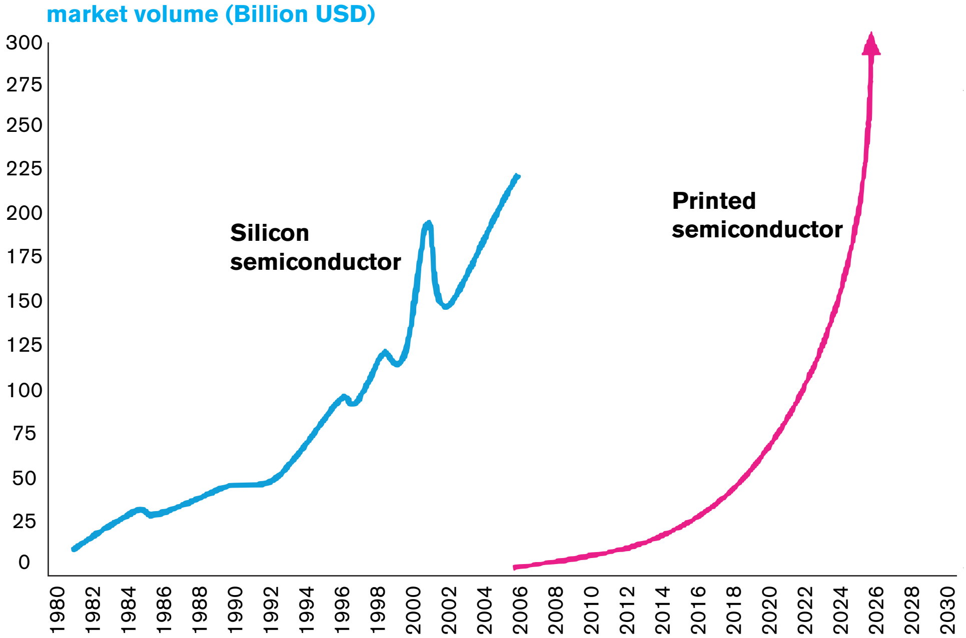


Figure 1. The changes of market volume of silicon semiconductors and printed semiconductors.

Ubiquitous service: Ubiquitous service is a kind of service which is ideally universally reachable in every place and time provided by efficient mobile and embedded technologies. In practice, some trade-offs are needed.

1 Introduction

The first printing revolution began with Johannes Gutenberg from Germany in the 1440's. The information stored in books broke the boundaries of institutions, so it stabilized scientific discussion and made it possible to refer to books. The second printing revolution came with the Internet and personal printing. It broke out a new level of communication that was predicted in Marshall McLuhan's pioneering book Gutenberg Galaxy in 1962 [mc1962]. It made paper and books old fashioned, slow, and reforms our society and science all the time. The third printing revolution is still coming. Five hundred years or so after the first, this revolution combines the achievements of the printing industry and those of the electronics and digitalization world. This presentation is trying to make this process visible to the common public — at least from some important points of view.

Printed electronics (PE) is a term that defines the printing of circuits on media such as paper and textiles, but also on a large number of potential media. The recent rapid development of PE technology is motivated by the promise of low-cost, high-volume, high-throughput production of electronic components or devices which are lightweight and small, thin and flexible, inexpensive and disposable.

Conventional electronics based on silicon material will dominate the area of "high-end electronics"applications with a high integration density and high switching speed in the foreseeable future. PE is not a substitute for conventional silicon-based electronics, but it opens a new world of low-cost printed circuits based on conductive, semiconductive and dielectric printed materials aiming at high-volume market segments where the high performance of conventional electronics is not required, as can be seen in Fig. 2.

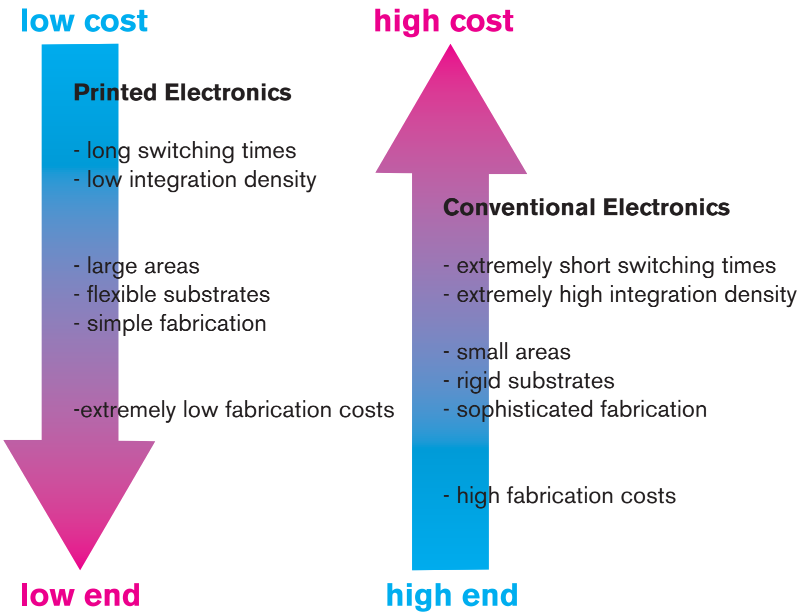


Figure 2. Printed electronics and conventional silicon-based electronics as complementary technologies. (Source: [15])

The actual processing power depends on various aspects, but readers can gain some understanding from these facts. The first printed transistor was made in 2003, and a ring oscillator was printed in 2005. The oscillator consists of 14 transistors at a printing speed of 0.8 m/s and its switching frequency was 1 Hz. The problem of manufacturing so-called organic complementary metal oxide semiconductors (CMOS's) like circuits, which contain both n-type and p-type semiconductors, was solved in January 2009 [1]. For comparison we must remember the computer on the Apollo landing module to moon. It was the first computer to use integrated circuits (ICs) running at 1 MHz, and it offered four 16-bit registers, one 4–kB RAM and one 32-kB ROM.

In the printing industry, the cost structure is different from traditional inorganic electronics technology, where labour and manufacturing techniques are the major costs in the end products due to the requirements of dedicated materials, doping compounds, encapsulation and so on for each type of devices. For instance, currently used silicon-based RFID devices are expensive for commodities such as food at the consumer package level. Currently silicon-based RFID tags cost more than $0.2 per tag, whereas acceptable cost requirements for item-level tagging are less than $0.01 per tag. The practicality of PE relies primarily on the development of ink used to create semiconductor electronic components, being here the main cost consumption, while traditional printing processes are applied. By keeping down production expenses, PE gains its potential value. In general, the cost of PE is expected to be two or three orders of magnitude cheaper than Si per unit area. Moreover, PE technology could provide a number of enabling factors like flexibility and robustness, allowing incorporation of electronics functions into objects that do not yet contain any active electronic components, e.g. toy applications, printed advertising material or electronic labels [2]. However, innovations in materials to enable printing depend on advances in material science that can produce functional ink forming electronic devices as well as the substrates where they are printed.

An extra advantage of PE is lower capital investment cost. It is estimated that a PE plant will cost $30 million in comparison with $3 billion for a silicon fabrication plant [3]. electronics)

PE, according to [4], covers a broad range of application and technology domains as follows.

- Optical codes (1-D bar codes, 2-D bar codes, reactive codes).
- Hidden or embedded codes (invisible codes, digital watermarks, magnetic codes).
- Electronic codes (RFID tags).
- Visual effects (holograms).
- Multilayer structures.
- Electronics (passive components, conductors, circuit boards).
- Optics (light guides, micro lenses).
- Displays (OLED displays, liquid crystal displays, thermochromic displays).
- Sensors and indicators (temperature, moisture, oxygen, chemical compounds).

It is important to analyze the technical applications that are emerging and that can appear in the future in relation to the improvement of the integration of knowledge and development from printing technology and electronics as well as from chemistry and materials science. Important economic and societal consequences can result from these applications.

Simple visual ontology of the printed electronics showing the interactions among different technical, scientific and application domains is shown in Fig. 3. It illustrates some major performance consequences of printed electronics technologies and emphasizes various domains that are closely related to development in this area.

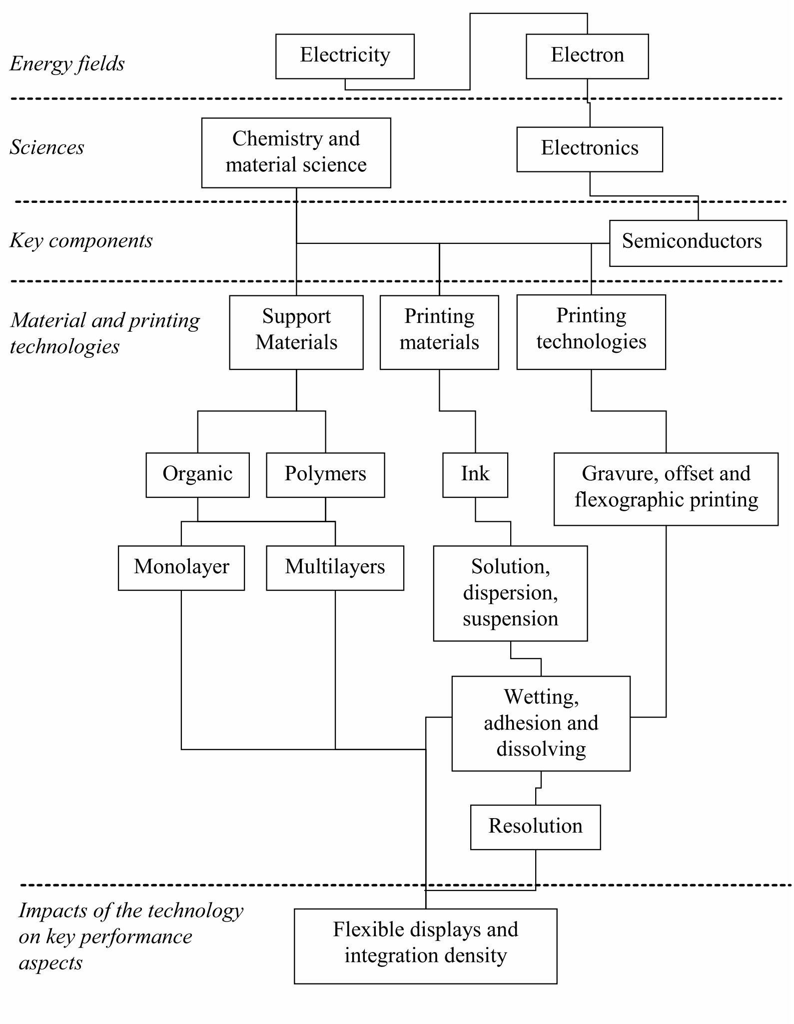


Figure 3. Graphic ontology of printed electronics technologies and potential fields of its applications.

2 Technology of Printed Electronics

2.1 Processes

Traditionally, the term *printing* refers to the process of reproducing text and images on paper. In the context of printed electronics, printing is understood as the process of adhering electronically functional materials to various parent surfaces such as paper and plastic. Traditional electronics manufacture utilizes technologies that are similar to printing plate production technologies. Discs of silicon are etched and patterned using a technology that resembles printing plate processing. In traditional printing, the printing plate is etched to produce a passive master pattern for prints to be made. In contrast, a functional circuit is produced as the end result of silicon semiconductor manufacture technologies. Regardless of the difference in the end result, the same technological advances work in both application areas. A natural continuation of this development is to utilize the full range of printing process technology to print the electronics directly.

Although the history of printing dates back to ancient times, perhaps the most revolutionary step in the history of printing was the discovery and the broad application of the printing press that utilized a movable type printing system. Movable type allowed composing limitless combinations of text with reusable and consistent letter elements. Combined with printing press technology, movable type reduced the cost and time to reproduce written text compared to the previous alternative of manual copying. The reduced cost and the vastly improved capacity to produce text caused a revolution in the spreading of information, heavily influencing communication and book-manufacturing, and consequently shaping the development of commerce, law, religion and culture.

The Chinese were the first to invent movable type printing technology in around 1040. However, the technology never gained significant popularity in China. The most obvious obstacle to commercial success in China is the fact that in written Chinese, a symbolic basis is used instead of an alphabet basis. The consequence is that implementing a movable type printing press requires thousands of elementary types instead of a few dozen. In addition, the technology was monopolized in China by the state. Metal movable type was invented in Korea around 1230 but similar difficulties prevented its popularity. In Europe, however, the situation was different. The commercial and technological aspects met in Johannes Gutenberg's press in around 1439, resulting in the rapid expansion of printing. An additional innovation was made by Gutenberg's student, Aldus Manutius. He was the first to produce inexpensive books in a small format whereas the traditional book size from a press used to be too big for practical portable use.

The earliest documented printing method utilizes wooden blocks in which the to-be-left-white areas were carved away. A print is simply produced by inking the block and pressing it against the target material surface, thus producing a negative of the engraved pattern. The movable type system uses the same relief printing principle of adhering ink to the surface of the type faces and then pressing against the target material. The following paragraphs will introduce several later printing techniques in more detail.

Intaglio printing refers to the family of printing processes where a plate or a matrix is carved with a pattern of recesses and then applied with a layer of ink. Next, extra ink is wiped away, leaving it only on the plate recesses. Lastly, the target material, e.g. paper, is pressed against the plate, allowing the ink pattern to adhere on the target material surface.

Lithography is a technique that involves the use of an entirely smooth surface plate. The differentiation between inked and non-inked areas is achieved through selectively applying a hydrophobic substance to the plate, creating the desired patterns. Because the hydrophobic substance is partially absorbed into the plate, the surface remains perfectly flat with only a thin surface film where the hydrophobic areas are located. By using a mixture of an oil-based ink and water and applying the mixture to the plate surface, the ink will only remain in the hydrophobic-treated areas. Subsequently, by pressing the ink-covered plate against the target material, an image will form. The benefit of lithography over intaglio printing is the fact that a flat plate surface allows longer and more detailed print runs. Lithographic technique, i.e. photolithography, has also been used in micro- and nanometer-scales, typically in semiconductor and micro electromechanical system (MEMS) manufacture.

Rotary printing processes are a family of printing techniques that are based on rotating cylinders instead of planar plates. Rotary printing can be divided into three main categories: flexography, offset (lithography) and rotogravure printing. Flexography printing typically utilizes a rubber or polymer cylindrical printing plate that has the desired to-be-printed pattern engraved as a positive relief in it. A print is produced by attaching ink to the printing cylinder with a specifically designed engraved roll in which the amount of ink is controlled by the engraved texture. The printing cylinder is then allowed to roll over the surface of the target material, transferring ink onto it. The quality achieved through flexography is generally considered sufficient only for low-precision task such as packaging material printing but recent development in the area allows for competitive quality gain. The benefits of the flexographic process compared to lithography are that a wider variety of inks can be used, e.g., water-based inks instead of only oil-based inks and the options for target materials are wider.

The second category of rotary printing is offset lithography printing. The basic principle of lithography holds but the lithographically produced print is not directly attached to the target material but first transferred to an intermediary cylinder, i.e., offset. The offset cylinder is typically made of a flexible material such as rubber to allow better contact with the surface of the target material. Consequently, quality is increased and the printing output is more consistent. In addition, the use of an intermediary offset cylinder prolongs the lifespan of the printing plates due to reduced wear and tear compared to directly contacting the printing plate with the target material. The quality of offset printing is high, only considered slightly inferior to the quality of the rotogravure technique.

The final main category of rotary printing is rotogravure. The rotogravure applies the intaglio printing technique to cylindrical printing plates. The rotary implementation of the intaglio printing allows very high printing speed and quality. A major factor behind the quality potential of the rotogravure process is the amount of ink it can facilitate, resulting in a high dynamic range of the printed output ranging from very light tones to very dark ones. A limiting factor of the gravure quality is that the printed output consists of small dots that are often visible to the naked eye.

The printing techniques mentioned above rely on applying pressure against the target surface. In contrast, screen printing allows printing without applying pressure and on nonplanar surfaces. The process of screen printing uses a mesh that supports an ink-blocking layer, stencil, forming a negative image. Ink is then applied on top of the stencil screen, filling the open areas of the mesh, and finally transferred to the target surface when the screen mesh contacts it. The ink moves from the mesh by the effect of capillary force and the amount of ink transferred is precisely controlled by the mesh or stencil thickness. The actual screen printing process may use flat, cylindrical or rotary mesh shapes. Due to the flexibility of the method, screen printing can be used in a variety of applications ranging from clothing printing to circuit board manufacture.

Whereas screen printing allows printing on nonplanar surfaces, different techniques are needed for printing on more arbitrary 3-D object surfaces. One such technique is pad printing. In essence, pad printing uses the basic principle of indirect offset printing, i.e., the to-be-printed pattern is first offset to a temporary surface and from there to the final destination. The temporary surface, in this case a pad, can be flexible enough to allow sufficient contact with the target surface 3-D shape. A typical pad material fulfilling the requirement is silicone. Pad printing is primarily used when the target surface is too difficult for other printing techniques.

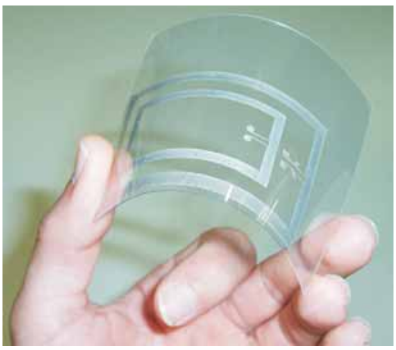
Digital printing makes highly customized printing jobs possible because a physical master of the to-be-printed image is not needed. Instead, the image is only represented as information in a digital form. The benefits are obvious, that is, every print can be different without an additional cost. Furthermore, less waste with respect to chemicals and target material is experienced. The printing methods most commonly implemented digitally are laser printing, dot matrix (impact) printing, thermal printing and inkjet printing. As a new area of applications, digital printing makes 3-D printing feasible.

Inkjet printing is a versatile technique for transferring liquid (ink) to produce a printed pattern. Three main technologies exist, thermal inkjet, piezoelectric inkjet and continuous inkjet. In thermal inkjet, a heating element causes a gas explosion in a small amount of ink, forming a bubble that is consequently directed to the target surface. In piezoelectric inkjet, a piezoelectric element changes its shape as a result of an electronic pulse, inducing a mechanical pressure to a small amount of ink that will as a consequence be forced out of the printing nozzle. Respectively, in the continuous inkjet, a constant pressure is applied to the ink, producing a continuous flow of ink that is then controlled to produce differently sized ink droplets. Typically, the droplet sizes in inkjet printing are in the scale of 50µm –60µm and the obtained resolutions can exceed 1400 dots per inch in home-market printers. In addition, as many as six different color ink cartridges can be utilized in photo-quality printing. Inkjet printing has a wide application range from ordinary printing to 3-D printing, printing of functional materials and production of microscopic items such as MEMS.

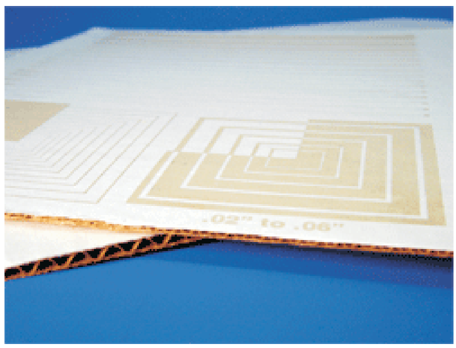
2.2 Materials

PE is based on electrically active materials that can be used as conductors, semiconductors, dielectrics, and luminescent, electrochromic, electrophoretic or other functional materials. Developing a material is the main challenge of PE since various conditions of the printing process have to be satisfied, like low temperature deposition, high throughput, interplay with other layers including compatibility of printed layers in terms of wetting, adhesion and dissolving as well as drying procedures after deposition of liquid layers, all having a large influence on the device performance.

The main requirement of printed materials, besides actual electronic functionality, is their processability in liquid form, i.e. solution, dispersion or suspension. PE can utilize various solution-based materials including both organic and inorganic materials. Typically inorganic materials used for printing are dispersion of metallic micro- and nano-particles, i.e. silver, gold or copper particles in a retaining matrix. These so-called metallic-based conductive inks are commonly used for printed antennas of RFID tags, conductive tracks and circuit components on both flexible and rigid substrates as shown in Fig. 4. There are also carbon-based inks with carbon flakes or particles in a retaining matrix, which due to lower electric conductivity, are mostly used for electromagnetic interference or radio frequency (RF) shielding (e.g., on monitor screens or speakers).



(a) A coil printed by conductive silver ink on polymer flexible substrate. (Source: [26])



(b) An RF antenna printed onto corrugated stock. (Source: [27])

Figure 4. Applications of conductive ink.

The development of printed organic functional materials started with the discovery of the so-called *inherently conducting polymers* (ICPs) in 1977 (Noble prize in chemistry in 2000). The discovery of new fundamental properties of polymers to conduct electricity to a degree approaching that of copper, when previously considered to be electrical insulators, gave rise to new applications. The applications of high conductivity polymers, labelled as *organic metals*, include conductors, electromagnetic shielding, batteries, capacitors, resistors etc. Lower conductivities are applied in antistatic applications or anticorrosion coatings. ICPs in the semiconductor state are used for the realization of organic light-emitting diodes (OLEDs), organic field-effect transistors (OFETs), solar cells, sensors and electrochromic displays.

Organic semiconductors are of great interest for electronic applications being solution-processable and compatible with direct-write printing-based manufacturing techniques. A crude measurement of organic semiconductors is charge carrier mobility, the speed with which charge carries traverse the semiconductor, determining the speed of transistor switching. However, the charge carrier mobility of organic semiconductors is much lower than that of crystalline silicon. Most transistors based on solution-processable organic semiconductors have low mobilities of less than 0.1 cm^2/Vs, though a number of solution-processable organic semiconductors have been shown that reach and even surpass the values known from amorphous silicon (a-Si) and are expected to reach those of polycrystalline silicon (p-Si) in the coming years, as can be seen in Fig. 5. This will be achieved with the development and optimization of small molecule materials and polymers as well as new materials, e.g. inorganics, carbon nanotubes, hybrid (organic-inorganic) materials.

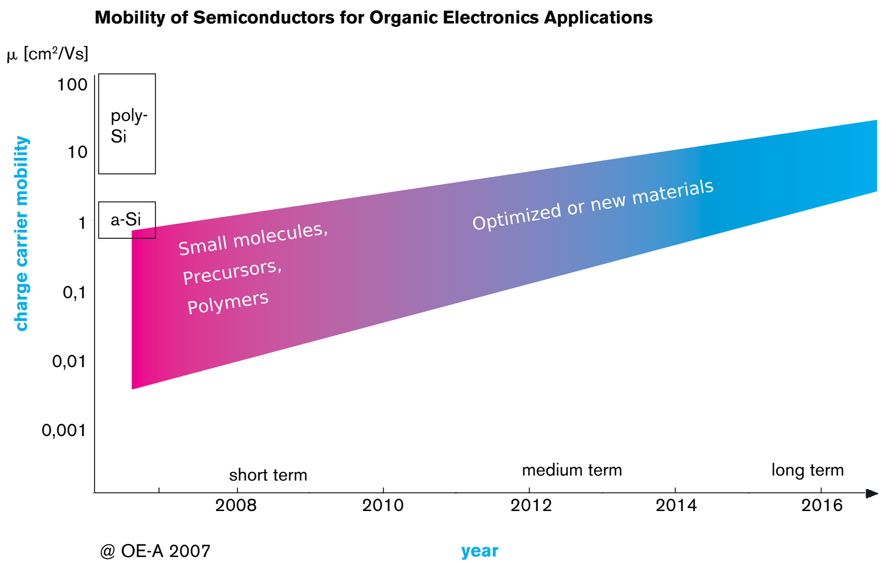
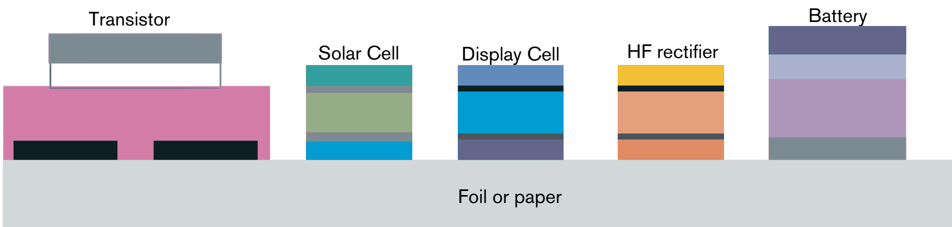


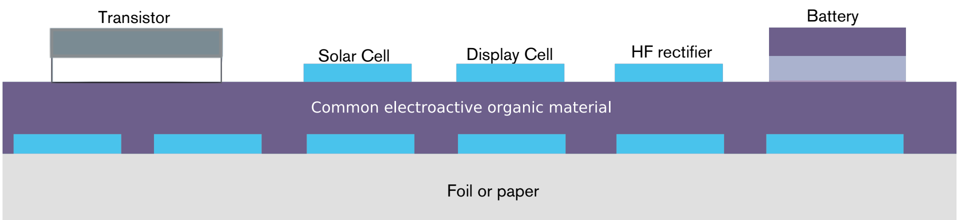
Figure 5. Roadmap for the charge carrier mobility of semiconductors for organic electronics applications given by Organic Electronics Association (OE-A). The values refer to materials that are available in commercial quantities and to devices that are manufactured in high throughput processes. The values for amorphous silicon (a-Si) and polycrystalline silicon (p-Si) are given for comparison. (Source:[10])

The realization of solution or dispersion processing of inorganic and small molecule organic semiconductors, besides commonly used evaporation techniques, allowed the compatibility of these materials with printing processes. Applications of inorganic PE is demonstrating a growing success, e.g. flexible AC electroluminescent displays (Pelikon and Elumin8, UK; Schreiner, Germany), flexible solar cells (Spectrolab, US), flexible electrophoretic display back plane driver (Toppan Prining, Japan).

In traditional printers, there are five to ten printing stations available, each including one or two convection, infrared or ultraviolet curing steps. The cost for printing scales linearly with the number of printing steps. The key to achieving low-cost printing technology lies in making simpler electronic systems that can be produced in fewer manufacturing steps. Multifunctional electroactive organic materials can offer the advantageous solution of being used for different devices of the same integrated system that differ only in device architecture and choice of electrodes as shown in Fig. 6.



(a)



(b)

Figure 6. One material to fit all? (a) The focus on individual components that is currently prevalent in the organic electronics community leads to a non-realistic device system that is almost impossible to print in traditional presses. (b) Instead, one common material could be used to make whole systems in just a few printing steps if the focus can be changed to using the same materials in different device architectures. (Source: [17])

It is a challenge for material scientists to design the material, or system of several materials, that will provide the necessary properties of all the discrete devices in a system. For example, poly[2-methoxy-5-(2'-ethyl-hexyloxy)-1,4-phenylene vinylene] (MEH-PPV) or pentacene are used as electroluminescent materials, which on the other hand possess decent field-effect mobilities in n- and p-channel operation combined with an appropriate gate dielectric in a transistor. So the same material can be used for the fabrication of field-effect transistors and light-emitting diodes. Thus a multifunctional organic material approach allows the reduction of the number of different materials used for making printed devices, as well as minimizing the number of patterning and material deposition steps. For organic components integration of multifunctional devices on a common substrate using a common set of manufacturing technologies is simpler than, for instance, for silicon-based devices. An example of a multifunctional device can be an ambient intelligent device monitoring some variable and providing information on request. Such a device might use a thin-film battery or a solar cell as a power source, OFET circuit for information processing, a keyboard or touchpad sensor for data input, and an optical display for visual access to the information stored in such a device [2].

Therefore, organic materials allow a number of advantages, i.e. large area coverage, processability in liquid form, low-temperature processing, structural flexibility and as well as possibility for functional properties adjustment by means of chemical modification. Earlier research showed that most organic materials are only p-type semiconductors where hole transport is favoured against electron transport, (e.g., pentacene and polythiophene). However, materials conducting both positive charge carriers (p-type) and negative charge carriers (n-type) are needed for printed CMOS circuits. Recently researchers have developed a polymeric n-channel semiconductor based on naphthalene-bis (dicarboximide) which are highly soluble and have an electron mobility between 0.45 cm^2/Vs and 0.85 cm^2/Vs and the ongoing research is targeted toward the improvement of this value up to that of a-Si: 1 cm^2/Vs [1]. Many organic materials, however, have stability problems in the air due to their interaction with the surrounding environment, which reduce the lifespan of printed electronic functional layers. For instance, some applications, like active-matrix OLED displays, require very high stability, as well as low charge mobility values. For many applications, the performance of fully printed organic transistors, in particular, is still insufficient. Besides material parameters, like charge carrier mobility, the switching speed of an integrated transistor circuit at certain operating voltage depends on the geometrical dimensions of the circuit. All-printed organic FETs have a limitation of achievable linewidths of 20 µm–100 µm, though some printing processes, like self-aligned inkjet printing, have been demonstrated allowing submicrometer channel lengths of organic transistors [2].

Carbon nanotubes (CNTs) could be one alternative to organic materials capable of outperforming some organic semiconductors and enabling faster circuits due to much higher charge mobility values. Recently the application of CNT films for printing various devices and components like thin film transistors, diodes, logic circuit elements, solar cells, displays, sensors, etc. has been the subject of profound research interest owing to the excellent electrical performance of CNTs, great mechanical flexibility, and potential for low-cost mass fabrication. Single walled CNTs are also suitable additives for conductive plastics, bringing a broad range of conductivity to plastics with fewer nanotubes needed to achieve the same desired conductivity (less than 1% in some cases) as with conventional carbon-based additives. At the same time material reinforcement and enhanced thermal conductivity are achieved. However, being a relatively new technology it is expensive. This currently limits the potential of these nano-carbon products.

Thus in PE, in contrast to traditional inorganic electronics, there is a high expectation for the materials performance, capable of offering a cost-effective path toward mass-production of large-scale electronic circuits without the need for special lithographic equipment.

3 State of the Art

3.1 Standards

Testing Standards If rapid implementation of a reliable and competitive supply chain is required for achieving the promises of very low-cost electronics, a key method of aligning potential suppliers and original equipment manufacturers is through the development of standards. Standardization, particularly through international organizations such as the Institute of Electrical and Electronics Engineers (IEEE) and the International Organization for Standardization (ISO), has long been instrumental in the formation of profitable enterprises. For example, the Wi-Fi standards, IEEE 802.11, have allowed for explosive growth in wireless local Internet access worldwide, which would have otherwise stagnated if a mix of proprietary standards was allowed to reign. There is a need for globally accepted standards to be in place to enhance the widespread commercialization of PE. In particular, standard methods of characterizing and reporting electrical properties of organic transistors and circuits are necessary for accelerated movement toward commercialization. During the pre-competitive development stage, this allows a stronger collaborative environment, with more rapid sharing of testing parameters. Finally, standardization allows efficient assessment of new materials, ink, and other supplies from vendors, qualification of press equipment and other manufacturing equipment, plus provides the foundation for quality assessment during device fabrication. The first successful standard in organic electronics was IEEE Std. 1620™–2004, *Test Methods for the Characterization of Organic Transistors and Materials*. The standard sets preferred methods of releasing data and test conditions, so that the results may be objectively evaluated. The effort of this standard is continuing with IEEE Std. P1620.1, developing a standard for characterizing ring oscillator circuits. The above two standards can be found in [5] and [6], respectively.

Manufacturing Standards The use of low-cost manufacturing techniques such as those used in graphic arts printing processes promises to enable the manufacturing of cheap flexible electronic products. Based on our analysis, few standards exist for printing colored ink. We did not find any at the time of publication for using printing techniques to manufacture electronics. Furthermore, the use of hybrid manufacturing processes such as inline use of inkjet printing and photolithography requires reliable communication among different pieces of equipment. In order to ensure successful product manufacturing, standards are required in data exchange specifications. Also, standards may need to be developed at the component level for the successful creation of contract manufacturing business for flexible electronics. Such a standard will include recommendations for component features, specifications, tolerances, test methods, shelf life, storage conditions, material handling procedures, and component integration methods.

PE is expected to have a great impact on the traditional product development process of the computer industry. Software is going to manage functions that were previously handled by hardware and vice versa. A new kind of collaboration in design and production is needed.

PE will provide a large variety of interactive components and sensor networks that are capable of collecting, holding, processing and sharing data. This also implies a radical change in programming paradigms related to communication without interference, concurrently running programs and complex management systems to monitor and adjust the overall operation. Developing devices with a miniature size will bring challenges with respect to computational efficiency, limited energy and bandwidth, heat balance and the changes in electromagnetic phenomena on a small scale, fault tolerance and error recovery. Knowledge of embedded systems can valuably support developing technology of PE.

Since the store of information is becoming more affordable and the amount of information grows constantly, it poses new requirements for managing the history of data. Many devices benefit if data can be updated frequently to reflect changes in the environment. In many cases, historical data has a specific value for predicting and adjusting future functionality. In the future, official documents will likely record a detailed log of the events in which the document has been involved.

Thus, the authenticity of electronic documents and their usage history could be verified in a new manner and with particular detail, for example with trade treaties, health statements, insurance agreements, degree certificates and diplomas. Many of these types of information could have a significant economic, political and strategic value. Society might become largely dependent on the reliability of electronic documents.

There is a need to store data in such formats and encodings that remain compatible and easy to interpret even in the far future. Metadata and redundant variants of the original data can help to accomplish this aim while still trying to keep the data in a compact form.

Electronic documents also require encryption techniques, but, due to their small scale and limited computational power, the structures might not easily allow suitable complexity for encryption. Also disposable documents pose a challenge to security.

An access rights management system could provide different kinds of rights for perceiving the data, modifying it and deleting it, making copies or transmitting the contents elsewhere.

Formerly, it was usual in product development to implement prototypes and to perform user testing, and with the gained results to iteratively develop better prototypes until an acceptable level was reached. With PE it is no longer so easy to control prototype testing since the spectrum of new devices is becoming more complex and can consist of many interacting components. Therefore, the user experience is reaching forms that are difficult to describe and measure. Many new services will be provided in a constant beta testing manner like currently many of the products of Microsoft and Google.

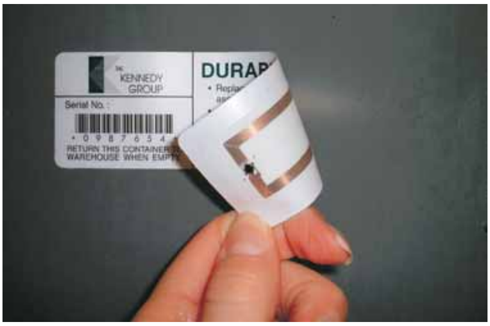
3.2 Main Applications

Radio Frequency Identification (RFID) Tags RFID is an automatic identification technology, relying on storing and remotely retrieving data by using devices called RFID tags or transponders. The first application dates back to World War II when it was used to identify enemy fighter planes during the war. Since the end of the 1970's, the RFID technology has been in use in both military and civil domains.

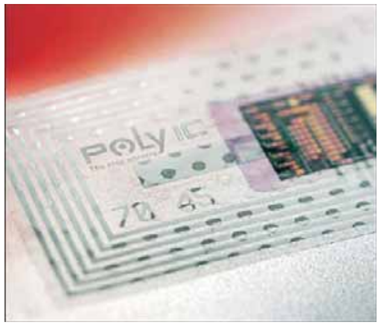
An RFID device mainly consists of two parts: a tag or transponder and an interrogator or reader. The tag or transponder is the part to which printed electronics technology can be applied. A typical RFID tag contains at least an antenna and a microchip. An additional power supply is also needed for active RFID tags. An RFID tag can be used in many aspects of people's daily life, e.g. labeling cartons for packaging and transportation, identifying items in shops like bar codes, and so on. In 2007, the sales amount of the RFID tag market was $3.8 billion, and it will rise to $8.4 billion by 2012.

The traditional manufacturing technique of the microchip and antenna of an RFID tag is based on the silicon semiconductor technique. Although the traditional technique is mature, the cost of an RFID tag is so high that the price of an RFID tag is more than $0.2. Therefore, RFID tags have not been widely used. For instance, the cost of a bar code commonly used now is only $0.001–$0.002, which is much cheaper than an RFID tag, so Coca Cola said that they would not consider using RFID tags until the price decreased to $0.01 per tag.

By introducing printing techniques, the microchip of a normal RFID tag can be replaced by printed transistors, so it is predicted that the price of a printed chipless RFID tag can be reduced to $0.01–$0.02, or even lower. In this case, RFID tags will



(a) A printed RFID tag. (Source: [18])



(b) A printed RFID tag by PolyIC from Germany. (Source: [19])

Figure 7. Printed RFID tags.

have a huge global market. For example, in identifying items in shops, RFID tags will become a competitive substitute with a considerable potential for bar codes, since an RFID tag can store much more information and can be sensed through a much longer distance than a bar code. Furthermore, a printed RFID tag can be applied to certain applications where a traditional RFID tag is difficult to attach. For example, it can be attached on the bent part of a carton due to its good flexibility. Fig. 7 shows examples of printed RFID tags and antennas.

The number of RFID devices was 0.6 billion in 2005, 1.2 billion in 2006, and 4.1 billion in 2007. However, in 2007, the number of printed RFID tags was just 125 million, 3% of the total 4.1 billion RFID tags, and the cumulative sale amount of printed RFID tags was just 0.8% of the RFID global market. It is predicted that in 2017, it will rise to 62.3% of the global market.

Nowadays, the antenna of an RFID tag is printed and the working frequency of printed antennas can reach high frequency (13.56 MHz) and even ultrahigh frequency (433 MHz–960 MHz), which meets the requirements that an RFID tag can work. However, current problems such that hinder the development of the printed RFID tag market lie in the printing of transistors which replace the microchip, because printed transistors, now, can only work under very low frequency which is not compatible with the working frequency of interrogators. In addition, at most, hundreds of transistors can be printed based on current printing techniques, whereas a normal printed RFID tag needs about tens of thousands of integrated transistors. Another problem is that the life of a printed transistor is not as long as a silicon transistor. Therefore, although printed transistors used in an RFID tag have been used since 2008, their features still cannot compete with traditional silicon transistors.

Accurately speaking, the printed electronics technology used in the area of printed RFID tags is still in the exploring phase. Of course, due to the huge potential of printed RFID tags, some companies, (e.g. IBM and Organic ID in the US and

PolyIC in Germany.), show great interest in developing printed RFID tags and have made some contributions to printed RFID tags. 3M in the US, developed a new cheap plastic material, pentacene, to replace the silicon crystal material to make RFID tags and their tests show that RFID tags based on pentacene can work quite well with an interrogator within the distance of several centimetres. Another US company, Organic ID, has developed RFID tags with a working frequency increasing to 17 MHz by the end of 2004. In 2006, PolyIC in Germany announced that they had developed an RFID tag with 8-bit memory capacity by using an R2R printing technique to integrate several hundreds of transistors, and they said that the life of these RFID tags could be at least one year. Then, in June 2007, they also developed RFID tags with 32-bit and 64-bit memory capacity and the working frequency was kept at 13.56 MHz. In 2005, IMEC in Belgium, developed an organic rectifier diode capable of powering a passive RFID tag operating at a frequency as high as 50 MHz. In addition, IMEC estimated that its rectifier design could be developed further to reach 800 MHz in the ultrahigh frequency range.

Moreover, for an active RFID tag, an additional power supply, such as a battery, is needed, so a thin printed battery with a flexible shape could be another potential application based on printing techniques. For example, Enfucell in Finland, specializes in developing this kind of printed battery. In 2007, they developed a printed battery, SoftBattery, and they estimated that once these batteries are put on the market, the price will go down to $0.01 and it will have an impact on printed RFID tags.

Organic Light-Emitting Diodes (OLEDs) An OLED is an LED that has an emissive electroluminescent layer which is composed of a film of organic compounds. The technology of OLED was found by accident in 1979 and the first diode device based on this technology was invented at Eastman Kodak in the 1980's. Then, there has been rapid progress in developing OLEDs during the last decade. In 2007, the global market for OLED products was $1.4 billion. It is forecast that in 2012 this number will be $10.9 billion and will rise to $15.5 billion in 2014.

Traditional OLEDs based on thin-film transistors have some obvious shortcomings. For instance, their life is shorter and the power cost is higher than a liquid crystal display (LCD). Moreover, the production cost of an OLED is so high that the application products of OLEDs are expensive.

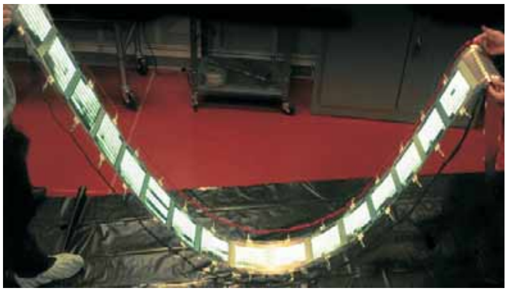
Nowadays, the manufacturing process of OLEDs based on printing techniques is known as an effective means to reduce the cost of an OLED display and as a good means to implement the production of large-screen OLED displays. Compared to the common LCDs, printed OLED displays enable a greater range of colours, brightness, contrast and viewing angle than LCDs, because OLED pixels emit light directly. In addition, the response time of a printed OLED display is more than one thousand times faster than an LCD, so printed OLEDs are quite suitable for displays.

Traditional printing techniques are inkjet printing, and screen printing. Inkjet printing is used to print light-emitting polymer materials with different colours and then to form the 100-nm-thick light-emitting pixel, and screen printing is mainly for manufacturing the cathodes for the displays. By these printing techniques, the efficiency of utilization and production of materials can be increased so that the cost may be reduced. Another important printing technique used in OLEDs is the R2R technique. Based on an R2R technique, OLEDs can be printed on very flexible and soft substrates, instead of on hard panel, so soft OLED displays will be an important potential application.

Nowadays, many companies invest a large amount of money in the development of printed OELDs. PlasticLogic, a UK company, invested $0.1 billion to set up a factory in Germany and produced the first OLED display based on the printing techniques. Add-Vision in the US developed a technology to process different structures in an OLED, (e.g. the hole transport layer, electron transport layer), by using a screen printing technique. In 2007, DuPont, in the US, achieved important milestones in demonstrating excellent performance of printed OLED displays using its own technology, a solution process technology. SONY in Japan, developed several prototypes of OLED TV, in 2007 and 2008, and the thinnest OLED TV is only 0.2 mm. In addition, a 27-inch OLED TV made by SONY can give high resolution, 1920×1080. In 2007, VTT in Finland succeeded in developing a soft OLED material which can be made by an R2R printing technique, so that the production cost of OLEDs decreased a lot. Since 2008, the R2R printing technique has been an advanced modern printing technique used in printed OLEDs. Soon after, a soft OLED screen by using the same R2R printing technique was made in Finland and its thickness is just about the same as three or four pieces of paper.

In addition to the display area, lighting is another area that printed OLEDs can be applied to. Being different from the display area, the lighting area will mainly focus on an R2R printing technique, so the OLED lighting products are almost soft and flexible. Generic Electric and Konica started to cooperate in the development of printed OLED lighting in March 2007. In March 2008, the OLED technology based on the R2R printing process was, at first, demonstrated by General Electric, as shown in Fig. 8(b), and this cheap production of soft OLED lighting panels by printing on a continuous roll like a piece of paper is a significant step toward changing the future green lighting landscape. In August 2008, Philips announced that their advanced printed OLED luminaire based on an R2R technique, Lumiblade, with the panel up to 50 cm^2 in different shapes, would appear on the market in 2009. It is predicted that the market of printed OLED lighting will rise to $4.5 billion by 2013. There are enormous opportunities for replacing a large proportion of conventional lighting in the long term because of cost, power, weight, space and other potential benefits coming from OLEDs. Up to 5% of conventional lights in advanced countries may be replaced by the years 2016–2020.

(a) A 2.5-inch, 160×120-pixel OLED display by SONY from Japan. (Source: [20])



(b) A soft OLED lighting panel by GE from the US. (Source: [21])

Figure 8. Different applications of Printed OLEDs.

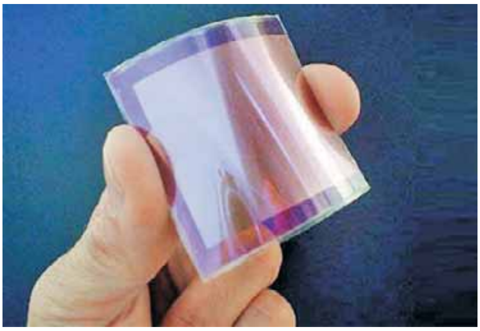
In all, whether printed OLED displays or printed OLED lighting, they are still in the exploring stage now and they cannot take the place of common LCDs and traditional lighting at the moment. When the lifespan and production costs of printed OLEDs are solved, they will have an impact on display and lighting areas.

Photovoltaic (PV) Cells Silicon PV cells that make use of solar energy have been researched for many years and different types of silicon materials have been applied to PV cells. The main purpose of PV cells is power generation. Due to technical improvements in PV cells, the cost for the power generation has decreased from $80/W to $3/W so far, but it is still ten times as high as that of traditional coal.

In addition, much of the high cost of silicon technology derives from the requirement that the silicon used must be purified (the purity degree: 99.9999%) at very high temperature which requires a large energy input. Also, the silicon used must be grown as crystals which also requires a large energy input and makes for a rigid product which must be handled with great care. Therefore, about 60% of silicon material is wasted during the course of processing of silicon. As a result, how to decrease the cost of PV cells is the most important problem.

The second generation technology involves making layers of thin films of silicon, thus reducing material cost without loss of power output. However, this still requires silicon to be ultrapure and is more of a refinement of existing technology.

Nowadays, printing technology is considered one of the potential technologies to reduce the cost of PV cells. The thickness of a printed PV cell can be only 1/100 of a silicon PV cell. Furthermore, by using an R2R printing technique, a printed PV cell which is flexible and soft is possible to make, to some extent, flexible and soft. At present, there are several types of printed PV cells, i.e. organic, Cu-In-Ga-Se (CIGS), and CdTe PV cells.



(a) "PowerSheet" printed photovoltaic cell by Nanosolar from the US. (Source: [22])

(b) Softness of products of Nanosolar SolarPly by Nanosolar from the US. Source: [23])

Figure 9. Printed PV cells.

Now some companies have started to study the implementation of printed PV cells. Nanosolar in the US, founded in 2002, is a global leader in solar power innovation and the company mainly develops PV cells used in the power generation, as shown in Fig. 9. By using proprietary ink, semiconductor materials are printed onto an inexpensive metal foil in a continuous R2R printing technique by Nanosolar. At the end of 2007, they announced that they would produce thin-film CIGS PV cells on a large scale by an R2R printing technique and it was the first printed CIGS PV cells produced massively in the world. The manufacturing cost of these kinds of cells is less $1/W. Once the conversion efficiency increases, the cost can be decreased further to $0.3/W, which almost is equal to the cost of coal. According to their plan, their production line in 2008 was 250 MW, and in 2009 it will increase to 430 MW. In 2008, another leading company, Konarka, in the US, started a new factory where the production capacity of printed PV cells could reach 1000 MW. In addition, Konarka continues to study conversion efficiency. In 2008 they increased the conversion efficiency to 6%, and in the future, this number can be increased to 10%. In addition, printed CdTe PV cells are a type of thin-film PV cells, and the CdTe thin-film can be made by screen printing techniques. Nowadays, the production capacity of First Solar, one of the companies that produces CdTe PV cells, is about 400 MW. However, thanks to the high conversion efficiency of CIGS PV cells, printed CIGS cells are considered the most probable product for use in industry.

According to an investigation, the production capacity for the market of printed thin-film PV cells was 181 MW in 2006, and 400 MW in 2007. On the other hand, by the year 2015, it is predicted that the global market for printed PV cells will reach $2.5 billion.

Electronic Paper (E-Paper) E-paper, was proposed in the 1975 by Xerox in Japan, and is actually a display technology created by printing a kind of special ink, electronic-ink (e-ink), on flexible substrates to mimic the appearance of ordinary ink on normal paper. E-paper is comprised of two different parts: the first is e-ink, sometimes referred to as the frontplane; and the second is the electronic circuit required to generate the pattern of texts and images on the e-ink page, called the backplane.

However, there is no display medium which is sufficiently like normal paper yet, that is, a display medium which is thin, flexible, cheap, capable of storing readable images without power consumption, highly readable in ambient light, and with good resolution, high whiteness, and good contrast. At the moment, organic thin film transistors (TFTs), are one of the suitable media. In addition, a semiconductor circuit in e-paper is mainly carried out by printing e-ink, which can make a display flexible and thin, like a piece of normal paper, as shown in Fig.10.

The main application of e-paper is e-paper displays (EPDs) or e-paper readers. Compared with normal paper, an EPD has two distinct features: one is high contrast and the other is that the contents shown on the EPD are erasable and changeable. It is predicted that the market of EPDs will rise to $0.28 billion in 2009.

(a) An e-paper display by Fujitsu from Japan. (Source: [24])

(b) A colourful A4-size e-paper display by LG.Philips LCD. (Source: [25])

Figure 10. E-paper displays on the market.

Some companies have made a great progress in the field of EPD technology, e.g. E Ink and SiPix in the US, as well as SONY, IBM, Philips, Fujitsu, Siemens, Epson, and so on. The products of EPDs have already entered the global market, so EPDs are, currently, in the phase of commercialization and the real market is predicted to be developed by the year 2012.

Founded in 1997 and based on research begun at the Massachusetts Institute of Technology's Media Lab, E Ink developed proprietary e-paper technology that already has been commercialized by a lot of companies, e.g. iRex Technologies and Sony, both of which already have commercial e-paper readers on the market. In 2008, Readius, a pocket size e-paper reader with a rollable display, was launched for a commercial use by Polymer Vision, a spin-off from Philips and a pioneer in mobile devices with rollable displays. Plastic Logic, a spin-off company from Cambridge University's Cavendish Laboratory, specializing in printed polymer transistors and electronic components, estimated that the mass-production of flexible A4-size plastic electronic displays with the thickness of a credit-card, storing various electronic documents, will appear on the market in 2009.

In addition, the thickness of a printed EPD is continuously decreasing. In 2006, EPSON developed an EPD that was 0.47 mm thick. Then, Bridgestone in Japan decreased the thickness further to 0.29 mm in October 2007. In 2008, Chiba University in Japan developed a 0.1-mm-thick EPD. The thinner an EPD is, the more flexible it is.

In October 2008, Samsung in Korea demonstrated the world's first CNT-based color active matrix electrophoretic display. This is one of the new directions toward which printed EPDs are developing. The display developed by Samsung is not based on an R2R technique, whereas the resin, used to create the cathodes, is screen-printed onto the cathode backplane. Earlier in May 2008, Samsung demonstrated a black and white version of an active matrix EPD with CNTs. Now they have released the first colourful EPD in an A4 format, suitable for handheld and mobile applications, due to its low power consumption and bright light readability.

In 2007, another new technology in e-paper, paper-based e-paper, developed in Korea. This technology uses real paper as the substrate and the semiconductor circuit is printed by e-ink by R2R printing. The e-paper based on this technology can be much thinner than normal printed e-paper and it is more flexible and soft. However, this technology has not been commercialized.

Other products to be marketed have more substantial potential applications. Thin colourful EPDs for packaging, currently under advanced development at Siemens, could display prices on products dynamically, instantly altering the price of a product when necessary. Furthermore, another potential application of EPDs is a dynamic expiration date, which would graphically display the amount of time remaining for food and drug consumption.

3.3 Hybrid Media, Printed Functionality, and Smart Objects

The term *hybrid media* is defined, according to [7], as a method for use in providing content that is made up of data includes providing a first portion of the data making up the content to a user, and making available for a limited amount of time an ability to stream a second portion of the data making up the content to a device having the first portion of the data. The second portion of the data includes essential information for reconstructing the content from the first portion of the data. Also disclosed are a storage medium storing a computer program to cause a processor based system to assist with providing content, and a system for use in providing content.

Hybrid media is a result of the convergence between printed and digital media and consist of multimedia such as

- many channels;
- many platforms;
- cross media;
- integrated publishing;
- adaptive publishing.

An example of hybrid media is the use of printed 2-D bar codes as a link to a web solution. This is very popular in Japan, where 27% of all mobile phone users deal with hybrid media solutions. It is estimated that half of the NTT DoCoMo phone-operator clients had a bar code reader integrated in their phones [Rusko]. The term hybrid media is heavily used by researchers from the Technical Research Centre of Finland (VTT) and the Department of Media Technology at the Helsinki University of Technology. It is considered an attempt to create its own specific research profile in Finland.

The history of the hybrid media can be divided into three phases as follows.

1. Manual
   - The user himself combines media elements, for example the codes of a TV program out of a newspaper.
2. Technology platform based
   - Chat programs with short message service (SMS) on TV, or bar codes and water marking linking a printed document to the web.
3. Integrated solutions
   - Digital (electronic) media that is part of flexible substrate, paper and plastics, having been printed with normal ink and conductive materials.

Advanced hybrid media is closely connected to printed functionality. Hybrid media and printed functionality are often implemented with the same kind of technological approach.

At least three different scenarios have been conducted in the area of hybrid media technologies. The first is that electronic codes replace optical codes. The second is that both technologies will coexist because of the prices of electronic ink and production methods. Electronic codes are suitable for high-end products and optical codes for mass production. The third scenario is that prices come down, but all coexist including new technologies such as reactive codes, holograms and electronic ink.

