Invest in Sweden

Wireless Systems

Roadmap 2005-2010

Contents

1 Executive summary

This wireless systems roadmap was developed during the spring of 2005 by the research center Wireless@KTH at the Royal Institute of Technology (KTH) under commission from Invest in Sweden Agency (ISA). The roadmap is focused on technology and industry trends. The time horizon is from today through 2010.

Technology trends 2005 - 2010
Speed of change will not be drastic over the next five years. We will see an evolution rather than a revolution. In a longer temporal perspective, about ten years from now, we can expect bigger and more dramatic changes of wireless systems and technology. The most important technology trend is perhaps that the communication network environment is becoming increasingly complex and heterogeneous. We are moving towards a multi-standard “ambient network” environment in which many different networks coexist and many different operators offer services. The three worlds of Fixed telephony, Mobile wireless, and Wideband data are converging and eventually users will care only about the services they are offered and not the type of network they use at the moment. The ”All IP” vision continues to develop and eventually both fixed and wireless networks will be IP based to a very large extent. User bit rates (“speed”) will also improve, but gradually rather than in radical steps. This will eventually lead to more symmetrical bandwidth capabilities in the networks than today. New types of low cost infrastructures for mobile or semi mobile access will be launched during the next five years. These will be based on existing and coming WLAN standards and the competition between access technologies will intensify especially in the second half of the period.

The two device trends that will have the biggest effect on the development of wireless systems until 2010 are the introduction of low-cost multimode terminals (especially those integrating WLAN with 2G and 3G cellular standards) and the increased storage capabilities (in the several Gigabytes range) which will enable new services based on downloading when it is cheap and off-line usage at the users convenience.

Industry trends 2005 - 2010
The industry is rapidly recovering from the recent recession and wireless will continue to be a very important sector for Sweden. The industry will, however, develop in two distinct directions, the Wide-area and the Local access industries with quite different characteristics. The wide-area industry is the traditional telecom industry, with large vendors selling complex, vertically integrated, closed, and very expensive systems to big operators. The local-access industry on the other hand is based on mass produced products sold through the consumer electronic channels. These are cheap and simple base stations (access points) that anyone can install. New types of very different “operators” will emerge, for example individuals, communities, mall-owners, and small businesses. The traditional telecom industry is not geared to handle this short range (on-premises, home) access infrastructure.

The wireless industry and the business environment in Sweden are well equipped for the near future and will play an important role in the global development of wireless systems and technology during the next five years. By acting wisely and focusing on the right areas and the nation’s competitive strengths, Sweden will be able sustain, and in some areas also improve, its position. Sweden’s competitive advantages in wireless system technology are mainly: (1) the strong regional clusters for research and development, (2) the high technological competence of companies, universities, and individuals, and (3) the existence of both the world-leading manufacturer of wide-area (cellular) wireless systems as well as many small entrepreneurial companies. The ability to develop, build, and operate complex technical systems will thus continue to be a strong point for Sweden for years to come.

Background trends

Driving these technology and industry trends are of course many different developments in other areas. The main societal trends affecting wireless systems are the: (1) gradual movements towards a more mobile society, (2) environmental issues, (3) continued globalization and the move towards the knowledge based economy, (4) increased economic importance of large NIC-economies (China, India, and also Russia), and (5) aging population in most of the industrialized world.

The demand for wireless services will increase but not explode. We can expect continued price drop as the 3G systems gradually are completed creating an excess capacity of wireless “bandwidth”. There will also be an increased competition between technologies adding to the price pressure. Users will become more mobile and thus demand more wireless services, as well as higher bit rates in the networks. At the same time users will become more and more different from each other, forming user segments with very different needs and usage patterns. Quality of service will continue to be important but partly in novel ways. Some users will for example trade high quality for low price. Others will use the large storage capacity in their device to download content at one time and consume it later. Still other have very high requirement on quality and reliability before they migrate from fixed to mobile.

The European regulators are moving toward increased technology neutrality and flexibility regarding the conditions for new services in allocations of frequency bands. In combi¬nation with new spectrum allocations this will probably more than double the bandwidth for wireless services by 2010. This will hopefully lead to cheaper and more abundant services for the users.

Potential showstoppers

In general, the future development of wireless services, industry, and technology looks promising but some problems can be identified which, if not solved, might threaten the development of the whole industry. These potential showstoppers include (1) collapse in managing increasingly complex networks, (2) power consumption in terminals, (3) biological effects of radiation (real or perceived), (4) chaos around Digital Rights Management (DRM), and (5) difficulties guaranteeing security, integrity, and, privacy in networks and services.

2 Background and Methodology

This study was carried out during April and May 2005 by the research center Wireless@KTH at the Royal Institute of Technology (KTH) in Stockholm under commission from Invest in Sweden Agency (ISA). The purpose is to formulate a roadmap for the development of wireless systems from today to 2010.

2.1 The assignment

In this study, *Wireless systems* is roughly defined as the infrastructure part of wireless or mobile communication systems, including for example:

- Cellular systems
- WiMax and WLAN systems
- Ad hoc wireless networks
- Multi-network convergence terminals

The concept *road map* is interpreted in a broad sense. It is a description of the expected development in this field of technology and business during the coming years. Parallel ISA-studies focus on roadmaps for mobile terminals and photonics systems.

The study has been performed by four experts representing a combined experience of decades of wireless business, spanning over several life cycles of systems and services.[1] This includes research, technical as well as business development, design, implementation, operations, and close-down activities. In addition, five leading experts from different sectors have formed a reference group giving feed-back on the work.[2]

The purpose of the road map is to support a dialogue with potential investors in Sweden and others in which the estimated development of the wireless systems sector is described and matched with Swedish actors and the nation's competitive advantage. The Wireless systems road map specifically describes the international technology and business directions along a *three to five years* time line. It also shows in what way Swedish technology and Swedish actors may be of importance.

The time horizon of the study, three to five years from now, is quite short in a wireless perspective. We will probably not see any unexpected changes in the wireless systems area in this time frame. Infrastructure systems change slowly and the experience from the last few years show that a broad adoption of new services by the public also takes much longer than we think. One expert[3] put this quite bluntly: *"Whatever new service you hear being touted at this year's 3GSM World Congress; don't expect it in a retail shop near you before 2008, at best"*. Still it is fruitful to develop an understanding of the current trends and development paths even over relatively short periods. However, since this is an infrastructure business, we have added a section pointing at the more long-term future as well.

Figure 1 illustrates, in a simplified way, the mechanisms and drivers behind the evolution of future wireless systems. Users ask for new services and demand that these have certain properties in terms

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1 Bo Karlson, Mats Nilson, and Jens Zander (all KTH), and Östen Mäkitalo (TeliaSonera and KTH)
2 Curt Andersson (IFI), Magnus Melander (CEO Brainheart Capital), Prof. Gerald Maguire (KTH), Bengt Nordström (CEO Northstream), Prof. Bertil Thorngren (Stockholm School of Economics)
3 Bengt Nordström, Northstream

of quality of service, security etc. These demands in turn call for new network technology which needs to be developed through R&D focusing on specific components or on the properties of the system as a whole. All this of course takes place in a societal environment also affecting the technology development paths.

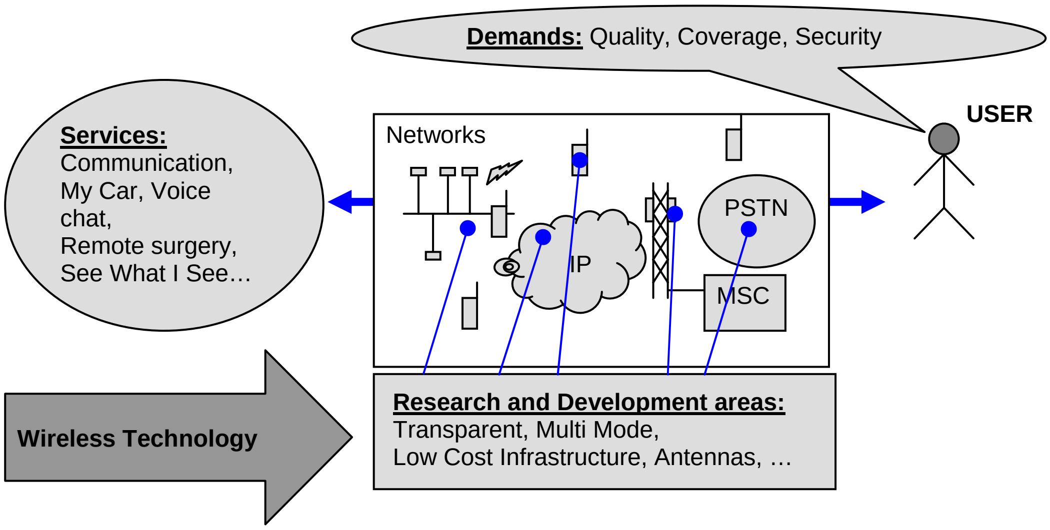

Figure 1: The wireless context

In the study, *technology* and *industry trends* are in focus. Other areas, e.g. societal development, users, wireless services, and the regulative environment are of course of great importance as well. Here, however, they are treated as background trends having an impact on the technological and the industrial development. It is also clear that the wireless systems and industry will develop differently in different regions of the world. All nations and regions have different starting points and different competitive advantages. Here the main focus is on Sweden and Swedish industry.

