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Wireless Communications in the Information Society

Thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Electrical Engineering

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Supervisor Prof. Matti Karjalainen
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Helsinki University of Technology **Abstract of Master's thesis**

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Wireless communications is currently one of the fastest growing industries globally. At the same time, the ongoing information society evolution is seen as important for enhancing prosperity of societies. The process touches many fields, and therefore there is a strong need to understand the developments of the two concepts and their relationships. The objective of this study is to provide interested readers with a concise overview to serve as a base for continued work and thinking.

The study begins by discussing the evolution of the information society concept, summarizes the current understanding and identifies the key solutions required to make the visions reality. The main technology developments that have led to the current situation are presented. Wireless communications is identified as a key enabler of information society.

Next, the major trends in wireless communications are identified and discussed, and the foreseeable development path of wireless communications technology is outlined. Attention is given both to terminal and transmission developments.

Last, the forces influencing the user and market adoption of technologies and innovations are discussed. The impact of technology in the process is emphasized.

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Langaton viestintä on tällä hetkellä maailmanlaajuisesti nopeimmin kasvavia teollisuudenaloja. Samanaikaisesti käynnissä oleva tietoyhteiskuntakehitys nähdään yleisesti tärkeänä yhteiskuntien vaurauden edistäjänä. Muutosprosessi koskettaa lukuisia aloja, ja siksi eri tahoilla esiintyy voimakas tarve ymmärtää näiden kahden ilmiön kehitystä ja niiden välisiä suhteita. Tämän työn tarkoituksena on antaa kiinnostuneille lukijoille tiivis katsaus aihepiiriin jatkopohdintojen perustaksi.

Työn aluksi käsitellään tietoyhteiskuntakäsitteen kehitystä ja esitetään yhteenveto tämän hetken yleisestä näkemyksestä. Tämän pohjalta esitetään olennaisimmat sovellukset visioiden toteutumiselle. Nykytilanteeseen johtanut teknologian kehitys kuvataan pääpiirteittäin. Langaton viestintä tunnistetaan keskeiseksi tietoyhteiskunnan mahdollistajaksi.

Seuraavaksi esitellään langattoman viestinnän kehitystä suuntaavat päätrendit, ja kuvataan näköpiirissä oleva langattoman viestintäteknologian kehityspolku. Sekä päätelaitteen että siirtotien kehitysnäkymät huomioidaan.

Lopuksi kuvataan teknologioiden ja innovaatioiden käyttöönottoon vaikuttavia tekijöitä. Teknologian roolia tässä prosessissa painotetaan.

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Trådlös kommunikation är för tillfället en av de snabbast växande industrigrenarna globalt. Samtidigt ses den pågående utvecklingen av informationssamhället som en viktig befrämjande faktor för samhällens välmående. Förändringsprocessen berör ett stort antal branscher. Därför finns ett kraftigt behov att förstå utvecklingen av de nämnda två fenomenen samt relationerna mellan dem. Ändamålet för detta arbete är att ge intresserade läsare en kompakt översikt i ämnet som en bas för fortsatt tänkande.

Inledningsvis behandlas utvecklingen av informationssamhällesbegreppet, och en sammanfattning av den aktuella allmänna uppfattningen presenteras. På basen av detta presenteras de tillämpningar som är mest relevanta för förverkligandet av framlagda visioner. Teknologiutvecklingen som har lett till den nuvarande situationen beskrivs i huvudsakliga drag. Trådlös kommunikation identifieras som en central möjliggörande faktor för informationssamhället.

Som följande presenteras huvudtrenderna som styr utvecklingen av trådlös kommunikation. Den inom synhåll varande utvecklingen av trådlös kommunikations-teknologi beskrivs beträffande både terminalen och transmissionsvägen.

Slutligen beskrivs faktorer som påverkar ibruktagandet av teknologier och innovationer. Teknologins roll i denna process understrykes.

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Concluding this thesis also means a definite end to a number of activities that have occupied my personal bandwidth for a long time. I therefore want to take the opportunity to thank those who have influenced, assisted, and supported me during the preparation of this study and during all my studying years.

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Helsinki University of Technology has educated a long line of engineers. I feel honoured to have had the opportunity to study in that environment of great tradition. In addition to the education of the university, the time spent at the Student Union, Teknologföreningen, and PO also taught me a lot. My warmest thanks to all friends from that time, and especially to Ainoa Oikea Hallitus. Of all magnificent groups I have belonged to, Humpsvakar must be the greatest. There I had the absolutely most hilarious and rememberable moments. I cannot thank you enough.

Loving thanks also to my parents, who gave me such good foundation to build upon, and to my brothers who seem to have an endless patience with their older brother.

My dear wife Kata has shared with me a major part of everything during these years. Thanks for being there all the time, life would be decades duller without you. Finally, I want to thank our daughter Inna who, with that undefeatable charm of one-year-olds, brings joy into any situation.

Pappilanmäki, Porvoo,
August 16th, 1999.

Samppa Ruohtula

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List of abbreviations

AAC	Advanced Audio Coding
A/D	Analog/Digital (conversion)
ADSL	Asynchronous Digital Subscriber Line
AMPS	Advanced Mobile Phone Service
AMR	Advanced MultiRate coding
ARPA	Advanced research Projects Agency
ATM	Asynchronous Tranfer Mode
bps	bits per second
CD	Compact Disc
CDMA	Code Division Multiple Access
CELP	Code Excited Linear Predictive Coding
CISC	Complex Instruction Set Computing
CLC	Cholesteric Liquid Crystal
DSP	Digital Signal Processor
DVD	Digital Versatile Disc
EDGE	Enhanced Data Rates for GSM/Global Evolution
EFR	Enhanced Full Rate
ETSI	European Telecommunications Standards Institute
FIM	Finnish Markka
FR	Full Rate
GPRS	Global Packet Radio System
GSM	Global System for Mobile communications (formerly Groupe Speciale Mobile)
HR	Half Rate
HSCSD	High Speed Circuit Switched Data
HTML	Hypertext Markup Language
ICT	Information- and Communications Technology
IP	Internet Protocol
IPR	Intellectual Property Rights
ISDN	Integrated Services Digital Network
kbps	kilobits per second
LAN	Local Area Network

LPC	Linear Prediction Coding
Mbps	Megabits per second
Gbps	Gigabits per second
MIPS	Million instructions per second
mp3	ISO/MPEG Layer 3
MPEG	Motion Picture Experts Group
NMP	Nokia Mobile Phones
PC	Personal Computer
PDA	Personal Digital Assistant
PDC	Personal Digital Cellular
PDP	Plasma Display Panel
PSTN	Public Service Telephone Network
RISC	Reduced Instruction Set Computing
TDMA	Time Division Multiple Access
UMTS	Universal Mobile Telecommunications System
WAN	Wide Area Network
WAP	Wireless Application Protocol
WCDMA	Wideband CDMA
WML	Wireless Markup Language
WWW	World Wide Web
MMM	Mobile Media Mode

1 Introduction

1.1 Background of the study

The title of this study incorporates two currently very popular concepts: *wireless communications* and the *information society*. In addition to being popular, they are extremely broad, and especially the combination of them seems initially very abstract.

In a few years time, the wireless communications industry has grown to become one of the largest in the world. The markets show significant growth, and the volumes are high. Around 165 million mobile phones were sold worldwide in 1998. Accordingly, companies involved in the industry have displayed record-breaking growth.

The information society concept has been introduced to the public already a couple of decades ago, mainly through utopistic visions of the future. During the 1990s, the concept has suddenly acquired more flesh and blood, thanks to the develoments in technology. The omnipresence of personal computers and, especially, the introduction of the World Wide Web and the enormous growth of Internet use that has followed, has concretized the originally abstract concept and has made people aware of the possibilities therein.

The industry is talking about the ongoing process of convergence, joining a number of earlier distinct industries. The third generation of wireless communications, and mobile internet and multimedia, are examples of current favorite topics of the press, industry visionaries, management consultants and best-selling populists. The lavishly presented visions of a "mobile information society" indicate clearly, that the two topics, wireless communications and the information society, are closely related.

The massive amount of writing on the information society has been very much a result of sociologic, philosophic, and political discussion. It has separated into many directions and is so broad, that a comprehensive view is almost impossible to acquire. The industry and other technology creators, on the other hand, seldom focus very much on the social aspects, leaving their messages about building the information society generally on a rather general and technology-oriented level.

Therefore, concise overviews that draw together the evolutions of wireless communications technology and the information society, and introduce the reader to the central concepts of the current development as well as their relations to each other, are rare.

The need for such representations is strong at the moment. The topics and the continued development of them touch most fields of economic, industrial and societal activity somehow. It is generally accepted that the currently ongoing transition, resulting in a knowledge-based information society, can bring enormous benefits to societies. Decisions made and actions taken today may affect the evolution considerably. Therefore individuals active in various fields need to have a basic understanding of the topics, their relation to each other and the factors influencing their combined evolution.

This study is motivated by the need described above. It is done at Nokia Mobile Phones, where the fast change of the technology and business environment, as well as the rapid growth both in profits and people makes it even more crucial to have concise material to share the basic understanding required.

1.2 The objective of the study

The objective of this study is to give the reader a broad view of the developments, key concepts, and technologies related to information society evolution, with a focus on the wireless communications technologies and their role in the evolution process. Giving perspective, it aims at assisting people active in the industry, the public sector, and in other fields as well, by providing a base for their continued work and thinking.

Questions addressed in the study are:

- How have the information society concept and the related technologies evolved to their current state?
- What is the role of wireless communications in the evolution?
- What are the current prospects for wireless communications technology development?
- What are the forces influencing the adoption of new technologies and their applications by the users and markets?

1.3 Scope and structure

This study builds on existing literature incorporating insights arising from the author's participation in vision and strategy work in the wireless communications industry.

The issues can be approached from a large number of dimensions. In this study, the viewpoint is that of a technologist, and although issues traditionally belonging more to the domain of social sciences are addressed, these will not be given thorough coverage. On the whole, the study aims at being on a reasonably general level, allowing readers not earlier familiar with the information society concept or with telecommunications technology to find it useful.

The study is organized as follows:

Chapters 2 and 3 present overviews of the evolution of the information society concept as well as the developments in technology related to the information society evolution.

Chapter 4 discusses the major trends that shape the wireless communications industry, and chapter 5 presents the actually foreseeable developments of wireless communications technology.

Chapter 6 discusses the forces and factors that influence the adoption of new technologies in the markets. Finally, chapter 7 summarizes the study and presents the conclusions drawn.

2 The information society

2.1 Definitions of the concept

The term Information Society appears constantly in contemporary discussion. It is stumbled upon in newspapers, magazines and books, in academic research papers, in political declarations, as well as in visions of enterprises. The difficulty to define the concept is well characterized, and at the same time the content of it somewhat clarified, when investigating the following examples of other names that have been used to describe the latest development stage of western societies: communication-, interaction-, automation-, postindustrial-, specialist-, service-, immaterial needs-, postmodern-, or learning society.[1]

The European Commission high-level expert group on the information society defines the information society as: "the society currently being put into place, where low-cost information and data storage and transmission technologies are in general use. This generalization of information and data use is being accompanied by organizational, commercial, social and legal innovations that will profoundly change life both in the world of work and in society generally."[2]

This definition is somewhat mechanistic, originating from the use of technology and leading to changes which are not very well characterized. The high-level expert group continues by stating that there will be different models of information society, and that when referring to the European information society, the emphasis should be on the social dimension.

In the latest revision of the Finnish national information society strategy, titled "Quality of life, knowledge and competitiveness", this social dimension is illuminated more. The Finnish strategy describes information society as being a society where "knowledge is the basis of education and culture and the most important production factor. Information and communications technology (ICT) significantly promotes interaction and exchange

[1] Mannermaa, M. 1998. Pages 70-71.

[2] European Commission, 1997. Page 15.

between individuals, business enterprises and other organizations, the utilization of information, and the provision of services and access to them."[3] This view, having been formulated one and a half years later than the definition by the European Commission, manages to bring a deeper social dimension into the concept.

2.2 Evolution of the Information Society concept

In the following, the evolution of the Information Society concept is outlined. The description of the development until 1990 is based mainly on overviews by Martin,[4] Nevalainen,[5] and Mannermaa.[6] It is by no means complete, but highlights some of the central contributions to the evolution.

2.2.1 The first decades

The concept of the information society emerged in the 1970s and throughout the 1980s. It rapidly became widely accepted. The contributors to the discussion and writing on the topic have ranged from scholarly and academic writers to best-selling populists.

Information and the information society were discussed in many fields during the first decades, and especially social scientists were able to predict the increase in the importance of information and knowledge rather well. One of the important early writers was Yoneji Masuda, who perceived the transition to the production of information values becoming a key force for the development of society, and wrote in 1971 about *Information Villages* as the social system of the future. The term *Information Society* was made familiar especially by Daniel Bell, although he apparently felt uneasy with the term himself and talked rather about the *postindustrial society*. Gradually, the concept became rather well understood, and the press covered it extensively.

In 1976, the French Simon Nora and Alain Minc published their work "L'Informatisation de la société".[7] This work introduced the term telematics to combine the fields of

[3] SITRA 1998/1.

[4] Martin, W. 1995. Pages 2-16.

[5] Nevalainen, R. 1999.

[6] Mannermaa, M. 1998. Pages 70-97.

[7] Nora, S. and Minc, A. 1978.

telecommunications and informatics, which would, according to the writers, initiate a new source of societal innovation. Very soon, the report led to the initiation of a massive project called the Minitel, a character-based public information service network accessible over the telephone lines. The Minitel system is still in use in France. Although it now can be regarded as "Stone Age telematics", along with other investments it made France a leading information society until the 1990s.[8]

Two writers who have done much to popularize the concept of the information society are Alvin Toffler and John Naisbitt. Naisbitt, in his 1982 book "Megatrends", recognized the computer as the liberator moving society from an industrial to an information society, and argued that the USA made this transition already in the 1960s and 1970s.

Alvin Toffler in turn characterized the technology-driven changes to society as the Third Wave of social evolution, meaning the transition to an information-based era.[9] The earlier waves were the shift from nomadic to agrarian culture, and the industrial revolution. The Second Wave witnessed technologies centralize and produce conformity, as masses of people came together to produce and consume masses of products. This standardization also determined how we handled information. A small number of publishers and even fewer networks determined what information was disseminated. Thus a shared information experience resulted, making publishing and broadcasting a unifying force in society. Toffler talks further of an information bomb exploding among us and of a resulting power shift in society, making the situation opposite to the Second Wave. He calls this "demassification". Examples of demassifying forces are for example CNN and cable networks – the earlier few television networks determined the shared experience of nations, now a large number of channels fragment this experience. Local radio stations have done the same.

The ideas presented were immediately attractive to the public. Since they also were presented colorfully and with high confidence, they fed imagination and helped sustain the vast amount of writing that followed. Not much effort was, however, put into definitions or deep categorizations. The focus tended to be on broad trends and on their implications on life.

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[8] As an anecdote illustrating the French attitude today, president Jacques Chirac has been quoted to having, as late as in 1997, dismissed the Internet as an "Anglo-Saxon network", and also to having declared the Internet as "a major threat to humanity". (Cairncross, F. 1997. Pages 95 and 180)

[9] Toffler, A. 1980.

One effort to define the information society, already a while after the initial writings was presented by William Martin in 1988. He defined the information society as "…a society in which the quality of life, as well as prospects for social change and economic development, depend increasingly upon information and its exploitation. In such a society, living standards, patterns of work and leisure, the education system and the marketplace are all influenced markedly by advances in information and knowledge. This is evidenced by an increasing array of information-intensive products and services, communicated through a wide range of media, many of them electronic in nature."[10]

This definition – although lengthy – takes a creditably broad position and clearly sees the societal dimension in the information society, instead of focusing on technological or economic aspects only. At the same time it illustrates well the diffuse nature of the concept and the confusion researchers and writers faced. Perhaps partly for this reason, Martin states in the 1995 revision of his original 1988 work that "… no attempt will be made to repeat the definitional exercise six years later…".[11] When examined closer, the definition has essentially a very similar content as the Finnish national information society strategy of 1998.

2.2.2 The digital era of the 1990s

In the 1990s, the concept continued to evolve faster. It acquired more flesh and blood, much due to the development of technology. The advances in personal computer technology and the emergence of new means of communications, for instance the increasing adoption of local area networks, modems and later wireless telephony for connecting the computer to remote servers and networks, and especially the rapid adoption of the Internet, started to prove that the earlier enthusiastic visions might be conceivable after all.

Underlying the technology developments was digital electronics. One of the most popular and influential writers in the field during the 90's has been Nicholas Negroponte, head of the MIT Media Lab. His best-selling book 'Being Digital' (1995), is based on the idea that the main focus of economic activity in society is shifting "from atoms to bits", following the

[10] Martin, W. 1995. Page 3.

[11] Martin, W. 1995. Page 3.

advancements in digital technology enabling an increasingly large proportion of products and services to become digital content of the information networks.[12]

The Negroponte ideology addresses the fundamentals of the information society, as it in a very simple and popular way distills one element, which is both the enabler and the result of the ongoing development. When a content item is digitized, it is reduced to its essence in information. If the object is by nature information-based, this digitalization will eventually be possible. Negroponte's writings also provided the public with understanding about the reasons behind the "demassification" concept Toffler introduced in 1980. This has continued to happen even faster during the 1990s thanks to the Internet, now threatening practically all determinants of shared information experiences in the fields of publishing news, magazines, books, music, videos etc.

An important player in the demassification process is also telecommunications. Since information becomes meaningful only in a particular context and when fuelling the creation of knowledge, information needs to be available, accessible and transferable between devices and users. Therefore, communications plays a crucial role in the information society. In the 1990s, a massive evolution has happened in this field as well.

2.2.3 National information society strategies

These developments led also governments to become active in the topic. Many countries commenced a number of projects to address the question of harnessing the information society development into good use and to create national and regional information society strategies.

In Japan, information society has been built with determination with the government and the enterprises co-operating since the early 1980s. In the USA, President Clinton and vice-president Gore launched the "Information Highway" -process, which led to a large amount of strategic writing. The basic ideas introduced by these American strategies have since spread around the world. In Europe, the designing of information society strategies originated from the so-called Bangemann report, the "White paper on growth, competitiveness, and employment" published by the EU in 1994.[13] This work was continued

[12] Negroponte, N. 1995.

[13] Bonn, M. 1996. Page 2.

by a high-level expert group, which published its final report "Building the European information society for us all" in 1997.[14]

In Finland, the work started immediately after the 1994 Bangemann report, and the first national strategy, "Suomi tietoyhteiskunnaksi; kansalliset linjaukset" was published in 1995.[15] Other countries have followed, including for example Sweden and Norway in Scandinavia, or Singapore in Asia. Since the field is very fast developing, it is no wonder that for example Finland has already published a revised version of the strategy, and that the work continues around the world.

The national strategies and the vast amount of work behind them have made practically every member of western societies aware of some transition going on. The information society concept itself has during the 1990s evolved to become even more difficult to define than during the earlier decades, but at the same time it has matured significantly. The new Finnish national strategy illustrates this well. It does not even mention a definition; instead it starts by describing what are the characteristics of an information society. The understanding has developed to realize that life will essentially be the same, and that information in the concept does not mean information technology, i.e. the new era will not be a computer society. Instead, the social aspects and possibilities for an enhanced quality of life for individuals, enterprises and societies are emphasized.

2.2.4 A summary of the current understanding

The current global understanding of the nature of the information society is summarized rather well in the various national strategies. The main points could be compressed into the following:

- An increasing portion of products and services can be produced, distributed and consumed electronically in digital format using information technology and networks.
- There will be a continuous increase in the interaction between individuals, enterprises and various communities as well as in the distributing and sharing of information

[14] European Commission, 1997.

[15] Valtiovarainministeriö, 1995.

- Information and knowledge become the fundamental elements of all activity, the main factor of production, source of competitiveness, economic growth and employment.
- As a result the scope of most activities expands from local or regional to global. This globalization affects information and content, economy, technology, R&D, lifestyles, consumption, regulation, and environmental problems, among others.
- The enabler for these developments is new technology making it possible to digitalize all information-based products, services and activities and handling the storage and distribution effectively.

The current development can be seen as a process, where a transition from the industrial society to the information society is happening. The driving forces for change are the globalization of economy and the fast development of information- and communication technologies. Figure 1 depicts the evolution.[16]

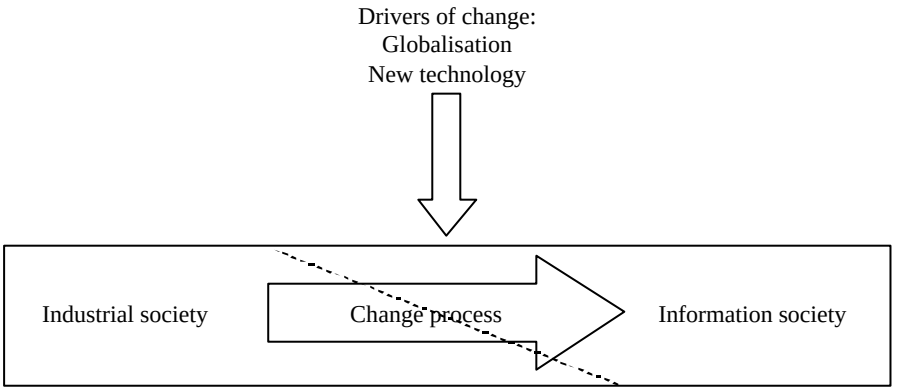

Figure 1. The information society process.

