Mobile Phone Devices

(Development, Features, and Effects on Health & Society)

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Chapter 1

Introduction to Mobile Phone

Mobile phone

Mobile phone

Inventor	Martin Cooper
Launch year	1983
Company	Motorola

Availability   Worldwide

A **mobile phone** (also called **mobile**, **cellular telephone**, **cell phone** or **handphone**) is an electronic device used for full duplex two-way radio telecommunications over a cellular network of base stations known as cell sites. Mobile phones differ from cordless telephones, which only offer telephone service within limited range through a single base station attached to a fixed land line, for example within a home or an office.

A mobile phone allows its user to make and receive telephone calls to and from the public telephone network which includes other mobiles and fixed-line phones across the world. It does this by connecting to a cellular network owned by a mobile network operator. A key feature of the cellular network is that it enables seamless telephone calls even when the user is moving around wide areas via a process known as handoff or handover.

In addition to being a telephone, modern mobile phones also support many additional services, and accessories, such as SMS (or text) messages, e-mail, Internet access, gaming, Bluetooth and infrared short range wireless communication, camera, MMS messaging, MP3 player, radio and GPS. Low-end mobile phones are often referred to as feature phones, whereas high-end mobile phones that offer more advanced computing ability are referred to as smartphones.

The first handheld cellular phone was demonstrated by Martin Cooper of Motorola in 1973, using a handset weighing 2 kg (4.4 lb). In the year 1990, 12.4 million people worldwide had cellular subscriptions. By the end of 2009, only 20 years later, the number of mobile cellular subscriptions worldwide reached approximately 4.6 billion, 370 times the 1990 number, penetrating the developing economies and reaching the bottom of the economic pyramid.

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Hybrid (multi cards) mobile phone

Hybrid mobile phone has capability to use SIM card and RUIM card altogether. HT-mobile G75 use hybrid technology GSM-GSM/CDMA and it means we can use two SIM cards or one SIM card and one RUIM card known as Dual On mobile phone. Whereas HT-mobile G78 has the ability Triple Cards On: GSM+GSM+CDMA. The other Triple On mobile phone is Nexian Hybrid NX-271D.

Mobile phones in society

Market share
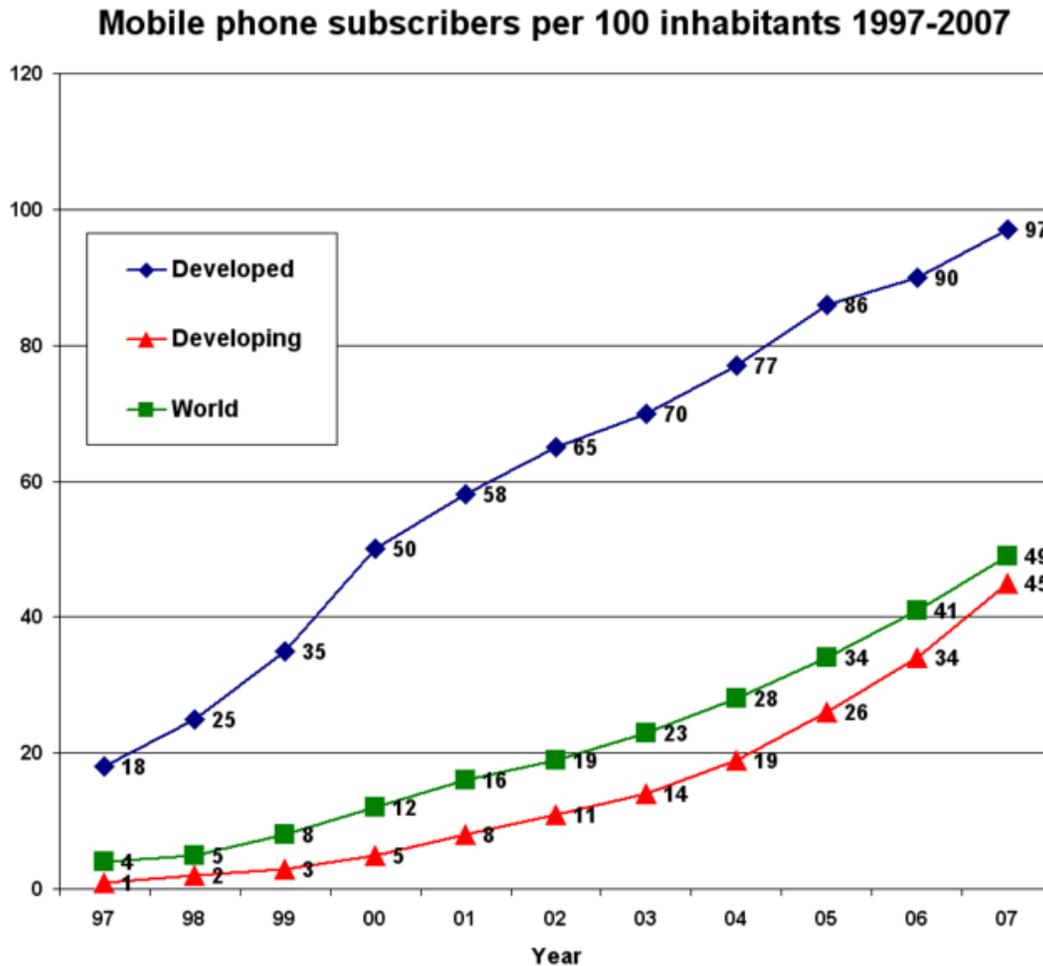
Mobile phone subscribers per 100 inhabitants 1997–2007

