ROADMAP
for Communication Technologies, Services and Business Models 2010, 2015 and Beyond

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Preface

This roadmap study was ordered by Tekes in 2010 and it was published on the 31st of Aug. 2010. By then the five-year GIGA programme was close to its end and Tekes was preparing a continuation effort under a proposed theme “Radical Changes in Wireless Communications” for the next five years. As a part of that process a roadmap was needed to vision the development in communication technologies, services and business models from the year 2010 towards 2015 and beyond. An important objective was to evaluate the prospective role of the Finnish small and medium sized enterprises and the Finnish industry in the field of telecommunication.

The work was carried out by VTT in close co-operation with Tekes and the GIGA research programme’s Thematic Groups where the work was profoundly commented and guided by several experts of business and technology on a number of occasions.

In this report we present a potential vision of the development of the critical communication technologies and services on a several year timescale. The focus is in those technologies that have a strong potential to develop further and which may provide opportunities for new services or applications as well as fresh businesses chances. These technologies are also potential objects for challenging research work. The roadmap that we present in this report is based on the public roadmaps (listed in Appendix 2) and it also integrates the wide material, which the GIGA programme’s thematic groups had gathered. Other important sources were the work done in the GIGA programme’s research projects, especially the latest studies that were done about business dynamics and modelling of business in the mobile internet section. Several specific interviews for focusing our view were also carried out with experts from the Finnish industry and the research organizations.

The actual writing process was divided in the following manner: Dr. Marko Jurvansuu and Mr. Jukka Mäkelä created most of the contents in Chapter 2 about the worldwide trends and visions in ICT while Jukka Mäkelä contributed to Chapter 5 as well. Mr. Jyrki Huusko and Dr. Petteri Mannarsalo sketched the vision of technology beyond 2015. Mr. Pekka Ruuska edited the report and wrote most of the text in Chapters 1, 3, 4, 6 and 7 and contributed also to Chapter 2.

We gratefully acknowledge the following people, who were interviewed: Mr. Juha Holkkola Nixu Software, Prof. Heikki Hämmäinen Aalto University, Mr. Santeri Kangas F-Secure, Mr. Veli-Pekka Ketonen 7Signal, Mr. Risto Saikkonen Nokia-Siemens Networks, Mr. Zack Shelby Sensinode and Mr. Sakari Vikamaa Nokia-Siemens Networks. We also like to thank the thematic groups Wireless Access Networks, Seamless Networking, Network Support Systems and Telecommunication Business of the Tekes GIGA programme for their active contribution to the roadmap process. An important contributor for our work was as well the SITRA’s workshop under the theme “The Future Trends in the Security of ICT”, where we were asked to participate.

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We would also like to express appreciation to Ms. Katja Ahola, Mr. Kari Markus, Mr. Timo Simula and Dr. Kari Tilli from Tekes for their valuable comments and guidance during the roadmap process.
Roadmaps are produced in companies, research organizations and standardization bodies for sketching the future and helping to make better strategic decisions. This roadmap report was funded by Tekes to vision the development in ICT from 2010 to 2015 and beyond. The technology focus of this presentation is in wireless communication systems due to their presently vital role in the Finnish industry and research. Another objective of the work was to estimate the market development in the established countries and in the most important developing economies as well as to evaluate the potential role of Finland’s telecommunication industry and the Finnish companies in the global business.

Tekes started the GIGA – Converging Networks research programme in 2005 and it is successfully finishing in 2010. In that programme five different thematic groups were formed for the experts of the research institutes and the participating companies to meet and target the research. The focus areas in the GIGA programme were wireless access systems, transparent networks, network support systems and services, telecommunication business and network security.

During the years, the thematic groups created their own topic related roadmaps and visions. This material was seen to provide such value, that an integration effort was needed to create a coherent image of the future directions of the ICT field. This is now concretely at hand within this roadmap, which integrates thematic group material and collects knowledge from latest public roadmaps published by various research institutions, funding bodies, technology forums, individual companies and standardization organizations.

During the work, the roadmap was constantly modified by the comments and feedback collected with interviews and in several workshops with GIGA’s expert groups.

The timescale and scope of this roadmap is development of network technologies and services from 2010 to 2015 and beyond. A vision of the potential business scenarios in the segment and their crucial changes is also presented. We analyzed the present situation in 2010 and evaluated the progress towards 2015. A precise classification to a year-by-year timescale would have needed foreseeing capabilities; rather we estimated the development on two levels, either within five years or beyond. We present the leading technologies, which are available and in everyday use and assess also the most central topics of research and development.

The roadmap content is as follows. After the introduction, Chapter 2 presents the worldwide trends that affect in society and in the ICT segment. Both business visions and views of the key technologies are illustrated. Chapter 3 gives a cross-sectional analysis of the technology situation in 2010. A roadmap of the expected development in various segments of technology towards the year 2015 is introduced in Chapter 4. A long-term vision of the Future Networked Society as well as technologies and services of the era beyond 2015 towards 2020 is sketched in Chapter 5. Potential business opportunities for small and medium enterprises in the rapidly changing technology environment are covered in Chapter 6. Finally a short summary and conclusions are presented in Chapter 7.
At the moment ICT sector is living a time of radical changes and this change enables the convergence between the physical and digital world. We are going ahead to a smart ICT environment, which may change the way of our everyday life. We are entering to a ubiquitous world. Some hints of this change of ICT are seen affecting us already, but the real change will take more than five years from now. At the same time the roles of different countries in the ICT business are changing as well. For example the continuing growth of China’s economic has lead to a situation where manufacturing has moved from developed countries to China. It delivers products not only to outside China, but increasingly more to internal Chinese growing market. For now on, eyes of the world are in China, India and Russia.

This change does not happen automatically and it has and will need a huge technology development as well. For example better, faster and cheaper broadband and mobile connections have enabled various new services. Since there are more users, the development of the different services will evolve even further. We have seen new powerful and easy to use devices like smartphones and internet television sets. 3D movies are already at cinema and 3D is reality at home and soon in mobile devices. New social network applications like Facebook have totally changed the way that people interact. The constant always-on-line has already started to be a problem for many, maybe since we are still new to the technology.

The rising use of ICT is not all about entertainment but it enables services like mobile payments and solution for more personal healthcare. With the new technology used e.g. like remote health monitoring realized with body area sensors and network solutions may be a significant help to people needing such service. Health in common is a sensual issue and the continuing growth of using ICT technology will probably turn more people against it in the future as well. This will require more specific studies about the dedicated technology effects to the health.

The use of ICT may also have a more global impact, in a good and a bad way. The hype around the climate change has put the Green ICT as one of the top trends also in the EU commission level [14] and of course, if the climate change is caused by people, we should be able to slow it down. It
is estimated that the global impact of the ICT technology (including mobile devices, PCs, servers, cooling, fixed networks, local area network, office telecommunications and printers) is 2% of the total global CO2 emissions; this is near the same as fuel consumption in the airline industry. So there is a need also in the ICT sector to look for more energy efficient solutions. However, ICT has a significant amount of untapped potential also to reduce the energy consumption in the future. In addition, the new upcoming cloud and cognitive solutions will increase the usability and reliability of the networks and services which will be parts of the ICT technology in the future as well. There are also a number of other trends and rising technologies as illustrated in Figure 1 and listed more detailed in section 2.2 which will be in our path towards the future world.

2.1 Market and business trends

ICT corporations enter new domains for ensuring end-to-end user experience

The key to attract users to new services and products is the end-to-end user experience. This is especially true with mobile phones. With iPhone, iTunes and AppStore, Apple showed how important it was to create both business ecosystem to provide attractive mobile applications as well as good user experience with “just works” fashion. End-to-end user experience requires that all parts in internet, device and application level work seamlessly together and not only just technically. The business ecosystem has to be well operational as well. Still, many new technologies are driven to market by their adaptation to new mobile phones.

The end-to-end concept is also used by Nokia with the Ovi store, Google with Android and others. Many of the “appstores” are tightly coupled with the phone operating system and thus with certain vendors and keep the users tied to the platform as well. For the application developers this is not the most efficient situation, if they wish to provide multiplatform applications.

From these examples one can also notice that as the phone manufacturers are increasingly providing mobile services to the end user directly, there will be less market for operator based mobile services and phone applications.

Another new domain that seems to interest many ICT players is the banking. Nokia Money is Nokia’s solution to provide mobile currency and mobile banking first of all for the developing countries with lack of decent banking infrastructure of their own.

There is also a tendency from the telecom and internet world to penetrate to the consumer device market. For example Nokia is producing a laptop and Nokia Home Music device. Google is also expanding towards home equipment and combined service offering with their Google TV open platform [22] that is based on an Android chip in TV receivers. It enables people to view internet with their TV sets and with the Google Chrome browser.

For network vendors, the services are becoming a bigger part of their business, not only they manufacture the network equipment, but also often provide installation, maintenance and even daily network operations to the operators [23].

Digitalization

Digitalization and quick transmission of all information proceeds further and changes both the business environment and people’s everyday life [25]. This development is currently best showing in the U.S and emerging to Europe. In the rest of the World many of the predicted changes do not occur as the old infrastructure never existed, still the new technology enters everywhere. As numbers the digital content grew by 62 % or 800 000 petabytes during the year 2009 [38]. The list of completely disappearing devices includes landline phones, fax machines and as well most of the single-purpose hardware such as GPS devices, calculators or e-book readers. All these get replaced by pocket-size or laptop computers, which provide all imaginable digital services. Most visible business changes are the appearing extinction of printed newspapers, general interest magazines and hard copies of books, music and movies. All people can and will utilize on-line services for both entertainment and also to banking, insurance services, health care or to buying tickets, cars and everything. The integration of online and store sales will essentially change the way that retail is done.

Freeness, cheapness

Freeness is a basic feature in internet and it can be penetrating to other sectors of life as well. The large customer bases in the internet have made it possible that the advertising can provide a reasonable income to those service providers that run popular services such as Google or Facebook.

In print media, the newspapers have had free internet editions available for a long time, whilst their paper
editions and related advertisements have provided the revenue. The subscriptions for the paper editions are decreasing, which puts more pressure to charging for the internet version, especially when there are more internet users than ordinary ones.

There is reluctance to pay licence fees at all levels: for example with free HTML5 it is possible to enable multimedia features that previously would have required Adobe Flash, Microsoft Silverlight or other licensed technologies. In addition, there are legal battles between e.g. Nokia and Apple regarding mobile technology IPR.

Openness
Openness is a major trend as well and it challenges many of the traditional business models. Formerly companies typically utilised software products from other companies in business-to-business fashion, but now they accept innovations from the user community side, for example by using OpenOffice software. There are also open mobile platforms like Android and recently this trend was followed by the earlier closed Symbian platform as well. The open API's provide developers simple ways to utilise mobile phone features such as sensor information. API's in network operator systems provides means to find location information of a phone [26]. An API in internet service, such as Facebook, provides a way to link the Facebook's social network with other services or applications.

Crowd sourcing
Crowd sourcing is an effective method to collect and refine information, for example WikiPedia dictionary services, OpenStreetMap map service or recent Mobiilimittari [28] mobile broadband speed evaluation service employ users to build their service. If there is a benefit for the user, he/she may be willing to contribute to the service in order to make it even more beneficial. Discussion forums can as well be sometimes considered as crowd sourcing. For example, discussion forum on a vendor page provides information to the manufacturer related to product usability and problems.

User information on sale
Internet has become such a large part of our everyday lives and in the future, we are expected to spend even more time and money with it than before. Internet will be connected to real life items and places in ever increasing pace. Through internet, one could “see” into people’s lives and habits in a very detailed manner. This is especially true when a single entity provides most of the key internet services. For example, the user actions, habits, likes/dislikes or social networks are valuable information for developing the internet services and targeted advertisements. That is actually one of the most prominent internet business logics at the moment. It is thus quite obvious that gathering and controlling the user information is a target for many corporations and governments.

Internet companies are very much growth based and need new users, but they also want to keep the former ones within their services. Google defines what information we find from the internet and in which order, they also provide mail, document, picture and mobile and TV related services and platforms. Google took a massive set of photographs all over the world for their Google maps, and created a database that is useful for linking internet services with real life places.

Facebook’s privacy settings have been under debate lately, they are also aiming for providing social networking to be a part of internet services. For example, one could see how members of one’s own Facebook social network have rated a product or an internet service. If this information is used for advertisement purposes, ads could contain information on how many of your friends have purchased the item and how they rate it.

User related content or web behaviour can provide additional value to services, but it raises a question about the user’s privacy. Collected data may be stolen, modified or misused and it may be difficult to find out who is responsible in such cases. Corporations holding the information may be out of the influence of the user’s own country legislation.

We can expect that in the future the user information will be the main trade item of the internet or even traded by the user him/herself [24].

Asia and China as the next financial superpowers
ICT manufacturing has been mostly moved from the developed countries to lower cost economies. The winner was especially China, which is attractive due to low cost and the biggest growing market in the World. Chinese companies are also very actively purchasing western corporations. China should not be seen as a copier of western products, but instead as a country of their own brands and products, that are sold all over the World in a large scale within the next years. In the fu-
ture, we expect that China will be generally seen as a source of high quality products, even superior to the Western counterparts. India is as well becoming a large-scale producer rather than a sub-contactor of the global companies. The Korean and several other East-Asian companies already have a strong market-share in the ICT business and there is no reason to expect that they would not success in the future.

**Developing countries**

For African countries or India, Brazil and other poorer countries there is yet a need for cost effective telecommunication infrastructure. The number of potential new users of mobile phones is massive and at the same time, the topographical area that needs to be covered is large as well. Rather than broadband speed these users would need cheap handsets and low subscription fees.

