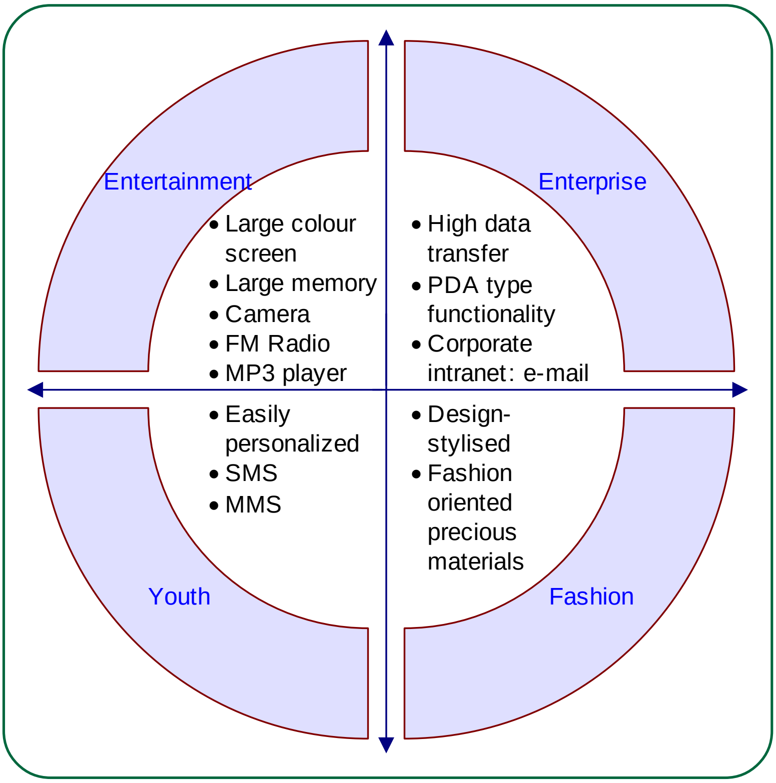
ESPOO 2007

VTT PUBLICATIONS 660



Markus Sihvonen

Adaptive personal service environment

VTT PUBLICATIONS 660

Adaptive personal service environment

Markus Sihvonen

Academic dissertation to be presented, with the assent of the Faculty of Science of the University of Oulu, Department of Information Processing Science, for public defence in Auditorium IT115, Rakentajantie 3, Oulu, on December 14th, 2007, at 12 noon.

ISBN 978-951-38-7055-3 (soft back ed.)
ISSN 1235-0621 (soft back ed.)

ISBN 978-951-38-7056-0 (URL: http://www.vtt.fi/publications/index.jsp)
ISSN 1455-0849 (URL: http://www.vtt.fi/publications/index.jsp)

JULKAISIJA – UTGIVARE – PUBLISHER

VTT, Vuorimiehentie 3, PL 1000, 02044 VTT
puh. vaihde 020 722 111, faksi 020 722 4374

VTT, Bergsmansvägen 3, PB 1000, 02044 VTT
tel. växel 020 722 111, fax 020 722 4374

VTT Technical Research Centre of Finland, Vuorimiehentie 3, P.O. Box 1000, FI-02044 VTT, Finland
phone internat. +358 20 722 111, fax + 358 20 722 4374

VTT, Kaitoväylä 1, PL 1100, 90571 OULU
puh. vaihde 020 722 111, faksi 020 722 2320

VTT, Kaitoväylä 1, PB 1100, 90571 ULEÅBORG
tel. växel 020 722 111, fax 020 722 2320

VTT Technical Research Centre of Finland, Kaitoväylä 1, P.O. Box 1100, FI-90571 OULU, Finland
phone internat. +358 20 722 111, fax +358 20 722 2320

Edita Prima Oy, Helsinki 2007

Sihvonen, Markus. Adaptive personal service environment. Espoo 2007. VTT Publications 660. 114 p. + app. 77 p.

Keywords adaptive services, personal services, adaptive environment, wireless communication, personal service environment, ubiquitous financial services, ubiquitous production administration services, profile negotiation requirements, mobile service environment

Abstract

Wireless communication will integrate seamlessly into our lives during the next decade. Device manufacturers will offer powerful portable multimedia communication devices with versatile features to single purpose sensors that have short-range communication capabilities. These very different devices will have the ability to form communication connections with each other either at the end user's request or in an ad-hoc manner. This will enable a nomadic end user to modify his/her personal service environment based on content he/she requests and on logical adaptation. The objective of this dissertation is to analyze the dynamic adaptability of a nomadic end user's Personal Service Environment by focusing on the adaptability requirements imposed by ubiquitous financial services and ubiquitous production administration service. This dissertation utilizes a constructive research method, in which results are validated by technical experimentation.

The main results of this dissertation are prototype implementations of the Active Service Environment Management (ASEMA) platform, which acts as an enabler for a dynamically adaptive personal service environment, and two use cases, one involving ubiquitous financial services and other involving ubiquitous production administration services, both of which utilize the platform. The Personal Service Environment (PSE) that is enabled by the ASEMA platform has the ability to adapt itself based on hardware and software capabilities available for a nomadic end user. The PSE is sensitive to the changes in quality of service it receives from the wireless network it is roaming to. The Personal Service Environment can combine two or more services together in order to offer a tailored service experience for a nomadic end user. Finally, the ASEMA platform enables an end user service to adjust its service offering to the existing capabilities of the Personal Service Environment at any particular moment.

Preface

My interest to further study wireless communication technology and its applications emerged while I was working for Nokia Mobile Phones as a VTT research scientist and project manager between the years 2000–2004. The atmosphere in those projects encouraged new innovations, which were created thanks to the support of Mr. Erkki Toivanen, Mr. Arto Pussinen and other Nokia employees I had privilege to work with. The VTT project team and management did provide invaluable support for this research work that was, in its beginning, done mainly in a project for industry. I wish to thank Mr. Hannu Honka and Mr. Hannu Rytilä for this great support.

Later I had an ideal chance to continue and eventually finalize my research work when VTT decided to launch the ITEA – IMPULSE project. Tekes – Finnish Funding Agency for Technology and Innovation was an important supporter and funding organization for the project. I wish to thank particularly Ms. Tiina Nurmi for her support of the IMPULSE project that made it possible for me to conclude this dissertation. I wish to thank the Finnish Consortium of the IMPULSE project for their excellent co-operation. Mr. Jouko Sankala, Mr. Jouko Tähtinen, Dr. Tapio Heikkilä and Mr. Tatu Dufva were very supportive partners in the IMPULSE project. VTT’s IMPULSE project team did a great job in putting the experimental ASEMA system together.

I would like to express my sincere gratitude to Professor Petri Pulli for the support and valuable advice he provided while conducting research for this dissertation. Discussions with Professor Olli Martikainen from the University of Oulu and the Research Institute of the Finnish Economy did help me a lot in enhancing the dissertation. I wish to thank Professor Samuli Saukkonen who provided me valuable support in the early phases of my research work. The manuscript of this dissertation was reviewed by Professor Jarno Harju from the Tampere University of Technology and Professor Do van Thanh from The Norwegian University of Science and Technology. Their constructive comments have greatly improved the final outcome of this dissertation.

Furthermore, I am thankful for the very fruitful discussions and valuable feedback from my colleagues and fellow researchers at VTT. Especially, I wish to thank Professor Tapio Frantti for his support.

Finally, and most importantly, I wish to express my gratitude to my family for their support during the years I have been working toward this dissertation. In the final phase my wife, Dr. Seija Sihvonen, did provide priceless support and guidance in finalizing the research work and the dissertation.

Contents

Abstract 3

Preface 4

List of publications 9

List of abbreviations 11

1. Introduction 15
   - 1.1 Motivation and background 20
   - 1.2 Research problem and objectives of the dissertation 22
     - 1.2.1 Statement of the research problem and the research method 22
     - 1.2.2 Outline of the dissertation 23
     - 1.2.3 Scope of the study 23
     - 1.2.4 The definitions 25

2. State of the art 29
   - 2.1 State of the art of enabling technologies for active service profiling 29
     - 2.1.1 Composite Capability/Preference Profile framework 30
     - 2.1.2 Extensible Mark-up language 31
     - 2.1.3 Resource Description Framework 32
     - 2.1.4 User Agent Profile 34
   - 2.2 State of the art of frameworks for enabling Personal Service Environment 36
     - 2.2.1 Mobile Execution Environment 36
     - 2.2.2 WV Mobile Instant Messaging and Presence Services framework 38
     - 2.2.3 ETSI presence service framework 39
     - 2.2.4 Generic user profile 41
     - 2.2.5 The mobile service customization and delivery system 42
     - 2.2.6 The ubiQos system 44
     - 2.2.7 Mobile Ubiquitous Service Environment 45
     - 2.2.8 Dynamically Adaptive Networking Service Environment 46
   - 2.3 Discussions 47

3. Constructs 50
3.1 Profiling requirements for Personal Service Environment 50
3.1.1 General requirements 51
3.1.2 Requirements by terminal equipment – mobile phone functional split 54
3.1.3 Requirements by enterprise systems 57
3.1.4 Requirements for ubiquitous financial services 59
3.2 Active Service Management System for Personal Service Environment 61
3.2.1 Profile negotiation subsystem 63
3.2.2 QoS monitoring subsystem 66
3.2.3 Other system components 67
3.2.4 Discussions 68

4. Use cases 70
4.1 State of the art of financial customer services 70
4.1.1 State of the art of technology platforms 71
4.1.2 Communication protocols 71
4.1.3 Authentication 72
4.1.4 Database technologies 73
4.1.5 Development platforms 74
4.1.6 The state of the art architecture of the use case 75
4.2 Ubiquitous Production Administration Service – M4MAMI 78
4.2.1 System requirements 79
4.2.2 Design solutions 79
4.2.3 Message oriented signaling 80
4.2.4 Database design 81
4.2.5 User interface design 82
4.2.6 The state of the art architecture of the use case 83

5. Summary of publications 85
5.1 Publication 1 87
5.2 Publication 2 87
5.3 Publication 3 88
5.4 Publication 4 88
5.5 Publication 5 89
5.6 Publication 6 90
5.7 Publication 7 90

5.8 Publication 8 91

6. Validation 92

7. Conclusions and analysis 101

8. Future research 105

References 106

Appendices

Publications 1–8

Appendices of this publication are not included in the PDF version.
Please order the printed version to get the complete publication
(http://www.vtt.fi/publications/index.jsp)

List of publications

This dissertation includes the following publications.

1. Sihvonen, M. Profile Negotiation Requirements in a Mobile Middleware Service Environment. ICEIS 2002, Fourth International Conference on Enterprise Information Systems April 3–6, 2002, Ciudad Real, Spain. Pp. 1009–1015. ISBN 972-98050-6-7.

2. Sihvonen, M., Jurmu, P. & Heikkinen, J. Negotiation Requirements for the Extended Mobile Service Environment. iiWAS 2002, The Fourth International Conference on Information Integration and Web-based Applications & Services, September 10–12, 2002, Bandung, Indonesia. ISBN 3-936150-18-4.

3. Sihvonen, M. & Holappa J. Negotiation Framework for the Next Generation Mobile Middleware Service Environment. International Conference on Engineering and Deployment of Cooperative Information Systems (EDCIS 2002), September 18–20, 2002, Bejing, China. ISBN 3-540-44222-7.

4. Pakkala, D., Sihvonen, M. & Latvakoski J. Towards a Distributed Service Platform for Extending Enterprise Applications to the Mobile Computing Domain. Proceedings of the International Conference on Internet Computing (IC´04), June 21–24, 2004, Las Vegas, Nevada, USA, CSREA Press. Pp. 416–422. ISBN 1-932415-44-0.

5. Sihvonen, M., Tähtinen, J., Pakkala, D. & Pääkkönen, P. Internet Enabled Wireless Mass Data System Requirements. Proceedings of the International Association for Development of the Information Society International Conference WWW/Internet Volume II (IADIS 2005), October 19–24, 2005, Lisbon, Portugal. ISBN 972-8924-02-X.

6. Sihvonen, M. Ubiquitous Financial Services for Developing Countries. Published in the Electronic Journal of Information Systems in Developing Countries, Vol. 28, 2006.

7. Sihvonen, M., Nieminen, M., Oikarinen, J. & Räty, T. Active Service Quality Management in ASEMA System. International Conference on System Networks and Communications (ICSNC 2006), October 29 – November 4, 2006, Tahiti, French Polynesia. Received award for Best Paper.

8. Sihvonen, M., Räty, T. & Räsänen, P. Adaptive Personal Service Environment Management System. The IASTED International Conference on Communication, Internet and Information Technology (CIIT 2006), November 29 – December 1, 2006, Virgin Islands, USA. ISBN 0-88986-613-9.

List of abbreviations

3GPP	3RD Generation Partnership Project
API	Application Programming Interface
ASEMA	Active Service Environment Management
CC/PP	Composite Capability / Preference Profile
DANSE	Dynamically Adaptive Networking Service Environment
DBMS	Database Management System
DDM	Data Description Method
DtDM	Datatype Definition Method
DTD	Document Type Definition
EJB	Enterprise Java Bean
EPROM	Erasable Programmable Read-Only Memory
EEPROM	Electrically Erasable Programmable Read-Only Memory
ETSI	European Telecommunications Standards Institute
GPS	Global Positioning System
GPRS	General Packet Radio Access
GCM	Generic Communication Manager
GNM	Generic Negotiation Manager
GUP	3GPP Generic User Profile
HTML	Hyper Text Mark-up Language
HTTP	Hyper Text Transfer Protocol
IP	Internet Protocol
IPSec	IP security
IMPS	Instant Messages and Presence Services
LAN	Local Area Network
LDAP	Lightweight Directory Access Protocol

M4MAMI	Mobile for MAMI
MAMI	Mass Production Administration by Multiple Inquiries
MExE	Mobile Execution Environment
MICE	Monetary Information Component Environment
MOM	Message Oriented Middleware
PC	Personal Computer
MUSE	Mobile Ubiquitous Service Environment
PDA	Personal Digital Assistant
PKI	Public Key Infrastructure
PSE	Personal Service Environment
QoS	Quality of Service
RAM	Random Access Memory
RTP	Real Time Protocol
SGML	Standard Generalized Mark-up Language
SIM	Subscriber Identity Module
SIP	Session Initiation Protocol
SMS	Short Message Service
SQL	Structured Query Language
SQoS	Scalable QoS
SSL/TLS	Secure Socket Layer/Transport Layer Security
TCP	Transmission Control Protocol
UAProf	User Agent Profile
UDP	User Datagram Protocol
UE	User Equipment
URI	Uniform Resource Identifier
VoD	Video-on-Demand

VHE	Virtual Home Environment
VPN	Virtual Private Network
W3C	The World Wide Web Consortium
WAN	Wide Area Network
WAP	Wireless Application Protocol
WCDMA	Wideband Code Division Multiple Access
WDP	Wireless Description Protocol
W-HTTP	Wireless HTTP
WSP	Wireless Session Protocol
WTP	Wireless Transfer Protocol
WTLS	Wireless TLS
WV	Wireless Village
XML	Extensible Mark-up Language

1. Introduction

The purpose of this dissertation is to analyze the problem of providing ubiquitous services to a nomadic end user in a dynamically changing personal service environment. This research problem is of paramount importance due to the ever increasing amount of wireless communication networks that complement each other. All wireless communication networks have capabilities that are unique to a particular network. Within the single wireless communication domain, network capabilities that wireless end user devices experience can vary greatly. Also, wireless devices are becoming more heterogeneous. New wireless device groups are constantly emerging and their and their capabilities can vary to some extent, even within a specific device group. More advanced wireless end user devices can change their capabilities dynamically while end user services are being executed.

Still, technology enablers are useless without services. The driving forces behind innovation of the system that offers both ubiquitous financial services and ubiquitous production administration services for nomadic end users were the following development visions of the ICT industry for 2020: An active end user interaction increased via personal devices that utilize long-range and local communication capabilities; End users should be offered, whenever needed, instant communication capabilities regardless of location. Due to the vast amount of available information, only meaningful information should be reached by the end user [1].

In the coming decade, wireless communication will become an essential part of our daily routine. Communication technologies will eventually evolve from the current pull service concept of receiving services at any location whenever needed to a content push service concept where nomadic end users have an adaptive Personal Service Environment that provides services via any available content transfer mechanisms. A Personal Service Environment (PSE) can include only a single wireless device or it can be composed of multiple devices that form a logical entity by contributing each device’s capabilities to a service environment. In this manner a PSE can dynamically change its configuration depending on the available hardware or software resources. Additionally, it can establish interfaces to other service environments and network infrastructures in an ad-hoc manner.

So far limitations in realizing seamlessly adaptive PSE have come from technology barriers. The design of wireless end user devices has generally been restricted by available materials and technology limitations. The technology limitations of input and output devices have restricted innovation and design solutions available for end user services. Another major threshold is performance limitations of wireless end user devices. The development of battery technology, new innovations for obtaining small electric current and innovative manufacturing materials create possibilities for new product innovations, evolution of an adaptive PSE and enhancements for the nomadic end user experience.

Eventually, the current development of enabling technologies will change the way end user devices form a PSE. End user devices will communicate with each other in a peer-to-peer fashion and be able to form a PSE on an ad-hoc basis. Multipurpose wireless multimedia devices will exist, devices whose features and capabilities will be able to be dynamically upgraded or downgraded based on the service requirements and context of a requested end-user service. Once mission dedicated simple devices emerge they will offer the end user districted services such as a Global Positioning System (GPS) services. They can participate in composing a PSE as long as they have some means to communicate. These future technologies and devices will act as an enabler for future nomadic end-user services which are dynamic and interactive with the surrounding environment and which will improve quality of life for end users.

Multimedia mobile devices will have truly versatile capabilities in the near future. For example, if a device is capable of receiving mobile TV broadcasts, it can be realized via different technologies. Table 1 illustrates broadcasting technologies selected by major multimedia device manufacturers [2].

Table 1. Broadcast technologies supported by major mobile phone vendors.

Tech./ Manufacturer	Nokia	Samsung	Motorola	LG	Sony Ericsson	BenQ Siemens
T-DMB	Not likely supported	**Supported**	Not likely supported	**Supported**	Not likely supported	Not likely supported
S-DMB	Not likely supported	**Supported**	Not likely supported	**Supported**	Not likely supported	Not likely supported
DVB-H	**Supported**	**Supported**	**Supported**	**Supported**	**Supported**	**Supported**
ISDB-T	Not likely supported	Not likely supported	Not likely supported	Not likely supported	*No firm decision, likely supported*	Not likely supported
MediaFLO	Not likely supported	**Supported**	**Supported**	**Supported**	Not likely supported	Not likely supported
DVB-H in S-Band	*No firm decision, likely supported*	*No firm decision, likely supported*	*No firm decision, likely supported*	*No firm decision, likely supported*	*No firm decision, likely supported*	*No firm decision, likely supported*
DAB-IP	*Not likely supported*	*No firm decision, likely supported*	*Not likely supported*	*No firm decision, likely supported*	*Not likely supported*	*Not likely supported*

There are a total of six potential broadcasting technologies that could be used as a capability by a Personal Service Environment. It is possible that a single multimedia mobile device may have more than one broadcasting radio as well, as there are multiple cellular radios today in a single mobile phone. This selection of numerous broadcasting technologies supported by the mobile device industry is just the tip of the iceberg, clearly illustrating the heterogeneity of multimedia communication devices that will emerge in the near future.

Figure 1 illustrates the requirements imposed on mobile devices by major market segments. These high-level market requirements directly influence the required hardware and software capabilities of mobile devices. Therefore today's mobile devices are extremely complex embedded systems where all functional blocks are custom-made for mobility. [3] Mobile devices that are in the entertainment category are usually marketed to young people. Depending on the price segment the mobile device belongs to, its design can comply with the very latest fashion. Mobile devices that belong to the enterprise market segment have very different features than devices in the entertainment segment, as illustrated in Figure 1. Capabilities of a mobile device that are derived from the market segment's desired feature set dictate the set of services an end user can use within his/her Personal Service Environment.

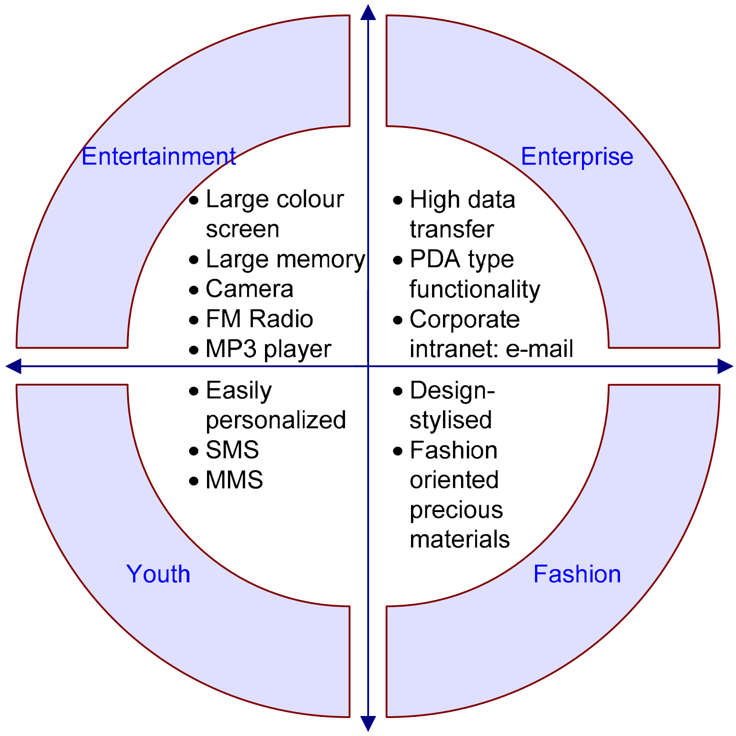


Figure 1. Major market segment requirements for mobile devices.

Mobile devices that have multiple features and capabilities offer versatile personalized services for end users. For example, when a mobile device has the capability to receive broadcasting and a fast Internet Protocol (IP) connection, an end user may enjoy a personalized set of multimedia services, such as recording video programs remotely, controlling video cameras remotely and receiving video-on-demand service to his/her mobile device [4]. Additionally, via a service platform a mobile device could, in the future, be part of a large service environment, such as the home service environment. It is important that the mobile device in this case has the required capabilities to interface with a home service gateway, which is a possible service platform for the future home service environment. [5]

Due to numerous variations in the capabilities of mobile devices and the vast number of service environments, a single mobile device needs to interact in order to successfully provide service to an end user; a service execution environment that acknowledges heterogeneous service execution platforms acts as an enabler for emerging ubiquitous services. The PSE is evolving into a more heterogeneous service environment with the help of current advances in technology, which enables it to include multiple devices that have a wide range of communication and computation capabilities. When wireless services become truly pervasive, there will be an enormous number of various types of wireless equipment that have long- or short-range communication capabilities – or even both. The various types of equipment will be able to communicate among each other to form a PSE in an ad-hoc fashion not bound by physical barriers or geographic distances. One of the major reasons for the rapid increase in wireless devices is that they are uniquely personal equipment [6]. It is expected that the amount of wireless equipment per user could greatly increase within the next few years, while in 2007 the European Union is currently experiencing a mobile phone penetration rate of 100 % [7].

Applications of an enterprise system, such as financial management or production administration systems, are typically used inside a secure administrated domain. They are most often guarded against attacks from the Internet by firewalls. Within enterprise domains a communication infrastructure is often based on Local Area Networks. Due to currently widely deployed wireless access technologies such as General Packet Radio Access, Wide Band CDM Access and Wireless Local Area Network (LAN), attractive business cases may be derived by extending access for the existing enterprise solutions to the wireless service domain. However, when establishing content transfer connections between two parties, using services from wireless and enterprise domains together will cause problems.

