Electronic Business With Mobile Personal Digital Assistants (PDAs)

Master Thesis in Computer Science

submitted by

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ABSTRACT

Wireless network enabled mobile devices offer interesting possibilities for electronic commerce business. Most electronic commerce application require a desktop operating system in order to work properly. Today, only notebooks offer the processing power to run a desktop operating system, but they are limited in mobility by their size and power requirements. Personal Digital Agents could promise a solution, but they don't offer the needed flexilibity and processing power, yet, in order to be used for electronic commerce applications on the Internet.

This thesis tries to analyse how PDAs could help streamline the processes of electronic business applications with the help of three scenarios: one in the business-to-consumer market, one in the business-to-business market, and one in e-government.

The goal of this thesis is to answer the following questions regarding mobile devices: What kind of applications will be possible in five years? Which technologies will gain momentum in the next five years? What functionality will PDAs offer in five years?

In order to answer these questions, this thesis takes a look at current technologies and extrapolates them into the future.

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1. INTRODUCTION

Devices are becoming smaller and more mobile as technology improves. The first step of putting a computer-like device into a really portable case has been made with the introduction of the Personal Digital Agent (PDA) around 1995. At about the same time, the Internet and the market penetration of mobile cellular phones started to grow dramatically.

With the Internet came the World Wide Web, and businesses all over the world suddenly were focusing on "electronic commerce": buying real goods by shopping in a virtual world. Telecommunication companies began to offer Internet access through mobile phones for notebooks, thus it was suddenly possible to access the Internet and its possiblities at any place.

Now, people get used to the idea of being able to do anything, anytime, anywhere. Network enabled small mobile devices promise an interesting business area for electronic commerce. But people are still restricted by the current technology, because

- mobile Internet access is slow,
- mobile Internet access is expensive, and
- mobile Internet access is only practical in conjunction with a notebook, but these are too heavy and too large to be carried anywhere, and use too much power to work reliable for a long time.

Hence, mobility is still restricted. PDAs could solve the problem: they are small, lightweight and have a large enough screen for relative simple applications. But current PDA solutions don't offer the flexiblity and capacity to be used as a front-end interface to e-commerce applications on the Internet.

This thesis tries to analyse how PDAs could help streamline the processes of electronic business applications with the help of three scenarios: one in the business-to-consumer market, one in the business-to-business market, and one in e-government. The goal is to answer the following questions regarding mobile devices:

- What kind of applications will be possible in five years?
- Which technologies will gain momentum in the next five years?
- What functionality will PDAs offer in five years?

In order to answer these questions, this thesis is takes a look at current technologies and then extrapolates them into the future.

This thesis is divided into three majors parts. The first part gives an overview of current hardware and software technologies with focus on mobile devices. In the second part, the thesis takes look at mobile wireless communication technologies, and the third part presents three scenarios of how future mobile devices could be used.

2. TECHNOLOGY

This chapter first describes the technologies behind mobile computing and its current limitations. In the first section, a historical view of computing paradigms and a short outlook of what might be the next big shift is given. The following sections describe specific hardware and software technologies, which are used to build current future mobile multimedia devices.

2.1 Trend

2.1.1 Moore's Law

Although Moore's Law[1] is older than 30 years, it still characterizes the general trend in chip performance. The law states that the number of transistors on a chip double every 18–24 months (cf. figure 2.1 for a trend line). He reasoned that, if this trend continued, computing power would increase exponentially over relatively brief periods of time.

But Moore's Law has other implications than just an increase in raw computing power: it also implies an increasing miniaturization and high integration of functions, and thus makes it possible to design and build machines according to human interface requirements instead of physical feasibility restrictions [Mey00].

[1] Stated by Gordon Moore in 1965, see `http://www.intel.com/intel/museum/25anniv/hof/moore.htm`

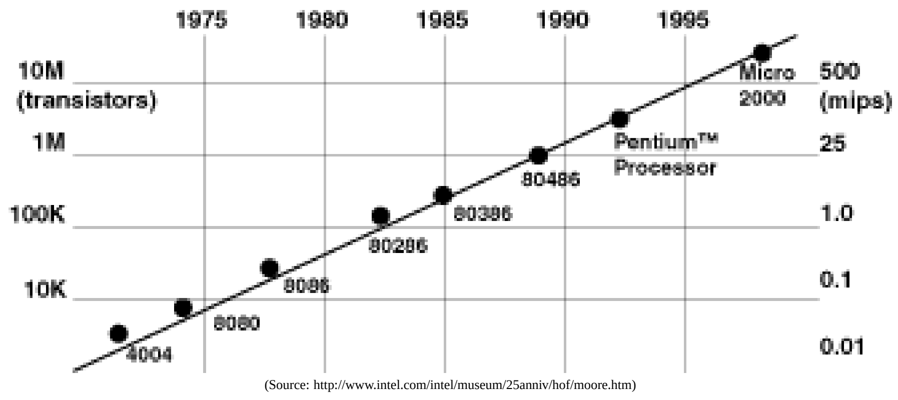


Fig. 2.1: Moore's Law

2.1.2 From Mainframes to Pervasive Computing

The first big shift in computing paradigms occured with the appearance of the personal computer (PC) in 1981. Networking introduced the next big shift in computing paradigms. Each of these shifts changed the profile of a computer user dramatically: the PC made the computing power of a mainframe accessible to the PC user, networking first made it possible for many users to share devices and then brought the Internet. The current computing paradigms can be put into the following taxonomy [Mey00]:

- Mainframe
  - between 1960–80
  - large powerful boxes
  - centralized system
  - users accessed a mainframe via terminals

- Personal Computer (PC)
  - introduced in 1981
  - everyone could buy a computer
  - highly configurable
  - enabled the introduction of graphical user interfaces (GUI)

- Network Computer (NC)
  - introduced around 1995
  - the goal was to combine the advantages of the mainframe and the PC
  - minimal or no local storage
  - needs a sophisticated network structure
  - "The Network is the Computer"[2]
  - was not really adopted by the industry

- Personal Digital Assistant (PDA)
  - breakthrough around 1995
  - PC in a small portable form
  - primarily used to store personal information
  - designed for use on the road
  - introduction of new concepts like pen-based input

- Nomadic Information Appliance Architecture
  - probably be next big shift in computing paradigms
  - combination of networking aspects of the NC and ubiquity of the PDA
  - concentration on wireless communication
  - concentration of collaborative use of nomadic appliances
  - Information and Internet Appliances

According to Meyer, it's clear that the direction of the trend computing paradigms pursue is to make the computing experience more pervasive and independent from locality. This leads from a *one thing at a time in one place* paradigm to a contextual *manything,manytime, manywhere* paradigm. But the vision of a *anytime, anything, anywhere* computer paradigm is misleading because

1. it doesn't make much sense to perform any task at any time at any place, and

[2] Vision of Sun Microsystems

2. it isn't even feasible to perform any task at any time at any place.

Although everything points into the same direction, there are many paths that are followed towards this vision [Mey00]:

- Mobile Computing (Notebooks, PDAs)
- Nomadic Computing (Information Appliances)
- Ubiquitous Computing (Mark Weiser, Xerox PARC)
- Perceptual Intelligence (Alex Pentland, MIT Media Lab)
- Agents (Pattie Maes, MIT Media Lab)

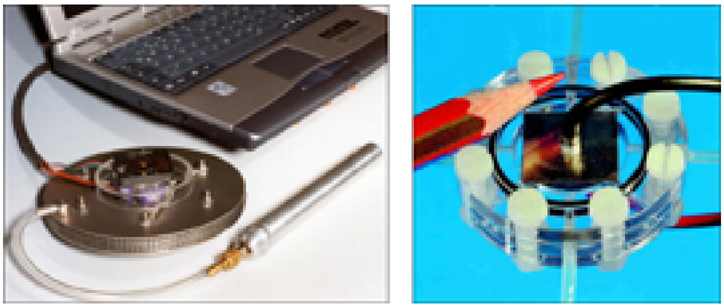
This master thesis concentrates on the next generation of Mobile Computing, mainly PDAs and cellular phones, and to some degree on aspects which count to Nomadic Computing (collaborative use and interaction of devices).

2.2 Hardware

It becomes apparent that mobile computing sets special limitations on the devices:

- Power consumption isn't a problem with stationary devices like PCs, but mobile devices have to run detached from a power plug. Thus battery technologies are an imperative for any kind of mobile devices.
- Wireless networking technologies are the most flexible solution in order to have network access anywhere, or at least 'manywhere'.
- More processing power means more power consumption, but you can't have too much processing power. Hence, there is a tradeoff between processing power and power consumption.
- Current display technologies still use much power and drain a battery too fast. This is why most PDAs still have a 1 bit LCD screen that can only display two colors. Less power hungry color screens have to be developed in order to increase the mobile experience.
- Storage capacity in a mobile device should be as shock resistant as possible. You don't want to lose all your appointments because you accidentally dropped your PDA. Currently, only chips meet this requirement, but memory chips are expensive compared to hard disks.

The following sections describe some of the current hardware technologies. The selection presented here is by far not complete but it should give an overview of what can be achieved with current technologies and where they are heading.



(Source: Fraunhofer ISE)

Fig. 2.2: Fuel cells developed by Fraunhofer ISE. Left: fuel cell powering a notebook. Right: a tiny fuel cell for use in applications such as cellular phones.

2.2.1 Power Consumption

As mentioned above, batteries are vital for mobile systems. Today, most modern mobile applications, especially mobile phones, use a battery pack with cells that are based either on lithium-ion (Li-Ion), or on nickel-metal hydride (NiMH). Li-Ion cells have a better energy/weight-ratio than NiMH-cells and are the preferred type for battery packs at the time being.

Unfortunately, Moore's Law doesn't apply to battery technologies. In this area, new technologies emerge slowly. This leads to interesting inventions like the one patented by Compaq Computer Corp. [Cha99]: they found a solution to recharge the battery pack of a notebook through a special keyboard. The kynetic energie that is set free when the user strikes a key is converted into electrical current and then used to charge the notebook battery. The more a person types, the more electricity is fed to the battery charger. This is a nice invention, but it doesn't really solve the problem.

Fuel Cells Another interesting approach are fuel cells [TZ00]. Fuel cells have been around since 1839, but they're full potential has never been exploited because of high investment costs – fuel cells were not economically competitive with existing energy technologies. NASA was the first agency which could afford the cost to invest into the technology and used fuel cells for their space flight program.

Nevertheless, the german Fraunhofer Institute developed and demonstrated a fuel cell with which they could power a notebook. They also developed a smaller one for an eventual application in mobile phones (cf. figure 2.2). But due to the nature of a fuel cell, there are some obstacles to overcome:

- A fuel cell produces electricity, water and heat by converting fuel and oxygen in the air. This requires complex devices such as an air pump and a heat exchanger which makes them difficult for usage in small portable devices.
- You can't recharge a fuel cell by putting it into a recharger and plugging the recharger into the next power outlet. You really have to refill them, which makes them not very useful for applications such as in a notebook. While traveling with your notebook, you'd not only have to carry around your notebook, but also enough liquid fuel in order to refill its battery.

Fig. 2.3: Miniature fuel cells developed by scientists at Motorola Labs and Los Alamos National Laboratory.

Scientists at Motorola Labs and Los Alamos National Laboratory eliminated the need for the air pump and the heat exchanger mentioned above and developed a miniature fuel cell [Mot00a]. Of course, this one too, is not as easy rechargeable as a traditional battery. But these fuel cells look like they have the potential to eventually replace conventional batteries in small portable devices, such as cameras or small electronic games (cf. figure 2.3).

Proton Polymer Batteries The most promising battery technology at the moment is the proton polymer battery developed by NEC (cf. figure 2.4). The battery is based on a polymer consisting of carbon, hydrogen and nitrogen. The use of this polymere gives the battery the following advantage over traditional batteries [NEC00]:

- The energy density of the battery is as high as the one of lead batteries.
- The battery offers a large current discharge, 20 times higher than possible with lead batteries.
- The battery can be recharged very quickly (recharging to the regulation limit in approximately 5 minutes).
- The battery is much more environmental friendly than conventional batteris, as the materials used exclude metals and halogens.
- Damage to the electrode active material in the polymer structure is minimal, even over a life cycle of several tens of thousand times. Basically, as replacement is not necessary, the battery can be mounted in on-board systems.

Conclusions Battery technologies still have a long way to go. For the future, there is no such thing as free lunch, and additional storage of energy always comes with additional weight and size. In order to extend battery life and increase the independence of mobile applications, it might be easier to reduce the power cosumption of the devices instead of increasing its energy capacity.

(Source: NEC)

Fig. 2.4: Proton polymer batteries developed by NEC.

2.2.2 Processing Power

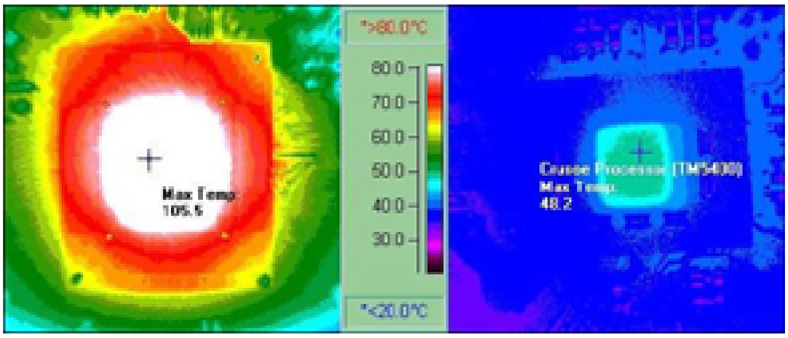
As mentioned above, one basically can't have too much processing power. But more processing power also means that the processor uses more energy [Mey94]. In the end, this means less mobility because a powerful processor drains a battery quicker than a less powerful one. Mobile devices add specific restrictions on processors:

- low power consumption
- reduction of the number of components because of limited board space
- low cost

In the mobile context, a distinction has to be made between absolute and relative power [Mey00]: high performance in mobile devices means high computing power per energy unit spent (MIPS/Watt). Given this definition, a current state-of-the-art Intel Pentium IV 1.5 GHz processor suddenly isn't the best choice for mobile applications, even if we mark out other requirements for an optimal processor for mobile devices.

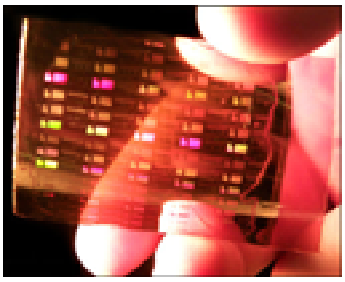
Lower power consumption usually is achieved by reducing or even stopping the processor clock. Stopping the processor clock and putting it into "sleep mode" can be done with the more popular processors used in handheld devices, like the Motorola "DragonBall" MC683xx, the Intel®StrongARM-110 and the ARM 720T [Mot00b] [Int00] [ARM00].

Another approach has been taken by Transmeta Corporation, which developed the Crusoe™processor. The power savings achieved with this processor not only come from its ability to reduce clock speed and voltage, but also from replacing large numbers of transistors with software [Kle00a]. The Crusoe processor adds a software layer to its inner core, a very low instruction word (VLIW) CPU. The surrounding software layer then emulates a x86 instruction set, eliminating the need to implement all the instructions in hardware. The software layer is called Code Morphing™software because it dynamically "morphs" x86 instructions into VLIW instructions. Another side effect of reducing the number of transistors is that the processor doesn't generate as



(Source: Transmeta Crop.)

Fig. 2.5: The thermal images of a Crusoe processor and a conventional "mobile" processor, running a software Digital Versatile Disk (DVD) player.



(Source: MIT Media Lab)

Fig. 2.6: A circuit pattern printed to micron resolution.

much heat as a comparable one, which reduces loss of energy even more (c.f. figure 2.5).

Completely new design aspects bring research in the fields of plastic electronics. The Molecular Machines Research Group at the MIT Media Lab[3] is developing materials and methods for the printing of high-quality inorganic semiconductor devices (c.f. figure 2.6 for a printed circuit pattern). Researchers at Cambridge's Cavendish Laboratory achieved significant progress in developing plastic materials with electronic properties [Uni99] [Mar00b]. A company called Plastic Logic now tries to produce microchips based on this technology and hopes to demonstrate commercial prototypes in summer 2001 [Kni00].

Conclusions Processor technologies have reached a state where we can start to design computers and devices around human needs. Hardware design restrictions because of the size and performance of processors are going to disappear already in the nearer future. As figure 2.7 shows, it's possible today to produce flexible semiconductors. This makes it possible to produce chips of completely new designs and shapes. Current processors already allow for speeds which are enough for certain multimedia capabilities in handheld devices, so this will only get better in the future. This leaves power consumption the only point left where real work has to be done, and where the

[3] `http://www.media.mit.edu/nanomedia/`

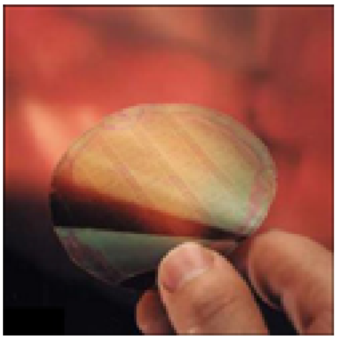

(Source: Philips Research Laboratories in Eindhoven, Netherlands)

Fig. 2.7: Prototype of a complex integrated logic circuits on flexible plastic substrates based on all-polymer transistors.

future path is most uncertain.