It should also be noted that, as we all know, predictions of the future more often than not are wrong. Or at least they often miss the most important breakthroughs. Telecommunications have had its fair share of mistakes in judging the future, or as one expert[4] puts it: *"While some of the biggest product launches in communication services over the last 20 years have delivered flops, seemingly trivial services have exploded."* He points to some interesting and recent examples shown in table 1.

	Telecoms Industry view at launch	**The consumer speaks – the "street" view**
ISDN	The next generation of telecoms – replace POTS	UK/USA: "Idiot Services Users Don't Need"
WAP	The mobile user will really go for this technology	"WAP is crap" – expensive, no services, difficult to use
Internet/WWW	Ignore… oh still there?!! horror – stifle… VoIP Wins	Just use it (@ no cost)
GSM – digital mobile	An extra (minor) feed for our fixed networks	Just what we need! – till we see the bill! – so PAYG rules
SMS	Minor supplementary service (CLASS for Mobile)	The *only* service (mobile or fixed) for many users

Table 1: Examples of mistakes in predicting the future.
(Source: Presentation by Simon Forge SCF Associates Ltd.)

[4] Simon Forge, SCF Associates Ltd.

2.2 The wireless environment today and in the future

Wireless systems is one of the strongest ICT areas in Sweden, with Ericsson as the world leader in mobile (cellular) network design and implementation. The fact that the infrastructure market leader is based in Sweden is of course of great significance for the future development. Ericsson also plays an important role as one of the biggest suppliers of platforms for mobile terminals and as a global provider of terminals in cooperation with Sony through the SonyEricsson joint venture. There are four cellular operators offering 2G services in Sweden (TeliaSonera, Vodaphone, Tele2, and Spring Mobil). The first three of these and one additional (3) also offer 3G services.[5]

Although the ICT sector has suffered from decay in recent years, the industry is now recovering. A recent study[6] shows that wireless still provides a significant contribution to Swedish industrial life and that Stockholm (in particular Kista) is the national center of gravity for wireless research and business:

- Wireless ICT generates a yearly business of over EUR 15 billion
- It employs over 50 000 people
- There are well over 400 companies in the industry
- 160 new wireless ICT companies where started in 2003
- 40 % of the companies focus on wireless infrastructure
- 72 % of the companies are located around Stockholm with the majority in Kista

Thus Sweden contains about 150 companies with *mobile systems* as their main business. More than half of these companies are located in the region around Stockholm while the rest are shared between Gothenburg, Scania in the southernmost part of the country, and a few other regions in decreasing amount. This also mirrors the distribution of personnel resources and competence. Ericsson is without any comparison the largest actor at each of these places but in addition there are also a number of fairly large consultancies with good system knowledge as well as smaller companies focusing on components, services etc.

There is extensive industrial R&D within wireless systems but it is conducted mainly within Ericsson and to some extent by the operator TeliaSonera. The public research is well spread among several universities with KTH and LiTH as the biggest actors followed by CTH, LTH, BTH, and LTU.[7] If radio electronics research is included, the total amount of professors engaged is over one hundred. The corresponding amount of PhD students is twice that amount. In addition there is quite a large institute sector, most notably the SITI institutes (Interactive, Viktoria, St Anna and SICS) with its 300 researchers. The Swedish Defence Research Agency (FOI) should also be mentioned, especially for their contributions to the area of ad hoc networks.

Despite the positive development, the last few years have shown how volatile a large perceived competitive advantage of the Swedish industry can be. Moreover, the transition from mobile telephony to wideband mobile data communication has only just started. There will be big opportunities during the coming five years and Sweden is well positioned for the future. The comprehensive competence and the track-record during the last decades suggest that Sweden will play a leading role in the current

[5] In addition to these five operators owning licenses and operating infrastructures, there are a number of so called Mobile Virtual Operators (MVNOs).

[6] ”Wireless Sweden”, Invest in Sweden Agency (ISA) and Northstream, Dec 2003

[7] KTH = Royal Institute of Technology, LiTH = Linköping Institute of Technology,
CTH = Chalmers University of Technology, LTH = Lund Institute of Technology,
BTH = Blekinge Institute of Technology, LTU = Luleå University of Technology

process of convergence of different network standards, like 2G, 3G, WiFi, WiMax, and the fixed network (both PSTN and IPN).

3 Background Trends

This section is focused on trends which, even though very important, in this study are considered as background trends affecting technological as well as industrial development in the wireless systems area.

3.1 Societal development

Society becomes increasingly mobile

Many people in the industrialized world live an increasingly mobile lifestyle. This will gradually increase the demand for communication and access to various types of data services while on the move. Moving towards such a *nomadic*, or meeting-oriented society, wireless technology becomes an even more important tool. As one expert[8], puts it: *"We are becoming nomads and we need technology for nomads."* The knowledge society we are entering is a much more mobile society than the industrial society we come from. We communicate more, we travel more, and we share ideas and know-how. Service production increases in importance and services are often produced where the customer is, not where the producer happens to be located. As the service sector increases in importance, so will the number of meetings and meeting places. To use the language from the quotation above; we will become nomads. Even if this might not be true for all of us and completely wrong for some of us, the trend seems clear. Society becomes more and more mobile. And nomads need to keep track of their lives, businesses, meetings, and friends, using mobile technology.

Environmental issues increase in importance

Environmental awareness in society has increased substantially during the past decade. It seems obvious that this trend will continue, forcing industry to develop increasingly environmentally friendly products. This will of course affect the wireless industry as well. Development of efficient communication solutions might decrease the need for traveling, thus having a positive impact on the environment. On the negative side, there are at least two areas of special importance for the wireless industry: energy consumption in terminals and networks and potentially detrimental substances used in terminals and other equipment. The global need for electric energy for the net and the wireless systems is not negligible compared to other sectors of society and industry. Each server park already consumes power in the megawatt range; add to this hundreds of millions of battery chargers, PCs, and base stations and the problem becomes significant. Environmental groups or governments might begin to focus their attention on the telecommunications industry, forcing companies to develop more energy efficient systems and products. Moreover, current research indicates that several substances, especially some brominated flame retardants (BFRs) used in terminal cases, might be dangerous to ecosystems if they leak from waste disposal sites.

Continued globalization and move towards the knowledge economy

Increasing globalization follows from the century-old trend of falling costs of transportation and (electronic and other) communication. Global trade and movement of people and ideas are increasing. These are long-term mega-trends and have been in place for centuries. War and political backlash can temporarily reverse this trend but in the long run it seems inexorable. The globalization trend has increased in speed during the least decades partly due to the shift to the service and knowledge economy gradually replacing industrial manufacturing as the major economic driver in the OECD

[8] Bo Dahlbom, see www.viktoria.se/dahlbom/

countries. The knowledge economy is now a growing sector in the NICs[9] too. The global market economy is stronger than ever and has few serious challengers in the long run even though counter movements will continue focusing on specific issues and problems in the market system.

There are many signs of positive development of the telecommunications sector and especially the wireless sector, in the most important NICs, e.g., China, India, and Russia. These markets are enormous and the growth rates are high. New companies are established with an ambition of becoming global players, for example, infrastructure vendors. The big NICs will become increasingly important not only as big markets for European, American, and Japanese companies, but also as countries where important new competitors emerge.

Aging population in the OECD countries

Demographic data show falling birth rates and that the older segment of the population will keep growing in most of the industrialized world. This will no doubt affect the societal development at large, as well as the telecommunications sector, e.g. the service markets. Elders will become an increasingly important market segments for wireless services.

3.2 Users and usage of wireless services

Increased user mobility

For obvious reasons, user mobility is an important aspect for use of wireless services and development of wireless technology. Studies of lifestyle and other related areas indicate that user mobility will increase. The work style has taken a disruptive step the last ten years. Office administration takes place also outside the traditional company buildings, at home or on the move. We will travel more and longer, both for leisure and professionally. We will also spend more time commuting.

