

State of the Art Report: Internet Development across the Decades

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Introduction

In this report we describe how the “internet” became the “Internet”—or how a small number of interconnected mainframes developed into a global communications network that has found its way into the everyday lives of more than one and a half billion people worldwide. Starting in the late 1960s, we trace the history and evolution of the Internet across the decades, covering the various factors that contributed to making it such a high-impact innovation. We examine the extraordinary growth of the network in terms of hosts, users, services and commercial value and thus provide a solid background for thinking about the future of the Internet.

Our goal is to understand how the Internet became such a vital, and even intimate, part of human existence and how such a major technical advance so quickly became embedded throughout developed societies. This requires an in-depth understanding of not only the technological dimension of networked computing, but also an appreciation of the host of social, cultural, economic, and regulatory issues that have accompanied the development. Too many analyses and forecasts have been driven by technology and neglected the crucial role of users and their needs. Making the nexus between technology and society a key part of this report, we will consider, for example, the extent to which “open” architectures contributed to innovation and growth, examine arguments of conformity by commercial forces that dominate the market, and map the challenges ahead as far as public policy is concerned. In doing so, we will pay special attention to the different forms of regulation and governance and their respective opportunities and challenges.

Our analysis is based on expert interviews and extensive desk research, reviewing and analyzing relevant literatures and publicly available data. As with every historical account, the challenge is to avoid foreclosing the analysis by premature definitions of problems and concepts. Hindsight rationalization and interpretation in the light of current affairs are often applied to a complex set of uncoordinated interactions, accidents and coincidents to make past developments appear planned and targeted.¹ While a report like this can never completely avoid such issues, we try to resist the temptation and maintain a working skepticism of over-simplifying explanations.

¹ The power of hindsight rationalizations in historical accounts is often signaled by language like “this decision turned out to be essential later.” See, e.g., Ben Segal, *A Short History of Internet Protocols at CERN*, April 1995, <http://www.ifla.org.sg/documents/internet/segb1.htm> (last visited July 6, 2009), p. 2; Yorick Wilks, *What Was Unanticipated or Unintended in the Development of the Internet: the case of the WWW and the Semantic Web?*, in: Helen Margetts & Christopher Hood (eds.), *PARADOXES OF MODERNIZATION* (2009).

The report consists of three parts:

- Part I recounts the early days of the Internet from the late 1960s to the mid-1990s, moving from the first attempts to link mainframe computers to the emergence of the World Wide Web and the many commercial and collaborative applications we experience today.
- Part II provides an extensive overview of the state of the Internet today and outlines the major issues in a variety of areas with relevance for public policy.
- Part III concludes by drawing some lessons from the analysis and extracts the main themes that will be relevant for the next phase of the project, the creation and assessment of scenarios for the future of the Internet.

Part 1: Where have we come from?

This first part describes the early days of the Internet and the path by which a small number of networked mainframes and minicomputers developed into what we call “the Internet” today. Covering the period from the mid-1960s to the mid-1990s, we trace major developments and important milestones. This period is still influential in shaping thinking about digitally networked environments. We have drawn on several existing historical accounts² but paid special attention to social dimensions and how they relate to technological innovation.

After sketching the evolution of networked computing from a rather technical perspective (1), we outline the main users and uses involved (2). Based on this analysis, we sketch the founding architectural principles (3) and look at the emergence of different forms of governance and regulation on the Internet (4). Part I concludes with an account of the World Wide Web and other factors that provided the basis for the large-scale and user-friendly Internet as we know it today (5).

1. The Birth and Growth of Networked Computing

The early history of the Internet was the formation of interconnected computer networks. While this process was highly complex and messy, several stages and milestones can be usefully distinguished.

1.1 The Idea of an “Intergalactic Network”

In the 1950s, the main method of computing was batch processing, which allowed only one person at a time to use a computer system—widely considered a waste of valuable resources.³ A large research effort therefore went into developing new forms of computing like time-sharing that allowed more than one person to use a computer. A key goal was to facilitate access from a distance and transmit data accurately and efficiently between remote workstations. The leased telephone lines originally used for this purpose were expensive, and few connections were made at that time. Still, the idea of connecting machines into a more extensive network was a key concern among computer scientists in the early 1960s, famously articulated by J.C.R. Licklider, head of the Information Processing Techniques Office (IPTO) at ARPA, the Advanced Research Projects Agency under the U.S. Department of Defense,

² See, e.g., Katie Hafner & Matthew Lyon, *WHERE WIZARDS STAY UP LATE* (1996); Janet Abbate, *INVENTING THE INTERNET* (2000); Manuel Castells, *THE INTERNET GALAXY* (2001), ch. 1 and 2; Barry M. Leiner et al., *The Past and Future History of the Internet*, 40 *COMMUNICATIONS OF THE ACM* 102 (1997).

³ See Abbate, *supra* note 2, p. 24-25; Howard Rheingold, *TOOLS FOR THOUGHT: THE HISTORY AND FUTURE OF MIND-EXPANDING TECHNOLOGY* (2000).

which would soon play a key role in the evolution of networked computing. It was Licklider who first documented the idea of an “Intergalactic Computer Network,” a globally interconnected set of computers through which everyone could access data from any site in the world.⁴

1.2 The Invention of Packet Switching in the U.S. and Europe

A major step towards such an “intergalactic network” was marked by the development and uptake of packet switching.⁵ In the U.S., Paul Baran at RAND had worked for some time on new ways of organizing communication networks that would survive a major military strike on infrastructure and came up with a new method called packet switching. In contrast to circuit switching, which required a direct and stable connection between hosts, packet switching split up all data into packets, which were then transmitted independently over the network and reassembled at their destination.⁶ Almost simultaneously, a group of researchers in Europe were working on a very similar idea, albeit from a different perspective. Donald Davies and his team at the British National Physical Laboratory (NPL) were not so much concerned with the survivability and robustness of networks, but with the potential of packet-switched networks as commercial time-sharing devices, which would improve access to scarce capacity and provide affordable interactive computing for commercial and entertainment purposes.⁷ Even though the groups were motivated by completely different concerns, the idea of dynamic and distributed routing systems was developed independently on both sides of the Atlantic.

The implementation of packet switching, however, took very different paths on the two continents. In the U.S., the collective effort of Baran and many other researchers resulted in the creation of ARPA’s first packet-switched computer network (ARPANET). On October 29, 1969 at 10.30 pm, the first link went live between terminals at UCLA and the Stanford Research Institute (SRI). Further nodes were added in the following weeks and months at other universities and institutions, leading to a cluster of 213 hosts by 1981. Implemented by the Boston firm Bolt, Beranek and Newman (BBN), the network was publicly demonstrated for the first time in 1972 at an international conference in Washington, D.C. The growth of ARPANET continued and is often seen as the major building block for what later became the Internet.

While Baran had been primarily concerned with the robustness of a decentralized packet-switched network against nuclear attacks in a military sense, this had not been ARPA’s original motivation to fund the research. As only a minor program in the ARPA portfolio, ARPANET was part of a more general effort in the IPTO to

⁴ J. C. R. Licklider, *Man-Computer Symbiosis*, 1 IRE TRANSACTIONS ON HUMAN FACTORS IN ELECTRONICS, 4-11 (1960); J. C. R. Licklider & Welden E. Clark, *On-Line Man-Computer Communication*, PROCEEDINGS OF THE MAY 1-3, 1962, SPRING JOINT COMPUTER CONFERENCE 113 (1962); J. C. R. Licklider & Robert W. Taylor, *The Computer as a Communication Device*, SCIENCE AND TECHNOLOGY (April 1968).

⁵ See, e.g., Leonard Kleinrock, *Information Flow in Large Communication Nets*, RLE QUARTERLY PROGRESS REPORT, July 1961, available at <http://www.lk.cs.ucla.edu/LK/Bib/REPORT/RLereport-1961.html> (last visited July 6, 2009).

⁶ See, e.g., Paul Baran, *On Distributed Communications*, Twelve Volumes, RAND Report Series (1964).

⁷ See Abbate, *supra* note 2, p. 27; Donald W. Davies, *A Historical Study of the Beginnings of Packet Switching*, 44 THE COMPUTER JOURNAL 152 (2001).

stimulate research in interactive computing and facilitate the sharing of computing time among various centres.⁸

The European efforts were not quite as successful. In 1966, Davies had developed a plan for a national UK packet switching network. In order to enable a range of commercial and entertainment services like remote data processing, point-of-sale transactions, or online betting, the plan was to set up central nodes connected by high-speed telephone lines and provide local access points, to which users could connect their terminals, computers and printers.⁹ Having neither the resources nor the authority to build such an infrastructure, Davies and NPL depended on the General Post Office (GPO) to realize the plan. Yet, not being convinced by the potential of data communications, GPO refused to collaborate and Davies had to settle for small in-house experimental networks later known as Mark I and Mark II. Only in 1977, long after ARPANET had gone live, did the GPO decide to build a data transmission network, the International Packet Switching Service (IPSS), by then using technologies from the ARPA spin-off Telenet instead of Davies' own creation.¹⁰

1.3 TCP/IP and the Interconnection of Networks

While the military-funded researchers at ARPANET had pioneered networked computing, they were not the only ones to appreciate the potential of networked computing. By the mid-1970, the list of live computer networks included the Department of Energy's MFNET and HEPNET, NASA's SPN, the computer science community's CSNET, and the academic community's BITNET.¹¹ Besides these government or university-based networks, major commercial initiatives were based on technologies such as IBM's SNA, Xerox's XNS and Digital Equipment Corp.'s DECNET.¹² Private companies like Compuserve and Tymnet started offering dial-up access to end-users. Another very successful application was a suite of Unix-to-Unix copy programs (UUCP) that became famous for distributing Usenet news and messages at low cost in computer-to-computer networks. UUCPnet expanded fast and also linked to the rapidly growing networked bulletin boards systems (BBS), of which FidoNet was particularly popular.¹³

Despite these initiatives, networks were still mostly run autonomously. Running on home-grown and often proprietary protocols, they were not able to communicate with each other. For example, while ARPANET had been built on the Network Control Program (NCP) protocol, the British IPSS was based on the X.25 standard that had been developed and fostered by the International Telecommunications Union (ITU).¹⁴ X.25 also became the basis, among other things, for JANET – a government-funded network for education and research in the UK. Other networks adopted and modified the X.25 standard for their own purposes, such as the Packet Radio Network with its AX.25 data link layer protocol. Further networks took advantage of both existing ARPANET and X.25 connections. In addition to UUCPnet and FidoNet, many other networks flourished, operating on a diverse range of incompatible standards and

⁸ See Castells, *supra* note 2, p. 10.