**Beyond the consume and growth based society**

Since the ICT related manufacturing and the market is in Asia and diluting from there also to other low cost countries, the need for ICT related R&D and manufacturing labour has decreased and yet will still decrease in the Western countries. Yet this sounds like a pessimistic future, there are good possibilities left for Europe and the USA still. One can think that Asia is now entering the manufacturing and society infrastructure growth period that the Western World lately experienced. For Europe it is time to take next step ahead and think what is beyond. As a matter of fact, it is a must. Cost can be too high to keep the current society structures as they are with the current productivity and price structure. As an example, the ageing of population and the simultaneous prolongation of the average life-span requires that not only people have to stay at work longer, but they need to be healthier and when coming to their golden years, have decent life quality at their homes. This is something that can be supported by ICT based solutions.

The importance of energy and politics around it is an ever increasing trend. As the seriousness of the threatening climate change has been recognised globally, we need to consider how to maintain growth without harming the environment. Green and clean technologies certainly provide possibilities also for the Finnish companies to export their technologies to those countries that are now are now in the consumer and production growth phase.

One must remember that the stabilised Western economies are still a big market and in which everyday local services have to be maintained. Internet is not the only option to develop business.

**2.2 Changing business environment**

The business related thematic group and the research projects of the GiGA programme produced various business model scenarios and analysis of business dynamics in the ICT sector. In the following we shortly go through the main findings along with information found from public roadmaps.

Two quite different business model scenarios are considered for the ICT business. In the (traditional) vertical model companies concentrate on sector-specific value chains. In the horizontal model companies try to find services and applications that might attract consumers and business customers across specific sectors. As an example, the same content or an application, with minor changes, is offered for all including users of mobile and desktop terminals and even through broadcasting systems. In the vertical business scenario the field is ruled by a few strong, vertically integrated companies, e.g. Microsoft started with operating systems and then advanced to applications, Google came from services to applications and networks, and Nokia emerges from plain terminals to user’s services [13].

At the moment it looks that there is an enormous market-potential in the network database value-added business. Still it is not simple to earn money with that, consumers or business-to-business companies do not understand it properly yet. There are numerous new service providers and all is changing fast, including such basics as channels, media, content, usage and context [12].

As key drivers for future ICT business models are open source coding, free data and the software as a service approach. New business models enter from internet/consumer business side; Apple’s iStore, Spotify, Nokia’s Ovi and others. All these accomplish in cloud computing, which will undoubtedly transform the IT industry.

Convergence of networks did not fully realize yet, but instead an important change is the divergence and fragmentation of the media landscape. Dozens of different social media applications appeared of which the most famous are Twitter, Facebook, LinkedIn,
Spotify as well as more special groups such as game societies or sports enthusiast's own networks (Traxmeet, Sportsdo, Nike+, Movescount, Runkeeper). It is evident that the access, identification and utilization of user's personal data, wherever it is located in the network is becoming a source of real competitive advantage.

Social media and its phenomena change industry structures and business models in unpredictable ways. Purely vertical or horizontal business models are deteriorating and companies are looking for short-cuts, side-tracks and across-traditional-segmentation strategies [12].

ICT is becoming a commodity in all parts of the World, all costs are declining, volume of network traffic is skyrocketing and services are truly ubiquitous, quick wireless connections are always available. Internet-centric pock- etable devices become cheap enough in all countries, server and Web-based applications can be accessed anywhere. People get a portable personality that encapsulates a user's preferred work environment, which the user can recreate across multiple locations or systems. It is possible to offer services and products, which billions of potential customers may reach.

**Consumer's changing needs and desires**

Several trends, which involve the service needs and desires of consumers worldwide, were identified in the public roadmaps. Some background issues derive from the explosion of social networking and global deployment of IP services. Consumers share information and their experience of everything, including the services and products they purchased. This means that marketing of consumer goods should be more entertaining, interactive and targeted. The World has also become flat and transparent, global markets are open everywhere, which decreases costs, increases efficiency and creates more synchronous business cycles. Virtual World is also turning to a business World; it is possible to utilize virtual money (such as airline miles) in buying things in the real World, which is a rising trend [33].

New or better technical solutions are needed for many things with a few years term: Users would want to navigate, search and organize contents seamlessly across content types and content sources. The currently existing domain-specific services for music or photos are not enough for long. Potential areas for new solutions are also in online shopping, which advances globally and may boost in China. Pocketable devices should support that easily and as well provide trusted payment methods.

Digital identity is rising in importance; identity verification and on-line reputation management need tools. Support of ubiquitous learning is another widely needed service, even SMS technology has been used for that. Elderly population is a potential growing customer group for services dealing with wellness, health, travelling and experiences. A new extreme expectation from the users is that devices should not only be simple to use, they should often automatically understand user's wants and proceed to them. Smart spaces and ubiquitous World means that user's interfaces appear everywhere, interaction with devices should always be natural and human [32].

**Trends that influence at the moment and continue to do so are green technology, cloud computing, quick appearance of new users in poor countries, users' expectations of getting everything free and utilization of user data in business. User's expectation of clouds is that they get all their services everywhere, seamlessly. For system development and business structures, cloud changes thing: software-as-a-service emerges; Web becomes dominant interface, security issues change from authentication and access control to more sophisticated identity and personal management solutions [33].**

Green technology is needed as prices of energy and materials rise. Eco-friendliness and clean energy keep their importance, research is done and consumers appreciate green solutions. Although free music and entertainment is widely delivered, it is still possible to get revenue by finding true needs and desires of consumers [30] [33].

**2.3 Long term vision towards ubiquitous world**

Today's industry vision is towards a ubiquitous world. This vision states that we will be surrounded with a huge amount of co-operating, small, embedded intelligent electronics, which contribute to our everyday life with situation relevant information and services fostering convenience and efficiency.

At the moment we are still both technically, culturally and business-wise quite far from that vision. However, there are many clear signs, which make us believe that the vision is to happen. It is also good to realize, that the evolution in ICT area has a higher pace than it was earlier. Who would
have though twenty years ago in 1990, how our lives would be so tied with existence of mobile phones and internet as they are now. This longish period was needed to establish a true communication platform that connects everybody to everybody i.e. internet in addition to person-person communication system based on cellular technology. Actually a quite new form of media was created.

Internet is an innovation platform, where things happen quickly and where masses of people experience them at once. It was hardly expected five years ago that we would send personal or business related videos to YouTube, while chatting in Facebook, both services which operate on a public information sharing principle! It can be thus expected that internet related things like new internet services and how people use them can evolve quickly within a couple of years. On the other hand, a longer time period of 5 to 10 years is expected for those things that require changes in our real life surroundings. For example, everyday house appliances like TV-sets and cars are changed in that time. Even a longer delay is needed for finding embedded electronics in buildings, homes and offices, especially when electronics must be embedded to walls in time of construction or renovation. Somewhat shorter cycles are possible with smart furniture.

Communication is an essential part of the ubiquitous world, whether it is performed between humans, humans and devices or between devices. With ever more present embedded electronics, we can assume that the latter two forms of communication are more profound than they are today. The communication channel is in most cases internet, whilst locally devices have direct connectivity with each other. Ubiquitous world will be the "heavy consumer" of communication and thus network technologies and device co-operation methods are essential backbones of it. In this sense, it would be quite natural to take communication capabilities and internet connectivity as a target when examining the evolution.

In the following Figure 2, several communications related eras are shown. One should notice that even when we speak about eras, the evolution is incremental and eras exist parallel and benefit from each other. In addition, Figure 2 includes certain keywords and descriptions to make the evolution more concrete and understandable.

In Figure 2, the starting point is the desktop internet, in which the users utilize mostly PCs’ and laptops for the internet; this is the case for the majority of the users today. We exploit internet services such as Google, Amazon and others, still we can work remotely while on the move or at homes.

The way how people use internet evolves constantly. Formerly internet was a place to find information or buy products from the web-stores, but now it has become a platform of social networking. The way that the internet is used is currently changing due to internet connected mobile devices. Mobile phone users have started to utilize their internet browser on a mobile phone to do similar things as they have used to do with desktop and laptop computers. The mobile internet is finally here! In some definitions, the mobile internet also includes laptop as the end device as laptops are often nomadic and connected wirelessly to the internet. In third countries, the desktop internet phase can be even over passed and mobile phone gives people their first internet experience.

The next step is when the devices, products and places connect with the internet. Bridgernet [9] may be used as a new to term to emphasize that this is about bridging the real world with digital one. A car or a home dish washer may have physical internet connection for software update purposes or there are additional information linked to the object on the web. For example a bottle of wine may have 2D-code or a RFID/NFC tag for fetching producer information with the mobile phone. In this era, mobile augmented reality has a huge potential to become the user’s digital eye to the World.

Once our surrounding devices and items get internet connected, they may be smarter as well due to ever decreasing cost of electronics, memory and processing power. The devices can find each other, share information and tasks within a local smart space. The smart space can be a room; an office, a public space or a bus, where-ever there are enough co-operation capable devices in the proximity of each other. The main challenge here is the interoperability between devices and systems over standards or vendor specific solutions. Car is likely to be the smart space that people encounter first, many of the interoperability issues are solved by the car manufacturers and mobile phones or game consoles may connect to a car entertainment system with WLAN or Bluetooth. The possible benefits of a smart space are decreased energy consumption, new kinds of services and ease of use of the otherwise complicated digital environment.

In the endpoint of the vision, we
see a Ubiquitous World, where it may be difficult to tell the difference between the real and virtual objects. For example, people working in the same company are located all around the World, but experience each others as they would be in the same physical place. For achieving this, many technologies exist and some are under development e.g. true-alike holographic representations. However, for fully utilizing this would require a new kind of thinking, different work culture and innovative solutions to how the offices are built.

2.4 Rising new technologies

In the following, we list important and rising technologies identified by us and mentioned in discussions of the GIGA's thematic groups [32]. The technologies are not in any specific order according to the importance. These technologies are selected to this roadmap because it is foreseen that they will have a major impact also to corporate strategies worldwide [43]. However, some technologies are more visible in countries like China and India rather than in Europe and the U.S. as mentioned in the list. It is also foreseen that significant number of users, customers, service providers and other companies will expect and probably also adopt these technologies; these are also the challenges that organizations will face through the upcoming years.

- **Social networking**: Social network applications and services like Facebook are widely used amongst family and friends. Social networks fulfil the basic need of people to stay connected with
friends and other people. They also enable easy way to establish social groups of people interested in the same things. Even though the social network applications have their limitations and drawbacks with their openness nature, social networking applications with the realtime communication capabilities might fit for the corporate interactions as well. This might help to get geographically separated people and teams to work more closely, and if social networking trend will continue its growth it is obvious that it will introduce more corporate targeted solutions as well.

- **Online services:** Widespread internet connectivity has enabled the use of digital content delivery services like online music services (e.g. Spotify), online internet TV services (e.g. YLE areena) or online video stream services (e.g. Youtube). The current trend of operators to offer flat rate based charging and faster Internet connections is feeding the trend to be online as well. The device manufacturers will adopt supporting technology in their devices and this will automatically offer better usability of the online services. When the device’s usability reaches the level that people have access to all services via their remote control it might be that digital content delivery will win out over broadcast television. New online services are not only for entertainment, but they include also services for e-learning, shopping, healthcare or virtual meetings.

- **Virtualization of devices:** Virtualization has been adopted and used typically in data centre’s infrastructure and it has already shown its benefits in operational efficiency, energy consumption and cost efficiency. What has not yet been widely used is the virtualization of the desktops mainly due to the complexity of the needed technology, however there is considerable progress made in technology which will boost the demand of this kind of solutions in the coming year. Large amount of this development will come from India where virtualized desktops will be more common in companies and schools in the upcoming years.

- **Cloud computing:** Current trend around the cloud computing includes a number of different technologies that are sometimes confusing. One definition for cloud computing is a system where massively scalable IT functionalities are provided as a service using Internet technologies to the customers. It can also mean virtualization technology where services are running remotely in a ubiquitous computing cloud. Anyway it is predicted that impact of cloud computing on IT vendors will be huge.

- **Green computing:** ICT consumes an increasing amount of energy so more energy efficient solutions in the ICT-area will be needed. However, the use of smart ICT also helps reducing energy and this is why ICT offers a way forward for reducing the total consumption of energy. Green computing is a big trend in business today and using green technology not only helps the environment but also reduce costs.

- **Cognitive networks:** Networks, network nodes and the management and maintenance of those are going to the cognitive direction, meaning that networks will adopt mechanism that automatically monitor, react and heal the networks in error condition. Fully cognitive network needs wide range of solutions from radio technology (e.g. cognitive radios) to dedicated applications (e.g. monitoring and decision mechanism). Fully cognitive system has succeeded when user does not recognize the error condition at all and instead of the user intervention, the system will fix the error condition itself. The fully cognitive networks are not reality within 1-2 years, although some self-adaptation and management features can be available. After longer period solution will be more common targeting to the minimization of expenses i.e. OPEX and CAPEX, and enhanced system robustness.

- **E-books and e-book devices:** Meanwhile Google and Chinese search engines and Chinese legislation have its own fight the visible trend of using portable devices for reading e-books and digital novel is rising. At the moment the trend is more visible in countries like China and it is expected that this area will continue its growth. New high speed technology and mobile devices with bigger screen will also speed up the use and availability of this kind of service.
• **Bluetooth:** Bluetooth 3.0 + HS (High Speed), as it is called now, will include the 802.11 Protocol Adaptation Layer that provides increased throughput of data transfer (theoretical rate of 24 Mbps) and quick ad-hoc connections. In addition, mobile devices including Bluetooth 3.0 + HS will realize increased power savings due to enhanced power control. Bluetooth 4.0 includes a new low-energy technology that is designed to the small devices such as sensors and devices that usually uses coin battery as their energy source.