The global turn over of hybrid media products is estimated to grow from €2.5 billion in 2005 to €70 billion in 2015. Materials and manufacturing correspond to €25 billion, displays €20 billion, sensors and electronic ink each €10 billion, and visual sensors for packing €5 billion.

These numbers describe only the manufacturing part. The process also has content makers; graphic designers, sound engineers, record players, and staff, who is needed to produce multimedia. Most importantly, new kinds of professions are needed (e.g. info-architects, virtual-testers and all kinds of other professions that can be formed by strange combination of normal words). For many new professions there will not be a clear reference in the past.

This creates possibilities for developing business and society. The number of companies dealing with this process is increasing from less than 30 to 500 globally, and in Europe similar figures are from less than 10 to 400. An exponential growth in the industry is estimated to begin in 2012 by the deployment of e-paper [9].

According to a survey in [8], the most important parties in hybrid media are publishers and the packaging industry, advertisers, consumers, mobile phone manufacturers, and service providers. The applications that increase interaction between consumers and advertisers as well as the applications that make everyday life easier are considered potential. The benefits are in the process of adding value to printed products, improving integration with printed and digital media as well as new ways of using mobile phones. All these give advantages and means for companies using hybrid media to differentiate themselves from others companies.

At the end of 2020 there will be the 7th generation of printed 16-bit ROM ID-card introduced in 2006 for game cards and tickets. We can call them smart objects, because they are objects with printed displays, organic circuits, batteries and organic sensors. The road goes through animated logos; printed displays, organic displays and batteries in 2010 (the 3th generation) used in marketing and brand protection and Din A4 size game boards with several sensors and displays used in gaming in about 2014 (the 6th generation) [10].

4 Advantages and Challenges of Printed Electronics

PE technologies first started to emerge as potential low-cost replacements to silicon-based electronics in some specific application areas. The main driving force of PE thus has been its promise of providing versatile electronic functionality with a price that will be eventually comparable to the price of producing prints at a traditional printing press manufacturing plant. This price advantage follows directly from utilizing well-known and established printing process technologies that are adapted to use electronically functional materials as inks. The printing processes used today are extremely productive and cost-efficient compared to processes used to manufacture silicon-based electronics. These benefits apply both to production unit costs and absolute production capacity; printing production volumes per spent time can be pushed very high with standard implementations compared to silicon wafer processing. Essentially, the utilization of high-end printing procesess as a means of manufacturing reduces the marginal cost of producing products very close to the cost of raw-materials used to produce print. In a traditional printing press, this implies paper and ink, in the PE case, the situation is essentially the same, only the options for the print base and ink materials are different. Estimates of this expected cost-reduction range from a magnitude of significance to several magnitudes. Even though silicon manufacture is highly optimized and utilizes large-scale mass-production, costs rise from its high technology requirements, capital intensiveness, and in the case of high-end products, yield percentage suffers as a function of the chipset size due to the increasing probability of defects.

Because PE can implement functions of traditional silicon-based electronics, competition between the two technologies is bound to influence the popularity of PE in the near future. Silicon-based electronics grew into a significant industry in only a few decades and in its present state, growth has not yet faced its limits. This has two major implications. First, it means that investments in silicon technology have been significant and continue to be so due to the relative novelty and technology-heaviness of the industry. Big accumulated investments have established a significant technology and knowledge capital for the silicon industry. Directly, this poses a challenge to the more pioneering and non-established PE area. Second, the vast size of the existing economic activities in electronics manufacture might cause protective (even aggressive) actions from traditional companies in an attempt to hamper any assumed direct competition from new players in the field.

The fear of direct competition causing difficulties is greatly diminished due to the fact that PE, at least in its early stages, does not offer competitive solutions to the same problems where silicon-based technologies are most popular. Instead, PE can be seen as a completely new industry that can and will coexist with its silicon-based predecessor. This is made possible by the second most important characteristic of PE (after the low-cost manufacture): printed electronic circuits can typically be produced in a flexible, very thin shape. Versatility of the base material options ranging from typical paper, plastic and textiles to the more exotic add to its attractiveness. In addition, the size of an integrated circuit made by printing is not limited by similar difficulties as in silicon semiconductor manufacture. Another factor contributing to the non-overlapping implementations is the limited nature of PE raw electronic processing power. Silicon-based computing is simply far ahead in absolute processing power and is expected to remain so for long. Consequently, PE will be applied mostly where electronics have not been applicable until now.

By combining the two properties of cheap unit cost and very flexible form, PE provides a means to implement even the more wild visions of ubiquitous computing. *Ubiquitous computing* means computation that takes place everywhere, all the time. All human-made objects could be implanted with printed functionality, resulting in a whole new range of applications from simple intelligent fridges to whole-heartedly Utopian visions with pervasive context-sensitive inter-object interaction revolutionizing the way we experience the world in the future. From a logistics point of view alone, global unit-level product identification and tracking is a major addition to the possibilities for optimization and management.

With clever material choices, PE has yet another advantage that will be more and more important in the future — it can be made biodegradable or suitable for disposal by incinerating. Ecological consequences are significant if PE production grows according to expectations - the difference between dumping discarded products in to a landfill or simply composting them is notable in our ever worsening environmental conditions.

An environmental challenge however is posed by the energy requirements of all electronics and PE is no exception. If PE is to be applied everywhere, there will be additional energy consumption everywhere! Technically, solutions for the energy sources for PE exist, (e.g., biological batteries and capacitors) but true solutions have to be self-sustaining, (e.g., printed solar cells and other active energy sources). If the energy issue is not managed wisely, the consequence might be that overall dependency on increasing energy production will continue to rise.

In the early phases of a new technology, technical challenges can be significant determining factors for the rate of growth. In PE, many open questions with respect to material properties are under investigation. Presently, several critical material functions cannot be implemented with printed materials. Thus, for the full promise of PE to be fulfilled, technological innovations and breakthroughs are needed to overcome material difficulties. Quality control is a major question. Material properties have to be controllable and repeatable in order for high quality and yield to be obtained from the manufacturing processes. In addition, environmental stability and durability of PE is under significant challenges. The materials have to be easily applicable to the surfaces but at the same time they must withstand normal environment hazards like humidity, wear and tear, sunlight, oxygenation etc. In part, these questions can be answered with active quality control measures that try to identify and remove the faulty units at the process stage. For example, computer vision inspection can be used right at the manufacturing process line at the natural speed of the printing process, thus avoiding a loss of efficiency. Similar computer vision quality control has already been applied to the extremely fast paper manufacturing process industry.

Digital printing and the customization it allows provides entirely new possibilities for easy and affordable small-scale electronics production. For example, having an electronics-printing inkjet would be enough for the simple creation of PE products. Whereas traditional silicon-based electronics construction has been limited to the enthusiast user segment due to the necessary number of specialist tools and expertise, digital PE can be available to all groups of people. Today, active peer-based communities are big contributors in many areas from the open source movement and Wikipedia to a great number of hobbyist internet forums. For PE, similar developments could lead to unexpectedly fast design and application proliferation.

The unauthorized proliferation of products is a serious problem. For example, 12% of drugs in Russia and 80% in Peru are counterfeit, whereas the total amount in the whole world is 2%. Smart packing is helpful in solving this problem. It also gives an opportunity to control illegal transport of government-subsidized AIDS drugs from Africa to the grey markets of the world. Control is not necessarily limited to drugs, but can also be used in other areas on merchandise such as DVDs.

Applied to food production, tags give a quality of service control from livestock to the customer's table. It is estimated that 10% of American Wall-Mart's overall sales costs are coming from storing, transporting and taking inventory of goods. A 4% cost reduction can be achieved by using RFID tags.

There are benefits to keeping tags alive beyond the supply chain. If the customer wants to return an item or items are returned on the basis of a product recall, the tags help the operation. Tagged items could also interact at home. A washing machine could automatically adapt its programs according to fabric care instructions embedded in clothing.

This trend challenges privacy. A group named consumers against supermarket privacy invasion and numbering (CASPIAN) finds a major threat to privacy when each item has a unique hidden identifier. They find that this technology will enslave humanity, automating shopping according to the profiles of customers and giving too much control to big organizations. Their net campaign against the textile company Benetton was successful and they have spread an RFID Right to Know Act 2003. It is their proposition as to how legislation should be developed.

It is possible to design a basic visual ontology of PE that highlights the consequences of the properties in the fields of application. In Fig. 11, some necessary elements are shown to illustrate the interactions with different applications of technology related to PE.

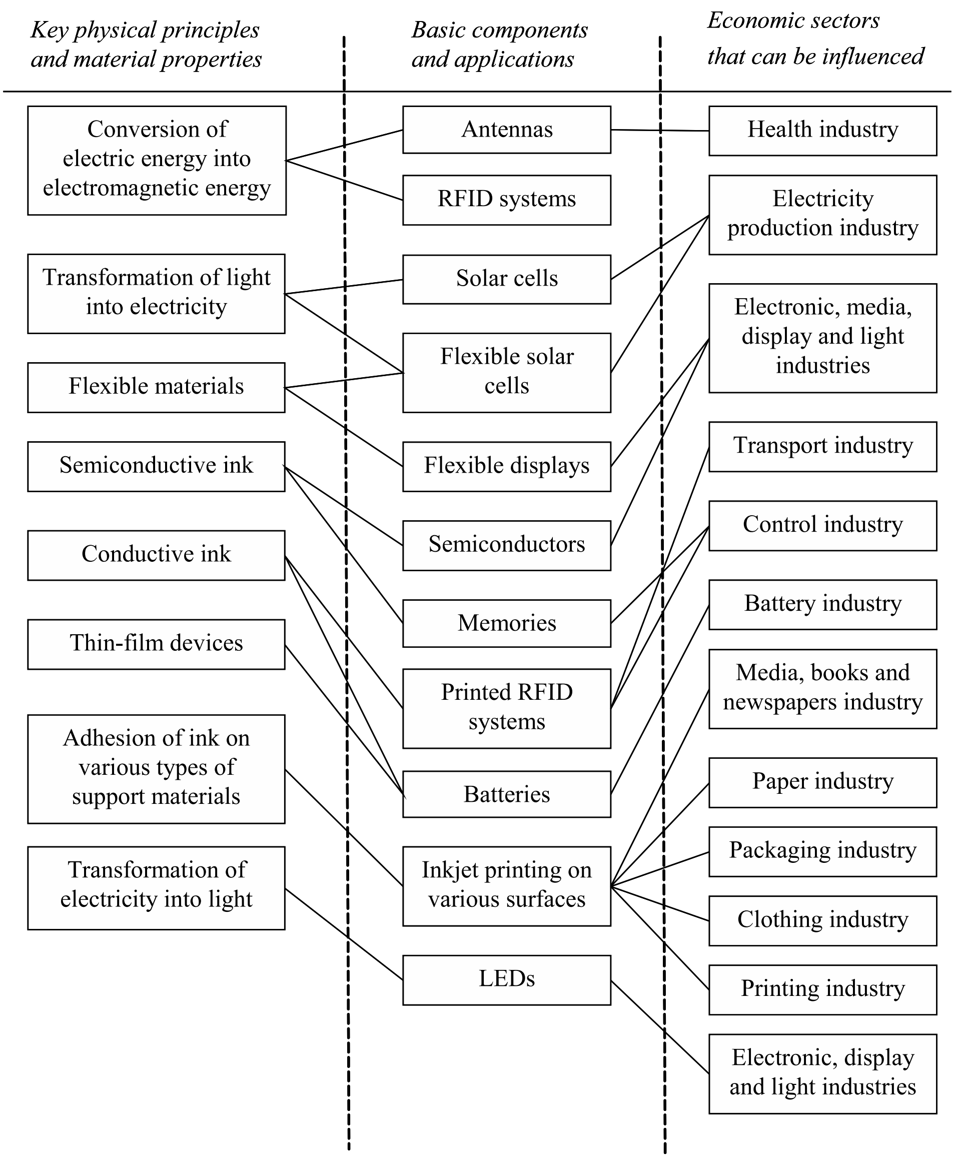


Figure 11. Impacts of key physical properties of printed electronics on basic components, applications and industrial sectors.

5 Discussions

5.1 Roadmap for Future Development

Adoption Proceeding from Industry to Consumers There are many different predictions concerning the future development of printed electronics. With respect to the emergence of new applications that can be adopted to everyday life, it is hard to estimate the trends. It is probable that many applications first will be used in the industrial domain, then adopted by some individual professionals and only after that will they become an active part of life for normal consumers [11].

This report has given specific emphasis to RFID tags, PV cells, OLEDs and e-paper. The first round of products will still be rather modestly intelligent and provide the services of simple hybrid media. In the industrial domain, RFID tags can help in monitoring logistics. Printed PV cells can secure energy supply in critical devices and OLEDs and e-paper can provide energy-efficient lightning and displays. At first products will also carry a higher price to cover the initial development costs. Creating efficient standards and environmental strategies may help in successful adoption.

Due to extra investment and limited robustness printed electronics will probably enter the market most strongly with RFID tagging. When compared to the other three main product categories, RFID gets special attention by offering a new type of functionality that has not been achieved with older technology (wireless tracking of objects) whereas conventional technology has been able to produce solar cells, lighting devices and displays.

New printed products will probably arrive first in restricted application domains in industries that focus on mass production and logistics. They benefit from predictable environments and activities. Even a small amount of printed devices can provide valuable support for industrial processes in well-chosen control points of an assembly line or at a gateway of transportation. Investment is easy to amortize since it provides a significant competitive advantage relative to more conventional manual labour.

The success of organic light emitting diodes and photovoltaic cells depends a lot on how easily they can be added to different surfaces and applied to various forms. Also the efficiency of the light emitting process and the photovoltaic process determine their usability. In large and dense sets of these devices efficient passage of light and managing heat becomes crucial. It would be favourable that the photovoltaic process could be added on top of any kind of printed electronics, especially on electronic paper and other displays. Also the ease of recycling, maintaining or updating old devices becomes increasingly important as volumes of the market increase.

Gradual Evolution of Functionality on the Market It has been predicted that the cross-influence of printing and electronics industries will produce a variety of intelligent and affordable PE devices that will heavily penetrate the markets of everyday life as mentioned in the introduction to this report. Kleper [12] suggested one future roadmap for PE that explains how, due to intensive research, the functionality of new products gradually rises during the subsequent decades, as shown in Fig. 12.

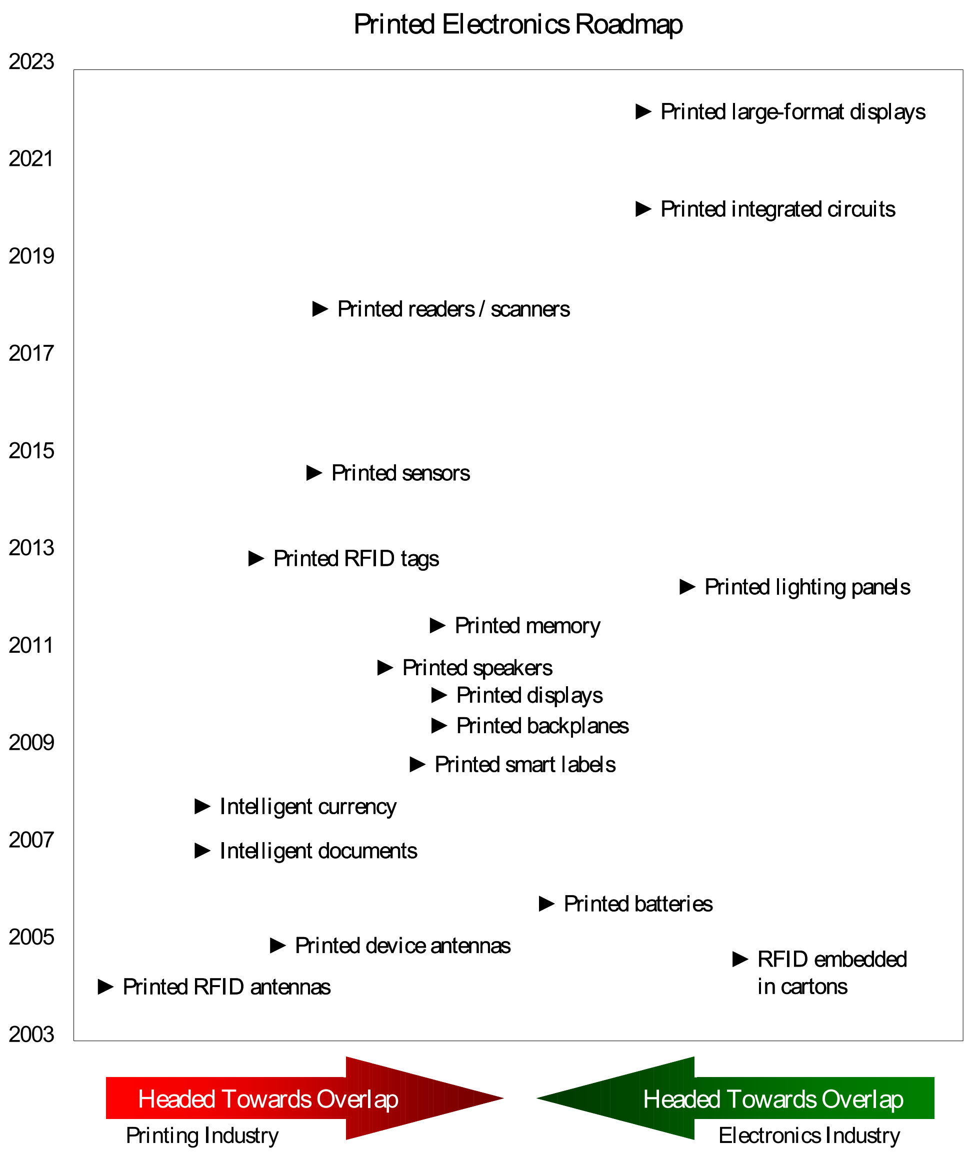


Figure 12. The cross-influence of the printing and electronics industries will likely produce an impressive array of low-cost, intelligent devices that will infiltrate nearly every aspect of everyday life. (Source: [12])

According to [12], one of the first applications of PE that has already rather actively appeared on the markets is RFID embedded in cartons. By 2010, some of the central products to emerge on the market, in an estimated chronological order, include: antennas, batteries, intelligent documents and currency, smart labels, backplanes and displays. Later on, by 2015, the hot novelties are estimated to include speakers, memory and lighting panels. Also printed RFID tags are supposed to be actively launched to the market. Printed sensors are appearing on the market as well. Then, by 2020, readers and scanners should have an increasing role in new products. Readers and scanners can refer to, for example, devices that can gather and analyze knowledge from printed items. Finally, by 2025, it has been predicted that integrated circuits and large-format displays will become widespread on the market. Integrated circuits can refer to a variety of complex devices built using printed components and large-format displays can cover a diverse set of light-emitting surfaces. In this listing photovoltaic cells are not mentioned but they are currently entering the market.

The global economic crisis starting in the year 2008 may give a reason to question the optimism of some earlier predictions concerning the development of PE. Thus, it is possible that development may significantly slow down.

Functional Inkjets as a Driving Technology According to [13], functional inkjet inks are predicted to gain a strong position in the future markets. New materials are supposed to lower costs and increase performance in comparison to traditional methods, such as silicon-based electronics. Jetted metal layers are expected to provide a new level of functionality in many areas. Being fairly inexpensive materials, jetted tin and lead solders have been convenient for fabricating interconnects in rather simple devices, for example resistors and many photonic devices. However, environmental risks due to these substances and increasing regulation for example in the European Union force the use of more environmentally friendly materials [14]. Jetted silver and copper can be used to reach smaller features and to provide higher connectivity than in current screen printing techniques used for printed circuit boards.

Many new kinds of inks are actively being developed and they can be, for example, conductive, photoactive, thermally sensitive, memory retentive or chemically sensitive. Different properties can be combined to provide inks tailored for specific needs but often combinations lead also to some trade-offs in functionality. Since inkjet does not require firm contact with a surface, it is well suited to sensitive and soft substrates, like textiles, boards and even human tissue. Inkjet is also a favourable technique, for example, in the production of wearable electronics, smart packaging, and drug delivery systems. Also products with large surface area benefit from inkjet, for example displays, lighting devices, RFID tags, sensors and photovoltaic cells.

Due to the very small size of the inkjet print head nozzle, producing new biomedical products may become possible. Diagnostic devices produced by inkjet printing could revolutionize the way medical care is provided for everyone. Other application sectors in this field include tissue engineering, drug delivery and screening, genomics, biotechnology and biosensors. One ultimate goal would be organ printing that means computer-aided jet based tissue engineering. The printing process could use specific tissues or cell types to provide required functionality, for example in transplantation and cancer treatments. Finally, organs could be printed using a patient's own cell type, thus eliminating rejection linked with donated organs. Promising results have been already gained with existing off-the-shelf printers.

Today already three-dimensional printing is used by many manufacturers for rapid prototyping [16]. Inkjet technology will offer new cost-effective and fast ways to provide three-dimensional modeling and prototyping. Especially fruitful results can be achieved when combining inkjet techniques with novel photopolymers, ceramics, polymer-clay nanocomposites and polymer blend inks [13].

Tailored Products based on Printed Electronics Products based on printed electronics will likely become tailored to different circumstances like heat, cold, wet or radiating environments. Their functionality and computational efficiency could be boosted for some specific energy consuming situations by adding inks that have an extremely high concentration of ions, good fluidity, low viscosity etc. The ink layers might also automatically adapt to the current environment. In displays the visualizations could be optimized to current lighting conditions and a person's vision. The principles of Gestalt psychology could be applied to visualizations. A display could automatically optimize shapes so that human visual system could use efficiently its innate skills of recognizing figures holistically instead of just as a collection of simple lines and curves. Thus, a person could perceive and learn intuitively as much as possible without even needing to focus attention systematically to collect pieces of information from illustrations.

Degrading inks could be maintained by adding or replacing its components. It might be possible to modify each ink layer separately using enzymes or nanorobots that are attracted only by some specific chemical compounds. An easily removable membrane could be placed between ink layers and removing it could activate new added functionality in the product. This removal of membrane could be applied to some specific areas of the printed circuit thus changing the flow of electrons corresponding to new computational needs. This could be applied to tickets, entrance permission documents, parking tokens and other coupons.

It might be even possible to connect separate printed items together to launch still other functionality. As in building puzzles, it could be possible to gradually expand the functionality of a printed product. Users could customize the desired functionality of the product by choosing those components that they need and joining them together with, for example, some kind of paper clips. Later it might be possible to just have a stack of printed cards and shuffle their order to achieve the desired functionality. For manufacturers this could allow easy market segmentation and versioning of products.

The products could hold secured content using confidential electromagnetic properties of the printed surface. The printed surface might also show visual notation that could be interpreted with some secret code. The printed surface could provide varying content and functionality depending on the access rights of the user. These access rights could be wirelessly indicated by holding another printed item beside the surface. While maintaining the trustworthiness of an official document, it would be useful to support making corrections and commenting. For this purpose, people might use specific devices to modify the functionality of a printed item.

Production of Printed Electronics Arriving at Home Wide-spread adoption of printing has had a large cultural impact. Due to cost-effective printing techniques, a broader range of readers has access to knowledge and also has been able to build on the intellectual work of earlier generations. Printing has provided new possibilities to analyze knowledge by offering a sustained and uniform reference for it and furthermore by easing comparison between conflicting viewpoints. Consumer-driven adoption of printed electronics can possibly accelerate this positive trend.

Until the late 1980's, printing at home and in offices was not very common, or it was done with limited quality compared to publishers, the main technology being often monochromatic matrix dot printers with low resolution. In the mid-1980's the first inkjet printers aimed at ordinary consumers were introduced. After the initial investment, inkjet technology enabled people to produce prints at home at relatively low cost, competing with the quality of publishers, especially in text and later in graphics. The development of the inkjet narrowed the quality range of publishers, express on demand print shops, and home printers. In two decades home printers more or less reached the level of print shops and photography laboratories. This evolution challenged seriously the business model of printing industry.

It is possible that in the production of printed electronics, progress will follow the same path as ordinary printing. In the first stage, consumers can acquire printed electronics mainly as the products of large-scale industrial manufacture. These products can be fabricated in a large variety of versioning but they are not printed on demand or specifically tailored to the needs of an individual consumer. In the second stage, printed electronics can be produced at local photography laboratories in customized formats on demand. At this point, the technology is still so expensive and complex to maintain that it is economical to keep these services centralized. In the third stage, producing printed electronics will become possible with consumer technology that is easy to use at home and is reasonably priced.

For instance, in 2030, a consumer can possibly download design templates for printed electronics from a network and modify and test them virtually to meet her needs of functionality. Then she can produce a corresponding artefact with a home printer that operates in the nanometric scale of the substance. In this situation, the uniqueness of an object begins to loose its meaning also affecting patents and immaterial rights. This resembles the visions of moving matter from one place to another instantaneously (teleportation). Instead of sharing just knowledge, also real-world functionality of context-aware artefacts could be easily duplicated all over the world.

5.2 Scenario

The basic idea in this paper is to describe possible technological innovation roads in PE. However, the real results of innovations come always in a combination of the consumer's ability to utilize these innovations and pay for them. This makes the innovation process rather hazardous and ruling companies try to control it as much as they can.

As a part of this paper, we decided to develop a scenario which tries to explain the broader trends related to the PE technology in the future. After the research process we guess and believe that the first breakthroughs in innovations in this area will deal with logistics, biological sensors, medicine (at least with smart packing) and computer aided self diagnosis of illness. All these innovations can be actively applied to the well being and health care industries. How is the Internet of "things" and service in 2020's AD? This scenario is based on the ideas of the following authors:

- P. Bourdieu (The ruling class uses symbolic violence against other classes of society.);
- S. Lash (Information is a part of person's identity and also a form of power.);
- M. Castells (Mega-cities and flows of information);
- B. Latour (Constant reassembling of society by the technological structures and human organisations).

Their ideas are combined with the technological possibility of PE, hybrid media and ubiquitous environment. This scenario has a strong bias toward Europe from the Finnish perspective and takes the health care system as an example.

PE makes it easy to establish the Internet of the "things". This means a world where all objects have their identity tags. Thus, each object can have a description of its origin and even some power of computation. It can be followed automatically, read by sensors or mobile devices. This phenomenon is put in practice at first in the area of logistics, but it causes a huge reassembling of social practices and service in the long run. Finnish citizens in the 2020's can use this process in different ways depending on their status and position in society.

Nomadic rulers are dealing with a constant flow of information and they are connected to megacities. Roles for some central regions are as follows:

- US: California (military, security and entertainment);
- Asia-Pacific: Singapore-China-Tokyo (manufacturing);
- Europe: Torino-London-Prague (high brow design and service).

Nomadic Finnish speak and understand three to seven foreign languages. The middle class and workers are less dependent on information flow. They use it in their work but do not make decisions of infra – their needs are regarded only as end-users. Both classes are relative stable in their housing and living. Finnish who are in the middle class speak two or three foreign languages, whereas those who are in the working class can only speak two foreign languages.

The peasantry (plebeian or peregrines) is the largest group in numbers. Almost 50% of the Finnish population is in this category. They are not interested in the information flow or they have an ambivalent attitude towards it. They usually speak two languages, Finnish and English. They are ready to move from place to place inside Finland and the Baltic countries in order to find the best place for themselves.

The mental attitude of the population toward the culture of consumption and service during the course of post-baroque (the art style of repeated and varied patterns) in Finland are in harmony with European trends. This taste of the European population is expressed with concepts dealing with the quality of service in food:

- Slow Food: A traditional look, emphasis of the products grown or made nearby with high quality. Tagging and licensing are very clear in every aspect of those products. It is more expensive than McFood.
- McFood: Consumer culture of markets. Tagging and metadata of products and service according to regulations. The origin of products from Asia-Pacific, food from industrial agriculture.
- Ethnic Food: No clear tagging – quality of service is not clear. Word of mouth marketing. Quality of products and service totally varies from exceptionally good to bad. There is no mechanism of price – resembles fashion.

All these trends are more like an individual's own decision, and they are not automatically supported by certain classes. Anyway, people having the Slow Food attitude are mainly from the nomadic or middle class.

The Application of these norms is to the Health Care and Well-Being Industry in Finland and it is the service of the 2020's.

The RFID technology and intelligent packing have contributed to making the logistics process precise. Metadata in each product is so clear that neo-Tolstoyic, which is referred to as Leo Tolstoy, is demanding that the taxation system of Europe be based on an ecological print collected from RFID data for each product which is consumed. The pharmaceutical industry and health care systems are the first to adopt advantages of metadata description methods in their business. Computer-aided medical diagnoses are reality. Also the customers are ready to pay for their health.

The process model for the logistics of drugs and health service is a re-think for people getting older and older in Europe. At the same time, the national health service is outsourced to private actors. The basic unit of health and senior service in this system is called "kitchen". The unit is a combination of a pharmacy and a kitchen preparing meals on demand (from fully ready to half ready - even raw materials for food) and delivering them to the apartments of its clients. Kitchen is a local actor. Its size is between 50 and 400 customers and it gives health service to a ten or even twenty times larger population.

The competition among kitchens is interesting. They can compete for price, location or specification. For instance, the Kuhmo community is famous for its kitchen of classical musicians coming from different countries. The kitchen broadcasts the best gala shows with top music programs by their own old artists all over the world.

The aim of the kitchen is to prevent the passive use of institutional hospital beds for the healthy elderly and to give support at home as much as possible. The RFID technology and intelligent packing gives quality control to kitchens in combination with western medical practices.

On the client's or patients side, tags are embedded into clothing and jewels. The tags contain the latest diagnoses and data gained from sensors measuring bodily functions. This helps in making reliable diagnoses and follows any changes in the health condition. This service makes the traditional profession of a doctor partly obsolete. Of course there are hospitals and clinics for more demanding cases - and clients. Finland is famous for good quality clinics and it markets them heavily to the east of Finland. The Russian high brow middle class from St Petersburg, Leningrad and Archangel Oblost use regularly the service – from giving birth to more difficult operations.

The spectrum of health care institutions is large – intimate Slow Food quality clinics for well paying customers and mega institutes for the plebeian population with good industrial McFood quality.

Nomadic rulers are interested in their bodily functions and health is a way of showing success. They are "plugged on". They use sensors to record their activities in real life. This is a way of analyzing their own identities and in case of emergency it is easily used for medical purposes. They have dealt with their insurance company on personal health care systems and the company wants their health data to estimate the risks. They use the best doctors and specialists to support their own well-being. The attitude varies between Slow Food and Ethnic Food.

In the case of the middle class and the working class, their ambition is Slow Food quality of service but it is achieved only in local areas to the north of the Turku–Helsinki–Tampere–Vyborg area. This makes country living (small villages and small towns) very attractive to these classes.

The majority of the population trusts McFood quality of service on a case of accident. Only those who have a contract with an insurance company can afford more. McFood service in health care is run by religious doctors having an ethical mission or simply belonging to a society of religious brothers and sisters. The most prominent ones are Francescans (due a Catholic mission), Buddhists and in the north of Finland a sect of Laestadian doctors.

The real attraction for all the population is Ethnic Food quality health service. All possible is available with no clear quality of service distributed by RFID. All sorts of healing traditions from Arctic healing with a Neolithic diet to Congo drumming, from South Chinese medications to Navajo herbs are in use. Charismatic healers establish their own kitchens, and clans of different tribes organize their own way of living and care.

Young students are especially eager to test different Ethnic kitchens. They test several of them and a bohemian way of life is back in a historical sense. A fact is that some of these Ethnic Kitchens have really good quality of service in health care for specific conditions. Thus, for example, a rapid decrease in suicides in Finland is a miracle to be solved.

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1.4 Cut the Last Cord by Nanolution

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Abstract

This chapter presents an analysis of carbon nanostructures from an information and communication technology (ICT) point of view. The impact of carbon nanostructures and the technologies based on them is analyzed based on current state-of-the-art in carbon nanostructures, development forecasts of carbon nanotechnologies and envisioned revolutionary nanotechnology applications. The analysis focuses on four application areas: solar cells, displays, energy storage systems and sensors. However, these applications represent only a part of the total potential of carbon nanotechnology (CNT). According to analysts, the CNT-applications can each have markets up to several hundred billion euros. However, there are several uncertainties related to each market.

1 Introduction

Nanotechnology means the making, manipulating and characterizing of materials in size scale ranging from the atomic level to the molecular level. The produced nano-scale materials are usually called nanostructures and typically nanostructures are defined as structures having at least one dimension less than 100 nm in diameter. Figure 1 depicts the size scale in which nanotechnology operates.

Mankind has been using nanotechnology unconsciously for thousands of years. Nanotechnology had been used for example in steel making (Damascus steel), producing paints and inks, and in vulcanizing rubber [1]. The potential of nanotechnology and nanostructures was noticed in 1959 by Richard Feynman [2]. He, for example, mobilized two open challenges to develop techniques to manipulate materials in nano scale.

Physical and chemical properties of nanostructures are determined both by electron structures of the individual atoms and by structural arrangement of these building blocks. The properties of nanostructures can differ tremendously from properties of bulk materials and this opens up possibilities to tailor the functionality of materials and to create completely new functions. The electrical, chemical, biological, and mechanical performance of the current materials can be enhanced and, for example, flexure resistance added. In addition, nanotechnology can naturally help develop smaller components and lighter structures in general.

The production of nanotechnology based or enhanced products can be described as a linear or sequential process in which first nanotechnology raw materials are produced (e.g. carbon nanotubes), then the raw material is further developed and in the end included with the final product or application. However, the sequential approach with independent steps is not always followed. For example, in the semiconductor industry the producing and depositing of nanostructures onto a surface and then post-treating or patterning the surface characterizes the whole process [3].

Figure 1. A comparison between natural and man made structures. Examples of nano level (at least one dimension less than 100 nm in diameter) structures are ATP synthase, DNA and Atom in natural category, and carbon nanotubes in man-made category.

Nanotechnology has been one of the most popular buzzwords of researchers from physics, chemistry and materials science over more than the last decade. The hype and expectations have been strong although some have also criticized the hype mostly because development has not been as fast as predicted. In 2005, the consulting company Gartner in their 2005 edition of Emerging Technology Hype Cycle set carbon nanotubes as "on the rise" to the "peak of inflated expectations" and their "time to plateau" as "more than 10 years". Carbon nanotubes weren't mentioned in either 2007 or 2008 editions of this chart [4].

Carbon nanostructures including fullerenes, carbon nanotubes and graphene were one of the first studied structures having extremely intriguing properties. They have a wide range of potential applications, e.g. in fields of electronics, optics and material sciences. Some properties of carbon nanostructures, especially carbon nanotubes, e.g. conductivity and semiconductivity, make them especially interesting from viewpoint of information and communication technologies (ICT).

1.1 ICT and Nanotechnology

Many ICT companies are currently doing research on nanotechnology and creating visions of the potential impact of nanotechnology on their markets and products. One example is Nokia's Morph concept phone that was presented at a press release in February 2008 [5]. The Morph concept demonstrates most of the potential nanotechnology applications in the mobile phone industry, eg. solar cells, sensors, flexible displays, transparent electronics and morphing structures.

Heavy investments and strong activity by companies give hints that there are expectations of great revenues (and impact) of this technology in question. In addition to Nokia's Morph press release, the corporation-based funding of nanotechnology research exceeded governmental funding in Finland in 2006. This happened even though the main governmental research sponsors, Finnish Academy and Tekes, had launched a big nanotechnology research program only a year before in 2005 [6].

As mentioned previously, carbon nanotechnologies have many potential applications in ICT. As with many new technologies, some new solutions are just incremental enhancements while others have the potential to produce more dramatic and wide-reaching changes in the ways things work, are organized, and even on how people think about them. These revolutionary possibilities of nanotechnology are in our main focus.

Predicting the great leaps and breakthroughs in science and technology is extremely difficult. The analyzer is always one step behind the latest research since the results are published quite slowly. In addition to this, in many cases the most successful applications of the development technologies have not been the ones that were predicted when the first development steps were taken. Difficulties in predicting the utility of certain technology is visible even in product development. For example short messaging service (SMS) was not predicted to be useful for sending messages from an individual cellular user to another but just to deliver information from servers and service providers to users.

However, revolution can also happen through incremental development. The development of the ICT field itself is a good example of this. The development of processors and memories, the central technologies in the ICT field, has followed what is called Moore's law (see f.e. [7]). The individual development steps have not been revolutionary, but, for the last 30 years, ICT development has profoundly changed with whom and how we communicate. Incremental development in one field can also produce huge impacts on other fields. When ICT is considered, energy (industry) is perhaps the most deeply linked field that has and will have major impact on what happens in ICT. It is estimated that the world's servers use 0,8% of global energy [8] and Gartner [9] estimates that the ICT sector accounts for 2% of global CO2 emissions, which is as much as the global airline industry. Interestingly for our study, nanotechnology also has applications in energy generation, storing, and consumption. One of the energy applications of nanotechnology, super- or ultracapacitors, was even identified as a potential disruptive technology by 2025 by the U.S. National Intelligence Council's (NIC) conference on disruptive technologies [10].

The overall importance of energy technologies and their special relationship to both ICT and nanotechnology are reasons why we have chosen energy as the underlying theme in this chapter. One cannot analyze nanotechnology's connections and impacts on ICT without taking into account energy technologies.

1.2 Aim and Structure of the Chapter

The aim of the chapter is to analyze the potential impact of carbon nanotechnologies on ICT. The time frame of the analysis is long, 15 to 20 years. We aim specifically to analyze the impact of carbon nanostructures by the year 2025. Our main research question is:

> *Will and can carbon nanostructures revolutionarize ICT in significant ways on or before year 2025?*

We consider both the straight impacts of carbon nanotechnology applications, e.g. flexible displays and smaller and cheaper sensors, and network impacts through other technology fields, especially through the afore mentioned energy technology.

The research was conducted iteratively. We began by getting the big picture of the carbon nanotechnology field. Based on the current visions of carbon nanotechnology applications we produced two user driven scenarios that depict the connections between ICT, nanotechnology, and energy in the year 2025. The first scenario is set in Finland and the other in the global business world. The scenarios can be found in chapter 7. The scenarios were used as tools to point out the most potential nanotechnology applications, which were then further analyzed. In addition we did an analysis of current megatrends and their links on nanotechnology and ICT. These are discussed prior to going into the scenarios in chapter 6.

The chapter has two major parts: description of current state-of-the-art in carbon nanotechnologies (chapters 2 to 4), and analysis of the potential impacts the carbon nanotechnologies could have on or before 2025 (chapters 5 to 7). The state-of-the-art description is divided to three parts: carbon nanostructures (chapter 2), potential applications (chapter 3), and industry (chapter 4). The analysis consists of key applications analysis (5.1 and 5.2), megatrends analysis (chapter 5.3) and concept frequency analysis (chapter 5.4). The concluding chapter 6 answers our research question about the revolutionarizing effect of carbon nanotechnologies on ICT. The scenarios that were utilized as basis of the analysis are presented in chapter 7.

2 Carbon Nanostructures

Carbon has physical features that make it interesting as a nanoscale building block. Carbon has four valence electrons and therefore it can form strong covalent bonds with neighboring atoms. These strong covalent bonds enable different carbon based materials, structures and allotropes. The allotropes of carbon are: diamond, graphite, amorphous carbon, buckminsterfullerene, aggregated diamond nanorods, glassy carbon, carbon nanofoam, lonsdaleite (hexagonal diamond), and linear acetylenic carbon. From the point of view of nanotechnology the most interesting ones are graphite (graphene) and buckminsterfullerenes (carbon nanotubes and carbon nanobuds).

Graphene consists of a one-atom thick layer of hexagonally arranged carbon atoms. Graphene is building block of other allotropes of carbon such as normal graphite which consist of strong graphene layers which are weakly bonded in direction perpendicular to sheet planes, carbon nanotubes which are rolled up graphene sheets and spherical fullerines. As the basic building block of carbon nanostructures, graphene structures have been widely studied in the academic world. Several production routes of graphene are known: mechanical peeling from pyrolytic graphite, chemical exfoliation, and reduction of carbides [11, 12]. Graphene is an excellent heat and electron conductor and the strongest known material available [13, 14].

Carbon nanotubes (CNT) can be imagined as rolled up graphite sheets. These sheets are categorized as either as Single-Walled Carbon Nanotubes (SWCNTs) or Multi-walled carbon nanotubes (MWCNTs). The first of these, the Single-Walled Carbon Nanotubes consists of a one layer of rolled up graphines. SWCNTs are typically around 1 nm in diameter while tube length varies from tens of nanometers to several centimeters. Depending on the arrangement of carbon hexagons in the tube, SWCNTs can have semi-conductive or metallic electron conduction properties. Metallic SWCNTs are ballistic conductors having minimal electrical resistance and having extremely high current carrying capacity. The main challenge when exploiting these electrical properties is controlling the alignment of the tube and electrical contact to external circuitry, which still limits the electrical performance of SWCNT-based products. SWCNTs are also two times better heat conductors along the tube axis than diamond. SWCNTs have the highest known mechanical strength-mass-ratio.

Multi-walled carbon nanotubes (MWCNTs) consist of several co-centric SWCNTs that are packed in a Russian Doll -like arrangement. MWCNTs have in many ways similar properties as SWCNTs. MWCNTs have larger diameters than SWCNTs due to several overlaying graphene layers and MWCNTs also show only metallic conduction.

Carbon nanotubes can be produced currently by using several production methods: arc-discharge, laser-ablation, substrate chemical vapor deposition, HiPCO and floating catalyst and aerosol processes. Different hydrocarbons, alcohols and carbon dioxide are used as carbon source in the CNT-growing processes. MWCNT-production processes are capable of producing several tons of product annually when quality and process control requirements are not too strict [15] making many mass requiring applications feasible. SWCNT-production has not yet reached similar quantities but typically quality and process control is in better shape in these processes. Tube length and diameter can be controlled in certain degree in some SWCNT-processes [16]. Semi-conductive and metallic tubes can be separated using liquid filtration processes [17].

Carbon Nanobuds™(CNB) are an allotrope of carbon in which fullerenes are covalently bonded to the outer sidewall of a single-walled carbon nanotube. CNBs were first discovered by scientists from Helsinki University of Technology [18]. This hybrid structure possesses many properties of conventional SWCNTs but fullerenes on tube sidewalls are chemically more reactive than bare sidewalls in SWCNTs. The number of chemically active sites is an important factor promoting the success of chemical functionalization of the structure which is important for sensor applications, SWCNT or CNB composites etc. Fullerenes also act as highly efficient field emitters. Due to electric field concentration on highly curved sites on the spherical fullerines, efficient field emission opens up several applications including field emission displays. Canatu Ltd., a spin-off company of Helsinki University of Technology, has several patents pending on synthesis, processing and applications of CNBs. Canatu uses an aerosol CVD-process to grow a mixture of highly crystalline SWCNTs and CNBs [19]. The aerosol process is suitable for producing homogenous thin coatings from tubular carbon nanomaterials.

3 Potential Applications

There are a large number of potential applications that could be completely created with or enhanced by carbon nanostructures. The different properties of nanotubes make them suitable for different applications. SWCNTs can be used to build both transistors and metallic conductors as they can have both metallic and semi-conductive properties. Low diameter SWCNTs also scatter only very small amount of light which enables their use as transparent electrical components. MWCNTs on the other hand don't have those appealing optical properties but other applications such as fuel cells and super capacitors don't require any use of optically transparent components. Production methods of MWCNTs are also on a more mature level and therefore large volume production already opens up many industrial applications such as lithium-ion batteries and super-capacitors.

In this chapter we focus on ICT related applications. The main ICT related applications are optically transparent electrodes (OTEs), transistors, displays, supercapacitors, and energy generation and storage (catalyst supports, charge carrying elements, etc.). Examples of products using these nanostructure applications are normal and flexible displays, solar cells and batteries. The strengths of nanotechnology in these applications are described more thoroughly below.

3.1 Optically Transparent Electrodes (OTEs)

Carbon nanotube networks can be utilized as optically transparent electrodes (OTEs). These networks are haystack-like structures that consist of randomly oriented carbon nanotubes or carbon nanotube bundles. Small diameter (1–4 nm) nanotubes scatter only a small fraction of incident light and this makes thin carbon nanotube networks relatively optically transparent. Haystack-like network morphology makes carbon nanotube OTEs more resistant to repeated flexure when compared to current OTE-materials like indium-tin-oxide. Currently SWCNT-based OTEs can match cold processed ITO-films in electrical and optical performance. Flexure resistance makes carbon nanotube OTEs potentially important components for flexible displays, solar cells, transparent antistatic coatings, smart windows and printable electronics applications.

3.2 Transistors

Chiral single-walled nanotubes have semiconductor properties. Therefore individual chiral tubes or very sparse random networks where semiconductive nanotubes are not short-circuited by metallic tube pathways show field-effect transistor behavior. Individual nanotubes have superior electrical mobilities like charge carrier mobility and current carrying capacity when compared with silicon-based transistors [20]. It is still difficult to manipulate tubes on an individual basis or grow them in a direction-controlled way. Therefore much of the interest has been on network transistors where the channel consists of more than one individual tube. The challenge that remains is in improving tube-to-tube contacts which limits the performance of these devices.

3.3 Displays

OTEs and transistors are essential building blocks of flat displays. Transistors are utilized as on-off switching elements in LCD and OLED displays. Utilization of carbon nanotube electrodes and transistors enables making displays flexible. Flexible displays are interesting both for small devices that could have large foldable or rollable displays when compared to the size of the device and large displays that could be rolled during transport and storage.

3.4 Supercapacitors

Carbon nanotubes and carbon nanobuds are used to make super capacitors with high-energy storage capacities [21]. Nanostructure based supercapacitors have extremely high power capacity, meaning faster recharging times than with conventional Li-Ion-batteries. Although the energy storage and release performance of the supercapacitor is superior when compared to Li-Ion batteries the lower energy density of supercapacitors is still a challenge if capacitors are considered as battery replacements. Advanced Capacitor Technologies Inc. provides commercially available supercapacitors which have an energy density of 30 W*h/kg which is already approaching typical values of Li-Ion-batteries of 160 W*h/kg [22].

3.5 Energy-generation Applications

Carbon nanotubes can be utilized in several roles in multiple energy production devices like dye-sensitized solar cells and fuel cells. Carbon nanotubes can be used as catalyst supports, charge-carrying elements, catalysts for energy conversion processes etc. These applications use the high aspect ratio, chemical stability, optical transparency, flexibility and extraordinary electrical properties of carbon. In dye-sensitized solar cells energy conversion efficiencies up to 11% were reported by 2008 [23]. Conventional crystalline silicon solar cells have typical conversion efficiencies of about 15%. Carbon nanostructured network electrodes enable manufacturing of flexible dye-sensitized solar cells. Flexibility would give the dye-sensitized solar cells the advantages of easy deployment of large area cells stored on rolls and also help to reduce manufacturing costs by enabling roll-to-roll-manufacturing.

Figure 2 shows how super capacitors and other nanotechnology based energy storage are dependent on basic research and several applied research developments.

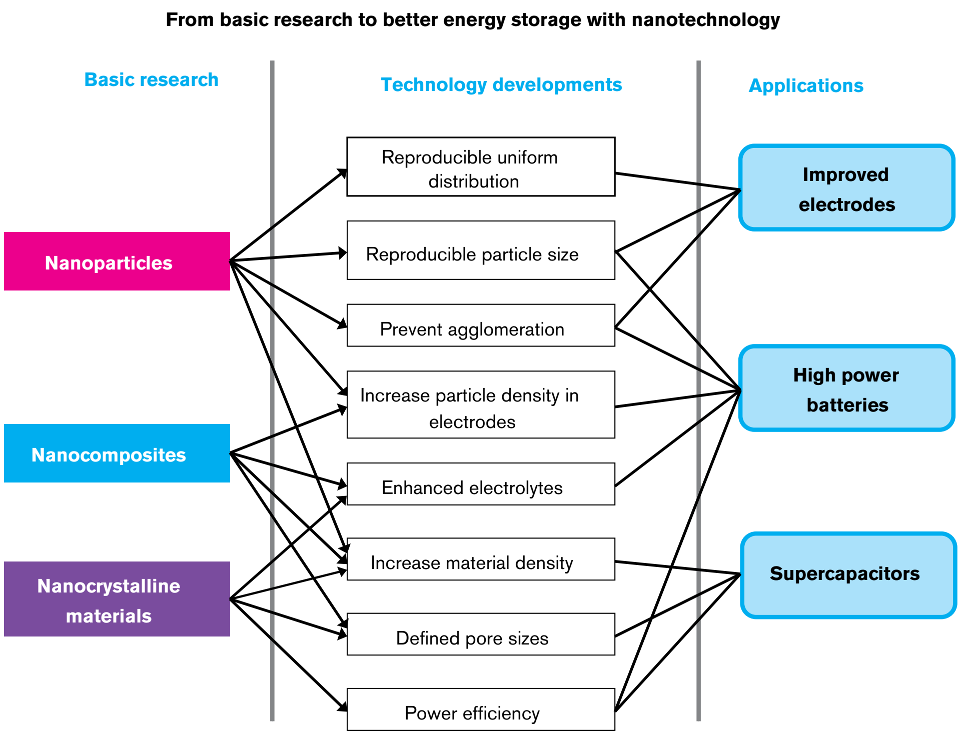

Figure 2. From basic research to better energy storage with nanotechnology

4 Industry

Nanotechnology is expected to have a substantial impact on the world's economy. However, it is not an industry that can be easily identified or defined because nanotechnology can contribute to many other industries and products. It can even enable production of totally new products, i.e. help to develop completely new industries. Nanotechnology is predicted to have impact on nearly every industry and region in the world [24].

There are multiple different market forecasts for nanotechnology. They all forecast a substantial increase in the market for nanotechnology during next few years. However the forecasts vary between quite moderate – 150 billion USD in 2010 to 1 trillion USD in 2015. The most optimistic forecasts predict the nanotechnology market will be larger than the prospected information and communication technology market [25]. According to best estimates, nanotechnology will appear in 15% of all manufactured goods by the year 2014. That would translate to a market size of about $2.6 trillion USD [26].

Carbon nanotubes and nanostructures are just a part of the whole nanotechnology market. Nano-scale oxides and metals will be making the greatest initial commercial impact but in a decade or two the impact of, for example, carbon nanotubes will grow substantially [27].

According to Global Industry Analysts, Inc. 2008 report, the US is the largest regional market and Western Europe the second largest [28]. The same report forecasted that Asia-Pacific would be the fastest growing market from 2002–2015. As an application area, electronics is currently the largest end-use market but healthcare is projected to bypass electronics in future.

4.1 Global Markets

Nanotechnology is a potential market for existing players as well as new ventures. Table 1 lists how different new ventures and established companies are targeting different fields in nanotechnology.

Table 1. Selected nanotechnology areas and developers [29]

Products	Ventures	Major Players
Fullerenes and Carbon Nanotubes	ONI, Hyperion, Canatu	Mitsubishi
Nanomaterials, Industrial Applications	Komarka, Eikos, Five Star Technologies	Samsung, Mobil Oil
Tools, Metrology and Manufacturing Software	Imago, Nanoink, nPoint, Zyvex, Veeco	IBM
Energy Storage	Altair nanotechnologies	ABB
Nano-life Science and Diagnostics	Nanofluidics, Nanosphere, Nanogen	Roche
Information Storage	Nantero, Nanochip, D-Wave Systems, Mitre	IBM, Seagate
Displays	Optiva Inc., Applied Nanotech Inc., CSIRO	Samsung
Nano-biotherapeutics	C-Sixty, iMedd	Bayer

The purpose of the table is to point out how the nanotechnology market can be divided in many different ways, and that many different kinds of big and small players are in the markets. The table is just referred by a source, but it does not indicate the leading position of the players. Mobil Oil, and other oil companies, are in nanotechnology markets, as well as pharmaceutical companies such as Roche. In addition, companies such as Samsung, Nokia, Ericsson and Sony are also developing systems with nanotechnology.

Figure 3 shows how nanotechnology research is distributed in the USA [30]. The map data is based on the zip codes of all universities, institutes and companies that are involved in nanotechnology. It is easy to see that with few exceptions all the states in the US are developing nanotechnologies, with a focus on Silicon Valley and Boston.