⁹ See Abbate, *supra* note 2, p. 29.

¹⁰ See Castells, *supra* note 2, p. 23.

¹¹ See Barry M. Leiner et al., *The Past and Future History of the Internet*, 40 COMMUNICATIONS OF THE ACM 102 (1997), p. 105.

¹² See Leiner et al., *supra* note 11, p. 105.

¹³ See, e.g., FidoNet.org, <http://www.fidonet.org/> (last visited July 6, 2009).

¹⁴ One exception could be found in Norway, where NORSAR, the Norway Seismic Array, was developed and linked to ARPANET in 1972. See *infra* Section 1.4.

protocols.¹⁵ However, a true “network of networks” would require a standardized communication protocol that could accommodate the existing landscape.

Among the first to tackle this issue were Robert Kahn at ARPA and Vint Cerf at Stanford University. Rather than standardize existing specifications, their approach was to develop a protocol that could run on top of most other networks. A crucial element of their concept was to delegate responsibility for the reliability of transmission to the hosts and not the network itself. This suited the structure of ARPANET, which had evolved with the “intelligence” located in the endpoints. In May 1974, Cerf and Kahn published a paper about their idea for “A Protocol for Packet Network Intercommunication,”¹⁶ which was formalized later that year in Request for Comments (RFC) 675. The document proposed a novel “transmission control program” (TCP) to the community of engineers, which could run together with the “internet protocol” (IP), and also coined the term “internet,” a short form of “internetwork.”¹⁷ With ARPA funding, a prototype system was developed and on November 22, 1977, for the first time ARPANET, Packet Radio Network and Atlantic Packet Satellite Network were successfully interconnected to exchange data despite their heterogeneous designs. After further refinement, TCP/IP emerged as the final standard in 1978 and was declared the only approved ARPANET protocol on January 1, 1983. From the same year on, the Berkeley BSD 4.1c/2.8 Unix release was bundled with free TCP/IP code for hosts and simple routers. This version of TCP/IP could also be used for commercial applications. In 1985, NSF decided to make TCP/IP mandatory for NSFNET—a critical decision given the leading role of the NSF in the privatization of the network infrastructure in the following years.¹⁸

1.4 UCL, CERN and the “International” Internet

As the history of packet switching has already shown, European researchers had been involved in the development of the Internet from the very beginning. In fact, the first link between a European network and the American ARPANET went live as early as 1973. Under the leadership of Larry Roberts, ARPA had had a strong interest in linking its 20-node ARPANET to Donald Davies’ working packet-switched network at NPL for research purposes. The original idea was to just break an existing link between Washington and NORSAR in Norway and add a drop-off point to include the NPL network. However, this plan proved unfeasible for both tariff implications and the political aspirations of the UK government to join the European Communities and thus avoid any major symbolic efforts to collaborate with the U.S.¹⁹ In 1971, Roberts and Davies therefore involved Robert Kirstein, a computer scientist at University College London (UCL), which—unlike NPL—was not directly accountable to the government.²⁰ The researchers agreed that ARPA would provide hardware for a UCL

¹⁵ Among these was, for instance, the mainly university-based BITNET, an experimental network on the basis of IBM’s RJE protocol. See Castells, *supra* note 2, p. 13.

¹⁶ Vinton G. Cerf & Robert E. Kahn, *A Protocol for Packet Network Intercommunication*, 22 IEEE TRANSACTIONS ON COMMUNICATIONS 637-648 (1974).

¹⁷ Vinton Cerf, Yogen Dalal & Carl Sunshine, *RFC 675 - Specification of Internet Transmission Control Program*, Dec. 1974, <http://www.faqs.org/rfcs/rfc675.html> (last visited May 6, 2009).

¹⁸ See Leiner et al., *supra* note 11, p. 105.

¹⁹ Peter T. Kirstein, *Early Experiences with ARPANET and INTERNET in the UK*, Unpublished Working Paper, July 28, 1998, available at <http://nrg.cs.ucl.ac.uk/mjh/kirstein-arpanet.pdf> (last visited July 6, 2009), p. 4.

²⁰ Peter T. Kirstein, *The Early History of Packet Switching in the UK*, IEEE COMMUNICATIONS MAGAZINE, February 2009, p. 20.

ARPANET node and allow us of the expensive transatlantic link to Norway if the UK established the link to Norway.

Despite some political resistance and funding problems, Kirstein and his team managed to establish the link and on July 25, 1973 the first data packets passed from the new UCL ARPANET node via Norway to the Information Sciences Institute in California, USA.²¹ This transatlantic link can be regarded as the first step towards a truly “international” Internet. However, despite this first and important connection, the U.S and European networks continued to develop on quite different paths for some time.

While many institutions, governments and individuals were involved in the development of networked computing in Europe, some major impulses came from CERN, the European Organization for Nuclear Research in Geneva, Switzerland. Already in the 1970s, CERN had operated a number of smaller networks for its researchers, the main one being CERNET, which allowed fast file transfers between mainframes and minicomputers. While CERNET was similar to ARPANET in structure and approach, its protocols had been developed independently. CERN staff had developed a protocol called STELLA, which was inspired by ARPA’s IP, but ran a different protocol on top of it. Purportedly, some of the designers had been in touch with Vint Cerf and his group, but a full transatlantic collaboration never materialized.²⁴ Only in 1984, CERN researchers proposed to introduce TCP/IP to interconnect the many smaller networks at CERN and TCP/IP was approved—but for internal connections only. According to Ben Segal, TCP/IP coordinator at CERN, the main reason for this hesitation was the political priority given to ISO-standard networking at that time.²⁵

This started to change in 1987 when CERN answered a request for support by Daniel Karrenberg, system administrator for the mcvox computer at the Amsterdam Mathematics Centre. With the mcvox acting as a gateway for all transatlantic traffic of the global USENET, Karrenberg’s plan was to convert the European side (EUNet) into an IP-based network and connect it to its U.S. counterpart, which also prepared itself for IP-based traffic at the time. Building on CERN’s experience with internal IP filtering and routing, Karrenberg managed to set up a European TCP/IP-based “internet” across existing UUCP networks and established Internet connectivity via the mcvox. Only a year later, CERN opened its first external connection and later also operated the principal link between the European and American networks.²⁶

Hence, it was not before the late 1980s that one could speak of a truly “internetworked” global network of computers—or “international” Internet. In the following years, much activity was geared towards consolidating and expanding the existing networks and backbones as well as opening the infrastructure and its management to a much broader set of uses and users. The NSF played a leading role and was instrumental in managing the transition from a government-funded to a privately-managed Internet. Despite increasing demand from non-academic users and private companies during the 1980s, NSF long prohibited backbone use for purposes “not in support of research and education” in accordance with government

²¹ See Kirstein, *supra* note 19, at 1.

²⁴ Ironically, the network which would have facilitated that collaboration had not yet been established. But also political reasons are said to have played a role here. See Segal, *supra* note 1.

²⁵ The only major exception had been made for DECnet. See Segal, *supra* note 1.

²⁶ For a more comprehensive account, see Segal, *supra* note 1.

regulations. Only regional networks were encouraged to seek commercial, non-academic customers. This inevitably led to the building of competitive private long-haul networks by companies like UUNET, PSI, or ANS CO+RE. It was only in 1995 that the NSF defunded its backbone and redistributed the recovered funds to the regional networks, which in turn bought connectivity from the new private providers.²⁷ Now built on modern commercial technologies, the Internet had grown into a conglomerate of more than 50,000 networks worldwide by the mid 1990s.²⁸

2. Early Users and Uses

While the history of networked computing demonstrated the evolution of technical standards and specifications, we will now focus on the social context of this development. In contrast to some accounts that exclusively emphasize the role of a small number of “Internet pioneers” and their respective “visions”,²⁹ we will adopt a broader view and include all those, who—in one way or another—have played a crucial role as early users of the emerging networks.

2.1 Researchers, Grad Students and Engineers

The earliest users of computer networks were those who had created them: scientists and engineers at universities and government-funded R&D initiatives. Already in the 1950s, RAND had supported researchers like Herbert Simon in Pittsburgh, PA in connecting computers via long leased lines. Beginning in the 1960s, computer scientists became increasingly interested in networked computing and began to form a growing community, connecting individuals in public research organizations like ARPA and CERN, major universities like UCLA, Harvard, and MIT, and private think tanks like RAND, the Stanford Research Institute (SRI), and Bolt, Beranek and Newman, Inc. (BBN). Most of the people thought of as “Fathers of the Internet”³⁰ today were grad students at the time. Vint Cerf, Steve Crocker and Jon Postel were all studying with Kleinrock at UCLA when they started working on Internet protocols. As part of the 1970s university culture, these students and their faculty used ARPANET for many activities—including those that cannot be straightforwardly considered research. For example, networked computers were heavily used for chats or private messaging. The first e-mail was reportedly sent from LA to the University of Sussex, UK, to retrieve somebody’s razor left at a conference.³¹ One of the most successful thematic mailing lists at the time was “SF-Lovers,” where science fiction fans shared their passions for cyborgs and robots rather than papers and protocols.³² In other words, the early computer networks constituted both the object of research and a platform for doing this research and socializing.