2.2.3 Memory

In the mobile field, memory chips underly the same rules as processors do: low power consumption, limited board space and low cost. Low power consumption isn't that much of a problem for memory chips as space and cost. Comparable to the processing power of processors, one never has too much memory. But in contrast to processor speed, today's memory is a limiting factor, especially if the mobile world wants to go multimedia. Current mobile processors may be fast enough to play back a video, but this isn't of much use if the mobile application has no memory space to store the video.

Random Access Memory Basically, there are two types of Random Access Memory (RAM):

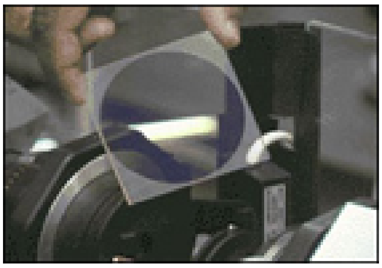
- SRAM: Static RAM. Static, because the RAM remembers its state as long as it has power.
- DRAM: Dynamic RAM. Dynamic, because the RAM tends to lose the state of its data cells, and therefore requires a periodic refresh cycle in order to keep its data [Ken98].

SRAM is preferred over DRAM in small mobile devices. One reason is because SRAM is simpler to address than DRAM. But the main reason is that SRAM uses less power than DRAM in standby mode, because there is no need to refresh the state of the RAM all the time. The downside of SRAM is that it's more expensive and uses more space than DRAM.

Flash Memory Even though Flash memory it is a pure electronic memory chip, it is used as a solid state storage device and not really a RAM, . The reasons are the following:

1. Flash memory is too slow to be used as a RAM.
2. Flash memory can't be rewritten unlimited times.

Fig. 2.8: From left to right: CompactFlash, SmartMedia™, Sony Memory Stick



(Source: National Research Council of Canada, Complutense University of Madrid)

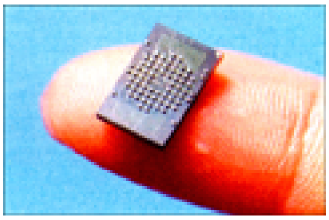
Fig. 2.9: Example of a holodisk storage prototype.

It's used in many electronic devices, such as digital cameras, as a storage facility to save larger amounts of data on. The reason why hard disks aren't used in these kind of devices — even though hard disks have a much higher memory density and a cheaper price/size ratio — is that flash memory is basically an EEPROM chip. Hence, it uses less power than hard disks and is more robust than hard disks. The speed makes it basically a hard disk without the moving parts. Flash memory comes in many different forms: BIOS chips, CompactFlash, SmartMedia™, Memory Stick, PC Cards or memory cards for video game consoles (c.f. figure 2.8 for some examples).

Polymer Memory, Molecular Memory New aspects into the field bring polymer memory technologies. A polymer memory is very cheap – it's just some kind of plastic – and because they store data in a three dimensional array, they can hold very high amounts of data per size (c.f. figure 2.9). The problem so far has been that the materials did shrink if they where used as a holographic storage, but this problem seems to have beeben solved by a team from the National Research Council of Canada in Ottawa and from the Complutense University of Madrid, Spain [Bal01].

Dramatic increases in memory density and decreases in cost could bring molecular-sized memory [RT00]. The components and interconnections of this type of memory would be "grown" with chemical self-assembly instead of being built with lithography. Although single memory switching devices have been demonstrated, an enormous effort still has to be done in order to be able to arrange and secure these switches in any manner and into whatever patterns the circuit diagrams dictates.

Conclusions Modern cellular phones use a combination of low-power-SRAM and Flash [Win01]. The firmware, software applications and user settings are stored in the



(Source: [Win01])

Fig. 2.10: A multichip semiconductor with 64 MBit Flash and 8 MBit SRAM.

Flash memory, while the SRAM is used as main memory. Flash memory is too slow to be used as main memory, but as SRAM loses its state after power goes down and Flash does not, there is a need for both kind of memories in these devices. This is why companies like Samsung offer combinations of Flash and SRAM memory chips on one chip, called Multichip Package (MCP) (c.f. figure 2.10).

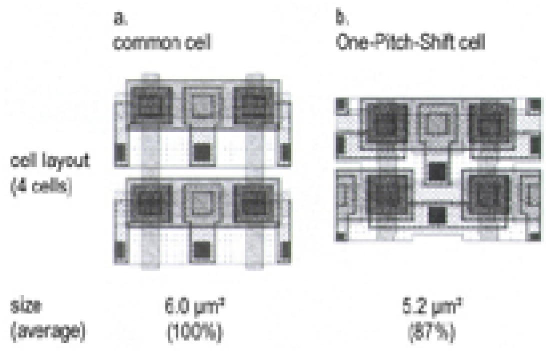
The space problem is addressed with new ideas like the one behind UtRAM (Unitransistor RAM). Each data cell of UtRAM consists of one transistor and one capacitor, just like DRAM does, but UtRAM acts as if it was a SRAM. Based on a similar concept is 1T-SRAM. 1T-SRAM is a DRAM with a SRAM that basically acts as cache between the DRAM and the chips interface, thus also the whole chip is acting as if it was a real SRAM.

Toshiba developed a few technologies which allow to pack transistors in different ways. The one-pitch-shift cell already reduces the cell size by 13% (c.f. figure 2.11), but their "Paper Thin Package" (PTP) allows chips to be built at the 3-dimensional scale of about one tenth the height of a conventional device [Har99c] [Har99b]. This makes it possible to stack up to eight layers of memory devices.

Polymer and molecular-sized memory devices still have a long way to go in order to become production ready. Eventually they may be ready when silicon based chips are predicted to be too expensive to produce. The problem might not even be the miniaturization of silicon based devices, but the financial outlays to build the fabrication facility. Many experts project that this will happen around or before 2015, when a fabrication facility is projected to cost nearly $200 billion [HH97].

2.2.4 Human Computer Interfaces

We have to somehow interact with computers. Currently, the most common interface for human computer interaction is a display and a keyboard. With smaller devices, e.g. Personal Digital Assistants (PDAs) like the Palm Pilot, the use of a touch sensitive display is more common. A touch sensitive display is a flat panel display, e.g. an LCD in combination with a digitizer. User input is given to the computer with a pen instead of a keyboard [Mey94]. Modern cellular phones, which are even smaller than PDAs, use a combination of a keyboard (usually just a numeric one), a display and perhaps voice recognition.



(Source: [PH01])

Fig. 2.11: Toshiba reduces the size of a chip by nesting the transistors and capacitors.

Display The quality of todays flat panel displays is still not excellent [Mey00]. The main reasons are the following:

1. Apart from the battery, the LCD panel is the second heaviest part in a mobile device.
2. LCD panels consume too much power for themselves and because of the back-lightning they need.
3. The resolution of an average LCD panel isn't satisfying for small displays yet.

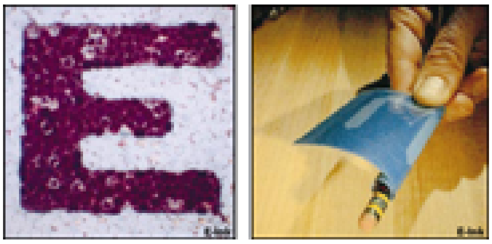
Some manufactures tackle the second problem by not back-lightning the LCD. They light the display with a series of LEDs at the border of the display, which saves power at the cost of a darker display and worse contrast. High resolution LCD panels do exist. Fujitsu announced a 3.2 inch LCD screen with a resolution 1280x1024 pixels already in 1996 [Fuj96]. But these screens are expensive and it's very hard to manufacture them in larger sizes, which is why they are mainly used for projectors. IBM developed a 16.3 inch active matrix liquid crystal display (AMLCD) which has a resolution 200ppi (pixels per inch) [IBM00], only the cost of this display is out-of-range for a mass handheld device.

All these flaws could vanish with newer technologies such as electronic ink displays [Kle00b]. Even though E-Ink[4] already achieves resolutions higher than 200dpi with electronic paper, the technology can't be used for mobile applications yet [Leg98]. Electronic ink is too slow and can't be updated quickly enough in order to show, e.g., a video. Eventually, e-paper becomes the big next step in display technologies. Currently, they're only used as large dynamic information panels in shopping malls which can be updated from a central point[5].

More promising are organic light emitting diode (OLED) devices [HP01] [Har99a]. As they emit light by themself, back-lightning can be omitted and the device doesn't consume as much power as LCDs do. It's possible to achieve resolutions as high as 720dpi with these kind of display devices (c.f. figure 2.13), thus making them a perfect candidate for small portable or even wearable devices.

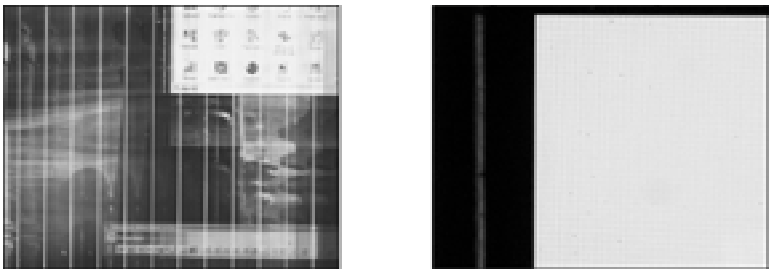
[4] E-Ink is the company founded by the inventors of a new electronic ink technology, J.D. Albert and Barret Comiskey. `http://www.eink.com/`

[5] See `http://www.where-its-at.com/spotlight.html`



(Source: E-Ink)

Fig. 2.12: Left: electronic ink paper with a resolution of 100dpi. Right: electronic ink can be coated onto virtually any surface, incl. paper or plastic.



(Source: [HP01])

Fig. 2.13: Photographs of an SXGA OLED-on-silicon microdisplay. Its dimension: 15.36 mm x 12.28 mm; Left: Video image; Right: all pixels on.

Speech, Voice Recognition Spoken feedback while interacting with the computer isn't just something for the visually impaired. A lot of work effort is made to create standards for the Web in order to be able to access Web sites via spoken commands, and listening to prerecorded speech, music and synthetic speech. This will allow people to access the Web while keeping their hands and eyes free for other things. It will also allow effective interaction with display-based Web content in cases where a mouse and a keyboard may be missing or inconvenient[6]

Although synthetic speech and voice recognition is more a software problem, it is a new way to interact with computer devices. Thus it feels more like a change in hardware for most people. Many cellular phones already implement a mechanism with which you can "attach" a spoken name to phone number. The idea is simple: you first have record the word you want to match with the number. When you speak a word into the phone it tries to match your voice with the recorded words in your phone book, eventually finds a match and then automatically dials the number. This may sound simple, but it requires a fair amount of processing power to try to match the spoken words with the recorded ones in real-time.

Conclusions It looks like we have to stick to LCD panels for another couple of years before the technology behind electronic ink, electronic paper and OLED is ready for main-stream mobile devices. The next small step will surely be that more and more mobile devices like PDAs and cellular phones will come with a color screen instead of a

[6] The standard for voice browsers and voice based Web sites is VoiceXML. See also http://www.voicexml.org/[7]nd http://www.w3.org/TR/voicexml/[8]

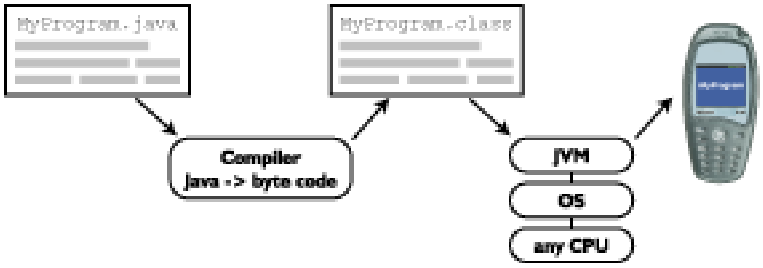


Fig. 2.14: Functionality of a Java Virtual Machine

monochrome one. Devices with which one primarily interacts with voice won't become pervasive in the near future. They might establish themselves in mobile areas like cars where people should concentrate on watching the street instead of watching a Web site build up, but before people will accept this kind of human computer interaction there has to happen another big paradigm shift.

2.3 Software

Software technologies are as important as hardware technologies. In a mobile environment where many different types of devices have to somehow interact with each other, protocol standards are important. A lot of effort has been put into developing technologies that fit the requirements of mobile computing.

2.3.1 Java

Java™is a programming language that doesn't compile directly into machine code but into byte code. The byte code is completely platform independent and thus the concept "write once, run anywhere" comes closer to reality with Java. Java lends the idea of using byte code as a preliminary step before having a running executable application from SmallTalk. A Java application executes on a Java Virtual Machine (JVM) that translates the byte code into natively executable machine code (c.f. figure 2.14). Of course, a JVM has to exist for the target platform in order to execute a Java application. Thus, Java forms a platform on its own.

The Java Platform Sun delivers three different packed editions of its Java technology: Micro[9] (J2ME™), Standard[10] (J2SE™), and Enterprise[11] (J2EE™). Each edition includes the Java platform and consists of three parts:

- The Java programming language: an object oriented programming language that is architecture neutral, simple to understand, but very nevertheless powerful.
- The Java Virtual Machine: it provides the execution platform for the byte code.
- An extensive framework and class library that provides a lot of common program functionality.

[9] http://java.sun.com/j2me/
[10] http://java.sun.com/j2se/
[11] http://java.sun.com/j2ee/

The Java^{TM}2 Platform, Micro Edition (J2ME^{TM}) specifically addresses the vast consumer space, which covers the range of extremely tiny commodities such as smart cards or a pager all the way up to the set-top box. In addition to the three common parts of a Java platform, the J2ME also comes with a specification of the minimum set of APIs useful for a particular kind of consumer device (set-top, screenphone, wireless, car, and digital assistant), and a specification of the Java virtual machine functions required to support those APIs.

Jini A Jini system is a distributed system based on the idea of federating groups of users and the resources required by those users. The overall goal is to turn the network into a flexible, easily administered tool with which resources can be found by human and computational clients [Sun00]. Jini technology consists of an infrastructure and a programming model that address the fundamental issue of how clients connect with each other to form spontaneous communities (c.f. figure 2.15).

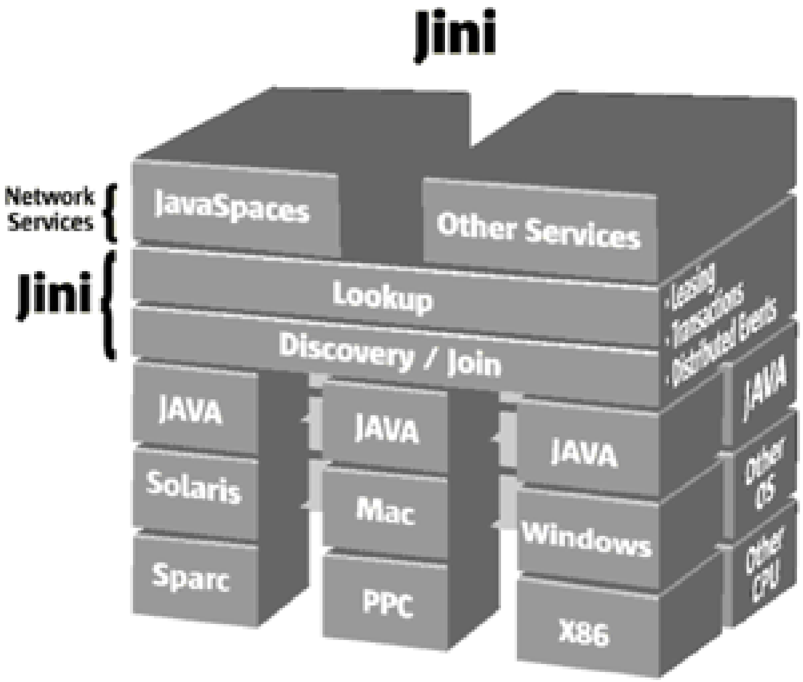
The idea is simple: when a new device connects to the network, it will announce its presence in the network and register with a proxy to itself at a registry service. The proxy provides an interface to the connected device. Devices can lookup any other device via a lookup service, which is provided in the registry, and can make use of the services provided by this device. The interesting thing about Jini is that the devices implementing the service don't have to know anything about the underlying architecture [Sun01]. This means that it provides an easy, simple, and fast way to interact with services simply by locating them on a network, with no further action required by the user. The visionary scenario is that one can connect any device to the network, e.g. a printer, and some seconds later the PC detects the printer. The user wouldn't have to install a printer driver because it's already been sent through the network to the PC [ZG99].

Conclusions There is a vast diversity of operation systems and CPUs for mobile devices, which enable the need for a platform independent way to bring applications to as many devices as possible. The success of the Java language is mainly attributed to its platform independence. All this makes the Java platform an ideal candidate for programming applications for the mobile world.

2.3.2 Operating Systems

No computer can exist without some kind of operating system. This is also true for handheld devices. The breakthrough for PDAs came in 1995 with the Palm Pilot (see also section 2.1.2. The Palm Pilot runs on a very specialized operating system, the Palm OS. More operating systems did enter this market in the following years of which the important ones are described here.

Palm OS As mentioned above, with Palm did bring the breakthrough for PDAs with their Pilot and the Palm OS in 1995. The Palm Pilot and its Palm OS did focus on the main applications of what a PDA should do: scheduler, personal phone book and a notepad. No whistles, no bells. Since then, they added color and wireless communication and began to license the OS to other handheld manufacturers, enlarging the market penetration of their OS. The current version is the Palm OS 4.0, but for the user, there didn't change very much from the early days in how it looks and feels (c.f.