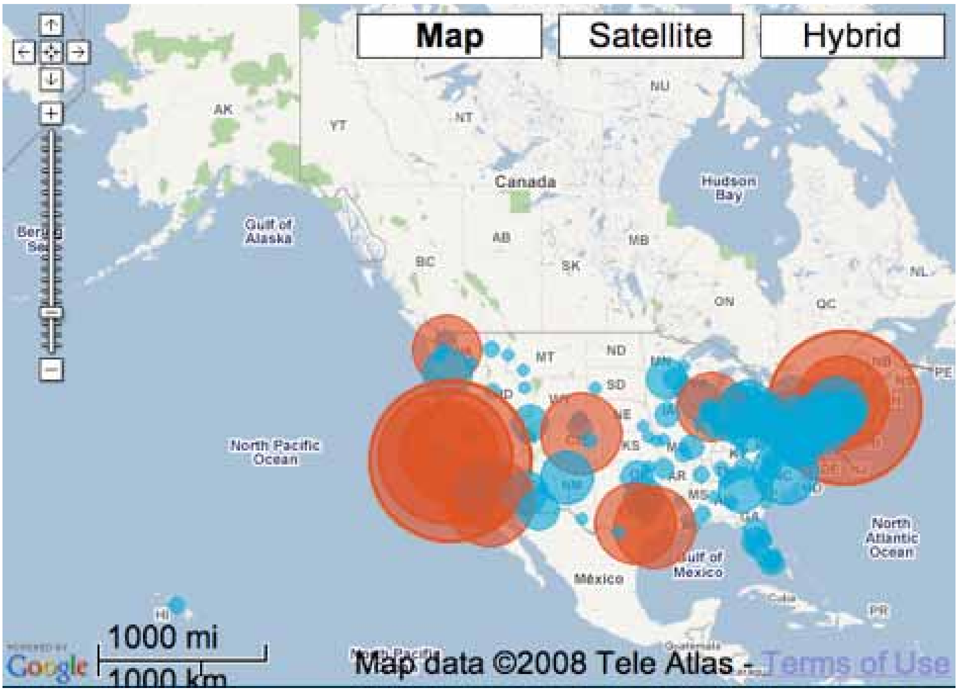

Figure 3. Putting Nanotechnology on the Map [30]

4.2 Nanotechnology Industry in Finland

Finland has a strong and active nanotechnology industry. In 2006 there were already 134 nanotechnology companies in Finland. There are also active world wide recognized research units in TKK, the University of Jyväskylä, and Tampere University of Technology. In addition to these, there is a major research-funding program which is coordinated by Tekes and the Academy of Finland [6]. The Tekes Finnano project has a total budget of 70 million Euros and the project's web page lists almost 100 projects. Half are academic research projects and practically all big Universities are represented (Joensuu, Turku, Kuopio, Lappeenranta, Oulu in addition to previously mentioned). VTT has several projects, and big companies such as Nokia, Vaisala, UPM-Kymmene, and Ahlstrom are joined with tens of projects from emerging ventures. There is a lot of action in Finland around nano and the cluster is heterogeneous.

4.3 Industry Dynamics

The carbon nanostructure market includes material, CNT-processing and applications. Carbon nanotubes are priced based on the type of tube, its diameter, purity, functionality, and quantity. The carbon nanostructure market has not developed as fast as expected. Some of the reasons are poor definitions of market segments and company strategies of focusing on patents and IPRs instead of on actual products [31]. Figure 4 shows how CNT raw material, CNT based components and end-user applications are linked in the markets.

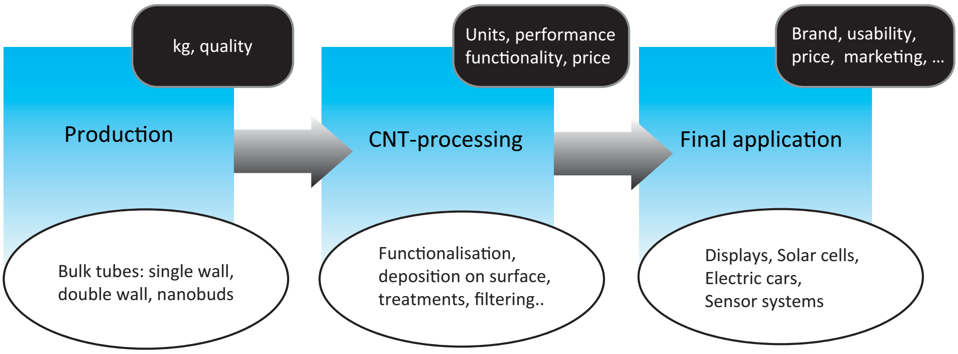

Figure 4. Value network for CNT based products

As an example, the nanoparticles pipeline could include production, functionalization, incorporation into nanocomposites and final application. The approach is not always this linear and could include sequential independent steps before the final application [3]. Similarly, the thin films pipeline includes production and deposition onto a surface, post-treatment and patterning, and application. Thin films production, like nanoparticle production, does not always follow this linear approach and for many applications, such as in the semiconductor industry, only the first 2 steps are normally implemented [3]. Hence, there are multiple approaches to nanotech and CNT production process, and as in case of Canatu, the core innovations take place in reorganizing and re-innovating the manufacturing process [32].

Furthermore, problems in producing the material, i.e. carbon nanotubes and other nanostructures, have further slowed the development of the market. The predictions of prices of under $300 for a kilogram of carbon nanotubes have not been realized. Current production units are not able to produce big enough quantities of carbon nanotubes [31]. Hence, market development is dependent on manufacturing innovations.

The figure 5 from [33] is a hypothetical timeline as to how the molecular manufacturing process will develop in time. There are two important claims in this diagram: in ten years the manufacturing process will multiply by 100 000 from a g/day to g/sec, and that we are currently in a phase of simple molecular products and we are yet to see complex, reprogrammable and self-replicating manufacturing processes.

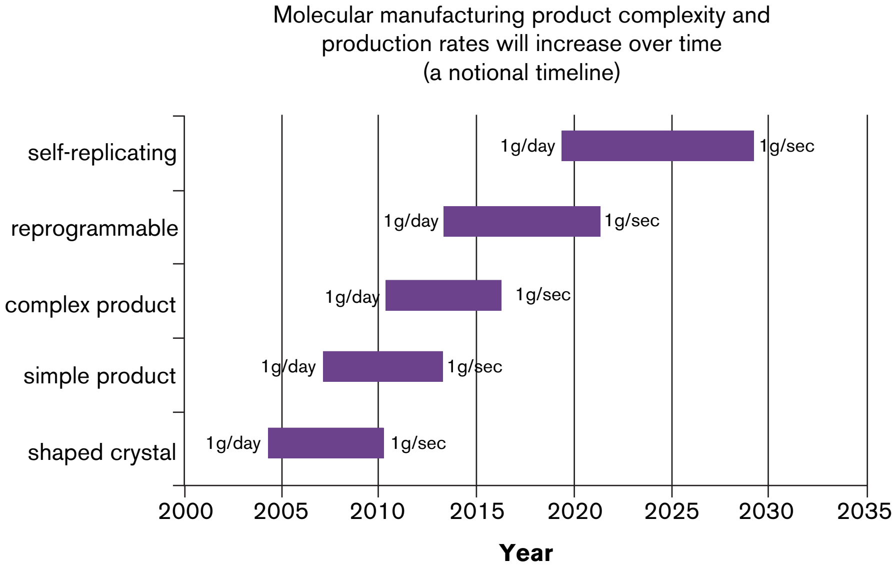

Figure 5. Timeline for molecular manufacturing process [33]

The driving forces of the market are predominantly in the applications domain. Consumers want better displays with nice new qualities. Industry wants solar cells. There is a need for rapidly recharging energy in various places. The electric car is probably the biggest market here. The nanotech industry is composed of CNT raw material and CNT-based components. In the applications market, there are many other value generating layers and nanotechnology is just one enabler among many. This is why it is hard to predict the growth of nanotechnology markets, because it first requires a good estimation of how the applications markets will develop, and how important a part will nanotechnology play in the development of these applications industries. Furthermore, the applications are further linked to other applications. In next chapter we will analyze our main IT-related nanotechnology components and their key applications markets.

5 Analysis

Our analysis is divided into three parts: literature based analysis, concept frequency analysis (using Google Trends search) and scenario analysis. In literature analysis we have been collecting information related to nanotechnology and applications industries in various conventional sources. We started the scenario analysis by organizing several brainstorming sessions, where we developed visions and narratives for future nanotechnology enabled technologies. We used the scenarios as a tool to collect our ideas and to put them in coherent user perspective. In next chapter we have collected the lessons learned from literature and scenario analysis. In later chapters we go further on with our scenarios and try to predict the unpredictable.

5.1 Key Applications Analysis

In the following five sections we will summarize our core findings for each of the core CNT-based component we have been analyzing. We believe that the most significant nanotechnology fields regarding ICT are solar cells, displays, sensors, and rapid recharging energy systems. In the tables, first the key features of CNT-components are described. We have been trying to identify such features that make the nanocomposite truly unique in comparison to other similar materials, and the features that are useful for commercial applications. Next, we have listed substitute technologies and systems for each application. The impact of these CNT-components is dependent on whether they can beat the substitutes in key market areas or create new markets that substitutes cannot cover.

After the substitutes the table lists key criteria, which this component must fulfill before it can make a significant market penetration. The fourth row in the table lists the most important improvements that have been enabled by nanotechnology in comparison to similar conventional compounds and applications. Finally we will introduce key application examples and a market overview.

We have tried to estimate the overall market impact, but the reader must understand that the figures are merely indicative and are our own estimates of the potential scale of the markets. We have used powers of ten in the table to indicate the market size. Hence, market size 9 refers to a rough estimate of a 1 billion () euro annual market for that technology. In addition, there is an indication of how dependent this application market is on nanotechnology. If it reads “benefits”, it means that the application can be created with other technology also, but nanotechnology can produce some incremental improvements. Such an application market can be a key driver for the nanotechnology industry only if the scale is large and the incremental improvement is significant. Then again, if it reads “dependent” or “highly dependent” after the application description, it means that the application won’t probably be introduced to in markets without nanotechnology or the significance of the application will drop several orders of magnitude in market size terms if it lacks the new features enabled by nanotechnology.

5.1.1 Solar Cells

Key features

- Marginal cost of energy production is low or almost zero
- Scalable (from very small size power generation for individual devices to high scale power plants)

- Unreliable (dependent on weather conditions and time of the day).
- Probably requires the same kind of battery system to guarantee quality of service when used as primary energy source.
- Flexible and portable.
- Can be used to cover various surfaces.
- Currently best-achieved energy conversion efficiencies are 10–12% for carbon nanotube utilizing dye-sensitized solar cells which is approaching typical efficiency of 15% of conventional silicon based solar cells which are not flexible [23].

Substitute technologies / systems

Wind power Fairly inefficient in less windy locations. Also works at night. Suitable for relatively large-scale units.

Diesel generators Pollution is the main drawback. Increasing oil prices make diesel generators inefficient. Stable and easy to produce and maintain. Suitable for various scales.

Biopower Inefficient to produce. Stable. Some pollution. Fairly big units.

Batteries Dependence on electric grid. Energy storage limited.

Conventional solar cells Similar functionality and limitations. Comparable or higher efficiency but no flexibility. Costly clean room environment is needed to manufacture conventional solar cells.

Key criteria to fulfill

Robust technology Solar cells need to be robust, lifetime of more than ten of years and can stand fairly harsh weather conditions.

Cheap price Flexible dye-sensitized nanostructured solar cells could be manufactured using fast roll-to-roll processing. Possibility to store solar cells in roll form reduces deployment costs.

Environmentally friendly The production process of nanotechnology-enabled solar cells should be environmentally friendly to boost adoption. The cells should be also easily recyclable.

Improvements enabled by nanotechnology

- In terms of efficiency nanotechnology can provide incremental benefits.
- In terms of usability and applicability in dynamic context, nanotech solar cells are revolutionary.
- Conventional solar cells are uniform, rigid and fragile for mechanical pressure.

Key application examples

Ad-hoc telecommunication infrastructure Base stations and power generation in rural areas could benefit from nanotech solar cells. (Market size: 8–9, benefits)

Complementary power source for cars and other vehicles All cars, busses, and trains could have a complementary power source in order to decrease power consumption. (Market size: 9–10, benefits)

Complementary power source for households and industry As with transport houses also could have a complementary power source from solar energy. It is especially useful to manage air conditioning. (Market size: 9–10, benefits)

Portable energy Large rollable solar cells are useful for all temporal events and operations, because it is an easy way to provide energy without additional infrastructure. (Market size: 7–8, highly dependent)

Airships Airships have potential to make a paradigm shift for air travel. Flexible and lightweight properties of nanotechnology are very useful in airships which are very weight critical. (Market size: 8–9, dependent)

Market overview

Solar cells have a big market. CNT can provide new features and expand applicability, but currently we can assume only few applications that are highly dependent on CNT technology. These markets seem small in comparison to the overall solar cell market. Hence the impact of CNT-technology on solar cell markets will depend on how much performance improvements it can produce.

5.1.2 Displays

Key features

- Random carbon nanotube structured networks are optically transparent and have comparable electrical conductivity as indium-tin-oxide films.
- Carbon nanotube networks can be flexible. This gives them potential for different kinds of surfaces. Flexibility enhances large area display's portability.
- No backlight requirement when applied to OLED-displays.
- Nanostructured field-emission displays are a potential future technology- The CNT-display can be also semitransparent

Substitute technologies / systems

Conventional (LCD or plasma) displays Conventional displays are produced in vast quantities. They are cheap, fairly lightweight and produce good quality images. They are also rigid and it is hard to process them to other than flat shapes.

Projectors Projectors are easily portable and can produce high quality large images on various surfaces. The problem of projectors is that they are sensitive to lightning conditions and due to its image generation mechanism it has some severe usability limitations.

Key criteria to fulfill

Image quality Image quality must equal to conventional flat screens.

Energy spending CNT-utilizing displays should spend equal or less energy than conventional

Price A CNT-utilizing display cannot be more than two or three time more expensive than conventional display. Preferably the price is the same as with, for example, LCD technology. For displays larger than 50” the price needs to be cheaper than it is currently.

Environmental The displays need to be environmentally produced and recycled.

Improvements enabled by nanotechnology

Nanotechnology has a key selling point in its flexibility. Itâ™s not currently a feature that is expected from displays, but it can be very beneficial in future applications. Lead solutions will create the need for this technology if they are successful. Conventional technology cannot provide similar qualities. Optically transparent carbon nanotube electrodes can be applied to both LCD- and OLED-technologies. OLED-displays provide a wider viewing angle and larger color-space than LCD-technology.

Key application examples

Public screens and windows Large (several meters) public screens and marketing windows could use nanotech based screens. Market size can be in hundreds of thousands or millions. The public screens have not become as popular as predicted early on with large LCD displays. (Market size: 7–8, benefits)

Personal portable screen A flexible rollable screen is a perfect companion for a mobile phone or a computer. The market is potentially several tens of percents of the total phone penetration, which means billions of displays. This is a several billion euro market. (Market size: 9–10, highly dependent)

Interiors If the price of screens becomes very cheap they can become decorative items, hence we can create digital paintings and coverings for table surfaces. This is a market for hundreds of million or billions of euros. (Market size: 8–9, dependent)

Large touch screens Large touch screens with several users with multiple touch points probably require some kind of camera technology. Transparent or semi transparent displays can be easily transferred as touch screens. These screens can also be used for document writing. Schools and offices are the biggest potential for such screens. (Market size: 7–9, benefits)

Market overview
The display market can be big, if a personal portable rollable screen becomes a must-have complement for a mobile computer. In theory, the combination of a portable rollable screen and a mobile device can be a tough competitor even for a laptop, or in emerging markets it can be the dominant IT terminal for all computing purposes. Other markets are significantly smaller and influenced by art, trends and content, which would utilize the new display form factor. Hence, if the personal portable screen scenario is not successful, then the CNT-screen will probably be a marginal market.

5.1.3 Sensors

Key features

- Status information for organic and chemical materials
- Sensors can be tuned to detect only certain molecules. A small number of molecules or electric current is sufficient to launch signal.
- Sensors are small and have low-energy consumption.

Substitute technologies / systems
Camera Camera based image recognition systems are a cheap way to make many kinds of analysis, whether it is biomonitoring or logistics monitoring. Cameras are a new step in the logistics chain and they are not integral solutions throughout the logistics chain.

Behavioral measures Behavioral measures (pose, speed of walking / talking etc..) can be used to measure physiological status. These can be used as substitutes for body sensors in some cases. Tracking behavioral measures might be significantly easier than implementing sensors.

Key criteria to fulfill
The criteria for logistics purposes and biomonitoring purposes are somewhat different.

Easy to install In case of logistics the sensors must be relatively easy to attach in packaging, so that they can be flexibly implemented in various packaging conditions. In the case of biomonitoring, the installation depends whether the sensor is an implant or some wearable device.

Information interface The information signaled by the sensor needs to be easily accessible by the logistics information system.

Cheap Unit prices of logistics sensors need to be very low. The unit price in biomonitoring can be significantly higher.

Harmless Sensors cannot cause any hazards. In any condition they cannot turn toxic for humans. If sensors are highly toxic (touch, little pieces) then this will add significant challenges for the application manufacturing.

Improvements enabled by nanotechnology
With traditional technology it is not possible to produce as accurate, and small sensors as with nanotechnology.

Key application examples
The applications are divided in to two categories: Logistics sensors (A) and biomonitoring sensors (B). Logistics sensors are used in the supply chain, for example, to ensure quality. Biomonitoring sensors are used to monitor a person's health or vital signs.

Fresh food (A) Fresh food is a potential market for nanotech sensors. The key selling point is not only detecting inferior products, but also the quality improvements in general. It is very hard to predict market potential for fresh food sensors. The potential is dependent whether sensors will be a value added service or an integral component in the logistics chain. (Market size: 7–9, benefits)

Manufactured food (A) Manufactured food is stored for longer periods. With proper sensors the food can be sold until it has deteriorated. Currently a lot of food is wasted because the predetermined last sale date has expired even though the quality in reality could be still adequate for eating. Over all tge manufactured food market is in the hundreds of billions euros worldwide. (Market size: 8–9, benefits)

Toxic chemicals (A) Nanotech sensors could be convenient way to monitor toxic chemical in logistics as well as in all different places with toxic material. (Market size 7–8, benefits)

Cosmetics (A) A key selling point for cosmetics is probably the resale potential. Users who receive information that the product is loosing its full potency are more eager to make a new purchase early on and use the product faster. Logistics sensors in cosmetics is also a marketing item, and because of this, the unit price can be significantly higher than with basic commodities such as food. Due to higher unit prices cosmetics is a potential early adopter market in the consumer sector. (Market size: 8–9, benefits)

Medical (B) The treatment of some of the most common diseases could benefit from accurate persistent body monitoring (such as diabetes). The medicine dosage could be more accurate. Nanotechnology applications in this industry can significantly improve human life. (Market size: 9–10, dependent)

Elder care (B) Older people with disabilities require constant monitoring. Location monitoring can be done with accelerometers or with RFID-tags which are at fixed locations and when combined with a reader device might provide more accurate indoors navigation methods than currently available. (Market size: 8–9, benefits)

Lifestyle (B) Body monitoring has several applications in sports, gaming, as well as the potential to initiate even new lifestyle processes like self-control tools (for example, alcohol use). This is a fragmented market with opportunities for various applications. There is a potential that this market could be huge. (Market size: 8–10, benefits/highly dependent)

Military (B) There are needs in the military to know the physical and mental condition of soldiers. This is a special market with a very number amount of buyers. If the US army would like to monitor all its soldiers then it would be an important case for the CNT-biomonitoring industry. (Market size: 7–9, dependent)

In addition to these categories, other potential uses of nanotechnology sensors could be for environmental measurements, and water supplies and sanitation in process monitoring. (Market size: 8–9, dependent)

Market overview

The CNT-based sensors market is very diverse. It is actually difficult to say that it is a single market. There are basically two ways to divide it: dividing into logistics and biomonitoring is one way, and to in electric and molecular detection is another way.

Furthermore, most of the sensors are sold in B2B markets, but there are potentially some B2C cases. Lifestyle market for biomonitoring sensors might actually be the biggest CNT-sensors market because there the potential customer base can be largets, but at the same time this market is probably the most uncertain. So far the lead application seems to be heart rate monitoring and all other monitoring applications for lifestyle markets are very marginal.

Also, the RFID based logistics sensor market has shown that the logistics market is not growing as fast as initially expected, hence the systemic demands related to sensors system implementation makes market introduction much harder than with stand-alone products.

5.1.4 Rapid Recharging Energy Systems

Key features

- In practice we are talking about supercapacitors instead of batteries.
- Rapid recharging means that the energy storage can be recharged in seconds rather than hours.
- With CNT the supercapacitors can be fairly lightweight
- Supercapacitors should have a high number of recharging cycles.
- The energy density of supercapacitors is still lower than the energy density of Li-Ion batteries by factor of 5.

Substitute technologies / systems

Conventional batteries There is quite a lot of ongoing development in conventional batteries. Lithium Ion batteries are widely implemented and cheap.

Fuel cells Fuel cells have the potential to outperform conventional batteries in efficiency. The recharge time of fuel cells is also significantly lower than with conventional batteries.

Power cord to electric grid For many applications the most conventional and efficient way is to have a plugged electric cord. In environments where energy is scarce, the usability of wireless devices could become a minor driving force in comparison to the cost of electricity.

Key criteria to fulfill

Lighter One of the key problems related to batteries is their weight. CNT-enabled supercapacitors cannot be heavier than conventional batteries. Lower energy density per mass unit makes achieving this goal a challenge.

Cheaper Batteries are a major cost factor in electric cars and there is small market potential for significantly more expensive energy storage systems.

Much faster If recharging times are incrementally higher, then the benefits of the new system become marginal. The cost of developing all the complementary products to fit a new kind of energy storage might be too high for large-scale commercial take off in the near future.

Safe Rapid recharging involves a high-energy current, which is demanding for connectors and insulations.

Improvements enabled by nanotechnology
Rapid recharging is a revolutionary feature. With a new kind of infrastructure it can really empower the electric car phenomenon as well as ubiquitous world.

Key application examples

Electric car The electric car market will be big, and rapid recharging super capacitors can become one of the most expensive components in electric cars. (Market size: 10–11, dependent)

Mobile devices Mobile devices could benefit greatly from rapid recharging features. The market is big and growing. It is possible that there will be soon more mobile devices than people on the Earth. The big question is how the rapid recharging will be adopted with mobile devices. (Market size: 10–11, benefits or depends)

Ubiquitous environment This application area can somewhat overlap with the previous one. There are some scenarios were super capacitors could be the enabler for truly ubiquitous environments. It is a big problem to have intelligent devices and furniture, a web of things, intelligent houses, active sensors, if there is a constant need for electricity. Rapid recharging energy systems with recharging robot are an alternative vision for managing the electric supply need for ubiquitous environments. (Market size: 8–11, benefits or dependent)

Robots Robots can become a major revolution within the next 15 years. Lengthy recharging is a common problem in conventional robots (vacuum cleaner and lawnmower robots). Robots could greatly benefit from rapid recharging. (Market size 8–10, benefits).

Market overview
There is potential huge market for rapid recharging energy storage. Our estimate is that the market can be as high as 100 B€–1 T€. Actually the key question is how the infrastructure can withstand the additional loads due to rapid charging applications.

5.2 Synthesis of Application Analysis

Figure 6 collects the final market predictions of our key applications. Based on this projection we claim that the biggest market for nanotechnology will be CNT-based energy storage and that this market will develop gradually starting after 2015 to become a blooming 50–200 B€ market[1].

1 This estimation is based on a calculation that energy systems share will be 3–5 % of ICT's 0.5–1.5 T€ market and 2–3 T€ of automobile market (market figure based on Datamonitor forecast), and 20–40% of the total CNT-based energy storage market's size will be related to infrastructure

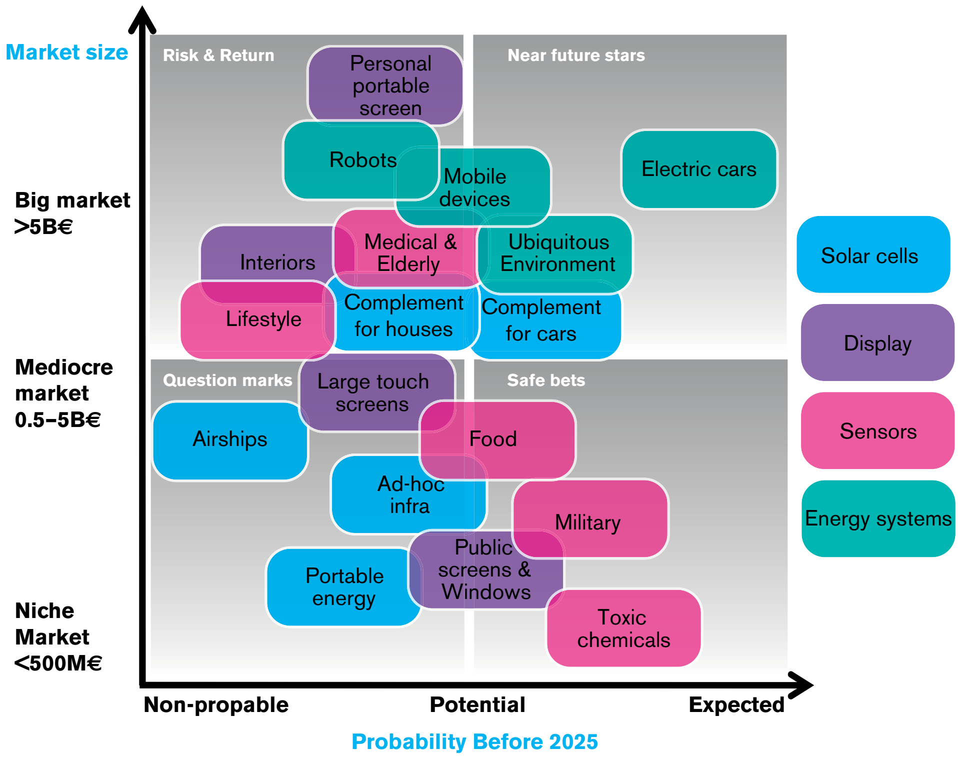

Figure 6. Market predictions for key applications

CNT-based displays will also hit markets in 2010–2015 and will become a significant display technology in 2025 with 10–40 B€ markets[2]. The reason for predicting slow growth in the market penetration is the fact that CNT-based displays need to compete mostly with pure performance and price in mass markets. The other qualities of CNT-displays are not driving forces in display markets, but regarded as additional features and part of a special design. It is very much possible that some revolutionary form factor will significantly nullify our estimation. For example if people want to have personal foldable displays, then the market could be almost tenfold our estimation.

We have had big difficulties estimating the overall markets for CNT-based solar cells. The solar cell market will be big, but it is very hard to estimate how big a share CNT-based solar cells will take before 2025. It is actually possible that the market penetration for CNT-technology could be 0% to almost 100%. If the price and performance even marginally increase over conventional technology the markets will quickly shift toward CNT. It is also very hard to estimate the total market potential. If many devices are equipped with a CNT-based complementary solar power source,

2 20–40% of the display market, and 20–40% share of end-user-price, in total a 300–400 B€ market based on extrapolation of Datamonitor data.

because of the flexibility and various surface qualities of CNT-technology, the markets for CNT-solar cells could easily double from a current estimation of 100–600 B€ solar markets in 2025[3]. The share of systems investments is probably less than 50% of total market volume. Most of the price is related to construction and maintenance. Anyway, the CNT-solar cell market could be big, up to 0.5 T[4]. Finally, we do not believe that there will be a significant CNT-based processor market before 2025.

5.3 Megatrends That Might Change Everything

Change is not always linear. Weak signals resonate with each other and suddenly we can be facing revolutions. In this chapter we will look deeper and try to estimate what kind of unexpected changes might appear, which would dramatically increase the need for nanotechnology-based solutions.

We can try to extrapolate from where we are now until 2025, but this approach will give a really narrow view of the future. Much depends on how quickly changes can generate the critical mass to really revolutionize how we do things. The network effects and unexpected consequences of seemingly multiple non-related technologies might have profound effects that are next to impossible forecast.

Here we go through some trends that we have deemed "megatrends", because they are, in our opinion, trends that either exist already, and a have huge effect on current technology developments or do not exist today. If they emerge, they will drive future technology developments.

5.3.1 Energy and environment

Energy will be a critical issue. NIC [10] estimate that "all current technologies are inadequate for replacing traditional energy architectures on the scale needed, and new energy technologies probably will not be commercially viable and widespread by 2025." They see that infrastructure investments are a major barrier for widespread use of alternative energy sources. They cite a study in which it was found that it takes 25 years on average for a new production technology to become widely adopted. Also, wide availability is not everything. Natural gas has been available since the 1970s, but its production lags behind oil, which is inferior in many ways to natural gas.

Nanotechnology also offers resource saving benefits not only through improvements to the efficiency of renewable energy sources (fe. solar cells, thermoelectric devices, fuel cells) or energy storage (fe. rechargeable batteries and supercapacitors, hydrogen storage), but also through reduced material consumption (fe. providing lighter and/or stronger construction materials, or increasing the specific activity of functional materials) and through the possibility of using alternative materials (fe. using nanostructured metal oxides instead of rare metals for catalysts). Ultimately, this

3 Global electricity markets in 2025 could be 3–5 T€ (extrapolation from Datamonitor data). Share of solar energy could be 3–15% (various estimations).

could mean fewer emissions, less waste, and a lower demand on limited resources. However, at the same time resource saving must also be viewed in terms of life-cycle assessment – will new products create a greater demand. Will new materials have recycling issues?

In our analysis we have already been considering that energy issues will be key drivers for nanotechnology development. Here we are no longer considering just energy price increases or pursuits toward green energy, but actual energy shortage on a system level. Furthermore, we are expecting that environmental pollution (mainly CO2 and other greenhouse gases) remains a big issue in the future with no real solution.

One possible way to overcome these energy infrastructure barriers is to find ways to make the transition with minimal or low-cost infrastructural changes. Better solar panels, windmills and batteries play a key role in this, because they enable energy generation and storage on a smaller scale on an ad-hoc basis. This way instead of depending on networks, it could be possible to generate energy where it is needed and bypass huge investments in building production and transportation infrastructure.

As described above in our key applications analysis, carbon nanotubes show potential in developing more efficient solar cells and energy storage. If these become cheap and widespread enough, the effects on our dependency on oil and coal could be lessened. While we see transition from hydrocarbon-based fuels as improbable, it is nonetheless a critical issue both economically and environmentally.

Environmental issues like climate change and population growth will also become critical issues by 2025. It is also possible that we might be witnessing a real global-scale environmental catastrophe by 2025 if sea levels rise more than ten centimeters in certain at risk areas and deserts continue to grow.

In both of these cases it is possible that governments will shift the emphasis of R&D spending toward technologies, which would help the situation. Nanotechnology can make a difference in multiple domains. Technology alone can't solve all these problems, but there are potential applications of using carbon nanotubes to, for example, make clean water. These applications are beyond our scope, but we do however note that environmental issues are a megatrend and we hope that in the future we will see advances in nanotechnology that could ease some of the pressing issues of the developing world.

It is estimated that by 2025, the world's population will have increased by one billion. Today already, 1 billion people do not have access to safe water. According to IFPRI [34], water is one of the main factors limiting future food production, and the World Bank estimates that food prices have increased by 50% by 2030. Access to clean drinking water is the main reason that the average life-expectancy has increased and infant mortality has decreased in the last century.

However, water-borne pathogens, pollution and increasing population are putting massive pressure on global water resources. As a result it is estimated that 20% of the world's population has inadequate access to clean drinking water and that by 2025 the increased demand on our water supplies will mean that each person will have approximately 25% the volume that they would have had in 1960. Although filtration and purification plants have been installed throughout the globe to provide clean drinking water, in some cases these have limited success due to the inefficiency of the active materials. For example, magnetic iron oxide nanoparticles can be used to remove arsenic from ground water. In this particular case, arsenic can be derived from both natural sources (minerals underground) and pollutants. This is a major global problem, particularly in countries such as Bangladesh, where it is estimated that between 46 and 57 million people are exposed to arsenic levels above World Health Organization (WHO) guidelines of 0.01 mg/l.

In their outlook to 2025, NIC [10] have ranked some technologies' breakthrough by 2025 as probable, possible, or plausible. Both clean water and energy storage technology breakthroughs are probable. Biofuels technology is seen as possible.

5.3.2 Nanocomputing

We are fairly sure that we won't see cheap single carbon nanotube (CNT) based processors in the supermarkets within the next 15 years. This is what our analysis says, but there are some who are more optimistic about nanocomputing. If the science and engineers manage to make an efficient process for manipulating single carbon nanotubes and make powerful processors, then we might also witness a nanorevolution in computing.

The processor industry has been following Moore's law and with a high likelihood will continue to do so. Traditionally one of the ways to make processors faster is to make them smaller, but the limits of nature are becoming increasingly visible. It is inevitable that more powerful processors will be introduced and that there is a market for them. On the other hand, we have recently witnessed the emergence of a new market for relatively low-power low-priced netbooks. Also, another recent phenomenon, cloud computing, is moving processing-intensive tasks from clients to massive server farms somewhere in the cloud. These trends might cause demand for faster and faster processors to fall and this would affect the market size for really powerful processors.

We can see benefits in nanocomputing in, for example, ubiquitous computing, but we don't see widespread adoption of CNT-based processors as probable by 2025.

5.3.3 Robotics Breakthrough

Today there are 1 million industrial robots in use around the world and this number is expected to grow to 1.2 million by 2012 [35]. In our analysis we have calculated that there will be some demand for nanotechnology because of robotics development, but we have estimated that this market will be still fairly small in 2025. Bill Gates seems to think differently. He says that there will be robots in every household within the next few years[36] and there are some industry reviews that claim that the next "factory of the world" after China won't be India or Africa but "everywhere" because of robots.

It is possible that we will see an exponential growth in robotics within next few years and we'll witness many unexpected uses for robots that we have not been anticipated. In this case there might be a market for billions of robots and the market size could be in trillions of euros. Robots can utilize nanocomposites in several ways: energy generation, energy storage (f.e. rapid recharging), interfaces, electric muscles (benefits of using nanocomposites compared to conventional), frame materials and sensors.

One requirement for a robotics breakthrough is that the market has to become a diverse ecosystem of actors like the PC industry. We see that a similar explosive growth of robotics could be possible through standardization and common platforms. We think that this kind of robotics ecosystem is beyond 2025.

However, a booming robotics industry could be unexpectedly high driving force for the nanotechnology industry because there are several systemic links in the markets. For example one of our scenarios was based on the idea that the ubiquitous computing vision could be enabled by supplying all IT-devices (which in ubi-scenario would mean most items everywhere) with rapid recharging. Another potential use is service robotics for the aging population, but it is not probable that these technologies will break through by 2025 and NIC has ranked a service robotics breakthrough by 2025 as "plausible".

5.4 Concept Frequency Analysis

Concept frequency analysis is an experimental analysis based on Google Trends data. The advantage of this analysis is to map the history and current status of how much certain concepts are referred to in the web. The power of this kind of analysis is based on the massive volume of referenced sites on the web. However, different concepts can have different dynamics and plural meanings, which distort the data. Nevertheless, for a single concept with a high reference volume the data can show fairly valid timelines.

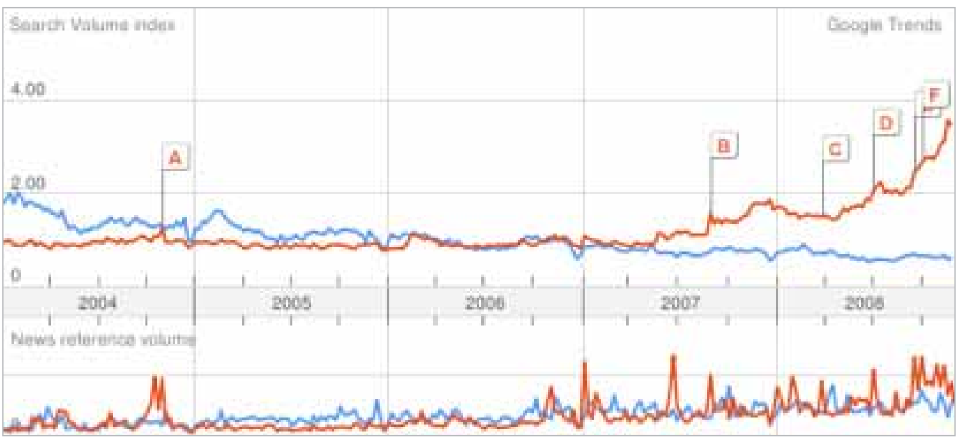

Figure 7. Source: Google Trends, keywords: Nanotech (blue), touch screen (red), accessed 11.12.2008

Figure 7 shows that nanotechnology is not currently an extremely hot topic in comparison to the past. As it happens, in 2004 the only references to "nanotechnology" on the web according to Google trends was "touch screen", but in 2007 and 2008 touch screen had become four times more popular, most likely due to iPhone and other touch-screen mobile phones announced during that period. Based on this data, we can say that nanotechnology is not hot now, but as the graph shows, it can all change within one or two years. It is important to note that the idea of touch screen was already introduced in the sixties, and in the eighties there were already commercial products.

Figure 8. Source: Google Trends, keywords: nanotechnology (blue), carbon nanotubes (red), flexible displays (green), super capacitors (yellow), nanobuds (violet), accessed 11.12.2008

Figure 8 shows the reference volume of nanotechnology in comparison to carbon nanotubes and some of the key applications, super capacitors, flexible display, and nanobud. It must be noted here that the terms consisting of two words are clearly at a disadvantage in comparison to single word terms. This figure shows that carbon nanotube is approximately 10% of the "total nanotechnology" in terms of web referencing. The applications are practically non-existent on the web in comparison to the main terms. Google Trends provides data about the geographic locations where the concepts have the highest frequency. It seems that India and other Asian countries have a high presence on the web related to nanotechnology and carbon nanotubes.

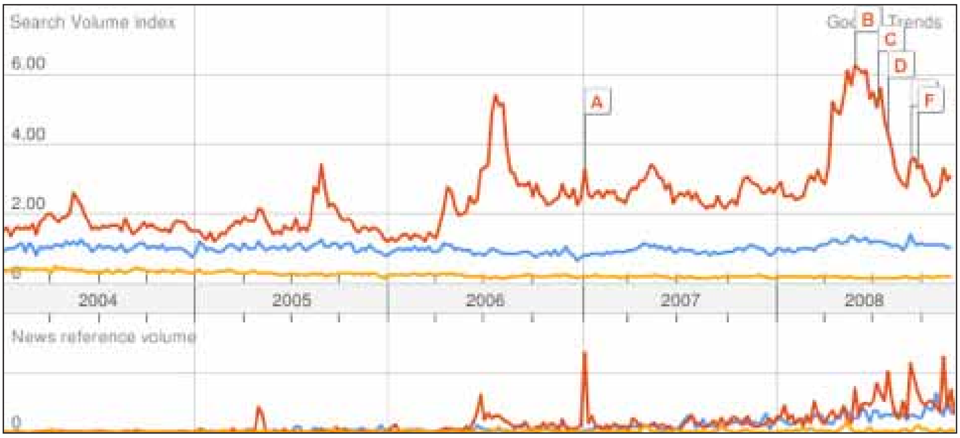

Figure 9. Source: Google Trends, keywords: electric car (red), solar cell (blue), biosensor (yellow), accessed 11.12.2008

Finally there is figure 9, which is related to CNT-enabled key applications: electric cars, solar cells, and biosensors. These words are selected because they are comparable. Plain “display” or “car” would have an order of magnitude higher volume index. This shows that during 2008 there has been hype around electric cars, and that there has not been anything like that related to solar cells or biosensors in the past five years.

6 Conclusions

Since carbon nanotechnology can provide advancements and interesting new features to ICT systems and devices, it is likely that it will have an impact on ICT. In addition, carbon nanotechnology can contribute to energy technologies in a way that has a direct link to ICT. The question, whether carbon nanostructures will and can revolutionarize ICT in significant ways on or before the year 2025, is however more problematic.

The most potential carbon nanostructure based or enhanced applications relating to ICT are sensors, solar cells, displays, and rapid energy storage systems. Energy densities of supercapacitors are gradually approaching conventional Li-Ion-batteries and supercapacitors still provide superior power density. Carbon nanostructures have an essential role in supercapacitor designs. The state-of-the-art regarding these applications is, however, too immature to allow easy prediction of timeframes for each application to enter markets.

However, the state of carbon nanotechnology is currently quite clear. Research is advancing both in nanostructure manufacturing and application development fields. There is also a strong interest in the ICT industry to develop nanotechnology based systems and devices. As a consequence it is possible that though nanotechnology will most probably grow to be an extremely big and important market, there might not be a nanotechnology revolution. The big players in the markets might stay the same and nanotechnology applications introduced to the markets slowly one by one. This would result in incremental development and no big surprises regarding new nanotechnology applications or functionalities. Without disruptions there will be no visible revolution.

A visible nanotechnology revolution in ICT is not, however, totally impossible. Some nanotechnology possibilities have the potential to enable totally new ways to use ICT. For example, super-capacitors, together with sophisticated robotics, could revolutionarize white-collar office work or at least the parts of it that are linked to using ICT. Also flexible and transparent displays as well as transparent solar cells could change the nature of ICT devices quite remarkably. Our scenarios describe some of the revolutionary characteristics of these applications (see appendix).

It is difficult to predict the future path of nanotechnology, especially its most important applications. Therefore, we do no wish to draw a traditional roadmap of future development of ICT related nanotechnology. Instead we suggest that our analysis summary (see the figure in chapter 5.2) can be used like radar to follow the development of the carbon nanotechnology industry. We believe that the most significant nanotechnology fields regarding ICT are displays, sensors, solar cells, and energy storage systems. By seeing in which order they hit the markets during next few years and with what kind of exact applications, one can keep track of the state of the nanotechnology. Our predictions of development trends can be read from the probability axes of the summary figure.

As an appendix we offer two scenarios that demonstrate in a concrete way what might be possible with nanotechnology in 2025. In these scenarios we'll explain how both work and leisure situations benefit from highly improved sensors, display, solar cells, and rapidly recharging energy systems.

7 *Scenarios*

7.1 Scenario 1: Ubiquitous Smart Robotics is Here!

Keywords: AI, mobility control system, fuel cells, energy storage, nanotech enhanced structures

Premises

MFRC (Mom's Friendly Robot Company) Inc. is one of many independent, successful robotics companies. It started as a spin-off from a major industrial company, from where it inherited most of its employees and knowledge of the field accumulated for years. The company is focused on highly specialized robots for industrial uses. Most of MFRC's success can be attributed to being one of the first to truly build robust, strong and flexible mechanical structures powered by fuel cells. So far, many companies have struggled with balancing robustness and flexibility, but thanks to advanced carbon nanostructure-based materials and fuel cells, MFRC has been able to overcome this problem.

In the last 20 years, nanotechnology and robotics proved both to be working and harmless. More importantly, they were accepted by society and some applications were even highly anticipated. People generally accept robots as reliable and trustworthy and the image of a robot future is not perceived as scary or intimidating. Early robotics products, which were mostly for toys for entertainment use or for simple home tasks, paved the way for more sophisticated robots for all purposes. These toys and vacuum cleaners did not use highly advanced materials or software, but the image impact was significant. There is at least one robot in each household, but these are usually vacuum cleaners or other specialized service robots.

A few key relevant technologies, for example, artificial intelligence, mobility control system and environmental abstraction have been greatly improved and are ready to be integrated. Much of the development effort came from the military and they funded much of the initial development costs for more advanced robotics. As these technologies got better, civilian and industrial uses became bigger and they were more interesting for robotics companies. Customers are also seeking new gadgets to entertain themselves. Thanks to rapid economy growth for the past few years, they have enough in the budget to do so.

The business ecosystem for robotics is diverse. Most hardware parts from the traditional industrial manipulator manufacturers gradually became standardized, and available off-the-shelf. Their business scale is starting to be comparable to the conventional industrial market. One the other hand, many software companies are starting to offer full software development kits for different modules or for the whole robot operating system. This has become a new rising factor for these companies. Like many other companies, MFRC Inc. buys most of its parts and software, concentrating only on their own core technology.

Story

John Connor works as a Program Manager for Advanced Robotics Development Unit at MFRC Inc. He is now involved in multiple projects, which aim to implement their new nano-enhanced robots with different applications. His work also includes keeping in contact with MFRC's suppliers, which provide the new technology that will further improve the performance of their robot products.

One of the important projects Connor manages is a marine ecosystem monitoring robotics project, where a mothership robot provides the charging and service system for a group of small, deployable robot units for underwater or possibly other hazardous operations. The mothership has its own power generating mechanism from the sea that makes the operation time for the whole system virtually unlimited. The small and deployable units consist of a swarm like robot community, which covers a wide range of the ocean, with their sonar communication system. They can accomplish very complicated missions with their joint effort.

For the moment, one of the major problems with long missions is how the robots can store energy. Fuel cells are a viable option, because they have many advantages over other energy storage methods. This is a new challenge for John, because in this project the unit robots do not have the capability to generate energy by themselves. In the projects that John had worked on before this was not a problem at all – and besides, the solar cells on robots' surface skin have been working so well that people began to think most robots did not actually need any power at all. Although, in fact, they still need to go to the charging station at some point autonomously.

This mothership project is in a pilot phase in Indonesia and Connor is on way to there to see how their new robots are working. He's coming from his office at MRFC's Spain office in Barcelona. For such long trip, he has chosen to fly on an airship. Instead of being cramped in the economy seat of a jet, Connor enjoys the same space and facilities for working as he would have in his office.

The oil problem is still largely unsolved, but alternative ways of transport like electric cars and airships have lessened the dependency on more oil-consuming ways. Airships are naturally much slower than more traditional jets, but they save time in other ways. Because they do not need a runway, Connor doesn't have to spend hours in taxi on the way to an airport, but can board his airship from the city center. While it's technically possible to operate mobile phones and laptops on a jet, he can make every minute of the additional travel time count, because he's not glued to a seat next to other business travelers.

He is able to work in his own cabin with full network connectivity even over the sea thanks to low earth orbiting pseudo-satellites. In fact, it has become a very popular way of traveling for a businessman like John. And a major improvement in airship technology is its nanotech enhanced structure, which has much lighter weight and more importantly, functions as a flexible cover for a solar panel. Using a fuel cell, again nanotech enhanced, on board, these airships are mostly self-sustainable. Furthermore, using energy efficient traveling like this, John will also get some "Green Points", granted by the UN, which means John's travel expenses will be reduced.

One of the main problems of robotics is how to perceive the world and nanotechnology allows for super-sensitive sensors. These sensors were one of the first nanotechnology success stories. They are much simpler and cheaper than other earlier sensors and have mostly replaced them.

Mechanical structures made from carbon nanostructures are strong and lightweight, which is an energy-saving solution. While such structures are becoming widespread in construction, using them in robots is still quite new.

7.2 Scenario 2: Cut the Last Cord

Keywords: cut the last cord, mobile electricity revolution, re-charging robot, wireless office. Nanotechnology keywords: rapid recharging, energy storage, light-weight structures

Premises

In the early 2020s nanotechnology -based batteries and energy solutions hit the market at full capacity - especially the carbon nanostructured supercapacitors that provide high energy capacity and extremely rapid re-charging times. High capacity supercapacitors provide recharge terminals. Entertainment devices and battery life can last several weeks without the need to re-charge.

The development of carbon nanostructured super-capacitor technology combined with fast wireless internet connections has cut the last cord for knowledge workers and students. Back in 2008 wireless internet connections were already widespread in developed countries but low battery capacity forced users to either "hibernate" or disable many features of mobile devices thus reducing potential uses for these devices as well as prevent complete freedom of movement as users had to stick to locations where electricity was available for re-charging. The development of battery technology has thus made work less localized and the division between work-time and free-time is blurred. Surprisingly, technologies that aimed at enhancing the equipment of mobile users had also a huge impact on normal office work. All wires disappeared and every device became a ubiquitous mobile device. Workers were freed to move all displays, printers, keyboards, and PC's seamlessly where they wished, based on their changing tasks and needs.

The killer service enabling new wireless offices were re-charging robots using nanotechnology-based super capacitors to provide extremely rapid re-charging services (1–2 minutes) for all equipment on office premises. Nanotechnology-based batteries provided enough energy for 7 days minimum – "usage time" for most of the devices. The re-charging robots would patrol around the offices during idle hours (i.e. nights and weekends) and made sure that all the devices were fully charged when the workers returned.

It is carbon nanostructured fuel cells that provide an energy storage solution to continuous high-power requiring applications, such as electrical cars. Hydrogen or methane-based energy storage and energy conversion into electricity using fuel cells is widely used, increasing energy efficiency for transport systems (public and private) and drastically reducing pollution emission levels. Super-capacitors are also used by the automotive industry as "load balancers" and for so-called "regenerative braking systems". However, the excess heat from the high efficiency fuel cells still limits their usability in mobile devices.

Carbon nanostructures are also used widely in the flexible and printable electronics industry. Flexible carbon nanotube conductors with high optical transparency are the backbone of large area displays and speakers that are widely used in both public places for advertisement and in homes for home decoration. Low cost "roll-to-roll" manufactured displays cannot quite match the performance of rigid displays for movie viewing purposes yet but cost-wise these displays have advantages. A similar technology can be used with lower production speed and higher cost to produce flexible high-resolution components as in wearable devices (similar to Nokia Morph). Roll-to-roll-electronics manufacturers are producing nanostructured RFID-tags that are integrated in various goods and other objects for use with mobile terminals. The widespread use of RFID-tags also provides GPS-like location services indoors and in all urban areas.

The political development of Finland has been stable for last 20 years. Finland is still a model citizen of the European Union. The main change has been aging of the population: in 2025 a bit over 50% of the population is retired. However, the effect of an increase in the aging population has been smaller than expected. The basic infrastructure in Finland is in good condition. After the latest nuclear power plants started to operate there is enough electricity to match the demand of technology enthusiasts. Global economic development forced companies to move factories and other manufacturing units abroad but the R&D units remained in Finland. The Finnish education system is still in good shape and the goals of building a world scale top university is starting to concretize.

Story

An Afternoon at Technopolis technology center.

Marika hears someone knocking on her door. She turns to face the door and encourages the visitor to come in. "Do you have a moment? I got some problems with the blueprints of the new system," Janne, one of the company's system architects, asks. "It will only take a minute," he adds while walking into the room. Marika sighs remembering that Janne is one of the most experienced engineer in the company and asks her advice regarding only really difficult problems.

Marika takes her primary display from her desk and puts it on the smaller desk next to Janne. The wireless display is easy to move around the office room and Marika has a habit of changing her work setup a couple of times every day depending on her tasks. Janne sends the image from his PDA to the display. "We probably need to check details from the blueprints," Marika mutters and takes a large display roll from her shelf. The display's battery indicator is green meaning that the battery is full. "The re-charging robot must have visited last night," Marika thinks while opening the display roll on the table. Janne switches the display on and selects the correct blueprint from company's server to be shown on the display. The large rollable displays have really helped in situations where there is need to work with colleagues on maps, satellite images, or complex diagrams. Janne and Marika can sit on opposite sides of the table and work with the diagram and look at the text and other "oriented" information from Marika's traditional display. After two hours almost all questions are solved. "Ok, I think we need to think those new features a bit more. Let's continue tomorrow and see if we can come up with a better solution! " At 6:15 p.m. Marika decides to go home as she has to prepare for the next Parkour London Marathon. The floor's re-charging robot whirls past Marika as she walks to the elevators. Marika starts her electric car and heads home before her training.

Marika is now near Finlandia-talo and has been running on the Parkour track. She listens to tunes from last year's biggest TV-series coming out of her Suunto activity monitor and stops running. She sits on the ground and looks at her wrist display. All signals are OK and the data streaming seems to still work. The time, 15 minutes through the Helsinki city center, is her new record. Marika has been an active free runner since high school and has even been nationally ranked. The new nanotech-enhanced Suunto activity system got her really hooked almost instantly. Running in and through an urban environment, performing stunts and finding new paths that others are not able to use fitted her needs for both physical and mental exercise. The free running community is quite active around Helsinki and has built a nice urban orienteering track that utilizes GPS and other location and navigation services to build virtual control points and flags. Marika takes her laptop out of her backpack and checks her email and today's schedule. Marika smiles at the backpack's NanoTechReinforced™logo and wonders if there are anything that is not somehow nanotech enhanced nowadays. She sees a reminder to check that everything is okay with her grandmother and that she has taken today's medicines. Marika starts a video conference and in a few minutes her grandmother appears on the screen. "Have you been running again?," grandmother asks a bit worried. Marika shrugs and tries to change the topic of the conversation. Grandmama has a question about her personal health monitoring system. Luckily Marika's mother joins the conversation. She is driving toward their summer cottage with the electric car given by her company. Marika's mother promises to explain how to utilize the new functionality. "I do not need to re-charge the car for 300–400 km but I'll stop for lunch soon and call you then," she says and disconnects from the call. Grandmama has a question about her personal health monitoring system. Marika sees that medicine levels are well under the limits and urges her to go to her doctor. She asks her if she wants her to make the appointment now but her grandmama says she'll do it via the Internet and then promises to call Marika again in few days.

Marika notices that her laptop battery is running out in few hours. "Has it already been a week? ," she wonders. Marika remembers that there is an electricity re-charging hub at a grocery store near the university and decides that she'll grab some fruit and milk on her way home. Marika throws the laptop back to the backpack, starts the recording systems and begins to run toward the university.

