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Doctoral Dissertation

Hannu T. Verkasalo

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Department of Communications and Networking

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Hannu T. Verkasalo

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Helsinki University of Technology
Faculty of Electronics, Communications and Automation
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Tel. +358-9-451 2461
Fax +358-9-451 2474
E-mail: hannu.verkasalo@tkk.fi

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Field of research	Network Economics		
Opponent	Professor Knud Erik Skouby (Copenhagen Institute of Technology / Aalborg University)		
Supervisor	Professor Heikki Hämmäinen (Helsinki University of Technology)		

Abstract

This dissertation defines a handset-based method for analyzing mobile service usage. The research method can be used in conducting empirical studies of consumer behavior. The method combines collected handset-based usage data with survey data, both of which are important in modeling consumer behavior. The process involves a handset-based software module that automatically extracts data on service usage, and transmits this data to centralized servers for the purposes of analysis. The method facilitates empirical research on the mobile Internet and computer like functionalities of new mobile phones.

The research method is compared to other methods of empirical mobile service research. On several occasions the value of the defined research method is significant, providing accurate logs of service usage along with location and time stamps. The combination of subjective survey and objective usage data provides new angles in empirical research. The research conducted claims that the handset-based data collection method and associated analysis approaches provide valuable information for the stakeholders of the mobile industry. Results can be used in developing and launching new mobile services. Academic domains for the application of the research method include measurement of service usage, contextual end-user research, modeling of service adoption, and analysis of moderating factors of usage.

Regarding the actual use of the method, three key observations are made. First, though the dissertation proves the novelty value of accurately monitoring the behavior of end-users in using device functions, mobile services, and various applications, the limitations of the method need to be carefully considered and only suitable research problems should be studied. In particular, the adverse selection of panelists creates challenges in the generalization of results. Second, in addition to descriptive statistics including ranking of services, contextual statistics of service usage, and application adoption metrics, future research should interpret and explain the results more thoroughly, seeking a deeper understanding of reasons for usage observed. Most importantly, future research should utilize customized surveys and usage data in parallel, as demonstrated in the dissertation. Third, in order to support the scalability of the research method, the panel study process should be modified. The dissertation identifies the key challenges to be solved when replicating the study process in bigger, international studies. Panelists should be provided with other than monetary benefits for participating in a study.

The handset-based research method is a new innovation, providing a tool for further research and applications. The early results indicate that the method can be utilized in research problems that have substantial practical relevance in the mobile industry.

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Valvoja	Professori Heikki Hämmäinen (Teknillinen korkeakoulu)

Tiivistelmä

Väitöskirja määrittää päätelaitepohjaisen tutkimusmenetelmän mobiilipalveluiden käytön mittaamiseen ja tutkimiseen. Tutkimusmenetelmän avulla voidaan yhdistää kerätty päätelaitepohjainen käyttödata kyselytutkimusdataan. Kummatkin ovat tärkeitä kuluttajan käyttäytymisen tutkimisessa. Tutkimusmenetelmässä käytetään päätelaitepohjaista sovellusta, joka automaattisesti kerää laitteesta tietoa palveluiden käytöstä ja lähettää tämän datan keskitetyille palvelimille analyysitarkoituksiin. Menetelmä tarjoaa mahdollisuuden tutkia mobiilitoimialan uusia ilmiöitä, kuten langattoman Internetin yleistymistä ja puhelinten uusia toiminnallisuuksia.

Päätelaitepohjaista tutkimusmenetelmää verrataan väitöskirjassa vaihtoehtoisiin kuluttajatutkimusmenetelmiin. Menetelmä tarjoaa lokitietoa kuluttajan käyttäytymisestä yhdessä monipuolisen kontekstitiedon (esim. aika ja paikka) kanssa. Menetelmä mahdollistaa myös interaktiivisen datankeruukanavan erilaisten kyselytutkimusmoduulien avulla. Subjektiivisen kyselytutkimusdatan ja objektiivisen käyttödatan yhdistäminen tarjoaa uusia kuvakulmia kuluttajatutkimukseen. Viisi väitöskirjaan kuuluvaa tutkimuspaperia näyttävät, että päätelaitepohjainen tutkimus yhdistettynä analyysiprosesseihin tarjoaa arvokasta tietoa toimialalle. Tietoa voidaan hyödyntää uusien palveluiden kehityksessä ja kaupallistamisessa, sekä kuluttajan käyttäytymisen mallintamisessa. Akateemisia soveltamisalueita ovat palveluiden käyttöstatistiikan kerääminen, kontekstipohjainen kuluttajatutkimus, palveluiden adoptiotutkimus, sekä kuluttajien käyttötottumusten mallintaminen.

Väitöskirja erittelee kolme johtopäätöstä päätelaitepohjaisesta kuluttajatutkimuksesta. Ensimmäiseksi, päätelaitepohjaisen tutkimusmenetelmän rajoitteet täytyy ottaa huomioon, ja ainoastaan soveltuvia tutkimusongelmia kannattaa tutkia. Tämä pätee siitä huolimatta, että tutkimuksessa esitetään useita kuluttajatutkimuksen osa-alueita, joissa menetelmä toimii hyvin Erityisesti panelistien haitallinen valikoituminen aiheuttaa hankaluuksia tulosten yleistämisessä. Toiseksi deskriptiivisen statistiikan, kuten adoptiometriikan, kontekstisidonnaisten tunnuslukujen, sekä sovellustason vertailujen lisäksi pitäisi pyrkiä selittämään syy-seuraussuhteita havaituille tulemille. Sekä käyttö- että kyselytutkimusdataa pitää hyödyntää yhdessä, kuten väitöskirjassa on demonstroitu. Kolmanneksi, tutkimusmenetelmän ja paneelitutkimuksen skaalautuvuustarpeiden takia panelisteille pitää tarjota muita kuin rahallisia korvauksia osallistumisesta. Esimerkiksi palvelut, joissa panelistit näkevät omaa käyttödataansa, ovat tarpeellisia, kun menetelmää sovelletaan isommissa tutkimuksissa.

Päätelaitepohjainen tutkimusmenetelmä on tieteellisesti uusi innovaatio, ja se tarjoaa alustan tulevalle akateemiselle tutkimukselle sekä kaupallisille ratkaisuille. Tietyissä tilanteissa tutkimusmenetelmä tarjoaa uuden kuvakulman kuluttajatutkimukseen. Useantyyppisiä tutkimusongelmia on tässä väitöskirjassa tutkittu päätelaitepohjaisen kuluttajatutkimusmenetelmän avulla, ja tutkimuspaperit osoittavat että menetelmä tarjoaa merkittävän kontribuution mobiilitoimialan mallintamisessa.

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Foreword

I would like to thank Professor Heikki Hämmäinen at Helsinki University of Technology for supervising my research and organizing a project context around our collaboration between the University, major Finnish operators, Nokia and others in the Finnish telecommunications industry. Professor Hämmäinen has continuously promoted my research both in academic and non-academic circles. I also thank Professor Knud Erik Skouby from Copenhagen Institute of Technology for acting as my opponent, and Professor Hitoshi Mitomo from Waseda University and Professor Louis-Francois Pau from Rotterdam School of Management for acting as external examiners of the dissertation.

"We should be taught not to wait for inspiration to start a thing. Action always generates inspiration. Inspiration seldom generates action." -Frank Tibolt

With regard to the very message above, I am grateful to many anonymous experts working in the turbulent environment of the mobile communications business, who have provided me with not only challenging research questions but also insights and feedback to the research results. These insights have helped me in explaining some of the empirical research findings. In addition to industry experts, I also thank my research colleagues at Helsinki University of Technology for constructive comments and lively discussions on mobile services and emerging market trends. In particular I wish to thank the key team members Timo Smura, Renjish Kaleelazhicathu, Antero Kivi, Mikko Heikkinen, Annukka Kiiski and Mathias Tallberg. I also thank William Martin for giving feedback on my early drafts of the dissertation.

I acknowledge financial support from the Tekniikan Edistämissäätiö, the Nokia Foundation, the Emil Aaltosen Säätiö, TeliaSonera's Research Fund, the Marcus Wallenberg Stiftelse and Helsingin Puhelin Oy's Research Fund. I additionally thank the academic and industry research institutions, such as Nokia Research Center, Tekes and our own COIN and MoMI projects, in providing forums for presentation of the results. I thank the three key Finnish operators for providing possibilities to share our academic results with mobile operators in Finland and to have creative discussions on the relevance, reliability and meaning of our research. I thank the MoMI project stakeholders (Elisa, AinaCom, DNA Finland, MINTC, Nokia, Accenture, Sanoma, Tekes and YLE) for providing a possibility to continue our research further. I thank the participants of the Helsinki Mobility Roundtable 2006, the CICT conference in Copenhagen 2006, the MUM conference at Stanford University 2006, the COIN project seminar at Dipoli 2007, the CTTE conference in Espoo 2007, the Mobiquitous 2007 in Philadelphia and the 21st Bled eConference in Slovenia for the constructive comments and opportunity to present my findings.

Without my friends, it would have been difficult to balance between work and free-time. I thank my parents, Matti and Kaisu, my brothers, and the rest of my family for encouragement with respect to my studies. Finally, I would like to express my deepest gratitude to Meri for endless support and never-ending happiness.

Helsinki, Finland, November 2008
Hannu T. Verkasalo

List of publications

Article 1: Verkasalo, H. (2007). Handset-Based Measurement of Smartphone Service Evolution in Finland. *Journal of Targeting, Measurement and Analysis in Marketing 16(1), pp. 7-25.*

Article 2: Verkasalo, H. (2008). Dynamics of Mobile Service Adoption. *Journal of E-Business Research 4(3), pp. 40-63.*

Article 3: Verkasalo, H. (2008). Handset-Based Measurement of Mobile Service Demand and Value. *INFO: The Journal of Policy, Regulation and Strategy 10(3), pp. 51-69.*

Article 4: Verkasalo, H. (2009). Analysis of Mobile Internet Usage among Early-Adopters. *INFO: The Journal of Policy, Regulation and Strategy 11(4).*

Article 5: Verkasalo, H. (2008). Contextual Patterns in Mobile Service Usage. *Journal of Personal and Ubiquitous Computing; February 2008 (Online First collection).*

All the articles mentioned above remain as sole individual contributions of the author. All the papers are based on the same datasets from Finland (2005 and 2006).

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1. Introduction

1.1. Motivation

This dissertation studies a *handset-based research method of analyzing the usage of mobile services*. Handset-based usage tracking technologies are used in collecting data on the behavior and context of mobile subscribers; and mobile service usage can be studied by processing and analyzing this data. The definition *handset-based* means that data is collected from handsets, and *analysis* narrows the scope of the dissertation to only analyzing data, not collecting it. The definition *mobile service usage* means that only services that are used by end-users with mobile phones are included in the scope of the analysis. The method introduced extends to various other industries than merely the mobile industry, as smartphones are gradually becoming multi-purpose devices. The defined research method tackles two major trends of the industry: significant growth in the supply of mobile services, and the heterogeneity of mobile services.

First, the mobile industry has experienced significant growth during the past two decades. As practically nobody owned a mobile phone in the 80s, today it is difficult to find a person without one. The penetration of mobile subscriptions commonly exceeds 100% in the developed world, and the number of subscriptions in developing countries is already outnumbering the number of subscriptions in developed countries. In fact, mobile phones are the largest consumer electronics industry today, and the new growth mainly originates from the developing economies. Incremental growth takes place also in developed countries as more advanced handsets (smartphones) are increasing in penetration. Mobile phones bring mobility, flexibility, connectivity and efficiency to both consumers and business users alike. Mobile communication has made such an impact on the ways people interact and conduct business, that a mobile phone is already considered as a daily necessity in most of the developed countries of the world. The mobile industry has spawned new revenue sources from communications to contextual advertising and from mobile content to ubiquitous payment methods. Mobile devices have become platforms for an increasing number of services. Business interests, therefore, are tied to the evolution of the industry. Empirical research that studies the usage of mobile services is of particular value.

Second, mobile services constitute a rapidly converging industry. Legacy mobile services include voice and SMS (*short messaging service*) that have been in the market since the launch of the first modern digital mobile communications networks. The development of both mobile handsets and network infrastructure drive the emergence of new services. End-users are increasingly recognizing that the mobile handsets of today support many kinds of new services ranging from business solutions to entertainment content, in addition to the standard communications services. The ongoing convergence of mobile services (see e.g. Booz Allen Hamilton 2003) drives the new wave of advanced handheld devices, i.e. smartphones. *Smartphones* are advanced mobile phones with multimedia and Internet

functionalities embedded, and applications can be in installed and run on these devices. These devices and emerging mobile services are penetrating to the developed markets. Operators promote new services to supplement conventional mobile services, and at the same time new kinds of business models are evaluated in co-operation with other actors such as handset vendors and content providers. In addition, the possible emergence of Internet actors in the mobile domain brings fresh competition to the mobile services market (Verkasalo 2007a).

Both of these trends are taking mobile services closer to end-users (consider e.g. user-generated content, and use of add-on applications), meaning that the empirical research methods of the future should be technically located closer to the end-user. The closest platform that facilitates automatic tracking of usage is the mobile handset.

The analysis of the mobile industry typically constitutes theoretical research and case studies. However, empirical research with actual data contributes to at least four major research challenges that are identified in this dissertation:

1. Modeling of service usage and identification of emerging needs of end-users
2. Contextual analysis of mobile device usage
3. Measurement of the adoption of mobile services
4. Analysis of moderating factors of usage and demand dynamics of the market

First, the developments of the mobile industry in general and open smartphone software platforms in particular (such as *Symbian* and *Windows Mobile*) drive new mobile service innovations. Add-on application adoption is already promising in early-adopter user groups (Verkasalo & Hämmäinen 2007). The existing Internet is built upon two important concepts: end-to-end connectivity and network edge based innovation. Now the mobile domain is experiencing a shift to Internet-like services, the shift being driven by enhanced packet-switched mobile networks (end-to-end connectivity) and open smartphone software platforms (driving network edge based innovation). The emergence of the mobile Internet is likely to cause disruptive effects in mobile business ecosystems, too. The major change is the movement away from operator-driven management of mobile services. The traditional wired Internet is already changing the business landscape of several industries; now a similar disruption is to be anticipated in the mobile domain. Mobile communication has one significant benefit that is lacking from “wired” communications. In wired networks the voice services and traditional data services have always been closed and local. It was not until the IP-protocol (Internet) provided a truly open communication platform in wired networks, driving the emergence of wired broadband Internet access. The dominating mobile network technologies have been global from the very beginning. In this way, mobile communication provides a totally new starting point for building new voice, data and multimedia services. Therefore, the analysis of mobile ecosystems and services under the emergence of the mobile Internet is one of the key research challenges for those working in the industry. In this dissertation it is not relevant to compare mobile services to wired services, but rather to analyze specifically *mobile* services in the light of new end-user needs and a truly open mobile Internet.

Second, mobile services are radically different from several other kinds of services, being free of spatial constraints. This means that mobile services can be used everywhere and there are no limitations with regards to the location of usage. Neither are mobile services

exposed to temporal constraints, given that the mobile handset is carried by the end-user all the time. Mobile services can also be personalized to a great extent, given that the user can be authenticated and the device is part of the individual's personal belongings. Because of these factors mobile services can be used everywhere at any time, and furthermore a significant degree of personal involvement is involved in the user experience. Together with the increasing heterogeneity of mobile services this means that the contextual and situational factors in mobile service usage are worthy of further analysis.

Third, although studies exist on the adoption behavior of end-users, little research focuses specifically on the adoption of mobile services. Most mobile Internet services have been technically ready for years, but still no major commercial breakthroughs have taken place. One good example, WAP (*wireless application protocol*), which was pushed to the market in the late 90s, has few active users today. The same has happened to MMS (*multimedia messaging service*), mobile email and video calls. It is difficult to say whether the bottlenecks for adoption are related to technical constraints, the type of value the service provides (e.g. there is no need for the service), commercialization strategies, pricing, social pressure or contextual constraints. Handset capability, promotion of services and user characteristics (capability, interest) are certainly additional factors that affect the adoption process. For these reasons, a more comprehensive approach for studying the adoption of mobile services is needed.

Fourth, the demand dynamics of mobile services should be modeled. For example, it is argued that usage-based pricing is not a suitable pricing method for mobile services (Saarikoski 2006). Currently a variety of pricing mechanisms ranging from usage-based to flat-rate exist. Valuable research can be conducted by projecting how people change their service usage given different pricing plans. Alternatively, the opportunity cost of time and the level of effort required might explain usage-level behavior (Pohjola & Kilkki 2006). A value-based methodology for analyzing mobile services potentially reveals new kinds of nuances regarding people's preferences and consumption patterns in the mobile domain. What actually drives the use of different kinds of services? Is average usage intensity increasing over the course of the service life cycle or not? How is the usage of mature and immature services concentrated?

The four challenges highlighted above have received little focus in the existing empirical mobile services research. Furthermore, no practical ways of doing proper analysis have been available to investigate more deeply the challenges presented. This, however, is accomplished in this dissertation by defining a method of end-user research in the mobile industry. A handset-based research method (Verkasalo & Hämmäinen 2007) is compared to alternative research methods, and its pros and cons are discussed in reference to potential applications.

1.2. Research problem and objectives

Most industry stakeholders are interested in empirical studies of the mobile industry and service usage patterns, mainly for the following reasons: First, the value of the mobile industry is high and the industry is expanding at a rapid pace. Second, the heterogeneity of mobile services and their delivery dynamics are among the most complex in electronic

services. The dissertation presents a handset-based mobile service research method that is geared to improve end-user studies.

The main research problem posed is:

> *"What are the advantages and shortcomings of the handset-based method in conducting mobile end-user research, and in what ways can the method be used in practice in studying important trends of the industry?"*

The objective of the dissertation is to answer the research problem above by discussing the unique characteristics of the method, and by empirically validating its practical application through case studies. The advantages and shortcomings of the method are discussed in relation to already existing, widely used, research methods. The articles included in the dissertation, on the other hand, each identify a specific topic, relevant from the perspective of mobile industry evolution, and study that topic with the handset-based method. The purpose of the articles is to demonstrate the practical use of the developed research processes and analysis practices.

1.3. Research methods

A literature review is carried out to understand the ongoing transformations of the mobile industry. In addition, the logic of mobile service delivery and the special characteristics of mobile services are discussed. Both the business and technical background is studied in the literature review, providing the motivation to define an alternative empirical research method.

The literature review is extended by discussing the relevant topics with industry experts. The research has been carried out in academic COIN and MoMI projects (both at Helsinki University of Technology) that are funded by the Finnish Funding Agency for Technology and Innovation (Tekes). The projects operate in close collaboration with Nokia, TeliaSonera, Elisa, DNA Finland, Sanoma, Digita, Accenture, YLE, the Aina Group, and the Finnish Ministry of Transport and Communications. The relevant objectives and topics for this dissertation work have been discussed with the project stakeholders. In addition, the results and implications of the dissertation have been evaluated through interviews with experts in the field.

The dissertation defines a handset-based end-user research method. This method is based on server-side infrastructure that communicates with monitoring software developed for Nokia S60 smartphones. In addition to the technical development of the client/server infrastructure, the application of the research method requires rigorous project management as the handset-based mobile end-user research is carried out through specialized panel studies involving several parties. (Verkasalo & Hämmäinen 2007)

In the handset-based research method, data mining, statistical and visualization tools available in *Stata, SPSS* and *Matlab* are used. Also applied statistical methods are required. In the articles included in this dissertation multivariate regression models together with path modeling and cluster analysis are leveraged to identify

interrelationships from the data. In making the data easier to analyze with statistical tools, computerized data mining procedures have been developed.

This dissertation documents the research method that has been developed over the years. The articles included can be considered as implementation examples in the application of the research method. The articles set out to provide exemplary research approaches in which the method has advantages over other available research methods. The dissertation studies the implementation and application of data analysis that together with data collection forms the handset-based research method.

1.4. Scope and limitations

The definition *mobile* restricts the scope of the dissertation to a particular subsection of the larger ICT (*information and communication technologies*) industry. The term *mobile* denotes here that the services are consumed through a mobile handset equipped with at least cellular communication capability.

Mobile services are consumed by end-users, whereas *applications* are considered as technical solutions that implement services. The *mobile Internet* is defined as the technical and business related phenomenon of IP-based services emerging gradually in mobile handsets.

In the empirical analysis this dissertation applies the handset-based research method. The process includes several possibilities to deploy questionnaires. However, the questionnaires are exposed to the challenge of the subjectivity of the panelists' capability to correctly answer the questions. To overcome this problem, the empirical studies included do not utilize only questionnaires, but the major proportion of empirical data is collected automatically from devices, without the panelists themselves having any possibilities to affect the data collection process after joining the study. Questionnaires are mostly used in acquiring data on demographic factors and perceptions of end-users. The dissertation combines questionnaire and usage-based empirical data in new ways. From the technical perspective of empirical mobile service research, the analysis of usage-level data collected from handsets forms the main contribution of the research method.

From the geographical point of view the study relies on two coherent datasets from Finland. All together, the empirical studies utilize accurate usage- and questionnaire-based data from more than 1 100 Finnish mobile subscribers. The recruited panelists are almost entirely consumers rather than business customers.

One of the major limitations of the dissertation is the difficulty of generalizing some of the results. The end-users participating in the panel studies are early-adopter users, typically more interested in new technologies than mass-market users. Therefore, special care has to be taken when evaluating the significance and relevance of the research results.

This dissertation utilizes a specific way of studying mobile subscribers. The data, capabilities of the research technology, the subscriber/demographic segments targeted and the objectives of the research setting are provided mutually by the stakeholders involved including regulators, network operators, device/network vendors as well as academia.

The underlying research setting focuses on the ongoing emergence of new smartphone devices and mobile services, thus providing an assessment of usage patterns and associated implications at this particular point of time in 2006-2008. The aim of the research is also to suggest relevant action points in further developing the research process. The technical development or assessment of the research technology is not in the scope of the research. Instead, the dissertation focuses on the analysis of data and practical modeling based on the developed approaches.

1.5. Structure of the dissertation

The first part of the dissertation offers relevant background to the research setting. This part discusses the evolution of the mobile industry from both technical and business standpoints. Earlier empirical research on behavioral patterns of mobile subscribers and adoption of mobile services is covered. Alternative methods of empirical end-user research on mobile services are also presented. The handset-based research method is introduced, and compared to other research methods available. The first part of the dissertation is carried out through a literature review and interviews held with experts, accompanied by documentation of the handset-based research method, developed in various academic projects throughout 2004-2008.

Through the literature review in the first part of the dissertation, six important trends of the mobile industry, related to usage of mobile applications and services, are identified. The dissertation evaluates the method's strong and weak points through the research conducted in the included articles, by experimenting with the handset-based method in analyzing the particular trends identified. All the trends relate to phenomena that can be empirically studied. The trends are:

Trend 1: Convergence of industries in the mobile domain (T_1)

Trend 2: Diffusion of the mobile Internet (T_2)

Trend 3: Complexity in valuing mobile services and modeling moderating effects of usage (T_3)

Trend 4: Heterogeneity in mobile service offerings and end-user consumption patterns (T_4)

Trend 5: Divergence in mobile network access technologies (T_5)

Trend 6: Diffusion of smartphones as multi-purpose mobile computers providing seamless connectivity and computing power (T_6)

The second part of the dissertation includes five articles. Article 1 provides an analysis of the Finnish mobile market utilizing the computerized processes of handset-based data collection and analysis. The Finnish market analysis provides an examination of the possibilities offered by the research method in studying smartphone users. Article 2

develops a model explaining the adoption of mobile services through path modeling. In addition, various metrics for the measurement of adoption process are invented. Article 3 discusses the value of mobile services. At the same time, it demonstrates some of the interesting characteristics of mobile service demand. Article 4 assesses the trends in the emergence of mobile Internet services, presenting empirical research contributions in that particular field. Article 5 presents a more technical approach for identifying context information from raw handset-based data. The article also presents possible future research approaches in utilizing the context algorithm.

The structure of the dissertation is presented in Figure 1.

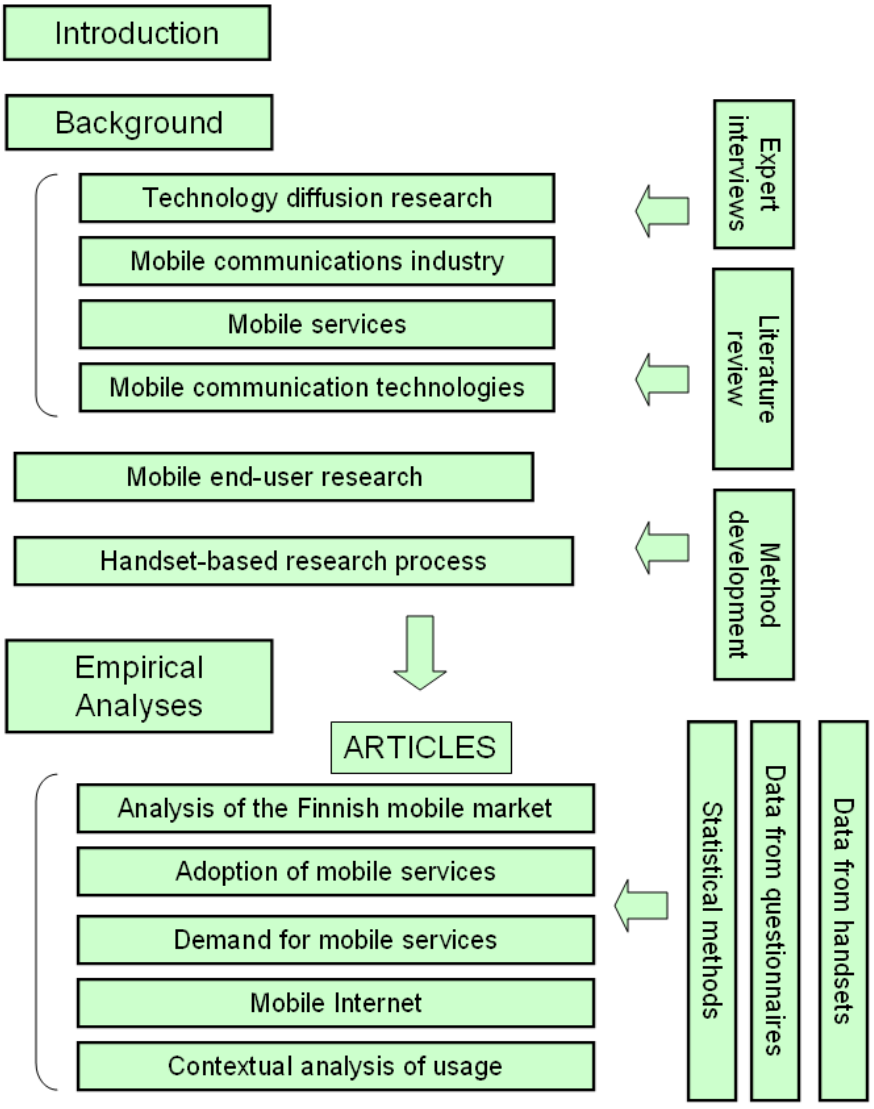

Figure 1 - Structure of the dissertation

2. Background

2.1. Mobile communications industry

2.1.1. Growth of the industry

All parties related to the provisioning of mobile services to end-users are part of the mobile industry. Mobile services are by definition consumed through a mobile handset, which is defined to mean a pocket-sized device with at least cellular connectivity capabilities. In the above mentioned definition of the mobile industry, network vendors, handset vendors, network operators, virtual network operators, service providers, content aggregators, third party software developers and emerging mobile Internet players are all therefore part of the mobile communications industry. Also the retailers of mobile handsets, companies serving as suppliers for the equipment vendors, and end-users, can be considered as part of the industry.