(Source: Sun)

Fig. 2.15: Jini System Architecture

figure 2.16). In 1999, 75% of all PDAs in use where powered by the Palm OS[12], a tremendous success.

Symbian Platform, EPOC The EPOC operating system from Symbian has primarily been used in the Psion platform, a handheld computer with a small keyboard (c.f. figure 2.17). In its new version Symbian renamed the OS to "The Symbian Platform Version 6.0"[13]. The Psion wasn't as successful as the Palm Pilot, but Symbian recently licensed the Symbian Platform to over 70% of the world's handset manufacturers. Nokia will be the first to deliver a product based on Version 6.0 of the platform,

[12] Source: IDC, Dec 1999
[13] See Symbian's homepage at http://www.symbian.com/technology/v6-papers/v6-papers.html

(Source: Palm, Inc.)

Fig. 2.16: Left: Palm IIIxe; Right: Palm m505

(Source: Symbian)

Fig. 2.17: Left: Psion Series 5mx, running EPOC Release 5; Right: Nokia Communicator 9210 running the Symbian Platform Version 6.0

(Source: Sendo)

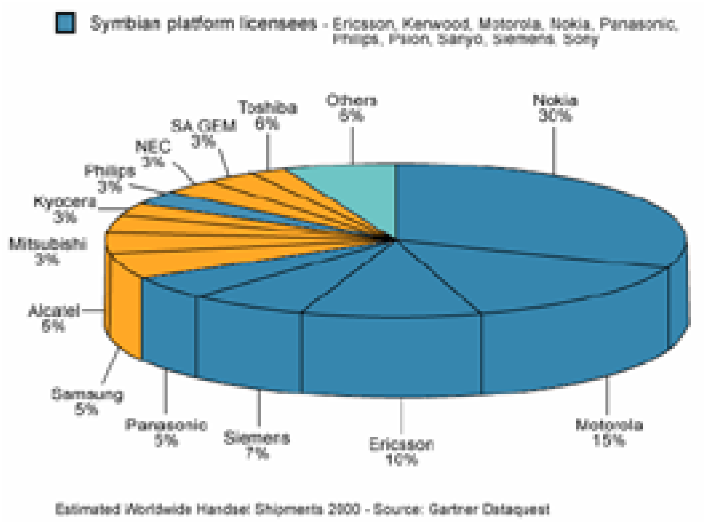
Fig. 2.18: Sendo Z100 Multimedia Smartphone based on Microsoft Windows® CE.

the Nokia Communicator 9210 (c.f. figure 2.17), with more manufacturers to follow.

Windows CE Microsoft tries to get a foot into the embedded and mobile world with Windows® CE, a modular version of their Windows operating system but with a much smaller footprint than the desktop version. According to Gartner research, Windows® CE is expected to be found in 17 percent of all PDAs sold in 2004. A new smart phone platform, code-name “Stinger” is built on a version of the Microsoft Windows® CE operating system and should bring PDA functionality to mobile phones [Mic01], just as the Symbian Platform does. Together with Sendo, a UK based mobile phone manufacturer, they developed and demonstrated a working “smart phone” based on Stinger in the first quarter of 2001 [Bet01] (c.f. figure 2.18).

Linux Linux is a free[14] Unix-like operating system originally created by Linus Torvalds with the assistance of developers around the world. During the last few years, Linux did prove itself to be a grown up server OS. Nevertheless, Linus expects the operating system to make some steps into the small embedded world in the near future [Roo01]. He may be right: handheld manufacturer Sharp already announced that they are going to produce a PDA based on Linux [Blo01]. The advantage of Linux is that

[14] Free as in “free speech”, and not as in “free beer”



(Source: Symbian)

Fig. 2.19: Market share of the licensees of the Symbian Platform.

it's free and that its source code is open. This makes it easy for manufacturers not to get locked into a proprietary platform and gives them freedom and flexibility over the system.

Conclusions There are many more proprietary systems available than the four presented here, especially in smaller mobile devices like cellular phones. But these four all have demostrated that it's possible to build the next big shift in computing paradigms with them. A JVM exists for all of these OSs, which makes it possible to port applications from one OS to the other in a relatively easy way.

Although the Palm OS is only used in handheld organizers, it still is the most popular operating system for mobile devices at the moment. For the near future, the trend seems to be "Palm OS for PDAs" and "Symbian Platform for smart phones", as Symbian managed to license its OS to the four largest phone manufacturers (c.f. figure 2.19). Microsoft won't have a big impact in the near future of PDAs and smart phones, even though they did show a working smart phone. But they make it difficult to forecast how the OS market may look like in the more distant future. The same counts for Linux. Linux still has a heavy momentum in the market and although it's not ready for the mobile market yet, manufacturers like Sharp hope to leverage that momentum easily into the handheld market.

2.3.3 Protocols

Protocols are a mean to exchange information between devices. Today, data is most commonly exchanged over the Internet, or a network based on the same technologies. The basis of the Internet is formed by the Internet Protocol (IPv4).

IPv6 Because is has some major limitations, the end of the currently used version of the Internet Protocol has been announced for quite a while now: Address space is getting rare, security at the level of IP is not available, the protocol is missing quality of service and thus there are no guaranteed delivery times, and routing tables are getting large which results in the routing of IP packets is getting slow. IPv6 or IPng (IP next generation) has been specified in 1995, but the roll out takes longer than expected. The "killer application" is missing. The killer application may come with the introduction of the third generation of mobile wireless networking devices [Mar00a]. These applications increase the need for IP addresses and quality of service, which IPv4 can't deliver. For cellular networks and users, IPv6 offers the following features over IPv4 [UMT00a]:

- Operators:
  - Auto configuration
  - Embedded encryption support and authentication
  - Embedded mobility
  - Embedded multicasting
  - Internet provider selection
  - Efficient packet processing in router
  - Real-time support
  - Protocol extensions for proprietary solutions
- End Users:
  - Easy management (auto configuration)
  - Efficient address location
  - Improved multicast management
  - Renumbering possible
  - Efficient network route aggregation
  - Efficient packet processing in routers
  - Real-time support

Mobile IP Mobile IPv6 (MIPv6) is a specific protocol derived from IPv6 for mobile communication. It has been specified by the IETF and essentially provides additional mechanisms for re-routing packets from one part of the IP network to another, which allows a mobile terminal to keep its fixed-assigned IP address while roaming between different networks [FH00]. In other words, Mobile IPv6 allows an IPv6 host to leave its home subnet while transparently maintaining all of its present connections and remaining reachable to the rest of the Internet.

HTTP In the middle between the IP and the Hypertext Transfer Protocol (HTTP) sits the transport control protocol (TCP). TCP establishes a stream for transferring data. HTTP sits on top of TCP, wraps data into packets and determines how they are sent. The simplicity of HTTP is its strength: the protocol is being used for many tasks beyond its intended use for hypertexts. For example, HTTP can be used as a generic protocol for communication between user agents and proxies/gateways to other Internet systems.

HTTP/0.9 was a simple protocol for raw data transfer accross the Internet. The next version, HTTP/1.0, added MIME-like messaging features to the protocol. The adoption of the MIME[15] type registry gives HTTP the ability to include metainformation about the data transferred. Nevertheless, some design problem still existed. The simplicity of HTTP/1.0 has its downside: it was required to open a new TCP connection for every single data packet requested. This resulted in the relatively short mean size of a few thousand bytes per GET[16] request. The user perceived this behaviour as poor performance. The work around was to open more than one TCP connection simultaneously, which resulted in a faster time to render the content, but at the cost of making HTTP/1.0's use of TCP "bad behaviour". Caching could have solved the problem, but content providers often defeated caching because the caching model in HTTP/1.0 is too primitive.

The goals for HTTP/1.1 have been clear: make HTTP a "well behaved" Internet protocol by adding persistent connections while resting backward compatible, and add means to control caching of data that application developers and users can rely on. This means that HTTP/1.1 should improve user perceived performance, reduce load of HTTP server, and decrease load of HTTP on the Internet.

HTTP/1.1 also addresses the problem of content negotiation, but doesn't solve it. Content negotiation is important for applications where users access the same information through different types of devices. Naturally, it is desirable to supply the user with the best available entity corresponding to the request, as the application server doesn't know what kind of preference the user has for "best entity". But HTTP/1.1 just added a hook[17] for mechanisms implementing content negotiation. The HTTP working group simply deferred transparent content negotiation because the caching design takes it into account.

In the end, by not explicitly addressing the problem of the diversity of user agents, especially mobile clients with a small screen, HTTP/1.1 certainly improved over HTTP/1.0 but deferred the problem of resource management [Mey00].

Wireless Application Protocol (WAP) The Wireless Application Protocol is the de facto standard for delivery of information to mobile phones and other wireless terminals with limited bandwidth and displays. The standard has been widely adopted by content providers in Europe. For once, the USA are behind in adopting a technology. In Japan, wireless services are very advanced and pervasive, but the proprietary I-Mode protocol is the more pervasive standard. I-Mode is described in the next section.

WAP is based on existing Internet standards, such as HTTP and TCP/IP. But unlike HTTP, WAP specifies an architecture and a protocol stack (c.f. figure 2.20). The WAP programming model is similar to the programming model of the World Wide Web (c.f. figures 2.21 and 2.22). The key components of the WAP architecture are the following

[15] Multipurpose Internet Mail Extensions
[16] "GET" is the HTTP command to fetch a data packet.
[17] The new HTTP Header "Alternates"

[Wir98]:

- Wireless Application Environment (WAE): The WAE specifies an application framework for wireless devices. The main objectives of the WAE effort are [**?**]:

  1. To define an application architecture model.
  2. To define a general-purpose application programming model.
  3. To provide Network Operators means to enhance and extend network services.
  4. To enable multi-vendor interoperability.

  The WAE includes a micro-browser environment containing the following functionality:

  – Wireless Markup Language (WML): an XML-based markup language, similar to HTML, but optimised for use in hand-held mobile terminals.
  – WMLScript: a lightweight scripting language, similar to JavaScript^{TM}.
  – Wireless Telephony Application (WTA, WTAI): a framework and an interface for telephony services. The WTA user-agent is an extension to the standard WML user-agent with additional capabilities for interfacing with mobile network services available to a mobile telephony device, e.g. setting up and receiving phone calls [Wir00].
  – Content Formats: a set of well-defined data formats, including images and bytecode formats for WML and WMLScript.

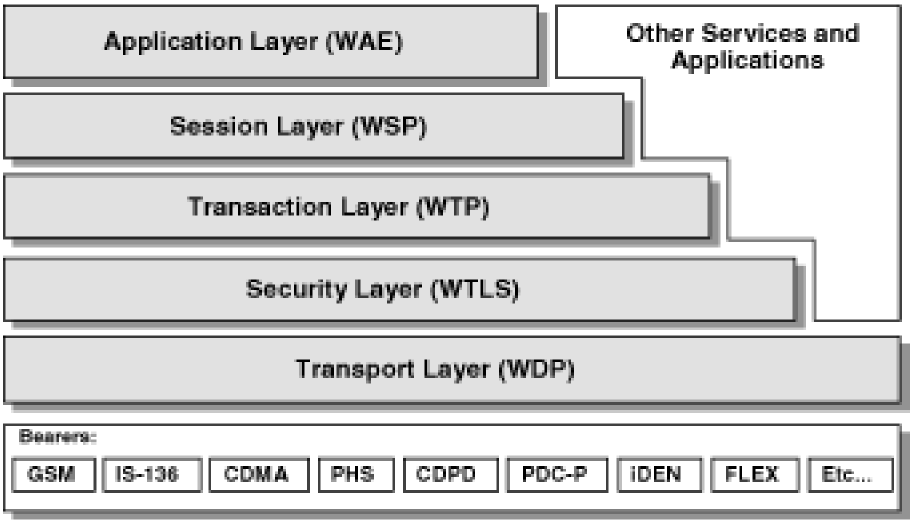
- Wireless Session Protocol (WSP): The Wireless Session Protocol (WSP) provides the application layer with session services. WSP is designed to function on the transaction (WTP) and datagram services (WDP).

- Transaction Layers: Wireless Transaction Protocol (WTP), Wireless Transport Layer Security (WTLS) and Wireless Datagram Protocol (WDP). These three protocols plus the WSP define the WAP protocol stack and specify interfaces for a secure way of communication, either connection-oriented or connection-less.

The delivery of WAP services is independent of bearer and device.

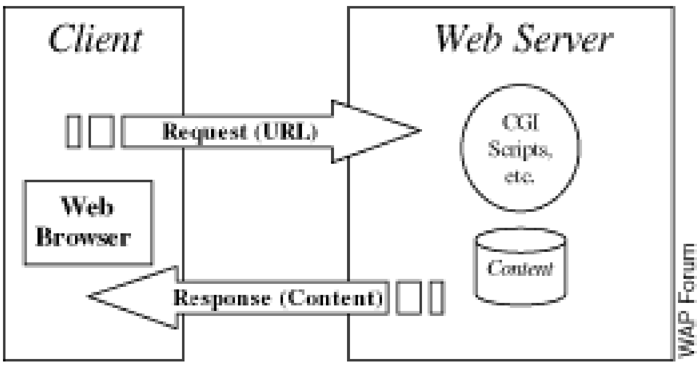
I-Mode I-Mode is a proprietary wireless service from NTT DoCoMo, a japanese telecommunication firm. NTT DoCoMo introduced the service in 1999 in Japan and now is the largest wireless service provider with 18.5 millions user. I-Mode is proprietary in the sense that NTT DoCoMo controls all aspects of the service: the I-Mode protocol, the markup language cHTML, and content. Even the design of the cellular phones is controlled by NTT DoCoMo.

On a first glance it looks as if it's easier to convert a HTML page into a cHTML page than into a WML page. cHTML is a stripped-down version of HTML [Kam98]. But in the end, the publication of a WML page is easier than a cHTML page, because (a) the main work isn't to transform a service from one language into another, but the adaptation for the device, (b) NTT DoCoMo collects a fee for publishing information via I-Mode, (c) WAP based services are independet from its bearer, whereas I-Mode is locked into its SMS-like bearer [Bor01], and (d) cHTML doesn't specify the possible use of client-side scripting languages.



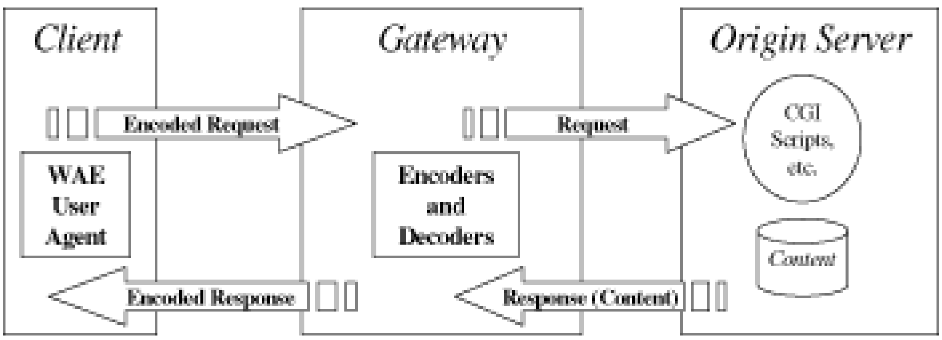
(Source: WAP Forum)

Fig. 2.20: WAP Architecture



(Source: WAP Forum)

Fig. 2.21: World-Wide Web Programming Model



(Source: WAP Forum)

Fig. 2.22: WAP Programming Model

Conclusions With the convergence of IP-based networks and cellular networks, IPv6 and MIPv6 will play a major role. Especially MIPv6 is well suited for cellular networks for a number reasons, one of them is the tremendous increase in address space. The increased addressing space does not require the mobile terminal to use dynamic address allocation, as there will be enough addresses available for every mobile device in the world to use at least two IP addresses.

In the short run, the fastest and easiest transformation from current eCommerce services to M-Commerce services is a proxy server between the HTML server and e.g. a WAP client. The proxy scans the HTML pages on-the-fly, transforms the HTML page into WML and sends the WML page to the client. But this is no long-term solution. Both, WML and the new version of HTML (XHTML) are markup languages based on XML. So the best solution would be an XML-based information server which transparently serves the right document type to the client.

Compared to HTTP, WAP has a well integrated security concept. Security is basically left to the next layer in HTTP. The WAP architecture seems to be stable enough for the future and might finally help boost IPv6. I-Mode in contrast looks like a toy next to WAP: there is a limit of 500 bytes per packet and speed doesn't exeed 9600 Bit/s. But the I-Mode model proofs that there is a need for mobile services.

2.4 Digital Signatures and Certificates

Digital signatures and certificates are a controversial matter in the Internet space. On the one side, digital certificates are needed in order to build trust between the involved parties of a transaction, on the other side the eCommerce business modiel is working very good even without the ability for the parties to verify their relationship.

This section first describes what a certification authority is, followed by a discussion why the ability to digitally sign a document or a transaction, and verify the validity of the signature is mandantory for the basis for secure data exchange.

2.4.1 Certification Authority

All Certification Authorities (CA) currently sign keys based on a asymmetric cryptographic scheme called public key encryption. The CA is an institution which issues the certificates used to encrypt data.

