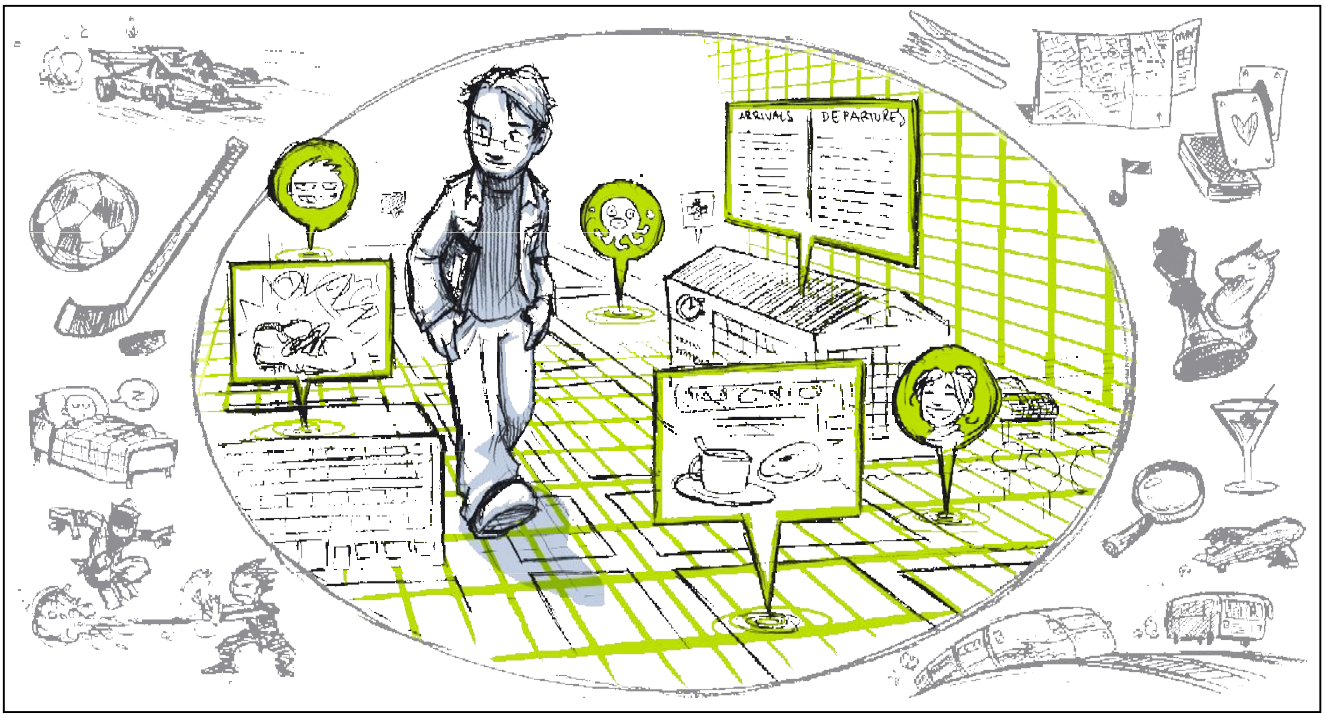

DEVICES AND INTEROPERABILITY ECOSYSTEM (DIEM)

Project in TIVIT (ICT SHOK)

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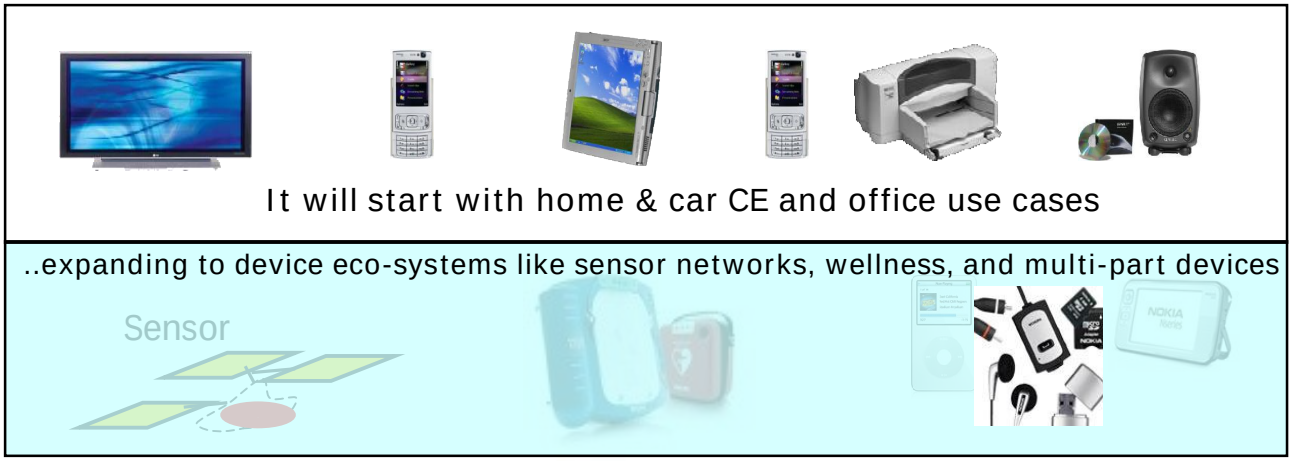
1 Introduction

ICT SHOK Devices and Interoperability Ecosystem (DIEM) project targets to define and open a completely new domain for technology and service innovation in a global scale. The project targets to enable news services and applications that are based smart environments that comprise of digital devices containing relevant information for different purposes. The key is interoperability between devices from different domains.



The enabling technologies for both computing and communication have matured to a level where cost efficient use of embedded, ubiquitous technologies makes sense. There exists of almost a plethora of communication technologies and standards for local communication needs that address low power, long battery life, extremely low cost, scalable performance, short or medium range, or several of these attributes simultaneously. The challenge of bringing in new functionality and smartness in a given space is typically first in the interoperability but very much also on the information level. The big opportunity is to bring the underlying information available to be used by others, i.e. other devices or services build on several devices.

From the user aspect, continually evolving information and communication technologies (ICTs) touch nearly every aspect of our contemporary life. Introduction of new applications or services must address the human dimension of technology. In the ambient services that use ubiquitous technologies, this human technology interaction will in nearest future extend to much more complex field of everyday life that it has been so far. Smart environment technologies presuppose indirect and proactive ways of interacting with people. In principle, technology is always intended for human use; it is designed to satisfy human needs and to aid people in reaching their goals.

2 Project plan

2.1 Summary

Name of the project: **Devices and Interoperability Ecosystems, DIEM**

Duration of the projects: **2+2 years, starting from 12.5.2008. This application is for the first two years.**

The big mission of the project is to create the concept and implementation of generic and scalable smart space interoperability solution and platform, which can be adapted to various domains and application. The main drivers are multivendor device environments; ease on use and intuitivity, and new application development paradigm. A key connection of the project is the Artemis subprogamme 3 on Smart environments. The intention is to contribute the findings to the Smart environment subprogramme and extend the ecosystem also with major European players in the field.

Concrete breakthroughs will be

- Internet like revolution in local spaces with interoperability solution that can scale to different domains and adopt to device legacy
- Smart application creation scheme, which mobilizes the domain experts and users of environments as the application developers
- Cutting edge research contribution in the global smart space and ubicom research area through journal

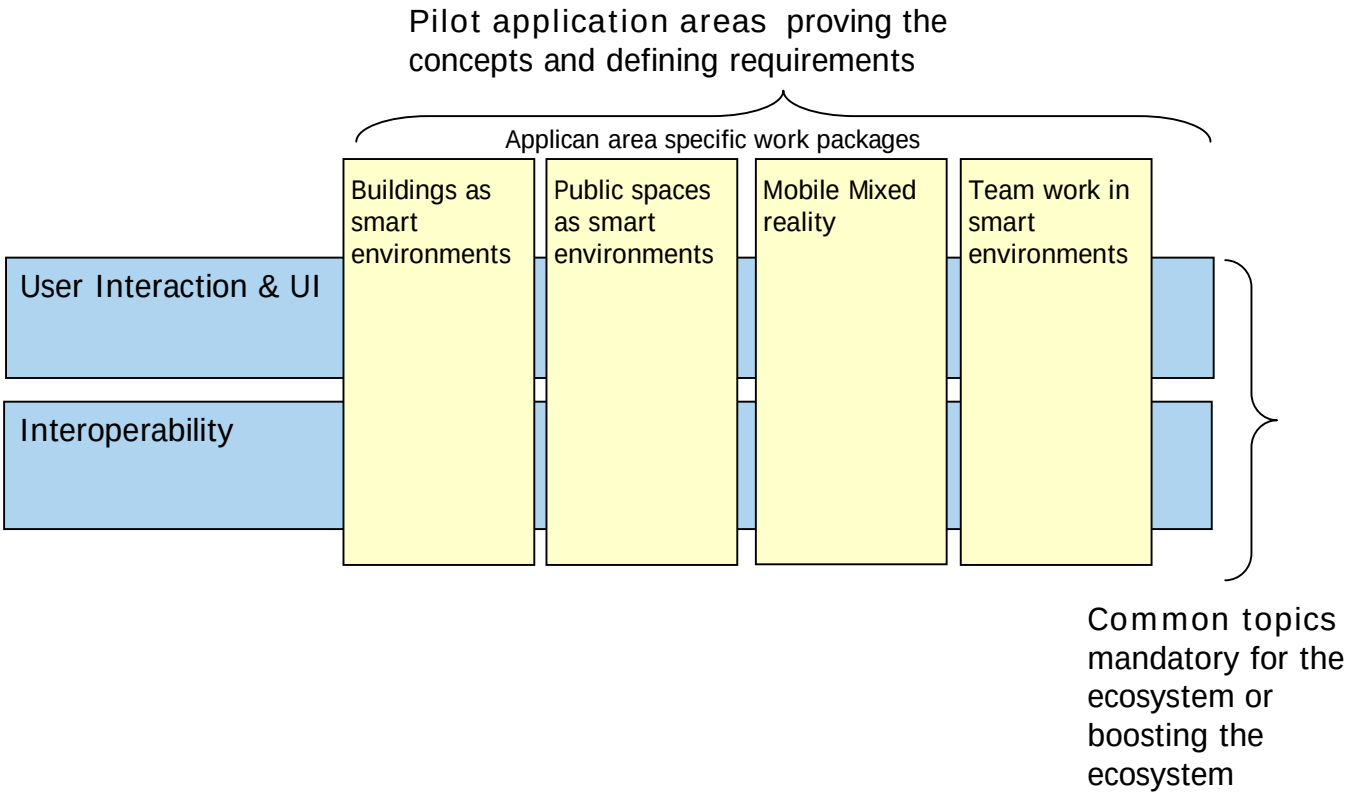
The basic structure of the project is an integrated project, which has a dual approach of vertical work packages for selected application areas and horizontal work packages driven the key elements of creating the ecosystem for device interoperability.