The number of mobile subscribers in the world has grown faster than the number of Internet users (see the figure below). However, this trend may change when the mobile users in developing countries start accessing the Internet with mobile handsets. Nokia has predicted that the number of cellular subscriptions is likely to surpass three billion in 2008 (Nokia 2005a). As this has already happened by 2008, Nokia estimates four billion for 2009 (MobileWorld 2008). The number of Internet connections is much lower, about 1 billion in 2005 (Computer Industry Almanac Inc. 2005).

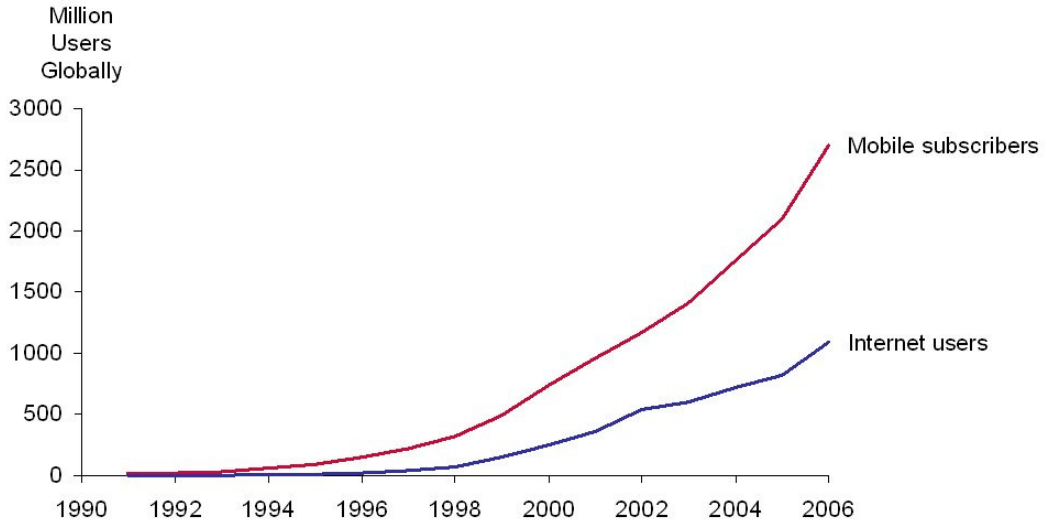

Figure 2 - Global growth of mobile phone and Internet users (adapted from ITU 2006)

The first cellular networks, analog ones, were opened in the late 70s in the U.S., growing in popularity in the 80s particularly in the Nordic countries. (Ahonen et al. 2004) However, the real mobile revolution began with digital (2G) networks (see the analysis of 2G and discussion of disruptive discontinues technologies in Palmberg & Martikainen 2003). The first digital GSM (*global system for mobile communications*) network in the world was opened by Radiolinja in Finland in 1991. Finland's early start in mobile telephony might be related to the geographical remoteness and the government's early deregulation policies (Henley 2002). The Europe-based GSM standard quickly became the most popular digital mobile phone technology, at least in Asia and Europe. Americans relied on CDMA (*code division multiple access*) technology, and they later suffered from fragmented standards that slowed the growth (because the network effects were less powerful; see Shapiro & Varian 1998).

In the developed countries of Europe and Asia the diffusion of mobile phones proceeded rapidly. The Nordic countries were first to experience quick growth, thanks to early adoption of cellular technologies despite the smaller size of the market (see market facts from Finland in e.g. EC 2001). Mobile phones have without doubt experienced rapid growth in penetration rates. (Banerjee & Ros 2004) In 17 years the total number of mobile subscribers already exceeds more than 3 billion. The number of mobile subscribers quickly surpassed the number of fixed line subscribers in many countries (Banerjee & Ros 2004).

A *mobile digital divide* emerged amidst the rapid diffusion of the mobile industry. A gap exists between the developed and developing countries. In most countries that were among the first to launch digital cellular networks, the number of mobile subscriptions either has already surpassed or is surpassing total population. In these countries the growth is marginal; in terms of penetration rates the saturation point has been achieved (see e.g. Banerjee & Ros 2004). At the other extreme, the developing markets in Africa, Latin America and Asia have significantly lower penetration rates. However, they are growing most rapidly and therefore have the greatest potential from the handset volume point of view. (Nokia 2005d) In Europe, Russia is an interesting market, as it has experienced fast growth lately (ITU 2005). Although the cellular telephony diffusion is faster in developing markets (see e.g. Rouvinen 2006), those markets do not adopt the most recent innovations of the industry at the same time as the developed markets do.

As market saturation of the mobile handset industry is reached, replacement sales represent the most important source of revenue for handset vendors. At saturation point the market is already sophisticated enough and the fundamental value networks are firmly in place. People are more inclined towards new technologies when they have adopted the first wave of technologies. This drives the kind of innovation that builds on the previous building blocks of the mobile industry. Mobility not only means an access to conventional means of communications (i.e. voice calling), but it inherits the mobile Internet, various messaging services and multimedia solutions (i.e. photos/video, mobile TV, offline multimedia content). Thus, the prevailing stage of the developed mobile markets influences the future of the whole industry. In emerging mobile markets conventional services (e.g. voice) are expected to prosper, whereas in mature markets people use mobile devices in more complex ways.

The competition is hard in handset markets of the developed countries. Innovative solutions with advanced features are brought to the market as this is the only way to differentiate and grow further through replacement sales in the high-end user segments. At the initial growth stage, in contrast, profits come from volume sales of mass-produced mobile phones. (Ahonen et al. 2004) These handset-oriented trends (from basic to advanced offerings) can be extended to mobile services. New mobile services from mobile email to streaming solutions gain currently more ground in markets where the subscriber penetration has risen close to 100%, meaning all the developed markets.

According to some studies, the growth of mobile communications can be divided into two. First, there is growth based on technological substitution. This type of growth takes place in developing and undeveloped countries where only a limited fixed line telephone network exists. Cellular networks provide a cost-effective solution to provide connectivity in these areas as a substitute to fixed networks. Technological substitution takes place in Latin-America and the lesser developed countries of Asia and Africa. Second, particularly in developed countries, the growth is of the economic type. In developed countries the fixed line telephone networks provide at least similar and usually superior quality to mobile networks, and from the technological sense mobile networks are unnecessary (there is some connectivity even without mobile networks). However, in these countries mobile networks gain popularity because they are more economical to build, and they complement instead of substitute the existing fixed networks. Also, the revenue from supplementary services and data transmission represent potential new business for operators. Effectively, cellular networks are deployed based on economic rationality. (Gruber 2001; Banerjee & Ros 2004; Gruber & Verboven 2001; Ahn & Lee 1999) In developed countries people also value the mere possibility to connect to others regardless of time and place. The value of mobility is high, and therefore people replace therefore their fixed telephone subscriptions with mobile ones.

2.1.2. Evolution towards 3G

The 3G technology was frequently in the news already in the 90s. However, not until now have 3G networks been deployed on a wide scale in Europe. Japanese operators were the first to bring 3G networks and services to end-users, whereas both European and American mobile operators postponed investments far into the new millennium. Some of the factors that have negatively contributed to the deployment of 3G in Europe include regulatory choices (e.g. the license auctions that resulted in absurd license prices paid by operators and their financial problems that followed), misunderstanding of end-users (e.g. the hype about WAP and video calls without evaluating what users really needed) and legacy business models (e.g. the European focus on business data services and price competition instead of aggressive innovation). Regardless of the slow roll-out in Europe, 3G technologies have facilitated new kinds of mobile services, and supported superior data transmission rates. WCDMA (*wideband code division multiple access*) is the continuation technology to GSM, supported by the GSM Association and 3GPP (*3rd generation partnership project*). Together WCDMA and GSM constitute currently about 82% of the world's mobile subscriber domain (GSM Association 2006).

In the future, the number of wireless wide area technologies will increase. Strong technological divergence is likely to take place at a level of radio access (Ahonen et al.

2004). The current 3G evolution in the developed markets is likely to evolve towards 4G through incremental innovation, for example through HSPA (*high speed packet access*) and 3G LTE (*long term evolution*) standardization. The mobile WiMAX (*worldwide interoperability for microwave access*) standard will serve as a potential complement/substitute for GSM and 3G technologies (Smura 2006). The divergence of radio access technologies might cause disruptions in the market, as end-users have more alternatives to cellular access technologies provided by incumbent operators. Mobile VoIP services, existing Internet solutions such as instant messaging and various kinds of content retrieval/management solutions can emerge in the mobile domain in suitable, less controlled conditions. Because of the divergence of radio access technologies smartphones and network edge based solutions (i.e. mobile Internet services) have become even more difficult to study, supporting the decision to study handset-based end-user research (Verkasalo & Hämmäinen 2007) in this dissertation.

In the developed markets the evolution of mobile communications takes place in several dimensions, whereas in developing and undeveloped countries operators are still building basic infrastructure. In the developed markets mobile infrastructure (networks and devices) entails significant potential for advanced services (Ahn & Lee 1999). On a horizontal layer new services can be established in different (functional) areas. Mobile services can also be vertically extended, for example by extending the camera function to better support the distribution of multimedia content and blogging in the Internet. In the developed markets the focus is already directed beyond the simple ramp-up of network infrastructure, and end-users are ready to extend their mobile experience into new dimensions. (Iimi 2005)

2.1.3. Value chains migrating into value networks

Porter (1985) suggests that companies (and more generally also industries) are structured around *value chains*. In a value chain different stages of production follow each other in a linear way. Upstream functions typically include, for example, inbound logistics, in the middle part of the value chain manufacturing operations take place, and downstream functions include, for ex ample, outbound logistics, marketing, sales and customer service. A value chain is typically complemented with supporting horizontal functions such as R&D and procurement. The linear model of company operations is old-fashioned as today most companies and industries actually structure around *value networks*, in which relationships are more complex and non-linear by nature. When moving from value chains to value networks also competitive positioning should be re-evaluated. (Allee 2002)

A concept of *mobile ecosystem* is defined in this dissertation as the dominant operating form of the network of industry players (Verkasalo 2007a). The term ecosystem (Moore 1993) refers to an operating logic in which actors actively collaborate with and are dependent on each other. To take an example, some network operators (such as the 3G operator '3') are pursuing collaborative strategies with new Internet actors in their mobile ecosystems. In many countries mobile virtual network operators have emerged (Kiiski 2007) and bring new logic to operator business ecosystems. In the mobile *virtual network operator (MVNO)* strategy the virtual operator rents network capacity from the network operator and provides typically only call switching, charging and billing functions. The examples of operator '3' and various MVNOs show that mobile ecosystems are today

different from the times when incumbent mobile operators managed everything from network ramp-up to service provisioning.

Mobile operator business models are typically vertically integrated (Vesa 2005; Verkasalo 2007a). This means that network operators retain most of the power in the ecosystem around them. Operators build and manage access networks, core networks and charging/billing systems. They also provide services (e.g. voice and text messaging). Operators (instead of device manufacturers or retailers) retain the ownership of end-users. The whole mobile value network is orchestrated by operators. The power of operators has partly originated from the legacy of public-owned telecommunications monopolies, inducing a regulatory environment (several regulations have asserted barriers of entry to the industry), and the attractive possibility of bundling network access with services through SIM (subscriber identity module) lock-in. Even if specialized services, for example SMS-based content retrieval, are introduced to the market, operators play the key role by providing the access to charging and billing.

In some markets, such as Japan, mobile network operators even distribute handsets and decide on the technologies to be used. The logic of selling handsets and subscriptions as a bundle offers possibilities to customize handsets and embedded software. The capability level of the installed handset base can be renewed often by pushing new models. Handset bundling with subscriptions is common also in the U.S. and many European markets. In some markets, the mobile industry structure is less vertically oriented in terms of operator power. For example, in Finland the extent of horizontal competition is high, and the market evolves towards low prices instead of service-based innovation (Kiiski 2007; Verkasalo 2007a).

Verkasalo (2007a) speculates about the impact of operator strategies on service usage, and develops a framework for the measurement of dominant mobile market ecosystems in two dimensions: technical modularity and value network openness. Two major conclusions are drawn based on the theoretical discussion and empirical observations. First, handset bundling and power of operators might have positive initial effects on the emergence and adoption of new mobile services. Although handset bundling does not drive architecture modularity, it provides a link between the supply and demand sides of the mobile market ecosystem. Consequently, operators have in the short term incentives to push new services. At the same time operators can better meet end-user needs by customizing handsets and preinstalled software on open software platforms. In the long term handset bundling, however, might weaken competition. Secondly, open-minded operator strategies are beneficial, and in the turbulent evolution of mobile business ecosystems operators have to carefully consider collaborative actions and in many cases join specialized content and service-level players in providing more value to the end-user. Collaboration between traditional cellular operators and Internet houses are likely to increase in importance in the future, and this holds irrespective of country.

The use of the mobile ecosystem metaphor is needed as business strategies are fragmenting and the mobile business itself is converging horizontally. This means that in addition to voice and messaging services more content, entertainment, and business services are emerging in the mobile market. In contrast to the telecommunications industry, these new services originate from the media and entertainment industries. New services induce business transformation, too. More external collaboration is required,

service offerings become more complex and competitive dynamics tighten. This is the first major trend taking place in the mobile industry today:

Trend 1: Convergence of industries in the mobile domain (T_1)

The convergence of industries drives radical changes. Hardagon (2003) claims that revolutionary breakthroughs in technology and business take place when different paradigms are combined together. In the crossroad of the traditional telecommunications world, media and content industries, Internet services, and emerging enterprise solutions the dominant business models of the mobile industry face significant transformations.

The first trend identified above raises serious questions from an empirical point of view. The mobile industry is expanding rapidly. Communication services are complemented with entertainment, information and multimedia services. The key challenge is to acquire empirical data in these new dimensions.

2.1.4. Drivers of mobile business transformation

The major drivers that transform the outlook and structure of the mobile industry include (Verkasalo 2008):

- New technologies (radio access, service platforms, network management)
- New services
- Regulatory framework
- Challenger business models
- Changes in end-user needs and behavior

The dominant mobile telecommunications business logic is structured around operators which have wide vertical power in value networks. Operators have "walled gardens" in place, controlling the services that are provided in their networks. However, the increasing convergence (Trend 1) makes it difficult to manage value networks in a controlled way.

An analogy of the increasing convergence comes from the Internet. Instead of network centricity the Internet leverages network edge based innovation and open standardized interfaces on the lower level of network architecture, the TCP/IP (*transmission control protocol / Internet protocol*) being the most famous protocol. On the higher OSI (*open systems interconnection basic reference model*) layers various proprietary solutions can be identified (i.e. overlay networks such as Skype) (Clark et al. 2006). No controlling actors exist in the Internet. The Internet is simply a network of connected computers, the networking part being standardized to some extent. The first Internet services were asynchronic person-to-person services, such as email that utilizes SMTP (*simple mail transfer protocol*) and POP (*post office protocol*). Client/server hypertext content services such as the WWW (*World Wide Web*), building on the HTML (*hyper-text mark-up language*) and HTTP (*hypertext transfer protocol*), emerged soon after. Hypertext and email served as the fist truly successful applications of the Internet. The most recent drivers of the Internet are various overlay networks including for instance P2P (*peer-to-peer*) file sharing (e.g. Bit torrent) and communication solutions (e.g. Skype) (Clark et al.

2006). The web 2.0 phenomenon underlines user-created content and more user-engaged Internet experiences.

Instead of centralized control the Internet supports a horizontal industry structure. Access network operators such as DSL (*digital subscriber line*) broadband operators are separate from businesses that provide end-user services (e.g. MSN, Ebay, Skype). The pricing mechanisms of the Internet are different from the ones in mobile ecosystems (in most mobile markets transaction and usage-based pricing still prevails; Saarikoski 2006). The broadband DSL Internet access, in contrast, is typically flat-rate-charged. In addition, most Internet services are actually free of charge, and many-sided business models ranging from advertising to add-on product sales, and from keyword marketing to auction revenue, are deployed.

Internet services utilize the IP protocol in *service delivery*. The all-IP movement is taking place (Alahuhta et al. 2004) and the IP technology is thus evading the mobile world, too. Mobile communication networks are typically dedicated. By dedication it is meant that the network is customized only for certain functions without standardized open layers. The Internet protocol (IP), however, entails that interfaces will be standardized and the technical layers (OSI model) are separated also in mobile networks. With mobile IP the deployment of innovative applications will be both faster and more cost efficient.

The potential for Internet services to succeed in the mobile world exists from the technical perspective. The question only remains that how Internet-oriented services can challenge circuit-switched voice or other operator-controlled services. Another interesting question is whether Internet business logic shakes dominant mobile business ecosystems in which operators have all the power. All in all, the emergence of the mobile Internet constitutes the second key trend of the mobile world (studied in detail in Article 4):

Trend 2: Diffusion of the mobile Internet (T_2)

Internet services initiate disruptive effects in the mobile market. By Christensen's definition (1997) the disruptive evolution involves initially a low cost challenger innovation that later overtakes the dominant innovation though the initial technical performance is inferior to the dominant design. Disruptive innovations shake also dominant business models. The mobile Internet obtains characteristics that entail disruptive potential with regards to the dominant mobile business ecosystems. The most important ones are open innovation (everybody can introduce services) and standardized interfaces (modular design is easier). In addition, spill-over effects are technically possible (i.e. porting of existing instant messaging services into mobile handsets).

Regulation of the mobile industry is worth discussion in the context of mobile industry transformation, as in many countries the telecommunications market is under the regulator's control. Regulators typically maintain competitive markets maximizing both the consumer and producer surplus. Regulators apply rules and restrictions in the field of mobile communications in many ways. For example, regulators decide on the attributes of network access (e.g. technology standardization, number of operator licenses handed out, frequency band), maintain oligopolies or even monopolies (by limiting the number of new entrants to the market), drive either horizontal (by e.g. pushing virtual network operators)

or vertical (by allowing handset bundling) business models and influence the creation of new business opportunities (by e.g. managing the intellectual property rights system and digital rights management solutions). As major trends in the mobile industry are gradually taking place, the choices made by regulators affect the industry evolution.

One last thing that is likely to drive the future of the mobile industry is the change in the preferences and role of end-users. Widely used mobile services are limited in number (only voice and text messaging). However, in the future the needs of end-users should be reconsidered as mobile handsets have developed and support an increasing number of different services. On a higher level the uncertainly in commercializing services mostly centers around the question *what do end-users really want to do with mobile handsets*. The hype of content-oriented services and rich calls is mainly originating from the producer side of the industry. However, eventually it is end-users who decide what they want to use. In addition, along the definition of the Web 2.0, end-users not only consume, but also interactively produce services and content (Friedman 2006).

2.2. Mobile services

2.2.1. Definitions

A *service* is generally considered as a non-material equivalent of a good. According to Kotler and Armstrong (1996) services are "activities or benefits offered for sale that are essentially intangible and do not result in the ownership of anything". *Electronic services* are thereby services which involve electronic transactions. A *mobile service*, further, is defined in this dissertation as a service that is consumed with a mobile handset. In this definition a mobile handset means a pocket-sized, handheld terminal which has at least a cellular radio capability.

In this dissertation the focus is particularly on *core mobile services*. Core services are built on top of enabler services. *Enabler services* are needed in implementing the core service. For example, a generic IP packet data interface is needed in implementing video streaming applications that utilize Internet protocols. In this example the IP packet data interface is a service enabler whereas the video streaming application itself is the core service seen by the end-user. All mobile services have unique characteristics, and therefore they should be managed in customized ways (Balasubramanian et al. 2002; Heinonen & Andersson 2003). Thus a good service classification framework separates different service types from others from the service management point of view. In the example above, the IP packet data platform can be positioned as a bit-pipe type of service from the operator perspective, whereas the video streaming service is a value-added service requiring a different business model (e.g. relationships to content owners and application developers).

Applications are defined in this dissertation as either network or handset-based pieces of software that run services. Application is therefore a more technical term referring to the technical solution, whereas service is the whole entity as seen by end-users. Circuit-switched voice calls and Internet-based mobile portals are clearly services, whereas music player and handset clock can be seen as applications. In this dissertation all solutions that

create value to end-users are called collectively as services, though sometimes the name application is used in reference to, for example, a specific handset application.

Mobile services have some special characteristics in comparison to other types of services. The key differences are related to spatial and temporal components of service usage. If one wants to meet a bank teller, she has to visit the bank (location) at a certain appointment (time). These restrictions are present to some extent even with many electronic services, such as online banking over a DSL Internet connection. Even though online banking services are available 24 hours a day (thus overcoming the problem of temporal availability), a fixed location is still needed for the DSL line (which is a spatial restriction). Mobile services, used with handheld mobile devices, overcome both spatial and temporal constraints (Heinonen & Pura 2006). An additional unique dimension of mobile services is the potential for individual personalization of service offerings (Clarke & Flaherty 2003). Mobile handsets are multi-purpose private computers. This provides an attractive setting for electronic service delivery.

2.2.2. Classification frameworks

A literature review is conducted to cover the earlier frameworks on the classification of services, with the primary focus on electronic services. Also papers studying service classifications from a more general perspective (see e.g. Lovelock 1983 and Kotler 1980) are studied. Electronic services, however, are different from traditional services. This is mainly because services are implemented over electronic interfaces, typically without any personnel being involved directly with end-users. A mobile handset acts as the main wireless delivery method for electronic services. A good mobile service classification framework should realize that mobile networks can also be accessed with other types of devices (e.g. laptops and tablet PCs), though the mobile service concept as defined in this dissertation only refers to those core services that can be used with pocket-sized mobile handsets.

Three streams of literature are identified with regards to mobile service classification. First, a combined technical/business perspective is a widely used classification setting. Technical and business approaches are often tied together in literature. This perspective is external to a service user. Second, an end-user centric perspective in classifying services is identified. The perspective is internal, looking at service offerings from the end-user point of view. Third, an emerging stream of literature focuses on the micro-level of service usage, dealing with, for example, context-specific use cases and special ways of implementing mobile services in particular. This third approach increasingly combines softer academic disciplines such as sociology or psychology with older user-centric approaches of mobile service literature.

Several papers cover business, strategic management or technical perspectives (see e.g. Angehrn 1997; Basaure 2004; Cerqueira et al. 2005; ECOSYS 2004; Meuter et al. 2000; Mitchell & Whitmore 2003; UMTS Forum 2001; Vesa 2005). These standpoints are defined in this dissertation uniformly as the technical/business perspective. It is common in this perspective that an end-user is not the focal actor in the classification approach, but the classification is based on business or technical interests. Business frameworks usually underline business models around services, while technical approaches emphasize the

implementation of the service (e.g. SMS-based, MMS-based, WAP-based). The technical approach to mobile service classification is probably easiest to deploy as technologies can be more easily classified into different classifications. Engineering concepts usually follow strict hierarchies on top of which it is easier to establish classification rules.

The end-user centric perspective is the most common approach in classifying services. According to Rodgers & Sheldon (2002), a particular need exists to classify mobile applications and services with the service user in mind. For example, the typology of UMTS Forum (2001) is too general in really evaluating the value of services to end-users. This is because end-users are overlooked in the classification approach. (Holtel 2006) From the end-user perspective mobile services are foremost considered as offerings to fulfill concrete needs, not as technical innovations or marketable products. The end-user perspective is applied at least by Anckar & D'Incau (2002), Dabholkar (1996), Giaglis et al. (2003), Hyvönen & Repo (2005), FMTC (2004), Järvenpää & Lang (2005), Kaasinen (2005), Nysveen et al. (2005), O'Loughlin (2000), Sullivan et al. (2005), Vanjoki (2003), Verkasalo & Hämmäinen (2006), Williamson (2003), Korhonen (2003) and Yoon et al. (2003). For example, in Verkasalo & Hämmäinen (2006) the different types of smartphone applications are classified generally based on the different needs of end-users, and Vanjoki (2003) distinguishes between different service evolution paths based on functional use cases (e.g. presence functions against multimedia services).

The end-user perspective is applied in many analyses. The arguments usually imply that with end-user centric classifications it is easier to serve end-users better in the future (Lovelock 1983). Heinonen and Pura (2006) suggest that there are four main domains in the classification of services. One of these domains is the type of consumption the service facilitates (e.g. utilitarian, hedonic; see Babin et al. 1994 and Novak et al. 2003). This approach is close to end-users. Although the end-user approach is suitable in use case analyses, it does not account for the technical or business-oriented implications. The latter implications are of value when considering services from a network operator's point of view, for example.

The most recent stream of service literature (particularly in the domain of mobile services) studies context and end-user value-creation. Context-oriented typologies model the contextual elements of mobile service usage (e.g. spatial and temporal domains), whereas the value-creation approach extends also to service implementation and end-user control. All in all, these studies tend to go deeper in sociological and psychological dimensions than other frameworks. Some of the papers utilizing this approach include the ARC Group (1999); Balasubramanian et al. (2002); Heinonen & Pura (2006); Heinonen (2004); Pura & Brush (2005); Van der Hejden et al. (2005).

Heinonen and Pura (2006) claim that the spatial and temporal (space and time) dimensions can be used in analyzing the characteristics of mobile services (see also Balasubramanian et al. 2002). The spatial and temporal dimensions can also be extended to include the social setting (see e.g. Okazaki 2005). Furthermore, it is suggested that the relationship between an end-user and service provider (e.g. the extent of personalization) should be used in the classification (Heinonen and Pura 2006). All these relate more or less to sociological, psychological or contextual service analysis.

2.2.3. Examples

Voice is the most important person-to-person service. It was the first service deployed in mobile networks, and it experiences significant fixed-to-mobile substitution opportunities as voice is also the number one service in fixed telecommunications networks. Voice is still the key mobile service offering today – despite the talks of rich calls (including e.g. video or presence information) replacing it. Voice is one of the few person-to-person services offered in mobile networks to be compatible with fixed line phone terminals. Though the fixed line voice subscriber domain is shrinking, the standardization and interoperability of mobile voice communication to PSTN remains important. Some of the new mobile services are described below.

Push-over-cellular (PoC) a.k.a. push-to-talk is a packet-switched service providing walkie-talkie kind of half-duplex person-to-person communication. Push-over-cellular is not circuit-switched, and it enjoys certain cost advantages reflecting in service provisioning costs and further in prices. PoC supports presence data feeds, delivering information on location and context of end-users.

Voice over IP (VoIP) is voice communication over packet-switched IP networks. Many kinds of mobile VoIP solutions exist. Some network operators leverage UMA (*universal mobile access*) and GAN (*generic access network*) standards and provide a combination of circuit- and packet-switched calls. For example, when the subscriber is at home, she can leverage her WiFi (*wireless fidelity*) hotspot with her mobile voice subscription. On the other hand, when she is somewhere else than home, she easily relies on cellular networks and normal circuit-switched calls. Incumbent network operators see VoIP as a horizontal extension of their current voice services. Vonage and some other players have a different strategy from incumbent operators, as they focus on other than cellular radio networks. They actively take advantage of existing Internet standards such as SIP (*session initiation protocol*) in building truly Internet-based voice services. Moreover, enterprises may invest in mobile PBX (*private branch exchange*) equipment by themselves (independent of operators) and route calls through WiFi networks at the office. Finally, some Internet players such as Skype develop proprietary systems, relying on their own clients that should be installed in devices. Together with some technical problems such as handovers and roaming the uncertainty over mobile VoIP technologies suggest that mobile VoIP is not yet a mass market service. However, it is likely that VoIP will hit the mobile market in the near future.