2.3 Information, knowledge and communication

Without the uninterrupted flow of information, society would quickly run into difficulties. Business and industry, education, leisure, travel and communications, national and international affairs, everything is vulnerable to a disruption in this sense. In more advanced societies, the vulnerability is heightened by the degree to which information really

[16] Hautamäki, A. 1999. Pages 15-19.

has become the "lifeblood of modern societies".[17] Even if the current discussion mainly sees information important in advanced societies, this is not the only case. All societies have been largely dependent on information, from those of the hunter-gatherers to the wired cities of today.

2.3.1 Perceptions of information

There are many different perceptions of information. A few of these are presented in the following.

The mathematical theory of communication, by Claude Shannon in 1948 has been highly influential in information definitions, despite the fact that the information in that case was a technical concept, completely lacking semantic content.[18] Shannon's theory applies the concept of entropy to the measurement of choice and uncertainty, where uncertainty was the measure of the statistical independence or degree of freedom of choice present in the selection of a message. A message whose content is known in advance gives little information. This is the case for example with a weather forecast stating that the sun will rise. But if the forecast predicts a tornado with high confidence, the amount of information is significantly higher. Thus, the less likely the message, the more information it conveys. Information measure must therefore be related to uncertainty. The greater the degree of uncertainty, the smaller the amount of information in the message.[19] Information in the sense Shannon defines it, can therefore be seen as the *reduction of uncertainty*.[20]

Information can also be seen as *a thing*. Information can be tangible, as opposed to knowledge, which is rather intangible by nature. In order to communicate knowledge it must be expressed or represented in some physical way as a signal, text or communication. Any such expression constitutes *information as a thing*.[21]

If information is seen as something tangible, the next step is to see the economic dimension of the perception and use of it. Information can thus quite naturally be seen as a *resource* or a *commodity*. The notion of *information as a resource* is very suitable in the current age of

[17] Martin, W. 1995. Page 18.

[18] Martin, W. 1995. Pages 20-21.

[19] Carlson, A. B. 1986. Pages 559-565.

[20] Martin, W. 1995. Pages 20-21.

[21] Martin , W. 1995. Paegs 20-21.

global information and communication flows. Regardless of the intangible nature of this resource and the fact that it is not directly treatable in economic terms, a plethora of national and international laws and policies exist to control trade in information and goods and services associated with it. The notion of *information as a commodity* is wider than the treatment of it as a resource. Viewing information as a commodity is related closely to the concept of value chains, as commoditized information increases its value as it flows through the various steps of the chain.[22]

2.3.2 Information and communication

There is intuitively a strong link between information and communication. Communication can be simply defined as the process of transferring data or information from a sender to a receiver. Communication starts, when the sender wants to influence the receiver, or the receiver needs information from the sender.[23] Communication can also be seen as the process through which individuals in relationships, groups, organizations and societies create, transmit and use information to organize with the environment and one another.[24]

It is important to re-emphasize the essentially social nature of the concepts of information and communication. All human relations can be depicted as a complex system of communication, involving nations and individuals, organizations and institutions in a continuing process. All types of communication can be regarded as a series of exchanges involving sharing expertise or attempting to learn from, or influence on, the opinions or behavior of others.

Information is central to such processes. Also important are the implications of the constantly expanding and increasingly sophisticated selection of technologies, which can be used to mediate the communication process and to transform it through the creation of new media and the facilitation of new relationships. It is clear that societies will change due to these developments. The evolution can lead either to more open and rational societies, or to a future where information users become information consumers through the privatization and commercialization of information.[25]

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[22] Martin, W. 1995. Pages 19-20.

[23] Halme, S. J.,1998. Page 10.

[24] Martin, W. 1995. Page 26.

[25] Martin, W. 1995. Pages 28-30.

2.3.3 From information to knowledge

In the vast amount of literature on information theory, -philosophy, -society and so forth, a common view is to make a hierarchic distinction between data, information and knowledge. Generally it is accepted that the generation of data does not automatically lead to the creation of information, and information can not be equated with knowledge. In everyday practice, knowledge is regarded as a higher order concept than information. A plethora of definitions and theoretical models exists of the relationships between data, information and knowledge, as well as additional related concepts as wisdom. Investigating these definitions deeply is beyond the scope of this study, and therefore only a brief overview of the discussion around the topic and the most commonly accepted relationships is presented.

Almost anything from printed characters and spoken words to DNA can be regarded as data. In the shape of recorded symbols, data can be things in themselves without any real world referent. Information in turn can be regarded as that property of data, i.e. the recorded symbols that represent the effects of processing them. Thus, information denotes any input that alters the cognitive content of the receiver's mind. Something that the receiver already knows, is not information according to this view. The understanding can be seen as knowledge, where the effect of information may actually change the knowledge. Information and knowledge are seen as mutually exclusive, where information is data and knowledge is concluded essence. Knowledge is the result of the understanding of information that has been communicated and integrating it with previously understood information.[26]

This view leads to the understanding that knowledge is the rational use of information. The challenge of individuals in the Information Society is to transform the mass of information available (and practically flooding over) into knowledge.[27] This transforming of information to knowledge can in fact be understood as learning. The view of the information society as a learning society has been widely adopted.[28]

[26] Martin, W. 1995. Page 25.

[27] Wheeler, T.E. 1995. p.59.

[28] European Commission, 1997. Page 17.

2.4 Towards a knowledge-based economy

The evolution of the information society is really a manifestation of a more profound change. The technology and tools are central characteristics and enablers of an information society. But as the conceptual development described in the previous sections already indicates, the fundamental element is not the computers and networks or the use of them. It is the fact that these enable a society where a major part of the activities is based on the communication of information and especially knowledge instead of dealing with physical resources and products.

Knowledge is fast becoming the driving force of economic growth, social development and employment and also the primary source of competitiveness in the world market. The industrial society relied on capital and resources, and especially the ownership of productive means as the key factors of production. In the emerging knowledge-based economy and society, information and knowledge constitute the key factors of production. The ideas of Karl Marx seem to become reality now, when more or less all countries have abandoned them, as workers really become owners of the factors of production, their brains.[29]

The recognition of knowledge as a central resource in society is by no means new. Western scholars have long been fascinated by the idea of a knowledge-based society. For instance, already the founding fathers of the United States of America saw knowledge as the key to building prosperity in society. The U.S. Constitution marked the world's first right of a citizen to own intellectual property: "To promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries;" [30] [31]

At the time when the USA was founded, the world had just started the transition towards the industrial society. What we now call information- or knowledge-intensive sectors was still something very distant. They have emerged mainly during the last decades along the advances in high technology.

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[29] Neuvo, Y. 1998.

[30] Ungson, G.R. and Trudel, J.D. 1999. Page 60.

[31] The United States Constitution. Article I, Section 8, Clause 8.

The knowledge-intensive sectors working mainly with information and communication technology have a high employing effect. The recession in Finland in the first half of the 1990s acts as a concrete example. Few actually realize how total and deep the recession actually was. In two years, Finland's GDP dropped by 14%. By way of comparison, the effect of the US depression in the 1920s was only half of this. What is remarkable is that knowledge intensive companies were able to constantly increase employment even throughout the recession. This process has accelerated since 1994. Some empirical evidence suggests that for each new job created directly in the knowledge intensive sector, half to one and a half indirect jobs are generated in subcontracting and related business services. In total, 120,000 new jobs have been created in Finland since 1994. A rough estimate is that two thirds of these are the result of this ongoing process towards a knowledge-based information society.[32]

Also inside traditional industries, a change towards knowledge-intensity is happening. Earlier, industries could be classified according to distinct, corresponding technologies. In the 1970s, single-technology products dominated: chemicals, metals, plastics and drugs. In 1990, complex multi-technology products were prominent: consumer electronics, computers, cars, airplanes, and telecommunications. Today's products are also more complex in their content. For half a century, the value-added to cars came from steel. Today, the greatest value-added is in the area of software, electronics and exotic materials. This applies not only to the end product, but to the tools used to make it as well. Table 1 illustrates how key characteristics of industrial and business activities have evolved during the past 400 years, and how they will continue to evolve in the upcoming century.[33]

Characteristics	**17th–19th century**	**19th–20th century**	**21st century**
Basis of competence	Factor-based	Machine-based	Knowledge-based
Product mode	Craft/factories	Automation/ hierarchies	
Scope	Local/regional	Regional/national	Global
Industry classification	Distinct; single	Distinct; multiple	Diffused; architectures

Table 1. The transition to a knowledge-based economy illustrated by selected characteristics of different eras.

[32] Neuvo, Y. 1998.

[33] Ungson, G.R. and Trudel, J.D. 1999. Page 62.

2.5 Information society in action

From the previous sections it should be clear that when speaking of an information society, the technology is not the point. Neither is information or knowledge in itself. Life in the information society will essentially be the same, but new technology will reduce the physical, resource based portion of services and other activities, thus increasing the importance of information and knowledge as keys to prosperity and quality of life.

2.5.1 Key services

To identify what services are expected in the information society, the latest national strategies provide a good base. They comprise the distilled perception of a large range of visionaries, specialists and policy makers and should therefore provide a good understanding of the wishes and needs.

Finland has been at the forefront of both technological development and also public activity considering information society evolution. Therefore, the Finnish strategy in many ways has a comparably clear view of what is expected of the evolution. Figure 2 illustrates the service framework for the Finnish information society presented in the national strategy published in 1998.[34]

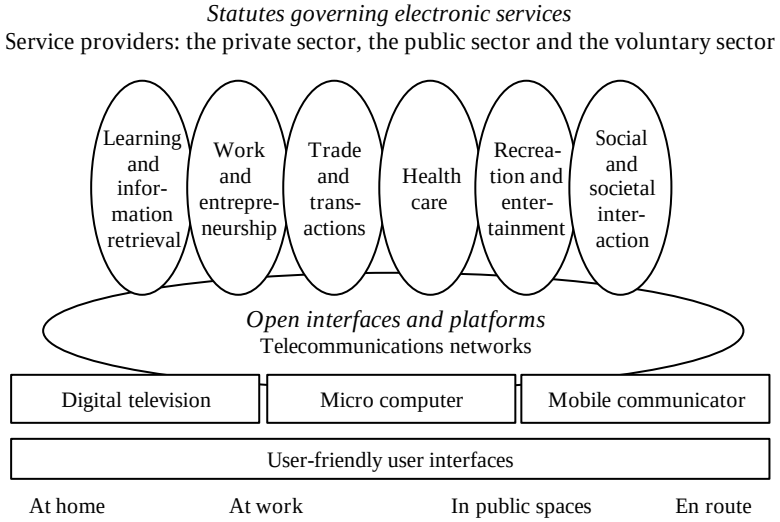

Figure 2. ICT in the service of man. The information society service framework presented in the Finnish national strategy.

[34] SITRA, 1998/1. Page 9.

According to the Finnish national strategy, information and communications technology needs to be placed in the service of man. In the information society, an increasing portion of all services is available electronically anywhere, anytime. The Finnish national strategy identifies six key service areas. The service providers are equally industry and commerce, the public sector, and organizations. The service areas are: [35]

- Learning and information retrieval
- Work and entrepreneurship
- Trade and transactions
- Health care
- Recreation and entertainment
- Social and societal interaction

These service areas are seen to be supported by the unified and open service interfaces and platforms created by telecommunications networks. Three types of terminals provide access to the networks: digital television, personal computers and mobile communicating devices. All terminals need to provide a user-friendly user interface. Through this array of terminals, access can be offered everywhere; at home, at the workplace, in public spaces and en route.[36]

Tangible examples of services belonging to the above categories and typical to the information society are presented in abundance in the literature and the public discussion. Common examples are e-mail, information retrieval, videoconferencing, virtual meeting spaces, tele-education, electronic banking, Internet shopping and electronic commerce, telework, telemedicine, online public services, traffic control and information, democratic participation, televoting, and so forth. Most of these are already in use at some level.

2.5.2 Key solutions

What are the key areas the telecommunications and information networks, as well as other technology and applications need to address to make such an information society reality? Based on the discussion above, five central requirements are proposed in the following.

[35] SITRA; 1998/1. Page 9.

[36] SITRA, 1998/1 Page 9.

The fundament is the global information and telecommunications network, which enables access to information resources, content, services, social entities, individuals, and other areas of activity. The connection needs to be, as specified in the framework, based on open interfaces and platforms, to enable access with any kind of device over all kinds of physical links. Any kind of content needs to be transmittable. Thus it is appropriate to broadly summarize this requirement to ***multimedia communications.***

In order to make it possible for an individual to be present in the electronic networks as smoothly, securely and reliably as in the physical counterparts, solutions for identifying the individual are necessary. This is required in all applications and services where it is crucial to identify the user, for example when using public services. Thus another central requirement is ***electronic identification.***

A sustainable electronic content and service environment will not be realized unless the electronic environment works according to the same economic principles as the physical world. Commerce, trade and the transaction of monetary assets need to become electronic. Therefore, it is essential to have working solutions for ***electronic money, commerce, and banking.***

As information becomes a central resource, easy and efficient management of it becomes critical. Tools for navigating in the information resources available and for building personal information bases and structures for easy further use will be essential. A fourth central need is thus to have excellent solutions for ***information and knowledge management***.

An increasing part of human activity will at some point need access to the information resources. Access cannot be restricted only to the home, the workplace or some other place or places. The more dependent society and its individuals become of the networks, the more critical it is to have a possibility for ***anytime, anywhere access.***

Table 2 summarizes the five key solutions identified above.

Key enabling solutions for the information society
Multimedia communication
Electronic identification
Electronic money, commerce, and banking
Information and knowledge management
Anytime, anywhere access

Table 2. Summary of the key solutions enabling information society.

From these key solutions it is evident that, even if the fundaments of information society are social, technology is essential in enabling the whole process. The following chapter describes the evolution of technology which has led to the current situation and which broad technology trends are driving the development onwards.

3 Digitalization and convergence

The enablers for the information society evolution process as described in the previous chapter are the astonishing advancements in technology that have happened during the past 50 years. In this chapter, an overview of that development and some key phenomena that arise thereof are presented.

A trend gaining stronger and stronger momentum is that of *convergence*. The term is used almost as extensively as that of the information society, with as many perceptions and interpretations resulting.

The solutions and technological characteristics of the information society are largely built on the convergence of three industries. These are telecommunications, originating from the telephone launched in the 1890s, broadcasting, based on the radio and the television dating from the first half of the 20th century, and personal computing that emerged in the 1980s. Originally, their product content and technologies were as distinct as those of, for example, the airline and pipeline industries were.[37]

The topic of convergence has been around for decades. One of the pioneers in presenting the concept was NEC Corporation. In 1977 the company first adopted "C&C", meaning "Computers and Communication" as their corporate slogan. NEC management foresaw many of the basic drivers pointing to convergence:[38]

> *"As digital technology finds its rightful place in communications, communications technology will inevitably converge with computer functions, and communications networks will become capable of more effective transmission of information. With distributed processing systems linking a group of processing units, the computer will become highly systemized and inseparable from communications."*

[37] Collis, D., Bane, P. and Bradley, S. 1997. Page 160.

[38] Yoffie, D. 1997. Pages 4-5.

Convergence arises from the parallel advancements in two fields: computing and transmission technology. The advancements in computing have their origin in the evolution of microelectronics, and the transmission technology owes its progress notably to the improvement in bandwidth capacity through the use of fiber optics and compressing capabilities.[39] [40]

As already the NEC vision from 1977 mentions, digitalization is a central element in the process. All content, be it text, voice, audio, video, which previously was analogue and required specialized hardware for manipulation and transmission, becomes technically the same through digitalization – bits. These can all be manipulated with the same equipment and transmitted over the same networks.[41]

The importance of the digital revolution for the information society evolution is that it alters fundamentally the availability of information in time and place. An especially important characteristic is also that it dramatically reduces the cost of providing the information for the user.

Therefore, it is evident that digitalization and the trend of convergence are very fundamental phenomena for the information society evolution process. In the following, the key technology concepts and their developments are examined more thoroughly.

3.1 The fundament – microelectronics

3.1.1 The transistor

It is easy to point out one single innovation in history, which has influenced our current society perhaps more than anything else. It is the transistor. Born on Christmas Eve in 1947 at AT&T Bell Laboratories, the transistor has become the main building block of all electronics products, and has significantly contributed in making electronics the second largest manufacturing industry in the world. The reason for this is the transistor's

[39] Collis, D., Bane, P. and Bradley, S. 1997. Page 160.

[40] As compressing capabilities again are related to the advancements in computing hardware and software developments, we see that there is a strong symbiose, or convergence, in the separate fields over a long time.

[41] The concept of digitalization and its implications has been covered extensively in the literature. Good introductions are, for example: Negroponte (1995), Downes&Mui (1998), Cairncross (1997), Makimoto & Manners (1997), and Yoffie (1997).

capability of effectively representing the ones and zeroes in the binary language of the digital world. Simplified, it is a fast and cheap switch, which can either be turned on or off to correspond to 1 or 0. What has driven this development has been the transistors' ability to be constantly miniaturized. The Bell Labs' original transistor was the size of a thumbnail, while a billion transistors today fit into the same space on a single silicon chip. The rate at which transistors and chips shrink has been predictable for the last 30 years.[42]

3.1.2 Moore's law

In April 1965 G.E. Moore, then director of Fairchild Semiconductor, predicted that the number of transistors that could be put on a chip would double each year. Later, in 1975, he returned to revise the trajectory to state that the number of transistors per chip would double every 18 months.[43]

This famous prediction is generally known as "Moore's Law". Today, after 34 years of its introduction, it has been referred to in so many different instances, that it will probably soon replace Ohm's law as the first thing electrical engineering students learn. The following recent quotation of Moore himself illustrates in its own way the omnipresence of the phenomenon.

> *"The definition of "Moore's Law" has come to refer to almost anything related to the semiconductor industry that when plotted on semi-log paper approximates a straight line. I don't want to do anything to restrict this definition. – G.E. Moore, 8/7/96."* [44]

The primary enabler of the trend described by Moore's Law has generally been regarded as the industry's ability to keep shrinking the feature sizes used in building integrated circuits at approximately a rate of 0,7× every three years, corresponding to each technology generation. There has been an approximately equal contribution from the rate of increase in chip size, also at about 2× every three years.[45]

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[42] Makimoto, T. and Manners, D. 1997. Page 74-75.

[43] Bondyopadhyay, P. K. 1998. Page 80.

[44] Handwritten note by G.E. Moore published in: Bondyopadhyay, P. K. 1998. Page 78.

[45] Chatterjee, P. K. and Doering, R. R. 1998. Page 176.

A key element in Moore's law is that this doubling of transistor capacity has been achieved without any significant increase in production cost. Consequently, in the last 40 years, the cost of a transistor has dropped to a ten-millionth. A popularized comparison with the automotive industry illustrates the dimensions of the development. With the same progress as the microelectronics industry has shown during the last 50 years, a Rolls Royce would do a million miles per hour, run half a million miles per gallon and would cost less than it costs to park it.[46]

3.1.3 Microprocessors

The microprocessor was the following revolutionary innovation after the transistor. Electronic devices had always been based on circuits designed for one particular purpose. At Intel, the idea came that instead of making special circuitry for separate functions in a device, one chip could be made that could do everything if the design was done with software. The first controller chip of this kind, which became the world's first microprocessor, was built for a Japanese calculator manufacturer, Busicom. Since then, the microprocessor has changed the whole electronics industry. The characteristics that distinguished one electronic product from another could be written in the form of software instructions while the controller chips could remain the same.[47]

The microprocessor brought with it a significant reduction in cost for electronics manufacturers, mainly in two ways. Firstly, design became cheaper, as the design of a custom chip is a rather big effort. Now the electronics manufacturer only needs to design the software. Secondly, economies of scale make manufacturing large quantities of identical processors very cheap compared to making a small amount of custom chips. Thus the products become significantly cheaper.

It is said that the invention of the microprocessor was as important as Gutenberg's printing press. The printing press gave the great mass of the population access to books, which had previously only been available to priests and nobles. The microprocessor gave the people access to computing power, which had previously only been affordable for companies and governments.[48] Thus, the microprocessor is one of the very fundaments in making the

[46] Makimoto, T. and Manners, D. 1997. Pages 73-75.

[47] Makimoto, T. and Manners, D. 1997. Pages 121-122.

[48] Makimoto, T. and Manners, D. 1997. Page 125.

information society really a society for all, and remains very central to the information and communication technologies.

3.1.4 Challenges

Currently, a certain anxiety exists among specialists on how Moore's law can continue to be valid in the future. Potential technology barriers arise from physical limitations of matter, and the major challenge is whether there is an ability to continue affordable scaling. An immediate concern is that the lithographic techniques used for manufacturing the chips are approaching their limits. The current deep-ultraviolet exposure tools will reach their physical limits as feature size approaches 100 nm. More distant problems, in view after year 2006, involve physical barriers relating to delay, capacitance, crosstalk etc.

The physical barriers mentioned above are coming together in the interconnects. The signal propagation delay over interconnect lines becomes a relevant issue as gates continue to shrink and become faster. Delay is not the only problem. As interconnects also shrink and come closer together, previously negligible physical effects like crosstalk become significant. Crosstalk arises when a signal travelling down one line is coupled by the capacitance of the active line to a quiet neighboring line, which can for example reset a latch and thus cause an error in the function of the chip.