• **Mobile web:** All smartphones and also most of the new basic mobile phones have some kind of data connection and a web browser. And for example in Western Europe and Japan, majority of the handsets will be smartphones which have proper web browsing capabilities. Lot of people are already using also dedicated web based applications like Facebook in their mobile phones. This trend will probably continue its growth when the wide-band and low-latency networks like Long Term Evolution (LTE) will be in use.

• **Portable mobile applications:** There will be a number of different mobile platforms that will have a significant presence in markets. Installable application that can be run on several software and hardware platforms will have very good chance to get lot of users. Portability of code is important on all levels of systems including software defined radios, which are slowly emerging, as well as in higher level applications.

• **Application stores:** Application stores like Apple's App Store or Nokia's Ovi service will be the primary way to distribute and sell applications to mobile devices. App stores provide a range of business support functions, such as payment processing, that assist smaller organizations. App stores are also a potential way to provide applications and service to other devices like the Internet TV boxes or any devices that need an easy way to install new available applications. Applications stores provide easy access to the international market which is beneficial especially for the smaller companies.

• **Enhanced location awareness:** Some predictions state that by the end of 2011 majority of pocketable devices shipped in mature markets will include a GPS. Devices will as well use other methods to achieve the location information e.g. Wi-Fi and Cell ID based systems are already working today. Devices do not only know their physical location but devices will be aware of the nearby objects, places and other devices as well and are able to communicate with them too.

• **Cellular broadband:** During the upcoming years there will be more mobile networks available and using high speed technologies. Technologies like WCDMA, HSPA and EV-DO will be the main technologies for a couple of years and it is most likely that in many networks these technologies will be coexisting. New technologies like LTE and WiMAX will start their upswing but according to some experts only few of the mature-market subscribers will adopt LTE in the next two years.

• **Touchscreens:** Everyone who is using smartphones has noticed that the touchscreens are the current trend of user interfaces. It’s also predicted that touchscreens will be a dominant user interface in mobile handsets with larger screens. According to some markets analysis most of the mobile devices shipped in Western Europe and North America in 2011 provide a touchscreen.

• **Machine-to-machine (M2M):** Embedded cellular modules will be cheaper and cheaper. At the same time the development in cellular broadband services will accelerate new M2M application video surveillance. In the future machine-to-machine solution with Smart Grid will have also opportunities in the Green IT field e.g. with better M2M based energy metering solutions. The trend is to use automatic M2M technology instead of having an eye-to-eye contact with the meter.

• **More generic security:** Security is quickly becoming important in all devices, not only personal computers or mobile phones [30]. Focus should be on security technologies, application technologies and sourcing options that enable applications that are secure, but less tightly tied to specific devices and platforms. Distributed applications do not require separate security tools to be installed on the client. This will enable delivering applications that can run on a wider range of devices.
2.5 The service enablers

New technologies, also those listed in the previous section, enable new potential services. Under Green ICT the realtime energy costs and consuming monitoring is one example that we will probably see also in Finland during the upcoming years. Remote monitoring of energy consuming is already used by the energy companies but monitoring ICT solutions may become also a part of people’s everyday life. Such solutions interest consumers because they will then know in real-time e.g. when the energy is cheapest. This may help to balance the energy consuming peaks by setting different prices for different times and allow controlling the use of energy. In the long-term ordinary houses may become energy producers with their wind-mills or solar panels, hybrid or full electricity cars may store energy. In back-bone electricity grid, there is thus need to know in close-real time about upcoming energy consuming or production in maybe tens of thousands of points. This is the field of Smart Grid research and development.

Cloud computing brings huge playfield by introducing IT infrastructure as a service. We don’t need any more huge computational power or huge hard-disks locally since we can buy those as service from the clouds. Many experts see cloud computing as big thing as the introduction of the Web was. Cloud computing is not a completely new issue but it hasn’t got a big commercial attention earlier. Another important driver for cloud computing is the multi-homing approach; users want to connect to the internet with multiple different devices and always get access to their personal data and working environment from the cloud.

The increasing coverage of the broadband connections fixed and wireless together with new short range technologies such as Zigbee, other IEEE 802.15 technologies and the new low-power versions of Bluetooth will enable various new services. For example healthcare systems typically have high quality requirements and obviously these solutions will get benefit with more reliable and more delay tolerant networks as well with the new versions of the short range technologies.

Better connections enable new services in the media business. Internet TV’s and other so called online services will appear more and more to everyday use. Evolvement of mobile networks together with new powerful, smart, easy to use and touchscreen equipped and internet enabled handheld devices increase the demand and interest of using online services even further.

Different application stores will enable the easy way to distribute applications and services to huge amounts of users. Usually application stores have built in earning logics in them which makes their utilization easy also for very small companies without any own investments.

New technology evolvements will enable more and more M2M communications which will bring a wide range of new networked devices and systems to operation. This will create need for new services as well. M2M will be one of the main technologies for enabling communication without any human intervention, which is also one of the challenges for the cognitive networks of the future.

The security services will change as well. The quickly increasing number of users and offered services need to be secured properly. Controlling authentication and access to systems is not enough anymore; protecting user’s social identity and personal data are becoming central issues. Cloud computing is already utilized in security systems and security as well as everything else can be sold as a service to the users.
Status of the latest technology, which is currently available in the market, is shortly presented in this section. The analysis was revised by various experts who were gathered to specific workshops or interviewed individually during the roadmap process.

3.1 User’s equipment in 2010

The separation in the roles of the fixed system’s desktop terminals and the mobile phones is now almost vanishing while as well several home appliances can access the Internet. The quick progress in processing power and memory size has made smart phones capable to work with most of the applications that were first developed for the fixed systems. As laptop computers prevail and wireless access systems emerge everywhere, the personal computers are better described as nomadic terminals.

Full and wide-band internet access is possible with handheld devices while only the extremely bandwidth- and power-hungry applications are too heavy for their hardware (e.g. real-time 3D gaming). The mobile devices support advanced operating systems such as Android, Linux, Symbian or Windows. Furthermore, mobile terminals provide an impressive set of technical solutions, which are usually not offered in laptop computers: Global Positioning System (GPS), Navigation, Near Field Communication (NFC) and high-resolution cameras. New home-automation applications for Bluetooth and low-energy Bluetooth (LE) are introduced and using mobile phones as wallets is starting. However, an essential difference between the desktop computers and the pocket-size devices is still the display size and the limited battery life. Therefore users may still need more than one physical computer appliance, if they want to be always on. And users must themselves take care of keeping their contacts and other personal information up-to-date in different devices.

It is reality that the web-services are nearly ubiquitous, social media and entertainment dominates in applications while easily used touch-screens and qwerty-keyboards have appeared. By acquiring a smart phone the user gets with the price of one device several useful technical tools for her daily life. Still today the best selling mobile phone models are technically rather simple providing GPRS/Edge or 3G interfaces. As seen from [2], only four smart phones are among the top 15 handsets (in Finland) currently. Apple iPhone’s share was about 1%, while another study showed that in page loads via mobile devices

<table>
<thead>
<tr>
<th>Model Name (of mobile handset)</th>
<th>Share of all handsets</th>
<th>Packet Data Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Nokia 2760</td>
<td>4,7 %</td>
<td>gprs/edge</td>
</tr>
<tr>
<td>2 Nokia 3120 Classic</td>
<td>4,1 %</td>
<td>wcdma</td>
</tr>
<tr>
<td>3 Nokia 1100</td>
<td>3,9 %</td>
<td></td>
</tr>
<tr>
<td>4 Nokia 2600 Classic</td>
<td>2,5 %</td>
<td>gprs/edge</td>
</tr>
<tr>
<td>5 Nokia 3310</td>
<td>2,4 %</td>
<td></td>
</tr>
<tr>
<td>6 Nokia 3110 Classic</td>
<td>2,4 %</td>
<td>gprs/edge</td>
</tr>
<tr>
<td>7 Nokia 2610</td>
<td>2,4 %</td>
<td>gprs</td>
</tr>
<tr>
<td>8 Nokia 1600</td>
<td>2,3 %</td>
<td></td>
</tr>
<tr>
<td>9 Nokia 6300</td>
<td>2,1 %</td>
<td>gprs/edge</td>
</tr>
<tr>
<td>10 Nokia E51</td>
<td>2,0 %</td>
<td>wcdma</td>
</tr>
<tr>
<td>11 Nokia N95</td>
<td>1,9 %</td>
<td>wcdma</td>
</tr>
<tr>
<td>12 Nokia 2310</td>
<td>1,8 %</td>
<td></td>
</tr>
<tr>
<td>13 Nokia E90 Communicator</td>
<td>1,6%</td>
<td>wcdma</td>
</tr>
<tr>
<td>14 Nokia 6060</td>
<td>1,6%</td>
<td>gprs</td>
</tr>
<tr>
<td>15 Nokia N73</td>
<td>1,5%</td>
<td>wcdma</td>
</tr>
</tbody>
</table>

Table 1. The most popular cell phones in Finland (in Q3/2009) [2]
Apple's two devices took a share of 34%. The 199 different Nokia devices were used in 61% of page loads in the same period [42]. And still, circuit-switched speech and SMS services continue to bring the biggest share of revenue for the network operators.

Machine-to-machine communication has appeared to home appliances and wired or wireless Internet access is possible through game-consoles, televisions, camcorders, navigators and even sewing-machines. Television sets and set-top boxes with IP connections operated with TV’s remote controllers were recently introduced. Remote and local monitoring and controlling of home and office devices and systems through wireless connections is expected to expand. User’s terminals are not anymore limited to the traditional keyboard, mouse and screen equipped devices.

3.2 Radio technology in 2010

In the following, wireless technologies are divided to different sectors by their role, transmission bands and their range. Roles of radio systems are depicted in Figure 3. There are different organizations with different policies that control and standardize each sector of radio systems. Progress of standardization strongly affects to the success of each technology.

Wide-area, high-power systems

The 2G and 3G technologies dominate in the World’s cellular systems while operators are just starting to offer the 4G service for packet-data transmission. In the US market WiMAX and LTE struggle while in Europe LTE seems to take over. A strong driver for LTE is its ability to utilize the TDD (Time-Division Duplex) bands, which is important especially in China [30]. For the success of LTE in Europe and other parts of the World as well, it is crucial how the radio-bands are allocated by the public authorities. The 800 MHz band is optional for LTE while in other bands (e.g. 2.6 GHz) it is harder to compete. Anyway, the recently introduced technologies HSPA

Figure 3. Roles of different radio technologies as Internet deploys to all systems
countries fixed and mobile WiMAX version are used. Flash-OFDM technology was introduced to the 450 MHz band but only few operators invest in it. The Chinese TD-SCDMA was not a success despite its strong governmental support. ITU-R has started standardization of IMT-Advanced and both latest versions of WiMAX and LTE specifications compete among other candidate proposals to get acceptance [31].

Wireless LANs

Wi-Fi as versions IEEE 802.11a/b/g and IEEE 802.11n (providing ultra-wide band and MIMO) is the leading technology in accessing the Internet without wires, currently 97% of laptops ship with Wi-Fi Integrated [5]. Recent amendments of the 802.11 specification are IEEE 802.11at (or 80211VHT Very High Throughput at 60 GHz), IEEE 802.11k (traffic load optimization), IEEE 802.11u (interworking with external networks), IEEE 802.11r (seamless mobility), IEEE 802.11y (high power 3.65-3.70 GHz) and IEEE 802.11w (improved MAC-layer security) [6]. Of these specifications, 802.11r is especially interesting as it may provide a real alternative to using the high-power systems in the densely populated areas.

Wi-Fi utilizes license-free bands, it provides transmission rates, which are fast enough for all applications and it is almost costless to users. Wi-Fi’s huge popularity has brought some interference problems, which occasionally may limit its use in the 2.4 GHz band (802.11b/g) but the 5 GHz systems face less problems. Wi-Fi networks are also often configured non-optimally, which reduces the throughput. Still it seems that Wi-Fi keeps its strong position for a long time, although specification of ultra-wide band, short-range LTE and WiMAX systems proceed. A potential use for the Wi-Fi systems is in pushing the cellular traffic to operator’s Wi-Fi in congested regions i.e. offloading [30].

As the 802.11n is not always capable to transfer HD video, several new approaches for the 57 to 64 GHz millimeter wave band are under development. These solutions may provide more than 1 Gbps or even 7 Gbps band-width at a shorter than 10 m range. Costs of the 60 GHz technology are still high, which is their major setback. The WiGig system is supposed to interoperate with the 802.11 systems while the competing proposals named as WHDI and WirelessHD (WiHD) were started earlier and provide some technical advantage. Standards for the 60 GHz band systems are under work within the ISO and in the IEEE 802.15c as well [21].

Broadcasting systems

Analog television is still used in majority of countries while the digital technology is advancing through various standards. In the US ATSC has specified HDTV 1080p with different frame rates. Elsewhere ETSI’s DVB standards have a strong role; use of DVB-T2 for terrestrial HDTV started and DVB-S2 for satellites is being deployed. However, using DVB-H in handheld devices was severely delayed in many countries by the copyright problems. Specification of DVB-NGH (Next Generation Handheld) with LTE transmission rates continues. At the same time in Japan and some other countries watching television through mobile handsets is popular and dozens of channels are available. Mobile digital radio services are offered as well and in many European countries (e.g., Britain) switch-off of the analog radio broadcasting is decided (2015) [37]. Traffic Message Channel (RDS-TMC) is being substituted with digital version providing multimedia content. IPTV provides a new alternative for broadcasting and it is quickly getting more market-share. Standards exist for HDTV up to 1080p50 although only few receivers (HD Ready) can achieve better than 1080i25 or 720p. MPEG4 is replacing MPEG2 and scalable video codecs are appearing enabling reception of a stream with receivers having different screen size (e.g. HDTV to mobile handsets). Interactive systems with a return channel are developed and implemented [31].