A number of messaging services are available for smartphone users. SMS is the truly successful messaging solution from GSM networks. Because SMS utilizes spare capacity in networks (effectively using signaling channels), it is a low-cost service for operators to deploy. SMS is also supported by almost all GSM handsets in the world. MMS (multimedia messaging) service was projected to hit the market already years ago. However, people have not adopted MMS as well as they adopted SMS (Verkasalo 2005).

Smartphones also transmit messages to close proximity through various alternative radio interfaces, such as Bluetooth and Infrared. These messages may include, for instance, photos and music files. Mobile email can be used with packet data access points and properly configured email boxes (utilizing common protocols such as POP and SMTP). In addition, webmail services are accessible via handset browsers.

Instant messaging and mobile chatting services are emerging. Applications such as AgileMessenger provide means to connect to existing instant messaging networks (e.g. MSN and Google Talk) with smartphones. Instant messaging is already a high-volume service in the fixed Internet, and therefore significant spill-over potential to the mobile domain exists (Verkasalo 2007a).

Despite the fact that smartphones are sometimes considered as mere communication devices, open software platforms and rapidly improving hardware capabilities (such as camera and FM radios) stretch the functionality of smartphones to new dimensions, from multimedia usage to office tasks. Many of the non-communication applications of PCs (music, news content retrieval, file sharing) are making their breakthrough to the mobile domain. There are various technical restrictions, such as the size of the screen and inputting interfaces, but most solutions are smartly downscaled to fit the user interfaces of mobile handsets.

PIM (*personal information management*) functions often accompany communication service usage. For example, Logs and Contacts are applications to browse phonebooks and to review recent call logs. On the other hand, schedules can be maintained with handset calendars.

Multimedia capabilities are actively used in promotion, as people commonly measure the competitiveness of a device model by the accuracy of the camera chip. No doubt, smartphone users capture video footage and photos practically everywhere, independent of temporal or spatial constraints. Furthermore, for example Nokia's Lifeblog application distributes this content even further, to the Internet. Smartphones serve as MP3 players and multimedia streaming clients. The newest smartphones have capabilities to receive Internet media streams, and also offline content can be viewed. Visual radio complements normal FM radio broadcasting. Smartphones clearly contribute to the emergence of new service innovations.

Games are a multibillion dollar business attracting today not only teenagers but end-users from any age class. Also, they are rapidly expanding to mobile handsets. Other new mobile services include mapping and navigation services, *infotainment* (information and entertainment) clients and image editing software. Because of open software platforms even 3rd parties and amateur programmers can develop services and compete with incumbent players.

Smartphones connect to the Internet with various radio access technologies (e.g. WiFi and WCDMA). Any smartphone application can initiate data sessions available in the handset, and most regular web services can be already used with Internet browsers of mobile handsets. Some mobile packet data services easily fall into communication and multimedia service categories that were already discussed earlier. For example, instant messaging, MMS and mobile emailing are communication services that utilize packet data interfaces, whereas video streaming and music downloads are multimedia data services.

In addition to messaging and multimedia a truly successful packet data service is browsing. With various browsing applications almost all kinds of hypertext documents can be accessed. Because of the high-resolution screens and adequate rendering power of

today's smartphones, it is not that difficult to load your favorite newspaper's Internet version using your mobile handset. Browsing has so far generated the biggest chunk of smartphone packet data traffic (Verkasalo 2005).

P2P (*peer-to-peer*) file sharing is one of the new service concepts that has great potential in the mobile domain. Because of the capability to play multimedia content also the need exists to download new content into handsets. P2P-oriented file sharing services generate a big chunk of packet data traffic in the fixed line Internet. As mentioned in Verkasalo & Hämmäinen (2006), the first mobile P2P file sharing client Symella is already making its entry to the early-adopter market. It remains to be seen how DRM (*digital rights management*) technologies, privacy concerns, operator strategies, memory capacity problems as well as other considerations are affecting the adoption and use of mobile P2P file sharing services in the future.

The mobile Internet domain is likely to experience similar transformations as the fixed line Internet did in the 90s. During the first phase of the fixed line Internet only basic communication-oriented protocols on top of TCP/IP, such as SMTP, were standardized. Then the WWW (using HTTP protocol) and static content emerged, pushing the Internet to a new era of content services (from mere communications). Now mostly multimedia and P2P traffic is seen in the Internet. Various overlay networks are emerging, too (Clark et al. 2006). Clark et al. (2006) define the term *overlay* to mean "*organized sets of infrastructure devices"* in the Internet handling application data "*in ways that are different from or in competition with what is part of the basic Internet"*. In other words, overlay networks utilize the Internet by building on the common core but at the same time customizing and perhaps deploying proprietary solutions on the application layer.

The first mobile data services were communication-oriented (e.g. mobile email and MMS). Currently, content services are spreading along the penetration of mobile browser applications. What is more, technologies such as SIP and IP multicasting push the packet-switched mobile domain towards the fixed line Internet in terms of the type of traffic flowing in the network.

All in all, packet data services are a hope to operators. Operators see their old revenue sources shrinking. Particularly revenues related to basic communication services are declining under heavy competition. Data services hold a lot of potential because new mobile services can be deployed that leverage the Internet. However, there are also challenges to incumbent operators. Particularly the emergence of alternative radio interfaces, such as WiFi, WiMAX and Bluetooth, is challenging operators. Incumbent network operators were earlier comfortable with the fact that only cellular access was available in mobile phones. Now operators face the fear of end-users using (costly) cellular access only in the case of absolute necessity, otherwise using free unlicensed radio access technologies. In this scenario operators are forced to compete even more with prices. This pushes them into the role of bit-pipes. Many technologies exist that provide new levers to network operators to fight against challenger Internet services. These technologies include IMS (*IP multimedia subsystem*; see e.g. Fulton 2005), and GAN (*generic access network*).

2.2.4. End-user needs

The discussion above on mobile services and their special characteristics indicates that each mobile service provides unique type of value to end-users. Evaluation of mobile services as perceived by end-users is therefore challenging. Some papers claim that the opportunity cost of time is what matters (Goolsbee & Klenow 2006). Some analyses also recognize the dimension of level of effort in using the service (Pohjola & Kilkki 2006). The complexity of valuing mobile services is the third identified trend taking place in the mobile industry (studied in detail in Articles 2 and 3):

> Trend 3: Complexity in valuing mobile services and modeling moderating effects of usage (T_3)

The management of mobile services largely depends on the type (e.g. core vs. enabler) and functional nature of the service. Appropriate business models in bringing new services to end-users are needed. Further, as legacy services (voice, SMS) were used practically by everybody, future services most probably experience variance of demand among different user groups. In other words, new services are targeted at smaller market segments (niche markets). For example, mobile navigation solutions might be successful among car owners, but not among retired people. Similarly simple bus schedule retrieval services might be successful among teenagers, whereas business men do not use public transportation and thus find little use for bus schedules. This all means that future mobile services are likely to address micro-segments of the market rather than the whole subscriber domain (Iimi 2005).

Special characteristics of mobile services – mainly the variability of situations in which mobile services can be used and the potential for personalization and context-awareness – mean that unified business models of service provisioning cannot be created. The fragmented market and complex usage context of mobile services pose challenges to researchers who are interested in mobile services. Even if the service is known already from another context (such as instant messaging in the fixed line Internet), the extension of the service to the mobile domain is unique (e.g. mobile instant messaging potentially substituting other interactive short messaging services and providing value only in special circumstances, such as when commuting in train and just “killing time”).

Mobile service demand is thus likely to face more variance. Though legacy mobile services (voice, SMS) can be considered generic in the sense that almost everybody is using them, the services of the future are likely to tackle narrower end-user segments. To take an example, mobile gaming can be successful among people who are interested in gaming and want to expand gaming usage in the mobile domain. Similarly mobile office applications are attracting business users. The establishment of new business models requires contributions in end-user segmentation practices, too.

The emergence of new mobile services and associated complexity thus constitutes the fourth identified trend in the mobile industry:

Trend 4: Heterogeneity in mobile service offerings and end-user consumption patterns (T_4)

2.2.5. The emergence of the mobile Internet

The trends identified above reflect the emergence of the mobile Internet. The heterogeneity of mobile services and evolution from basic communication services towards more advanced services lead into a market structure which favors fast innovation cycles and rapid commercialization of new service concepts. Incumbent mobile operators are sometimes slow and rigid, and they rationally stick to existing (significant) revenue streams from circuit-switched voice services. They do not necessarily have incentives to push new mobile services. This is one of the major factors slowing down the emergence of IP-based mobile services in Europe. Enabler technologies have been out there, but incumbent operators minimize risks and instead drive older vertically oriented business ecosystems. This is not only because fewer risks are involved as less change is taking place in the market – but also because incumbent mobile operators are controlling these dominating business ecosystems and significant changes in the market structure would not be for their benefit.

Companies playing challenger strategies have their greatest chances in *disruptive evolution* of mobile services. According to Christensen (1997) disruptive evolution typically results from low cost challenger alternatives, along the lines visualized in the figure below. Most mobile IP services reflect disruptive potential. These include, for example, instant messaging clients, web-based applications (e.g. web-based calendar and email) and VoIP services.

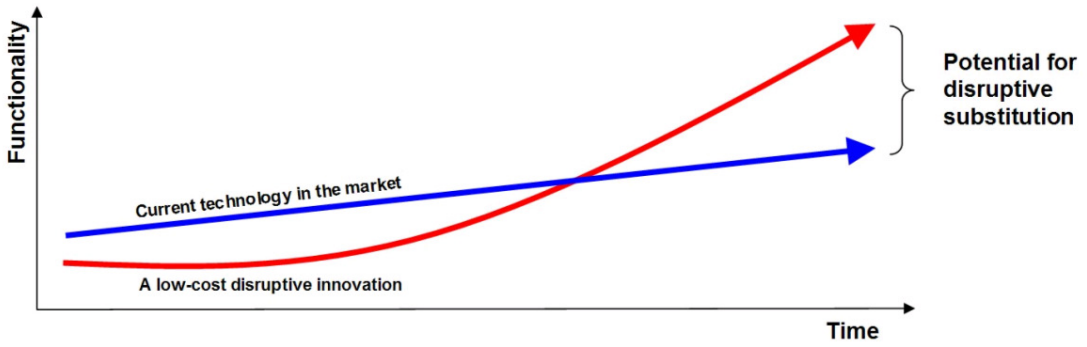

Figure 3 - Disruptive evolution (adopted from Christensen 1997)

The disruption in the mobile services sector might originate from spill-over effects of the fixed line Internet. For example, the different kinds of overlay networks of the Internet – such as Skype, MSN and P2P file sharing communities – benefit from spill-over effects taking place in the mobile domain (Verkasalo 2007a). According to recent research results in the Finnish market (Verkasalo 2007b), the technical complexity of setting up email accounts in messaging applications serves as a bottleneck for mobile email service adoption. Truly Internet-like services such as webmail services and Skype only require log-in – no complicated configuration processes are needed. Being at the same time free,

there exists potential for these services to fly in the mobile domain – even after considering the restrictions in usability. Bandwagon network effects and horizontal potential in the extensions of Internet services serve as strong forces that change the business dynamics of the mobile industry. Major questions are that in which timeframe and to which extent Internet-like services emerge, and who provision the services in the mobile domain.

Companies that are challengers rather than incumbents have better incentives to push for new alternative business models. Challenger companies do not have that much to lose, and this provides an incentive to explore radically new services and business models. For example, Hutchison, operating 3G networks in Europe, is pursuing collaborative strategies with Internet actors such as MSN and Skype. In pushing mobile Internet services to end-users operators lose something, as they have to give up the part of value chain related to service provisioning. This is taken for granted already in vertically disintegrated value structures of the fixed line Internet, but in the mobile industry incumbent operators have fiercely kept their central roles in managing mobile value networks. Challenger companies in any industry deviating from the mainstream market strategy are usually the ones taking the first steps in bringing something new into the business. In the future some challenger operators might push incumbents aside by pursuing new and open-minded strategies with disruptive services and business models. The technical improvements and trends taking place in the services sector reflect in the dynamics of mobile business ecosystems.

2.3. Mobile communications technologies

Mobile services are the core focus of this dissertation. However, in analyzing mobile services the interaction between technologies and services should be acknowledged. All services are built on top of technologies. Legacy technologies (e.g. GSM and GSMA roaming networks) form the basis of mobile voice and text messaging services. New technologies (such as mobile IP packet data access), on the other hand, provide possibilities for new kinds of mobile data services. The portfolio of technologies influencing the evolution of mobile services is becoming more heterogenic all the time. In addition to network technologies, for instance software innovations, authentication / authorization / accounting solutions, digital rights management systems and content delivery platforms are emerging. All these influence the mobile service market.

2.3.1. Networks and access technologies

Enhanced cellular networks and new convergent mobile handsets have gained lots of media attention during the past couple of years. The movement from older 2G digital cellular networks to enhanced 2.5G technologies, like GPRS (*general packet radio service*) and EDGE (*enhanced data rates for global evolution*), has proven to be a flexible solution on the path towards new 3G networks. (Garber 2002) Also the future 4G networks (Shaver 2004) are under dispute, with the first commercial steps towards these new generation networks having already been taken (Nokia 2005c). The figure below illustrates the evolution of mobile infrastructure.

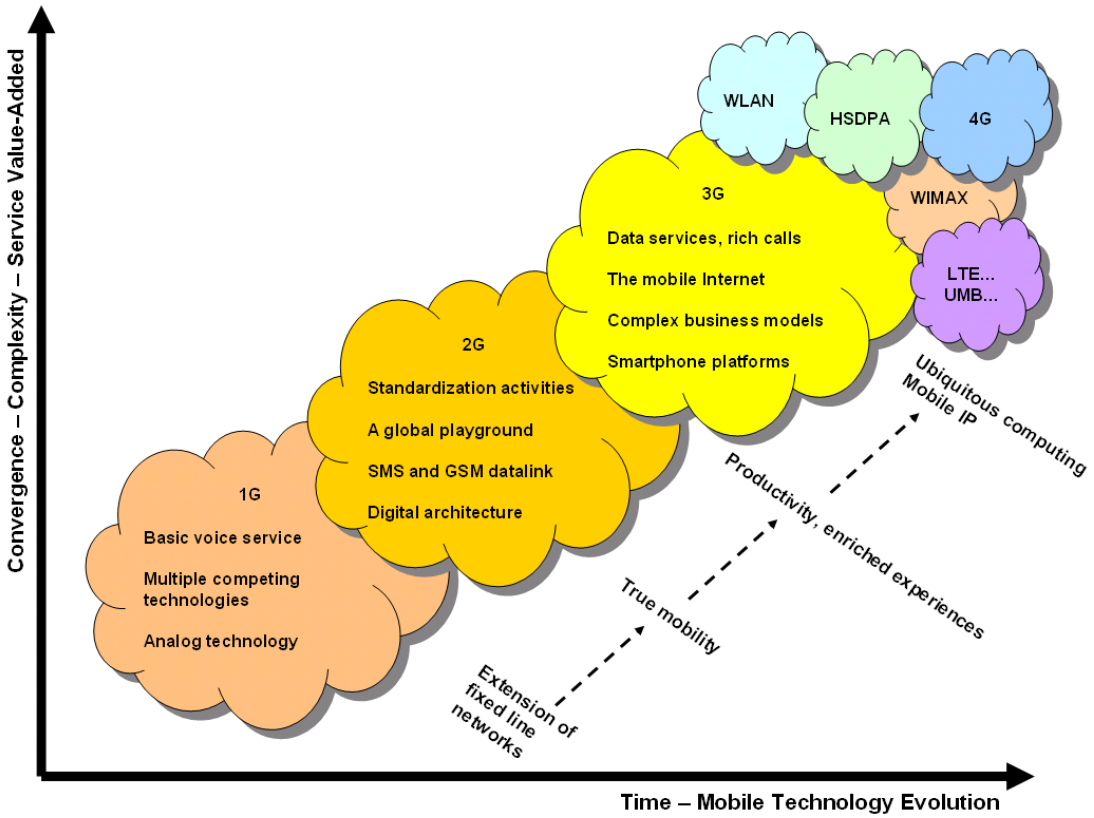

Figure 4 - Evolution of mobile network technologies

The Europe-originated GSM evolution path is strong, though there are also other network technologies (e.g. CDMA-driven path in North America, and Japanese PDC systems). Currently the 3G cellular evolution is divided into operators who deploy WCDMA and operators who have instead chosen CDMA2000. The rise of 3G promises more cost-effective network provisioning and increased capacity for operators, at the same time attracting end-users with new services.

The roll-out of 3G networks is pushing the next generation of mobile services. 3G networks provide operators with more network capacity, and they support higher transmission rates making new data services comfortable to use. Many of the new services, such as multimedia streaming, cannot be deployed in legacy mobile networks. Emerging new services include video streaming, video calls, mobile gaming, P2P file sharing, presence services, instant messaging, gambling and Internet browsing. The WCDMA technology that mainly draws on the European standardization bodies has already been deployed in many European and Asian countries. CDMA2000, that has its roots in the U.S., is chosen as a 3G standard in many parts of North-America. In practice, however, a fragmented 3G technology deployment is to be seen both in Asia and North-America. Regulatory and political issues have played a significant role in the launch of 3G networks. (Garber 2002)

Japan was the first country to deploy 3G networks. Many European countries had difficulties in managing a fair allocation of spectrum licenses. Prices of licenses reached several billions of euros in Germany and the UK. Together with the investments needed to

build 3G network infrastructure, these problems drove the popularity of "evolutionary technologies", such as EDGE, instead of directly changing to pure 3G. Operators had difficulties because of the negative cash flow from license rents and network investments, delaying the introduction of 3G in Europe. However, currently all European mobile communications markets, such as Germany, Italy, the UK and the Nordic countries are increasingly covered with 3G networks. The less developed countries both in Europe and elsewhere in the world still count on 2G and 2.5G technologies for some years to come.

New technologies have affected the market of mobile data services. Higher throughput rates support the implementation of new services and exploitation of innovative business opportunities. Internet services are expected to challenge the traditional roles of incumbent mobile operators. For example, in the end of the day voice will be transmitted in packet data networks instead of circuit-switched ones. The main revenue of cellular operators currently still comes from circuit-switched voice. Together with alternative radio access technologies, IP-based services are causing disruption in the mobile playground. In general, 3G network standards are already geared towards IPv6 (Kanter et al. 2000). European mobile network operators have responded somewhat slowly to new emerging technologies, while their counterparts in Japan have already experienced significant success (Vesa 2005).

Future radio access technologies are diversified. An emergence of WiFi and WiMAX based solutions can already be seen. These solutions provide in some circumstances comparable (or better) radio connectivity to mobile devices than cellular networks. From the techno-economic point of view the future mobile WiMAX might serve as a potential substitute for cellular networks (Smura 2006). Some major actors, such as Sprint in the U.S., indicate that they will deploy WiMAX as their next generation wireless broadband access network (Sprint 2007).

The mere technology to be deployed is not the only relevant aspect, as also business models behind the network matter. As cellular networks are strictly controlled by mobile operators who also control most of the services, authentication, authorization and accounting, the challenger radio access technologies provide potential (in some cases because of the regulator's decisions) for more horizontal business models in which the network and service operators are separate entities. The turbulence in the evolution of network access technologies (and support for access technologies in handsets) constitutes the fifth major trend in the mobile industry:

Trend 5: Divergence in mobile network access technologies (T_5)

Divergent access networks require new solutions in devices, too. Multi-radio devices of the future should be able to connect automatically to the most suitable access network available. WiFi hotspots are utilized when they are available, cellular networks are still required in rural areas, and ad-hoc networking through close proximity technologies such as Bluetooth might be flexible in certain contexts in which end-users exchange photos or any other personal content.

2.3.2. Mobile devices

In addition to enhanced mobile networks, evolution of mobile devices is critical. Smartphones are here defined as pocket-sized computer devices that provide at least cellular circuit and packet switched connectivity. Smartphones can be also called as multimedia computers (Nokia 2006) or converged devices (Canalys 2007). Smartphones access wireless networks through various radio-access technologies, such as WiFi, 3G and EDGE. Processing power and memory capacity of smartphones support advanced services, from games to office applications. Smartphones effectively combine traditional offline functions, such as personal information management or office applications, with online services such as person-to-person communications or Internet browsing. Effectively smartphones are migrating from communication devices towards computers. (Iftode et al. 2004)

Some future scenarios suggest that smartphones become multi-purpose devices, integrating the functions of electronic money, keys, communicators and computers into one device. Some of the casual functions needed in everyday life are primitive, and they can be eased with electronic means (Weiser 1991). According to Iftode et al. (2004), today's smartphones hold the largest potential in becoming multi-purpose devices supporting everything from communications to digital wallets and from personal data assistants to authentication/authorization devices. One of the most important arguments for this statement is the high penetration of mobile phones, and the increasing popularity of smartphone devices in the mobile phone market.

In addition to communication functionalities, smartphones include, among other things, megapixel cameras, GPS (*global positioning system*) receivers, enhanced video rendering chips, powerful Internet browsers, and even support for mobile television broadcasting. Older mobile phones are dumb devices at the edge of the network, while smartphones can process a lot of information and perform complex actions. (Iftode et al. 2004)

In comparison to older PDA (*personal digital assistant*) devices, the main difference of smartphones is their capability to connect independently to external networks (Lettiere & Srivastava 1999) and freedom to install add-on applications. Indeed, the differences in the cost structure of smartphones and PDAs are mainly related to required memory capacities and radio interface technologies (Garber 2002). A lot of effort has been recently put on optimizing smartphones with regards to user interfaces and battery capacities (see e.g. Funk 2004, Väänänen-Vainio-Mattila & Ruuska 1999, Agrawal & Famolari 1999).

Most smartphones, as of 2008, are run by Symbian operating systems. Symbian has already wide support among the key handset manufacturers. (Vaughan-Nichols 2003) However, there are various Linux and Microsoft Windows Mobile based smartphones that challenge Symbian. New challengers include Google Android devices and Apple's new IPhone. It is expected that smartphones represent 9.3 % of annual mobile handset volumes in 2009, in comparison to only 3.7 % in 2004 (Sharma 2005). The share of smartphones is significantly higher in developed markets where high-end technology gadgets gain popularity quicker and purchasing power of consumers is better.

Convergence is the trend in the evolution of smartphones. Mobile phones are becoming more computer-like devices. It is, however, difficult to pick up the winner – or dominant –

design. Although some convergence with regards to the list of core functions (camera, web browsing, video calls etc.) in smartphones takes place, still unknown dominant technical standards with regards to interfaces between devices and/or networks, radical technology innovations in batteries, evolution of software architectures and user interfaces influence future smartphone designs. (Funk 2004) Increasing customization and segmentation can be observed in future smartphones. Different device models and form factors are targeted for different purposes (exemplary device models including navigation devices, imaging phones and mobile office devices).

Operating systems in smartphones are not that different from operating systems running PDA devices and pocket computers today (Hallet 2004). Smartphones are expected to support advanced add-on applications and complicated operations and thus it is required that the operating system is advanced enough, providing APIs for add-on applications and adequate processing power to support, for example, multitasking. Symbian is the market leader in providing operating systems for mobile convergent devices, i.e. smartphones. Symbian was established by mobile phone manufacturers in the 90s. On top of the operating system a platform with user interface components is also needed. Nokia is developing the S60 (earlier Series 60) software platform on top of Symbian, and brands it aggressively in corporate communications (Nokia 2005b). The S60 is licensed to other mobile phone manufacturers, such as LG Electronics, Lenovo, Panasonic and Samsung.

One of the powerful elements of computer-like operating systems is their openness. Practically everybody can develop new services on open platforms. This openness is important in "tipping" the market, in reaching a wide installed base. Considering the key elements in the success of the Internet – end-to-end connectivity and network edge based innovation – open platforms make these forces applicable eventually also in the mobile domain. This constitutes the next trend of the mobile evolution (studied in detail for example in Article 1).

Trend 6: Diffusion of smartphones as multi-purpose mobile computers providing seamless connectivity and computing power (T_6)

Although this dissertation attempts to tackle the mobile industry in general, the primary focus is on new services and devices. This means that smartphones are a relevant locus of interest in empirical research. Actually the main research method of this dissertation – the handset-based mobile service research method – is built for Nokia S60 smartphones, and therefore the scope of the empirical studies is narrowed down to smartphones.

2.3.3. Internet and fixed-mobile convergence

Different technologies can be utilized in provisioning mobile services. In the past only basic circuit-switched services were available, and network operators provisioned services in a controlled way. The network was the point of service intelligence. Voice mailboxes and SMS servers were all located in the network and the mobile phones were dumb terminals on the edge of the network.

Currently there are two major trends taking place in the mobile service business. The first trend deals with the emergence of new services – many of which are based on IP protocols and packet data. These services – as discussed already in this dissertation – are likely to bring the technologies of the fixed line Internet to the mobile domain. Client/server architectures emerge and more interaction is likely to be seen between clients (mobile devices) and servers (any server provisioning the service through the IP protocol) via wireless networks. Innovative solutions for mobile service delivery are likely to be seen. Some challenger service operators might utilize overlay service architecture (Clark et al. 2006) in building proprietary solutions on the application layer and then utilizing IP data access in mobile devices. Legacy network operators remain as simple bit pipe providers in some business scenarios. While Internet oriented solutions bring innovation and speed to the game, they suffer from controlled access networks (legacy operators might block Internet traffic), technical challenges in the handset base (low initial penetration of smartphones and technical problems in, for example, mobile browser usability) and difficulties in truly driving mobile e-commerce and means of mobile AAA (authentication, authorization and accounting) independent of cellular operators.

The other major trend is fixed-mobile convergence. According to Celtic-Ecosys (2005) this means *"the end-to-end provisioning of services independent of the underlying access and core network technologies"*. In other words communications and data services will experience convergence in the future in the sense that the access network (various mobile and fixed access network technologies) does not matter and seamless connectivity is to be expected. Similar services are likely to be seen both in the fixed and mobile domain. An example can be taken from instant messaging. Instant messaging can be used with laptop, desktop computers or integrated multimedia/entertainment systems (structured e.g. around TV sets or game consoles) while at home, and with mobile handsets while "on the move". The access network is chosen based on a set of attributes, such as static/mobile dimension, price, bandwidth, context and location.

IMS is one of the key technologies in deploying fixed-mobile convergence. It is built on top of the Internet protocols, though it is then complemented with a set of technologies to account for more flexible and suitable mobile-specific service provisioning. The IMS standard is developed in a mutual collaboration of mobile operators and vendors. IMS separates applications from the session and transport layers. IMS provides a possibility for fixed line operators to invade to the mobile domain through fixed-mobile convergence, whereas for mobile operators IMS provides a technology to provide value-added services and to fight against challenger IP services with a more customized IP-based service delivery platform. (Celtic-Ecosys 2005; Bellman 2006)

All in all, more fragmentation will be seen not only on the service layer but also on the service delivery layer. IP-based platforms such IMS, the Internet client/server delivery model, emerging overlay networks and new technical innovations in the mobile e-commerce scene are likely to drive future models of mobile service provisioning. Incumbent operator driven models (continuation of network-centric service provisioning such as MMS, PoC, IMS) can be contrasted to truly Internet-like service delivery models (overlay networks, credit card billing, client/server architecture).

2.4. Adoption and diffusion theories

This dissertation mainly studies the diffusion and adoption of mobile services, applying different research angles depending on the specific research problem under consideration. By the definition of this dissertation, in discussing the diffusion of new technologies, the focus in on macro-level issues such as transformations of the whole market. Technology diffusion is seen in this dissertation as the penetration of technical capabilities to the market. On the other hand, the focus of adoption studies is considered to be in specific adoption processes that individuals experience when using services. This dissertation assumes that in the optimal adoption research the technical capabilities are already in the market (diffusion of technologies is therefore taken as given).