Major project deliverables are

- Interoperability platform, which will evolve to de-facto standard
- Common user interaction methods and solutions that provide ease of use and can foster adoption of new services across different domains and spaces
- New kinds of application and services in the piloted areas, which represent new ways of working, and which are basis for new businesses
- Smart space demonstrators integrating shared information and services from several domains demonstrating the capability of open innovation platform

2.1.1 Work package structure and summary

The project has a dual approach of vertical work packages for selected application areas and horizontal work packages driven the key elements of creating the ecosystem for device interoperability. The horizontal work packages are driving for general solutions for key aspects of the project mission and vertical packages are setting requirements and piloting the solutions and concepts in various applications areas. These areas are representing different environments, applications and business models.



The project may be added with additional application areas.

2.2 Participants

The project follows a work packages structure so the participants are presented per by work package.

Project management	
Nokia	Project lead and coordination
User interaction and UI	
UTA/TAUCHI	Work package leader, constructive user interface research, multimodal interaction
VTT	User's role in smart environments, multimodal interaction techniques
TUT / IHTE	User experience design and evaluation
Nokia	Multimodal multi-device interaction
Oulu University	Computer vision, gestural interaction
Sun Microsystems	Runtimes for UI
TUT/SW	Runtimes for UI
Nomovok	Runtime implementations for UI
VTI	Accelerometers and gestural interaction
Interoperability	
VTT	Work package leader, smart spaces, middleware, interoperability research
HUT	Ontologies, dynamic configurability, interfacing, connectivity

Åbo Akademi	Rapid prototyping tools for interoperability platform
Nokia	Device, service and information level interoperability research and implementation.
Building automation	
STOK	Work package leader
Ensto	Device driver and application development
Logica	Service interfaces and user interfaces
Nokia	Technology provider and system integrator
Norpe	Device driver development
Oras	Device driver development
TAC	Information security and application development
Siemens	Platform, device driver and application development
YIT	Service development and piloting
Edge	Device driver development
Fatman	Service development and piloting
Hermia	Small house piloting
ProgICT	Service development and piloting
TKK/AS	Service development and piloting
TKK/ME	Planning, management; core, driver, service and UI development
TKK/ELE	Device driver development
TKK/Talo	Service development and piloting coordinator
VTT	Planning, piloting; core, driver and service development
TAMK	Device driver development
Public spaces	
City of Oulu	Work package leader. Piloting environment owner. Defining user requirements and community services. Piloting services for citizens.
VTT	Service concepts and business studies, support industrial pilots. Creation of piloting and testing environment. Defining needs of interoperability ecosystems.
UoO	Service concepts, support industrial pilots. Defining user requirements and business models
Polar	Technology and services development, piloting personal devices and novel services
Incode	Technology and services development, piloting personal devices and novel services for handicapped and other special groups
HeathEx	Defining user requirements and business models. Piloting smart sporting environment concepts and services.
HUR	Training devices and human interaction, device development
HP	Piloting new devices and services. Service platform development. Social context.
Nokia	Technology and services development, piloting personal devices and novel services.
Planray	Access management. User-building –interaction.
Fidelix,	User-building –interaction. Building automation and facility management.
Snowpolis (+partners)	User requirements and SPEXS-concept development. Piloting devices and services.
Mobile mixed reality	
Nokia	Work package leader. Enabling technologies, application development and service pilots.
Sesca Mobile Software	Application development – integration of algorithms for applications.

Helsinki University of Technology	Development of the enabling technologies – SW algorithms, and SW and HW solutions.
Tampere University of Technology / IHTE	User-centric design – evaluation and optimization of the user experience.
VTT	Application development – integration of algorithms for applications. Service pilots.
Team work	
Nokia	WP leader, pilot case provider, technology enablers
VTT	Main role: technology enablers, secondary role: service concepts and business studies, will also support industrial pilots.
University of Jyväskylä	Main role: human & organizational research, secondary roles in technology enablers and business studies
Movial	Technology enablers, user research
Humap	Technology enablers, human & organizational research
Itella	Case definition and trial

Responsible persons and work package leaders:

DI project leader: Petri Liuha, Nokia

User Interaction and UI, work package leader: Roope Raisamo, UTA

Interoperability, work package leader: Juha-Pekka Soininen, VTT

Building automation, work package leader: Fredrik von Schoultz, STOK/Posintra

Public spaces, work package leader: Vesa Tornberg, Polar

Mobile mixed reality, work package leader: Ville-Veikko Mattila, Nokia

Team work, work package leader: Jari Tuhkanen, Nokia

2.3 Objectives

The main objective of the Devices and interoperability ecosystem project is to create an ecosystem that

- develops enablers for device interoperability
- defines system architectures supported with tools and methods for the exploitation of services and information in those environments
- creates proof of concepts and complete service pilots and demonstrators that can be exploited globally
- develops efficient and scientifically justified methodology and industrial practice to user analyses

The big vision is to extend human senses to the sensing of local and also global information through Internet. The possibility to use and exploit the data, information and services that can be made available from our proximity opens up a huge potential for improving the quality of life and efficiency. The impact to the society can be as profound as Internet's impact. The business potential includes the device manufactures, service

developers and the industry capable of making their own processes more efficient through the use of smart environment.

The emergence of smart environment and the ecosystem requires solutions to technical, social, and business challenges. Technical challenges are related to how to make devices able to communicate and understand each other. There are issues at physical, service and application layers that need to be solved before interoperability can be achieved. In the social domain, the privacy, security and usability are most important topics. It is unknown in what degree and in what conditions the people are ready to use this kind of services. In business domain the openness, standardization and earning logic need to be considered.

The breakthrough targets can be summarized:

- DIEM project has created solutions that are the foundation for scalable local digital services and devices in heterogeneous application areas.
    - These solutions bring in the a large amount of installed base of devices and digital user data to a new local information ecosystem.
- DIEM solutions are successfully deployed in the selected application fields with first real business cases, and first new applications and services.
    - The solutions are also piloted in new applications fields and promoted through international forums and other related initiatives.
- DIEM has achieved in seven years
    - New businesses with start-ups or extended business activities in participating companies in at least 20 application areas.
    - DIEM solutions produce or capture annual business value of $ 5B for the technology providers, device manufacturers and service operators involved.
    - Emerging application developer community with >100k developers in companies, and universities.
    - Head start for Finnish companies and research

2.4 Project background and research themes

The communication capabilities and computing capacity of both portable and embedded devices plus the ongoing development in the areas of sensor networks, ad hoc networking, location-based services are all examples of foreseen possibilities of local, networked and heterogeneous smart environments where different kind of contextual and user information can be accumulated and used for new purposes, and for eventually services and businesses.

The project has the dual approach of vertical and horizontal work packages.

2.4.1 Connection to SHOK vision, objectives and strategic research

The project addresses the Devices and Interoperability SRA as a whole with an integrated project approach. It pushes the long-term digitalization trend especially in the areas of local and location based applications, where the connection to physical objects and to different kinds of devices is essential. In broad terms, it aims to create structure for the fragmented local digital information and ease-of-use and basis for new innovation in the area. Key aspect is ecosystem development. This is addressed by fundamental research on key areas, which are the user interaction and interoperability, and with four (now planned) application areas.

2.4.2 Analysis of the current state of the project area, future challenges and opportunities, and main development needs

Device and Interoperability Ecosystems project relates to smart environment or smart spaces research that is also called ubiquitous computing, ambient intelligence or Internet of Things depending on the point of view. Ubiquitous computing has been the third main computing paradigm after mainframe and personal computing. The idea is to embed the computing to everything in our environment. The first main ideas of ubiquitous computing were invented at 1988 and since then the theme has been under active research.

In spite of 30 years of research the commercial success stories of ubiquitous computing are very limited. Touch-based approaches (near field communication, RFID) are the best example of local information sharing. They are rapidly becoming very popular in logistics as an efficient way of storing and sharing data. Some research examples exist where tags are used as interfaces to more complex services or functionality, but applicability is limited due to touching requirement and data transfer and processing capacity.

When interoperability is extended to more complex services the typical solution has been to connect interoperable objects to Internet and to let Internet technologies solve the problems. Internet related interoperability research has also been active and it has produced working solutions to many issues. The problem is overheads in complexity, energy efficiency and performance. Overheads are caused by connectivity issues (communication, protocol headers, etc.), security, privacy, positioning, etc. In case of local, physical space related interoperability these overheads are in many cases not acceptable and can even prevent feasible solutions.

UPnP and DLNA are examples of interoperability solutions to specific application areas, i.e. home entertainment where short range radios are applied. Sensor network technologies and ad-hoc network research have also produced commercial products, but they are still very limited.

The biggest challenge of local interoperability is the lack of common backplane or platform where interoperable devices could connect. In the Internet the TCP/IP protocol is such manufacturer independent open platform. The common platform is focus area of interoperability work package and it enables new kind of mash-up applications that use information and services of interoperable devices. There are three basic reasons why common platform is missing.

Firstly, the industry has not wanted it. Companies have traditionally wanted to provide complete solutions that are based on proprietary technologies. Separation of platform and applications that is a consequence of common platform opens competition in the application side. Common platform also means opening of the product to others and this has been seen dangerous and expensive.

Secondly, the development of systems requiring interoperability has been done from application domain perspective. There are research projects aiming at smart environments for elderly people, health care, etc. In such projects the solutions are naturally biased towards filling the requirements of applications that make it impossible to apply the results efficiently in other domains. The outcome has been experimental proprietary solutions that cannot be taken to global markets.

Thirdly, the idea convergence is relatively new. The research has been technology oriented and trying to solve interoperability from technology perspective results to overkill solutions that do not scale to the needs.

The second major challenge is to understand the role of physical space in the development of smart space concepts and applications. All physical spaces are owned by someone, who at the end decides what kind of infrastructure and services exist in the space.

Our environment is relatively fixed. Typical life-cycle of a building is 50-100 years. We need to take into account the existing legacy. Smart environment solutions must be such that existing devices and structures can be included and solutions for connecting them needs to be developed as planned in building automation work package. Physical spaces are also dynamic by nature. The set of devices, appliances, and objects that can be part of smart environment changes over time.