Short range, low-power systems

Smart spaces or short-range wireless sensor systems are widely applied e.g. in logistics, medical and industrial applications [1]. Introduction of smart spaces to home and office devices creates huge expectations, it is anticipated that the number of radios would grow hundred-fold in a few years. Standard radio in sensor motes currently is Zigbee, which is based on the IEEE 802.15.4 specification. With its latest amendments 802.15.4 looks very promising; it probably keeps its strong position for five years easily [30]. Other serious choices are low-power Bluetooth and UWB (IEEE 802.15.3a). Bluetooth provides technically simple connectivity to mobile handsets while UWB offers 100-480 Mbs band-width at short range (3m-10m). Anyway, in
 Securities in wireless access systems

The physical and other low layer protocols are vulnerable to several threats of which basic examples are interference, eavesdropping, manipulation, unsolicited traffic and physical tampering. LTE introduces a new approach to security including enhancements to 3G security, advanced solutions for handovers and security mechanisms for inter-working with non-3GPP access networks also [7]. WiMAX supports AES encryption and authentication of users, which provides security level comparable to 3GPP. Security of the MAC layer in wireless LAN systems was found weak (control messages are unencrypted) and work with IEEE802.11w was started. In the low-power systems processing resources are so limited that security solutions are difficult and often compromised. Security of smart phones is a new challenge, which immediately comes true, when the abusers find that there is money accessible in the handsets [30] [32].

3.3 Networks and their support systems in 2010

Convergence of the heterogeneous network systems progressed slower than expected while new network types appeared to the low-energy sector. Anyway, wireless or wired IP connectivity from all devices (Internet of things) is even in a more vital role than before.

Transmission of circuit-switched voice and short messages through the 2G and 3G networks continues to bring the major share of operators' revenues. Accessing Internet with smart phones is increasing still it is not even nearly as popular as with desktop terminals. Fixed wide-band connections to homes and offices are currently priced higher than the wireless alternatives, which raise their popularity also among users with desktop terminals.

Transmission in the gigahertz bands and with high speeds consumes electricity. Energy consumption is becoming a critical cost factor for the operators and it is also delaying the deployment of the wireless wide-band services [8]. Figure 4 depicts some of the currently central topics in network technology and network based services.

IPv6 deployment

Despite its technical advantages in security, mobility, QoS mechanisms, multicasting capabilities and the maturity of IPv6, IPv4 is still going strong. According to a recent survey 92 per cent of Internet Service Providers (ISP) are not using IPv6 and are themselves unsure about whether to promote IPv6 uptake to their customers [3]. Still it looks that IPv4 numbers are running out for NATs 2010-2012, which should boost the IPv6 deployment.

Femtocells

Femtocell approach in hot spots for supporting packet-switched transmission is considered promising although the predominant Wi-Fi systems leave little room for all other options. For reaching success the femtocells should offer a cheaper or a technically superior option when compared to the Wi-Fi devices [30]. Still the seamless wide-range roaming and the better security of LTE systems could create a role for femtocells in replacing the open access Wi-Fi systems.
Convergion of networks

Convergion of network systems has progressed in standardization while only few operators provide such services and many real trials to do business with that were withdrawn. Handsets with both Wi-Fi and cellular interface are common, still only few of them support seamless handovers. Actually, a smart handset may support ten different radio interfaces. Inter-working functions between Wi-Fi systems and WiMAX were specified but their implementing is slow. One reason for this is the fact that almost any application works properly although the IP address changes, the only major exception being the VPN connections that really do not accept any IP address change without in-bound mobility solution [32].

Mesh networking

Mesh architecture is used in several public wireless LANs and 802.11 devices. The approach has business potential in emergency systems; military applications were followed by mobile ad-hoc security systems and even mobile, live wide-area broadcasting for thousands of people has been done with the mesh approach. Smart spaces are another potential sector for the mesh architectures. Sometimes the mesh architecture solutions have been vulnerable to active and selfish users, who may poach resources from all others [32]. Quick utilization of the mesh type of systems is not expected, still it would start immediately, if the users would really benefit of it.

QoS

Classifying network connections by their bandwidth requirements and employing QoS mechanisms in wireless or core networks is still a rare solution. Among the widely deployed systems QoS classification was specified to the 3GPP’s WCDMA system and the IEEE 802.11 provides some support for QoS but these are activated only seldom in operating networks. In the core systems MPLS (Multiprotocol Label Switching) is widely used for controlling traffic and it could also be employed in classifying connections but that is rarely done. The
QoS mechanisms always bring complexity to systems while they provide more performance only in rather specific conditions. Still the QoS functions could aid VoIP applications and they are a potential solution to optimize utilization of the radio resources [31].

**Network support systems and services**

Network operators are more and more concentrating to their basic business and leaving support activities to other companies [34]. Virtual network operators are even more willing to outsource their activities to others. Network testing, performance measurement and optimization are typically left for specialized service providers. Actual QoS delivered to the customer becomes more crucial as legislation sets more precise requirements and the customers are getting more quality conscious. In network design the device vendors are taking more responsibility. Customer experience management is another important activity where outsourcing is typical.

**Security in networks**

The Internet’s basic protocols were developed before security became a difficult issue; therefore all its security solutions are later add-ons. Any radical new solution for Internet’s security is not in sight although they are strongly needed [4]. A new security problem is cloud computing as confidential information from both enterprises and private persons is stored in the network systems. Some experts claim that cloud kills security [33] while it as well offers new ways to implement security monitoring systems. List of various security threats is long, still the user’s ignorance and behavior are the most severe security risks, threatening all systems [33]. Advancing security of systems always requires resources, which creates costs, and may weaken system’s usability or performance. Therefore the goal is always to reach an adequate security level, which satisfies user’s expectations in various cases and in different contexts.

### 3.4 Services offered in 2010

Services offered in the wired and the wireless networks converge as the smart phones and the nomadic desktop computers mainly differ by the size of the display screen. All popular internet services are offered also as mobile versions while the specific features of the pocket devices create exciting new opportunities. Machine-to-machine communication through internet is another sector where specific new services are required. Cloud computing is coming to reality, applications that run in handsets or desktops utilize clouds and software-as-a-service (SaaS) approach appears to office section first. Many services are close to being ubiquitous as through smart pocket devices they are available almost anywhere.

**Services in fixed networks**

Social media, sharing of music, video are the hottest applications in all networks; they were first developed for desktop users and quickly adopted to mobile devices. IPTV is advancing and it is bringing HDTV to homes before the wireless broadcasting systems. As an expansion of the hugely popular YouTube, Google TV opens thousands of TV channels to homes and offers translation services as well. Other competing services are soon expected. 3D televisions are now available still the 3D service is not expected to boom as the 3D in cinema has not been a tremendous success either. Video games are popular and in their success 3D capable video accelerators and wide bandwidth are in a vital role. Teleconferencing is another widely used service, which is specific for fixed systems and also telepresence is offered. Legal use of P2P (peer-to-peer protocol) based applications for transmitting content is another emerging trend.

**Services in wireless networks**

Use of local context, NFC, positioning and navigation abilities provides exciting opportunities for developing specific applications to mobile terminals. Game designers may utilize locality and presence to bring more thrill to users, social media becomes more tempting and in the commercial and industrial section of applications wide prospects open. LTE and other wide-band technologies together with flat rate charging advance VoIP, still it isn't very attractive to users yet. Utilization of mobile handsets in authentication is starting. NFC has progressed, a major vendor (Nokia) has published their support for technology for incoming years and its use in payment looks promising. DVB-H was introduced, but in many countries conflicts about copyright costs have stopped its use. NATs and firewalls limit some advanced applications.
This section illustrates the expected development of technology between the years 2010 to 2015. The analysis was revised by various experts who were gathered to specific workshops or interviewed individually during the roadmap process.

4.1 Technology enablers to 2015

Development continues towards faster and faster transmission rates and supporting ubiquitous services with a wide range of wireless technologies, which simultaneously compete and supplement each other. ICT solutions become a commodity everywhere and ease of use drives the progress. However, lack of spectrum and its scatteredness, limited energy resources, increasing complexity of systems and the difficulties in standardization and regulation partly delay the development [30]. Other key challenges are the interference and coverage issues, security and customers’ confusion towards the non-interoperable technologies [21]. It is believed that no quick and radical technology changes realize within the next five years. Still a real breakthrough is expected by many in Software Defined Radio technology before the year 2015 although all experts do not share the vision. Otherwise the probable development materializes through changes of price level of components and services, to some extent through quite new innovation but mostly by improvements of the existing solutions, many of which exist in some form today. The development is roughly evaluated on a time scale in Figure 5.

Dynamic and Optimal Spectrum Use

Technology to support flexible spectrum use is adopted and first utilized in uncoordinated local deployments. Standardized solutions for primary and secondary user types in the new white space bands exist. Major wireless technologies are developed to exploit spectrum sharing. Efficient co-existence of different radio systems in the same band with equal access is put into operation. However, adoption of flexible spectrum use is still limited as many of the obstacles in standardization and regulation remain; the ITU-R World Radiocommunication Conference 2012 is expected to clarify these issues [31].

Software Defined Radio (SDR) and Cognitive Radio Systems (CRS)

ETSI’s standards for Software Defined Radio Architecture Baseline are finalized before 2015. A flexible control and signal processing environment with agile RF front-end and antennas becomes available within a few years. The substantial difficulties in satisfying linearity requirements with SDR and also many of the real problems in (parallel) programming and with portability of code get gradually solved. After that it becomes possible to utilize the same RF hardware with all wireless access technologies. SDR solution finally becomes the most viable implementation option for radio systems. First the network infrastructure radios and later also all handsets provide SDR solutions [30] [31].

Lack of spectrum drives the development and cognitive radio capabilities are required in majority of technologies. Global bands for cognitive radios are identified and standards for some technologies exist. Devices with cognitive radio capabilities are available on the market, while band-specific fixed RF-front ends still restrain implementing true cognitive radios. Different technical solutions and algorithms co-exist while device centric, distributed and ad-hoc approaches compose the main stream of the development.

Technologies for the 60 GHz band

Several technologies co-exist in the 60 GHz radio band. The WiGig solution gets a strong market share as it smoothly interoperates with the IEEE 802.11n devices and provides both low power and high power options. For specific applications such as 3D over wireless or in WPANs WiHD technology, which is capable of 10-28 Gbps data
rates, is used. In low-power systems the 60 GHz solutions are rare although IEEE 802.15c specifications for sensor networks are released [21].

**Antennas**

New strict requirements for antennas derive from the deployment of LTE systems and acceptance of MIMO solutions to Wi-Fi, WiMAX, DVB-H and UWB among several other standards. Increased number of frequency bands, higher transmission rates, cognitive radios and the wide diversity in user’s terminals physical structure create interesting challenges to antenna design. Limiting the effects of RF-emissions to body may become more stringent and hearing-aid compatibility (HAC) becomes a standard requirement.

Dynamic and efficient radiator sharing and re-allocation drives the antenna design. Both electrically and mechanically flexible antennas exist while the device’s radio part can track the protocol’s demands and may select different radiators for different protocols. The radiators and RF front-ends become highly tunable. New antenna features can be implemented by programming. Radiators can be combined and often it is possible to utilize device’s mechanic parts as radiators to boost the performance. Advanced reconfigurability with near-field manipulation and control characteristics describe the antenna systems [31].

**MPEG4**

Analog switch-off is done in Europe and several other parts of the World, which enables utilization of several advanced DVB features. Replacing MPEG2 with MPEG4 provides 3D rendering, Blu-ray level high definition as well as many interactive features. As MPEG4 is efficient across several bit-rates, it gives opportunities for hybrid systems, where collaboration with cellular networks is employed. Broadcasting is not always
real-time streaming of video or music; it is more like data casting where capability of reaching unlimited number of receivers with high data rates is utilized.

**Scalable video**
Scalable video codecs are widely used in handsets and other minor devices, enabling reception of a stream with receivers having different screen size before the year 2015.

**Wired Ultra High Speed Connections**
Optical cables to homes and offices enable implementing access connection with bandwidths of tens of megabytes per second. In Finland it is an official goal to bring 100 Mbps connections available to all homes before 2015 [10] although the costs of the last mile of the connection may remain high. Real-time streaming of high definition video becomes possible and potential applications are teleconferences and telepresence. Sending home-produced HD video to others is straightforward with such facilities. As also the prices of large flat screens continue to fall HD video attracts users. A real limiting factor is in the core network resources, which simultaneously are stressed with video load, increasing number of user connections and mobile terminals with wide-band connections.

**Smart Space Technology**
Progress in energy harvesting, steadily advancing capabilities of tiny hardware and the wide-band short range radios boost wireless sensor applications to appear everywhere. Homes, gardens, offices and factories are filled with wireless sensors, which may take care of security monitoring, heat and light controlling at homes, health care applications and environmental systems as well as dozens of other duties. Sensor systems communicate with user’s pocket devices through low power Bluetooth while they utilize the latest versions of the IEEE 802.15.4 radios for their internal connections. Wireless USB implemented typically with Wi-Fi (or UWB in personal/body area) is a basic interface in all devices that process images or large amounts of data. Most devices can communicate with each other through wireless interfaces: TV screens can be used as a mobile handset’s display, MP3 music from a pocket device is listened through Hi-Fi stereos, a camcorder can send its contents to any local set top box or projector and no plugs, sockets or wires are needed.