Increased demands on speed

It is clear that the wireless service markets will develop from today, essentially only consisting of voice and simple messaging. More advanced types of rudimentary services, surfing, information retrieval, small payments, news, etc., still account for a small fraction of the usage. As 3G services pick up, users will get used to the increased speed of communication, downloading etc. which will lead to increasing demands on speed (bit rate). The demands will however increase gradually rather than revolutionary.

User groups become more and more different

The old world was a very simple place! All telecommunication users were offered the same service, voice telephony. And this service was offered by one company only, the state owned telephony monopoly. Gradually the amount of different types of services offered has increased, both over wireless and wireline systems. With the introduction of mobile (broadband) data this development becomes even more pronounced. We will see a further differentiation of users of wireless services into segments with quite different needs and characteristics. Some users will subscribe only to the most basic services, perhaps voice and text messaging only, whereas others will use various kinds of advanced wireless services. An example of a segmentation model is presented in a book about the wireless world in 2015 written by authors linked to Wireless@KTH.[10] Five important, but quite distinct, segments of wireless service users are identified: (1) Mobile Kids With Lots of Friends (MOKLOFS), (2)

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[9] NIC = Newly Industrialized Country

[10] "Wireless Foresight: Scenarios of the Mobile World in 2015", Karlson, Bria, Lönnqvist, Norlin, and Lind, Wiley, 2003

Young Urban People/Parents with Lack Of Time (YUPPLOTS), (3) Elders, (4) Mobile professionals, and (5) Industrial users.

Service quality will increase in importance, but in a novel way

As a consequence of the increased differentiation of service offerings and user groups, the differentiation of *quality of service* levels and offers will also increase. Voice-only users might still value a low level of lost calls, coverage, and perhaps price as the main quality parameters. Corporate users demand a high level of security through e.g. VPN-tunneling.[11] One size fits all is no longer applicable. At the same time, traditional quality of service might become less and less important as we for example have more and more processing power and storage capability at the device. Thus, for off-line information, bit errors can be covered not simply by coding, but by stored knowledge and content. Interrupts will matter less and less, because much content is already cached and we can use higher level models to synthesize missing content.

Even though this is a clear trend, it also seems that the more traditional quality aspects still are, and will be, important. Complete (or almost complete) coverage *is* important, especially for basic services such as voice and simple messaging, not to mention for emergency services. At the same time users will, due to cost reasons, have to get used to the fact that advanced services requiring very high bit rates only will be available at specific locations, e.g. public hot-spots or at the office. Other locations might be perfect for services sensitive to delay or variation in delay, e.g. communication services such as voice and video telephony.

Several of the air interface standards that are currently being introduced (e.g. de facto versions of GPRS and EDGE, CDMA2000 EV-DO) and some of those that will be introduced in a few years (e.g. HSDPA) are asymmetrical.[12] They provide higher bit rates in the downlink (to the user), then in the uplink (from the user). This is because most users today receive more information than they send. This might, however, change in the future. Traffic could even become asymmetric in the opposite direction. The demand for higher bit rates in the uplink will increase when for example video telephony takes off or when the amount of images sent increases (from private individuals, security cameras, etc.). More importantly, users want to be able to have high speed in both up- and downlinks - but it need not always be at the same time. It may be asymmetrical in use, but symmetrical in capability.

In the same vein, guaranteeing *security, integrity, and privacy* in networks and transmissions is becoming an increasingly important problem affecting almost all individual users as well as enterprises. The difficulty and complexity of this issue and the unsuccessful efforts to guarantee security on the fixed internet so far, suggest it may take a long time to solve this problem. The difficulties are even greater in the wireless world, because when you send over radio, in essence you send to everyone. An added complexity is user perception. Even though integrity, privacy, and security cannot be guaranteed, it might be that users don’t perceive it as a problem or they just don’t care.

The increased differentiation of the quality of service concept will lead to users trading quality against low price. Many of us will probably accept rather poor quality, at least compared to traditional telecom quality, if the price is low enough. In the PC world, we accept a low quality level of products, systems, and services, probably mostly because computers have become available at consumer price levels!

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[11] VPN = Virtual Private Networks, closed user groups within larger network systems
[12] HSDPA = High Speed Downlink Packet Access

3.3 Wireless services

The demand for wireless services will increase, but not explode

An important conclusion when looking back at the service market during the last five years is that it develops slowly. With the exception of voice and messaging, and perhaps also with the exception of Japan and South Korea, usage of data services is still very low. It is, however, increasing and with the introduction of 3G and with the gradual increase in performance of networks and terminals this market will grow. But there are *no* signs of an explosion, or of a killer application waiting to be found.

Continued prize drop on services

We can expect continued decrease in price of wireless services. In many countries, not least in Sweden, authorities take measures to increase competition among operators and to remove remaining “monopoly areas” used by the incumbents to keep tariffs up. We will also see an excess capacity of wireless “bandwidth” when the 3G systems gradually are completed. The total voice capacity will increase substantially and this will probably not be covered by a similar growth in demand. There will also be an increased competition between technologies adding to the price pressure. In just a few years, consumers can choose not only operator, but also between GSM/GPRS/EDGE/ UMTS and CDMA2000. In addition there will be an increased usage of wireless Voice-Over-IP services and user owned and operated networks, e.g. WLAN networks.

Increased focus on easy to use services

In parallel with the increase in number of different types of access networks, services, terminals, and users, *ease of use* will become even more important. Both services and devices need to be simple, almost intuitive, to use.

Today’s user interfaces of wireless terminals are based mainly on physical or virtual buttons (on a small touch-sensitive screen), input devices like micro-joysticks or roller wheels, and sometimes simple voice recognition. The output capabilities of wireless devices are hampered by the small size of the devices, battery constraints, and the cost of displays and sound cards. This has important limitations for usability, especially when we consider senior citizens, disabled persons, and other people with special needs. The user interface of a physically small device has to be small, at least today.

In addition to the devices, the service itself has to be easy to understand and easy to use. The rather slow uptake of new wireless services (for example over WAP and now the 3G systems) can probably partly be blamed on complicated service architectures. Also content will have to be specifically developed for use on small screens, at least during the first part of the five-year period. Device design and easy to use services are very important areas of research for the future.

Communication services continue to dominate

Gradually the variety of services will increase. Some will be simple, whereas others will be very advanced. Some services will be generic and offered to users all over the world independent of location, whereas others will be personalized, location based, and context dependent. Still, over the coming five year period, communication services will continue to dominate. The simplest peer to peer service, voice, will continue to be the bread-and-butter for wireless operators. Messaging services such as SMS, MMS, and email will also be very important. We can expect an increase of more demanding messaging, such as sending and receiving high-quality images and eventually video telephony and “See what I see” services.

New affordable everyday services for the mass market

Professional users is in many ways a leading market segment. These users are very price-insensitive and require high-quality information services as well as commerce and business services. They are usually seen as early adopters of new communication technology.

However, as time goes by, professional users and simple peer to peer communication services for the private individual will be complemented by growth of *everyday data services* at low prices for the mass market. Examples might be browsing for generic or location based information, payment services (wireless wallet), scheduling, booking tickets etc. These are small and simple services saving time and cost in our private lives as well as in business life and in the public sector. Where do I find the closest available plumber? Please load service truck 19 with seven spare parts of type 25 and two of type 135! Tomorrow there is a cancellation at your hairdresser; do you want that slot? Who of our substitute English teachers would like four hours in the community high-school this afternoon? Don't forget the outing at daycare today!

There is an enormous amount of potential services of this kind, each of which is too small and simple to be really interesting for the operators individually. However, the cumulative amount may be very large and hence interesting from a financial perspective. Also, the benefit for the users and their employers might be very large.

Growth of Machine-to-Machine (M2M) services

Machine-to-machine communication is enabled by the integration of very cheap communication modules into portable computers, digital cameras, security and logging systems, house appliances, industrial devices, vehicles, etc. The sheer amount of M2M communication will gradually generate quite a large amount of traffic. The amount of data exchanged between different devices will often be quite small, for example a few kilobits sent by a remote control or an alert from a security system. In some cases the data transfer will be very large, for example a few gigabits when transferring a movie from a digital video camera to a TV set. M2M communication is implemented by cheap radio modules, based on for example Bluetooth or similar standards. Most personal computers, PDAs, digital cameras, and even some home appliances (fridge, TV set, etc.) will have a module like this preinstalled.