This is a new situation for designers, as such problems did not exist earlier. There seems, however, to exist solutions to these problems to take the industry below 100 nm line width. New schemes for clock and signal communicating within chips, 3D architectures for active interconnect systems, and new technologies like optical interconnect or on-chip RF connections are currently under research.[49]

In addition to the problems related to technology and basic physics, a threat is posed by economics. The capital investments required for building the fabrication facilities for semiconductors are also growing exponentially with each technology step. It is not altogether certain that the industry will be able to generate the capital necessary. If this is not the case, it will have significant impact on the evolution of technology as well.[50]

[49] Hamilton, S. 1999. Pages 43-48.

[50] UMTS Forum, 1999. Page 31.

Regardless of the problems, physical and economical alike, the industry is rather optimistic with the future and is determined to take Moore's law into the next century.

3.1.5 Digital convergence

Convergence is not happening only on the level of originally very dissimilar technologies and industries. It happens also inside the actual products.

The development of microelectronics enables digital devices to become continuously smaller and more integrated. Color TV's, video recorders, video cameras, laser printers, fax machines, scanners and mobile phones have been reduced from luxury items to commodities. Radios, cameras, calculators, watches and clocks have been reduced from commodity items to giveaway consumables. The ability to reduce all these products to a single, pocketable item is within sight.

As the number of transistors on one chip keeps increasing, so does the complexity and performance level of a device which can be implemented on a single chip. A simple electronic product like a calculator or a digital watch needs a few thousand transistors, and with the order of 100 million transistors the complexity and performance level of a modern personal computer is achievable. When more and more transistors are squeezed onto each chip, fewer and fewer chips are needed to make a product. When, finally, the number of chips in a product is one, the price becomes very low.[51]

Such affordable, one-chip devices behave like single components. They can easily be joined to form new multi-purpose devices. These devices and their applications converge to form new classes of digital, personal tools.[52]

Probably, the generation currently in their teens will be able to amaze their children with tales of their youth when the telephone, the television and the computer were all separate pieces of equipment performing unique functions. The impact of affordable processing is such that it eliminates entire technologies and the businesses on which the technologies were based.[53]

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[51] Makimoto, T. and Manners, D. 1997. Page 76

[52] Neuvo, Y. 1999/1.

[53] Wheeler, T.E. p.59.

The technology area, which has most directly developed hand in hand with microelectronics, is computing. In the next section, the advances in computing are outlined.

3.2 Advances in computing

The history of the computer and closely related industries during the last fifty years falls into three time periods. The first began in the early 1950s, when the established electrical equipment and business machinery companies that had started making computers for military and government purposes started to enter non-governmental engineering, industrial and commercial markets. The second period began in the mid-1960s, when IBM invested massively in new products and processes and created the System 360. The third period, in turn, started in the early 1980s as a new product, the microcomputer, began to challenge large, general-purpose systems.[54]

This third period is the most important from the point of view of this study, since precisely personal computing is the one, which has been part of the convergence process. It also coincides in the timeline with the adoption of the information society concept in general. The diffusion of the computer to every desk in offices and at home has been building the actual applications and solutions as well as the public understanding of the information society concept little by little in a concrete way.

3.2.1 Hardware

Since the introduction of the personal computers, the key development is the absolute increase in performance. This development was already discussed in conjunction with microelectronics and microprocessors. Also compared to size and price, performance increases. Therefore, the trend has been towards downsizing, with smaller and more powerful machines replacing the larger ones. Mainframe computers start to be very rare except in very extensive power-consuming calculations like airline reservations and banking applications. Personal computers are today gaining territory even in these fields, as the power increases.

Desktops are increasingly substituted for laptops, and even smaller laptops, so called notebook or sub-notebook computers increase in popularity as the earlier inferiority to

[54] Chandler, A.D. 1997. Pages 37-122.

desktops in processor performance, disk storage space and display characteristics is gradually diminishing. The key driver in the progress towards portable computers is the user appreciation of mobility.

The so-called Personal Digital Assistants or PDAs form a young class of computing devices. These were originally built around calendar and notebook features, but have lately increasingly incorporated even light software applications for word processing and spreadsheet calculations. Along the lines of convergence, they also start to offer connectivity to data and telephone networks for fax, email and Internet access.

Data storage

An essential part of the computer is the ability to store the vast amount of data used. The development of secondary storage[55] has been very central to the information society development. The uncountable Internet hosts for example all have data stored on hard disks, accessible from any computer in the world attached to the web. Increasingly, these hard disks are not only for storage of local information, but essential components of the global pool of information.

Secondary storage consists mainly of magnetic media in the shape of hard disks. Optical storage, namely the CD-ROM has also become very popular as a means of distributing software and data, as the discs are cheap and provide an easy and efficient distribution media for software vendors.

Secondary storage capacity will be a critical factor even in the future. The growing amount of multimedia in the content of the information networks requires vast amounts of storage capacity. Magnetic discs continue to be the main medium. The new MicroDrive launched by IBM boasts a record-high storage density of 775Mb/cm^2. Digital Versatile Discs (DVDs), the successors to CD-ROMs offer a storage capacity of 8,5 GB on one side, and both can be used. DVDs exist also in writable format, but a common standard is still lacking.[56] Further advances will include for example holographic storage on a plastic disc, expanding not only the storage capacity but also makes the reading significantly faster.[57]

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[55] Primary storage refers to the actual memory of the computer.

[56] Dutta-Roy, A. 1999. Pages 49-50.

[57] Martin, W. 1995. Pages 41-42.

Peripherals

Various computer peripherals have had a high influence on how the information and communication technologies have developed and been taken in use. Until the beginning of the 1990s, the computer was more or less the traditional package with processor, memory, secondary storage, keyboard and display. But then, multimedia made its entrance, influenced mostly by games and other entertainment. This also influenced the Internet content after the World Wide Web was introduced. Currently most PCs are sold with multimedia equipment, i.e. a sound card, often with advanced synthesis and signal processing capabilities, and a graphics board with a separate processor and memory taking care of the graphics output. A modem or an ISDN adapter has also become more or less the standard as access to the Internet is seen as a key use of the computer.

3.2.2 Software

The advances in computing industry naturally originate from hardware. But the information society development is at least as much dependent on the advances in software.

Software can be divided into two categories. The first, “information highway software”, is being developed to enable the information superhighway to function as more than a simple data transmitter. It combines elements of both transmission and manipulation. The second, the “traditional manipulation software”, includes operating system software and stand-alone applications.[58] In this section, the manipulation software is omitted, and only some relevant developments in the information highway software are described.

Databases

As elements of the global pool of information, databases and database management software are intuitively relevant. Not long ago, databases were automated or manual stores of records. The development has led to a more multifaceted content, consisting increasingly of a mixture of data, text, image, graphics, voice and multimedia. This kind of more diffuse and more difficulty recordable content strongly influences the database management software.

[58] Collis, D., Bane, P. and Bradley, S. 1997. Pages 176-180.

Developments during the personal computer era have been for example those of the introduction of text based systems being able to manage free-form text instead of rigidly structured records and relation databases.

The largest database in the world has become the Internet, where all connected hosts act as parts of a vast, decentralized system. Finding information in this endless pool requires efficient searching techniques. *Hypertext* is the basis for the Internet database management. It applies a combination of both document and database systems and allows exploration of the information content through associative links. The approach provides the integration of text, pictures, sounds, data and multimedia into one package. The content of the endless databases is handled as "pages", screenfuls of text and images with the possibility to have moving pictures and sound embedded in them.

Search engines and agents

Finding anything specific on the Internet only through browsing through links is rather impossible, as it is also in local databases. Therefore, the approaches for searching information have evolved much during the Internet era. *Search engines*, like AltaVista by Digital have influenced daily computer use dramatically. They keep track of the content of the continuously changing web pages, and thus provide an intermediate database where the user can run the searches and then proceed through hyperlinks to the actual pages where the content is found.

But as the information keeps multiplying exponentially, even advanced search options tend to be insufficient. Therefore, the development points towards *intelligent software agents*, which are personalized pieces of software designed to help the individual improve the way they organize their own computing. Typical tasks for agents could include filtering e-mail, scheduling appointments, making travel arrangements and finding information from the databases of the Internet. They will also have to be able to assist in finding answers to questions when the user is faced with an overwhelming mass of sources. Although still in their very infancy, much effort is currently put into the research of intelligent agents and *data mining*.

3.3 Advances in data transmission

It can be claimed that telecommunications has become the true catalyst for change in society. The building of the information society has been very much a product of technological determinism. At first the effort was a result of the developments in computing, but along the deepening of convergence it has increasingly been affected by the advancements in telecommunications. Most current visions of the future claim that in the future, everybody will have access to virtually unlimited information. The universal telephone service is converging with the world of data communications, and will eventually be replaced by universal information services.

The basic telephone service has remained essentially much the same since its launch in the end of the 19th century. As long as the only content transmitted was voice communication, the development at first focused mainly on making the switching easier and smoother, and later on making the sound quality better through terminal and network technology. But the physical links themselves have stayed largely as the same kind of copper wires for over one hundred years.

Copper cables have been the major medium for data transmission during the whole existence of electronic communications. Copper continues to be used, and so does coaxial cable for local environments where high-speed data traffic and television signals are required. However, fiber optic cable and the related equipment have diminished in price significantly, and have been installed into large parts of new networks. New state of the art digital cables are running under the oceans between Europe and the USA, and between Japan, Australia and the USA. These provide very reliable circuits for fast transmission.[59]

Broadband cable networks have the potential to carry a wide spectrum of services with bandwidth unsurpassed by any wireless alternatives. Thus, cable continues to be used and new developments in bandwidth are likely to be seen, although wireless communications grows its share of traffic.

In order to increase the bandwidth to allow efficient data communications, many developments have been made during the past decades and years. Some of these, as well as some future solutions based on other physical channels as the existing copper wires are

[59] Martin, W. 1995. Pages 66-67.

presented in this section.

3.3.1 Integrated Services Digital Network (ISDN)

The Integrated Service Digital Network, or ISDN, is a service enhancing the capacity of the traditional copper wire phone line significantly. The basic rate service offers two 64 kbps B channels and one 16 kbps D channel (2B+D).[60] The B channels provide transparent digital transmission of voice or high-speed data. The D channel provides a non-transparent channel for signaling, telemetry and low speed packet switching. Compared with even fastest modems currently, ISDN offers superior transmission quality and speed. Although ISDN has existed a long time, it has started to gain popularity among users only in the last few years. Many telecom operators have in fact begun marketing the service only recently, and the price for upgrading a traditional phone line into an ISDN service is still comparably high, even if the cost for the operator is very low.[61] [62] This is in a way surprising, since the rapid diffusion of ISDN services among users would very much speed the overall information society process, and would most certainly benefit the operators. All in all, however, ISDN has represented the first possibility for private users to connect to the Internet and other data services digitally and with adequate speed. The popularity is growing accordingly.

3.3.2 Asynchronous Digital Subscriber Line (ADSL)

ADSL, standing for Asynchronous Digital Subscriber Line, is a very promising technology to provide a fast local loop connection. Relying on the same old copper wires as ISDN, it increases the maximum data rate to 6 Mbps downstream and 64 kbps upstream. This makes it very suitable for the envisioned future applications, where a home user downloads large amounts of data in the shape of video and multimedia services on demand, while the upstream transmission remains at a more modest level, consisting mainly of email and internet queries. The maximum distance is approximately 3600 meters, which is estimated to be near enough to a trunk-line telephone cable connection to allow 80% of the developed world's 560 million people to adopt ADSL. Over 30 network operators in Europe, the USA,

[60] There is also a more advanced service available, which in europe offers a (30B+D) channel structure.

[61] Martin, W. Pages 75-76.

[62] Makimoto, T. & Manners, D. Pages 105-106.

Asia and Australia have already performed ADSL trials, and commercial deployment should not be far away.[63] [64]

3.3.3 Asynchronous Transfer mode (ATM)

ATM has been described as "…the definitive technology for high-speed digital networks, the springboard to the next great leap forward in telecommunications". ATM can be regarded as an improvement of ISDN for widespread applications. It is a set of international standards that define a new method for sending large quantities of multimedia information over networks. It provides a common transport mechanism for digital communications traffic, regardless of whether it takes place between computers on a LAN or across a public telephone network. Information is broken up into packets or cells, each labeled with an address. The initial data rate offered by ATM is 155 Mbps, and it has the potential to be increased up to 2,4 Gbps.[65] [66]

ATM is easy to install and maintain, as it uses standardized components and can run on existing fiber networks.[67] Its real advantages to consumers are that it is packet-switched and provides a true integrated service, capable of eventually taking over all the functions of the existing networks.

3.4 The Internet

In this section, we turn to the networking phenomenon that has created the backbone and become one of the most important enablers of the entire Information Society - the Internet. Few phenomena have acquired as much coverage in the media ever before.

[63] Makimoto, T. and Manners, D. Pages 106-108.

[64] Martin, W. 1995. Page 73.

[65] Fist, S. 1994. Pages 37-41.

[66] Martin, W. 1995. Page 76.

[67] Fist, S. 1994. Pages 37-41.

3.4.1 Internet origins and evolution

The origins and evolution of the Internet have been described in many instances in the literature. The following summary is based mainly on overviews by Cairncross and Downes & Mui. [68] [69]

Many of the Internet's most important characteristics existed well before the invention of the World Wide Web in 1989. The roots of Internet are in the late 1960. At that time, computers were large, expensive, and scarce. The American Defense Department's Advanced Research Projects Agency (ARPA) backed an experiment at the small company Bolt Beranek and Newman (BBN), to connect computers across the country as a way of multiplying their power. By building electronic links between machines, researchers in different universities could share resources and results. The computerized switch that was the basis for the national network, called ARPANET, was installed at UCLA in 1969. The ARPANET was the foundation for the Internet, which now is a global network of both commercial and non-commercial computer networks. The size of these networks ranges from enormous to very small, all linked by a web of leased telephone lines.

The founding idea was, though, not only sharing scarce computer capacity. The Cold War was a central driver as well. Two key technological aspects of the Internet are that it is distributed and packet-switched. Already in the early 1960s, Paul Baran at Rand Corporation was interested in designing a communications system that could survive a nuclear attack. The idea for the solution was distributed networks designed like a fish net, instead of the centralized topology of telephone networks. If one link in such a network would be knocked out, a message could always take an alternative route. To make this traveling easier, the second idea of Baran was to split the message into fragments and send each other separately. A network of digital switches, or computers, would read the address on each message and send it on to the next junction. This process would be repeated at each junction, until the message reached its destination. There, other information encoded in the message would allow it to be reassembled into its original form.

This system of transferring split messages is called *packet switching*. The packets of an Internet message can be slotted into continuous streams of bits. Compared with circuit

[68] Cairncross, F. 1997.Pages 87-118.

[69] Downes, L. and Mui, C. 1998. Pages 23-33.

switching used in telephone calls, where a circuit is established and kept end to end for the actual call alone, it is very bandwidth efficient. Now packet switching has become the main way to send data around the world.

The Internet is built on a single standard. The original reason for this is political: the U.S. Defense Department, being the world's largest buyer of computers in the late 1960s, was compelled by law to be fair to competing computer manufacturers, and since a large variety of machines existed, all with different operating systems and standards, a common standard had to be designed to get the computers connected. The first real protocol was completed in 1971. The protocol that now dictates the format in which all data is packaged for the Internet is TCP/IP, formally introduced in 1983, the date usually taken as the Internet's proper starting point.

An important characteristic of the Internet is its public nature and freedom. The protocol has emerged from public funding and academic research; it is public property, available for anybody to use for free. Throughout the early 1980s, the main users were large research universities, who connected their Ethernet-based local networks to the Internet. This open quality has stimulated much creativity. The Internet has no central command. Even if the traffic mainly runs on lines leased from telecommunications companies, they neither manage nor take responsibility of it. Nobody owns, runs, maintains or regulates the Internet. Anybody can send a message, create a site, or place a file for anybody's use on a computer accessible by anyone. The few decisions that need to be taken centrally, on issues such as refining the protocol or establishing principles for allocating addresses or domain names are taken by a handful of specialists who run the Internet Society and some other bodies. The approach is, however, very informal and permissive.

3.4.2 The World Wide Web WWW

Even if Internet technically had been around for years, and the use of it actually doubled each year throughout the 1980s and the early 1990s, it wasn’t really until the launching of World Wide Web (WWW) it really exploded. The WWW itself was invented in 1989 by Tim Berners-Lee, a British researcher at CERN in Switzerland. The Web sprang to life in 1993 through the creation of the graphical browser called Mosaic. The creator was the young programmer Marc Andreessen in the University of Illinois, together with his

colleagues. The Mosaic browser was commercialized in 1994 as the Netscape Navigator.[70] [71] It became possible for the Internet to accommodate on-line graphics, sound, and moving pictures in an easy to use way. This made the Internet significantly more versatile and more interesting to look at. It allowed easy, mouse-controlled navigation from one screenful or "page" of information to another, even if the pages were physically situated on different computers in different parts of the world.

The growth of Internet during the 1990s has been remarkable. Figure 3 illustrates the development of the number of host computers on the Internet.[72] The main driver for this growth has undoubtedly been the WWW.

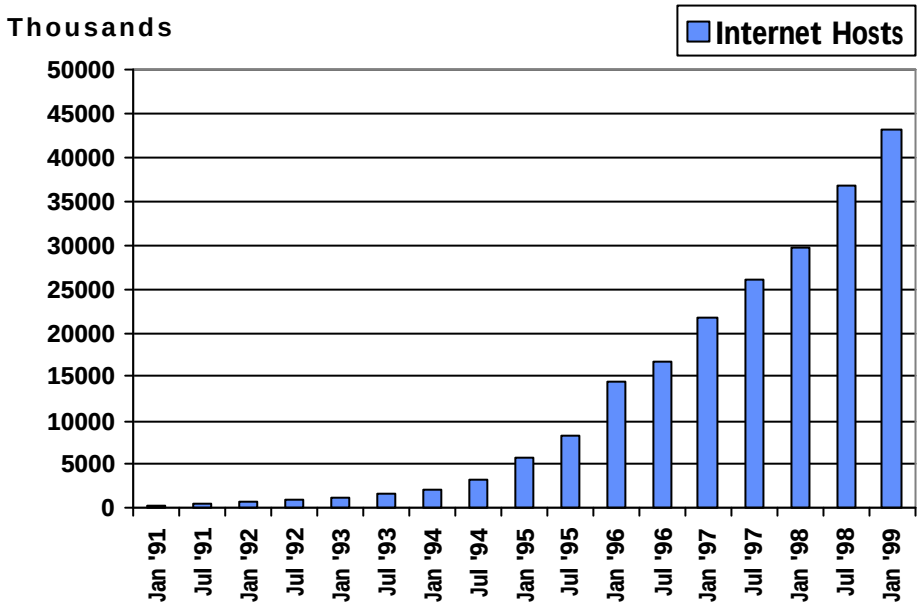

Figure 3. Growth of Internet hosts during the 1990s. Source: Network Wizards.

3.4.3 Metcalfe's law – explaining the growth

Moore's Law governing the evolution of microelectronics and being the basic enabler of digital convergence has an equivalent in explaining and illustrating the exponential growth of networks, and especially the Internet. Moore's Law can be used to explain why the technology is rocketing away and why more and more killer applications of the converging

[70] Cairncross, F. 1997. Page 11.

[71] Downes, L. and Mui, C. 1998. Pages 23-28.

[72] Network Wizards, 1999.

electronics are presented. But it doesn't explain why these applications spread and are taken in use as quickly as they do. This is where the so-called Metcalfe's law is illustrative.

Robert Metcalfe, founder of 3Com corporation and the designer of the Ethernet protocol, observed that new technologies become valuable only if many people start to use them. Specifically, he suggested that the usefulness, or utility, of a network equals the square of the number of users. This function is known as Metcalfe's Law. The more people who use a software, a network, a standard, a game, or a book, the more valuable it becomes, and the more new users it will attract, increasing both its utility and the speed of adoption of even more users. [73] If only two persons have a telephone, for example, the usefulness is rather limited, but with a million-subscriber network, not to mention virtually anybody in the world, the utility for a single user approaches the infinite.

3.4.4 The uses of Internet

The Internet and the services it offers are instrumental in the evolution of the information society. The Internet combines the computer's ability to process and store lots of information at low cost with the telephone network's ability to reach millions of people around the globe. It has thus multiplied the capacity of both sorts of networks. Unlike the telephone and television, however, the Internet has no established principal use. Instead, it has many uses, including carrying telephone calls and television programs. It is an open medium, capable of transmitting anything in digital format.[74]

Some of the already central and some promising future uses are presented in the following.

Electronic mail

The most useful and also most popular Internet service has undoubtedly been electronic mail. The first electronic mail was sent in 1972, and today hundreds of millions of e-mail messages travel each day around the world. Various sources support the importance of e-mail as the central Internet service. One study found that two-thirds of those who use Internet for e-mail at work do not use any other feature, [75] another observed that 93% of internet users had used e-mail during the past week which was clearly the highest

[73] Downes, L. and Mui, C. 1998. Page 24.

[74] Cairncross, F. Pages 87-89

[75] Cairncross, F. 1997. Page 104.

percentage among the alternatives.[76] Coupling the ability to send a message with the perfect reproducibility of digital information, e-mail makes sending information in various forms virtually free.[77] From large business documents to private messages, from drawings and snapshot photographs to software files – everything can be sent in an email message either to one or multiple recipients without the cost and work of physical transactions. In the near future, new applications like electronic bills are taken in use, making the versatility even higher.