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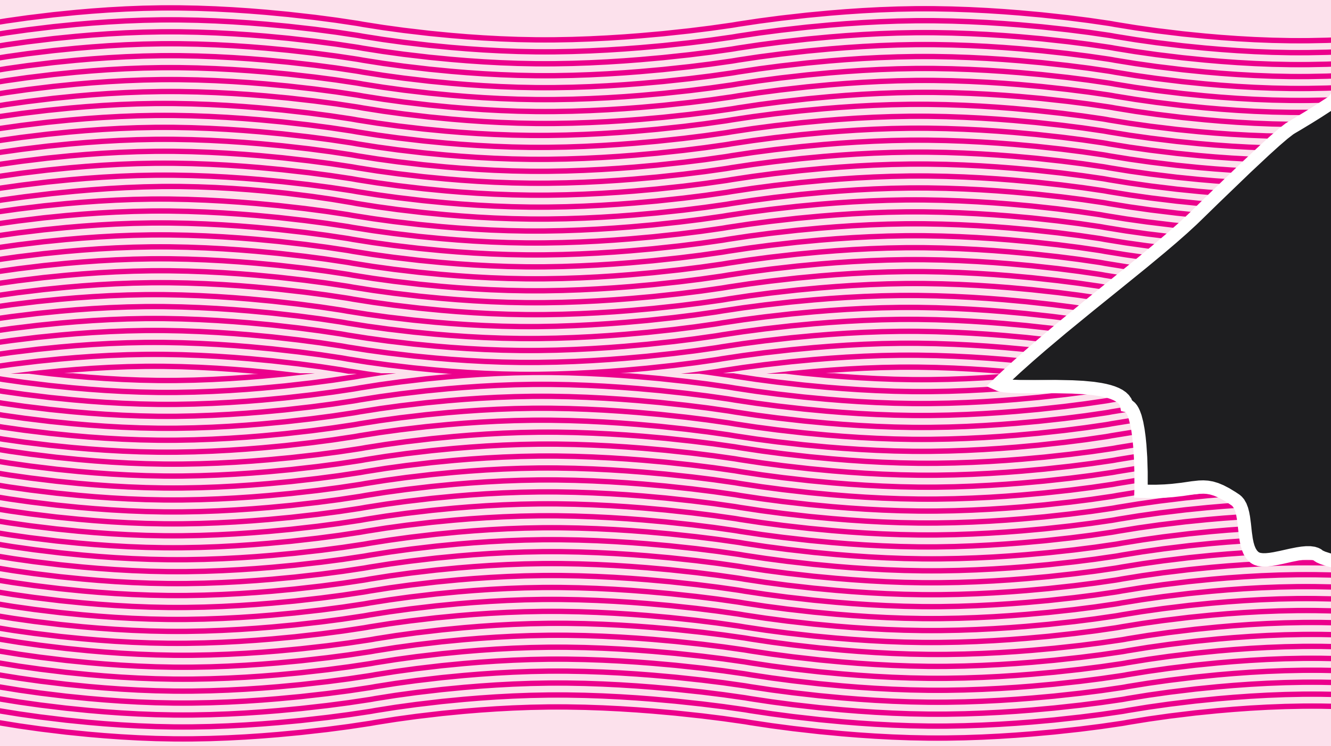

2
Rays to the Future

2.1 The Future of Media – Free or Fantastic?

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Abstract

The rapid growth of media usage, convergence of different media branches, emergence of new media formats and platforms, involvement of consumers in content production, spread of the Internet and digitalization are the most significant changes we have witnessed in the media landscape during the last decade. The future of Media in 2025 is still a puzzle with millions of pieces. Our study aims at fore-sighting the future of different media branches and the fundamental dimensions shaping them. We

categorize future media into six branches, including printed media, radio and audio, social and Internet media, Television, gaming, and out-of-home media, and focus on the changing trends in terms of production, consumption, distribution, revenue model, and social effects. In 2025, the media consumer is estimated to reach six billion around the world connected to digital networks. Media will play a more important role in people's daily life. Thus, many of people's daily activities, ranging from work, leisure, education, to social life, will be mediated. The media landscape will change dramatically, but some fundamentals of the media business will probably remain as we know it now. Big companies are expected to finance the premium content production, control distribution and create global media phenomena. Users will be empowered to choose what to consume and contribute to the production of content.

1 Introduction

Media is inevitably becoming one of the most influential ways we receive, share and perceive information about the world around us. In 2009, we are exposed to media at an unexpected level, as much time as we spend at work or asleep. The amount of information we receive through media is steadily rising and, as seen in Figure 1, is estimated at almost 90 hours per week in 2025 [26]. Media as we know it now, is controlled by big media empires that dominate the content production and supply chain. In 1995, the media landscape was not as diverse as it is today. The Internet did not exist; printed media was dominant; and few television channels fulfilled peoples need for daily entertainment. The traditional way of distributing media; print and postal service, or analog broadcast of radio and television, had defined the way big media empires operate. Due to the digitalization of new types of content distribution, automatic content production and content localization have become possible. In addition, for example graphical browsers, mobile devices, and new display technologies for example enable new content consumption experiences and easier access to content everywhere. Recently, we have witnessed the boundaries of these empires to shaking. Social media has empowered users to publish their own media and we all have become not only content creators, but also leaders in innovating new types of media products by reusing and re-mixing what others have created [34]. This demonstrates that consumers have a more dominant role in the supply chain of the media industry. The old way of operating in the media business is becoming less sustainable. Thus, empires are losing their control position. The change from 1995 to today has been dramatic. Is there going to be a similar shift in the control position in the next fifteen years, or will the empires strike back?

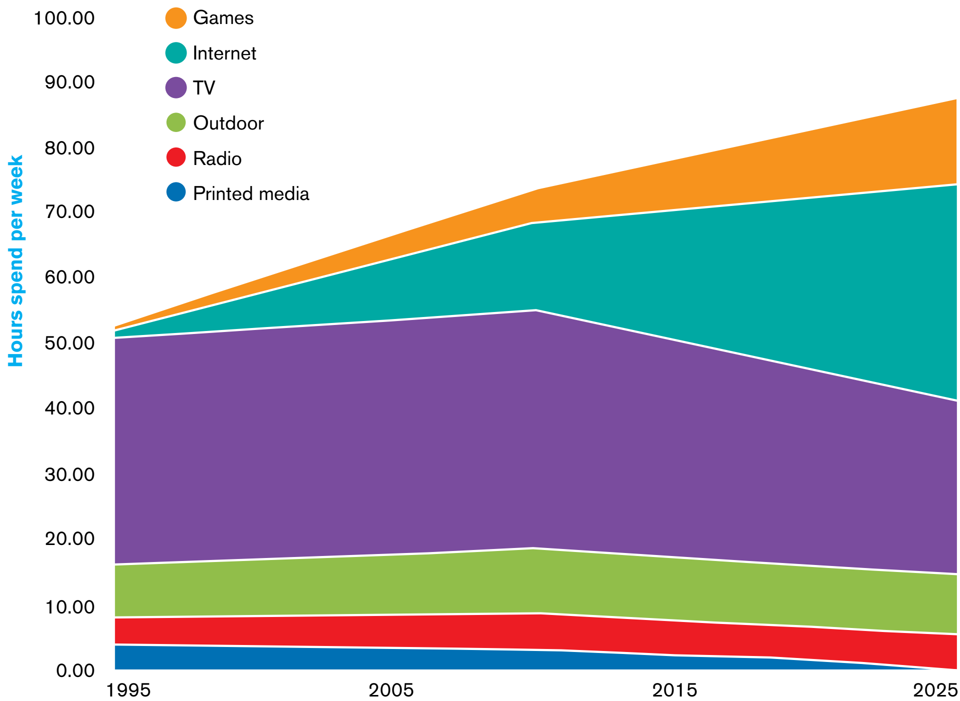

Figure 1. Media consumption will grow rapidly and is expected to reach 90 hours per person per week around 2025.

According to Comscoren [13] in December 2008, a billion users accessed the Internet. This is not just an indication of the take up of the Internet as a content mediator, but as the transformation of the whole media industry. The fragmentation of media channels shows that broadcasted mass media, such as television and radio as we know them now, as the main communication media are fading away, while the time spent consuming on-line and on-demand media is increasing. Microsoft predicted that by 2010, the Internet will overtake traditional TV [21]. It seems that the media industry is affected by the long tail effect [6], where 80 per cent of the content is rarely consumed, but formulates the majority of the total content consumed. The focus shift can also be seen in advertising as in the last five years, on-line advertising has grown more than 100 per cent.

Despite the fast changes in the media landscape, there remains real value in traditional media production and distribution processes. Distributors such as broadcasters, publishers, and agents will continue to play an important role in the media landscape as long as they can effectively establish and create added value. In practice this value added is created by utilizing the scale advantage of marketing resources, brands, content aggregation, financing and customer management. Foremost, big players can also provide scalable infrastructures where user innovation and user generated content

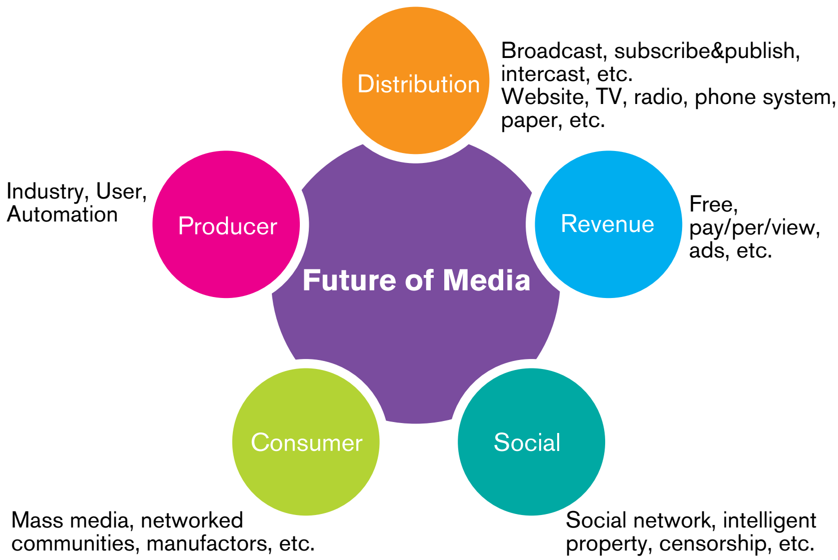

Figure 2. Dimensions shaping the field of the future of media. The success of the different media types, such as printed media, TV or social media depends on understanding the dynamics of content production, distribution, consumer behavior and selecting the right revenue models and supporting the social layer to enable the content production, aggregation and sharing.

production reach a critical mass. These are the fundamental assets that empires can use to maintain their position in the media environment.

We will present our vision of the most important elements that will affect media industry in the future. We start with a vertical analysis of the media landscape by looking at the future of media in five different perspectives: consumer, social, revenue, distribution and production. This vertical analysis is complemented with a horizontal analysis of the future of media types as we currently know them: print, radio and audio, social media and the Internet, TV and video, games, and out-of-home media. Finally, we present conclusions and give conclusion of the media landscape in 2025 by focusing on projected market changes, change drivers and possible disruptive future media phenomena.

2 Media Landscape

The landscape of future media is not only dependent on new technologies, but a complex combination of technologies, social phenomena, and business practices. We see five major dimensions, shown in Figure 2, that shape the media landscape.

Consumer One of the dominant aspects of changes in the media landscape is the role of consumers. Easy and cheap distribution methods, easy-to-use production tools and content interfaces, and peer support is empowering users to become producers. This has enabled the growth of media of different scales; mass media at the head of the curve, mid-sized semi-professional publishing at the shoulder, and an extended tail of micro production with small audiences and value [6].

Social media The term social media, credited to Chris Shipley, refers to the way people communicate information, typically words, pictures, video and audio, online through participation and collaboration [24]. Social media is facilitated by interactive digital technologies. Recently social media has been seen not only as a platform for social networking, but also as a source for innovating new products by reusing and re-mixing what others have created. This phenomenon is often referred to as user-centered innovation [34]. The distributed production and re-mixing of content brings up the questions of management of intellectual property rights and access policies, even censorship. Socializing is one of our core activities as human beings. Therefore, facilitating social activity is a new core functionality for media.

Revenue models at the Internet, most of the popular services are free. However, there are many ways to turn free services into revenue. [3, 7]. The primary way of converting free into business is based on advertising revenue. In addition, utilizing information about the users can be a source for business. For example there is the lead generation model, where one is able to sell qualified names of potential customers and aggregated or statistical data about consumer behavior. Business models could be based on sponsorship or paid inclusion, where results are included in search or recommendation results. Furthermore, the content can be sponsored or the user generated content can be resold. However, there is a limit to free services. People are willing to pay for good quality content, and free-based business models can support only a limited amount of content production. Enabling easy payment is one of the key factors of successful revenue for paid content. Therefore, new types of payment systems are being developed all the time. These systems enable micro-billing and are generally much easier to use than existing online purchasing systems. Furthermore, new types of products are emerging. For example, virtual assets sales are a dominant business model in many virtual worlds and new content packaging schemas mix content and products. Merchandising, that means using media brands for selling conventional products and different types of value added services are an increasing. And also regular business models, like pay-TV, attract more customers in many countries when procurement and pricing have been changed. Finally, most media products use many parallel revenue models. This trend is expected to get stronger.

Content distribution The most radical change in the media landscape in the last decade is digitalization. Digitalization has the biggest impact on content distribution.

Using digital technologies, it is possible to distribute more with the same bandwidth, create interactive services and dynamic aggregated content. Due to digitalization, the share of traditional mass media, such as broadcast television and radio, or professionally produced newspapers, is decreasing. New media producers can distribute efficiently, cheaply all over the world. This change in distribution logic is driving the markets and even though digitalization has made distribution much easier, the ability of the distribution channel to reach desired customers is non-trivial.

Content production While media empires are struggle to adapt to changes, production logic in the business is changing. Recent development shows that regular media users are becoming content producers. This so called user generated content (UGC) is increasingly made publicly available over the Internet. For example, 50% of Korean Internet users report having a homepage or a blog [23] and social networking sites, where users are sole content producers, are becoming the most popular websites worldwide [25]. YouTube is full of user generated content, and some of the user generated content is very popular. In addition, professionals are also changing their ways of working. Journalists are co-working with communities in producing print content. Film producers are utilizing communities in content production and replacing expensive production equipment with low cost standard digital systems. New media professionals are more agile and do not identify the old business borders.

The following sections will analyze the state-of-the-art and future development of traditional forms of media in the light of the presented dimensions. We focus on printed media, radio and audio, the emerging field of social media, television and video, games, and outdoor media. The technological enablers of the possible future development is discussed in each of the sections.

3 *The Future of Printed Media*

Printed media is the most traditional media and includes well established forms of media such as magazines, newspapers, brochures, books, advertisements, packaging, and product specifications. As shown in Figure 3, the emergence of electronic and optical technologies, such as on-line magazines, e-paper technology and augmented reality technology, create great challenges for printed media. This new media is able to mediate additional audio information, videos, and animation that have not been available in the printed media. On the other hand, printed media has become much closer to consumers' interests and we are already starting to see services, such as customized-content and on-demand printing, that allow users to affect the content they receive or produce. Customization and on-demand consumption will adduce the demand for revenue models that enable accessing individual bits of content for limited consumption.

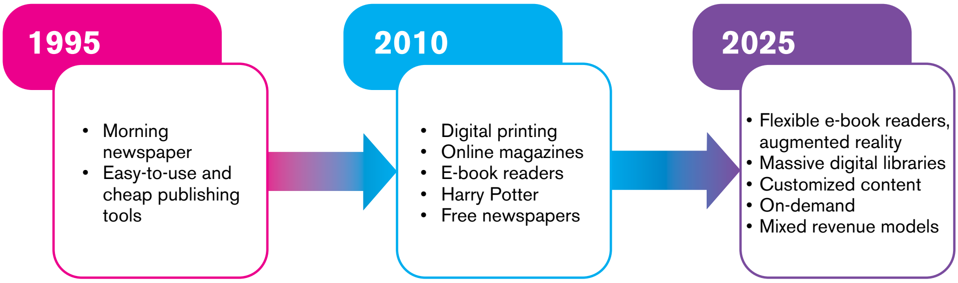

Figure 3. The shift in publishing from printed media, such as printed news papers to digital on-line content is predicted to continue. In 2025, we will see digitalization to take over the devices that are used to access the content, and aggregation of the content to massive digital libraries and archives providing customized and on-demand content. Printed media is expected to merge with other media types to a hybrid media.

Professional publishers will still be the main producers for the new media content and the value added services offered to consume, produce or re-mix the content. For example, the Sanoma Group, the largest publisher in Finland, has been shifting from passive media usage to active media usage by developing an on-demand content service in 2000 and a user-generated content service in 2005. In the near future, new media services, such as mobile videos, Internet content management technologies, such as the semantic web, and devices, such as the e-book reader, will allow people to spend less and less time on traditional printed media.

Consumer behavior for the future of printed media is going to witness a radical change in the near future. Professional business services that are the most time critical will benefit most from the on-demand or even intelligent push-services. Such services are customizable and able to deliver the information packaged. In general on-line value added services will become dominant for the consumers. Consumers are expected to demand more value added services to make the content suit more specifically to their needs. In particular, niche consumer groups such as college students and teenagers, who like to show their modernity and experience new technologies may formulate new markets. In business-to-consumer niche markets on-demand printing will become more popular.

The delivery of the new media is expected to vary case by case. For example, in the case of flexible e-book readers, delivery will probably be combined with service provided by publishers, like the delivery of the iPhone content. This is because users will expect the news and information shown on the readers to be sufficient and updated in time. For media which does not need the service support (e.g. video screens embedded in traditional printed media or product packaging) delivery will probably be the same as common commodities. On the other hand, for the delivery of content based on highly customized on-demand content, peer-to-peer and multi-cast delivery through the Internet will probably be dominant.

Revenue models in future printed media will be different from the traditional printed media. For the new media, such as flexible e-book readers and augmented reality media, the purchase of the media itself leads to a part of the revenue for the manufacturers. In addition, using the service provided by the content producers must be purchased and therefore it will give rise to another part of continuous revenue for original content producers. For instance, producers could be able to charge for every downloaded stream, for every click or for a longer period subscription. It has been predicted that the value-added service markets will have a yearly growth between 10% to 20%, while traditional print media will grow only around 2% [8]. The value-add services are expected to reach an 11% share of total media revenues by 2012. The trends of free magazines, and even free value-added services are expected to be increase, so advertisements are becoming anincreasingly important revenue model for value-added services in the printed media sector as well. However, the share of advertisement based revenues has been stable at around 50% in the US and around 40% in Europe and is not growing. Therefore, printed media products can be expected to have strong revenue models that are not based on advertisement. Furthermore, the development of technologies leads to the emergence of new media, and vice versa. Thus, new media can promote the related industries: electronic, printing, and IT-service industries.

Customized and on-demand media will be much better focused and targeted than traditional newspapers. Now already customers can, for example, comment on the content, rate the news, or receive customized advertisements. Well-packaged content, such as magazines, still seem to deliver value-added for customers and is growing faster than many other traditional printed media products. Services, such as on-demand printing of magazines, may change the markets and even affect people's lifestyle and consumption preferences. In summary, user generated content and even on-demand printing are becoming important in the future. However, professionally produced and packaged content, such as magazines and professional on-line media will also dominate markets in the future, but the majority of printed media content will be hybrid and have extensions as on-line products.

Flexible E-Book Readers A normal e-book reader has already appeared on the market. It may be a device specifically designed for one purpose, or one intended for other purposes, such as PDAs or mobile phones [19]. By using the printed electronics and roll-to-roll printing technologies, the flexible e-book reader is promising, and it could replace traditional newspapers and books. Its main advantages are portability, convenient updating, and a long battery lifespan [22]. It can provide all the functions that a normal newspaper includes, and its content includes text, images, audio information, and videos. In addition, the content can be updated in time by wireless connections.

Augmented Reality and Hybrid Media An augmented reality media means services that provide functionality as the combination of a real-world and a computer-generated virtual reality, where computer graphic objects are blended into a real footage in real time [15]. Hybrid media means media that have an extension from its printed counterpart. For example, users could have extra information about articles or news from the web. In the future, augmented reality media can be applied to printing areas, such as magazines and books. With a special device connecting to a computer, the images printed on the magazines are read into a special device via the web-camera, and then the images are digitally processed to formulate real footage relating to the images and can be played on screen so as to make the readers understand what the image is more deeply.

On-Demand Printing On-demand printing means a publishing technique and a business process where user generated or semi-professional content can be printed and delivered on-demand. Every product to be published, usually books, is edited, typeset, and then saved in a computer with a digital copy. HP's MagCloud is an example of a working solution of on-demand printing. The copy of the product will not be printed until an order from a customer is placed. By using this technique, the printed products need not to be stored in stock, and consequently storage can be saved and the corresponding costs can be decreased enormously.

Customized-Content Services A customized-content service is provided to strengthen the relations between the sponsor of the media and the media's audience [20]. The customized-content service is usually provided by producers, normally publishers, and is sponsored by a single company, brand, association or institution. It is designed to reach a special group of customers or members. This will open up opportunities for more targeted advertisements and smaller content producers.

Massive Digital Libraries A digital library is a library where collections are stored in digital formats [14]. The products in a digital library may be stored locally, or accessed remotely via computer networks. With the development of the Internet, a digital library becomes more popular and more important in academic and industrial fields, but also for leisure use. Though there are some digital libraries at present, such as Harvard University Digital Library or the Google Books project, and it is expected that in the future, a massive digital library will emerge. In particular, a massive digital library with artificial intelligence technologies will be more convenient for users and will be able to collect, aggregate and combine information from multiple sources. We can expect a digital library that can answer a user's information need or even a user's intention by providing relevant information and suggesting actions that the user might want to evoke.

4 The Future of Radio and Audio

For a long time, radio was the only way of broadcasting audio, including music, to large masses. Television surpassed the radio as the most popular media. In the US, this already happened in the 1950s and in Finland in the 1960s. Nowadays 80% of the Finnish population listens to the radio daily and 95% weekly according to the Finnpanel report 2008 [17]. Traditional radio channels have around €180 million revenue in 2006 according to the Finnpanel report this includes €126 million of public funding received by the National Broadcasting Company Yleisradio.

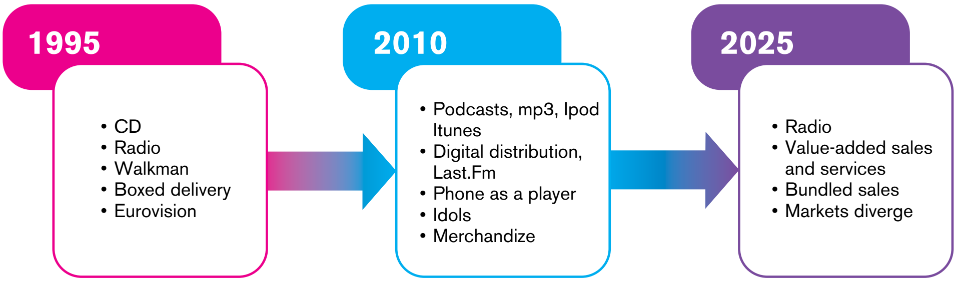

Figure 4. Traditional physical media in storing the audio is fading away in day-to-day consumption and customized Internet audio streams and music databases are emerging. Markets will diverge and physical media will only remain dominant in long term storage of memorabilia.

Recently, as shown in Figure 4, the Internet has had an enormous impact on audio content distribution. Easy file sharing between users has risen and is more popular than the original broadcasting media. This has forced the industry to invent new models for generating revenue and to renew its distribution channels.

The change in the distribution and consumption of audio content also implies changes in the model of how the users interact with the radio. The possibility of selecting the content users wish to listen to, for example from a list of songs, has emerged as an on-demand radio that can be customized based on users' listening profile. However, the habits of consuming audio content are deeply wired; approximately 18% of radio listening is still done while driving a car.

The Internet radio business models are mainly based on advertising revenues: web banners and audio advertisements. There is yet an upcoming model to make the business as bundled content. Nokia has already revealed its plan to bundle the mobile phone with music service. The idea is to sell the actual tangible product like a mobile phone with access to network service where one can download content for the device without additional costs. Another novel business model is to minimize the market chain and sell the content so cheap, it is almost meaningless to steal it. Also subscriptiosn based revenue models, where a user subscribes to a service that provides a huge collection of music with a monthly fee, are emerging.

Internet and services benefiting from the long tail have made it possible for niche music producers to find consumers. For example, indie bands can publish music and find enough audience through Internet services to sustain themselves. Even some popular bands have had experiments in distributing their recordings through the Internet free of charge. These have been often based on either an idea of making the band known or do image marketing. On the other hand, some models have been based on voluntary payment.

Radio itself seems to keep its popularity. While the technologies and the underlying distribution models may go through radical changes, radio is expected to remain as a push media, where the distributor provides content for the consumers.

Music Databases Music from available in large music databases originating from multiple record labels are increasingly available through the Internet. These can be services, where customers pay a subscription fee or access to service in a bundled way buying by a physical device, such as mobile phone or music player. The service revenues might also be advertisement based. The intelligent services enable content recommendation, targeted advertisement and increase customer loyalty. These databases are inevitably replacing music storage and will become major competitors for traditional and Internet -based radios.

Podcasts Internet technology called podcast is changing both producer and distribution models. With podcast the idea is that anyone can publish content as audio. A typical podcast is a website where the owner of the site publishes audio files frequently. The subscriber of the podcast feed receives audio files such as news, talk shows or music. Adding content to a podcast service is easy as users can upload and publish any audio files through the Internet. Listeners can subscribe to podcasts and listen to the received podcast whenever they want.

Customized Music Feeds A rising trend in Internet audio is filtering based services such as Last.fm and Pandora. These services are Internet radio channels, but the content is customized based on user's personal profile and preferences. Other users are allowed to suggest music and the whole system generates a database of music taste. Even though these services do not produce the music themselves they generate additional value for the users.

5 The Future of Social and Internet Media

The Internet, as one of the most important innovations in the 20th century, has changed the world by connecting people together and enabling access to information worldwide. It has also played an important role in driving traditional media like TV and radio into the Internet era. Recently, a new form of media, namely social media has emerged. Social media provides a service for people to build social relationships while publishing user-generated content, discovering and sharing information, as the services in Figure 5.

The Internet is a global network providing wide access to a large amount of information and content over the world. However, the easy and cost-effective access to huge amounts of content does not come for free. Before the invention of the search engine, people had to give an accurate web page address, which became very difficult for information discovery since the amount of information online has doubled yearly. In addition, various content types such as video and audio make the search online much more complex. Search engines are expected to be smart enough to understand the information involved in different content as well as what users are looking for. Hence, future search engines will incorporate the translation of human language and semantics in human language, images and videos. For example, search engines such as Wolfram Alpha[6] or Powerset[7] are able to reason regarding the data rather than just match terms in the documents to the search terms given by a human.

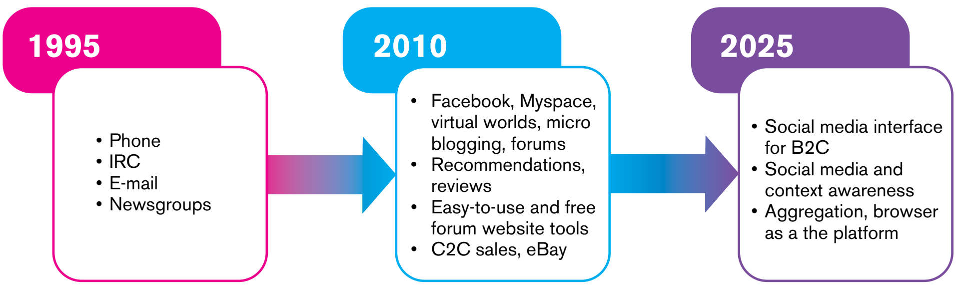

Figure 5. Social media has transformed from analog voice communication, e-mail and newsgroups to social media services, where, for example, sharing the information and performing consumer-to-consumer business transactions between friends and user communities is possible. In the future, we expect the social media to become context-aware and raise interest in business-to-consumer communities. Aggregation of the content from multiple sources will emerge new markets and enable value-add services.

6 http://www.wolframalpha.com/
7 http://www.powerset.com

The Internet opens a door for consumers into content production, while social media provides a public platform for publishing user-generated content. Since the first blog appeared in the 1990s, blogging has developed from a personal diary and information sharing into a publishing channel for companies, organizations and communities. [4]. Commenting in a blog, discussion in a forum, and later the posting on social network websites like YouTube, Facebook, and MySpace becomes an important part of people's daily life. People not only share information, but also build and enhance their social relationship over the social media. For the younger generation, identities in a virtual world like Facebook even become more popular than their presence in the real world.

User generated content is a clear trend. However, traditional media houses will still exist in the future. Individual and community maintained sites are growing in popularity and competing with professional publishers. In the future, traditional media houses will still have an edge for selling advertisement and professional publishing. Community maintained sites might also provide high-quality content, but are more focused on niche markets. Hence, it's quite hard to predict whether community publishing will win the competition and in which markets.

There are a variety of revenue models for social media. Advertisement is already common as the main profit source. Social media is typically able to categorize users, for example, by their hobbies, locations, occupations or other personal profiles. Therefore, a popular site with a large customer base could gain profit by collecting and selling users' information. By users' information, companies can deliver their advertisements to potential customers more effectively.

Even for the individual site, it is also possible to gain profit in the future. Sponsorship can be expected to be a potential revenue model. Readers of the web-site consider the review of products as an objective analysis whereas it can actually be a paid advertisement. We are already seeing individuals who live on the profit gained from individual sites or user generated content provided for social media sites.

Semantic Web and Internet of Things Customization or filtering of the content for some digital media streams, such as news, can be already done. However, current systems are still mainly based on text-based search techniques and poor in actually understanding what the content is about. The semantic web [11] is supposed to transform the Internet from a document collection to a database, where it would be possible to retrieve the information much more precisely according to the user's information need. Creating such web of data can be done manually by tagging up to some point, but artificial intelligence systems, such as natural language understanding [36] or image and video annotation [5], will become important to open the bottlenecks of content annotation. The Internet of things promises to take annotation even further by annotating not only the digital content, but also physical real world objects. For example, every car or even every pair of shoes could have its own IP address and information about these physical objects could be available through the Internet.

New Payment Systems Although the amount of free or almost free content will increase, paid content will still be very important in the future. For example, entertainment and games will still mostly be based on the core value of the content or the game itself. However, revenue models such as pay-per-view, pay-per-hour or micro payments require a totally new kind of payment infrastructure. This will most probably be built on top of the current mobile telecommunication infrastructure that allows relatively secure data transfer and the identity of the customer can be ensured. New payment systems that are based on the Internet also form huge repositories of information a about user's buying behavior that can be seen as a source for revenue. Users can get compliments, such as discounts or even free products, if they are willing to provide their behavior data to be used for marketing or other purposes. These are already loyalty programs and we are even seeing the first useful services built on top of this information such as health information based on grocery shopping behavior.

Community Aggregation The menace of the customized media vision is the overload of information that cannot be effectively used to improve the services or content targeting. In other words, it is difficult to build attractive contents just on top of a single information flow, for example health monitoring services based on grocery shopping behavior. On the other hand, if the grocery product information can be easily or even totally automatically attached to other information on the web, for example, nutritional values provided by health institutes, and even to a user's personal health information, new services will become useful and implementable with no-cost or very low cost. This information aggregation could be taken even further to involve social networks and other user's information flows. This enables a new form of social media that we call community aggregation. For example, software systems could make product or service recommendations based on aggregated content from the Internet combined with other user's (community) behavior that seem to behave similar to the user or are in the user's trusted social network. One could think this as a form of automated word-of-mouth effect with extremely high network effect and large availability of aggregated information that affects the decisions of the consumers. These content services should also be easily monetizable, because they can be very precisely targeted and in many cases can lead to the purchase of products. Even brand advertising could be customized for communities to better support generating the desired images of brands and products.

6 The Future of Television

Television (TV) has played an important role in people's daily life by entertaining them and bringing them information since the 1950s. According to the Three Screen Report[12] published by Nilsen in the 4th quarter of 2008, American consumers spent about 151 hours watching TV at home every month, including about 7.2 hours for time-shifted TV. Although live TV was still the favorite of the TV audience, watching time-shifted TV was becoming more popular, since its popularity has increased more than 30% from the year 2007. In addition, using the Internet for watching TV on different devices including mobile phones has become popular. These phenomena imply the audience's increasing demand for being able to freely choose what, when and where to watch. Accordingly, the supply from the TV industry is expected to adapt to the audience's demand.

The traditional TV industry consists of a supply chain including professional content providers, content distributors, and device providers. The work flow of the supply chain is very straight-forward. TV programs made by the content providers are delivered to the audience through broadcasting systems owned by content distributors, while the audience sits in front of TV sets watching scheduled programs in a passive way.

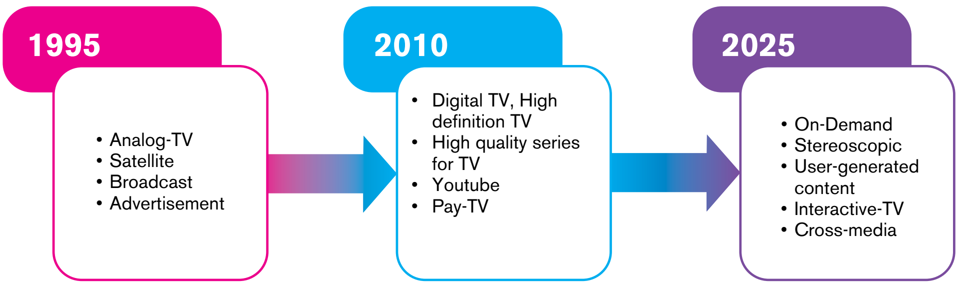

Figure 6. Traditional broadcasted television has been replaced with digital and high quality television transmission. It is expected that already in 2010 on-demand Internet television will become more popular than traditional broadcasted television. In the future, we can expect interactive television using stereoscopic techniques and user-generated content to take over. Television will probably merge with other media types to a hybrid media.

Nowadays, the TV audience is becoming increasingly fragmented, and is starting to require the ability to search their favorite TV programs and make their own schedule for watching them. To better meet the audiences' requirements in this respect, video on demand (VoD) system [16] was first introduced in the Cambridge cable network in 1994. In VoD systems, videos selected by audience are unicast or multi-cast to a single user or a group of users upon their requests. Although traditional broadcast TV still dominates today's TV consumption, VoD with a double-digit growth will have a dominant position in 2025.

As the Internet has become more and more popular, video delivery has also started to utilize Internet Protocols. The TV networks using Internet protocols can be divided into two categories, namely, Internet Protocol TV(IPTV) and Internet-TV. The key difference between the two is in the openness of the TV networks.

The majority of current IPTV systems are run in closed and proprietary networks, owned by Internet network operators like TeliaSonera in Finland. The Internet network operators control the content generation and distribution. The videos are generated by Hollywood and other professional media producers, while the quality of video delivery to customers can be guaranteed with reserved network resources. IPTV can provide the same TV services as traditional cable and satellite TV systems. In addition, it can combine VoD with voice calls and Internet services like web browsing, video gaming and online advertisement. The Internet network operators hence become Internet service providers at the same time. However, the deployment of IPTV systems often results in upgrading or rebuilding the whole network architecture - a huge investment whereas the competitive advantage over other technologies is not clear yet.

In contrast to IPTV, Internet TV like YouTube is often provided on a website, which can be accessed from the Internet. Publishing video this way is possible for individual home video enthusiasts and professional media producers alike. Compared to professional content providers, it is often argued that the information disseminated in user-generated content can be less reliable. In addition, user-generated content is difficult to control, and thus it might break content regulation rules in some regions, and the publishing through the Internet makes the protection of intellectual property more difficult. However, the popularity of Internet TV indicates the growth of user-generated video content [18] and shows the attractiveness of becoming a video producer. Individual users usually create videos without expectations of profit or revenue. They create videos in order to share knowledge, to achieve a certain level of fame, to connect with peers, or just to express themselves. The popularity of user-generated content enriches the available online information, and increases the efficiency of information publishing. In addition, Internet TV can also be delivered in peer-to-peer networks [10] without the support of dedicated video servers or dedicated network infrastructure. Hence, the installation cost of Internet TV is much lower than IPTV so that anybody with sufficient network and server resources can become an Internet TV service provider, and most Internet TV services are free to view, though there is no guarantee of quality of service.

Internet TV will become more popular and coexist will IPTV and traditional TV in 2025. The TV industry has to take care of two types of customers at that time. Some customers will be active in watching on-demand programs, while the others will still prefer watching live TV. By that time the group of terminal devices used for watching TV will include all devices with Internet connections. Consumers can choose to watch TV on different devices at different locations. For example, a consumer can use a 3-D display to watch movies at home, while using a mobile device when traveling on a bus.

Traditional TV industry gains major profit from TV licensing fees and advertisements. In future, more free-to-view or non-advertisement programs will appear. Advertisements will be more elastic to changes in customers' preferences. For example, advertising containing location-based information and social networking links will become more popular among the younger generation who prefer on-demand services on mobile devices [30]. In addition, pay-per-view, full ownership of a paid download, or a monthly subscription fee can be applied to on-demand services.

The future trends toward television can be summarized as the individualization of content distribution and as the distribution of content generation. The first part is reflected by emerging on-demand services, while the other part is caused by the growth of user-generated content. In the future, consumers will shift from being passive content-consumers to being active content consumers and providers. The Internet industry will join the war in the TV industry. More value-added services with various revenue models will become available, which also have an impact on other business areas. For example, VoD has the potential to replace the DVD rental and retail sales market.

User generated content Outside of "the best home videos"program format, user generated content has been rarely seen on TV. Digitalization, the increased availability of more professional video equipment and using the Internet as a transport channel improved the feasibility of generating more popular user content.In the near future most people will carry high quality video cameras in their mobile phones wherever they go. This increases the possibility of more and more interesting events ending up on "film". The videos can easily be edited and sent to TV companies using home computers and broadband Internet connections already available today. It can even be done on mobile devices connected to the television network via wireless Internet.

Peer-to-peer video on demand Current video-on-demand (VoD) services, most notably YouTube, are based on the traditional client-server model, which sets limits on video quality and scalability of the services. When VoD services move on to a peer-to-peer(P2P) model, the limitations will be less serious. Video quality can be increased and services will scale to larger numbers of customers without the need to invest massive sums on server resources. This will allow new players to enter the market, Thanks to the P2P model, even a VoD service being run from someone's bedroom can survive the flood of viewers caused by a video becoming "slashdotted"(i.e. becoming linked on a popular website).

7 The Future of Games

The game business has had dramatic growth in past decades. Computer games are emerging as a media for all, and an interaction mechanism that mediates a wide variety of activities from education to dating. The games business practically equals the digital games business, although there are games other than digital games such as cards and board games. Digital gaming is divided into three major blocks: consoles, PCs, and portable devices. In addition, there are a few other game domains, for example mobile phone gaming, web-based casual gaming, arcade gaming, and TV-gaming. The big three are well-established industries and significant media markets. A few highlights as to the importance of the games business in 2009 are the following facts: GTA4 launched in 2008 was the most profitable media product launch everm surpassing all movies and books such as Harry Potter; there are over 10 million players in the massive multi-player online role-playing game World of Warcraft who pay a monthly subscription; overall game sales in the world topped 32 billion dollars surpassing DVD and Blue-Ray sales.

In the future the traditional digital games market will probably grow faster than media business in general, but it is probable that emerging game domains will become commercially more significant, which means that the domain will become somewhat more fragmented. New business models such as digital distribution, value added game services, extensions, virtual assets and advertisement, become more significant revenue for games. It is probable that boxed game distribution will vanish before 2025.

Figure 7. Among traditional console and PC-based gaming, digital gaming is growing towards games supporting new types of networked terminals and even pervasive mobile gaming. Utility and edugaming is a rapidly growing trend, where gaming spreads to new domains.

For every 7–10 years we have witnessed a new generation of consoles. According to this trend we will have two more generations of consoles before 2025. This is a realistic scenario, but it is somewhat hard to predict the feature set of the next console generation [9]. So far increasing computing power and better graphics have been the driving force for console development, but Nintendo's latest console Wii has set a new landmark introducing a new console with comparatively reduced computing power but some totally new games features. Nintendo's core feature is a new movement detecting interface. Nintendo Wii is a radical innovation.

A few key reasons tor claim a stable future for consoles is console's unique business logic and lack of competitive game infrastructures. Console's business logic is based on premium and good quality games and heavily subsidized dedicated console hardware. Practically, console developers are the primary financiers in the games business. Revenue logic of an online console platform is not challenged by piracy because some of the key interfaces in the platform are secured. Console games are the biggest and best quality, and there will be a demand for good quality games in the future. PC games have some unique qualities, but it is not a significant market. The business logic is different and a large number of consumers prefer playing with a console. Web-based games are a growing domain and are attractive for casual gamers. However web-based games lack an efficient finance mechanism, and it is very hard to provide similar game quality with browser-based games than with dedicated hardware.

There are many ways to develop a game. Many classic game titles such as Tetris, Pacman and Space Invaders are still played today, but it takes only few days for one skilled programmer to develop such a game from scratch. Many new web games can be developed with few person week or person month resources. Then again, developing a popular console title such as GTA4 can consume the work of hundreds of person years. For this reason there are several different types of game studios and game developers. The group work nature of developing games will be emphasized in the future. There will be more elaborate and easy-to-use game platforms, which means that studios do not need to take care of most of the complicated coding. The screen-writing and design will be a more significant part of game development. Furthermore, user generated content and content mixing will be important parts of game development [32]. In practice all users will automatically produce content for others in multi-user gaming. However, players will produce new level designs and game world assets in most of the games in 2025. Overall, the games domain has been revolutionized several times. There is the rise and decline of Arcade and Atari, Nintendo's position has changed dramatically. Sony succeeded in becoming a dominant player in the gaming domain by surprise [9], and now the key players in the domain are Microsoft, a re-emergent Nintendo and massive game world operators such as Blizzard. It is probable that we will see new players dominating the games domain in 2025.

During the 1980s and 1990s, it was obvious that digital games were a teenage boy's hobby. As we approach 2010, the games are widely spread among many age groups and both genders. Currently the average game profile is a 30-year-old male and over 26 per cent of gamers in the US were over 50 [1]. In 2025 the average gaming profile is 35-year-old people, and both genders equally represented. For a long time, males designed games for boys, but during the last decade we have witnessed several titles, such as SIMS and web-based casual games, which are clearly targeted for the female audience, and today the games industry employs a significant number of female workers. It is shown that computer games rate better in satisfying customer's demands at least in following categories: fun way to spend time, stimulates imagination, and keeps mentally fit [2]. A strong privacy free console environment with an easy payment infrastructure positions the console platform as a potential distribution channel for all kinds of media. We can already see weak signals of how thematic video content can be distributed within a game. For example, the GT5 game has episodes on the popular BBC car magazine program Top Gear. Currently, advertisers are learning how to use games as a marketing platform. In 2025 games will be as big an advertisement media as videos. Overall, in 2025 digital games will be an activity of much wider demographic, and games will have more central roles in the media landscape. Furthermore, gaming will spread to new domains outside of entertainment.

Utility gaming Utility gaming means games, which produce other benefits than pure entertainment. Popular utility gaming domains are simulation, training, edugaming, info-gaming, exergaming, therapy-gaming, and collaboration and group work gaming. The idea of utility gaming is to direct the motivation, flow, immersion, identity creation and feeling of fun related to playing games to some other targets. Utility gaming is currently a marginal activity, but there are some popular mass market cases such as Brain-training and Wii Fit by Nintendo, which are already popular products and can be considered as utility gaming. So far there is still little hard evidence about the efficiency of training with these popular games, but it is evident that this kind of gaming is good fun.

The US army has been using digital games for simulation, recruiting and training for some time. It is common that Formula drivers keep up their driving skills by driving in simulators. It has been shown that actively playing first-person shooters can increase player's ability to recognize color contrasts, which basically means better eyesight [29]. Training eyesight was earlier considered impossible. In 2025 we could use games and playing as a common group working method because it makes group interaction naturally organized, efficient, and minimizes hierarchy burden and stimulates creativity. While people play games they are liberated from their own identity, which enables them to do less idea filtering and self-censorship, which is often deconstructive for creativity. Also a big part of physical exercising could be in the form of gaming. Schools could use educational games in many ways in their curricula and old people could possibly avoid dementia by playing games. Biofeedback games could be used in the psychotherapy in order to teach patients to better control their emotional responses.

New Interfaces Currently most games have plain button interfaces. Buttons are intuitive and easy-to-use, but they are not very precise, pervasive and immersive. Other kinds of game interfaces such as sensors, haptics, cameras, and biosignals are already used in games, and in 2025 the majority of games will probably use novel and intuitive sensor-based interfaces. Nintendo Wii was a radical step in introducing the use of new interfaces. Wii uses a combination of infrared camera and accelerometers to provide a tangible game interface, which is intuitive for use in, for example, sports.

Biosignals means use of brain-waves, skin conductance, pulses, breathing, muscle activities and other autonomous body measures to identify human emotional and cognitive abilities. Advances in sensor technology and real-time computing have enabled the use of these techniques, originally designed for medical purposes, in everyday computing and gaming [28]. With the help of biosignals, games can be more responsive to players' cognitive and emotional needs, and games can teach players to understand and control their phychophysiological responses better. Camera technology, positioning and other pervasive sensors can be linked with mobile phones. Together they will enable gaming everywhere. Furthermore, it is possible that some future digital games will have no video interface, but work based on audio or haptics only.

8 The Future of Outdoor Media

We have chosen to merge the chapters on outdoor media and media amusements together because there are some interesting underlying technological trends that suits both of these phenomena. Most people do not regard outdoor media as a significant business or media domain and do not believe that they consume outdoor media actively. For most of us outdoor media is just big advertisements on the side of the walk. Historically out-of-home media is very old, much older than audio or video for example. In fact, one could say that the origins of out-of-home media are paintings on the church altar and iconostasis. These paintings were purposely built for a certain space. They were meant to be consumed by a public audience, and ultimately there was a message delivered by the painting. Out-of-home media is space dependent media and is less dependent on established media infrastructures. However, from a business perspective it can sustain higher unit investments, but scales poorly. Thus, the building of a single media site can be approached individually. For this reason producing outdoor media is a different process than other media production.

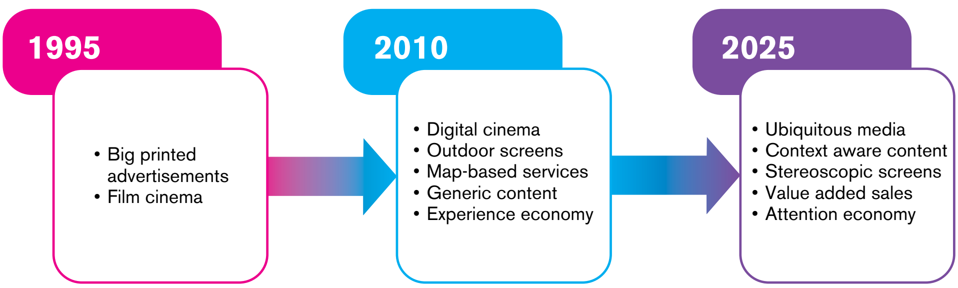

Figure 8. Out of all media types, out of home media is facing a biggest change. Emerging ubiquitous media and context-aware content is expected to take over in the current pervasive world. This will enable new kinds of business- and revenue models to formulate attention economy, where users can receive right content in the right place and time.

When one analyzes out-of-home media, one should also think about what media is? Can the design of a house be considered media? Probably not, but what if the house is temporary? How does it differ from a big advertisement? It is common that some commercial buildings are designed to appear as an advertisement! For example, graffiti is important part of out-of-home media and is a pioneering example of user-generated content, which has become a significant phenomenon in other media branches later in the 90's and 00's. In 2025 the interface between architecture and media will become less strict. It is possible to cover a single building with displays, and, in this case, it is equally important for the architect to design the content of the screens as she would design a geometric shape of a house. From the technology perspective, the future of out-of-home media is digital. It is driven by two technologies: large digital screens and local sensor networks. In other media branches it is not possible to apply similar massive installations. On the other hand, it is also hard to attract as many eyes in front of the same screen. Hence, outdoors media is never mass media in a same way as broadcast TV, but will stay as localized media. Currently outdoor media consumption has been a passive process. Large displays and novel interfacing technologies turn outdoors media interactive. Interactive outdoors media can be social in a new way. Actually, it is probable that in 2025 outdoors media will be extensively used to facilitate social interaction in physical space.

Ubiquitous Media Environments

Ubiquitous computing and media is currently a popular concept. The term was originally coined by Mark Weiser around 1988 at Xerox PARC labs [35]. In practice ubiquitous computing or ubiquitous media is related to the following concepts: pervasive computing, ambient intelligence, every-ware, physical computing, the Internet of Things, haptic computing, and things that think. The last five concepts have a strong physical component, which is not necessary when we talk about ubiquitous media, but on the other hand, ubiquitous media has a strong dependence on the surrounding space. Hence, media is expected to be integral parts of various objects and activities. The technology is not emphasized but it is an integral, sometimes hidden, part of the surroundings.

A popular scenario of ubiquitous media is location-based media, for example, location tagged user-generated photos and videos. Another often proposed scenario is augmented reality media channel through special glasses, which helps the user see additional information and graphical layers on top of objects. Furthermore, ubiquitous media can be also robots entertaining people. It can be a very simple video projection, which is based on some information received from video sensors. In general, we need to consider ubiquitous computing applied to physical electronic commerce, or u-commerce. When objects can be automatically identified and more intelligence can be associated with them, it is possible to build new types of automatic services and retail concepts. A leading example of ubiquitous media is malls that already have stereoscopic screens and Bluetooth media spammers.

In 2025 we will be surrounded by ubiquitous technologies in use. Most of the ubiquitous technologies will be used for producing media experiences. Positioning is probably one of the most important technologies, which will become integral for many objects and pervasive in a sense that it is everywhere but you do not need to pay a lot of attention to it. Furthermore, technology advancements in nano-computing may enable new types of display technologies, which are transparent and flexible. Such displays could be located everywhere and a common physical surface could display content on-demand. Finally, personal mobile devices could be used, for example, for personal identification, personal area network hot spots, sensors, cameras, access points and displays. However, people might start using identification implants and some other body integrated computing devices that would reduce the importance of personal mobile devices. Ultimately, ubiquitous media environments will not be implemented with the name of ubiquitous media. The environment will grow mostly bottom up, and will emerge as a combination of several systems and media components.

Digital Cinema

Digitalization is a bigger step for cinema than it was for TV. Cinema used to be the only moving image media. Today it is one of many, and the total hours spent in the cinema is marginal in comparison to other media such as TV and games. However, cinema still has biggest screens. People are willing to pay significantly higher amounts of money for cinema experiences than home video experiences, and cinema is a highly space dependent service [31]. There are three different concepts within digital cinema. D-Cinema is a Hollywood led high quality, highly standardized (DCI standard) and protected cinema protocol for distributing, for example, major studio content. E-Cinema is a significantly cheaper installation with basic projectors and mostly Internet-based distribution. The third concept is stereoscopic projection, which enables 3D projection. Many 3D installations also support D-Cinema standards. The most obvious benefit for digital cinema is cheaper distribution. Currently, film copies are expensive and cumbersome to distribute. Digital distribution is flexible, scales efficiently, and one cinema can have a much higher catalog of various films. However, cinemas have to cover the cost of new projectors and the distribution system, whereas distributors are the main benefactors [27]. There are many advantages in digitalization of cinema beyond distribution. Digital cinema can provide dynamic and interactive content and it can be integrated to other digital systems to provide richer media experiences. An interesting trend in digital cinemas is showing other than film content in cinemas, often referred to as alternative content. Current examples of alternative content are live sports in Cinema, live opera in Cinema and alternative cuts of films. In the future we might see game-like content in the cinema and ubiquitous shows which combine digital controlled light technologies, various sensors, and stereoscopic projection. In 2025, cinema is expected to be mostly digital [33]. Currently the overall significance of cinema for video producers has decreased constantly, and stereoscopic projection is the only new innovation, which could change this shift in the near future. If the trend continues, in 2025 the cinema will be a marginal, but still important, media channel.

Show Installations and Amusements

The significance of show installations can be described in the following example: Madonna is having a show in Finland, and the revenue for this one show is higher than the aggregate revenue of domestic films in a Finnish box office for one whole year! Many artists in the music business are making most of their money in live-shows and music sales are mostly considered a marketing tool for shows. In most cases modern show technology, mostly video screens, enable such massive events. Without a big screen the audience cannot really see enough of the show. Furthermore, new technology can enable new types of audience interactions when all of the audience can participate in the show with their mobile phones or other portable devices. On-demand print can increase the value added to the show by producing various goods on-site. Many emerging technologies like 3D displays, large screens, and ubiquitous technologies could recreate new growth for outdoor gaming. Overall, shows and amusements can be expected to be an important part of the entertainment business in 2025. Furthermore, a much bigger part of the shows and the amusements will be produced with media and ICT technology.

9 Discussion

In the previous sections we have presented the state-of-the-art and emerging social, technical and business phenomena in different media branches, including printed media, radio and audio, social and Internet media, television, gaming, and out-of-home media. Our analysis has been based on five fundamental dimensions affecting the media landscape, including production, consumption, distribution, revenue model and social effect. Now we will present our predictions for the year 2025 from the perspective of disruptive future technologies, possible market change and drivers behind this possible change.

	Printed Media	Radio & Audio	TV	Social & Internet Media	Gaming	Out-of-home Media
User-generated Content	User photos	Myspace	Best home videos	YouTube, blogging	Dynamic gaming environment	Graffiti
Customized Contentand On-demand	On-demand printig	On-demand radio	Video on demand	Publish-subscribe	Digital distribution	Publish screen
Semantic Web and Internet of Things	Amazon Kindle	Web radio	Internet TV	YouTube	Digital distribution	Publish screen
Community Aggregation	Personalized print	Personalized audio	Personalized TV	Facebook	Multi-player games	On-site recommen-dations
New Revenue Models	Micro-payment	Bundled sales	Pay-per-view	Free	Virtual assets	Mobile payment

Figure 9. Five mega-trends will shape media across all media types. User generated content and customized and on-demand content supply will affect both how the media is produced and how it is distributed. Emerging web of data that formulates semantic web and the Internet of things offers new possibilities to search, aggregate and even automatically remix content according to users needs. This content can be further aggregated and utilized in user communities. The new digital content will enable novel revenue models to be applied across the whole media landscape.