Increased usage of entertainment and media services, but in novel ways

It seems inevitable that users gradually will start using their mobile terminals as entertainment and media devices. The terminal will incorporate not only Mega-pixel camera, broadcasting radio receiver, and MP3 player but television capabilities as well. However, this does not necessarily mean that we will use these services in real-time. Since streaming[13] at high bit rates places very high demands on the networks and terminals this might become a quite expensive service. Many users might instead choose other and cheaper ways of downloading the content and using it off-line instead. Examples include downloading at a cheap public hot-spot or at home, using USB memory sticks, etc. There will soon be terminals with several Giga bits of storage available at consumer prices. Users will for example be able to store thousands of songs and make their own music playlists. Alternatively they can down-load the playlist rather than the music itself from a radio station or a friend. One terminal manufacturer[14] recently released a phone featuring stereo audio from a variety of sources: from local storage, from a built in broadcast radio receiver, and from over one of the many two-way wireless links

[13] Streaming = Continuous downloading of the bit stream during service consumption
[14] Motorola

the phone supports. This opens up the possibility of separating downloading from usage. Download now – Use later!

Tailored and specialized applications
Niched and tailored services using the same hardware and software platforms will expand, starting with professional user groups and mobile workforces. Large corporations and perhaps whole industries will be attracted by such tailored services. These users are for example people working as sales staff, logistics experts, couriers, etc., jobs that make them highly mobile and in need of fast and high-capacity data links with their offices or organizations. In many cases the links might take the form of hidden communication between the personal terminal and a central server, i.e., M2M communication. Issues such as flexibility, data speed, coverage, positioning, security, tailor-made services, and integration with other systems are important issues. Cost is less important and the terminals might become something between a PDA and a laptop, i.e., rather powerful and expensive.

3.4 Regulative trends

A slow process for spectrum allocation
The wireless regulative development is focused on allocation of new frequency bands and on specifying conditions for using those bands. International harmonization leading to usage of new wireless frequency bands is a very slow process. The GSM 900 band in Europe was allocated in the late 1970s but real services were not opened until 1992.[15] The initiative to create world wide allocations for 3G was taken in 1986.[16] The commercial services were launched in 2000 starting with CDMA2000 followed by UMTS/W-CDMA and right now UTMS-TDD and TS-SCDMA.

Towards neutrality and technology flexibility
In general, a clear trend is that the regulators are moving toward neutrality and increased flexibility regarding the conditions for new services in allocations of frequency bands. In the first generation of wireless systems (NMT and TACS in Europe), the technical specifications formed part of the license and changes or up-grades of these services needed approval from the regulators. In the second and third generations (GSM and UMTS) it has been fairly easy to upgrade the systems, GPRS/ EDGE for GSM and HSDPA for UMTS are examples of this. From now on, the conditions will be further relaxed as can be seen in the process of reallocation of the present GSM bands and technology neutral positioning for the next set of 3G bands.

The wireless frequency allocations that will affect the period up to 2010 in Sweden and Europe are (see figure 2):

- 2.5 - 2.69 GHz
  A frequency band for “technology independent” 3G services to be ready for launch by 2007
- 5.725-5.875 GHz
  A new allocation for nomadic (semi-mobile) services
- 3.6-3.8 GHz
  An additional 200 MHz that will be allocated for fixed wireless access (FWA) services with the addition that mobility is allowed[17]

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[15] However, interim national systems such as NMT 900 and TACS were in operations from 1986.
[16] Key acronyms in this were CCIR/FPLMTS and later ITU-R/IMT-2000.
[17] This can be seen as an addition to the existing 200 MHz FWA-band on 3.4-3.6 GHz.

These new spectrum allocations will in essence more than double the bandwidth for wireless services during the next few years. Apart from increased competition, the effect of this is that a larger variety of technology standards and systems can and will be introduced. Hopefully this will lead to cheaper and more abundant services for the users.

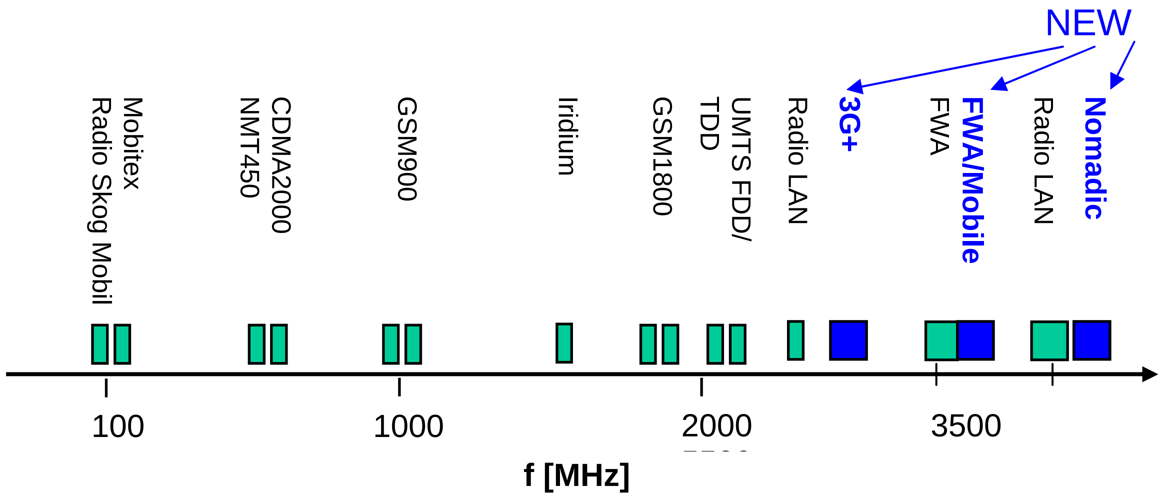

Figure 2: Available frequency bands for wireless services in Sweden and Europe by year 2010

4 Technology and Industry Trends in a 3-5 year Perspective

Speed of change will not be dramatic over the next five years. This might seem like an odd thing to say in a world of very rapid technological development. However, wireless systems is an infrastructure business, and large infrastructures change only very slowly. Moreover, it takes several years to launch new wireless services to a mass market. Sweden's new 3G networks (UMTS, EDGE, CDMA2000/450) will maintain world class in terms of wide area coverage and quality of service. At the same time the competition between 3G evolution and other networks (e.g. IEEE802.xx), will intensify and become fierce during 2007–2010.

4.1 Technology trends

A very complex and heterogeneous network environment

The total communication network environment is becoming increasingly complex and heterogeneous. The wireless information flow is already today transferred by systems consisting of several networks; a *network of networks*. This gradual shift towards multi-standards is today referred to as "Ambient Networks". This wireless world contains many different types of networks, from simple to complex, operated by many different types of operators. Users are served by many different access technologies - but several of those developed today will not survive. A multitude of "niche" wireless standards targeting specific problems such as coverage, bandwidth, reliability, capacity, or cost are under development, leading to a situation where no single "4G" radio standard will appear and dominate the market as has been the case for the 1-3G systems.

Consequently, a specific wireless network can in itself be very simple in relation to the cellular networks of today, but the functions to administrate for example user mobility and billing will become more and more complex. The large network of networks is very complex, even though each individual network might not. An important driver of this ambient networking is the development of transparent handover, roaming and service provider solutions. The trend is that wireless is slowly moving into this direction.

Network standards and technologies

The introduction of new wireless systems takes many years from proposal to operations but several new network standards and technologies will be ready for launching during the next few years. In addition to the cellular 3G networks currently rolled out, we hear about Super 3G, HSDPA, WiMax, WiMedia, ZigBee, UMTS-TDD, CDMA2000 1X/EV-DO, Flash OFDM, Iburst, Ripwave, Wibro all offering high data rates. It is, however, not clear which technologies that will be winners and which will be losers.

The three worlds of Fixed telephony, Mobile wireless, and Wideband data are about to *converge*. Eventually users will care only about the services they are offered and not the type of network they happen to use at the moment. This will be supported by new standards and features like:

- The Unlicensed Mobile Access (UMA) standard that supports 2G, 3G, and WLAN cross traffic, for example in homes
- Triple Play – a common function for telephony, data, and media (television and entertainment) services

The UMA standard is especially interesting since it offers a pure wireless operator (one without a fixed network of its own) to become a full-service operator by simply purchasing wireline capacity from a broadband operator. In the same way, a pure fixed network operator might protect its business by purchasing wireless capacity and then implementing UMA.

The *"All IP"* vision will continue to develop. Both fixed and wireless networks will be based on the Internet Protocol (IP) to a large extent, even though this protocol is not very efficient over the wireless link itself. Some large operators, like British Telecom and TeliaSonera, have already announced their decision to convert their networks to IP. The migration of traffic from the traditional fixed networks to the cellular networks, as well as to voice over IP (VOIP) over wireline broadband has already started. And it will continue. The development indicates that within five years, the majority of many operators' traffic has migrated to VOIP. The shift to IP will be a step by step process that will take several years.

User *bit rates* ("speed") will also improve gradually, following a staircase without drastic steps. Wide area cellular services will improve substantially from the present peak rates of a few hundred kilobits and the local WLANs will speed up from the present top speeds of hundred megabits per second. User demands on increased bit rates in the uplink as well as in the downlink will eventually lead to more symmetrical bandwidth capability in the networks. This is more evident for the 2G and 3G standards were uplinks are not prepared for advanced image and data transfer.