There are differences in the applications and operational environments of enterprise and wireless domains. In enterprise domains, applications are often developed for a Personal Computer (PC) environment that has a vast amount of hardware and software resources available. Wireless service domain has, on the other hand, strictly limited capabilities. PCs in the enterprise system domain are often connected by using fast fixed access technologies, while wireless devices use limited wireless access technologies to establish data connections. There are also differences in applied middleware technologies between these environments. These fundamental differences can create problems, for example, when trying to access the resources of Internet-based financial services provided by a bank's server infrastructure via an application developed for a wireless domain.

Yet from a nomadic end user's point of view, existing wireless devices have features that give them distinct advantages over PC equipment. In general wireless end user devices consume very little electricity compared to PCs. Their batteries are easily chargeable by small solar panels or wind generators. Wireless communication devices are less expensive than PCs, which lowers their purchasing threshold. The latest multimedia wireless devices feature multi-radio capability which enables them to choose at least two long-range and two short-range radios for communication purposes. IP-based wireless communication technologies are getting to be mature enough so that fundamental services such as a full set of financial services or production line management services can be provided by utilizing the wireless communication infrastructure. An adaptive PSE composed of one or more wireless device and middleware components that enable dynamic service configuration will be a basic tools for the nomadic end user of the next decade.

1.1 Motivation and background

In order for end user services to be successfully and truly pervasive, they need to be adaptive to changes in a Personal Service Environment. In particular, adaptation of services to the hardware and software capabilities of a PSE guarantees quality of service to a nomadic end user in a changing service environment. The preference profiles of a PSE play an important role in finding the services that suit a nomadic end user's needs. After finding those services, however, they need to be adapted to the particular circumstances of a PSE. Such an adaptation can have many forms, and may take place both before starting a service and while a service is being used.

Two important types of adaptation are distinguished based on what is adapted:

- Content adaptation: This includes adaptation that chooses or changes the content delivered by a service, based on network and device capabilities, user preferences, and context information.

- Logic adaptation: Another form of adaptation is altering the logic of a service. It considers the occurrence and order of the basic steps within a service, and the logical relations between different services.

A significant factor is when this adaptation takes place. There are distinctions between two categories:

- Static adaptation or configuration: This includes information regarding all relevant service and content parameters prior to the start of execution of the service in a PSE.
- Dynamic adaptation: It includes adapting a service or its content to dynamically changing capabilities of a PSE while the service is being executed [8].

In order to support adaptation and execution of end user services in a nomadic PSE, the requirements should be supported on two levels: 1) adaptation of contents, and 2) adaptation of the logic of a particular service. It should be possible to adapt content to an underlying network and a PSE's capabilities. Especially in a nomadic PSE, content adaptation must usually be performed on-the-fly due to changes in Quality of Service (QoS) levels. Full adaptation of services to a target environment includes adapting content and service logic. At the present time, no commonly acceptable solution is known for full service adaptation. Usually service logic and structure are 'hard-coded' and not truly capable of being fully adaptated.

From a nomadic end user perspective, it should be possible to access various services in an integrated manner at the right moment and regardless of the underlying infrastructure. It should be possible to utilize any group of services based on existing end user needs. In the next decade it should also be possible, via the help of an adaptive PSE, for a nomadic end user to employ integrated ubiquitous services simultaneously at the level of service logic and the level of content delivery.

1.2 Research problem and objectives of the dissertation

The goal of this study is to analyze the problem of providing ubiquitous services to a nomadic end user in a dynamically changing personal service environment from a technical point of view. Services impose technical requirements on a Personal Service Environment by requiring capabilities specific to a particular service from a PSE. Therefore ubiquitous financial services and ubiquitous production administration services are chosen as use cases in this dissertation. They help to analyze the research problem from an end user services point of view. This chapter defines the research problem of this dissertation in detail, including the research method applied. The terms most commonly used in this dissertation are also defined in this chapter.

1.2.1 Statement of the research problem and the research method

<u>The research problem of the dissertation is to analyze the adaptability of a dynamic Personal Service Environment used by a nomadic end user.</u>

- How can a nomadic end user's PSE dynamically evolve in order to execute services requested by the end user?
- Can a dynamic PSE adapt itself to changes that occur outside its domain?
- Can the developed approach meet the requirements of the emerging demanding applications?
  - What are the requirements imposed on the dynamically adaptive personal service environment by the ubiquitous financial service case which is aimed at any nomadic end user?
  - What are the requirements imposed on the dynamically adaptive personal service environment by the ubiquitous production administration service case which is aimed at a restricted set of nomadic end users via a public network domain?

The research method used in this dissertation is a constructive research method validated by experimentation. A constructive research method based on theoretical analysis is applied in the first four publications that are attached to this dissertation. Publications five through eight, which are attached to this dissertation, evaluates the results achieved in publications one through four. The new theoretical analysis done in the last five publications, which are also attached to this dissertation, are validated by experimentation as well. The descriptions of the experimentations are added as use cases to this dissertation.

1.2.2 Outline of the dissertation

The purpose of chapter two is to introduce the existing state of the art of research and technologies used for service profiling. Also introduced are standardized service frameworks and research platforms that aim to provide service profiling features for a wireless service environment. Chapter three discusses profile negotiation requirements from a nomadic end user point of view that utilizes an adaptive PSE. Chapter four introduces the state of the art analysis of the both use cases, the ubiquitous financial service and the ubiquitous production administration service, applied in this dissertation. Chapter five summarizes the included publications and the author’s contribution to them. Chapter six validates the results of this dissertation. In chapter seven, this dissertation is concluded and the results of the research work are further elaborated upon in connection with the objectives of this dissertation. Chapter eight outlines future research work. Chapter nine lists all the references of this dissertation. Finally in chapter ten, all the publications are listed that contain scientific innovation from this dissertation.

1.2.3 Scope of the study

This dissertation studies two use cases: 1) financial services offered by the banking industry to the general public, a group of users that is expected to behave in a nomadic manner while using the service and 2) the ubiquitous production administration service aimed at a restricted nomadic end user group. In the first use case the focus is on a stock portfolio management service, one of the most demanding and versatile financial banking services available to a nomadic end user. The use case includes management of financial transactions via a PSE, real-time push content transfer capability to a PSE and stock portfolio management capability within the means and capabilities offered by a PSE to a nomadic end user. This use case was chosen due to its versatility, amplitude of possible service enhancements and because of the lack of vision on the part of the financial industry concerning the utilization of wireless technology to its full extent to provide meaningful services for nomadic end users. Due to the versatility of this chosen use case, the innovations and technical solutions are transferable as such to other service scenarios.

The second use case, the ubiquitous production administration service, is used to analyze the research problem from a traditional enterprise service point of view, one meant only for the professional end user. The service is, in this case, extended to a nomadic end user. In this use case the major challenges from the dissertation point of view is to solve the problem of the need to transfer a massive amount of data when a nomadic end user utilizes the service. Naturally, the user interface and information security issues have their special challenges when this type of service is used by a nomadic end user. Both use case services have recognized individual challenges but those which eventually have similar technological solutions.

The research in this dissertation does not focus on service discovery mechanisms in a nomadic service environment for ubiquitous services. In this dissertation the proposed solution assumes that an end user has a service available that he wants to use, which is in this case a financial portfolio management service and ubiquitous production administration service. The research does not consider handover issues between different network infrastructures. The proposed solution is aware of the present QoS and in the prototype solution an end user must choose between available wireless connections. The research work and the proposed solution is based on ALL IP connectivity and layers below IP are not considered in the dissertation. Context aware research is also out of the scope of the dissertation, with exception of an end user device having a context aware capability. From the point of view of this dissertation, an adaptive PSE can have a context aware capability. This dissertation does not consider information security issues either. It is also treated as a capability that an adaptive PSE can have. Finally, business models are not in the scope of this research work.

The main result of this dissertation is a proven concept of the dynamic adaptability of a Personal Service Environment for the financial services and a ubiquitous production administration service provided to a nomadic end user. This is achieved by collecting requirements for service profiling of a wireless PSE. In addition, requirements for stock portfolio management and financial transaction for a wireless PSE were examined. Also, requirements for extending traditional enterprise services to a nomadic end user were researched. The solution for more effectively transferring a vast amount of content over a wireless connection was introduced. Additionally, an innovative content synchronization scheme was created for decreasing data transfer over a wireless connection. Since QoS of an underlying transport network is an important factor for a PSE's service capability, the solution was developed for a PSE to be QoS aware. Finally, an innovative profile management solution was developed for controlling the capability profiles of a PSE. The results were tested in the ASEMA prototype and the results were also applied to Qprojects's commercial Mobile for Mass production Administration by Multiple Inquiries (M4MAMI), which is derived from the ubiquitous production administration service use case.

1.2.4 The definitions

This chapter defines the main terms that are used in this dissertation. They are used throughout the document.

Personal Service Environment

A personal service environment is an environment that assists a user in finding, adapting and using services that fulfill an end user's needs, given his personal requirements, his mobility and his context [9]. An environment is created by a computer or any group of computers. Services are used via computers that create a personal service environment. Since an end user has defined his own service environment based on his/her needs, it is called personal.

Middleware

Middleware provides implementation guidelines and frameworks to ease development of heterogeneous distributed systems [10]. They are usually computer software components that provide generic services which can be used by more than one application or an end user service. Middleware is often used to support complex and distributed systems and applications. Middleware components can generally be found from web servers, mobile devices, multimedia devices, application servers, content management systems and Personal Digital Assistant (PDA) equipment.

Nomadic end user

A nomadic end user is a person that moves from one place to another while using wireless services [11]. The word nomadic itself means a person who moves constantly from one place to another. End user refers in this case to a person that uses a product that is a computer application. Therefore a nomadic end user means a person that moves from one place to another while using a computer application.

Dynamic adaptability

Dynamic adaptability is the ability of a piece of software to meet requirements according to the context it is used in [12]. The context can change at any time while a piece of software is being executed. This is a dynamic feature. Regardless of changes in the context, a piece of software can adjust itself to meet the requirements of the changed context. This is an adaptive feature.

Active Service Environment Management platform

An active service environment management platform aims to fulfill the promise of "right content at the right time" in heterogeneous service environment to nomadic end users. It is composed of distributed middleware components that provide services to end user applications in a PSE.

Ubiquitous services

Ubiquitous services are provided by heterogeneous small devices that communicate with each other to form a ubiquitous computing environment. Services provided by them are ubiquitous services [13]. Ubiquitous services have the capability to be available anytime anywhere. Ubiquitous services have the following characteristics:

- they are provided to or triggered by conditions external to a PSE,
- they can be provided when a user is not expecting them, because they are triggered automatically by the system but not by the user's intention.

Enterprise domain

An enterprise domain is an intranet domain that provides services to a limited or restricted user group. A domain itself refers to the kind of purpose for which users use a software-based system. Enterprise domain infrastructure is based on wire lines and the typical access method to its services is a PC.

Wireless domain

A wireless domain is composed by any wireless communication networks and devices that utilize wireless networks. A domain itself refers to the kind of purpose for which users use a software-based system. A wireless domain can be restricted to a particular end user group or open to any end user.

Hardware capabilities

Hardware is particular equipment in a computer such as the keyboard, screen and amount of physical memory. Hardware has a physical form that can be touched and looked at. A capability describes what that particular equipment can do when it is used by a computer for the benefit of an end user.

Software capabilities

A software capability is a piece of software that is part of a computer's whole software configuration. It can be an operating system, middleware component or a web browser. A piece of software is a program that enables a computer to perform a specific task. It is not a physical component or capability.

Quality of Service

Quality of service refers to the nature of the packet delivery service provided, as described by parameters such as achieved bandwidth, packet delay, and packet loss rates [14].

Mass production Administration by Multiple Inquiries

Mass production Administration by Multiple Inquiries (MAMI) is a Decision Support System (DSS) which was developed by a company called Qprojects in 1995. Since then it has been used worldwide in the manufacturing, telecommunications and consumer electronics sectors. It combines a large part of a company's business functions and processes, offering an overview from one data source. The MAMI system controls large organizations' entire production process and handles products from several different production units. Users of the MAMI are mainly production, production planning, buyers, sales and marketing personnel and logistics operations. Each user has his or her own information needs and for those needs MAMI offers several different viewpoints to the company's information space [15].

Mobile for Mass production Administration by Multiple Inquiries

The Mobile for Mass production Administration by Multiple Inquiries (M4MAMI) is a wireless extension to the MAMI. It enables a nomadic end user to use the MAMI system via a PSE. It utilizes the ASEMA platform in order to provide requested services to a nomadic end user.

2. State of the art

The purpose of this chapter is to illustrate the existing state of the art of dynamic service profiling of a Personal Service Environment. First the chapter introduces the state of the art of enabling base technologies for service profiling. Second, there is a review of the most important standardized state of the art service profiling frameworks and research platforms that have been developed by other research projects worldwide.

2.1 State of the art of enabling technologies for active service profiling

This chapter introduces mainstream enabling technologies for realizing service profiling in a Personal Service Environment. First, a Composite Capability / Preference Profile (CC/PP) framework is introduced. This framework offers a standardized method for expressing the capabilities of wireless end user devices as well as user preferences. The CC/PP framework expresses device capability and user preferences in an Extensible Mark-up Language (XML) document format that conforms to an RDF model and syntax, which are introduced in the next chapters. Finally, a User Agent Profile introduces a standardized vocabulary for expressing device capabilities and user preferences in a Personal Service Environment.

Due to the nature of the technologies used, new schemas, as long as they are in conformance with the CC/PP framework, can be created for specific purposes to describe device capabilities and user preferences. When feasible, the existing User Agent Profile (UAProf) schema can also be extended based on new requirements. The ASEMA platform utilizes the CC/PP framework as it is defined. One of the contributions of this dissertation is its defining of new vocabulary needed for describing the capabilities of an adaptive PSE. Figure 2 illustrates a logical technology model for active service profiling in a layered structure.

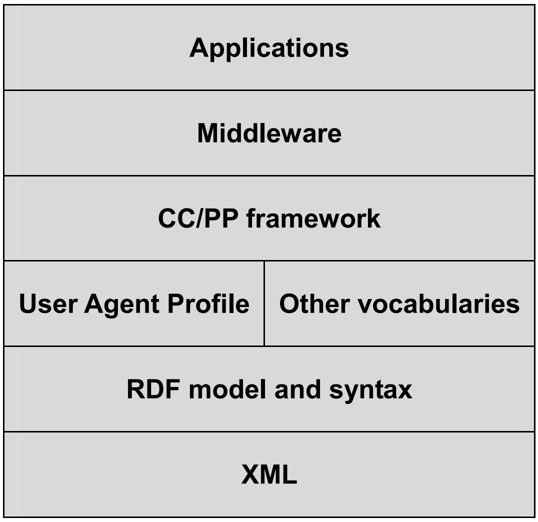


Figure 2. Logical technology model for service profiling.

2.1.1 Composite Capability/Preference Profile framework

The Composite Capability/Preference Profile framework defines a method for wireless end user devices to express their capabilities and user preferences to the service environment that they are part of. CC/PP data is represented as Extensible Mark-up Language documents conforming to the Resource Description Framework model and syntax. CC/PP specifies a profile structure divided into categories called components, which in turn consist of data attributes. [16] An attribute can either define a single value, or contain a list of values following RDF conventions. CC/PP itself does not dictate what type of data is stored in a profile or how it is named. This is done by extending the standard with the specific vocabulary definitions using XML namespaces. A vocabulary's attributes are specified in a schema file. The Uniform Resource Identifier (URI) is used to locate the files, and therefore it is included in the CC/PP document. A commonly used vocabulary for CC/PP is the User Agent Profile, which describes hardware and software capabilities in mobile phones. These capabilities include, for example, screen resolution, supported character sets and web browser features. UAProf is aimed at profiling phones with Wireless Application Protocol support. [17], [18] The CC/PP framework allows the use of different vocabularies for applications that communicate with each other as long as the vocabularies are built by using principles defined by the framework. The guidelines for defining new attributes are as follows;

- Avoid reusing existing attributes. The names using different namespaces can be freely mixed in a profile, so there is no use in redesigning attributes.
- An attribute name must be unique within a profile.
- An attribute definition should indicate the type and interpretation of the associated value. The values should be expressed in literal text, URI, tokens, integers and rational numbers.
- Interpretation of an attribute must not depend on other attribute values.
- "interCap" name styles should be used. A name starts with a lowercase letter. The second and the subsequent words within the name start with a capital letter and no internal punctuation is used.
- An attribute should have a specific applicability. [17]

2.1.2 Extensible Mark-up language

XML standardization efforts are managed by the World Wide Web Consortium (W3C). The XML standard describes a class of data objects that are called XML documents. The standard also partially describes the behavior of a program that processes the XML documents. An XML document's construction is in conformance with the Standardized Generalized Mark-up Language (SGML) standard. The aim of the XML standard is to create a simple, easy-to-use document format. Therefore it is more restricted than the SGML document format. [19], [20]

In the XML standards, entities are basic building blocks of the XML documents. Information – the data – is stored in the entities either in parsed or unparsed format. Actual characters construct parsed data. Some of the characters are mark-up data and the rest is character data. The purpose of the mark-up is to encode a description of the document's storage layout and logical structure. XML provides a mechanism to impose constraints on the storage layout and a logical structure. A software module called an XML processor or XML parser is used to read XML documents and provide access to their content and structure. [19]

A data object is a well-formed and valid XML document if it complies with the following set of constraints. An XML document must always have a logical and physical structure. The physical structure of a document is formed by entities. An entity may refer to other entities to cause their inclusion into the document. A document must always start from the root or document entity. The document is logically composed of declarations, elements, comments, character references, and processing instructions. All logical elements are indicated in the document by explicit mark-up. The logical and physical structures must nest properly, which means that no start-tag, end-tag, empty-element tag, element, comment, processing instruction, character reference, or entity reference can begin in one entity and end in another. [19]

2.1.3 Resource Description Framework

The purpose of RDF is to support the interoperability of metadata. The RDF allows descriptions of different data resources, which are usually located on the Internet, to be made available in machine understandable format. It is based on a concrete formal model utilizing directed graphs that conform to the semantics of resource description. The basic concept is that a resource is described through a collection of properties called an RDF description. Each of these properties has a property type and value. Any resource can be described within the RDF. The basic RDF data model is composed of three different object types, which are:

I Resources

All things that are described by the RDF expression are called resources. A resource can be a Hyper Text Mark-up Language (HTML) document, XML-element, collection of Web pages, entire Web site or it might not be accessible via the Internet at all. But resources always have a URI and they can have optional anchor ids. The extensibility of a URI allows the introduction of identifiers for any entity imaginable.

II Properties

A property is a particular aspect, characteristic, attribute, or relation, which is used to illustrate a resource. A property always has a particular meaning which defines its allowed values, the types of resources it can describe and its relationship with other properties.

III Statements

A particular resource along with a named property and the value of that property for that resource comprise an RDF statement. These three individual parts of a statement are called the subject, the predicate, and the object, respectively. The object of a statement can be another resource or it can be a literal resource or a simple string or other primitive data type defined by XML [21].

The RDF data model is illustrated via a simple example in Figure 3. The nodes in Figure 3 are drawn as ovals and they represent resources. The named properties are presented as arrows. The nodes that are drawn in the shape of rectangles represent string literal. The direction of the arrows is important. Arrows always start from the subject, which is the resource, and point to the object of the statement. The diagram illustrated in Figure 3 can also be read as: "The Person whose name is Markus Sihvonen, e-mail<markus.sihvonen@vtt.fi>, is the creator of http://www.vtt.fi/home/sihvonen". The intention of this sentence is to make the value of the creator property, http://www.vtt.fi/home/sihvonen, part of a structured entity. In the RDF, this type of entity is represented as another resource. In this example the structured entity does not have a name, which is illustrated as an empty oval in Figure 3.

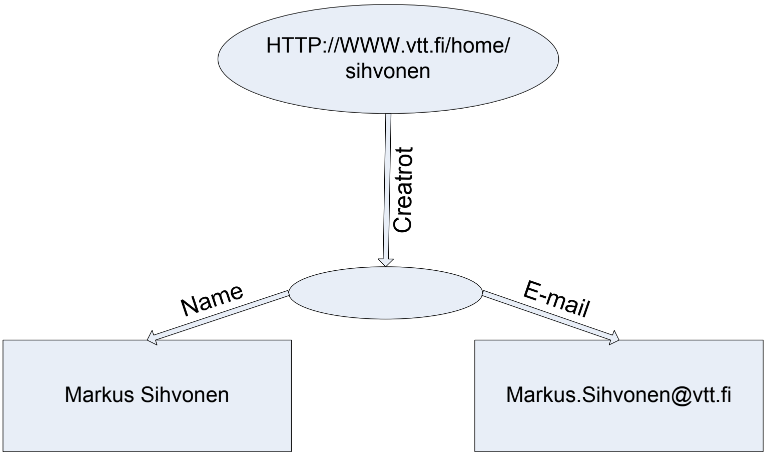


Figure 3. RDF data model.

The RDF extends the XML model and syntax for describing resources. It utilizes the namespace facility of XML. The XML Namespace, which points to a URI, makes it possible for the RDF to uniquely identify a set of properties. The set of properties is called a schema and it can be accessed by the URI, which is identified by the namespace. RDF also inherits all the XML syntactic flexibility, which includes white space rules, quoting using either a single quote (') or double quote ("), character escaping, case sensitivity, and language tags that enable the support of multi-lingual metadata [22].

2.1.4 User Agent Profile

The User Agent Profile specification describes mechanisms for conveying user agent profiles intended to contain device capability and preference information. It was originally standardized by the Wireless Application Protocol Forum. Once the Open Mobile Alliance was established, the UAProf standardization work was transferred there. The user agent profile can be used by origin servers for content customization purposes. The UAProf vocabulary is intended to be in conformance with the CC/PP framework. The UAProf schema has the following key components:

– The hardwarePlatform, which is a collection of properties that describes the hardware characteristics of terminal equipment.

- The softwarePlatform, which is a collection of attributes associated with the operating environment of terminal equipment.
- The browserUA, which is a set of attributes to describe an active HTML browser application.
- The networkCharacteristics, which is the information about a network-related infrastructure and environment such as bearer information.
- The wapCharacteristics, which is a set of attributes belonging to Wireless Application Protocol (WAP) capabilities supported by terminal equipment.
- The pushCharacteristics, which is a set of attributes describing push specific capabilities of User Equipment (UE).

The additional components can be added to the UAProf schema, providing that the previously introduced guidelines for defining new attributes to the CC/PP framework are being fulfilled. [23]

Table 2 introduces three attributes of the UAProf specification's SoftwarePlatform component that are mandatory for a Mobile Execution Environment (MExE) enabled device. [24] According to the CC/PP framework requirements, all three MExE-specific attributes have unique names and descriptions of the intended usage. The resolution type for each attribute is locked, which means that the final value of the attribute is determined by the first description outside the default description block. Override and append resolution types are also possible. The former defines that the final value equals the last description of the attribute, and the latter that the final value is a list of all the descriptions of the attribute. There are four possible types available for an attribute:

- Number, which can have positive integer values.
- Boolean, which can have yes or no values.
- Literal; such a value can be any alphanumeric string.
- Dimension; such a value is a pair of numbers.

Finally, there needs to be a sample of the possible attribute values. [23]

Table 2. UAProf properties mandatory for MExE device.