Public and Private Key The cryptographic basis for a secure transaction is the public and the private key. With the private key, the owner of the key can encrypt a document together with the public key of the recipient of the document, decrypt a document together with the public key of the sender, or sign a document. The public key of another person is used to verify that the document is encrypted by the person who has the corresponding private key. If the public key is certified by a CA, the recipient can be sure that the sender of a message is the person he claims to be.

Digital Fingerprint A digital fingerprint is created by calculating a short and unique hash value of a document. The hash value makes it easy to verify if a document has been intercepted and changed by comparing the hash value of the document from before it has been sent and after it has been received.

Digital Certificate A digital certificate verifies the connection between the public key and the owner of a certificate. The certificate is only as trustworth as the CA which signed it.

Digital Signature The digital fingerprint of a document is encrypted with the private key of the sender. The resulting digital signature can be decrypted with the public key of the sender and thus guarantees authenticity, integrity and the source of the signed document.

Public Key Infrastructur A Public Key Infrastructur (PKI) manages services like creating and managing keys and certificates. It usually also provides different directory services in order to retrieve and verify public keys.

Registration Authority A Registration Authority (RA) is an organization that offers an interface between the user and the CA. An RA verifies the identity of a user and can invalidate certificates.

The PKI forms the basis for secure transactions over the Internet. It should guarantee the following points [Gru01]:

- Data integrity: it must be ensured that modified messages are marked as such by the computer of the receipient.
- Confidentiality: cyptography ensures that the content of a transaction remains confidential and that a “man in the middle” attack is unsuccessful.
- Authenticity: a person has to be authorized in order to send certain legal documents. Digital signatures and certificates should ensure that only the person who is authorized to send this message can sign it.
- Identification, non-reputation: the sender should not be able to deny the content of a message. A digital signature proofs that the message has been signed with the private key of the sender and that its content hasn’t been altered with since then.

2.4.2 Problems

There are some problems with the implementation of a PKI. The current market situation shows that there is no real need for customers to have a digital equivalent of a passport in order to be able to shop on the Internet. Although Web-retailers have an active interest in authentication and identification of the customer, the retailer has other means to ensure that he receives the money. For the customer, the legal situation is very uncertain in case his digital ID is misused by someone not authorized [Kre01]. Governments are behind adapting the legal system to the virtual space. This is one of the reasons that there isn’t a good and pervasive PKI yet.

For a CA to be trusted, it has to able to verify the link from a public key to the owner of its private key. The more rigid the verification process, the more trustworth is the CA. But this implicates that the hurdle to get a certificate is pretty high. Another major problem is that at the present-day a digital ID costs a multiple of a real ID just to be issued, not to mention that the customer has to pay a yearly fee to keep his digital ID. In the B2C market, the cost of a digital ID stays in no relationship to its benefits.

2.4.3 Conclusions

The governments in many countries are in the process of giving digital signatures and certificates a legal status. This makes it possible for governments to authorize or even run a PKI themselves. Personal data are identified and registered by the government. The data is then transferred to the CA, where the private and the public keys are generated and the private key is given to the client. The key point for a CA is to set up a reputation of trust. The backing of the CA by its government is certainly a good thing.

Although the technology is available, digital signatures are not yet pervasive. The people behind this technology hope that this will change eventually with the increased use of mobile Internet terminals like cellular phones and PDAs, as it would be useful to integrate authentication software directly on the Smart Cards, which are used to identify the mobile deivce on the network. In the end, regulation from the government side stands against the lazyness of the users. If the user doesn't see any benefit in basically what's additional work to him, he doesn't want to use it [Kre01].

The business-to-business (B2B) market will adapt digital signatures much faster than the B2C market, as digital signatures could streamline the business process by moving processes from paper to electronic documents. For example legal documents could be exchanged by emails.

3. MOBILE COMMUNICATION

The focus of this chapter is mobile communication. The first section shows some general trends in the mobile sector. The following sections describe current and future technologies which enable mobile communication on the micro and the macro level.

3.1 Mobile Trends

Humans are used to mobility. They like the freedom of going wherever they want to go. Imprisoning people is a form of punishment. Article 13 of the Universal Declaration of Human Rights[1] states:

1. Everyone has the right to freedom of movement and residence within the borders of each state.
2. Everyone has the right to leave any country, including his own, and to return to his country.

3.1.1 Demand for Mobility

The problem with many types of devices is that they lock people into a certain location. One of the most annoying devices has been the telephone, as it is the primary device for long-distance communication. Although the basic idea of cellular phones originated in 1947, they needed a long time to "catch fire". Mobile telephones were rare, limited by a lack of available communications channels, until a dozen years ago. The big breakthrough in technology came when AT&T Labs divided wireless communications into a series of cells that automatically switched callers as the terminal moved, so that each cell could be reused. This led to the development of cellular phones and made today's mobile communication possible. But the final breakthrough from the user side came in the 1990's, when the cellular phone devices became smaller, lighter and cheaper, and thus a lot more handy to use.

It's estimated that the current number of subscriber is more than 400 million. The number of subscribers is expected to double every five year in the whole world, reaching as high as 1'730 Millions mobile subscribers in the year 2010 (see table 3.1 and figure 3.1).

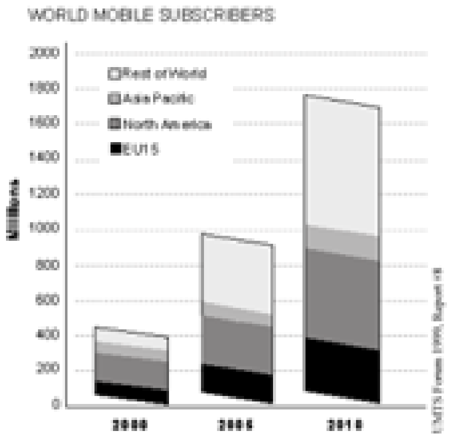
Figure 3.2 shows that growth in the EU has been dramatic over the last two to three years and is already declining. This is because market penetration levels are already high and with the expected increase in competition and availability of service across

[1] http://www.un.org/Overview/rights.html

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

(Source: [UMT99])

Tab. 3.1: World-wide Mobile Market Forecast



(Source: [UMT99])

Fig. 3.1: World Mobile Subscribers from 2000 to 2010

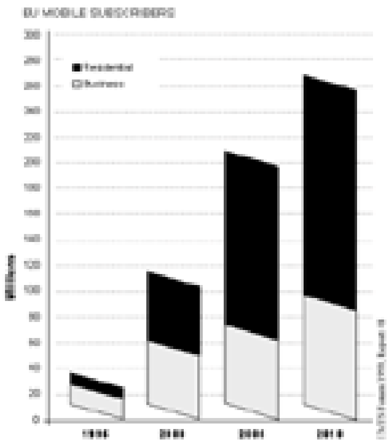
Europe, the penetration level of mobile subscribers is expected to reach 50% to 90% by 2005 in some of the more developed markets such as Scandinavia, Italy, the UK, France and Germany. Average EU penetration levels are anticipated to reach as high as 52% in 2005, and 67% in 2010 [UMT99].

Together with the ever growing number of mobile subscribers in the 90's, the Internet attracted an even higher number of users and businesses. And with it grew the need to connect any device to the Internet, if possible without any wires. But getting rid of wires is not the only implication of wireless communications. As [Mey00] points out, there are two subtly different views of mobility that are made possible by wireless communications:

- Micro mobility describes the freedom to relocate within a small closed area, such as a room or a building. Wireless local area networks (WLANS) are the technicals enablers of micro mobility.

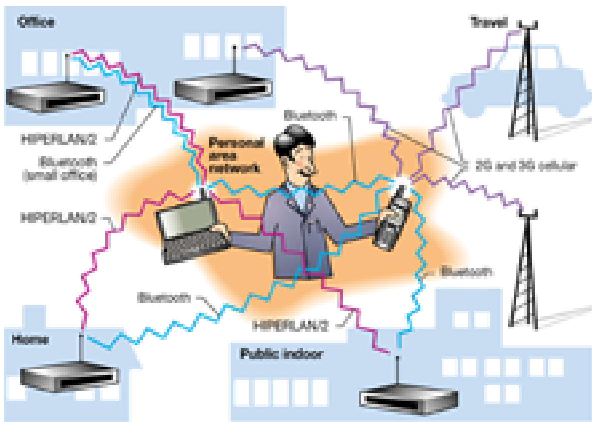
- Macro mobility describes the freedom to relocate on a large scale, i.e., worldwide. This is accomplished by relying on cellular or satellite communications.

Figure 3.3 illustrates the end-user's personal area network (PAN). For instance, while users gain access to their network, e.g, the Internet via HIPERLAN/2, the Bluetooth technology enables them to link individual communication devices together with



(Source: [UMT99])

Fig. 3.2: EU Mobile Subscribers from 1995 to 2010



(Source: [KJMST])

Fig. 3.3: Typical usage of communication standards.

the PAN, and UMTS — a 3G cellular phone service — is used for communication while traveling.

3.1.2 Impact on Terminals

Mobility has a direct implication on the terminal used. A mobile terminal has to be as small and lightweight as possible. Otherwise, the hassle of carrying around the device is too high for the user and wireless communications won't be useful to him. Mobile terminals require to be of small size, low weight and low power consumption. In 1987, a mobile telephone did weight 7kg. Thanks to Moore's Law (c.f. section 2.1.1), technology did help shrink everything and modern mobile telephones now weight not even 100g. But there is a limit on how small devices can get: this limit is usability. It certainly is a technological challenge to cram a complete computer into a wrist watch[2]

[2] http://www.research.ibm.com/WearableComputing/factsheet.html

(Source: IBM Research, http://www.research.ibm.com/WearableComputing/)

Fig. 3.4: The “Linux on a Wrist Watch” prototype developed by IBM Research.

(c.f. figure 3.4), but it doesn’t really make sense from a usability point of view. Of course, in the end the user has to choose himself what kind of device offers the perfect match between portability versus usability to him.

The smaller and the more mobile a terminal is, the greater becomes the risk of damaging it. It’s too easy to accidentally drop a small device, sit on it or expose it to heavy vibrations. Typically, there are no hard drives supported in PDAs or mobile digital cameras. Because of their structure, disk drives are not very resistant to physical shocks and usually use too much power. Instead, memory cards without any moving parts are used[3]. (See chapter 2.2.3 for a description of some different types of memory.)

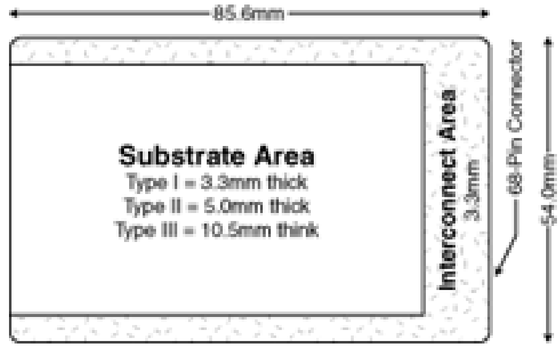
Extension Cards To solve the problem of extending mobile devices, the first PC Card standard has been defined by the Personal Computer Memory Card International (PCMCIA) and the Japan Electronic Industry Development Association (JEIDA) in the early 90’s. The first release of the PCMCIA Standard Release defined the 68-pin interface and the Type I and Type II PC Card form factors. Release 2.01 later added a the new Type III card type. The three types measure the same length, width and interface. They only differ in their thickness (c.f. figure 3.5). The card types each have features that fit to the needs of different applications [Bri98]:

- Type I PC Cards are typically used for memory devices such as RAM, Flash, OTP, and SRAM cards.
- Type II PC Cards are typically used for I/O devices such as data/fax modems, LANs, and mass storage devices.
- Type III PC Cards are used for devices whose components are thicker, such as rotating mass storage devices.

But the PC Card form factor is only suitable for larger mobile devices, such as notbooks. For smaller mobile devices, like PDAs or cameras, a different form factor is needed. In 1996, the SmartMedia™card was introduced by the SSFDC Forum[4], and

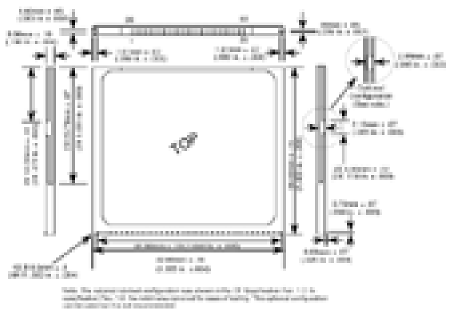
[3] IBM took the challenge and developed a 1” microdrive, a hard disk in a CompactFlash form factor [Com99]. The current Microdrive capacities include 1GB, 500MB and 340MB, and has a low enough power consumption in order to be used in some digital cameras. See http://www.storage.ibm.com/hardsoft/diskdrdl/micro/ for more information on the Microdrive.

[4] “SSFDC” stands for Solid State Floppy Disk Card.



(Source: http://www.pcmcia.org/)

Fig. 3.5: The form factors of the different PC Card types.



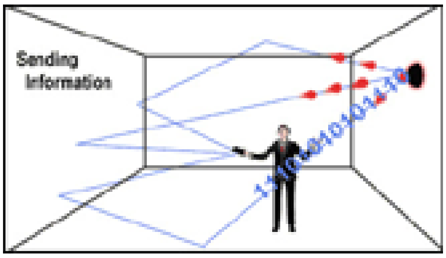
(Source: [Com99])

Fig. 3.6: Type I CompactFlash Storage Card and CF+ Card Dimensions [Com99].

since then other form factors like the CompactFlash card (c.f. figure 3.6), the SmartStick from Sony and the Secure Digital format from Toshiba, SanDisk and Matsuhita appeared. (See figure 2.8 in chapter 2.2.3 for pictures of the different expansion cards.) All with the same goal in mind: expanding mobile devices in a small and cheap way. As every of these "standards" body wants to push its own format, device manufacturers have to chose the one they want to support [MR00]. As users don't want to buy new expansion cards every time they buy a new device, this might lead to an eventual dependence to one manufacturer for the user.

3.2 Micro Mobility

Micro mobility is defined by wireless local area networks (WLAN). A WLAN can be established by using two communication technologies, one is based infrared (IR) communication, the other on radio frequency (RF) communication. In the first category, only the IrDA standard is in widespread use. For communication based on RF, however, there exist four different technology standards: Bluetooth, Wireless LAN (IEEE 802.11), and the ETSI standards DECT and HIPERLAN. The following sections describe the characteristics of each of these standards.



(Source: http://www.spectrix.com/)

Fig. 3.7: How infrared diffusion works.

3.2.1 IrDA

Overview Infrared has almost all the physical properties of visible light, except that our eyes can't see it. This would make an infrared based system optimal for applications where wireless RF is unsuitable or undesired because of security, interference, or safety problems. The important advantage of the diffuse transmission is that the signal is broadcasted into many directions, creating an omnidirectional transmission like RF (c.f. figure 3.7). Unlike an RF based system, infrared doesn't pass through walls; it bounces off from them. Thus infrared based communication is pretty secure, as the physical properties restrict it to a room.

In 1994, the Infrared Data Association[5] (IrDA) defined a protocol stack for universal two way infrared communication between electronic devices. Two devices which have the IrDA technology implemented are able to create a wireless connection and talk to each other. For example, it's possible to transfer electronic business cards from one cellular phone to another without using the cellular network, or a notebook can connect to and use a printer in an easy way.

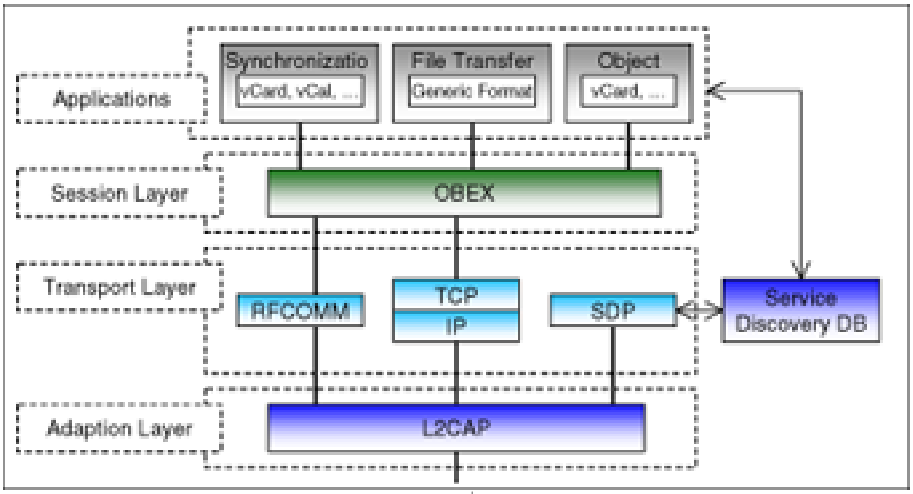
Conclusions Because of the way the IrDA standard is defined, devices can only connect to each other if they have a line of sight, and only within a very limited range. Typically, the connection fails if the devices are more than two meters away. As IrDA only defines a two way connection, a IrDA "network" is limited to two devices. For some reason, the IrDA standards body failed to standardize a way for diffuse transmission with its technology, thus blocking the way to use it for secure wireless networks.

3.2.2 Bluetooth

Overview Bluetooth is a short-range RF communication standard. It has the same main goal as the IrDA standard: it's designed to replace the wiring between devices. Just as IrDA, the Bluetooth standard defines a protocol stack and several profiles. The profiles specify for how devices have to behave in order to guarantee that links and channels always can be established between Bluetooth devices. Figure 3.8 shows the Bluetooth protocol stack while figure 3.9 shows how the different profiles are stacked to each other. The Bluetooth SIG[6] specified the following profiles [S^{+}99b]:

[5] http://www.irda.org/

[6] Bluetooth Special Interest Group, http://www.bluetooth.com/



(Source: [S+99a])

Fig. 3.8: Part of the Bluetooth Protocol Hierarchy.