The space is also the interface to applications. In case of interoperable devices the user interface is not necessarily a single device, but the complete space and the user experience is not necessarily achieved though the device, but through the space. These issues will be studied in user interaction and mixed reality work packages.

The third main challenge is to promote the sharing of information, functionality and resources of devices. The vision is that all devices and appliances in our physical space share information so that new and innovative applications can be easily developed on the top of this “innovation platform”. The sharing is not obvious from single device perspective since the benefits are not direct, but comes from the combined experience of all devices and objects as it will studied in public space work and teamwork work packages.

The common interoperability platform can create a similar kind of boost to ubiquitous computing that TCP/IP did for mainframe computing and HTTP did for personal computing. The key issue is to develop solutions that enable the emergence of innovation platform of physical spaces. The criteria are reusability of services by all applications, simplicity of adding interoperability capability to current environments and new products, simplicity of use, small overheads, scalability to various uses and environments, and support for open innovation.

2.4.2.1 User interfaces and interaction

The present mobile user interfaces can be difficult to use: the user needs to navigate menus on a small screen and enter text using a small keypad. The challenges are even greater when the ongoing activity prevents full focus to the interaction or prevents keeping the terminal stable. Physical and multimodal user interfaces offer a viable solution for this problem. When the terminal can be commanded with simple physical actions, the user does not need to interrupt the ongoing activity to operate the terminal's UI. The end users can interact with the environments using natural interaction techniques, including speech, haptics, gestures and visual user interfaces.

Improving the input and output capabilities of mobile devices has much focus within the human-computer interaction research field at the present time. Researchers are investigating the design of new keyboards and gestures for input (Williamson, 2007). These can reduce the bottleneck of inputting information and allow for easier input when the user is actually mobile. For output tactile displays (Brown, 2006, Brewster, 2007), audio (Brewster, 2002) and 3D audio (Marentakis, 2006) have been investigated. These techniques have been shown to improve interactions on the move, allowing people to input text more reliably and get a rich display of information. In this project we extend the research on this kind of novel interaction techniques used in multidevice, multimodal context.

References:

Brewster, S.A. Overcoming the Lack of Screen Space on Mobile Computers. Personal and Ubiquitous Computing, 6 (3), 2002, 188-205.

Brewster, S.A., F. Chohan, and L.M. Brown. Tactile Feedback for Mobile Interactions. In Proceedings of ACM CHI 2007.(San Jose, CA), ACM Press, 159-162.

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Marentakis, G.N. and Brewster, S.A., Effects of Feedback, Mobility and Index of Difficulty on Deictic Spatial Audio Target Acquisition in the Horizontal Plane. In Proceedings of ACM CHI 2006 (Montreal, Canada, 2006), ACM Press, 359-368.

Williamson, J., Murray-Smith, R., Hughes, S. Shoogle: Multimodal Excitatory Interaction on Mobile Devices. In: Proceedings of ACM CHI 2007 (San Jose, CA), ACM Press, 121-124.

2.4.2.2 State of the art of the interoperability work package

Interoperability work package focuses on the smart environment concepts in general, on the description of information in the environment and on the design methods of applications. The implementation issues as technological problems and new communication solutions are out the scope.

Smart spaces and ubicom research

Ubiquitous computing research has resulted to significant amount of scientific publications. In IEEE Explorer alone there almost 3000 references (more than 360 journal articles) related to ubiquitous computing, almost 200 related to ambient intelligence and smart spaces each. In these works vast amount of different approaches are presented. However, in the recent survey by (Alahuhta and Ailisto 2008), it is noted that the research typically deals with personal and person related data, it is application specific, and has strong links to Internet and Web-technologies. Serious attempts to create standards or open interoperability solutions are missing.

Reference: Alahuhta, P. & Ailisto, H.: Review of Ubicomp Research Directions between 1999-2007, Submitted to Ubicomp 2008.

Service description ontologies

Existing semantic approaches for describing the services, including their functional capabilities, QoS, and context, have following advantages and disadvantages:

– Several service ontologies contribute to the service creation, provision, and execution to a varying extent by using different description languages. Web Ontology Language for Services (OWL-S), Web Service Modeling Ontology (WSMO) and Internet Reasoning Service (IRS) provide specific ontology building blocks for particular purposes of use. Conversely, METEOR-S targets the extension and integration of the existent Web Services and Semantic Web technologies. OWL-S, the most widely used approach, combines the expressiveness of description logics, as it builds on OWL. The WSMO is a relatively new effort and is based on the Web Service Modeling Framework (WSMF). All of the approaches provide specific advantages that are missing from another approach. However, the approaches do not individually provide complete description support for service semantics.

– The existing QoS ontologies address different ontology layers. A lack of completeness is common for all approaches; only one or a few qualities are considered, and the vocabulary or/and metrics are missing. Moreover, there is no support for making tradeoffs between quality attributes or managing QoS at run-time.

– The most popular context ontologies are: Context Ontology Language, Context Broker Architecture, Service-Oriented Context-Aware Middleware, COntext MAnagement oNTOlogy and Standard Ontology for Ubiquitous and Pervasive Applications. Most of the approaches address the vocabulary ontology needs in the domain of pervasive computing. The context ontologies include a set of vocabularies for describing people, agents, and places, as well as a set of properties and relationships that are associated with these basic concepts. However, rather little emphasis is placed on services, including their functional properties and related aspects, such as user interfaces and devices on which these services are deployed, along with temporal contextual information. No attempts have been made to align service and context ontologies.

Several freeware and commercial tools to support the development and use of ontologies are currently available: SWOOP is a hypermedia based OWL ontology editor; Protégé is a free, open source ontology editor and knowledgebase framework; TopBraid Composer™ is an enterprise class platform. From the service modeling perspective, what is missing in those tools are the features that would make the contextual semantic information related to service descriptions easier to understand and to be used by an application developer. The visualization support is limited to mainly showing the abstract structural relations of the ontology classes and their instances. These tools are not well suited for understanding and modeling the semantic relations and services in a complex dynamic physical world related to application scenarios. This leaves the step of adopting semantic approaches in service oriented application development excessively high for most programmers.

This project will go beyond the state of the art by enhancing ontology engineering by a stakeholder-centric modeling approach and providing support for i) developing industry strength business ontologies, ii) generic ontologies for QoS metrics and QoS execution management, iii) application specific domain ontologies and iv) integrated orchestration

of the developed ontologies in service engineering practices. Furthermore, developer tools will be provided with specific support for software engineers and system administrators including the engineering of semantic services, their deployment, and subsequent management.

Reference:

Kantorovitch, J., Niemelä, E., Service Description Ontologies, Encyclopedia of Information Science and Technology, Second Edition, in press.

Development methodology

Model Driven Development (MDD), a multi-paradigm approach, focuses on models as primary artefacts. The architectural description is organised by views, which conform to the viewpoints selected. A viewpoint covers one or more concerns of one or more stakeholders who are interested in the architecture. MDA (Model-Driven Architecture) provides a standardization framework for MDD. The Foundation Models in the context of MDA are instances of meta models of the Meta-Object Facility (MOF) consisting of model elements and links between them.

Quality driven architecting methods contribute defining quality properties in architecture design by providing methods for selecting an appropriate software architecture, capturing and mapping quality requirements to the architecture, and evaluating the maturity and quality of the architecture. Quality evaluation methods are scenario-based methods or predictive methods. Scenario-based methods start from usage scenarios and produce mostly qualitative results on how well the architecture meets the quality requirements. Predictive methods use mathematical models and algorithms for predicting quality characteristics of the architecture (or a system) by using estimates (in early phase) and/or measurements (when available).

MDA and Service Oriented Architecture (SOA) communities are focusing on ontology oriented service development and advantages of ontology driven architecture development. SOA is an architectural style that values coarse-grained loosely-coupled components that relate closely to real-world business functions. Ontologies act as glue by integrating architectural knowledge with service development and evolution aspects enabling effective quality control.

The development of ontology has realized a lot of attention in the past years. To this end, several technologies for implementing ontology driven systems already exist. The applicants have worked with a combination of Eclipse for the application development environment, OWL for the ontology modelling, and Jena for the ontology file management. So the existing ontology-based modelling system including ontology document management, ontology query and modelling already exists and deserves as a basis for integrating the ontology based approaches into the security modelling and monitoring.

This project aims at going beyond the state of the art by:

– Combining model and quality driven development in service creation, deployment and management.

– Strengthening the model and quality driven service development by service ontologies which include functional and non-functional descriptions of services and their contexts.

– Developing tools for service and application developers that support model and quality driven development based on a combined usage of the developed service ontologies.

2.4.2.3 State-of-the-art in building automation

The development of the Building Automation gateway has already started in former projects by STOK and TKK. Results, including prototype oBIX server from the AVO/oFMS project, will be utilized in the project to help the development. Also, all other significant BA web services standards are taken into account and will be implemented if seen necessary. Project has important connections to other notable projects that are currently running or have already ended.

Since 2001, TKK has been developing information architectures and systems for an "Internet of Things" that would make information about any "Thing" (product, device, shipment, domestic appliance, building etc.) accessible and possibly allow these "Things" to communicate actively. The system was initially developed in the Dialog project in 2001 and is being further developed in PROMISE and TraSer EU projects. Both the experience and possibly pieces of software (published under LGPL) will be used in the current project.

I3CON - Industrialised, Integrated, Intelligent Construction is a four-year (2006-2010) EU Integrated Project (IP) targeting to the transformation towards European construction industry delivering Industrially produced, Integrated and Intelligent building systems using distributed control systems with embedded sensors and ambient user interfaces extended by wireless sensor networks. New value based business models for the delivery of high performance spaces, smart business services and lifecycle solutions are also key areas of the research. VTT is responsible e.g. for the development of methods and applications for standard and SOA/Web Service based new integrated building information services. The integration will cover real-time information from building automation systems and product model information from Building Information Model.

PARK (Pelastusautoon raportoiva kiinteistö) was a collaborative industrial project carried out in 2003-2007. The outcome of the project was the SOA/Web Services based emergency management support system (PARK system), which produces focused real time information about the building in fire into the moving rescue vehicle. The PARK system combines the location based real time information from life safety and other building automation and information systems with static FM information. Presently the system is in piloting phase in several big buildings in Finland. VTT has been responsible for the software development of that system.