2.4.1. Diffusion of technologies

Rogers (1962) can be considered as a father of the technology diffusion research. According to Rogers, new innovations emerge in the market over a *diffusion curve*. All technologies face the same process of diffusion – only the pace at which the diffusion proceeds is uncertain. Rogers suggests that the most technologically enthusiastic people (so called innovators) adopt new technologies at first, followed by early-adopters, then also by the early and late majority of the market, and finally by laggards. The needs, interests and capability levels segment potential end-users of the market into one of these categories. By projecting the penetration of a new technology it is possible to see the diffusion process speeding up after a slow start, as the technology reaches wider customer domains along the technical and commercial maturity. According to Rogers, technical innovations gradually penetrate to the maximum market penetration with a long diffusion tail as the last laggards join the group of technology users.

Rogers' framework does not account for some other determinants in the diffusion of innovations, such as the role of disruptive competing technologies (Christensen 1997), the differing nature of the technology to different succeeding user groups, i.e. *technology chasm* (Moore 1991), and path dependent economic impacts (see Nelson & Winter 1982) such as the bandwagon effect (Leibenstein 1950). Nevertheless, Rogers' framework encompasses the generic idea of technology evolution in terms of market penetration. Figure 5 shows Roger's model of soaring adoption rate as penetration increases at the beginning, while the diffusion slows down when the market is saturated at the end.

Most empirical papers on technology diffusion study only the speed of diffusion (i.e. how quickly the penetration is increasing), whereas less interest is generally targeted at the development of usage activity along the diffusion. This research gap is identified in Grajek & Kretschmer (2006), for example. When studying service usage, usage data can be collected only from the specific group of users who really use the service. Thus at an early stage of service life-cycle, only innovators and early-adopters use the service, and average usage intensities are therefore high. Gradually the user base widens, but the marginal users are less technologically advanced. Consequently, the observed usage is decreasing in intensity of usage, though the user base is increasing in number. This theoretical model of decreasing average usage intensity along the diffusion is called as the *heterogeneity* or

rank model (Karshenas & Stoneman 1993) in contrast to the *epidemic model* (Geroski 2000) in which all users are assumed to have identical preferences for a new technology.

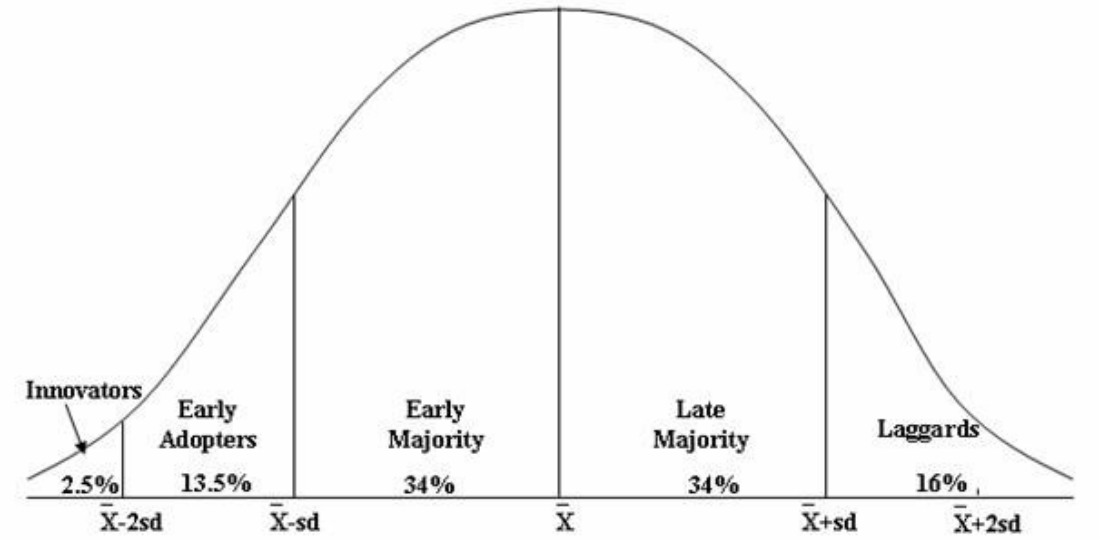

Figure 5 - Roger's diffusion model (adapted from Rogers 2003)

The user heterogeneity model implies that in longitudinal comparisons the observed usage intensities of the service should be decreasing, given that all users of the service are included in the analysis. Furthermore, it suggests that at any point of time the users using the service should have differing preferences, and therefore usage distributions should be skewed. The more variance in user preferences, the more skewed the usage distribution. People most interested in using a particular service should use it more actively than people with less interest. This will lead to an accumulation of service usage, in other words a small base of users generate most of the overall usage. This can be called as a variation of the *long-tail effect* known in a variety of contexts, typically when studying content business (see e.g. Anderson 2006 and Kilkki 2007). The implications of the user heterogeneity model should be more evident with newer services, in which user preferences potentially involve more variance than in mature services such as mobile voice.

Other forces having an impact on the usage intensities observed include network effects (see e.g. Farrell & Klemperer 2006), substitute technologies (Porter 1980) and competitive pressures (Koski & Kretschmer 2005). *Network effects* suggest that the utility from the increased base (network) of users is increasing and therefore this increasing utility might push usage intensity along the diffusion. A good example comes from the success of Skype VoIP service, the value of which is in the network of Skype nodes (i.e. users). People extract more utility from Skype as more people join the network. This motivates people to use Skype more actively. *Substitute technologies* that eventually appear on the market might distribute usage among a higher number of services thus decreasing a particular service's average usage intensity as the service matures. For example, short messaging service usage intensity can be decreasing as more and more instant messaging clients are appearing in the mobile market. *Competitive pressure* in the market can be assumed to increase as the service matures. In several cases this takes the form of price

competition, which further feeds in as increased usage if the price elasticity of demand is negative (typical assumption). One more potential driver of increasing usage over service life time is the *technical maturity* of the service. In other words, improvements in usability and performance might induce more usage from end-users. These examples demonstrate that the final net impact of service maturity on observed usage intensities might be either negative or positive. The field of mobile service diffusion research, therefore, is both complex and still to a great extent unexplored.

2.4.2. Theories of technology adoption

In adoption research, by the definition of this dissertation, the focus is not in market-wide issues such as service penetration – but instead in the adoption process of individual end-users.

A huge domain of adoption research stems from the information systems adoption science. Information systems adoption research utilizes fixed theoretical models that were developed a couple of decades ago. These earlier models attempting to explain adoption of technologies (particularly information system technologies; this is why the approach is sometimes called as IS adoption science) include the *theory of reasoned action (TRA)*, *the theory of planned behavior (TPB)* and *the technology acceptance model (TAM)*.

The theory of reasoned action (Fishbein & Ajzen 1975) is based on the individual's attitude towards the action itself and subjective norm of the action (expected behavior of others in response to the individual's action). Together these determine the behavioral intention to use the technology. Ajzen later expanded the model; in a theory of planned behavior (Ajzen 1985; 1991) a third concept exists, namely the perceived behavioral control. This reflects the difficulty of performing the action. These models communicate that technology adoption depends both on the individual's own perceived benefit of performing the action and the social norm driven by people around the individual. These frameworks suggest that usage patterns not only depend on the individual's own capabilities and interests, but also on the sociological environment and norms in the culture. The theory of planned behavior (TPB) is illustrated below.

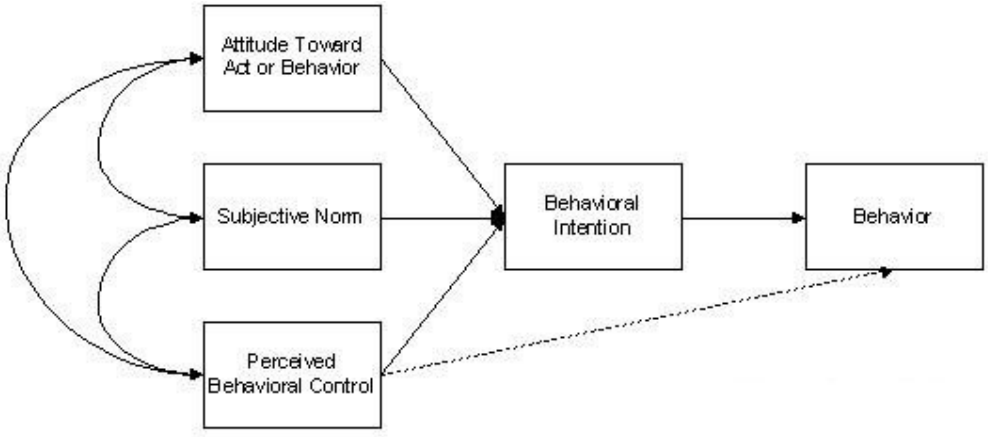

Figure 6 - Theory of planned behaviour (TPB) (adapted from Ajzen 1991)

Davis (1989) follows a similar logic in his technology acceptance model (TAM). He distinguishes two concepts. First, the concept of perceived usefulness reflects expected benefits from using a certain technology. These benefits can be utilitarian or hedonic value. Second, the concept of perceived ease of use reflects the same thing as the perceived behavioral control in the theory of planned behavior, i.e. how difficult it is to use the technology. The figure below presents the main elements of the TAM model.

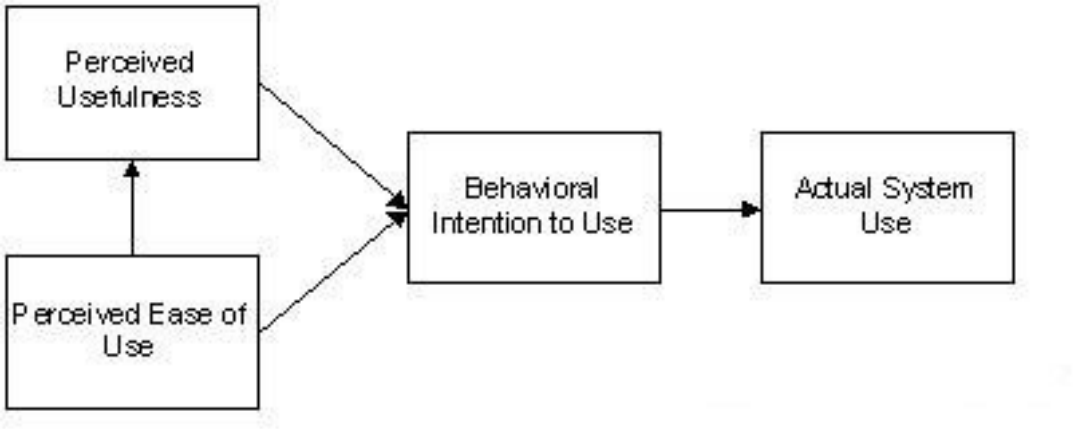

Figure 7 - Technology adoption model (TAM) (adapted from Davis et al. 1989)

In predicting information technology adoption, the TAM model developed by Davis is the most frequently used framework, and by 2000 more than 400 journal articles had cited the two original TAM articles (Venkatesh & Davis 2000). Despite its popularity, also further development of the TAM model has taken place. For example, the original model suggested that perceived usefulness and perceived ease-of-use mediate all external factors (e.g. demographics) though this is not always the case (see e.g. Burton-Jones & Hubona 2005). Applications of the framework are needed as the original model typically explains only 40% of usage intentions and 30% of actual use (see e.g. Venkatesh & Davis 2000 and Meister & Compeau 2002).

Holistic adoption models (see e.g. Pedersen and Thorbjørnsen 2003) stemming from the TAM model have been earlier utilized in specific mobile service research settings. Holistic behavioral models typically utilize statistical methods such as structural equation modeling (SEM), and they derive from theoretical models illustrated above (particularly Davis' research). In Nysveen et al. (2005) the approach of utilizing variations of the TAM model with SEM analysis is called as information systems research, as most studies utilizing structural equation models from the adoption perspective deal with the adoption of ICT services and systems. Due to this increasing context-specific nature and various ubiquitous characteristics (Heinonen and Pura 2006; Rask and Dholakia 2001) mobile services should be considered carefully when applying earlier information systems adoption models, and several models therefore extend the basic TAM models with study-specific hypotheses.

The other approaches to study adoption of technologies include a uses and gratifications research approach (see e.g. Leung and Wei 2000; Höflich and Rössler 2001) and a domestication perspective (Haddon 2001; Ling 2001; Skog 2002). The former approach

(*gratification research*) deals with the gratifications that users look for when using mobile services. These gratifications can be either utilitarian (business value or direct utility) or hedonic (entertainment oriented benefits) (Flanagin and Metzger 2001). The latter approach (*domestication research*) has close linkage to sociology, anthropology and ethnology. Sometimes domestication research does not focus on only the individual user adoption process, but tackles the adoption process from the cultural or societal point of view (see e.g. Ling and Yttri 2002). Domestication research studies the consequences of service usage and the integration of the technology in the end-user's every day life (Pedersen 2005). These two frameworks reflect softer scientific disciplines in studying technology adoption.

Many additional research areas study micro-level user behavior in detail. Some of these approaches resemble the adoption frameworks as described above. Some of them utilize micro-economic models, such as Pohjola & Kilkki (2006). Pohjola and Kilkki claim that people compare marginal utility (e.g. utilitarian or hedonic benefits) from using the service to the marginal cost of service use. This entails that marginal costs do not only refer to the monetary cost of using the service, but also to the opportunity cost of time and effort exerted in using the service. The present dissertation studies both the generic adoption process of end-users and the micro-level determinants of usage.

3. Mobile end-user research

3.1. Alternative research methods

In order to empirically analyze mobile services, several data collection methods and research approaches can be applied, ranging from surveys to interviews. Empirical data, with both qualitative and quantitative research approaches, provides value to industry players at least in the following dimensions:

- Analysis of service adoption
- Research on stickiness of application usage
- Measurement of technical performance
- Evaluation of end-user experience
- Collection of end-user feedback

Mobile end-user research methods are here divided into seven main categories. First, questionnaires tackle end-user experience through a pre-specified list of questions. Second, interviews offer an interactive method of acquiring data from end-users. Third, laboratory and road tests are flexible in observing actual service usage in a controlled test environment. Fourth, network based traffic trace measurements provide an aggregate approach to study data flows. Fifth, server-side measurements provide data from application-specific servers. Sixth, accounting systems and CDRs (*customer charging records*) of operators reflect the charging events have been caused by end-users. Finally, the most recent stream of end-user research is centered on user-centric (e.g. handset-based) measurement platforms.

In her survey handbook, Fink (1995) divides different survey techniques of end-user research into self-administered questionnaires (the end-user fills a prepared questionnaire), interviews (the researcher intervenes and interactively leads the discussion), structured record interviews (includes specifically prepared templates which guide the data acquisition process in the context) and structured observations (includes specific rules which guide the observer in looking for particular kind of events or observations in the context). Surveys by this definition are therefore a wider concept including questionnaires, interviews and laboratory oriented research settings. Earlier research utilizing surveys includes, for example, Aaker et al. (2004) and Kim (2001). Despite the framework of Fink, questionnaires are below distinguished from interviews, and interviews further from laboratory tests, because the ways of deploying these research methods are different.

In addition to data collection, practical analysis practices and models of marketing research are needed. The data need to be converted into information, and established models of demand analysis, usage studies, adoption research, and other useful models should be used (see e.g. Farris et al. 2006 and Wierenga 2008) in delivering insights and concrete KPIs (key performance indicators). In the case studies of this dissertation, some earlier models are used, and also new analysis frameworks are developed that particularly match with the nature of handset-based behavioral data.

3.1.1. Questionnaires

Different kinds of questionnaires are applied, from single answer to multiple answer ones, and from fixed answer to open answer ones. The specified questions should deal with the research problem, providing the respondent with a possibility to give answers that help in answering the research question of the researcher. Different questionnaire deployment methods are applied. In the past questionnaires were printed on paper and distributed via mail or presented in special occasions (such as in events where many members of the target group were present at the same time, e.g. academic conferences or class-room events). Nowadays electronic means to deploy questionnaire studies are increasingly used. Particularly Internet technologies provide new ways to implement questionnaire studies. WWW-based questionnaires provide a possibility to quickly reach a wide selection of end-users, and through electronic means the analysis of questionnaire results is quick.

Questionnaires are a flexible method to end-users, who fill in the questionnaire when they have the best occasion to do so. Questionnaires can include many kinds of questions. Open questions let the respondent to express her real open-ended opinions on the topic. Fixed pre-specified answers on the other hand are quicker to fill in. The cost per respondent is low in questionnaires.

On the other hand questionnaires are subjective. End-users do not always know the answer, and they might give false answers either intentionally or unintentionally. The interpretations of both questions and answers pose challenges, too (Martin 1983). Questionnaire structures are typically fixed beforehand, providing less flexibility in study deployment. Questions have to be planned and structured beforehand, and no interaction can be achieved with the respondent. The nature of data that can be acquired through questionnaires is of special kind, too. No accurate service usage issues, for example, can be asked, because respondents either are not aware or cannot remember the specific details of their usage behavior. Questionnaires should be used when a wide base of respondents is required, and the set of questions to be asked is specific and the answers brief.

3.1.2. Interviews

Interviews are an interactive method of end-user research, where an interviewer asks questions directly from respondents. The interviewers can guide the discussion based on their own research interests. This is both a challenge and an advantage. The discussion should not be guided too much, because that would spoil true interactivity. On the other hand, if the discussion goes off in a wrong direction, the time is running out or if the answers are incomplete (more details are needed to interpret them correctly), then the interviewer has a possibility to control the discussion and get it back on track.

Interviews are in several cases valuable because of the interaction involved. Complicated research problems can be solved by asking both structured and unstructured questions from end-users. In qualitative research problems interviews of end-users provide the most accurate channel to tackle particularly end-user experience and perception related

dimensions that are basically impossible to study with any computerized empirical research methods.

The setback of interviews is the expense in carrying them out. Doing interviews is slow, and the interviewer has to invest time in both preparing and executing the interviews. No scale economies exist and extensive interview studies are either expensive or logistically impossible to carry out. Interviews, just as questionnaires, also face the problem of subjectivity. Interviews are at their best in studies which require detailed and open-ended answers to a specific set of questions.

3.1.3. Laboratory tests

Laboratory and road tests refer to preplanned tests taking place in a fixed context (such as in a laboratory). Road tests are different from laboratory tests in that they take place in more natural contexts, in places where also actual use cases happen. Both laboratory and road tests follow the same principles. Services are provided to end-users in controlled environments, and during the experiment observations are done regarding end-user behavior. In some tests questions are also asked from end-users to complement usage-level observations.

Laboratory and road tests require effort in setting up the test environment. A context for testing has to be arranged, services and devices have to be prepared for testing, observation processes have to be planned and end-users have to be recruited. Accurate observations can be done on user behavior in almost normal usage contexts, but as with interviews, the process does not scale up easily. No automation can be implemented easily, and the cost per participating end-user of laboratory/road tests is high. Laboratory tests best suit for specific research needs in which both actual usage-level observations and end-user opinions are needed. Usability designers typically use laboratory tests.

3.1.4. Traffic measurements

The research methods discussed above provide few possibilities for computerized data mining. More integrated platforms of end-user research are now discussed, which allow for integrated data mining procedures. Integration here means that data collection and analysis can somehow be integrated together and to some extent computerized (made automatic). The sources of more technical usage data can be identified in Figure 8 (Kivi 2007). Four kinds of technical measurements are identified in this dissertation: traffic gateway, server-side, charging record and handset-based measurements.

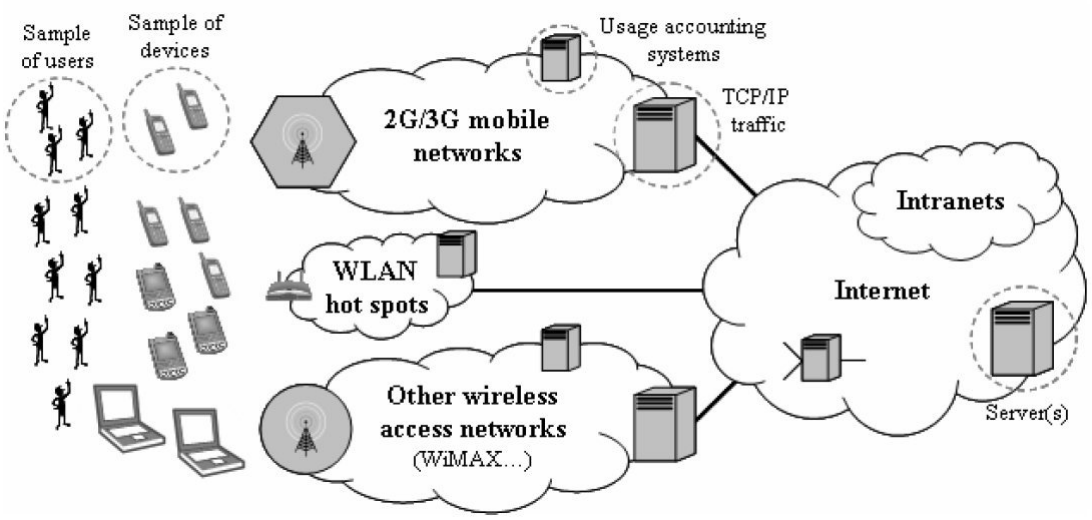

Figure 8 - Sources of technical measurements (adapted from Kivi 2007)

First, traffic measurements take place in network gateways. Examples from the academic community include among others Peuhkuri (2005), Viipuri (2005) and Kivi (2006). Typically packet data traces are collected in network gateways, for instance at the mobile operator's GGSN (*gateway GPRS support node*) interfaces. A point of convergence should be found, because at these points a maximum coverage (e.g. maximum number of data flows) can be achieved. The divergence of mobile access networks (Trend 5 identified earlier in this dissertation) makes it more difficult to use network-based measurement methods in holistically studying mobile service usage at any one point of network, through which all the data from the device would flow. Not every mobile service nowadays requires network connectivity (e.g. games, GPS navigation, adhoc Bluetooth connectivity, offline multimedia playback).

In traffic trace measurements individual packets (their header information) are studied and classification schemes are used in modeling data flows (e.g. distinguishing between different protocols, source devices or operating systems). Sometimes the analysis is easy (e.g. based on TCP port numbers), but in many cases different kinds of "TCP finger printing" methods are used in categorizing the traffic by operating systems (Kivi 2006).

Traffic trace measurements provide a scalable and computerized method for studying packet data service usage. This restricts the method only to packet data studies, but on the other hand the amount of data to be studied is often extensive. The access to the operator's network is a challenge for external researchers. Also legal problems exist. At best traffic trace measurements provide an extensive amount of data on many interesting factors, and particularly the scalability and potential for automation is high.

3.1.5. Server-side measurements

Servers are application specific, and not all mobile applications require servers at all (e.g. offline music playback). Typical Internet servers provide content for multimedia streaming (e.g. video on demand), manage email traffic (e.g. IMAP servers) or serve clients who ask

files to be sent through HTTP (e.g. Apache servers). By doing measurements at servers, specific data points can be collected that reflect the server's functionality in the network. For example, from WWW servers the specific types of documents and sub-sites that users retrieve can be observed.

As with traffic measurements, server-side measurement processes can be computerized, and given that a server is heavily loaded, lots of accurate data can be captured. The setback is that an access to the server should be first achieved, and additionally potential legal problems (with regards to e.g. end-user privacy) should be solved in advance. At best server-side measurements provide complete data on specific applications. Examples of server-side measurements include can be found in Kamvar & Baluja (2006) and Opera (2006).

3.1.6. Charging records

Services that utilize the operator's infrastructure can be charged for by the operator. These services include such things as voice calls, SMS messaging, packet data traffic, MMS messages, downloadable ringing tones and wallpapers. If charging records are available for research purposes, they can be utilized in analyzing service usage in several dimensions.

Legal problems are a major challenge for the utilization of charging record based studies in the academic domain. Charging records reveal private information on end-users. If a structured study with legal problems solved can be arranged, however, the studies utilizing charging records provide accurate data on service usage. Also the analysis of charging records can be computerized (see e.g. Wei & Chiu 2002).

3.1.7. Handset-based data collection and processing

Terminals have been used earlier in collecting behavioral data, for example, on TV consumption. The research is typically conducted with specialized technologies or software applications that are embedded into terminals. For example Nielsen and ComScore have been monitoring TV (Szczypka et al. 2003) and web (Wood et al. 2005) usage for years in coordinated panel studies. According to Lohse et al. (2000), panel studies of this kind, also called audience measurements, have certain challenges, mainly attrition bias (loss of panel participants over time), panel selection bias (people in the panel are different from the population to be studied), and conditioning effects (the implementation of the panel affects the behavior of panel participants). Audience measurements in TV, web and radio domains provide insights from real-life consumption, and these panel studies can be of either dynamic (new panelists replace old ones gradually) or static (the panelists stay the same) nature. Audience measurements in mobile phones are still an unexplored territory in academic research.

Smartphones are becoming powerful multimedia computers. This evolution opens new possibilities in mobile end-user research. In particular, today's smartphones provide a possibility to build intelligence in the handset for data collection and processing. Specific software can be developed that monitor handset and service usage and store usage data

into local databases in a coordinated fashion. On the other hand, handset-based intelligence might benefit in other dimensions as well, such as in developing contextual and presence-based mobile applications.

Handset-based software collects data at the ultimate point of convergence – the handset. By relying on the definition of mobile services (i.e. they are used with mobile handsets), all mobile services somehow involve the handset in the technical delivery of the service. Therefore data that is extracted from the handset is of a wide scope. This data is also objective, as end-users cannot subjectively manipulate the data points that are collected. Usage data collected from handsets should, therefore, reflect actual usage pretty well. Given that handset-based usage data can be outputted in a standardized form, some automation of data mining can be developed.

The process of arranging panel studies (with handsets including the monitoring software) for a given set of research objectives is a challenge in all handset-based end-user research. The problem reminds of laboratory tests, as arrangements have to be made in order to set up a study. Also the development and management of the piece of software collecting data pose challenges. For example, the data acquisition process can be arranged in various ways. One possibility is to store all the data in the handset, and then manually copy the data afterwards from the handset. The other possibility is to deploy centralized servers to which usage data can be constantly uploaded. All in all, the implementation of the whole handset-based study process in addition to the mere client is challenging.

Later in this dissertation a specific handset-based research method is introduced in detail. Its technical architectures along with the research process are discussed. The method to be introduced belongs to the group of handset-based end-user research approaches.

3.2. Comparison of research methods

The feasibility of available end-user research methods can be studied on many levels. Fink (1995) mentions reliability (no measurement error), stability (are measurements stable, or do subsequent measurements differ from each other although they should reflect the same thing), control of equivalence (are different observations of the same thing equivalent and comparable to each other) and validity (do measures really measure what desired) as dimensions of comparison. Fink's framework can be extended with other important dimensions, such as the amount of data available (see Kivi 2007), flexibility and speed of the research process, and multidimensionality/variety of the data available. Each data acquisition technique can be compared with respect to these dimensions.

Table 1, which can be found on page 42, compares each of the methods in the dimensions identified.

Subjectivity reflects the extent to which end-users or researchers can affect the data collected with their own interpretations. These interpretations are not always aligned with the original meaning of the question or research problem. Because end-user perceptions are a mix of real and imaginary things, the answers of end-users may include statements that are not real or accurate. For example, when asking if an end-user used mobile TV

broadcasting, she might answer yes though she only downloaded video clips through the Internet and then watched them (thus she used video download, not broadcasting by definition). Computerized research methods are more objective, as they do not rely on any kind of perceptions in the data collection phase.