Finding information

The Internet has brought with it the ability for anybody to access virtually unlimited information in an affordable way, armed only with a mouse and a keyboard. Most of the available information is free. Advantages are many. Information that previously was too difficult or too expensive to collect and distribute can now be made available instantly and accessible to everybody.

In the ocean of information now flooding over the Internet, search skills and tools are essential. The first tools to facilitate this are the various indexes and directories kept on different sites. The homepages of individual users constitute the simplest forms. The best known commercial index is Yahoo!, which sorts sites into categories much like books in a library. Search engines, like AltaVista, Lycos, and Infoseek, send software "spiders" out into the web to follow every link on every page, and create databases of the results. When a search engine user types in a few key words, the search engine returns a link to every web page recorded in its database that contains those key words.

Indexes and search engines still are rather primitive means of finding the relevant information from the vast amount available. The intelligent software agents that are very much under development are among the solutions promising a bettering of the situation.

Telephony

Using the Internet costs only a fraction of the price of an international telephone call. Still, the traffic is mainly carried over lines leased from telephone operators. This price gap is an obvious point to make use of. The worldwide market for voice telephone services is worth

[76] TEKES, 1999. Page 70.

[77] Cairncross, F. 1997, Page 105.

around 600 billion USD.[78] Only a small part of that would change the value of the Internet enormously. Internet telephony, or IP telephony as it is called due to the transmission protocol used, is currently a very hot topic in the information and telecommunications industries. Already, several companies exist that offer the possibility to call any normal telephone but using the Internet as a transmission network. The sound quality has been dreadful, but is developing constantly. IP telephony is expected to grow significantly in the near future. There are also solutions offering companies the possibility to route internal calls over the Intranet, thus making only one network required inside the office.

Radio & Television

The improvement of audio and video coding efficiency makes it possible to use the Internet also as an inexpensive way to distribute radio programs. The RealAudio software by Progressive Networks allows streaming of audio, i.e. listening to the audio stream as it is transmitted, and not requiring it to be downloaded first. Radio stations operating in this way over the Internet have started to emerge. For example, the Finnish national broadcast company's popular music-oriented channel "Radio Xtrem" in Swedish, started sending their entire program also over the Internet in the winter 1998-1999. Since the streamed transmission can also be stored for listening later, radio-on demand is also possible.

The same development is in sight with the TV. Already a few years ago, certain special occasions have been "webcast" over the Internet. The characteristics of an Internet radio station apply also to a TV station. The problem with both applications is transmission capacity – a station becomes easily jammed, if it becomes popular.

Electronic commerce

The Internet is fast becoming a place for economic activity. Electronic commerce is currently growing at a high speed, and is fast changing the whole established way of doing business. Therefore it is no surprise, that electronic commerce, or e-commerce, has been one of the hottest buzzwords lately, generating a plethora of articles, books, and business seminars.

[78] Cairncross, F. 1997. Page 107.

This is no wonder, since the Internet is an ideal medium for bringing buyers and sellers together. A customer can find information about products easily, there is no need for moving or calling around.

Naturally, the medium is ideal for distributing products and services that are in digital format. But also physical goods are experiencing a rapid growth in the Internet marketplace. The possibility to order goods through the Internet and get them delivered straight to the home saves large amounts of time, effort, and money. It also diminishes traffic, as everybody does not need to circulate around a number of shops to collect what is needed. The delivery can be arranged in a more rationalized way, thus making e-commerce an economical as well as ecological solution. Items that suit especially well for Internet ordering seem to be those that are information-based otherwise as well, like books and records. Companies like the bookstore Amazon.com, and the record shop Boxman are among those that have grown very fast.

A significant impact of the Internet on business is that any enterprise, regardless of size, can be present in global markets. In this way even products and services targeted to a small niche group can attain a sustainable market.

An increasing amount of the services available through the Internet require a way of collecting the payment from the customer. Credit cards have been used much, and when security issues with sending the card number over the networks now begin to be solved, it looks certain that credit cards will be an important method of payment even in the future. But many payments are very small, as in the case of ordering one piece of music, or one stock quotation, or one screenful of news headlines. In the future the revenue generated by one customer visiting the electronic marketplace needs to be split into many small parts and allocated to the various players along the value chain. Therefore, solutions for micropayments are under development.

A key issue in the development of the whole information society is that the security level of monetary transactions needs to be the best possible. Otherwise the services will not gain the trust of the users. Since most of the envisaged future services require some form of payment logistics to be interesting and viable in the long run, this really is one of the absolutely most crucial topics to be addressed, and which requires actions not only from the industry, but from governments and policy makers as well.

3.4.5 Network convergence

As the Internet is becoming the Network of all Networks, the backbone of Information Society visited by most communicated bits at some stage, it also plays a central role in the convergence development. Currently, the various network players in the various fields of communications are striving to expand their territories.

There are already several telephone operators offering international calls utilizing IP networks at some point. At the same time, radio and television channels increasingly offer their content also through the Internet. And when possible, other players than telephone operators offer Internet access, the most obvious being cable TV operators.

In this way, not only the actual devices converge, but networks as well. From the user point of view, the whole technology infrastructure between the user and the content becomes increasingly transparent. The three major network industries are expanding their territories and converging, as illustrated in Figure 4.

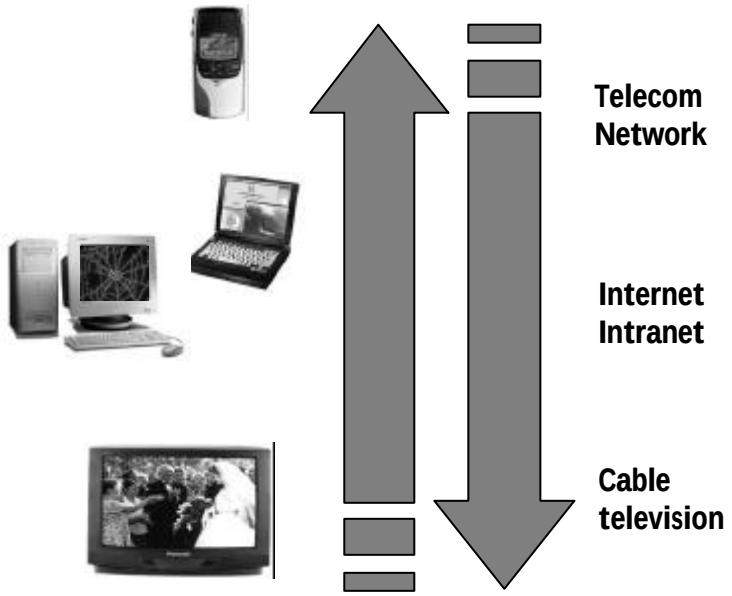

Figure 4. The networks are converging.

3.5 Wireless Communications

3.5.1 Nobody loves to be wired

Alongside the Internet, the second major disrupting technology solution of the 1990s has been wireless communications. From the introduction of the handheld cellular telephone in the late 1980s, the technology has evolved from an expensive gadget, mainly for business use, to a very commonplace and affordable device used by everyone.

The growth in mobile phone use has been of the same order of magnitude as the growth of Internet use. Where the Internet has actually become the backbone infrastructure of the various information society services, mobile phones have become the personal communications terminals of choice.

This is due to the fact that communications in order to really satisfy the needs posed by the way of life in the information age, needs to be completely untethered. The *anytime, anywhere* access to the global information networks and services is not complete if a fixed wire connection is required. Wireless communications is the glue, which ties together the computing and communications technologies. Together with the increasing digitalization and the Internet, wireless communications is a key in building a working information society environment. The case supporting wireless communications and explaining its success reduces to a very simple observation: *Nobody loves to be wired!*

3.5.2 Mobile market trends

Penetration

Cellular telephone penetration has been increasing with an astonishing speed along the growth of the sales volumes. In the most penetrated markets cellular phones have already exceeded fixed telephones in penetration. Such a country is, for example, Finland, who has shown the highest penetration figure in the world for some years. In March 1999, the penetration in Finland surpassed 60% of the whole population. Figure 5 shows penetration levels of some of the major cellular markets in the world.

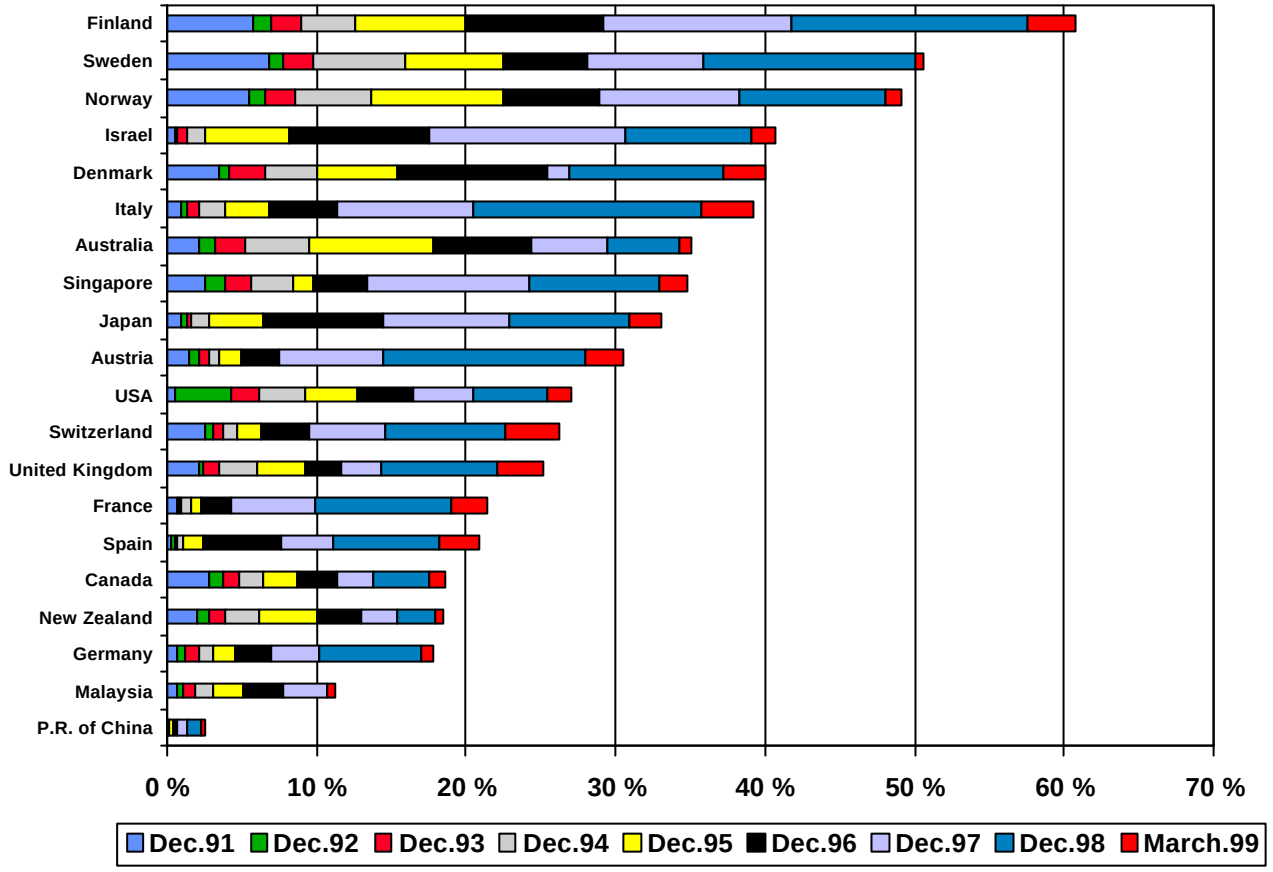

Figure 5. Global major markets cellular penetration in the end of March 1999.

The point in time when mobile telephone penetration surpasses fixed lines is in many markets rather close. In Finland this has already happened.

Market volume

In 1998, 163 million cellular phones were sold worldwide. This was more than the combined sales of personal computers and passenger cars being approximately 90 and 34 million, respectively. Figure 6 illustrates the development in the sales during the 1990s.[79]

[79] Neuvo, Y. 1999/2.

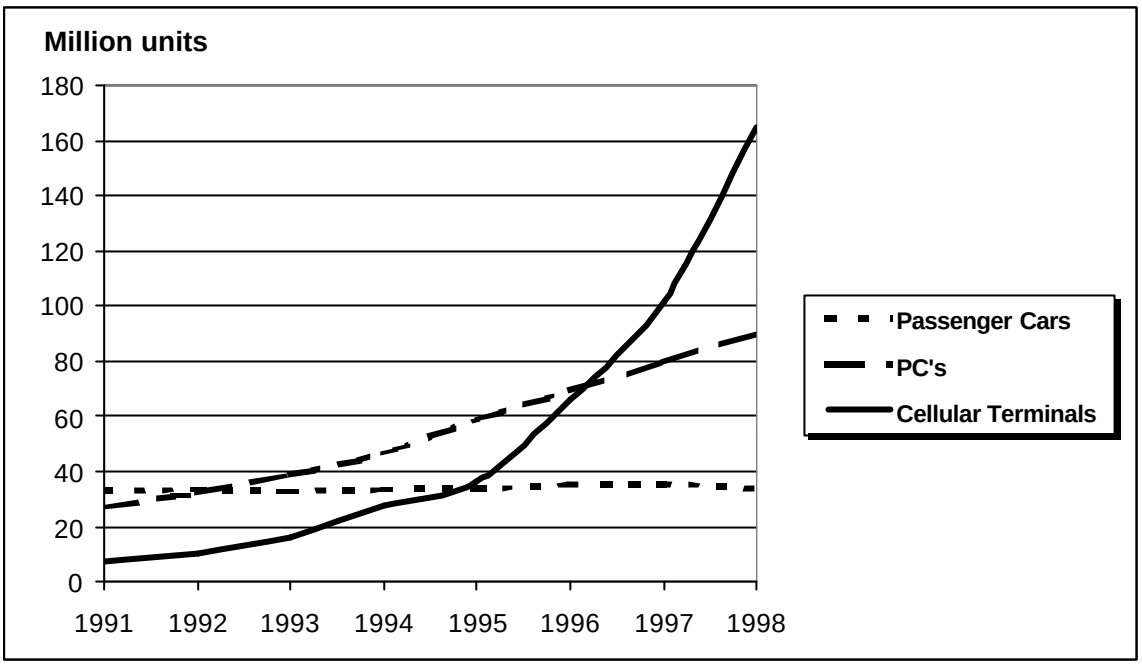

Figure 6. The development of the annual sales of passenger cars, personal computers and cellular phones.

One might argue that the products are completely different and that their volumes cannot be thus compared. This is indeed true, one cannot claim that they are comparable for example as investments. The figures are, however, illustrative and come as a surprise to many people considering especially the car as a very high volume item.

Several forecasts of the development of the wireless markets have been presented. The UMTS Forum forecasts a total of 1,73 billion users of terrestrial mobile services by year 2010. Table 3 displays the forecast in detail.[80]

Physical users in millions	2000	2005	2010
Europe, EU15	113	200	260
North America	127	190	220
Asia Pacific	149	400	850
Rest of the world	37	150	400
Total	426	940	1730

Table 3. Forecast of physical users of terrestrial mobile services including multimedia.

3.5.3 The nucleus of convergence

As fixed and mobile networks converge, integrated mobility services will be provided. These offer the benefits of mobility and personalization and allow the user:

- to access some services via either a fixed or mobile terminal
- to be contactable anywhere regardless of location
- to modify their service profile to meet their own personal preferences and needs.[81]

The mobile phone is the only of the current technical devices that can offer the required anytime, anywhere access to the information networks. It is also already the most personal electronic device. This personality is even increasing. The social necessity to have a mobile phone increases as penetration levels rise, and more services and information migrate to the domain of the mobile. In such an environment the phone becomes a commoditized instrument of self-expression much like clothing and watches. This can already be seen in high-penetrated markets like the Scandinavian countries. The market volumes already indicate that the mobile phone and its future evolutions are the most common information devices. They are affordable, accessible to all, and natural to own.

The mobile phones of today provide a natural starting point for personal management of information society tasks and services. Therefore, it is rather clear that the future personal wireless communications device is the nucleus of the convergence evolution.[82] The other terminals, mainly the digital TV and the PC, will certainly remain important. However, they will assume roles of specialized secondary devices for services, applications and situations where the wireless terminal cannot be used due to bandwidth, location, ergonomic, or other special reasons. The first choice, however, will be the wireless device.

[80] UMTS Forum, 1999. Page 9.

[81] UMTS Forum, 1999. Page 18.

[82] Alahuhta, M. 1999.

4 Wireless communications trends

As the information society evolution proceeds and convergence becomes deeper and wider, the role of wireless communications grows in importance. In the previous chapter, the wireless terminal was identified as the nucleus of convergence, the device becoming the most natural and important interface between individual users and the multitude of services offered over the global information networks. The basic mobile services that exist already will remain important. These are:[83]

Voice:
- Simple one-to-one and one-to-many voice (teleconferencing) services
- Voicemail

These services are tariffed on a per minute basis.

Messaging:
- SMS (short message service) and paging
- Email delivery
- Broadcast and public information messaging
- Ordering/payment (for simple electronic commerce).

These services are tariffed on a per message basis.

Switched Data:
- Low-speed dial-up LAN access
- Internet/Intranet access
- Fax

Legacy services – mainly using radio modems such as PCMCIA cards, are not expected to be very significant by 2005. These services are tariffed on a per minute basis.

In addition to the services existing currently, a number of new ones are emerging. The mobile phone is also growing in significance, as the identification of it as the nucleus of convergence predicts, and accordingly conquers new areas of activities and applications.

[83] UMTS Forum, 1999. Pages 18-19.

There are a few major trends in this evolution, which are described in the following three sections.

4.1 From voice to multimedia

During the whole existence of the telephone, voice services have been the central application of the technology. But this is changing rapidly. The development is clearly leading to a shift from voice only to a broader communication content incorporating text, data, images and video along speech.

It has been convenient for the telecommunications industry to make a distinction between voice, data and video. This distinction is becoming more and more blurred, as any content essentially consists of the same bits, and the different types are more and more used together in a single communication session. The trend is clearly towards an environment, where the communication between people and the usage of global information resources happens increasingly in a shape best characterized as multimedia. This has become evident especially during the last five years, when significant developments have occurred considering multimedia computing power, CD-ROM technology, digital television, the Internet/Intranet and IP-based services and mobile communications.[84]

A recent study by the UMTS Forum identified three market trends that will have the most significant impact on the size and nature of demand for mobile multimedia services:

- The market for fixed networked multimedia services is growing rapidly (Internet/Intranet).
- Computer-based communications is being widely accepted and embraced by society.
- There is growing demand for accessing both information and entertainment services while mobile.[85]

Most of the services developed and taken up by fixed network multimedia users will also emigrate to mobile multimedia. In addition a number of services will be developed specifically for mobile. It is also clear that the nature of the traffic flow and traffic distribution will have a significant impact on the quantity of spectrum required, and hence

[84] UMTS Forum, 1999. Page 11.

[85] UMTS Forum, 1999. Page 26.

on the cost of service provision. At present, spectrum is a scarce resource and a key constraint in the development of mobile networks. In order to capture this critical characteristic of the evolving market, three generic mobile multimedia service types have been defined:[86]

Medium multimedia (asymmetric)	Asymmetric services which tend to be 'bursty' in nature, require moderate data rates, are characterized by a typical file size of 0.5MBytes, with a tolerance to a range of delays. They are classed as 'connectionless' services and are tariffed on a per Mbyte basis. Examples of applications are: • LAN, and Intranet/Internet access • Application sharing (collaborative working) • Interactive games • lottery and betting services • sophisticated broadcast and public information messaging • simple online shopping and banking (electronic commerce) services.
High multimedia (asymmetric)	Asymmetric services which also tend to be 'bursty' in nature, require high data rates, are characterized by a typical file size of 10Mbytes, with a tolerance to a range of delays. They are classed as 'connectionless' services and are tariffed on a per Mbyte basis. Examples of applications are: • fast LAN, and Intranet/Internet access • video clips on-demand • audio clips on-demand • online shopping.
High interactive multimedia (symmetric)	Symmetric services which require reasonably continuous and high-speed data rates with a minimum of delay, and are tariffed on a per minute basis. Applications include:

[86] UMTS Forum, 1999. Page 19.

- Videotelephony and videoconferencing
- Collaborative working and telepresence.

The majority of what a person senses is received through the eyes. Thus it is clear that multimedia has extreme potential. The success of the WWW has already shown the ability of information networks to distribute multimedia content, and when this ability is integrated even in the mobile terminals, it is clear that eyes will become the main receptor of wirelessly transmitted content.

4.2 Internet to everyone's pocket

The Internet continues to evolve at an increasing speed. What started out as a campus experiment has become the foundation for the global information networks connecting the whole globe.

A plausible prediction is that there will be at least 500 million Internet and Intranet users worldwide by year 2005. This could be even more than the number of PC's in use, due to the fact that the PC will in the future be only one of the terminals used for Internet access. Televisions, network computers, handheld games units, and especially wireless terminals will also provide access.[87] Mobile Internet is indeed one of the hottest topics in the converging industries currently, and a plethora of initiatives for solutions have been presented.

Since the Internet is a packet switched network, it is clear that the current solutions for wireless Internet access based on existing wireless transmission protocols are not ideal. In order to utilize spectrum efficiently, and also enable pricing that is in line with the very varying nature of Internet traffic with large bursty downloads followed by long idle periods, packet switched Internet access would be needed as well. The General Packet Radio Service GPRS brings a much-needed advancement in this sense.