The world's largest individual mobile operator is China Mobile with over 500 million mobile phone subscribers. The world's largest mobile operator group by subscribers is UK-based Vodafone. There are over 600 mobile operators and carriers in commercial production worldwide. Over 50 mobile operators have over 10 million subscribers each, and over 150 mobile operators have at least one million subscribers by the end of 2009 (source wireless intelligence).

Source	Date	Nokia	SAMSUNG	LG	RIM	Sony Ericsson	Others	References
IDC	Q1/2010	36.6%	21.8%	9.2%	3.6%	3.6%	25.3%	
Gartner	Q1/2010	35.0%	20.6%	8.6%	3.4%	3.1%	29.3%	

Other manufacturers include Apple Inc., Audiovox (now UTStarcom), CECT, HTC Corporation, Fujitsu, Kyocera, Mitsubishi Electric, NEC, Panasonic, Palm, Matsushita, Pantech Wireless Inc., Philips, Qualcomm Inc., Research In Motion Ltd. (RIM), Sagem, Sanyo, Sharp, Sierra Wireless, SK Teletech, T&A Alcatel, Huawei, Trium, Toshiba and Vidalco. There are also specialist communication systems related to (but distinct from) mobile phones.

Media

In 1998, one of the first examples of selling media content through the mobile phone was the sale of ringtones by Radiolinja in Finland. Soon afterwards, other media content appeared such as news, videogames, jokes, horoscopes, TV content and advertising. Most early content for mobile tended to be copies of legacy media, such as the banner advertisement or the TV news highlight video clip. Recently, unique content for mobile has been emerging, from the ringing tones and ringback tones in music to "mobisodes," video content that has been produced exclusively for mobile phones.

In 2006, the total value of mobile-phone-paid media content exceeded Internet-paid media content and was worth 31 billion dollars (source Informa 2007). The value of music on phones was worth 9.3 billion dollars in 2007 and gaming was worth over 5 billion dollars in 2007.

The advent of media on the mobile phone has also produced the opportunity to identify and track Alpha Users or Hubs, the most influential members of any social community. AMF Ventures measured in 2007 the relative accuracy of three mass media, and found that audience measures on mobile were nine times more accurate than on the Internet and 90 times more accurate than on TV.

The mobile phone is often called the Fourth Screen (if counting cinema, TV and PC screens as the first three) or Third Screen (counting only TV and PC screens). It is also called the Seventh of the Mass Media (with Print, Recordings, Cinema, Radio, TV and Internet the first six).

Usage

Examples

Mobile phones are used for a variety of purposes, including keeping in touch with family members, conducting business, and having access to a telephone in the event of an emergency. Some people carry more than one cell phone for different purposes, such as for business and personal use. Multiple SIM cards may also be used to take advantage of the benefits of different calling plans—a particular plan might provide cheaper local calls, long-distance calls, international calls, or roaming. A study by Motorola found that one in ten cell phone subscribers have a second phone that often is kept secret from other family members. These phones may be used to engage in activities including extramarital

affairs or clandestine business dealings. The mobile phone has also been used in a variety of diverse contexts in society, for example:

- Organizations that aid victims of domestic violence may offer a cell phone to potential victims without the abuser's knowledge. These devices are often old phones that are donated and refurbished to meet the victim's emergency needs.
- Child predators have taken advantage of cell phones to communicate secretly with children without the knowledge of their parents or teachers.
- The advent of widespread text messaging has resulted in the cell phone novel; the first literary genre to emerge from the cellular age via text messaging to a website that collects the novels as a whole. Paul Levinson, in Information on the Move (2004), says "...nowadays, a writer can write just about as easily, anywhere, as a reader can read" and they are "not only personal but portable."
- Mobile telephony also facilitates activism and public journalism being explored by Reuters and Yahoo! and small independent news companies such as Jasmine News in Sri Lanka.
- Mobile phones help lift poor out of poverty. The United Nations report that mobile phones—spreading faster than any other information technology—can improve the livelihoods of the poorest people in developing countries. The economic benefits of mobile phones are go well beyond access to information where fixed-line or Internet are not yet available in rural areas, mostly in Least Developed Countries. Mobile phones have spawned a wealth of micro-enterprises, offering work to people with little education and few resources, such as selling airtime on the streets and repair or refurbishing handsets.

Sharing

In some parts of the world, mobile phone sharing is common. It is prevalent in urban India, as families and groups of friends often share one or more mobiles among their members. There are obvious economic benefits, but often familial customs and traditional gender roles play a part. For example, in Burkina Faso, it is not uncommon for a village to have access to only one mobile phone. The phone is typically owned by a person who is not natively from the village, such as a teacher or missionary, but it is the expected that other members of the village are allowed to use the cell phone to make necessary calls.