Attribute	**Description**	**Resolution rule**	**Type**	**Sample**
MexeClassmarks	List of supported MExE classmarks	Locked	Number	“1”, “2”, “3”
MexeSpec	The first two digits of the MExE specification version which the MExE equipment conforms to.	Locked	Literal	“3.3”, “4.1”
MexeSecure Domains	Indicates whether or not the equipment supports MExE security domains.	Locked	Boolean	“Yes”, “No”

2.2 State of the art of frameworks for enabling Personal Service Environment

The purpose of this chapter is to introduce state of the art enabling platforms for Personal Service Environments. First, relevant standardized platforms are introduced, followed by an introduction to research platforms. They all have the very same goal: to provide to provide the experience of seamless services to nomadic end users regardless of dynamically changing device capabilities and user preferences. It is notable that the XML document format is well utilized in both standardized and research platform frameworks. None of the proposed solutions are used today in commercial products as a whole package, but selected best technologies can be found from advanced products.

2.2.1 Mobile Execution Environment

The European Telecommunication Standards Institute is the governing body that oversees development of the MExE framework. It is a platform within a wireless device that enables the execution of dynamically downloadable applications. MExE is a part of the Virtual Home Environment, also standardized by the European Telecommunications Standards Institute (ETSI). Virtual Home Environment (VHE) is defined as a Personal Service Environment that expands beyond the boundaries of a single network and between different mobile devices. The underlying concept of the VHE is that end users are able to gain access to the same personalized features, including customization of the user interface and selection of services, regardless of the physical location of a user, the network being used or a wireless device. Naturally, limitations are imposed by the actual capabilities of a particular wireless device and the network infrastructure used for providing the requested service to an end user. [25]

The MExE service environment can be composed of several service nodes, each providing MExE services that can be transferred to a wireless device via any available transfer mechanisms. Service nodes can be located anywhere in the Internet. The MExE service environment may also include a proxy server to translate the content defined in standard Internet protocols into their wireless optimized derivatives. The MExE enhanced device can access downloadable services via any communication infrastructure available. [24]

MExE has four classmarks that determine which technologies must be used for building applications. Naturally, technology selection also dictates the type of services that can be created for that particular classmark. Classmark 1 is based on the Wireless Application Protocol and it is aimed at less powerful wireless devices. Classmark 2 includes the Personal JAVA Application Programming Interfaces (APIs) with the addition of JAVA Phone API. Its focus is for consumer electronic devices such as PDA equipment and multimedia mobile phones. Classmark 3 is based on the Connected Limited Device Configuration API set with the added Mobile Information Device Profile requirements. It is tailored for mobile devices that have very limited resources available, but which are still are required to run JAVA executables. Classmark 4 is based on the Common Language Infrastructure Compact Profile, which aims to support a wide range of connected end user devices. A single device may have any combination of MExE classmarks. [24]

The MExE framework also has a set of generic requirements that must be complied by all MExE classmarks. The most important generic MExE requirements are Composite Capability / Preference Profile negotiation and security domains in an MExE-capable end user device. The function of CC/PP negotiation is to optimize the content of the downloadable service for an end user device. The CC/PP negotiation occurs after the service has been discovered but prior to downloading it to the end user device. The CC/PP negotiation engine is located in the MExE server that is a node supporting MExE services in an MExE service environment. The downloaded service is placed into the relevant security domain in the end user device, which defines the available functions for it [24].

The mission of MExE is to provide a secure means to dynamically download 3rd generation services into wireless end user devices, in a manner of the content of the requested service being tailored for the particular needs of the user and the used device. In principle, the MExE service can be anything from a simple call forwarding service to new core software that reconfigures the end user device. Once a user does not need the service anymore, it can be removed from the device. [24]

2.2.2 WV Mobile Instant Messaging and Presence Services framework

The purpose of the Wireless Village initiative is to define Mobile Instant Messaging and the Presence Services framework for a nomadic user's PSE. They are to be utilized by mobile devices, mobile services and Internet-based Instant Messaging services. The Wireless Village (WV) Instant Messages and Presence Services (IMPS) solution includes four primary features: Presence service, Instant Messaging, User Groups and Shared Content. In the WV model, Presence service includes client device availability, user status location, client device capabilities and searchable personal statuses such as mood and hobbies. The Presence information is only available to subscribing parties according to an individual user's wishes. The WV aims to enable interoperable mobile instant messaging to nomadic users in concert with other features and services to provide an enhanced user experience. The Group service feature enables both telecom operators and end users to create and manage groups. Users can invite their friends and family to chat in group discussions. Telecom operators can build common interest groups where end-users can meet each other online. The Shared Content service allows users and operators to setup their own storage area where they can post pictures, music and other multimedia content while enabling sharing with other individuals and groups in an IM or chat session. [26]

The IMPS system architecture is a traditional client server model. The WV server has the central role in the system. It is composed of four application service elements, which are Presence Service, Instant Messaging, Group and Content service elements. They all are accessed via a Service Access point. It has the following functionalities: Authentication and Authorization, Service Discovery and Service Agreement, User Profile Management, and Service Relay. The system architecture allows usage of any application-level protocol as long as all parties within the session support the chosen protocol. Session initiation is handled with Hyper Text Transfer Protocol (HTTP), Session Initiation Protocol (SIP) or Wireless Session Protocol / Wireless Transfer Protocol (WSP/WTP) and for secure sessions one must utilize either IP security (IPSec) or Wireless Transport Layer Security (WTLS). Supported transport protocols are Transmission Control Protocol (TCP), User Datagram Protocol (UDP) or Wireless Description Protocol (WDP) over IP. Short Message Service (SMS) is also supported for instant messaging. [27]

In the IMPS framework Presence information is in attribute data that is encoded by XML. It can be retrieved from internal data storage and external data storage to the IMPS framework. The Presence information is well formed and valid XML documents, which enables the usage of Document Type Definitions (DTDs) and namespaces. The IMPS framework defines a set of attributes for client to server and server to server negotiation purposes. It also allows proprietary extensions for existing sets of attributes, as long as they are formed according to the general attribute structure defined by the IMPS framework. [28]

2.2.3 ETSI presence service framework

The European Telecommunication Standards Institute oversees standardization efforts for the Presence service framework. The purpose of the Presence service framework is to provide additional value to existing Telecom operator services. Presence services may function as an enabler for Internet-based new communication and advanced information services for a Telecom operator-controlled mobile telecommunication network. The Presence service results in the presence information of a user and information on a user’s devices, services and service components being managed by the network. Together they form a presence entity that is called presentity [29].

The Presence service is attribute-related information and is a service that can be exploited to create additional services. The Presence service framework offers interfaces to virtually all existing mobile network components. It has client-server architecture where a Presence server can be located in a Telecom operator domain or in the Internet. The Presence service framework has the capability to support and manage presence information via watchers and presentities in a manner so that applications and services can utilize presence information. A watcher is an entity that has the ability to retrieve presence information and a presentity is an entity that can update and modify presence information. [29]

The attribute-based Presence information is in the Presence Tuple format, which forms the logical information model. The Tuple is illustrated in Figure 4. The Presence information register can contain any number of Tuples. A Presence Tuple must have a status attribute, which can have values that are open, closed and not disclosed. The description of a Communication Address, which is the second mandatory attribute, is divided into two sub-attributes that are Communication means and Contact address. Other Presence Mark-up fields may contain any other Presence information. When a mobile Telecom operator wishes to offer proprietary Presence services in order to distinguish itself from the competition, the Other Presence Mark-up field is the location for the Presence attributes that enable the unique Presence services. [30]

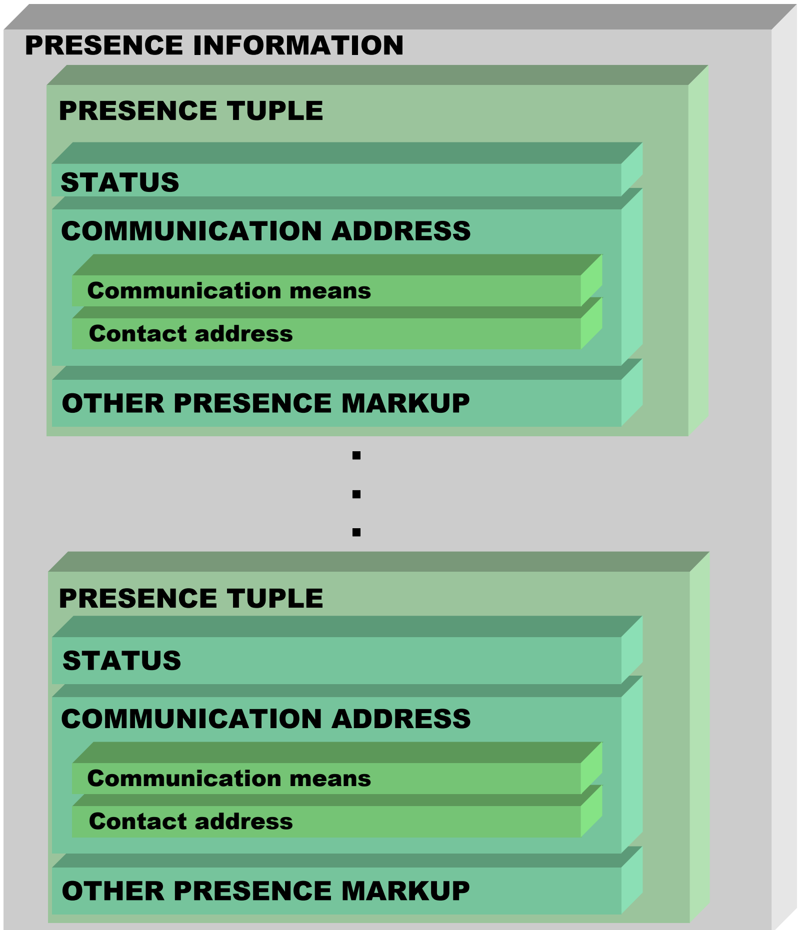


Figure 4. Presence Tuple.

2.2.4 Generic user profile

The European Telecommunication Standards Institute oversees the development efforts of the Generic User Profile. It is a set of data that is particularly related to a user's service environment. A 3GPP Generic User Profile (GUP) can be stored in multiple entities in various locations. An end user can create specific service portfolios according to the requirements entered via GUP data to his PSE. GUP information can be stored virtually anywhere in the Internet. GUP data is public, meaning that anyone can access it. The purpose of the GUP is to share the following information among service-providing stakeholders:

- User preference management: Enable applications to read and utilize a limited set of user preference information
- User service customization: Enable applications to read and utilize personalized service information, i.e., individual settings for a particular service
- Terminal capability management: Enable applications to access terminal-related capabilities
- User Information sharing: Enable applications to read and utilize application-level information, e.g., address book information
- Profile key access: Enable applications to use a unique identity as a key to access profile information, .e.g., any public user identity or an alias. [31]

The GUP has Data Description Method and the Datatype Definition Method to describe GUP information. A GUP is a collection of profile components and a GUP must have at least one profile component. A profile component is a collection of data elements. A data element contains an individual profile value. The Data Description Method (DDM) describes how to organize GUP data. It is based on XML schema. The Datatype Definition Method (DtDM) describes how to define new data types to GUP. It is also in accordance with XML schema. Therefore, all GUP are well-formed and valid XML documents. [32]

2.2.5 The mobile service customization and delivery system

Researchers from The University of Guelph have designed a system for customizing and delivering mobile services using software agents and Composite Capability/Preference Profiles. In the proposed operating scenario, an end user using a mobile client device requests a certain type of service from a network server. The server returns a service customized to match the user's preferences and device characteristics. Both browser-based WAP applications and native J2ME applications are supported as offered services, depending on the client device's capabilities. [33]

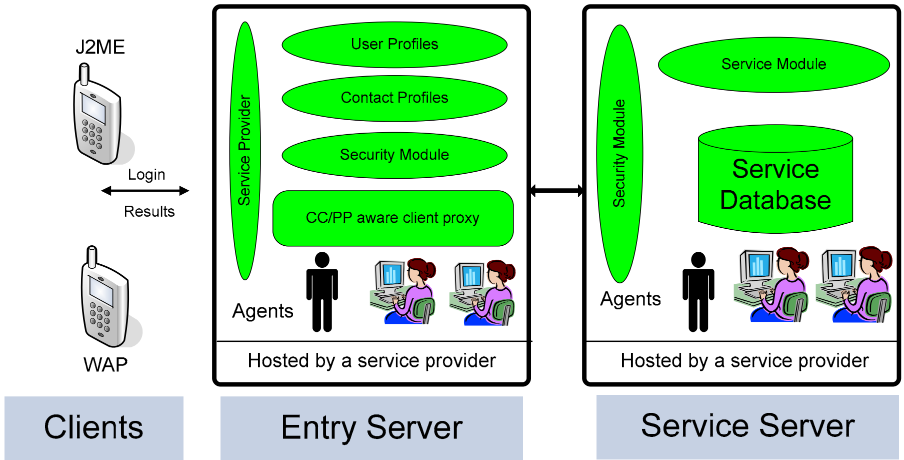


Figure 5. Architecture of the mobile service customization and delivery system.

The system's client/server architecture is depicted in Figure 5. The server tier is split into Entity and Service Servers. The Service Server hosts services and their descriptions. The Entity Server handles communication between clients and Service Servers, profile management as well as client location tracking. It uses mobile agents to retrieve suitable services from the Service Server and provides them to clients based on end user service requests, location information, time of day and attributes derived from user profiles. [33]

The system uses "reference profiles" for defining the client device's default capabilities, for example, using the UAProf vocabulary. Upon end user login, the client sends a third party URL for the appropriate reference profile to the entity server. Differences to the reference profile in the client device are subsequently sent as in-line XML fragments. The entity server merges the reference profile and the differences into a single user profile, and stores it in permanent storage. [33]

The prototype implementation for the system has been built using Java. The agents have been implemented using Java Remote Method Invocation. Service and profile data is stored on the servers in a MySQL database accessed using Java Database Connectivity. A Java Servlet in the Entity Server communicates with mobile clients, using a WAP Gateway component for supporting WAP devices. For transferring the CC/PP profiles, the prototype system supports the CC/PP ex, Wireless Hyper Text Protocol (W-HTTP) and WSP protocols. CC/PP ex and W-HTTP use the HTTP protocol, and WSP uses WAP. [33]

2.2.6 The ubiQos system

UbiQoS is an application-level middleware for Quality of Service tailoring and adapting Video-on-Demand over IP networks. UbiQoS uses application-level technologies such as Java's Multimedia Framework in implementation and Real-Time Protocol for video streaming. User preferences and device capabilities are described in Composite Capability/Preference Profiles. [34]

When a user requests a Video-on-Demand (VoD) flow, ubiQoS retrieves a user preference profile and current device capabilities profile from Lightweight Directory Access Protocol servers. No centralized profile storage server is used; Light Weight Directory Protocol (LDAP) server sub-components are placed in ubiQoS gateways. Using discovery service, ubiQoS searches for a server with requested VoD content and a QoS level greater or equal to the level defined in profiles. After finding a suitable VoD server, ubiQoS establishes a network path from server to client for the VoD flow. Matching the QoS to the requested level is done in ubiQoS components along the network path, and each component along this path decides which downscaling operations to perform at which nodes. UbiQoS also accepts new VoD requests for enhancing the current VoD flow at runtime, if enough local resources are available at the request time. [34]

The state of the system and network resources along the network path dictates how QoS is adapted for VoD flows. A monitoring component controls resources' states during service provisioning and triggers adaptation operations to adjust the QoS level if resources change. The adaptation can affect the VoD data itself, for example by changing the video resolution or frame-rate, or the adaptation can lead to modifying the existing network path. When this occurs, ubiQoS triggers a new negotiation phase and distributes new middleware components where needed. The type of adaptation operation depends on the client's user profile and terminal's capability profile, which defines priorities to available adaptation modes. [34]

UbiQoS network architecture, depicted in Figure 6, is a gateway architecture, which consists of proxies, gateways, client and server stubs. UbiQoS is organized into hierarchies or domains considering clients, servers and networked resources. Proxies migrate throughout the network, composing a dynamically determined active path between client and server, depending on client location at provision time. Proxies perform admission control and reservation for incoming and outgoing flows. Proxies also monitor system- and application-level resources and trigger local QoS adaptation operations. [34]

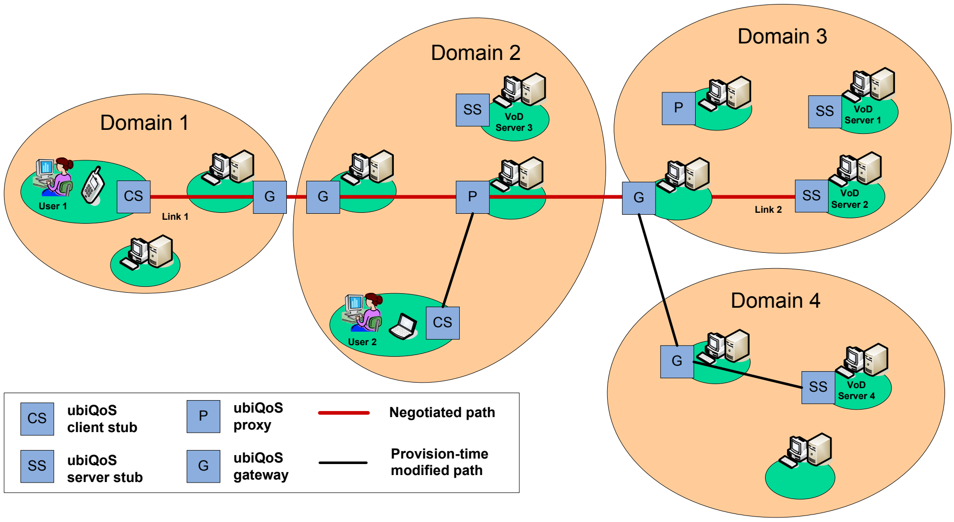


Figure 6. The ubiQoS architecture.

Gateways expand ubiQoS proxies with additional naming and coordination functions being the most complete component, because it includes all basic modules. Each domain contains one ubiQoS gateway. The UbiQoS gateway is the only component that can fully view neighbor domains and ubiQoS components inside these domains, which helps ubiQoS to provide scalable naming solutions and make structure management decisions. [34]

Stubs integrate the ubiQoS infrastructure with legacy VoD servers and players. Client stubs transparently forward VoD requests to ubiQoS components and Real Time Protocol (RTP) flows to local visualization tools. Server stubs reply to service requests from ubiQoS components by transparently encapsulating server VoD flows into RTP flows. [34]

2.2.7 Mobile Ubiquitous Service Environment

The Mobile Ubiquitous Service Environment aims to enable users to get 'always best service experience' according to their requirements and preferences wherever they are and whenever they need. It is built over wired or wireless heterogeneous access networks and intelligent distributed terminals aggregating through networks around users, and employing the reconfiguration mechanism, and provides capabilities of heterogeneous networks and distributed terminals cooperatively. The goal of the Mobile Ubiquitous Service Environment (MUSE) service architecture is that the variable terminals and heterogeneous access networks will form a service environment to provide and present services to users. The services will be constructed via the standard control functions exposed by the MUSE, which are independent from the implementation details of the networks and terminals. The goal is to integrate the development trend of the future Internet and wireless network domain. The purpose is to provide Always Best Experience to users [35].

The MUSE uniformly merges networks and terminals into a ubiquitous service environment which has support capabilities of mobility, customization, pervasive perception and adaptation based on available services. The MUSE emphasizes such a service environment's heterogeneity and the reconstruction capability of the network and terminal, the collaboration between the network and terminal service environment, especially the possibility of the rich services supported by the cooperation between a personal area wireless environment and a wide area wireless environment. The MUSE also emphasizes easy service creation via a standard interface to shield the detail change of the network or terminal. In the concept model of the MUSE, the function of the network and terminal is abstracted into capabilities and mechanisms, and for the sake of the smart management and effectively collaboration, these capabilities and mechanisms can be detectable, re-presentable, valuable, expansible and adaptable [35].

2.2.8 Dynamically Adaptive Networking Service Environment

The Dynamically Adaptive Networking Service Environment aims to coordinate creation of a telecommunication service environment according to an end user's requirements and context. The goal of the Dynamically Adaptive Networking Service Environment (DANSE) is to enable the better use of services and network resources. The DANSE requirements are the following:

- A user should have access to an optimal service environment for his/her current context that can be easily constructed without her having any special knowledge about the available services or network resources.
- A service provider should be able to have information about the number of end users of its products in order for it to reach as many potential users as possible. [36]

The DANSE handles network resources uniformly in heterogeneous networks, from local area networks to public telecommunication networks. It aims to dynamically coordinate creation of a service environment and actively proposes it to the user by adapting to the user's requirements and context. It combines all network resources flexibly to achieve dynamic assignment of network resources to a particular service. It actively proposes alternative service environments to meet user requirements to the greatest extent possible if an appropriate service environment cannot be initially obtained due to a lack of suitable network resources [36].

2.3 Discussions

The UAProf is vocabulary that is used for describing hardware and software capabilities of a given device. A collection of capabilities of a given set of devices used by a nomadic end user describes capabilities of his Personal Service Environment. The UAProf has a limited set of standardized and available vocabulary. Since it is in conformance with CC/PP framework, new attributes can be developed purposes yet to be discovered. If there are custom developed attributes downloaded into an environment that does not recognize them, they should not cause any problems as long as custom made attributes are in conformance with UAProf specification.

The described MExE platform focuses on downloading services dynamically to a single end user device at the time. The device capabilities are defined by its classmark but in principle they are not designed to be dynamic. The requested service by an end user has in its use device capabilities according to a device's classamark. The service either works or does not work in the device that it is downloaded to. The IMPS and presence service framework are used to deliver presence information of a single end user device and end users presence service status. The IMPS additionally has instant messaging, user group and shared content services. The General User Profile has similar features as other solutions described above, combined. It aims to manage end user information and capabilities of an end user device.

The mobile service customization and delivery system adapts WAP- and Java-based services to a device configuration. In this system also device capabilities are considered static. The ubiQos system just aims to tailor VoD data itself based on available QoS provided by the underlying network. It takes into consideration user profiles and capabilities of and end user device. The system does not consider dynamic changes in an end user's device configuration. The Mobile Ubiquitous Service Environment introduces a concept of a ubiquitous service environment that is composed of heterogeneous access networks and independently distributed devices working together. It aims to deliver the best service experience to the end user, but the actual solution is yet to be presented. It also does not consider devices as a single platform that has dynamically changing capabilities to provide services to a nomadic end user. The Dynamically Adaptive Networking Service Environment is focusing changes in the telecommunication network environment. It aims to maximize end users within a service provider's network infrastructure and does not consider dynamic changes in a nomadic end user's Personal Service Environment. Table 3 below further illustrates the target purpose of the previously described frameworks for enabling PSE.

Table 3. The focus state of the art frameworks.

The framework	Target purpose
MeXE	It aims to create and standardize execution environments within the mobile device. Execution environments are categorized according to used platform technology to create end user applications and execution rights for applications.
WV IMPS	The purpose is to define and standardize instant messaging and the presence service framework. Features to be included are presence service, instant message, user groups and shared content.
ETSI Presence Service framework	The purpose is to standardize presence the service framework to provide additional value to existing services of telecom operators.
GUP	The purpose of GUP is to standardize a solution for end users to create user profiles themselves. End users can define the set of services they would like use and also share application-level information such as a personal address book.
The Mobile service customization and delivery system	The prototype system is used to deliver customized services to and end user. It considers user preferences and existing device capabilities.
UbiQos	The focus is to tailor QoS in the VoD service. It tends to find the best possible network path based on a requested QoS level for VoD transfer.
MUSE	The purpose is to provide the best possible service experience to an end user and easy creation of services via a standard interface.
DANSE	The focus is on creation of an end user’s services according to an end user’s requirements and context.