2.4.2.4 State of the art in public spaces as smart environment area

In the area of Public spaces as smart environment (PS), research and existing applications concentrate mostly to exploit sensors and sensor networks and to increase applications' context-awareness. In sporting environments, especially in stadiums, RFID and smart card based applications are used to the automated access control, which can also be connected to Customer Relationship Management systems. Other services provided through these systems are quite traditional, e.g. product advertisement or sport information. These kind of information systems are used e.g. in the Manchester Stadium (UK) and Cardinals Stadium (Arizona, USA). In world-class sports there are going on many research projects concentrating to measure performance through sensors in practice environment. Also athletes' different stress and physical values are transferred

to the system (University of Cambridge). In the area of personal telehealth The Continua Health Alliance (comprised of technology, medical device and health care industry leaders around the world, www.continuaalliance.org/) is dedicated to make it reality.

Living Lab – Projects in Finland (e.g. Forum Virium and Snowpolis) are starting up and some of them are connected to European Network of Living Labs (ENoLL). The SmartTouch project (ITEA) is the largest effort on piloting Near Field Communication technology in the European Union. SmartTouch explores the use of touch-based user interaction to demonstrate new and innovative mobile services. There also have been projects to study intelligent sport environments, sport technology applications and to define platform architectures for these systems. These projects haven't yet leaded to breakthroughs.

This PS project lean on R&D work mentioned before and produce new type of outlines there user/customers needs are fulfilled assistance of totally interoperable devices and services integrated in physical environment. Real time interaction between domains, service user, service provider and ambient public space enables the environment to become an active ingredient of the service provision

2.4.2.5 State of the art in mobile mixed reality area

The rapidly increasing penetration of mobile phones equipped with cameras has brought for the first time a SW development platform available enabling the introduction of augmented reality-based (AR) applications for masses. The fragmentation of the platform implementations between manufacturers has however required optimizations of the developed applications. Here, ARToolKit and ARToolKitPlus SW libraries have typically been adopted as the starting solutions for marker-based registration between real and virtual displays. In Khronos, the OpenGL ES standardization has created more unified, low-level application programming interfaces for 3D graphics programming. The increasing display resolution of new mobile devices together with the introduction of 3D graphics acceleration HW provide means for more natural alignment of real and virtual displays. In addition, the improvements in camera technologies, considering increasing capture resolution and better optics, contribute to more natural AR. Moreover, the integration of location tracking technologies, such as GPS, Cell-ID and triangulation, to mobile devices and wireless broadband connections are important steps forward for mixed reality consumer applications.

In Finland, VTT has developed AR applications for mobile devices, particularly for architecture design and furnishing. These solutions have been based on marker tracking and client-server system architecture. VTT's AROnSite is a mobile augmenting implementation on ultra-mobile PC, based on map location and GPS information, and vision based tracking with interactive initialization. Nokia's MARA project has gained worldwide attention by providing an MMR interface on mobile phone (with compass and gyrometer) to annotate buildings and identify people in the surrounding environments. A more recent prototype system by Nokia performs locationing and tracking by proactive search of features from image data base, related to the environment (pilot implementation at Stanford University campus area). VTT's AROnSite is a mobile augmenting implementation on ultra-mobile PC, based on map location and GPS information, and vision based tracking with interactive initialization.Globally, research has progressed in ten years from wearable AR with PCs and navigation equipments in a rucksack to handheld solutions on PDAs and mini-PCs and further to camera-phone applications. The direction of research is turning to developing solutions to AR-content

creation and authoring. Research on multimodal interaction technologies in AR has also started with the interest in developing multimodal user interfaces bringing together the visual, auditory and haptics modalities. Also, the usability and perceptual quality of AR applications have recognized as new, important research areas.

2.4.2.6 State of the art on team work area

Research area of team work is linked to a larger area on ubiquitous or pervasive computing, knowledge systems, and Computer Supported Collaborative Work (CSCW). In addition to the present main project partners, relevant research has been and is carried out, e.g., in HUT and TUT, and will be linked to this workpackage via shared tasks with other wps. In everyday life email and phone are nowadays the most common tools used for team work, but they do not any more adequately support building the relationships and feeling of co-presence which are needed for effective team work. Also, as the globalizing and networking working life increasingly requires collaborative competence, we need models to support productive collaborative groups and to integrate normally separate activities, tools and applications (mobile tools, awareness tools, social media) together in a productive way (Dillenbourg & Jermann, 2006). Mobile devices can enhance productive group interactions, serve as cognitive tools that reorganize how team members think, and enable us to integrate within a single scenario (script) the activities that occur across multiple spaces (Dillenbourg & Jermann, 2006; Laru & Järvelä, 2007). Computer-supported collaborative work is complex phenomenon and has been found difficult to successfully realise in authentic work settings (e.g. Häkkinen, Arvaja & Mäkitalo, 2004).

Existing commercial systems used for team work include groupware software from vendors like IBM and Microsoft, and high-end videoconferencing environments by HP and Cisco, which can provide quite pleasant experience of telepresence, but these systems are limited in that sense that they are typically proprietary systems providing no interoperability, too expensive to be widely used in organizations, and their use is limited only to session-based collaboration. There are also a number of new emerging tools like wikis, blogs, social networking services (LinkedIn, MySpace, Facebook) and virtual environments (SecondLife, Sun MPK20), which offer possibilities for new ways of working together, and web-based collaboration tools (like WebEx and Google Office), which may change the business landscape in this area.

The novelty in the proposed approach is that it is an attempt to apply web 2.0 approach (software as a service, community mechanisms and simple UI) in local context for work-related use cases, to create new smart workspaces solutions utilizing heavily existing enablers and focusing on interoperability. The work package differs from the earlier approaches also in its strong business-driven approach, and that it simultaneously and interdisciplinary addresses the organizational research and user-perspective, interoperability aspect and technological enablers, as well as business studies and ecosystem creation.

Dillenbourg, P. & Jermann, P. (2006). Designing integrative scripts. In F. Fischer, H. Mandl, J. Haake & I. Kollar (Eds.), Scripting computer-supported collaborative learning: Cognitive, computational and educational perspectives. New York: Springer.

Häkkinen, P., Arvaja, M. & Mäkitalo, K. (2004). Prerequisites for CSCL: Research approaches, methodological challenges and pedagogical development. In K. Littleton, D. Faulkner & D. Miell (Eds.), Learning to collaborate and collaborating to learn (pp. 161-175). Nova Science Publishers: New York.

Laru, J. & Järvelä, S. (2007). Activity patterns in mobile technology mediated collaboration among two working communities. Educational Media International Journal.

2.5 Work plan

The work plan is presented by each work package.

2.5.1 WP Interaction, Usability and User Experience in Smart Environments (UI)

The main aim of interaction research in Devices and Interoperability SRA is to understand the aims and the needs of the users as well as the benefits and limitations of technology which are essential in having successful technological adoption. Our vision is that easy to use, seamless and adaptive interfaces allow fluent use of different devices and services. This will result in device interoperability to be widely accepted by the users enabling them to make use of full potential of the new technology.

The general goal of the research in this work package is user experience design methods and guidelines for multimodal multi-device applications in smart environments. These will be studied through user-centered research and development, involving users in all phases of the project.

2.5.1.1 UI Objectives

The main objectives of the work package are the following:

1. Developing general design principles and guidelines for adaptive mobile services and smart spaces, for example, how to abstract and represent available resources and functionalities to the user or how to move between different devices and UI modalities.

2. Making initial integration easy, also contributing to users' trust in the systems.

3. Studying existing interoperable technological ecosystems and early adopters. These include home studios and home theatres, LAN game parties and infrastructural solutions in small companies.

4. Developing new innovative services and interaction technologies able to make use of interoperability in new ways and in new domains. Studying affordances and developing interaction concepts.

5. Carrying out deep analysis of mental and social processes in this context.

2.5.1.2 UI Work package substructure

The work will be divided in the following main tasks and activities (the coordinating partner is the first one in the list, average resources per year are estimated in each task):

Activity 1 Developing user experience design methods and guidelines

- Gathering user requirements for interoperable, multi-device, multimodal ubiquitous environments, and creating design guidelines and user-centered design methods for designing such environments

- Development of design methods for incremental development and agile user-centered design of smart spaces

- Methods for user acceptance studies, especially methods to design and evaluate users' trust. Methods to identify critical ethical issues in the design. Ethical guidelines.

Activity 2: Designing, prototyping and testing of multimodal multi-device applications in smart environments

The prototypes are tested with target users in living lab environments. This task is based on constructive user-centered research and development, and contains the following activities:

- Designing the application prototypes based on user requirements and validated use cases

- Prototyping and testing of multi-device multimodal interaction technologies for smart environments. The modalities studied are visual, audio/voice, haptics used in adaptive multimodal interaction.

- Prototyping and testing of controlling the environments through physical user interfaces and sensors: The focus is on short-range RFID technology and on acceleration sensor based gesture control. A set of symbols for advertising the locally available services to the user is designed.

Activity 2.1 (note previously Act3, now combined to Act2): Literacy in smart environments, user's role in building smart environments, making integration easy

- Studying and supporting literacy in smart environments so that users can easily discover and understand the embedded affordances as well as grab to the affordances.

- Studying trust in smart environments. E.g. how users understand the information flows in smart environments: what is transferred and where and also how the user can control what is taking place.

- Studying interaction concepts also in setting up the environment, setting up connections and providing content to the environment.

- Providing feedback to the interaction design and indicating design requirements for architectural solutions.

Activity 3. Runtimes for UI.

- Implement an efficient, secure Rich Application environment (web/mobile runtime) that can be deployed in mass-market mobile devices.

- Study and improve web runtime performance in mobile devices.

- Define practical libraries and APIs for mobile web applications, as well as improve the native bindings between JavaScript and native libraries.

- Develop a test suite and sample JavaScript applications for the web/mobile runtime.

- Define general web software engineering principles and guidelines for web application development for mobile devices.

2.5.1.3 UI Expected results

- user requirements (document)
- user experience design methods (documents + methods)
- application design, use cases (documents)
- guidelines for multi-device multimodal interaction (documents)
- multimodal interface prototypes for studying interaction techniques (software + hardware)
- software components based on interface prototypes (software) à vertical WPs
- literacy and trust in smart environment (documents)
- easy setup of the environment, connections and content (documents + methods)

2.5.1.4 UI Links to other work packages

Pilot applications (vertical activities) of the D&I SRA provide requirements for this work package and apply the results as guidelines and software components in their systems. Individual interaction techniques developed in UI WP will be directly used in vertical work packages. There is especially strong collaboration between UI WP and MMR WP including shared tasks in interaction technologies and interaction techniques. Workshops will be organized between the UI WP and vertical WPs to create a common ground and understanding of the needs in each application area.