In this context, an important role is often attributed to the conditions under which at least U.S.-based researchers worked. Despite receiving extensive funding from the Department of Defense (DoD), they enjoyed a considerable amount of financial and

²⁷ See Leiner et al., *supra* note 11, p. 105. ARPANET had been decommissioned already in 1990.

²⁸ See Vinton G. Cerf, *Computer Networking: Global Infrastructure for the 21st Century*, <http://www.cs.washington.edu/homes/lazowska/cra/networks.html> (last visited July 7, 2009).

²⁹ See, e.g., William F. Slater, III, *Internet History and Growth*, Presentation, Chicago Internet Society, September 2002, available at <http://www.docstoc.com/docs/297578/Internet-History-and-Growth> (last visited May 6, 2009). For the opposite view, see Abbate, *supra* note 2, p. 3.

³⁰ See, e.g., Mike Harvey, *Who Were the ‘Fathers of the Internet’?*, TIMES, Sept. 25, 2008, available at http://technology.timesonline.co.uk/tol/news/tech_and_web/article4823707.ece (last visited June 1, 2009).

³¹ Hafner & Lyon, *supra* note 2, p. 187-88.

³² See Castells, *supra* note 2, p. 19.

intellectual freedom. ARPA and IPTO were largely autonomous in structuring their initiatives and research agendas. Researchers were not expected to produce any immediate results of military use. Rather, the goal was stimulate research and innovation in the field of cutting-edge technologies without stifling creativity. The result of this policy were highly experimental projects like ARPANET, “whose actual content was never fully understood by the overseeing committees.”³³ Thus, by granting researchers a great deal of autonomy and letting them choose what they perceived as the most promising lines of inquiry, the U.S. government had created an environment in which creativity and experimentation could flourish.

In many ways, the design of the Internet reflected the spirit of its creators. The researchers and grad students did not aim at building a carefully planned and standardized global network or exercise control over users’ behaviour. Network management was largely seen as a burden to be avoided by elegant protocols that could run effortlessly on the network.³⁴ It also seemed reasonable to these researchers to keep the options open for future growth and innovation.³⁵ Abuse and anti-social behaviour was not a concern since all users at the time were part of a rather close-knit and trusted network of researchers and scientists from the same cultural background with a shared set of values and beliefs.

2.2 Hobbyists, Sysops and Virtual Communitarians

A further group of users joined the Internet once networked computing became accessible beyond academic circles in the late 1970s. Attracted by the new possibilities of computer-mediated communication, a large number of hobbyists and “virtual communitarians”³⁶ connected their machine at home or work first into local networks and later to the Internet.

One of the earliest and most popular services in networked computing were Bulletin Board Systems (BBS). Arguably the first of its kind was the Computerized Bulletin Board System (CBBS), which had been developed by two Chicago students, Ward Christensen and Randy Suess, in January 1978 and allowed hobbyists to remotely leave messages in a central database.³⁷ Initially, bulletin board systems allowed users to connect and login to local systems via telephone lines and modems, later via other means like Telnet, packet switched network connections, or packet radio. Logged in to a BBS, users could exchange messages with other users via e-mail or public message boards, read and contribute news, download or upload software, or even play early text-based online games. Most BBSes at the time were run free of charge by computer hobbyists, many of whom had strong ties to the amateur radio community. Later, fee-based BBSes like The Well, Mindvox, and Echo NYC emerged and developed close-knit communities of dedicated users. While most BBSes were initially run as stand-alone systems that provided self-contained platforms with no direct exchange with other systems, this changed when users started to experiment with interconnecting BBSes. The first and best-known of these systems was the non-commercial FIDONET. Founded in 1984 by Tom Jennings, it allowed operators of FIDO-based BBS software to connect into a network so that electronic messages

³³ Castells, *supra* note 2, p. 19.

³⁴ See Jonathan Zittrain, *The Generative Internet*, 119 HARVARD LAW REVIEW 1974 (2006), p. 1989.

³⁵ See National Research Council (U.S.) Committee on the Internet in the Evolving Information Infrastructure, *THE INTERNET’S COMING OF AGE* (2001), p. 40-41.

³⁶ Castells, *supra* note 2, p. 52.

³⁷ Cf. Ward Christensen & Randy Suess, *The Birth of the BBS*, available at <http://chinet.com/html/cbbs.php> (last visited July 6, 2009).

between users could be conveniently exchanged beyond the narrow confines of a single BBS.

Many of these early grassroots networks developed into “virtual communities,” and are often linked to the countercultural movements of the late 1960s.³⁸ Many of the early BBSes like The Well had a dedicated followership of “people who had tried life in rural communes, PC hackers, and a large contingent of the Deadheads, the followers of the Grateful Dead rock band.”³⁹ Soon, these communities spread and grew around whatever users had a shared interest in. There were sex-oriented systems like Kinky Komputer, the Catholic Information Network, Zen Connections, and BBS communities specialized on earthquakes, weapons, photography, Star Trek fandom, Zionism, feminism, environmental issues, and much more.⁴⁰

Besides BBSes, people used a number of other ways to connect in grassroots organizations. Very similar to bulletin board systems was Usenet with its equally anarchic and diverse newsgroups. The main difference between a Usenet group and a BBS is that Usenet does not rely on a central server, on which data is stored, but on a meshed network of a large number of constantly changing servers through which messages are stored and forwarded.⁴¹ In contrast to the homegrown cultures of BBSes and Usenet, a number of large-scale networks were run as commercial online services. Finally, a further point of access to networked computing were the so-called free-net community networks. Networks like Cleveland FreeNet or Blacksburg Electronic Village provided public access to community information and other resources via dial-up connections. While many of these early users did not consider themselves as researchers, they often had connections with academic institutions. Most community networks and applications depended on powerful backbones, which could only be found at universities.

2.3 Hackers, Geeks and Open Source Advocates

Often portrayed as a subset of the emerging online community culture, the technology-savvy geeks and hackers deserve special attention. While the concept is contested, hackers are commonly understood as members of “a community, a shared culture, of expert programmers and networking wizards that traces its history back through decades to the first time-sharing minicomputers and the earliest Arpanet experiments.”⁴² Castells defines hacker culture more specifically as “the set of values and beliefs that emerged from the networks of computer programmers interacting on-line around their collaboration in self-defined projects of creative programming”.⁴³ He emphasizes two features: (a) the autonomy of projects vis-à-vis institutional and corporate arrangements and (b) the use of networked computing as the technological basis for this autonomy.⁴⁴

Hacker culture played an important role in the development of new applications and platforms on the Internet. A case in point were the struggles to defend the openness of

³⁸ See generally Howard Rheingold, *THE VIRTUAL COMMUNITY: HOMESTEADING ON THE ELECTRONIC FRONTIER* (2000).

³⁹ Castells, *supra* note 2, p. 54. See also Katie Hafner, *The Epic Saga of The Well*, WIRED, May 1997, available at http://www.wired.com/wired/archive/5.05/ff_well_pr.html (last visited May 31, 2009).

⁴⁰ See Rheingold, *supra* note 38, chapter 4.

⁴¹ See Wikipedia.org, *Usenet*, <http://en.wikipedia.org/wiki/USENET> (last visited May 31, 2009).

⁴² Eric S. Raymond, *THE CATHEDRAL AND THE BAZAAR* (1999), p. 231.

⁴³ Castells, *supra* note 2, p. 42.

⁴⁴ *Id.*

UNIX, an operating system originally developed in 1969 by a group of AT&T employees at Bell Labs. Members of the hacker culture had worked early on with UNIX. For example, the software underlying Usenet drew heavily on UNIX and UUCP by allowing UNIX computers to communicate outside the ARPANET backbone. However, when AT&T decided to claim proprietary rights in the UNIX operating systems in 1985, Richard Stallman, then a programmer at MIT's Artificial Intelligence laboratory, decided to found the "Free Software Foundation."

Discontent with the control of big corporations over the source code of UNIX, Stallman proposed to substitute the existing proprietary copyright in software with what he called "copyleft." Copylefted—or "free"—software would be licensed in a way that required future users to require others to adopt the same license terms for work derived from copylefted code.⁴⁵ The idea became known as the General Public License (GPL) and enabled programmers to develop software without the constraints of traditional copyright.⁴⁶

As a starting point, Stallman and his colleagues began to develop an alternative operating system called GNU under the GPL.⁴⁷ In 1991, Linus Torvalds, a student at the University of Helsinki, released the source code for an operating system kernel under the same terms. The kernel could be complemented by existing work on GNU and soon became the core of the new Linux operating system. Thousands of volunteer programmers have been working on the open source code of Linux since then and developed it into a powerful piece of software, used today on a large number of servers and home computers.

In the following years, many other open source projects formed and became technically and commercially successful. Examples are the Apache HTTP Server, the Mozilla project, and even the protocol stacks implementing the Internet Protocol.

2.4 Entrepreneurs and Network Operators

A further group of early users consisted of entrepreneurs and business people that saw primarily the commercial potential of the Internet. While networked computing had early been identified as an opportunity for businesses and private households, initiatives were long held back because of the funding arrangement behind the early Internet architecture. While the European vision of an Internet had included commercial interests from the very beginning,⁴⁸ at least on ARPANET this had been highly problematic. Since ARPANET was funded from public sources, any commercial exploitation was prohibited. Until 1995, NSF insisted that commercial access to the Internet should only be granted at the level of regional networks, but not the backbone.⁴⁹

As a consequence, a number of commercial companies developed businesses that operated outside of the ARPANET backbone. Early examples were online services

⁴⁵ The most common copyleft license is the General Public License (GPL). The latest version 3 can be found at <http://www.gnu.org/licenses/gpl.html> (last visited May 30, 2009).