Environmental issues

The ubiquitousness and rapid technological change has led to mobile phones becoming a component of the waste stream. Electronic waste such as mobile phones contain materials that are toxic when they enter into ecosystems and recycling is now carried out to some extent.

Comparison to similar systems

Car phone
> A type of telephone permanently mounted in a vehicle, these often have more powerful transmitters, an external antenna and loudspeaker for hands free use. They usually connect to the same networks as regular mobile phones.

Cordless telephone (portable phone)
> Cordless phones are telephones which use one or more radio handsets in place of a wired handset. The handsets connect wirelessly to a base station, which in turn connects to a conventional land line for calling. Unlike mobile phones, cordless phones use private base stations (belonging to the land-line subscriber), which are not shared.

Professional Mobile Radio
> Advanced professional mobile radio systems can be very similar to mobile phone systems. Notably, the IDEN standard has been used as both a private trunked radio system as well as the technology for several large public providers. Similar attempts have even been made to use TETRA, the European digital PMR standard, to implement public mobile networks.

Radio phone
> This is a term which covers radios which could connect into the telephone network. These phones may not be mobile; for example, they may require a mains power supply, or they may require the assistance of a human operator to set up a PSTN phone call.

Satellite phone
> This type of phone communicates directly with an artificial satellite, which in turn relays calls to a base station or another satellite phone. A single satellite can provide coverage to a much greater area than terrestrial base stations. Since satellite phones are costly, their use is typically limited to people in remote areas where no mobile phone coverage exists, such as mountain climbers, mariners in the open sea, and news reporters at disaster sites.

IP Phone
> This type of phone delivers or receives calls over internet, LAN or WAN networks using VoIP as opposed to traditional CDMA and GSM networks. In business, the majority of these IP Phones tend to be connected via wired Ethernet, however wireless varieties do exist. Several vendors have developed standalone WiFi phones. Additionally, some cellular mobile phones include the ability to place VoIP calls over cellular high speed data networks and/or wireless internet.

Chapter 2

History of Mobile Phones

The **history of mobile phones** begins with early efforts to develop mobile telephony concepts using two-way radios and continues through emergence of modern mobile phones and associated services.

Radiophones have a long and varied history going back to Reginald Fessenden's invention and shore-to-ship demonstration of radio telephony, through the Second World War with military use of radio telephony links and civil services in the 1950s, while hand-held mobile radio devices have been available since 1973. Mobile phone history is often divided into *generations* (first, second, third and so on) to mark significant step changes in capabilities as the technology improved over the years.

Pioneers of radio telephony

The early years of the 20th century saw the first attempts at wireless and mobile telephony. In 1908, U.S. Patent 887,357 for a wireless telephone was issued to Nathan B. Stubblefield of Murray, Kentucky. He applied this patent to "cave radio" telephones and not directly to cellular telephony as the term is currently understood. Two years later Lars Magnus Ericsson installed a telephone in his car, although this was not a radio telephone. While travelling across the country, he would stop at a place where telephone lines were accessible and using a pair of long electric wires he could connect to the national telephone network.

In Europe, radio telephony was first used on the first-class passenger trains between Berlin and Hamburg in 1926. At the same time, radio telephony was introduced on passenger airplanes for air traffic security. Later radio telephony was introduced on a large scale in German tanks during the Second World War. After the war German police in the British zone of occupation first used disused tank telephony equipment to run the first radio patrol cars. In all of these cases the service was confined to specialists that were trained to use the equipment. In the early 1950s ships on the Rhine were among the first to use radio telephony with an untrained end customer as a user.

However it was the 1940s onwards that saw the seeds of technological development which would eventually produce the mobile phone that we know today. Motorola developed a backpacked two-way radio, the Walkie-Talkie and a large hand-held two-

way radio for the US military. This battery powered "Handie-Talkie" (HT) was about the size of a man's forearm. In 1946 soviet engineers G. Shapiro and I. Zaharchenko successfully tested their version of a radio mobile phone mounted inside a car. The device could connect to local telephone network with a range of up to 20 kilometers.

Top of cellular telephone tower

In December 1947, Douglas H. Ring and W. Rae Young, Bell Labs engineers, proposed hexagonal cells for mobile phones in vehicles. Philip T. Porter, also of Bell Labs, proposed that the cell towers be at the corners of the hexagons rather than the centers and have directional antennas that would transmit/receive in three directions into three adjacent hexagon cells. At this stage the technology to implement the ideas did not exist nor had the frequencies had been allocated and it would be some years until Richard H. Frenkiel and Joel S. Engel of Bell Labs developed the electronics to achieve this in the 1960s.