Testing of prototypes is planned to be carried out in cooperation with Flexibility Services Ecosystem SRA / User Driven Open Innovation project (Living labs).

Volume of work

Participants	Person Months per activity			
	#1	#2	#3	Total
UTA/Tauchi	18	48		66
TUT/IHTE	21	12		33
VTT	27	28		55
OU		33		33
Nokia		22	36	58
Sun Microsystems			22	22
TUT/SW			11	11
Nomovok			110	110
VTI		22		22
Total	**66**	**165**	**179**	**410**

2.5.2 WP Interoperability (IOP)

The goal is to define the smart environment architecture and operation principles based on device level interoperability and open sharing of services in the physical space. The architecture must be scalable to various types of devices, different levels of interoperability, and different types of environments. Devices capable to interoperability are for example simple tags, sensors, switches and plugs, appliances in our environment, embedded control systems, entertainment systems, machines, computers, etc. Levels of interoperability range from sharing data, functionality, and resources of devices to interoperability of applications and systems. Environments range from simple peer to peer reading of data value from sensor very near to football match with 100 000 people (and devices).

Also, the goals is to create middleware platform and supporting tools for easy development and decomposition of smart environment applications, consisting of heterogeneous technologies and multi-vendor devices.

2.5.2.1 IOP Objectives

The smart environment architecture and the middleware platform of should address

- Make development of innovative and intelligent applications easier.
- Allow straightforward implementation of these applications using mixture of heterogeneous domains.
- Make development of interoperable consumer devices easier for device manufacturers.

- Make development of interoperability capability into all devices and appliances easy
- The solution must be implementation-wise scalable from simple energy source limited sensors to powerful mains operated workstations.
- Improve usability and ease user understanding of smart space services
- The platform should scale to all vertical domains

The tools should address metaphor for describing applications that will address not only the composition of the functionality of the application but also the distribution of this functionality on the computational nodes in the environment. The tool will also allow some level of simulation of the application.

2.5.2.2 IOP Work package substructure

Activity 1. Requirements and mapping

Requirements are gathered and analyzed. The sources are vertical sub projects, UI horizontal sub project and external sources, including potential Artemis partners. Partners map existing commercial and research solutions with the requirements. The aim is to create one or multiple solution skeletons for the middleware platform and the application development platform that makes the smart space interoperability vision a reality. Further, the aim is to identify the needed additional research work to fully comply with the requirements.

This task will be done in 2 iterations, one at the beginning and the second in late 2009 to synchronize with the verticals.

Activity 2. Research

The task conducts research on the following topics. The final research questions will be aligned with the requirements from Task 1.

Subtask 2.1 SHOK Middleware platform architecture: The goals of the subtasks are to further develop the existing interoperability platforms in the following areas.

Scalability and energy awareness: To identify scalability limits of the existing systems and to propose solutions to overcome the limitations. In particular most of the related research and trials have addresses web services in a virtual Internet world. The main challenges are related to applying the existing semantic web technologies in embedded devices in a physical environment, distribution of interoperability platform into multiple devices and how to make the platform scalable enough for thousands of heterogeneous device and application configurations to interact with the middleware platform.

Dynamic configuration, interfacing and connectivity: To align the existing middleware platform solutions to cope with use cases where applications dynamically binds with the platform using a multitude of protocol interfaces and connectivity technologies. The connectivity should also address the scalability challenge described in subtask 2.1.

Subtask 2.2 Product creation methods:

The goal of this task is to develop approaches for creation of products using the SHOK middleware platform. The central issue in this task is the development of ontologies, but we will also study design methods and tools to compose and evaluate the smart space applications based on the semantic tools and enablers for decomposing the functionalities to different physical resources and entities of concrete environments.

Interoperability ontologies: The objective of the task is to define the ontologies that facilitate interoperability of services in smart spaces. The ontologies provide state knowledge of the particular smart space, e.g. the functional and non-functional properties of services available in the smart space.

Application creation tools: Given the ontology and the application interfacing methodology with the middleware platform an application development tool suite are created. The tool suite includes stub-generators, application description tools.

Application creation methodology: The application needs to be mapped onto a distributed architecture. In this task we will study the required methods for doing this. It involves identifying appropriate computational nodes in the smart environment, splitting of functionality, and ontologies, while taking into account the computational power of the nodes, and their energy efficiency.

Activity 3. Test implementation

The task implements of the middleware platform and application development platforms. Note, the subproject is not seeking consensus at this point but may implement multiple solutions. The results of this task should guide the research work done in task 2.

Subtask 3.1 SHOK1 middleware platform: The subtask specifies and implements an initial middleware platform using mainly existing solutions. The purpose the platform is to later test the results from task 2 and contribute the platform as an input to Artemis SRA3 project.

Subtask 3.2 Test ontology: The subtask specifies a simple ontology (e.g. SHOK home ontology) for testing SHOK1 middleware platform in a selected environment and proposes an ontology creation process.

Subtask 3.3 Test applications The subtask specifies and implements few simple applications utilizing the SHOK1 middleware platform and the test ontology. The test applications emerge from merger of multiple information creators and consumers whom indirectly interact with each other by though the middleware platform.

Activity 4. Trials

Subtask 4.1. Showstoppers: Risk analysis of possible critical issues related to smart spaces. First solutions to possible problems related to user acceptance issues.

Subtask 4.2. Mapping test implementation to a vertical task: The test implementation is ported to a selected vertical and few vertical use cases are implemented using the architecture and technology of the subproject. The aim of the subtask is to demonstrate the business potential of the solution.

IOP5 Dissemination

The task prepares technology transfer from SHOK to Artemis and other relevant direction. The task prepares contributions to Artemis and organized workshops and concept level publications. Scientific contributions are expected directly from other tasks.

The purpose of workshops is primarily promoting sub-project results for various industry organization including SHOK verticals.

Activity 5. Techno-economic analysis

Early analysis of feasibility from the views of all ecosystem partners.

2.5.2.3 IOP Expected results

The main results of this horizontal project after two years are:

1. Interoperability platform implemented as a middleware including the core services, mechanisms for dynamic configurability, and smart space ontology.
2. First proof of concept as a concrete demonstrator of smart space application based on interoperability platform.
3. A prototype tool-set for developing mash-up applications for smart environments.

In order to achieve the results this work package will have close co-operation with all DI vertical work packages and Artemis SP3 project. So, the additional results are:

1. Impact to DI verticals and solutions that are developed and experimented in them.
2. Contribution to smart environment solutions being developed and used in Artemis SP3.

The work package will contribute to white papers and scientific publications defined for the complete DI project (related to interoperability and smart environment concepts) and write scientific publications from specific results.

2.5.2.4 IOP Links to other work packages

Key expectations from other work packages. Typically requirements from verticals to horizontals and releases solutions from horizontals to verticals.

Expected deployment of results (if though vertical cases).

Volume of work

Participants	Person Months per activity					
	#1	**#2**	**#3**	**#4**	**#5**	**Total**
Nokia	18	50	70	50	10	198
VTT	8	30	30	15	5	88
Åbo Akademi	6	32	22	6	6	72
HUT	4	15	12	8	5	44
Total	**36**	**127**	**134**	**79**	**26**	**402**

2.5.2.5 IOP Second phase challenges

The main challenges of the second phase of the project (2010-2012) are related to:

- Generalization of results towards device interoperability standard.
- Expanding the experimentation to new areas and domains (new applications and use cases, industry, machines, etc.).
- Evaluation and improvement of usability of both interoperability concepts and tools for mash-up application development.
- Supporting the launching of interoperable device ecosystem. Demonstration of benefits to all others (device and appliance manufacturers, industrial and human processes, society).

2.5.3 WP Building Automation (BA)

The project aims to develop an open source based Service Gateway between the electrical building systems and ICT world. This will not only enable interoperability between the devices but also creates new technological applications to the buildings, and thus works in the favour of creating new ICT and service business model. Service Gateway will be an open source WWW-server, which offers a standard XML based oBIX interface for the control and management of the building systems.
Project scope also includes development of device / bus adapters, services and application on the top of the Gateway architecture. Also, Gateway, adapters and services will be tested in real environments in case / demos. The requirements from the case / demos will be taken into account already from the beginning of the Gateway core development.

All the generated source code will be available for all the participants to use according to the used Free Software (Gnu General Public License) license. Architectural decisions will try to support the use of open software tools. All the material related to the Gateway and its software documentation will be located at STOK web site and they will be available for anyone to download and use. STOK

will maintain and update the site at least to the end of the currently running term of The Centre of Expertise Program (OSKE), 2013.

2.5.3.1 BA Work package substructure

Activity 1 – Architecture plan

Plan for the most essential parts of the integration platform is produced in this work package. The goal is to assure the direction of the development and compatibility of different sub-components of the developed system.

Architecture of the oSSG platform is designed. Also, internal and external interfaces of the software are designed and documented. It includes interfaces to the system components, for example, HCC and also defines the user control levels.

Activity 2 – Building Automation Web Services platform

In this work package, the most essential parts of the integration platform are produced.

The actual core of the oSSG platform is implemented, including data base, etc.

oBIX interface and services are implemented and integrated to the core.

BACnet WS interface and services are implemented and integrated to the core.

A series of test programs will be implemented. Later, these programs will be used to test device adapters and services. Also, systematic testing of the oSSG platform will be done.

Activity 3 – Device interfaces

In this work package, interface and connections for the devices from different parties are developed. Device adapters for connecting devices / busses to the oSSG are implemented. Equipment interface is extended by HCC platform from Nokia to solve the problem with user control and to avoid developing adapters for two platforms.

Activity 4 – Services and user interface

In this work package, services and user interfaces for the oSSG platform are researched and developed. Both services and user interfaces can be new and implemented for the platform or already existing applications that are connected through an interface.

Scalable and flexible user interface is planned and implemented for the management of the oSSG server.

Tools are developed to make it easier to connect services to the oSSG interfaces.

Services and service platforms are connected to the oSSG using tools developed earlier.

Energy efficiency and operational space related applications are developed and already existing services are connected to the system.

Activity 5 – Case / demo

Work package consists of four different case / demos. Targets are selected to represent important application fields for different participants of the project

Work package consists of sub work packages. More detailed descriptions can be found at the following sub-package descriptions.

Case 1 – Small house

Developed software, services and applications are tested to be suited for the needs of a small house. Tens of technology based pilots are carried out in small houses at the selected areas. It is essential to develop new business models while executing the piloting.

Case 2 – Public building

Developed software, services and applications are tested to be suited for the needs of a public service building.