**Seamless Automatic RF Interface Selection**
User’s handheld and desktop terminals may automatically select an RF interface, which satisfies the cost requirements and the real QoS expectations of the user. The terminal identifies the active applications and always selects the interface which in addition to strong signal can provide uncongested connections. And for modest applications, such as chatting, the terminal may take the cheapest interface. This is important especially for roaming users, who want to be always connected without wondering about their access network. Latest amendments of the IEEE 802.11 standards and the expected expansion of LTE to local systems bring more network choices for all users. Still it is possible that operators cannot reach an agreement of roaming policies and the seamless system changes do not fully come true.

**Cloud computing**
Cloud computing becomes the basic approach for all applications that utilize internet access. As a part of seamless user experience all data is stored in one virtual place allowing use of online and social services ubiquitously. It is equally important for the enterprises to keep their latest business information in one safe place, where it is always quickly available for their own use. Software is offered as a service first for the office applications and later in the entertainment sector. New software offerings and their updates become immediately available for all. The Web is the dominant platform for developers of all types of software including very specific devices as well as mobile phones or personal computers. User’s devices do not necessarily need as much processing resources as before while the wide-band access systems enable quick use of sophisticated applications. The cloud solution pushes the development of all users’ terminals becoming both mobile and energy efficient.

**Network architectures**
LTE’s SAE architecture emerges to non-3GPP systems supporting heterogeneous radio access networks for nomadic and mobile devices. Still other solutions persist and they are not quickly replaced as long as they can satisfy the quickly growing bandwidth requirements. IMT-Advanced is the dominant architecture in the first installations of radio access networks.

Mesh networking is an optional functionality in all network technologies still it remains invisible to users. Machine-to-machine communication and interworking between networks is simple with the mesh approach. Local
communication can be done with femtocells in a mesh, which are out of the reach of base station control. Self-configuration and self-healing characteristics of the mesh approach boost their utilization among the operators and the approach is used not only in ad-hoc or emergency and military activities.

**Utilization of heterogeneous systems**

Specifications for heterogeneous network architecture are finalized within the IEEE and ETSI. Mobile Independent Handover (MIH) or the IEEE 802.21 standard covers vertical hand-off preparation, security and authentication issues as well as QoS. Implementations of MIH can be found in some Wi-Fi and WiMAX systems. In the cellular systems GAN (Generic Access Network) exist to support handovers between Wi-Fi and 3GPP systems. Anyway, due to several practical weaknesses of the vertical handover approach, users prefer LTE based solutions for seamless internet access when they are available.

**Future Internet**

Doubling of internet traffic in less than every two years, the new recognized challenges and the known issues such as unwanted traffic, choking of the routing system, resource consumption and congestion, lack of trust and reputation of the system have activated extensive research programmes to address these issues [40]. The most critical of the known challenges are according to a leading expert [27] exhaustion of IPv4 addresses, problems in controlling of multihoming and explosion of routing tables. The first crisis should occur in Q3 of 2011, the latter two will be faced within five to ten years. However, some progress and results can be expected of the research efforts; at least the often forecasted collapse of the Internet is probably avoided. Improvements are made in network management mechanisms, routing procedures and in controlling mobility and multihoming. Anyway, many of the widely anticipated solutions, e.g. content-based addressing, which is supposed to replace the current location-based addressing, will hardly come true according to many experts.

**Energy efficiency and Green ICT**

The rise in power consumption due to utilization of higher radio frequencies and wider bandwidths brought energy efficiency important also in the radio infrastructure devices. To achieve the radio coverage of one 2G base station, 3G requires four times more sites and LTE needs 16 times more than 3G. Also the wired wide-band systems consume clearly more energy when transmission speed rises. In 2009 ICT’s share was 7.4 % of all consumed electricity (in Finland) of which 69 % was consumed by the user’s terminals and other CPE. It is expected that the ICT’s consumption rises 50 % before 2015. In the radio infrastructure energy is saved by using sleep mode and the newly introduced DC feed. DC feed is efficient and suits better to solar cells and other alternative energy sources; it is widely used first in Japan [8]. Promoting green ICT is as well a key asset for device vendors, which their customers appreciate and in some countries energy efficiency is under governmental regulation [34]. Carbon remediation costs will be included in business cases even before it becomes a regulatory issue.

Dependence of batteries is critical in handsets as it brutally limits flexible use of many popular and important applications. In smart space systems the need to change batteries can form a critical cost factor for the users. While the fuel cell technology advances still it is not believed that they can replace batteries before 2015. Better expectations lie in energy saving solutions, which enable implementing increasingly complex energy-autonomous devices. Wireless sensor motes do not always need their coin cells anymore; they get their energy from their environment with energy harvesting. Main technologies to achieve this are use of vibration, thermoelectricity, photovoltaic energy and utilization of the received RF energy from the broadcasting systems. Also the simplest mobile phones may work with energy harvesting and while smart phones need more energy, also their energy efficiency gets better.

**Proceedings in security**

Controlling people’s and organizations’ network identity and network privacy is the key challenge, which has become quite central, when social networking applications appeared. Another driver for changes is the emerging cloud approach in storing personal and intimate information. Security mechanisms have to develop from authentication and access control to complicated identity and personal data management solutions. Technically most of the security issues can be solved while a constant threat is the user’s behavior. People are often ignorant, careless or easily misguided to leave doors open to systems or to giving passwords for strangers. Currently 15 000 new security threats appear every day [33]. The basic securing approach must turn from self-managed security to trust
managed mechanisms. Another critical concern is securing payment with smartphones or simple handsets in the globally heterogeneous financing and banking infrastructure. The smart space devices are as well vulnerable to attacks and often their resources are too modest for proper protection, cloud computing can be the key to this problem.

4.2 Communication technologies to 2015

Smartphones have overtaken personal computers as the most common Web access device worldwide, first as the secondary access device and then as the primary connection. As a consequence the Web pages must be simplified; still the demand for video services and other bandwidth-hungry applications is only growing. Context aware computing is in central role in mobile consumer services and relationships.

By the year 2015 wide adaptation of MIMO solutions enables to utilize transmission rates of 150 Mbps for the long range and up to 1 Gbps in local area communication. Progress in energy efficiency brings longer battery-life to handsets enabling better utilization of complex applications and more capable devices in wireless sensors. Cloud computing is the basic approach to implement applications for all devices and users can securely and easily trust their private data in the clouds. Software Defined Radios are widely utilized and cognitive features are appearing to network systems. The development is roughly put to a time scale in Figure 6.

**Wide area networks: IMT-Advanced prevails**

It is strongly believed that LTE or LTE-Advanced wins the competition of becoming ITU-R’s world-wide 4G technology, which is named officially IMT-Advanced. LTE has then become the dominant technology for public wide-
band access networks. It has a share in local networks too and it provides ultra-wide short range and machine-to-machine to communication capabilities together with ease of roaming for mobile users. However, 2G technologies still have a role in areas where no resources to build dense base station systems exist and besides the energy-efficiency of 2G continues its life-time in all countries. Circuit-switched speech service is often replaced with VoIP. Deployment of WiMAX 2 or IEEE 802.16m offering 100 Mbps band-width with MIMO-technology has progressed. Still a large share of operators changes to LTE, which offers equal performance plus simple compatibility with 2G and non-3GPP networks. Flash-OFDM may be used in some minor and special services, for instance on fast running trains, and in areas where 450 MHz or other low frequency band is available.

Local area networks: Wi-Fi continues to dominate, new bands utilized

The worldwide high penetration rate of Wi-Fi devices, the systems technical merits and its low costs keep IEEE 802.11 based systems in strong position. The 5 GHz band is fully utilized and the millimeter waves in the 60 GHz band provide ultra-wide short range capacity for HD and 3D video transmission in WLANs. LTE and WiMAX provide equal or slightly better capabilities for the short range, but the costs of building infrastructure and lack of spectrum keeps their market share low. Public Wi-Fi-systems that support roaming and offer secure connections with longer range and wider bandwidth are immensely popular and they may partly replace the cellular systems in handset use too. VoIP connections are often activated through the local area networks though social networking with context-aware applications is vital both for business and private users.

Broadcasting: High Definition proceeds

Analog television is not much used in Europe after the year 2015 and technologies based on DVB standards have emerged to wide areas of the World. In the North and South America other digital standards are used, while everywhere a resolution of at least 1080i25 is considered normal. The signal gets more and more often delivered through IP networks in the real-time mode also and typically user's terminal is a set-top box or a television set, which can be used for many purposes. However, as the costs of 100 Mbps fiber connections are still considerable in most countries, wireless broadcasting continues normally. Cellular systems’ handsets typically provide scalable video codecs and they can receive DVB signal also from satellites or from terrestrial links with high resolution. Interactive use, where the return channel is a cellular connection, is a common solution with handsets especially.

Short range systems

Progress of energy-harvesting methods together with less and less consuming hardware enables extensive use of wireless sensors in industrial applications. Simultaneously devices with rather modest hardware become capable of IP communication. Machine-to-machine communication is not limited to proprietary systems; more and more devices can collect information and send it through the Internet. Embedded systems in cars, boats, offices and homes operate autonomously and communicate with each other typically without human control. However, the radio interfaces of battery-operated and energy-autonomous devices are still minimal and narrow-band IEEE 802.15 protocols are most often used [30]. In the home-appliances and machines that are not energy-limited low-power Bluetooth is used to communicate with handsets while otherwise Wi-Fi is a typical solution. UWB has a minor share in the personal or body area systems and the 60 GHz option is specified but rarely used.

Evolution of networks and their support systems

In the access network systems 100 Gbps with Ethernet is typically used. In addition to wider band-widths over the air-interface, number of users, amount of data traffic from wireless devices and quickly increasing video transmission to both uplink and downlink directions brutally stress the core systems [4] [27]. Still the real bottleneck for wide-band applications is the radio interface. IPv6 is finally becoming the predominant protocol in new implementations although IPv4 still lives for long. Mesh architecture appears as an option to major radio network standards. The self-configuring, scalable and self-healing characteristics of the mesh solutions attract some network operators to utilize mesh architecture with femtocells. As several heterogeneous radio access systems are continuously utilized, user’s terminals become capable to select automatically an optimal radio interface and an uncongested network segment for each application or each session. QoS classification of connections is
sometimes employed in wideband radio access networks. Multihoming of users is enabled through new routing approaches. Several cognitive features such as sensing and learning are introduced to radio networks. Development of short range radio systems proceeds towards truly ubiquitous world.

Virtual and traditional network operators may offer all types of wireless services to their customers and they need more specialized service providers to support these activities. Tools for controlling network performance develop to provide full and real-time end-to-end view of the delivered QoS. For offering specific services and applications outsourced service providers are used [39]. Customer experience is monitored with more advanced tools, which are often implemented with the cloud approach.

4.3 Services offered to 2015

Social networking and the need to many-to-many communication rather than person-to-person contacts with any device is vital. Ubiquitous services extend gradually everywhere and their utilization becomes part of life just as the IP services are today.

Services in wired systems

Services offered through wired connections compete with LTE and WiMAX offerings as long as copper wires are used. Deployment of 100 Mbps optical fiber connections to households and offices creates new interest to high definition videos. All users can easily reach hundreds of TV channels. User can control the system through set-top boxes with TV's remote controller. Video and music as well as any other content can be easily and wirelessly shared between local devices. Telepresence and video meetings turns from high-tec to standard solution, which anybody can use. Wide-band uplink connections are important for sharing music and videos or for real-time security monitoring applications.

Services in wireless systems

All commonly accepted IP applications are implemented first as versions, which are intended for handsets. The simple user's interfaces can always be activated from desktop computers also and the currently typical approach of offering services and applications for large-screen terminals only, slowly disappears. The extreme context-awareness of handset devices creates a new segment of services, which are utilized with smart phones. Navigation ability, as well as capability to physically locate devices, services and even people creates exciting chances for both business and entertainment uses. Utilization of presence information advances in business use as well as in games and all types of social networking. When paying simply with handsets everywhere becomes possible, including the minor fees and when roaming abroad, offering charged IP services boosts up immediately. Near Field Communication is commonly utilized, buying anything by simple clicks of handsets changes shopping habits. Internet shopping with handsets starts in broad scale probably first in countries like China, where desktop systems are not as common as mobile devices.
In this chapter we provide a glimpse to a technological vision beyond the year 2015 towards the 2020 and even beyond that. The previous chapters provided us already the first technological roadmap towards the environment, which can be called as “Future Networked Society”. In ‘90s Manuel Castells and Jan van Dijk specified the term “Network Society” as a society where the key structures are organized around information networks. The “Network Society” can be seen as an enhancement of the information society. In this case, it is not only the technology that defines the behaviour of society, but also political, cultural and economical factors together with information society’s technological advances build up the network society. It can be also seen that different social and media networks itself shape the organizational forms and the most important infrastructures of the society.

The Figure 7 is adapted from the Future Internet Cross-ETP Group (including the work groups from eMobility, NEM, Nessi, ISI and EPoSS) vision of the major challenges in network research for future Internet. This figure depicts well the main technology pillars towards the future society. The Network Society itself leans on the social networking between individuals and organizations having a strong human intervention to relationships and functionalities. In a wilder vision of the future society, not only the technology, social and media networks, but also smart networked devices and artificial intelligence are building and affecting to structures of society.