During the 1950s the experiments of the pioneers started to appear as usable services across society, both commercially and culturally. In the 1954 movie *Sabrina*, the businessman Linus Larrabee (played by Humphrey Bogart) makes a call from the phone in the back of his limousine. In 1957 a young Soviet radio engineer Leonid Kupriyanovich from Moscow created a portable mobile phone, and named it the LK-1 after himself. This mobile phone consisted of a relatively small handset equipped with an antenna and rotary dial, and communicated with a base station. The LK-1 weighed 3 kilograms and could operate in a range of up to 20 or 30 kilometers. The battery lasted 20 to 30 hours. The LK-1 was depicted in popular Soviet magazines as *Nauka i zhizn*. Kupriyanovich patented his mobile phone in the same year. The base station serving the LK-1 (called ATR, or Automated Telephone Radiostation) could connect to local telephone network and serve several customers. During 1958, Kupriyanovich produced a "pocket" version. The weight of improved lighter handset was about 500 grams.

In 1969, a patent for a wireless phone using an acoustic coupler for incoming calls was issued in US Patent Number 3,449,750 to George Sweigert of Euclid, Ohio on June 10, 1969, but did not include dialing a number for outgoing calls.

In all these early examples, a mobile phone had to stay within the cell area serviced by one base station throughout the phone call, i.e. there was no continuity of service as the phones moved through several cell areas. The concepts of frequency reuse and handoff, as well as a number of other concepts that formed the basis of modern cell phone technology, were described in the 1970s. In 1970 Amos E. Joel, Jr., a Bell Labs engineer, invented an automatic "call handoff" system to allow mobile phones to move through several cell areas during a single conversation without interruption.

In December 1971, AT&T submitted a proposal for cellular service to the Federal Communications Commission (FCC). After years of hearings, the FCC approved the proposal in 1982 for Advanced Mobile Phone System (AMPS) and allocated frequencies in the 824–894 MHz band. Analog AMPS was eventually superseded by Digital AMPS in 1990.

A cellular telephone switching plan was described by Fluhr and Nussbaum in 1973, and a cellular telephone data signaling system was described in 1977 by Hachenburg et al. In 1979 a U.S. Patent 4,152,647 was issued to Charles A. Gladden and Martin H. Parelman, of Las Vegas for an emergency cellular system for rapid deployment in areas where there was no cellular service.

Emergence of commercial mobile phone services

Alongside the early developments outlined above, a different technology was also growing in popularity. Two-way mobile radios (known as mobile rigs) were used in vehicles such as taxicabs, police cruisers, and ambulances, but were not mobile phones, because they were not connected to the telephone network. A large community of mobile radio users, known as mobileers, popularized this technology that would eventually give way to the mobile phone. Originally, they were installed permanently in vehicles, but portable versions were later developed known as transportables or "bag phones".

The first fully automated mobile phone system for vehicles was launched in Sweden in 1960. Named MTA (Mobile Telephone system A), it allowed calls to be made and received in the car using a rotary dial. The car phone could also be paged. Calls from the car were direct dial, whereas incoming calls required an operator to determine which base station the phone was currently at. It was developed Sture Laurén and other engineers at Televerket network operator. Ericsson provided the switchboard while Svenska Radioaktiebolaget (SRA) and Marconi provided the telephones and base station equipment. MTA phones consisted of vacuum tubes and relays, and weighed 40 kg. In 1962, an upgraded version called *Mobile System B (MTB)* was introduced. This was a push-button telephone, and used transistors and DTMF signaling to improve its operational reliability. In 1971 the MTD version was launched, opening for several

different brands of equipment and gaining commercial success. The network remained open until 1983 and still had 600 customers when it closed.

In 1958 development began on a similar system for motorists in the USSR. The "Altay" national civil mobile phone service was based on Soviet MRT-1327 standard. The main developers of the Altay system were the Voronezh Science Research Institute of Communications (VNIIS) and the State Specialized Project Institute (GSPI). In 1963 the service started in Moscow, and by 1970 was deployed in 30 cities across the USSR. Versions of the Altay system are still in use today as a trunking system in some parts of Russia.

In 1959 a private telephone company located in Brewster, Kansas, USA, the S&T Telephone Company, (still in business today) with the use of Motorola Radio Telephone equipment and a private tower facility, offered to the public mobile telephone services in that local area of NW Kansas. This system was a direct dial up service through their local switchboard, and was installed in many private vehicles including grain combines, trucks, and automobiles. For some as yet unknown reason, the system, after being placed online and operated for a very brief time period, was shut down. The management of the company was immediately changed, and the fully operable system and related equipment was immediately dismantled in early 1960, not to be seen again.

In 1966, Bulgaria presented the pocket mobile automatic phone RAT-0,5 combined with a base station RATZ-10 (RATC-10) on Interorgtechnika-66 international exhibition. One base station, connected to one telephone wire line, could serve up to six customers.

One of the first successful public commercial mobile phone networks was the ARP network in Finland, launched in 1971. Posthumously, ARP is sometimes viewed as a *zero generation* (0G) cellular network, being slightly above previous proprietary and limited coverage networks.