Case 3 – Many large real estates

Developed software, services and applications are tested to be suited for the needs of a collection of large real estates.

Case 4 – Senior living

Developed software, services and applications are tested to be suited for the needs of senior living.

Activity 6– Creating a developer community

In this work package, generation of a developer community is helped. Most importantly, web site for the oSSG is created and maintained. Also, information about the oSSG will be shared to educational institutes and topic will be discussed in seminars and in related media.

Web site for the oSSG will be built. Also, site will be kept updated, questions coming from the developers will be answered and contributions coming from the community will be integrated to the oSSG distributions.

In this work package, state of the oSSG development and possibility to take part and benefit from the results are informed.

Activity 7 – Project management

Work in this package tries to make sure that the goals are achieved within the budget and the timetable.

2.5.3.2 BA Expected Results

The most important result from the project will be the oSSG software and corresponding documentation. Based on GPL license, software will be publicly shared and open source. In addition to the platform, also many device adapters and services will be developed. Documentation describing the structure of the general adapter will also be produced to ease the development of new adapters in the future.

Software companies

Service Gateway provides a standard interface for IT companies to connect to the building automation systems. This makes it possible for a new kind of services to be built. Different kind of building service software companies have the key role. It is possible to create solutions for the end users to actively utilize building systems as part of their own business processes. At the same time, oSSG enables possibility for IT companies better to network with device manufacturers and system integrators. Probably some IT companies also specializes in distributing the Service Gateway and producing the services. Thus, oSSG can be seen as a business platform for ICT companies.

Service companies

Networking the devices at home and other buildings open possibilities to offer more easily different services directly to the end user, building owners and property maintenance companies. Thanks to the standardized interface at the Service Gateway, service companies can offer services directly via the Internet to large number of customers.

Device manufacturers

Applications built on the top of the Gateway make devices more useful and rise the value of them in the eyes of the end user. It is also easier for device manufacturers to create concepts and outsource the application development.

Service Gateway creates new way to connect devices from different manufacturers together. In this solution, same kind of problems to create interoperability does not exist that when connecting at the bus level.

Gateway opens a possibility to bring new standard product solutions for building management to the market. New companies do not have to offer wide-range automation systems but they can specialize at the niche market and bring large Gateway compatible product range to the market in stages. This makes it possible for small and innovative companies to compete with larger companies using their special knowledge. Device manufacturers can immediately after the development work to benefit from the Gateway solutions in their own products. This way, device manufacturers are the first ones to get the commercial profit.

Building owners

For the building owners Gateway opens possibility to integrate building systems more closely to their own business processes. Building automation and other electrical systems were earlier managed only by the administrative personnel but can now serve

all its user groups. This can rationalize utilization of the building, make the main functions more efficient and that way enhance business processes of the building.

Gateway offers a way to exploit better existing systems from different manufacturers and to update and upgrade legacy devices and systems in stages. Building owner is not dependent on the device manufacturer or the company that delivered the system.

Building maintenance companies

Companies specialized in the property maintenance can develop a unified system for managing all their properties independently on the systems below. This enables more efficient processes and even developing new service concepts.

Research institutes

The developer community built up from the oSSG development offers a natural networking environment for the research institutes. In many applying research projects different kind of systems are integrated together and applications are built on the top of them. Service Gateway functions as an integration platform which assures that the integration work remains usable later both in their own and in the projects of other research institutes and companies

2.5.3.3 BA Pilot demos

There will be four primary field tests included in the project where Service Gateways are installed to the pre-selected targets. Services offered by the oSSG will be used in actual real life situations based on the needs of end users. Project effects at these field targets are under the particular interest of many parties and expectations are really positive. The targets have been intentionally selected to be of very different nature from each other. This assures that received feedback corresponds as widely as possible to the needs of the produced software.

2.5.3.4 BA Links to other work package

As activity 5 creates requirements to the activity 1, the requirements are evaluated in both horizontal work packages, Interoperability and User Interaction & UI.

Results from the activity 1, are reviewed in horizontals to ensure the quality of the implementation in activity 2.

In activity 5 and most importantly in case 2, Public Spaces work package outputs important data that are used at the beginning to define the requirements for the case(s).

User interface development in activity 4 creates first requirements for the User Interaction & UI WP and outputs a user interface that horizontal can use in other connections with verticals.

Volume of work

Participants	**Person Months per activity**							
	#1	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**total**
Ensto	0	0	6	10	4	0	0	20

Logica	0	0	0	11	11	0	0	22
Nokia	6	4	60	10	23	2	2	107
Norpe	0	0	6	0	0	0	0	6
Oras	0	0	12	0	0	0	0	12
TAC	0	8	0	4	0	0	4	16
Siemens	0	2	4	2	2	0	0	10
YIT	0	0	0	8	20	0	0	28
Edge	0	0	6	0	0	0	0	6
Fatman	2	0	0	42	6	0	0	50
Hermia	0	0	0	0	6	0	0	6
ProgICT	0	0	0	4	4	0	0	8
STOK	0	0	10	4	3	2	14	33
TKK/AS	0	0	0	4	14	0	4	22
TKK/ME	8	29	56	22	4	9	4	132
TKK/ELE	0	0	10	0	0	0	0	10
TKK/Talo	0	0	0	3	0	0	4	7
VTT	4	5	9	12	1	0	0	31
TAMK	0	0	4	0	0	0	0	4
Total	20	48	183	136	98	13	32	530

2.5.4 WP Public spaces (PS)

Devices and Interoperability Ecosystem project targets to define and open a completely new domain for technology and service innovation in a global scale. In this work package we concentrate on indoor and outdoor sporting environments called “Smart Public Exercise Space (SPEXS)”. Work package defines and creates concepts, novel smart services and piloting environments (e.g. RAATTI sporting area) and test bed for SPEXS. Important is to increase attractiveness, usability and markets of services and products by adding interoperability capability into them. PS is realized and put into practice close and active connections with all other work packages.

2.5.4.1 Background

Public spaces are formed of all kinds of built environment consisting of buildings (hotels, offices, city halls, hospitals, schools etc.) and their environments, infrastructures (streets, roads etc.), parks and other human influenced natural landscapes. Real time interaction between the service user or provider and the ambient public space enables the environment to become an active ingredient of the service provision. Notably a person may have several roles as a user of the services, and the roles may overlap being simultaneous or take place in sequence, depending on the tasks and needs in time and space. Typically there are many different user groups using the same public space at different times and it is always a challenging task to design these places and their services to equally suit these varying requirements. In this way, we approach the advantages of novel user-, environmental context- and task centric information and innovation management. As the public space services become increasingly mediated though multimodal communication, there is a need for interactive ways to utilize and adjust the physical means.

The importance of exercises for well being is increasing along with the aging population. It is obvious that the period of employment is lengthening supposing working population

and young people need to activate and find new ways of keeping up fitness even more than before. One way of activating people is Smart Public Exercise Spaces which support versatile sporting activities among different demographic groups.

2.5.4.2 PS Objectives

Objectives for the first project "Smart Public Exercise Space (SPEXS)" are:

- To define and create common concept for Public Spaces as Smart Environments. Concept's first specific piloting area is SPEXS.
- To demonstrate the feasibility of device interoperability concept to be developed in ICT-SHOK device and interoperability ecosystem project.
- To develop collaboration between services, service providers, content providers, consumers and public actors.
- To create novel smart services in sporting environment through the sharing of the data, functionality and resources of devices that exist in the environment.
- To make RAATTI and other piloting environments and test beds for Public Spaces as Smart Environments and the most intelligent exercise surroundings of the world.
- To be among first who change the way we will live and experience.

2.5.4.3 PS Work package substructure

The research is composed of five main activities, solving items of

1. Framework for public sporting environment space as a platform for human-centric service provision,
2. To create novel smart services in sporting environment though the sharing of the data, functionality and resources of devices that exist in the environment
3. Piloting and testing environment.
4. Management

Activity 1. Framework for public sporting environment space as a platform for human-centric service provision,

The task starts with collecting and analyzing requirements for Public Spaces as Smart Environments. Based on these requirements common concept will be created. The concept consists of description of user and organizations needs, possibilities, enabling technologies, devices and possible services. Concept's first specific piloting area is SPEXS. To enable piloting and testing, concept for SPEXS is also created.

Activity 2. Testing environment (SPEXS) for Public Spaces as Smart Environments (T7 – T16)

Testing environment is based on the concept of Smart Public Exercise Space. Environment is built together with industrial partners, research institutes and public actors. Consortium of industrial partners and research institutes collect outline proposals of novel smart services to be developed. This compilation of services is based on industrial partners' own development work and new ideas produced in Task 1.

Piloting and testing environment is built. Main piloting environment is Raatti sporting area. Environment consist physical infrastructures and ready concepts for piloting and testing. Physical infrastructures consists communication capabilities and computing capacity of both portable and embedded devices plus the ongoing development in the

areas of sensor networks, ad hoc networking, location-based services, are all examples of foreseen possibilities of local, networked and heterogeneous smart environments.

Framework of Smart Public Exercise Space is used as a tool to select services. These selected services are developed together with companies to be tested and piloted in Raatti and other test environments (Task 3).

Activity 3. Developing, piloting and testing devices, interoperability and services (T2 – T24)

Industrial partners and research institutes develop, pilot and test together devices, interoperability and services in SPEXS testing and piloting platform. Developing, testing and piloting platform consists:

- Processes how piloting services can be brought into SPEXS platform
- Means to test and monitor piloted services, devices and their interoperability
- Real user and customer pool and possibility to collect and analyse their experiences
- Concept for research and industrial partners and communities to cooperatively develop services for smart public environments.

Research institutions coordinate testing environment and City of Oulu coordinates RAATTI sporting area.

Activity 4. Management (T0 – T24)

Develop project plan, regularly track it and synchronize the project activities as to achieve the expected results and report project results. The project will actively pursue opportunities to disseminate the service concept and service technologies through attendance at relevant industrial and academic conferences, and through the publication of articles in appropriate journals. The project will also participate in different specialized seminars. Co-operation with Artemis smart environments sub-program.

2.5.4.4 PS Expected results

- Requirements, specification and the concept for Public Spaces as Smart Environments and Smart Public Sport Environments are presented.
- A constant physical, generic test platform (RAATTI test bed) is generated.
- Concrete business cases and business models are produced for smart environments. The application and services are demonstrated in pilots.
- Devices and interoperability factors considered, included and realized in test bed.
- New applications and services are created and provided for people, businesses and communities as well as real user and customer experiences collected and analysed.
- Results can be generalized to other public spaces (hotels, shopping centres, parks…) and they create knowledge base for interoperability ecosystem.
- New disciplines and competences are created in Finland for ICT area that results in new business on global level.