New types of *low cost infrastructures* for mobile or semi mobile access will be launched during the next five years. These will be based on existing and coming WLAN standards (IEEE802.XX). Such networks will in some cases be operated by new types of operators focusing on for example specific customer segments or a certain service in a certain geographical area. Local access in home and office environments will be provided mainly by these IEEE systems. At the same time, wide-area coverage based on digitalization of the 450 MHz band will be established to support consumers in sparsely populated areas, as well as industries operating in such areas, for example forestry. These systems will decrease the demands on surface coverage put on other system standards operating in higher frequency bands.

Wireless DSL will increase in importance as a "Hot region" complement to existing broadband services through cable lines and as 3G complement. This is especially accentuated in rural areas or for households far away from the closest telephone station. There are several candidates for this application, the most important being the UMTS-TDD, Flash OFDM, and WiMax standards. It is quite clear that these will be complementing rather than substituting 3G.

Wireless machine-to-machine networks will be improved to meet high requirements on cost and reliability, such as improved RFID and ZigBee, enabling a growth of M2M communication. Another example is the very short range communication at 13.56 MHz (e.g. Nokia-NFC).

Wireless terminals

The technical roadmap for terminals is treated in depth in a separate ISA report. It is therefore enough to briefly point to the device trends that have the biggest effect on the development of wireless systems.

- Low-cost multimode terminals
  Of especial importance is mass market entrance of devices integrating WLAN with 2G and 3G cellular standards. This is a first essential step on the way to "transparent ambient networks".

- Megapixel cameras and high-resolution video cameras
  A wide spread usage of such cameras will lead to users demanding high bit rate uplinks as well as downlinks (users want to both send and receive images).
- Large storage facilities in terminals (+Gigabytes)
  New services based on downloading when it is cheap and convenient and off-line usage will be introduced.
- Improved screens
  New screen technology and eventually “virtual” screens will drive user demand on high bit rates.

Specific technology developments

In addition to the technology improvements mentioned above, there is of course a rapid development in other areas as well. Some of these will contribute significantly to the progress during the next few years, such as:

- Antenna technology
  The development in the fields of multiple ports (MIMO) technology, smart units, and high gain terminal antennas is especially important.
- Man-Machine-Interfaces (MMI)
  Examples include advanced speech recognition and synthesis
- Dynamic Spectrum Access (DSA)
  Smarter and more flexible ways to use the limited spectrum resource.
- Solutions for Security and Digital Rights Management (DRM)
  To stop eavesdropping of transmissions and the widely spread illegal copying of entertainment and software products is an important key in enabling trust and reliability and thus progress in the wireless business.

4.2 Industry trends

Geographical clusters

The wireless industry in Sweden is rapidly recovering from the recession two to three years ago. The industry is growing again and wireless will continue to be an important sector for the country. Today one out of hundred working people are engaged in the wireless business in one way or another. Sweden has since the 1970s established several clusters for the communication industry. The main clusters are situated in Kista/ Stockholm, Lund/Malmö, Linköping and Gothenburg. In addition, ICT clusters on a smaller scale are operating in Karlskrona/Ronneby, Uppsala, Gävle, and Luleå. The largest cluster is without doubt Kista.

The clusters contain a mix of university research and companies of all sizes. In general, the clusters are growing and some of them, like the largest one in Kista, have made advanced plans for further investments for growth. In several of the clusters, Ericsson or SonyEricsson play an important role. The growth in the areas where Ericsson is situated is significant and a trend is that more and more foreign companies establish R&D and other activities in the clusters.

The ability to design complex systems and products will be a Swedish specialty

The ability to develop, build, and operate complex technical systems has been a strong point for Sweden for a long time. The development of the latest generations of cellular systems has involved many thousands of professionals working together in an extremely complex effort. This requires a mix of a cooperative mindset, administrative order, and innovative skills. External organizations may establish themselves here to access this resource.

The wireless industry develops in two directions: Wide-area and Local access

The wireless industry will gradually develop in two quite distinct directions, the Wide-area and the Local access industries. This process has already started. The *wide-area wireless industry*, with big vendors (Ericsson, Nokia, Alcatel etc.) supplying large operators (Vodafone, France Telecom, TeliaSonera etc.) with complex, vertically integrated, closed, and very expensive systems, will undergo increased consolidation both in the operator and the vendor segments. It will continue to be heavily affected by political and regulative decisions. The governmental control tools visible for the next few years are licensing, competitive regulation, and opening of new frequency bands. This holds true both on national and European levels. Sweden is a very sparsely populated country, which in itself will drive the implementation of high-coverage systems and local service development. On the doorstep we have long range base station arrangements, network transparency, and terminals adapted for off road usage. Ericsson will remain an important engine for national business in the wide-area industry.

The development of the *Local access wireless industry* is more unclear but it seems evident that we will see an increased access infrastructure competition. Hotspot (non-cellular) and Hot region technologies will take significant market share for personal communication in local business and home applications as well as in public hotspots. The base stations in this segment are not the complex, industry grade, high reliability products we are used to from the wide-area industry. These base stations (or access points) are mass market commodity products with low profit margins. Their capacity for self-configuration and adaptation will increase over time, making them easy to install even for regular consumer. Neither the traditional operators, nor the large telecom vendors are geared to handle this short range (on-premises, home) or medium access infrastructure. This is consumer electronics and the home-turf of the computer industry. New types of very different “operators” will emerge. Individuals, various types of communities, mall-owners, and small businesses are examples of possible local-access providers. It is unclear which Swedish actors that will address these emerging local access needs.

How successful will 3G be?

GSM users of today will be 3G users of tomorrow. In a couple of years from now, all phones sold will be multimode GSM/3G. This facilitates a firm migration from second to third generation. But terminals will incorporate WLAN technology as well, which will affect user habits. The ongoing regulatory trend to be more flexible and technology neutral will increase competition from other non-3G services. Still, WLAN competition will be strong for the local access (one room or building only) but not for the fully mobile environment.

Continued globalization leads to increased competition

Outsourcing of both manufacturing and R&D to Asia and Eastern Europe continues.

China, India, and later Russia will dominate as the most important markets. These nations will become increasingly important as industrial players as well. South Korea and Japan will be strong markets for development of new wireless services and applications.

Defense and consumer technology merge

The ongoing defense research in Sweden has during the last five years or so turned towards adapting and using commercial “civilian” systems and technology as a complement to military communication systems. This combination will create new business possibilities within the next three to five years.

5 Open Questions

There are areas in which the development is quite unclear. We might see a commercial breakthrough during the coming five years or we might not. These are the open questions.

5.1 Peer to Peer communication using multihop networks

Peer to peer (P2P) communication using multihop technology is often referred to as “ad hoc” networks. The prime function of these networks is their ability to use several terminals or other simple nodes to transfer or relay information between themselves. This can for example be used as a very cost efficient way to extend the coverage of a cellular wireless network. It can also be used for direct communication between individuals or nodes without using a hierarchical network structure; a simple example being a traditional walkie-talkie service. Although some “pre-functions” are available, for example in existing WLAN technology and in machine to machine (M2M) technology for industrial sensor networks, these systems are still under development in the research labs.

If successful, the multihop technology no doubt has the potential of transforming the mobile communications market into “a world without base stations” and without the present types of operators. A breakthrough in peer to peer communications will change the wireless infrastructures drastically, and new ways of financing, implementing, and operating these services will appear. However, several significant obstacles need to be overcome. Therefore this technology will probably not reach mass market before 2010.

5.2 Satellite services

In the late 1980s and early 1990s the expectations on mobile satellite communications were high. A number of such services were launched in the late 1990s and onwards. The business generated from these systems has been a disappointment. One of the main reasons for failure in predicting the development has of course been the massive rollout of cellular systems such as NMT, AMPS, GSM, and CDMA which in turn has undermined the possible number of subscribers going for satellite service. The development of user demand for mobile space communications is an open question. It will probably increase but only slowly.

5.3 Fixed Wireless Access (FWA)

Fixed Wireless Access is a hot topic today. “Wireless DSL” has established itself as a cost efficient solution for offering broadband services in areas with low population density. Right now several rollouts are under way. In spite of this fact, it is unlikely that this expansion will continue for years to come. Most of the FWA technologies will offer mobile or semi mobile services. The regulative trend is to not limit access to fixed point-to-point applications but rather to open up. FWA as a pure point-to-point service will probably be of less importance by year 2010 in favor of mobile or semi mobile services. FWA will probably become an important complement to wireline DSL and to some extent to 3G services.