⁴⁶ While there is considerable argument over the meaning and correct use of the terms "free software," "open source software" and the respective acronyms F/OSS or FOSS, we will use the term "open source software."

⁴⁷ GNU is a recursive acronym for "GNU's Not Unix." For an overview and analysis of the Linux project, see Raymond, *supra* note 42.

⁴⁸ See *supra* Section 1.2.

⁴⁹ This was also the reason why UUCP had not been allowed to use ARPANET or NSFNET connection, with a few, tolerated exceptions.

like CompuServe, The Source, or Prodigy that offered fee-based access to their servers. Cut off from existing Internet technologies, these companies developed their own applications and business models for audiences broader than just researchers and hobbyists. As early as 1978, for instance, CompuServe started to offer e-mail service capabilities and technical support to subscribers.⁵⁰ Later, the company pioneered the development of real-time chat systems with “CB Simulator”, a multi-channel chat service introduced in 1983. Centrally managed content platforms and later also Internet connectivity followed.

Since these companies understood themselves primarily as commercial providers of an new online experience with graphical user interfaces and innovative services, they mostly operated on proprietary protocols and restricted access to subscribed members. Many of these services were quite costly. In 1985, for instance, a user had to pay \$12.50 per hour to connect to CompuServe services on non-holiday weekdays between 8 a.m. and 6 p.m., and \$6 per hour at all other times.⁵¹ Still, for many users these companies provided a convenient—albeit expensive—way of taking part in the new online experience. By 1987 CompuServe had 380,000 subscribers, compared to 320,000 at Dow Jones News/Retrieval and 80,000 at The Source.⁵²

Another case of commercial activities outside the existing backbone were investments into an alternative long-haul infrastructure made by Internet Service Providers (ISP) like PSINet or UUNET in the 1980s. Building their own and technologically superior networks alongside existing lines, they could offer alternative network access to paying customers, basically building the infrastructure for today’s Internet.

2.5 The Anonymous User

A final group of users is rarely mentioned in analyses, but no more or less important for the evolution of the Internet than any other: the anonymous users. By testing applications, giving feedback, participating in discussions, and choosing between competing services, a large number of nameless people participated in the “production” of technologies, services, and content.⁵³ Many open source projects, for example, critically depended on feedback from the so-called periphery of users for bug reports and suggestions of new features. Companies often responded to these user demands and managed to improve their services. While such user-driven innovation was already observed and discussed in the 1970s, it later became a key theme among analysts of the emerging Web.⁵⁴

As this section has shown, the evolution of the Internet cannot be understood as a merely technical phenomenon. Rather, the network of networks emerged as a set of complex social dynamics, involving millions of people around the globe. Engineering-minded researchers and grad students, amateur sysops and hobbyists, libertarian hackers and open source advocates, resilient entrepreneurs ad

⁵⁰ See Wikipedia, *CompuServe*, <http://en.wikipedia.org/wiki/CompuServe> (last visited July 6, 2009).

⁵¹ Cf., e.g., Jean W. Pierce, *Computer Network*, 14 EDUCATIONAL RESEARCHER 19 (1985), p. 19.

⁵² Andrew Pollack, *Ruling May Not Aid Videotext*, N.Y. TIMES, Sept. 15, 1987, <http://www.nytimes.com/1987/09/15/business/ruling-may-not-aid-videotex.html?sec=&spon=&pagewanted=all> (last visited May 31, 2009).

⁵³ See, e.g., Claude Fischer, *AMERICA CALLING: A SOCIAL HISTORY OF THE TELEPHONE TO 1940* (1992).

⁵⁴ For an early analysis of the role of users in innovation processes, see, e.g., Eric v. Hippel, *The Dominant Role of Users in the Scientific Instrument Innovation Process*, 5 RESEARCH POLICY 212-239 (1976). See also Eric v. Hippel, *DEMOCRATIZING INNOVATION* (2005).

businesspeople, as well as an army of anonymous users—all these people have been critically involved in the complex evolution of the Internet.

3. Founding Architectural Principles

What architectural principles best characterize this early phase of networked computing? Principles, in this context, should not be viewed as fixed or authoritative rules, but rather shared beliefs and guidelines that are invoked at various points in debates about appropriate design and behaviour in relation to the Internet. The focus here is mostly on the positions of users and researchers concerning infrastructure and technical network design.

3.1 Locating Architectural Principles

While there is no “official” or authoritative code or constitution stipulating rules for the Internet’s architecture, a number of authors have tried to pin down a set of principles that help understand the characteristics of the early Internet.

A good first indication can be found among the original design community itself in the Internet Architecture Board’s (IAB) Network Working Group. Titled “Architectural Principles of the Internet”, this document suggests that there are certain shared beliefs about the Internet’s architectural design. Among other things, it states that the community’s belief is “that the goal is connectivity, the tool is the Internet Protocol, and the intelligence is end to end rather than hidden in the network”.⁵⁵ The Request for Comments document describes in further detail why it is important that devices are interoperable and how this is achieved through an open universal protocol and related standards.

Numerous other authors have expressed these ideas in different ways. For example, Castells points to three aspects he sees exemplified in Baran’s conception of packet switching: a decentralized network structure that is easy to expand; distributed computing power throughout the network so that no node is essential for the functioning of the whole; and redundancy in functions to minimize risk of disconnection.⁵⁶ Another metaphor that has frequently been used to describe the architecture of the Internet more generally is that of an hourglass (see Figure 1).

⁵⁵ Brian Carpenter, *RFC 1958: Architectural Principles of the Internet*, Internet Engineering Task Force, June 1996, <http://www.ietf.org/rfc/rfc1958.txt> (last visited July 6, 2009).

⁵⁶ See Castells, *supra* note 2, p. 17.

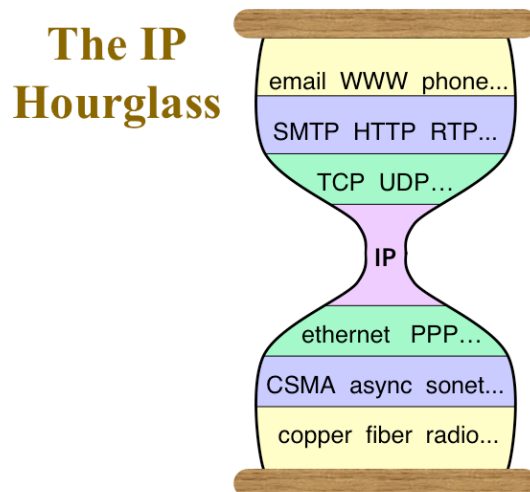


Figure 1: IP Hourglass Architecture
(Source: Steve Deering 2002)

The technical infrastructure of the Internet is conceptualized in layers, at the core of which a single and narrow Internet Protocol (IP) is located. This is assumed to maximize interoperability and minimize the number of service interfaces, demanding only little from service providers and users to connect at the narrowest point.⁵⁷

3.2 Openness, Interoperability, Redundancy and End-to-End

Four key architectural principles can be extracted from these analyses: openness, interoperability, redundancy, and end-to-end.

Openness: A term often used to describe the Internet's architecture and design process is "openness." While sometimes advocated as a principle of its own, it is difficult to pin down precisely. Most generally, the attribute "open" has come to denote the absence of centralized points of control—a feature that is assumed to make it easy for new users to join and new uses to unfold. Consequently, people talk about "open" networks, "open" source software, "open" identity, or "open" standards, or call for an "open" Internet policy⁵⁹ and "open" democracy⁶⁰ in "open" internet coalitions⁶¹, "open" net initiatives⁶² or "open" rights groups⁶³. In many ways, the attribute has come to be a general icon for a commitment to a culture of distributed authority, cheap and easy access to infrastructure, and widespread and "democratic" user participation.

As a political concept, it may be of limited use for technical network design. However, it has certainly shifted the focus from technical standards to the far-ranging social implications of basic architectural decisions, framing many of the contemporary debates about the Internet's architecture. At any rate, using "openness"

⁵⁷ See, e.g., Steve Deering, *IPv6: Addressing the Future*, Presentation at Global IPv6 Summit, March 15, 2002, Madrid, Spain, available at http://www.6journal.org/archive/00000012/01/steve_deering.pdf (last visited July 6, 2009).

⁵⁹ Danny Weitzner – Open Internet Policy, <http://people.w3.org/~djweitzner/blog/> (last visited May 28, 2009).

⁶⁰ Open Democracy, <http://www.opendemocracy.net/node> (last visited May 28, 2009).

⁶¹ Open Internet Coalition, <http://www.openinternetcoalition.org/> (last visited May 28, 2009).

⁶² OpenNet Initiative, <http://opennet.net/> (last visited June 1, 2009).

⁶³ Open Rights Group, <http://www.openrightsgroup.org/> (last visited May 28, 2009).

as an architectural principle requires careful specification of who, which, or what exactly is open to what, which, or whom under which circumstances.

Interoperability: The principle of interoperability requires that new devices can be easily connected to the network and communicate seamlessly with existing ones. A rough working definition would treat interoperability as “the ability to transfer and render useful data and other information across systems (which may include organizations), applications, or components”.⁶⁴ Sometimes discussed under the rubric of “connectivity” or “compatibility,” interoperability is often regarded as crucial for expanding a network. Clear and transparent standards for connectivity allow independent actors to add nodes to a backbone without central planning.

Interoperability is also viewed as one of the main drivers behind, though not necessarily a condition of innovation.⁶⁵ At the same time, it has been noted that interoperability naturally favours network economies of scale and should therefore be seen as a tension between connectivity, cooperation and reach on the one hand and concentration of power on the other.