Handheld cell phone
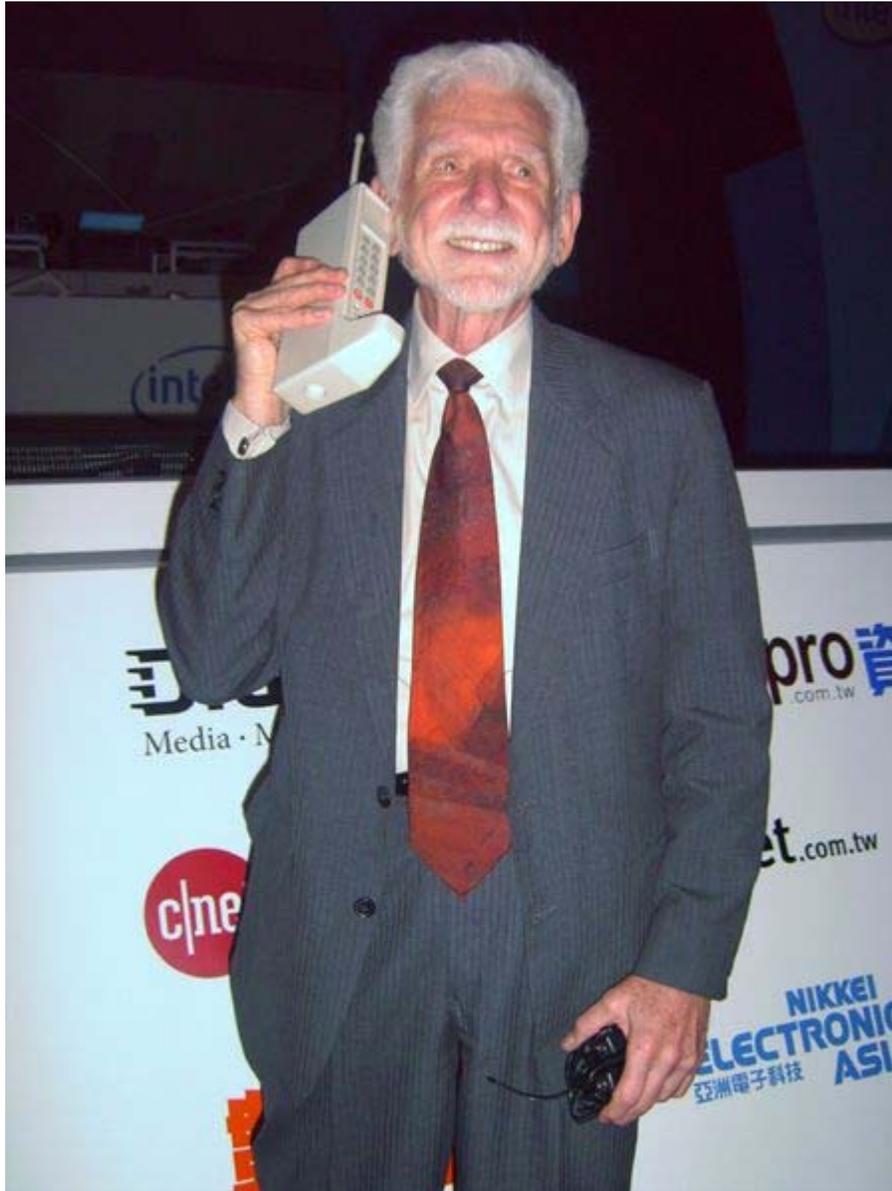
Dr. Martin Cooper of Motorola, made the first US analogue mobile phone call on a larger prototype model in 1973. This is a reenactment in 2007

The modern handheld cell phone era began in 1973 when Motorola invented the first cellular portable telephone to be commercialised, known as Motorola DynaTAC 8000X. Martin Cooper, a Motorola researcher and executive is considered to be the inventor of this mobile phone for use in a non-vehicle setting. There was a long race between Motorola and Bell Labs to produce the first such portable mobile phone. Cooper is the first inventor named on "Radio telephone system" filed on October 17, 1973 with the US Patent Office and later issued as US Patent 3,906,166. Other named contributors on the

patent included Cooper's boss, John F. Mitchell, Motorola's chief of portable communication products, who successfully pushed Motorola to develop wireless communication products that would be small enough to use outside the home, office or automobile and he participated in the design of the cellular phone. Using a heavy prototype mobile phone, Cooper made the first handheld cellular phone call on April 3, 1973 to Dr. Joel S. Engel of Bell Labs..

First generation: Cellular networks

The technological development that distinguished the First Generation mobile phones from the previous generation was the use of multiple cell sites, and the ability to transfer calls from one site to the next as the user travelled between cells during a conversation. The first commercially automated cellular network (the 1G generation) was launched in Japan by NTT in 1979. The initial launch network covered the full metropolitan area of Tokyo's over 20 million inhabitants with a cellular network of 23 base stations. Within five years, the NTT network had been expanded to cover the whole population of Japan and became the first nation-wide 1G network.

Analog Motorola DynaTAC 8000X Advanced Mobile Phone System mobile phone as of 1983

The next 1G network to launch was the Nordic Mobile Telephone (NMT) system in Denmark, Finland, Norway and Sweden in 1981.. NMT was the first mobile phone network featuring international roaming. The Swedish electrical engineer Östen Mäkitalo started work on this vision in 1966, and is considered to be the father of the NMT system, and by some the father of the cellular phone itself. The NMT installations were based on the Ericsson AXE digital exchange nodes.