3. Constructs

This chapter introduces a prototype solution that proves the concept of adaptive Personal Service Environment for a nomadic end user. Adaptive capability is achieved by the PSE when it has all or some of the following features:

- Capability adaptation: New devices can be added or existing devices removed from the PSE. New hardware and software components can be added or existing ones removed from a device that is a part of the PSE. Adaptation is based on a network QoS level, user preferences or context information.
- Logical adaptation: New services can be created by combining an existing service's service logic.

The adaptation of PSE is always dynamic since it can be seen that an end user always has a PSE even thought it might not include any roaming devices. From the service point of view adaptation can also be static, since the adaptation process can take place prior to the start of service execution.

The Active Service Management System (ASEMA) controls the adaptation process called profiling for a nomadic Personal Service Environment. The following Sections first discuss the profiling requirements for the ASEMA system that enables a PSE. Second, the ASEMA prototype system is introduced.

3.1 Profiling requirements for Personal Service Environment

The purpose of this chapter is to discuss requirements for adaptive preference profiling in a nomadic PSE. Firstly, general profiling requirements are introduced. Next, profiling requirements for terminal equipment – mobile phone functional split when roaming in a cellular network are discussed. This is a special case which has its own requirements for profile negotiation due to a PSE's interaction with Telecom operators' cellular network. Then, service profiling requirements are discussed from the view point of an enterprises system. Finally, there is an analysis of profiling requirements from the ubiquitous financial service perspective. All of the above requirements are further illustrated in Figure 7 below.

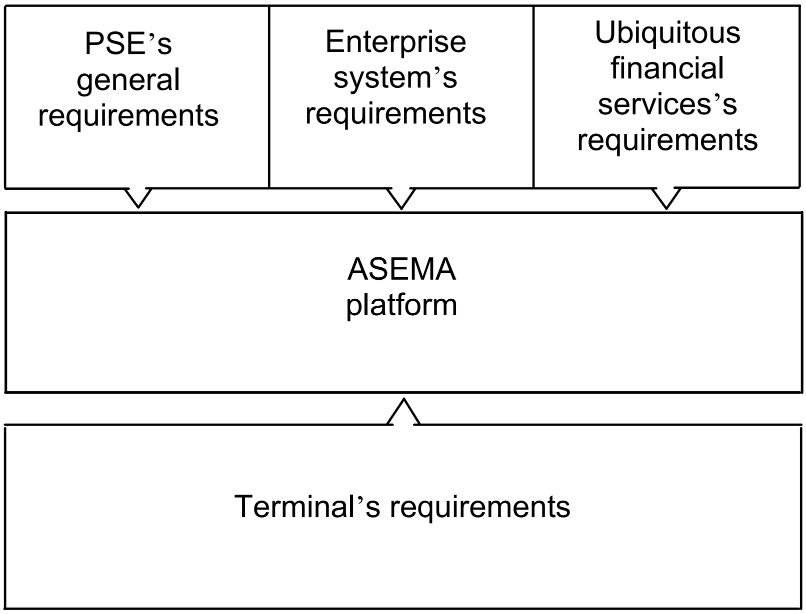


Figure 7. Parties imposing requirements on the ASEMA platform.

3.1.1 General requirements

An adaptive PSE profiling offers a nomadic end user the freedom to have a customized PSE for different situations. There can be separate service environments for home, automobile and office since each environment can have specific devices that momentarily become part of the nomadic PSE. An adaptive PSE enables better access for a nomadic end user to context-specific services or a context-enhanced service. In order to achieve dynamic reconfiguration of a PSE, the environment must have a well functioning profiling capability. A profile negotiation has the following requirements for an adaptive PSE:

- Successful and complete delivery of a required part of the profile description for a negotiation session
- Portability of profile information of a PSE

- Secure means of delivering a PSE's profile information
- Preservation of scarce wireless network resources
- Metadata register for services. A service should have a metadata register of where the URI is located at the same location as the application itself. A metadata register of a service can be stored elsewhere.
- Full profiling information of a PSE should be divisible into multiple independent registers.
- Separate profiling registers should be storable into multiple locations in the Internet.
- All profiling registers must have a specific URI, which can be used to retrieve them whenever needed.
- Device-specific profile URIs must also be stored into the device itself.

When an end user device boots up, the PSE is also established. Interfaces with network components can be added to the PSE. At the initial roaming the necessary parts of the profile information is negotiated among new network components. The same applies if new end user devices are added to the PSE. After the initial profile negotiation, the PSE is ready to discover services. Once requested, services are discovered and before initialization of a content transfer, session service-based profiling negotiation will be conducted. Based on the results of the negotiation session, service execution is either started or rejected. During service execution, profiling negotiation sessions occur whenever needed. If a service session is rejected, instructions about utilizing the service can be provided to the end user. Instructions can advise an end user on existing limitations in the PSE and propose additional resources to be obtained for the PSE in order for it to be able to use the requested service.

An active use of indirect referencing of a profile description by a URI requires that profile data repositories must be updated promptly. This is not the problem with values of the permanent Hardware and Software profiles, since they are installed permanently into end use devices in a manufacturing phase and cannot be erased or modified. However downloaded software components and applications can change the software platform configuration or the hardware profile can be altered when additional equipment such as a full keyboard or larger screen is added to the PSE. Modifiable profile information that is stored in a user database should be updated immediately after the changes occur in the PSE. The profiling information of a PSE may change when it is not connected to any network. While the PSE's profile configuration changes when it cannot connect with a profile database, the synchronization of profile information is made again in the initial connection.

The remote referencing technique, backed up with the direct transfer of a profile description, ensures the uploading of the required profile information for the negotiation session. Since remote referencing is the primary procedure, the requirement for preservation of wireless resources is being fulfilled. The portability of PSE profile information is achieved, since it is stored in end user devices, by a profile database in the network and manufacturer's profile data repositories. When an end user introduces a new device into the PSE, all the profile settings of new equipment from different data repositories are included into a part of the PSE.

All documents, referred to as profile registers in PSE, should be encoded with well-formed and valid XML and be in conformance with UAProf specification. Attributes should have unique names and should have only one attribute to describe in a single quality. All profile registers should be accomplished with a common attribute syntax. All profile registers should be arranged in a tree structure, and when attribute data is updated only the new information is transferred with the correct path of the updated attributes. The most common application-level protocols should be support for the profile negotiation session, the most common ones being HTTP, WSP, SMS and SIP.

The Metadata register of a service is a file that describes the minimum requirements for a service environment where that particular service or application can be executed. The schema and the properties of a service metadata register should be based on UAProf specifications, as are the schema and the properties of profile registers. A metadata register, similar to profile registers, must be accessible via a URI, which enables the PSE to download it for profiling purposes.

3.1.2 Requirements by terminal equipment – mobile phone functional split

A more intelligent PSE is achieved when additional devices that have their own communication means and processing capabilities are added to it. For example, a single mobile phone may provide cellular communication means in a PSE for other equipment such as a simple PDA or lap-top computer, which are examples of terminal equipment. Recent development has shown the emergence of smart phones that have selected features from cellular phones, PDA equipment and lap top computers. Smart phones have become so successful that they seem to be capturing markets from PDA equipment. A mobile phone can also provide more than just a modem connection between Internet services and other terminal equipment. It can provide additional value to service logic to be provided to an end user via a PSE. Due to the emergence of new end-user devices there will be devices in a PSE that can play both roles: terminal equipment and mobile phone. Additionally, multiple devices can have the same role in a PSE. There are additional requirements for a PSE's service profiling when mobile phone and terminal equipment are part of it. The functional requirements proposed by the 3rd Generation Partnership Project (3GPP) for terminal equipment are the following:

- The functional split applies to both Circuit-Switched and Packet-Switched domains
- It should be possible to control which mobile terminals and terminal equipment belong to the service environment.
- A standardized application protocol interface must be provided for both the mobile terminal and terminal equipment in order to interact with each other.
- It must be possible to develop applications for terminal equipment that can use standardized radio modules.
- Security requirements dictate that, regardless of the physical separation of terminal equipment and a mobile terminal, the security must be equivalent to devices that have both parts physically integrated and a Universal Subscriber Identity Module must remain in a mobile terminal [37].

The functional requirements for mobile phones by the 3GPP are as following. The phone must

- have a radio attachment to the standardized network,
- authenticate subscriptions to services in a Telecom operator's domain,
- communicate with a Universal Subscriber Identity Module and a Universal Integrated Circuit Card on behalf of terminal equipment,
- create, activate and deactivate connections on demand from terminal equipment,
- include mobility management function including security functions, and
- terminal equipment should be able to use services and capabilities offered by a mobile phone. In any scenario, a mobile phone must have final control of a service environment, such as ultimate control of active connections. [37]

The functional requirements for the terminal equipment – mobile terminal functionality split do not specifically define how the capability negotiations of terminal equipment are to be executed in a PSE. The general functional requirement is that a mobile terminal manages service events and connections of the symbiosis of mobile terminal and terminal equipment with a network. Since 3GPP standardized functional requirements must be taken into consideration, the following profiling requirements for a functional split are derived from them.

Terminal equipment must be capable of conducting a service profiling session with a PSE. Otherwise terminal equipment added services cannot be utilized by a PSE. Therefore, terminal equipment must have its own profile register in conformance with other profiling registers in a PSE. A mobile phone must have the final authority of network connections and therefore it should be able to transfer a terminal equipment's profiling information to possible network components. When a mobile phone is managing a profiling negotiation for terminal equipment, it needs to know where to retrieve its capability data. This information must be in a mobile phone's own capability register and a new attribute, TerminalEquipmentRegister, is needed to store a URI of the terminal equipment's profiling data. A mobile phone can also transfer the URI of terminal equipment to network components in the event that a profile negotiation is conducted by a network entity. Since a terminal equipment's profile register is referred by a URI, it can be divided into subsections that can be stored in multiple locations on the Internet and mobile network. A profile negotiation strategy where capability attributes are permanent and are stored in network entities instead of terminal equipment can be executed only by applying the TerminalEquipmentRegister attribute. A remote referencing profile negotiation strategy saves wireless network resources and, in most cases, limited resources of terminal equipment and mobile devices.

Due to the versatility of terminal equipment, there is a need for two new memory control attributes in the device profile register. The InstallationMemory attribute indicates the amount of memory left for installation of a new service into terminal equipment which is non-volatile memory such as flash memory, Erasable Programmable Read-Only Memory (EPROM) or Electrically Erasable Programmable Read-Only Memory (EEPROM). The ExecutionMemory attribute indicates how much memory there is available for executing services in the equipment which is volatile memory such as static or dynamic Random Access Memory (RAM). The purpose of the Installation Memory attribute is to prevent a user from downloading a service to terminal equipment that cannot be installed due to a lack of memory space in the equipment. Therefore, the Installation Memory attribute indicates the current status of free available memory for the installation of services. When the attribute prevents a user from downloading a service to terminal equipment there are two alternatives for further actions: either free up some memory space in equipment and try re-downloading the wanted service or abandon downloading of the service. The ExecutionMemory attribute prevents a user from downloading a service onto terminal equipment that cannot be executed under any circumstances by that equipment. Therefore it indicates the maximum available memory for execution of a service in the terminal equipment. Circumstances may arise when the Execution Memory attribute allows the downloading of a service into the terminal equipment, but still there is not enough free execution memory available in the equipment at that moment. That indicates that the downloaded service needs most of the total available execution memory for itself and perhaps must be executed alone. However the ExecutionMemory attribute does not prevent downloading of a service into the equipment since it does not describe temporary execution memory in terminal equipment but maximum available execution memory. Both memory control attributes prevent unwanted situations where an end user tries to download a service that cannot be executed on the target equipment.

3.1.3 Requirements by enterprise systems

Services of an enterprise system are typically used inside a secure administrated domain, which is guarded against attacks from the Internet by firewalls. Within an enterprise domain a communication infrastructure is often based on Local Area Networks. Due to widely deployed wireless access technologies such as General Packet Radio Access, Wideband Code Division Multiple Access (WCDMA) and Wireless LAN, attractive business cases may be derived by extending access for the existing enterprise solutions to a nomadic end user's adaptive PSE. However, establishing communication connections between parties of mobile PSE and enterprise domains cause problems.

There are differences in services and operational environments of enterprise and wireless service domains. In enterprise domains, applications are often developed for a PC environment. In a wireless PSE, battery life, memory and CPU power are limited, as well as the capabilities of user interfaces. Enterprise PCs are often connected by using fixed access technologies, while mobile devices usually use wireless access technologies to establish data connections. There are also differences in applied middleware technologies between these environments. These fundamental differences can create problems when trying to access resources of an enterprise system from an application developed for mobile domains.

Traditionally, object- and session-oriented middleware solutions such as DCOM, Java RMI or CORBA have been deployed in enterprise domains. They are expensive to purchase, but provide support for application development. The benefits of object-oriented frameworks are modularity, reusability, extensibility and inversion of control for software developers [38]. Unfortunately they are not directly applicable in wireless PSE domains. Java RMI in a wireless domain suffers from heavy use of TCP connections and heaviness of the protocol itself. The problem with DCOM is the lack of support for platform-independency. The CORBA's challenges in a wireless environment are reliability of transport and mobility support for terminals [39]. Therefore, a Message Oriented Middleware solution is required to enhance content transfer between nomadic PSE and enterprise domains.

As previously discussed, existing enterprise applications and services are particularly designed for the enterprise environment. Therefore, mobilizing existing applications by replacing the fixed LAN connection with a wireless Wide Area Network (WAN) connection, even if the problems of an object-oriented middleware in wireless environments could be overcome, does not provide a satisfactory result. Instead, extending the existing applications with newly designed mobile extensions is an approach that can guarantee fluent, reliable and secure operation in a nomadic PSE. These extensions should be designed so that the amount of transferred data in the wireless Wide Area Network is optimized. A processing scheme of data between the server and mobile client should be carefully planned because of limitations and varying resources of different mobile terminals. A workload allocation between the server and nomadic PSE could be adaptive to a PSE, dynamically changing resources and network capabilities. An adaptive PSE can just include a very low-end mobile device that has a small amount of execution memory and permanent data storage capability. Further design considerations for mobile extensions of enterprise applications are due to the intermittent connectivity of wireless networks. A user interface design is also challenging for a nomadic PSE as input/output capabilities are usually constrained by small screens and limited keyboard input methods differ from the traditional mouse and keyboard combination.

Typical enterprise environments are also trusted domains. When extending enterprise applications outside an enterprise domain to a nomadic PSE, security becomes a matter requiring special attention. This is because access to enterprise networks has to be granted from outside the enterprise premises in order to enable use of WAN access. A popular way of handling data security is to tunnel and encrypt the data that is passed outside an enterprise domain by Virtual Private Network technologies. Additional security considerations arise from mobile terminals that are usually carried and can easily get into the wrong hands. Therefore, users must be authenticated prior to accessing enterprise networks.

The requirements for a nomadic PSE for mobilizing enterprise applications mainly come from the differences between the enterprise and mobile computing environments. A nomadic PSE can provide middleware-based services that can partly hide and overcome these differences, or provide option for services to deal with the differences fluently. On the other hand, some requirements for every mobile application are set by the end user. The requirements of personalization, adaptive- and context-aware services are partly required by the user and partly by the nomadic PSE characteristics.

First, a nomadic PSE should take advantage of both the object- and message-oriented middleware. Object-oriented middleware has clear advantages over Message Oriented Middleware (MOM) in the enterprise environments and should not be replaced there. However, when extending the enterprise applications to be used from a nomadic PSE, object oriented middleware technologies become less applicable and MOM technologies should be favored in a nomadic PSE.

Because a nomadic PSE resides in a wireless domain outside the normal enterprise system's boundaries, security also poses some requirements. For enterprise system-based services, a nomadic PSE should have a strong centralized user authentication. In addition, the data that is transferred inside the distributed service platform should be encrypted with Virtual Private Network (VPN) technology. As a PSE incorporates wireless links, it should provide services for network state monitoring for services utilizing it. There should be a QoS monitoring feature generally available in the PSE because it is needed for the adaptive functionality of services. It can be extended to security-level monitoring when needed for service execution purposes.

A nomadic PSE should support two different kinds of interaction models to enable use of versatile enterprise system services. First, the web-style access using full and mini browsers, representing the pull interaction model, enables access from almost any connected terminal from a PC to a mobile phone. Second, it should support a combination of pull and push interaction models to enable truly distributed and highly interactive services that provide added value compared to a web-style interaction model.

3.1.4 Requirements for ubiquitous financial services

Financial services provided by an enterprise system are typically used inside a secure administrated domain. They are most often guarded against attacks from the Internet by firewalls. When financial services are used outside of this restricted domain, content is heavily encrypted or VPN technology is utilized between the enterprise domain and remote location. Within an enterprise domain, as discussed earlier, a communication infrastructure is often based on Local Area Networks or other fast network connection. This is not always the case when a nomadic PSE establishes a content transfer session with an enterprise's system servers that provide financial services. It still has to manage to deliver reasonable end user experience by utilizing relatively slow cellular connections such as General Packet Radio Access (GPRS) or GSM.

The requirements for the ubiquitous financial services business case were derived by interviewing financial online service providers and mobile solution providers. The top general requirements derived from the financial services industry were that the system must support the market transaction decisions of end users, provide real time market information without end user interaction, be easy to use and ensure that the existing content of online services is usable by the system. The system must also support all the existing services that online systems provide today, such as the buying and selling of publicly traded financial instruments, an end user authentication mechanism, a secure end-to-end connection, real time market information, online news service and the setting of alarm limits for chosen stocks.

The requirements that arose from the interviews with mobile solution providers were end device usability, system integration to other services and system environments and fast branding. Device usability in this case means high device penetration so that the mobile client part of the system is installable and usable by as many different mobile devices as possible. The system's easy integration into other Telecom operator services such as billing and location information must be possible – it should be able to utilize all variants of operator environments. The fast branding requirement means that the system must be made to look and feel as if it were tailor made to each client with minimal system development effort, even though they are running the very same service. Finally, the system must have interfaces to existing system infrastructures in place in financial institutions.

3.2 Active Service Management System for Personal Service Environment

Based on the research of requirements for a PSE, an Active Service Management system prototype is built to test a concept of an adaptive PSE for a nomadic end user. The ASEMA system includes components for wireless devices that form a nomadic end user's PSE and components for the network side that serve as an interface from the PSE to services in general. The purpose of the ASEMA system is to control an adaptive PSE composed of multiple middleware components that are distributed among end user devices and enabling network components. It will keep track of the service environment's dynamically changing software and hardware capabilities. The ASEMA system is mostly invisible to the end user. It provides information about installable services and devices such as an extended keyboard or headset to end user. It may also inform the end user about new components that must be installed before a particular service that is requested can be executed in the end user's service environment.

The prototype ASEMA system architecture is illustrated below in Figure 8. It is composed of four mobile end user devices; four Symbian based multimedia phones, (Nokia N92, Nokia E70, Nokia 6680 and Nokia 9500), and the Linux-based Internet tablet Nokia 770. In addition, there is one more end user device, a laptop with an M4MAMI PC-based end user client installed. The ASEMA server cloud contains all the necessary server components required by the system. Finally, there is a web camera that can stream video and can be controlled remotely by an end user.

All the communication and content transfer within the ASEMA system is IP based. TCP or UDP connections over IP are used for content transfer within the system. TCP sessions have the advantage over UDP due to the acknowledgement of the delivered content package. UDP was chosen as an alternative protocol since not all simple wireless devices support TCP. SIP is used mainly for opening push sessions from the network side in the PSE. RTSP and RTP are used for video content streaming purposes. Both protocols are chosen in order to achieve a wider range of applicable end user devices for video content streaming purposes. HTTP is used as the basic content transfer protocol in the system. The Generic Communication Manager (GCM) in the ASEMA system was created for the M4MAMI and can easily be utilized in any other service scenario.

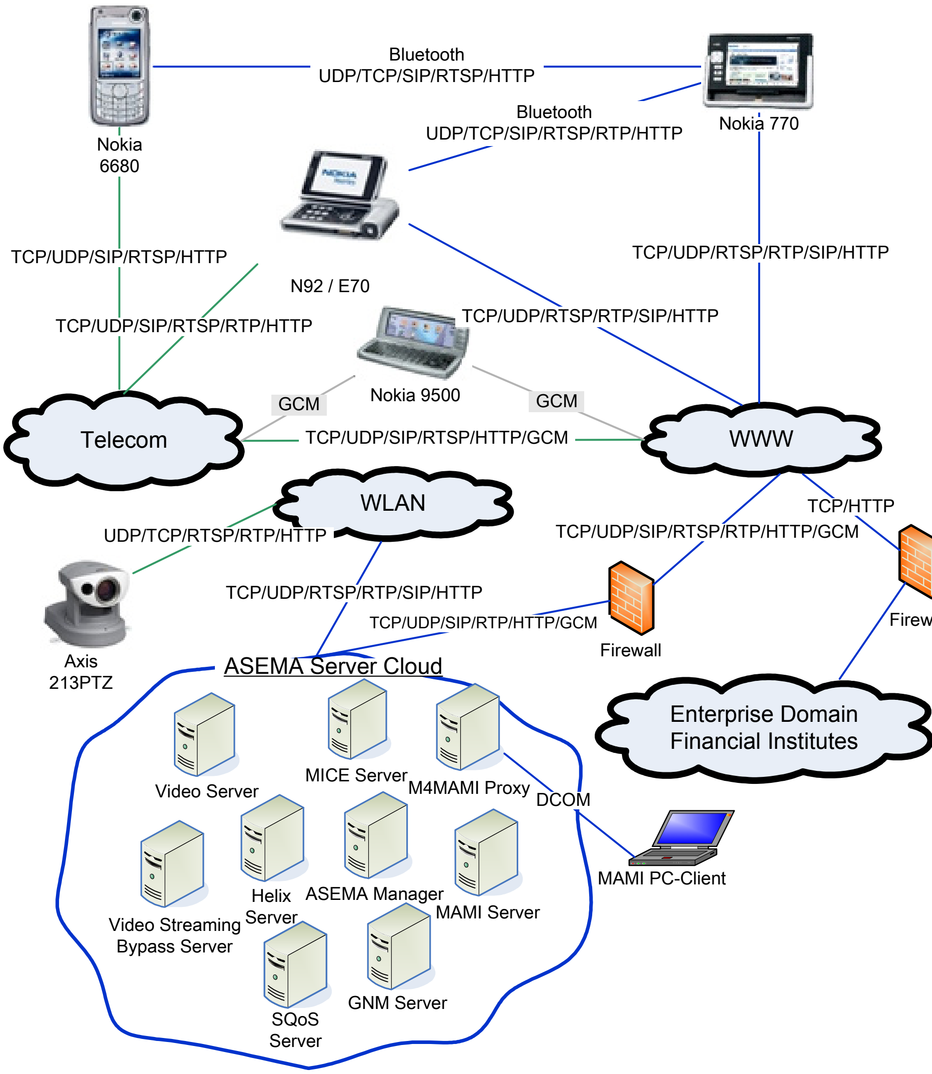


Figure 8. The ASEMA prototype system.