Redundancy: Redundancy refers to the idea that the same network function can be carried out by more than one element. This principle may be most clearly articulated in Baran’s and Davies’ idea of packet switching. Instead of having to rely on a single, stable connection between two points to transmit data, alternative nodes would route packets through the network and compile the full message only at the destination. While redundancy does not lead to the most efficient use of network resources, it renders the network more robust and reliable. Best-effort routing can easily circumvent obstacles or defective nodes as envisioned by Baran under the scenario of a major military strike. Similarly, the redundancy built into the network can also act as an insurance against interventions at the content level, such as in the case of censorship. Sometimes these ideas are also summarized under the rubric of “robustness.”⁶⁶

End-to-end: Finally, the most famous early architectural principle is the end-to-end principle. First articulated by Saltzer, Reed & Clark, it stipulates in its technical form that “certain end-to-end functions can only be performed correctly by the end-to-end systems themselves.”⁶⁷ A more simple version is offered by RFC 1958: “The network’s job is to transmit datagrams as efficiently and flexibly as possible. Everything else should be done at the fringes.”⁶⁸ Thus the end-to-end principle assumes that the network itself performs no function beyond transmitting data packets efficiently while all additional functionality is to be done at the end points. In this regard, the Internet differs fundamentally from other technical networks such as the telephone network, where telephones remain relatively “stupid” while major functions are executed in the network.⁶⁹

⁶⁴ Urs Gasser & John Palfrey, *Breaking Down Digital Barriers*, Berkman Publication Series, November 2007, <http://cyber.law.harvard.edu/interop>, p. 4.

⁶⁵ See Gasser & Palfrey, *supra* note 64, p. 18.

⁶⁶ Communication on the Internet in the Evolving Information Infrastructure et al., *THE INTERNET’S COMING OF AGE* (2001), p. 39-40.

⁶⁷ See, e.g., Jerome H. Saltzer, David P. Reed & David D. Clark, *End-to-end Arguments in System Design*, 2 ACM TRANSACTIONS ON COMPUTER SYSTEMS 277 (1984).

⁶⁸ Carpenter, *supra* note 55.

⁶⁹ See David Isenberg, *The Rise of the Stupid Network*, <http://www.rageboy.com/stupidnet.html> (last visited May 18, 2009).

Again, this design feature is not just a technical phenomenon, but also has far-ranging social implications. For example, if a network acts as a mere transport facility, it is less likely that central points of control will emerge at the level of infrastructure, but rather at the endpoints, on the machines and devices of users and their access points to the Internet.

Recently the end-to-end principle has been criticized as too narrowly focused on a macro perspective on network structure. The argument is that the original end-to-end argument neglects the endpoints themselves, which may be of little use when locked down and not inviting user-driven innovation.⁷⁰

3.3 Some Exemplary Cases

Many of the milestones in the development of networked computing discussed in Chapter 1 exemplify these principles and the many ways they are interrelated. For example, TCP/IP was designed to be agnostic to the underlying network, positioning all major data processing functions at the endpoints of the network in the spirit of the end-to-end principle. At the same time, this allowed users to connect relatively easily across heterogeneous infrastructures and thus contributed to interoperability. By the mid-1980s, everyone with some basic technical knowledge could join the network, which allowed the network to grow without central planning or investments. In combination with packet switching, the best-effort approach embodied in TCP/IP also made specific nodes in the network redundant and therefore robust against local disruptions of or attacks on network infrastructure.

Architectural principles also can help us understand how and why certain design approaches and initiatives succeeded or failed. Many of the most successful technologies in terms of distribution and uptake were created by amateurs and geeks, who benefited from the open architecture of the Internet. Chat rooms, BBSes and e-mail were all developed on top of an interoperable and “stupid” infrastructure that allowed them to flourish. This was not the case for other network protocols and standards, most prominently X.25.⁷¹

Developed by the post and telecommunications offices of major European governments and officially standardized in 1976 by the International Telecommunications Union (ITU), X.25 was based on virtual circuits. Network functions were largely under the control of a small number of providers, operating centralized and homogeneous communications infrastructures like the French Minitel managed by the French PTT. As already indicated in Chapter 1, this approach had considerable implications. Trying to safeguard their investments, state-owned telecommunications carriers were naturally reluctant to let private companies connect to their networks. X.25 thus stood in sharp contrast to ARPANET’s TCP/IP, which could accommodate many different protocols and run on heterogeneous networks. Ultimately, this led to the X.25 protocols being overtaken by TCP/IP, the code of which was open and freely available for everyone to use.

In sum, the Internet’s early infrastructure is best characterized as an hour-glass architecture aimed at facilitating real-time and best effort communications over lossy networks. Besides the rather general notion of “openness”, key principles include interoperability, redundancy, and the end-to-end principle, exemplified and enacted by a number of protocols and standards like TCP/IP and packet switching. Though

⁷⁰ See Zittrain, *supra* note 34, pp. 2029-36.

⁷¹ See Castells, *supra* note 2, p. 25

often discussed in rather abstract terms, these principles have important policy implications by limiting control over information flows and providing guidelines for designing scalable and adaptable communications networks. As such, these principles are themselves negotiated and contested and can inform the more recent debates about IPv6 and other standards discussed later in this report.

4. Emerging Governance and Institutionalization

While architectural principles are useful for describing a complex network infrastructure from a technical perspective, they cannot capture the broader dynamics of coordination and control that take place in and around computer-mediated communication. This section describes the different forms of governance that emerged on the early Internet at different levels of the network. Governance here refers generally to the dynamics of coordination and control in a specific social setting. In order to better understand emerging governance regimes on the Internet, it seems useful to trace processes of institutionalization rather than describe the field as a static arrangement of organizations, procedures, and committees. “Internet governance” is very much a field in flux that has continuously changed its focus with new users, uses, and technology.⁷²

4.1 Network Management: RFC and Consensus-based Decision-making

One of the earliest governance regimes can be found in the area of network management. Exchanging data on a common infrastructure required at least a minimum of coordination and control at the level of technology and standards. The early patterns of interaction emerging in this area have sometimes been described as “ad hoc governance.”⁷³ Given the rather small and close-knit group of engineers and academics who were involved in the early Internet, coordination and control took largely place on an interpersonal basis wherever a problem was identified. Problems were conceptualized as mostly “technical” ones, which just needed to be “engineered” with the tools and approaches people used in their day-to-day professional work.

A good illustration of such an engineering approach is the informal “Request for Comments” (RFC) procedure that the early engineers used to exchange and coordinate their views on Internet architecture and design. Under RFC, an author or a group of authors publish a document very similar to an academic paper, in which they sketch a new idea for a standard or specification, or just share an insight they think would be valuable for others. The goal is to receive comments and feedback on an RFC document so that it can be revised, improved, or abandoned if needed and get a sense of the dominant opinion in the community. From the beginning, RFC was not designed as a formal governance instrument, defined by a set of rules or mechanisms for oversight and enforcement. Instead, RFC was first used by a group of Stanford grad students around Steve Crocker and Vint Cerf as a way to get feedback on a new idea. The junior researchers were unsure about the potential and implications of some new network elements they had developed. So instead of single-handedly implementing their ideas, they posted their proposal as RFC 1 and received valuable feedback from the community. The procedure, which did not involve any membership, procedures, or formal voting, proved useful in the eyes of those involved

⁷² See, e.g., Jeanette Hofmann, *Internet Governance: A Regulative Idea in Flux*, Unpublished Working Paper, available at

<http://duplox.wzb.eu/people/jeanette/texte/Internet%20Governance%20english%20version.pdf> (last visited July 6, 2009), p. 2.

⁷³ Castells, *supra* note 2, p. 31.

and became an early institution of governance on and of the Internet. Anyone could post or comment on an RFC, no special membership or formal qualifications were required. The documents provided a focal point for the concerns and communications of a group of technologically-inclined people and allowed for cheap and easy participation of a potentially large number of people.

Later, the RFC process was adopted by the Internet Engineering Taskforce (IETF), which started in 1985 as an informal quarterly meeting of researchers and engineers. An informal community without a legal form, it was open to anyone and became the primary institution for standard-setting at the network level.⁷⁴ A good example of the unconventional practices employed by the IETF, which differ substantially from those of other standard-setting organizations, was the mode of decision-making used in face-to-face meetings. IETF participants do not simply vote on standards and specifications but hummed to indicate their approval or disapproval; the option with clearest humming would win, if not overruled by the parallel discussion on the IETF mailing list.⁷⁵ While this may not be recommended as a universal model for group decision-making, it proved useful in the context of the culture and ethos of the IETF engineers and researchers. To illustrate the commonly held beliefs of IETF, authors often quote MIT's David Clark, an early participant in the IETF: "We reject kings, presidents and voting. We believe in rough consensus and running code".⁷⁶

4.2 Community Governance: From Netiquette to Open Source

However, reducing early Internet governance to technical standard-setting and engineering meetings, would be too narrow a perspective. As already mentioned, a large number of more or less "virtual" communities had developed on the network, centered around shared interests and activities. As a result of these new forms of social organization, new forms of governance emerged. Many mailing lists and Usenet discussion groups, for example, had developed sets of norms in response to new forms of anti-social behaviour. A common occurrence in e-mail communications was so-called flaming, i.e. increasingly hostile and insulting interactions among participants, which usually killed off the discussion.⁷⁷ In this context, a set of conventions for good behaviour in text-based online discussions emerged, which has been sometimes called "netiquette."⁷⁸ Another element of such early governance regimes were moderators, who held more or less authority or even technical powers to ban or approve individual users on mailing lists or discussion boards.