Figure 9 shows five underlying trends in that we believe formulate the media today and in the near future. First, user-generated content is the force reshaping media production, and may challenge the dominance of professional media. Second, customized content and on-demand distribution are changing the ways of distribution, and also consumption habits and business models. Third, the semantic web and the Internet of things are revolutionizing trends combining social and distribution dimensions, and in general enable interoperability across the media industry. Fourth, community aggregation, based on social mechanisms, is a new way of producing content, and has the potential of becoming the dominant content discovery mechanism. Fifth, new revenue models often come with business models, and have an impact on consumption and social dimensions around media. Professional media have to find new revenue models. Who controls new revenue models will determine how media is produced in the future.

We have seen dramatic changes in the media landscape over the last 15 years, and we predict that even bigger changes will happen in the next 15 years, like democratizing the means of production, efficient and seamless distribution and practically pervasive consumption. Today we already spend most of our waking time using media, especially in Western countries. These megatrends capture the technological and social phenomena underlying the change. However, the media landscape will also go through changes in terms of business: markets will grow, and merge, and completely new market areas will emerge.

In the next 15 years, the media industry will grow at above general industrial growth rates. While real estate, energy, and transportation will still be bigger businesses, media will surround us everywhere in 2025. It will be very hard to calculate the size of the media business when it emerges with communications and computing, and professional media becomes a significant part of many other industries. In our report we have been concentrating on ”traditional” media branches and their evolution, and have included professional media and mobile phones in the discussion of each media branch instead of defining them as separate media.

Important issues that have not been discussed in detail in this article are copyright management and privacy protection. Copyright is a key mechanism for protecting and monetizing in the media business. The copyright period is 50 or even 70 years plus the author's life in most cases, hence for most of practical purposes the copyright can be considered permanent protection for the artistic work. Creating, acquiring, controlling and selling copyrights have become an important part of the media business. In some cases, the all rights reserved copyright law has been too forceful and limiting, and today there is an open content movement, which is parallel to the open source movement in software. Hence, creating and distributing media without total copyright protection is becoming popular. Overall, the question of copyright and how the copyrighted material is protected is a very important question today. The web is full of the illegal distribution of copyrighted material. Many media players utilize some kind of digital rights management system, which is basically a combination of encryption and license management. However, the usability of such system is somewhat handicapped when users cannot easily transfer purchased media to other systems. For this reason, many big media empires are opening their DRM policies and allowing distribution of copyrighted material without DRM. This means that it is fairly easy to copy and redistribute material. Still, media companies believe that better usability will boost sales and there will be enough people who will acquire music with appropriate licenses. In year 2025 the issue with copyrights and DRMs will still be relevant. There will be no one DRM system for all devices, and there will be new updates in copyright law. It is probable that there will be a lot of new businesses which utilize a great variety of licensing and offer material with fewer rights reserved than currently. This is important especially when we are dealing with user generated content and the remix culture. In addition to copyright there is also another important law related issue in the media business which is privacy. Privacy

2010	Change Drivers	2025
4 billion users, US and Europe are the key markets	Population growth, economic growth in Asia, rural areas gain media access through mobile devices	7 billion users, China, India and Americas are the key market
Media consumption is 75 hours /week	New content types and media channels, parallel content consumption, pervasive and background media, media facilitates everyday activities and work	Media consumption is 95 hours / week
Media industry revenue 800 B$	Constant growth of 6.6% is estimated for the upcoming years, media industry will exceed GDP growth index also in the future, communication and entertainment will merge with media, professional media becomes big	Media industry revenue 1900-2500 T$
Media consumer lives in a family, is 30 years old, and primary media is television	Family structure is changing, population is aging, all old people use media, media consumption is fragmenting, everybody will have Internet access	Media consumer lives alone, is 35 years old, and primary media is Internet

Figure 10. In the next 15 years, media market will grow rapidly in terms of number of users, time consumed and revenue.

is especially important in social media, personalized media and advertisement, and in multi-user interactive systems in general. Protecting children from media related abuse is important today and still will be in 2025. There are several ways private information received via media can be misused. The question how private information management takes place in social media networks is important today and still will be in 2025. Currently, it is very hard to erase pictures and information users have uploaded to social media networks because the pictures can already have been distributed to several sites without central access point. There will be probably several legislative updates regarding to privacy, but it is probable that the responsibility for privacy control will be based on educated users. Hence children and even adults will be thought to manage their privacy. In general media education is a big issue during the next fifteen years. Skillful media users should not be only able to read, but they should be able to analyze the reliability of what they are reading, and also be able to generate both text and video.

In addition to new megatrends in technological development, emerging social phenomena and intellectual property rights, it is worthwhile to take a look at market trends in the media industry and examine how the changes affect the development of individual media types.

Figure 10 shows key market trends in the media domain, such as total globalization, changes in the structure of households, market shift towards Asia, and pervasive consumption. The data shown in the figure was calculated based on several different industry sources and as such the projections are direct extrapolations of current trends. Our analysis focuses more on the prediction of dramatic changes in individual media branches, rather than the growth of the whole media industry. We therefore have not paid significant attention to the current global economic recession.

Printed media is going through the most dramatic change of all the media branches. Although it is still the biggest media branch according to our division, pure printed media is going to disappear gradually in the next 15 years. We will still have printed books and magazines, whereas no significant publishing house will be solely dependent on the print medium. All publishing brands will include some cross media components, like websites, video archives, and mobile services. Meanwhile, we will still have the journalistic professions like writing and photography, but none of them will be working with the printed medium only. Then again, print, as a memorabilia, could become a collector's items or value added component derived from other media branches like games, audio and out-of-home media. Digital printing technology is an essential technical driver behind these changes, and customization and personalization will become key trends development in printed media.

Video and television are expected to experience similar changes. The majority of the existing players will remain in business and much of the content we have today will still be there in 15 years. Meanwhile there will be radical changes in the general structure of the television domain. The broadcast as such will lose its dominant position to on-demand video distribution, which will also change the ways that the content will be produced. It is still probable that a significantly bigger part of video content consumption will be directed to marginal content. However, it will be a rarity that some TV content like television drama would attract more than 20% of the total population.

For radio and audio, the big changes have already taken place. In the future, digital distribution will become significant, but it seems possible that even traditional analog radio could still survive for the next 15 years.

Social and Internet media are new players that have emerged in the media industry in the last 15 years. They have gained a large user base, though they have not gained a dominant position from a business viewpoint. It is still unclear how big the business of social media will be, but it is evident that the significance of social media will continue increasing. In the next 15 years, we will probably see yet new social media networks emerge, and at the same time social media merge with other media. At that moment, it would be hard to find a significant media branch without a social media component. The use of social and Internet media will become pervasive, and people may use several social media in parallel.

Games might be the media branch which will be merged with social media in the most integral ways. Multiplayer games and social play are key trends today, and probably all games will have some kinds of social component in the next 15 years. Furthermore, games will become more and more a utility activity, and not just entertainment. Games will be used also for some utilities like education, training and group working. Actually, games as well as other media will be more than the communication of information and entertainment, but a facilitator of everyday activities and a stimulator in most of our social interactions.

Out-of-home media, including outdoor media, public and semi-public physical space media, cinema and advertisements, is currently much less significant than the

2010	Change Drivers	2025
World wide web is website media	Positioning, IPv6, sensors, cheap cameras, new algorithms, content annotation, user profiles	Intelligent and seamless networks, Internet of things
Social media networks have hundreds of millions of users.	Communication through social networks is efficient, social media strengthens existing networks, social networks are useful for work and leducation	Average person is using several social media systems for different purposes
Gaming is becoming common activity among all ages	Wii and exergaming, growth in edugaming domain, new utility gaming branches, game interaction can mediate efficient knowledge generation	Gaming is common interaction paradigm among many activities
Digital distribution is significant, but radio is going strong	Audio consumption has stable position, radio has little need for technology change, more need for customization	Digital distribution becomes more pervasive, but analog radio will survive
On-demand is less than 10% of video consumption	Better bandwidth, efficient micropayments, new content packaging systems, new content formats	Majority of television type content is on-demand
Cinema is analog and outdoors advertisement is based on print	Ubiquitous environments, sensor networks, digitalization, new screens and projectors, new social space dependent experiences	Majority of out-of-home media is adaptive and pervasive
Publishing is the biggest media branch	Magazines are key revenue sources for print, big growth in online consumption, hybrid media, on-demand printing	It is hard to define publishing revenues only, all print houses are cross-media

Figure 11. The most important change drivers for different media types.

other branches in terms of hours spent and direct revenue. However, in 2025 out-of-home media will play more important roles in our daily media consumption, due to the wide deployment of new and cheap large displays, and the application of advanced image capture and manipulation techniques. We will be surrounded by a ubiquitous media environment, which is enabled by location sensitive technologies and integrated communications among personal communications devices like mobile phones and out-of-home media. Other media will also be merged into the ubiquitous media environment, due to the development of digitalization, the Internet, mobility, and location services. The boundaries of media branches will be blurred, and in 15 years we will be living a cross-media age.

Figure 11 captures the key trends of each media branch. But, this might not be all. There are some marginal developments, which might become very big and result in more dramatic changes in the media environment. For example, augmented reality could really change how we live our lives and consume media when people start wearing augmented reality glasses all day. Augmented reality is a potential and fairly logical extension to ubiquitous vision. Yet, a more dramatic vision is related to biosensors and how they interact with the media. If people implant communication sensors in their body, it might enable a telepathy type of functionality, and merge our communication and thinking with the future intelligent Internet of things. In such a vision we will not be the humans that we used to be, and the sense of being will

2010	Change Drivers	2025
Augmented reality is not in wide spread use	Positioning services, augmented reality technologies, glass technology **SIGNPOST: 1 000 000 people switch regular glasses to augmented reality glasses**	Virtual visual information layers are critical for working and living
Media is accessed through devices, sensors are rarely deployed to humans	Biosensors, wireless networks, nanotechnology, ubiquitous networks **SIGNPOST: 100 000 people have sensor implants**	Sensor networks turn humans to cyborgs and enable advanced communication and interfaces such as telepathy
Live shows and cinema are created around celebrities	Big digital screens, real-time video manipulation, mobile devices, sensors, digital lights SIGNPOST: Mega-concerts (50 000+ participants) without celebrity artist	Main attraction in a show is not celebrity but the social atmosphere and non-human brand
Media business is controlled by media empires	**User generated content, new production tools, community aggregation, independent distribution and billing services SIGNPOST: Less than 50% of media consumption goes through big media company distribution**	Operators and facilitators are monetizing media and media houses are vanishing

Figure 12. Disruptive changes that could rapidly change the way how we experience the world using media.

dramatically alter. However, although 15 years might be too short a time for such a radical change, we might already see the first significant signpost, which predicts that this kind of vision will become the truth.

In Figure 12 we list some potential disruptive changes. While augmented reality and biosensors can really change how we consume media, there might also be some other radical changes that target the media structure ever more. Celebrities have been utilized by most media branches as key marketing mechanisms for promoting media consumption. However, due to the advent of social media, generative graphics and interactivity, the function of celebrities is not necessarily sustainable. Web-celebrities are narrower in their scope, even though global. It might be such that big global celebrities will vanish and we will have more temporal and domain specific celebrities. Or the roles of celebrity as such will vanish. Instead, events, locations, service and group brands will become more effective than celebrities. Meanwhile, the changes in media production mechanisms might change the balance in the media business so that big media empires vanish and the biggest businesses in the domain will be bit pipe operators and complementary service providers. For the future of media, the key question will be whether the established media houses can still be the key financing sources for professional media production, or whether most of the media will be financed in other ways. Will media be produced and delivered by the big empires, or will most of the content be produced by users? Will the media be free, fantastic or both?

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2.2 Future of Living

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Abstract

The purpose of this chapter is to highlight some important issues such as the energy, urbanization, transportation, the smart home, work, and health and wellbeing within the context of the future of living in Finland in 2025. We conclude, based on our review, that the future of living is highly dependent on consumers' beliefs and attitudes toward more sustainable and environmentally friendly habits. As described in our scenario, people's lifestyles will probably not change drastically. However, people will adopt new technologies that help them in their everyday lives increasing their overall wellbeing. Finland can be an example of a society in which innovation, high living standards and sustainable economic development is obtained without straining the environment too much. Further, regulation imposed by authorities can encourage people to make sustainable choices.

1 Introduction

The objective of this chapter is to describe and explain some of the main drivers of the future of living around 2025. The main topics discussed are energy production, urbanization, transportation, smart homes, work and leisure, and health and wellbeing. Figure 1 graphically presents our approach. Making progress in these domains should lead to improved quality of life in the future and maintain Finland as a competitive and attractive country to live in and invest in.

Fig. 1. Discussion framework for Future Living in 2025.

The main topics in modern urban planning are how to develop cities and communities to increase welfare and at the same time take account of sustainable development and the scarce resources of our planet. Energy production and distribution will be important factors affecting sustainable size and location of both urban and rural communities. Energy production and distribution innovations can also provide a reduced cost of living and workplaces in biomass production and processing in rural areas. In the Urban Planning chapter we will present some problems of developing modern cities and some ideas about modern urban planning.

Transportation issues have far reaching effects on society and they are a matter of our daily lives. The central issues in the future of transportation are environment, energy, and city and regional design. Practically, the challenges related to them are pollution, safety, energy security, and people flow. We will discuss these issues from the perspective of the individuals as users limited by the use of context, cultural and economic constraints.

A central issue for the future of living is a higher quality of life. The characteristics of a future smart home include many attractive features such as higher energy efficiency, smarter network, and better security and care for people of all ages. All of these driving forces for future homes are discussed in detail, as well as a look into the future challenges and promising solutions.

Work and leisure have become increasingly mixed in individual lives and new work forms challenge the work rhythms of working communities. Despite a long historical trend that has shortened the working week, for last ten years, working hours have remained rather stable in the European region. In Europe, for full-time employment there are on average 42 work hours per week and in Finland 40 work hours per week correspondingly (Eurostat, 2009). On average, European women have fewer paid work hours per week than men but on the other hand they often contribute more in household work. Table 1 shows the general time use per day for Finnish people, 20–70 years old.

Table 1. The general time use per day for Finnish people, 20–70 years old. Time expressed in hours and minutes (Eurostat, 2002).

	Men all / employed	Women all / employed
Free time, unspecified time use	6:08 / 5:06	5:29 / 4:38
Meals, personal care	2:01 / 1:55	2:06 / 2:02
Sleep	8:22 / 8:12	8:32 / 8:32
Travel	1:12 / 1:17	1:07 / 1:16
Domestic work	2:16 / 1:59	3:56 / 3:21
Gainful (paid), study	4:01 / 5:32	2:49 / 4:20
Total	24 / 24	24 / 24

2 Energy

Cheap and easily available energy sources have an impact on the economic and technological development of society. Primary energy sources with low greenhouse emission levels are preferred. Finnish climate conditions require a long heating season. Long distances increase the need for transportation and industry is heavily concentrated on the energy intensive forest industry.

The largest energy consumers in Finland are industry, homes and transportation. Industrial energy consumption is highly significant, it has consumed on average 50 % of all the produced electricity in Finland (VTT, 2007). Housing, which consumes roughly 25 % of the electricity, has the largest energy saving potential, as it has been estimated that by replacing or complementing electrical heating systems and connecting houses to district heating systems electricity consumption could be decreased up to 20 % from the current level. Due to the large energy saving potential we concentrate on housing related energy issues.

2.1 Energy in Finland in Year 2009

Increasing public awareness and global environment protection agreements limit the emission levels of primary energy production. Increasing energy efficiency (conversion of chemical, mechanical or nuclear energy to electricity or heat) helps to utilize energy content to a larger extent. In combustion power plants, particulate emissions per kWh are inversely proportional to the size of the unit and therefore centralized (village/town scale) power generation has a smaller environmental impact. Biomass utilizing energy production is considered as CO_2 neutral and therefore can help to reduce the environmental impact of energy production.

Finland has a high quality electrical distribution network which is maintained by FinGrid. The transfer network consists of 400 kV, 220 kV and partly 110 kV and a distribution network with lower voltage levels down to 230 V. Voltage in the main transmission lines is maximized to minimize ohmic and reactive losses during transmission. Transformation to low voltage is carried out close to the end-user. Transmission and distribution losses are small in the Finnish electrical network. Average losses of 4 % were realized by 2000 whereas EU average losses were 7 % (VTT, Energy use). The network has not suffered from long down-times which also suggests high overall quality (VTT, 2007). Distribution losses have decreased as the local production and usage of electricity have balanced out between the northern and the southern parts of Finland.

District heating is currently available for 2.5 million Finnish people (VTT, 2007). The distribution network is effective and losses are on average around 7 %. The Helsinki area has the largest connection density and more than 90 % of the apartments are connected to the district heating system. Besides district heating there are couple of existing district cooling networks in Helsinki, Turku and Lahti. District cooling systems will reduce need for electrical cooling in larger buildings which typically have air conditioning.

2.2 Fossile Fuels

Fossile fuels including coal, oil and natural gas are utilized to produce both electricity and heat for homes and industry and kinetic energy for transportation needs. Fossil fuels have a high energy content per unit mass. The technology is well established, cheap, reliable and easily adjustable to varying power needs. Large CO_2 emissions and limited resources of these fuels globally are serious drawbacks.

Finland has utilized excess heat from electricity production from fossile fuel combustion plants to provide heat, especially in metropolitan areas where more than 90% of the population is connected to the district heating system. Co-production of electricity and heat greatly increases the energy conversion efficiency and a larger portion of energy per unit CO_2 emissions is transformed to usable form. Physical and technological reasons limit the conversion efficiency to electricity to ~50 % when excess heat is not utilized. When heat is used to heat up buildings the conversion efficiency for the total process can raise up to ~90 % (Gaia Group, 2007). District heating systems have therefore a huge potential to reduce CO_2 emissions. Due to pressure drops and heat losses in heating pipelines and relatively high infrastructure costs, municipal heating systems are economically viable only in rather close to heat generation areas and therefore this technology is mostly used in cities where the building density is rather large.

2.3 Hydropower

Hydropower is the conversion of the potential energy of water to electricity. Conversion plants typically consist of artificial lakes where one is in an elevated position with respect the other lake. Dams are used to build up hydrostatic pressure to the elevated lake as the water level rises. Large water reservoirs help to provide needed power during peak loads. Greenhouse emission levels of hydro power in cold climates are extremely small but dams and artificial lakes have strong impact on fish populations which dwell or breed in nearby rivers. There is no significant non-built hydro power potential in Finland without severe environmental drawbacks.

2.4 Nuclear Power

Fissile nuclear power-plants are high power and low greenhouse emission primary energy converters where radioactive nuclei are converted to heat. Heat is used to generate electricity via turbine-generator-systems which are traditionally used in combustion power plants. Currently waste heat from electricity generation is typically wasted to the cooling water (roughly 2/3 of the produced energy) which reduces the energy conversion efficiency of the nuclear power plants. Nuclear power generates no CO_2 emissions if the construction phase is excluded. Modern reactor and safety system designs reduce the risk of catastrophic accidents. The most important environmental issue is related to safe storage of highly active used nuclear rector fuel. Geologically Finland has highly stable bedrock which should provide safe conditions for nuclear waste storage.

2.5 Biofuels

Wind energy is a promising new renewable primary energy source. Finland has some wind power potential in Lapland and near the sea shore where winds are strong enough for plausible large scale electricity production. Solar power has been utilized to provide electricity for the needs of remote summer cottages, but not for large scale energy production as Finnish solar flux conditions are not high enough, especially during winter. Biomass-to-liquid processes are utilized to some extent. Neste Ltd. has been producing bio-diesel using their proprietary NexBTL-process from 2007 onwards. This biodiesel outperforms conventional petrodiesels in many performance characteristics including low temperature performance (Neste, 2007) The raw material utilized is tropical palm oil which has made the true environmental impact of this low CO_2-emission fuel controversial.

2.6 Energy in Finland in the Year 2025

Electricity consumption will continue to increase. This will happen due to an increasing amount of home appliances as well as electrical and plug-in hybrid cars. Passive house design will be the governing building standard for detached houses. Passive houses outside rural villages will mainly utilize heat generated by home appliances and low cost electrical heaters will be used during the coldest winter months. The increase in electrical heating will be compensated for as district heating systems in urban areas continue to increase their penetration rate. Small-to-medium scale heat and electricity generating power stations will provide CO_2-emission free energy, largely eliminating the need for electrical heating in non-insulation-renovated buildings in rural areas. Large cities will rely on co-production of heat and electricity from fossile fuels. Plans to build new nuclear powerplants near Helsinki-area will be in the planning phase as resistance for CO_2 generating energy production builds up. Waste heat from the electricity production processes of nuclear power plants will be used for district heating, thus improving the energy efficiency of nuclear power close to 90 %. Finland will be among the first countries seriously considering the utilization of nuclear district heating.

The structure of the electricity network will continue to decrease the distance between electricity generation and end usage for reduced transmission losses. New power plants will be built near densely populated areas and waste heat from combustion type of power plants will be used for district heating for improved energy efficiency. Another development trend is the emergence of small- and medium-scale combined heat and electricity generation for the needs of village scale communities. These power plants utilize CO_2-emission free biomass and provide low cost heat and electricity for rural villages.

The need for heat will stay at a high level as global warming has increased temperatures only slightly in Finland. Building stock will be renewing at roughly 2 % annually and even though most of the new buildings are low energy or passive buildings, a large portion of building stock is consuming roughly 1000 kWh/m^2 of heating energy per year as they did in 2009. District heating will serve urban buildings and larger villages. Detached houses outside the reach of district heating will be actively renovated to improve thermal insulation and the heating system of those houses will also be modifies with air and ground heat pumps for improved energy efficiency. Small scale wood combustion will have some importance in rural areas where particulate emissions from an incomplete burning process are not a big health risk.

Biomass will be utilized in multiple scales in year 2025. Large scale biomass-to-liquid and biomass-to-gas conversion provides fuel for internal combustion engines which are utilized mainly for transportation. Forrest industry has been transforming toward energy production and new conversion processes have helped this industry to renew itself and survive in Finland.

3 *Urbanization and Urban Planning*

For the first time in history there are more people living in cities and urban areas than in the rural areas and this development is not going to change. At the same time, the scarce resources of our planet have been understood by society and every government. The level of urbanization has never been so high and this has caused an increase in the importance of urban planning. The development of urbanization varies a lot between areas of the world. In this chapter we are mainly concentrating the problems of urbanization and urban planning in Finland.

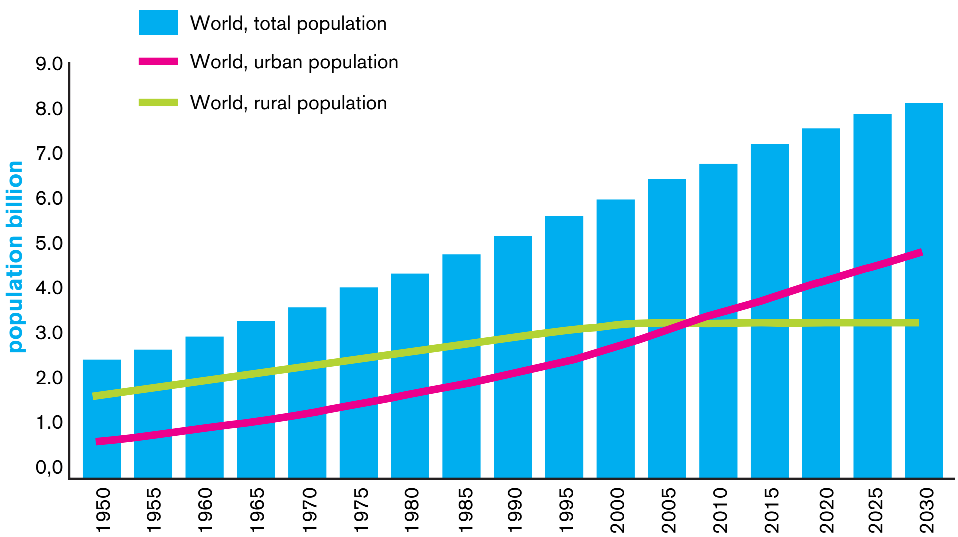

Fig. 2. The urban and rural population of the world.

In the recent decades in the Nordic countries the urbanization has not led to the certain areas of towns being reduced to slums (as in many parts of the world) but the rural areas have become almost desolate.

The working population moves to the cities and the rural areas will suffer from depopulation. Rural areas have more or less become retirement communities. At the same time the Finnish government's rural area politics aims to ensure vital and actuating rural areas by the reformulating of trade and work, the hoisting of level of capabilities, the improvement of basic services and possibilities of housing and strengthening the capacity of actions (Sisäasiainministeriön julkaisusarja 2007).

Also the EU has recognized the problem and there are some plans to relieve it. In the EU's territorial agenda there are among other things, aims to strength the urban-rural partnership. The territorial agenda suggests : Tailor made policy solutions to be developed for different types of rural-urban settings in order to fully utilize the variety of potentials in rural and urban areas and their interrelationships. Rural and urban areas to be are encouraged to cooperate as equal partners in order to identify their common development assets, endogenous potentials, as well as development strategies and to diversify their economic base by stimulating local entrepreneurship. New forms of governance are to be exploited for improving efficiency, productivity and sustainability of this partnership (territorial agenda 2007). This means that it is also a goal at the EU level to keep also rural areas inhabited (http://www.un.org/esa/population/publications/WUP2005/2005urban_rural.htm).

3.1 Sustainable Development and Urban Planning

The concept of the sustainable development of cities has become more and more important in urban planning. Mankind is consuming more than our planet can handle. Our living habits are causing several problems such as, pollution, large scale climate change and to some extent also growing social inequality.

Sustainable development can be defined in many ways. Maybe the most well known definition comes from the Brundtland Commission in 1987. It defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

Wheeler, in his 1998 article, defined sustainable urban development: "development that improves the long-term social and ecological health of cities and towns" (Wheeler, 1998). He suggests a framework that can help everyone to better understand what a 'sustainable' city might look like. These include: Compact and efficient land use, less automobile use and better access. Resources should be more efficiently used and the usage should produce less pollution and waste. Housing and living environments should be good and social ecology should be healthy. Economics should be developed, sustainable with community participation and involvement. At the same time this should preservative local culture and wisdom.

Although these ideas are unquestionably correctly crafted the challenges are to implement them in practice. In the real world the plans are often influenced not only by long-term ecological and social health but also by the shorter term economical situation and local and global politics.

3.2 Planners Triangle

Scott Campbell has presented a concept he has called "The planners Triangle" to analyze the different goals of planning and its related conflicts.

Fig. 3. The planners triangle (Campell, 1996)

In the Planners Triangle there are three main goals which are all important for the city planners. The goals (see figure 3) that Campbell presents are social justice, overall economic growth and efficiency and environmental protection.

Campbell argues that city planners should try to achieve all three goals and also achieve sustainable development. The problem is that there are several obstacles in the way. These obstacles are presented in the figure as conflicts. The first of them is property conflict. This means that there is collision between social justice and equality and overall economic growth and efficiency. Another collision is resource conflict. This means that there are always opposite interests between economic growth and environmental protection. The core of this conflict is linked to natural resources. When one strives for maximum economic growth there is often a need for waste resource consumption. At the same time environmental protection supports the conservation of resources. The last conflict is the development conflict. This means the there are always difficulties in achieving prosperity for the needy which is connected to the economic growth and at the same time strive environmental protection simultaneously. (Campbell, 1996).

Based on Campbell's ideas sustainable urban development is hard to achieve. He argues that successful implementation of sustainable development requires a reorganization of society (Campbell, 1996). The goal is not easy but it is worth of trying.

3.3 Smart Growth

Smart growth is a concept or theory that concentrates growth in the center of the city to avoid urban sprawl. A smart growth city is compact, transit-oriented, walkable, and bicycle-friendly. It includes neighborhood schools, complete streets, and mixed-use development with a range of housing choices. For example, in Helsinki urban sprawl is a recognized problem. In Finland there has traditionally not been a lack of space so the city has expanded outside of the urban communities. This responds to the Finnish ideal of housing, but it has requires public resources to excess. In the future the urban sprawl will be prevented by centralizing the construction building to the areas nearby to the public transportation routes (Helsingin kaupunkisuunnitteluvirasto 2008)

Smart growth focuses long-range development. It strives for sustainability over a short-term focus. The goals of the smart growth are to achieve a unique sense of community and place. It also pursues to expanding the range of transportation, of employment, and of housing choices. Similarly the concept of smart growth includes ideas of equitably distributed costs and benefits of development. In addition natural and cultural resources should also be preserved and enhanced and public health promoted.

3.4 Urban Villages

Another concept of urban planning and design is urban villages. Urban villages are typically characterized by: medium density development, mixed use zoning, good public transit, and urban design – where pedestrianization and public space are emphasized.

They are seen as alternative possibilities to today's urban development especially in western cities. The concept of urban villages aims to reduce car reliance and promote cycling, walking and public transportation use. Working, recreational and living areas should be joined together. Also the social side of living has been taken in to consideration in the urban village concept. The interaction between the inhabitants and community institutions is also facilitated. The concept of urban villages was formally born in Britain in the late 1980s with the establishment of the Urban Villages Group (UVG)(Aldous 1992).

3.5 Slow Housing/Slow City

The slow movement originally began 1986 with a protest against the fast food and fast food restaurants. It evolved to a slow food movement with local chapters worldwide especially in western world. The low City movement is instead mainly a European concept. Both slow food and slow city movements are promoting sustainability and conviviality. In the concept of a slow city there are aims to protect and enhance urban livability and the quality of life (Mayer and Knox 2006).

The opposite of the slow movement is" the fast world" which has been generated by globalization. Places have become more alike. These places and people are directly involved as producers and consumers. This development has led to a situation where developers design and create theme parks, shopping malls, marketplaces, renovated historic districts and neotraditional villages and neighborhoods. The slow city movement favors local and traditional culture and a relaxed pace of life. It is hostile to big businesses and globalization. The motivation behind slow cities is not so much political, but ecological and humanistic. The aim of the slow city movement is to promote the development of spaces that are robust and vital based on good food, healthy environments, sustainable economics and traditional rhythms and seasons of community life. (Knox 2005)Slow housing is connected to the other aspects of a future sustainable society. Self-sufficiency is one of the key elements of the concept. Communities should be able to produce all or at least some of the energy they use, and the waste they produce should be utilized or recycled.

3.6 Diversified Living Habits

In Finland the state has articulated that both urban and rural areas need to be developed simultaneously. previously the development of the cities was not driven by ecological concerns or energy consumption and the structure of communities was quite dispersed. Land in the sparsely populated country has been available and rather cheap. In the future, development of the cities is aims at a more dense structure.

At the same time today's experience economy the living habits of people is diversified. People seek individuality to express their way of life and identity (Heinonen 2008). In urban planning this means an increasing need of different kinds for housing models and different kinds of communities.

Common to all future sustainable development urban planning models is the scale of communities. They are rather small and independent units and communities are closely connected to the environment. In Finland we have only few experiments in sustainable development of communities or parts of a city. In Helsinki there is the Viikki-area which was developed and constructed with a lot of hype. Many of the original ideas were not executed in practice but still the area has quite good reputation and people are willing to move there because of the eco-area label.

In the future small communities inside cities are one solution toward more sustainable cities. In the cities there are old buildings that cannot be torn down, but their energy economy can be improved. There are certain areas in cities where almost all buildings were made at the same time, like suburban areas. In these areas the buildings need to be renovated almost simultaneously. Thus, the renovations can be guided by regulations to obtain more energy wise areas.

The government also pursues keeping the rural areas populated. In the future this means some changes are inevitable. For example, the professions of people in rural areas will change. Farming is not going to be a solution although there is some evidence that organic food production and local production is a rising trend. Today many professions are already quite mobile so the emerging trend of making summer cottages in second homes may support that. People could live and work in two different places. Simultaneously with changing professions in the rural areas, energy production and distribution can be developed. Models like urban villages and slow cities support this kind of development. Rural communities and villages could quite easily produce their own energy. Inhabitants often own forest and farming land. When harvesting the forest or farming the land there are often certain king of side products which could be used to produce energy. If these secondary products are used to produce energy locally, transportation costs stay low and feasible. This development is largely dependent on the regulations both governmental and municipal.

4 Transportation

Throughout the human history, people have been trying to invent better, more efficient and comfortable ways to transport different kinds of objects and people. A transportation system consists of organized fixed public installations of infrastructure such as roads, railways, airways, waterways and local installations like elevators and escalators. The installations are utilized by using vehicles such as cars, airplanes, trains and ships. These systems are used by individuals and other objects.

Transportation has far reaching effects on society. According to recent objectives of research effort on transportation at Massachusetts Institute of Technology, the main challenges are to create a sustainable and environmentally friendly transportation ecosystem which influences the world's energy problems and especially in the efficient design of cities and regions (MIT, 2009). Further, according the report by (Ehligh-Economides, Christine and Longbottom, Jim, 2008) the main practical drivers of the future development of low energy consuming transportation systems are driven by challenges such as traffic congestion, environmental pollution, safety and energy security.

4.1 Context Dependent Solutions

Transportation systems are a part of an ecosystem with a mutual dependence on energy, land-use, and production. Therefore, traffic planning and infrastructure need to be adapted to different contexts depending, for instance, on the size of the urbanization from small villages to megacities. Consequently, there is no one solution but various intentions to adapt means of transportation and different ways of living in different places. Further, we want to emphasize that the challenges also differ greatly between contexts, in a city such as Tokyo in which millions of people move daily in a relatively small area of land is quite different from a relatively small city of a metropolitan area of Helsinki with "only" one million people. Considering rural areas, long distances can be a daily issue. For instance, in Finnish Lapland elementary school students have to travel 100–200 km on a daily basis (Lapin lääninhallitus 2007).

The installed infrastructures facilitate and also limit the future development of transportation systems due to investments and habits of using them. The infrastructure by itself does not provide the means of transportation, but different kinds of vehicles need to be used. Therefore, different kinds of vehicles have been developed along the history. We can categorize them by their power source.

A vehicle can be powered naturally by a man or an animal. Some examples are a bicycle and a carriage. Alternatively, a vehicle can be motor driven. These vehicles include cars, metros, trains, buses, airplanes, ships and so on. The latter types of vehicles can be used in different ways to provide different kinds of value to their users. The development of these vehicles is mainly based on more efficient ways to provide an energy source to the motor engine.

4.2 Individual Needs for Traveling

The individual level of a transportation system is based on the needs of the users. Individuals have different alternatives of transportation available from which they select the most feasible options to their consideration set which best fit to their practical needs. These options could be limited or developed in a direction which includes more nature friendly options. Because of the current economic turmoil and environmental issues, more attention should be focused on changing people's beliefs and attitudes. However, people are constrained in their use of transportation systems in different ways. For instance, demographic, economic, and social norms may influence the use of the various systems.

By their actions, individuals may greatly influence the future development of transportation and especially future options. The issues of transportation are actively discussed and negotiated politically at the world level, the EU level and in national development strategies. Further, political will, policies, investment policies and taxation are ways to influence people in their future transportation choices.

Transportation is also matter of resources, specifically money and time. At the individual level people around the world on average are willing to spend only about 0.8 to 1.5 hours per day per capita traveling (Ehligh-Economides, Christine and Longbottom, Jim, 2008). This is known as the travel time budget. The travel money budget is stabilized at about 15 percent of GDP. As incomes rise, however, actual spending on travel increases, and vehicle miles traveled (mobility) increases. This relationship suggests a growing economy will demand more mobility.

There have been many intentions to build different innovative transportation systems throughout human history. However, most of the "non-conventional" systems have failed. Even though, some of them are promising ideas, the lack of general infrastructure, investments in vehicles and adaptations to people's habits have made most of these systems fail or they have become very niche tourist attractions. Many innovative transportation systems are introduced in a portal maintained by Jerry Schneider at University of Washington (Innovative Transportation Technologies, 2009). There are lots of different projects ongoing in the field of new transportation systems, vehicles and motor engine. Practical examples of future systems are shown in a virtual exhibition maintained by University of California Berkeley Library (Transportation Futuristics, 2009).

4.3 Finnish Transportation

According to the Finnish authorities of roads and transport Finnish people make 2.9 trips a day and spend 71 minutes in transit. One trip is on average 25 minutes long and the average distance is 25 kilometers. Finns move approximately 42 km per capita on one day. There were 3.15 million cars in Finland at the end of the year 2008 of which 2.70 million were private cars. There are 591 cars per 1,000 inhabitants (Tiehallinto, 2008). The amount of traffic has been constantly increasing in line with the increasing GDP. However, with the current economic turmoil there will be a radical decrease at least in the short term before the economic situation stabilizes. Fortunately, thanks to improvement in more nature friendly engines, the amount of CO_2 should start slightly to decline toward 2020 with even more traffic.

The importance of the transportation issues may be observed from current national level political initiatives. The Ministry of Transport and Communication in Finland has started a project to investigate the possibilities of using smart transportation systems. By smart systems they mean using information and communication technologies (ICT) in traffic guidance. It is a part of the national transportation strategy with the objective of improving safety and traffic flow. Its purpose is to make commercial transport and logistics more efficient by using information and communication technologies. These smart systems should also consider environmental issues and enforce sustainability (LVM 2009)

4.4 Trends for the Future

There will be no single solution for transportation issues due to the different needs of people from the perspective of demographics, culture and established infrastructure. All systems cannot be replicated from one environment to another. There are cultural, political and practical issues that may prevent their success. There are high investments made on existing transportation systems which are practically non-replaceable. These infrastructure elements and systems such as roads, railways and metro lines should be easily upgradeable with more efficient, environmental technologies with more people using them.

There is an intention to reduce the use of natural resources and improve the energy efficiency of transportation systems, even though, all efficiency gained is always to provide more value (more kW and Horse power/CO_2) and thus, the original idea of savings is lost (Efficiency myth). If the goal is to prevent the use of this saving towards new value then there have to be political and societal controls on these issues. People learn socially and accept certain levels of pollution, CO_2 emissions and consumption through higher awareness and marketing efforts. Political actions are needed to make change happen. The use of public transportation should be encouraged. Public transportation has to be comfortable, easy and safe. It has to fit to the practical needs of people including individuals, families, elderly and other groups.

There are several ways to solve these different challenges. For example, finding new sources of power for the motor engine can result in new kinds of vehicles, such as the electric car. Even though oil will still be the most used source of energy for many decades there is a relatively open and positive attitude towards new sources of energy. The new systems may be also a source of new business for Finnish industry (T&T, 2007). We can conclude worldwide that the transportation systems are highly dependent on the context, constraints and culture. In varying locations of Europe and Finland, whether it is a village or a city, the transportation systems cannot be in most cases imitated and generalized. However, we can learn from existing practices.

In Finland, especially long distances and low density population maintain the problematic situation of private car preference over public transportation. However, the Helsinki metropolitan area will be growing and the efficiency of public transportation will increase.

5 The Smart Home

The home today has intelligence everywhere – heating systems, air conditioning, home appliances, computers, televisions, stereos – even a stove can have more processing power than a PC had just a few years ago. This, combined with the emergence of reliable wireless technologies during the last couple of years, enables people to control their home, regardless of place and time.

The terms smart homes, intelligent homes, or home automation have been used for more than a decade to introduce the concept of networking devices and equipment in the house. Smart home technology can be defined as the integration of technology and services through home networking for a better quality of living (Patric 2006). This definition gives an emphasis to a home environment that should be able to respond and modify itself continuously according to its diverse residents and their changeable needs. Generally, there are three key driving forces for home automation, which are higher energy efficiency, smarter environment by using information and communication technologies, and better security and care for people of all ages.

5.1 Energy Efficiency

A modern house, besides providing a higher quality of life, will consume less energy and resources than a traditional one. This development was originally driven by rising energy costs, and later was driven by increased awareness of environmental issues. Generally the energy consumption is directly proportional to the CO_2 emission level. In 2008, it was estimated that buildings had consumed 40% of the energy used in Europe and contributed to 40% of greenhouse gas emissions (Smart Energy Home 2008).

There are many ways to make more efficient use of energy such as using innovative insulation materials and building envelope, advanced windows and lighting etc.

One of the most effective solutions is to improve the efficiency of HAVC, referring to the Heating, Ventilation and Air Conditioning system. Since the late 80s, manufacturers of HVAC equipment have been making an effort to make their systems they manufacture more efficient. There are several methods for doing so. Take the heating system, for example. Water heating was more efficient for heating buildings and was the standard for many years. Later people found out that forced air systems could double for the air conditioning and it became more popular. Then geothermal heating, the direct use of geothermal power for heating applications, was regarded as an even more efficient means of central heating (Fridleifsson 2008). Besides, a modern house equipped with a passive heating and cooling system can bring a large amount of energy savings with reducing CO_2 emissions as well. For example, in Finland a refurbished passive house can save energy by 55% with a CO_2 reduction of 406 kg. In Germany, the energy saving for a refurbished passive house reaches up to 72% with a CO_2 reduction of 4226 kg (Promotion of European Passive Houses 2006). The absolute CO_2 reduction for Finland is relatively low, due to relatively high energy uses for the passive house (due to the cold climate).

5.2 Smartness

Smartness, within a smart living environment, will make people live more conveniently and comfortably. Building blocks for an intelligent house are readily available on the market, such as smart refrigerators, heating systems that can adjust the room temperature, security systems with touch panels, programmable thermostats, self-adjusting curtains, configurable set-top boxes, self-operating outdoor lights and much more. The problem is that all these systems are separate and one ends up having a dozen remote controllers and miles of cable in the living room. Besides, these wired systems are often expensive to deploy. In contrast, a smart house will enable people to gain control over different home appliances from anywhere at any time by using only one simple terminal, such as a mobile phone or a web browser. With entire terabyte-sized home libraries and access to your home control system following you wherever you go, you can listen to songs and watch movies from your home server just as easily as you can switch off the coffee machine that you left on while rushing to work.

From a technological viewpoint, the focus is the development of a better integrated sensor network. Although many network technologies, standards and industry consortiums already exit in the smart home market, no single sensor network technology can solve the challenges in this field. Several promising network technologies are X-10, Z-Wave, ZigBee, and KNX, which are all attempts to define a common command language for home networks (Nokia white paper 2008). X-10 was originally for the electricity grid, Z-Wave and ZigBee for radio frequencies and the KNX for wired solutions. These various protocols differ from a user interface perspective. For example, Z-Wave is designed for the home environment and thus tries to define robust device profiles so that devices from various manufacturers will work together. Nevertheless, the Z-Wave specification does not define how the physical world interacts with such devices. ZigBee is developed to fit well for many purposes and it is not as rapid to agree on the basic profiles as Z-wave is, for example. However, it has a clear advantage in the pursuit to become the de-facto standard since it is now supported by all the major players. KNX's roots are on the industrial automation side, so the implementation of the system is remarkably expensive and demanding, since they are also eager to make it more affordable for mass market adoption. Hopefully, by 2025 these problems will be solved.

5.3 Security and Care

A smart home will provide better security and care, yet an economical living experience for people at all ages. Regarding the home automation market within several European areas, a web study conducted by Nokia in 2008 (Nokia web study 2008) showed that security, together with energy saving, was the the most popular functionality among the top valued functionalities in a modern house. Although in the end energy saving won with 55% of the votes, security applications were slightly ahead of energy saving when it comes to willingness to pay.

For the elderly and disabled, home automation can be implemented as a viable option for those who would prefer to stay in the comfort of their home rather than move to a costly health care facility. The transition to a health care facility can cause a lot of anxiety and home automation can either prevent or delay this anxiety (Cheek 2005). For elderly people (over 55 years old), as shown in Table 2, what they need most within the home environment are security, care, services and comfort (Patric 2006). Smart homes can provide them with many different types of emergency assistance systems, security features, fall prevention alert, automated timers, and so on. These systems allow for individuals to feel secure in their homes knowing that help is only minutes away. The same also applies to the disabled since smart homes give them the opportunity for independence, which will help them gain confidence and determination.

Table 2. What people of varying age need most within the home environment (Patric 2006).

	< 35 years 1 or 2 person households	35-55 years family	>55 years 1 or 2 person households	Elderly in need of care
Security	*	**	***	***
Comfort	**	**	***	**
Services	***	**	***	***
Care			*	***
Communication	***	***	**	**
Data Systems	***	***	*	**
Entertainment	***	***	*	**

5.4 Challenges

The price for smart home solutions is still relatively high. Figure 4 describes the demand-price curve in 2008 for three different packages, namely security, energy saving and smart gateway (Nokia web study 2008). For example, if we price a security solution at €800, less than 10% of the population would be interested in buying one. However, when the price is decreased to €200, nearly half of the population would be interested in buying one. This has shown a positive demand for smart home solutions, if the package and price are right. As the technology advances while the total cost decreases, most of the households will be able to afford to buy a smart home package in the future.

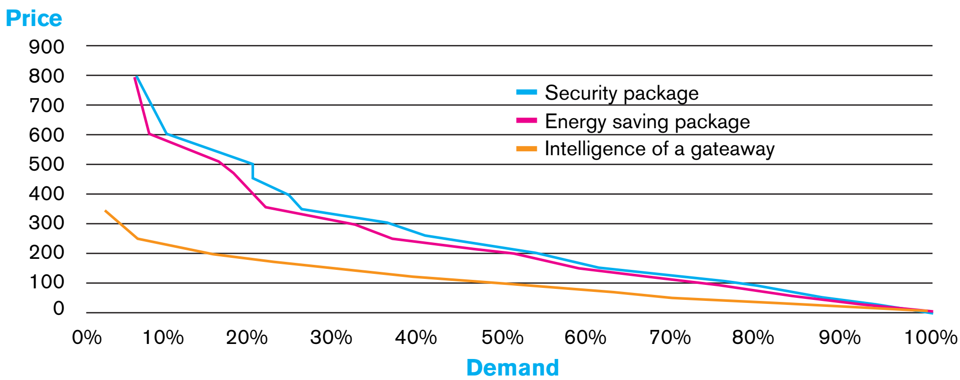

Fig. 4. Demand – price curves for security, energy saving and smart gateway packages (Nokia web study 2008).

Another challenge is the consumer's failing awareness of possibilities and opportunities, as well as lacking distribution channels. Overall in the year 2008, the interest in smart home solutions followed the 33% - 33% - 33% theorem quite well (Nokia web study 2008). This means that one third of the population is very interested in smart solutions for their homes, another third is somewhat interested and the rest don't want to see any more technology in their homes. In addition, over half of the respondents had no clear preference regarding where to buy the package, while the rest were quite evenly divided between on-line stores, purchasing from an Internet service provider and slightly more preferring domestic appliances stores, department stores, and electric utility stores. This can be partly solved by giving specific training to people in the real estate business and installation business to increase the speed of knowledge spread.

There is still a gap between research and actual implementation since fully networked smart houses are still rare. There is no dominant network and too many standards exist. In fact, the continuous development of sensor networks is also part of the problem: how to ensure that the older versions are also compatible with new ones? Common agreements among various vendors will be heavily required. Finally, one should not neglect the importance of developing solutions for the existing homes, rather than building new ones. These are the challenges for 2025.

5.5 The Smart Home in the Future

Lower energy consumption is a crucial feature of a future house. A home equipped with passive heating and cooling system, or a passive house, points in a promising direction to move. The passive house does not need a heat distribution system. Thus it saves energy and reduces CO_2 emissions as well. Actually, the passive house is not a new concept today. The first passive house was built in Germany in 1989 and in 2008 there were approximately 10,000 to 20,000 passive houses in the world. Most of them are located in Germany and Austria, but there are also a few hundred of passive buildings in the Scandinavian countries. Up to the year of 2025, the number of new passive houses in Finland will grow to 8, 000, accounting for an expected market penetration of 26% of new dwellings. The number of refurbished passive houses will increase to 4,000, accounting for an expected market penetration of 22% of refurbishments (Promotion of European Passive Houses, 2006).

As for smart sensor networks, the trade-off in protocols is often between compatibility and flexibility. Although many protocols are expanding to other means of communications as well, there is no one-size-fits-all solution in managing home networks (Nokia white paper 2008). In some situations radio works well, while in others the power grid via powerline communications (PLC) provides the best solution. Hence, it can be assumed that a future home will use several different technologies. However, the user interface will be much simpler and more adjustable. Instead of using multiple remote controllers, people can easily access home appliances by using a mobile phone or a web browser at anytime, anywhere in the world.

Aging societies will have bigger needs for home automation. The percentage of people over 65 years of age in European societies is due to rise to 20% by the year 2020 (OECD Annual Report 2005). Not only will the group of people over 65 become a large proportion of the European society, but there will also be a significant increase in the number of people over 80. To better take care of the elderly and disabled, smart home systems will make it possible for family members to monitor their loved ones from anywhere with an Internet connection. This can be realized by locating advanced sensor networks inside the walls. These sensors need no extra power supplies since the energy is converted through a power harvesting process from solar panels, wind mills or even from the heat emitted from human bodies. These sensors will monitor people's heart rate and blood pressure in real time. Should any emergency happen, warning signals will be immediately sent to nearby medical centers and relatives.

Finally, it is worth mentioning that technical solutions should be inspiring and supporting, not making decisions for the user. In the end, the user himself or herself is the key factor in realizing the goal of improving the quality of life.

6 Work

We suggest that the evolution of working practices in next decades will be based on three driving forces: development of information and communication technology (progress in ICT), the tendency toward increasing independence of location (mobility) and managing work processes through various flexible interfaces or shared distant desktop schemes (virtual work). All these aspects and their development are strongly related to each other and their success depends on a balanced investment in all of them. Furthermore, we see work and leisure as two activities completing each other. Even if the borderline between work and leisure is blurring we feel that work typically has stricter requirements for directly measurable productivity. Despite the differences, evolving practices and technology used in work are inevitably reflected in how modern free-time is spent. Thus we state that the driving forces identified for future work are also applicable for future leisure.

The first generation that has lived whole its life surrounded by networks and the Internet will arrive in the labor market after 2010. This generation has skills and preferences differing from all earlier worker generations. It has been estimated that the early and constant experiences of Web communication belonging to people born in 1980's or later makes it very natural for them to adopt distant working practices. Besides enabling working flexibly in various places, the adoption of distant work can be also seen as an argument favoring a sustainable environmental way of living by reducing unnecessary traffic. We consider that the reform of the educational system will be based on the same driving forces as earlier stated for work and thus new studying techniques will follow work practices. In many Western countries, an aging population requires making new kind of prioritization in services for society to maintain welfare with diminishing worker generations.

6.1 New Forms of Work

The European Commission's green paper on a Partnership for a New Organization of Work has initiated development efforts at the European level. The basic aim of this paper was to find consensus on ways of reaching "better organization of work at the workplace, based on high skill, high trust and high quality" (European Commission, 1997). Based on public consultation the Commission issued a communication (European Commission, 1998) that lists some main issues in the domain: ensuring proper training, developing working time packages, diversification of working relations and new forms of work, ensuring optimal conditions for the use of new technologies, promoting worker's involvement for motivation and adaptability, and supporting equal opportunities. These reports have pointed out the need to speed up the modernization process. In this development, partnerships between firms, social partners and all other stakeholders have a high value.

Anttila and Ylöstalo (2005) have referred to "proactive workplaces" in which "personnel have increased possibilities to exert influence, and at the same time increased responsibility. [...] In the proactive way of working (in an ideal case), the management controls the goals and how they are reached. The worker controls the working methods and the results of his/her work, by which the goals of the organization are reached" (Antila & Ylöstalo, 2005: 9–10).

Technology and media content (text, images, sensor data, audio and video) are merging in a way that offers new perspectives for working. In the future, work and leisure will be increasingly mixed in people's everyday life. One of the reasons supporting this trend is the ability for distant working. Due to advanced communication technologies, people can be practically everywhere and stay in contact with other people and their information sources. Information is increasingly stored in data clouds that allow easy access from all global locations. However, in professions requiring high security, distant work will still not reach the same popularity. Advanced encryption technologies make it possible to protect data traffic but simultaneously advanced computational power and parallel computing resources cause a threat to durability of encryption.

An important general trend is that small computing devices are becoming more and more used in various working tasks to control processes and to manage data. Due to the relatively cheap price of new devices and a continuous supply of a bit outdated ones, it becomes feasible to place computing devices almost everywhere. They serve basically either as intelligent terminals (having their own data repository, sensors, processors and user interface) or as dumb terminals (relying on data and computational results retrieved from a cluster). They effectively use networks to share information in real-time and can be accessed with smart phones. Despite challenges of limited bandwidth and coverage of base stations, wireless connectivity will increase progressively enabling communication in varied locations and even while in transit.

6.2 Combining Competences

Based on the available empirical research a number of features have been identified affecting new networked working environments (Business Decisions Limited, 2002: 18):

- The way work is organized within operational activities (semi-autonomous teams, multi-skilling as opposed to single tasks, job rotation)
- The way work is coordinated across the organization (non-hierarchical decision making, open information policy about performance, frequent team/management interaction for decision-making, performance measurement with financial and non-financial measures)

– Supporting human resource management policies (regular off-the job training for all employees, in job-specific and generic skills, reward systems depending on performance).