As illustrated in the Figure 7, the network infrastructure will form the basis of the future society, on top of which the technology pillars can be firmly established. In order to build robust and firm basic infrastructure, the network system needs to support several main characteristics. These characteristics are defined as the main technology challenges especially for the

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**Figure 7. Technology pillars of Networked Society**

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![Diagram of Future Networked Society with Technology Pillars](image-url)
future networks and services, including at least security, scalability, efficient data and traffic management and control, adaptability to heterogeneous environments, energetic and economical sustainability, and adequate simplicity of the system. In addition the network infrastructure is foreseen not as a single technology but as a co-existing and co-operating infrastructure of different local and global networks, the Internet. Today, we are already living in the information society and we have solutions for some of the main challenges and technologies. However the wider penetration of the technological solutions is still to come and most probably for some of the technologies such as cognitive management systems and network, and autonomic wide-spread ubiquitous Internet of Things will penetrate to markets only after 2020-2030. In spite of that, we are well on the road to new type of networked society.

Considering the technology pillars for the Future Network Society, the first one “Internet for the people and Internet by the people” is needed to facilitate people’s, communities’ and organizations’ everyday life by allowing new business and breaking the barriers between information consumers and producers. The goal is to foster new breed of prosumers i.e. people and communities who are part of the creative process not as plain consumers but also producers of the content and services. For example the future Internet Cross-ETP Group has seen this as a one of the main pillars, which is fostering already now the emergence and development of new technologies such as Web 3.0.

This kind of accommodation of user ideas and requirements leads to “Internet of Media” (IoM), which can be also called as Internet of content and knowledge. In a nutshell the system should provide solutions and mechanisms for content and knowledge dissemination in a way that it enables the diffusion of knowledge and culture by promoting learning and dissemination of information and content. In the scope of Future Networked Society, the Internet of Media expects that all the media is digitalized and can be delivered through the network and to variety of networked devices. Although “Internet of Media” is good enabler for new information and content delivery based business, it will generate big challenges for the system in order to cope with increased number and size of the information and to provide secure and trusted content access. In addition the efficient search and discovery mechanism as well as information and content storage systems are becoming more and more important. For example the digital video distribution and increasing number of sources creates need for efficient multimedia search engines. The network multimedia communication is also leading to 3D video delivery over the network, requiring efficient utilization of bandwidth and resources.

The third pillar – “Internet of Things” (IoT) is mainly about smart objects, the “Things”. Although there is no standard definition for the IoT, in the vision for “beyond 2015” and for the Future Networked Society the IoT could be defined as a global network for uniquely addressable interconnected objects. Now-a-days we still consider the “Things” as rather uniform devices what comes to their purpose and properties although there is some heterogeneity in object capabilities. However, it is foreseen that the heterogeneity will increases also in terms of functionality, technology and application field in the devices belonging to same, common communication environment. Under the IoT vision, the different type of objects will be for example able to implement automated processes themselves such as harvesting the energy they need and configure and adapt themselves to new operating environments. These smart objects will also provide the means to integrate operations in the real world and virtual and digital worlds as augmented reality and augmented virtuality. According to European Technology Platform on Smart Systems Integration the backbone of the IoT will be formed by smart wireless identifiable devices such as ElectroMagnetic ID (EMID), Ultra Sound ID (USID), Radio Frequency ID (RFID), and Millimetre Waves ID (MMWD) among others. The application field which the IoT will open is vast and there are good business opportunities for the service and application developers starting from home automation to military applications, retail logistics to healthcare, environmental monitoring, public safety and robotics. However, from technological point of view there are still several advances which need to be taken before the IoT can be reality. First of all the communication in terms of inter-machine communications protocols, antenna and radio technologies, and global identifiers as well as interoperability issues and trust & security need to be solved. Secondly, the energy consumption and harvesting requires new solutions since in the current technologies the energy capacity and processing power are way too low. In addition the key topic of the IoT, the
actual intelligence of the devices i.e. context-awareness and cognitive behaviour needs to be well taken care of.

The “Internet of Services” (IoS) describes how the services are provided and operated on the network. In the IoS vision, the access to the services is not only based on technical characteristics (e.g. IP-location and web service identifiers such as URLs) but the access can also be based on the contextual information. The IoS will provide consumers and prosumers permanent, transparent, seamless, context-aware, empowering and trustworthy service access and interaction. The permanent service interactivity means in this case that there is no time limit and user can access and interact with service when ever he/she wants to. The transparency is defined in a way that consumer gets only the benefits of the service which he/she is using. The third requirement, seamless interactivity is described as a support of mobility without the interruption when user changes location or devices. Context-awareness can be defined in a way that user interaction will be adapted to different context such as device characteristics, location and user preferences e.g. social networks which he/she belongs to. Although this kind of automatized service interaction with context-awareness is sometimes useful it would be also required that users are able to configure themselves the way they want to get the access. Thus user level empowerment of service interactions is required. In order for users to feel confident that the interaction with service is safe, the IoS needs to guarantee the trustworthiness of service too.

In order to proceed towards the global IoS several main technological challenges have been identified. Since the IoS is about large-scale service-oriented computing allowing access not only to content but complex physical compute resources and data/software functionalities one of the main challenges lies in this loose coupled interaction (i.e. the interactions are not based anymore on the tight properties such as IP addresses of machines) and “cloud computing” paradigm and its scalability and flexibility. The second challenge lies on the openness of the service platforms. The open service platforms would allow easy deployment of user-designed services and service components and therefore lead to intense co-creation and development of services with end users, driving also forward the prosumers for service development. In order to progress towards global coherent IoS, open service platforms need to overcome current incoherent standards and architectures and improve service platform service interfaces and interoperability. The third challenge is on autonomic computing aiming to create computer and computing systems capable of self-management. The complexity of computing systems management is already now increasing due to high amount of distributed data, services and applications. The complexity of management is seen as significant factor in the further development of distributed large-scale computing systems, cloud computing and data centre federation. In addition, the energy consumption is one of the limiting factors for very large-scale service-oriented infrastructures and clouds. The sustainable ICT for energy consumption in future service and computing platforms is required.

In this chapter a vision for beyond 2015, targeting to Future Networked Society was presented. The chapter also identified the four key technology pillars required for the building up the society infrastructure. Comparing the presented vision, its technological requirements and challenges, and the main trends presented in previous chapter, we can see that quite many of the current technology trends are already working towards the Future Networked Society. However, we can argue that in order to reach the adequate technological level we are still far from the target. In the following sections of the chapter 5 some main new technologies and services are presented supporting this long period vision starting from nanotechnology for ICT to quantum computing and communications.

5.1 User’s daily life in 2020

The following scenario illustrates the daily life at Future Networked Society. The scenario is adopted from vision by Industry Expert Group which was published by EU Commission in 2009 [20]. The scenario presents few technological solutions which will be reality in the future networked society.

In Helsinki, Matti’s bedside display wakes him at 6.45 a.m., a bit earlier than usual because his calendar includes a telemeeting at 8.00 a.m. in the office. The clock display shows him a reminder of the meeting. After getting ready, Matti takes his electric car to drive to the office. The car’s communications system reminds him of missed calls. Matti calls his colleague while driving using the handsfree communication system. For the rest of the trip, he listens to his personal music channel. The 99 channel music from his home system is adapted to the 6 speaker setup in
the car to create a perfect acoustic rendering of the conditions of the original recording.

When he gets to the office Matti hooks the car up to the company’s recharging point. His car is sufficiently intelligent to be able to negotiate with the energy company so as to take power at the cheapest rates. As demand varies during the day so does the price and Matti asks the car only to take power once the price is below a set level, providing he has enough power in the batteries to get home. It’s a windy day, so there is likely to be a surplus of power from the newly installed wind energy capacity.

In the office Matti takes a seat in the meeting room in front of a terminal, which serves as 3D desktop allowing documents to be felt by touch and moved around. The system automatically recognises him from his biometric data and calls up relevant documents. At the same time, his phone switches to silent work mode. During the telemeeting, Matti shows a presentation to all participants, shown on the big display in all meeting sites. Another participant makes notes on a shared whiteboard.

After the meeting, Matti opens his office terminal and starts to work on a shared document from another colleague on his 3D desktop. As Matti is immersed in work, his phone remains in silent mode. Matti can opt to leave his real desk to enter into a shared virtual space where he can communicate with other members of his work team. He observes that two of his team members are visiting a customer, one is immersed with browsing a specification document, and one is having a networked work session with a colleague.

Matti’s phone rings his boss was notified of Matti’s status change to ‘pause mode’ and uses the opportunity to give him a call where they discuss the results of a lab test. A record of the call, with a context record including links to relevant documents, is placed in both Matti’s and his boss’s work diaries.

During midafternoon, Matti peeks into his Home Sizzle Channel to see that his daughter is in a café with her friends after school and his son is at home. He is also reminded that his wife will be working late, and Matti is expected to pick up Chinese takeaway for the family dinner while commuting home. Matti places an order for the food. The ordering system gives him a personalised recommendation, but for variety Matti changes one of the suggested courses.

Driving home, near the shopping mall Matti gets a friendly reminder to stop for the food. At home, Matti again plugs the car into recharge with instructions to watch the dynamic pricing. After dinner, Matti decides to edit the video material from his son’s birthday party. He opens the video editor using his home office terminal, and fetches the video files from the family’s online digital storage. He is happy the files were automatically synchronised there from the camera big relief compared to the past! While working on the video, Matti listens to music and news from another of his favourite subscribed channels. After editing the video, he publishes it for access by the boy’s grandparents and other close family. He observes that his mother has commented a photo journal published previously, and spends a moment peeking into the notes left.

Later, Matti joins his wife in the living room to watch an episode of their favourite TV show, recorded in the family’s media storage. Then he watches a realtime football match of Italian premier League. He enjoys the 3D webcast: during a penalty kick he places his viewpoint between the goalposts, guessing where the penalty is aimed. He can also stop the game for a play from any viewpoint. Using a wireless keyboard, he also chats with a Dutch colleague who is watching the same match, as Matti saw in his Social Sizzle Channel. They place a bet on the number of goals in the match; Matti loses! They agree to share another match viewing in two weeks.

After the match, Matti peeks into tomorrow’s work schedule using the living room display. There will be a customer visit in the afternoon, so he looks at its context record. He reminds himself to ask about how the art project of the custom-er’s spouse Tiina has progressed.

In bed Matti reads another chapter of his Chinese language course using his lightweight wireless reading terminal. The terminal speaks the sentences to him, and when he recites them back it records them and corrects his pronunciation and intonation which is especially important in Chinese. While Matti is reading, the display of the terminal is adapted to the ambient lighting of the bedroom. Before dozing off, Matti reflects on how much easier life is with information at his fingertips the whole time. He wouldn’t have it any other way.

### 5.2 Technologies and services around 2020

The core and backbone networks will be based on fibre-optic communications, as already today. To support new bandwidth-hungry applications, like 3D television, a wide deployment of optical access networks and fibre-to-the-home solutions is also expected in near future. Simultaneously, the role of wireless networks is expected
to strengthen, due to the need of being always connected as well as the increasing number of services using ad hoc networking. In developing countries, wireless communications could even provide a more cost-effective solution than wired links to connect distant cities and regions.

The future communication environment will be pervasive, connecting people, machines and surrounding spaces by dynamic networks of networks, and supporting features like identities, security, and interoperability. In order to design, implement and manage such complicated systems, new flexible architecture and management frameworks need to be defined. To support this process, several research projects have been funded lately by EU and NSF. There is a consensus that the amount of embedded intelligence ensuring automatic management and control will be increasing dramatically in the future networks. Moreover, many of the proposed architecture frameworks are utilizing the notion of virtual networks hiding the details of the physical networks from the higher layers. Some initiatives focus on evolutionary improvements and others try to reinvent Internet infrastructure and services from scratch. The final outcome will most likely be a so-called “cleaned state” compromise, where evolutionary progress enhanced by some clean slate ideas.

The energy issues become ever more important in the future. Optimizing the power consumption of the end devices is a necessity for a prolonged connectivity. In some actuator and sensor networks, the energy for communications could be produced by utilising the environmental energy sources, like vibration, heat or light. However, globally the largest energy savings are reached when operators and manufacturers start implementing genuinely energy aware networks with cognitive management and services.

The white paper by the European Future Internet Initiative [18] visions that different smart systems can be addressed in a common way to represent a significant part of the services offered by the future internet. The examples of smart systems include utilities (electricity, water, and urban security), communications, traffic (intelligent traffic systems, public transport and pedestrian guidance), healthcare, ubiquitous access to content and safety & security. Additionally, the functionalities related to context-aware content management able to find, format and deliver information are considered as basic services in the future internet.

There will always be some special application where the general approaches and services do not work. Military and emergency applications requiring a fast implementation on rough and hostile conditions may need to be based on special ad hoc networking technologies and solutions. Another example is the underwater environment where wired, acoustic, RF and optical communications have all lots of limitations. Finally, broadband inter-planetary communications will be needed in the future. Optical communication is considered to be superior to radio frequency links but only the quantum communications would be a major step forward [19].

In the long term, nanotechnology will enable developing alternative mechanisms to encode and process information. To overcome the bandwidth limitations of the current wireless technologies, terahertz wireless communication systems are supposed to supplement or even replace the present WLAN or WPAN [35] systems in short range communications [15] [36]. In wired communications, we are in the way toward all optical networks as more and more network elements can process optical information without conversion to electronic signal. Quantum communication networks [16] and molecular communications [17] are providing totally new communication paradigms. Quantum networking could usher a new era of secure communications extending from the nanoscale devices to global satellite communication networks. On the other hand, nano-networks interconnecting nano-machines by molecules have applications from bio medics to industry and military. All these are promising solutions but their practical implementations are not going to take place in the near future.
6

Business opportunities

This section presents scenarios of potential business opportunities for the Finnish small and medium sized enterprise between the years 2010 to 2015. Several optional business models were presented as reports (mostly in [12]) and discussed further in workshops and in interviews with several experts during the roadmap process.