5.4 User interfaces

Very thin, flexible, low cost screens as well as new projection methods will eventually change the wireless communication industry. Today, both applications and users make a clear distinction between hand held terminals and laptop PCs with radio capability. They have different capabilities and they are used in different ways. New ways to present information may in fact cease the existence of laptops. The main, and open, question is of course when this type of equipment will be available.

Voice control technology will bring completely new man-machine communication methods. We will go beyond voice activation - the system will be constantly building and modifying a model of our voice and our speech including content, thus allowing for very good recognition and synthesis. The implementation of voice based support in technical systems has been slower than expected. It still remains to be seen if advanced voice control will be a significant part of wireless communication services before 2010.

6 Potential Showstoppers

In general, the future development of wireless services, industry, and technology looks promising even though we cannot expect an explosive development of the kind we saw in the second half of the 1990s. It is much more likely that we will see a gradual development, perhaps broken off by bigger steps at intervals. However, there are some clouds in the sky. A few problems can be identified which, if not solved, might threaten the development of the whole industry. These are the potential show-stoppers.

6.1 Collapse in managing increasingly complex networks

In a future world with users seamlessly connected over a number of heterogeneous networks, system complexity will be much higher than today. It will probably be unmanageably complex to have centralized control for billions of users operating various terminals to access many networks with handover, roaming, context-sensitive user profiles, billing, uninterrupted sessions, etc. These issues have to be addressed and *decentralized* solutions for handling complexity developed. This calls for open APIs[18] such as IP and adherence to open standard interfaces.

6.2 Power consumption in terminals

With the very rapid development of processor power (following Moore's law) and memory capacity, making new services possible, the power consumption of wireless terminals will increase dramatically. At the same time, battery capacity develops much slower. From a user's viewpoint, long *usage time* between charging the device is an important feature. Most users are accustomed to quite long usage and standby times on their GSM phones. It will therefore be very hard to convince the mass market to use power-hungry services if battery time drops too much.

6.3 Biological effects of radiation – real or perceived

The complicated problem of electromagnetic radiation from wireless terminals and base stations has to be taken very seriously by the industry. Even if, as most experts argue, the radiation levels permitted today are in fact harmless, they are a threat that needs to be dealt with. The problem is that no proof of danger is not the same thing as proof of harmlessness. If users are afraid of using wireless technology, it *is* a problem, justified or otherwise. The industry should consider taking precautions and should for example advice users how to minimize the radiation penetrating their body. It could also develop modularized terminals where the radio unit is removed from the absolute vicinity of the most sensitive areas of the body etc.

6.4 Chaos around Digital Rights Management (DRM)

During the last years we have seen an intensified debate between content owners (the movie and music industries in particular) and people (often labeled pirates) arguing for free sharing of music and movies. An increasing amount of people might continue sharing information between themselves in small and large clusters using Napster-like applications, thereby distributing digital content such as news, movie clips, and music on a peer to peer basis. Despite generating quite a lot of traffic in the networks, this could lead to serious implications for the content providers. In attempts to protect their

[18] API = Application Program Interface

content, the content providers come up with new ways of encrypting their information, but these solutions might eventually be hacked by underground groups that distribute their work rapidly in the networks. This might lead to a situation where the big content owners refuse to distribute their content over the wireless networks which of course will affect traffic volumes as well as revenues for the whole industry.

Consequently, some experts argue that settlement and acceptance of methods and techniques for DRM will lead to larger consumption, benefiting the whole industry. Other experts argue that the problem is not that big, at least that it doesn't matter as much as the big record and movie companies think. It can be argued that most content is in fact not controlled by them. They just control the very tip of the iceberg. Manufacturers of wireless devices could instead support the small artists by offering a way around the major music distributors, enabling free sharing of content over wireless networks.

It is quite difficult to judge what will happen and who will “win” this battle, the content owners or the file sharing community and it is not clear what the outcome will be for the wireless industry. However, it seems obvious that if the matter is *not* resolved in a sustainable and long-term fashion, it might hamper the development of the whole industry.

6.5 Difficulties guaranteeing security, integrity, and, privacy in networks and services

Security and protecting the integrity and privacy of users will no doubt be one of the most important service features in the future. Better techniques to ensure *protection of data and user privacy* (position, traffic patterns, private information, etc.) have to be developed. Ways to provide very secure connections and secure data transfers, at least in services like electronic payments or banking, have to be studied. Unauthorized tracking of users or access to personal and private information has to be avoided. The problem of hacking and virus creation needs to be managed. The whole area of security, privacy, and integrity has to be approached very seriously; otherwise this might hamper the development of the whole industry for years to come.

7 The Wireless World in 2015 and Beyond

As already stated, it is quite unlikely that any dramatic changes of wireless technology and systems will appear during the next three to five years. There are, however, signs of big changes at the horizon. This is the reason why this section of the report has been expanded somewhat, even though the temporal perspective (10 to 15 years from now) goes beyond the one in the roadmap itself.

Wireless technology will gradually transform from an expensive, highly visible, hi-tech technology to a *disappearing technology*, one that everyone can afford, use, and deploy. Eventually we will take it for granted. An interesting analogy is the development of electricity. Around 1900, a light bulb was an exclusive piece of equipment which few could afford. In the middle of the century the technology had become available to everyone and now it is a pervasive technology where rooms are equipped with lots of light bulbs and electrical outlets are taken for granted. Most users, also those with limited skills, are capable of “deploying electrical applications” and parts of the infrastructure on their own. In mobile communication, at least when it comes to cellular telephony, we have in many countries reached the state where almost everyone has it and where service availability everywhere is taken for granted. Wireless access to data services has been an exclusive technology but is now growing. Similar to the power grid, it is not likely that there will ever be anytime-anywhere coverage for really high bandwidths neither wired nor wireless. Still, the users will be always connected with a variety of non-visible wireless access technologies offering connections of various types.

7.1 The wireless world in year 2015: A user scenario

A warm spring breeze filled Berlin as Sara went for a sightseeing walk. She put her positioning-enabled projection goggles on and her agent projected her personal start screen in the semitransparent eye field. She spent about a minute looking at her headline news, the Berlin weather for the next six hours, a few local offers her PDA had accepted, plus the five restaurants recommended by her agent for the dinner tonight with Michael. She found one restaurant interesting and had a quick look at recent pictures from the restaurant webcam to get a flavor of the atmosphere. Sara used the voice control to ask her agent to make the suggested table reservation.

She changed to the Berlin city guide and accepted the fee for the 3D guide, which included the cost of the heavy data downloads. The screen changed and suddenly she was transported to Berlin in the 1960s. Interlaced over the Berlin street where she was standing, she saw projections of how the buildings used to look and in the streets she saw people and cars from the 1960s. She turned around and was almost shocked by the projection of the Wall standing just 10 meters in front of her. Sara took off her goggles for a moment and looked at a peaceful street with no visible sign of its history. She put them back on and a voice-over started telling the story of the place.

Sara started to feel hungry so she turned to the city guide again. Her PDA projected a map of the nearest blocks and when she clicked on “salad type” places it marked the ones matching her profile. The closest, Organic IT, was a salad bar owned and operated by a former athlete, Sven-Goran. It’s business concept not only included serving organically grown food, but also offering Internet access and various entertainment services such as downloading of music, videos, and games. Sven-Goran had just bought a Voodoophone access package consisting of wireless access points from his local home electronics vendor. Voodoophone is one of the many small wireless operators that have emerged during the last years providing comprehensive access services, but owning almost none of the physical infrastructure. "Simpler than programming my VCR", Sven-Goran thought, as it took him less than half an hour to mount and connect the small self-configuring units, instantly making them a part of the Voodophone network. In exchange for offering his customers Voodoophone access and content services, the operator offers him free broad band access to the salad bar and free access to his family to the network at home and while traveling.

After finishing the salad, Sara used the pen to open her mailbox on the PDA screen. She remained unaware of Voodoophone, as her PDA negotiated an access deal while Sara started looking at the 12 new live mails. The first words of the transcripts were displayed on the screen. Most were voicemails but one was a medium quality videomail from a client in Tornedalen. The agent had already downloaded the videoclip in her PDA using Organic IT's hotspot. One of the other mails was a demo for a marketing film for one of her other projects. This file was very large and the agent had decided not download it at this location. Passing the exit, she glanced at the lunch bill as it popped up on her handheld and accepted it together with the suggested rounded 8% tip suggested by her PDA agent.

As Sara walked into her hotel room, her PDA did a handshake with the room's equipment and the large wall screen sprang to life, showing the Berlin weather and a reminder about her dinner engagement. Her PDA had already anticipated that she would be interested in restaurants so it had downloaded and cached a number of marketing videos in addition to the latest songs of her favorite music artist while walking by the ultra-high speed infostation in the hotel lobby. She looked through the rest of the inbox and video-called the Tornedalen based client. He was on a flight somewhere over the Atlantic with his PDA on the air-seat table in front of him. After talking with him for a few minutes, Sara closed her mailbox and left for her dinner.