While these cases reflect comparatively simple governance regimes, much more sophisticated organizational structures can be found in areas where users collaborated on a common project. A prime example were the emerging open source projects, in which programmers worked together on a piece of software in loosely-coupled and

⁷⁴ In 1992, IETF was incorporated under the umbrella of the newly founded Internet Society, but maintained its authority in the area of Internet standards. See also Ian Brown, *Standards (Global): Internet Engineering Task Force*, in: Chris Marsden et al. (eds.), *OPTIONS FOR AND EFFECTIVENESS OF INTERNET SELF- AND CO-REGULATION* 51-60 (2008).

⁷⁵ See Paul Hoffmann, *The Tao of IETF: A Novice's Guide to the Internet Engineering Task Force*, Network Working Group, Feb. 16, 2009, <http://www.ietf.org/tao.html>.

⁷⁶ Quoted in Hoffman, *supra* note 75, Section 3. Another famous quote describing the culture of the IETF is attributed to Jon Postel: "Be conservative in what you send and liberal in what you accept."

⁷⁷ For an analysis of the reasons for "flame wars" in computer-mediated communication. See Justin Kruger, Nicholas Epley et al., *Egocentrism over Email: Can We Communicate as Well as We Think?*, 89 JOURNAL OF PERSONALITY AND SOCIAL PSYCHOLOGY 925-36 (2005).

⁷⁸ For a rough summary, see RFC 1855, *Netiquette Guidelines*, <http://tools.ietf.org/html/rfc1855> (last visited May 30, 2009). See also Mac Bride, *THE INTERNET* (1995), pp. 144-45,

computer-mediated networks. The key feature of these collaborations was full disclosure of the code produced by a participant for a specific module of the project in order to allow others to spot bugs and build upon that work to create the next best version. As Lawrence Lessig put it: “Open source and free software is like Kentucky Fried Chicken sold with the ‘original secret recipe’ printed in bold on the box.”⁷⁹

While some open source projects are small enough to be governed by consensus, larger projects have developed more complex governance arrangements.⁸⁰ Often participants in development projects are divided into core and periphery: while the periphery comprises a large number of users who can test pieces of software and spot bugs, the core consists of a small number of leaders with responsibility for certain parts of the project.⁸¹ The decision-making processes within the core can differ substantially across projects. The Mozilla community, for example, is supported by a foundation and has developed a complex system of formal and informal roles and responsibilities including module owners, peers, super-reviewers, staff, and many more.⁸² The Apache community has developed a formal system of e-mail voting for its membership.⁸³ Another more general mechanism stemmed from the dependence of most projects on a large number of contributors. Since under most open source licenses nothing prevented a group of users at least in principle from taking the code and starting their own project (a process called “forking”), there was a basic incentive to reach consensus and comply with the dominant governance regime.

These examples demonstrate that governance regimes emerged in many forms and contexts on the Internet—not just at the level of network management, but in a variety of likely and unlikely areas.

4.3 The Beginning of “Internet Governance” as an Area for Policy and Research

A feature frequently attributed to the early Internet was its ability to undermine traditional forms of governance, particularly state-based law and regulation. While the jurisdictional challenges that “virtual” computer networks posed to territorially constituted nation states were more or less intuitive, many early users experienced and conceptualized computer-mediated communication as a “space,” also referred to as “cyberspace.” This cyberspace was regarded as egalitarian by design, defying the authority of traditional political institutions.⁸⁴ This view is perhaps best illustrated in John Perry Barlow’s “Declaration of the Independence of Cyberspace,” which famously proclaimed:

Governments of the Industrial World, you weary giants of flesh and steel, I
come from Cyberspace, the new home of Mind. On behalf of the future, I ask

⁷⁹ Lawrence Lessig, *Open Source Baselines: Compared to What?*, in: Robert W. Hahn (ed.), *GOVERNMENT POLICY TOWARD OPEN SOURCE SOFTWARE* 50-68 (2002).

⁸⁰ See generally Steven Weber, *THE SUCCESS OF OPEN SOURCE* (2004).

⁸¹ Kevin Crowston & James Howison, *The Social Structure of Free and Open Source Software Development*, 10 FIRST MONDAY (2005), http://firstmonday.org/issues/issue10_2/crowston/index.html (last visited May 30, 2009).

⁸² See Mozilla Website, <http://www.mozilla.org/> (last visited May 30, 2009).

⁸³ See Weber, *supra* note 80, p. 187.

⁸⁴ See, e.g., the early academic debates in the field of cyberlaw between David R. Johnson & David G. Post, *Law and Borders – The Rise of Law in Cyberspace*, 48 STANFORD LAW REVIEW 1367 (1996) and Jack L. Goldsmith, *Against Cyberanarchy*, 65 U. CHI. L. REV. 4 (1998).

you of the past to leave us alone. You are not welcome among us. You have no sovereignty where we gather.⁸⁵

Academics argued that the Internet “radically subverts a system of rule-making based on borders between physical spaces, at least with respect to the claim that cyberspace should naturally be governed by territorially defined rules.”⁸⁶ The Internet was perceived “ungovernable” in the sense that state sovereignty could not effectively be exercised. In the absence of borders and clearly enforceable rules, it was asked what other institutions or actors would take the place of the traditional forms of political authority—if any.

In contrast to such libertarian ideas, others argued that the role of national and international law and regulation should not be underestimated and was in fact a necessary element of governance in digitally networked environments.⁸⁷ Some even questioned whether the Internet constituted a special field of regulation at all and suggested that a “law of the Internet” was as useless as a “law of the horse.”⁸⁸

New models of Internet governance were proposed, grounded in layered network architecture⁸⁹ or legal domains.⁹⁰ In a hugely influential book, Lawrence Lessig pointed out the normative role of code, i.e. the software and hardware that regulates behaviour or at least makes behaviour regulable.⁹¹ Similarly, the notion of “lex informatica” became popular, drawing an analogy to *lex mercatoria*, the non-state-based cross-border merchant law that had developed in the Middle Ages.⁹²

A key insight from these debates was that network infrastructures should not just be seen as objects of regulation, but also as regulating entities themselves that enabled or prevented certain forms of behaviour. It was these academic and policy debates over a perceived vacuum of political authority that marked the beginning of “Internet governance” as a dedicated field of study in the 1990s.⁹³

As this brief overview has shown, there has always been governance of, on, and through the Internet—albeit in many different forms. The moment people interact and start coordinating actions, they discover patterns of behaviour; reflect and articulate rules and guidelines that may develop into fully fledged institutions. In this sense, the activities of policy-makers are not too different from the academics that struggle to conceptualize governance. While analyses of early Internet governance often exclusively focus on the institutional ecosystem of network management, it is important to keep in mind that also the various online communities developed a diverse set of governance regimes. Virtually all of these developments happened in the absence or the shadow of the law.

⁸⁵ John Perry Barlow, *A Declaration of the Independence of Cyberspace*, <http://homes.eff.org/~barlow/Declaration-Final.html> (last visited May 28, 2009).

⁸⁶ Johnson & Post, *supra* note 84, p. 6.

⁸⁷ See, e.g., Goldsmith, *supra* note 84.

⁸⁸ Frank H. Easterbrook, *Cyberspace and the Law of the Horse*, 1996 U. CHI. LEGAL F. 207, 212–13.

⁸⁹ See Yochai Benkler, *THE WEALTH OF NETWORKS* (2007), chapter 12.

⁹⁰ Viktor Mayer-Schönberger, *The Shape of Governance: Analyzing the World of Internet Regulation*, 43 VA. J. INT’L L. 605, 617 (2003).

⁹¹ Lawrence Lessig *CODE, AND OTHER LAWS OF CYBERSPACE* (1998).

⁹² See Joel R. Reidenberg, *Lex Informatica: The Formation of Information Policy Rules Through Technology*, 76 TEXAS L. REV. 553 (1998).

⁹³ Cf. Hofmann, *supra* note 72, p. 6.

5. Take-off 1995: World Wide Web and Beyond

The mid-1990s are often portrayed as a key milestone in the development of the Internet. In fact, many accounts (and especially success stories) of the Internet start around 1995 when the “network of networks” became more easily accessible to a large number of people and turned into the pervasive communication infrastructure that we know today. While many factors contributed to this development, we will highlight a few of the most important in this section.

5.1 The Birth of the World Wide Web

While CERN had played a key role in the interconnection of early computer networks, it may be best known for another innovation that saw the light of the world on its Geneva premises. A young researcher by the name of Tim Berners-Lee published with his colleague Robert Cailliau a proposal for a “hyper-text project” called the “WorldWideWeb” (or “w3”) on November 12, 1990.⁹⁴ This proposal describes hyper-text as “a way to link and access information of various kinds as a web of nodes in which the user can browse at will” and proposed an implementation that would incorporate several different servers available at CERN.⁹⁵ By Christmas 1990, Berners-Lee had developed prototypes of the key elements of the web: a web browser, a web server, and a web page, which reportedly described the project itself. When on August 6, 1991 Berners-Lee published a short summary of the project on the alt.hypertext newsgroup, the web became available for the first time to a wider public.

While in hindsight the activities at CERN marked a historical milestone in the development of the Internet, the idea of a hypertext system was not new. Researchers had been working on ways to organize knowledge by linking documents since the 1940s. In 1945, Vannevar Bush published an essay in which he described a microfilm-based system called “memex,” “a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility.”⁹⁶ In 1968, Douglas Engelbart proposed the “oN-Line System,” which featured not only a graphic interface, but also a mouse, which Engelbart had co-invented with Bill English.⁹⁷ Another key figure in this development was Ted Nelson, who had coined the term “hypertext” in his 1965 book “Computer Lib/Dream Machines.”⁹⁸ Since 1960, Nelson had been working on Project Xanadu, a self-evolving hypertext system with the goal of linking all available information without simulating paper.⁹⁹ Nelson later criticized the World Wide Web for doing exactly that—“trivializ[ing] the original hypertext model with one-way ever-breaking links and no management of version or contents.”¹⁰⁰

⁹⁴ Tim Berners-Lee & Robert Cailliau, *WorldWideWeb: Proposal for a HyperText Project*, Nov. 12, 1990, available at <http://www.w3.org/Proposal.html> (last visited May 30, 2009).