6.1 Potential business opportunities for Finnish SME in the ICT section

After a deep analysis of common trends, ICT technology convergence, industry structure and business & ecosystem several rather detailed conclusions for various business sections of SME were given in [12] and also in [13] and [41]. These conclusions were further discussed in GIGA’s workshops as well as in interviews and meetings arranged for the roadmap process.

Consultants of ICT business and industry

Consultants working to serve business and industry see many opportunities, and threats as well, in the currently proceeding convergence of wired and wireless networks, IP based services and ICT. It is not quite clear yet if the drivers for change are the network operators or the network users, but in any case the business and the role of the operators are changing. Still it happens that use of several networks by one organization continues and the roles of different networks will overlap for long.

Figure 8. Consulting is a changing business

Convergence of systems may give chances for new players and especially with the low-cost business models where indirect earning logic prevails. For the service providers, it is important that all offerings are packaged, were they products, services, connections or content. Industry-specific vertical solutions are not expected to succeed, instead the integration and interoperation should span (horizontally) over industrial borderlines. It is probable that newly started smaller companies will later merge just as happened before in other segments of the ICT and software business.

Software application developers

Producers of industry-specific software applications have also learned to live with the indirect business models. The consumers do not seem to be willing to pay anything of application software while it can still be sold with media contents and through networking with aggregating parties. Brand is important in this business and the firm’s competence is in technical and project management skills in software development. Cloud computing is a big issue; it will renew the existent software-as-a-service concept and in general virtualized infrastructures, applications and services. Various competing and collaborating cloud platforms will be implemented throughout the value chain to various industrial segments. Personal computers become much more personalized as they are attached to clouds.

New kind of business opportunities may emerge in data-centric and data-intensive services and applications. Not only the operators but actually all others who are involved in the cloud platforms can access and refine data for various value-adding needs. New players appear and new roles are found in service business for device vendors, operators, software developers and even the users, who may produce contents or some services too. As flat rate charging becomes the norm, new profit making scenarios are
needed, which concerns the big players as well. The network systems may converge, still the technology and applications are rather diverging and still becoming more complicated. Context-awareness in applications is one driver. Technical expertise of software development is continuously needed.

**Infrastructure software developers**

The infrastructure becomes more complex as the scope of required solutions extends and wider competence is expected. Infrastructure solutions must work with different network technologies, applications and various service operators’ systems. Infrastructure software developers co-operate with device manufacturers, network operators and internet service providers. It is believed that convergence of networks creates new business opportunities, but it is still difficult to exactly identify, which are the most potential. At the same time high maturity of technology keeps the business shrinking. Several infrastructure software developers have moved towards service business by applying fixed service payment schemes with their customers.

**System and infrastructure integrators**

Companies that specialized in the provisioning of software have to face tough global competition. Role of system and infrastructure integrators was growing as the number of subcontractors was reduced in several companies and customers wanted more turn-key, end-to-end system solutions. Still the end-customers are more reluctant to pay for system integration services; therefore advertising partners are becoming important source of earnings also in this business.

Essential changes are that system integrators have become neutral towards software and hardware vendors as well as their ability to provide service delivery platforms instead of plain integration platforms. Business model transforms to service aggregation where content access and user transactions are charged.

**Infrastructure and application service providers**

As the Internet deployed the business of the infrastructure service operators strengthened. Anyway, the fixed line operators strongly believe that as the Internet and TV are integrated while demand of high-definition services expands, fixed line connections not only remain but become more important. Another strong driver for their business is the cloud computing along with the software-as-a-service approach. Still it was believed that only few big operators survive and the emergence of the new service types is not creating many chances for new players. Television sets and set-top boxes are also taking the role of a service access point for all entertainment and including cloud-based data access. Downloading of software to users may even completely vanish. Facebook is regarded as a forerunner for the new type of active virtual...
services, when compared to operator-based passive service platforms.

**Hardware developers**
Device manufacturers are active actors in the wireless business and changes of technology always create new chances for them. New opportunities for new devices exist in usage-centered, context-based and situational features or so called smartness of the systems. Ubiquitous computing devices for intelligent sensing and actions are needed while also the basic mobile applications and services get smart features. Truly ubiquitous devices are still rare. Content access, content aggregation and other new characteristics of internet applications reflect to hardware platforms requiring more advanced devices. Device-based access to automatically created usage data is not widely exploited yet or its refinement and use for business or individuals.

**Producers of network support systems and services**
Worldwide hundreds or thousands of operators and virtual operators are potential customers for network support systems and services. However, the business model of the big network operators has basically changed; they used to lead research and development but currently they out-source everything. Operators rather buy products and services developed by others, which means more business with existing products. But getting operators as customers can be hard, even from a company that was among the World leaders in its specific field of technology, took about five years to get the first operators actually to buy their products [34]. At the same time the large device vendors and SME as well do not co-operate with operators in research as before, which is negative for all. Furthermore, a new end-to-end service model is emerging from China and all other providers must soon follow that [32].

The Finnish market is small and it is both costly and difficult to build your own brand, therefore interest towards niche market is strong. The worldwide players show serious interest to products of SMEs and would also buy them, if they could trust that the small vendor survives for more than the next two years. A potential solution to these problems is in cooperating with bigger local companies, some encouraging examples of that exist.

A potentially growing business is IMS for which a new interest is rising again. Control of IP address space and IPv6 have also potential but it is still to be seen when the switch to IPv6 really starts. Cloud computing brings both challenges and more development work at all levels, which means new business opportunities. Social media is also a big opportunity, which brings work for device and application developers [34]. A good chance for SMEs is as well in AppStore, Nokia’s Ovi and other such services, more and more of which are emerging. Technology and legislation for internet stores are still developing, current problems with payment of small charges and in roaming payment get probably solved.

**Content producers**
Media houses have certainly found the Internet as their delivery channel. New customer sections for them are the users of smart phones, who will become the major segment in a few years. Due to small screen size of the pocketable devices, Web pages must be simplified for satisfying these users. At the same time interest towards videos and music as basic contents only grows. Also the user with other types of home devices, for instance those who must use TV’s remote control for accessing Web, should be served well.
This roadmap was produced by analyzing several public roadmaps and the specific roadmaps generated in the special interest groups of the GIGA research programme. Comments and feedback of the work were gathered with interviews and live discussions with experts of business and technology working in both small and large ICT companies as well as in research institutions. The most important topics and their development towards 2015 and beyond are shown in Table 2. The main trend of development is now from a world of divergent wireless internet systems towards a truly ubiquitous world.

The GIGA research programme, which started in 2005, focused on converging networks. The work done in the programme produced magnificent research results and it gave all participants a deeper insight to technology and its future development. Based on that view the development of technology is analyzed in this roadmap under five different clusters: user’s devices, radio technologies, networks, services and security.

Changes of business models were discussed in the GIGA thematic groups and several different and even contradictory views were considered potential. In the past, radical changes of technology have inevitably altered the scene and the old players have given way to others. Even giants, such as Kodak was in photography, have lost their status while new companies have taken a central role. Currently it looks that the social media and its phenomena are altering the industry structures and business models in unpredictable ways. Purely vertical or horizontal business models are deteriorating and companies are looking for short-cuts, sidetracks and across-traditional-segmentation strategies.

The long term trends in society and in the development of network technologies have existed for years, they probably still continue for long and many of them affect in all segments of technology. In addition, the cycle that produces new network technologies from the first proposals to everyday use can be about ten years. The long development delay is mostly due to the difficulty of standardization and sometimes even changes of legislation are required. As a result, the probable technological development of the wireless and wired network systems is rather predictable still it is always difficult to estimate the commercial success of the new technologies.

At the same time, new short term changes are almost unpredictable, while they may quickly and radically change the business environment and business scenarios. Typically the hit technologies (e.g. touchscreen) are not really new or ingenious, often they become hot after their price level changes or a new business innovation opens new opportunities for them. Crucial technological breakthroughs also happen; these are easier to predict as often they result from a long-term work in basic research (e.g. digital paper is in such process currently). Nevertheless, we named several technologies and services that we expect to succeed within a few years.

Global technological trends are ICT becoming a commodity in all parts of the World, declining of all costs and especially the device prices, availability of quick wireless or wired connections to Internet everywhere. The explosion of social networking is a recent and essential change, which revolutionized the vision while the same could have happened years earlier. The World has also become flat and transparent, global markets are open always and everywhere. An interesting detail is that the virtual World is turning to a real business World too; it is possible to use virtual money in buying things in the real World.

The Finnish companies providing products and services in the telecommunication section have to face a tough competition from both the free offerings and the global enterprises. The only key to success is hardly in pushing the production to low-cost countries. As an example, when producing a smart phone (Nokia N95) almost completely outside of Finland, 70% of the value produced by Nokia
and 35% of the total value of the final product was generated in Finland [29]. The strengths of the Finnish technology research and development environment are still the education system, safe and working infrastructure, governmental support for research and innovation (Tekes) and the straight contacts with some of the global players. The quickly changing and developing technology continuously creates world-wide demand for new and innovative products and service solutions.

The main findings in segments of technology
We evaluate the trends of technology in five different segments. Still we emphasize that as we live in a complex World, individual changes affect in many segments and some of them influence on all fields of technology.

User’s devices
Handsets challenge the desktop computers, local wireless communication pervades to all devices and home-appliances as well as other instruments are turning to network equipment.

User’s pocketable devices become more and more versatile. Accessing the Internet for activating many-to-many connections both for entertainment and for business purposes is almost a standard expectation for any user’s device. Smart handsets have developed to being extremely context-aware devices and that allows implementing fascinating applications to them. Number of RF interfaces in handsets has grown, but it is expected that the deployment of LTE or IMT-Advanced systems changes this. The device that links the user with the digital universe is more and more often a handset or other type of computer that utilizes wireless access networks.

Desktop computers provide large displays and more computing resources, which are really of use only for the extremely power-hungry applications. However, energy-efficiency is a critical issue, which still substantially delays the development towards using handsets as the only tool that the users actually need.

In addition to being versatile, all types of user’s devices are expected to understand and proact users desires and wishes. However, the simple and cheap cell phones do not disappear. A strong potential is in smart spaces based on wirelessly co-operating devices. That may radically change the way that devices and systems are developed within a few years.

Radio technologies
More bandwidth is provided in all segments, cognitive radios are slowly coming true.

There are great expectations in radio technology: finally all wireless interfaces should be implemented with truly cognitive software-defined radios. The coming solutions will provide better QoS, more bandwidth, less energy consumption and wild new utilization opportunities.

It is believed that IMT-Advanced gets worldwide support as the wide-area high-power radio network standard. ITU-R probably accepts either LTE or WiMAX as the core solution of IMT Advanced. At present it seems that LTE is winning in Europe and Japan, while WiMAX has support in the USA, Korea and in many countries without existing GSM infrastructure. The circuit-switched 2G networks still continue in service for long as they do not require any dense, expensive and energy-consuming base-station system.

In local area networks no real alternative for IEEE 802.11 is in sight. With its latest enhancements, the system challenges the high-power systems in the urban areas. LTE and WiMAX as well provide new wide-band options for the short-range still the more than 90% penetration rate of the Wi-Fi devices is difficult to change.

Switch to digital television takes place in most European countries before 2015 and new users for DVB based devices emerge worldwide. Broadcasting continues and it finds new roles with interactive systems where often handheld terminals are used. At the same time fibre cables are bringing 100 Mbps connections to many households, which allow real-time high-definition transmission with up to 1080p50 resolution.

The number of short range radio devices may face an exponential growth. Applications based on local wireless machine-to-machine communication and sharing of information are expected to boom. Homes, offices, public spaces, cars, boats and other environments are supposed to develop towards smart spaces while no radical change in the basic short range radio systems are likely.

Networks
More bandwidth, users, mobility and traffic load to both access and core systems. Machine-to-machine communication creates new challenges and chances.