7.2 A highly heterogeneous wireless environment with a multitude of technologies

In a future 10 to 15 years from now, wireless communication is provided by a large variety of systems; many more systems than we see today. There are self deployed broadband access points working in unlicensed spectrum, like WLANs, complementing the cellular systems at hotspots. Large capacity is also provided in cellular systems through picocell solutions. DAB[19] and DVB-T[20] provide spectrum-efficient broadcast services over large areas. Technologies like Bluetooth offer very short-range wireless access. Together with high-altitude platforms, satellites, etc., all these systems make the future wireless world very *diverse, complex, and difficult to integrate*. Most of the time, this heterogeneous infrastructure is not hierarchically organized, meaning that different systems are connected directly to each other without centralized control from a higher system level. Distributed control solutions are chosen instead. Base stations and access points are adaptive, self-configuring, and use smart antennas to increase capacity and reduce interference where resources are scarce. The wired backbone network is packet switched (IP) and is available in most homes and offices, either directly (through wire or fiber) or through BWA[21]. Networks are transparent for packets at the IP level, making it easy for service providers to develop and offer new and customized services to large numbers of users.

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[19] DAB = Digital Audio Broadcasting
[20] DVB-T = Digital Video Broadcasting, Terrestrial
[21] BWA = Broadband Wireless Access

7.3 Abundance of easily accessible, affordable, and reliable services and terminals for all uses

Terminals will come in many shapes and forms in the future. Some will be cheap, simple, and very basic; others will be advanced and expensive. Demands on flexibility, adaptability, user friendliness, usage time, and radiation levels are driving the development. The terminal of 2015 is a common device in most people’s pocket and its capabilities range from basic to very advanced functionality. Industry markets everything from very simple and service oriented terminals targeted at for example elders, to the most advanced 3D-capable screen-enabled device for handling the very high bandwidth requirements of professional users. Many terminals are modularized with clearly defined interfaces between modules, for example radio unit, input/output unit, screen, and keyboard. The different modules are sold as separate components and are then used to create individual device systems. Many of these cheap and service-dedicated wireless components are integrated into fashion items like clothes or accessories or into portable computers and PDAs. Such wearable device systems are managed as BANs[22]. Routing of data through many devices or modules is simple, easy to implement, and easy to set up and run for the end user. System-on-chip technology, where the processor and the wireless communication unit are integrated into a single chip, has enabled such ultra-small and low-cost components.

Most terminals feature several functions that greatly facilitate communication and use. Advanced solutions are common for voice control, touch screens, and interactive control. The same service can be provided on different input and output devices, such as a big screen on a wall, a desktop or laptop computer, and a PDA for people on the move. Advanced display technology allows the virtual size of the display to be much larger than the physical size of the screen. Self-learning devices help the user to personalize the interface and to filter and organize information coming from various service providers, content providers, or the internet. Advanced voice interfaces can eliminate buttons, so the size of the terminal can be very small.

7.4 Context and location aware information and entertainment services dominate

Services based on identification and positioning of the user becomes increasingly common. Content becomes more and more personalized and context dependent in 2015. Many services are provided in an instant turnkey fashion and they disappear when the user moves to a different location. Virtual information agents, portals, and information brokers assist the users in finding, filtering, and personalizing information. Two examples are personal assistants that keep track of a user’s meetings, tasks, alarms, or address books; and virtual guides for tourists in unfamiliar cities or museums. It also seems likely that entertainment services, such as music, movies, on- and off-line games, and gambling, will become increasingly popular and will be commonly offered over mobile networks.

7.5 Local access infrastructure deployed and maintained by janitors, electricians, and consumers

Reducing the cost for building wireless infrastructure is an important issue for the future, being necessary to decrease the cost per transmitted bit and boost traffic. Ad hoc access points deployed by users or operators will constitute a large part of the access infrastructure in 2015, especially in the case of broadband hotspots or other solutions offering mostly indoor coverage. A lot of traffic will go through spontaneous ad hoc networks, for example users sharing information between two portable

[22] BAN = Body Area Network

computers or a video camera sending a movie to a backup server. These kinds of system will mainly operate in unlicensed bands. Ad hoc deployments will be present outdoors as well, but perhaps to a somewhat lesser extent. The reason is that un-licensed operation and coexistence of different systems in the unlicensed spectrum might lead to inefficient spectrum utilization and interference created by neighboring access points.

Future wireless devices and infrastructure components have to be deployed and maintained by owners or user without specific skills and special training. This means that the devices need to be adaptive and self-configuring, sensing their physical and logical environment. These are highly reliable networks and systems built from large numbers of consumer grade devices.

7.6 Global wide area coverage but with varying quality of service

One of the biggest factors behind the success of mobile telephony and in particular GSM, is the extensive coverage and the possibilities for users to use the same terminal in many regions of the world, through roaming agreements between operators. This will of course continue to be an important aspect ten years from now as well. As device technology improves, the possibility of manufacturing multi-mode terminals (handling different standards and/or frequency bands) at low cost increases. Even if the wireless world becomes more and more heterogeneous, we can expect that most users who need it may get global coverage at a reasonable price. At the same time there will be an increased variation in types of services, quality levels etc. offered at different locations on the globe. Some places will probably only have rudimentary coverage, whereas very advanced services might be offered at other places.

7.7 More spectrum for mobile/nomadic communications

Previous it was stated that the available bandwidth for wireless services will double to the year 2010. A new set of allocations will further increase this bandwidth. This will become reality 10-20 years from now. Three main efforts can be anticipated:

- 470-600 MHz - lower bands for wide area (rural) coverage
- 2.7-6.0 MHz - in higher bands for high bit rates for full mobility services
- 6-70 GHz - in even higher bands for bit rates over 100 Mbs for nomadic services

The days when spectrum for open mobile wireless networks was a fraction of the allocations in comparison with broadcasting and defense applications are soon gone. In fact defense communication and broadcasting will to a large extent take place over the so called mobile wireless spectrum in the future.

7.8 Fierce competition and many actors offering services and access

If the wireless world develops according to the image just painted by 2015, the long-term effect on the industry will be substantial. The old telco world with closed, vertically integrated solutions give way to layered open architectures based on the Internet Protocol (IP), a development which might benefit attackers from the datacom industry. As the industry matures, new players enter the scene and profit margins are squeezed. The technological development creates new markets but eventually turn profitable products into low-margin commodities. Industry fragmentation and vertical disintegration accelerate when companies become more and more specialized. When performance of any given technological function is good enough, design and manufacturing knowledge around this function is no longer a critical asset and modularization set in. Consequently, this part of the market split into several new niche markets.

8 Competitive Advantages of the Swedish Industry

According to a newly published study,[23] Internet usage in Sweden is the highest in Europe, both for private and company users. Combined with the very high penetration of mobile phone subscriptions and a general openness to new technologies, this makes Sweden is an excellent market for testing new ICT service concepts to large groups of users.

8.1 The Swedish wireless industry is growing again

According to the report "Wireless Sweden",[24] published in December 2003, the wireless industry is expanding again. The number of companies in the sector increases and is almost back to the same level as before the crisis. Many of these companies are technology based start-ups focusing on network development and deployment, radio technology, infrastructure components, service platforms, and service delivery. Not only is the wireless industry growing, but the crucial spirit of entrepreneurship and innovativeness that was the hallmarks of the sector in Sweden is back.

8.2 3G and other wireless data networks

The wireless networks in Sweden are generally characterized by very good wide-area coverage, despite the country's low population density. Sweden is served by a variety of high quality networks containing a mix of NMT, 2G, 3G, Hotspots, Wireless DSL systems, and other more dedicated networks supported by excellent fiber and wire-line infrastructures. The development of these networks can be seen as nationwide test-beds for technical and early market activities. The competence built around developing and deploying these networks is very interesting for other nations in similar situations.

8.3 Low cost for wireless access in the future

The excess capacity for voice services that probably will develop in the cellular networks when the 3G systems are completed a few years from now will generate a significant price pressure on the market. New operators entering the market and other initiatives will drive prices further downwards, which in turn generates excellent opportunities for service development and provisioning and in the end market growth.

8.4 Nationwide availability of excellent engineering competence

One positive aspect of the recession in the industry is that it has led to an availability of high-class and very experienced engineers and marketing people. Currently there is a good opportunity for entrepreneurs and existing companies to staff their businesses with competent personnel. This situation will of course change as the industry grows and by 2007 or 2008 the situation may be different. On the academic side, it can be noted that the interest for ICT related university studies is returning. The number of vacant positions on the national bachelor and master programs is decreasing at most universities. It also seems relatively easy for many research groups to attract enough PhD students for the time being. The supply of competent personnel to the wireless sector seems quite good both in the short and in the long run.