4.2.1 Wireless Application Protocol WAP

Mobile, handheld terminals are inherently handicapped compared to personal computers when it comes to accessing the Internet. The displays are small, typically 4 rows with 10

[87] UMTS Forum, 1999. Page 30.

characters, the graphics are limited, their UI is restricted as there is no full keyboard and no mouse, the CPU and memory of handheld terminals are inferior to PCs, and the data rates currently offered for transmission are way too low for enjoying the Internet content.[88]

WAP, or Wireless Application Protocol, is a protocol for adapting the Internet content to a format suitable for handheld mobile terminals, thus making it possible to surf the web and use the various services offered while on the move. The organization behind WAP, the WAP Forum, was founded by Nokia, Ericsson, Motorola and Unwired Planet, and has acquired around 100 members up to mid-1999.[89] The members have agreed to offer products utilizing the WAP protocol before the end of year 2000.[90]

WAP is to a high extent similar to the Internet protocol and its components. Instead of the HTML (Hypertext Markup Language) language used in the computer world, the WML (Wireless Markup Language) is used for creating the web documents. Due to the restrictions of the display, not able to fit web pages as such, the fundamental unit in WML is a *card*. Cards can contain for example a part of an html-page, or a part of a form. A larger entity is formed by a collection of related cards, called a deck. The content provider can also use WML scripts in the same way as in HTML and JavaScript to automate functions and sequences.[91] [92]

Figure 7 illustrates the WAP architecture. The essential part is the WAP gateway, to which the wireless client connects, which further connects to the required Internet site, and converts the standard pages written in HTML to WML, if necessary.[93] As WAP usage grows, more and more sites will be written in both WML and HTML already from the beginning.

[88] WAP Forum, 1998. Page 9.

[89] WAP Forum, 1999. Page 2.

[90] Nyman, B. 1999. Page 18.

[91] Nyman, B. 1999. Page 19.

[92] WAP Forum, 1999. Page 9.

[93] WAP Forum, 1999.

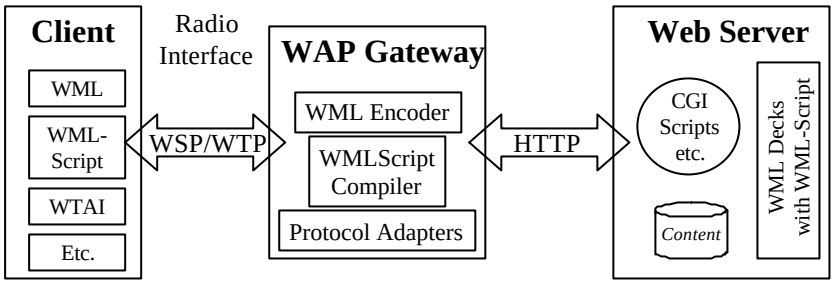

Figure 7. The WAP architecture.

WAP is currently a subject for tremendous enthusiasm and hype in the industry as well as in public discussion. The possibility to deliver advanced Value Added Services to mobile users has initiated a large amount of business activity, even if WAP terminals are not even yet available in the market. Figure 8 shows a picture of the first mobile phone with WAP capabilities, the Nokia 7110.

Figure 8. The world's first WAP enabled mobile phone, the Nokia 7110.

4.2.2 Mobile Media Mode; the WWW:MMM

As an effort to simplify the technical jargon and make mobile Internet more understandable and adoptable as a concept, Nokia, Ericsson and Motorola jointly announced the Mobile Media Mode (WWW:MMM) in March 1999.[94] The MMM has little to do with the technology solutions involved in making Internet mobile. It is more a marketing innovation, targeted at making MMM the symbol of mobile Internet, in the same way familiar as WWW is today in fixed-line Internet. It will for example become possible to have web addresses of the type *mmm.something.com*.

[94] Nokia. 1999/2.

4.2.3 Satellite based mobile Internet access

Mobile Internet is planned also to be offered through satellite based services. Although the economic success of even satellite-based mobile telephony is unproven, there are already three broadband satellite networks under construction (Spaceway, SkyBridge and Teledesic) with the target of providing internet access everywhere. For example Teledesic will work on a system of 288 satellites, and is expected to be operational in 2003. The business rationale behind such massive investments is that building a fixed broadband access network outside the most densely populated centers is too expensive, and thus it is wise to offer the access over satellites.[95]

4.3 From mobile phones to personal trusted devices

The mobile phone is evolving and continuously expands its territory. Not only from voice- and text communication to tasks earlier handled by the computer world like information access and multimedia communication, but also to incorporate areas of use which have earlier been handled by completely different items.

The mobile phone is already the most personal electronic device and that this personality is even increasing. This is natural, as more and more of the everyday tasks a person needs to handle evolve to be accessible and manageable through the personal communications device. That future device will incorporate the roles of many common personal items we today carry around and use constantly, as well as important items today staying permanently in the home. The trend clearly points towards the current mobile phone becoming a *personal trusted device*.

In the following, the various uses the future personal trusted device incorporates are described.

4.3.1 Dimensions of usage

There are various personal items and devices people use in everyday life, and which today are seen to eventually be overtaken by the personal mobile terminal, the personal trusted

[95] Raivio, J. 1999.

device. The uses of this device can be categorized into three dimensions. Figure 9 illustrates these. The framework presented in the figure is discussed in the following sections.

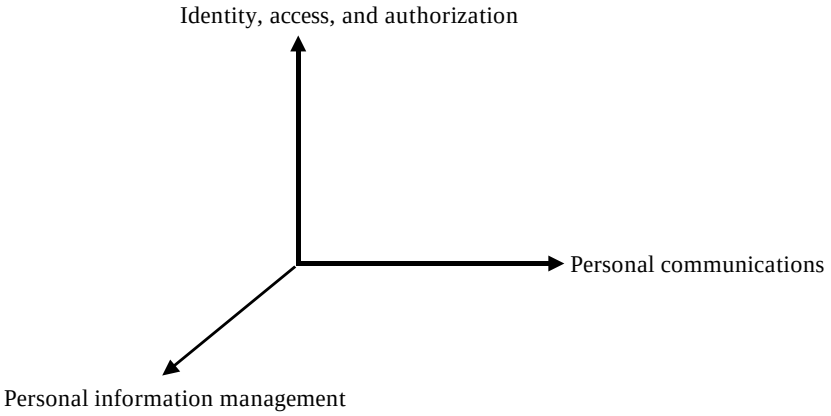

Figure 9. The dimensions of the use of the personal trusted device.

4.3.2 Communication

The first and most obvious usage dimension is personal communication. The mobile phones of today make up the origin for this use. Speech has been the main medium, and it will remain central even in the future. But alongside speech communication, text-based messaging has come up. The short message service SMS has created a new way of communicating, especially popular among the young. New classes of products, like communicators, have already incorporated fax and email properties into the mobile terminal as well.

The variety of means for communication, which become accessible from the personal, wireless terminal will increase. Apart from text and voice, images and video make their entrance into wireless communications. Image messaging, i.e. sending and receiving digital images, and video telephony are seen as very central applications of future devices.

4.3.3 Information management

Another dimension of user needs is managing information. Traditional means for this in portable fashion have been mainly the calendar and the notebook. In the world of digital devices, the PDAs have started out from this direction.

But personal information management includes more than just calendar and notebook activities. Newspapers, magazines, books, timetables, any form of information that the user carries along and needs while on the move is subject to this use. As communication technology increases in versatility, all information now accessible in some physical location becomes eventually accessible from a mobile device as well.

At first, this dimension was nonexistent in mobile phones. Gradually it has evolved, from the phonebook and storage of a few SMS messages in the phone, to the more advanced contacts directory, notebook and calendar features included in communicator-type devices and PDAs. Currently, Internet access and email handling through the personal mobile terminal is subject to growing interest, and with the foreseeable advancements in terminal and transmission technology, most of the information access, storage and management tasks now performed with a PC will shift to the personal wireless terminal.

4.3.4 Identity, access, and authorization

The dimension named "Identity, access, and authorization" has been minor until very recently, but will increase in importance significantly in the near future.

A major part of services coming available will require a possibility to link the user of the terminal to a piece of information existing somewhere, acknowledging the user with a right to do something. These kinds of links are currently physical items kept in the wallet. Examples are money, passports, driver's licenses, credit cards, bank cards, cash withdrawal cards, keys, various tickets and so forth. In the information society, the majority of these linking entities are required in the digital environment as well, and the specific information, related to the link in question, needs to be accessed and updated in real time.

The growing need for a possibility to identify the user makes solutions for this dimension essential. Electronic commerce requires solutions for monetary transactions or credit verification, an electronic identity is needed in most commercial and public services, and so forth.

5 Wireless communications technology

5.1 Terminal evolution

5.1.1 Hardware features

Convergence of the networks and applications, and the resulting growth of multimedia content delivered to wireless terminals leads to an increase in the functionalities of the wireless terminal. This means that the hardware features incorporated in the devices will also increase. Accordingly, the UMTS Forum has concluded that advances in semiconductor and user interface technologies are those most influencing the functionality, performance and cost of future terminals.[96]

Multimedia communications makes displays central. There is, however, a certain paradox with high-quality displays of adequate size, and the miniature environment of mobile devices. Display technology is therefore a topic for hectic development, and is evolving constantly. Examples of new display types are plasma display panels (PDP) and cholesteric liquid-crystal (CLC) screens.[97]

For visual input, cameras are also entering wireless communications. In their simplest form they will be small digital still cameras, usable for snapshots that can be sent over the network as electronic postcards or picture messages. An important application in the future will be video telephony, which in turn requires miniature digital video camera units.

Audio input and output are developing from supporting only voice services to systems with high-quality audio capabilities meeting the needs of the new multimedia services. Music, games and moving picture sound are among the applications requiring more advanced solutions than the current audio equipment designed for speech communication. The physical restrictions of the small devices are the main limit for audio as well. Alhtough headphones can be used, these are in many cases unconvenient in a mobile environment. Therefore the speakers integrated in the mobile terminal need attention. The capability of a

[96] UMTS Forum, 1999. Page 30.

[97] UMTS Forum, 1999. Page 31.

speaker to reproduce sound of a specific frequency is very dependent on the physical dimensions of the speaker. This means that low frequencies are a difficult task. Due to the necessity to produce physical movement, the battery consumption of high-quality audio is an issue requiring constant attention.

5.1.2 Hardware performance

The hardware performance requirements are growing as the features get more advanced. The beginning of the third generation of mobile communications has a large impact in this development as well. The entrance of high-quality sound, photographs and video to mobile communications makes a continuous improvement of processing power in the terminal necessary. Table 4 illustrates these developments.[98]

	2G terminal today	*2G terminal 2002*	*3G terminal 2002*
Memory size	4 Mbit	16 Mbit	64 Mbit
Radio channel	30 MIPS	30 MIPS	200 MIPS
Speech coding	3-30 MIPS	3-30 MIPS	30 MIPS
Voice control		50 MIPS	50 MIPS
Video coding			100 MIPS
CTRL processor	8-16 bits, 10 MHz	8-16 bits, 10 MHz	16-32 bits, 50 MHz

Table 4. Terminal technology today and in 2002.

Power consumption, cost and size of future terminals

The rapid evolution of DSP processors and ASIC technologies leads to the analog RF section becoming the biggest power consumer in normal speech terminals. The dominating power consumers on the RF side are the power amplifier and frequency synthesizers. The transceiver cost depends on every required component. So far, the division between analog RF and digital baseband sections has been roughly half and half. The trend points, however, towards the analog part growing its share as the integrated signal processing side is continuously shrinking and eventually reaches one chip. The actual analog and digital data processing functions, like encoding, decoding, filtering, mixing and equalization, are not very crucial in terms of the total terminal size. This may have been the case in the past, but today the dominant components are the battery and the interfaces. On the data path

[98] Neuvo, Y. 1999/2.

side, some components such as the duplex filter and possibly the antenna may occupy a large amount of space. Developing the first third generation mobile terminals is far from easy. They should incorporate all the current second-generation features, and also include new ones related to high data rates. Since users want to be able to connect to existing systems as well, dual- or multimode terminals are needed.[99]

	1992	1994	1996	1998	2000
Gate density (gates/mm^2)	2000	5000	15000	30000	50000
Processing power (MIPS)	20	50	80	120	200
Relative power consumption (1/MHz)	100	30	10	3	1
Relative power consumption (max MIPS)	100	75	40	18	10

Table 5. Development of DSP and ASIC technologies. [100] [101]

5.1.3 Operating systems

The mobile environment places special requirements as well as certain restrictions on the operating system of the device. First of all, the devices are small in size, with limited possibilities for UI realization and with a computing capacity far smaller than in personal computers. Secondly, the level of ease in using the device must be rather high, as the devices are targeted to a much wider group of users with less interest in digging into computer specialties than traditional information technology users have. Partly from this, but especially from the need to work in a reliable way in a multitude of conditions caused by the mobility of the devices, it is evident that the level of reliability must be on a completely different level than in traditional computers.

The operating system needs to be such that crashing and re-booting is virtually never needed. This is especially important as applications involving the transmission of personal information, identification data, money and access authorization increases.

Several proposals for the ultimate operating system for a mobile communications device have been presented during the last years. Of these, two are currently most likely to

[99] Ojanperä, T. and Prasad, R. 1998. Page 281

[100] Ojanperä, T. and Prasad, R. 1998. Page 281.

[101] Neuvo, Y. 1997.

succeed. It is still premature to say which one will emerge as the winner, as new moves to one direction or the other happen constantly.

Symbian EPOC

Symbian EPOC is an operating system optimized for the needs of wireless information devices. EPOC includes connectivity software for synchronization with data on PC's and servers. It is a full application suite including messaging, browsing, office, personal information management and utility applications. EPOC offers a flexible architecture and programming system to support compact but powerful software. Many languages are supported, including C++ and Java for the actual devices and Visual C++, Visual Basic and Delphi for PC-based connectivity or datasync programming. Also OEM tools for building and localizing wireless information devices are offered.[102]

The primary requirements for the design of EPOC arise from the specific requirements of small, portable, and battery powered wireless information devices. The primary requirements have been identified as:[103]

- effective use of battery power
- instant access to user data
- reliable handling of user data
- adaptability to different device types
- integration with other wireless information devices, handportable computers, PCs and servers
- communication using Internet and phone protocols

Symbian EPOC is backed by major cellular telephone manufacturers, for example Nokia and Ericsson.

Windows CE by Microsoft

Windows CE by Microsoft is another operating system platform for small communications, entertainment and mobile-computing devices. It has similar characteristics to EPOC in many ways.

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[102] Symbian Ltd, 1999.

[103] Symbian Ltd, 1999.

The Windows CE operating system is a 32-bit, multitasking, multithreaded operating system with an open architecture design, and suitable for a variety of devices. WinCE-based devices can communicate with each other, with enterprise systems and the Internet, and enables sharing and exchanging information with Windows-based PCs. Windows CE is designed to be compact for memory efficiency, scalable, and manages power efficiently.[104]

A main difference to the EPOC is that while EPOC is designed from the beginning to meet the requirements of a small, mobile device, WinCE is basically a reduced version of Windows. Due to the widespread adoption of the Windows operating system, WinCE has massive backing behind it, and thus the WinCE vs. EPOC competition is currently rather hectic.

5.1.4 Close range connectivity

Earlier, when mobile phones have been dedicated for traditional communications use, they have been mobile terminals of the operator network.

Earlier in this study, the three dimensions of terminal use were presented. Identity and authorization were identified as being central to future solutions. Services belonging to the domain of this dimension include, for example, money, access control and identification. In many instances, these types of service require fast communication of small amounts of data between two devices, of which one is the personal terminal and the other can be a door lock controller, a cash register in a shop, a bus ticket control device etc. In all these, it is rather inefficient, considering both capacity usage and time, to use operator networks to transmit the data. A solution providing connectivity at close range would be much more appropriate.

Close range connectivity is also needed to provide connectivity between various devices a person uses. This type of connectivity can consist of, for example, simply eliminating the cable between devices and their peripherals, creating ad hoc networks between devices when workgroups meet, or creating personal computing and communication environments where the desired functionalities are split among a number of personal devices being constantly connected.

[104] Microsoft ltd, http://www.microsoft.com.

A method already much in use for close-range connectivity is the use of infrared links (IrDA). Although cheap, the solution has several disadvantages. The range is short, typically only a couple of meters. For successful connection, exact positioning is needed. Obviously, there must not be any obstacles between the two communicating ports. In addition, only two devices can exchange data simultaneously.[105]

The most promising initiative for such a protocol is Bluetooth. The Bluetooth consortium was founded by Nokia, Ericsson, IBM, Intel and Toshiba in spring 1998. Since then, a large number of manufacturers have joined the consortium, and many more have declared they will take the technology in use. Basically, Bluetooth is a low power, short-range radio protocol. The Bluetooth chip can be embedded in practically any electronic device, allowing a vast number of applications requiring radio connectivity at close range.

One marketing slogan for Bluetooth, which effectively – and enthusiastically – illustrates the whole concept is: "Forget plug'n'play – just play!"

Bluetooth technology

In order for Bluetooth to be operable around the world, the frequency band needs to be free everywhere. It must also be freely in use for radio devices without a license. A frequency band fulfilling these requirements is the 2,45 GHz "free" ISM band. In most of Europe and USA this band is located between 2400 and 2483,5 MHz. In France, Spain and Japan it is not possible to use such a wide band, and in these countries the 2471-2497 MHz area is used.

The transmitting power of Bluetooth is very low, less than 1mW. The typical operating range is up to 10 meters. Bluetooth offers rather high user data rates, up to 730 kbps. This makes even rather bandwidth-consuming future applications possible. The protocol in use is a combination of circuit- and packet switching. Data transmission is based on frequency hopping and time division.

Two or more Bluetooth devices may form ad hoc networks. Such a network is called a *piconet*. All devices have the same level of hierarchy, but the first one to transmit data in a

[105] Miettinen, P. and Joronen, J. 1999. Page 60.

piconet becomes the master, while the rest become slaves. Devices joined in a piconet can, however, switch roles when necessary.[106]

5.1.5 Software configurable radio

A convenient and flexible way to implement a mobile terminal would be based on a software configurable radio. In this way, several different systems could be accessed with a single terminal, simply by dynamically changing the radio configuration through selecting or downloading the appropriate software configuration. Flexible and global roaming would thus be achieved.

Software configurable radio is not an easy task. The RF section must support transmission and reception of differently modulated signals within several frequency bands. This calls for good linearity, low losses, and wide frequency ranges in the power amplifier and antenna. In order to perform the channel filtering digitally, a dynamic range A/D converter and a wide filter are needed. In the baseband part, the different equalization approaches for TDMA and CDMA must be supported. So far, the mobile terminals have been speech-oriented, and thus a number of source codecs have been implemented in the handsets. Increasing need for video coding and other data processing rises the requirements for application support by the software radio.[107]

Regardless of the still unsolved technical problems, software configurable radio is seen as an important element in future mobile communications. It is very welcomed from the operator's point of view, since two or more air interfaces can be accommodated without investing in a completely new infrastructure. Multi-mode terminals can in this way be realized, and thus manufacturers of terminal and infrastructure equipment can access global markets in a cost-efficient way.[108]

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[106] Miettinen, P. and Joronen, J. 1999. Pages 60-63.

[107] Ojanperä, T. and Prasad, R. 1998. Pages 314-315.

[108] UMTS Forum, 1999. Page 33.

5.2 Speech and audio coding

5.2.1 Speech

It needs to be emphasized that speech services will remain central even in the future. As wireless communications more and more replaces fixed-line telephony, users expect the quality of the wireless services to be of the same level or better. Therefore, the quality of speech services is a central topic for the development of wireless communications, and a subject for constant improvement efforts.

Digital speech transmission over a radio interface in a mobile environment is demanding. Errors are difficult to avoid, and the bandwidth in use places restrictions. Mobile phones are used anywhere, as long as sufficient coverage exists. Large distances from the base station, attenuating structures in the way, and the terminal moving at a very high speed are examples of difficult conditions for maintaining an even speech quality.[109]

In all digital mobile communication systems speech is coded to improve the efficiency of spectrum usage and to achieve an even speech quality. Digital signal processing methods have continuously assisted in improving the algorithms used, and wireless communications systems have influenced the speech codec development significantly. Currently, the speech quality of the current fixed network is targeted. For ISDN this means a bandwidth of 300-3400 Hz, 64 kbps data rate, and A/μ law PCM. Almost this is reached with codecs operating at 10 kbps.[110] [111]

Speech coding is based on removing information redundant and irrelevant for the hearing, i.e. information that the human ear cannot distinguish, from the speech signal. Also the speech production mechanisms are used as a base. The best results have been achieved with Linear Prediction Coding (LPC), vector quantization and Code Excited Linear Predictive Coding (CELP). Table 6 lists a few relevant speech codecs, the ITU-T G.711 and the three GSM codecs available, full rate (FR), half rate (HR) and Enhanced Full Rate (EFR). MOS

[109] Suvanen, J. 1998. Page 211.

[110] Mouly, M. and Pautet, M-B.1992. Pages 129, 154-160.