Several other countries also launched 1G networks in the early 1980s including the UK, Mexico and Canada. A two year trial started in 1981 in Baltimore and Washington DC with 150 users and 300 Motorola DynaTAC pre-production phones. This took place on a

seven tower cellular network that covered the area. The DC area trial turned into a commercial services in about 1983 with fixed cellular car phones also built by Motorola. They later added the 8000X to their Cellular offerings. A similar trial and commercial launch also took place in Chicago by Ameritech in 1983 using the famous first hand-held mobile phone Motorola DynaTAC.

As mentioned above, in 1982 the FCC approved AT&T's 1971 proposal for Advanced Mobile Phone System (AMPS) and allocated frequencies in the 824–894 MHz band. Analog AMPS was superseded by Digital AMPS in 1990.

In 1984, Bell Labs developed modern commercial cellular technology (based, to a large extent, on the Gladden, Parelman Patent), which employed multiple, centrally controlled base stations (cell sites), each providing service to a small area (a cell). The cell sites would be set up such that cells partially overlapped. In a cellular system, a signal between a base station (cell site) and a terminal (phone) only need be strong enough to reach between the two, so different base stations could operate using the same frequencies with little or no interference.

Vodafone made the UK's first mobile call at a few minutes past midnight on 1 January 1985.

The technology in these early networks was pushed to the limit to accommodate increasing usage. The base stations and the mobile phones utilised variable transmission power, which allowed range and cell size to vary. As the system expanded and neared capacity, the ability to reduce transmission power allowed new cells to be added, resulting in more, smaller cells and thus more capacity. The evidence of this growth can still be seen in the many older, tall cell site towers with no antennae on the upper parts of their towers. These sites originally created large cells, and so had their antennae mounted atop high towers; the towers were designed so that as the system expanded—and cell sizes shrank—the antennae could be lowered on their original masts to reduce range.

Second generation: Digital networks

Two 1991 GSM mobile phones with several AC adapters

In the 1990s, the 'second generation' (2G) mobile phone systems emerged, primarily using the GSM standard. These 2G phone systems differed from the previous generation in their use of digital transmission instead of analog transmission, and also by the introduction of advanced and fast phone-to-network signaling. The rise in mobile phone usage as a result of 2G was explosive and this era also saw the advent of prepaid mobile phones

In 1991 the first GSM network (Radiolinja) launched in Finland. In general the frequencies used by 2G systems in Europe were higher than those in America, though with some overlap. For example, the 900 MHz frequency range was used for both 1G and 2G systems in Europe, so the 1G systems were rapidly closed down to make space for the 2G systems. In America the IS-54 standard was deployed in the same band as AMPS and displaced some of the existing analog channels.

Coinciding with the introduction of 2G systems was a trend away from the larger "brick" phones toward tiny 100–200g hand-held devices. This change was possible not only through technological improvements such as more advanced batteries and more energy-efficient electronics, but also related to the higher density of cellular sites needed because of increasing usage. The latter meant that the average distance transmission from phone to handset shortened. Both factors led to increased battery life for customers whilst on the move.

Personal Handy-phone System mobiles and modems used in Japan around 1997–2003

The second generation introduced a new variant of communication called SMS or text messaging. It was initially available only on GSM networks but spread eventually on all digital networks. The first machine-generated SMS message was sent in the UK on 3 December 1992 followed in 1993 by the first person-to-person SMS sent in Finland. The advent of prepaid services in the late 1990s soon made SMS the communication method of choice amongst the young, a trend which spread across all ages.

2G also introduced the ability to access media content on mobile phones. In 1998 the first downloadable content sold to mobile phones was the ring tone, launched by Finland's Radiolinja (now Elisa). Advertising on the mobile phone first appeared in Finland when a free daily SMS news headline service was launched in 2000, sponsored by advertising.

Mobile payments were trialled in 1998 in Finland and Sweden where a mobile phone was used to pay for a Coca Cola vending machine and car parking. Commercial launches followed in 1999 in Norway. The first commercial payment system to mimic banks and credit cards was launched in the Philippines in 1999 simultaneously by mobile operators Globe and Smart.

The first full internet service on mobile phones was introduced by NTT DoCoMo in Japan in 1999.

Third generation: High speed IP data networks

As the use of 2G phones became more widespread and people began to utilize mobile phones in their daily lives, it became clear that demand for data services (such as access to the internet) was growing. Furthermore, experience from fixed broadband services showed there would also be an ever increasing demand for greater data speeds. The 2G technology was nowhere near up to the job, so the industry began to work on the next generation of technology known as 3G. The main technological difference that distinguishes 3G technology from 2G technology is the use of packet switching rather than circuit switching for data transmission. In addition, the standardization process focused on requirements more than technology (2 Mbit/s maximum data rate indoors, 384 kbit/s outdoors, for example).

Inevitably this led to many competing standards with different contenders pushing their own technologies, and the vision of a single unified worldwide standard looked far from reality. The standard 2G CDMA networks became 3G compliant with the adoption of Revision A to EV-DO, which made several additions to the protocol whilst retaining backwards compatibility:

- the introduction of several new forward link data rates that increase the maximum burst rate from 2.45 Mbit/s to 3.1 Mbit/s.
- protocols that would decrease connection establishment time.
- the ability for more than one mobile to share the same time slot.
- the introduction of QoS flags.