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[23] "Internet usage by individuals and enterprises 2004", EU Eurostat, May 2005
[24] "Wireless Sweden", Invest in Sweden Agency (ISA) and Northstream, Dec 2003

8.5 Highly competent wireless clusters

There is a strong tradition of extensive collaboration between industrial R&D and academic research in Sweden. The funding mechanisms from the government are firmly established and reasonably reliable. Funding agencies such as Vinnova, SSF and Nutek have played an important role for many years in the wireless industry. The densest cluster in Sweden is Kista/Stockholm where a majority of the national ICT industry is established together with many foreign companies.

8.6 Areas of particular strengths in industry and academia

With the strong trend of increased outsourcing to regions with lower labor costs (India, China, Eastern Europe etc.), it seems manufacturing of ICT products and components is not the most promising sector for the future. There are of course examples of successful manufacturing companies and also of companies using manufacturing experience in R&D activities, but still this is not where the growth will be. Instead Sweden should focus on highly complex systems and products produced in small volumes but with high service content. Wireless systems is a good example of a product of that kind. There are a number of more specific areas that attract inter-national interest today. Examples are:

- The competence as well as team and company culture needed to design new network architectures for a highly complex and heterogeneous future is in place. New systems and products based on a mix of network elements and large core networks will continue to be designed by Swedish actors.
- The knowledge in complete design of radio nodes such as base stations and terminals is a strong area in Sweden.
- In relation to the size of the country, Sweden has an amazing number of antenna researchers, developers, and manufacturers.
- Audio processing such as compression, recognition, and synthesis has a strong foothold. This skill is essential for efficient transmission and improved terminals.

One thing in common for all these areas is that knowledge is developed through extensive collaboration between universities, research facilities, institutes, and industry.

8.7 Home market for the leading wide-area infrastructure manufacturer

The fact that the global leader on the wide-area wireless system market is Swedish is of course very important. Ericsson still performs most of it research and development in Sweden, thus accounting for a major proportion of the activity in the national wireless business. Engineers in other companies (start-ups as well as established firms) are very often previous Ericsson employees. Access to Ericsson knowledge, their cluster of subcontractors, consultants, and platforms is a prime driver in Sweden’s mobile communications community.

9 Conclusions

This road map of wireless systems covers the period 2005 – 2010 and is focused on *technology* and *industry trends*. In this field this is quite a short temporal perspective. Infrastructures change slowly, mass market adoption of novel mobile services is surprisingly slow in most cases, and the regulative work with allocating new spectrum for wireless services is long and cumbersome. It therefore seems quite clear how wireless will develop over the coming three to five years. The wireless systems will develop gradually, but in a stepwise fashion. We will see an *evolution* not a revolution. In a longer temporal perspective, let's say ten to fifteen years from now, we can expect bigger and more drastic changes.

The wireless industry and the business environment in Sweden are well equipped for the near future and will play an important role in the global development of wireless systems and technology during the next five years, and probably longer. Being a country with only nine million inhabitants, we can of course not be global leaders in all parts of the technological development. But by acting wisely and focusing on the right areas and on our competitive strengths, we will be able sustain our position. We will be able to develop into a global leader in a few novel fields as well.

Sweden's competitive advantages in wireless system technology are:

- Strong clusters for research and development
- High technological competence of both companies, universities, and individuals
- Both world-leading manufacturers and small entrepreneurial companies in several fields of wireless technology

10 Glossary of Common Wireless Terms and Abbreviations

1G	first generation mobile technology, analog voice (NMT, AMPS, TACS, etc.)
2G	second-generation mobile telephony, digital voice (GSM, IS-95, D-AMPS, etc.)
2.5G	2G with added data capacity (GPRS, etc.)
3G	third-generation mobile systems (IMT2000)
4G	a broad concept for future advanced mobile technologies
AAA	authentication, authorization, and accounting, the three functions required for secure transactions
ADSL	asymmetric digital subscriber line
AMPS	American Mobile Phone System, American version of 1G
API	application program interface, the set of functions specified by the software vendor that other programmers can use to communicate with the software when integrating it with their own systems
ARPU	average revenue per user
ATSC	Advanced Television Systems Committee, US standard for digital TV competing with DVB-T
BAN	body area network, network involving only devices on the body
Blackberry	two-way paging service offered over a Mobitex network
BFR	brominated flame retardant
Bluetooth	wireless standard for short-range cable replacement
BWA	broadband wireless access
CDMA	code division multiple access
CDMA2000	a 3G standard
CDMA2000 1X	cdma2000 supporting one carrier, 154 (later kb/s
codec	coder and decoder
DAB	digital audio broadcasting, standard for digital radio
DSA	dynamic spectrum allocation
DRM	digital rights management
DVB-T	digital video broadcasting, terrestrial, the dominant global standard for digital TV competing with ATSC
DVD	digital versatile disk, used for storing video or other data on a CD-sized disk
EDGE	Enhanced Data for GSM Evolution, an upgrade of bitrates in GSM
EV-DO	high bit rate service in cdma2000, 2.4 Mb/s downlink
FDD	frequency division duplex, a way to organize transmission
Flash-OFDM	a data transmission format/product
FOMA	Freedom of Multimedia Access
FWA	fixed wireless access
Gb	gigabit, unit for measuring data storage and traffic capacity
GHz	Giga Hertz (billion cycles per second)
GPRS	General Packet Radio System, a “2.5G” technology
GPS	global positioning system, system for geographical location using triangulation of signals from GPS satellites
GSM	Global System for Mobile, 2G mobile service
HAP	high-altitude platform, such as an airship or balloon

hotspot	small location where broadband wireless access is available
HSDPA	high speed downlink packet access for UMTS, 3-14 Mb/s
GHz	Giga Hertz (billion cycles per second)
i-burst	a data transmission product based on smart antennas
ICT	information and communication technology
IEEE	American engineering association, among other responsible for the W-LAN 802.xx standards
iMode	wireless technology for mobile internet in Japan
IP	Internet Protocol
IPR	intellectual property rights
IR	infrared
IS-95	a 2G standard based on CDMA
ISDN	integrated services digital network
ISP	internet service provider
ITS	intelligent traffic system
ITU-R	International Telecommunication Union – Radio (a United Nations function)
J2ME	Java 2 Platform, Micro Edition
kbps	kilobits per second
LAN	local area network
LEO	low earth orbit
M2M	machine-to-machine communication
MHz	Mega Hertz (million cycles per second)
MIMO	multiple-input multiple-output antenna function
MMI	man machine interface, human interaction device
MMS	multimedia messaging service
Mobitex	packed-switched, narrowband, data-only mobile system
MP3	a compression format, a de facto standard for music players
MVNO	mobile virtual network operator, a mobile operator without its own network. The MVNO buys network capacity wholesale from mobile networks and resells it to consumers under its own brand
MSC	mobile switching central
Napster	web service for free sharing IPR-protected music between users
NFC	near field communication, (few centimetres)
NIC	newly industrialized country
NMT	Nordic mobile telephone, global 1G standard
Nutek	the Swedish Business Development Agency
OFDM	orthogonal frequency division multiplexing, air interface with high capacity used in WLANs
PAN	personal area network, immediate vicinity around the person
PC	personal computer
PDA	personal digital assistant
PIN	personal identification number
POTS	plain old telephone service
PSTN	public switched telephone network
QoS	quality of service
R&D	research and development
RF	radio frequency

RFID	radio frequency identification
SAR	specific absorbed radiation
SIP	Session Initiation Protocol
SMS	short messaging service
TDD	time division duplex, a way to organize transmission
TDMA	time division multiple access, a coding standard for the air interface used in 2G systems such as GSM
TS-SCDMA	a Chinese 3G standard
UMA	unlicensed mobile access
UMTS	Universal Mobile Telecommunication System, a 3G standard
UWB	ultra wide band
VoIP	voice over IP
VPN	virtual private network
WAP	Wireless Application Protocol, protocol for GSM and GPRS data traffic
W-CDMA	wideband CDMA, the format for the air interface used in UMTS
WiFi	international association to certify interoperability of WLAN products based on the IEEE 802.11 specification
WiMax	the product name for a new WLAN standard
WISP	wireless ISP, also known as public WLAN or P-WLAN
WLAN	wireless LAN
VPN	virtual private network, closed user group within a larger system
WRC	World Radio Conference, diplomatic body under ITU-R for international settlement of spectrum issues
WWRF	Wireless World Research Forum
WWW	world wide web
ZigBee	a low cost M2M standard

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