[111] Suvanen, J. 1998. Pages 208-212.

stands for Mean Opinion Score, a codec quality test score based on listening test evaluations. The scale runs from 1 (Bad) to 5 (Excellent).[112] [113]

Standard	Algorithm	Bit rate	MOS
ITU-T G.711	A/u-law PCM	64	4.3
ETSI GSM-FR	RPE-LTP	13	3.7
ETSI GSM-HR	VSELP	6.5	3.6
ETSI GSM-EFR	ACELP	12.2	4.2

Table 6. Four important speech codecs and their characteristics.

The latest addition to GSM codecs is the Advanced MultiRate coding (AMR), standardized by ETSI. In the spring 1999, AMR was selected as the mandatory speech codec for 3G systems.

5.2.2 Audio

With the entrance of multimedia into the wireless terminal, broader audio services become relevant besides voice communication. Music and video, either broadcast or on demand, are main examples where new types of audio services are required.

The popularity of portable music devices makes the wireless market extremely attractive to the music industry. The mobile terminal may then become a substitute for portable radios, cassette and CD players. As the information networks evolve, the music and other high quality audio data may be retrieved in digital form straight from the provider of such a service, bypassing the traditional distribution logistics and business of physical storage media like cassettes and CDs.

Audio compression is needed to make transmission over the networks possible. Various audio codecs exist, the most important of them developed by the Motion Picture Experts Group (MPEG). The MPEG-1 and MPEG-2 both offer three audio layers, both offering sampling rates up to 48 kHz, and providing audio which in listening tests has been perceived to be of CD quality. MPEG-2 supports also multichannel audio, which is used, for example, in surround sound applications.

[112] Ojanperä, T. and Prasad, R. 1998. Page 7.

[113] Suvanen, J. 1998. Pages 211-213.

The ISO/MPEG Layer 3 is currently the best choice in terms of quality at a given bit rate. Single chip decoders as well as real-time software decoders for most computer platforms are available. (PC, Mac, SUN, Silicon Graphics, etc).[114] It has lately been subject for vivid discussion. Popularly called the mp3 format, it has become a very popular means of distributing music over networks. The Internet is currently flooding with .mp3 –files, and since much of the music available has been unauthorized pirate copies, many disputes with the record industry have arisen.

The dispute got even more hectic in the autumn 1998, when mp3 significantly expanded its territory through the introduction of the Rio PMP300 mp3-player by Diamond Multimedia. Other manufacturers soon followed. The product concept is a small, walkman-type portable music player, not based on any physical storage media. Instead, it plays mp3-files, which are transferred to the device over a cable connected to a computer. The device is in many ways superior to existing solutions, since it is completely non-sensitive to motion, has small power consumption, is very small and light and still offers CD-quality audio.

The new MPEG-2 Advanced Audio Coding (AAC) multichannel codec with high audio quality was standardized in 1997. AAC is not backwards compatible with MPEG-1. It is capable of handling up to 48 channels. It offers 12 sampling rates between 8 and 96 kHz, leading to bit rates of 32-576 kbps/channel.[115]

As a reply to the popularity of the mp3, the music industry is also preparing similar audio codecs. The main difference will be that these codecs contain solutions for preventing unauthorized listening or copying of the data.

5.3 Video coding

For successful wireless multimedia transmission, the video compression technologies need to be very efficient. Low bit rate video coding is therefore an important topic. Two bodies have produced standards for low bit rate video coding. ITU has produced the recommendation H.263, which specifies a coded presentation for compressing the moving picture component of audio-visual signals at low bit rates. Currently ITU is also developing the H.263+ codec, which has more efficient compression technology, and H-263L, where L

[114] Dietz, M *et al*, 1996. Page 60.

[115] Virtanen, A. 1998. Pages 199-200.

stands for long term standard, aimed at achieving a dramatic increase in compression efficiency. The ISO-MPEG4 in turn aims at a generic audio-visual coding system for multimedia communications.[116]

The bit rates required for video telephony depend on the used video codec, the desired picture quality and the required frame rate per second. The actual video sequence also influences. Using an H.263 codec, the minimum acceptable quality for low-motion video requires over 20 kbps. Such a low-motion video is constituted of a simple head and shoulders scene, for example. For generic video telephony, the data rate requirements rise to over 40 kbps. A higher quality can be achieved, if more bandwidth is available. [117]

5.4 Transmission capacity needs

The bandwidth consumption of future services is not simply growing. The need for transmission capacity varies much from service to service. Basic voice can be provided over a very small capacity, while video broadcasting requires a vast amount of bandwidth. Table 7 presents an overview of various services and the required data rates both uncompressed and compressed.[118]

Application	Data rate Uncompressed	Data rate Compressed
Voice, 8 ksamples/s 8 bits/sample	64 kbps	2-4 kbps
Video telephony (10 fps), frame size 176x120, 8 bits/pixel	5,07 Mbps	8-16 kbps
Audio conference, 8 ksamples/s, 8 bits/sample	64 kbps	16-64 kbps
Video conference (15 fps), frame size 352x240, 8 bits/pixel	30,41 Mbps	64-768 kbps
Digital audio (stereo), 44,1 ksamples/s, 16 bits/sample	1,5 Mbps	128 kbps - 1,5 Mbps
Video file transfer (15 fps), frame size 352x240, 8 bits/pixel	30,41 Mbps	384 kbps
Digital video on CD-ROM (30 fps), frame size 352x240, 8 bits/pixel	60,83 Mbps	1,5-4 Mbps
Broadcast video (30 fps), frame size 720x480, 8 bits/pixel	248,83 Mbps	3-8 Mbps
HDTV (59,94 fps), frame size 1280x720, 8 bits/pixel	1,33 Gbps	20 Mbps

Table 7. Required bandwidth for different multimedia applications.

[116] Ojanperä, T. and Prasad, R. 1998. Pages 69-71.

[117] Ojanperä, T. and Prasad, R. 1998. Pages 69-71.

[118] Leskinen, T. and Niemi, M. 1997. Page 3.

5.5 Evolution from second to third generation

As the content becomes more bandwidth consuming, network capacity needs to evolve to support the heavier requirements. The current cellular systems are capable of rather modest data rates, the 9600 kbps of the GSM system does not yet allow for very heavy content transferring.

The third generation of mobile communications, which has acquired much attention lately, will bring a significant increase in the data rates. The development of the third generation is, however, not a single burst. Instead, the development follows more an evolution path, enabling especially operators to gradually increase the performance of their equipment.

Figure 10 presents the evolution path of network performance from the current GSM systems to third generation radio.

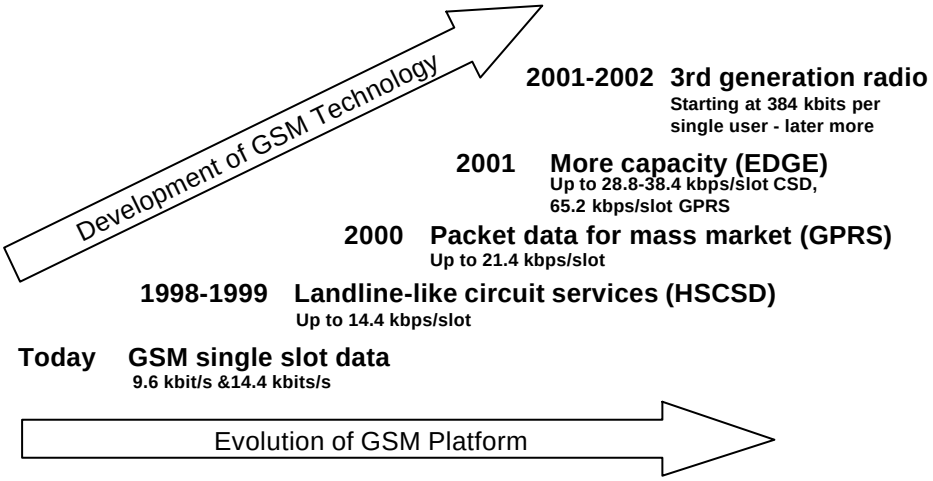

Figure 10. Evolution of network performance.

5.5.1 GSM

The GSM protocol is an heir of ISDN, and has thus been designed from the start to offer many data services. Basically, most services, which are provided to fixed telephony users and to ISDN users have been included, as far as the limitations due to radio transmission allow. Altogether, the GSM specifications list around 35 services.

The main limitation of GSM when moving to more advanced services is the data transmission speed. In the original Phase 1, the maximum rate is 9,6 kbps, based on circuit-

switched technology. This rate is applicable for transparent and non-transparent bearer services in data, as well as facsimile transmission.

In order to meet the increasing demand of advanced services, higher data rates and better quality, GSM is evolving. The European Telecommunications Standards Institute (ETSI) has specified a set of GSM enhancements. This set is called GSM phase 2+. The GSM Phase 2+ in many ways sets the reference point for third generation systems as well, since the third generation systems have to exceed the capabilities of the second generation systems in order to succeed commercially. The most important service enhancements of GSM Phase 2+ are:[119]

- Enhanced full rate speech codec (EFR)
- Advanced multirate codec (AMR)
- 14,4 kbps data service
- High speed circuit switched data (HSCSD)
- General packet radio service (GPRS)
- Enhanced data rates using optimized modulation (EDGE)
- GSM cordless system, i.e. a home base station solution.

In the following sections, some of these evolution steps towards third generation are discussed.

5.5.2 High Speed Circuit Switched Data HSCSD

One of the main features in phase 2+ is High Speed Circuit Switched Data (HSCSD). It is an enhancement of the current circuit switched GSM data services designed to cover user data rates higher than 9,6 kbps. The first commercial services were launched in the end of 1998.

The architecture is based on the physical layer of the current data services. The increased user rate is achieved by using a combination of more than one full rate traffic channels (TCH/F) for a single connection. The allowed channel types provide data rates 4,8 kbps, 9,6 kbps and 14,4 kbps per channel, respectively. Thus, the maximum non-transparent data rate is 57,6 kbps achieved by using four 14,4 kbps channels. In transparent data

[119] Ojanperä, T. and Prasad, R. 1998. Pages 9-10.

transmission mode the maximum data rate is 64 kbps.[120] Thus HSCSD provides a transmission rate equal to one ISDN B-channel, putting mobile data at the same level as the existing fixed PSTN services.

Table 8 illustrates the various bit rates available.[121]

Timeslots used	9.6 kbit/s channel coding	14.4 kbit/s channel coding
1	9.6 kbit/s	14.4 kbit/s
2	19.2 kbit/s	28.8 kbit/s
3	28.8 kbit/s	43.2 kbit/s
4	38.4 kbit/s	57.6 kbit/s

Table 8. Bit rates offered by HSCSD.

The majority of the extensions in HSCSD compared to GSM are in the data and signaling protocols. The physical characteristics have been kept in the air interface and the network infrastructure. Thus the additional investment required from operators is small.

In the GSM air interface, one 200 kHz carrier is divided into 8 TDMA time slots. One of these is used for each channel. In HSCSD, multiple time slots can be allocated to one mobile terminal. HSCSD also allows asymmetric operation. This allows for receiving with a higher data rate than transmitting. Examples of asymmetric downlink+uplink channel configurations are 2+1, 3+1, 3+2 and 4+1. Asymmetric operation is useful for example during an Internet session, where the majority of the traffic is downlink, while uplink traffic is more occasional.[122]

New mobile applications that are not feasible with 9.6 kbit/s data require HSCSD. Practical examples of such applications are:[123]

- E-mail download and upload
- Bandwidth-secure mobile high speed LAN access
- File transfer

[120] Hämäläinen, J. 1999/1.

[121] Nokia, 1998. High Speed Circuit Switched Data. White Paper. Page 12.

[122] Hämäläinen, J. 1999/1.

[123] Nokia, 1998/2. Page 10.

- Vertical applications such as batch-type field sales info or document transfer
- Real-time applications demanding a constant bit rate and transmission delay
- Time-critical wireless imaging
- Mobile video telephony

Applications such as mobile navigation services and other services using maps and graphics will also benefit greatly from the enhancements provided by HSCSD. HSCSD will make current applications more attractive, because they will be more convenient to use and faster, and new mobile applications such as video will become feasible. It is therefore an important step on the network evolution path.

5.5.3 General Packet Radio Service GPRS

Current mobile and fixed telephone networks are based on circuit switched connections. It is the optimum way of connecting to any data source if there is a continuous data stream to be transmitted. For example applications such as video transmission require a constant bit rate and transmission delay, and therefore run best with circuit switching. Typical IT applications in Local Area Networks (LANs), Wide Area Networks (WANs) and the whole Internet use packet switched connections instead.

General Packet Radio Service provides the mobile user with packet access to data networks. The GPRS air interface is based on the same principles as the current GSM system, and belongs, like HSCSD, to GSM phase 2+. In addition, new radio link control and medium access control layer functions allow flexible retransmission capabilities needed for packet access.[124]

For users, an important advantage of GPRS is the possibility of charging base on traffic volume instead of time spent online. During idle periods, the spectrum is given to other users. From the user perspective, the access is also virtually instant, since there is no setup time like in circuit-switched connections.[125]

GPRS offers a significant increase in data rates available for the user. The transmission capacity is variable according to the actual need, with a maximum rate of 171,2 kbps. An important characteristic of GPRS is that it offers four different bit rates per timeslot,

[124] Ojanperä, T. and Prasad, R. 1998. Page 10.

[125] Hämäläinen, J. 1999/2.

depending on the applied channel-coding scheme. Depending on the need for bandwidth, the user can select to use from 1 to 8 timeslots simultaneously. Thus the possible data rate combinations give numerous alternatives. Table 9 illustrates the possibilities.

Coding Scheme	1 Timeslot	2 Timeslots	3 Timeslots	8 Timeslots
CS-1	9,05	18,1	27,15	72,4
CS-2	13,4	26,8	40,2	107,2
CS-3	15,6	31,2	46,8	124,8
CS-4	21,4	42,8	64,2	171,2

Table 9. The different throughput alternatives of GPRS in kbps depending on the selected coding scheme and the number of timeslots in use.

Different QoS classes can also be established. While some users may need the fastest and most reliable throughput possible at all times, and are willing to pay for it, others may settle for a lower level of quality for a lesser price. The typical burstiness of data traffic enables sharing of the radio interface and network resources by several users without decreasing the experienced efficiency of each individual transmission much. As a result, the operator may achieve increased revenue per unit of available spectrum, even though each individual user experiences decreased cost.[126] [127]

GPRS enables applications with a seamless on-line network connection independent of time and place. All existing TCP/IP-based applications can be used with GPRS as if they were connected to a LAN. Since all Internet applications are run on TCP/IP, GPRS is an optimal bearer for Internet connection and any other packet switched application as well. Internet addressing is used and Internet services can be accessed. An IP address number will be allocated to the mobile terminal as well.[128]

5.5.4 HSCSD or GPRS?

Comparing HSCSD and GPRS with each other, it seems that GPRS has a number of advantages. However, there is an enormous installed base of PSTN modems and ISDN terminals in the field. To connect to these and other circuit switched services, especially

[126] Hämäläinen, J. 1999/2.

[127] Ojanperä, T. and Prasad, R. 1998. Page 10.

[128] Nokia, 1998/1. Page 12.

with time-critical applications, HSCSD is the best solution. Therefore, there is a clear market need for both HSCSD and GPRS, as illustrated in the figure below.[129]

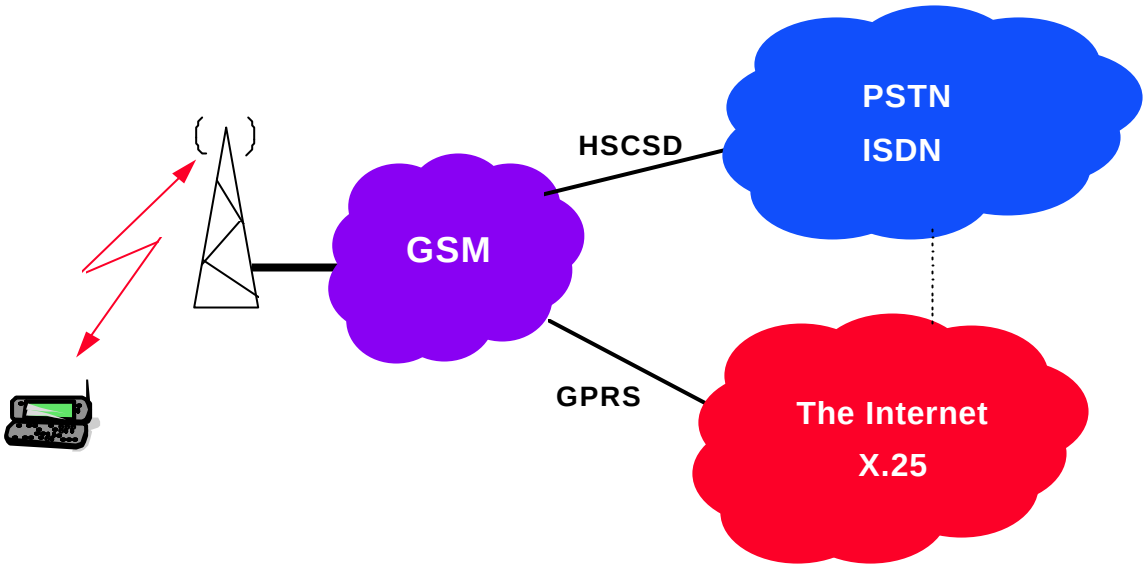

Figure 11. The roles of HSCSD and GPRS in wireless communications.

5.5.5 Other second generation systems

Apart from the GSM, other digital 2nd generation systems are in use. The most important of these are US-TDMA, IS-95 and PDC. The data rates offered are similar as in GSM.

US-TDMA is a time division multiple access system. There are actually two variants, the older IS-54, with an analog control channel and the IS-136 with a digital control channel. Today, IS-136 is the commonly used term when referring to US-TDMA. IS-136 is operational in North and South America, and some parts of Asia. The IS-136 is a dual-mode standard, since it specifies both analog (AMPS) and digital (US-TDMA) modes.[130]

The narrowband CDMA standard originating from in-house trials by Qualcomm is called IS-95. IS-95 is, like US-TDMA, a dual mode standard with an analog AMPS mode. Backward compatibility with AMPS has been taken in account. For example, a handover from the digital to the analog mode is possible. The data rates of IS-95 are similar to those of the GSM system. The original 9,6 kbps has since been upgraded to 14,4 kbps, and the IS-

[129] Nokia, 1998/1 Page 10.

[130] Ojanperä, T. and Prasad, R. 1998. Pages 4-12.

95B upgrade, which allows for example eight codes in use for a transmission, increases the maximum rate to 115,2 kbps.[131]

A third digital standard in wide use, although only in Japan, is Personal Digital Cellular (PDC). It was standardized by the Ministry of Post and Telecommunications and the Japanese Research and Development Centre for Radio Systems. Commercial PDC services are offered in the 800 MHz and the 1,5 GHz bands. Recently, packet data has been developed for the PDC standard.[132]

5.6 Third generation mobile communications

Although the introduction of solutions such as HSCSD and GPRS brings the data transmission capabilities of GSM terminals to the same level with current modem and ISDN –based solutions, this is not yet enough to satisfy the needs of future advanced multimedia services. A significant development step will be the launch of third generation mobile communications services. Manufacturers and operators have targeted year 2001 as the year when the system becomes operational.

[131] Ojanperä, T and Prasad, R. 1998. Pages 4-12.

[132] Ojanperä, T. & Prasad, R. 1998. Pages 4-12.

Figure 12. Third generation video terminal as seen by Nokia.

Third generation mobile communications has lately acquired much public attention. Concept images of future terminals, like the one above, have been published in publications ranging from daily newspapers to women's magazines, and various service visions and scenarios for future information society wireless communications have been presented with much pomp and hype.

Regardless of the hype, third generation will be extremely important. The main advantage is simply increased bandwidth. The higher data rates, up to 2Mbps, bring the possibility to offer the broad range of services already existing and further emerging in the global information networks even to mobile users. Wireless communications will in turn fuel a variety of new services specific to the mobile environment. Thus, third generation will be a very important evolution step in the evolution of the information society.

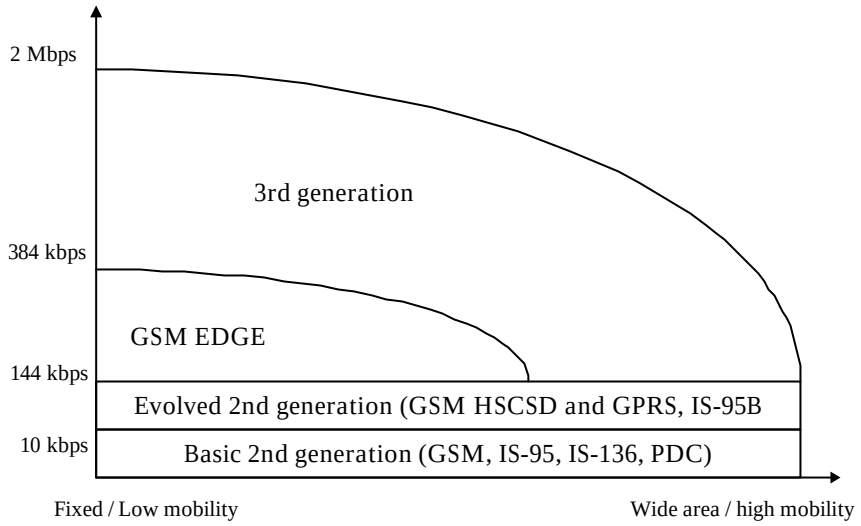

Figure 13. Third generation user bit rates compared to coverage and mobility.[133]

5.6.1 Third generation standardization

Third generation systems aim at integrating all the different services of second-generation systems, providing new opportunities for competitive service provision that reaches large markets, and covering a wide range of broadband services consistent and compatible with technology developments taking place in the fixed telecommunications networks.[134]

In the ITU, third generation networks are called IMT-2000, and in Europe, UMTS. IMT-2000 has been under development since 1985, and UMTS since 1990. In the ITU, the main objectives for the standardization work of the IMT-2000 air interface can be summarized as:

- Full coverage and mobility for 144 kbps, preferably 384 kbps;
- Limited coverage and mobility for 2 Mbps;
- High spectrum efficiency compared to existing systems;
- High flexibility to introduce new services.[135]

The targets for third generation systems are wide and system solutions will vary from one to another depending on the main driver. The need to take new systems in use varies much

[133] Ojanperä, T. and Prasad, R. 1998. Page 13.