Detail of accuracy reflects the amount and type of data that is collected. The more data collected per target object (e.g. data session), the more detailed level of accuracy can be obtained. Humane ways of data collection (e.g. interviews or questionnaires) typically provide less accurate usage-level observations, as people have limited knowledge on their own usage patterns. For example, after terminating a mobile browser session the end-user may be able to indicate whether the session was successful and give her general perception of the session quality, but she cannot tell accurately the size or duration of the session. Many computerized methods acquire a comprehensive set of parameters that can be utilized in end-user research. Computerized methods often have access to the very details of usage (e.g. on the technical layers of data sessions).

Type of data acquired is of critical importance as available research methods collect different kinds of data. Some research problems require deep understanding of, for instance, the end-user's motivation and perceptions in using mobile services. In these cases open answers with explanations are needed. Sometimes accurate usage-level quantitative data is needed, for example when calculating average throughputs of access points. In these occasions quantitative data is more appropriate than qualitative data. Although interviews support the acquisition of detailed data interactively and directly from interviewees, the challenge is that this data cannot easily be processed and analyzed automatically. Instead with, for example, network-based measurements more straightforward and standardized data can be acquired and further computerized processing of data is easier.

Target services differ in each research method. Target services derive from the objective of research. For example network packet data gateways provide a possibility to study mobile data services, whereas a focus group consisting of a bunch of teenager interviewees is a feasible method in studying mobile multimedia services, for example. All research methods have limitations in terms of the number and type of target services. For example, interviews provide a possibility to only ask about services that interviewees are aware of. Many interviewees do not even know what is meant by 'multimedia streaming' or 'browsing'. Another example comes from charging record based measurements, in which data is available only on services that generate charging events. Handset-based measurements are at the point of convergence, as all mobile services utilize the handset itself (regardless of whether the service is network/offline service, or whether it is charged for or not). Therefore, handset-based research methods have the advantage of tracking almost all possible mobile services.

Reach and scalability refer to the type of end-users to be studied. If the reach and scalability is good, the research methods can collect data from a good sample of the target population, and no technical barrier to collects lots of data exist. However, some methods (such as the handset-based approach) are slightly biased, and only particular subsets of the target population can be studied (in this case early-adopters).

External validity reflects the possibility to generalize results from the sample to a wider set of people. In other words, if the external validity is in order, the results obtained from a smaller sample can be used in statements regarding larger populations. For example, if a sample of teenagers are being interviewed and research results are obtained on some specific characteristics of mobile multimedia service usage, these results can be generalized (thus the external validity is good) if the teenagers of the sample are thought to be well representing the target population (teenager end-users).

Reliability of data and *internal validity* reflect the reliability that is involved when studying the data obtained from the sample population. If the data acquired has few errors and data points accurately reflect the things they should reflect, the internal validity is in order. The empirical research process is well standardized and all sources of error have been solved if the internal validity is in order. Typically research processes have to be standardized over time in order to improve the reliability. Many research institutions that conduct empirical research have quality assurance processes just to verify that the process goes as it should go and the obtained data is reliable.

Research flexibility is good if the research process can be adjusted or changed during the research process to better account for the context. For example interviews provide a good possibility to change questions on the course of the interview as new information becomes available. If the research method, on the other hand, has to be fixed before the study, it is difficult to account for surprises. For example, network traffic will be captured at gateways according to the principles based on which the monitoring processes were programmed before the study. Similarly questionnaires have to be planned before the data acquisition process. This means that no new questions can be added as soon as the questionnaires are sent to the target end-user domain.

Potential for computerization is important particularly if large datasets are to be analyzed. The more data, the more benefits to be obtained if the data analysis and mining processes are computerized (and automated). If data is difficult to input to computers (e.g. open-ended questionnaire answers) manual work has to be done in analyzing and interpreting them. This has three disadvantages. First, more man-hours have to be allocated on the analysis task (expenses). Second, the more time it requires to complete the analysis process (time). Third, the probability or errors increases as manual non-standardized (or not perfectly repeatable) analysis steps have to be taken (reliability).

Based on the discussion above all research methods have some pros and cons. However, the older manual research methods in particular are inadequate for larger studies due to higher costs. On the other hand, computerized research methods deployed earlier mostly rely on network or server-side measurements (narrow scope). These research methods inadequately study end-user behavior in the world of more complex mobile services.

A specific handset-based mobile end-user research method is introduced in the next section. This method solves many of the challenges evident in legacy end-user research methods.

Table 1 - Summary of mobile end-user research methods

	Questionnaires	Interviews	Laboratory / road tests	Traffic measurements	Server measurements	Charging records	Handset-based clients
Subjectivity	High	High	Low	Low	Low	Low	Low
Detail of accuracy	Poor	Poor	Good	Very good	Very good	Good	Very good
Type of data	Qualitative + quantitative	Qualitative	Qualitative + quantitative	Quantitative	Quantitative	Quantitative	Qualitative + quantitative
Target services	Basic services that the user is aware of	Basic services that the user is aware of	Services that are used by the user in special conditions	Any services utilizing the network	Any services requiring network servers	Any services generating charging events	Any mobile services
Reach / scalability	Moderate	Poor	Poor	Good	Good	Good	Moderate
External validity	Moderate	Moderate	Moderate	Good	Good	Good	Poor
Reliability of data / internal validity	Poor	Poor	Moderate	Good	Good	Moderate	Good
Research flexibility	Poor	Good	Poor	Poor	Poor	Poor	Moderate
Potential for computerization	Poor	Poor	Poor	Good	Good	Good	Good
Pros	Cost-efficient, good coverage	Flexible, interactive	Studies use cases with coordinated research settings	Good coverage, data mining automation	Good coverage, data mining automation	Good coverage, data mining automation	Wide scope of research questions, point of convergence
Cons	Inflexible, rigid	Costly and slow	Not a natural usage context, costly	Access to network gateways needed, only network services included	Access to network servers needed, only client/server services included	Access to charging records needed, only services generating charging data included	Early-adopter bias, complicated process of data acquisition
Typical research contexts	Feedback for new services, analysis of user perceptions	End-user experience studies	UI development, prototype testing	Network load and traffic flow patterns, QoS studies	Measurement of service-specific parameters (e.g. URL distribution)	ARPU studies, customer segmentation	New service adoption research and analysis of usage patterns

4. Handset-based research process

4.1. Introduction

The benefits of handset-based research methods include the accuracy of data, position at the point of mobile convergence (handset), and technical possibilities to study future mobile services and end-user behavior with both usage and questionnaire data.

Hardware-based limitations have earlier challenged the attempts to acquire user-level usage data efficiently. Handsets have lacked adequate capability of independently tracking usage. No earlier methods or associated processes have existed for handset-based end-user research.

Today the handset technologies have advanced and particularly the emergence of programmable smartphone platforms provide a possibility to develop suitable handset-based software for end-user research. A tailored handset-based end-user research process can contribute to solving research problems that have not been possible to address earlier.

4.2. Background

A particular smartphone usage monitoring client has been developed on Nokia's Symbian/S60 software platform, and this proprietary technology is utilized in all of the research papers included in this dissertation. The development of the monitoring software and the first test panels took place in 2003, while the first academic results utilizing the software were introduced by Verkasalo (2005). The handset-based mobile end-user research process is mutually developed by Nokia and Helsinki University of Technology, while the data acquisition platform is developed and owned by Nokia (see e.g. Nokia 2007).

The handset-based data collection (i.e. tracking, monitoring) software is utilized in a specific process of end-user research. This process is developed in parallel with the handset-based technology. Large end-user panels consisting of 200-1000 mobile subscribers are constantly deployed all around the world. The data logged by the piece of software running on smartphones is transferred to centralized servers through packet data access on a daily basis. End-users participating in the study agree on the contract provided by Nokia, and thus they give the legal permission for Nokia to study them. Usage data is complemented with various questionnaires integrated in the process. Both usage and questionnaire data is utilized later by doing data mining exercises and data analyses.

New end-user panels are launched by Nokia throughout the world in co-operation with mobile network operators and academia. To academics and market analysts accurate usage-level data provides information on various usage patterns in mobile

communications. Although the research method first originated from technical needs to monitor usage, it is nowadays strongly tailored towards different kinds of mobile end-user research. The handset-based implementation of data acquisition is a pioneering method of end-user research in the mobile domain.

Due to involved lower level software interfaces and private application programming interfaces the monitoring software cannot be easily developed by external actors. Even more work is required in establishing the whole research process encompassing the recruitment of end-users, development of the technical architecture, management of servers and coordination of data analysis work.

Mobile operators can use handset-based technology in exploring their subscribers. It is generally acknowledged that in the future operator revenues come from other sources than mere voice. Data traffic, multimedia services, e-money and mobile networked games, just to mention a few, are good examples of potential future revenue sources (see e.g. Saurio 2001; Weber & Rader 2002; Cohen 2002 and Bell 2002). In order to test these new solutions, handset-based software extracting, processing and delivering usage data is needed. The handset-based software provides a viable alternative to network-based monitoring technologies in holistically collecting data.

The academic domain benefits from the handset-based research method because of new data points that cannot be extracted with earlier empirical research methods. The possibility to combine questionnaire data with accurate usage-level data facilitates a number of research approaches:

- Econometric modeling of end-user behavior
- Segmentation of end-users
- Formulation of statistical models for adoption dynamics
- Assessment of new service emergence
- Studying emerging business models
- Modeling the emergence of mobile e-commerce and Internet applications
- Quantitative modeling of location dynamics

In this section the new handset-based mobile end-user research method is first introduced. Then advantages and challenges involved in the research process are discussed. Finally some key research areas are introduced. Some of the most prospective research approaches are then demonstrated through the research papers included in the dissertation.

4.3. Description of the research process

The defined research process is centered on three entities (see Figure 9). First of all, the objects of study are end-users. Both behavioral (usage) and background (questionnaire) data is collected from them. All the data is stored into a centralized data repository that not only collects the data sent automatically by handsets, but also hosts various administrational tools and the questionnaire platform. The data is analyzed separately, typically after the data collection process, by researchers. The three entities are physically separate, together forming the research process that includes both the data collection and analysis processes.

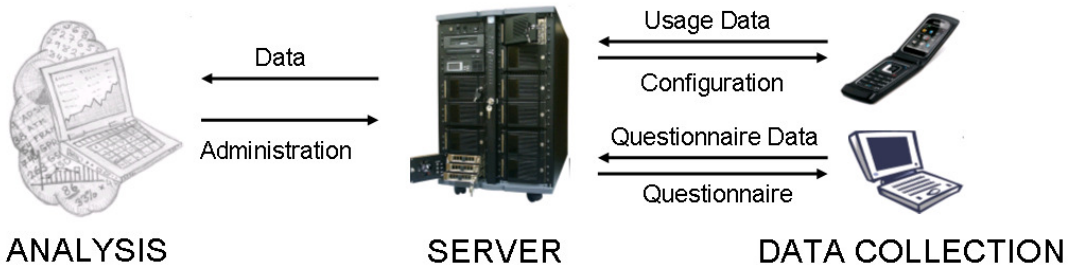

Figure 9 - Conceptual research process

Figure 10 illustrates the technical implementation of the data collection process. The recruitment is open towards the public Internet, the front-end being implemented as a normal WWW site. End-users are recruited through advertising in handset shipment boxes, sending out promotional SMS messages, and promoting over the Internet. When the end-user has filled in the registration questionnaire, and installed the research client, he becomes a panelist. Panelists need to be over eighteen years of age (due to legal restrictions). Depending on the panel project, some panelists are compensated for participating in the study process. The trend in handset-based research projects is to eliminate direct compensation, because that might affect usage patterns and therefore produce biased results.

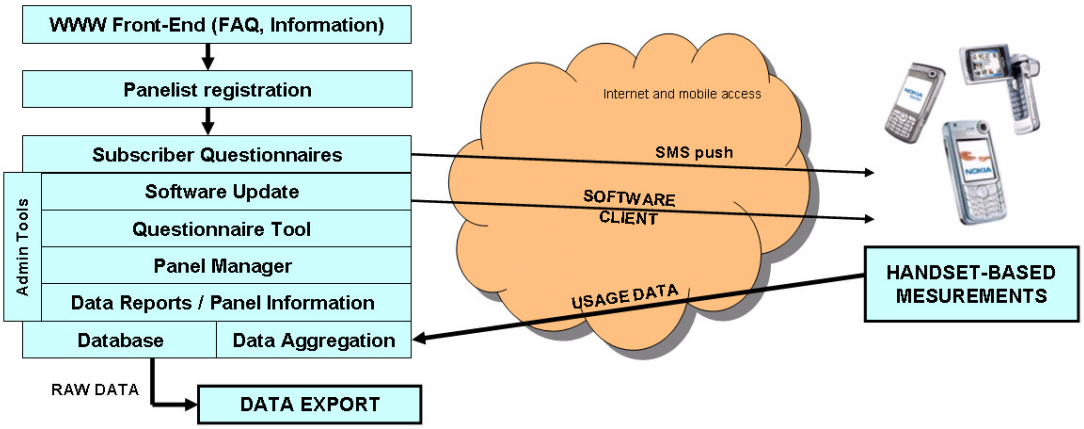

Figure 10 - Technical infrastructure

A typical panel project includes several phases from the perspective of panelists:

1. Recruiting (with SMS messages, advertising)
2. Filling in the beginning questionnaire in the Internet (web)
3. Downloading and installing the research client
4. Using the device for 2-3 months (the client automatically transmitting data logs)
5. Answering mobile pop-up questionnaires (1-2 times / month)
6. Filling in the final questionnaire (web)
7. Removing the research client

At first panelists are in interaction with the web-based recruitment system. After filling in basic information (name, IMEI code, phone number), they receive a system-generated SMS message with a link to the research client. Panelists download and install the application through this link. On the level of databases, each panelist is provided with an identification number. Panelists and usage data are only mapped together with these identification numbers. Anonymity and real identities are thus protected in the studies. After all, personal identities are not needed in the research, and collecting them might break privacy laws in some countries. The whole system facilitates some automatic reporting during panel projects, but manual data analysis is typically utilized, along the lines of the research papers in this dissertation. Handsets automatically transmit usage data logs through a GPRS link either on a daily or weekly basis, depending on the data points involved.

The research process can be considered as part of the larger orientation towards more intelligent network edge based software. Smartphones can process a large amount of information. In addition, on the network edge the extracted data on end-user usage patterns is accurate and comprehensive. The care for privacy and security are some of the issues that are constantly discussed on the path towards future technologies (IVA et al. 2000), also in the case of more intelligent handset-based software. The utilization of such software as the monitoring client of this study asks not only technological understanding, but also legal, business and marketing capabilities. Also, though some of the technical functionality can be developed on top of open application Symbian/S60 programming interfaces, many of the data points here involve knowledge on lower level software interfaces that are protected. Therefore, the development of the monitoring software would not be possible by external actors.

The monitoring software overcomes existing problems in studying usage-level factors. Most importantly, the data is objective. That is, sometimes end-user perceptions of their usage are not in line with actual usage. Because the monitoring software acquires data straight from the handset, end-users cannot directly affect the results through own interpretations. Secondly, the monitoring software acquires data on all relevant smartphone functions, and with high accuracy. To take an example, end-users or network-based monitoring platforms cannot provide accurate data on the absolute amounts of data transmission contingent on the used application client (e.g. messaging, gaming or browsing). Other similar research challenges exist, which have been identified, among others, by Minges (2005). Handset-based end-user research overcomes many of the existing empirical research challenges. New possibilities to utilize the handset-based monitoring software are explored constantly.

4.4. Handset-based research

Little research on micro-level behavior of smartphone users is available. Basic information about traffic loads, messaging activity, etc. can be found, but only at the network level. The key network-based measurement methods include the operator's management systems, network gateways, servers and charging records. However, it is difficult to retrieve data on usage level factors, for example average number of messages sent by a particular kind of users, daily time distribution of streaming video usage, number of photos taken with the handset's camera on a typical day or number of actions taken on an

average week in customizing the handset (e.g. installing ringing tones or downloading wallpapers). Questionnaires do not help either, because end-users rarely recognize and control their usage level behavior. Rather, end-user behavior is often intuitive. Specialized laboratory-based usage studies and street surveys might help. However, they have their own restrictions in detail and scope of data. It is difficult with older research methods to collect data for a long period of time and link it reliably to background factors of end-users. Handset-based technologies provide a more user-centric research method.

An earlier academic project has experimented with handset-based technologies (see ContextPhone project from Raento et al. 2005). The research group's Nokia S60 client is tailor-made specifically for context-oriented applications, though they have also supported academics in various other areas, too. For example, Eagle (2005) has used the ContextPhone client in modeling end-user life patterns and sociological encounters.

The research method introduced in this dissertation is also handset-based, but it is specifically prepared for end-user research. This method will be introduced in the next section. It is a centralized platform, as the data is automatically collected to servers where analyses are then done in an aggregated fashion. The ContextPhone application (see above), on the other hand, is meant to be standalone, and the main purpose of ContextPhone is not to conduct market research but to bring intelligence to the network edge and deploy content-specific applications.

The handset-based method utilized in this dissertation has been used outside of this dissertation, too. These studies are focused on the method itself (Verkasalo & Hämmäinen 2007), statistical tools in utilizing usage-level data (Verkasalo 2005), and comparison of the handset-based method to other methods of mobile service research (Kivi 2006 and Kivi 2007). New perspectives regarding the use of the handset-based method are being developed currently in the Networking Laboratory at Helsinki University of Technology. Already published research papers are focused on cross-country comparisons (Verkasalo 2007a), data service adoption (Verkasalo 2006a) and the emergence of mobile multimedia services (Verkasalo 2006b).

The main difference of the handset-based end-user research process utilized in this dissertation to, for example, Raento et al. 2005 (or any other privately developed handset-based monitoring client) is the emphasis of the developed method to particularly help in end-user research through panel studies. The surrounding research process and resources are not trivial to deploy efficiently, and they require years of understanding and leaning from the method deployment.

4.5. Data analysis

The first part of the handset-based research process is data collection, taken care by the specialized technology discussed above. An equally important second part of the process is data analysis (see Figure 11).

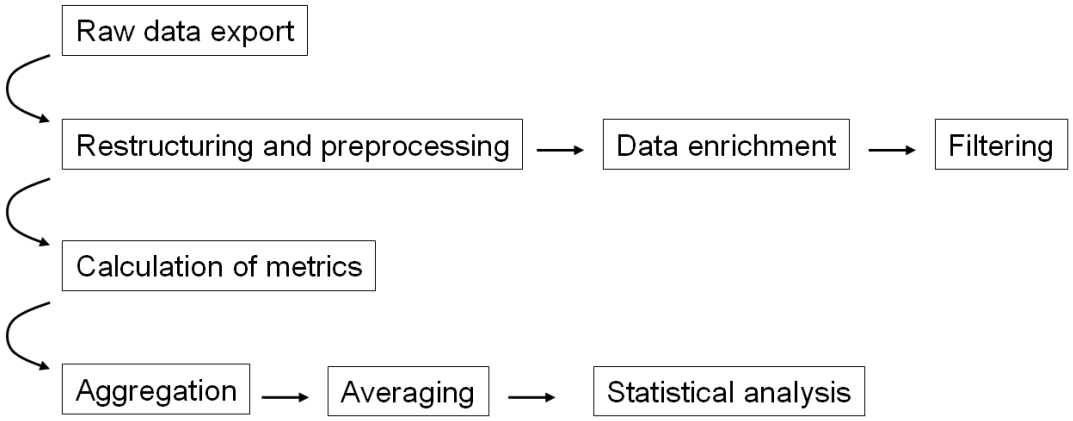

Figure 11 - The process of data analysis

Data that is collected with handset-based usage monitoring and questionnaire tools is stored in MySQL databases. Individual data tables include all the data that relates to a specific observation category. For example, all application activations are stored in one data table, and all cell-id data (connectivity jumps from base-station to another) are stored in another table.

In order to make sense from this raw-level data, the following processes are required:

- Data processing and filtering
- Calculation of derived metrics
- Averaging and aggregation calculus

Regardless of the research approach (five exemplary research settings are demonstrated in the included articles), all of the above mentioned processes are typically required in the data analysis phase.

Data analysis is centralized, and conducted with separate computers. Thus the data collection platform (handset-based client and server-side infrastructure) and data analysis computers are physically separate environments. Data analysis is done with both manual and semi-automated analysis procedures. However, some of the automated analysis procedures could be integrated to the smartphone clients of the future.

4.5.1. Data processing

Data processing and filtering manage data before any concrete calculus. In this process the data is imported into suitable statistical tools (e.g. SPSS), and sorted, for example, into chronological order in order to support further analysis. Additional data points (data that is directly derived from raw-level data points) are typically extracted, for example simple calendar dates (1.6.2008) are converted into days of week (Sunday), which is reasonable if, for example, weekend and workday usage are to be analyzed separately.

In addition, complementary metadata is added to data files. For example, this dissertation project has built a comprehensive list of Symbian applications, and mapped each application into specific application categories. This mapping assigns a specific application category identifier (e.g. multimedia, instant messaging, office application) to each application. This kind of metadata is valuable when studying end-user behavior on the level of application usage.

In addition to preprocessing and metadata addition processes, this stage of analysis typically includes filtering. In other words, only particular kind of data is included in the data files that are to be analyzed. Typically for example operating system processes (that are initiated by the device platform) and panelists who have not generated enough data (e.g. occasional data from the first couple of panel days only) are excluded from the final dataset.

4.5.2. Calculation of derived metrics

The second stage of analysis includes mathematical calculus of derived metrics. The word 'derived' means that output variables are calculated based on raw data, and in general add more meaning to the data. For example, more meaning can be added by deriving the average number of device usage minutes per day per user, rather than reporting the total number of application activations per user during the panel.

Typically derived variables are calculated on a per-user basis. Typical metrics include:

1. Usage indicators
2. Intensities of use
3. Frequencies of use
4. Static metrics

Usage indicators are typically Boolean-scaled variables, that communicate whether the user has used a certain service or not. For example, a Boolean usage indicator for MMS communicates whether MMS was used during the panel study or not. Several thresholds can be assigned on usage indicators. For example, another usage indicator can be named "Weekly MMS usage", and this metric equals 1 only if the end-user used MMS messaging on a weekly basis.

Usage intensity figures communicate usage activity per unit of time. Usage is observed only on days of actual service usage. In addition, the number of days each panelist has spent in the panel can be calculated based on raw data. By dividing the amount of usage (e.g. usage sessions, usage minutes, amount of packet data generated) by the period of time spent in the panel, the derived intensity metric communicates average usage per unit of time. Intensity figures are comparable with each other, even though different panelists have spent different amounts of time in the panel.

The third category of derived metrics includes usage frequencies. Usage frequencies communicate the proportion of all panel days during which a particular service was used. For example, if the end-user used MMS on average every second day, she would have usage-level observations for MMS on 15 days if she spent one month in the panel. The

usage frequency would consequently be 15/30 = 50%. Intensity figures are difficult in some analysis approaches because there is no absolute upper bound for them. Usage frequencies, by definition, cannot exceed 100%. From this perspective they "behave" better than intensity figures.

One last category of derived metrics is static measures that do not require normalization or averaging processes on a level of users. Examples are the number of unique phonebook contacts in the device, or utilization ratio of mass memory. Both of these can be randomly polled once during the panel study process. These metrics can be derived from direct observations (e.g. listings of all fields that are stored in the phonebook, including phone numbers, addresses, names), but do not require normalization.

Derived metrics can be calculated on different bases of research subjects. For example, average usage intensities can be calculated for each application (in this case the figure tells how users of the application have used it), or each panelist (in this case the figure tells how a particular user has used a particular set of applications the figure is to reflect). In some cases it is not useful to aggregate data too much. For example, with raw-level data related to data session sizes and lengths it is possible to calculate the session's average usage intensity per unit of time (e.g. average megabytes per minute of application usage). This is a derived metric, calculated for the data session. The procedures that are introduced in the next subsection can be applied easily on the data that has been processed through this level of calculus.

4.5.3. Averaging and aggregation calculus

After the calculus of derived metrics, that last stage of analysis is to either average or aggregate data over meaningful parameters. For example, a dataset after the derived calculus procedure may include typically 600 panelists, for all of whom average number of weekly usage minutes for six different mobile service categories is calculated. This is still data in a format that cannot be communicated easily (there are 600 * 6 = 3 600 metrics in the dataset).

Averaging makes communication and result interpretation easier, as it summarizes the data points (potentially hundreds of values of different metrics), in other words cases, into a smaller set of figures, still reflecting the original data. In the above mentioned example, a specialized analysis script could calculate the average number of voice minutes over age groups, and identify whether statistically significant differences exist in voice usage between different categories (segments) of people.

Another important procedure is data aggregation, in which data is summed over parameters. For example, in order to analyze how mobile services are used on an aggregate level, the service intensity figures (usage activity per unit of time per user) can be summed up over segments of users in order to form aggregate service usage intensities. In a similar vein, all of the data session sizes can be summed over radio bearers, and for example aggregate WiFi usage can be compared to cellular radio access usage.

In addition to this simple data averaging and aggregation, advanced statistical methods can be used in finding relationships and statistical patterns out of the data that was prepared in

the derived metrics calculus. For example, multivariate linear and non-linear regression methods, factor analysis, cluster analysis (Article 1) and path models (see Article 2) are some of the statistical methods that can be used in analyzing the data.

4.5.4. Automation of data analysis

An infinite number of different analysis procedures exist, and the variety of data extracted by the defined handset-based end-user research method is diverse. Therefore only the imagination restricts the development of analysis methods and procedures.

However, some of the more typical analysis procedures are repeated often. For example, almost always in data analysis the average number of voice call minutes per user per day should be extracted. For these procedures some automation can be built. Because the data is in a standardized format, any data processing tool that supports scripting can be used. For example Matlab or SPSS can be used in preparing scripts that repeat predefined calculus procedures on the data. In many cases these scripts make the analysis procedures smooth to repeat time after time. In addition, they provide reliability and reduce the probability or human error when repeating analysis procedures.

4.6. Advantages of the research method

The handset-based mobile end-user research method has several advantages over other available research methods. The following sections cover these advantages in greater detail.

4.6.1. Type of data

The type of data acquired with the handset-based end-user research method is versatile. On the one hand accurate usage-level data can be acquired (e.g. communication contact network details, SMS message parameters, data session details, application session lengths, battery consumption traces etc.). In general the accuracy of usage-level data is good, and the technical measurements (*data*) can be processed into *information* concerning end-user behavior and usage patterns. When elaborating the pieces of information, it is possible to create new *knowledge*.

On the other hand, various kinds of questionnaires can be deployed both in the beginning and end of the panel project through customized panel management tools. In addition, the newest update of the handset-based client includes a possibility to push pop-up questionnaires into handsets that deal with context-specific issues such as the perceived user experience in browser data sessions.

4.6.2. Combination of data points

The other advantage is the possibility to combine and cross-link different kinds of data points together. Usage data is objective and accurate, but it is difficult to tackle end-user

perception and satisfaction related issues by merely observing actions taking place in handsets. Questionnaire data is therefore used in interpreting the findings. To take an example, adoption surveys may ask about people's interest and motivation to use certain services and then researchers can further check with usage data whether actual usage took place or not. In addition, those users who used particular services (e.g. navigation) can be asked more specialized questions (in the pop-up manner, for example) specifically related to, for example, navigation experiences. Thus the two different types of handset-based empirical research data (usage-based and questionnaires) complement each other.

Different kinds of usage-based data points can be combined with each other, too. For example, location and context data can be utilized when studying multimedia service usage. Though the datasets are logically separate from each other and technically different data points are measured with different techniques in the handset, together they might create new research approaches. Possibly unique patterns in using mobile multimedia services across different contexts can be identified in the example above.