- The *Generic Access Profile* specifies the common requirements and functionality used by the transport and application profiles.
- The *Service Discovery Application Profile* is used to locate services that are available on or via devices in the vicinity of a Bluetooth enabled device. A Bluetooth device can implement more than one service. This profile enables users to select the service he wants to make use of.
- The *Cordless Telephony Profile* defines the protocols and procedures that shall be used by devices that implement the use case called '3-in-1 phone'[7].
- The *Intercom Profile* specifies the intercom part of the '3-in-1 phone' use case. It is also referred to as the 'walkie-talkie' usage of Bluetooth.
- The *Serial Port Profile* covers the scenario where Bluetooth is used as a cable replacement through a virtual serial port abstraction.
- The *Headset Profile* helps implement Bluetooth into wireless headsets, increasing the user's mobility while maintaining privacy.
- The *Dial-up Networking Profile* specifies the protocols which allow a wireless modem or cellular phone to connect to, e.g., a computer.
- The *Fax Profile* specifies the protocols for how to use a Bluetooth cellular phone as a fax modem in order to send or receive fax messages.
- The *LAN Access Profile* defines LAN access using PPP over RFCOMM. RFCOMM is the Bluetooth equivalent to IrComm, a serial port emulation. This profile specifies how PPP networking is supported in the following situations:

[7] The '3-in-1 phone' is a solution for providing an extra mode of operation to cellular phones, using Bluetooth as a short-range bearer for accessing fixed network telephony services via a base station. This use case includes making calls via the base station, making direct intercom calls between two terminals, and accessing supplementary services provided by the external network.

  - LAN Access for a single Bluetooth device.
  - LAN Access for multiple Bluetooth devices.
  - PC to PC (using PPP networking over serial cable emulation).

- The *Generic Object Exchange Profile* is the basic profile for usage models which require object exchange capabilities, like, for example, synchronization, file transfer, or object push.

- The *Object Push Profile* allows to push and to pull objects from and to Bluetooth devices. An object can be an electronic business card on a Bluetooth enabled mobile phone.

- The *File Transfer Profile* specifies how a Bluetooth device can access an object store of another Bluetooth device. Accessing an object store means that it's possible to

  - navigate the folder hierarchy of another Bluetooth device,
  - transfer objects (files or folders) from one Bluetooth device to another, or to
  - manipulate objects on another Bluetooth device.

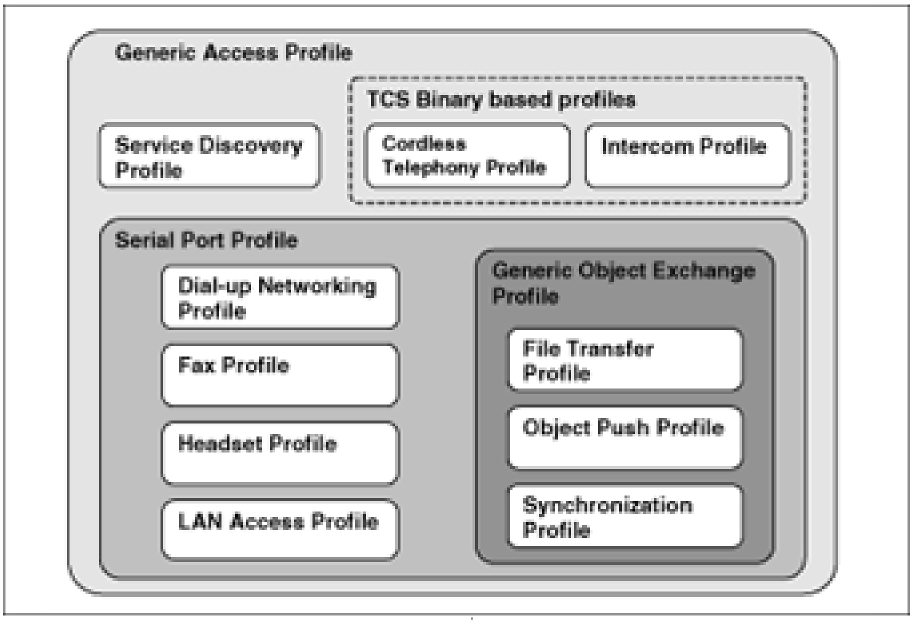
- The *Synchronization Profile* is used to be able to synchronize data between different Bluetooth devices. For example, if a mobile phone or PDA enters the RF proximity of a computer, the devices automatically exchange their PIM (Personal Information Management) data, including the necesserary information to ensure that the PIM data in their object store is made identical.

Conclusions Even though the IrDA standard defines transfer rates up to 4 MBit/s and Bluetooth only delivers a maximum of 723.2 KBit/s, Bluetooth will eventually replace IrDA. The reason is user convinience. Bluetooth doesn't have the limitations of IrDA: Bluetooth doesn't require a direct line of sight between the devices, works within a range of 10 to 100 meters[8] (depending on the signal strength), and it enables spontaneous networking with up to eight devices [ZB99] [Bet00]. Members of the Bluetooth SIG are already thinking about version 2.0, which probably will specify bandwiths of 4 MBit/s and more.

3.2.3 Wireless LAN (IEEE 802.11)

Overview The purpose of the IEEE 802.11 standard is to provide wireless connectivity to devices which move within a local area. As other IEEE 802-based standards do, the 802.11 standard defines the protocols necessary to support networking in local areas. The current IEEE 802.11b standard (also known as 802.11 High Rate) features transmission rates of up to 11 MBit/s within the unlicensed 2.4 GHz ISM frequency bands. Although the IEEE 802.11a standard defines data rates up to 54 MBit/s within the 5 GHz U-NII bands, a supplement to the existing standard for achieving higher data rates based on the initial proposal within the 2.4 GHz bands is in developement. This new extension to the IEEE 802.11b standard should be interoperable with the

[8] This small range of local area networking is called PAN: Peronal Area Network



(Source: [S+99b])

Fig. 3.9: Bluetooth Profiles

original one and will be ratified Q4/2001 [MBS00]. In contrast to the Bluetooth standard, 802.11 only specifies protocols for the physical layer and the data link layer (c.f. figure 3.10) [3Co00]:

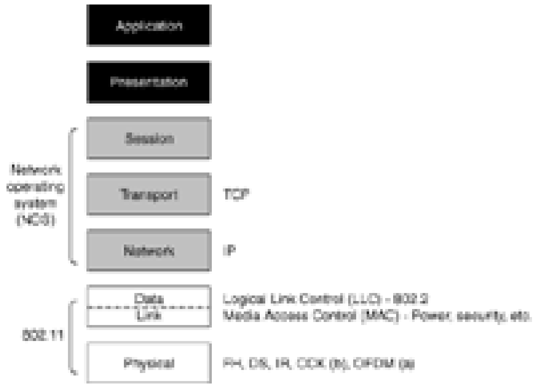
- Originally, the 802.11 standard defined three *physical layers*, two spread-spectrum radio techniques (frequency hopping spread spectrum [9] (FHSS) and direct sequence spread spectrum[10] (DSSS)), and a diffuse infrared specification. Because of government regulations, the higher speeds specified in the 802.11b standard can only be implemented by using the DSSS technique.

- The *data link layer* consists of two sublayers: Logical Link Control (LLC) and Media Access Control (MAC). 802.11 uses the same 802.2 LLC and 48-bit addressing as other 802 LANs, allowing for very simple bridging from wireless to IEEE wired networks, but the MAC is unique to WLANs. Such a bridge is called access point (AP). The AP acts as the base station for the wireless network, aggregating access for multiple wireless terminals onto the wired network. As the user can move with his terminal between different APs[11], there has to be a mechanims on how the terminal chooses an AP, and the MAC layer is responsible for how a terminal associates with an access point (see figure 3.11).

[9] Using the frequency hopping technique, the 2.4 GHz band is divided into 75 one-MHz subchannels. The sender and receiver agree on a hopping pattern, and data is sent over a sequence of the subchannels. The different hopping patterns should minimize the chance of two senders interfering with each other.

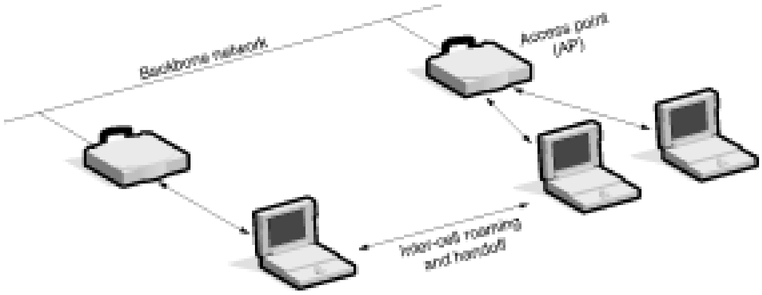
[10] The direct sequence signaling technique divides the 2.4 GHz band into 14 twenty-two MHz channels. Each bit of user data is converted into a series of redundant bit patterns called 'chips'. The inherent redundancy of each chip combined with spreading the signal across the 22 MHz channel provides for a form of error checking and correction.

[11] This behaviour is called 'roaming'.



(Source: [3Co00])

Fig. 3.10: IEEE 802.11 and the ISO Model



(Source: [3Co00])

Fig. 3.11: Access Point Roaming

Conclusions The Wireless LAN standard is an alternative technology for connecting devices to the commonly used wired Ethernet. The benefits of IEEE 802.11b over Bluetooth are that it offers much higher transfer rates (currently up to 11 MBit/s compared to 723.2 KBit/s) in the same frequency bands, and that a WLAN signal can carry these transfer rates over a multiple of 100 meters. But even though the same applications Bluetooth targets could be built on top of a WLAN, the strength of a WLAN lies not in peer-to-peer connectivity but on Internet connectivity. The IEEE 802.11 standard and the Bluetooth standard can coexist without much interference (c.f. table 3.2). Cost may be the primary factor for the survival of the 802.11b standard: it's too expensive for low-cost applications and too slow for higher-speed applications [Man01].

3.2.4 HiperLAN/2

Overview The Broadband Radio Access Networks (BRAN) project of the European Telecommunications Standards Institute (ETSI), too, is working on standards for different kinds of wireless broadband access network. One of these standards, the high performance local area network (HIPERLAN) [Eur98] has been enhanced and the new version, HIPERLAN type 2 (HIPERLAN/2), will provide high-speed communications access to different broadband core networks, including 3G mobile core networks, ATM networks and IP based networks, and moving terminals. Similar to the IEEE 802.11a standard, the HIPERLAN/2 standard makes use of the 5 GHz frequency

Characteristics	Bluetooth	IEEE 802.11b
Frequency Band	2.4 GHz ISM	2.4 GHz ISM
Max. Data Transfer Rate (current)	723.2 KBit/s	11 MBit/s
Max. Data Transfer Rate (planned)	6 MBit/s	20 MBit/s
Range	10 to 100 meters	>100 meters
Defines Protocols for OSI Layers	1 - 7	1, 2
Cost (relative)	very low	medium
Power Consumption (relative)	low	high
Primary Market	Consumer Devices	Corporate Networks

Tab. 3.2: Comparision of Bluetooth and IEEE 802.11b

band, but in contrast to it, HIPERLAN/2 supports asynchronous data and time-critical services (for example, packetized voice and video) that are bounded by specific time delays [KJMST], while the scope of the IEEE 802.11 standard mainly applies to asynchronous data applications.

HiperLAN/2 is a connection-oriented protocol. This means that prior to transmitting data over the network, the mobile terminal and the AP first have to establish a connection with each other, using signalling functions of the HiperLAN/2 control plane. There are two types of connections [Joh99]:

- Bidirectional *point-to-point* connections, and
- *point-to-multipoint* connections, that are unidirectional in the direction towards the mobile terminal.

In addition, there is also a dedicated broadcast channel through which traffic reaches all terminals transmitted from one AP.

Conclusions HiperLAN/2 is a complement to present-day wireless access systems, giving high data rates to end-users in hot-spot areas. It's straightforward to implemented support for QoS (Quality of Service) on a HiperLAN/2 network, as the standard works connection-oriented. QoS support is needed for applications that need steady high transmission rates, like video or voice. Nevertheless, even though HiperLAN/2 is suited for a larger range of applications and can also be deployed as a private WLAN, it will have a hard time competing against the WLAN standard IEEE 802.11 in this area because there already exist a lot of 802.11 devices. At least, the ETSI Project BRAN has worked closely with IEEE-SA (Working Group 802.11) and with MMAC in Japan (Working Group High Speed Wireless Access Networks) to harmonise the systems developed by the three fora in 5 GHz. A comparision between the IEEE 802.11 and the HiperLAN/2 standard is given in table 3.3.

3.2.5 DECT

Overview The ETSI standard Digital Enhanced Cordless Telecommunication (DECT) is an indoor version of the popular celluar phone system GSM — the Global System for Mobile Communications. The major difference between the two standards is that GSM is a fully featured network specification, whereas DECT is an access standard which defines the interface between a mobile cordless terminal and a base station. Although the DECT standard has been primarily designed with telephony services in mind, it is very flexible and supports a wide range of applications [DEC97]. Its data transfer rate ranges from 24 KBit/s to a maximum of 502 KBit/s.

The DECT standard was optimised for the high traffic levels that are required in high-density user environments such as offices, exhibition centres and shopping malls, or Micro Mobility in general. Users are typically moving around no faster than at walking speed, and cordless communication access is required only on the premises. The GSM standard on the other hand was originally optimised for Macro Mobility: to provide continuous wireless communications access for people who may be travelling at speed by car or train, and even roaming from one country into another.

Conclusions Bringing together the complementary strengths of GSM and DECT systems offers the possibility of offering a seamless mobile communications service using DECT access while the user is in the office, and GSM access while the user is off site. The necessary dual-mode phones, combining both GSM and DECT access, have been developed but never gained much market acceptance. The only current application for DECT are cordless phones for households and offices. DECT does play a major role for the upgrade path from 2nd to the 3rd generation mobile service UMTS, as it the only cordless standard with applications ranging from voice over to high speed data transmissions to mobile multimedia [FV98].

3.3 Macro Mobility

As pointed out earlier, macro mobility describes the freedom to relocate on a large scale, i.e., world-wide. This is accomplished by relying on cellular or satellite communications. A key aspect of macro mobility versus micro mobility is that the user moves at relatively high speeds (car or train), compared to the walking speed indoors. Higher performance rates are harder to achieve at high speeds. Figure 3.12 shows for a comparision of the different technologies, it's data rates and the movement speed of a mobile terminal.

The following sections describe upcoming technologies which will serve the users need for macro mobility. Older technologies such as the 2nd generation cellular phone standard GSM will still be in use for a while but will be replaced within the next few years (c.f. figure 3.13).

3.3.1 3G Mobile Services

Overview In order to understand some of the consequences of the market situation for third generation (3G) mobile services, an overview of the different organisations developing 3G standards and services is given (c.f. figure 3.14):

- ITU: The International Telecommunication Union (ITU) is an international organization within which governments and the private sector coordinate global telecom networks and services [12]. The ITU has been working since the late 1980s to

[12] http://www.itu.int/

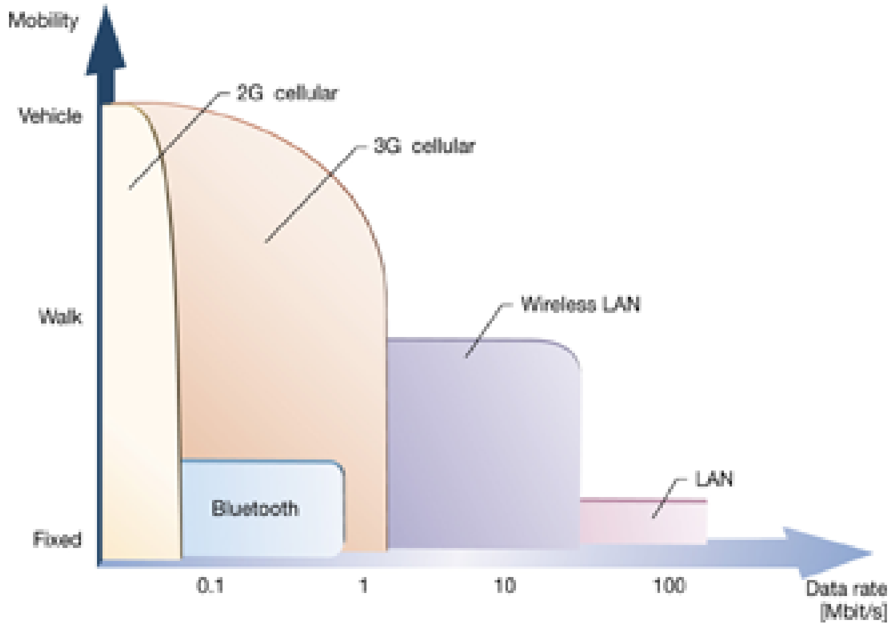


Fig. 3.12: Mobility and data rates for communications standards.