2.5.4.5 PS Links to other work packages

- Interaction & User Interface (UI) has important role in developing, testing and piloting devices and applications' user interfaces and collecting user experiences. SPEXS provides test environments for UI.

- Interoperability (IOP) results are demonstrated and elaborated in SPEXS environment. SPEXS provides use cases and user experiences as well as user needs for IOP.
- Building automation (BA) and PS work firmly together with domains of public building as a smart environments.
- Mobile Mixed Reality (MMR) develops technologies and applications used in SPEXS. Public Spaces as Smart Environments provides use cases for Mobile Mixed Reality and offers extensive interactive real life piloting environment.
- Team Work (TW) results are exploited in SPEXS as a communal and social exercise environment. Applicability of team work for mobile maintenance and service teams are studied in PS testing beds.

Volume of work

Participants	**Person Months per activity**				
	#1	**#2**	**#3**	**#4**	**total**
VTT	12	12	34	8	66
UoO	12	12	34	8	66
City of Oulu	16	24	24	8	72
HealthEx	2	4	18		24
Polar	3	3	10		16
HUR	6	6	15		27
Nokia		10	22		32
Total	52	71	157	24	303

2.5.5 WP Mobile Mixed Reality (MMR)

This MMR work package will develop algorithms, methods and service applications to pilot user- and community-created, mixed reality content and context-dependent search and presentation of content and information, particularly with the means of augmented reality. Here, content and information associated to physical places, objects and situations can be accessed and then aligned with the real environment for display. Hence, the project builds new kinds of contextual interfaces to media and information. In a way, the environment can be made more transparent to the surrounding data, concerning information, advertising, content, connectivity and metadata. In the same time, the environment becomes more personalized matching user's need and desire of media and information based on his and others both current and past user data.

Project's mission may be summarized to enable physical locations to become knowledge hubs, combining physical context with social networking and aggregated content.

2.5.5.1 MMR Work package substructure

MMR work package implements its mission with four focused sub work packages that all contribute together to new mixed reality service applications to be introduced to the public. The work packages are Enabling Technologies, Application Development, User Experience of MMR Services, and Service Pilots.

Activity 1 Enabling Technologies

WP MMR1 concentrates on enabling technologies making it possible to implement the applications in WP MMR2. The main areas of work are: geometry and lighting aligned rendering, interaction design, gaze-tracker with virtual see-through, proactive information search and inferring relevance.

Activity 2 Application development

WP MMR2 focuses on performing development and integration of methods and algorithms for mobile mixed reality (MMR) applications. Prototype solutions are first subjected to user-centric evaluation and design; selected applications are developed and delivered as pilots in Public Spaces smart environments; finally the developed methods contribute as an MMR toolbox to the general D&I software platform.

The work package develops and combines mixed reality technologies, including augmented reality, audio and display devices, information retrieval, personal data management, user interfaces, multimodal content creation and interaction tools into mobile software solutions, HCI testbed and application prototypes. Moreover, WP MMR2 develops enabling technology and tools for location-based content creation by mobile users, and delivers prototypes and applications for HCI testing and evaluation, and as pilots in Public Spaces smart environments.

Activity 3 User Experience of MMR services

The main goal of this Work Package is to ensure the optimal user experience and user acceptance of the developed technology and application concepts. This work package contributes to MMR's main research challenges by considering the human aspects and user requirements. The MMR research challenges mainly focused in this WP are: merging the virtual and real world without disturbing natural space-perception or human-human interaction; presenting user-generated content and information with the means of augmented reality; information retrieval by searching with images, videos, sounds, speech or other relevant cues; the usability and perceptual quality of the augmented reality services and applications.

WP MMR3 focuses on defining design guidelines and requirements for the user experience and multimodal user interfaces in the MMR applications. It evaluates the application and service prototypes with potential end users, and measures their user acceptance. Finally, WP MMR3 contributes to the design of the MMR applications and services developed in WP MMR2 and WP MMR4, Service Pilots.

Activity 4 Service pilots

This Work Package implements mobile mixed reality service pilots for application in real life events and use cases. The pilots are designed, implemented and promoted in co-operation with Ubiquitous Helsinki environment, which is established by Forum Virium partners and is part of Helsinki Living lab concept. "Sustainable environment" is taken as one of the main service content themes. Results are analyzed by usage data analysis and interactive feedback from the application users.

The Work Package's main contribution to Devices and Interoperability mission is piloting in Public Spaces smart environments.

WP MMR4 aims at piloting the service applications, initially developed in WP MMR, Application Development to evaluate their technical and business feasibility. Application examples are chosen from the context of Helsingin juhlaviikot/Art Goes Kapakka and/or national events. Location-based sustainable environment service content will be planned and created in co-operation with Greenpeace International. Service features and usability are analyzed based on log data and user interviews.

2.5.5.2 MMR Expected Results

- Enhanced marker-based tracking library
- Prototype of markerless tracking. Prototype of lighting aligned rendering
- Near-to-eye display with gaze-tracking and virtual see-through
- Gesture recognition library
- Context logger for dynamic, real-time user data aggregation
- Proactive and contextual information retrieval methods
- Prototype of relevance and multimodal relevance feedback systems
- Adapting and developing MMR solutions to mobile platform; report and solutions
- Generic tools for mobile user interface and interaction, report and solutions
- Mobile AR tracking toolbox on Symbian
- Testbed system for MMR applications
- First iteration of general-purpose application prototypes for usability evaluations
- Second iteration of selected application prototypes, for piloting in Public Spaces smart environments
- Prototype systems for AR visualization and MR content retrieval, in two iterations
- Tools for MMR content creation, e.g. “Digital Graffiti” and “GeoStickers”
- Prototype system for MMR blogging, supporting personalized creation and sharing of multiple media
- Early user requirements, design guidelines and concepts for MMR services/applications and user interfaces.
- Further elaborated design guidelines and concepts, reports from quantitative and qualitative user studies of the developed applications and services.
- Research reports of test measurements and design implications for the perceptual factors in the designed MMR technologies and applications/services.
- Service pilot application for a limited test audience and another application for public audiences
- Professional content and facilitation of user-created content for the service pilot applications
- Feedback analysis requirements and report planning
- Report/analysis of the service pilot applications

2.5.5.3 MMR links to other work packages

As described above, the MMR WP closely integrates its four work packages together. In addition to this, MMR will co-operate with the Interaction, Usability and User Experience in Smart Environments (UI) work package to develop solutions for spatial UI and ambient interaction. Here, MMR participates in Activity 1 in developing user experience design methods and guidelines that are later applied to the incremental development of service applications. Moreover, the design of multimodal interaction for information retrieval is developed together with the Activity 2 of the UI work package. MMR also co-operates with the Public Spaces (PS) work package, in particular with the Activity 2 and 3, to enable user-created content and socially-defined information to be linked to Smart Public Exercise Spaces. Finally, the MoniVisio project in the Flexible Services SFA has expressed interest in following MMR for potential co-operation in future.

Volume of work

Participants	Person Months per activity				
	#1	**#2**	**#3**	**#4**	**total**
Nokia	99	28	11	11	143
Sesca		22			22
HUT/AIRC	22	22			44
HUT/MT	44				44
TUT/IHTE			33	11	44
VTT	22	28		16	66
Total	187	100	44	38	363

2.5.6 WP Team work (TW)

Key target of the work package is to develop novel solutions, service concepts and operational models for distributed networked operations and businesses.

Highly interdisciplinary approach and tight collaboration with leading industrial partners is required to achieve this goal.

2.5.6.1 TW Objectives

The objectives of the work package are to:

- Obtain a better understanding of distributed knowledge work, e.g. from behavioural, sociological & psychological perspectives.
- Identify and evaluate technological enablers needed in teamwork applications and solutions.
- Create concepts in the area of collaborative solutions, to combine the needs identified in human research with technological enablers, resulting with new product and service ideas.
- Observe users and their teamwork in real life situations to get reliable data on their everyday life needs and requirements.
- Carry out business studies to better understand products, services, markets, competition, and value chains in this research area.

2.5.6.2 TW Work package substructure

Several interlinked activities are needed to cover issues of teamwork as well as developing technologies and solutions for distributed knowledge work. Typically this research is conducted as iterative cycles of user research - concepting - prototyping – trial.

Activity1 - Human & organizational research: interdisciplinary research is needed to obtain a better understanding of distributed knowledge work, e.g. from behavioural, sociological & psychological perspectives.

Activity 2 - Team work technology enablers: parallel to studies focusing to user and organizations, the work package includes a technology-driven approach to identify and evaluate technological enablers needed in teamwork-solutions.

Activity 3 – Industrial team work pilots: to support both human-focused and technology-driven research case studies will be used to observe team work and collaboration in the challenging real team work environments within the case companies.

Activity 4 – Service concepts and business studies: to be able to successfully create a team work application ecosystem, business studies are needed to better understand products, services, markets, competition, and value chains in this research area.

2.5.6.3 TW Links to other work packages

This work package will expect horizontal work packages to provide enablers and design This work package will serve the case companies by analyzing their most topical challenges in developing their team work practices (Activity 1). From this starting point, the work package provides requirements for the horizontal work packages (Activity 2). Thus these user cases offer platforms for piloting the actions carried out in the horizontal WP's (enablers and design methods, user interface interoperability, communication interfaces and design methodology for smart environments, Activity 3). Finally, the service concepts and business studies (Activity 4) will be carried out together with other work packages (e.g., IOP Activity 5), considering the value chains for the whole interoperability ecosystem. This could further contribute to requirements of designing the enablers from the horizontal work packages.

Volume of work

Participants	**Person Months per activity**				
	#1	**#2**	**#3**	**#4**	**Total**
Nokia	6	22	14	2	44
JYU	20	8	8	8	44
VTT	2	20	14	8	44
Humap	1	5	4	1	11
Movial	2	14	4	2	22
Itella		2	5	2	9
Case2					
Total	**31**	**71**	**49**	**23**	**174**

2.5.7 Work packages contributions to project's main deliverables

The main contributions and impacts of each work package to project's main deliverables are described shortly in the following table.