Business Decisions Limited (2002: 21) has drafted a categorization of users according to their propensity to use new forms of work organization: non-users, transition users and system users. For new forms of work organization it is typical to have characteristics of a virtual organization. By combining several definitions, Dumitrescu et al. (2008) list some of the main characteristics of a virtual organization. It is a geographically distributed entity having a flexible structure based on knowledge. The intensive use of technology is enabled by a set of activities concentrated around competences. Teams that work together are grouped based on their competences. There is high specialization of members and free and real-time communication with minimal control and multiple coordination points.

Besides instant messaging and file sharing, new collaborative working practices include web conferencing that uses shared desktops and visualizations in an efficient manner. For example, presentations can be given in a way that allows all participants to fluently communicate and observe available material according to their individual needs. Advances in projector and display technology allow using bigger and more detailed live images in web conferencing.

Distant work may also be available in transportation systems. The infrastructure to support new communication technology will be introduced step by step into buses, trains, taxis, etc. First, these services will be offered as a premium service with extra cost. Later they will become a norm and in crowded urban areas they will also be offered to motivate people to use collective transportation. Working practices in transportation systems rely largely on wireless technology but also on aspects of ergonomics and comfort which must be taken increasingly into account in the design of vehicles.

6.3 Varying Levels of Adoption

It is important to note that virtuality of an organization is basically a matter of degree and can take various forms. Both inside and between organizations virtuality can emerge also as virtual collaboration and virtual teamwork. In a survey of the top 500 manufacturing, financial, retail and technology companies in the UK, it appeared that 25% used virtual teams "to a large extent", and further 58% used them "to some extent" (Edwards & Wilson, 2004: 88). Virtual teams can be defined as "groups of geographically, organizationally and/or time dispersed workers brought together by information technologies to accomplish one or more organization tasks" (Powell et al., 2004).

Due to constant technological development virtual organizations and teams can adopt new technological tools and practices as they emerge. In the early 1990s, virtual collaboration relied largely on for example email and teleconferencing over the phone line. The term eWork has been promoted especially by the European Commission (European Commission, 2003) to indicate progress from previous stages of virtual collaboration, typically referred to as telework or telecommuting. eWork typically comprises any type of telemediated remote work and can for example have the following forms: individualized or shared-office based work, collaborative work or work which is performed in the context of principal-agent type relationships, and work interaction that is inter-organizational or intra-organizational. A survey of 19 persons involved in distant work clearly expressed that distant work helps the workers to have strength in the work life, is a part of quality of work and enables to save time (Työ- ja elinkeinoministeriön julkaisuja 25/2009).

6.4 Effects on Lifestyle

Distant work brings challenge for the work rhythms of working communities. Basically, various individual rhythms can be supported but this can cause difficulties for synchronizing activities in an efficient way. Thus, for corporations it can be common to have a certain time window defined for everyday so that everyone is expected to be reached at that time, either in person, online or virtually. Time previously spent for travelling to work can be used as leisure. Many work affairs can be handled conveniently from any location but, as a downside, active workers can have difficulties in finding their own time reserved just for leisure. Messages concerning work can arrive at anytime interrupting free time activities. Corporations and work unions will probably start defining conditions and recommendations about how enough individual leisure time can be guaranteed. Also, for the active working time, new methods need to be developed to control the number of interruptions. People will note that for efficient working it is necessary to have time to focus on projects without being interrupted or fearing interruption.

In many professions work is also getting features that make the work activities approach leisure activities. Working places can easily become customized for individual esthetic preferences with new display and projector technology. Also, with sound environments (for example, nature sounds and music) the working atmosphere can be improved a lot especially for rather monotonous work tasks. In computer applications, it is possible to develop new kinds of user interfaces that make working with data more like playing a computer game. For example, classification and sorting tasks can be presented to the worker with figures, animations and sounds that make them more appealing. The development of educational technology will probably provide new general methods that can be applied equally to studying, working, leisure or recreation for the elderly. Gaming in its various forms will enable a new kind of immersion with multimedia content mapped to an individual's characteristics and interests.

Corporations are becoming increasingly aware of the importance of having devoted workers who have strong emotional ties to their work and to the data they handle and produce. Thus, personal emotional needs can be supported increasingly with customized work flows and processes. Also, for many professions it becomes important to define motivating storylines for long-lasting projects. These storylines can effectively combine factual information with emotionally loaded experiences. In this approach, advanced multimedia technology can play an important role.

7 Life in Finland 2025 -

Pekka (age 49) and Liisa (46) are married with two children, Ella (15) and Akseli (17). Pekka is a medical doctor working for both public and private medical care providers and Liisa is a consultant in a medium sized IT services company. They live in Helsinki but they have also a summer cottage in Elimäki. Liisa is originally from Elimäki and her parents are still living there. When Liisa was young the family was farming potatoes but nowadays Liisa´s father Olavi (62) is working in a gas station as a supervisor near their home. In his current job Olavi is responsible for biofuels of the station. Liisa´s mother Maija (67) has been a housewife already four years.

Pekka works part-time at few private health stations as a doctor and rest of the time carries out a research project funded by state and some medical companies. He thinks that virtual meetings cannot yet fully compete with being face to face but already gives a lot of consultation to patients with high-definition videoconferencing. He does most of his research collaboration in virtual teams with a sophisticated shared desktop.

Liisa is working as an actively traveling IT consultant selling hardware and software solutions for various corporations and also giving maintenance support. While on the move, she has high wireless connectivity to clients and colleagues. She can make an analysis of the operation based on reports automatically generated by the monitoring system installed in the customer's hardware. She can make various queries to an intelligent system that enables comparing theoretical predictions and empirical samples.

The school has been reorganized so some additional education is available through the network. Ella and Akseli can follow these interactive educational presentations with their mobile computing device in any place they prefers (in their own rooms, in the library with friends, in the bus, etc.).

Helsinki has grown to a metropolitan dense area with a population of 2 million people. Pekka's family is living in a five room apartment in Herttoniemi in the eastern part of Helsinki. In the year 2025 the natural borders of parts of the city areas have disappeared because of the dense community structure but borders are more like activity based lines. They define for example how waste is collected and how energy is distributed. As a part of its environmental policy the city of Helsinki determined Herttoniemi area to be one of the ecovillages of the city. That was one of the biggest issues when Pekka and Liisa decided where they wanted to live. Ecovillage in Helsinki means that building has to be renewed according to the newest environmental regulations. The building was originally built in the 1950's and it has been totally renewed once by their family in 2020 when taking advantage of a low season in construction business and cost were low. For example, the energy efficiency of the building has been upgraded to a state of the art level by adding insulation and upgrading the heating system to an intelligent one. At the same time solar panels were installed on the roof of the building to provide a portion of building's electricity, especially during the spring, summer, and autumn. During the winter the solar panels are also used but their efficiency is not very good. Local energy production has become rather popular due to increasing electricity prices and increasing efficiency of modern, easily deployable solar cells. The building is also connected to the district heating system. Heat production in the metropolitan area is centralized for improved efficiency and lower emission levels. Also the recycling system is customized to suit the environment of the area of Herttoniemi. There is an intelligent recycle center in every apartment block. This means that there are sensors that always monitor the capacity and the conditions in the sorting unit and deliver information to the collectors.

The transportation experience has been improved. Even though there are more restrictions and regulations for controlling the private car traffic, public transportation has been improved. In 2025 traffic is controlled by smart systems that create a better flow of people and vehicles within the city. For example, public transportation is prioritized at the traffic lights. In Finland, the weather has been always one important attitudinal issue in using public transportation, especially in the context of families with children. Therefore, bus stops are equipped with systems that make the waiting nicer and warmer. Further, people have their personal mobile entertainment and office systems and even intelligent clothing that make the traveling experience more comfortable. These days people can also attend meetings relatively easily even while on the move. The quality of the sound and video transmitted in mobile broadband provides an acceptable experience.

Today the family is leaving from Helsinki to Elimäki. Elimäki is a town with 6500 inhabitants and 115 kilometers from Helsinki. There is a brand new highway to Elimäki. Pekka has packed their hybrid car with the family luggage. The car is full of entertainment for the children so they do not get bored during the trip. After that he takes care of the apartment. He uses his mobile phone to tell to the home control that they are leaving and the apartment will be empty at least one day. This means that the room temperature will be lower at an energy saving mode when they are away and the security system will be in an alarm mode. He also takes care of waste by sorting it and taking it to the recycle center of the house. Children are already at home and after Liisa arrives from work they leave for Elimäki. Although it is possible to travel to Elimäki by buss, the family decides to go there by their own car because Pekka stays there only one day and the family will stay there a few days longer. Still, the private car is the most preferable transport option for families to travel to their summer cottages to spend their weekends since they want to have control over their traveling time table Therefore, there has not been much change in attitudes. However, the vehicles are used in a much more environmentally friendly way and new cars practically do not pollute. Furthermore, introduction of toll roads has reduced using private cars especially in urban areas.

The trip only takes about an hour and when they arrive Elimäki Olavi welcomes the family already in the yard. He has just arrived from daily work and now he is leaving for his side job. Olavi is a member of energy cooperative called ElHeC (Elimäki municipal heating cooperative). In this cooperative there are several owners who are local people. They manage and run their small unmanned power plant, which is situated just few hundred meters away of their home. The power plant produces both heat and electricity from scrap wood and farming waste (both animals and plants) which the cooperative members are collecting from their own forests and farms. Instead of scrap wood the power plant currently uses bio methane and it is closely connected to a local cow barn. The system consists of a bio methane reactor and a boiler which produce both heat and electricity. In that power plant the process needs monitoring all the time so it is run by a company, owned by the farmers and a local electricity company. Local heat and electricity production decreases energy costs and provides the energy source for internal combustion engines which are utilized in farming machinery.

Olavi is actively collaborating with a colleague who is currently located at a production plant. Together they adjust processes of the plant through a distant control panel that shares the workload between them intuitively. To agree on the distribution of work and responsibility in maintaining the mechanical generators and pipelines they use a specific user community forum. Through this forum Olavi takes also part in global chat discussions to share expertise and gather useful information for future reference. Here automated translation services assist in fluent communication. Auctions organized at these virtual communities help to find the best prices when buying and selling machinery and services.

Through the years the village has changed quite a lot. Some thirty years ago there were several farms in the city and they produced milk, pork, and grain. The distance between the farms was from several hundreds meters to a few kilometers. Today there are just three big farms depending only on farming and they have a field area of over 5000 hectares each. All the other farms are doing more or less recreation like farming, bed and breakfast services, and nature activities for families with children. People work outside of the village or they are already retired. Many of the inhabitants have built themselves passive houses with modern conveniences. Passive houses are popular since the house can heat and cool itself without using an extra heater, hence "passive". Besides comfort, living in a passive house is economical and environmentally friendly. Although the initial investment in a passive house is a little larger than that in a normal house, the operating and life cycle expenses are remarkably lower than in a normal house. In addition, the heat loss of a passive house is rather small so that a normal heat distribution system will be unnecessary, which reduces a large amount of CO_2 emissions in return. Besides, the houses are now placed closer to each other and the village has become like one entity. This closely build community has enabled for example their cooperation for energy production.

When Pekka and his family have said hello to their grandparents and had an official cup of coffee, they leave for their summer cottage. It is only half a kilometer away from the grandparents place just beside a small lake. For Finnish urban people it has remained as an important recreational activity to own separate summer cottages closer to nature, even if this increases their living costs. Through the years Pekka has renovated the old summer cottage to a modern house with all the conveniences. It is also connected to the village energy grid and there is a wireless broadband connection. The walls of the cottage have been installed with advanced sensors to monitor the heart rate and blood pressure and the falling sensors are distributed under the floor. Should any emergency happen, an instant warning message will be sent to the community medical facility and to Pekka's mobile phone. Because of the high standard of equipment, Liisa quite often stays at the cottage for a longer period of time. There she can work and also spend time with her parents and children. Also during this weekend she has to prepare herself for the upcoming meeting which will take place in Kouvola on next Monday. To support sustainable housing they have also added their partly idle summer cottage to a global community that lets members to live at each other's houses while traveling.

After spending a relaxing evening and night with sauna and good food at the cottage, Pekka has to leave for Helsinki on Saturday morning. He has emergency duty which starts at 2 p.m. in University Hospital of Helsinki. Because of the state subsidized buss connections he can leave the car for his wife and take a bus to Helsinki. During the trip he already starts to do his writing work using high speed internet connections provided by the bus company. Before the bus arrives at the station he also informs their home control system via Internet that he will be at home at 10.30 p.m. and he wishes that the sauna could be ready at that time.

8 Conclusions

We have discussed several important development directions which will affect future living in Finland from 2009 to 2025. These include developments in energy production and utilization, urban planning, transportation and health and wellbeing.

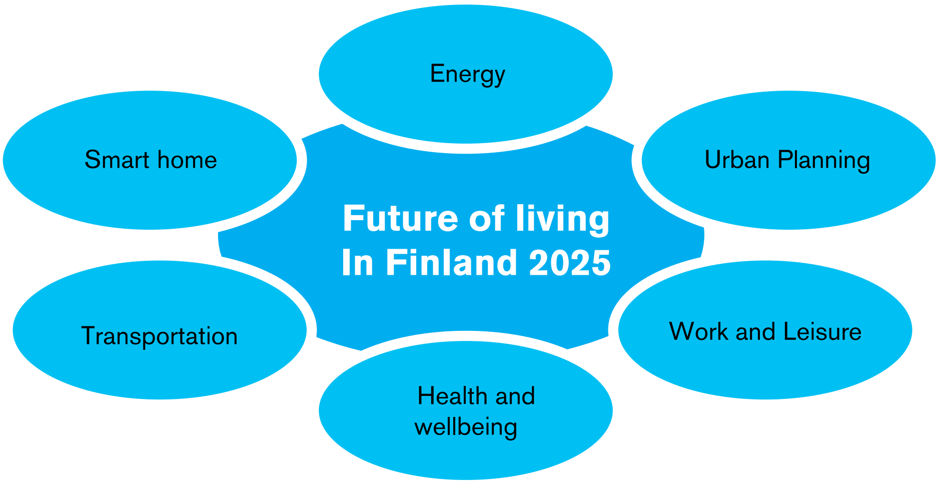

Fig. 5. Discussion framework for Future Living in 2025 and the driving forces

The main developments in energy production and distribution will be increasing electricity consumption, improved energy efficiency by co-production of heating power and electricity and utilization of biomass as transportation fuels. Both urban and rural areas will be diversified by increasing needs for different kinds of housing models and different kinds of communities. Energy efficiency requirements will drive development towards denser structures. In rural areas plausible development directions are related to various eco-concepts in which communities consist of small and independent units.

Housing will get smarter and more energy efficient. Home automatization systems will be more common and get simple unified user interfaces, for example, operated via mobile phones. Home automatization will provide a better quality of life especially for an aging population which requires assistance and health care services at home. Health care innovations like gene-treatments, mobile bio-monitoring and exercaming provide additional quality of life for an aging population. Passive houses will be the building standard for improved energy efficiency, especially in areas outside the district heating network.

Work practices will largely rely on mobile intuitive user interfaces. Information is stored and communicated in networks, decreasing travel to work. Distant working combines collaborating competencies efficiently in virtual teams but introduces diversification of time-use patterns and mixes work with leisure. Learning can be supported with personalized gaming schemes.

The aging population will have lots of free time and multiple ways to entertain itself. Summer cottages and second homes located near public transportation connections and providing easy access will experience a new boom. Public opinions towards public transportation will become positive due to cost-efficiency, wide availability and low environmental impact. Private transportation will be less common and the available private transportation options will have significantly lower environmental impact than in 2009.

The aging population forces society to determine new priorities concerning public services. Regulation imposed by authorities can encourage people to make sustainable choices.

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2.3 Wide Wide World – Globalized Regions, Industries and Cities

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Abstract

Globalization is a complex phenomenon that has deep historical roots. In this chapter we make an effort to understand the impact of globalization by introducing three case studies: the Dongguan region in China, the Russian automotive industry, and the city of Varkaus in Finland. We focus on the challenges they face, the benefits they enjoy, and the capabilities and strategies they develop in order to adapt to the globalized world. In addition to the case studies, we analyze the relationship between globalization and technology, focusing on the four technological areas presented in the first part of this book. In the final section of the chapter we produce two scorecards for globalization, consisting of indicators that are extracted from the case-focused analysis.

1 Introduction

Globalization as a term is mainly known and used in the public when talking about the globalization of economic exchanges. It is true that nowadays globalization is mainly analyzed from an economic perspective. However, historically globalization has been primarily a question of geographic movement of populations. Globalization can, therefore, be described as the process of transformation of local or regional phenomena into global ones. It can also be described as a process by which people around the world are unified and increasingly function together. This process is a combination of economic, technological, sociocultural and political forces. In the following sections we will elaborate these perspectives on globalization.

We begin with a review of the history and fundamental features of globalization. The emphasis is on the description and critique of the economic aspects of globalization. The general discussion on globalization is followed by the presentation and analysis of three case studies: the Dongguan industrial region of China, the automotive industry of Russia, and the city of Varkaus in Finland. For each case we present the history and the current situation, as well as the different strategies adopted by local and global decision makers. In the subsequent section the focus is moved on to the relationship between globalization and technology. We utilize the research done in the previous chapters in this book, especially by relating globalization to the discussed themes – processors and memories, telecommunication and networks, printed electronics, and carbon nanotechnologies. We conclude the chapter by introducing two scorecards to present the salient indicators of globalization – people, geography, and economy – and connect them with the three case studies and the four areas of technology.

2 Some Fundamental Aspects of Globalization

2.1 Short History of Globalization

An important aspect of globalization has been the travel of merchant groups in different areas of the world. This aspect involves humans, their way of living, their cultures, as well as the environment and geography. Repressed and often limited to relations with foreigners, mercantile exchange was governed and controlled by political powers. For instance, commercial activity between the Mesopotamian cities more than 4000 years ago was ruled by the power in place, which selected the merchants, paid them, defined the prices and controlled the quantities of goods.

It required more than a millennium for the Phoenician cities of Tyr, Sidon and Carthage to produce a class of merchants organized in the form of guilds that were liberated from the political power. Focusing entirely on maritime activities and totally disinterested by military conquests, they built their supremacy on commercial domination. In this respect, they anticipated the strategy of Venice, 2000 years later. This initial step of the trade economy was also pursued in Greece. According to Jean Baechler [1] this was due to the absence of a centralized political power and the presence of multiple independent and rival cities, such as the Greek state-cities, Phoenician towns and later on Italian state-cities in the Middle Ages.

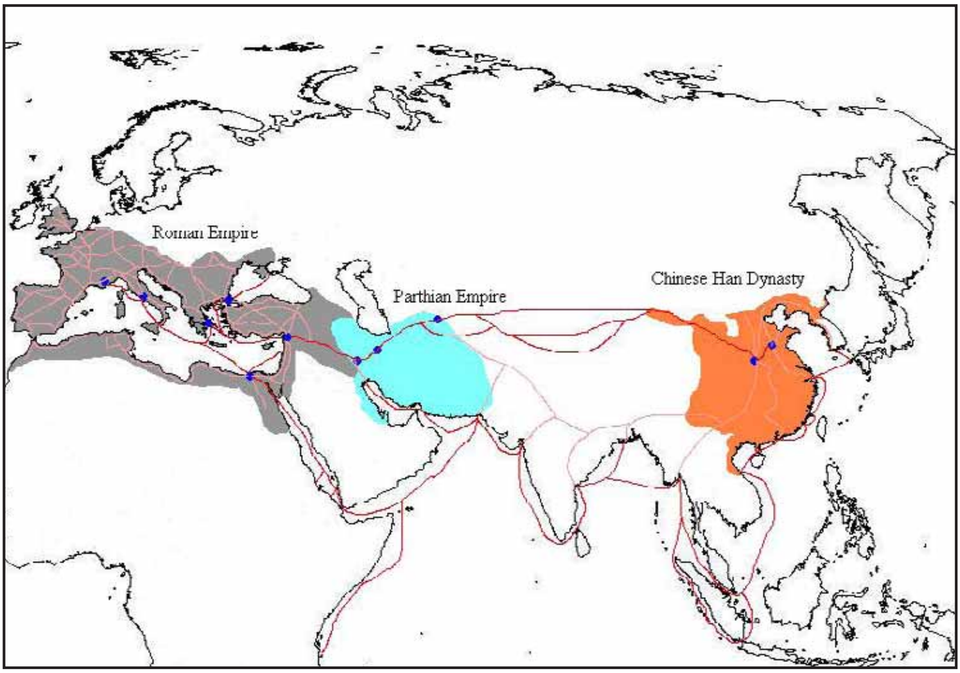

Fig. 1. The Silk Road combined the Roman Empire with the Parthian Empire and the Chinese Han Dynasty in the 1st century.

The historical paradox is that the trade dynamic was initiated in Europe, during the Middle Ages, despite the fact that the Christian culture was opposed to the idea of profit. Europe was at that time economically and politically underdeveloped, compared to its Asiatic and Middle Eastern counterparts. Nevertheless, the trade dynamic slowly imposed itself by destroying social and cultural barriers. The originality of the European town, according to Max Weber [2] was to be composed of free citizens not placed under the absolute power of royalty, but only militarily protected by the nobles. This social structure was the starting point of an accumulation phenomenon that had perpetuation as its main goal.

The other central characteristic of Europe at that time was the unique type of interaction between kings, nobles and merchants. According to Eric Hobsbawm [3], the development of commercial activities such as fairs in England and France was the basis for industrialization. Opening of the Gibraltar strait, amplified by the discovery of America, radically modified the social and economic structures of Europe. During this period the feudal system collapsed and was replaced by nation states. The industrialization process took mainly place in England and France because it used the depth of the internal markets consolidated during the 18th century in those two countries. The integration on the national level of markets, labour and capital made possible the industrial take-off. The engine of wealth accumulation shifted from external commerce to internal production. However, the European production market was limited by the protection of the internal markets and by the control of capital. This period has been called the *first globalization* by Suzanne Berger [4].

The market was limited abroad by the competition between empires, and internally by workers' resistance. Undeniably, wars at the end of the 19th century and first half of the 20th century were for a major part the consequence of this competition. After the crisis of the 1930s, a Keynesian reaction emerged in order to reintegrate the dynamic of accumulation under the control of nation states. This reaction took the form of the New Deal in USA and the Popular Front in France. This evolution was also visible at the international level, where the institutionalization of economic relations and financial aspects was organized by creating institutions such as Bretton Woods and GATT. However, these agreements were not able to resist the internationalization of the exchanges and the mobility of capital. During the second part of the 1970s, the movement of liberalization ruled economic policies. Politicians were obliged to accept the constraints of competitive and financial credibility imposed by companies and markets. In addition, the rapid industrialization of the Asiatic area encouraged the strategies of delocalization and sub-contracting performed by multinational companies. As a consequence, the pressure on the Keynesian social agreement, inherited from the post-war period, increased considerably.

The progressive opening of China, India and the collapse of the Soviet block have doubled the volume of the work force integrated to the world market. It has resulted in a great disruption in the organization of production and exchange in the world. Now, 3000 years after the deployment of the first Phoenician state, for the first time we have an integrated world market and consequently also a global productive system. This system places production, services, capital and workers in a state of competition. Geography, social concerns and political power place fewer and fewer constraints on the economy. Market ideology penetrates all aspects of social life: education (i.e. the university system in Finland), culture, sports, information, and politics. Social protection and public services are themselves threatened by market ideology. Exclusion, social insecurity, financial instability, cultural impoverishing, and helplessness of politicians are the corollary of the corrosive force of the market system that the nation states are no longer able to domesticate.

2.2 The Impact of Two Central Constituents of Globalization: Capitalism and Market Economy

Capitalism and market economy are two key elements of the globalization phenomenon. The relationship between the two can be analyzed in two distinct ways. On the one hand, historians like Fernand Braudel [5] believe that market economy should be distinguished from capitalism, and on the other hand, economists and sociologists see market economy as the seed that has given birth to capitalism. This divergence is a central issue, because, it means that supporting the distinction between the two terms suggests that it is possible to quit capitalism while keeping market economy. Jacques Sapir maintains that market economy leads to various forms of capitalism [6]. These forms depend on the institutions selected to organize production and to coordinate the actors. Another potential consequence resulting from this perspective, followed by Braudel and many other historians, is to consider that finance – which is the source of the capitalistic power – can be dissociated from production and market economy. Following this logic, it is possible to conserve the dynamic of market economy while abandoning the speculation and the inequalities contained in capitalism.

On the contrary, considering that capitalism and market economy are only two facets of a similar reality leads to two opposite positions. The first one maintains that capitalism is unavoidable, because, by its nature, it includes the market economy. The second position resulting from this economic perspective maintains that the market economy should be reserved to domains where it has proved to be efficient, and avoided in domains where social cohesion is important. This position also leads to another central question: Is market economy really ruled by full and perfect competition between the different actors?

Several economists have noticed that the ideal market described by Adam Smith [7] is often replaced after a certain period of time by oligopolies or monopolies. In all markets, the free game of competition leads increasingly to the concentration of supply in the hands of a small number of corporations. The reason for this is that competition costs a lot. Companies need to spend an important part of their turnover in marketing expenses, research, and development.

In other terms, most modern economic activities are localized in global markets, where brand and innovation play a key role. In this type of economy, activities require a lot of capital to cover all the material and immaterial investments. The size of the investments required limits the emergence of newcomers and eliminates competitors that are unable to invest the required resources. Because of the level of the entry investments, there is an absolute need to sell in order to pay off the initial investments. In order to limit the risks, companies tend to create cartels or oligopolies. The concentration phenomenon has been very rapid for the last 40 years. Nowadays global companies are facing nation states that can in most cases only act nationally. The nation states increasingly face blackmailing and lobbying. Robert Reich, a former minister under U.S. President Bill Clinton, maintains that democracies are in danger [8].

Can we consider that competition has vanished from the markets? No. Indeed innovations play a central role that can radically change the situations where the position of oligopolies or monopolies looks perfectly established. For example, the invention of the personal computer has been the cause of the declining influence of IBM. In the same manner the development of software that can be used remotely through the Internet (cloud computing) can be a sign of the end of the reign of Microsoft.

What Karl Marx announced 150 years ago is becoming a reality – the market is nowadays global. This global market is visible in many ways: opening of the borders, multiplication of supply, and standardization of consumption. Customs charges have constantly diminished over the past decades. Enormous progress has been made in the transportation sector and in telecommunications. Standardization has been developed through the conjoint action of ISO and industrials. The standardization of consumption is visible through products created by companies such as Zara offering new identical products every 15 days, in Madrid, Paris, Berlin, Shanghai or Hong Kong. This tendency is accompanied by increasing segmentation. But, on the other hand, the products are increasingly similar in the different markets. This is the case for Nokia and many other brands as well.

2.3 Opening the Exchanges: a Positive Characteristic of Globalization?

Faced with the failure of the policies proposed by the institutions of Bretton Woods, great criticism has been placed on the policy followed by the IMF and the World Bank during the 1990s [9]. Indeed, the developing countries that have accepted opening their borders to foreign products and services following the advice of the IMF and the World Bank have experienced less growth than developing countries, which have decided to keep protections on their internal market. According to Dani Rodrik [10] it is better for developing countries to first protect their internal markets in order to obtain a level of development that is sufficient when engaging with the bigger players. The intervention of nation states is necessary in helping to develop a strong economy in close collaboration with the private sector. Another aspect is the time required for becoming global. It has taken 60 years for Toyota to become the world leader in the car industry. It required 100 years for United Kingdom to become the leader in the textile industry in the 18th and 19th centuries. By contrast, for an Internet company like Google, it took only 10 years to acquire a truly global position. Yet, the adaptation to globalization often requires time; a long political, social and economic process. No serious professionals nowadays maintain that a simple liberalization of the exchanges is the unique answer for benefiting from globalization.

2.4 Globalization And Market Economy: a Natural Law of Nature?

Can we summarize the history of economy as the history of universal expansion of market mechanisms? The idea of the market as an economic invariant is one of the axioms of the liberal economic movement. According to this perspective, the fact that the market economy really commenced its development in Europe first, and not in China, is only due to historic momentary constraints. For Adam Smith this fundamental law results from the inner psychological character of humans. According to this viewpoint, the expansion of the market took time because of natural obstacles (mountains, oceans), but it was a natural penchant of humans. This simple evidence from liberal thought is nevertheless greatly challenged by important results in anthropology. Indeed, Marcel Mauss's [11] analysis of gifts in archaic societies has demonstrated that the circulation of goods is not utilitarian but governed by other kinds of values. Exchange based on interest has been mostly marginal in societies. Karl Polanyi considers the ideas of Adam Smith on economic psychology of the first humans equally as wrong as the vision of Rousseau on their political psychology [12].

2.5 Globalization and Ecology

Market mechanisms involved in globalization are also used in order to promote a more sustainable economy. A key dilemma is that market mechanisms, which often lead to the destruction of the environment, are also used to promote sustainable behaviour. The question in this section is not to discuss this internal contradiction but more to analyse the manner in which political authorities use the market approach to tackle environmental issues. What are those market mechanisms, and are they efficient in solving ecologic issues?

The special form of market system treated in this section was inaugurated in 1995 in the USA to reduce the amount of sulphur dioxide (SO2) and nitric oxide (NO) gases sent to the atmosphere. Both of these gases are supposed to be responsible for acid rain. This initial initiative took the form of an emitting permit market for these gases. The same principle has been used in Europe to build a carbon emission exchange market. Since the 1st of January 2008, an exchange system of carbon has been implemented in Europe. Since the 1st of January 2009, the Regional Greenhouse Gas Initiative (RGGI) is testing the first US regulated carbon market in 10 Northeast states [13]. The goal is to reduce the emission levels of the electric power plants by 10% in ten years. To achieve this goal the companies will have to invest to improve their energy efficiency. They will also be able to buy emission rights from other RGGI companies having rights that they do not use because of an improvement in their energy efficiency. The companies will also be able to finance energy savings projects outside the USA. Before the creation of RGGI, the USA only had a voluntary carbon market (the Chicago Climate Exchange, CCX). Companies participate in this market on a free basis, which is different from RGGI. This initiative is limited compared with the European initiative. At the moment the impact of this market approach on the cost of a ton of carbon dioxide (CO2) is not obvious both in USA and Europe.

2.6 Globalization and Society

Relations based on non-mercantile exchanges remain very important in contemporary societies. This fact was demonstrated by Marcel Mauss in the traditional societies of the Pacific Islands. Jacques Godbout and Alain Caillé [14] have shown how this fact remains valid in the contemporary societies through neighbourhood relations, gifts for parties and birthdays. This consideration of the importance of gift-giving in human society conflicts with the liberal vision of history presenting all the human behaviours as expressions of a rational homo oeconomicus, aiming to follow his interests and avoiding obstacles created by the political and religious powers. This vision hypothesizes that the market has been always and everywhere guiding human adventure. Reality is much more complex, because human needs link in the same manner as goods. This is another aspect of globalization, which is not elaborated on deeply in this chapter but would require a complete book. State welfare and rules are manners to preserve these links between humans, especially when they are under attack by the corrosive power of the market economy.

Summary of the key aspects of globalization:

- Globalization has following economic advantages:
  - o International trade enables more efficient production by allowing the use of resources in places where they bring the most added value.
  - o Globalization has clearly increased the total wealth in the world
  - o Consumers have more options and cheaper prices
- Globalization has the following problems in business:
  - o Global markets are difficult for new entrants
  - o Global competition and marketing requires a lot of effort
  - o Multinational brands unify global consumption
  - o Even if globalization increases the total wealth, the increased wealth is divided very unequally.
- The result is that the global market favors monopolies and oligopolies created by multinational companies
- Globalization produces an ecological dilemma:
  - o Globalization increases the need for transportation, which is a major source of CO_2 emissions. Newly industrialized countries have major problems with polluting factories making products for the markets of developed countries.
  - o However, there are different attempts to restrict CO_2 and other emissions with global agreements.

3 Case Studies: Dongguand, Russian Automobiles, and Varkaus

Now we move on to discussing the three cases: the Dongguan industrial region of China, the automotive industry of Russia, and the city of Varkaus in Finland. The aim is to cover both the developing and the developed parts of the world, and also offer different perspectives on the aspects, characteristics and history of globalization.

3.1 Electronics Factory of the World

More than 170 years ago, Lin Zexu led an army of volunteers and local people in the Dongguan region in China to fight against the British invaders and managed to destroy the opium trade. It was a touching and inspiring event in Chinese history. In addition, Dongguan is the forerunner of Chinese reform and opening-up policy. In 1978 the first enterprise in China engaging in processing, assembling and compensation trade was founded there [15]. Dongguan, situated in Southern China near Hong Kong, is one the fastest growing cities in China. Since 1979, the average GDP growth rate has been over 20%. Within 20 years Dongguan has developed from an agricultural region into an international city famous for its manufacturing. However, Dongguan is an urban area of "withouts." It is the largest urban area in the world without an international airport or an urban rail system. Finally, Dongguan is probably the largest relatively unknown urban area in the world, although the city had 7 million inhabitants at the end of 2008, among which there are 2 million local residents and over 5 million permanent immigrants from inner China. As a major export manufacturing centre Dongguan draws employees from all over China. Like Shenzhen and other burgeoning manufacturing centres, low-income people from rural China flock to Dongguan seeking a better life. Often workers are housed in dormitories provided by private employers.

Dongguan is now an international manufacturing base for products of all types and grades. ICT products, electrical and mechanical products, textiles and garments, furniture, toys, papermaking and paper products, food and beverages and chemical materials are its eight pillar industries. Dongguan is also one of the most export-oriented economies in China. The impressive record of economic growth can be explained by the city's reliance on foreign trade, which represented 2.55 times its GDP in 2006. This ratio is one of the highest among all cities in China. In fact, export accounted for about 80% of the city's gross output of industrial enterprises above the designated size in 2006. In 2006, Dongguan's exports amounted to US$ 47.4 billion, accounting for 4.9% of the national total.

A production Base Attracting Foreign Investors

Over the years, Hong Kong and Taiwan businessmen have set up export processing facilities in Dongguan. They mainly import materials and semi-finished products like plastics, metals, integrated circuits and semiconductors to manufacture electronic and electrical products, auto data processing equipment and parts, and other high tech products, all of which have become the city's major export items. Processing related industry trade accounted for 94% of the city's exports.

Overall, Dongguan is a very popular destination for FDI (foreign direct investment) and utilised US$ 1.8 billion in 2006. Foreign-invested enterprises (FIEs) are the main economic driving force. In Dongguan, 16,021 industrial FIEs account for about 60% of the industrial output value. Heavyweights, which have invested in Dongguan, include e.g. General Electric, Duracell, Du Pont, Nestle, Nokia, Thomson, Sony, Canon, NEC, Philips, Samsung and V-tech. Dongguan is also gaining importance as a trading hub. The town of Humen is an important national distribution centre for garments and textiles. Many expos in various areas are held in Dongguan. In recent years, the city has been taking steps to discourage high pollution and high-energy consumption industries.

In Dongguan, the strong supply chain is backed by a well-connected industrial system. Dongguan's output of computer magnetic heads, motherboards, monitors, power supplies, scanners, disk drives and micro-motors ranks among the top in the world. Major computer manufacturers worldwide have decided to source in Dongguan. In fact, Dongguan is so important as the world's leading exporter of PCs and accessories that an often quoted saying goes: "If there is a traffic jam between Dongguan and Hong Kong, 70% of the world's computer market will be affected."

Local private enterprises play an important role in the supply chain, with thousands of local suppliers clustered around specialty townships. Each town specialises in a specific industry. With ample supply of both upstream and downstream products, enterprises are assured a strong supply chain as they can easily find low-cost supporting industries, products and spare parts in the locality.

Price of Globalization

Dongguan has definitely got its benefits from globalization. However, it comes at a price. The city and province have been known for the arrival of a great number of workers, many of who are females in their early age (so-called factory girls) coming from agricultural areas. Reports have shown that their living and working conditions are rather poor. [16]

The situation is even more critical for the workers now when the global market is at a downturn. Every Chinese new year (mostly during February) there is a major stream of population flow from Dongguan back to the rural areas. However, in year 2009, this flow did not seem to return to Dongguan. 600,000 migrant workers in Guangdong province were laid off in late January 2009, according to the provincial bureau of Labour and Social Insurance. What makes the situation even worse is that some factory owners ran off without paying salaries to the workers. These workers are typically very young and do not have any special skills. For them it is hard to stay in the city without any stable income and it is also hard to return back into the villages too. It has become potentially a serious situation for society.

China's industrial heartland of Guangdong, recorded an average of 76 days of haze in 2007, the highest level since the year 1949 and a marked increase over normal years, according to a new report released by Guangdong's meteorological bureau. The industrial heartland of the Pearl River Delta fared the worst. Dongguan, with its 213 hazy days tops the provincial black spots. Hong Kong and Guangdong have committed to ambitious air-quality reduction targets by 2010, including cutting sulphur dioxide and suspended particulate emissions by over 50 percent compared with 1997 levels. However, the end results of these actions are yet to be seen.

Facing rising production costs and bottlenecks in supplies of land, labour, water and energy in recent years, Dongguan is seeking to develop new industries, such as high tech and services, and shifting from mere processing to activities with higher value added. In a bid to avert social turmoil, cities in Guangdong, including Dongguan, aim to provide training in a variety of skills for migrant workers. The Dongguan city government is planning to ask all enterprises to pay into a government reserve fund to guarantee workers' wages if factories close. [17]

Trusting in international trade and cooperation, the province will put more effort on the emerging overseas markets, including ASEAN, Africa, South America and Russia. Export of advanced manufacturing and hi-tech products, as well as overseas investments is encouraged. Guangdong will try to attract more leading companies to set up their regional headquarters there and attract foreign investors by launching modern service and manufacturing projects in the province. Cooperation with Hong Kong and Macao as well as ASEAN countries are the main focus of Guangdong in regional collaboration. [18]

3.2 Automotive Industry in Russia

Global technological development in the automotive industry has greatly expanded the electronics and computer content of modern vehicles, with such applications as improved fuel economy, reduced emissions, enhanced safety systems and chassis controls, as well as on-board communication systems [19]. Automobile companies form joint ventures to develop vehicle components and share the architecture, use common manufacturing and assembly equipment, reducing engineering and development costs while producing various car models of unique style and features on the common platform. Besides equity alliances in the automotive industry, global research partnerships are formed with manufacturers, suppliers, universities and government agencies. This global collaboration enables new technology development and its implementation throughout the world. But, in spite of potential growth opportunities, risks of entering a new market influenced by differences in culture, language, business strategies and engineering practices, always exist and should be understood as an important aspect of globalization.

In this section we look at the automotive industry in Russia. Russia is nowadays one of the fastest-growing automotive markets in the world, with estimated total sales of 2 million units worth US$ 30 billion in 2007 [20]. Recently a number of world-known car manufacturers have established assembly facilities in Russia with ongoing future plans. Russia has not only experienced an increasing global demand for raw materials (with oil, natural gas, metals, and timber constituting more than 80% of Russian exports abroad), but also a strong inland consumption growth. Russia also experienced impressive economic growth after the financial crisis of 1998, with GDP increasing by 69% between 1998 and 2007, real income of the population increasing by 82% and poverty rates reducing from over 50% to below 14% [21].

The serial production of automobiles was established in imperial Russia in 1908 at the Russian Baltic Carriage Factory in Riga. Practically all the parts were done by hand, but still it was possible to organize mass production: about 500 automobiles were produced in 7 years, among which there were also truck models. Car models АМО – Ф15 (trucks) and НАМИ-1 were the first automobiles of the Soviet time, produced in Moscow between 1924 and 1930 (see Figure 2).

A) *B)*

Fig. 2. A) Russian truck model АМО-Ф15 and B) car model НАМИ-1.

According to the first Five-Year Plan to industrialize the USSR, Stalin determined the need for modern plant creation to produce autos for the Soviet Union. The Soviet political and economic officials showed great interest in the achievements of industrial America, especially of the Ford Motor Company; their car and tractor output, economy of scale, and automated factories [22]. The oldest Soviet automaker - GAZ (Gorkovsky Avtomobilny Zavod, "Gorky Automobile Factory") was originally developed with the technical assistance of Ford, as in those days there was no experience in creating a national automotive industry in the Soviet Union.

Manufacturing in the USSR at the end of the 1920s and the beginning of the 1930s experienced problems: poor quality of materials and devices; factories managed by top-down planning and distribution administration (vertical system of coordination); dependence on state budget and regulations; lack of experienced supervisory and technical personnel; poor labour discipline. Soviet automobile production achieved only 23,879 units in 1932, and 49,710 in 1933 (mainly from GAZ). The industry of the Soviet period of the 1920s and 1930s gained a reputation of slow production of poor quality vehicles. The main characteristics of automotive production in the USSR were simplicity and durability of vehicles for the domestic market and absence of foreign competition.

The role of domestic automobile production increased tremendously during World War II. The Soviet automotive industry favoured heavy industry programs, production of weapons and military equipment. During the 1970s and 1980s automotive production in the USSR continued its rapid growth. The production grew by about

1 million units per year, and truck production grew by 250,000 per year. In 1966 a new car factory – AvtoVAZ – was built in the USSR with the help of the Italian automobile manufacturer Fiat. AvtoVAZ, located in the city of Tolyatti, was producing automobiles for individuals, e.g. the most popular car, known in Russia as the Zhiguli, originally a licence-built copy of the Fiat 124. Fiat installed machine tools built in Britain to manufacture most of the parts. The car design was mechanically upgraded for domestic driving conditions and cold winters. By the early 1980s over 60% of Lada production was exported mainly to Western Europe, Canada and some developing countries, and sold at a relatively low price.

Nowadays, foreign automotive manufacturers regard Russia as a market full of opportunities, with the size of the market being the key factor. Russian consumers prefer global standards and have become wealthier, increasing the demand for foreign vehicles. Russian labour is qualified due to the presence of a large automotive sector in Russia for many years. Moreover, the import tariffs in Russia are relatively low compared to other emerging markets, in addition to the lower costs of local energy and natural resources. Russian consumers also prefer a foreign car, even if they are assembled in Russia, as foreign cars are known to have better quality, design and reliability than domestic ones [23]. Domestic automakers cannot produce good inexpensive cars and are lagging behind their foreign counterparts in production technology.

The current trend for Russian automakers is to develop collaboration with global car manufacturing leaders in order to learn the advanced technologies and provide a modern competitive product, as well as including acquisition of licenses, purchasing production facilities and setting up joint ventures. In 2006 GAZ, owned by a Russian aluminium magnate, bought an assembly plant from Chrysler in Michigan. $150 million was spent to purchase equipment and licenses from Chrysler, establishing an agreement to allow the GAZ Group to import car components at low customs rates (0-3% instead of 5-15%).

The main advantage seen in such cooperation with global automotive leaders lies in the opportunity to master advanced technologies used in the global automotive industry. The market, where the investments are made, is concentrated in the Western corridor from St. Petersburg in the north to the Samara Region in the south (see Figure 3). OEM (Original Equipment Manufacturer) projects continue to develop the production in Russia in spite of the global difficulties experienced by the automotive industry. For instance, GM, Suzuki, Nissan, Toyota, Hyundai, Volkswagen and Ford, as well as hundreds of suppliers are setting up production facilities in St. Petersburg to supply the growing domestic market. The forecasts made by foreign producers estimate 1.6 million new cars to be sold in Russia by 2012 (see Figure 4). However, due to the global financial crisis, one of the Russian auto factories, Izhavto, had to stop its production for an indefinite term in April 2009. The main reason was the devaluation of the Russian rouble, thus making the purchase of a vehicle set for the assembly of Korean Kia in Russia economically irrational.

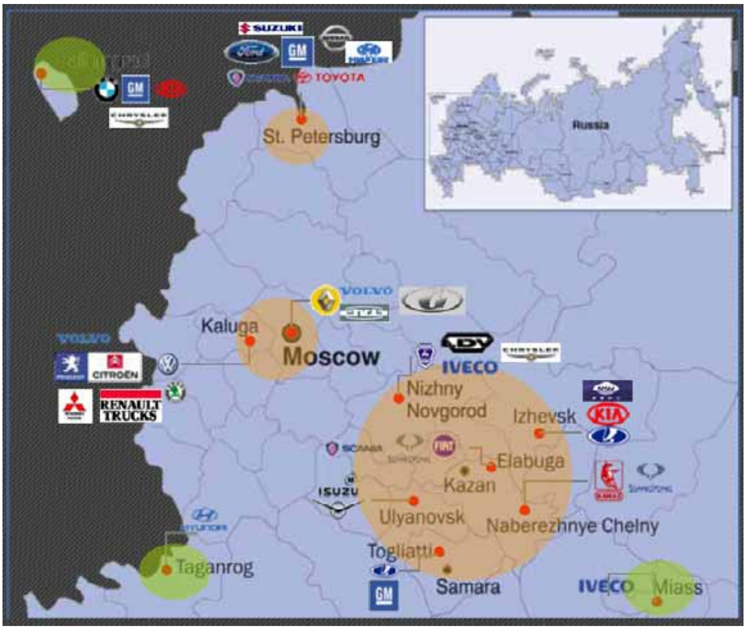

Fig 3. The presence of foreign car manufacturers in Russia [24].

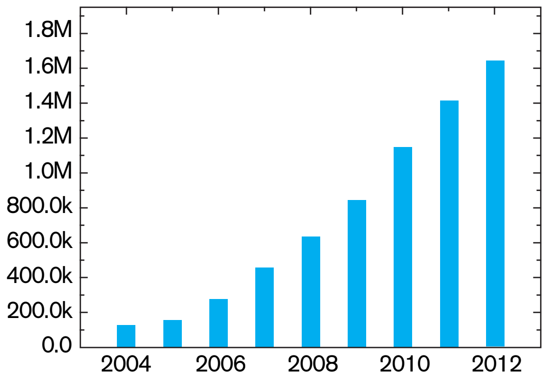

Fig 4. Production of foreign car brands in Russia 2004–2012 [25].

An important aspect of foreign car production in Russia is the promotion of linkages to local companies. Before the WTO accession negotiations there used to be obligations for foreign car producers to use domestic components. However, even now component manufacturers are likely to invest in Russia due to the needs of in-time deliveries, cost minimizations, and border delays. Advancement of Russian domestic technology and the training of workers and engineers is an important positive effect of globalization. The creation of new production plants brings job opportunities to Russian regions. International environmental and safety standards and emission requirements force local OEMs to invest in modern equipment and new technology for car production in Russia. Utilizing the comparative advantage of Russia in low cost energy resources could allow automotive companies to focus not only on the Russian market, but on export as well. The major drawback is the poor state of Russian car manufacturers who are losing their popularity and authority in the domestic market.

The Union of Russian Automobile Manufacturers has developed a draft strategy of Russian automobile industry development in 2008–2015 and for the period until 2020. According to this draft the implementation of the strategy will be done under government support in three stages: 2008–2010 – organization and expansion of automotive equipment and components production by enterprises with foreign capital, domestic enterprises re-equipment and creating new prospective models of automotive equipment; 2011–2015 – creating new, export-oriented automobiles and component production facilities; 2016–2020 – satisfying the country's internal demand for automotive equipment, manufacturing about 70% of the value in the Russian territory, thus ensuring growth of exports to 30% of the production volume [26].

3.3 Varkaus – Lost in Globalization?

The industrial history of Varkaus began in 1815, when businessmen from other parts of Finland built the first iron works. In that time, there were several advantages to building industry in that specific place. First, the area between two lakes was a very good place to use hydropower as a source of energy. The lakes also provided very good transportation connections for raw material and industrial products. Second, there were a lot of sources of raw material nearby: bog iron and wood. Third, there was a long tradition of cross-border trade, because of the proximity of the border of Sweden and Russia (formerly Novgorod) between 1323 and 1809 in that area. [27]

Industry in Varkaus grew and diversified during the 19th century; foundries, sawmills, paper factories, machinery and docks were built. At the beginning of the 20th century, the Finnish family owned corporation Ahlström bought almost all of the industrial plants in Varkaus, one by one. Varkaus became a market town in 1929, but the owners of the Ahlström company were still responsible for developing the city infrastructure in the same manner the ironwork owners before them had done. As late as in 1960s Ahlström was responsible for almost all the municipal services in Varkaus (healthcare facilities, schools, churches, apartments for workers). When Varkaus became a city in 1967, the municipality took finally the responsibility for the basic services for the town people.

In the beginning of the 1980s, there were about 25,000 inhabitants in Varkaus, and Ahlström factories in Varkaus employed about 4000 people. In the late 1980s and in the beginning of 1990s, the Ahlström company began to concentrate on specialty papers and nonwovens, and started selling its Varkaus plants one by one. This process started in 1987 by selling the paper factories and sawmills to Enso Gutzeit. Later in the 1990s Danish Hartmann, Foster-Wheeler from the USA, Austrian Andritz, Canadian companies CAE and AFT, and Honeywell and Tellabs from the USA bought the rest of the Ahlström plants in Varkaus. When Enso Gutzeit merged with the Swedish Stora in 1998 and became a part of the Swedish company, all the plants of Varkaus had received foreign owners. [27]

At first, the change of the ownership had a positive effect on the plants in Varkaus. New global owners brought new capital for development, which would have otherwise been a major problem during the severe recession in Finland in the 1990s. With new owners, these plants became a part of the global network, which brought new contacts, markets and customers. New ownership also introduced new knowledge and more efficient sourcing possibilities. The movement from the ownership of one company to several companies also changed the business environment. While the culture during the Ahlström years had been that the company did almost everything by itself, the new owners, in contrast, looked for local subcontractors. In the beginning of this millennium the new owners described their units in Varkaus in very positive terms: modern, skilful, flexible, innovative, and having valuable technology and cost-effective production [27] [28].

However, later on in the decade new challenges began to threaten the city. Increased international competition and an emerging recession have forced the companies to cut down costs. Even though labour costs in Varkaus are lower than in Western Europe and in North America, the costs are much higher than in Eastern Europe or Asia. And, although Varkaus was a very good place for new industries 200 years ago, it is not one any more. Varkaus is far away from everything – suppliers, customers, harbours and also the sources of young talented people, as found in universities. In 2007 Stora Enso had already announced the closure of two paper machines and the lay-offs of hundreds of people. Also machinery companies such as Foster Wheeler are going to decrease their personnel in Varkaus. This is why the future of current industrial production is in a real danger in Varkaus, especially if society around the factories does not respond to the situation. And even though the plants in Varkaus were rather successful at the beginning of this decade, the population of the city has decreased by about two percent annually. Therefore, the decisions of the foreign owners have a tremendous effect on the industrial future of Varkaus and the city in general; the potential closure of plants may challenge the whole existence of the city.

Still, this is not the first time plants have been in trouble in Varkaus. The first ironwork was not successful, because it quite soon turned out that the quality of bog ore was poor and that there was a lack of a proper work force, capital and good quality wood. Despite a couple of changes in the ownership of the iron works, the factory was closed in 1851. However, the new ironwork owners enlarged the selection of industries in Varkaus by building sawmills and workshops, which maintained industrial production in Varkaus. In 1860s and 1870s new industries emerged as a result of a boost in the Finnish economy and more liberal regulations.

Also in the beginning of the 20th century the plants in Varkaus experienced severe financial trouble. Then Ahlström bought all the biggest plants and continued to develop the industry. Although Ahlström is a Finnish company and Varkaus is located far away from Swedish speaking areas of Finland, most of the plant managers' mother tongue was Swedish or German almost all the time Ahlström owned the units in Varkaus.

In 2009, when the former Ahlström plants in Varkaus laid off hundreds of workers, globalization brought also good news and new hope for the townspeople. A company called European Batteries has agreed to supply batteries for small electric cars, which are designed in cooperation with Finnish and Chinese developers and manufactured in China. The production facilities for these batteries will be built in Varkaus, and the factory will be ready at the end of 2009. The plan is that this factory will employ about 200 workers in 2012. [29]

Fig 5. Varkaus. City centre is situated in the middle of the factories.

4 Globalization and Technology

As can be seen from these case studies, the relationship between technology and globalization is complex, at the very least. For example, certain technologies enable delivering of both material and immaterial artefacts from one place to another and thus assist the global dissemination (or globalization) of other technologies. In general, new technologies enhance old ones and enable novel ways to operate and to develop and manufacture new things, services and technologies. In addition, the speed of technological development is accelerating. In fact, this acceleration is one of the key features of the modern world and globalization.

In addition to the multifarious relationship between technology and globalization, people and technologies also have complicated connections. Technologies are developed and designed, manufactured, distributed, and utilized by people. Since technologies can also be part of other technologies and one technology can be used to manufacture or design other technologies, the roles of certain actors can be different when looked at from different viewpoints. For instance, the manufacturer of processors sees the computer manufacturer as a user of processors, while the user of computers sees both manufacturers of processors and manufacturers of computers as manufacturers of computers or computer related components.

To analyze the relationship between technology and globalization one needs to take into account all three variables – globalization, people and technologies. The variables can have different impacts on each other depending on the situation and form of analysis. In this chapter the structurational model of technology [30] framework is adapted to analyze the relationships and impacts of globalization and technology.