[134] Dasilva, J.S. *et al*. 1996. Page 70.

[135] Ojanperä, T. & Prasad, R. 1998. Page 12.

depending on the penetration level in the specific market, and thus several IMT-2000 variants are likely to emerge. Different backward compatibility requirements also influence the technology that is applied to third generation systems.[136]

The original goal for ITU standardization work was to reach a single, global standard. Currently it seems that there will be two major standard families, one CDMA-based and one TDMA-based. The CDMA-based approach originates from a number of proposals, and has gone through much harmonization work. The first important selection was when WCDMA was selected as the base for Japanese third generation systems. A clear thrust for WCDMA came when NTT DoCoMo, the world's largest cellular operator decided to proceed development with WCDMA in 1996.[137] ETSI, the European telecommunications standardization organization, selected WCDMA as the European standard in 1998. Currently, the CDMA-based approach enjoys wide support around the world, and consists of elements from WCDMA, TD-CDMA, and cdma2000. The one TDMA-based standard is UWC-136, which is essentially the same as EDGE.

5.6.2 Satellites

While more than 80% of the European population can be expected to be covered by terrestrial UMTS/IMT-2000 in 2010, less than 20% of the world's total land area will be covered by terrestrial cellular networks within the envisaged timescales of UMTS/IMT-2000. Satellite systems are therefore important to UMTS/IMT-2000 to provide complete coverage.[138]

[136] Ojanperä, T. and Prasad, R. 1998. Page 13.

[137] Ojanperä, T. and Prasad, R. 1998. Pages 17-18.

[138] UMTS Forum, 1999. Page 6.

6 Adoption of technology and market evolution

In the previous chapters it has been shown that the foundations exist for wireless communications to play a leading role in the information society. Technology evolution and outlooks are promising and the market has initially responded to wireless communications with a roar. There is also a clear societal determination evident in the actions taken by policy makers to successfully make the transition from the industrial to the information era. It is, however, still very unclear what exactly is going to happen. Is technology going to develop as forecast, and will the wireless communications industry be able to bring relevant products to the market at a suitable pace? The most important question is, whether the users and markets will adopt the information society and the advanced converging technologies, especially those involving wireless communications.

History contains many examples of highly innovative new technologies, which still have been failures commercially. The complexities involved in the diffusion of a given innovation are often a problem. Therefore, a technological innovation does not necessarily bring economic benefits to its inventor, but to its successful diffuser.[139] Often a technology or other innovation never reaches the users, regardless of its superiority compared with the alternatives. The diffusion of technologies and innovations into society and the markets is clearly a very complex process, where many influencing factors act, and unlimited interconnections and causalities are present.

Minor variations can have big effects, thus making exact forecasting based on a few parameters almost impossible. For example, three quarters of Canadian homes have multichannel cable or satellite television. Australia, the country with perhaps the most similar culture to Canada, the same figure is only one in twenty.[140] France and Sweden have rather equal GNPs, but still cellular telephone penetration is 2,5 times higher in Sweden.

[139] Reddy, N.M., Aram, J.D. and Lynn, L.H. 1988. Page 152.

[140] Cairncross, F. 1997. Page 21.

6.1 Factors influencing adoption

In this study, the following four topic areas, used by the UMTS Forum as a base in their mobile multimedia market forecasting work, are used as a structure for discussing the factors influencing the adoption of wireless communications technologies by the markets:[141]

- Technology developments
- Social and market trends
- Industry structure and competition
- The regulatory and political environment

Figure 14 displays a chart of these factors.

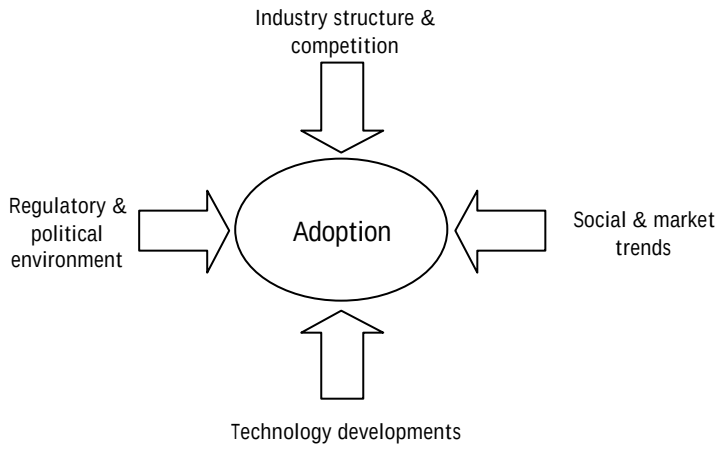

Figure 14. The factors influencing adoption of wireless communications technologies for the information society.

6.1.1 Technology developments

The outlooks for wireless communications technology were presented in the previous chapter. They appear very promising, as many such solutions, that are required to create the service environment of the information society, are expected in a rather near future.

Developments in technology lay the foundation for the evolution of the markets. In addition to advances and pure technological ingeniousity the technology need to meet a number of other criteria as well to ensure a successful adoption by the markets. Some of the more important are discussed below.

The true benefits of new technology

New technologies must offer notable improvements over those already in use to justify their costs. Users are generally unwilling to spend money on something only slightly better than what they already have. Regardless of the attractiveness of a new technology, it will only have impact in applications where it brings significant improvement in meeting the needs or desires of the consumer at a price, which the consumer feels to be good value.[142] [143]

The true advantages of a new technology or innovation, bringing the significant improvement necessary, may initially be hard to see. At first people tend to use new technologies to perform old tasks better, instead of immediately starting to use the technology for the purpose it turns out to be best in. Numerous examples can be presented. The automobile was initially seen as a horseless carriage and the television as a radio with pictures. Personal computers boomed in homes only after people realized it was a powerful games machine. This may have come as a surprise for many early pioneers in computing. Instead of becoming the liberator of home information management (accounting, shopping lists, recipes etc.) computer games have occupied most of the computer time of homes, and have also taken a position as one of the most demanding application areas in computing.[144] [145]

The fact that the best use of a new technology is not always directly seen applies to its inventors and designers as well. Technology often has a much greater effect in a field outside that for which it was originally proposed. Especially in communications the effect has frequently been other than the anticipated. When Bell invented the telephone, the intended use was as a device for delivering music and news to the home, i.e. broadcasting. Instead, it evolved into a device for communication. The radio in turn was soon realized to be very suitable for dissemination of information and entertainment, instead of only point-to-point telegraph communication as the planned use was. While information and entertainment distribution took advantage of wireless broadcasting technology,

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[141] UMTS Forum, 1999. Page 36.

[142] Gross, H. 1995. Page 120.

[143] Forrest, J. R. 1996. Pages 1-2.

[144] Cairncross, F. 1997. Page 20.

[145] Mannermaa, M. 1998. Page 42.

telecommunications became a point-to-point service, making use of the nationwide wired infrastructures.[146]

Currently, the technological development of cellular telephones is again releasing the point-to-point communication from the wires. This development has led Nicholas Negroponte to postulate that the transfer of information through fixed wired networks will switch places with over the air transmission. This so-called "Negroponte Switch" would be wise, it is claimed, since the value of the radio spectrum for truly mobile applications is superior. Thus telecommunications would be carried out over wireless and broadcasting over wired infrastructures, as in the original concept of Bell. This development illustrates well how technology often alters the business structure of an overall communications process by changing the balance of complexity and cost between parts of the process. [147] [148] [149]

It remains to be seen how the communication applications currently launching will start off and actually be taken in use. The imaging features of future mobile phones have been mainly promoted as making it possible to send an instant electronic postcard, for example. Simply put an SMS with an image. The final use might again turn out to be something surprising, outside the domain of actual person-to-person communication.

Design

While users expect to see profound differences between older and new technologies, they do not adapt well to products or systems that require them to change habits significantly. Technologies that require an entirely new set of skills to operate do not fare well in the marketplace. The more effort it takes to master the use of a technology, the slower and more limited its diffusion will be.[150] [151] Many recent examples of this phenomenon exist. The great masses started to adopt the Internet only after the introduction of graphical WWW browsing made the level of convenience appropriate. Applications have followed.

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[146] Forrest, J. R. 1996. Page 2.

[147] Forrest, J. R. 1996. Page 2.

[148] Negroponte, N. 1995. Page 24.

[149] The "Negroponte Switch" is a rather simplistic postulate. What is more likely to happen is that applications in both broadcasting and telecommunications will use either wired or wireless infrastructures depending on the needs of the business and end-user considering the application and usage situation in question.

[150] Gross, H. Page 120.

[151] Cairncross, F. 1997. Pages 20-21.

Home-based activities relying on data communications like telework and home banking were almost judged as complete failures in the beginning of the 1990s. Home banking has been possible with a computer for example in Finland from early in the 1980s, but the growth was very modest during many years. After the introduction of WWW-based graphical banking services in, the use exploded, and currently MeritaNordbanken, the largest bank in Finland, reports around 2 million logins each month to the WWW service. Over one fourth of bill payments are handled through the Internet service, and more than half of the stock exchange orders come that way.[152]

Figure 15 shows as an example the development in the change of the preferred way of bill payment in Finnish banks. The figure does not show actual usage percentages, but indicates which of the possible ways is preferred by the customers. The long slow growth of computer payments, followed by the rapid expansion that started after WWW introduction in 1997 is visible.

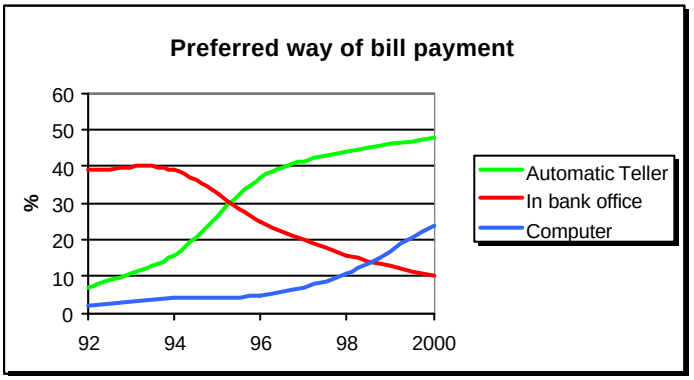

Figure 15. The change in the preferred way of bill payment in Finland.[153]

Design and convenience is also highly situation dependent. Some technologies can be more readily used in some situations than others can. Listening compared to watching while driving is an obvious example.[154] This example applies the other way as well, and speech recognition is correspondingly a hot research topic currently.

All in all, it can be concluded that the way a technology or innovation is packaged for use can either enable or destroy its success in the markets.

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[152] Pohjola, M. 1999.

[153] Suomen Pankkiyhdistys, 1998. Pages 4-6.

[154] Cairncross, F. 1997. Pages 20-21.

Costs

The cost of new technology naturally influences adoption significantly. Though new products must eventually be affordable to a broad population, they first rely on affluent and enthusiastic consumers willing to pay initial high prices.[155] At this stage demand is usually still moderate. Demand will be boosted when new technologies cut costs. In the Internet case, demand has boosted where access is cheap, and also Internet itself lowers costs for many services.[156] In the case of physical devices, the first generation products are usually very high priced. The prices diminish as the technology matures, the volumes grow and manufacturing becomes cheaper both due to economies of scale and development of manufacturing processes.

6.1.2 Social and market trends

Adoption of technology and innovations in the markets is highly dependent on the atmosphere and state of the society and the markets at the moment. The major social and market trends influence the market readiness for adopting a new technology, and also the industry's decisions on how to introduce the new technologies, in which kind of applications, and to which users and market segments.

Demographics and culture

Demographics reflect the structure of the society and the markets. Therefore, demographics have traditionally been among the most important data for technology and market forecasting. The interest and ability to adopt new technologies varies much among segments of the population. Factors affecting include wealth, education, culture, and age.

Not surprisingly, those most likely to lead the process of are younger and better educated. [157] In the case of new digital, converged technologies and products, this is even more evident. Older generations are or have been required to learn the principles of information technology usage and digitality as a completely new thing, often rather abstract compared with the earlier physical machines and devices. The children and young who have grown up

[155] Gross, H. Page 120.

[156] Cairncross, F. 1997. Page 20.

[157] Gross, H. 1995. Page 120.

with computers and 64-bit video game consoles, cellular telephones and tamagotchis, do not experience any initial difficulties in using the new products.

Often the reluctance for change among older people is not only related to the difficulty to understand the new technology or its use. The habits and culture also influence. If people are used to doing things one way, they may be slow to change. This is probably especially true with the growing age group of older people in wealthy countries.[158]

Culture is a key determinant otherwise as well. Some markets adopt everything, some almost nothing. Naturally, there is a clear division between the rich industrial countries and the third world. But wealth is not the only factor. For example Japanese homes are stuffed with various electronic gadgets most other markets regard ridiculous, like electronic meters for monitoring the pH of food.

Demographics and culture are rather obvious factors influencing the adoption, but at the same time they are very difficult to exactly uderstand. In the USA it has been observed, that Internet connectivity in a region is related to the general attractiveness of the region. This could support the hypothesis that firms, consumers and workers will migrate to more attractive areas as geographical constraints are loosened by the improved communications.[159] An other possible explanation is, that attractive regions are, according to supply and demand mechanisms, usually occupied by people more well off, being more ready to adopt new technologies in general.

Non-market organizations

Beside the actual markets – or as a part of them – there are various non-market or non-profit organizations influencing the development, diffusion and adoption of technology and innovations. Examples are professional societies, trade associations, governmental agencies, independent research and coordination agencies and public service organizations. All these play a crucial role in the process. Along more official bodies like standardization organizations, unofficial forms like the grass roots community action groups have been

[158] Cairncross, 1997. Pages 20-21.

[159] Froeb, L.M., Oliver, R.W. and Weiskopf, D.A. 1996. Pages 480-484.

successful.[160] For example the nuclear power industry or the pulp and paper industry would technologically look somewhat different had not these groups been active.

Social embeddedness of technology

Although technology must be seen as one of the fundamental drivers of change, the above discussion on the role of non-market organizations shows how technology not only needs to be relevant in itself and in addition accepted by the markets. Other interests conduct the way the tehnology is adopted significantly. Technology development can thus be seen much as a social process, instead of an external factor to which society and individuals must adapt. In this process technology changes the needs and is changed by the needs as well. Technical innovation rises from within the economic and social system and is not merely a reaction to transformations coming from outside the system. Thus technology needs to be socially embedded in order to become successfully adopted.

The formerly Socialist countries of Eastern Europe serve as a suitable illustration. They experienced very little growth and development, although massive investments were made into science and technology and higher education. The lack of a market to separate the technically feasible from the economically feasible pushed science and technology into isolation, which led to the absence of any social and organizational integration of technological change. As a result, science and technology was imposed on society and workers, which consequently led to a failure for example in producing efficiency improvements on the actual shop floor.[161]

The actual implementation and economic success will be crucially dependent of the conditions of application and use, and not so much of the characteristics of technological development itself. Successful social and organizational embeddedness is central in this development.

6.1.3 Industry structure and competition

New technology development depends highly on the industry structure and competition. The number of companies offering similar products, their size, their co-operation and the

[160] Reddy, N.M., Aram, J.D. and Lynn, L.H. 1988. Page 154.

[161] European Commission, 1997. Pages 17-18.

fierceness of the competition are factors that very much determine what kind of products enter the markets and how they succeed.

Industry structure and value chains

The industry structure can be perceived as value chains. A value chain is a sequence of consecutive, or parallel, steps of distinct activities by the same or different industry participant, in order to deliver the product or service to the end customer. Each part in the industry value chain will increase the value added to the ultimate product or service.[162] As a suitable example in this context, a value chain framework for the interactive information networks industry presented by M. Kajanto is shown below.

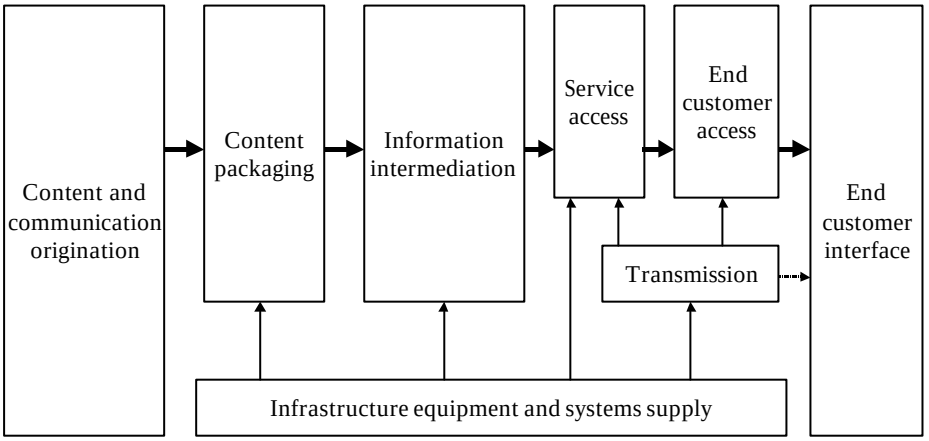

Figure 16. Value chain framework for the interactive information networks industry. The thick arrows show the primary value chain.[163]

One company can be present in the industry value chain in many ways. Some companies compete in many steps of the chain, some are present only in one. If a single enterprise controls the entire value chain, its position is naturally very strong. The structure of the industry value chain determines much how the technology and products of various players in the chain are adopted in the markets.

[162] Kajanto, M. 1996. Page 16.

[163] Kajanto, M. 1996. Page 32.

Competition

Competition has a high impact on the development of any industry and technology, but it is especially powerful in improving communications. It can even be seen as the best guarantor of choice, quality service, and low prices. The benefits of competition may seem obvious, but in the field of telecommunications – especially in the telephone and television industries – a very high level of protection has existed when compared with automobiles or other consumer durables for example. In most countries, governments have run the telephone service, and in many they own or finance at least one television channel. Lately, many countries have started dismantling their national monopolies in these fields, and have even put the governmental operators on sale.

In countries with competition, telephone ownership rises quickly, prices decline, and networks modernize briskly. It has also been observed that the Internet develops faster in countries where telephone services compete than where they do not. Internet access in countries with competitive markets has grown six times faster than in monopoly markets. The technological quality of the service is also higher in markets with competition. New entrants in the market bring along better services. They generally install the latest equipment, which encourages established operators to do the same. This has clearly influenced mobile telephony. In countries that originally licensed more than one mobile operator, penetration soared in the 1990s, while in countries that did not, it remained flat.[164]

Standards and de facto standards

Although competition is desirable, some issues benefit from being non-competed. This is where standards come in. Common standards are essential for networks and systems. They allow users of networks to communicate with each other, and make the different parts of a system compatible with others. Common standards make industry work efficiently. Standards bring large benefits, since users usually prefer products that support a wider standard, as it has most likely has more content to offer, and is less prone to become obsolete.

This benefit of longevity of standards can also be a drawback. A well established standard that has become inadequate can prevail for a long time, although better alternatives would

[164] Cairncross, F. 1997. Page 167.

exist, since it would be too difficult and expensive to change. The QWERTY keyboard may serve as an example – being developed to hinder typists from typing too fast, it clearly isn't one that would be selected were the selection made today.[165]

Standards are not only commonly agreed by the industry in official standardization bodies. They can also be unofficial agreements between a number of important enterprises to support one common technology. Recent examples related to wireless communications are the Bluetooth low power radio, the Symbian operating system and WAP. In all these cases, the initial number of companies has been rather small, but has very fast expanded to a big number of supporting suppliers. This type of achieved recognition in the markets is often called a *de facto* standard.

Sometimes a technology or product of a specific company reaches such a large penetration in the markets, that it becomes a de facto standard alone. The most typical example is Microsoft, whose Windows operating system is currently the dominating in the world. Such systems are in addition so important that companies controlling them, frequently invade other parts of the value chain, like Microsoft who, through the Windows dominance also controls the majority of standard PC applications.

Metcalfe's law, presented earlier, can well be used to explain the emergence of de facto standards. Since the usefulness of a network, a technology or application grows exponentially in proportion to its users, the inertia of masses is clear. The probability of a new technology, innovation or application to eventually become successfully adopted increases the longer it has traveled along Metcalfe's curve. The first product to reach the inflection point, the knee of the curve, has best chances to become the de facto standard in the field. This explains the enthusiasm of companies to get support for their technology through standards, unofficial agreements and alliances.