All the ASEMA components that are found on the client devices are depicted in Figure 9. The ASEMA system Camera Control component is found on both Symbian- and Linux-based client devices. It is solely used for controlling the Axis camera and it offers services to video players used in the system. The ASEMA SIP manager is in the Nokia 770 and can be installed in all the Symbian phones that have Symbian OS 8.0 or a later version. It offers an easy-to-use interface to an SIP stack for all client applications. The Generic Negotiation Manager (GNM) and Scalable Quality of Service (SQoS) components are implemented into both Symbian and Linux platforms. The GNM controller is used to manage sessions with the ASEMA server to initiate and respond to a request for when capability negotiation sessions are required. The Video Streaming Bypass component is needed for video streaming monitoring purposes for the Nokia 770 since it does not offer others means of monitoring streaming traffic at the client end as Symbian-based Nokia phones do. The GCM implementation was done only for Symbian phones for demonstration purposes and will be done on a later occasion for the Nokia 770. The common feature for all the components is that they are dynamically downloadable and installable to client devices. This enables the end user to build his PSE based on individual service needs and desires.

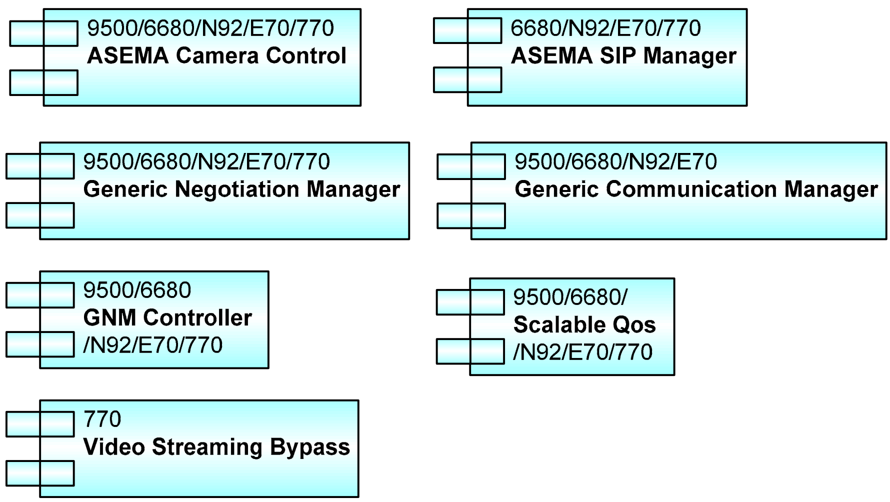


Figure 9. The ASEMA system's end user device components.

3.2.1 Profile negotiation subsystem

The core of the ASEMA system is its profile negotiation subsystem. Figure 10 illustrates the profile negotiation sub-system architecture. Both the wireless device and ASEMA server end contains profile registers of PSE. The GNM server is responsible for maintaining valid PSE-related profile data in profile registers on the server end of the system. When a new device is introduced to the PSE, it requests from the Internet the available device-specific profile data, which is now part of the end user's PSE, to its profile register database. This session is initiated and controlled by the ASEMA manager. If needed, the GNM server requests the ASEMA manager to open a session with the wireless device for updating the target device's profile register. There is a database synchronization scheme applied so that only the changed profile data is uploaded to the wireless device.

Before the GNM server can request a new device's profile data from the Internet, the device needs to publish its existence in the PSE to the GNM server. The minimum information it needs to transfer from itself is the type of device it is and the URI where the profile registers can be uploaded. In the wireless device the ASEMA SIP manager is an interface to the SIP stack and is used to initiate and control SIP sessions. The GNM controller initiates and manages profile negotiation sessions with the ASEMA manager. In the case of the new device in the PSE, the controller uploads the device URI and device type information to the GNM server. The GNM component is dedicated to managing profile registers in wireless devices.

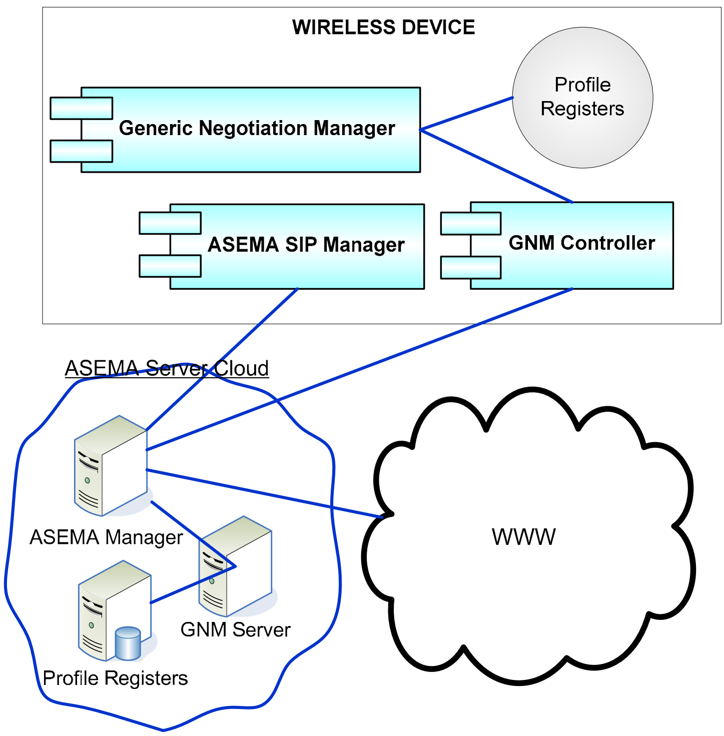


Figure 10. The ASEMA system's profile negotiation sub-system.

The ASEMA profile registers are in compliance with Composite Capability Preference Profile (CC/PP) syntax and schema. The example of the ASEMA system profile is illustrated in Figure 11. There are three ASEMA-specific attributes described:

– <rdf:li_asema:version=”1.0”>SQoS</rdf:li>
– <rdf:li_asema:version=”1.0”>VideoPlayer</rdf:li>
– <rdf:li_asema:version=”1.0”>GCM</rdf:li>

It is specified on the following lines, above the attributes, that they are client device attributes. (<rdf:Description_rdf:about="http://www.example.com/about# DeviceSoftware">and<rdf:type df:resource="http://www.example.com/schema# DeviceSoftware"/>). In this particular case, the SQoS software component, Video Player and GCM component versions 1.0 are installed to the end user device. The system profile also includes the software platform attributes InstallationMemory and ExecutionMemory. The TerminalEquipmentRegister is a hardware platform attribute that is crucial to the ASEMA system since its value is location information where device manufacture profile data can be retrieved.

```
<?xml version="1.0" ?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:ccpp="http://www.w3.org/2002/11/08-ccpp-schema#"
  xmlns:asema="http://www.example.com/schema#">
  <rdf:Description>
    <ccpp:component>
      <rdf:Description
        rdf:about="http://www.example.com/about#DeviceSoftware">
        <rdf:type
          rdf:resource="http://www.example.com/schema#DeviceSoftware" />
        <asema:AsemaComponents>
          <rdf:Bag>
            <rdf:li asema:Version="1.0">SQoS</rdf:li>
            <rdf:li asema:Version="1.0">Video Player</rdf:li>
            <rdf:li asema:Version="1.0">GCM</rdf:li>
            ...
          </rdf:Bag>
        </asema:AsemaComponents>
      </rdf:Description>
    </ccpp:component>
    ...
  </rdf:Description>
</rdf:RDF>
```

Figure 11. The ASEMA system’s profile register example.

The ASEMA system profile data is stored at the server end in a relational database. It is managed by the GNM server. At the mobile client end, the profile date is stored in the Extensible Mark-up Language document format, which is managed by the GNM client component. The XML document format was chosen since databases in mobile devices are relatively slow and resource consuming. Also, a single client device only manages its own profile instead of the whole profile of the ASEMA system that the server manages. The capability profile transfer session is initiated by the SIP either by the ASEMA server or the GNM controller in a client device. HTTP is used to transfer payload between the client GNM and the GNM server.

3.2.2 QoS monitoring subsystem

The ASEMA system also has a Scalable Quality of Service (SQoS) management subsystem. There are two SQoS subsystems alternatives deployed, as illustrated in Figure 12. The first solution is end-to-end communication, where each device can perform as a client or a server. The second solution illustrates a relatively similar approach, but with a central server to handle QoS information, including notifications to performing servers leading to actions on the transmission. Both alternatives have the same basic frame of functionalities. Each end user device entails a preference profile in the XML document format.

After the initial connection, SQoS-related setup capability profiles are transmitted from the performing SQoS client to either the performing SQoS server that is one of the client devices in the first solution, or to the central SQoS server in the second solution. Each device contains its own CC/PP profile, which contains specific capability information of the device such as screen size, discrimination of end device efficiency, connection type, only video, no audio and preferred file types for other content. In the latter solution, the central SQoS server is informed of the QoS capabilities and desires of the end devices' communication means. In the first scenario, the performing SQoS server that is one of client devices internally deduces this information itself. After the rest of the session initialization procedures have been conducted, the media session may begin. The video and audio transmissions should be conveyed with the RTP protocol. By employing the RTP protocol, the beneficial RTCP Sender Reports and Receiver Reports can be used in assessing the quality of the connection.

Based on the assessment, the connection can then be modified. The quality and the quantity of the transmission content can be refined during transmission.

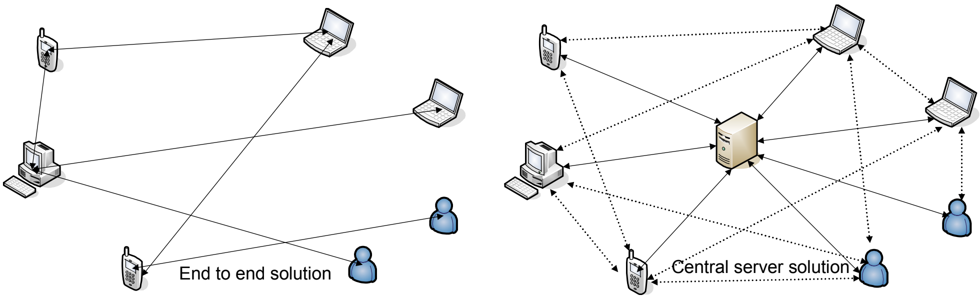


Figure 12. The ASEMA system's SQoS sub-architecture.

3.2.3 Other system components

The purpose of the video streaming bypass server is to offer an interface for monitoring video stream. It gathers video stream throughput data for scalable QoS calculations. The media player in the client device opens a connection to the video streaming bypass server which in turn opens a socket connection to the device that transmits video stream to the ASEMA system, which is in this case a web camera.

The video server is used for monitoring possible image uploads from any video or image source. In the ASEMA prototype system environment, images are pushed from the AXIS 213PTZ camera. The uploaded images from the camera are converted into MPEG-4 video stream format for streaming purposes to the client devices. Once new images are received from the camera by the video server, the ASEMA manager sends an SIP message to a roaming client device which is notified about a new available video file. The GNM server keeps track of the end user's roaming client devices in the ASEMA system at any given moment.

The purpose of the M4MAMI proxy is to convert DCOM messages of the MAMI system into GCM messages and vice versa. The M4MAMI proxy communicates with the GCM component in the mobile device illustrated in Figure 8, which in turn offers interfaces to applications in the mobile client. The database management scheme is used to transfer only meaningful information over wireless connections. These ASEMA server cloud and mobile client MAMI components are used to enhance wireless communication capabilities of an enterprise system that is used to manage massive production lines.

The purpose of the MICE server in the system is to provide financial stock information to ubiquitous financial services that utilize other ASEMA system services such as capability negotiation and scalable QoS. The HELIX server in the ASEMA system is used for streaming MPEG-4 video files that are made from the images sent by the AXIS camera to a roaming mobile client. The MAMI server in the system is a standard production server which sends and receives DCOM messages to and from the M4MAMI proxy.

The ASEMA manager in the ASEMA server cloud contains the main logic of the system. It manages all the servers in the system and reacts to service requests made directly or indirectly by the client components. It initiates requested sessions in a roaming client device and responds to session requests by client devices and the Axis camera. After the sessions are created, content is transferred directly in an end-to-end fashion between necessary components on the server and client side.

3.2.4 Discussions

The illustrated ASEMA system is composed of any set of heterogeneous devices. It can contain just one single end user device or it may be composed of multiple end user devices and, e.g., intelligent devices in a home environment when a nomadic end user is at home. The configuration of the ASEMA system changes dynamically. When the nomadic end user leaves home, only the devices that he carries with him will form the ASEMA system at that time. If the nomadic end user enters a car that has equipment that can interact with the ASEMA system, again they become a part of the ASEMA system. Basically, devices can enter and exit the ASEMA system dynamically. This same dynamic feature also applies to a single device in the ASEMA system. The device can dynamically obtain more hardware or software resources to its benefit.

The ASEMA system capability configuration, which is composed of devices and their hardware and software capabilities, is known on the network side of the ASEMA system. This enables service to adapt to the present configuration of the ASEMA system or vice versa. First of all, the system knows if the service requested by the end user is executable in the current ASEMA system configuration at all. If there are multiple versions available related to the requested service, the ASEMA system can choose the best possible version of the requested service. In this case the requested service adapts to the ASEMA system. In a case where a service is not executable in the ASEMA system or a nomadic end user wants to use more advanced version of the requested service, an end user can add new capabilities to his ASEMA system. In order for this adaptation to be possible, services also need to publish a list of capability features required by the service environment. The capability negotiation among the ASEMA capabilities and capability requirements of the requested service should take place immediately after the service has been discovered.

4. Use cases

At first purpose of this chapter is to introduce financial services offered to end users. The second is to study the base technologies used for making financial services to the public. These systems and services are obviously designed for wired Internet subscribers. The traditional thinking that wireless devices are just extensions of the wire-connected Internet does not provide the service experience required by a nomadic user in a dynamically changing Personal Service Environment.

4.1 State of the art of financial customer services

This chapter presents online banking services offered to private customers by major Finnish commercial banks. They are realized mainly by using HTTP or WAP browsers and when push type information is needed it is realized by SMS based services. Trends in the financial industry in Finland have created fully diversified one-stop financial warehouses. This paper focuses on mobile online investment services that are currently offered and their future development. Banking services are categorized as the following:

1. account services
2. loans and credit services
3. insurance services
4. investment services [40], [41], [42], [43], [44], [45].

It is noticeable that WAP-based online investment services are rarely offered and no one offers an SMS-based stock information service. Naturally, all of them have HTTP browser-based online investment services [40], [41], [42], [43], [44], [45]. This means that all the offered services are pull type and therefore the customer does not receive information when critical changes occur in the markets such as a rapid fall in the value of a stock that she is heavily invested in. Online services can be accessed by PDAs and smart phones that have an HTTP browser, but the content and user interface is not optimized for the small, low-resolution screens that these devices have. Also, these services are not designed for mobile environments where the QoS of a service network cannot be guaranteed and can be reduced to zero at any time. In order to make mobile online investment services successful, one must re-think the service scenarios with mobility in mind. The main challenges for a nomadic end user that uses financial services can be summarized in following list:

- Real time information should be available in all circumstances,
- critical information should be pushed to an end user,
- received information should be optimized to any end user device,
- critical information should be available regardless of an end user device's capabilities,
- critical information should be received by an end user regardless of the QoS of a network that an end user device is roaming to.

4.1.1 State of the art of technology platforms

This chapter presents the fundamental technologies and practices involved in typical web services, which are also offered by major system providers such as IBM, Oracle, Microsoft and Thales, to the financial services industry. The client/server model is the fundamental operational model of financial applications in the world of networked computers. It describes the relationship between two computer programs in which one program, the client, makes a service request from another program, the server, which fulfils the requests. This term is important, especially when considering distributed and networked systems.

4.1.2 Communication protocols

UDP or TCP over IP are suites of layered communication protocols used to connect hosts on the Internet. Both of these represent the de facto standard in computer networks and many client server applications rely on them. TCP and UDP offer data communication to upper layers of the protocol stack while relying on the IP protocol. The UDP offers only a minimal transport service, non-guaranteed datagram delivery. TCP instead includes mechanisms to establish a full duplex virtual connection between the endpoints and guaranteed data delivery [46], [47], [48]. TCP is well suited for data transport for financial services since it guarantees the delivery of content. The downside is that it requires a bit more network resources than UDP. The TCP client stack is available today in most multimedia mobile devices.

HTTP is the primary method used to transmit information on the World Wide Web as well as within online financial consumer services. It is a request-response protocol between the clients and servers. The request-response process is initiated by the client by establishing a TCP connection to the server. The transmitted information is mainly in HTML format. Better security is achieved by using secure version of HTTP, HTTPS, in which the content of the traffic is encrypted with Secure Socket Layer/Transport Layer Security (SSL/TLS) method [49], [50]. Figure 13 illustrates the protocol stack of protocols used by the banking industry.

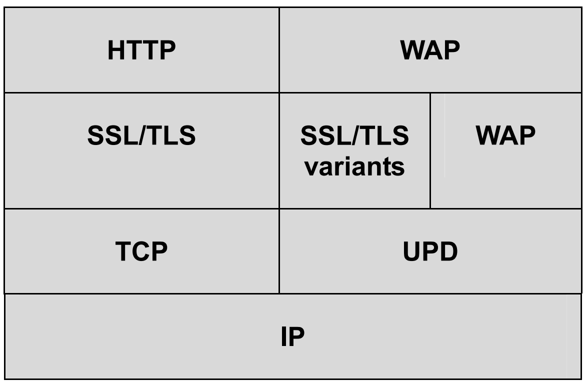


Figure 13. Protocol stack.

4.1.3 Authentication

The SSL/TLS protocol provides a secure channel between computers in a network, i.e., it provides confidentiality and integrity for the Internet banking system while being the de-facto standard. Solutions for authentication and non-repudiation depend on the system and its manufacturer and are not standardized. However, SSL is being replaced by the newer TLS. Although TLS is based on the older SSL, they are incompatible [51], [52]. The SSL/TLS layer is located between the application protocol and TCP. This is illustrated in Figure 13. The SSL/TLS is not intended to run over UDP or directly over IP. However, there are some SSL/TLS variants meant for datagram transport protocols like UDP. HTTPS consists of the usage of the ordinary HTTP over the SSL/TLS channel.

Before any secure communication can be established between the client and server, at least one endpoint must be authenticated. Typically, even when using SSL/TLS, only the server is an authenticated instance and the initial user side authentication is handled with passwords mechanisms. Client authentication for banking services through the use of a single password is not generally considered secure enough. In addition to user name and password, banking services usually require solving one challenge, for example providing an extra password from a bank-supplied one-time password list. [53]

It is also possible to authenticate clients and users by using mechanisms like Public Key Infrastructure (PKI), X.509 being the most widely accepted standard. A PKI ensures the trustworthiness of public keys by binding them to their correct owners. This is done by distributing public keys in digitally signed certificates issued by trusted third parties called Certificate Authorities. The certificates can be distributed and stored insecurely, as their digital signature can be independently verified by the client. The X.509 provides the standardized certificate format which, in addition to the public key data, defines, e.g., issuer and user IDs as well as a validity timeframe. [54] Thales is specialized in providing online financial service access control solutions such as cryptographically strengthened passwords.

4.1.4 Database technologies

Databases currently in use by online financial services are mostly relational databases. Later developments in the field, such as object and XML models, have been incorporated into popular relational database products as extensions. Database solutions come bundled with a suite of software called a Database Management System. In addition to managing the database itself, the Database Management System (DBMS) provides metadata catalogues and services for, e.g., transaction support, concurrency control, recovery and authorization. The Structured Query Language is the de facto standard in database definition, retrieval and manipulation languages. Most of the major Structured Query Language (SQL) implementers also use their own extensions or variants. Furthermore, there are numerous differences in how popular implementations actually handle the features of the SQL standard they support. This means that if the database platform of a service is switched, the previous database's SQL operations and definitions may not work without major alterations, if at all [27]. The most widely used commercial DBMS products are Oracle's self-titled database, IBM's DB2 and the Microsoft SQL Server. Gartner's DBMS statistics from 2004 show Oracle and IBM in a virtual tie over new license sales, each with a market share of around 30%. Microsoft was the third most popular vendor with 20%, followed by smaller competitors each with shares of a few percent. Free open source alternatives like MySQL and PostgreSQL also exist, but businesses like financial services tend to favor commercial systems. It must be noted that while all the aforementioned products are commonly referred to and regarded as relational databases, they do not strictly conform to the actual relational model, which even the SQL itself does not officially support. [55], [56], [57].

4.1.5 Development platforms

The Microsoft .NET framework is a development and execution environment for Windows-based applications. The framework enables Windows-based application development using different programming languages and libraries. The aim of .NET is to provide easy networked application and web service development through standard network protocols. Web services can be perceived as small units of code handling limited sets of tasks using XML-based protocols for communicating. The .NET can be understood as a Windows platform component handling the "plumbing" of development, leaving the focus of the application's business logic to the developer. The environment is indented to be used only in Windows-based platforms. The main component of .NET framework architecture is Common Language Runtime which handles runtime services, e.g., language integration and security enforcement, as well as memory, process and thread management. Other important components of the .NET framework are Framework class libraries (FCL), a consistent, object-oriented library. These classes provide standard functionalities in input/output, network communications and user interface design features [58].

The Sun's J2EE platform defines means to develop network-based multi-tier applications that are only bound to the Java programming language. Simply, this means that application logic is divided between platform components, which are in turn divided between network locations, e.g., client and server. J2EE's main task is to simplify building enterprise applications for better portability, scalability and integration with legacy applications and data [59], [60]. It introduces several components for building an application. The uppermost component is the Java application client, a GUI component which typically resides on the client device. Applets are also GUI components typically executed in web browsers. Servlets and Java Server Pages reside on the server device and can be used to generate HTML documents for the client device's user interface. Enterprise Java Beans components are executed in a managed environment supporting transactions. Enterprise Java Beans (EJBs) typically contain the application's business logic. [61]

4.1.6 The state of the art architecture of the use case

Figure 14 illustrates the high-level architecture of the ubiquitous financial prototype service. It is designed in a manner that it fully utilizes ASEMA system services and therefore interacts with the PSE. When the PSE adapts to changes in a service environment the financial service can provide the nomadic end user a service experience according to the new PSE configuration. The ubiquitous financial service can also set requirements for the PSE to fulfill before a certain set of sub-services can be used.

The existing systems that financial institutions have are behind the firewall and the aim of the prototype system is to utilize the content they provide. The interfaces required for communication with existing financial services are included in the prototype's network component, in this case, the Monetary Information Component Environment (MICE) server. The MICE server is a subcomponent of the ASEMA system that provides middleware services for the ubiquitous financial service prototype. The purpose of the MICE server is to retrieve the requested information from the existing financial systems and upload it to an end user device that is part of the PSE. It contains middleware components that generate the retrieved data compatible with the wireless service environment. Since the MICE server contains all major interfaces to the existing financial systems, it ensures high system portability and no changes to existing content are required. Instead content is transformed into the proper format in the MICE server prior to uploading it to the PSE. Also, general communication functions and network-side service logic needed by the ubiquitous financial service prototype is part of the ASEMA system. It contains all the interfaces needed to utilize a Telecom operator's standardized system services and it can also be accessed via the Internet. This ensures that the system can be enhanced with Telecom operator-specific service offerings but can also provide its services to the end user as long as it is connected to the Internet regardless of the connection of the service provider. The main functions of the MICE server are summarized in the following list:

- interfaces needed for communication with existing financial services,
- retrieve information from existing financial services at the request of an end user,
- upload the requested information to an end user device in a PSE,
- transform retrieved information into a proper format prior to uploading it to a PSE,
- to ensure high system portability.