⁹⁵ *Id.*

⁹⁶ Vannevar Bush, *As We May Think*, THE ATLANTIC, July 1945, available at <http://www.theatlantic.com/doc/194507/bush> (last visited May 30, 2009).

⁹⁷ Douglas Engelbart, *Study for the Development of Human Augmentation Techniques*, Final Report under Contract NAS1-5904, SRI Project 5890 for NASA Langley Research Center, Stanford Research Institute, Menlo Park, Ca., July 1968, available at <http://sloan.stanford.edu/MouseSite/Archive/Post68/FinalReport1968/study68index.html> (last visited May 30, 2009).

⁹⁸ Ted Nelson, *COMPUTER LIB/DREAM MACHINES* (1974).

⁹⁹ Project Xanadu, <http://xanadu.com/> (last visited May 30, 2009).

¹⁰⁰ *Id.*

According to commentators, a key factor in the success of the World Wide Web was the combination of hypertext and the Internet. The two technologies had largely developed in different communities so that it needed an extra effort to merge the two.¹⁰¹ Three key components provided the technical core of the web: Hypertext Transfer Protocol (HTTP), an application-level protocol for retrieving interlinked documents; Hypertext Markup Language (HTML), which provides a syntax for describing the structure of web pages, including embedded images and other interactive content; and the Uniform Resource Locator (URL), which locates a specified resource and provide a way of retrieving it. All protocols had been continuously developed and refined in the RFCs process until the late 1990s and were finally accepted as standards by the responsible committees and the World Wide Web Consortium (W3C), the international standards organization for the World Wide Web. Berners-Lee founded in October 1994.¹⁰²

One aspect that is often viewed as crucial for the success of the web from the mid-1990s was the openness and public availability of the protocols and initial software. In contrast to proprietary systems like Apple's HyperCard, the World Wide Web actively invited users to develop their own clients or add extensions. When CERN officially released the World Wide Web software into the public domain on April 30, 1993, their key motivation was "to further compatibility, common practices, and standards in networking and computer supported collaboration."¹⁰³

5.2 Browser Wars

Once Berners-Lee made the first version of his browser available on the Internet in 1991, people started building their own clients based on Berners-Lee's protocols. Early adaptations included "Erwise" in Helsinki and "Viola" at UC Berkeley. The most user-friendly version, however, was created by Marc Andreessen and Eric Nina at the University of Illinois' National Center for Supercomputer Applications. In contrast to other projects, their browser "Mosaic" could retrieve and distribute images over the Internet and also incorporated other multimedia capabilities—a major advance towards a more attractive web. After first releasing their browser on Usenet in 1993, Andreessen and Bina joined Jim Clark to set up Mosaic Communications, which later changed its name to Netscape Communications. The company developed and released the web's first commercial browser, Netscape Navigator, in December 1994.

Impressed by the success of the Netscape Navigator, other companies started to explore the market potential of the new application. Some smaller companies developed their own browsers and HTML editors like Navipress, which was later bought and used by America Online (AOL), or the Opera Software Company, which launched its Opera browser in 1996. However, the most significant competitor for Netscape became Microsoft, which had recently established itself in the emerging market for graphical operating systems.

In August 1995, Microsoft released its own browser "Internet Explorer" and distributed it as part of the Microsoft Plus! software package, which was shipped together with the Windows 95 operating system. While Netscape manage to stay on top of the market for some time, the competition over the emerging browser market

¹⁰¹ See Tim Berners-Lee, *WEAVING THE WEB* (1999).

¹⁰² See W3C – World Wide Web Consortium, <http://www.w3.org/> (last visited July 6, 2009).

¹⁰³ CERN Website, *Ten Years Public Domain for the Original Web Software*, <http://tenyears-www.web.cern.ch/tenyears-www/Welcome.html> (last visited May 18, 2009).

grew increasingly fierce. In a neck-and-neck race, Netscape Navigator and Internet Explorer courted the steadily increasing number of Internet users and tried to trump each other with new features and updates. The downside of this development, it was reported, was a neglect for the less visible, but equally important features like stability and bug fixes.

Over time, however, it became clear that Microsoft had a number of competitive advantages. First, it could cross-subsidize browser development with the earnings from its operating system sales. This was not only a strategic advantage for developing new features and extensions, but also allowed Microsoft to keep the Internet Explorer free. Second, it could bundle its browser with other software products. Beginning with Internet Explorer 4, Microsoft started integrating its browser directly into its widely used Windows operating system, which considerably increased user numbers. Third, Microsoft's engineers managed to be the first to adopt W3C specifications. Finally, Microsoft managed to make deals with AOL and Apple, and made its Internet Explorer the standard browser for their services.

In 1998, Netscape could no longer withstand Microsoft's attacks. It decided to discontinue the development of Navigator and released its source code into the public domain. Later this source code became the basis for the Mozilla project, which developed into the popular Firefox browser, a new competitor of Internet Explorer.

In the wake of the browser wars, Microsoft was accused by both the U.S. Department of Justice and the European Commission of having abused a monopoly position by bundling Internet Explorer with its operating system. While the U.S. trial ended with a settlement in 2001 in which Microsoft—among other things—was required to provide an API to third parties,¹⁰⁴ the European anti-trust case ended with a judgment in 2004, which fined Microsoft a record sum of €497 million.¹⁰⁵

This episode illustrates a number of key insights about emerging online markets. First, it demonstrates how software and platform development became a lucrative commercial activity and fiercely contested market. Second, it points to the importance of network effects and economies of scale in the emerging information economy. Third, it shows how technology—in this case the bundling of a browser application with an operating system—can be used as a design feature to achieve a (questionable) competitive advantage.

5.3 From the Net to the Web: Networked PCs, Cheap Storage and Web-based Applications

The advent of the web was an important milestone in the development of the Internet. What had started out as a computer network for file exchange between trusted parties, now offered an attractive interface that made the network user-friendly and accessible. Besides the opening of the Internet for commercial uses, three trends can be seen as crucial for this development.

The first was the new visual and interactive world the web enabled. Graphical interfaces and the interactive design of the World Wide Web turned out to be an important factor, rendering the Internet more attractive for a larger number of users. Establishing an extra layer on top of TCP/IP and the routing infrastructure, the web

¹⁰⁴ See the U.S. Department of Justice's Website for a history of the case, http://www.usdoj.gov/atr/cases/ms_index.htm (last visited May 30, 2009).

¹⁰⁵ See Commission Decision of 24.03.2004 Relating to a Proceeding under Article 82 of the EC Treaty (Case COMP/C-3/37.792 Microsoft), C(2004) 900 final.

allowed dynamic connections through hyperlinks and tags, which could be easily accessed via browsers. Users could add images to text, displayed with fully rendered fonts and colours—a remarkable improvement compared to the previous typographical monoculture of ASCII code. New tools like Macromedia Flash were able to display animated images and later full motion video. With the Hypertext Transfer Protocol Secure (HTTPS), secure connections could be established and used for exchanging sensitive data, like payment details. And JavaScript enabled access to content in other applications, making websites increasingly dynamic. All these technical innovations contributed to a genuine multimedia platform that enabled new uses and became increasingly attractive for commercial applications (see Figure 2).

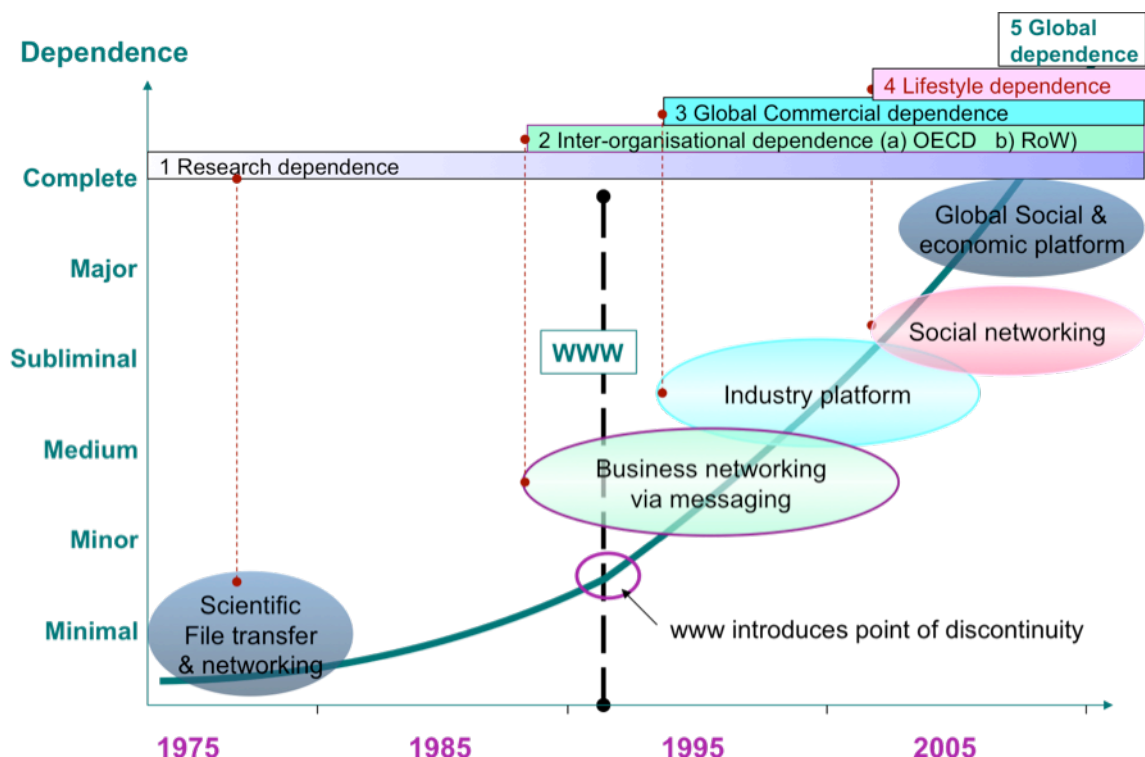


Figure 2: Internet Take-off
(Source: Simon Forge)

A second trend is often overlooked. The development of the Internet as a network of connected PCs rather than a proprietary network of information appliances was of crucial importance for its growth and adaptability.¹⁰⁶

The early large-scale networks like CompuServe or Prodigy were designed as “walled gardens” that connected subscribed members only with content approved by network operators.¹⁰⁷ For a long time, the ability of ordinary PCs to connect directly to the Internet was limited; users had to sign up for the proprietary networks to take advantage of applications like e-mail, chat or early online games. This only changed with the release of Trumpet Winsock, software that allowed PC owners under Microsoft Windows to establish a direct TCP/IP connection with the servers of the

¹⁰⁶ See Zittrain, *supra* note 34, p. 1990-91.