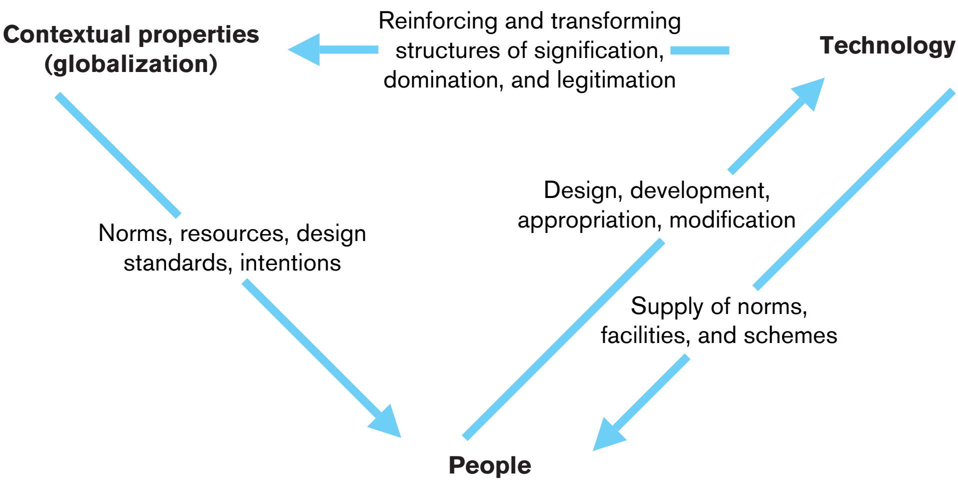

Fig. 6. Orlikowski's [30] structurational model of technology adapted to analyze the relationships and impacts between globalization and technologies.

According to Orlikowski's model, technologies are always used (and developed) by people in some context [30]. Since our analysis focuses on the impacts and relationships of globalization and technology, globalization can be seen as the context in which people act with different technologies. Figure 6 depicts the main impacts between technology, people and context (in this case globalization).

From the perspective of the analysis framework, technologies are both products of human action and mediums of human action. This means that technologies are outcomes of such activities as design, development, appropriation and modification, and at the same time technologies enable and constrain human action by providing norms, facilities and interpretive schemes. For their part, technologies impact their context of use by reinforcing and transforming structures of signification, domination and legitimation. At the same time contextual properties establish norms, resources, and design standards to the people.

From the perspective of globalization the most interesting technologies are those that either strongly reinforce or transform the driving forces behind globalization. Information and communication technologies (ICT) have had a major impact on with whom and how people have possibilities to communicate. As a consequence the relationship between the core technologies of ICT (processors, memories and telecommunication networks) and globalization is especially interesting.

Other interesting technologies from the perspective of globalization are those that have an impact on manufacturing value networks or the division of wealth on a global scale. Printed electronics has the potential to dramatically change the manufacturing processes and practises of many ICT products, and nanotechnology is an example of an emerging technology that can provide energy solutions that can enable underdeveloped countries to build ICT infrastructure in rural areas.

The following subchapters analyze the technologies presented previously in this book by using the structurational model of technology framework. The themes studied are processors and memories, telecommunication networks, printed electronics, and carbon nanotechnologies.

4.1 Processors and Memories

Processors and memories will not be the limiting factor of future products and services. Computer technology will develop to a level in which almost everything that is desired is also producible. The advancements in processors and memories will probably turn enhanced realities, artificial intelligence and robotics, and universal user interfaces into megatrends by 2025. (Chapter: The digital evolution – from impossible to possible)

Virtual realities, artificial intelligence, and universal user interfaces are all examples of vague technologies, i.e. technologies that are defined through their usage. They are, thus, products of human action. The applications enabled by the development of processors and memories do not seem to be very selective on how or for what they are used. These technologies enable geographically unrestricted communication and automate increasingly complex decision-making.

The general themes of communication and automation, i.e. assisting people in complex and/or repetitive tasks are the main actions that the applications promote. In practice, this means enhancing the already good possibilities for people to communicate with whomever they wish to communicate, regardless of the time or place. In this sense, the development of processors and memories affects globalization, generating on its part the space of flows, the material organization of simultaneous social interaction at a distance [31].

However, this global village is constrained by cultural barriers. It is also a village in which only a limited group of people can participate in, as successful action requires quite advanced skills in language and communicative know-how. In this sense, the level of education and expertise needs to be raised globally in order to enable more people to work in this borderless and omnipresent global village.

Globalization is potentially an excellent context for utilizing communication and automation applications. Global business relies on effective communication technologies, and, on the other hand, automation can make the production of goods and services, i.e. the core business of the companies, more effective. However, automation contrasts with one important aspect of globalization, namely the size of the available workforce. The case of Dongguan demonstrates the importance of available, cheap labourers. If production processes were to be more fully automated due to advances in processors and memories, one great advantage of Dongguan would be less prominent.

Open and user-defined technologies can change the power structures of companies and other organizations. Since tools enable, for example, new ways of communicating, and do not dictate what is communicated, users can exploit the technology almost as they wish. Thus, it is hard to control the technology, and technology can push forward more open cultures to organizations and even nation states. Promoting change is, however, a problematic phenomenon. Transforming existing structures of domination and legitimation is not easy and does not happen overnight. There can also emerge a counter-movement, which tries to pull the rug from under the promoters of change. Nevertheless, the institutional consequences of processors and memories will open up even better opportunities for globalization, by limiting hierarchical structures and introducing novel communicative alternatives.

4.2 Telecommunications and Networks

In the core of the evolution of telecommunication and networks is digital convergence, in which computing, telecommunications, and ad-hoc sensor networks all merge into a single digital stream. This is manifested in seamless network connectivity when moving across networks. The users access the networks via miniaturized, yet converged, high-speed *portable devices that consume less energy than nowadays.* (Chapter: Life Unwired – The Future of Telecommunication and Networks)

The new telecommunication applications and media develop on the basis of the old, meaning that the cultural form of established media use affects the appropriation of new media and new communication means. Every medium has advanced to answer certain communication needs and uses. In the first place it might have been developed with only a technological incentive, but its success relies largely on the communicative preferences of the users. In order for telecommunication and networks to be able to thrive they need to adapt to the existing practices and customs of communication, increasingly on a global level. As a product of human action, content distributed globally by telecommunication technologies also faces cultural barriers.

The contemporary, communication culture can be labelled as a tele-mediated culture. Because of the major developments in telecommunication and networks, distance is not an obstacle to communication anymore, and communicative situations are no longer determined by the physical location. Many of the interactions are therefore mediated. In the future, for example, when mobile phones become almost ubiquitous on a global scale, this mediated nature of communication will be a major transformation on the global level. The proportion of face-to-face interaction will probably diminish due to the emergence of advanced telecommunication technology. This again underlines the significance of diminishing distances and other geographical barriers. For instance, the inhabitants of Varkaus, although far away from global hubs, can enjoy new forms of economic prosperity aided by fast and ubiquitous communication networks. However, the educational level needs to be raised to match the demands of the transition from manufacturing products to offering services.

A key alteration in the use of telecommunication technology is that it is not used only to contact other people but also to access the vast information space of the Internet. Telecommunication technology is about perpetual connection, both to other humans, as well as to information. The Internet is turning into a truly global information infrastructure, through which most mediated communication is channelled. In addition, the Internet acts as a global space where immaterial goods and services are transported and offered, where more and more people interact, and where an increasing amount of different global processes takes place. The Internet has already acquired a central place in today's society, and it will have a huge, maybe an unimaginable impact on daily life in the year 2025. As a consequence, access to the Internet should be considered as a global fundamental right.

In accordance, the conditions created by communication technology lead to new institutional consequences. These institutional conditions motivated by new communication technology might not yet directly affect the labourers in Dongguan or the Russian automobile plants. However, freely flowing information on the Internet can provoke change in the stability of the social structure, as people become more aware of their rights as workers and can demand more fair pay and other benefits. Thus, as always, communication technology entails the potential for social change and the wider dissemination of welfare.

As widespread global networks provide ubiquitous access to information, the transparency of institutions is enhanced, or at least the institutions are forced to become more transparent. Networks offer better chances for civic participation, if only the governmental actors are willing to accept a participatory relationship with the public. However, mere access to information is not adequate. Skills such as literacy are indispensable in building a more participatory culture.

4.3 Printed Electronics

In 2025 printed sensors are utilized everywhere and even integrated circuits and large format displays can be manufactured by printing. Thus, printing enables both adding intelligence to otherwise non-intelligent products and objects, and to expanding or modifying the functionality of certain products by printing additional components and attaching them to the product. Printing and affordable printers also enable local production, since the consumers can obtain design templates and print the needed products with desirable functionality. (Chapter: Printed Electronics, Now and Future)

Printing can result in dramatic changes in product development and manufacturing value networks. The designers and manufacturers move further away from each other and the designers and customers move closer to each other. This means that designers can have more possibilities for communicating their thoughts to the customers. However, since customers manufacture (print) their own products, the designers have less to say about what kind of products are actually produced. All in all, printing as a technology can enhance the complexity and variability of our technological environment. The technological scene can become as complex as social and cultural worlds are.

Though printed electronics seems to give everyone an opportunity to become a manufacturer and thus enable manufacturing, the true emphasis is in knowledge (business). No matter how easy manufacturing is, someone still needs to design the manufactured items, and new and easy ways to manufacture do not lead to easy ways to design. Since printing provides an affordable way to produce and also test designs, the traditional competitive advantages, i.e. raw material supplies and production capabilities, do not play as big as a role as nowadays. Printed electronics can, therefore, open up more fair global markets.

Intentions to open up global markets will probably smoothen the way to printed electronics. However, economic recession or other problems can also result in countries beginning to control their markets more tightly. Printed electronics can be a problematic beast for decision makers trying to control their own markets. If globalization is seen as a process toward an open world where people, products and money move freely, it is also a fruitful environment for printed electronics as a technology.

All in all, printed electronics and printing as technology seem to reinforce the globalization trend. Printed electronics offer promising advances and economic savings in manufacturing and especially in transporting products.

4.4 Carbon Nanotechnologies

Based on the chapter on carbon nanotechnologies, the most significant nanotechnology fields relating to ICT in 2025 are displays, sensors, solar cells, and energy systems. The carbon nanotechnology value network consists of the production of bulk material (i.e. carbon nanotubes), processing of nanomaterials (i.e. filtering and functionalization), and final application production (i.e. displays and solar cells). However, the production pipeline is not always linear. (Chapter: Cut the Last Cord by Nanolution – An ICT Revolution Through Carbon Nanotechnologies)

The main markets predicted for nanotechnology products in 2025 are not globally evenly distributed. Solar cells are a good solution for areas that have a lot of sunlight, whereas transparent and flexible display markets are probably high-end markets, and sensors are most needed in logistics and manufacturing. Energy systems are distinct, as they are something that is needed everywhere where there are people.

Different areas and countries are in dissimilar positions relating to the value network. For example, bulk material production would be sustainable near industries that produce carbon dioxide (CO2), i.e. have raw material nearby. In cases where the pipeline is shortened, the bulk producer might also become a nanomaterial processor and developer. Since nanomaterial is usually just a part of a product, the final application production will probably be done where the application is most convenient to produce and not necessary where the nanomaterial itself is produced.

Nanotechnology is most visible in the product names and verbal descriptions of products. There will not be new nanotech products, but products that have some new features because of nanotech. Thus, it is hard to predict how nanotech will be produced by human action. At the moment, the physical dimensions (size and weight) and some special characteristics (e.g. semiconductivity of carbon nanotubes) are the driving forces for researchers and designers. How the users will appropriate nanotechnology, is not clear. Some hints of the problems have emerged in discussions on the health effects of nanoparticles. Nanotech does not depend on globalization, but globalization makes the successful future of nanotechnology more probable (global value network).

If the analysis of the carbon nanotechnology chapter is correct, nanotech will be heavily used in energy solutions and it will be most useful in rural areas and Africa, for example. This means that nanotech can possibly facilitate a more even distribution of wealth on a global scale, since many of the users and benefactors live in poorer areas. However, it is possible that there is no such strong balancing activity to be mediated, and thus solar cells and other current visions will not be realized in a globalized world. The strong link to energy systems speaks, however, for nanotechnology. In a globalized world energy consumption and needs will be even bigger than now.

Energy is a scarce resource in the future world. Globalization seems to result in more and more people living by Western standards and thus consuming huge amounts of energy. As a consequence, nanotechnology's link to energy systems makes it a very interesting technology in the globalized world. Institutional conditions for developing and utilizing products and services based on nanotechnology seem very good in the year 2025. However, the main driver for nanotechnology development seems to be the general aim for smaller and faster solutions in ICT.

5 Scorecards for Globalization

We have created two scorecards to give an overview of the different parameters that have been analyzed. In a scorecard the different dimensions are scored to give an overview and make comparisons between the different alternatives [32].

From the three cases, we have extracted the main indicators of globalization. These indicators belong to three interconnected themes: people, geography and economy. We present in Table 1 a scorecard to describe the impacts of these indicators on the cases. These indicators are measured in respective metrics. For each metric, an ideal objective is defined as maximize, minimize and target, depending on the indicator. Maximize/minimize refers to a strategy to increase/decrease the value of the indicator's metrics in order to be competitive in the globalized world. When minimizing or maximizing some metrics does not bring the best possible result, target represents a strategy to tune the indicator's metrics, so that it can be optimized.

In Table 1, people refers to the effects that the local people and their culture and living conditions have on an area's competitiveness. Geography refers to the existing hardscape environment and services, natural resources and distance to the markets, as well as environmental issues. Economy includes indicators, which are easier to measure in monetary terms. The table also presents the direction of development for each indicator by presenting whether the indicators are going closer or further from the objective, or if the situation will also remain the same in the future.

The purpose of Table 1 is also to present the areas for the three case examples where they have relative advantage. By defining these advantages, it may be possible to find suitable strategies for the future. An overall view from this table is that Finland is rather competitive according to many of these indicators, but China and Russia are approaching Finland.

Table 1. Summary of the main indicators of globalization and their development for each case.

				Distance for cases to the ideal objectives (1: min, 3:max)			Prospective evolution of these criteria		
Indicators		**Metrics**	**Ideal Objective**	**Case China**	**Case Finland**	**Case Russia**	**Case China**	**Case Finland**	**Case Russia**
People	Educational level, expertise	% of population with certain diploma	Maximize	•••	•	••	↗	→	↗
	Size of the work force	Amount of working age people	Target	•	•••	••	↘	↘	↘
	Level of the welfare system	Unemployement benefits, minimum salary level, social security, life expectancy, etc...	Target	•••	•	••	→	→	↗
	Stability and homogenity of the social structure	Ratio between higher and lower incomes	Minimize	•••	•	••	→	→	↗
	Cultural barriers	Conflicts between different ethnic groups and religions	Minimize	••	••	•••	→	↗	→
	Individualism vs. collectivism	Average size of the family nucleus	Target	••	•••	••	↗	→	→
	Hierarchical structure	Bureaucracy, division of power	Target	•••	•	••	→	↗	→
Geography	Established infrastructures	Number of factories, power plants, communication networks, etc.	Maximize	••	••	••	↗	↗	↗
	Natural resources	Availability of minerals, fuels, water, etc.	Maximize	••	••	•	→	→	→
	Distance to market	Time, km	Minimize	••	••	•	→	→	→
	Ease of transportation	Availability of different transport modes	Maximize	•	••	••	→	→	↗
	Environmental costs	Level of pollution	Minimize	•••	•	••	↗	↗	↗
Economy	Size of the markets	Number of potential customers	Maximize	••	••	•	↗	→	↗
	Cost structure (taxation)	Money	Target	••	••	•	→	→	→
	Capital	Interest rate	Minimize	••	•	••	→	→	→
	Marketing	Level of competition, cost of marketing	Target	••	••	••	↗	↗	↗
	Technology, innovation	Number of patents	Maximize	•••	•	•	↗	↗	↗

Technologies have a multifaceted relationship with globalization. They present coping opportunities regarding global markets as in the form of developing know-how related to a specific emerging technology. Some technologies emphasize the globalization trend by enabling easier information sharing and communication possibilities on the global scale. Finally, in some cases certain technologies can present new requirements for global players. Examples of this are new education and expertise needs that emerge as new (and more complex) ICT solutions are adopted.

Table 2 summarizes the impact of the main indicators of globalization on the analyzed four key technologies, i.e. processors and memories, telecommunications and networks, printed electronics, and nanotechnology. Different technologies demand different strategies from the global players. Telecommunications and networks are clearly a technology field that has the strongest influence on globalization. Their influence is based on the fact that communication networks provide an infrastructure that enables global information sharing and communication. Thus, for regular players in the global economy the needed actions are more in line with keeping the telecommunication infrastructure up to date than in the field of technology development. Processors and memories present a somewhat similar field. They are core parts of ICT systems and have been developing fast and steadily for the last decades. The main challenges in the ICT field in general seem to lie in utilization of the new systems and devices. The potentials are vast, but the utilization strategies need to be thought through case by case. Interesting research in the area is currently being done, for example under the topic of distributed and mobile work.

Printed electronics and nanotechnology are emerging technologies and represent opportunities to become players in actual technology development, or to be the first to utilize the developed technologies and reclaim the promises relating to them. Printed electronics include the potential to change the product manufacturing value networks by allowing the users to manufacture (print) their own products. Nanotechnology, for its part, can provide big leaps in the field of energy technologies. Energy and environmental technologies are expected to have huge markets in the near future and thus nanotechnology can prove to be an interesting opportunity for many actors globally.

Table 2. Summary of the analyzed technologies' relation to the main indicators of globalization. The cases where a technology has linkage or interaction with a certain indicator are marked with 'X'. In cases where no clear interaction can be recognized the cell is marked with '-'. In addition to recognizing the relations, examples of the types of relations or applications of the technology that create the interaction are also specified.

		Processors and memories	Telecommunications and Networks	Printed Electronics	Nanotechnology
People	Educational level, expertise	X (easy information sharing, increased educational needs)	X (easy information sharing, increased educational needs)	X (increased educational needs)	X (new electron microscopes allow to study matter at the atomic level)
	Size of the work force	X (automation decreases manual work requirements)	X (enables distributed and distant work)	X (enables distributed and customer driven manufacturing)	-
	Level of the welfare system	-	-	-	X (healthcare applications)
	Stability and homogenity of the social structure	-	X (new communication tools)	X (RFID technology to track people)	X (microscopic observation devices)
	Cultural barriers	X (language translators)	X (new communication tools)	-	-
	Individualism vs. collectivism	X (online games)	X (social media)	-	-
	Hierarchical structure	-	X (flattens information distribution hierarchies)	X (changes manufacturing value networks)	-
Geography	Established infrastructures	-	X (increasing quality requirements for communication networks)	X (decreases needs for big factories)	-
	Natural resources	X (manufacturing needs)	X (remote working)	X (requires resources)	X (alternative energy sources)
	Distance to market	-	X (software products can be distributed trough communication networks)	X (distributed manufacturing)	-
	Ease of transportation	-	X (software products can be distributed trough communication networks)	X (distributed manufacturing)	X (lighter materials)
	Environmental costs	X (ICT systems require a lot of energy)	X (ICT systems require a lot of energy)	X	X (renewable energy, filters to reduce emissions)
Economy	Size of the markets	-	X (global distribution channel)	X (manufacturing can be done is scale with the markets)	-
	Cost structure (taxation)	-	-	-	-
	Capital	X (requires investments)	-	X (requires know-how investments)	X (requires know-how investments)
	Marketing	-	X (decreases marketing costs)	X (price-tags, intelligent advertisements)	-
	Technology, innovation	X	X (information sharing makes innovation easier)	X (lot of innovation possibilities)	X (new materials and products)

6 Conclusions

As can be seen from the historical perspective, globalization has been the strongest when one or a few empires or countries have managed to enlarge the areas they are operating in, either by the aid of strong military or technological and economic power. The main driving force behind the current stage of globalization is the global work that has been done to promote free trade by decreasing different tariffs and customs, reducing capital control and eliminating subsidies to local businesses, and by securing intellectual capital by creating universal copyright laws and recognizing patents worldwide. Improved global supply chain strategies together with recent technological development, in particular the Internet, have also accelerated globalization by offering cheaper and faster transportation modes and by creating possibilities for real-time information exchange around the world.

In our view, the connections between globalization and the technologies presented in the earlier chapters in this book (processors and memories, telecommunication and networks, printed electronics, and carbon nanotechnologies) relate mostly to the accelerating development of the global communication infrastructure and the flow of information and immaterial goods. However, in addition to hastening the pace and reach of communication around the world, the discussed technologies also have an impact on manufacturing processes and practices, the division of wealth on a global scale, as well as on providing energy solutions for underdeveloped countries.

In this chapter, the underlying assumption has been that the current globalization period will continue as it has for the last 65 years. However, there are possibilities that a similar process will not continue. One alternative is that the global recession will increase the popularity of nationalist politicians. In an economic downturn, populist parties get always a lot of votes by picturing foreign people as incurring unemployment and increasing social security costs. If these parties get more power, it could have a negative effect on globalization.

The other alternative which may slow down the globalization development, is the new world order. The collapse of the Soviet Union blanked out the divide into two different blocks. Because of their sole power, USA and the Western world have been able to set the rules for global trade. However, the situation might change, when China becomes as powerful as the USA or even bypasses the USA in significance. This new situation may have negative effects for globalization in several ways: (1) The blocks may re-emerge, although in a new form, or (2) China and the USA are not able to agree on the rules for global trade, which will lead to protectionism.

Therefore, in this uncertain world, the future of the three cases presented is not evident or clear. Nevertheless, we want to close this chapter by presenting three scenarios for the year 2025.

In China, Dongguan will still be the main electronic industry manufacturer in the world in 2025. However, there are also other industries in this area, and the local people and companies have become more important customers for these companies.

The living standards of local people have increased, while there are still many immigrants coming from other parts of China, who continue to live in rather primitive conditions. Dongguan might also become a “training centre” for many new companies in China, which are located more in the centre of the country. Many consulting companies will help these new companies to set up their facilities and build links with international cooperation. The Dongguan area will also have raised many high technology companies with the help of incentives from the government. They are targeted more to the growing domestic demands of China. The living standard of the area has improved dramatically, with more basic facilities constructed, and more investors willing to go and live within its vicinity, which has further promoted the development of the economy in the region.

In 2025 the Russian automotive industry is still growing at a fast pace. Passenger car ownership in Russia will have greatly increased and manufacturing leaders will have established their assembly facilities in the Russian territory in order to satisfy the internal car demand as well as producing export-oriented automobiles. Russian automakers will have been able to adopt the latest technology and designs through collaboration with global car manufacturers, and, with the aid of strong governmental support, they will have expanded their production activities, evolving towards international quality, safety and emission standards based on imported technologies. This modernization has been driven by increased competition with foreign producers. The realization of the need for more effective energy saving technologies and the introduction of clean, renewable energy in Russia, due to environmental problems and the threat of natural resources depletion of this global oil and natural gas exporter, has resulted in various actions. Under the pressure of politicians and environmentalists traditional car industries have refocused toward the production and active marketing of eco-friendly cars: plug-in hybrid vehicles (with bio-diesel, cellulose ethanol or other bio-fuels instead of gasoline as a non-electric fuel option) and purely electric vehicles, recharged on a clean power grid or using hydrogen fuel cells. Models of cars with transparent solar panels on the roofs or windows for constant battery charging have become especially popular. The automotive industry has been able to benefit from the development of such technologies as nanoscience, printed electronics, telecommunications and networks, and processors and memories, by producing lighter and stronger, faster and safer, more intelligent, and cost-effective cars.

In Varkaus, there are several possible alternatives for the future, depending on the decisions that the city administrators make. The most probable scenario is that industrial mass production will depart well before the year 2025. Therefore, the biggest question is, is something going to replace it? The worst alternative is similar to what has happened in many old coal-industry based cities e.g. in North-East England; a part of the former mines and factories are still working with the help of considerable public support, but as a result of automation and other technical developments, they employ only a portion of the people that used to work there before. The inability to renew Varkaus’s strategy could lead to a decrease in the population of the city and an increase in the average age of the inhabitants, because the factories would not be able to hire new, young people. The other alternative is that the city will find new uses for the old factory buildings. Some of those facilities could be used for small companies, or then for companies from totally different branches as happened in Hamina, Finland, where Google's servers took over an old paper mill. Another possibility could be that different research companies together with other companies could use these old factories as test areas for new operation management concepts, such as production line design and industrial service development. The advantage for Varkaus is that there are suitable facilities, a work force with experience in several industries, a peaceful and clean environment, as well as a secure and high standard living for educated people.

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2.4 Augmenting Man

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Abstract

The rapid development of information technology has started the development of autonomous machines. Eventually, their emergence will lead to profound changes in the way humans and machines coexist. Our current rules of society are not well equipped for dealing with the resulting problems and inappropriate regulations stiffle technological progress. We propose new practices as a method for uniting a parallel machine society and the human society. We develop a new financial instrument and use it to create an ultimate machine.

Keywords: intelligent machine, ultimate machine, etc.

1 Introduction

'Now I am become Death, the destroyer of worlds.'
Rober J. Oppenheimer

"In a properly automated and educated world, then, machines may prove to be the true humanizing influence. It may be that machines will do the work that makes life possible and that human beings will do all the other things that make life pleasant and worthwhile."
Isaac Asimov

There are only a few technological developments that are considered so fundamental that they name eras; e.g. the discovery of iron, the discovery of gunpowder, or the invention of the steam engine. Though revolutionary, these transitions are dwarfed by a different type of singular events. Certain discoveries force decisions that irreversibly change the future of all mankind. In 1951 mankind stood at such a crossroads for the first time: scientists created the blueprints for a doomsday device (footnote: Edward Teller and Stanislaw Ulam created a nuclear weapon design that allows the construction of thermonuclear weapons of almost arbitrary power), a machine, if built, powerful enough to eradicate human life on earth. Today for the second time mankind is standing at a crossroads: global warming is threatening to unpredictably change the planet's ecosystem. Machines have enabled huge population growth that resulted in an unsustainable increase of fossil fuel consumption causing the green house effect. Soon mankind will again stand at the crossroads for the third time: it will create a new species that could possibly supercede it. Machines by then will outperform man on all significant levels allowing them to act autonomously.

This third change will be more fundamental than the two preceding it. Essentially, the dilemma of nuclear power and global warming are scaled up conventional problems that could be solved in a traditional reference frame. The emergence of intelligent machines is fundametally different. It poses new challenges to almost all aspects of human life. Until today nearly all machines have been cyborg technology, i.e. technology whose sole function is the augmentation of man. In essence, a conventional machine is entirely useless without a human operator. On the contrary, the ultimate machine can emancipate itself from its creator. The question is whether this process will ultimately resemble the growing up of a child or rather the machine abandonning its creator in a Frankenstein moment.

How much we benefit from this change depends on our success in creating new practices that unite machines and human society. This is first and foremost a practical and not a philosophical problem. The example of nuclear technology teaches us that technology can be either beneficial or devastating depending on how we use it. The civil use of nuclear energy also shows that powerful technology can even be dangerous when used with the best intent. In such cases society establishes procedures to mitigate the technological risks. This is typically done by reducing the likelihood of a catastrophic event and by pricing the residual risks. This works well for established technologies whose risks are understood. However, for dynamically developing technologies rules and regulations can often stiffle development. This article employs a heuristic approach to identify the specific chances and challenges posed by the emergence of intelligent machines. On this foundation we then develop suggestions for new practices as means to address some of these problems.

We start our analysis by taking a look at the historic development of machines and the practices that it has shaped. We showcase the transition from the time of simple machines to the system age in Europe. We learn that new technology always also creates new practices. These practices can be an answer to problems arising from this new technolgy. In general new technologies are not always adapted widely or without protest when they arise. Nevertheless there are powerful motivations that perpetuate the spread of mechanisation. To illustrate this we discuss the economic case for machines in the light of the luddite uprising.

After this we highlight current trends in machine design. We also discuss the role that scientific and technological advancements play in this process. A particular focus is put on the trends and developments within engineering science. This leads to understanding of why we believe that machine intelligence will be the defining trend until 2025. We explain why the original approaches to artificial intelligence failed and how a new approach is going to be successful in creating intelligent machines.

We start our look into the future by showcasing examples of intelligent and autonomous machines in military and civil applications. We discuss the problems that a proliferation of this technology is likely to cause. The rest of the section is dedicated to the development of new practices. We concentrate on ideas of how to cope with the ever-complicating problem of complexity by means of combining law, technology and ethics. We argue that one way to address this problem in practice is by creating a new oath for technology developers. Finally, we address the problem of the inherent residual risk of machines by introducing a novel insurance machine, the first embodyment of an ultimate machine.

We restrict the scope of our article to creating practices that deal with the immediate averse effects machines create intentionally or by accident. We leave it to the reader to imagine further the possibilities of a world populated by ultimate machines.

2 *Historic Machines and Traditional Practices*

There are two sides to the coexistence of man and machine: the extreme use of technology in wars and the use of technology within a civil society. In the first case the destructive and revolutionary aspects of technology are unhindered. In the second case the use of machines has to abide by underlying laws, foremost the laws of economy.

Studying the historic impact of technology and its related practices helps to identify the fundamental questions that technology raises on every level of human organisation.

2.1 Longue Durée of Technology in Europe

Man has been a cyborg from the very beginning; the use of fire (500,000 years ago) and stick as both tool and weapon is one of the defining features of human beings. We depend on technology and tools, but tools are not enough. Humans use tools in combination with practices. This becomes clear when we, as an example, look at how military technology and discipline have developed in Europe over the past 10,000 years. This history contains a seemingly steady development with sporadic leaps. However, this technology, and with it social change, is accelerating. It took several thousands of years for the adaptation of agriculture to spread while it was only a mere 700 years from the invention of gunpowder in China until it became the decisive factor in naval gunnery in Europe in the 16th century.

We use the terminology of Ferdinand Braudel, the French historian. We will concentrate his idea of "Longue duree – a long term cycle" in this part of our article and divide history in three phases of the machine evolution; the time of simple machines, the time of complex machines and the era of systems. At the same time we display the central features of technological innovations and social practises using waging war as evidence. Our contribution is Eurocentric – and so very limited.

A. Simple Machines

Up to the Iron Age: the use of simple machines

With the agriculture came trade. Societies spread along waterways. Boats and navigation together with the development of metallurgical processes were the main technologies. Technology and people appeared on the European stage. History told by books started.

The Iron Age started in 1300–1200 BC. in Anatolia and iron was used in weapons. The same process reached Northern Europe around of 600 BC.

B. Complex Machines

The great leap (500 BCE to 1200 CE): the time of emerging complex machines

The standardization of the alphabet by the Greeks and Phoenicians was a break through. Easy information storage and distant communication begun. The unique military formation of the Greek phalanx was very effective during the Persian wars and it was the basic idea of warfare until Middle Ages. The use of heavy cavalry also started by the conflict with the Sarmatians and Romans. Sea battles occuring in huge rowing boats caused collapses trying to push the enemy boat. Both rowing boats and the phalanx fighting needed very precise coordination of fighters and fighting units.

Another technological revolution was the minting of gold by Krosios (the king of Lydia 560–546 BCE). This practice boosted commerce enormously. Later the Byzantine gold mint solidus or in the Greek language nomisma ruled the economy of Europe starting from the year 309 CE for more than 700 years, and, with a little inflation, also a little longer until the Venetians took rule of Byzantine trade routes.

Atlantic Europe advances 1200 CE to 1800 CE: the rise of complex machines

A mechanical screw and bolt was the invention of Europe. Wooden ones have been used as wine pressers ever since, but the first mechanical bolt made from iron came from the 14th century – in the helmets of knights. At the same time matchlock guns based on the same bolt idea were introduced and the modern hand weaponry was in use. The noisy introduction of the artillery happened 1346 and "the Siscilian Vesperin" 1282 ended the victorious story of the Norman knights by a combination of lance solders and archers. The time was ready for barbarian west to start rising. War needed more skills to run; co-operation of artillery, cavalry and infantry created a different kind of professionalism than before. The cities of Venice and Milan subcontracted in the wars to independent professional units. This was the reason for a careful economic counting system in these cities. It opened markets for independent arms factories. In the year 1480 artillery was mature enough to break the walls of cities and in1543 they could cast a functional iron cannon. The second bronze age, the age of huge bronze cannons, was over.

Innovations in shipbuilding from the Baltic Sea and the Atlantic were combined with Mediterranean skills. Together with the innovation of naval gunnery, Europeans were ready to destroy and conquer the trade routes of Africa, India, and America.

The mechanical bolt was the basic technology in the printing revolution, as well as the military revolution Europe. It helped the nations of Europe be in a good position when the industrial revolution started. Printing stabilized knowledge through books and made commentaries possible, thus enabling the unprecedented growth of information and its distribution. Military technology helped Europe to rob colonies all over the world.

Mass production 1800–1940: the era of the complex machines

Standards were an important innovation by the Napoleonic war machine. A common measurement system based on meters and kilograms established common grounds for industrial activities.

Technological innovations based on coal, steam machine, and later on oil as an energy source are the most visible in the era of mass production. The real impact on mass industry comes from the inventions of iron from furnaces. Bessemer and Siemens-Martin processes from the 1850´s pushed the volume of iron- and steel production. Steel in different forms is the base of our modern industry. At the same time a new kind of legal creature appeared in the economic sphere and organized it. The corporation with limited liability was approved in 1856 in the corporate law of England. The same also happened in the USA a little later. There had been corporations earlier, but the whole risk was personal to the stock owner and his property. Now the risk was limited only to the value of stocks. This monetary instrument opened a new way of raising capital for colossal projects.

Totally new industries of chemistry and electricity appeared. In 1866 Farady introduced the electromagnetic generator – and created a new technological network, the power grid for electric distribution.

Printed material made it possible to educate masses for the sophisticated actions needed by this economic mass fabrication of things and objects. Taylorism was the first idea to put the human individual in the rhythm of machinery.

C. "System Age"

Science in action (since 1940): the time of emerging ultimate machine

The wars in Europe (and outside) from the years 1914 to 1945 introduced ordinary Europeans to the military methods and technology used in colonial wars outside Europe. It forced the governments to put all available resources into action. The best example is the Manhattan Project: at the peak of the project there were 120 000 workers including the world?s leading physicists, and the expenses were over two billion dollars. We have to remember that until the last tests, there was no evidence of a positive result – the project was a risky business. This kind of activity had already started in 1916, when English government founded the Department of Scientific and Industrial Recourses together with a private corporations. The Rand Corporation (1946) founded by US Air Forces and Douglas Inc. is a clear example of the development of what the Manhattan Project constitutes a project model. This experience was later used in design of Apollo missiles. It was also imported into automobile industries and ended up in everyday use in our computers. If you open a Microsoft Project program, there it is.

The Manhattan Project had however peaceful side results. Atomic energy power stations distribute energy to Europe, but they also create a possibility of a new kind of risk. This risk was realized in Tshernobyl in 1979. It is an interesting question, whether the catastrophe would had happened to a private corporation. In any case, who is going to take responsibilities for the consequences and how are they taken care of "Who pays"?

In 1947 Bell Labs introduced the transistor replacing electronic tubes in electromechanical devices. This gave rise to the miniaturization of all electronic devices, adding reliability and lowering their production costs. A computer became an everyday gadget. After the collapse Soviet Union, together with cold war?s ARPANET, the idea of a packet based information delivery system become the backbones of our civil, social, and military life in Europe.

Computerization and the increasing capacity of computing data, storing data and transferring it, creates an impact on all kind of simulations and modelling. The next step for this modelling is real time simulations of human biological processes; science penetrades in to human physiology. This process started in the 19th century with chemistry when it helped to create antibiotics. With the development of penicillin in 1928 western pharmacopia helped a growing number of humans escape from the hands of diseases. The II world war increased the production of penicillin. In 1942 in the US, there was only enough penicillin for the treatment of ten patients, but in 1944 during the Normady Invasion almost 15 % of causalities were prevented with the help of penicillin. The use of the antibiotic has caused the population to get older and older in Europe.

Mass media and advertisements together with the break from tradition have created a mentality among individuals, who are more and more interested in consumerism. This trend has caused serious problems in the world?s ecology including the warming effect of the climate.

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2.2 The Economic Case for Machines

In introductory-level microeconomics, the means of production are usually divided in to labor and capital, where the latter usually means machines. Production is therefore a mix of these two and the ratio of them is used to classify industries into labor- or capital-intensive. Similarly, the cost of production can be divided into wages and interest. The challenge therefore is to use these two resources as efficiently as possible.

The importance of machines in an economic analysis is already visible in the first chapter of Adam Smith's Wealth of Nations, called "Of Division of Labor". Here Smith explains how the division of labor into smaller, repeatable tasks will lead to better efficiency.

This idea was taken to a new level when Taylor introduced his system of scientific management, where productivity was scientifically measured and each task was monitored for efficiency. "In the past, the man has been first; in the future the machine must be first," he famously said. He also "ignited a debate about man versus machine that continued far into the 20th century."[18]

While many might see Taylorism as inhuman, seeking efficiency is natural. Every day everyone tries to improve his or her work in a larger or smaller way. Using machines to improve this efficiency is just the next step. The father of the calculation engine, Charles Babbage pointed out in his "On the Economy of Machinery and Manufactures (1832)" several fields where machines have contributed significant efficiency. Machines, after all, excel at dull, repeatable tasks and can do things humans are not capable of or do them in a significantly shorter period of time.

The word robota, the term coined by the Czech Karel Capek in 1920, literally means "forced labour". And indeed, industrial robots overwhelmingly do simple, monotonous and mundane things. In factories these robots are caged like wild animals because they are oblivious to their surroundings. Thanks to computing power, this is about to change. The complexity of tasks that robots can handle is continuously increasing. Now robots leave their cages and enter into our homes and offices.

The Luddite "Fallacy"?

So far each evolutionary step machines took has provoked a strong response from the humans affected by them. The range has been from moral condemnation, to religious bans, to civil unrest. One example was the introduction of labour saving machines. Then suddenly obsolete workers did not welcome change. In the early nineteenth century, these Luddites destroyed many new machines they feared would destroy their jobs. This so called "Luddite fallacy", that labour-saving technologies will ultimately cause more unemployment, has survived well to the 21st century. "If the Luddite fallacy were true we would all be out of work because productivity has been increasing for two centuries."[19]

This fear from workmen was one reason that during the Industrial Revolution, many of the classic economists started to consider wether the introduction of machines might have some adverse effects. One of them was Ricardo who in his 1817 book "Principles of Political Economy" first argues that using machines must lead to more employment, because labour is needed to build, operate and maintain these machines. This, of course has changed. Machines build other machines. Indeed, some of them are already completely autonomous and can fix themselves or others.

The second argument, by Ricardo and others, against permanent unemployment caused by automation is that even if these new machines replaced humans, better efficiency would either mean the owner of the machine makes bigger profits or consumers buying the products made by the machines will see lower prices. This means that either or both owner and consumer have more money to spend on new things. Lower prices also mean that the demand for the product will increase, and some of this supply might need new labour. This is what happened between the introduction of cotton-spinning machinery in 1760 and a parliament inquiry in to the number of persons engaged in spinning and weaving of cotton in 1787 in England. At the time of the introduction of this new machine, there were 7 900 persons in this industry. However, by 1787, there were 320 000 persons employed in this sector [20].

Time and time again, automation is seen as permanently displacing human labour, even though it is just a natural continuation of technological advance in production efficiency [20]. As Krugman [21] points out, "to observe that productivity growth in a particular industry reduces employment in that same industry tells us nothing about whether productivity growth in the economy as a whole reduces employment in the economy as a whole." For example, improvements in the steel industry, that might cause job reductions for steel workers, will have positive effects on other industries that use steel. The crucial difference to see here is that one shouldn't look at machines creating jobs, but production. Nevertheless, can we rely on the old mechanisms continuing to work even in the advent of the ultimate machine?

3 The Next Big Step in Machine Evolution

Looking at the history of machines in its entirety the trend is obvious: machines are getting more complex. This overall trend is overlaid by additional developments. Some of the more relevant in the past decades lead to huge advancements in efficiency, miniaturization and increased mobility. In recent years additional new research trends have emerged. In laboratories of universities and companies we can get a first glimpse of several resulting developments that we can expect to see in machines by 2025: e.g. machine-machine interaction, convergence, replication, and intelligent/autonomous behavior. Growing interest in machine-machine interaction is a result of an evolving technology ecosystem. While output of machines used to be mainly processed or consumed by humans now a growing number of machines means that a large percentage of products and services created by machines will also be consumed by other machines.

The convergence toward the ideal of the omnipotent machine has long been a dream in various fields; from the perfect kitchen machine, to the robot servant, or the ultimate car. Nevertheless we have mainly seen specialization. The reason is that in conventional machines increased capabilities result in increasing complexity, cost, and unreliability. Also the resulting complex user interfaces have been stifling convergence. However, the advanced combination of mechanics and electronics are slowly changing this correlation. In particular we can see the first concept for unified user interfaces (e.g. iPhone 3.0) that will help various machines, for instance; cars, refrigerators, houses, merge in a seamless unit.

Conventionally machines are built using different tools/machines in several steps from raw materials. However, today already we find devices that can produce a large number of their own parts from basic components. Most 3d printers can replicate all of their mechanical parts. Only its logic/electronic components still require a more sophisticated production process. Nevertheless, it is easily conceivable that future technologies allow us to create replicators that can produce all their parts from very basic components (see printed electronics chapter). Eventually, these devices will become replicators that are able to copy themselves virtually unlimited times.

Recent advances in IC technology have made vast processing capacity cheap and readily available. Its integration into machines allows them to react to sensory input from their environment. Besides allowing the improvement of conventional machines as a result also strictly predefined - mechanic-behavior is no longer necessary. Instead future machines can be expected to show a great deal more autonomy on all levels.

If we try to look far beyond the horizon we can ultimately expect developments that will render the concept of machines useless. Progress in nanotechnology and bioengineering is already blurring the distinction between machines and living organisms. Bioreactors are producing chemicals using genetically modified bacteria. And once protein folding is better understood the detour of modifying organisms might no longer be necessary. At this point parts of or entire machines could become indistinguishable from living organisms.

In this report we will concentrate on the development we believe will have the largest impact on our coexistence with machines until 2025: the emergence of intelligent machines.

3.1 The Role of Science and Technology in Machine Development

One set of emerging factors dominant over all others in technological advancement is the social character of machines. The social characteristics of complex machines go far beyond that of primitive tools. In its more complex form, the machine takes on a semi autonomous role playing ability of its own [4]. It can also replace the human senses and intelligence in certain applications. In this section, the evolution and technological trends of machine design and machines toward the future are discussed.

3.2 Evolution in Machine Design

The dawn of information power added flexibility to processes and products. It allowed for the flexible automation of machines which can then take over routine or calculation intensive intellectual operations to certain degree. This was a new feature in the evolution of machines, and novel machines are built up till date that could not have been built in the past. [1] Greater adaptivity in machine control has been another trend being pursued. For instance, a machine can take its environment into account to a greater extent and adapt to it independently. Machines typically are precise, repetitive, and mute. Thus, they can be controlled by a set of rational principles beyond the human body. There is no doubt that information power can provide substitutes for human capability that reaches an even greater degree of certainty and precision. Of late, many machines work as part of a global communication system and distances between machines and human manipulators have become insignificant [1][6].

Significant accumulation of scientific knowledge began in the eighteenth century and expanded rapidly into the twentieth century. Science began its separation from philosophy two centuries ago and these occurrences have made it possible to classify scientific discovery into scientific disciplines. A relatively recent unifying development has been occurring in the sense that, machines or systems have general characteristics independent of the area of science they belong to [10]. The evolution of the science of systems or machines is quite evident through the examination of cybernetics, general systems, and systemology.

Cybernetics is the science of purposeful and optimal control of complex processes in nature and society. It has brought important contributions to the area of regulation and control [12]. General systems theory now provides science and machine designers with useful frameworks and allows for the comparison of concepts. Systemology is the science of systems and their formation. It is used as a more appropriate application of system science as this discipline is evolving from the formation and interaction of different disciplines [10].

The industrial revolution brought about mechanization, the substitution of machines for people as a source of physical work. Thus in this Machine Age, the world was taken to be the sum, or result, of an understanding of its parts, which were conceptualized as independently of each other as was possible [13]. In the 1940s a gradual shift from the Machine Age to the System Age took place. Unlike in the Machine Age, attention is focused in the System Age on groups as part of a larger purposeful societal system.

This transition has brought with it a change in the conception of the universe and the realization of the complexity of nature, of man-made machines and a basis for improvement in man's position relative to these machines.

3.3 Machine Convergence

Through intensive research activities, we stand at the threshold of a new renaissance in science and technology. This is justified by an understanding of the structure and behavior of matter from the nano-scale up to the complex system of the human brain. As stated previously, Science began its separation from philosophy two centuries ago, but at present there is unification of science based on unity in nature. [15]

There is holistic investigation of this unification at present which will lead to technological convergence and thus a more sophisticated system or machine (dubbed the ultimate machine in this paper) (Figure 1) and to an efficient societal structure by the year 2050. Rapid advances in convergent technologies have the potential to enhance both machine performance and a reduction of their ecologic footprint. Concentrated efforts from the early decades of the twenty-first century are bringing together nanotechnology, information technology, and biotechnology. This is due to intensive scientific researches, advancement in digital technology and new humane technologies based in cognitive science. Rapid advances in convergent technologies have the potential to enhance machine design and the perfection of human-machine interfaces.

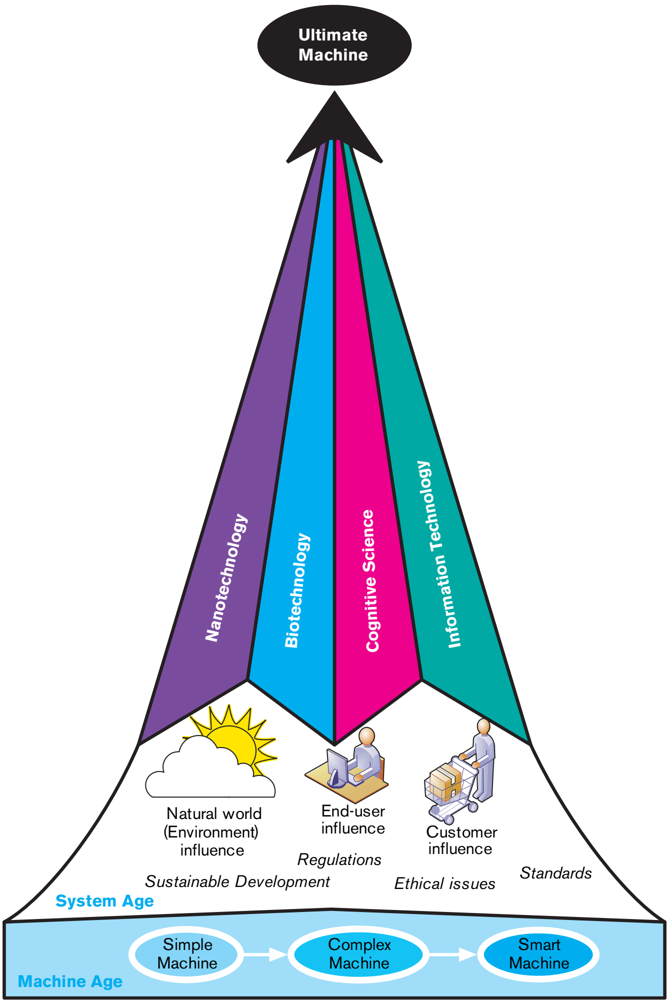

Figure 1. Evolution and factors enhancing the trend of machine development into 2025

According to Roco and Bainbridge [15], convergent technologies refer to the synergistic combination of four mayor provinces of science and technology, each of which is presently progressing with immense stride. These are; a) nanoscience and nanotechnology; b) biotechnology and bioengineering, including human-factors engineering; c) information and communication technology, including advanced digital computing and media technology; d) cognitive science, including artificial intelligence.

Accelerated progress toward an ultimate or a super intelligent machine is envisaged toward the year 2025 by a combination of research methods and results across these provinces (Figure 1). Science and technology unification is achievable and is being gradually realized on the basis of four key principles. This is through material unity at the nanoscale and technological integration from that scale. Innovative advances are blurring the interfaces between the previously separated fields of science and technology.

Development in a system approach, through the use of systems engineering processes in conjunction with convergence technology will allow for a thorough understanding of the natural world [9][10][14]. The unification of science and converging technology will diminish the line between existing intelligent machines. Intelligent machines can be characterized by an increasing physical and psychological closeness and interaction between man and machine.

The idea of an all-powerful machine (intelligent machine, robot) has been a major design focus or a dream for many machine designers. Nevertheless, according to the classification above, there are currently machines with specializations. This may be attributed to existing barriers between technology and science, and also due to the increasing complexity and cost of machines. Convergence of machines has so far been very evasive. Eventually, science and unified technology will allow for machine convergence to create an omnipotent machine. The smart machines of the future will be human assistants, helping people do what they want to do in a natural and intuitive manner. These machines will be capable of performing the same work that was once totally dependent on cognition and the intuition of human experts. The classification of the various machines will diminish, and the line between robots, autonomous machines, and cyborgs will be blurred as an ultimate machine will be able to perform the various tasks of the individual machines like a human being.

3.4 What is an Intelligent Machine?

Three categories of intelligent machines are presented. The first category consists of industrial automation machinery. The second category includes autonomous machines, i.e., autonomous robots. The third category is comprised of "cyborg technology". Cyborg technology is defined in this context as technology that functions in a tight interplay with a human – directly augmenting human capability.

The key characteristic of the industrial automation category is externalization of intelligence. Typical machines in this category are assembly line robots and machinery. Industrial robots in particular are extremely adept at following instruction with high precision but the intelligence of the instructions is externally created and controlled. In this sense, a typical industrial production machine is not intelligent in itself. Yet, the functions these types of machines implement are complicated and require a high level of engineering finesse to work.

The autonomous machine has to be able to operate independently in a complex environment. The distinction from the industrial machine category follows from the level of freedom of the machine. An industrial robot has very limited degrees of freedom and mobility. An autonomous robot on the other hand is typically mobile and has not only a larger scope of freedom but also a much more sophisticated sensory system to operate in and interact with its environment. Typical present day applications include vacuum cleaner robots, cruise missiles, and unmanned reconnaissance airplanes. In the future, autonomous machines are expected to operate in more demanding tasks, e.g., as automatic taxis. One big application area in this category is the field of service robotics. Home assistance, company, and security services are all included in this category.

Cyborg technology itself can be further divided into two classes based on the nature of the human-machine interface. The interface can be either external or internal. An internal interface cannot be removed easily and/or has a high degree of integration to the human body. At present, internal interface cyborg machines include cochlear implants and artificial pacemakers. In both cases, the machine is tightly bound to human function and the distinction between the human and the machine gets fuzzy. The external interface on the other hand is accessible on a voluntary basis. Switching on and off from an external interface is quick and the level of physical integration between the machine and the human is typically low. The field of external interface cyborg technology is extremely broad, including anything from bicycles, pocket calculators, mobile phones, and computers to cars, airplanes, remote controlled mining machinery, and simple tools. Intelligence in cyborg technology is tightly bound to human intelligence, either being fully dependent on the human mind or augmenting human intelligence with a degree of complementary intelligence. For example, a present day intelligent car has several driving safety augmenting features such as forced emergency breaking, driver attention monitoring, parking aids, and ESC (Electronic Stability Control).

3.5 Creating Intelligent Machines

The transition from dumb machines to truly intelligent machines does not happen without problems and important considerations. As a machine becomes more and more intelligent, it starts to pick up human-like characteristics such as an increased tendency to err. The trend is already visible in software engineering where the more complex software packages are infested with bugs, apparently regardless of the amount of human effort to eradicate them. At first sight, the problem might appear to be of a quantitative nature – by having a larger amount of software code, more bugs will appear in a linear fashion. But in reality, the problem is much more severe if the reason behind the perceived phenomena is the complexity itself.

The classical concept of artificial intelligence (AI) that has been presented in the popular media and science fiction is of a machine that makes perfect, complete, and cold rational inferences about the world. Regardless of the amount of inferential and logical capabilities, these AI machines are depicted to express bad decisions from a human point of view. The popular image is both deeply flawed and practically correct. The flaw is to believe that a perfect classical AI inference machine would make stupid mistakes due to being too rational. Rationality itself is not the antithesis of common sense. The underlying truth in the popular image is the fact that such a perfect machine is considered impossible to implement. (footnote? Basing on Dreyfus's critique of the classical AI movement, Kenaw argues that the human mind and its intelligence cannot be modeled with a purely logic based solution [17]). The failure of the classical AI movement in the past underlines the observation – perfect artificial intelligence is not feasible.

Why is it impossible to make a machine that would be both perfectly correct and perfectly intelligent? The classical AI approach did use an approach based on a system of logic that was doomed to failure. But the reason behind the impossibility is not a lack of a rigorous formalism for intelligent or rational inference. Bayesian inference rules implement a perfectly sufficient system for both describing states of information gathered about the world and making optimal decisions based on the information. The problem arises from the laws of complexity, of the number of combinations between entities. When inference tasks become more complicated, the amount of computational resources required for perfect Bayesian inference increase exponentially.