The end user devices chosen were the Nokia 6680 and Nokia 770 internet tablet. They both have an SIP stack that enables push content delivery and a high degree of middleware component transferability among Symbian and Linux operating systems. These devices combine to form the adaptive PSE for the nomadic end user. The ASEMA system components are distributed among the devices so that the 770 complimented the services executed in the Nokia 6680 when the PSE roams to a Telecom operator network. The communication between the devices is realized via Bluetooth radio. The PSE can also be accessed by WLAN radio in Nokia 770. The ASEMA system also enables remote consulting via video call to experts, e.g., a stock broker. This is done by enhancing the ubiquitous financial service with a video call service.

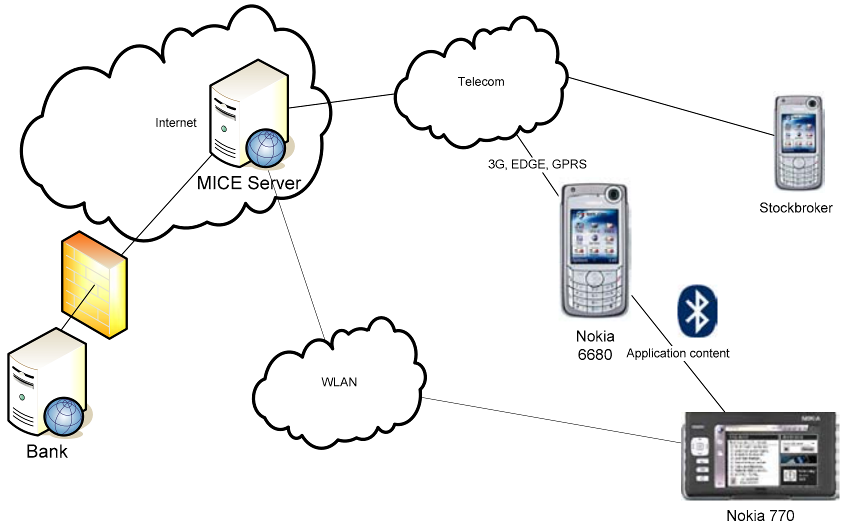


Figure 14. Ubiquitous financial services architecture.

The ubiquitous financial services utilize ASEMA system components for generic services. The purpose of the ASEMA middleware components is to capsulate generic functions of the system that are not dependent on a particular service. Interfaces among different systems are also considered to be a part of the ASEMA system middleware. The SIP is used for opening sessions, which enables push-type messaging to the PSE. We cannot assume that the network in which the PSE is roaming always supports IP data messaging, so as a last resort stock price level warnings are delivered to a PME via the Short Message Service. The ASEMA system contains a functionality that is aware of the PSE's roaming status. This requirement excludes the use of UDP and therefore TCP connections over IP are the only way to proceed so that the network part of the system knows the roaming status of the PMSE. This is because the UDP does not confirm the connection status prior to sending content to the receiving device nor does it confirm that content has actually been received by the device. The protocols used for transferring content are HTTP, FTP, RTP and RTSP depending on the nature of the content to be transferred. If needed, SSL/TLS encryption is used for the data.

The ASEMA system also includes a component that pre-selects online news to a PME based on pre-installed end user preferences. An end user can set a preference for headlines that he wants to receive. Selected news is stored on an

MICE server and only the headlines are delivered to the PSE. Only the new stories a user wants to receive are uploaded to the PSE and stored in the database of a device that is part of the PSE at that moment. This solution saves scarce wireless network resources and makes the system more user-friendly.

The ASEMA system is responsible for deciding whether a secure connection is needed. SSL/TLS encryption is used only for transactions in which financial instruments are traded or other confidential customer information is uploaded to the ASEMA system or PSE. In other cases unnecessary encryption is avoided in order to save wireless network resources. The ASEMA system also provides end user authentication services to the ubiquitous financial services. The ubiquitous financial services utilize the ASEMA system database to store service-related data. The PSE also has the service-related data stored within its end user devices. In order to avoid unnecessary duplication of data, the ASEMA system synchronization management service is utilized by the financial service prototype.

4.2 Ubiquitous Production Administration Service – M4MAMI

M4MAMI stands for Mobile for MAMI. The MAMI product (Mass production Administration by Multiple Inquiries), which is developed by a company called Qprojects, has been around since the 1990s [15]. The M4MAMI is a new product for Qprojects, whose innovations and technological solutions are based on the ubiquitous production administration service use case of this dissertation. The need for this use case emerged when a business need for this service was identified.

The aim of the ubiquitous production administration service is to expand the existing PC-based MAMI system to the mobile domain. A principle requirement for a mobile client is the capability to use both the GPRS/EDGE and 802.11b Wireless LAN radio access interfaces for communication purpose. The client that is in a mobile domain must be able to gain access to the same set or subset of services that are available for the PC Clients in the MAMI enterprise domain.

4.2.1 System requirements

The MAMI product is composed of the MAMI server, the MAMI database and PC clients. The MAMI server collects production and order information via SAP-based (Systems Applications Products) interfaces. The information is saved to a database hosted by the server. PC Clients in the enterprise domain access the database via the MAMI server. The applications in PC clients use DCOM-based object-oriented middleware in the communication with the MAMI server.

The ubiquitous production administration services system is composed of the existing MAMI product, a Nokia 9500 communicator including the M4MAMI client software and the ASEMA platform. The Nokia 9500 Communicator was chosen for mobile client device since it meets the hardware requirements of the use case. The system must also have fast, low-cost wireless data access from the MAMI server to mobile clients. The system solution must also be reusable for the transport of application messages in other similar business cases where the transfer of a vast amount of data is needed, such as enterprise solutions for the financial industry.

However a number of problems arise from the system infrastructure and the mobile terminal. In the existing enterprise infrastructure the DCOM object-oriented middleware solution is used, which would be difficult to expand to the mobile domain [39]. The low radio bandwidth of the GPRS/EDGE access technology limits communication between the mobile and enterprise domains. The mobile terminal has limited resources to store data. The mobile terminal has limited battery and CPU power. The mobile terminal has limitations regarding end user menus and the visualization of data.

4.2.2 Design solutions

In order to meet the requirements of the ubiquitous production administration services case and deal with the problems mentioned above, the following design solutions were applied. Since the DCOM middleware solution is Microsoft proprietary technology and not originally meant for small wireless devices that have limited processing capabilities, it is difficult to be expanded to the mobile domain. Therefore, a MOM-based solution was chosen instead of DCOM. Due to the mobile terminal's limited software performance capabilities, compression mechanisms were not applied to the design. Because of the requirement of low cost and fast access to mobile services, the utilized solution should minimize the amount of overhead of transmitted data. This requirement led to the design of a reusable XML binary-based MOM solution that minimizes the overhead of transmitted data. The mobile terminal has an M4MAMI production database to minimize traffic over the wireless connection. The user interface needed to be redesigned for the mobile terminal.

4.2.3 Message oriented signaling

The purpose of the MOM solution is to enhance application-level messaging between enterprise and mobile domains. In order to enable this functionality a three-tier architecture consisting of the mobile client, proxy and server was chosen. The role of the proxy is to act as a middleman between the server and the client, translating message-oriented signaling (MOM) to object-oriented communication (DCOM) and vice versa. The architecture and protocol stacks of the nodes have been described in Figure 15. The MOM solution is between the applications and communication interfaces in the protocol stack, and is transport independent. It guarantees reliable delivery of MOM messages between the required entities. A MOM entity is any entity/application using the API of the MOM service. A basic requirement of the MOM-solution was to be reusable for application messaging in many business cases as a middleware integration framework. In other words the MOM-solution should provide a service for generic application messaging.

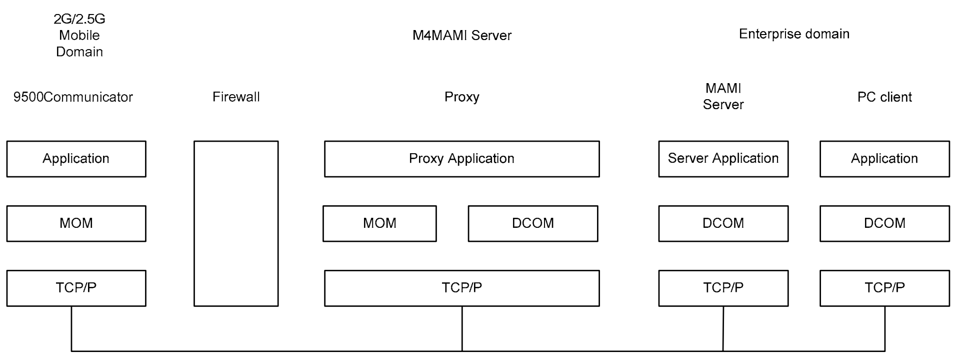


Figure 15. Communication protocol design.

Overhead of the MOM solution can be optimized by minimizing the data format to be used and not applying any application layer solution, which would produce additional payload in the form of protocol headers. In the design phase compression of a text-based format was not considered, because it would lead to additional processing in resource-limited devices. Instead a binary format was chosen. The minimization goal led to the definition of fields with the Length-Value approach. The minimum size of the common header is 21 bytes, and the parameter, 11 bytes.

The performance analysis was performed comparing the binary and text-based XML formats. It was observed that utilizing the text-based XML format causes a huge amount of overhead compared to the binary-based alternative, when the application message has no parameters. The overhead is big even if the number of parameters is increased, and the parameter size is relatively small. When the parameter size is increased to over 300 bytes the overhead between the alternatives is not significant anymore and with parameter sizes of 1000 bytes or more the difference is minimal.

4.2.4 Database design

The database of the ubiquitous production administration services use case is distributed between the server and the mobile client in order to minimize traffic over a wireless connection. Both the server and the mobile client side of the system have identical databases. Physically, data is stored on an MMC (Multi Media Card) in the mobile client. The size of the available MMC dictates in this case the maximum amount of data to be stored in the mobile client. This will have an effect on the amount of data to be transmitted during a session and on information available during offline operation.

The protocol chosen for initiating a database synchronization session is SIP (Session Initiation Protocol) due to its capability to initiate push sessions [62]. It enables the server side to initiate a session with a mobile client when its database requires updates. If the mobile client is not roaming to any wireless network, the server will try to initiate a session in predetermined intervals. Once the session is established successfully, it is the end user’s decision whether to accept or deny database synchronization.

The synchronization module operates as a continuous loop and has application logic that is almost similar on both the server and the mobile client sides. The M4MAMI server receives the data from the MAMI system and updates the server side database if the data is changed. If the data is updated the SIP-Agent is called to initialize an SIP session with the client. The client side module loops by calling its own SIP-Agent to listen for incoming INVITE requests. After a session is initialized successfully, two URLs are then returned from the message body of the INVITE request to the server side module by the client side SIP-Agent. After that the actual data transfer is done by TCP. Unfortunately the Nokia 9500 communicator does not have an SIP stack available for third party software developers. Therefore in the ubiquitous production administration services use case the initiation of a synchronization session had to be done in a conventional manner by mobile client polling on the M4MAMI server. The functionality of the synchronization module that utilizes SIP for establishing a session was experimented with a client that was on a laptop computer.

4.2.5 User interface design

The Nokia 9500 communicator imposes strict restrictions on the user interface due to its limited keyboard, screen size, wireless connection and performance restrictions of the mobile processor. Visualization of production information had to be redesigned in order to be suitable for the mobile device. A visible production time scale is smaller than on a PC user interface. Therefore, there was a need to utilize scrolling in time scale functionality for the user interface in the mobile client. In order to avoid heavy calculations on the mobile client end, the utilized graphics were simplified. Since the system uses an expensive wireless connection, an end user must have control via the user interface to accept data connections. Due to increased potential of security breaks, additional end user authentication is offered via the user interface. Because of keyboard limitations on the Nokia 9500, the end user's way of using the MAMI system was redesigned for the ubiquitous production administration services use case. Figure 16 illustrates the main view of the user interface on the Nokia 9500 communicator.

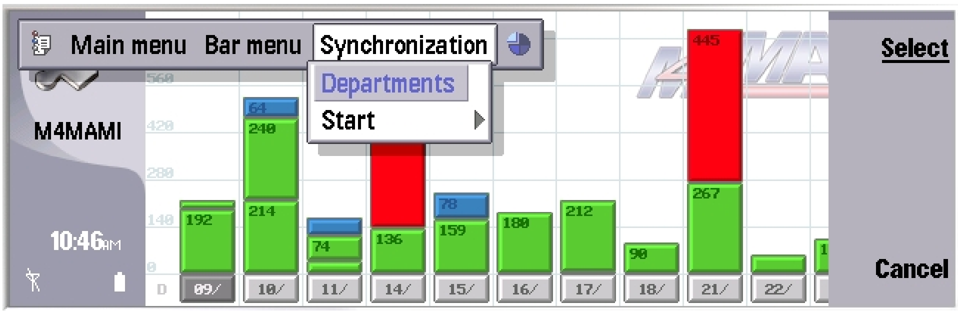


Figure 16. Main view of the mobile client's user interface.

4.2.6 The state of the art architecture of the use case

The main challenges in extending the enterprise service to a nomadic end user comes from limited hardware and software resources offered by small portable end user devices. Also, the limitation of usable services by a nomadic end user comes from QoS limitations of wireless connections. In later cases, any device that operates via a wireless connection has the very same limitation of available QoS. The solution innovated for the M4MAMI use case is aimed at solving these challenges listed above.

The binary XML-based MOM solution with TCP while overhead is optimized was chosen to enhance application-level messaging between the mobile client and the enterprise domain. Data compression as an alternative solution was discarded since the mobile client domain is a performance-restricted environment. It was noted that when parameter size increases to over 300 bytes, the advantages of overhead optimization starts decreasing. When the 1000 bytes mark is reached, the optimization advantage is minimal.

The advantages of M4MAMI database synchronizations between the mobile client and M4MAMI server are decreased data traffic over the wireless connection and enabling of off-line operations by the mobile client. Decreasing data traffic is done principally in two ways: data with a static nature is retrieved from the mobile client's database when required by the mobile application, and dynamic data is synchronized over the wireless connection bi-directionally only when necessary. A data synchronization session is triggered by the synchronization policy.

Available memory in the mobile device may restrict the size of a database in the mobile environment. Some of the very latest mobile phone models available on the market can store a few gigabytes of information. The user interface design for a mobile phone is challenging due to fact that everything is small. The main problem in the use case was displaying real-time production information, which requires a massive amount of data to be presented to the end user in an easily understandable format. This goal had been achieved by designing a versatile and easy-to-use menu structure. Also, careful selection was made regarding the information that was necessary to display. This decreased the complexity of the screen views and increased performance of the mobile phone.

5. Summary of publications

The purpose of this chapter is to introduce the scientific research done in the enclosed papers. They introduce new innovations for active service profiling from a financial services perspective. There are a total of eight papers enclosed. Their topics are the following:

1. Profile Negotiation Requirements in a Mobile Middleware Service Environment
2. Negotiation Requirements for the Extended Mobile Service Environment
3. Negotiation Framework for the next generation mobile Middleware Service Environment
4. Towards a Distributed Service Platform for Extending Enterprise Applications to the Mobile Computing Domain
5. Internet Enabled Wireless Mass Data System Requirements
6. Ubiquitous Financial Services for Developing Countries
7. Active Service Quality Management in ASEMA system
8. Adaptive Personal Service Environment Management System.

Each of the papers listed analyzes the research problem from its own perspective and proposes a solution to the research problem discussed in the particular paper. They are divided into parallel and partially overlapping topics where the overall research problem has been analyzed from its particular focus area. Figure 17 depicts the workflow and development of innovation among the publications. It also illustrates the main validation method utilized over the lifespan of the research work. The first three publications focus on the theory of service profiling. They analyze profiling requirements for a wireless service environment from a PSE perspective on their specific research topic areas. The fourth publication discusses the problem of extending services provided by the traditional enterprise wire-connected system to a wireless service environment. It approaches the research problem from a theoretical point of view and analyzes requirements for successful service delivery transfer from a traditional enterprise system to a nomadic end user's PSE. The fifth publication proposes a solution for extending a wireless PSE to an existing production management system that is a traditional enterprise system requiring fast communication capabilities in order to operate satisfactorily. At first case-specific requirements were analyzed and eventually a prototype system was built to experiment with selected technologies and to prove the applicability of selected solutions to the problem. Finally the M4MAMI product was built based on the solutions introduced in the publication. Publication 6 focus on the theory of providing financial end user services to a nomadic PSE. It analyzes the specific requirements of financial service case and a prototype service was built for proof-of-concept purposes. Publication 7 proposes a solution for dynamic service management in a PSE. The proof of concept prototype was built for experimenting with the selected solutions. Finally, Publication 8 introduces the experimental Active Service Environment Management System of which components are distributed among end user devices and network nodes. The mission of ASEMA is to enable ubiquitous financial services to a nomadic end user in a dynamically adaptive Personal Service Environment. All the research work from Publication 1 to Publication 8 contributes to the research topic of this dissertation. The new innovations in these papers are further discussed in the following paragraphs. The main new findings in each publication are underlined.

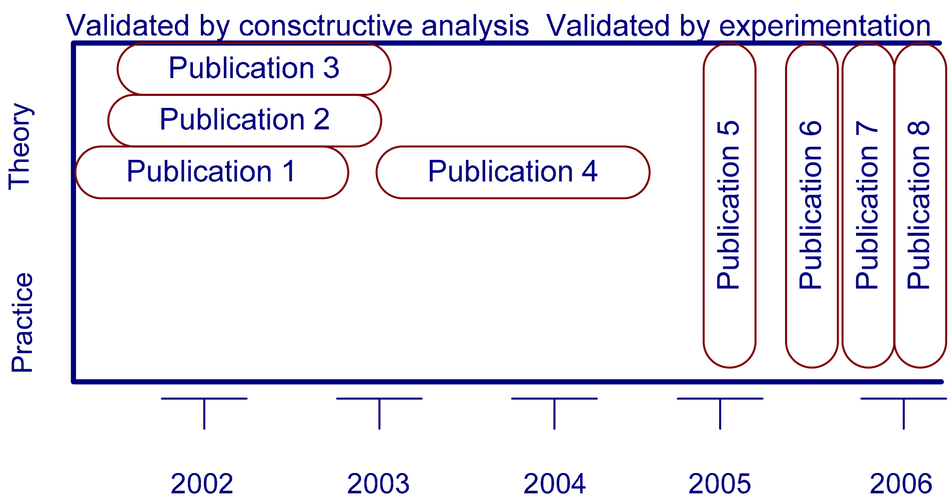


Figure 17. Publication workflow.

5.1 Publication 1

The paper “Profile Negotiation Requirements in a Mobile Middleware Service Environment” was published in the 4th International Conference on Enterprise Information Systems, which was held in Ciudad Real, Spain April 3–6, 2002. The focus of the paper is to research profile negotiation requirements from the perspective of a middleware platform that resides in a wireless end user device. The main findings of the paper are that a full service platform profile description in a wireless end user device should be divisible into multiple independent profile registers. A separate platform profile description register should be storable in multiple locations distributed on the Internet. An application that is executed on top of the service platform should have its own metadata register. All profile registers should be accessed via a published Uniform Resource Identifier. The author is the sole writer of the publication.

5.2 Publication 2

The paper “Negotiation Requirements for the Extended Mobile Service Environment” was published at the Fourth International Conference on Information Integration and Web-based Applications and Services, held in Bandung Indonesia, September 10–12, 2002. The research focus of the paper is to analyze profiling requirements for a functional split of terminal equipment and a mobile service environment. The main findings are that in the functional split, profile negotiation should be managed by the wireless terminal that is part of the mobile service environment and which is at the same time slaving terminal equipment. The findings also propose three necessary capability attributes for a device profile: TerminalEquipmentRegister, InstallationMemory and ExecutionMemory. The SIP should be utilized for initiating profiling sessions and HTTP for content transport. The author is the main writer of the publication and all the new ideas were also developed by the author. Mr. Petri Jurmu and Mr. Jouni Heikkinen provided help by proofreading the publication.

5.3 Publication 3

The paper “Negotiation Framework for the Next Generation Mobile Middleware Service Environment” was published at the international conference of Engineering and Deployment of Cooperative Information Systems in Beijing, China, September 17–20, 2002. The focus of the paper is to research technological solutions for profile and capability negotiation of a service platform that enables its communication with other similar systems, and at minimum, prevents system failure in the possible event of unknown profile data. The main findings are that documents referred to as profile or capability registers should be encoded with well-formed and valid Extensible Mark-up Language (XML). Attributes must have unique names and they should have only one at-tribute to describe in a single quality. Common attribute syntax should be applied for all possible profile and capability frameworks. Capability and profile registers should be arranged in a tree structure. When attribute data is updated only the new information should be transferred with the correct path of the updated attribute. The author is the main writer of the publication and all the new ideas were also developed by the author. Mr. Jarkko Holappa provided help by proofreading the publication. His purpose was also to familiarize himself with the problem domain in order to later conduct information security research in the service profiling research area.

5.4 Publication 4

The paper “Towards a Distributed Service Platform for Extending Enterprise Applications to the Mobile Computing Domain” was published at the International Conference on Internet Computing in Las Vegas, Nevada, USA, June 21–24, 2004. The focus of the paper is to analyze challenges in extending existing enterprise services to the wireless communication domain. The primary findings are that traditional enterprise computing domains differ vastly from the wireless communication environment. Therefore, a middleware that provides a message-oriented solution for a wireless extension is proposed. A network state monitoring capability is needed for a service environment to enable personalized context-aware end user services that perform well. Also, the two different interaction models need to be supported: the traditional pull access using an available web browsers or dedicated applications, or push interaction realized by a short message service or session initiation protocol. Mr. Daniel Pakkala is the main writer of the paper. The author's contribution is the proposal of a QoS aware PSE and the addition of push content transfer capability. Mr. Juhani Latvakoski's contribution was to proofread the paper.

5.5 Publication 5

The paper "Internet Enabled Wireless Mass Data System Requirements" was published at the IADIS international conference on WWW/Internet, held in Lisbon, Portugal, October 19–22, 2005. The focus of the paper is to solve the problem of extending an existing enterprise information system that has massive content traffic when in use on a wireless domain that is characterized by limited communication capabilities and end user devices that have limited processing capabilities. The main findings are that the content transfer solution between the network server and a wireless end user device is based on the binary XML-based message-oriented middleware over TCP where overhead is optimized. It is noticeable that when parameter size starts to exceed 300 bytes, the advantages of the overhead optimization scheme start decreasing, up to the point when a parameter size of 1000 bytes is reached and the optimization advantage becomes minimal. The advantages of the innovative database synchronizations scheme, utilized between a network server and an end-user device, were decreased data traffic over the wireless connection and the enabling of off-line operations by the mobile client. The menu structure of the end user application was redesigned for limited device capability in such a manner that there was no loss of information due to limitations of a display device. The goal was achieved by designing a versatile and easy-to-use menu structure from a small screen point of view and by careful selection of the information that was necessary to display to the end user. The author is the main writer of the paper. His contribution to the paper is concept innovation of the content transfer solution of a data synchronization scheme. Mr. Jouko Tähtinen developed a new graphical user interface for resource-constrained PDA equipment. Mr. Daniel Pakkala and Pekka Pääkkönen made implementation-based development and enhancements for the content transfer solution. Eventually, the company Qprojects Oy applied these innovations to its product, M4MAMI.