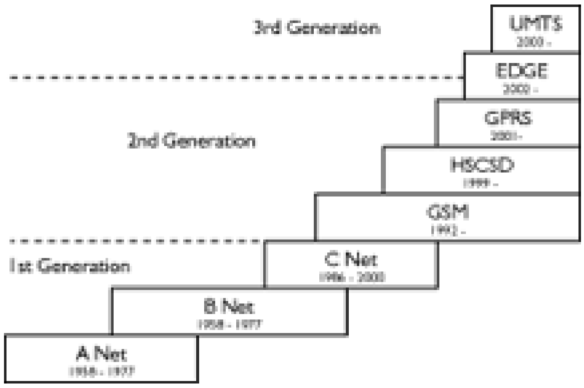
develop global standard for wireless access to the global telecommunications infrastructure. The International Mobile Telecommunications at 2000 MHz (IMT-2000), formerly known as Future Public Land Mobile Telecommunications Systems (FPLMTS), is ITU's standard aimed to advance and unify the diverse systems that exist today into a common flexible radio infrastructure.

- 3GPP: The standards body European Telecommunications Standards Institute (ETSI) introduced the Partnership Project concept in 1997 as part of its new working methods, to facilitate the Institute's practical co-operation with similar organizations in specific market sectors. The Project's results will normally be published as ETSI deliverables and, potentially, as deliverables of the other partners. The goal of the Third Generation Partnership Project[13] (3GPP) is to develop globally applicable specifications for the next generation of the GSM standard. Even though the 3GPP also defined the standards High Speed Circuit Switched Data (HSCSD), General Packet Radio Service (GPRS) and Enhanced Data rates for GSM Evolution (EDGE), these three standards are nothing more than an intermediate step before fully deploying 3G services (c.f. figure 3.13).

- 3GPP2: The Third Generation Partnership Project 2[14] (3GPP2) is the equivalent of the 3GPP for Northern America and Asia.

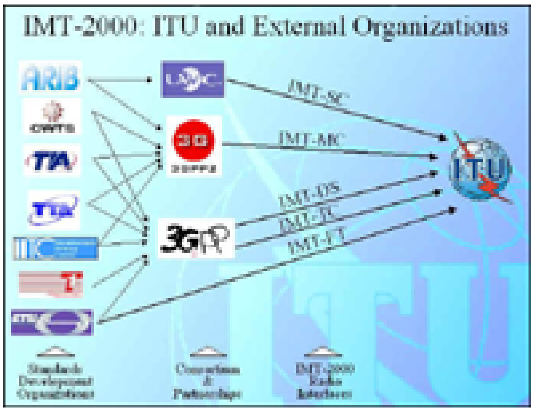
- UMTS Forum: The UMTS Forum[15], which defines the 3G service UMTS, joined the 3GPP as partner in 1998 [ETS98]. The Forum has been established in December 1996 and is a standards body comprising over 150 companies world-

[13] http://www.3gpp.org/
[14] http://www.3gpp2.org/
[15] http://www.umts-forum.org/



(Source: [Sie01a])

Fig. 3.13: History of Mobile Communication and expected deployment of 3G.



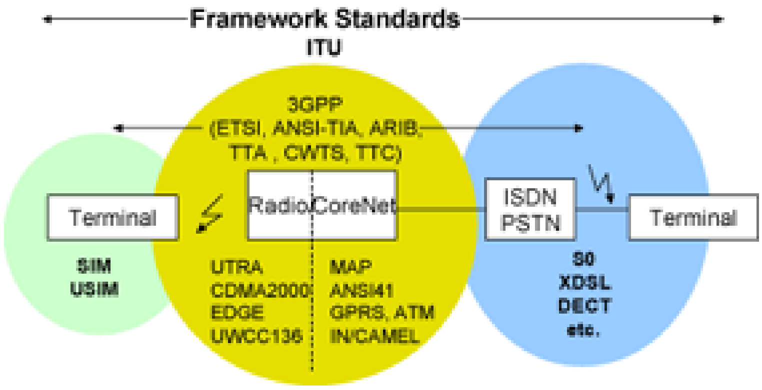
(Source: http://www.itu.int/imt/what_is/imt/)

Fig. 3.14: IMT-2000: ITU and External Organisations

wide. The goal of the UMTS Forum is the successful introduction and development of UMTS. UMTS is one of the major new 3G mobile systems being developed within the IMT-2000 framework which has been defined by the ITU (c.f figure 3.15).

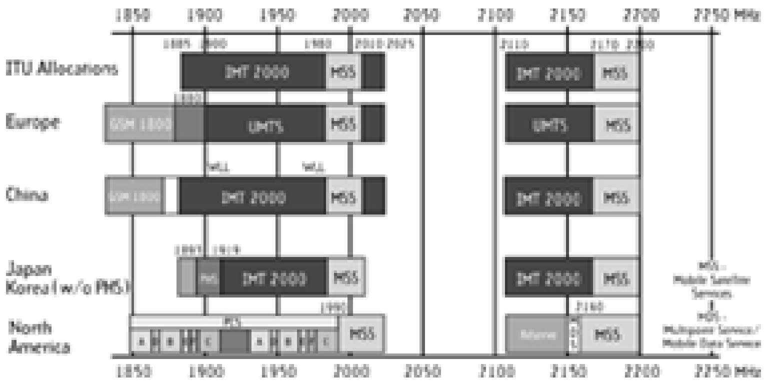
The idea behind the word 'Universal' in UMTS was to create and deploy a world-wide standard with a unified interface for mobile systems [Sie01a]. But in parallel to UMTS, the International Telecommunications Union (ITU) developed a series of standards called IMT-2000 for which the same boundaries have been specified:

- Mobile terminals should be small and lightweight.
- The frequency bands should be world-wide the same.
- International roaming.
- Integration into mobile satellite communication and the conventional telephone network by keeping compatibility with ISDN.



(Source: [UMT00b])

Fig. 3.15: UMTS Standardisation Scenario in the Framework of IMT-2000.



(Source: [UMT98])

Fig. 3.16: IMT-2000 Frequency Bands Allocations

In the end, not one but five systems for mobile communication have been developed (c.f. table 3.4). Europe will deploy IMT-DS and IMT-TC, eventually America will deploy IMT-MC and Asia IMT-DS, while Japan didn't even allocate a frequency band yet.

Frequency Bands The major reason why the ITU specified five systems for mobile communications is the difficult allocation of a single frequency band world-wide. The frequency bands the ITU has allocated for IMT-2000 are not yet available world-wide. Early estimates of IMT 2000 spectrum requirements showed the need, under critical conditions, for at least 230 MHz of radio spectrum bandwidth [IR00]. Although WARC-92[16] identified 1'885 - 2'025 MHz and 2'110 - 2'220 MHz as being available on a world-wide basis for use by IMT-2000, there are a number of spectrum considerations that affect the availability of IMT-2000 (c.f. figure 3.16):

- The bands identified by WARC-92 are shared with other radiocommunication systems and services, and in many cases are already in use.
- These bands are used differently in various countries.

[16] World Administrative Radio Conference of 1992

Characteristics	802.11	802.11b	802.11a	HiperLAN/2
Spectrum	2.5 GHz	2.5 GHz	5 GHz	5 GHz
Max physical rate	2 MBit/s	11 MBit/s	54 MBit/s	54 MBit/s
Max data rate, layer 3	1.2 MBit/s	5 MBit/s	32 MBit/s	32 MBit/s
Medium access control / Media sharing	Carrier sense	CSMA/CA		Central resource control / TDMA/TDD
Connectivity	Conn.-less	Conn.-less	Conn.-less	Conn.-oriented
Multicast	Yes	Yes	Yes	Yes[a]
QoS support	PCF[b]	PCF[b]	PCF[b]	ATM / 802.1p / RSVP / DiffServ (full control)
Frequency selection	FHSS or DSSS	DSSS	Single carrier	Single carrier with Dynamic Frequence Selection
Authentication	No	No	No	NAI / IEEE address / X.509
Encryption	40-bit RC4	40-bit RC4	40-bit RC4	DES, 3DES
Handover support	No[c]	No[c]	No[c]	No[d]
Fixed network support	Ethernet	Ethernet	Ethernet	Ethernet, IP, ATM, UMTS, FireWire, PPP[e]
Management	802.11 MIB	802.11 MIB	802.11 MIB	HiperLAN/2 MIB
Radio link quality control	No	No[f]	No	Link adaptation

(Source: [Joh99])

[a] Two different modes supported, multicast via a dedicated MAC-ID (same as for 802.11) and N*unicast for improved quality.
[b] Point Control Function, a concept defined in 802.11 to allow certain time slots being allocated for realtime-critical traffic.
[c] Requires signalling over the fixed network, which is still proprietary.
[d] Requires signalling over the fixed network, to be specified by H2GF.
[e] Ethernet supported in first release.
[f] Supports dynamic rate shifting between 1 MBit/s, 2 MBit/s and 11 MBit/s.

Tab. 3.3: Comparision of 802.11 and HiperLAN/2.

IMT-2000 Specifications	
IMT-DS	Direct Sequence, alias WCDMA
IMT-MC	Multi Carrier, alias CDMA2000
IMT-TC	Time Code, alias ULTRA-CDD, or TD-SCDMA
IMT-SC	Single Carrier, alias EDGE
IMT-FT	Frequency Time, alias DECT

(Source: [Sie01a])

Tab. 3.4: Family of specifications defined by the ITU-R for 3G mobile communication systems.

Technology	ISM-Band	Effective cell radius	Expected level of penetration		Advantages	Limitations (today)
			Resid.	Corp.		
Infrared	N/A		High	Low	Price, no regulation worldwide	One room, line of sight
Bluetooth	Yes	10 m	Low	High	Nearly all applications in a sphere of 10 m	< 1 MBit/s, 8 active devices
Home RF / SWAP	Yes	< 50 m	High	Low	Combines benefits of 802.11+DECT	Smaller cells due to EMI
802.1x	Yes	< 50 m	Low	High	Best wireless data for SME, High rate — up to 54 MBit/s	EMI / Lack of interop-erability
HIPERLAN/2	No	< 50 m	Low	High	Max. 25 MBit/s, QoS support	Price range (high)
DECT	No	20-300 m[a]	High	High	Proven technique, IMT-2000 member	Protected band, only in some countries
Licence-exempt UMTS / Third Generation	No	20-300 m[a]	High	High	One technology at any place, protected band	Not allocated worldwide

(Source: [UMT00a])

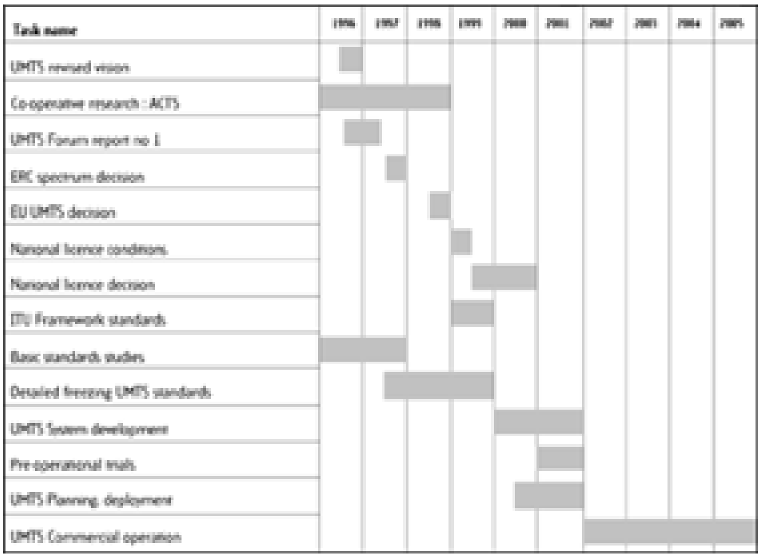
[a] not indoor

Tab. 3.5: Comparision between Wireless Technologies in the Non-Public Environment.

- The traffic and service mix carried by IMT-2000 networks may vary from country to country, and within countries.
- Initially, IMT-2000 will need only portions of these bands and the use will grow with time.

It is planned that administrations around the world should make the full allocated spectrum available by the year 2010. Licensing of the frequency bands started 2000 in Europe. The prices telecom carriers paid for a license have been absurd high. For example, carriers in Germany and Great Britain paid around 600 Euro per user, even though the current per-head turnover is not even 500 Euro per year [Sie01b] [Nik00].

Conclusions A technical comparision between UMTS and GSM shows that UMTS doesn't differ that much from GSM. In the 1990's, when the foundation for UMTS was laid with RACE, nobody could foresee the impact of the Internet on mobile communication. As voice communication needs the same transfer rates up- and downstreams, UMTS has been designed as a symmetric real-time system. But data service are highly asymmetric: the user enters a small command and receives a complete movie. Like GSM, UMTS is a communication system optimised for speech that also offers the possibility to transfer data [Sie01a]. Under optimal conditions, UMTS offers transfer rates



(Source: [UMT98])

Fig. 3.17: UMTS Schedule for Europe

up to 2 MBit/s, but these rates drop down under 128 kBit/s if the terminal moves around at high speed.

Telecom carriers have to bring in the cost they had in order to afford a UMTS license. This puts pressure upon them to push UMTS into the market as wide-spread as possible. Future 3G multi-mode terminals that are able to also operate via 2G systems such as GSM 900, 1800 and 1900 will further extend the reach of many UMTS services. With these terminals, UMTS based terminals will be able to roam in the non-public environment using APs similar to the ones used by WLAN (see section 3.2.3). Table 3.5 shows a comparision between the different technologies that could be used in the non-public environment[17].

In any case, the 3G standards are specified and systems and devices are being rolled out. It's planned that 3G systems will be deployed world-wide by 2002 and should stay in commercial operation at least until 2005 (c.f. figure 3.17) [UMT98]. The same way GPRS and HSCSD extended GSM, the UMTS standards will be enhanced during this time in order to accomodate the growing number of users and the growing need for transfer rates.

3.3.2 4G Mobile Services

As 3G systems are specified, the newly created Wireless World Research Forum[18] (WWRF) is already thinking of year 2010 and beyond. With the fourth generation of mobile services, the following problems have to be addressed [Sie01a]:

[17] Please note that the table seems to be biased towards DECT and UMTS. Bluetooth is a very low-cost technology that is going to be implemented in a lot of consumer devices, thus having a good chance reaching high penetration levels in residentual homes.

[18] http://www.ist-wsi.org/wwrf.htm

- The global allocation of frequency bands has to be thought over. The available spectrum for mobile radio communication gets rare while the 390 MHz wide spectrum for TV broadcast is nearly unused: over 90% of the population receive their TV programme by cable or satellite. A world-wide reallocation is impossible in reality, but even just for Europe, the time frame to apply for a reallocation of the frequency bands gets short as the European Radiocommunications Committee (ETC) plans to finally adapt the 40 year old allocations by 2005.
- As long as the allocation of frequency bands isn't unified world-wide, there will be different radio communication technologies. Because this political matter won't get solved in the near future, this problem has to be solved with technology. The most flexible solution presents Software Defined Radio[19] (SDR). SDR provides software control of a variety of modulation techniques, wide-band or narrow-band operation, communications security functions (such as hopping), and waveform requirements of current and evolving standards over a broad frequency range. Instead of either having two different devices for each frequency range, or implementing different send/receive units for each frequency band in a multiband terminal, the hardware can be reconfigured with a new firmware that can be downloaded on-the-fly.
- In order to further improve the connection to terminals, the cellular system needs to be split up into different sized cells. This way the different states of users, from a fast moving to stationary, can be covered in an optimal way (c.f. figure 3.18).
- Technologies like adaptive antennas[20] could help improve the frequency band situation. The electromagnetic field of smart antennas is directed at the mobile terminal and not broadcasted around the antenna like a sphere. This enables better allocation of resources like frequency channels and time slots, and results in faster connections and additional numbers of terminals per radio cell.
- As people get used to accessing Internet based services from wherever and whenever they like, IP-based services have to be integrated seemlessly into telecommunication services.
- A system has to be developed with which a user can be reached anywhere at any time by one world-wide available address. With the penetration of technology into everything we do and wear, users become traceable. Because of this, users may of course own more than one address so that the can protect their privacy. Technologies like MobileIP allow roaming between different IP subnetworks and media types.
- The World Wide Web didn't evolve around the user, but around technology. With 4G mobile services, the industry wants to try to focus on the user and develop the technology accordingly. As pointed out in chapter 2 the upcoming generations of semiconductors will make it possible to design devices according to human needs and without restrictions because of hardware technologies.
- The symmetric structure of 3G has to be extended to support symmetric and asymmetric data streams. A symmetric data stream is needed for real-time communication (voice, video conferencing), while an asymmetric data stream makes sense for, e.g., surfing the Web.

[19] http://www.sdrforum.org/
[20] http://www.nt.tuwien.ac.at/mobile/research/

(Source: [Cal99])

Fig. 3.18: The ITU vision of global wireless access in the 21st century.