In the communications and information networks industries relevant to the information society evolution, this tendency to form alliances that eventually approach monopolies is in contradiction with the overall atmosphere of promoting competition. But, as explained by Metcalfe's law, these particular industries have a natural tendency to concentrate. In USA, the telecommunications act in 1996, which allowed competition in the formerly strictly regulated markets, was immediately followed by the merger of two large regional telephone

[165] Cairnross, F. 1997. Pages 161-162.

operators, Bell Atlantic and Nynex. Japan Telecom, a domestic carrier and International Telecom Japan, an international operator, did the same after Japan's liberation proposals in the beginning of 1997.[166]

6.1.4 The regulatory and political environment

The political actions of society reflect formally the social and market reactions to and the acceptance of new technologies, the social and cultural change these initiate, and the evolution of the industry environment. The political environment thus influences the way new technologies and innovations are created in the industrial and academic world. The public funding affects research and the regulatory activities the business environment, and eventually the way how users adopt the technologies and applications. Actions of policy makers are also needed to provide legislation certain applications need to operate.

Industry regulation

Industry regulation can be divided into four categories:

- antitrust regulation or regulating competition
- economic regulation of the monopolies
- regulation of acceptable behavior
- health, safety, and environmental regulation.

Regulation has been relevant especially for network-based industries, which are to a large extent tied to the expensive and extensive, even monopolistic infrastructure. [167]

A form of regulation very relevant to communications is radio spectrum regulation. Regulation of the right to use spectrum is essential to ensure that the legitimate users obtain the required quantity and quality of radio communication services without disturbing interference. Without appropriate licensing and assigning frequencies, the radio spectrum would become unusable. National regulatory authorities are primarily responsible for regulating the use of spectrum.[168]

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[166] Cairncross, F. 1997. Page 156.

[167] Kajanto, M. 1997. Page 44.

[168] UMTS Forum, 1998. Page 8.

Different approaches exist for governments when distributing licenses. In most countries, a license fee is charged from the licensee. Traditionally, the principle *First come, first served* is the most applied method of selecting licensees. *Comparative bidding* involves selecting the best applicant according to pre-defined selection criteria. *Auction*, sometimes called competitive bidding, awards the license to the applicant that makes the highest bid. Also *lotteries* have been arranged on the licenses.

Auctions have been used much, for example in the USA. The market theory –based logic behind auctions is that spectrum becomes allocated to those that value it the most and will make the most cost-efficient use of the spectrum. This does not ensure that efficiency is achieved from the end-user's perspective. Auctions lead to high license fees, which will increase the tariffs for the consumers, slow down the development of new, innovative services, diminish the infrastructure investments and harm competition.

Lotteries are not a perfect approach either, since no assurance that a competent operator will be awarded a license is provided. All in all, for example the UMTS Forum recommends that when selection of licensees is necessary because of lack of frequencies, the administrative comparative approach should be preferred over auctions or lotteries.

Spectrum pricing may be used as an incentive for efficient spectrum use, provided that the charges are reasonable and fair, and motivated by cost-recovery and not by maximization of revenue. If spectrum pricing becomes an instrument of taxation, it will have a direct negative impact on the growth of the telecommunications market and the general economy, and will in the long run diminish the total tax income.

One approach, although rare, which is applied for example in Finland, is to give the frequencies away for free. The selection of the licensees is based on the comparative approach, where the potential of the applicants to provide high-quality service is the main criteria. This approach has been seen to promote better quality of service for the customers at lower prices. As a recent example, Finland awarded licenses for the third generation spectrum on March 18th 1999 as the first country to do so.[169]

It is worthwhile mentioning that in Finland the licensing of frequencies is, in fact, the only form of licensing left in telecom operations. Nowadays, a license is not even needed for the

[169] Finnish Ministry of Traffic and Communications, 1999.

actual operating, but only for acquiring the radio spectrum. Otherwise a notification of starting operations is sufficient.[170]

Content regulation

As the information society brings all content accessible to everyone, the problems of regulating what is appropriate becomes a difficult task. Traditionally, practically all societies, even the most democratic, have applied some form of content regulation, or censorship. The principles vary from country to country, rising from either the social and cultural, or the political atmosphere of the particular country. Thus content regulation addresses the following two categories of content:[171]

- Socially questionable content
- Politically questionable content

The market acceptance of the new information society technologies and applications will depend much on how people and governments react to the situation of more uncontrolled information flows. Certainly, solutions for overcoming some of the problems need to be developed. At the same time, a basic issue is the fact that if society accepts the new technologies, it also has to accept, to a great extent, the complexion and characteristics of the content.[172]

Political activities

Advanced technological solutions often require some special legislation to make the use possible and secure. Therefore, the political environment can have a significant influence on how a technology is adopted by the markets. If the legislative activities of the policy makers are slow, the adoption might never happen even if all other conditions were satisfied.

In the field of communications, although regulation is diminishing and the controlling activities of society more in general also, there are some crucial issues which the political decision mechanism needs to tackle in order to enable functional information society solutions.

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[170] Palonen, V. 1998.

[171] Kajanto, M. 1996. Page 46.

[172] Kajanto, M. 1996. Page 45.

In most information society solutions it becomes necessary to be able to securely identify an individual user electronically and to ensure that data transfer can be made in an absolutely secure way. The electronic identity and identification of individuals, electronic commerce, and electronic banking, are among issues requiring determined actions from policy makers on a rather fast schedule. The positive development may be slowed down, or even reversed, unless these conditions are satisfied.[173]

In addition to identifying individuals, a problematic topic is the identification of content. Intellectual property rights and the enforcing of them have faced a completely new situation in the digital era. The technology development has been so fast that the legislation and regulations is generally lagging behind.[174] Also, if the industry and the policy makers are not able to solve the problems with IPR, content and services will not be offered on the networks in the necessary extent. This will lead to diminished interest and stagnation or even negative adoption.

6.2 The disrupting effect of technology

A topic appearing regularly in the literature and discussion is whether the push of technology is the origin for social change, or vice versa.

The diffusion of technology into society happens often according to the following chain of developments:[175]

- New scientific inventions lay the foundation for technological innovations.
- Technological innovations create new economic potential, production, consumption and markets.
- As technological innovations become commercialized and markets grow, the consumption habits of people change because of the new innovations.
- The decision mechanisms of society start to react only after the stages listed above.

Naturally, change is not as straightforward as described above. Markets and the development of technology are increasingly dependent on user response. The complex

[173] Alahuhta, M. 1999.

[174] Kajanto, M. 1996. Page 45.

[175] Mannermaa, M. 1998. Pages 40-41.

interaction processes between the different players in society. Individual market groups and areas can very much influence the way technology is developed, as the markets are a very effective way of determining what eventually diffuses and what does not.

Regardless, the base for change is usually laid by scientific progress, embodied by technological innovations. In these fields, change is fast. Economic change is usually not as fast, but still happens far more rapidly than the change of people's habits and activities as consumers. Societal change processes in turn happen very slowly. At worst, the democratic decision making mechanisms burden and slow down changes that already have proven technologically and economically feasible and have the acceptance of users. Internet development acts again as a suitable example – policy makers have followed the development from aside, and have not yet been able to influence the development very much.[176] Technology thus has an effect, which acts disrupting on society. Downes and Mui talk about the *law of disruption*, which they formulate as follows: *Social, political, and economic systems change incrementally, but technology changes exponentially*.[177] The law of disruption is presented graphically below.

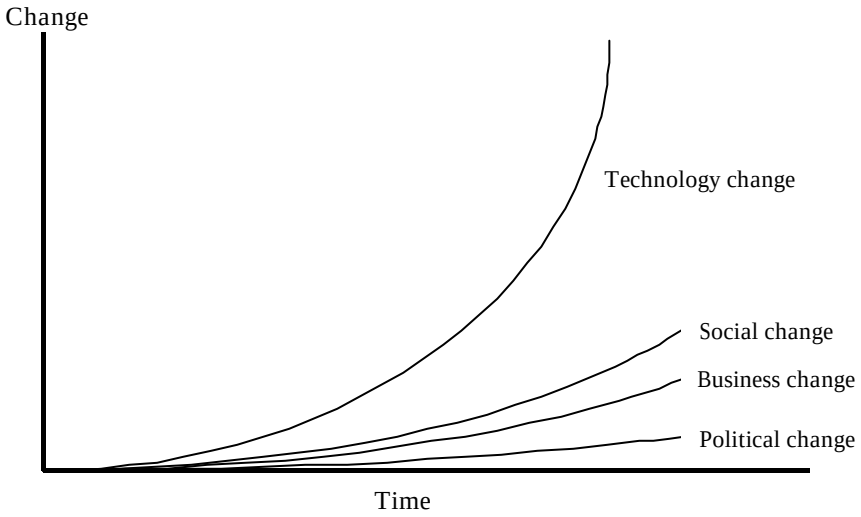

Figure 17. The law of disruption.

[176] Mannermaa. M. 1998. Pages 41-42.

[177] Downes, L. and Mui, C. 1998. Page 29.

7 Summary and conclusions

This study set out to discuss the role of wireless communications in the information society mainly through four questions:

- How have the information society concept and the related technologies evolved to their current state?
- What is the role of wireless communications in the evolution?
- What are the current prospects for wireless communications technology development?
- What are the forces influencing the adoption of new technologies and their applications by the users and markets?

In the following, a summary and conclusions based on these questions is presented.

The evolution

The information society concept has emerged and evolved mainly during the last three decades. From an originally abstract object for discussion mostly among sociologists, it evolved into a widely accepted concept, much thanks to the simultaneous advances in microelectronics, computing and communications. A successful information society evolution is currently seen as the foundation for future prosperity in contemporary strategy work of most western societies.

Besides "information society", a plethora of terms and definitions exist describing the future knowledge-based society. As a conclusion, the current understanding of what the information society means is summarized as follows:

- An increasing portion of products and services can be produced, distributed and consumed electronically in digital format using information technology and networks.
- There will be a continuous increase in the interaction between individuals, enterprises and various communities as well as in the distributing and sharing of information
- Information and knowledge become the fundamental elements of all activity, the main factor of production, source of competitiveness, economic growth and employment.

- As a result the scope of most activities expands from local or regional to global. This globalization affects information and content, economy, technology, R&D, lifestyles, consumption, regulation, and environmental problems, among others.
- The enabler for these developments is new technology making it possible to digitalize all information-based products, services and activities and handling the storage and distribution effectively.

Practically all existing information and a growing amount of services will be available digitally over the Internet and other possible future evolved global information networks. Many of the services relevant in the future are somehow in use already. It is clear that technology for accessing and using the information and services plays a crucial role in the actualization of the information society. Only computers and connection links offering fast enough data rates to connect to the Internet are, however, not enough. The key solutions needed, that require joined efforts of technology creators and other players alike are:

- Multimedia communication
- Electronic identification
- Electronic money, commerce and banking
- Information and knowledge management
- Anytime, anywhere access

The role of wireless communications

The last one of the above solutions, *anytime, anywhere access*; is crucial. As services increasingly move to the information networks, access must be possible from more and more places at any time. The electronic services offer a significant benefit over their physical counterparts only if access is not tied to time or physical location.

Two major phenomena of the 1990s, rising from digitalization and convergence are the Internet and wireless communications. The Internet already is the global information network that establishes the fundament of the information society. To achieve the anytime, anywhere access identified as crucial above, wireless communications is the natural – and obvious – solution.

The explosive growth of the mobile phone market shows the huge potential the wireless communications terminal has as a connecting device everyone possesses. The volumes,

together with the other characteristics of the cellular terminal indicate that the device will be the natural nucleus of convergence. No other current device family has the same potential of evolving into the most personal node for accessing the information networks and the advanced services offered. The enormous user base also makes the mobile telephone the most attractive starting point for creators of new services, offering a gateway to a point far down the Metcalfe curve.

The technology prospects

The mobile phone market growth shows yet no signs of leveling off. The number of mobile phones has already surpassed fixed telephone penetration in some markets, and it is expected that penetration levels will eventually surpass 100%, as people are most likely to own more than one wireless terminal. Wireless communications is fast developing towards fulfilling its expected role as the central link between the human, and the network and its services. The following major ongoing trends shaping wireless communications and expanding its role have been identified:

- *From voice to multimedia*. Wireless communications is fast evolving from offering only speech communications services to becoming a full-fledged user terminal and connection link to information society services. Multimedia communications will be essential in the future to use all the services, and thus the terminals are required to have visual capabilities in addition to high-quality audio.

- *Internet to everyone's pocket*. Continued convergence eventually brings now distinct networks together into the Internet, and in the future for example speech and video telephony, radio and TV broadcasting, video on demand, and all various multimedia services converge to be accessed through the web. These need to be accessible anytime, anywhere for the information society to work. Accordingly, mobile Internet is one of the hottest topics around, and many involved parties work hard to create the enabling solutions.

- *From mobile phones to personal trusted devices*. As the wireless terminal is used for more and more information, entertainment, and everyday errand applications, it gradually grows in importance for the individual. The mobile phone is already one of the most personal technical devices, and this development is seen to be growing. An

increasing amount of the functionalities currently resident in various very traditional objets and devices, like keys, money, calendars, notebooks, tickets, cards, etc. become digital and converge into the wireless terminal. The terminal uses have three main dimensions: *1) communications, 2) information management, and 3) identity, access and authorization.*

The prospects for wireless communications technology look very promising. The major obstacles rising from the limited bandwidth are diminishing, through the introduction of evolved second-generation systems and eventually the third generation, offering up to 2Mbps data rates. Together with the advances in data compression algorithms, rather advanced multimedia communication can be achieved with the wireless terminals.

Mobile Internet is very close. Wireless Application Protocol has gained strong momentum in the industry and among service creators, enabling the Internet content to be used already on wireless terminals. The versatility becomes significantly better, when packet radio creates true IP connectivity and possibilities for rational tariffing and use of spectrum.

Close-range connectivity, especially in the shape of Bluetooth low-power radio, enables versatile ad hoc networking and connectivity solutions, such as personal networks for efficient information management, identity and access control, and instant monetary transactions, for example.

Together with the advancements in microelectronics and other component technologies promising smaller, more efficient terminals with new, multimedia hardware features like cameras, high-quality displays, and advanced audio output, the technology development is clearly pointing towards the wireless terminal really becoming the envisaged personal trusted device.

Forces influencing adoption

In the last chapter of the study, the factors influencing the adoption of new technologies on the markets were discussed. The adoption process is complex, with many interdependencies influencing the whole.

Technology developments can in many ways be seen as the origin of change. In addition to the technology or innovation itself, the way it is served to the markets influences adoption much. To become successfully adopted in the future, a technology or innovation needs to

fulfill the following criteria. Firstly, it has to offer clear benefits compared to existing solutions. If an earlier solution does not exist, the new technology needs to convince users that there are benefits with taking it in use. Secondly, the user must not need to learn new skills to use the technology, or the learning must be very intuitive. The technology needs to be convenient to use in all situations where it might be needed. For example, a mobile phone needs to be usable also while driving. Thirdly, the cost of the technology needs to be reasonable and justified for markets to welcome it.

Social and market trends naturally reflect the actual adopting body. These are therefore among the central factors investigated when the potential market is analyzed. Age, wealth and education are central influencing demographic parameters. Habits and culture also have a great significance in determining what is adopted and how.

A group not usually regarded as part of the markets is the large umber of various non-market groups representing various interests. Through their activity, the development and adoption of technologies is highly affected. The impact of these groups also indicates the importance of social embeddedness of new technologies.

Industry structure and competition forms the third main group of influencing factors in the adoption process. The industry structure can be described as value chains. The way companies are present in a certain value chain has high impact on the way the industry works and evolves. One company can be present in many parts of the value chain, or focus on only one step.

The ferocity of the competition varies in various parts of the value chain, and is a powerful element influencing how technologies evolve, what is presented to the markets and what is eventually adopted. In communications, competition has been seen as important in promoting the development of networks and services.

Regardless of the importance of competition, for wireless communications and information networks it is also important to have common *standards*, ensuring functional service environments and true interoperability between devices and networks. Standards may either be officially agreed by common standardization bodies, or, as is happening more and more in the case of new converging technologies, agreements and consortia formed by a number of manufacturers. Often these unofficial agreements on a certain technology become de facto standards, used by almost everyone.

Metcalfe's law explains well the importance of standards and the competition of which technology is selected as a standard. The usefulness of a certain technology or application increases as the number of users it has grows, and the technology that becomes a standard or de facto standard is most likely to succeed even commercially.

The regulatory and political environment determines what kind of rules and legislation is agreed upon for the industry and the markets. It also reflects the major opinions of society. Industry regulation aims at creating a healthy competition environment and hindering monopolies from being established. It also has the targets of regulating acceptable behavior in the industry and assuring that health, safety and environmental requirements are met. Regulation is very relevant to network-based industries, requiring extensive and often monopolistic infrastructure. One form of regulation of the telecommunications industry is the allocation of the scarce radio spectrum. Industry regulation has a high impact on the possibilities for technologies and innovations to become adopted.

Content regulation, sometimes approaching censorship, faces a new situation in the information society. As practically all information is globally accessible, earlier country-specific principles for regulation of socially or politically questionable content become obsolete. The adoption of the information society technologies may be influenced surprisingly much by this. If people do not accept that all content is available, they may not accept the whole networks and services either.

A topic requiring special emphasis is the role of the regulators and legislators in the ongoing information society evolution. The relevant legislation and actions concerning information security, electronic identity, electronic payments and commerce, possible regulation of Internet content, IPR, and so forth, are currently taking shape. If the legislation process fails to meet the needs and to predict the fast-changing needs precisely enough, the legislation may become a burden, hindering continued development and leading to solutions that are obsolete before they are launched.

Many of the factors presented seem to support the fact that technology is the central origin of change. Regardless of the social, economic and political dimensions of the adoption process, *technology has a disrupting effect*, and increasingly so in the digital era of convergence. *Technology changes exponentially, while the social, economic and political systems change incrementally*. This is clearly illustrated by the explosive growth and

development of the Internet and wireless communications. The technological foundations for a mobile information society exist, and people have already begun to use these possibilities. The big challenge is how the industry, the business environment in general, and the official bodies of societies can follow in order to enhance the versatility and relevance of the systems.

Relevance of the study

In the introduction, the need for concise overview work concerning the relationship between wireless communications and the information society was emphasized. This study can be seen as fulfilling many of such requirements. An objective was to keep the study on a general level, so that it could be read without prior knowledge in the fields. This has succeeded rather well, and the work serves well the needs it was intended for. It is suitable to be read as an introduction to the topics relevant for understanding the current discussion and developments.

During the preparation of this study, the author has participated in many projects where material has been prepared for communicating the visions and prospects of the future mobile information society both inside the company and to external audiences. The content thus reflects rather well the view of NMP. Being currently the largest manufacturer of mobile phones, the statements of the company have a significant influence on the markets. In many cases the insights acquired during the preparation of this study have directly influenced the messages communicated by the company, and thus the contribution of the author can be seen as having significance.

Topics requiring attention

In this study several issues relevant to the development of wireless communications and the information society had to be omitted or passed with a very superficial mentioning. Some such issues that would benefit from further study are discussed in the following.

The role of *wireless LANs*, or W-LANs, in the information society development is still a bit unclear. LANs constitute a very central part in the Internet infrastructure, and local wireless access to them will definitely have a high impact on how the networks are accessed in offices and other organizational buildings and spaces. The relation of the roles of the personal wireless terminal, the wireless networks of the operators, and the W-LANs is therefore a topic requiring attention.

A related question is also that of *interoperability* between devices and networks. It will be crucial to have seamless solutions for accessing the information networks with a number of devices by different manufacturers and even for different standards. To ensure this interoperability, much cooperation and standardization is needed.

An increasing part of productive activity is directed to *software*. As the digital content of the information networks increases, software acquires a role growing in importance constantly. This has not only to do with traditional manipulation software applications. The software designed for the efficient use of the content and services is crucial in making the technologies usable, thus creating possibilities for the information society to develop in a positive direction. Tools for *navigation in the information* are essential, and thus much attention should be given to software technologies like intelligent agents, Java, voice browsing, information and knowledge management and sharing, networked intelligence, and so forth.

Another topic deserving deeper coverage than was dedicated in this study, is the coming advances in the *user interface*. As was identified in chapter 6, the design and convenience of use has a significant effect on adoption. The user interface of a personal trusted device needs to be very human. Speech recognition, handwriting recognition and design of the graphics are among the issues currently under strong development, and will have a major influence on how information society continues to evolve.

The nature and *impacts of convergence* are still not very well understood, and although the term is becoming familiar, relevant literature is scarce, and discussion still very much on a buzzword level. How does convergence really affect the way devices evolve and are used in the future? In this study, the mobile phone was identified as a natural nucleus of the convergence development. What this really means for the user, for the industry, and for the information society development, demands deeper investigation.

Along the lines of digitalization and convergence, sudden disruptions in the established industry structure are bound to happen. A recent example of such was the portable mp3-player, which caught the record industry pants down. A deeper understanding on how convergence proceeds, and what surprising applications are likely to come up, is a very relevant topic.

The mp3 example touches IPR issues deeply. This shows how actions are required from public authorities, policy makers and legislators to create the rules for operating in the information society. Currently, the central *legislation* concerning electronic identity, information security, IPR, and electronic commercial transactions, is being created. To support the legislative work, the participants need a deep insight in the implications of digitalization and convergence. If the decisions are made based on incomplete grounds and loose assumptions, the whole development, which has started very positively, may slow down or even be reversed.

A topic related to the continued development is also the *diffusion of converging technologies* into society. The traditional tools for forecasting diffusion have lately shown signs of obsolence. They are generally designed to examine a distinct new technology or a new generation of a technology. In the process of convergence, such distinctions become increasingly difficult to make. New methods for forecasting should therefore be developed.

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