4.6.3. Suitability in the context of mobile industry trends

The analysis of mobile industry trends revealed earlier in this dissertation that services are getting more complex, and they are increasingly converging device-wise (smartphones run several kinds of applications today and the intelligence is moving to the network edge) and diverging network wise (some mobile applications do not need network connectivity, most data services can utilize a variety of radio access technologies). Therefore the usage monitoring process that takes place in the handset is superior to other methods in acquiring direct data on smartphone usage.

The emergence of the mobile Internet affects the provisioning of mobile services. No centralized point can be found outside of the handset in which all mobile services can be measured. In addition, innovation cycles are fast-paced in the world of the Internet and the possibility to both scale and scope up easily is important. Because the developed monitoring client captures the whole portfolio of computer-like operating system events in mobile handsets, the method can be directly applied in the research on add-on applications and challenger services.

The emergence of new business models, matching of data points, evaluations of individual end-user behavioral patterns and complementary nature of questionnaire and usage data all provide interesting research streams. Matching of pricing information and accurate location with time stamps to user actions along with comprehensive background information on end-users (from questionnaires) provide prospective data points in new approaches of consumer surplus estimation and micro-level modeling of user behavior in real usage environment. The heterogeneity of mobile services suggests that end-user experience should be studied extensively in the future. In this sense the questionnaire side of the research method is useful in complementing usage-based data collection.

4.7. Weaknesses of the research method

The data utilized in this study is unique and accurate. However, there are certain restrictions when it comes to the use of data. The sections below list the most important restrictions, in comparison to the other research methods available.

4.7.1. Sample size and comparability

First, handset-based datasets are still limited in terms of the number of participating end-users. The main limitations in arranging larger panels are the difficulty and cost of recruiting end-users. The greatest challenge is not to develop the software or server-side solutions for handset-based usage monitoring but instead to build up the whole process of launching, managing and reporting of panel studies involving typically both contractual (legal) and contextual (attracting suitable target population) problems.

The datasets acquired are typically incomparable to each other. This is mostly due to differences in the recruitment processes. In some cases operators participate in handset-based studies and they push certain subscriber segments in the recruitment more than others. Therefore the recruitment is not always following random sampling. Similarly other stakeholders that launch handset-based panel study project might influence the type of target population attracted to the study. Because of these reasons many kinds of background factors might emerge such as pricing plans or network coverage that are difficult to assess in background questionnaires, but which nevertheless affect the results. These factors are uncontrolled factors in handset-based studies. A long way still remains to a process in which handset-based smartphone studies recruit end-user populations randomly across countries, operators and segments, the datasets therefore being better comparable to each other.

4.7.2. Adverse selection of panelists

Still today most panelists (every panelist owning a smartphone device by definition) are dominantly early-adopters – people who adopt new technologies in the beginning of the technology diffusion cycle (Rogers 1962). Smartphone owners are typically more technologically advanced than other people, largely signaled by the fact that they bought a more capable device in the first place. In handset-based panel studies panelists have both the interest and capability to install the monitoring client to the handset. These things limit the heterogeneity and size of panel study projects, and at the same time they weaken the possibilities to generalize the findings. These kind of panel studies will provide externally valid findings in the future, as smartphones hit the real mass market. For example, it is expected that the penetration of smartphones in Finland (6% in 2005) is more than doubling annually in 2006-2008. At the same time Finland should experience a movement to mobile data services, such as content retrieval and multimedia. (Snellman 2006)

It should be acknowledged that panels are typically biased towards high-end end-users. The prerequisite being the ownership of an S60 smartphone, people included in handset-based studies are early-adopters, high-tech enthusiastic people. Even more, end-users

included in the panel must be technology-oriented enough in order to install the monitoring software into their handsets. The panel studies, arranged in a way described in this dissertation, suffer from the bias due to active selection of certain sub-segments of the smartphone population and recruiting them to the study. Future research should tackle the alternative implementation issues in deploying the research technology with more representative panel populations, taking the key challenges of panel studies (Lohse et al. 2000) into account.

Problems in generalizing the results exist because of the lack of mass-market end-users that best represent market-specific differences. Although various statistical methods (see Verkasalo 2005) can be used in controlling for demographics and other background factors, it is very difficult to control for the different mindset and immeasurable differences in consumption and technology adoption patterns.

Currently handset-based end-user studies only tackle smartphone users and this sets limits to generalization. This is both a blessing and a challenge. On the one hand new services can better be studied with panelists who are more likely to be interested in exploring them and giving also subjective feedback through questionnaires. On the other hand the results obtained cannot be generalized outside of the research context, and therefore, for example, market-level phenomena cannot be studied.

To overcome the challenges of adverse selection, all of the panel studies should be somehow positioned in dimensions that can be measured. For example, general demographic distributions should be always provided when explaining data samples. These distributions should be compared to reference panels. In addition, reference figures should be presented for the whole market of interest, if possible. To take an example, in repeating the Finnish smartphone study for 2006 the demographic distribution should be compared to that of year 2005, and also to the demographic distribution of the overall mobile subscriber population in Finland in 2006. The fact that the proportion of female panelists has increased can, for example, mean that the panelists of 2006 are more mass market oriented than in 2005. This is due to a fair assumption that early-adopter user segments predominantly consist of men (Verkasalo 2005). The comparison to the demographics of the overall mobile market additionally gives insights whether the panel of 2006 still has significant demographic deviation from the general mobile subscriber population.

4.7.3. Legal challenges of panel studies

The handset-based data collection client resembles spyware or adware. The technology discussed in this dissertation is, however, neither of them, because panelists are aware of the data collection process and they acknowledge it by accepting the conditions of the panel contract. The monitoring client runs smoothly in the background of handsets, and therefore the research process does not require active interaction with panelists, except for the questionnaire studies.

Spyware (see Webopedia 2005 and Gutzman et al. 2003) is commonly considered as illegal software, whereas the handset-based software in this project is completely *de jure*, according to law, because of all the contracts end-user are required to approve before

joining the panel project. End-users also need to go through the registration process before they are applicable for the panel project. Furthermore, the results of the panel studies are used mainly in R&D (*research and development*) or marketing and sales functions of the participating organizations, or in preparing market specific academic reports (see e.g. Verkasalo 2007). Therefore both the research process and objectives of the key stakeholders differ from spyware software and associated criminals.

4.7.4. Impact of uncontrolled background factors

Although many things affect the data points acquired, certain statistical methods can control some of them. A good division in the factors having an impact on the data is the availability of data. If data is available on background factors, it can usually be somehow utilized in controlling for their impact. If important background data is not available the unexplained variance of the data increases.

Typically variables for which background data can be acquired (either automatically from the handset or through questionnaires) nowadays include:

- Demographics
- Location and context
- Handset model/capabilities/design
- Compensation plan for participants of the panel study
- General attitude towards mobile services

The information that is usually more difficult to acquire and, therefore, to control include:

- Structure and level of pricing
- Context-specific end-user motivation
- Temporal handset/network performance
- Service availability in the market
- Timing of marketing campaigns

All in all, the possibility to combine usage data with questionnaires provides a better approach to control for important background variables than any other computerized end-user research method. As discussed, however, there are always some exogenous factors that cannot be controlled in handset-based studies.

4.8. Ethical considerations

Handset-based research raises questions related to ethical code-of-conduct and end-user privacy. Most legal constitutions in the developed world set restrictions on the use and distribution of private customer information. In the EU two directives (95/46/EC and 2002/58/EC) exist which restrict the *"…the processing of personal data and the free movement of such data*" and emphasize *"the protection of privacy in the electronic communications sector"*. There are various national implementations of these directives among the EU member countries.

The fundamental issue is clear: the research method presented in this dissertation should not be used against the will of end-users. Therefore the process requires that each and every individual who participates in a panel study has accepted the contract provided by a panel project organizer, explicitly giving the organizers the right to retrieve usage-level data. Even after accepting the contract, various actions are taken in order to protect the end-user privacy. For example, information related to personal data, such as IMEI (*international mobile equipment identity*) codes, names or phone numbers in the phonebook, message content as well as multimedia content is never acquired. Furthermore, all the data sent to the centralized server is encrypted, so no other party can understand the data even if they get the data in their hands.

From the ethical point of view a question remains: How does this research contribute to the end-user's best interest? All the study projects in handset-based end-user research are currently anchored to the idea of better understanding end-users. This better understanding leads to a better assessment of end-user needs and satisfaction, which further leads to the possibility to develop better services in the future.

Panelists are typically compensated for their packet data costs due to the handset-based monitoring client. The transmission of usage-data from handsets to a centralized server typically causes some costs panelists have to bear. Therefore a flat compensation voucher for packet data transmission costs is usually handed out (~20 euros in Finland). This compensation typically covers more than the marginal cost due to packet data traffic of the monitoring client. Typically no other compensation is considered necessary because it might make end-users to deviate from normal usage patterns. The research process is justified to end-users through this compensation. In the future the handset-based research method is likely to be developed to the direction in which participating panelists can view statistics on their own usage with WWW-based services.

4.9. Examples of research streams

Mobile handsets are ubiquitous by nature, and they provide possibilities to deploy many kinds of services. Consequently a need exists to acquire holistic data in end-user research. This subsection describes some examples of the kind of studies or applications facilitated by the handset-based research method. Some of the prospective research streams are tested in the case examples of the included research papers of this dissertation.

4.9.1. Micro-level behavior of end-users

One of the prospective topics is the research on end-user experience. This research stream tackles end-user perceptions, usability bottlenecks, feelings, experiences and other issues which directly relate to immediate usage of a particular service. For example, Pohjola & Kilkki (2006) developed a methodology for analyzing how services create value to end-users, and how different improvements in, for instance, usability may increase the value end-users retain from usage. Handset-based research data can provide input data for this kind of studies.

Even more directly, by tracking key presses and other events on the usability level, researchers can study how people navigate in user interfaces, for example menu structures. Another micro-level example comes from application sessions. Certain patterns in launching applications can reveal when multitasking is not used correctly. The follow-up research can further develop user interfaces and multitasking features so that end-users benefit from the multitasking function more than earlier.

Various application rankings and detailed use case analyses along the lines of Verkasalo & Hämmäinen (2006) provide statistics on applications which are considered important among a certain subset of end-users. In general, the handset-based end-user research method provides a number of possibilities to better tackle issues of both direct and indirect end-user experience. Direct user experience means, for example, pop-up questions tackling the immediate user satisfaction after a browsing session. Indirect user experience can be addressed, for instance, by observing the intensity of usage over time for a particular end-user.

4.9.2. Cross-market comparisons

Country markets can be compared against each other with the handset-based research method (see more on this from Verkasalo (2007). In mobile service studies, cross-country comparisons can be helpful in understanding the drivers and bottlenecks of each market. The possible differences between markets can be explained either through techno-economic or socio-cultural frameworks (Verkasalo 2007). A techno-economic framework includes factors such as the economic purchasing power of consumers, market competition, innovation dynamics and regulation. Socio-cultural issues, on the other hand, refer to issues such as cultural impacts and societal norms in mobile service usage.

By studying differences between markets not only the most advanced markets can be identified in terms of mobile service usage, but also reasons explaining why certain markets lag behind others can be identified. By looking at a potential market failure or inefficient regulatory intervention, it is possible to give recommendations how to improve the market, and therefore to improve the portfolio of services seen and used by end-users. The use of the handset-based research method in regulatory decision making was discussed in Hämmäinen et al. (2006). Some of the regulatory study topics include the use of unlicensed radio bands such as Bluetooth and WiFi (e.g. operator-originated Bluetooth disabling has caused legal battles in the U.S.) and the role of handset bundling (which is acute in, for example, Finland, which now experiments for the first time with 3G handset and subscription bundling) (Tallberg et al. 2007).

Though the developed research process facilitates cross-country comparisons, one should acknowledge that the problem of adverse selection makes all kinds of market-wide generalizations challenging. This problem has been identified in Verkasalo (2007), and in future studies more rigid recruitment methods and comprehensive background data is required in order to make datasets from different countries comparable.

4.9.3. Contextual research approaches

The context of mobile service usage is increasingly gaining attention in the academic community (see e.g. Heinonen & Pura 2006 and Heinonen 2004). Most mobile service use cases are context-dependent. For example mobile Internet browsing may be useful in places where no other browsing possibilities are present and when the end-user has some time available, such as when traveling. Chat or instant messaging services, on the other hand, are value-adding when both participants have time available and are interested in establishing a wireless messaging link through mobile handsets. Various non-communication use cases, such as video streaming and imaging, are free-time oriented whereas end-users dominantly consider voice calling as the most important business function of smartphones.

The ContextPhone application (see Raento et al. 2005) is developed for prototyping context-dependent applications. However, it is predominantly a standalone application rather than a centralized end-user research method. With the handset-based end-user research method, however, loads of data can be automatically analyzed. Algorithms and heuristics can be developed that model the context of usage. Possible outcomes of these studies include categorizations of services into leisure or business, for example. In addition, it is possible to study how usage patterns differ in different contexts, and how communication functions are used in different situations. By using the method, context-specific data such as location and time can be acquired, and therefore contributions to the further development of such pioneering applications as ContextPhone can be made.

4.9.4. Disruptive applications

The emergence of new mobile applications drives the interest in their usage-level research. By gaining understanding on the usage of emerging applications a contribution can be made from the R&D point of view and the development processes of applications which prove popular and useful can be improved. By arranging coordinated panels in various corners of the world insights on emerging applications can be acquired. At the same time interesting patterns in the usage of these applications can be observed, starting from session durations (e.g. in the context of packet data usage) to the timing of application launches (differentiation between e.g. daytime, evening time and night time usage).

Some of the mobile applications which are worth closer studies are

1. Mobile instant messaging
2. Mobile P2P file sharing
3. Mobile Internet browsing
4. Mobile VoIP calls
5. Mobile video/music streaming and broadcast
6. Operator portals and infotainment clients
7. Mobile gaming
8. Location-based services and navigation
9. Presence functionalities

Some of these applications might cause turmoil among operators by potentially providing threats to incumbent services (e.g. instant messaging replacing SMS/MMS, or P2P file sharing providing an alternative to operator portals). Together with unlicensed radio bands such as WiFi these applications are worth a longitudinal follow-up.

One potential approach is to analyze the adoption dynamics of mobile services. Identification of user motivation to use, actual use, and the moderation of these concepts by demographics or contextual factors might reveal explanations why certain services fly and who is using them.

4.9.5. Sociological studies

Sociological mobile service studies study the clustering of people based on daily routines and personal attributes, and then utilizing this in providing better services. This study stream is closely related to the contextual research approach mentioned above. Eagle (2005) has developed a range of computerized methods in studying handset-based data and interpreting various behavioral patterns by simply processing usage-based data.

With the handset-based research method any data available in handsets can be utilized. Even on a generic level it is valuable to study how different means of communications are used. Furthermore, end-users can be segmented based on their choice of communication method (e.g. "conventional voice users" or "young multimedia messaging explorers"). Also the relationship between communication usage and non-communication usage can be studied. For example, do those same end-users who have active communication usage patterns also take advantage of other smartphone functions, such as mobile video streaming and imaging, which have practically nothing to do with communications.

4.9.6. Value of mobile services

Goolsbee and Klenow (2006) suggest in their paper that the analysis of pricing is not enough when trying to analyze the factors that affect the usage of electronic services. In addition to price paid also the opportunity cost of time or level of exerted effort along the lines of Pohjola and Kilkki (2006) should be acknowledged.

A relevant stream of research therefore emerges from the challenge of analyzing the value of mobile services. Pricing dynamics (i.e. how prices and pricing plans affect mobile service usage), analysis of consumer surplus and the value of service sessions based on a holistic view (i.e. value extracted, prices paid, time used, effort exerted etc.) are all relevant research themes.

The new handset-based end-user research method provides a possibility to acquire accurate usage data on a session basis, and this data can be combined with questionnaire answers acquired straight from end-users. Questionnaires can be customized for study-specific research questions, and, for example, subscription types (post-paid vs. pre-paid) can be extracted if end-users are willing to share that information. Based on this diversified set of data points analyses focused on mobile service value-creation can be improved.

4.9.7. Handset-based technology in prototyping new services

With regards to the further development of the handset-based research process, new logic in recruiting and compensating panelists should be considered. Currently panelists are provided with monetary compensation. Although the technical side of the method (e.g. database management) is easier to scale up, the panelist compensation issue provides a bottleneck in significantly increasing panel sizes in the short-term future.

One topical are of future research is to develop services that utilize handset-based data but instead of research purposes feed this data into services. For example, web services utilizing the already existing client/server technology can plot data points in Internet-based profiles of panelists, and to visualize behavioral patterns. This is a possibility to compensate panelists for their participation in the studies by providing a view on their own behavior and mobile service usage. After this it is potentially unnecessary to continue monetary compensation mechanisms. This idea of developing services out of handset-based data collection potentially links to wide-scale innovation around Web 2.0 services and user-originated data. In this case the data would not need manual creation (e.g. capturing of photos, blogging, or sharing of multimedia content), but instead the Internet service would automatically feed presence and mobile service usage data to the Internet.

This line of research relates to overall process development – and there are also various business opportunities out there.

5. Contribution of the articles included

This section summarizes the conclusions of the research papers included. The papers demonstrate the viability of the handset-based research method in studying mobile end-user behavior and service usage.

The datasets of this dissertation include two Finnish panel studies in 2005-2006. All together 565 panelists from the study of fall 2005 and 695 panelists from a similar study in 2006 are included in the analysis. In account of the adverse selection problem indicated earlier in this dissertation, the demographic distributions for the datasets are presented below (market statistics provided by Statistics Finland 2007 and Kivi 2007). Both of the panels have a disproportionate share of young male people, and, therefore, the early-adopter bias is evident. However, a slight change in the panel structure towards mass market can be observed. For example, the proportion of women in the panel increases from 2005 to 2006.

Figure 12 - Comparison of dataset structures

Both of the panels (2005 and 2006) are conducted in a similar way. Finnish mobile operators who participate in the study send thousands of SMS messages randomly to those of their subscribers who own a Nokia S60 device. This SMS message promotes an URL to the panel recruitment site, where end-users are provided with background information on the study. Those who decide to join the study give their primary contact information on

the recruitment site and agree at the same time with the conditions of the study. After this, the handset-based monitoring client is sent to panelists via an SMS link. All panelists (in both 2005 and 2006) are offered a fixed 20 € voucher to cover the data transfer costs due to the monitoring client. On top of that, 10 new smartphones are awarded to panelists in a lottery in the end of each study. Web-based survey studies are conducted both in the beginning and end of the handset-based data collection process.

5.1. Handset-based measurement of smartphone service evolution in Finland

A handset-based mobile end-user research method provides a holistic approach in studying smartphone service usage in coordinated research panels. Article 1, summarized here, provides an empirical look at the Finnish mobile market, thereby demonstrating the capabilities that the new method possesses. Most of the analysis is done with programmable (and therefore scalable) data analysis tools specifically tailored for this project only. The studied panelists are early-adopters, all using Nokia S60 smartphones.

The objective of this article is to highlight the variety of data points available with the handset-based research method, and through these data points to build a comprehensive understanding of mobile service usage habits of Finnish early-adopters. In addition, the objective is to utilize some of the predefined analysis procedures identically on two separate datasets, the first one collected in 2005 and the newer in 2006 (longitudinal analysis of the market). However, the article primarily reports the results of the panel study of 2006 (snapshot analysis of the market).

Voice and SMS are still the most popular mobile services in 2006. These services experience usage penetration rates of 100% (everybody use them), and median usage frequencies of 80-90% (meaning that people use them practically every day). Camera (94% has tried), productivity applications (85%), browsing (70%), MMS (67%), and offline multimedia usage (64%) have attracted decent masses (penetration more than 60%), too, though median usage frequencies are only 10-15% (meaning that these services are used on average once a week). These results indicate that people are interested in exploring new mobile services. A high share (90%) of the studied early-adopter panelists say they would like to see similar functions in their smartphones as in today's computers.

In total aggregate usage time, the share of time end-users spend with multimedia and browsing has significantly increased (see the figure below) from 2005 to 2006. Absolute time spent with messaging and voice has not changed that much between 2005 and 2006, but because of the emergence of new services their relative proportion of total usage time has fallen.

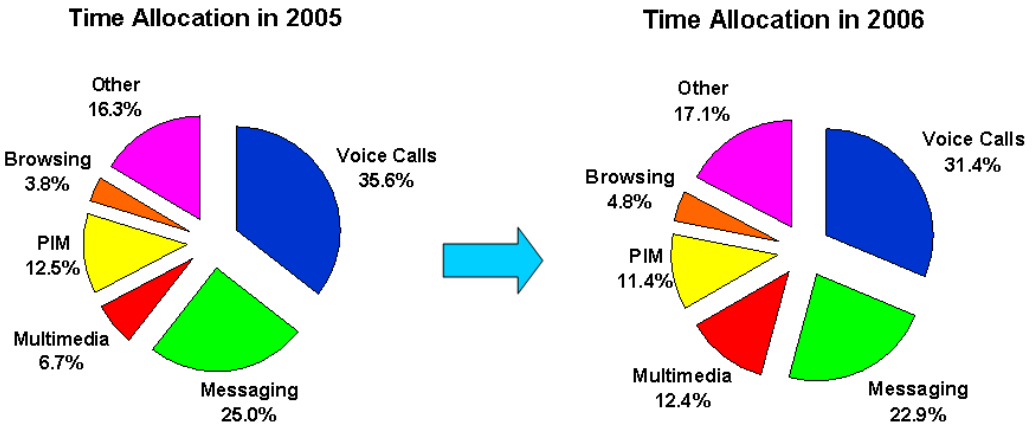

Figure 13 - Time allocation of mobile services in 2005 and 2006

57% of panelists have tried games, and infotainment applications (operator clients, news portals, content access clients) achieve usage penetration of 39%. 8% of panelists have tried dedicated 3rd party email clients, and 43% and 59% have explored movie and music playback applications, respectively. 24% of panelists have tried map or navigation applications. Multimedia and maps are the application categories that are quickly emerging alongside more mature voice, messaging and data services.

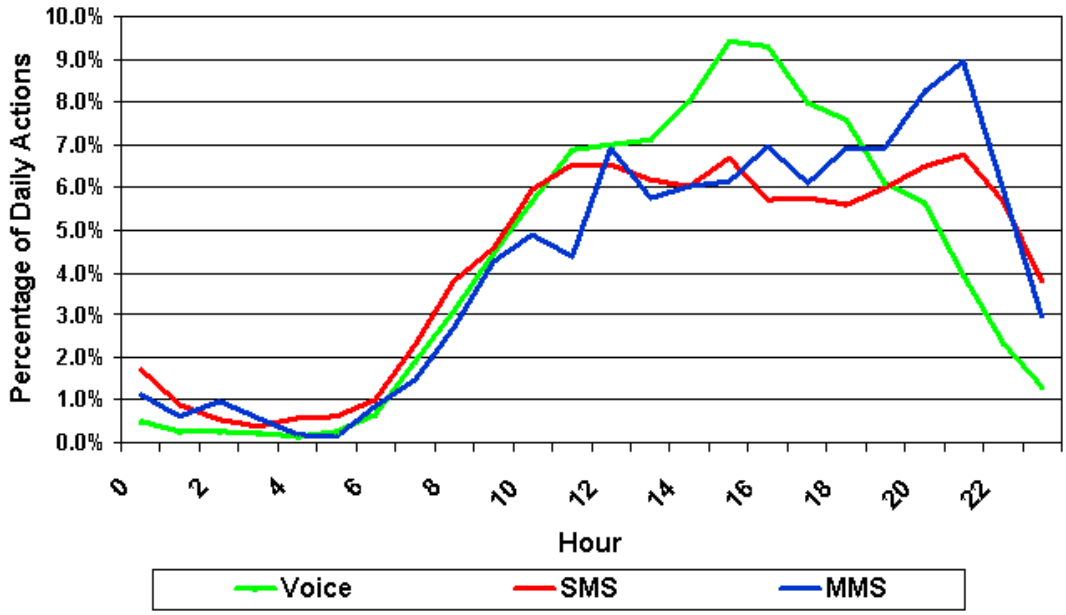

Figure 14 - Distribution of communication actions

Voice is mostly used in daytime (see the figure above), whereas both SMS and MMS experience the highest peaks in the early evening. This reflects that voice and messaging services are used for different purposes, and therefore they have different observed patterns of usage. Messaging is more personal a service, whereas voice is used also for business purposes.

Table 2 - Mean packet data traffic [MB/Month/User]

	Usage-based	Block-priced	Flat-rate	All
2.5G Phone	1.21	3.68	0.75	1.46
3G Phone	8.34	6.73	42.08	8.63
Total	5.64	6.39	39.02	6.72

Average data usage statistics (arithmetic means) are reported in the table above. In comparison to voice and SMS, data services are more price-elastic. End-users who have a proper data plan (not usage-based) are more likely to explore data services. More accurate studies indicate that in addition to data plans the type of handset significantly affects data service usage. Modem usage has been explored by 8%, 22% and 52% of usage-based, block-priced and flat-rate data users, respectively. 5% of all panelists generate at least 20 MB of packet data traffic / month. About 20% of panelists generate at least 5 MB / month. In cumulative terms 10% of top panelists generate about 80% of all packet data observed in the panel study, and 20% of top panelists generate about 90% of all packet data

observed. 8%, 46% and 48% of subscribers with usage-based, block-priced and flat-rate data plans generate at least 4 MB / month of data traffic.

In terms of data service evolution the share of multimedia traffic has increased from 0.7% (in 2005) to 17.5% (in 2006), and the share of messaging traffic has declined from 20.3% (in 2005) to 15.7% (in 2006). The figure below projects the trends of mobile data usage. The mobile Internet usage is getting closer to the fixed domain as people move from simple data services (messaging) to advanced (multimedia). By studying mobile browser usage the study finds that the share of public Internet domain accesses (vs. operator or device vendor sites) in 2006 has remained almost the same at ca. 65% as in 2005. Though people increasingly explore public Internet content, the bundled subscriptions with preloaded operator bookmarks have a counter effect on the emergence of the mobile Internet outside of "*walled gardens*".

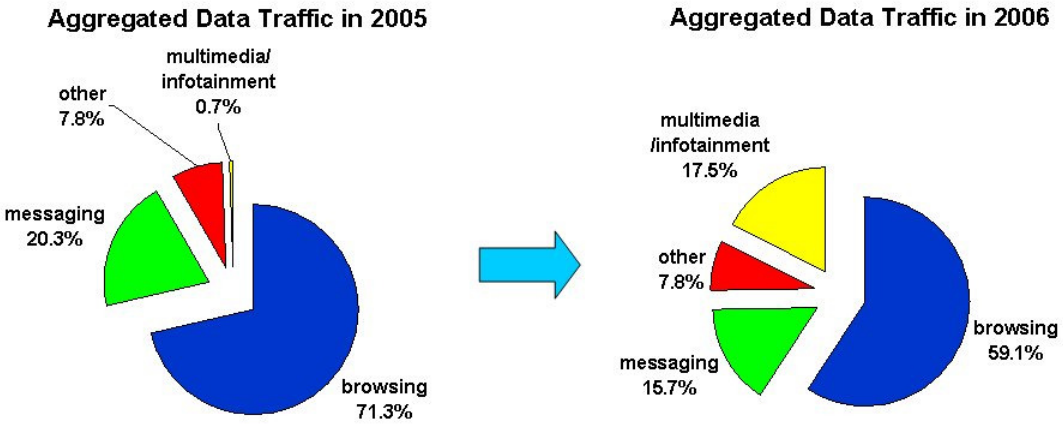

Figure 15 - Mobile data service trends

In summary, early-adopter Finnish smartphone users spend increasing amounts of time with smartphones, and particularly emerging smartphone services such as browsing and multimedia capture relatively higher shares of end-user time than earlier. The mobile Internet is gradually emerging, but various technical problems still remain as bottlenecks for wider adoption of these services. New pricing plans (block-priced and flat-rate plans) have a significant positive effect on the usage of all voice, SMS and data services. The article also demonstrates that new segmentation models can be deployed with the handset-based research method. The advantage of these segmentation models is that they utilize data of actual end-user behavior.