¹⁰⁷ *Id.*, p. 1991.

newly emerging ISPs.¹⁰⁸ Winsock enabled PC owners to bypass the proprietary networks run by commercial intermediaries. These services became decreasingly useful and hence many of the early full-scale online service operators become mere access providers and ISPs. When Microsoft started bundling Winsock with later versions of Windows 95, this trend became overwhelming.

A third trend concerned the steady increase in computing power, bandwidth and storage capacity. Already in 1965 Intel founder Gordon Moore had predicted that the number of transistors per integrated circuit would double roughly every 18-24 months.¹⁰⁹ This estimate, which came to be known as “Moore’s Law”, has proven remarkably accurate (see Figure 3).

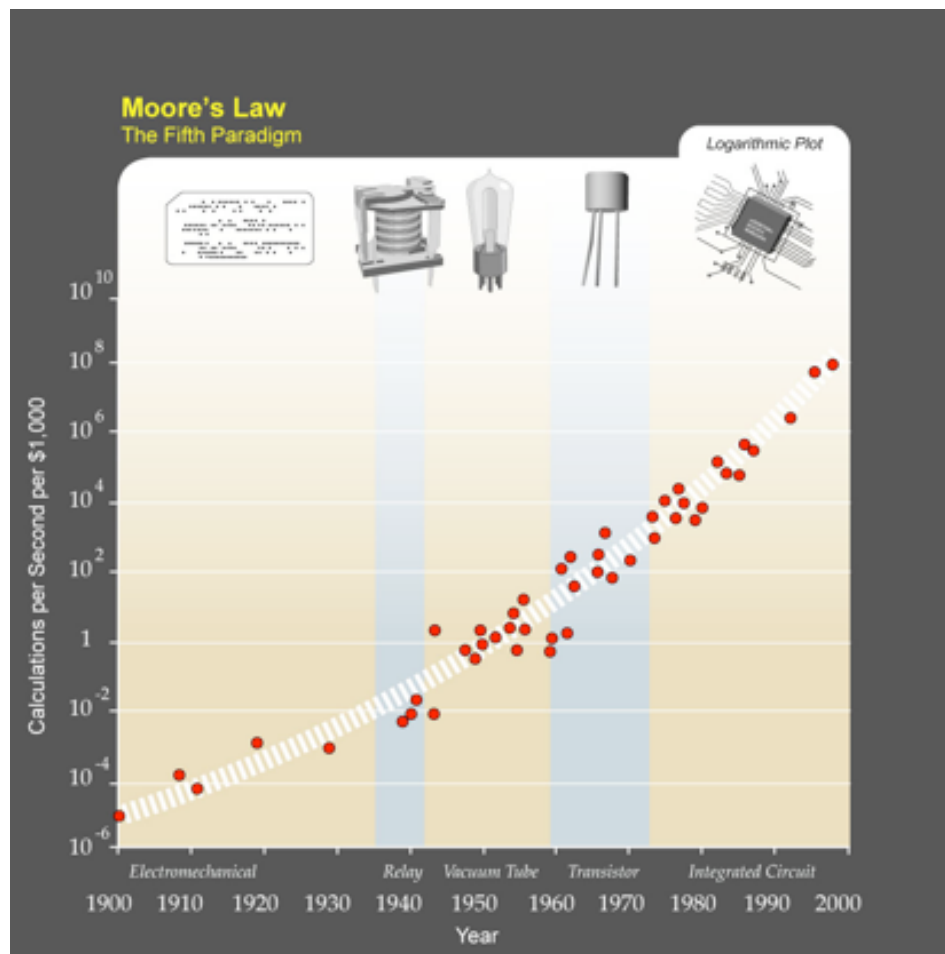


Figure 3: Moore's Law
(Source: Ray Kurzweil, *The Law of Accelerating Returns* (2001))

As a consequence, PC prices fell rapidly: an enormous reduction in price:performance could be observed from 1980 to 2000 for the equivalent computing device. In addition, telecom industries in both Europe and the U.S. were deregulated from the 1980s on and transitioned from the stranglehold of state control to the competition of markets. This further lowered the costs of telecommunications services and allowed an increasing number of people to access the new computer networks.

¹⁰⁸ Winsock Trumpet had been authored by Peter Tattam, a hobbyist, who worked in the psychology department of the University of Tasmania. See Zittrain, *supra* note 34, p. 1992.

¹⁰⁹ Gordon Moore, *Cramming More Components Onto Integrated Circuits*, 38 ELECTRONICS MAGAZINE (1965).

Thus, the combination of the increased connectivity of ordinary PCs, cheap and easy access to computing capacity, storage, and bandwidth, as well as the emergence user-friendly interfaces of the new web technologies turned the Internet into a mass medium. With the steady influx of new users and businesses, the amount of information available on the web exploded. The first search engine providers emerged and offered sophisticated taxonomies and algorithms to sort through indexed content. The businesses of the “new economy” took advantage of the new scalability and started peer-to-peer marketplaces like eBay or online retailers like Amazon. While some organizations like CNN brought their old skills to the web, others like PayPal developed completely new business models. Web-based e-mail was increasingly offered for free to users, financed by advertising in banners and e-mail signatures. And file-sharing systems like Napster allowed users to easily share their music with total strangers. By 2000 the Internet had developed into a truly interconnected network of individual PCs, providing access to the graphical world of the web and other interactive, networked applications.



In conclusion, it is possible to extract a number of lessons from the analysis in Part I. While the history of the Internet can be told in many different ways and the account given here is by no means comprehensive, a few lessons stand out.

First, even though a historical account of the evolution of the Internet appears necessarily ordered and path-dependent, it is important to acknowledge the overall messiness and contingency of the process. The idea of an “Internet” is the result of a complex set of interactions between a large number of people, often mediated by technologies. Consequently, what the Internet is at any given point in time has changed radically over the decades.¹¹² Originally conceptualized as a solution to the rather narrowly defined problem of time-sharing in view of scarce computing resources, it soon became a medium for file exchange between trusted parties, developing into the pervasive multimedia platform of the World Wide Web. As many observers pointed out, this development was not so much driven by the “vision”, “foresight”, and “planning” of a small number of chosen experts, but by accidents, coincidents, boredom, procrastination, tinkering, and trial-and-error of a large and uncoordinated group of people.¹¹³ The freedom to tinker on an open platform without major financial or institutional constraints played a key role for both the well-funded ARPANET researchers and the countless amateurs, businessmen and private users.

Second, it would be misleading to regard the Internet exclusively as a technical phenomenon. As the history of networked computing and its social dynamics have shown, social and economic dynamics played a crucial role from the very beginning. The diverse and not always research-related motivations of computer scientists at ARPA, UCL, CERN and other institutions turned out to be as relevant as the many smaller communities of hackers and hobbyists that formed around BBSes and university networks. The Internet has consequently been characterized as a “cultural creation”,¹¹⁴ which is “as much a collection of communities as a collection of

¹¹² Cf. Abbate, *supra* note 2, p. 6.

¹¹³ See, e.g., Segal, *supra* note 1.

¹¹⁴ Castells, *supra* note 2, p. 33.

technologies”.¹¹⁵ Against this backdrop, it is not surprising that analyses that take network design and standard setting as their starting points and assume that everything else will follow, are likely to be of only limited use.

Third, it is noteworthy that the Internet was not the direct result of any government program or activity—it was neither planned nor “plannable”. While it is true that ARPA funded the initial research, the general policy was to provide researchers with a great deal of freedom and autonomy to do whatever they saw fit. The same was true for the diverse ways in which business models and applications evolved. This policy stands in sharp contrast to European attempts at the state and industry level to develop and decide on how a future Internet should look like in order to pursue specific goals.

Fourth, such distributed creativity was also possible because of the way the technical infrastructure had developed—arguably best described with architectural principles like “openness”, interoperability, redundancy and end-to-end. While allowing a large number of amateurs to access, build on, and expand the existing grid may not have been a sufficient condition for innovation, it turned out to be highly beneficial for unleashing the initiative of a large number of people.

Fifth, it is important to realize that this form of distributed creativity can be found at many different levels of the network. While network design and standard setting are obvious examples, also the development of applications, business models and even regulation and policy-making can rely on new distributions of power and authority. The cases of open source development teams, virtual communities, or the IETF provide vivid examples.

Yet, while all these are important insights, it is important to keep in mind that these regimes and dynamics often emerged under highly idiosyncratic circumstances and to a large extent have been social and historically contingent. The challenge is therefore to tackle these issues with an open mind and draw on our historical experience without idealizing it.

¹¹⁵ Barry M. Leiner et al., *A Brief History of the Internet*, available at <http://www.isoc.org/internet/history/brief.shtml> (last visited July 6, 2009).