All these were put in place to allow for low latency, low bit rate communications such as VoIP.

The first pre-commercial trial network with 3G was launched by NTT DoCoMo in Japan in the Tokyo region in May 2001. NTT DoCoMo launched the first commercial 3G network on October 1, 2001, using the WCDMA technology. In 2002 the first 3G networks on the rival CDMA2000 1xEV-DO technology were launched by SK Telecom

and KTF in South Korea, and Monet in the USA. Monet has since gone bankrupt. By the end of 2002, the second WCDMA network was launched in Japan by Vodafone KK (now Softbank). European launches of 3G were in Italy and the UK by the Three/Hutchison group, on WCDMA. 2003 saw a further 8 commercial launches of 3G, six more on WCDMA and two more on the EV-DO standard.

During the development of 3G systems, 2.5G systems such as CDMA2000 1x and GPRS were developed as extensions to existing 2G networks. These provide some of the features of 3G without fulfilling the promised high data rates or full range of multimedia services. CDMA2000-1X delivers theoretical maximum data speeds of up to 307 kbit/s. Just beyond these is the EDGE system which in theory covers the requirements for 3G system, but is so narrowly above these that any practical system would be sure to fall short.

The high connection speeds of 3G technology enabled a transformation in the industry: for the first time, media streaming of radio (and even television) content to 3G handsets became possible, with companies such as RealNetworks and Disney among the early pioneers in this type of offering.

In the mid 2000s an evolution of 3G technology begun to be implemented, namely High-Speed Downlink Packet Access (HSDPA). It is an enhanced 3G (third generation) mobile telephony communications protocol in the High-Speed Packet Access (HSPA) family, also coined 3.5G, 3G+ or turbo 3G, which allows networks based on Universal Mobile Telecommunications System (UMTS) to have higher data transfer speeds and capacity. Current HSDPA deployments support down-link speeds of 1.8, 3.6, 7.2 and 14.0 Mbit/s. Further speed increases are available with HSPA+, which provides speeds of up to 42 Mbit/s downlink and 84 Mbit/s with Release 9 of the 3GPP standards.

By the end of 2007 there were 295 Million subscribers on 3G networks worldwide, which reflected 9% of the total worldwide subscriber base. About two thirds of these were on the WCDMA standard and one third on the EV-DO standard. The 3G telecoms services generated over 120 Billion dollars of revenues during 2007 and at many markets the majority of new phones activated were 3G phones. In Japan and South Korea the market no longer supplies phones of the second generation. Earlier in the decade there were doubts about whether 3G might happen, and also whether 3G might become a commercial success. By the end of 2007 it had become clear that 3G was a reality and was clearly on the path to become a profitable venture.

Growth of mobile broadband and the emergence of 4G

Although mobile phones had long had the ability to access data networks such as the Internet, it was not until the widespread availability of good quality 3G coverage in the mid 2000s that specialised devices appeared to access the mobile internet. The first such devices, known as "dongles", plugged directly into a computer through the USB port. Another new class of device appeared subsequently, the so-called "compact wireless router" such as the Novatel MiFi, which makes 3G internet connectivity available to

multiple computers simultaneously over Wi-Fi, rather than just to a single computer via a USB plug-in.

Such devices became especially popular for use with laptop computers due to the added portability they bestow. Consequently, some computer manufacturers started to embed the mobile data function directly into the laptop so a dongle or MiFi wasn't needed. Instead, the SIM card could be inserted directly into the device itself to access the mobile data services. Such 3G-capable laptops became commonly known as "netbooks". Other types of data-aware devices followed in the netbook's footsteps. By the beginning of 2010, E-readers, such as the Amazon Kindle and the Nook from Barnes & Noble, had already become available with embedded wireless internet, and Apple Computer had announced plans for embedded wireless internet on its iPad tablet devices beginning that Fall.

By 2009, it had become clear that, at some point, 3G networks would be overwhelmed by the growth of bandwidth-intensive applications like streaming media. Consequently, the industry began looking to data-optimized 4th-generation technologies, with the promise of speed improvements up to 10-fold over existing 3G technologies. The first two commercially available technologies billed as 4G were the WiMAX standard (offered in the U.S. by Sprint) and the LTE standard, first offered in Scandinavia by TeliaSonera.

One of the main ways in which 4G differed technologically from 3G was in its elimination of circuit switching, instead employing an all-IP network. Thus, 4G ushered in a treatment of voice calls just like any other type of streaming audio media, utilizing packet switching over internet, LAN or WAN networks via VoIP.

Chapter 3

Mobile Phone Features

There are many **mobile phone features** found in today's mobile phones that offer users many more capabilities than only voice calls or text messaging.