The article suggests that future handset-based studies should focus on emerging mobile services and new phenomena, such as the emergence of the mobile Internet, contextual usage patterns and alternative radio access technologies. In many circumstances the new research method has advantages over alternative ways of doing mobile end-user research.

5.2. Dynamics of mobile service adoption

Article 2 discusses the adoption of mobile services. Some mobile services are truly successful in the market, whereas some others attract publicity but few people actually adopt them. A need exists to acquire data on user perceptions and actual service usage in order to understand the actual dynamics of mobile service adoption.

The article utilizes a handset-based research method in conducting both questionnaire studies and measuring usage-level variables of mobile services. This data is collected for ten new mobile services that are emerging in 2006. The data is analyzed with descriptive statistics and a specialized path model. In addition, various indices are developed that communicate the characteristics of mobile services.

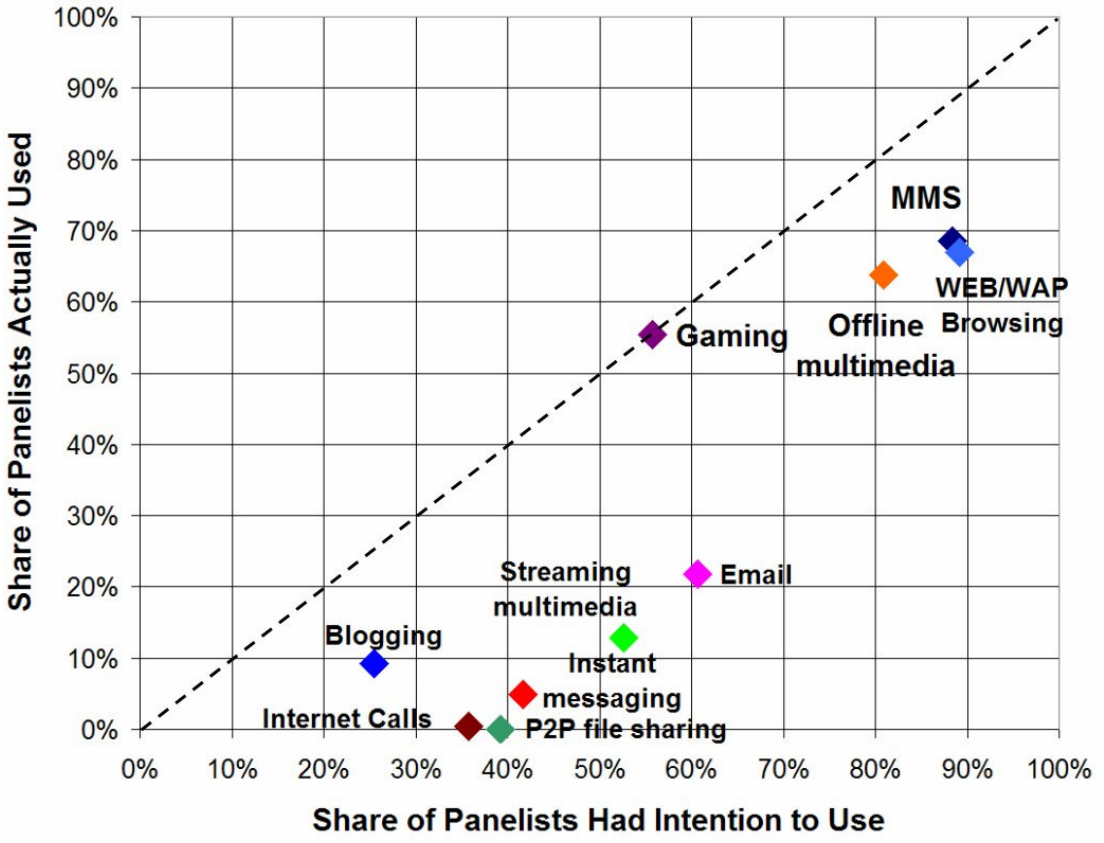

Figure 16 - Adoption matrix

The figure above reflects for each of the studied service the proportion of panelists who had an intention to use the service, and the proportion of panelists who both intended and used the service. These descriptive statistics reveal that for most services not all intentions of use (when asked before the panel) are fulfilled, in other words not all panelists intending to use the service are actually using it. Therefore, bottlenecks for adoption exist in the market. Some of these bottlenecks include the unavailability of services and difficult technical configuration.

Those strongly intending to use the service, ceteris paribus, expectedly have higher probabilities of adopting the service in practice, as can be seen in Figure 17. However, still major differences exist between services regarding the overall penetration of services. For example, relatively fewer of those having strong intentions to use email actually use it, in comparison to browsing, for example. These differences reflect external (not related to user intentions and needs) rather than internal bottlenecks.

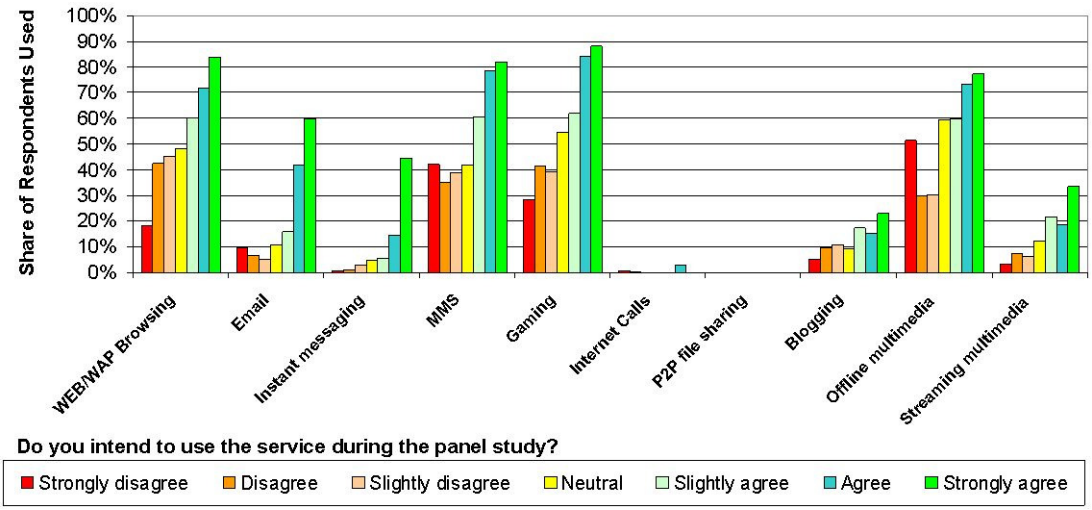

Figure 17 - User intentions and actual service usage

The article develops five indices that can be measured over time and, therefore, utilized in longitudinal analysis. These indices communicate the general attitude towards mobile services (*attitude index*), short-term intentions of use (*intention index*), the current propensity of taking services into use (*timing index*), the extent of service use (*usage index*) and the probability of using the service given intentions (*adoption index*).

Table 3 - Measured service indices

	Attitude Index	Intention Index	Timing Index	Usage Index	Adoption Index
WEB/WAP Browsing	73%	88%	92%	69%	72%
Email	87%	61%	65%	22%	31%
Instant messaging	79%	42%	42%	5%	10%
MMS	94%	89%	90%	67%	70%
Gaming	68%	56%	58%	55%	71%
Internet Calls	83%	36%	34%	0%	0%
P2P file sharing	63%	39%	41%	0%	0%
Blogging	76%	25%	26%	9%	13%
Offline multimedia	95%	81%	82%	64%	70%
Streaming multimedia	85%	53%	52%	13%	19%

Attitude index	Share of panelist thinking that the mobile service has replaced / will replace corresponding existing use of the service (i.e. computers)
Intention index	Share of panelists having an intention to use the service in the near future
Timing index	Share of panelists intending to use the service in the near future out of those having a (long-term) positive attitude
Usage index	Share of panelists having used the service during the panel study
Adoption index	Share of panelists having actually used the service out of those who intended to do so

The table above summarizes the calculated indices for the identified services. By looking at the attitude index, people have positive attitudes (future expectations for mobile services replacing their use of corresponding services with other devices) towards most services, the most so towards offline multimedia playback, MMS (replacing corresponding multimedia messaging clients in desktop computers, such as some IM clients) and mobile email. The second column (intention index), however, tells that most people have short-term interest to use only browsing, MMS, games and offline multimedia services. Indeed, the timing index is higher than 50% only for these services. These services are likely to experience wider use sooner than others. Some other services (having high attitude indices) might be successes further in the future according to the panelists, an example being mobile blogging which has a rather positive attitude index but low intention and consequently timing index. Also mobile VoIP services (Internet calls) have promising prospects, as many people have positive long-term attitudes towards the service though no short-term interest (intention) to use the service exists. The timing index reflects current propensity of taking the service into use, given that there is a positive attitude towards the service. The fourth column projects the actual share of panelists having used the service during the panel, and finally the adoption index in the fifth column states that only offline multimedia, browsing, MMS and gaming have been adopted without significant bottlenecks. All of these five indices can be measured over time. Longitudinal comparisons can provide comparisons on the development of services over their individual adoption curves.

The measured indices communicate that panelists have on average high attitudes towards mobile versions of the services included in the study, but only mature mobile services (introduction more than a year ago) experience positive short-term intentions of use and consequent adoption. Mobile services are clearly experiencing different phases of their life-cycle. The developed indices can be utilized in projecting the phase of diffusion for each service emerging in the market.

Path analysis is used in verifying the theoretical hypotheses of this article. Path analysis is an extension of multiple regression. Wright (1921; 1934; 1960) was first to utilize path analysis in empirically studying direct and indirect effects of theoretical models. In essence, path analysis extends multiple regression by including a number of equations instead of only one (Schumacker & Lomax 2004). Pedersen and Thorbjørnsen (2003) is used as a basis for the theoretical model developed here. The adoption model used in this article is introduced in Figure 18. This model is analyzed with AMOS (add-on package for SEM in SPSS), using the maximum likelihood approach.

The estimated path models reveal that perceived hedonic (enjoyment) benefit is the strongest driver of both attitude and intention towards the service. This is in contrast to earlier findings that utility-centric benefits drive intention to use mobile services. In the estimated models of the article perceived utility drives only intention to use mobile email. In general, many of the newly developed mobile services should be considered as generating hedonic rather than business/utilitarian value to end-users. The social setting around panelists or expected technical difficulties do not explain intentions to use. This is most likely due to the panelists in the dataset being early-adopters (independent and technically advanced users). Pricing of data traffic has a strong effect only on browsing and email that are the key data services. Multimedia services, on the other hand, benefit

from the higher capability of handsets. However, the intention of end-users to use the service is the most important driver of actual use of services.

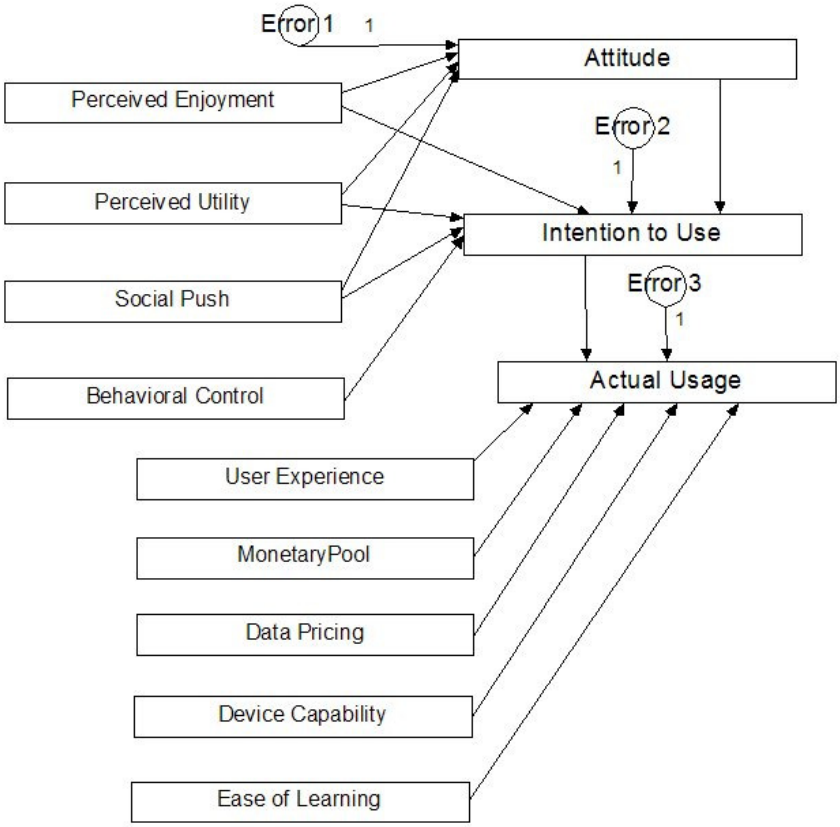

Figure 18 - Developed theoretical path model of mobile service adoption

The estimated path models do not have a good fit. In addition, instead of using the standardized groups of questions in TAM and structural equation modeling in verifying the theoretical model, a more simplified path modeling approach is chosen due to limitations in the panel study implementation (mainly the lack of comprehensive questionnaire data). Improvements of the theoretical model remain as a future task in addition to the acquisition of more comprehensive datasets supporting not only path but also the measurement part of SEM analysis. One of the key conclusions of the article is, however, that the internalized variables poorly explain the variance observed in intention and usage-level variables. Therefore, most new advanced mobile services have special characteristics and external sources of variance in adoption dynamics that are not depicted in this analysis. These likely originate from the supply side of the market. Nevertheless, the fitting of empirical adoption data with path analysis is demonstrated to be an efficient method in explaining the adoption of emerging mobile services.

From the business perspective a profitable mobile service business entails two necessary conditions. On the one hand, one has to attract a reasonable base of end-users. On the other hand, one should make money out of that end-user base. This study indicates several implications with regards to the first condition. First, the perceived hedonic benefit (perceived enjoyment of using the service, entertainment value, possibility to “kill time”) is the biggest source of user interest in emerging mobile services. Second, intentions of

users clearly drive realized use. Therefore, effort should be put on generating intentions among the end-user population. The probability of mobile services replacing already existing services (long-term attitude), social network effects and perceived ease of use do not play that large a role in driving intentions. Rather, promotion and a good availability of services (that were not internalized in the model) probably do play a significant role. Third, new handsets push particularly multimedia use and services built in the Internet, such as webmail. Fourth, data pricing structures (being block-priced or flat-rate) drive the use of the most important data services (e.g. browsing). When asked from end-users, the technical problems of new advanced services together with suboptimal pricing are the major causes of non-realized use.

5.3. Handset-based measurement of mobile service demand and value

Article 3 discusses potential determinants of mobile service usage. From the theoretical point of view the earlier research underlines adoption and diffusion dynamics in driving the use of new technologies. To build understanding on the mobile services market, the article studies the characteristics of new mobile services with the handset-based research method. The article develops visualizations and measures that characterize services. In addition, a theoretical model is built determining value of mobile services. The model is estimated with handset-based data collected from Finland in 2006.

The figure below demonstrates how cumulative usage profiles for different services reflect their life cycle. First of all, outbound voice calls have the most linear cumulative usage distribution. There exists little variance between end-users in voice usage because it is a mainstream necessity service, and its penetration has already reached 100%. SMS and imaging have a penetration of close to 100%, too, but the slopes of the cumulative curves are higher. This means that usage is relatively more concentrated than in voice, and more variance can, therefore, be observed in needs for imaging and short messaging than in voice. Moreover, Internet browsing experiences a penetration rate of 70% and as much as close to 90% of all browser usage in the panel has been generated by the top 25% of panelists. The similar 25% concentration ratio for offline multimedia is more than 90%. For relatively new and advanced services the cumulative usage distribution curve, therefore, is significantly different from the ones of mainstream services. Usage is here measured by sessions per month per user to make services comparable to each other.

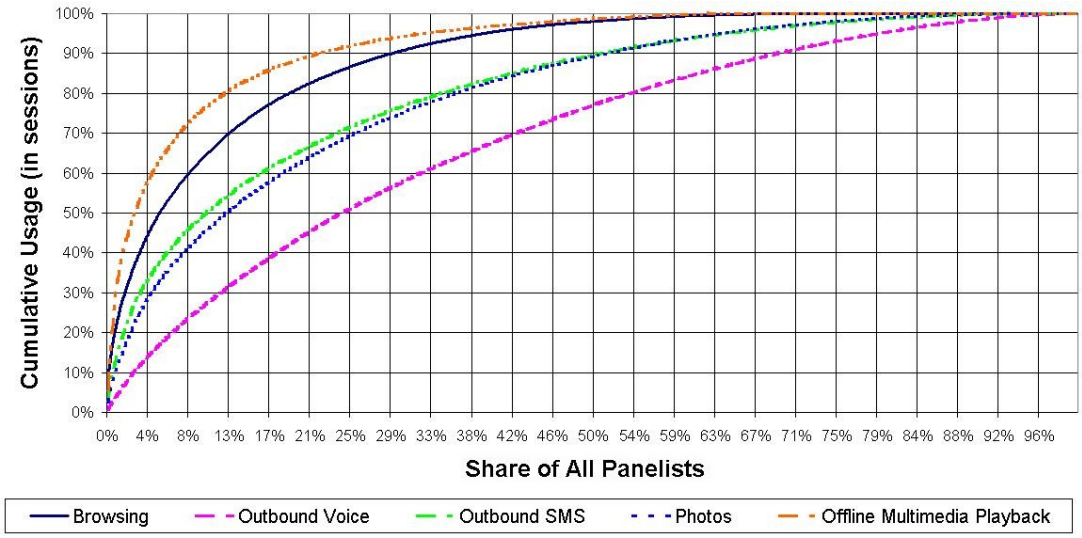

Figure 19 - Cumulative usage of a sample of mobile services

The article finds that mobile service life-cycle can be empirically measured, and the characteristics of different services can be identified with various data points available with the handset-based service research method. Most importantly, the article identifies three kinds of quantitative measures reflecting usage profiles. First, *penetration* reflects the extent of service diffusion by projecting the number of people using it. Second, service *concentration* indices reflect the accumulation of service usage to the top users. Third,

service *diversity* indices reflect the differences between the most active and most passive actual service users.

Table 4 - Measurements of service usage

	Penetration	Mean usage intensity / month	Median usage intensity / month	Minimum usage intensity / month	Maximum usage intensity / month	Relative usage intensity index	Skewness	**Cumulative usage at 25% (concentration index)**	Cumulative usage at 50% (concentration index)	Cumulative usage at 75% (concentration index)	Share of usage generated by top 20% of service users	Share of usage generated by bottom 20% of service users	**Usage diversity index**
Voice (out)	**100%**	60.8	50.6	0.6	285.0	82%	1.50	**51%**	77%	93%	44%	5%	**9**
SMS (out)	**98%**	63.2	30.9	0.4	1339.8	84%	5.33	**71%**	90%	98%	65%	2%	**39**
MMS (out)	**53%**	2.2	1.3	0.3	27.5	2%	3.77	**84%**	99%	100%	58%	3%	**17**
Data	**91%**	12.3	5.7	0.3	241.8	15%	5.28	**75%**	93%	99%	65%	1%	**45**
Browser	**69%**	7.6	2.6	0.3	228.4	7%	7.30	**87%**	98%	100%	72%	1%	**64**
Email	**16%**	4.8	1.3	0.3	95.3	1%	5.51	**100%**	100%	100%	77%	2%	**48**
Streaming multimedia	**13%**	1.1	0.5	0.3	10.2	0%	3.94	**99%**	99%	99%	58%	6%	**10**
Offline multimedia	**64%**	7.7	1.7	0.3	193.4	7%	5.98	**92%**	99%	100%	81%	1%	**69**
IM	**5%**	11.1	1.8	0.4	197.7	1%	5.37	**100%**	100%	100%	87%	1%	**86**
3rd party applications	**86%**	26.8	8.9	0.3	594.1	31%	4.82	**83%**	96%	100%	74%	1%	**105**
Non-communication usage	**100%**	73.9	51.1	0.4	581.4	100%	2.45	**59%**	82%	95%	52%	4%	**15**
Application installations	**44%**	2.3	0.9	0.3	37.1	1%	5.55	**90%**	100%	100%	64%	3%	**24**
Radio	**27%**	4.0	1.3	0.3	88.0	1%	5.70	**99%**	100%	100%	76%	2%	**45**
Utility applications	**86%**	12.4	3.7	0.3	401.2	14%	7.06	**84%**	96%	99%	77%	1%	**79**
Productivity applications	**85%**	6.0	3.4	0.3	80.0	7%	3.75	**70%**	91%	99%	59%	2%	**24**
Gaming	**55%**	15.3	3.2	0.3	257.9	11%	3.97	**95%**	99%	99%	81%	1%	**124**
Photo capture	**94%**	18.3	9.7	0.4	302.1	23%	4.38	**69%**	89%	98%	61%	2%	**31**
Video recording	**57%**	2.6	1.4	0.3	19.7	2%	2.46	**81%**	98%	100%	57%	3%	**16**
Calendar	**95%**	14.8	7.1	0.3	288.6	19%	4.85	**72%**	91%	98%	64%	1%	**43**

Based on the dataset from 2006, these measurements are conducted for a sample of services (see the table above). By using these measures the article illustrates how mature services such as voice experience wide adoption and steady usage concentration, whereas some new services such as multimedia playback or Internet browsing catch a smaller number of users, have significant concentration of usage and lots of usage-level differences between "explorer" and “sustainable” user groups. User heterogeneity (and/or adverse selection) effect is evident in the data, too. New panel studies consist of users with relatively normal preferences towards new services (against the more technology enthusiastic people in older panels), and this explains the declining penetration and usage intensity figures for some rare mobile services such as instant messaging, application installations, and email. No significant changes in the use of older services exist between 2005 and 2006. Multimedia services (imaging and multimedia playback) potentially benefit from the better capabilities of new smartphone devices, and for this reason they experience increasing usage.

The value of services is difficult to reflect with ABPU (because not all services are charged for). The same is true for cumulative usage time or session lengths (because

different services require different amounts of time and effort), or frequencies (because some services are by nature for everyday use while some are for occasional use). This article compares net utilities to users with a simplified theoretical model, in which the time spent with services is used as a proxy of the real value of the service to end-users. The table below shows the calculated average values of the services over their particular users. The calculations are based on the handset-based dataset from 2006. The calculations normalize observed usage minutes of services to usage minutes of mobile voice. The value units are, therefore, normalized to apply the logic of opportunity cost of time. As can be seen, the value of SMS messaging and Internet browser seem to be almost equivalent to 50% of voice call value. Among the particular service users, music player actually achieves a normalized value of 75% (those who use Music Player catch relatively high value from it), and Camera and Calendar are far behind with less than 30% of the value of mobile voice.

Table 5 - Measured usage-level variables of key smartphone services

Service	Penetration [min. 1 min / day]	Usage Minutes per Day / Service User [MEAN; min. 1 min / day]	Voice Call Minutes per Day / Service User [MEAN; min. 1 min / day]	Avg. Value of Service [Relative to Voice]
Voice	98%	12.2	12.2	1.00
SMS	85%	5.5	12.9	0.43
Calendar	25%	2.9	13.9	0.21
Internet browser	27%	5.4	13.3	0.41
Music player	13%	8.1	10.8	0.75
Camera	45%	4.0	14.1	0.29

Two kinds of extensions to this article should be considered. First, the identified measures and visualizations should be applied in both longitudinal and cross-service studies. New services are emerging all the time, today's new services are maturing over their life-cycle, and old services are being integrated into the everyday life of *mobile citizens*. Insights on the characteristics and trends in the mobile services market should be acquired constantly employing the research approach of this article, leveraging the developed handset-based mobile service research method and associated analysis procedures. Second, the theoretical model of service valuation should be further developed. This article illustrates a simplified approach to compare mobile service values as perceived by end-users. However, constructing a theoretical analogy of the real world phenomena always asks for simplifications. Alternative approaches to understand the value of mobile services and to estimate explicit/implicit utilities and costs of using mobile services should be deployed.

5.4. Analysis of Mobile Internet Usage among Early-Adopters

In addition to regulation, trends in the evolution of business ecosystems, technologies and end-user adoption affect the rate of mobile Internet growth. Disruptive potential exist in the mobile Internet, as the logic of the ecosystem is different from the current vertically-oriented cellular operator driven mobile ecosystems (see Figure 20).

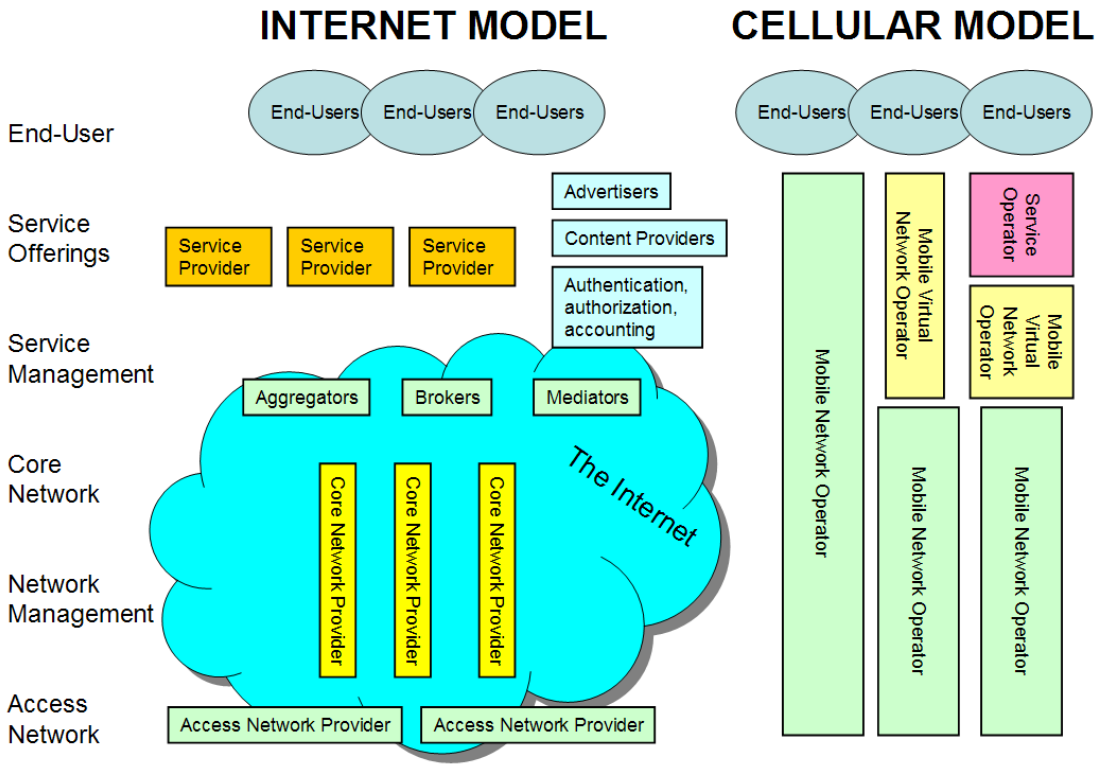

Figure 20 - Internet model vs. cellular model of service delivery

Article 4, summarized in this section, suggests several variables that can be used in measuring the emergence of the mobile Internet. First, metrics reflecting the evolution of open mobile handset software platforms and network edge based innovation are presented. Second, metrics indicating both the absolute usage and functional break-down of packet data traffic in mobile networks are specified. Third, comparisons between Internet and legacy cellular communication functions reflect the substitution of incumbent mobile communication services by challenger Internet person-to-person services. All the introduced measurements can be conducted with the handset-based end-user research method (Verkasalo & Hämmäinen 2007).