The continuing urge to increase bandwidth in all segments of wireless and
Table 2. Summary of technology roadmap

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>Towards 2015</th>
<th>Beyond 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>User’s Devices</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diverging devices</td>
<td>Pocketable devices challenge desktops, still the screen-size and</td>
<td>Energy efficiency brings new applications</td>
<td>IMT-advanced (Cognitive, LTE base) becomes the primary air-interface</td>
</tr>
<tr>
<td></td>
<td>batteries limit them</td>
<td>RF interfaces to home appliances</td>
<td>Devices can select best resources from networks</td>
</tr>
<tr>
<td></td>
<td>Handsets provide touchscreen,</td>
<td>Home devices communicate automatically M2M and may share resources</td>
<td>All devices co-operate through wireless connections</td>
</tr>
<tr>
<td></td>
<td>ubiquitous IP, GPS, Navigation, RFID, Context-awareness</td>
<td>100 Mbps and more to homes</td>
<td>SDR in all handsets</td>
</tr>
<tr>
<td></td>
<td>Up to 10 different RF interfaces in one handset</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>IPTV, HD and 3D emerge</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unwanted traffic, several security issues remain</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Radio Technologies</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wide bandwidth</td>
<td>2G and SMS still strong</td>
<td>150 Mbps wide area, 1 Gbps local radios</td>
<td>Truly cognitive wide-band radio networks, systems that sense and learn</td>
</tr>
<tr>
<td></td>
<td>First LTE systems, HSPA dominant</td>
<td>MIMO standard solution</td>
<td>Fully flexible spectrum use</td>
</tr>
<tr>
<td></td>
<td>Interest in WiMAX falls</td>
<td>SDR in Infrastructure radios and handsets proceeding</td>
<td>Tuneable RF front-ends enable truly adaptive SDR</td>
</tr>
<tr>
<td></td>
<td>Wi-Fi prevails and develops</td>
<td>New cognitive radio technologies standardized</td>
<td>Simultaneous RF transmission and reception</td>
</tr>
<tr>
<td></td>
<td>DVB as HD to handhelds</td>
<td>Frequencies allocated for dynamic spectrum sharing</td>
<td>Energy efficient, low-price UWB, on one chip</td>
</tr>
<tr>
<td></td>
<td>MPEG4 utilization grows</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>802.15.4 in short range</td>
<td></td>
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<tr>
<td></td>
<td>Cognitive radio and SDR in research</td>
<td></td>
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</tr>
<tr>
<td><strong>Networks</strong></td>
<td>Ethernets to RAN connections</td>
<td>Seamless automatic RF interface selection</td>
<td>IMT Advanced everywhere</td>
</tr>
<tr>
<td></td>
<td>Femtocells introduced</td>
<td>More IPv6</td>
<td>Global self-operating, interconnecting community</td>
</tr>
<tr>
<td></td>
<td>Heterogeneous systems exist with few users</td>
<td>Clouds, video load, new users, new mobile users boost traffic</td>
<td>Ubiquitous World exists</td>
</tr>
<tr>
<td></td>
<td>Mesh architectures in public WLANs</td>
<td>Cognitive networks develop</td>
<td>Optical switches, Quantum computers</td>
</tr>
<tr>
<td></td>
<td>IPv6 penetration low</td>
<td>Wireless sensors common</td>
<td></td>
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<tr>
<td></td>
<td>QoS mechanisms seldom used</td>
<td></td>
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<td></td>
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<tr>
<td><strong>Services</strong></td>
<td>Social networking appears everywhere</td>
<td>Presence and context awareness important</td>
<td>Fully context aware applications</td>
</tr>
<tr>
<td></td>
<td>Positioning, navigation is free</td>
<td>Content sharing in devices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NFC advances AAA with handsets emerges</td>
<td>VoIP grows, CS for speech continues</td>
<td></td>
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<tr>
<td></td>
<td>P2P to legal use</td>
<td>Video meetings common and video house-sitting, petsitting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Google TV starts, HD-resolution and IPTV proceed</td>
<td>Cloud computing standard</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Security</strong></td>
<td>Internet’s vulnerability</td>
<td></td>
<td>Built-in risk-based security</td>
</tr>
<tr>
<td></td>
<td>Privacy and digital identity</td>
<td></td>
<td>Explicit representation of reputation and trust</td>
</tr>
<tr>
<td></td>
<td>Payment methods, paying with handsets</td>
<td></td>
<td>Balance of privacy</td>
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</tbody>
</table>
wired networks still dominates the development. Other strong trends are growth in number of users, quick expansion of mobile data traffic and the swell of video load. Yet another important driver is the cloud computing approach. Furthermore, it seems that there is now end in inventing new applications and uses in which Internet is needed. The network management mechanisms, routing procedures and control methods of mobility and multihoming require new solutions. Making the internet still more usable and more reliable should be the main goal of its research and development for many years as one of the World’s leading experts of internet technology recently said [27].

Several standardized mechanisms to utilize heterogeneous wireless networks smoothly in accessing the Internet exist, but only few systems are used at present. However, new solutions that optimize network utilization will appear. Adaptation of IPv6 has also been slow, for many strong reasons IPv4 has kept its position, but finally that will change. Optional mesh type of architecture solutions emerge to standards and can be utilized in specific services.

Network operators and virtual operators outsource more and more of their activities while offering a wider service selection to their customers. Users become more quality conscious as the pricing of service can be QoS dependent. Providers of specified network support systems and services are continuously needed.

A long term development in radio networks is to apply cognitive features, sensing and learning while new features such as supporting multi-homing emerge to real systems [27]. Costs of building wide-band radio networks and as well their energy expenses become even more critical than before and require new solutions.

Personal and body area networks, which are applied to human-to-machine or machine-to-machine interaction will boom as the smart spaces get fully deployed. Both direct local cooperation and internet based communication will quickly raise their volume in sensor networks. Ubiquitous world gradually becomes reality introducing communication with virtual objects.

Services

Social networking drives the development, smart phones provide full context-awareness and deployment of ultra high speed fixed connections changes the scene

A rather recent and crucial change in the IP based services is the abrupt appearance of social networking, which for several years will be in essence of all development. Users want to do all their communication, and with any device, rather through the social media instead of the plain person-to-person communication. Presence and context-awareness are becoming more important for all new services and especially the services accessed with handsets proceed to being fully context aware.

Smart phones become more and more capable providing services like positioning, navigation, use of near-field-communication in shopping, controlling of home appliances and sharing information with all devices. Use of handsets in authentication, authorization and accounting is expanding quickly, mobile currency and mobile banking has a big potential market in the developing countries. Popularity of VoIP services advance when LTE is deployed. Sharing of content wirelessly and automatically between the home devices proceeds.

Ultra high speed fixed connections to most households enable services that began from delivery of music and videos to approach wide deployment of high definition real-time video services from servers throughout the world. Use of peer-to-peer protocols legally for business as well entertainment increases. Telepresence is presently in business use but it probably develops to a widely used service in all social contacts. Advanced 3D version of telepresence will be introduced.

Security

From authentication and access control to securing identity and personal data

Securing properly the heterogeneous, more and more complex, quickly expanding and worldwide network systems presents a huge challenge. The emergence of social networking has brought a strong new need of securing peoples digital identity. Individuals may want to keep several roles or identities, e.g. business identity and private identity that should be kept strictly separated. Network identity replaces the plain IP address in all communication. Another goal for research and development is securing safe paying in the network with handsets and all types of terminal devices. Users need trust managed security instead of the self-managed solutions that we have today. The aim is to create built-in risk-based security in all network systems.
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Appendices

Appendix A. List of symbols

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>2D/3D</td>
<td>Dimensions</td>
</tr>
<tr>
<td>2G/3G</td>
<td>2nd/3rd Generation Cellular Mobile Phone System</td>
</tr>
<tr>
<td>4G</td>
<td>4th Generation Wireless Information Network</td>
</tr>
<tr>
<td>3GPP</td>
<td>3rd Generation Partnership Project, based on GSM Technology</td>
</tr>
<tr>
<td>3GPP2</td>
<td>3rd Generation Partnership Project 2, based on 2G CDMA Technology</td>
</tr>
<tr>
<td>AAA</td>
<td>Authorisation, Authentication &amp; Accounting</td>
</tr>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>ATSC</td>
<td>Advanced Television Systems' Committee, American digital television standards</td>
</tr>
<tr>
<td>AES</td>
<td>Advanced Encryption Standard</td>
</tr>
<tr>
<td>B2B</td>
<td>Business-to-business</td>
</tr>
<tr>
<td>CAPEX</td>
<td>Capital Expenditure</td>
</tr>
<tr>
<td>CENELEC</td>
<td>European Committee for Electrotechnical Standardization</td>
</tr>
<tr>
<td>CO2</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>CPE</td>
<td>Customer Premises Equipment</td>
</tr>
<tr>
<td>CR</td>
<td>Cognitive Radio</td>
</tr>
<tr>
<td>CRS</td>
<td>Cognitive Radio System</td>
</tr>
<tr>
<td>DVB</td>
<td>Digital Video Broadcasting project, cooperation of ETSI, EBU and CENELEC</td>
</tr>
<tr>
<td>DVB-H</td>
<td>DVB Handheld</td>
</tr>
<tr>
<td>DVB-NGH</td>
<td>DVB Next Generation Handheld</td>
</tr>
<tr>
<td>DVB-S</td>
<td>DVB Satellite</td>
</tr>
<tr>
<td>EBU</td>
<td>European Broadcasting Union</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>EV-DO</td>
<td>Evolution-Data Optimized</td>
</tr>
<tr>
<td>ETSI</td>
<td>European Telecommunications Standards Institute</td>
</tr>
<tr>
<td>Flash-OFDM</td>
<td>Fast low-latency access with seamless handoff OFDM</td>
</tr>
<tr>
<td>GAN</td>
<td>Generic Access Network</td>
</tr>
<tr>
<td>GIGA</td>
<td>A funding program by Finnish public authority Tekes from 2005 to 2010</td>
</tr>
<tr>
<td>GPRS</td>
<td>General Packet Radio Service</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile Communications</td>
</tr>
<tr>
<td>HAC</td>
<td>Hearing-Aid Compatibility</td>
</tr>
<tr>
<td>HDTV</td>
<td>High Definition Television</td>
</tr>
<tr>
<td>HTML</td>
<td>HyperText Markup Language, a structured language for Web pages</td>
</tr>
<tr>
<td>HSPA</td>
<td>High-Speed Packet Access</td>
</tr>
<tr>
<td>ICT</td>
<td>Information &amp; Communication Technology</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>IETF</td>
<td>Internet Engineering Task Force</td>
</tr>
<tr>
<td>IMT</td>
<td>International Mobile Telecommunications, ITU's 3G Standards</td>
</tr>
<tr>
<td>IMT-Advanced</td>
<td>International Mobile Telecommunications, ITU's 4G Standards</td>
</tr>
<tr>
<td>IPR</td>
<td>Intellectual Property Rights</td>
</tr>
<tr>
<td>IPTV</td>
<td>Internet Protocol television</td>
</tr>
<tr>
<td>Java</td>
<td>A programming language</td>
</tr>
<tr>
<td>JavaScript</td>
<td>A Java based scripting language</td>
</tr>
<tr>
<td>LAN</td>
<td>Local Area Network</td>
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<tr>
<td>LTE</td>
<td>Long Term Evolution</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>MAC</td>
<td>Media Access Control, a low layer protocol</td>
</tr>
<tr>
<td>M2M</td>
<td>Machine-to-Machine</td>
</tr>
<tr>
<td>MIH</td>
<td>Mobile Independent Handover</td>
</tr>
<tr>
<td>MIMO</td>
<td>Multiple Input Multiple Output</td>
</tr>
<tr>
<td>MP3</td>
<td>MPEG-1 Audio Layer 3 (not MPEG3)</td>
</tr>
<tr>
<td>MPEGx</td>
<td>Moving Picture Experts Group, audio &amp; video compression standards</td>
</tr>
<tr>
<td>MPLS</td>
<td>Multi-Protocol Label Switching</td>
</tr>
<tr>
<td>NFC</td>
<td>Near Field Communication</td>
</tr>
<tr>
<td>NSF</td>
<td>National Science Foundation (USA)</td>
</tr>
<tr>
<td>OFDM</td>
<td>Orthogonal Frequency-Division Multiplexing</td>
</tr>
<tr>
<td>OPEX</td>
<td>Operational Expenditure</td>
</tr>
<tr>
<td>QoS</td>
<td>Quality of Service</td>
</tr>
<tr>
<td>P2P</td>
<td>Point-to-Point protocol or Peer-to-Peer</td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research &amp; Development</td>
</tr>
<tr>
<td>RDS</td>
<td>Radio Data System</td>
</tr>
<tr>
<td>RF</td>
<td>Radio-Frequency</td>
</tr>
<tr>
<td>RFID</td>
<td>Radio-Frequency Identification</td>
</tr>
<tr>
<td>SAE</td>
<td>System Architecture Evolution, LTE’s core network architecture</td>
</tr>
<tr>
<td>SDR</td>
<td>Software Defined Radio</td>
</tr>
<tr>
<td>SME</td>
<td>Small and Medium-Sized Enterprises</td>
</tr>
<tr>
<td>SMS</td>
<td>Short Message Service</td>
</tr>
<tr>
<td>TDD</td>
<td>Time-Division Duplex</td>
</tr>
<tr>
<td>TD-SCDMA</td>
<td>Time Division Synchronous Code Division Multiple Access</td>
</tr>
<tr>
<td>URL</td>
<td>Uniform Resource Locator (IP address)</td>
</tr>
<tr>
<td>USB</td>
<td>Universal Serial Bus</td>
</tr>
<tr>
<td>UWB</td>
<td>Ultra-Wide Band</td>
</tr>
<tr>
<td>VoIP</td>
<td>Voice over IP</td>
</tr>
<tr>
<td>VPN</td>
<td>Virtual Private Network</td>
</tr>
<tr>
<td>WBAN</td>
<td>Wireless Body Area Network</td>
</tr>
<tr>
<td>WCDMA</td>
<td>Wide-band Code Division Multiple Access</td>
</tr>
<tr>
<td>WLAN</td>
<td>Wireless Local Area Network</td>
</tr>
<tr>
<td>WPAN</td>
<td>Wireless Personal Area Network</td>
</tr>
<tr>
<td>Wi-Fi</td>
<td>“Wireless Fidelity” a trademark of Wi-Fi Alliance (IEEE 802.11 certified devices)</td>
</tr>
<tr>
<td>WiGig</td>
<td>Wireless Gigabit Alliance</td>
</tr>
<tr>
<td>WiHD</td>
<td>Wireless HD Consortium</td>
</tr>
<tr>
<td>WiMAX</td>
<td>Worldwide Interoperability for Microwave Access (IEEE 802.16 standard)</td>
</tr>
<tr>
<td>TV</td>
<td>Television</td>
</tr>
</tbody>
</table>
Appendix B. Background material


eMobility Technology Platform, Working Group on Post-IP Next Generation Internet, White Paper on “Experimental Facilities with focus on Wireless research and requirements”, 2008


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