The simple consequence is that quite quickly, all the energy and resources in the known universe are not sufficient for obtaining an analytical solution. For this reason, a universal and perfect intelligence is out of the question. To be intelligent, one has to limit the scope of modeling with prior assumptions and model restrictions, to be context-dependent. The approach is no different from human intelligence that is highly tuned to surviving in dynamic but not unrestricted conditions. If the changes come too fast, human intelligence will lose tuning and at the same time loose intelligence itself. Consequently, intelligence can be seen as an adaptation to the local relevant environment and its characteristics.

The failure of classical AI did not stop the development of artificial intelligence research. Quite the opposite, hard realization opened up approaches that would have been considered unacceptable or undesirable from the old point of view. Modern AI was born. Instead of trying to reach for perfection, modern AI is evaluated by its practical performance. In brief, "if it works, it is good". The price to pay for practical success is the loss of absolute certainty. An intelligent machine is no longer infallible. The proneness to errors results from the use of approximations, or heuristic inference rules. Whereas heuristics are extremely powerful and efficient on average, they are vulnerable to perturbations or exceptions in world conditions.

The more intelligent and efficient machine intelligence is, the more likely it is vulnerable to making occasional errors. The phenomenon follows from simple logic – efficiency is obtained with simplicity and the world itself is infinitely complex. Thus, the more simplifications are made, the more incomplete the model is. This does not mean that machines could not perform tasks that require intelligence. Quite the opposite, machines could be made such that they do perform much more reliably and efficiently than humans in demanding tasks. The only thing lost is the absolute certainty of the old machine clockwork logic. An important observation to make here is a distinction between simple tasks that only require mechanical "intelligence" and really complex tasks that cannot be simplified. In the complex task case, the notions in this section apply, in the simple case a well-designed clockwork type machine can handle the task perfectly. For this reason, it is essential to distinguish the two categories of tasks accurately in order to pursue a suitable solution. In other words, intelligence as understood in this context should not be put where it is not absolutely necessary. Preferably, a pacemaker is kept "stupid" (simplistically logical) and reliable instead of intelligent and potentially unreliable. "Human error" is a phenomenon that will become as relevant in the context of truly intelligent machines as it is today for humans themselves.

The implications of the limitations on the absolute reliability of intelligence are numerous. The concept of machine will have to evolve into a more flexible and tolerant direction. The set criteria for the operation of machines will be relaxed and the resulting consequences are managed in other ways. Instead of denying the reality of machine intelligence unreliability, the arising consequences have to be dealt with.

4 Towards 2025 and Beyond (New Machines and Practices)

4.1 Application Examples for Future Intelligent Machines

The science fiction author William Gibson famously remarked: "The future is here already it is just not evenly distributed". Based on this assumption we take a closer look at some technologies that are still experimental today, under development, or too expensive. These are the applications that we assume will have wide proliferation in 2025. We limit our focus to two types of machines: military robots and industrial robots. Military technology is also a showcase of a future with lifted constraints. For industrial robots it is most evident how rules, law, and technology interplay.

Military Robots: Soldier Augmentation.

In a violence adverse society war is the worst nightmare. For politicians of shrinking western countries the image of soldiers returning in body bags is often an indicator of the imminent ending of their careers. Especially in asymmetric conflicts conventional technological advantage can be outmaneuvered and sheer population numbers decide success. Thus, in the past, the western military has invested heavily in using machines to augment their soldiers. Nowadays this isn't enough anymore. More and more autonomous or semi-autonomous machines are replacing human soldiers in critical or boring situations. A wide variety of drones are deployed on/under the sea and in the air. From remotely controlled drones to terminators, the numbers will rise and the degree of freedom of these machines will increase. Eventually there will be issues with friend-foe recognition.

What the U.S. should have learned since Vietnam, is that in modern "asymmetric" conflicts even the ultra modern stealth bombers or nuclear submarines, that signify modern "military might", are of limited use. [17] The urban-guerilla operations in modern battlefields shift the focus from aircraft carriers back to the soldier. Much of the development of future weapons system involves the equipment a soldier carries with him. The U.S. military has its Future Force Warrior program that should have technology ready for deployment by 2010.

Other similar projects focusing on soldier equipment are also underway, for example: The American military research organization, DARPA, is funding development for exoskeletons. Current systems use external hydraulic and pneumatic systems, which make them unsuitable for battlefield use. Another approach is to use nanotechnology and smart fabrics that would function as "second skins" for soldiers, making them "stronger and less vulnerable". For example, smart fabrics can generate energy from sunlight or contract "like an artificial muscle".

Another area of research is sniper location using sound sensors on a soldier's clothes. These sensors can determine a sniper's position through acoustic analysis of a sniper rifle's shot. In addition, SRI International, which develops the sound sensor, is also developing a penetrating-radar technology that "allows soldiers to see inside a building before entering it".

These developments are starting to raise ethical and philosophical questions. Colonel Kip Nygren, head of the Department of Civil and Mechanical Engineering at the Military Academy at West Point says that when it comes to making soldiers more machine-like, there ought to be more discussion about where to draw the line. [17]

The Ghost in the Machine

The U.S. military has been using advanced autonomous robot warriors in recent conflicts, like the TALON SWORDS systems. [See: http://www.foster-miller.com/lemming.htm] The main challenge is to make these systems even more effective killbots while making sure the robots abide by the rules of war (e.g. Geneva conventions) and avoid "friendly fire" incidents. The aim is to have an ethical robot warrior. The U.S. military has recognized that this is a much harder problem than what one might first imagine. As the U.S. military is currently the key driver for more autonomous robots, these problems are something that need to be solved in when more "peaceful" robots gain more autonomy.

There exists in science fiction literature "the three laws of robotics", imagined by Asimov in his science fiction novels on robots. These laws were first explicitly stated in his 1942 short story ”Runaround". However, as seen in many of Asimov's novel s (although surprisingly, not in his short story "Runaround", which was only the first to explicitly list the three laws) and also today in practice, those kinds of top-down hardcoded principles are not enough and might cause unplanned consequences.

One of the problems with Asimov's three laws and U.S. military robots is that while the former were set up to prevent robots from harming people in any way, the latter's only reason to exist is to kill.

One believed benefit from using robots in war is that, unlike human judgement, a robot's judgement might not be affected by stress or emotions. The problem, on the other hand is that "a robot with a conscience might give the generals more than they bargained for. To some degree, it gives the robot the right to refuse an order." [The Economist. "Robot wars", Jun 7th 2007, http://www.economist.com/science/tq/displaystory.cfm?story_id=E1_JNQJNDT]. Nick Carr also has his questions: "Can ethics be cleanly disassociated from emotion? Would the programming of morality into robots eventually lead, through bottom-up learning, to the emergence of a capacity for emotion as well? And would, at that point, the robots have a capacity not just for moral action but for moral choice – with all the messiness that goes with it?" [Nick Carr, Rough Type, "The artificial morality of robot warrior", http://www.roughtype.com/archives/2009/02/the_artificial.php]

Civil Applications

Whereas in the US, robotics research funding places a high emphasis on the military domain, in Europe and Japan, the emphasis is almost exclusively on the civil application side. In the following, some current civil applications are presented in addition to some trends related to the application areas.

Forest & Agricultural Machines

Labor intensive tasks in the forest and agricultural industries of the Western world are highly mechanized but still require constant human control. The tasks include e.g. tree felling, harvesting, and trunk collection in the forest and ploughing, seed planting, and harvesting in the field. In principle, the tasks are relatively easy to automate due to the environmental constraints in the tasks (known target areas, controlled and restricted access to the work area, static conditions) and thus active research is ongoing to add human-independent function to forest and field machines. Naturally, both forest and agricultural machine automation are under persistent research in Finland. The benefits of automation in the agricultural and forest industries do not only come from the reduced need for human work force but also from the potential gains in resource efficiency. For example, tree cutting could be optimized if a forest harvester machine can infer the tree structure and dimensions even before felling the tree. In addition, present performance in tree harvesting is essentially limited by human endurance and skill – a machine capable of the most strenuous tasks alone would improve the total work efficiency of the machine-human cooperation. Similarly on the field, water and fertilizer usage can be localized and monitored with an automatic smart machine-based distribution to reduce waste and eutrophication of the surrounding ecosystem.

Vehicle Operating Trends

In the three domains of land, air, and water, automating vehicle operation has progressed at very different paces. Although it may be a little counter intuitive, machines are easiest to operate autonomously in domains with the most degrees of freedom, i.e., the air. Airplane autopilots are nothing new and military applications have driven the automation further – modern unmanned aircraft are capable of performing whole missions from takeoff to landing without human interference. On the other end of the spectrum, autonomous land vehicle operation is still on the research table due to the related difficulties and risk factors. Only in controlled and limited environments can mobile land devices operate autonomously, e.g., robot trucks operating in mine shafts and harbor area logistics robots. Both of the aforementioned applications exist today but their domain is strictly off-limits to humans while they are working and thus the same principles do not help in the real world with much more uncontrolled variables around. However, trains operate increasingly autonomously and the trend toward train automation seems clear. Similarly, operating sea vessels today is in a sense automatic with GPS piloting systems in place, only the task of navigating a ship in and out of the harbor is still under human supervision. In the future, unmanned cargo ships are probably going to be reality before we see autonomous trucks operating on public road networks. All in all, the trend toward a higher degree of autonomous operation has started from various pioneering solutions and is progressing toward the masses and public environments.

Cooperative Robotics for Monitoring

Another present focus area of Finnish intelligent machine research in addition to forest and agricultural robots are robots operating in groups. For example, in the European SWARM project, groups of robots are used to gather data in shallow tracts of water. The health and condition of coastal areas can be monitored with a system of autonomous robots in a way that surpasses traditional data sampling methods. The robot swarm achieves a much denser sampling by employing numerous cooperative units and by allowing the robot agents to float and move along with the sea currents. This is possible only if the robots are able to communicate and behave autonomously under difficult and changing conditions. Similar monitoring solutions can also be applied to hostile environments where constant human presence and supervision is either very expensive or even impossible. The EU project DAMOCLES is pursuing such technological solutions for monitoring arctic areas with the use of numerous separate sensory systems.

Healthcare

Healthcare is a major application area for the more intelligent machines of the future. Today, surgical robots operate on patients under direct human control and are nothing more than mechanical extensions of the surgeon's capabilities. However, eliminating the human from the equation might be close for most simple routine operations where the difficulties of sensory feedback control and complex insight of the human biological system are not a restricting factor. In the early phases of development, surgical robots could be taught to operate by simply directly following and adapting human-performed actions.

In the field of diagnosis, computers already play an important role as information databases. A logical step forward would be to allow an intelligent diagnosis machine to collect all the relevant health-related information and to make probabilistic inferences on the patient diagnosis. A medical doctor could use the diagnosis machine to guide her decisions in the first phase, but in the future, the diagnosis process could be standardized and automatized so that artificial intelligence including all the data from world's health records would do the job far more reliably and efficiently than the average general practitioner.

Combined with the diagnosis machine, health monitoring with everyday data collection would revolutionarize the way healthcare works. Instead of responding to symptoms, the presence of rich data from intelligent health monitoring machines and sensors would shift the emphasis to preemptive measures. A simple example would be a smart fridge tracking the user's nutrient intake and giving warnings and corrective suggestions on the early signs of heightened risk to health.

The field of implants and prostheses has developed fast in recent years. In extreme cases, limb prosthetics have been even seen as causing unfair competetive advantage on the Olympic level of sports. The step towards the truly augmenting prosthetics is a short one. Instead of replacing lost function, the emphasis is on augmenting the existing capabilities. Similar development has been going on in the neural domain as well as the mechanical. Cochlear implants are common and central nervous system electrical implants are used to treat conditions previously considered untreatable. A cochlear implant can restore a sense of hearing that is superior to the natural modality in a dramatic way – an artificial sense of hearing can be turned on and off at will! Chronic pain, Parkinson's disease, tremors or depression have all been adressed with electrode implants operating inside the brain through deep brain stimulation procedures. Again, the step towards enhancing neuroimplants is close. Neural interfaces have been used successfully to replace lost senses but the same principles could just as well be used to provide humans with enhanced or additional senses or even extra robot limbs. Simply implementing a general neural interface to a computer could be considered as permanently enhancing human capabilities.

4.2 New Practices

"Later Aliide heard stories of fields covered with dolomite, and trains, filled with evacuated people, crying children, soldiers, pushing people from their homes and weird flakes, glittering strange, which filled the farms, and that the children tried to catch, and the little girls wanted to decorate their hair, but the flakes disappeared, as later the hair from children's heads." [1]

The text above describes radioactive fallout after the Chernobyl disaster. In 1979, the inherent risk of nuclear energy was realized with well-known consequences. Nuclear energy is a peaceful side effect of the Manhattan project. Even though the purpose for which nuclear technology was used was within the legitimate interests of our human society, it still caused an enormous amount of human suffering. The disaster is an example of an error made by a man responsible for a machine. The same can happen anytime in the future. In fact, since machines are getting more complex and error prone the probability for accidents is likely to increase. Consequently, we argue that without proper actions our society is heading for disaster. Those disasters can happen either because the purpose for which the machine is used, as in cases of military machines, is likely to cause human suffering, or those disasters might arise from the fact that complex, intelligent machines do not work like clockwork.

To diminish the probability for disaster new practices for machine development are required. We introduce two ways to reduce those risks. First, we suggest that every machine developer should take an oath that would tackle both issues related to the purposefully dangerous killer machines and the risks related to the unreliability of machines. Such a developer oath could, for example, be introduced by including it into the system design requirements. Secondly, we introduce a new insurance machine, which is an example of an ultimate machine, that solves issues related to the residual unreliability of complex, intelligent machines.

Solutions

Killer Applications and Unreliable Machines: Oath for Developers

There is an ongoing willingness to figure out killer applications in industry. Unlike the so called killer application which increases the sales of the platform it runs on, in the following, a killer application is seen as an application which is capable of causing human suffering, by means of killing.

The military industry is one of the driving forces in the development of robot technology. The interface between science fiction and reality is not always so clear and lately it has become obvious that many of the problems we face in today's technological environment have been recognized previously in science fiction literature. One of these problems is the ethical dimension of robot development. (see Asimov's “three laws of robotics” footnote: Decades ago, science fiction writer Isaac Asimov developed three laws of robotics. According to those rules 1) a robot may not injure a human being or, through inaction, allow a human being to come to harm, 2) a robot must obey orders given to it by human beings, except where such orders would conflict with the First Law, and finally 3) a robot must protect its own existence as long as such protection does not conflict with the First or Second Law.) In reality, robots cannot take responsibility for their actions and arising out of this the ethical responsibility rests on someone else, namely on the developer of the machine.

‘Engineering ethics’ is a specific kind of ethics in a sense that the value of the work is often instrumental. There is no fundamental intrinsic value, such as justice or health, but the results of this work aim at instrumental goals. These goals are often value dependent. [2] The goal of an engineer is to develop a machine, which works as it should work. A good machine is a machine that has the functionalities mentioned in the specifications. However, that is not the whole story.

Even as the complexity of machines increases also the need for engineering ethics weighs in equally. The ever-complicated process of creating machines needs to be balanced with a counter-force. That force is ethics with increased need for transparency. Also, the general public requires possibilities to observe the methods and ways of doing science. One way to respond to that need could be an oath that all machine designers should take in order to be able to practice their profession. In fact, it could be seen as a system design requirement. The improvement of human performance in context with complex systems/machines is essential and that can be partly done by adding an oath to design approaches.

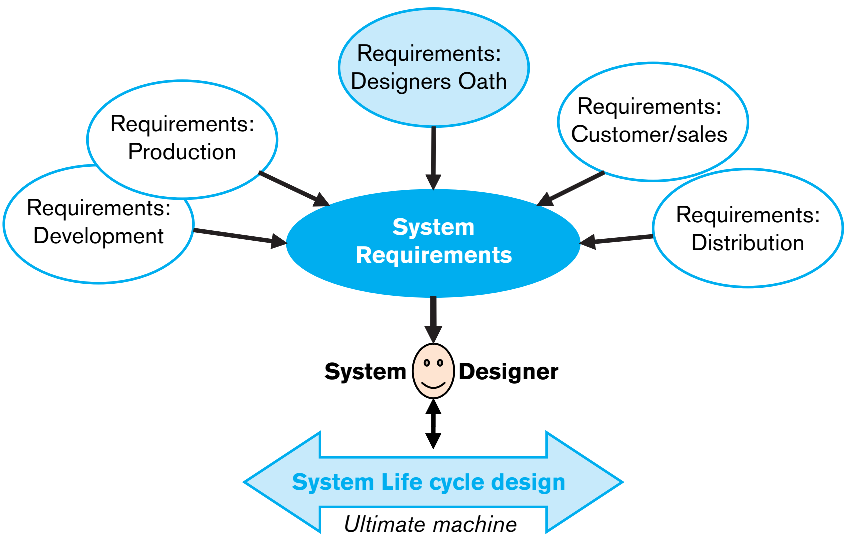

Figure 2. Ultimate machine system life cycle design and system requirements

The oath could be based on an Archimedes oath mentioned in 2001 ICSU research "Standards for Ethics and Responsibility in Science – an Empirical Study", a follow-up to the 1999 World Conference on Science and of the decisions of the UNESCO General Conference. [3]

The New Archimedes' Oath – Institut National Polytechnique de Grenoble (2000)

1. I will practise my profession abiding by the ethics of human rights and I will be aware of my responsibility for mankind's natural heritage.
2. In all acts of my professional life I will assume my responsibility towards my institution, towards society and towards future generations.
3. I will pay special attention to promoting fair relations between all men and supporting the development of economically underprivileged countries4. I commit myself to explaining my choices to decision- makers and citizens, making these choices as transparent as possible.
5. I will give priority to the forms of management permitting broad co-operation between all the actors with a view to making everyone's work and innovations meaningful.
6. I pledge myself to respecting ethical codes as well as examining and using means of information and communication critically.
7. I will take special care to honing my professional skills in all aspects of technological, economic, human and social sciences involved in my work.

The principle of transparency is key here. Therefore, the oath should be completed with the principles of hacker ethics. Those principles include Sharing, Openness, Decentralization, Free access to computers, World Improvement, Meritocracy and Equal Opportunities. [4]. The free and open source software movements contain all of the ingredients of hacker ethics. However, not only the interests of the general public should be taken into account but also the interests of the industry giving funding to the projects. Not all the results of the work can be published in accordance with the hacker ethic. However, the methods of doing the work must be transparent.

Also, the work ethic introduced by Himanen, Torvalds and Castells [5] should be taken into account. For Himanen, the central points are creativity, passion, freedom and creativity in sharing the results freely. Intelligent machines are becoming forced labor, so we humans are used for creativity intensive professions. This should be taken into account in the development of working practices. Greater productivity is likely to be achieved not by monitoring tasks for efficiency, but by encouraging creativity.

The oath as a design principle defines best working practices and reduces the risks that machines pose for humans. However, even when we apply the best practices and intentions, we are left with a residual inherent risk. Ethical and technical liability issues should be kept separate. It should be emphasized that even if the ethical issues are solved, liability issues remain. Himanen and Torvalds found inspiration for their work from the Finnish Sampo Mythology. Likewise, the remaining liability issues are addressed in the following chapter [and in the follow-up paper] with a magical artifact, namely with an insurance machine that will bring fortune to its holder.

Machine Rights and Responsibilities: The Ultimate Insurance Machine

Despite enormous economic promises, the development of intelligent machines is slow since the field faces tremendous challenges from current legal systems. Technological development is stifled by liability risks. Currently, the manufacturer or operator is held liable dependant on the circumstances. However, it has been suggested that the situation has changed if the robot starts to act autonomously. [6]

In the 18th century, the Lord Chancellor of Great Britain [7] remarked about corporations that they "had no soul to damn and no body to kick" and were therefore hard to hold accountable for misdeeds. The same thing will probably apply to intelligent machines. While they have a "body to kick", it won't do much good as they still lack a soul to damn.

Nevertheless, since the early days of digitalization there has been a debate going on regarding the idea of the civil rights of robots. [8] Lately a British Government Report anticipated a "monumental shift" in the area of robo-rights if only the robots would become intelligent enough. [9][10][11] While it is true that the courts have recognized robot judgment as superior to human judgment in certain circumstances [12][13][14] it should be pointed out that the capability of developing artificial intelligence is not connected to civil rights. In other words, rationality is not the decisive point in circumstances when it comes to human rights. Even if the machines worked perfectly correctly and perfectly intelligently in compliance with the Bayesian inference rules, the rights and responsibilities rest on humans. Humans can be obliged to comply to orders given by an aircraft autopilot, as in those court cases mentioned above, but at the same time, robots belong to the property of humans. Not even the dynamic sensor systems increasing the level of freedom of autonomous machines have as a consequence robot liberation comparable to human rights.

The next question is then: is the relationship between a robot and owner then similar to that of slave and dominus in ancient Rome? Slaves enabled the wealth and glory of Rome. They were forced labor belonging to the master. Slaves didn't have rights; they only had their masters. However, there are some fundamental differences between the legal status of robots and slaves. Most importantly, the manufacturer has to be taken into account when it comes to robots. While the robot belongs to its owner's property, the manufacturer is, in some cases, strictly connected to the use of the robot, at least if the robot does not work like clockwork and some damage is caused either to humans or other property.

The dynamic performance capabilities of artificially intelligent machines leads up to the fact that machines make mistakes. In a sense there is a tendency as seen from Plato's ideas and Newton's clockwork model toward practicality and error prone machines. Due to ever-increasing complexity it can be argued that machines come closer to the human-like characteristics. Consequently, one could ask if machines should be entitled to social benefits. If a robot has a malfunction could it be regarded as on sickleave (and get paid for that)? According to the social contract theory (Socrates, Platon, Hobbes, Locke, Rousseau, Rawls) [15] people enter into an agreement with the state to form a society. The rights and obligations of citizens are based on this social contract. Robots are not capable of entering into the social contract i.e. because of their status as property. Consequently, they are not entitled to social benefits. (compare British Government Report] Machines do not have rights or responsibilities themselves. Accordingly, software bugs and human bugs are treated differently.

Socrates stated that social contract is binding, as all men are free to choose whether they want to stay in the state area or move somewhere else. If a free man makes a decision to stay in the city he at the same time approves the authority of the state. [ref 15] Can a similar kind of rule be applied to robots? Possibly, the rule would only be slightly modified: the prerequisite for a robot to enter into the market would be that the robot has insurance. In other words, the robot would not be capable of entering into the market without a proper contract with an insurance provider. Accordingly, the insurance contract would be 'the social contract' for robots.

In this context it is important to keep in mind that not all machines need to be involved in the insurance machine constellation. There are two kinds of machines: unreliable intelligent complex machines and stupid pacemaker style machines, which still are kept reliable. The insurance machine is meant for machines which cross a certain kind of intelligence level and thus get closer to human like characteristics, such as unreliability.

Liability issues will be analyzed in more detail in a follow-up paper 'the Finnish Machine Stock Exchange'. It is worth mentioning that the insurance machine constellation could be compared to a limited liability corporation (approved in England in 1856). The liability risks inherent in complex, autonomous intelligent machines are allocated to the market through an insurance machine by means of liability stocks. Liability risks are thus transferred from the developers to the liability stocks market, which decides the price of the liability risks. The liability risks of the developers will be limited to a certain negligable level. Some of the most important issues to consider are then: who is liable for obtaining the insurance, what level of intelligence is required of the robot to be obliged to have an insurance and how to handle the negligence cases of developers.

Finally, machines don't have rights and responsibilities, but it can be argued that the ultimate insurance machine emancipates the machine. After all, machines or at least the men behind the machines are liberated. The requirement for liberation is, however, that machines have a tight link to the liability stock market. Consequently, machine liberation is not implemented by a human rights approach but by creating new kinds of financial instruments.

1 Sofi Oksanen: Purge. p. 215
2 Arto Siitonen: 'Insinöörin etiikka', in Airaksinen, T. (toim.): Ammattien ja ansaitsemisen etiikka, Yliopistopaino, Helsinki, 1991.
3 http://portal.unesco.org/shs/en/files/6500/10951486621Ethical_oath_sci.pdf/Ethical_oath_sci.pdf
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5 Himanen, P.: Hakkerietiikka ja informaatioajan henki, WSOY, Helsinki, 2001
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15 http://www.iep.utm.edu/s/soc-cont.htm

5 Conclusion

The combination of machines and ICT has brought exponential development into the engineering world. As a result we see the emergence of autonomous machines. The complexity of tasks as well as the complexity of environments where these machines can work is steadily increasing. We can build cars that can navigate autonomously through city traffic finding destinations without any human intervention. Therefore, it is fair to say that machines have, on a functional level, already reached cognitive abilities comparable to horses or dogs. But this is not the end of development. Soon there will be no type of manual labor in which machines will not outperform humans. This is technically already true today. Currently, machines are merely held back by economic and societal constraints. The weakest of these constraints is the cost of hardware. Moore's Law guarantees that computing power that today can only be found in supercomputers will be available in pocket sized devices in little a more than a decade. Some other constraints are more difficult to overcome. The more powerful and more complex a machine is, the more damage it can potentially create. This is the reason there are no self-steering cars on the roads yet. We have suggested a path of best practices and ethics to improve machines and reduce intentionally malicious behavior. Nevertheless, even those best practices leave us with a residual risk. This residual risk is not necessarily small. It may indeed be so large that certain types of machines will not be able to enter the market because of liability concerns. This limitation will only be overcome by the creation of an ultimate machine. For human parents responsibility and liability for a child ends with it becoming an adult. Similarly a machine can become an ultimate machine by emancipating itself from its manufacturer/owner and indeed becoming a distinct legal or even social entity. Interestingly, this can be done by creating a legal construct around this ultimate machine that in itself has economical value.

Nevertheless, the big question remains: how will our societies hold up to this rapid change? For example, currently our entire tax and social system, indeed most of our culture, is centered on the concept of work as the means of creating one's livelihood. For example, the European Union has set a goal of increasing the part of the population (between 15 and 64 years of age) in gainful employment to 70 per cent up to 2010. Yet when machines are able to perform manual labor cheaper and more efficiently than humans, what jobs will remain? Former US Secretary of Labor, Robert Reich, assumes that manual labor will eventually be replaced completely by machines. Nevertheless he argues that there will still be a high demand for a human work force. These new workers will have to be highly educated and trained "symbolic analysts" – lawyers, doctors, journalists, consultants, and the like – which create value beyond mere manufacturing. [23] However currently only a fraction of the labor force is capable of performing these jobs. Even though goverments have stated their intention to increase investment in education it is questionable whether this goal can be achieved for everyone. And even if it were possible, the advancement in information technology is not restricted to manual labor. Machines have augmented the physical performance of man to the point were he becomes superfluos. The same augmentation is also taking place with our cognitive abilities. The famous quote of the computer being a "bicycle for the mind" [24] becomes evident when we consider the vast amount of data a single person can analyze with the help of a personal computer. Therefore, the observation that machines in the long run are not destroying jobs but creating new ones is merely that; an observation and not a law. There might well be a threshold of automation that changes the rules of the game entirely. If that should happen this would be one aspect in which we have to change our culture radically.

In any case, how well we are prepared for these new machines will determin the social acceptance and ultimately the cost of the transition. Since development is still gradual, there will be several years left to create new practises. There is likely not a simple nor a single answer. The convergence of disciplines and the accelerating speed of technological progress will require a holistic approach and result in ad-hoc solutions. Fortunately, we can start learning about the problem and its solutions already today. After all, the future is already here, just not equally distributed.

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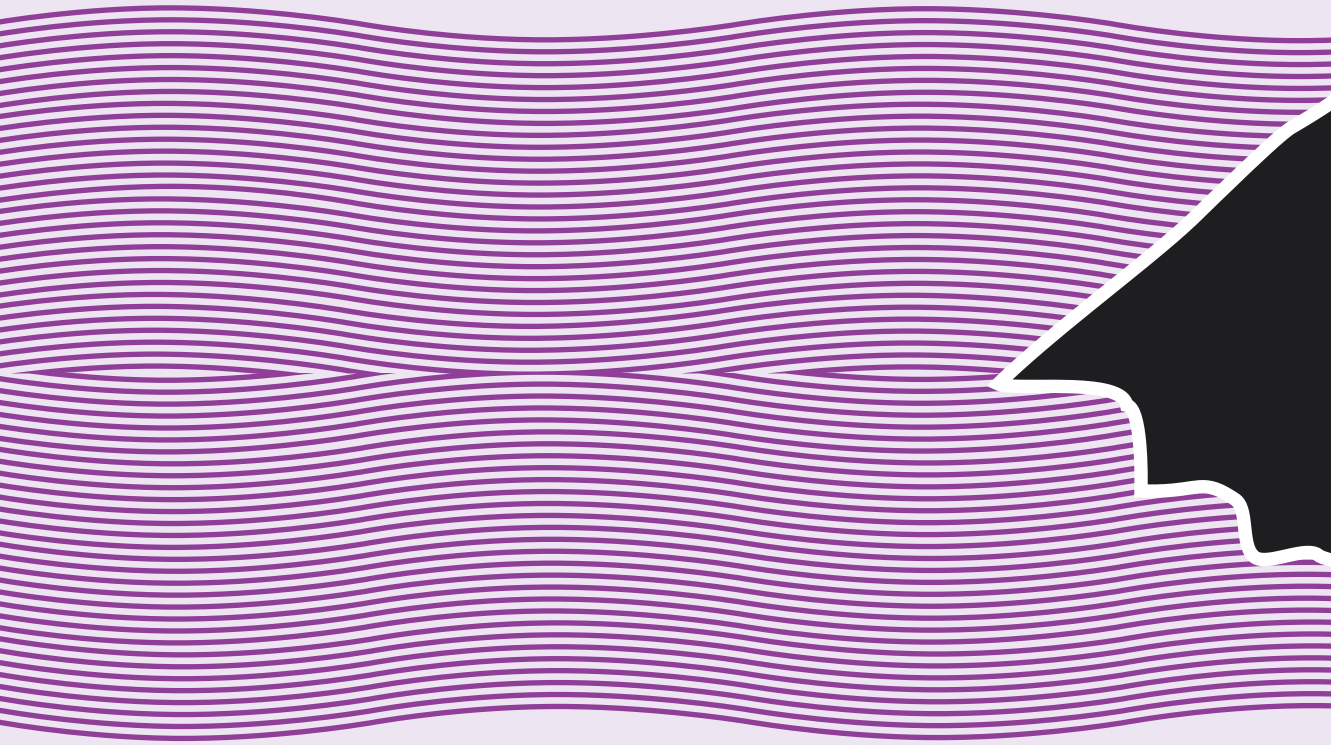

Appendices

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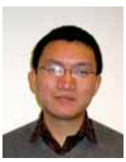

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Period fall 2008–spring 2009

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Sivonen Pekka, Chairman of the Board, Digia Oyj

Vasara Petri, Dr. Tech, Pöyry Forest Industry Consulting Oy

Välikangas Liisa, Professor, HSE Innovation management

Välimäki Mikko, Adjunct Professor at TKK, Patenting Strategies

3 The Course Books

Chou Timothy (2005). The End of Software.

Christensen, Clayton M. (1997). The Innovator´s Dilemma: When New Technologies Cause Great Firms to Fail.

Doz, Yves & Kosonen, Mikko (2009). Fast Strategy: How Strategic Agility Will Help You Stay Ahead of the Game.

Karlson et al. (2003). Wireless Foresight.

4 Bit Bang – Study Tour to California

Contents & timetable of the tour (Sunday 22.2.–Saturday 28.2.2009)

Sunday 22.2.2009
12.00 Meeting at the airport.
14:20–15:55 AY005 Helsinki-New York.
17:45–21:25 AA177 New York-San Francisco.

Monday 23.2.2009 (Background info group A, report group C)
Monday 23.2. University of California at Berkeley, start at 9.00 AM
Host: Roger Strauch Professor emeritus David G. Messerschmitt
Address: Department of Electrical Engineering and Computer Sciences, 402 Cory Hall, University of California at Berkeley, Berkeley CA 94720-1770
Contact person: Roger Strauch Professor emeritus David G. Messerschmitt, cell phone 925-285-9651

Program:
09.00–10.00 Prof. David G Messerschmitt, overview of the University of California, Center for New Media (BCNM), and Center for Information Technology Research in the Interest of Society (CITRIS) 400 Cory Hall (Hughes room, on the SW corner next to elevator)

10.30–11.30 Prof. David Wessel, overview and demos, Center for New Music and AudioTechnologies (CNMAT) 1750 Arch Street

11.45–12.30 Lunch with a few PhD students in the School of Information
South Hall, room TBD

12.30–14.00 Raymond Yee, Lecturer, class "Mixing and Re-mixing Information"
http://www.ischool.berkeley.edu/programs/courses/290-mri 110 South Hall

14.10–16.30 Visit Lawrence Hall of Science (LHS)

16.30–18.00 Pizza social with graduate students from EECS, SI, BCNM
606 Soda Hall and nearby alcoves

18.00 End of visit

Tuesday 24.2.2009 (Background info group B, report group D)
Departure 08:45 AM from the hotel lobby

10–12 AM: Digital Chocolate
Host: Trip Hawkins
Address: 1855 S Grant St San Mateo, CA 94402
Contact person: Trip Hawkins, office phone: 650-372-1600 or 357- 6136

1–3 PM: Sun Microsystems
Host: SVP of the database group at Sun Microsystems Mårten Mickos
Address: 17 Network Circle Menlo Park, CA 94025
Contact person: Assistant Tracy Nelson, cell phone 650-740-5167

4–6 PM: Nexit Ventures at Palo Alto hotel
Host: Venture capitalist General Partner, Nexit Ventures, Michel Wendell, Palo Alto Sheraton hotel
Contact info: Michel Wendell, phone 408-725-8400
Conference room booked (from 4.00 to 7.00 PM) from the Palo Alto hotel

Wednesday 25.2.2009 (Background info group C, report group A)
Departure 8:15 AM from the hotel lobby

9–10.30 AM: IDEO
Host: Software Experiences Practice Lead at IDEO Deuce Cruse
Address: 100 Forest Avenue, Palo Alto, CA 94301
Contact person: Senior designer and project leader at Ideo Larry Cheng, phone 650- 289-3400

11–12 AM: Stanford University
Host: Assistant Professor of Communication Director, Virtual Human Interaction Lab (VHIL) Jeremy Bailenson, virtual worlds
Address: Stanford Campus, 100 Forest Avenue, Palo Alto, CA 94301.
Bailenson´s room: Wallenberg Hall, Building 160, 450 Serra Mall
Contact person: Jeremy Bailenson

1.10–3.30 PM: Nokia Research Center
Host: John Paul Shen
Address: Nokia Research Center Palo Alto, 955 Page Mill Road Palo Alto, California 94304
Contact person: Admin assistant Julia Beal, phone cell/work 650-353-8042

4:30–6:00 PM: Stanford University, Kresge Auditorium, Entrepreneurship week: “The Next Big Thing”: A special presentation of the Entrepreneurial Thought Leaders Lecture Series

6:30-7:30 PM: Entrepreneurship week: Networking Reception and SEN Fair

Thursday 26.2.2009 (Background info group D, report group B)
Departure 7:45 AM from the hotel lobby

9–11 AM: IBM
Host: Ray Strong, Impact of Future Technology
Address: IBM Research Almaden Research Center
650 Harry Road San Jose, CA 95120
Contact person: Assistant Cristina V. Payan, phone: 408-927-1998

12 AM–2 PM: Google
Host: Kai Backman
Address: Building 46, 1565 Charleston Rd (MTV-46) Mountain View, CA 94043
Contact person: Kai Backman

3–5 PM: HP Labs
Host: Senior Vice President, Research and Director Prith Banerjee
Address: 1501 Page Mill Road Building 3U, MS 1179 Palo Alto, CA-94304
Contact person: Carl Chow, Customer visits program, phone 650-857-5308

19.00 Wrap up buffet dinner sponsored by Sitra at the Palo Alto Hotel

Friday 27.02.2009
07:50–16:15 AA024 San Francisco-New York.
17:45–08:50 AY006 New York-Helsinki.

5 Study Tour Summary Report

Monday 23.2.2009

09.00–10.00 Prof. David G Messerschmitt, overview of the University of California, Center for New Media (BCNM), and Center for Information Technology Research in the Interest of Society (CITRIS) 400 Cory Hall (Hughes room, on the SW corner next to elevator)

- David described us the history of California.
- California has three-tiered level education system, which consists of so-called first level educational institutions like the University of California and private Universities like Stanford etc... The first level's main priority is in research.
- The second level includes California State University. Mainly concentrated in educating bachelor graduates.
- Community College System which is high school equivalent educational institution and functions as entry point to the higher education.
- Some statistics for BERKELEY :
  - o 41,000 graduates per year.
  - o 1.3 million degrees in total.
  - o 55 Nobel prizes
  - o 7.5% of U.S. doctorates.
  - o 20 students per each senior faculty staff.
  - o One of the TOP 10 universities in the world.
  - o Tuition fees depend on the annual income for students family. Students from families less than 60.000$ annual income are freed from tuition fee.
  - o Funding is based on state, federal and private sources. The private donations are tax free which is approximately 50% deductible.
  - o Strengths, global sourcing of staff and students, tiered educational master plan, political independency, location, private funds which follow quality, competition from private universities.
  - o Doctorate students typically do research and teaching as a part of the education which means that tuition is paid. Usually, a PhD. student is usually only a researcher.
  - o There are approximately 8 PhD. students per one professor and one PhD. graduate a year.
  - o Usually PhDs are recruited to post doc system through social networks (MIT and Standford).

Key learnings: The competition between universities is believed to improve the quality. The large focus on education by the state and its fairness (possibility for an education for all (lots of funding available for poor or poorer students) despite high fees was a pleasant surprise.

10.30–11.30 Prof. David Wessel, overview and demos, Center for New Music and AudioTechnologies (CNMAT) 1750 Arch Street

- A small academic unit of one professor and two post-docs.
- They are building new musical instruments by using human gestures as input to the computer which generates the audio.
- High computational requirements such as haptic feedback and multitouch user interface.
- PhD. students are especially are working as laboratory assistants building musical systems.
- The challenge has been to combine give artistic impact on engineering.
- 75 students early. The recruit people that have high knowledge about music and strong interest in technology, too.
- They do live performances on the internet.
- Companies are involved in education through seminars and research collaboration.
- Focus in baby babbling and body engagement.

Key learnings: There is still a lot to do with different input interfaces in music. These ideas could be applied for example in the human-computer interaction improvements in such areas like digital games in which experience is a key issue. Technology and culture mixing at their best.

12.30–14.00 Raymond Yee, Lecturer, class "Mixing and Re-mixing Information" http://www.ischool.berkeley.edu/programs/courses/290-mri 110 South Hall
We participated to a student lecture by listening student presentations and engaging the discussion in small groups. Main themes were web 2.0 mash-ups. First a brief introduction by teacher Raymond Yee. He introduced also one of his future project dealing with transparency of government (database combining knowledge about political decision making).

Group themes were

- "Dead man switch". A service in which after you die you can give all your history to your family.
- Photo editing in the internet without client software.
- Music mass customization service based personal profile.

- Context based tourist guidance on mobile phone.
- Life blog. A service in which all activities are stored automatically.

Key learnings: We can be innovative too. These students were not “smarter” than any of us. One step (or more) behind Europe in terms of practical knowledge. Expected to be more surprised.

14.10–16.30 Visit Lawrence Hall of Science (LHS)
We visited the Lawrence Hall of Science comparative to Heureka. This place is located in the California hills which had a marvelous view to the city. LHS was place mostly dedicated to families. It was exceptionally well designed for small children and the equipment looked like a 1990s state sponsored event that was not updated and some of the stuff for the kids was actually broken. There were several themes such as water works, astronomy, animal grossology.

Key learnings: Heureka can improve. cavernous. not well organized.

16.30–18.00 Pizza social with graduate students from EECS, SI, BCNM 606 Soda Hall and nearby alcoves
Only few students and faculty members appeared. However, we had very interesting discussion about the current state of the research such as interactive media.

All in all, this day was a good start to understand the spirit of innovation at Berkeley. We think that it seemed to be quite relaxed but very professional research and study environment compared to Stanford. Also discussions about current research trends with local students face to face gave positive inspiration.

Key learnings: If you do not do marketing about your offering, nobody knows about it + good timing counts too. Some students showed up still the main reason too early = students were in class. At 8/9Pm the pizzas would have been a smash

Tuesday 24.2.2009

Digital Chocolate

Host: Trip Hawkins
Key words: Leverage, patience, strategy, social value, omnimedia

Trip Hawkins, the founder of Electronic Arts and 3DO and Digital Chocolate, gave a good speech of his career path though the years and some personal insight of the digital world, especially about gaming industry, where he has been involved for about 25 years. The speech itself was truly an inspiring one with a lot of interesting comments about the ICT business. The phrase, 'it is all about leverage', was definitely cruel, but yet truthful. The way to gain the muscle during 'combat' requires some real guts and foresight, in another words, strategy. To be able to always see the whole picture is perhaps the only way to survive in the digital business.

His personal career has not always run smoothly. The 3DO console experience was certainly for him, in his own words, 'a bumpy road'. It took years for him to admit that it was a failure and give it up to start something new.

Hawkins told a story from his time at EA, when NHL was insisting on EA to include their logos and team members' names in the game. He refused, in order to gain enough leverage for the future. Now, EA sports is virtually 'the brand' for most of the sports games and sponsored by most of the major leagues. Hawkins has applied the same strategy in Digital Chocolate.

Actually, Hawkins saw strategic value as the most important thing regarding any company. In DC's case it means positioning the company in distributing and brand/licensing dimensions so that the company is not dependent on any content provider (brand owner) or any distributor (operator). Thus DC tries to build its own brands and uses web as a marketing channel to let people find the games after which they can buy them from their operator's market places.

Mr. Hawkins mentioned that the worst situation in their business is to be in between two major players: brand owners and delivery companies, who both try to charge more and more and in that way decrease the margins of Digital Chocolate ('squeeze play').

Hawkins said that Digital Chocolate does not even try to use the latest technology in its products. Instead, they prefer to do simpler products, which can be used also with older machines and on the mobile content platform. The business idea behind this decision is that it is simpler to develop the product and interface design does not require so much resources.

Regarding the future of ICT business, not surprisingly, he remarked that the new 'next big thing' will be social applications and business built around social value. He emphasized the importance of social life in general, people belonging to networks (however, these do not include the day-care system). There is nowadays a true need for social media. Social media is also an interesting field since the business models are different from traditional media. In social media memberships and subscriptions are the same as content and single products in traditional media.

Hawkins introduced the concept of 'omnimedia'. Omnimedia refers to hundreds of millions or even billions of people using interactive digital media. Omnimedia means the true media of masses. In few years there are billions of people online and they will not want to understand technology but just have simple 'casual game' experiences.

The 'omnimedia revolution is about simplicity and convenience', not better fidelity. Thus, people stuff their MP3 players or phones with low-fidelity compressed music, because it is convenient to have all the music in one portable device, and the quality of the sound is not as important. The omniconsumers also prefer casual games, which is in contrast to the conventions of the hardcore consumers. Casual games are smaller, easy to download, cheap and easy to play, designed that everyone wins; hardcore games are hard to play, designed to challenge the player.

The social aspect is important in omnimedia, and for instance gaming is more about social action than cutting edge games; 'Wii is a party'.

Sun Microsystems

Host: Mårten Mickos
Key phrases: Serve the underserved, Open source is not charity, Business model, What you do and what you do not do

First, we took short a tour at Sun Microsystems. Black box is an interesting project that was presented for us. It is basically a mobile data centre, which is supposed to be power efficient and much easier to be installed than conventional data centres. (http://www.sun.com/emrkt/blackbox/story.jsp)

Mårten Mickos, CEO of former MySQL, which was acquired by Sun, gave an excellent presentation about the history of MySQL and the open source industry in general. His comment about open source not being about charity, but being a different business model was quite insightful. Mickos told the following about the business idea of MySQL: MySQL is free software, but the company charges for any installation, modifications and support for the customer. When compared to the competitive products, e.g. Oracle, MySQL offers cheaper and simpler alternative for smaller companies. almost all ICT start-ups need database services for their products. The huge number of developers creating new business in start-up companies are the underserved, who need to be served.

Mickos' presentation ended with discussion about the future of the Internet. Mickos had picked three themes: 1) the huge amount of mobile Internet users in near future, 2) problems of open source licensing models in software as a service models, and 3) web freedom, neutrality and democratization. The first trend is based on the fact that there are three times more mobile phone users already in the world than computer users. The second one is a notion that open source licensing is currently based on the idea that the distributor of (open source) software is required also to distribute the source. However, in the software as a service model the software is not distributed and thus the licensing scheme breaks up.

Nexit Ventures

Host: Michel Wendell

"Do not compete with others, let others compete with you."

"When the business idea of a Finnish company is to offer technology, the American idea is to solve the problem that potentials customers may have."

Michel Wendell, a venture capitalist gave a presentation of his life-journey to the Silicon valley. He described the relationship between the venture capitalist and the entrepreneur as a 'forced marriage'. Therefore, according to Wendell, the entrepreneur must be careful when acting with experienced venture capitalists:

- Firstly, the entrepreneur must search background information of the financier he is going to act with.
- Secondly, there must be clear agreements about the role of the financier, because the financier usually has valuable information, and the entrepreneur must be sure that the financier uses it to increase to success of the company.
- Thirdly, the entrepreneur must think as far as possible the business issues of the company. Otherwise, the venture capitalist has stronger position in negotiations and may even be not interested in participating in financing of company.
- And related to the last two comments, the entrepreneur should not give too much shares and power to the financier. If the financier has the majority of the shares, the venture capitalist is able to make hard decisions by himself.
- Common mistakes of applicants: fail to admit the failures. According to Wendell, the true experience of an entrepreneur consists of mistakes he has made. If he does not even admit the mistakes, he is not able to become a better entrepreneur.

Wendell's decision making theses:

1. Risks: Is this bigger risk for you or for the others
2. Everything takes more time, resources, everything you can think of both positive and negative
3. Get to know your skills and define the game you play accordingly: let others try to compete in your game

Wednesday 25.2.2009

Ideo

The IDEO design company trip was normal presentation. They were showing grand tour of their office and explaining their working methods, user centric approach to design and some customer cases. The presentation was normal, the same things are studied in Taik or in TKK. Their office looked like an avantgarde design studio. You can taste the feeling by visiting Design Factory at TKK.The second part of the presentation was dealing with design the Nokia N-Gage, 2:nd generation, phone.

Stanford University

The Stanford ecosystem was briefly introduced. Professor Stango defined three key success factors of Silicon Valley. Firstly, major universities provide graduates to become employees. Secondly, Silicon Valley has managed to lodge lots of venture capital. These two factors are important ingredients for entrepreneur environment. Finally, the physical environment should not be underestimated. The mild climate and good outdoors provide plenty of possibilities for mountain biking, hiking, and running, for instance.

The Virtual Self

Jeremy Bailenson gave us a presentation that combined research on virtual worlds, avatars and human behaviour. Using a virtual world as the environment for studying human behaviour allows experiments to be made that would otherwise be impossible - or extremely difficult to do. This approach opened some very interesting findings on the way humans perceive themselves and how the perceived self-image affects their behaviour. Rather surprisingly, the 'physical' properties of a virtual avatar have a significant influence on the human subjects, i.e., how they interact in the virtual world. For example, the attractiveness of the subject's avatar influenced how he or she makes eye contact and how she approaches other avatars in the simulation. In a similar way, the height of the subject's avatar had several long-reaching consequences in the experiments that could be measured. It was even shown that the effects on these self-perceived avatar properties carried on subtly to the real world after the experiments in the virtual world had been finished. The research presented was an exemplary example of how combining different disciplines can produce interesting and novel scientific findings.

Nokia Research Center Palo Alto

Our second visit on Wednesday the 25th of February at Palo Alto in California was to the Nokia Research Centre (NRC). It was a sunny afternoon around 14.00 local time. We went through the formal procedure of signing legal documents and receiving name tags as visitors. The atmosphere was very relaxed with a somewhat Finnish flavour as the program started with the host, John Paul Shen first inviting us for coffee, soft drinks, some sandwiches, and confectioneries. This was followed with numerous presentations initiated by our host, who explained to us the significance of the NRC in Palo Alto and the core research programs and trends. The presentation then shifted down to research specifics with team leaders and members from various research groups presenting their current research projects. These presentations were always followed by questions and healthy discussions. It also gave us a wide perspective on Nokia´s future and how they are preparing for the next big thing; the great convergence.

There was a pause in the presentations and discussions for more coffee and drinks as the time spend in NRC was long, almost three hours.

Entrepreneur Week – Panel Discussion "The Next Big Thing"

Wednesday's last visit brought us back to the campus of Stanford University. The Stanford Technology Venture program had organized a panel discussion as part of the Entrepreneurship Week closing final that would give insight on the hot entrepreneurial opportunities of today and tomorrow. When we arrived the auditorium was already packed to the last seat with a diverse crows of students, researchers, and professionals waiting for the start of the discussion. Unsurprising, given the lineup of the high profile featured speakers:

Tim Draper, Managing Director Draper Fisher Jurvetson, and "Father of Viral Marketing". He was #7 on Forbes Midas List and #52 on the list of the most influential Harvard Alumni. He was also named Always-On #1 top venture capital deal maker for 2008 while his company DFJ was honoured as #1 Dealmaking Venture Capital firm for 2008. On his side were Tony Perkins, CEO, AlwaysOn, and Venture Partner of DFJ Frontier. He is also the creator and former editor-in-chief of Red Herring, a weekly magazine that was focused on the business of funding, building, and taking new technologies to market. The moderator's part was played by Michael Moe, Founding Partner of ThinkPanmure, and acclaimed author. After he forecast the rise of Starbucks as a stock analyst in 1992 he recently summed up his ideas on foresight in the bound-to-be bestselling book "Finding the Next Starbucks: How to Identify and Invest in the Hot Stocks of Tomorrow".

The panel discussion about "The Next Big Thing" did mirror the broad knowledge and experience of the speakers. The range of topics spanned from energy technology, to the entertainment industry, and social learning. All panelists agreed that the current financial crisis is going to be an excellent starting point for new entrepreneurs. It allows innovators to perfect their ideas without being forced into a business model. They see the economic playing ground levelled by the internet and in particular the web 2.0. Companies that are unprofitable on their own can become an indispensable part of much larger corporations. Tony Perkins illustrated this point by calling Hotmail "the best acquisition Microsoft has ever made".

Thursday 26.2.2009

IBM

IBM Research Almaden Research Center is located in a very special place near San Jose on the top of the beautiful country side hills. Such a remote location hints that something special and secret is done here. Our host Ray Strong gave as a very inspiring lecture about the impact of future technology. The talk explained the various research methods Mr. Strong is using in his work as a futurist in IBM. He pointed out the problems of predicting future as well as the promises of what his work can offer. The examples were focused on various perspectives on how to predict the future energy production. Mr. Strong introduced us a concept called signpost, which basically means a clearly definable future event which can be measured and used as a indicator of whether a scenario is realizing and how it is realizing. Finally, Mr. Strong answered to many of our questions regarding the course topics.

Google

After IBM, the Google presented us a totally different kind of corporate culture. In Google people are relatively young, the houses are colorful and the outlook is generally more relaxed than in IBM. Our host in Google Mr. Kai Backman showed the Google premises and introduced as for example their lunch system. Every employee can have free lunch from a wide variety of good quality options. Some other special details related to Google were Google's own garden for producing herbs for lunch and the copy of SpaceShip One hanging in the lobby. Our host explained how Google team structure is special; each group have high degree of freedom but also responsibility to deliver. Google showed also some examples of their server infrastructure and explained how their approach in building server infrastructure is very pragmatic and is based on scalable and robust software layer instead of high quality and expensive hardware technology.

HP

In our visit to HP we had a great chance to see the original offices of the founders of HP, Bill Hewlett and David Packard. These famous engineers can be considered to be founders of Silicon Valley. HP presented few very technical and interesting presentations. They presentation had high scientific quality and they were specialized to optical computing. The presentation in HP was different to what we saw in IBM or in Google. All three companies really showed different corporate culture. HP wanted to emphasize how they are transforming from products and hardware company to a solutions and services company.

Bit Bang – Rays to the Future looks at the impacts of digitalisation until 2025

Bit Bang – Rays to the Future was a one year post-graduate course on the broad long-term impacts of information and communications technologies on lifestyles, society and businesses. The 22 students were selected from the three units making the upcoming Aalto University: Helsinki University of Technology (TKK), Helsinki School of Economics (HSE) and University of Art and Design Helsinki (TaiK). Cross-disciplinary team working was part of the learning.

During the fall semester the students were assigned to study four interesting technology trends until 2025. The topics were processors and memories, telecommunication and networks, printable electronics, and carbon nanostructures. The spring semester focused on the impacts of new technologies on a broader scale. The spring topics were globalisation, future of living, future of media and intelligent machines. This joint publication contains the reports of the teams.

The texts have been written by the doctoral students and they were encouraged to take a fresh and possibly even a radical look at their assignments. The book is aimed at a general audience.

This course was an experiment on the content and structure of a multidisciplinary graduate course and also an experiment on how the upcoming Aalto University can add value at the level of doctoral studies. The feedback received from the students has been extremely positive and clearly shows the added value the Aalto University dimension will create.

This book is published in co-operation with Sitra, the Finnish Innovation Fund.

HELSINKI UNIVERSITY OF TECHNOLOGY
MIDE

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