Table 6 lists the suggested factors that should be measured in understanding the nature and extent of mobile Internet usage.

Table 6 - Handset-based measures of mobile Internet potential

Measure	Description
Share of add-on application usage out of all smartphone application usage (in application activations)	As open software platform (in the sense that customers can install own applications on the edge of the network like in the PC world) are critical in pushing mobile Internet usage further (with e.g. multimedia and file sharing applications), a viable variable indicating the extent of network edge based customization is the share of add-on application activations to all application activations.
Share of panelists installing add-on applications to mobile handsets	The share of panelists installing add-on applications tells about the overall extent of add-on application usage. The higher this share, the closer the smartphone usage to normal computer usage.
Absolute packet data volume / month / user	The overall utilization of packet data access points (measured in data volume) indicates the general extent of packet data service usage that further should correlate with the emergence of the mobile Internet.
Share of panelists using handset browser	As browsing is one of the key accesses to Internet services, the share of panelists using mobile handset browsers should indicate how high a share of people actually have explored this possibility in the mobile domain.
Functional packet data distribution (in aggregated data volume)	The functional break-down of packet data volume tells about the type of data traffic flowing in mobile networks. The first Internet services (in the fixed Internet) were all about messaging (email), after which static content emerged (WWW). The newest trends include other kinds of traffic such as P2P (VoIP and file sharing) and multimedia (streaming). By studying the functional distribution of mobile packet data the trends of the mobile Internet can be identified.
Share of public Internet URL retrievals to operator URL retrievals with handset browser	Because handset browsers are used both in retrieving operator-specific content and services (WAP and other operator portals) and in retrieving purely public (WWW) content, the dominance of either one of these domains indicates the relative role of the Internet or cellular business ecosystems. Operators can push their own bookmarks and services if handset bundling is allowed, but on the other hand many customers might adopt truly open Internet-based services.
Share of Internet communication actions to all communication actions (in session activations)	In communication services the usage of legacy cellular operator driven mobile person-to-person services should be compared to challenger Internet person-to-person services such as email, instant messaging and VoIP in order to measure the emergence of mobile Internet communication.
Share of users using mobile Internet communication services	As earlier, the share of users actually using Internet communication services in mobile networks tells about the overall popularity of these challenger services.
Share of users using Internet multimedia services	The share of people using streaming multimedia services indicates whether users have adopted multimedia oriented Internet services (e.g. video streaming, music downloads etc.) or not.

Though the results of the article indicate that some promising signs can be seen in the use of packet data and Internet oriented mobile services (see Figure 21), no significant changes between 2005 and 2006 exist in service penetration numbers (see Figure 22). In addition, the use of Internet services in comparison to corresponding cellular services is insignificant. Perhaps Finnish subscribers have a mental lock-in to legacy services, and operators are able to push their own services with handset bundling thus counteracting the emergence of the mobile Internet.

The suggested measures can be used in the future in cross-sectional or longitudinal studies on the evolution of the mobile Internet. Therefore this article provides a pioneering measurement framework specifically intended for studying the mobile Internet with the handset-based mobile service research method.

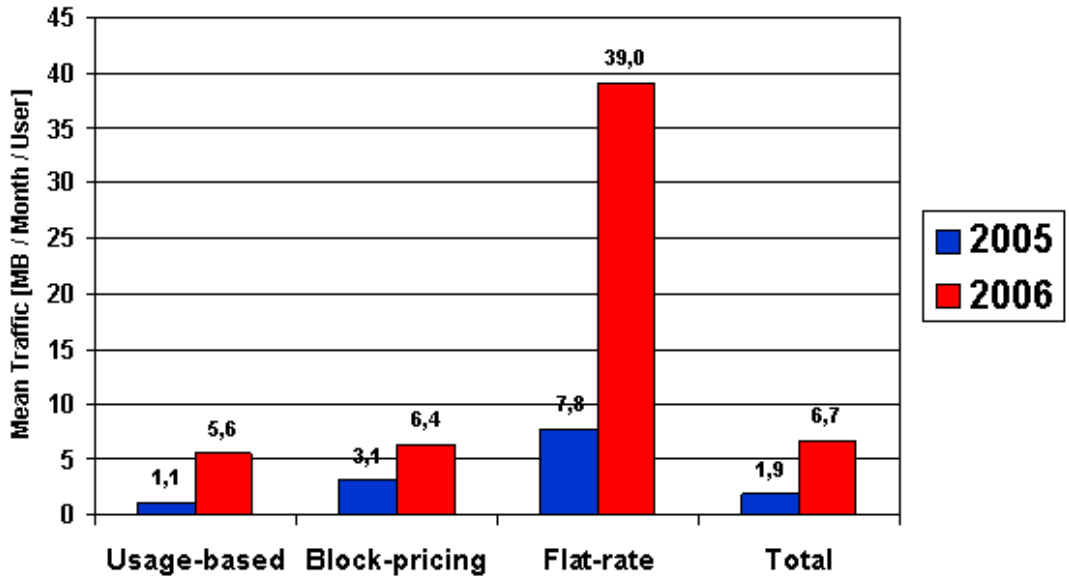

Figure 21 - Absolute packet data usage per user

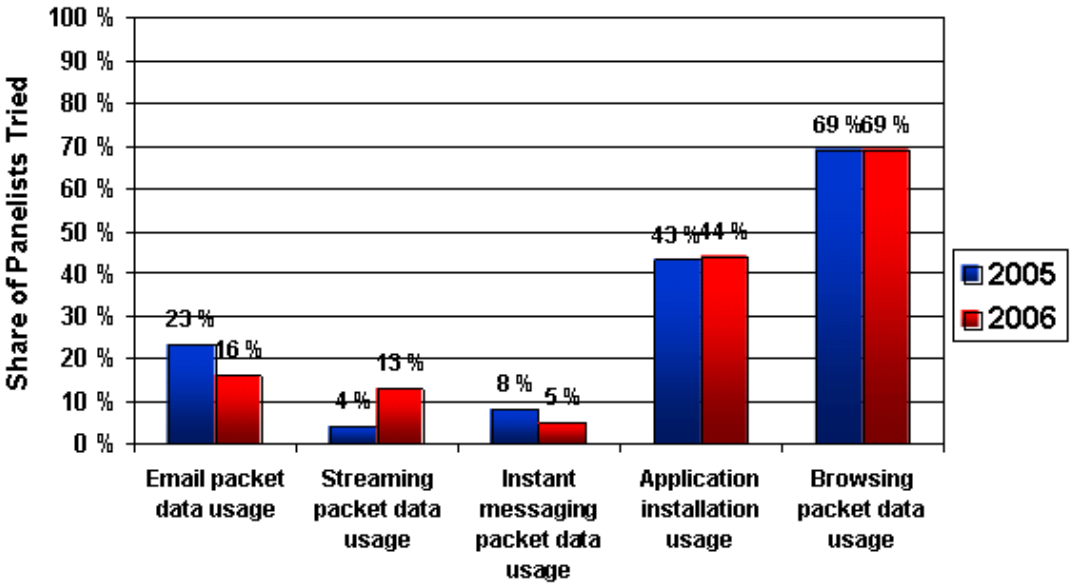

Figure 22 - Adoption of Internet-related services

5.5. Contextual patterns in mobile service usage

Mobile services possess characteristics that are not found from other services. Most importantly, mobile services can be used anywhere at any time. Mobile services are therefore ubiquitous. The mobile services of today range from hedonic to utilitarian ones. A need exists to extract contextual data from mobile phones. This would facilitate new kinds of end-user studies, and serve as ground work for future context-sensitive applications.

A specialized context algorithm is developed in Article 5 to be used together with a handset-based end-user research method. The algorithm along with the associated process of obtaining and automatically analyzing loads of usage-level data help in assessing the contextual dimensions of mobile services. The new algorithm is tested with a case example, including data from Finland and the UK from autumn 2006. The handset-based end-user data is processed in the algorithm with the steps described below.

The stages of the context algorithm are:

1. For each particular customer the cumulative usage (e.g. active hook-up hours) of each cell-id is calculated over the whole panel period. Then the relative share of usage for each of these cell-ids is calculated by dividing the number of a particular cell's active hours by the total number of active hours spent in the panel.
2. For each cell-id achieving a relative share of usage more than 10% (i.e. there is significant usage under a particular cell) a hypothesis is made that the cell-id must represent either home or office usage (both are fixed locations with potential for a high number of active usage hours).
3. The cells with at least a relative usage ratio of 10% are analyzed in greater detail by weighting their hourly and weekday-based distributions with corresponding statistics (provided by Statistics Finland) indicating people's averaged location dynamics per weekday and hour. Those cells that receive relatively more hits during typical home context hours get more "home points", and vice versa with office context.
4. "Home" and "office points" are summed up in order to classify cells with relatively high cumulative usage either into home or office contexts. If the cell received more home points all usage taking place under that cell is considered home usage, and vice versa for office.
5. All the cells receiving less than 10% of all cell-id hits are considered as "on the move" context. The assumption is thereby made that people do not spend more than 10% of cumulative time in any of the "on the move" cells.
6. All users for whom three separate contexts with significant (> 100 hours) usage per context are identified and included in the final dataset for usage-level comparisons.

The outputs of the context algorithm are mapped together with usage data in order to classify all end-user actions into one of the three contexts. Based on this classification accurate usage-level comparisons can be made on the services under interest.

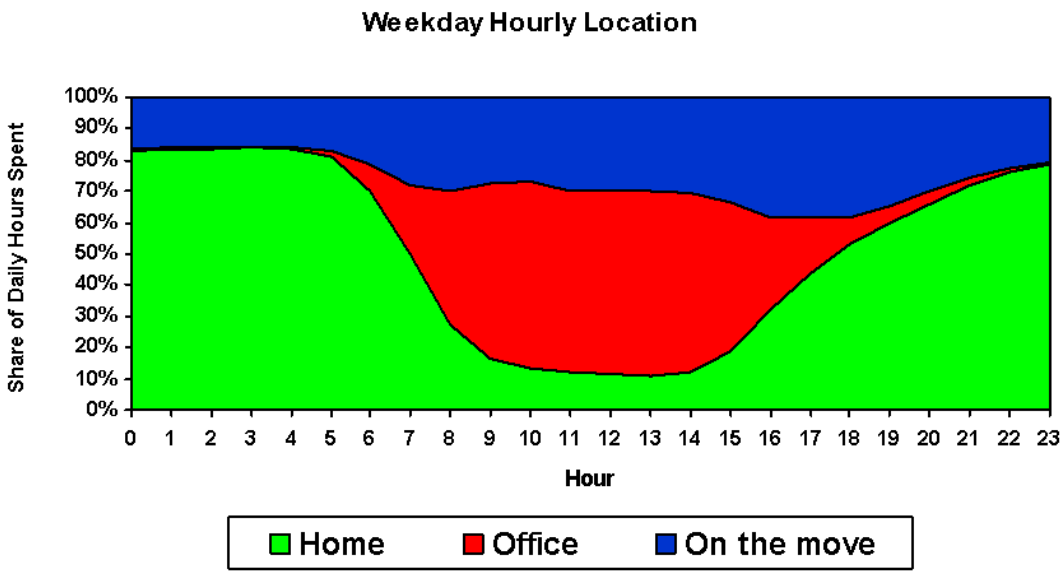

Figure 23 - Weekday hourly distribution of locations

Based on the aggregate data, panelists on average are located 49.9% of weekday time in the home context, whereas office and "on the move" contexts represented 23.5% and 26.6% of the time, respectively. The home context acquires the most time because people typically not only hang around a lot at home, but they also sleep at home (thus generating a lot of inactive presence at home). The figure above presents averaged weekday context distribution. As can be seen, office context acquires the most usage between 8am and 3pm, reflecting typical office hours. Some "on the move" usage can be identified in the night time, reflecting, for example, foreign trips, holidays, visits to friends etc.

According to the service usage analysis with contextual data, multimedia and Internet services are used actively "on the move", whereas legacy SMS and voice services experience more evenly distributed usage among home, office and "on the move" contexts. These observations can be made by comparing the total aggregate minutes of use of multimedia and Internet services to total aggregate minutes of voice and messaging use in each of the contexts (see Figure 24).

People have unique mobility patterns, and, therefore, future research should focus on micro-level service studies and associated segmentation research. Only aggregated results are presented in this article. Other levers for the developed algorithm are context-aware applications such as presence solutions. The algorithm and usage-level data retrieval method provide valuable information on mobile end-user behavior and service usage patterns.

The main venues for technical contributions are related to an update of the algorithm with seamless cell-id logging. In addition, future handsets with embedded GPS chips can provide even more accuracy to the identification and modeling of contexts. In particular, the context can be identified with higher accuracy, and moving buses can be separated from stable locations such as cafeterias, for example.

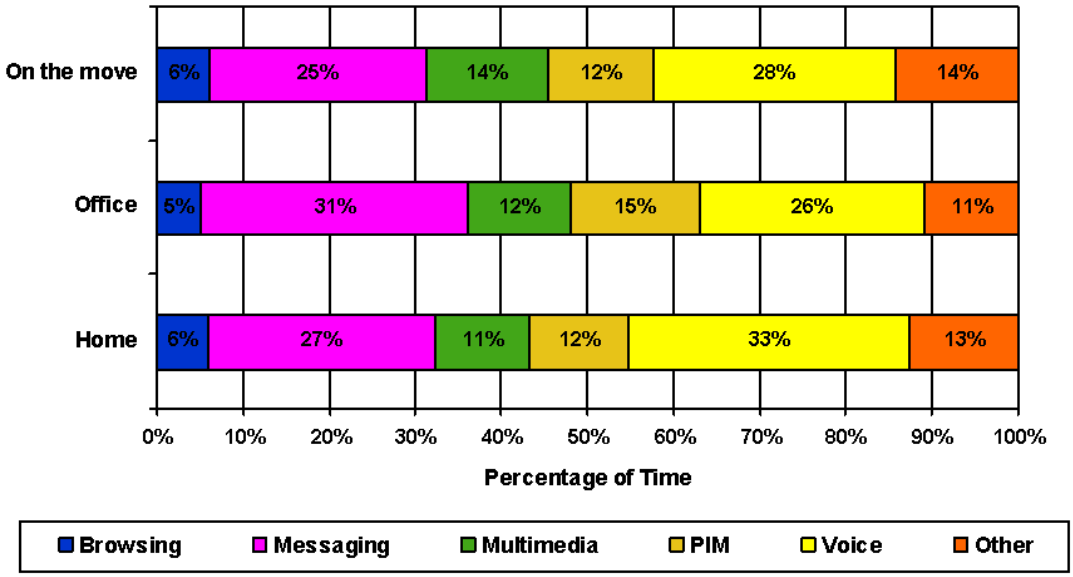

Figure 24 - Smartphone time allocation in different contexts

5.6. Conclusion: the implications of the empirical case studies

This dissertation identified six major trends of the mobile industry. All of the articles included in this dissertation use the handset-based research method in studying these trends. The table below identifies the key trends of interest in each of the articles.

Table 7 - Link between the articles included and trends of the mobile industry

	Article 1 : Measurement of Smartphone Service Evolution in Finland	Article 2 : Dynamics of Mobile Service Adoption	Article 3 : Handset-Based Measurement of Mobile Service Demand and Value	Article 4 : Analysis of Mobile Internet Usage Among Early-Adopters	Article 5 : Contextual Patterns in Mobile Service Usage
T1: Convergence of industries in the mobile domain	X			X	
T2: Emergence of mobile Internet service delivery				X	
T3: Complexity in valuing mobile services and modeling moderating effects of usage		X	X		
T4: Heterogeneity in mobile service offerings and end-user consumption patterns		X	X		X
T5: Divergence in mobile network access technologies	X			X	
T6: Diffusion of smartphones as multi-purpose mobile computers providing seamless connectivity and computing power	X				X

The first article demonstrates holistically the variety of data points available from the handset-based data collection process. From the perspective of mobile service analysis, the article particularly emphasizes the movement towards new mobile services and emergence of the alternative mobile access technologies, without going into the details of end-user behavior or service-specific characteristics.

The second and third articles focus on the micro-level explanations of mobile service usage. The focus is on end-user adoption and service valuation. Why do certain users adopt mobile services quicker than others? How can the stage of mobile service market penetration be empirically measured? What drives the value of mobile services as perceived by end-users? Mobile services are put against each other in both of the articles.

The fourth article studies mobile Internet services, and associated usage-level observations. The article discusses the ongoing trend of converging industries (Internet and cellular) in the mobile domain. The Internet brings a whole new portfolio of services into mobile devices. Alternative radio access technologies together with the Internet-based service delivery stretch the limits of the mobile industry.

The last article of the dissertation is more technical, as it provides an algorithm which extracts contextual information from handset-based research data. This article studies context-specific characteristics of mobile services, assuming that smartphones are truly ubiquitous devices that people carry everywhere at all times. Because of this it is

beneficial to utilize handset-based data in analyzing not only mobile service usage, but also in tackling the wider contextual behavior of users.

The table below provides a summary of the included articles.

Table 8 - Research settings of the included articles

	Article 1	Article 2	Article 3	Article 4	Article 5
Title	Handset-Based Measurement of Smartphone Service Evolution in Finland	Dynamics of Mobile Service Adoption	Handset-Based Measurement of Mobile Service Demand and Value	Analysis of Mobile Internet Usage among Early-Adopters	Contextual Patterns in Mobile Service Usage
Research questions	Has the Finnish smartphone market changed between 2005 and 2006? What are the emerging trends in the mobile services market in Finland? How to combine questionnaire data with usage data in analyzing mobile service usage?	What are the major bottlenecks in mobile service adoption? Which factors mediate adoption of mobile services? What kind of measures can be utilized in studying the adoption process?	How can the stage of mobile service life cycle measured? Do mature services differ from new services in terms of end-user valuation and adoption rates? What are the key (time-varying) characteristics of mobile services?	What is the essence of the mobile Internet? Is there a visible movement towards the mobile Internet? What are the key metrics that should be looked upon when studying the emergence of the mobile Internet?	What is the role of context of use in mobile service usage? Can the context of usage be identified automatically with handset-based usage data? How do different mobile services differ in contextual usage dimensions?
Research methods	• Descriptive statistics • Cluster analysis • Longitudinal comparisons	• Descriptive statistics • Path modeling	• Micro-economic modeling of usage • Descriptive statistics	• Literature review • Descriptive statistics	• Heuristic data mining
Research focus	The general Finnish mobile market, end-user segments	The process of mobile service adoption (from interest to actual usage)	Characteristics of different mobile services, service life cycle	IP-based mobile services	Location, time and context stamps of mobile service usage
Dataset	Finland 2005 and 2006 (565 and 695 panelists)	Finland 2006 (548 panelists)	Finland 2005 and 2006 (565 and 695 panelists)	Finland 2005 and 2006 (500 and 695 panelists)	Finland and UK 2006 (324 panelists)
Key results	People spend increasing amounts of time with smartphones. Significant adoption problems exist in new mobile services. Flat-rate and block-priced service subscriptions significantly drive usage.	Potential exists for many mobile services, though no short-term adoption can be seen. Hedonic benefits drive intension to use instead of utilitarian benefits. The supply side of the mobile market is a serious bottleneck.	Usage of mature mobile services is wider (more users). Usage patterns of mature and emerging mobile services are significantly different. People value mature mobile services significantly higher than new services, which better create value in narrow end-user segments.	The mobile Internet experiences little usage in Finland. However, positive developments can be seen in many mediating factors, such as in the structure of mobile data traffic.	Handset-based data provides a possibility to automatically extract the context of end-users. Mobile services have context-specific characteristics that should be realized when studying end-users.

Each of the included articles has a unique research problem and setting, but they all utilize the handset-based research method. In addition, the articles serve as case studies, demonstrating that the method can be used in assessing the identified six key trends of the mobile industry. The articles also provide examples showing the dimensions in which the method has advantages over other available methods of end-user research.

The first article (Measurement of Smartphone Service Evolution in Finland) studies the convergence of industries, divergence of mobile network access technologies, and diffusion of multi-purpose smartphones. The study discovers that Finnish early-adopters

use a multitude of mobile services. In addition, the developed metrics, such as the amount of time spent with a given service, indicate that the defined handset-based research process facilitates the analysis of most new mobile services, including multimedia and data services. This means that the services of the converging industries (communications, media and Internet) can all be measured with the research method, at a single point (smartphone) of measurement. On the other hand, the case study also reports the use of different radio bearers, and patterns of add-on application use, for example. The article covers a number of data points, and shows that particularly the variety of data, even with quite simple analysis procedures, can help in the assessment of the three industry trends. The value of this kind of research increases as more longitudinal data becomes available.

The second (Dynamics of Mobile Service Adoption) and third (Handset-Based Measurement of Mobile Service Demand and Value) articles focus on the analysis methods, rather than the data itself. In both articles, a set of services is chosen as focus areas, and a research framework is developed by using a set of data points in modeling the adoption of mobile services. The articles conclude that the valuation of mobile service usage as perceived by end-users is not easy, and questionnaire data is required in order to explain the reasons for observed usage and potential moderating factors. Many of the implications of the two articles also indicate that mobile service usage habits are heterogenic, different people having their unique areas of interest and consequently individual patterns of service usage. The analysis and statistical methods introduced in the article, however, show that the defined research method can be used in modeling complex usage patterns, thereby assessing the two key trends of the industry (value and moderating effects of mobile service usage, and increasing heterogeneity of end-user preferences). However, it is found that the fitting of questionnaires and collected usage data is critical, and statistical methods should be used in modeling causal relationships. More effort is required in the future to interpret the results more deeply and to be able to provide convincing arguments for the possible reasons of observations that are related to the two key industry trends studied.

As the first article is more data-centric, and the second and third articles are more method-centric, the fourth article (Analysis of Mobile Internet Usage among Early-Adopters) is a more substance-oriented article than the others. In other words, the emerging data services are studied in particular. The article confirms that many kinds of data points are available in the handset-based method for building metrics of mobile Internet service usage. The observations and illustrations emphasize the variety of services used over packet data access points. The article proves that the mobile Internet diffusion can be studied, and also the associated convergence of the industries can be assessed with the method. The measurement point is in the handset, this meaning that all of the radio interfaces from WiFi to cellular can be measured. In this way, the article shows that at least the assigned three trends of mobile industry evolution are tackled in this case study. The article also shows that the method can be used in specific research topics of significant substance value, instead of mere data analysis exercises.

The last article (Contextual Patterns in Mobile Service Usage) tackles the ubiquitous nature of mobile handsets, and through the developed algorithm shows that the sixth trend (seamless connectivity and computing power of mobile handsets) is critical in using mobile handsets as context-detectors. The article also tackles the fourth identified trend (heterogeneity in end-user consumption patterns) by showing that end-users behave

differently across contexts. The main benefit of the last article is the prototyping of such algorithms that could be used as built-in functionalities of mobile handsets in the future. In particular, the ubiquitous nature of mobile handsets facilitates always-on access to the status and location data of end-users through handset-based sensor technologies.

All in all, the articles conclude that a number of research areas can be found for the application of the handset-based research method. The key advantages are the vast amount and objective nature of micro-level data on end-user behavior and service usage, the main shortcomings being the adverse selection of panelists (still mainly early-adopters), and amount of time required for the post-processing and analysis of data.

6. Future research

The dissertation shows the novelty value of the handset-based research method in accurately modeling end-user behavior in different contexts, studying adoption dynamics, and assessing the actual usage of services and applications. However, the future development of the handset-based *research process* should consider the following important points:

- What are the most appropriate research areas in which the handset-based end-user research method provides value-added? The limitations of the method should be taken into account.

- How to explain descriptive results? Future research should find ways of better utilizing, for example, questionnaires in explaining and interpreting the empirical observations.

- How to scale up the panel study process? This involves the suggested new service ideas that make the handset-based data feeds available also to end-users instead of mere researchers.

This dissertation demonstrates the use of the handset-based research method with five articles. The articles cover different angles in utilizing the available questionnaire and usage-level data. Although the associated panel studies typically consist of early-adopter users, the nature and accuracy of data makes several pioneering research approaches possible. In addition, particularly in micro-level service studies the defined method is a novel way of data acquisition. In these studies biased datasets have a less serious negative impact, as the idea is not to generalize the results to the whole market but to instead focus on micro-level research topics.

Five distinct *domains of research* can be identified that are worth exploring with the method in the future.

First, the potential of mobile services and the associated linkage to service diffusion should be modeled in detail. For example, long-term intentions (i.e. potential) to use certain mobile services can be directly asked from end-users. The long-term potential can then be compared to short-term potential, and further to actual service adoption. Adoption gaps can be identified in cross-service study settings. For example, it can be found that there is potential for mobile Internet calls, but little realized usage is observed. Adoption research can extend diffusion research by tackling the potential bottlenecks, and therefore explain why the service potential is not realized into actual use. Service life-cycle studies compare usage-level patterns of mature and immature services, and therefore they fit smoothly with both diffusion and adoption research approaches.

Second, on a micro-level the behavioral patterns of end-users are complex. For example, when having a need to access news content from the Internet, end-users face a problem. Their decision to launch a smartphone browser depends, among others, on availability of substitute devices, network coverage, remaining battery life, context of usage, time of day, and usability of the Internet browsing service. A separate research track can tackle the micro-level determinants of usage with appropriate methods.

Third, operators are interested in potential sources of revenue. In addition to the above mentioned extensions of diffusion research, a new research task can be initiated that models end-user behavior with econometrics. This research task should focus on the estimation of price elasticity of mobile service demand, correlation of ARPU and service usage, and methods of segmenting end-users. The segmentation exercise could explore the possibility to segment users not based on demographics but instead based on actual service usage, in other words real behavior. Profitability of different end-user segments can then be evaluated with a usage-based segmentation approach – not with typical demographic or psychographic based approaches.

Fourth, mobile services are used in a variety of situations. The handset-based end-user research method provides unique datasets on location and time of smartphone usage. All cell-id transitions, end-user actions with mobile services, time of usage and even geographic coordinates are logged in the handset and are available for data mining purposes. This provides a novel possibility to model the location dynamics of mobile nodes. In addition, a unique approach to continue contextual and sociological modeling of mobile end-user behavior and service usage exists. Because of the improving location data collection process the presented contextual research approach can be extended.

The handset-based method also supports application testing. Currently the handset-based mobile service research is geared towards understanding end-user behavior. One subtask could, however, be to test whether the process can be used in improving agile mobile service development in controlled study settings, by closing the design loop and providing valuable feedback from markets to developers. Controlled panel studies would be valuable in contextual and adoption studies, too. With controlled panels the adoption process can be studied from the moment of end-users installing new applications for the first time onwards. In addition, controlled panels facilitate the research on the role of social networks in application diffusion or communication behavior.

Fifth, mobile Internet studies can be continued. The mobile Internet evolution is inevitable. With the handset-based research method the most advanced end-users can be studied and therefore adoption measurements of new mobile services can be deployed. In addition to the mobile Internet, also multimedia services should be studied in detail. New smartphones can be positioned as substitutes to existing consumer goods, such as cameras and MP3 players. Mobile Internet and multimedia studies therefore provide interesting data that have business relevance also outside of the core mobile communications domain.

Longitudinal analyses, in particular, provide a new dimension in analysis. It is also likely, that in the future the generalization of the results is easier, as smartphones are quickly penetrating to mass-markets in developed countries. This means that the introduced method can be also used in studying more mass-market oriented consumers in the future.

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