3.4 Conclusions

From the current market situation, the following conclusions can be made:

- In the next five years, UMTS and its derivates in Japan (FOMA) and America (cdma2000) will play a major role. Especially in Europe, carriers just can't throw away the money they spent on UMTS licenses.
- Because of problems with the allocation of enough frequency bands for IMT-2000, hardware manufactures will have to implement more than one send/receive unit into devices to support for world-wide roaming. Most devices will still be specific to one radio standard and one protocol standard.
- Although UMTS is prepared for roaming between different cell types, e.g. moving from a picocell into a microcell, it's questionable if and when APs will be made available for residentual users. APs would allow faster and cheaper network access at home.
- Mobile users with larger devices such as notebooks will make use of UMTS, as it offers the best data rates while traveling. But UMTS is too slow and too expensive for fast long time Internet access. A notebook will still require other radio communication technologies, e.g. a WLAN PC-Card, so that a user can take advantage of the fast and cheap Internet access in the office by using the installed WLAN infrastructure of the company.
- Although the HiperLAN/2 standard seems to be superior to IEEE 802.11b, Industry leaders such as Dell already ship notebooks with integrated WLAN controller. HiperLAN will have a hard time to catch up with the already installed WLANs in corporations and universities.
- It looks like Bluetooth is on the best way to replace the IrDA standard. Bluetooth chips are cheap and small enough to be implemented in a large range of

consumer devices. As soon as the interoperability between Bluetooth enabled devices from different manufacturers is fixed, its pervasivity among consumers will grow quickly.

4. SCENARIOS

This chapter describes three scenarios which could gain relevance in the next ten years in the domains of business-to-consumer, business-to-business and eGovernment. All three scenarios have been developed not just with the technology in mind, but also with user behaviour. Nevertheless, each scenario provides a forecast of when which technology might be available in order to implement it with a reasonable price/cost ratio.

4.1 Business to Consumer

4.1.1 Introduction

The Business to Consumer (B2C) market in electronic commerce (eCommerce) is growing. But even though research groups forecast an estimated doubling every 18 month (c.f. table 4.1), the last few years of the eCommerce business did show that people generally didn't change their shopping habits, they just added a new one.

Keeping this behaviour in mind, the following scenario is based on a customers shopping habit for buying groceries. Groceries are something consumers will only buy over the Internet if they really don't have the time to walk into a grocery store. Customers will probably buy groceries over the Internet every now and then, but as they like to see and touch the fruits and cereal packages before they finally buy them, stores of the old economy will exist for another 10 years at least.

	2000	**2001**	**2002**	**2003**	**2004**
eMarketer	$60	$101	$167	$250	$428
Forrester Research	$53	$96	$169	$284	$452
Gartner Group	-	-	-	$380	-
Goldman Sachs	$238	$494	$870	$1,392	$2,134
IDC	$59	-	-	$213	-
Merill Lynch	$218	$398	$734	$1,317	-
Ovum	$29	$49	$81	$133	$219
Source: eMarketer, 2001; various, as noted					

(Source: eMarketer, Inc.)

Tab. 4.1: Comparative Estimates: Worldwide B2C eCommerce Revenues, 2000–2004 (in billions).

4.1.2 Scenario

The scenario is well known to everybody: a customer walks into a grocery store, walks through the ailes between the shelves and selects the goods he likes to buy.

His shopping list is saved on his mobile phone, which has PDA functionality built in. In the kitchen at home, he has a quasistationary Web pad with a keyboard attached. As the stockings run out, he and his wife enter the shopping list gradually into an application which the Web pad interfaces. They build the shopping list centrally because they don't know in advance who is going onto the next shopping tour. Before they go to the store, they do a final check in the kitchen and enter what they need into the Web pad.

On the shopping list, his wife also added an entry "lotion", but there are too many different ones on the shelf for cosmetics. As he doesn't have a clue which one his wife prefers, he calls her from his mobile. The mobile has a built in video camera. Instead of letting his wife explain which lotion she likes, he simply points the camera at the shelf and she can look for herself. Finally, everything on his shopping list is marked off and he walks to the cashier.

At the cashier, the goods still have to be placed on the conveyer band. But most of them carry a RFID[1] tag, so it isn't necessary for the cashier to wave the product in front of a barcode reader. While the cashier makes sure that all goods have been entered into the system, the customer enters his cellular phone number into a terminal. Seconds later, he receives an invoice on his mobile phone, digitally signs it and with one click accepts the invoice. Another moment later, the cashier accepts the payment and our customer can go home with his purchases. At the end of the month, the bill from the grocery store shows up as an entry on the invoice he receives from the telecom company.

4.1.3 Technology

Shopping List The original shopping list is actually not saved on the Web pad in the kitchen, but on a server somewhere on the Internet. The Web pad is used to edit the list. In order to make use of the shopping list application from within a store, the user might have two choices:

1. She accesses the shopping list application running on the Internet live from her mobile phone. This requires the mobile phone to have Internet access.
2. She transfers the shopping list to her mobile phone. This requires the mobile phone to have a storage facility in order to save the list.

The first solution can be achieved by additionally developing a WAP interface to the Web interface. But this solution only works if the mobile phone can access the Internet from within the store, and the cost accessing the Internet from the mobile phone is low enough to justify its use. The downside of this solution is that if there is no Internet access from within the store, the application can't be used.

The second solution doesn't require complete network coverage, but a more enhanced infrastructure on the mobile phone:

[1] http://www.aimglobal.org/technologies/rfid/

- To be able to view the shopping list on the mobile phone, the data format for shopping lists has to be standardized.
- An application has to be developed so that the shopping list can be edited using the mobile phone.
- Some means of transferring the shopping list between the different systems has to be developed. The system should be able to synchronize the shopping list on the mobile phone with the one on the Internet server, as sometimes a certain good isn't available in the store. This good still has to remain in the system.

The upside of the second solution is that the user has full functionality of the application from wherever and whenever he wants. The downside is that a lot of things have to work together. For example, if the husband has a mobile phone from a different manufacturer than his wife has, will the application work on both devices?

From the technology point of view, both solution can be implemented today. Products like Web pads and Internet enabled mobile phones do already exist. The second solution would require a mobile phone with better PDA functionalities. These kind of phones can't be bought yet but as prototypes have already been presented, devices will be available within the next 12 months. From the software side, the first solution can be implemented by creating an XHTML interface and a WML interface in order to access the data (see section 2.3.3), the second one can be implemented using Java.

Full coverage of Internet access from within stores may not be given at the present-day. Also, access speed is too low, even for a small application like the one presented. But the main point is cost. For an application like this to be justified, telecom carriers have to change their accounting model [Sou01] as todays prices for mobile Internet access are too high.

Video Phone Even though the video phone has been announced a long time ago, it may finally arrive in the next few years. For a mobile video phone to work reasonably, the following requirements have to be met:

- The electronics to implement a video camera into a mobile phone have to be small enough. Charged Coupled Device (CCD) already have high enough resolutions for a good quality video stream, but they can't be used in a mobile phone yet.
- The radio network has to be able to deliver high bandwidth for a steady video and audio stream.
- The mobile phone should have a large enough color screen with a high resolution that delivers a sharp video image.

It doesn't look as if the industry can't keep up with the promises of Moore's Law in the next few years. This allows to forecast that in the near future, existing attachable digital camera devices for PDA devices will be so small that they can be directly implemented into a mobile phone. It would be nice to have OLED displays implemented in such a phone (c.f. chapter 2.2.4), but these aren't mandantory as color LCD displays offer a good enough experience for the user. And as 3G standards like UMTS deliver high enough bandwidths to accomodate video streams, 3G concept devices like the one in figure 4.1 will be reality within the next five years.

(Source: Nokia)

Fig. 4.1: Nokia Concept Phone

Electronic Payment Mobile phones could actually replace debit or credit cards. The key element of the subscription to a GSM or UMTS service is the Subscriber Identity Module (SIM) card. A SIM card is a smart card that enables a mobile phone to be identified. Java based UTMS SIM cards (USIM cards) have already been developed [Obe00], so that SIM cards and SIM-related software and services enable cellular phone service operators to provide a wide range of value-added services over their networks. One of these services could be the implementation of an electronic payment service [UMT00b].

Using a mobile phone to make payments would be the solution in the search for electronic money. A cryptographic key could be placed directly on the SIM card of the mobile phone. This key could be used to securely sign documents. The validity of the digital signature could be verified by the issuer of the SIM card by having a directory of public keys corresponding to a respective private key on the SIM card. The identification wouldn't be the name of the user of the mobile phone in which the SIM card is placed, but the phone number which is bound to the SIM card. Therefore a SIM card based payment method would guarantee at least as much privacy as a debit card, if the user doesn't publish his mobile phone number.

The system would be more secure than credit cards, even without the end-to-end application security given by the UMTS system [Gus01]. The private key doesn't have to get out of the SIM card, as the signing procedure of a document happens directly on the SIM card. This way the user can't accidentally give his private key to someone with fraudulent intentions. And to ensure that only he can sign documents even if his SIM card has been stolen, access to the private key can be secured with a PIN code, just ATM cards alike.

With the described infrastucture, the steps in a secure payment scenario would look like this:

1. The customer enters the number of his mobile phone into a terminal or a dedicated box on the check-out page of his online shop.

2. The system of the store sends an electronic invoice to the given telephone number. This doesn't have to be sent through the cellular network. For example, if the telephone has a Bluetooth interface and there is a way for the store to query the phone number, the system can send the invoice directly to the phone.

3. The customer should receive the invoice on his mobile phone within seconds. Upon reception of the invoice, the customer has to enter his PIN code and the

invoice will be signed on the SIM card and sent back to the store. The invoice must be standardized in order for the cell phone to be recognized as such.

4. The store then sends the signed invoice to the payment system of the telecom company. The payment system checks the validity of the document, bills the customer and sends an acknowledgment of the transfer to the store.

5. The store presents a “payment okay” message to the customer.

6. At the end of the month, the customer receives one bill from the payment system of the telecom company, listing his purchases in the same way a bank does.

Step 3 could be taken further, so that the customer can verify the invoice for its identity. To be able to do that, the store must sign the invoice before sending it to the customers mobile phone. Then, the customer can check the validity of the signed invoice the same way the store does.

The advantages of such a system would be that the customer would have an easy, versatile, portable, secure and unified method for paying his purchases. He could use his mobile phone to shop on the Internet, from home as well as from the office, and he could use it to go shopping in a real store. And at the end of the month he'll receive one single invoice. The advantage for retailers to use such a system would be that he could be sure that he will receive the money from the customer.

The described system could offer telecommunication companies the solution for the dept they created by buying the licenses for UMTS. But before such a system could be implemented, telecommunication companies would have to acquire the required knowledge from credit card banks. It is very easy to imagine further big Acquisitions and Mergers in the upcoming years, but this time between telecom companies and banks [Gus01].

4.1.4 Conclusions

Table 4.2 shows that most of the technologies used in the presented B2C scenario already exist today. Especially all the required technology for the electronic payment part of the scenario are available, so the major problem for implementing the presented B2C scenario isn't actually technology, but politics in the corporate field. The digital signature used here doesn't have to be regulated by the government, as the usage of such a system only depents on the contract with the telecommunication company or the credit card bank. A first step in the direction of the described system is paybox.net[2], a subsidiary of Deutsche Bank. But it's foreseeable that for such a system to be fully adopted by customers, it has to be implemented by a consortium of banks and telecommunication companies. Every electronic payment system that was introduced by a single bank, e.g. swissnetpay from Crédit-Suisse, failed to reach market acceptance. In Europe, Europay International[3] would have the power to create the market acceptance needed. But this takes time, for example Europay International first introduced “Maestro”, a progamme that is aimed at completely replacing the paper based eurocheque system, in 1993 and expects to finally pull the euroecheque system from

[2] http://www.paybox.net/
[3] http://www.europay.com/

Requirement	Availability	Technology / Product
Web Pad	now	Voyager (Monec), Screenpad (Swisscom)
Standardized Data Format	now	XML
Synchronization	now	Bluetooth
Presentation Languages	now	XHTML (Web), WML (WAP), cHTML (iMode)
Cheap Mobile Internet Access	2002	GPRS, UMTS
Cross-platform Programming Language	now	Java
Integrated Camera	2003	CCD
High Transfer Rate	2002	UMTS
High Quality Color Display[4]	2002 (2005)	LCD (OLED)
Extendable Smart Cards	now	SIMphonIC 3G (Oberthur)
Cryptography Standards	now	Public / Private Key algorithms

Tab. 4.2: Forecasted availability of the required technologies for B2C scenario.

the market by January 1, 2002.

The presented individual parts of this scenario could be reality within the following time frame:

- The key factor for the shopping list part is the cost of mobile Internet access. With the introduction of packet-based standards like GPRS, telecommunication companies can introduce content billing as an alternative to the current time-based billing. This should bring down costs for this kind of application. Most of the carriers already offer GPRS, but because of current lack of mobile devices implementing the standard, packet-based services might gain momentum later this year [ttCtEPtE$^+$01].
- The video phone scenario is the one that relies the most on technology. High transfer rates will be introduced with 3G systems in 2002, but it will probably take another two years to produce video cameras with specifications that make it possible to integrate them into mobile phones.
- At the moment, the “electronic” payment system is the credit card. For the electronic payment part to work, the first step is for two big businesses to get together and define a way to make this reality. This might even happen within the next three years, but it will take at least another five years to be rolled out. We probably won’t see a unified fully electronical payment system like that until the year 2008.

	2000	2001	2002	2003	2004
eMarketer	$226	$449	$841	$1,542	$2,775
AMR Research	-	-	-	-	$5,700
Computer Economics	$3,068	$5,232	$6,815	$9,907	-
Forrester Research	$604	$1,138	$2,061	$3,694	$6,335
IDC Research	$213	-	-	-	$2,244
Gartner Group	$403	$953	$2,180	$3,950	$7,290
Morgan Stanley Dean Witter	$200	$721	$1,378	-	-
Goldman Sachs & Co.	$357	$740	$1,304	$2,088	$3,201
Ovum	$218	$345	$543	$858	$1,400
Source: eMarketer, 2001; various, as noted					

(Source: eMarketer, Inc.)

Tab. 4.3: Comparative Estimates: Worldwide B2B eCommerce Revenues, 2000–2004 (in billions).

4.2 Business to Business

4.2.1 Introduction

Even though people talk more about B2C, the business to business (B2B) market is larger and more profitable than the B2C market (c.f. table 4.3). Electronic commerce can enhance the B2B market significantly by streamlining business processes not just inside a corporation but across the entire business chain.

The following scenario might not save much money from using electronic mobile devices on the first sight, but it enhances the old process and offers higher service quality. The scenario takes place in the gastronomic market but can easily adapted to other areas.

4.2.2 Scenario

Overview Restaurants and Hotels usually don't buy the fruits and vegetables they need to prepare the menus with in the grocery store. They order the needed edibles from one or more distributors and get them delivered. The distributors are specialized in knowing where to find what fruit, which season brings what quality of vegetables, and of course in getting the best prices for quality. Distributors buy their goods from different places: at the market, directly from local farmers, from importers, or even import some of the fruits and vegetables themselves. This simple model is shown in figure 4.2.

Process Let's say a restaurant places an order for the following day. An order triggers the following (simplified) process:

1. Restaurants can place an order at the distributor either by telephone, fax, email or directly on the Web via a browser. If the order isn't placed on the Web, the distributor has to enter the order into the system with a terminal, preferably Web based. An order encompasses the goods and the desired quantities.

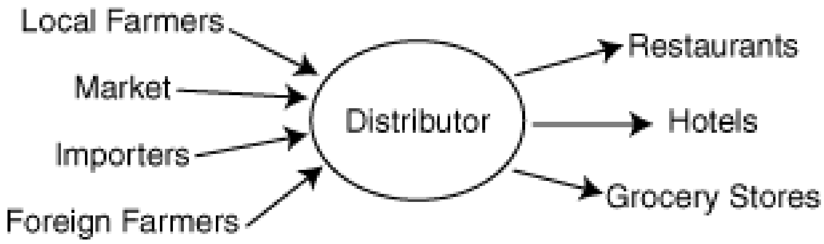


Fig. 4.2: Business Model of a Distributor for Groceries

2. After the order has been entered into the system, it will be assorted the night before delivery. Every good has be weighted or counted, and the quantity which will be delivered has to be entered into the system.

3. Only after the goods have been assorted can the price of the order be calculated and fixed in the system. The price of each good depends on the following factors:

   - average cost
   - delivered quantity
   - time and distance to get to the restaurant
   - other factors like special discounts

The assembled fruits and vegetables are ready for delivery now. Everything is usually delivered until 10am. The drivers of every delivery truck take each a small mobile device (PDA) with them. The PDA is connected to the order process system of the delivery company. A delivery includes the following steps:

1. The driver has to log into the order process system using his PDA. A list of the orders that have to be delivered by the driver appears on the screen.

2. The goods are loaded onto the truck. The driver has to confirm that the orders are on the truck by changing their respective order status in the order process system.

3. A GPS tracks the location of the truck in real-time. This is a feature needed for enhanced customer service. Restaurants need their order on-time, but the delivery can be delayed by a lot of factors, mainly traffic. Restaurants get nervous if the delivery is delayed by more than 30 minutes and call up the distributor. For example, with a GPS tracking system on the PDA, the PDA can constantly send the location data back to the order process system. Assumed that the restaurant has access to the order process system, it can enquire about the tracking status and its current location by logging into it.

4. When the order is unloaded at the restaurant, the driver has to mark the order as delivered.

5. It can happen that a restaurant did order a wrong good, that a good has not the right quality, or that it simply forgot to order a good. In such a case,the driver has to mark the specific good on the order as declined, and an express order has to be triggered. This express order can directly be made by the driver using the PDA.

(Source: Source: Rand McNally; Pretec Electronics Corp.)

Fig. 4.3: Left: Clip on system “StreetFinder GPS” for the Palm III from Rand McNally; Right: Pretec’s CompactGPS, a GPS sytem on CompactFlash card.