5.6 Publication 6

The journal paper "Ubiquitous Financial Services for Developing Countries" was published in the Electronic Journal of Information Systems in Developing Countries, volume 28, 2006.The paper focuses on the middleware requirements, as well as the system and software design solutions needed in order to realize ubiquitous financial services. The research work is based on the constructive method, which was conducted by analyzing related publications, industry trends and interviewing experts from the financial industry. Finally, the new innovations were experimented within a laboratory environment and a prototype service was created for testing the technological solutions. The findings of the paper are that in order for the ubiquitous financial service, and any potential new services it might provide to work, the service must be able to fully utilize the content of existing financial services. The service must be able to support an end user's decision process when managing financial assets. The system must support push messaging, content database synchronization, online news services and it must contain the necessary security features. It became obvious that ubiquitous financial services must have an offline mode, meaning that on the occasions when an end user is not connected to the Internet, such an unconnected situation does not cause interruptions in the planning and managing of financial assets. From a service provider point of view, the system of ubiquitous financial services must be easily transferable to other domains in a manner that it has the look and feel of the domain that the service is transferred to. The design of the overall prototype system is modular based and each of the components publishes interfaces that provide access to the services it provides. Due to this design requirement, the ubiquitous financial service prototype is scalable to an available personal service environment and end user preferences. The author is the sole writer of the publication.

5.7 Publication 7

The paper "Active Service Quality Management in the ASEMA system" was published at the International Conference on Software Engineering Advances (ICSEA 2006), held in Tahiti from October 29 to November 4 2006. The research problem of the paper is to find a solution for a proactive approach to managing multimedia service performance in a dynamic service environment.

The solution proposed in the paper includes a prototype system that has negotiation functionality which dynamically updates ASEMA profiles according to dynamic changes in an end user's service environment. The quality of service management functionality in the ASEMA system actively monitors the underlying networks at the QoS level. It adjusts quality of video stream according to changes in the QoS levels of the network infrastructure used. The author is the main writer and innovator of the paper. Mr. Mikko Nieminen and Johannes Oikarinen are research trainees whose responsibility was to implement innovations to prototype solutions. Mr. Tomi Räty contributed the state of the art research part of the publication and in the innovation of QoS management functionality.

5.8 Publication 8

The paper "Adaptive Personal Service Environment Management System" was published at the IASTED International Conference on Communication, Internet and Information Technology (CIIT 2006), held in the Virgin Islands from November 29 to December 1, 2006. The paper focuses on innovations experimented with in the ASEMA (Active Service Environment Management System) prototype. The research problem of the paper is to develop and experiment with methods and technologies that can deliver the correct content to a nomadic user at precisely the right time in a wireless communication environment. The correct content means the content requested by the end user directly or indirectly can be processed in a meaningful format for the end user. The right time means in this case the exact moment when the content has meaning to the end user. ASEMA includes the following innovative solutions that enable ubiquitous services for nomadic wireless service end users: a profile negotiation system that dynamically manages hardware and software resources in the ASEMA system environment, an active end-to-end QoS management system that enables services to adjust to possible changes in the quality of service level, a database management and synchronization scheme for managing massive databases in a wireless environment and enhanced communication protocol for wireless extensions of enterprise systems. In addition to QoS management feature, Mr. Tomi Räty contributed an innovation for scalable QoS functionality. The author is the main writer of the publication and the innovator of the all new solutions researched in the ASEMA publication. Mr. Pauli Räsänen contributed to the background research on the state of the art in the publication.

6. Validation

The ultimate result of this dissertation is proof that the concept of the ASEMA prototype system verifies new innovations. At first the dissertation concentrates on the theory of enabling an adaptive PSE. Eventually, in addition to the theory, proof of the concept technology experimentations is introduced in the dissertation. The innovations are tested and verified by the experimental ASEMA system.

One of the main findings was that the profile register of a PSE should be divisible into independent profile registers. The PSE profile registers in the ASEMA system are divided into logical sets of registers that together form the profile register of a complete PSE at any given time. It was required in the first publication that these profile registers of the PSE be storable anywhere on the Internet and they must have a published URI. The PSE profile registers in the ASEMA system can be stored into wireless devices and network components. The ASEMA system can retrieve device-specific profile information for the PSE from anywhere on the Internet, an action which can be tested in practice with Nokia products. On its Web site, Nokia publishes the device profile registers of their products. When a new Nokia device is added to the ASEMA system, it retrieves the needed profile register of that added device from Nokia's Web site identified by the URI. Also the new finding is the requirement for a metadata register of services. This register is used to communicate to the target PSE the minimum profile requirements imposed on the PSE by the requested service. Therefore profile negotiation between the PSE and a requested service should take place after the service has been discovered but not yet downloaded to the PSE. This functionality guarantees that once a service is installed to the target PSE, it functions as expected. This feature is verified in the ASEMA system by the features of ubiquitous financial service. These features support the research problem of this dissertation by supporting in their own part the dynamic nature of a PSE.

The new innovation in the ASEMA system includes a role in the PSE among devices when the PSE is roaming into a cellular network that is a Telecom operator's domain. The slaving device in profile negotiation in a possible functional split of a mobile phone and another device that has processing capabilities should be a mobile phone that includes the Telecom operator's

Subscriber Identity Module (SIM) card. This requirement was researched in the ASEMA system with the ubiquitous financial service case. When the PSE is formed with a Nokia 6680 mobile phone and the Nokia 770 Internet tablet, the slaving device is in all service scenarios in the mobile phone, including in the case of profile negotiation. When the connection to a cellular network is lost or when the Nokia 770's WLAN radio is used for connection to services or other ASEMA system network components, the roles among devices can change. The ASEMA system also includes three new necessary attributes for device profile registers. The TerminalEquipmentRegister attribute is used for storing the URIs of device profile registers that compose the PSE at any given time. The value of that attribute changes according to dynamic changes in the PSE. The InstallationMemory attribute is used to guarantee that content requested by the PSE can be stored on a device or devices that compose the PSE. The ExecutionMemory attribute guarantees that the requested service can be executed in some of the PSE's devices. The described attributes are included into the profile registers of the devices that form the PSE within the ASEMA system. These described features support the abilities of the PSE to adapt to services when its configuration and roaming network changes.

This dissertation also introduces the structure of device profile registers that form a PSE. The main findings are that all profile registers should be valid, well-formed XML documents. All attributes should have unique names. There should also be only a single attribute to describe a single quality. These requirements are implemented into the profile registers of the ASEMA system. Since all attributes have unique names, there will not be system failures due to an attribute value that is out of the acceptable value range. As long as attribute names meet these requirements, it is possible for third parties to design new attributes that are specific to services or devices that have not been developed yet. Then these new attributes are easily usable when needed in an existing PSE. These features support a PSE's adaptation to new entities that interact with it or enhance it.

The ASEMA system fully supports the CC/PP framework. All the profile registers are proper XML documents in conformance with RDF. Therefore the ASEMA system can support any specific profile vocabulary. The standardized UAProf is fully supported by the system. There is also existing ASEMA-specific vocabulary as described in previous chapters. The chosen profile description framework enables a PSE to adapt new profiles as part of the system as long as there is a schema available for the new vocabulary and it conforms to the syntax used. If these requirements are followed, new devices and services which are yet to be developed can be utilized within the PSE supported by the ASEMA system.

This dissertation also analyzes problems in extending enterprise system services to a nomadic end user's PSE. The findings support a middleware-based message oriented solution that enables enterprise system-based services to extend to the wireless domain. Due to the nature of wireless networks, QoS monitoring capability is proposed for supporting PSE service execution. In order to enable versatile services for nomadic end users, a push interaction model should be applied along with the traditional pull service model to the PSE. These basic requirements enable the PSE to successfully interface with enterprise systems that traditionally transfer a massive amount of content in a single session. The role of the middleware components is to re-generate content of an enterprise system to a format that is easily handled by a PSE. Transferred content should not cause unnecessary loading of the wireless connection and it should be easily processed by end user devices in a PSE. Therefore, middleware components that enable the PSE's interaction with an enterprise system should be distributed between wireless end user devices that form the PSE and serving network components. Generic services that are needed by the PSE should be provided by these middleware components. These services are, for example, end user authentication and QoS monitoring. Naturally, generating enterprise system content for a wireless domain is not enough. Service requests and content originated from the PSE must be transferred to an enterprise system-readable content format. These requirements are transferred into the ASEMA system design principles. They enable the PSE to adapt to more versatile service scenarios and to form new services by combining existing services.

The experimental ASEMA system includes a ubiquitous production administration service prototype solution that extends an existing MAMI enterprise system to a nomadic PSE. The solution is called M4MAMI and its middleware components are part of the ASEMA system. The middleware components convert the MAMI system's DCOM-based content into binary-based XML content and vice versa. The GCM component is used for transferring content between the PSE and a M4MAMI proxy at the server end. The M4MAMI proxy contains server implementation of the GCM and the client implementation is in the PSE. The GCM is used over TCP and its advantage is highly optimized headers. The GCM middleware components can be used to transfer any content to the PSE and back to the enterprise system. Message sizes below a 1000 byte optimization scheme have a clear advantage over standard content transfer protocols. With message sizes above 1000 bytes, the relative size of the header fields in the message decreases to the point that any achieved advantage diminishes. Since MAMI system transfers massive amounts of content during a single session, a data synchronization scheme was applied to the M4MAMI extension to a nomadic PSE. The PSE has its own MAMI production information database that is updated only with changed production information. After the initial production database is established in the PSE, the database synchronization scheme considerably decreases content transfer between the MAMI system and the PSE. The MAMI database in the PSE also enables off-line use of M4MAMI applications in the PSE. The ASEMA system synchronizes the MAMI database with its counterpart in the enterprise network once a new connection is established.

The dissertation analyzes the challenges of utilizing an enterprise system-based service in a nomadic PSE. They analyze the requirements and provide a solution not for services designed for a wireless environment but for services designed to be used in a completely different kind of system environment. The required components can be added dynamically to any PSE as well as can network components to the server side. Based on the successful technology experimentation of dynamic enterprise extension and ubiquitous production administration service to an adaptive PSE, the prototype middleware components further enhanced the product quality and are now part of Qproject's M4MAMI product. The M4MAMI product is a wireless Personal Service Environment extension to the MAMI product, a production administration system.

Eventually the dissertation analyzes requirements for the adaptive PSE from the viewpoint of ubiquitous financial services. The chosen financial service is an end user's investment management service. It was chosen since it is technically one the most demanding services to provide to a nomadic end user. First of all, the ubiquitous financial service has very demanding real-time reliability requirements since prices of investment instruments can vary as often as every second. A PSE must be capable of securing connections and reliable end user identification when investment instruments are sold or purchased. The service should be able to support a nomadic end user's decision process of managing the stock portfolio. Therefore the PSE must provide push content support for the financial service. The push content should be at least price changes of selected investment instruments and online news selected according to certain criteria, such as a company name. Due to the availability of a vast amount of investment instrument-related information, the information filtering feature in the ASEMA system is a crucial service to the ubiquitous financial service in order to avoid excess load on the wireless connection and to avoid performance limitations of wireless devices in the PSE. In the online news case, only news headlines are pushed to the PSE based on the end user's pre-selection criteria. Based on the headline of the news, an end user decides to download the full news story or not. The pre-selection criteria are part of the service metadata register which is received for end user input. In this particular case the metadata register of the ubiquitous financial service is used to communicate to the PSE the basic capability profiles it needs to function as expected and it offers the end user the possibility of enhancing its operation with added profile information. The ubiquitous financial service must have an off-line mode. It is not reasonable to expect that in all situations the PSE is able to provide a working IP connection for the financial service to its needed network side middleware services. Therefore, there is the ubiquitous financial service-specific content database in the PSE, provided that the required devices that physically contain the databases are part of the PSE. In order to minimize content transfer between the database in the PSE and the network server, the ASEMA system's database synchronization service is applied. In the prototype service, the Nokia 6680 and Nokia 770 are required to be included in the PSE in order for the nomadic end user to have the full set of ubiquitous financial services available to him. If one of the devices is missing from the PSE, the nomadic end user still receives the financial services, but available services are restricted. It was also found that the ubiquitous financial nomadic end user service should be easily modifiable to other domains so that it has the look and feel of the new domain that it is modified to. Adaptability is expected both from the PSE and the service that utilizes the PSE.

Table 4. Main conclusions and results of the first four publications.

	Conclusions and results	Validation
Publication 1	➢ **Profile register of a PSE should be divisible to independent register.** ➢ **Profile registers must be storable in the Internet.** ➢ **Profile Registers must have public URI.** ➢ **Services should have a metadata register that are incompliance with the syntax and schema of the profile registers.**	➢ Constructive analysis method ➢ Experimented in the ASEMA platform
Publication 2	➢ **Three new attributes for device profile management.** ➢ **Slaving rules defined among devices in a PSE in case of a functional split.**	➢ Constructive analysis method ➢ Experimented in the ASEMA platform
Publication 3	➢ **Defines structure of profile registers that describe capabilities of end user devices that form a PSE.**	➢ Constructive analysis method ➢ Experimented in the ASEMA platform
Publication 4	➢ Middleware-based message oriented communication model was chosen for extending traditional enterprise system services for a dynamic PSE domain. ➢ Both push and pull interaction models must be usable. ➢ Middleware components re-generate content to be transferred to a PSE into a format that is easily handled by devices that form the PSE and saves resources of a wireless connection. ➢ Generic services required by the PSE should be provided by the middleware components.	➢ Constructive analysis method ➢ Experimented in the ASEMA platform

This dissertation also focuses on an actual real-life use case of extending enterprise-based services to an adaptive PSE for a nomadic end user. The ubiquitous production administration service use case results are directly transferable to the ubiquitous financial services service case. The financial services case builds on the ubiquitous production administration service case results and adds more demanding financial service domain-specific requirements on top of it. Also, the ubiquitous production administration service has a smaller number of potential users compared to potential users for ubiquitous financial services. This enabled the ubiquitous production administration service developers a certain design freedom not possible for developers of services that are mass distributed to potentially millions of users via the Internet.

This dissertation describes a prototype profile negotiation management system that manages profile registers of a PSE. It also introduces a prototype QoS monitoring system for a PSE. Both systems are based on middleware components that are distributed among wireless devices in the PSE and in the relevant server on the network side. The profile management system dynamically manages changing profiles within the PSE. It also compares metadata registers of services to PSE profile registers to analyze if the requested service is executable in the current PSE configuration or not. The QoS monitoring system provides QoS information to services that are executed within the PSE. This enables services to adapt to possible changes in the underlying network's QoS changes. Both of these systems are part of the ASEMA prototype system. They contribute the PSE's adaptive capabilities to changes in its operational environment.

Eventually the dissertation describes the overall prototype ASEMA system that enables a dynamically adaptive PSE for a nomadic end user. The experimental ASEMA system is used to test all the previously discussed novel innovations. Generic middleware services are provided by ASEMA for end user services executed in a PSE. By combining domain-specific end user services such as ubiquitous financial services and video call service an end user can create new enhanced services within his own PSE. The generic ASEMA services such as QoS monitoring can be used to enhance a combination of end user services or a single end user service. Also, generic ASEMA services can be combined when necessary. For example, a QoS monitoring service could be combined with Scalable QoS functionality. The SQoS service is a generic middleware service that can be dynamically included in the ASEMA system. The true innovation in the ASEMA system is its ability to combine middleware and end user services together in multiple ways so that in each different combination a new enhanced service is formed for the nomadic end user. Tables 4 and 5 summarize the main results of this dissertation.

This dissertation does not consider service discovery problematic. Therefore end user services are always considered to be available to a PSE. Security and context awareness are considered capabilities of a PSE. Underlying network issues such as handover mechanisms and roaming technologies are not considered. The nomadic end user manually selects roaming networks whenever necessary. Business models are also beyond the scope of this dissertation.

Table 5. Main conclusions and results of the last four publications.

	Conclusions and results	Validation
Publication 5	➢ **Prototype middleware components that optimize use of wireless connection.** ➢ **Transfer content into proper format for a PSE and from PSE to enterprise system.** ➢ **Utilize a service provided by a middleware components that provide an intelligent synchronization scheme.**	➢ Experimented in the ASEMA platform
Publication 6	➢ **Real-time requirements for the financial services are strict.** ➢ **Communication sessions must be secure.** ➢ **Financial service must support asset management decision making process.** ➢ **Push interaction model must be supported.** ➢ **Information filtering service must be provided (a generic service that is provided by the platform).** ➢ **The financial service must also have an off-line mode.** ➢ **The database synchronization service provided by the ASEMA platform must be utilized.** ➢ **The financial service must be easily modifiable.**	➢ Constructive analysis method ➢ Interviews with representative from financial industry and ICT-service industry ➢ Experimented in with the prototype service which utilizes the services provided by the ASEMA platform.
Publication 7	➢ **A PSE's profile negotiation management system that enables dynamic changes in the profile.** ➢ **A PSE's QoS monitoring system.**	➢ Experimented in the ASEMA platform
Publication 8	➢ The ASEMA prototype platform that enables dynamic and adaptive PSE for nomadic end user	➢ Constructive analysis method ➢ Experimentation with the ASEMA platform prototype

7. Conclusions and analysis

This dissertation defined requirements for service profiling of an adaptive personal service environment for a nomadic end user. At first it analyzed general requirements and then focused on the ubiquitous financial services use case. Once the requirements were discovered, it focused on technological innovations meant to enable the adaptive personal service environment. The new innovated solutions were evaluated in the ASEMA prototype system. The ASEMA system is composed of distributed middleware components that enable an adaptive personal service environment. The ASEMA system itself can also evolve dynamically system by system, meaning that two separate ASEMA systems can dynamically form entirely new enhanced ASEMA systems. It enables simultaneous usage of various sub-systems and even end user services. This enables an end user to build his Personal Service Environment component by component and to form new services by combining the service environment elements together in new ways. Some of the innovations experimented with in the ASEMA system are applicable to commercial products.

This dissertation presented a prototype solution for the defined research objective. The prototype ASEMA platform enabled a personal service environment to adapt to external changes that influence an end user's service experience. An end user could introduce new hardware, software and even new devices to be utilized by the service environment to enhance end user's service experience and to widen a range of available services. The prototype ASEMA platform also adapted to changes that it could not influence, such as changes in the Quality of Service level of underlying roaming networks. It also provided means for adaptive end user services to react to changes in a personal service environment.

The prototype use case, a financial ubiquitous service, showed that a dynamically changing and adaptive Personal Service Environment can indeed provide services that are meant for professional or semi-professional use to a nomadic end user. The ASEMA prototype platform demonstrated the ability to adapt to profile requirements of the financial service prototype service. Additionally, if the ASEMA platform was not capable of adapting to all the profile requirements imposed by the requested service, the ASEMA platform offered means to the financial service itself to adapt the present configuration of the Personal Service Environment. One of the major requirements was that the ubiquitous financial prototype service must support an end user's decision making in managing his investment portfolio. This dissertation has shown that by utilizing innovations described in it, this goal can even be achieved for a nomadic end user. Therefore, it can be concluded that the research objective has been achieved within the described restrictions and limitations.

In order for a Personal Service Environment to successfully carry out profile negotiation there must be a guaranteed full delivery of the required profile description for that particular negotiation session. Portability of a Personal Service Environment's profile information is needed to give a nomadic end user as much freedom as possible in his choice of wireless devices. Naturally, technology constraints within an individual device set limitations when selecting from available wireless devices. A secure means of conducting a personal service environment's profile negotiation with third parties is necessary to guarantee the proper functionality of the environment and end user services to be executed on top of it. Usually, a wireless connection is the bottleneck for a nomadic Personal Service Environment when content is being transferred between a service provider and a nomadic end user. This also applies to profile negotiation of a nomadic Personal Service Environment. Therefore it is of paramount importance that wireless network resources are also preserved during a profile negotiation session of a nomadic Personal Service Environment. A nomadic Personal Service Environment should know, prior to subscribing to a service or downloading any content to it, if the target environment can process the requested service or content. This unnecessary burden on a Personal Service Environment and wireless networks can be avoided by conducting a negotiation session prior to subscribing to any services or downloading any content. Therefore, a metadata register is needed for any content that is intended to be downloaded to a nomadic Personal Service Environment. Since this metadata register is used for profile negotiation purposes with a Personal Service Environment, it must be in compliance with the CC/PP framework as well. Since at any given moment a full profile register of a nomadic Personal Service Environment is dynamic and composed of the capabilities of multiple devices, it must be divisible into separate independent registers. The independent profile registers must be storable to anywhere in the Internet. Therefore each of them must have a specific URI. The individual device must have URIs of the profiles it is composed of for a nomadic Personal Service Environment to conduct negotiation sessions.

When a nomadic Personal Environment has more than one device that has communication capabilities with the Internet, additional requirements must be considered. A Personal Service Environment should provide a nomadic end user control of the Internet connection used. Applications should be able to use any available means to transfer content to and from the Internet regardless of which device has requested radio interface to the Internet. For example, an application that resides on the Nokia 770 can utilize the cellular radio capabilities of the Nokia 6680 when they are part of the same Personal Service Environment. End user devices that form a Personal Service Environment must have standardized protocol interfaces that enable them to interact with each other.

When linking a nomadic Personal Service Environment to a traditional enterprise system that provides services designed for end users to be used via a PC, additional challenges must be considered. In order to enable versatile service scenarios, a Personal Service Environment must support both pull and push interaction models with an enterprise system. Content transfer between a Personal Service Environment and an enterprise system must be designed to minimize data transfer over a wireless connection to a bare minimum. Due to changing wireless network resources, a nomadic Personal Service Environment experiences a workload between roaming from one wireless network to another. When this event occurs, enterprise systems servers should be adaptive to the changing resources. Many times enterprise systems are trusted domains. Therefore, a nomadic Personal Service Environment should have a security level similar to that of the enterprise system with which it communicates. Mostly this problem can be solved with virtual private network technologies. The downside is that it consumes scarce wireless network resources. Naturally, whenever a nomadic end user requests access to an enterprise system, end-user authentication must be conducted. Challenges also arise when considering what to do for confidential data that is stored on wireless devices during a service session with an enterprise system. One can either erase all the session data from the wireless devices or store the data in a secure storage area within the wireless devices. A drawback of the first alternative is that when a new session is established all the static data needs to be downloaded again and wireless resources are wasted. The second alternative does save wireless resources but there is a risk that someone can decrypt data from the wireless device when it falls into the wrong hands. Also, existing cryptography technologies consume performance of a wireless device, which may cause a decrease in an end user's service experience.

The system that enables financial transactions and stock portfolio management is a special case of a traditional enterprise system's services. It has all the previously discussed challenges and some additional requirements. In order for financial services to be truly ubiquitous, a Personal Service Environment should be able to provide real-time market information for a nomadic end user at any moment. It must provide assistance and decision support in managing financial assets. One of the most difficult challenges is to provide a nomadic end user with the right information at the right moment. Therefore, the ASEMA prototype platform does support versatile communication means and push and pull interaction models to achieve optimal communication coverage. Since the development of graphical Internet browsers, the information available to a financial investor has increased dramatically. In order for an investment service to support an end user's investment decisions, information filtering schemes must be put in place, along with schemes that pre-analyze the information before it is forwarded to an end user. If information is not filtered properly it can, in some cases, even overload the capabilities of a wireless network connection and possibly crash end user devices. When an adaptive Personal Service Environment is the target, it would not permit excessive content transfer.

8. Future research

Information security and user identification issues are reserved for future research work. When financial transactions are dealt with in nomadic access, the available security measures should be utilized to the highest feasible level. The minimum required security level should be defined for particular financial services. Then strengths and weaknesses of these security solutions should be analyzed. The security of a ubiquitous financial service should be studied from the whole system point of view in order to get a full picture of potential security threats. For example, applying VPN tunneling technologies for content transfer is not enough if a proper end-user identification system is not in place. Even if a PSE has the best possible security features available, the organization that provides the enterprise system services to a nomadic end user could be the weak link. If the service providing organization does not have proper security mechanisms in place at the enterprise level, the utilization of expensive information security technologies does not provide the required system security level.