Deliverables	User interaction	Interoperability	Building automation	Public spaces	Mixed reality	Teamwork
Interoperability platform	New possibilities	Main responsibility of platform	Requirements and validation	Requirements and validation		Requirements and validation
Methods and tools	User experience design	Application development methods and tools	Gateway based application development methods	Integration to living lab test bed	Mixed reality design methods	Adds system level inter-operability needs
Applications and services	Multimodality, adaptive services	Enabling mash-up applications	New technological applications to buildings	Novel interoperability based applications	Novel user interface technology	Novel application domain
Demonstrators	New interaction technologies	Demonstration of open innovation platform	Service gateway-based demonstration platform	Device interoperability based demonstration platform for other WPs	Novel user interface technology	Work process views to demonstrators
Impact to European and global research	Through Artemis (SOFIA)	Co-operation to Artemis (SOFIA)		Links to NFC research, ITEA2		
New ecosystem	Enablers through novel user interfaces	Key enablers for new ecosystem	Pilot case examples in BA domain	Demonstration of benefits of sharing and openness in scalable pilots	Enablers through augmented reality	Extends the usability of developed enablers

2.6 Connections to other activities and research on the area, international co-operation

The project is linked to a larger research area on ubiquitous or pervasive computing. However, the main differentiator is that the project is addressing largely the interoperability aspect and ecosystem creation.

In the Finnish context, the Tekes Ubicom program is closely related to the area. It is expected that many technical solutions developed in the Ubicom program can be used in the concepts developed in the DI project.

The European Artemis JTI (Joint Technology Initiative) and especially the Smart environments and scalable digital services subprogramme SP3 is very much on the same agenda.

Different work packages have related activities. Some of the most important of them are listed here:

Interaction, Usability and User Experience

The project participants are involved in the following projects that have synergies with the DIEM project:

- Mobile Haptics (UTA/TAUCHI, Nokia), collaboration with Stanford University, USA. Research on mobile haptics technology. Funded by Tekes by the Spring of 2009.

- Technologies for Ubiquitous Computing – TÄPLÄ (UTA/TAUCHI, TUT/IHTE, Nokia). Research on speech, auditory, vision and haptic technology in smart homes. Funded by Tekes by the end of 2009.

Multimodal gaming environment promoting awareness of health in a social and positive way (UTA/TAUCHI, TUT/IHTE), collaboration with UC Santa Barbara, Stanford University, and Sendai University in Japan. Funded by Tekes by the end of 2009.

Interoperability

In order to fully exploit the state of art results the project participants are currently co-operating with the following academic non-Finnish organizations and projects:

- Massachusetts Institute of Technology and DERI Innsbruck at the Leopold-Franzens-Universität Innsbruck on semantic web technologies

- St.Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences on the area information distribution and availability

- FP6 IP project AmiGo - Ambient Intelligence for the networked home environment (2004-2008) where the aim was to support interoperability between equipment and services within the networked home environment.

- ITEA2 projects ANSO (2005-2007) and CAM4HOME (2007-2010), where the focus have been autonomic distributed middleware for small office and home office environments, and enabling development of personalized and seamlessly interworking multimedia applications.

In order to transfer the results the subprogram aims to harmonize its middleware solution with Smart Environment SRA of Artemis. The middleware platform should also be made available through multiple commercial and near commercial service architectures such as but not limited to DLNA/UPnP forum www.dlna.org/ , NoTA initiative http://www.vtt.fi/notaconference/, web services http://www.w3.org/2002/ws/ and Bluetooth http://www.bluetooth.com/bluetooth/. These links will be created during the project by utilizing the existing links and on-going connections of the participants.

Building automation

- Building Automation WP has direct input from the preliminary projects that have already ended. The most importantly, there is a prototype oBIX server already developed in collaboration between TKK and STOK.
- In SHOK level, Flexible Services program shares some common interests with the Building Automation WP and the whole Devices and Interoperability program. TKK takes part in both programs and meetings are organized between groups from both programs to share requirements, results and other knowledge.

Public spaces

- The SmartTouch project (ITEA) is the largest effort on piloting Near Field Communication technology in the European Union. VTT etc.. 2006 – 2008.
- Data management and exploitation during the use of a facility (DAMEX). 2005 – 2008. Participants: HUT, VTT, UoO.
- Mobile Facility Management Services (FACMA). VTT. 2005 – 2008.
- IPCity (FP-2004-IST-4-27571) is a EU funded Sixth Framework programme Integrated project on Interaction and Presence in Urban Environments.
- I3CON - Industrialised, Integrated, Intelligent Construction; EU FP6 IP: Support PS effort. VTT ym. (2006-2010)
- Rich model for strategic cooperation in smartphone cluster (ROOSTER). UoO, VTT. 2006 – 2007.
- Ecological Approach to Smart Environments. The aim of the project is to identify, model and evaluate the ecology of smart environments from the perspectives of people, technology and environment
- Roadmap for ICT-based Opportunities in the Development of Built Environment. VTT. 2008.

Mobile mixed reality

The work package will collaborate with the Human Interface Technologies (HIT) laboratory of the University of Canterbury in New Zealand in the area of augmented reality. An interim from HIT-NZ will be visiting Nokia to work in the work package and Prof. Mark Billinghurst will provide guidance for the work.

Potential collaboration partners in user research and social media research are Prof. Marc Hassenzahl from the University of Koblenz-Landau and Prof. Jenny Preece from the University of Maryland. The form of collaboration may cover, in addition to knowledge transfer, to organize visiting researchers to Tampere University of Technology and common workshops in international conferences.

The MoniVisio work package in the Flexible services SFA has also expressed their interest in following the research and development of the MMR work package for potential common service applications and pilots.

Team work

The work package is linked to earlier and ongoing multidisciplinary human technology research on collaborative work, knowledge management, user-interaction, and cross-cultural communication, carried out together with international networks at the University of Jyväskylä. (e.g., projects: Innovations in Business, Communication and Technology, Towards Cross-cultural Agents, ITEA 2 Easy Interactions, THESEUS: User Psychology and Human-driven Design, Production 2010, Collaboration and authenticity in virtual learning contexts, Computing and Optimization in Multidisciplinary Applications).

Research on team work technology enablers, particularly in unified communication and enterprise mobility solutions have been carried out at VTT e.g. in projects Unicom – unified communication and presence systems (VTT), Expeshare - Experience sharing in peer networks (ITEA2) and Mobile Enterprise Factory (Tekes/Vamos).

2.7 Project budget summary

The project costs and Tekes support are summarized here in total and per work package. The numbers are for two-year plan.

Work package	Cost		Share of costs	Share of Tekes support
Project management	612 212 €	Companies	100%	100%
	2.3 %			
UI	4 825 334 €	Companies	59.8 %	44.6 %
	18.1 %	Public	40.2 %	55.4 %
Interoperability	4 826 028 €	Companies	57.6 %	38.9 %
	18.1 %	Public	42.4 %	61.1 %
Building automation	5 415 527 €	Companies	66.2 %	51.8 %
	20.3 %	Public	33.8 %	48.2 %
Public spaces	4 321 000 €	Companies	49.7 %	36.2 %
	16.2 %	Public	50.3 %	63.8 %
Mixed Reality	4 401 200 €	Companies	54.3 %	36.8 %
	16.5 %	Public	45.7 %	63.2 %
Team work	2 258 512 €	Companies	51.0 %	36.5 %
	8.5 %	Public	49.0 %	63.5 %
TOTAL	26 659 813 €	Companies	58.7 %	42.6 %
		Public	41.3 %	57.4 %
Total Tekes funding	13 394 094 €			
Public funding of total cost			63.1 %	

2.8 Working mode, organization and management

Project management team will consist of project leader and work package leaders. The project management team will agree on the execution and approval of project-level tasks and deliverables. It will also follow-up the shared tasks between work packages.

DIEM project and work packages will be operating in collaboration very much on iteration basis. There is no water fall model that can be assumed.

Collaboration between work packages is done by:

1. Shared tasks between work packages. Horizontal and vertical work packages are linked with shared tasks where both will participate and create the results.

2. Also, between horizontal and vertical work packages and also between horizontals, persons will be participating in meetings cross work packages.

3. Basic requirements set by vertical WPs to horizontal WPs, like use case requirements from verticals to horizontals.

Top level planning is done with 6 month milestones starting from T0 (project start). Project is organizing project-level workshops, and work-packages together and separately are creating the demonstrations.

2.9 Impact of the project and measuring

The project will create key elements for the new application and service ecosystem. This is the foundation of new businesses, which are expected first at the selected four application areas. Later, further service and technology innovation can be anticipated in new areas.

The use of the new services and applications will increase productivity or create cost savings for the companies and users acting in the applications area. When entering a new domain, the new services and technologies call for new type of service and technology providers. These can open opportunities for existing players, but in many cases call for new entrances with totally new innovations. Some are probably linked with internet services (and technologies) but the local and heavily heterogeneous, ambient nature of the domain opens new and fertile ground for businesses and business models. While these can be developed in a rather constrained and small environments, it is likely that they can be copied and adapted globally, given the widely spread technology basis in the ICT area.

The Finnish ICT industry has been strongly developing the mobile technologies. These technologies can also form an essential part of a new ubiquitous ecosystem. The ubicom technologies like sensor networks, ad hoc networking, embedded system technologies in general are also an active research area in the Finnish research community. Device and Interoperability Ecosystem provides a wealthy research and business development are for the Finnish ICT industry and academia. Finnish ICT industry and research will be in the forefront of deployment of smart space solutions.

The project has close link to Artemis Smart environments sub programme (project SOFIA) having a similar goal. The horizontal (common) work packages will be closely linked to the SOFIA project, and if feasible the work can contribute also directly there.

Eventually, the project will have an impact in the formation of standards in this area. However, it is expected that the formation standards will not be done in the traditional way of agreeing with large group of parties. The project has potential to create the de-facto solution that can be the basis of a future standard.

In application development, a major paradigm shift is expected in two ways. Firstly, the effort and expertise needed for creating application will be on much more easier and higher level (e.g. “Yahoo pipes” concept). Secondly, the ecosystem will mobilize many new partakers to the application development when space owners or process owners will bring their domain knowledge and domain information to the same forum.

Key measures of success are after seven years are:

- New businesses with start-ups or extended business activities in participating companies in at least 20 application areas.
- DIEM solutions produce or capture annual business value of $ 5B for the technology providers, device manufacturers and service operators involved.

- Emerging application developer community with >100k developers in companies, and universities.
- Head start for Finnish companies and research

In particular, there are also many specific impacts of different areas.

The user experience studies will form a basis for new technology development in such a way that will ensure the user acceptance of the developed systems and concepts. In a long run this basis will be a central enabler for the development of human-centered device & service ecosystems.

In many cases, the solutions provided by the Devices and Interoperability Ecosystem can provide energy savings through smart use of physical resources, which supports ecological sustainability.