6. Fruits and vegetables are usually delivered in seperate small skeleton containers made out of plastic. These aren’t cheap and have a certain value to the distributors because of the amount of containers in circulation, but are worthless to the restaurants. As mentioned above, restaurants sometimes get their goods delivered by more than one distributor. Thus, drivers should get back the correct amount of outstanding containers from the restaurant, which they can look up in the order process system.

7. The system has to be able to support a way to sign the receipt on the PDA, because some restaurants require signed the delivery receipt. If there has been changes to the order, the new delivery receipt will be brought with the next delivery or sent by mail.

8. While the driver drives the truck to the next restaurant on his list, the express order is already assorted and being delivered to the restaurant.

4.2.3 Technology

Location Tracking The Global Positioning System (GPS) allows accurate position tracking since 1993 [TK]. Today, GPS receivers are small enough to be carried along with a PDA, but they are too clumsy and not very suited for tough environments (c.f. figure 4.3). As it isn’t necesseray to know the exact location of the truck — a range of a few hundert meter would be sufficent — it would make it easier and cheaper if the system could retrieve the location from the cell the mobile PDA is currently connected to.

There are several Internet protocols defined, such as the Service Location Protocol[5] (SLP), that help developing location-based services. Mobile IP’s “location tracking” scheme currently relates only to the location of a terminal within the network (its fixed IP address), and not to the location of the end user. Protocols have to be extended to support user location information.

[5] http://www.ietf.org/rfc/rfc2608.txt

At the moment IP applications have not been considered in 3G cellular networks but as times goes by and the deployment of IP in cellular networks becomes more stable, it is expected that most applications will be IP-based [UMT00b].

Changing the Order The driver has to be able to request a change in the order system while being on the road or at the destination. Additionally, he has to be able to submit an express order for a restaurant. This requires the PDA to have constant access to the order process system. As time is a critical factor for this kind of business, the Internet connection should be very responsive. It doesn't have to be a high speed connection, as the application doesn't use much bandwith.

Cost of the Internet connection is another factor that can't be left out: a mobile Internet connection that is billed only accoring to the connection time will be too expensive to justify such a system, even if customer service could be improved by a significant factor.

Document Signing The restaurant has two choices to sign the delivery receipt:

1. As the PDA has a touch sensitive display it can be used to sign the document with a stylus in the 'old fashion'. The signature will be attached to the document as a picture, prooving that the delivery is okay.

2. The document can be signed using a cryptographic process as described in section 2.4. The cook from the restaurant who signs the document has his private key saved on a mobile terminal, e.g., on the SIM card of his mobile phone (see also section 4.1). The driver first transmits the delivery receipt to the mobile device of the cook. The cook then signs the receipt with his private key and then transmits it back to the PDA of the driver.

The first version is already implemented and deployed by large transportation companies like FedEx.

As far as technology goes, the second version could be implemented within the next year. The major problem is that the digital signature must have a legal status in order to be valid in front of a court. For digital signatures to be functional in a business environment, they have to be issued by an certification authority all involved partners can trust. Section 2.4 describes the problems behind setting up a CA.

4.2.4 Conclusions

The key factors for the presented application to work are responsiveness and cost of the mobile Internet connection, as well as the possibility to be able to inquire the position of the mobile terminal. Responsiveness is mainly a matter of transfer speed, which should be solved with the introduction of 3G systems. Online cost for this kind of application will come down when telecomm companies introduce connection-less communication protocols like GPRS and accounting schemas like content-billing.

The individual parts of this B2B scenario could be reality within the following time frame:

Requirement	Availability	Technology / Product
Synchronization	now	Bluetooth
Presentation Languages	now	XHTML (Web), WML (WAP)
Cheap Mobile Internet Access	2002	GPRS, EDGE, UMTS
Location-based Network Information	2005	Extensions to MIPv6
Touch Sensitive Display[6]	now	LCD
Extendable Smart Cards	now	SIMphonIC 3G (Oberthur)
Cryptography Standards	now	Public / Private Key algorithms

Tab. 4.4: Forecasted availability of the required technologies for B2B scenario.

- Location tracking will be the hardest part to implement, as there doesn't even exist a standard way to retrieve this information yet. Not only is the standard missing but people don't like to be tracked in general. A legal framework has to be developed by the governments so that people can be sure of their privacy. As there is a need for location based services, standards for retrieving the location of the terminal will be defined within the next few years. By the year 2005 it will be technically possible for an Internet service to make use of this kind of information.

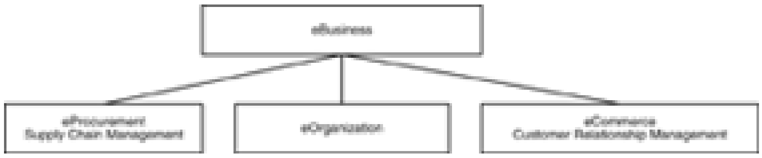
- A mobile interface to the order process system theoretically can be built with available technologies. Therefore, changing the order status and the order itself is possible today. Nevertheless, the system would be a pain to use as the transfer rates of current mobile Internet connections are very low and unreliable. The delivery of large quantities of GPRS terminals is still pending, contributing to the delays in the transition from 2G to 3G systems. It's expected that these terminals we gain market acceptance within the next 12 months [ttCtEPtE$^+$01].

- Version 1 of the document signing part is already in use world-wide by large transport companies. For the second version to work, digitally signed documents have to be accepted as legal documents by governments. For example, this is already the case in Germany. The people of Switzerland have to wait until mid-2001, when they can vote on the introduction of the new regulative work which will bring digital signatures into the legal system. As soon as this is accepted, governments have to help to build the needed infrastructures for CA, and the industry has to implement a standard way to introduce SIM card on which a person can save its private keys. This will add at least another year, so that the signing documents part will be practical in the year 2003 at the earliest.

4.3 eGovernment

4.3.1 Introduction

As eGovernment is a relative new research area there has been a lot of discussion about how to define eGovernment. In this document I will use the following definition from Michael Gisler [GS01]:



(Source: [GS01])

Fig. 4.4: Elemements of eBusiness

> *Definition eGovernment:* eGovernment as in regulative eGovernment defines the design of the environment for the information society, and eGovernment as in participating eGovernment defines the utilization of the new information and communication technologies by the public government.

According to his definition, eGovernment encompasses two things: (1) regulative eGovernment – the definition of the rules of how a information society should work together, and (2) participating eGorvernment – how the government should make use of new information and communication technologies.

If people speak of eGovernment they usually speak of eGovernment as in participating eGovernment, and if they speak of eGovernance, they usually mean eGovernment as in regulative eGovernment.

Regulative eGovernment Gisler [GS01] defines regulative eGovernment as follows:

> *Definition Regulative eGovernment:* Regulative eGovernment or eGovernance defines the design process of the environment for the information society. The definition may be used irrespective of the process being done by a private entity or a government.

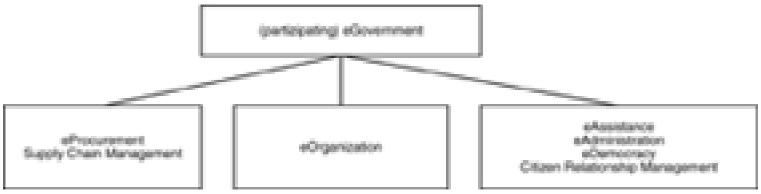
At the current pace at which our economy changes, especially at the speed it embraces technology, a government has no chance in trying to regulate all aspects of the environments of the society. As the changing speed only seems to get faster, a government has to trust the market to regulate itself and should only try to regulate those aspects of our life which aren't socially acceptable.[7]

In other words, regulative eGovernment is the work a government does in trying to regulate the organisational, legal and technical environment in order to allow all people, regardless of their social status, and businesses to access and use the devices and processes information and communication technologies make possible.

Participating eGovernment Again, I quote Gisler [GS01]:

> *Definition Participating eGovernment:* Participating eGovernment encompasses the support of the relationships, processes and political participation within the different levels of the government, as well as the ones between the different entities in the government and its partners by providing electronic possibilities for interaction between the entities.

[7] Schweizerischer Bundesrat: Strategie des Bundesrates für eine Informationsgesellschaft in der Schweiz vom 18. Februar 1998. Bern, 1998.



(Source: [GS01])

Fig. 4.5: Elemements of eGovernment

For an eGovernment solution to work properly you have to look at the whole process. Analogue to eBusiness, which can be split into the three elements eProcurement, eOrganisation and eCommerce (see figure 4.4), we have three fields in eGovernment (see figure 4.5). eGovernment suppliers fit into the field eProcurement, internal use of new information and communication technologies is called eOrganization and citizen relationship management is split into the three application fields eAssistance, eAdministration and eDemocracy.

Similar to successful eBusiness solutions, a critical point is that governments have to integrate the electronic communication between the different partners as seamlessly as possible into the one internally used [GS01], otherwise this might be fatal to the success of the eGovernment solution. A seamless integration of the used technologies also minimizes support requirements and costs because you don't have media or data format changes which might require different hardware or software, or even manual transfer onto a different system, and leverages the use from one department to the other [Pri00].

Citizen Expectations A study conducted by in Germany showed that a high percentage of citizens would like to use online services offered by the government: 70% of the people who own a computer, and 50% of the people who don't own a computer. The same study asked the citizens to rank different kinds of services according to their preference. The result was that people most wanted information about recreational services, such as ticket ordering, followed by online ordering of forms and 24 hours contact to the government. Interesting to note is that political participation did only show up in the lower ranks [Sch].

4.3.2 Scenario

The following section describes an eVoting scenario. eVoting is a part of eDemocracy, the government equivalent of B2C. The electronic voting platform is implemented as a Web application on the Internet. The citizen can interact with the system either using a full size Internet terminal, or using an Internet enabled PDA or mobile phone.

Before the actual election/day of voting, the government sends out an envelope to each citizen containing the following material[8]:

- A card which identifies the citizen and makes sure he can cast his vote only once.
- The ballots with which the citizen casts his vote.

[8] The male form is used for both, female and male.

- An envelope into which the ballots have to be put in order to make sure the voting is anonymous.

This material is used to either cast the vote in person, cast the vote by mail, or cast the vote in electronic form. The following walk-through explains you how the third possibility works:

1. The citizen opens a dedicated Web site where he will be presented with the different motions. Along with the choices to vote, he can get background information of the different motions.

2. For every motion he wants to cast his vote on, he first has to enter his vote and then has to click a button. By clicking the button his vote will be transfered into a basket, similar to the envelope for the non-electronic voting or the shopping basket of an Internet shopping application.

3. When he has finished selecting and entering his votes, he still has to make his cast final by clicking on a “Cast my votes”-button.

4. He then will be presented with a form where he has to enter his personal identification number from the card he received in the envelope from the government (his voting ID), and his mobile phone number.

5. Seconds later, his mobile phone receives a message from the voting system. The message states his name and the voting ID. The citizen now has to sign this message with his personal private key and send it back to the voting system. The signature process on the mobile phone is further protected with a PIN code only the user knows.

6. Finally, the voting system acknowledges that the voting was successful by presenting the user a message on the Web and by sending another message to the mobile phone.

As soon as the citizen has used his voting ID, the voting system ‘ticks off’ the respective ID in its database. Every voting ID will only be used once and will change for every election and voting. The message has to be signed with a key distributed by the government for a every single citizen. The reason the message with the voting ID has to be signed and sent back to the system is that (a) the citizen can be sure that only he can use the respective ID for voting and (b) the government can verify that citizen and ID belong together. After the verification process, the system could even throw away the voting ID in order guarantee the citizens privacy.

Ticking off or removing the voting ID is a necessary step, as the citizen still has the paper version. If he tries to cast another vote by mail or in person, the government can verify if a person did cast a vote already by checking the ID in the system. If the ID doesn’t exist, the citizen already casted a vote.

This verification process should be enough to make sure that fraud is nearly impossible.

Signing via Mobile Phone versus Signing via Email The presented solution could be implemented equally easy by sending the message to sign by email. Nevertheless, a smart card based solution in conjunction with a mobile phone offers some significant features over an email based solution:

- The private key on a smart card can't be read or copied directly. If the private key would reside on the hard disk on a citizens computer, it would be possible for a cracker to read, copy or destroy the private key, as it is just another file on the hard disk.
- It's possible for a computer virus to destroy the private key on a harddisk forever, as personal computers often don't get backed up. On the other hand it's nearly impossible to destroy the private key on the smart card without destroying the card completely.
- The citizen isn't restricted to cast his vote from his personal computer at home. As the message is signed with help of the mobile phone, the citizen can cast his votes from wherever he can take his mobile phone.
- It's very probable that a citizen looks after his mobile phone with the inserted smart card more careful than he would look after his private key of his certificate — which is nothing else than another file on his hard disk.

As it's more likely that a file on hard disk is destroyed than a mobile phone stolen, a smart card based solution seems to be more secure.

4.3.3 Technology

An eVoting scenario like the one presented in the previous section depends mainly on two things: a government supported CA including the regulations for digital signatures and certificates, and a smart card in a mobile phone that can be used to sign electronic documents. The upcoming USIM card that will be used in UMTS mobile phones would allow such an application. See section 4.1.3 for an overview of the USIM card.

Before a government can issue certificates to rely on digital signatures, a lot of regulative work has to be done to adapt the legal system. In Switzerland, the first step of the regulations has become effective on April 12, 2000 with the regulations for CAs [Der00], but it will take a while until the complete regulative work is finished. For further information on CAs, please see section 2.4.

4.3.4 Conclusions

eVoting offers a win-win situation for the government as well for the citizen: the government can streamline the process, lower costs, and is able to communicate more directly and optimize its business. While for the citizen political participation gets easier, information content will get better, and dealing with government affairs will get simpler and faster [Mül].

In the end, the citizen has to decide when he wants to trust digital signatures. Even though the technologies and regulations will be ready within the next two years, it might take much longer than expected to introduce cryptographic procedure in conjunction with government affairs. For example in Switzerland, the much simpler introduction and wide acceptance of safety belts in cars took decades [Gri01].

5. CONCLUSIONS

This thesis presented some of the most relevant technologies for mobile electronic communication devices that are available today. Some of these technologies aren't past the prototype stage yet, but offer potential to shape the future of mobile devices and how people interact with these devices. Of course predicting the future by extrapolating from the past and current social and technical trends is a very difficult issue.

5.1 Results

Personal Digital Agents will always be only useful for a specific kind of electronic commerce. By definition, PDAs are small mobile devices, thus they will always be restricted by the following limitations: small screen size and awkward input possibilities.

Nevertheless, as soon as manufacturers and telecommunication companies offer third generation phones and services, mobile commerce has a good chance to grow rapidly in the business-to-consumer market. Entertainment services, infotainment services, games and ticket services will profit from the new capabilities.

The business-to-business market can only make indirectly profit by using PDAs, either by offering a better service to customers thanks to PDAs, or by putting corporate information on an extranet, so that company information can be accessed anytime and anywhere by the employees.

In an eGovernment environment, future PDAs will only bring significant enhancements if they implement some means for identification, e.g., by integrating cryptographic functions on a smart card for use in conjunction with certificates. Otherwise, eGovernment users will mainly profit from public available information. Enventually they will be able to order a specific form using the Web, but they would still have to do all the paperwork.

5.2 Outlook

In the future different sized devices will be available. These devices won't differ that much in their technical capabilities as much as in how and where they are going to be used. It will be possible to have the power of todays personal computers in a wrist watch tomorrow.

It can be expected that Personal Digital Agents will vanish in the near future. Their functionality will taken over by mobile phones, so-called “Smart Phones”. These will offer larger screens than they do today. The user interacts with these devices over a touch-screen and a few buttons. The touch-screen can also be operated with a stylus,

(Source: Nokia)

Fig. 5.1: Concept Phone for UMTS

in a simliar fashion today's PDAs are operated. Mobile phones will be the most pervasive commodity. The status of a mobile phone has changed from "nice-to-have" to "need-to-have".

The next generation of mobile phones could look like the one in figure 5.1.

Bluetooth will be the standard for micro mobility, while UMTS and its derivates in Japan (FOMA) and America (cdma2000) will be the communication standard for macro mobility. Cheaper UMTS phones will use UMTS to connect to the Internet, while more expensive ones also implement a WLAN interface for fast access to the Internet in in-door environments.

The computing power of a mobile phone and the network connection will be enough to finally bring the video phone into existence, as most of the mobile phones will also have a small digital camera integrated. Color won't be a feature, it will be standard.

People might not own a computer, but they will own a mobile phone. Thus, it can be expected that the mobile phone will be the main tool for communication and information retrieval. If they buy a ticket, most of them will do it on the Internet using their mobile phone.

Larger mobile devices will be Web pads. Web pads are basically just a thin screen, but with the power of a full-size computer, thus replacing notebooks. A Bluetooth enabled keyboard and a mouse can be connected to a Web pad for easier user input. Web pads will come by default with Bluetooth and WLAN built-in, and probably also UMTS.

Telecommunication companies will fight a battle with credit card banks for standards for integrating an easy way to make payments over the Internet, using mobile phones. Eventually they have to join together or will even have merge in order to aquire and bundle the know-how and expertise. If these two businesses could work together, a secure standard for electronic payments will finally emerge.

The development for devices in the 4G area will focus on wearability. These devices will offer the same functionality as mobile phones do, but they will either be

(Source: [RKSHVVMN01])

Fig. 5.2: Future Mobile Device User Interfaces

integrated into clothes, or will be flexible and light weight enough to be worn all the time (c.f. figure 5.2).

In the future, dreams won't be limited by the technology to build it, but by the human who dreams it.

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