The other important factor is business models for services aimed at an adaptive PSE. A PSE can roam to networks of different service providers simultaneously or one at a time. Today, different connection service providers tend to differentiate themselves by providing, to some extent, a unique set of end user services to their subscribers. There is not a working revenue sharing model in place today for network service providers that would allow them to profit from allowing non-subscribers to utilize end-user services that they offer to subscribing end users. Once there is a business model in place that enables adaptive PSEs to utilize end-user services from multiple service providing parties simultaneously, the available service combinations will expand exponentially for nomadic end users. It will most likely also lead to increased innovation of single-purpose wireless devices as well as portable multimedia computers. This would again give more ideas, freedom and opportunities for service designers to develop new end user services.

Naturally, security issues should be considered together with developing business models. Security research has both vertical and horizontal dimensions. If a profit sharing model is not secure and widely trusted, it will not work as desired to function as an enabler for opening up virtually unlimited possibilities for a nomadic end user to combine services within the adaptive Personal Service Environment.

References

[1] Tafazolli, R. & Saarnio, J. Mobile and Wireless Communications Technology Platforms. eMobility; Strategic Research Agenda; Version 4, November 23, 2005.

[2] Worldwide Forecast by Technology & Network to 2011. Mobile TV: Broadcast and Multimedia. 2nd edition; informa telecoms & media; 2006 informa UK Ltd.

[3] Neuvo, Y. Solid-State Circuits Conference, 2004. Cellular Phones and Embedded Systems. Digest of Technical Papers. ISSCC. 2004 IEEE International February 15–19, 2004. Vol. 1. Digital Object Identifier 10.1109/ISSCC.2004.1332581. Pp. 32–37.

[4] Yih-Farn, Chen, Huale, Huang, Jana, R., John, S., Jora, S., Reibman, A. & Bin, W. Personalized multimedia services using a mobile service platform. Wireless Communications and Networking Conference, 2002. WCNC2002, 2002. IEEE, 17–21 March 2002. Vol. 2. Digital Object Identifier 10.1109/WCNC.2002.993394. Pp. 918–925.

[5] Takizawa, M., Minato, T., Furukawa, T., Seki, K. & Shimada, H. Future Service Platform for Home Gateway. Information and Telecommunication Technologies, 2005. APSITT 2005 Proceedings. 6th Asia-Pacific Symposium on November 9–10, 2005. Pp. 236–241.

[6] Lankhorst, M., van Kranenburg, H., Salden, A. & Peddemors, A. Enabling Technology for Personalizing Mobile Services. Proceedings of the 35th Annual Hawaii International Conference on System Sciences (HICSS-35'02). ISBN 0-7695-1435-9.

[7] Slocombe, M. Mobile Penetration In Europe To Hit 100% By 2007: Analysis. Digital-Lifestyles.info, May 6, 2005. URL: http://digital-lifestyles.info/display_page.asp?section= platforms&id=2177.

[8] Bekkum, M., Bijlsma, M., van Kranenburg, H. & Lankhorst, M. Personal Service Environment: Analysis and Research Issues. Deliverable D3.2.4 version 1.0 of the GigaMobile project; December 15, 2000.

[9] Biernans, M.C.M., van Kranenburg, H. & Lankhorst, M. User Evaluations to Guide the Design of an Extended Personal Service Environment for Mobile Services. Wearable Computers, 2001. Proceedings. Fifth International Symposium on October 8–9, 2001. Pp. 94–101.

[10] Hugues, J., Pautet, L. & Kordon, F. Contributions to middleware architectures to prototype distribution infrastructures. Rapid Systems Prototyping, 2003. Proceedings. 14th IEEE International Workshop on June 9–11, 2003. Pp. 124–131.

[11] Kamouskos, S. Supporting nomadic users within virtual private networks. Service Portability and Virtual Customer Environments, 2000 IEEE 1 Dec. 2000. Pp. 128–133.

[12] Brandt, R. & Reiser, H. Dynamic Adaptation of Mobile Agents in Heterogeneous Environments. Springer Lecture Notes in Computer Science 2240, December 2001.

[13] Yamazaki, K. Research Directions for Ubiquitous Services. Proceedings of the 2004 International Symposium on Applications and the Internet, January 26–30, 2004. ISBN 0-7695-2068-5.

[14] Shenker, S. & Wroclawski, J. Network Element Service Specification Template. IETF Network Working Group, Request for comments: 2216, September 1997. URL: http://www.apps.ietf.org/rfc/rfc2216.html.

[15] Qprojects, 2006. URL: http://www.qprojects.fi/index.php?path=content_eng/Products/MAMI.

[16] Franklin, R., Hjelm, J., Dawkins, S. & Singhal, S. Composite Capability/ Preference Profiles (CC/PP): A user side framework for content negotiations; W3C Note November 30, 1998.

[17] Klyne, G. et al. Composite Capability/Preference Profiles (CC/PP): Structure and Vocabularies 1.0. W3C, 2004. URL: http://www.w3.org/TR/2004/REC-CCPP-struct-vocab-20040115/

[18] Wireless Application Group. User Agent Profile Specification, 1999. URL: http://www.wapforum.org/what/technical/SPEC-UAProf-19991110.pdf.

[19] Rusty, E.H. XML Bible. IDG Books Woldwide Inc. Foster City California, 1999. ISBN 0-7645-3236-7.

[20] [XML] http://www.w3.org/TR/2004/REC-xml-20040204/.

[21] Franklin, R. & Frystyk, H.N. Staff members of W3C. CC/PP Exchange Protocol based on HTTP Extension Framework. W3C Note June 24, 1999.

[22] Brickley, D. & Guha, R.V. Resource Description Framework (RDF) Schema Specification. W3C Proposed Recommendation March 3, 1999.

[23] WAG UAPROF Proposed Version 30-May-2001; Wireless Application Protocol; WAP-248-UAPROF-20010530. URL: http://www.wapforum.org/what/technical.html.

[24] 3rd Generation Partnership Project. Technical Specification Group Terminals; Mobile Execution Environment (MExE). Functional description; Stage 2 (Release 6), 3G TS 23.057 V6.2.0 (2004-09).

[25] 3rd Generation Partnership Project. Technical Specification Group Services and System Aspects; Service aspects. The Virtual Home Environment (Release 5), 3GPP TS 22.121 V5.3.1 (2002-06).

[26] Wireless Village. The Mobile IMPS Initiative: White Paper.

[27] Wireless Village. The Mobile IMPS Initiative: System Architecture Model Version 1.1, WV Tracking Number: WV-020.

[28] Wireless Village. The Mobile IMPS Initiative: Presence Attributes Version 1.1, WV Tracking Number: WV-030.

[29] 3rd Generation Partnership Project. Technical Specification Group Services and System Aspects: Presence Service. Stage 1 (Release 7), 3G TS 22.141 V7.0.0 (2005-12).

[30] 3rd Generation Partnership Project. Technical Specification Group Services and System Aspects: Presence Service. Architecture and Functional Description (Release 6), 3G TR 23.841 V6.0.0 (2002-07).

[31] 3rd Generation Partnership Project. Technical Specification Group Services and System Aspects: Service aspects. Service requirements, Stage 1 (Release 6), 3G TS 22.240 V6.5.0 (2005-01).

[32] 3rd Generation Partnership Project. Technical Specification Group Terminals; 3GPP Generic User Profile (GUP); Stage 2; Data Description Method (Release 6), 3G TS 23.241 V6.1.0 (2004-06).

[33] Mahmoud, H. & Wang, Z. Customizing and Delivering Mobile Services using Software Agents and CC/PP. Proceedings of the Consumer Communications and Networking Conference 2006, IEEE, Las Vegas, Nevada, USA, 8–10 Jan. 2006, Vol. 2. Pp. 1114–1118.

[34] Bellavista, P., Corradi, A. & Stefanelli, C. Application-Level QoS Control for Video-on-Demand. Internet Computing, Vol. 7, Issue 6, November–December 2003, pp. 17–22.

[35] Ji, Yang & Zhang, Ping. MUSE: Vision for 4G Service and Architecture. Vehicular Technology Conference, 2004. VTC2004-Fall. 2004 IEEE 60th Vol. 7, September 26–29, 2004. Pp. 4842–4845.

[36] Itao, T. & Matsuo, M. DANSE: dynamically adaptive networking service environment. Global Telecommunications Conference, 1998. GLOBECOM 98. The Bridge to Global Integration. IEEE Vol. 2. Pp. 8–12.

[37] 3rd Generation Partnership Project. Universal Mobile Telecommunication Systems (UMTS); Report on Service requirements for UE functionality split (3GPP TR 22.944 V6.0.0 Release 6 2005-01).

[38] Fayad, M.E. & Schmidt, D.C. Object-Oriented Application Frameworks. Communications of the ACM, October 1997, Vol. 40, No. 10, pp. 32–38.

[39] Campadello, S. Middleware Infrastructure for Distributed Mobile Applications. PhD Thesis, Department of Computer Science, University of Helsinki, Finland, 2003.

[40] Sampo, 2005: http://www.sampo.fi.

[41] Nordea, 2005: http://www.nordea.fi.

[42] OP, 2005: http://www.op.fi.

[43] Tapiola, 2005: http://www.tapiola.fi/.

[44] Eqonline, 2005: http://www.eqonline.fi/.

[45] Evli, 2005; http:// www.evli.fi.

[46] Postel, J. Internet Protocol: DARPA Internet Program Protocol Specification, RFC 791. September 1981. URL: http://www.ietf.org/rfc/rfc0791.txt.

[47] Postel, J. User Datagram Protocol, RFC 768. 28.8.1980. URL: http://www.ietf.org/rfc/rfc0768.txt.

[48] Postel, J. Transmission Control Protocol: DARPA Internet Program Protocol Specification, RFC 793. September 1981. URL: http://www.ietf.org/rfc/rfc0793.txt.

[49] Fielding, R. et al. Hypertext Transfer Protocol HTTP/1.1, RFC 2616. June 1999. URL: http://www.ietf.org/rfc/rfc2616.txt.

[50] Egan, M. ISO OSI 7 Layer Model forced with TCP/IP. 8.7.2000. URL: http://mike.passwall.com/networking/netmodels/isoosi7layermodel.html.

[51] Dierks, T. & Allen, C. The TLS Protocol, RFC 2246. January 1999. URL: http://www.ietf.org/rfc/rfc2246.txt.

[52] Rescorla, E. SSL and TLS – Designing and Building Secure Systems. Addison Wesley, 2000. ISBN 0-201-61598-3.

[53] Hiltgen, A. et al. Secure Internet Banking Authentication, IEEE Security & Privacy. March 15, 2005.

[54] Housley, R. et al. Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List Profile, RFC 3280. April, 2002. URL: http://www.ietf.org/rfc/rfc3280.txt.

[55] Blomgren, M.I. Are SQL Server, DB2, and Oracle really relational? Master thesis. Department of Informatics, Göteborg University, 2003. 50 p.

[56] Codd, E.F. A relational model of data for large shared data banks. Communications of the ACM, Vol. 13, No. 6, 1970, pp. 377–387.

[57] Date, C.J. When's an extension not an extension? Intelligent Enterprise, Vol. 2, No. 8, 1.6.1999. URL: http://www.intelligententerprise.com/db_area/archives/1999/990106/online1.jhtml.

[58] Microsoft 2005. MSDN .NET Framework Developer Center, Technology Overview. URL: http://msdn.microsoft.com/netframework/technologyinfo/overview/default.aspx.

[59] Pawlan, M. Java 2 Enterprise Edition Technology Center, 23.3.2001. URL: http://java.sun.com/developer/technicalArticles/J2EE/Intro/.

[60] Sun Microsystems. Java 2 Platform, Enterprise Edition (J2EE), 2005. URL: http://java.sun.com/j2ee/index.jsp.

[61] Shannon, B. Java™ 2 Platform Enterprise Edition Specification v5.0, 20.6.2005. URL: http://jcp.org/aboutJava/communityprocess/pr/jsr244/index.html.

[62] Rosenberg et al. SIP: Session Initiation Protocol. RFC 3261, 2002.

References used in the publications that are listed in the dissertation but are not used in the body of the dissertation

3G TS 22.057 V5.1.0 2001-03; 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Mobile Execution Environment (MExE); Service Description; Stage 1 (Release 5).

3GPP TS 22.101 V5.3.0 2001-06; 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Service aspects; Service principles (Release 5).

3GPP TS 23.228 V5.1.0 2001-06; 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; IP Multimedia (IM) Subsystem – Stage 2 (Release 5).

Adwankar, S. Mobile CORBA. Presented at Third International Symposium on Distributed Objects and Applications (DOA'01), Rome, Italy, 2001.

Arvin, T. Comparison of Different SQL Implementations, 7.9.2005. URL: http://troels.arvin.dk/db/rdbms/.

Bray, T., Hollander, D. & Layman, A. Namespaces in XML. World Wide Web Consortium, January 14, 1999.

Bray, T., Paoli, J., Sperberg-McQueen, C.M. & Maler, E. Extensible Mark-up Language (XML) 1.0 second edition. W3C recommendation October 6, 2000.

CC/PP. Composite Capabilities / Preference Profiles: Requirements and Architecture; W3C Working Draft July 21, 2000.

Eisenberg, A. et al. SQL:2003 Has Been Released. SIGMOD Record, Vol. 33, No. 1, March 2004, pp. 119–126.

Figueras, J. The Wireless Enterprise: Two Years on. IEEE Computing & Control Engineering, Vol. 14, 2003, pp. 10–13.

Handley, M., Schulzrinne, H., Schooler, E. & Rosenberg J. SIP, Session Initiation Protocol. March 1999. IETF, Internet Engineering Task Force, RCF 2543.

Hausheer, D. & Stiller, B. Design of a Distributed P2Pbased Content Management Middleware. Presented at 29th Euromicro Conference (EUROMICRO´03), Belek-Antalya, Turkey, 2003. Pp. 173–180.

Jung, D.-G., Paek, K.-J. &, Kim, T.-Y. Design of MOBILE MOM: Message Oriented Middleware Service for Mobile Computing. Presented at International Workshop on Parallel Processing, Wakamatsu, Japan, 1999.

Lassila, O. & Swick, R.R. Resource Description Framework (RDF) Model and Syntax Specification. W3C Recommendation February 22, 1999.

Meer, S. & Arbanowski, V.D. From Unified Messaging Towards I-Centric, Services for the Virtual Home Environment. In: Proceedings of IEEE Intelligent Network Workshop (IN2001), Boston, MA, USA, 2001. Pp. 489–492.

Menasce, D.A. MOM vs. RPC: Communication Models for Distributed Applications. IEEE Internet Computing, March-April Issue, 2005, pp. 90–93.

Nilsson, M., Hjelm, J. & Ohto, H. 2000. Composite Capabilities / Preference Profiles: Requirements and Architecture. World Wide Web Consortium, W3C Working Draft July 21, 2000.

Ohto, H. & Hjelm, J. CC/PP Exchange protocol based on HTTP Extension Framework. W3C note June 24, 1999.

Pakkala, D. Lightweight Distributed Service Platform for Adaptive Mobile Services. Presented at the 2004 International Conference on Pervasive Computing and Communications (PCC-04), Las Vegas, Nevada, USA, 2004. 7 p.

Raatikainen, K., Hohl, F., Latvakoski, J., Lindholm, T. & Tarkoma, S. Generic Service Elements for Adaptive Applications. Wireless World Research Forum (WWRF) WG2, White Paper, 2003.

RealNetworks inc. Helix DNA server. URL: https://helixcommunity.org/.

Saroiu, S., Gummadi, K.P., Dunn, R.J.S., Gribble, D. & Levy, H.M. An Analysis of Internet Content Delivery Systems. Presented at OSDI '02: 5th USENIX symposium on operating systems design and implementation, Boston, MA, USA, 2002. 13 p.

Satyanarayanan, M. Fundamental Challenges in Mobile Computing. Presented at Annual ACM Symposium on Principles of Distributed Computing, Philadelphia, Pennsylvania, United States, 1996.

Schulzrinne, H. et al. Real Time Streaming Protocol (RTSP). April 1998, URL: http://www.ietf.org/rfc/rfc2326.txt.

Schulzrinne, H. et al. RTP: A Transport Protocol for Real-Time Applications. January 1996. URL: http://www.ietf.org/rfc/rfc1889.txt.

Sihvonen, M. Technology framework for the commercial web services in the mobile execution environment. The Web in Public Administration, EuroWeb 2001 Conference 18–20 December 2001. Research Area of the National Research Council (CNR), Pisa, Italy, Proceedings; Felici Editore, Via Ravizza 10, 56121 Ospedaletto, Pisa, 2001. ISBN 88-88327-33-9.

Wetzel, R. CDN Business Models – The Drama Continues. Business Communications Review, 2002, pp. 51–57.

Wireless Application Forum, LTD. Wireless Application Protocol, WSP Wireless Session Protocol Specification. Wireless Application Group, WAG May 28, 1999.

Wireless Village. The Mobile IMPS Initiative: Client – Server protocol Transport Bindings Version 1.0, WV Tracking Number: WV-005.

Wireless Village. The Mobile IMPS Initiative: Presence Attributes Version 1.0, WV Tracking Number: WV-010.

Wireless Village. The Mobile IMPS Initiative: System Architecture Model Version 1.0, WV Tracking Number: WV-001.

Appendices of this publication are not included in the PDF version.
Please order the printed version to get the complete publication
(http://www.vtt.fi/publications/index.jsp)

Series title, number and report code of publication

VTT Publications 660
VTT-PUBS-660

Author(s)
Sihvonen, Markus

Title

Adaptive personal service environment

Abstract

Wireless communication will integrate seamlessly into our lives during the next decade. Device manufacturers will offer powerful portable multimedia communication devices with versatile features to single purpose sensors that have short-range communication capabilities. These very different devices will have the ability to form communication connections with each other either at the end user's request or in an ad-hoc manner. This will enable a nomadic end user to modify his/her personal service environment based on content he/she requests and on logical adaptation. The objective of this dissertation is to analyze the dynamic adaptability of a nomadic end user's Personal Service Environment by focusing on the adaptability requirements imposed by ubiquitous financial services and ubiquitous production administration service. This dissertation utilizes a constructive research method, in which results are validated by technical experimentation.

The main results of this dissertation are prototype implementations of the Active Service Environment Management (ASEMA) platform, which acts as an enabler for a dynamically adaptive personal service environment, and two use cases, one involving ubiquitous financial services and other involving ubiquitous production administration services, both of which utilize the platform. The Personal Service Environment (PSE) that is enabled by the ASEMA platform has the ability to adapt itself based on hardware and software capabilities available for a nomadic end user. The PSE is sensitive to the changes in quality of service it receives from the wireless network it is roaming to. The Personal Service Environment can combine two or more services together in order to offer a tailored service experience for a nomadic end user. Finally, the ASEMA platform enables an end user service to adjust its service offering to the existing capabilities of the Personal Service Environment at any particular moment.

ISBN
978-951-38-7055-3 (soft back ed.)
978-951-38-7056-0 (URL: http://www.vtt.fi/publications/index.jsp)

Series title and ISSN
VTT Publications
1235-0621 (soft back ed.)
1455-0849 (URL: http://www.vtt.fi/publications/index.jsp)

Project number
21207

Date	Language	Pages
October 2007	English	114 p. + app. 77 p.

Name of project	Commissioned by
IMPULSE 2	Tekes, VTT

Keywords
adaptive services, personal services, adaptive environment, wireless communication, personal service environment, ubiquitous financial services, ubiquitous production administration services, profile negotiation requirements, mobile service environment

Publisher
VTT Technical Research Centre of Finland
P.O. Box 1000, FI-02044 VTT, Finland
Phone internat. +358 20 722 4404
Fax +358 20 722 4374

VTT PUBLICATIONS

641 Toivari, Mervi. Engineering the pentose phosphate pathway of *Saccharomyces cerevisiae* for production of ethanol and xylitol. 2007. 74 p. + app. 69 p.

642 Lantto, Raija. Protein cross-linking with oxidative enzymes and transglutaminase. Effects in meat protein systems. 2007. 114 p. + app. 49 p.

643 Trends and Indicators for Monitoring the EU Thematic Strategy on Sustainable Development of Urban Environment. Final report summary and recommendations. Häkkinen, Tarja (ed.). 2007. 240 p. + app. 50 p.

644 Saijets, Jan. MOSFET RF Characterization Using Bulk and SOI CMOS Technologies. 2007. 171 p. + app. 4 p.

645 Laitila, Arja. Microbes in the tailoring of barley malt properties. 2007. 107 p. + app. 79 p.

646 Mäkinen, Iiro. To patent or not to patent? An innovation-level investigation of the propensity to patent. 2007. 95 p. + app. 13 p.

647 Mutanen, Teemu. Consumer Data and Privacy in Ubiquitous Computing. 2007. 82 p. + app. 3 p.

648 Vesikari, Erkki. Service life management system of concrete structures in nuclear power plants. 2007. 73 p.

649 Niskanen, Ilkka. An interactive ontology visualization approach for the domain of networked home environments. 2007. 112 p. + app. 19 p.

650 Wessberg, Nina. Teollisuuden häiriöpäästöjen hallinnan kehittämishaasteet. 2007. 195 s. + liitt. 4 s.

651 Laitakari, Juhani. Dynamic context monitoring for adaptive and context-aware applications. 2007. 111 p. + app. 8 p.

652 Wilhelmson, Annika. The importance of oxygen availability in two plant-based bioprocesses: hairy root cultivation and malting. 2007. 66 p. + app. 56 p.

653 Ahlqvist, Toni, Carlsen, Henrik, Iversen, Jonas & Kristiansen, Ernst. Nordic ICT Foresight. Futures of the ICT environment and applications on the Nordic level. 2007. 147 p. + app. 24 p.

654 Arvas, Mikko. Comparative and functional genome analysis of fungi for development of the protein production host *Trichoderma reesei*. 100 p. + app. 105 p.

655 Kuisma, Veli Matti. Joustavan konepaja-automaation käyttöönoton onnistumisen edellytykset. 2007. 240 s. + liitt. 68 s.

656 Hybrid Media in Personal Management of Nutrition and Exercise. Report on the HyperFit Project. Ed. by Paula Järvinen. 121 p. + app. 2 p.

657 Szilvay, Géza R. Self-assembly of hydrophobin proteins from the fungus *Trichoderma reesei*. 2007. 64 p. + app. 43 p.

659 Qu, Yang. System-level design and configuration management for run-time reconfigurable devices. 2007. 133 p.

660 Sihvonen, Markus. Adaptive personal service environment. 2007. 114 p. + app. 77 p.

Julkaisu on saatavana	Publikationen distribueras av	This publication is available from
VTT PL 1000 02044 VTT Puh. 020 722 4520 http://www.vtt.fi	VTT PB 1000 02044 VTT Tel. 020 722 4520 http://www.vtt.fi	VTT P.O. Box 1000 FI-02044 VTT, Finland Phone internat. + 358 20 722 4520 http://www.vtt.fi

ISBN 978-951-38-7055-3 (soft back ed.)
ISSN 1235-0621 (soft back ed.)

ISBN 978-951-38-7056-0 (URL: http://www.vtt.fi/publications/index.jsp)
ISSN 1455-0849 (URL: http://www.vtt.fi/publications/index.jsp)