General features

Mobile phones are designed to work on cellular networks and contain a standard set of services that allow phones of different types and in different countries to communicate with each other. However, they can also support other features added by various manufacturers over the years:

- roaming which permits the same phone to be used in multiple countries, providing that the operators of both countries have a roaming agreement.
- send and receive data and faxes (if a computer is attached), access WAP services, and provide full Internet access using technologies such as GPRS.
- applications like a clock, alarm, calendar and calculator and a few games.
- Sending and receiving pictures and videos through MMS, and for short distances with e.g. Bluetooth.
- GPS receivers integrated or connected (i.e. using Bluetooth) to cell phones, primarily to aid in dispatching emergency responders and road tow truck services. This feature is generally referred to as E911.
- Push to talk, available on some mobile phones, is a feature that allows the user to be heard only while the talk button is held, similar to a walkie-talkie.
- features aimed toward personalisation, such as user defined and downloadable ring tones and logos, and interchangeable covers, which have helped in the uptake by the teenage market. Mobile phone content advertising has become massively popular but has also drawn a great deal of criticism. Usually one can choose between a ring tone, a vibrating alert, or a combination of both.

As a result of all these features packed into a tiny device, mobile phones have recently gained reputations for their poor ergonomics. Their small size, plethora of features and modes, and attempts at stylish design may make them difficult and confusing to use.

Multi-mode and multi-band mobile phones

Most mobile phone networks are digital and use the GSM, CDMA or iDEN standard which operate at various radio frequencies. A multi-mode phone operates across different standards whereas a multi-band phone (also known more specifically as dual, tri or quad band) mobile phone is a phone which is designed to work on more than one radio frequency. Some multi-mode phones can operate on analog networks as well (for example, dual band, tri-mode: AMPS 800 / CDMA 800 / CDMA 1900).

For a GSM phone, dual-band usually means 850 / 1900 MHz in the United States and Canada, 900 / 1800 MHz in Europe and most other countries. Tri-band means 850 / 1800 / 1900 MHz or 900 / 1800 / 1900 MHz. Quad-band means 850 / 900 / 1800 / 1900 MHz, also called a world phone, since it can work on any GSM network.

Multi-band phones have been valuable to enable roaming whereas multi-mode phones helped to introduce WCDMA features without customers having to give up the wide coverage of GSM. Almost every single true 3G phone sold is actually a WCDMA/GSM *dual-mode* mobile. This is also true of 2.75G phones such as those based on CDMA-2000 or EDGE.

Challenges in producing multi-mode phones

The special challenge involved in producing a multi-mode mobile is in finding ways to share the components between the different standards. Obviously, the phone keypad and display should be shared, otherwise it would be hard to treat as one phone. Beyond that, though, there are challenges at each level of integration. How difficult these challenges are depends on the differences between systems. When talking about IS-95/GSM multi-mode phones, for example, or AMPS/IS-95 phones, the base band processing is very different from system to system. This leads to real difficulties in component integration and so to larger phones.

An interesting special case of multi-mode phones is the WCDMA/GSM phone. The radio interfaces are very different from each other, but mobile to core network messaging has strong similarities, meaning that software sharing is quite easy. Probably more importantly, the WCDMA air interface has been designed with GSM compatibility in mind. It has a special mode of operation, known as punctured mode, in which, instead of transmitting continuously, the mobile is able to stop sending for a short period and try searching for GSM carriers in the area. This mode allows for safe inter-frequency handovers with channel measurements which can only be approximated using "pilot signals" in other CDMA based systems.

A final interesting case is that of mobiles covering the DS-WCDMA and MC-CDMA 3G variants of the CDMA-2000 protocol. Initially, the chip rate of these phones was incompatible. As part of the negotiations related to patents, it was agreed to use compatible chip rates. This should mean that, despite the fact that the air and system interfaces are quite different, even on a philosophical level, much of the hardware for

each system inside a phone should be common with differences being mostly confined to software.

Data Communications

Mobile Web

The **Mobile Web** refers to the use of Internet-connected applications, or browser-based access to the Internet from a mobile device - such as a smartphone or tablet PC - connected to a wireless network.

In 2008 an important milestone in the transition from fixed to mobile Web use was reached when mobile access to the Internet exceeded desktop computer-based access for the first time (source: International Telecommunications Union, Oct 2009).

Mobile Web access today still suffers from interoperability and usability problems. Interoperability issues stem from the platform fragmentation of mobile devices, mobile operating systems, and browsers. Usability problems are centered around the small physical size of the mobile phone form factors (limited resolution screens and user input/operating limitations).

The distinction between the Mobile Web and native mobile applications is anticipated to become increasingly blurred, as mobile browsers gain direct access to the hardware of mobile devices (including accelerometers and GPS chips), and the performance of browser-based applications improve (speed- and capability-wise). Persistent storage and access to sophisticated user interface graphics functions may further reduce the need for the development of platform-specific native applications.

Once users are unable to differentiate between native and mobile web applications, the Mobile Web will refer generically accessing the web from a mobile device.

Mobile Internet

'Mobile Internet' refers to access to the Internet from a mobile device, such as a smartphone or laptop via integrated capabilities or via an independent device (such as a USB modem or PCMCIA card).

Today USB modems are HSPA (3.5G) modems. Many users "tether" their smartphones to their laptop or personal computer with the wireless device providing access to the Internet via 3G, GPRS or CSD.

Standards

Total data consumed by Opera Mini users worldwide (TB)
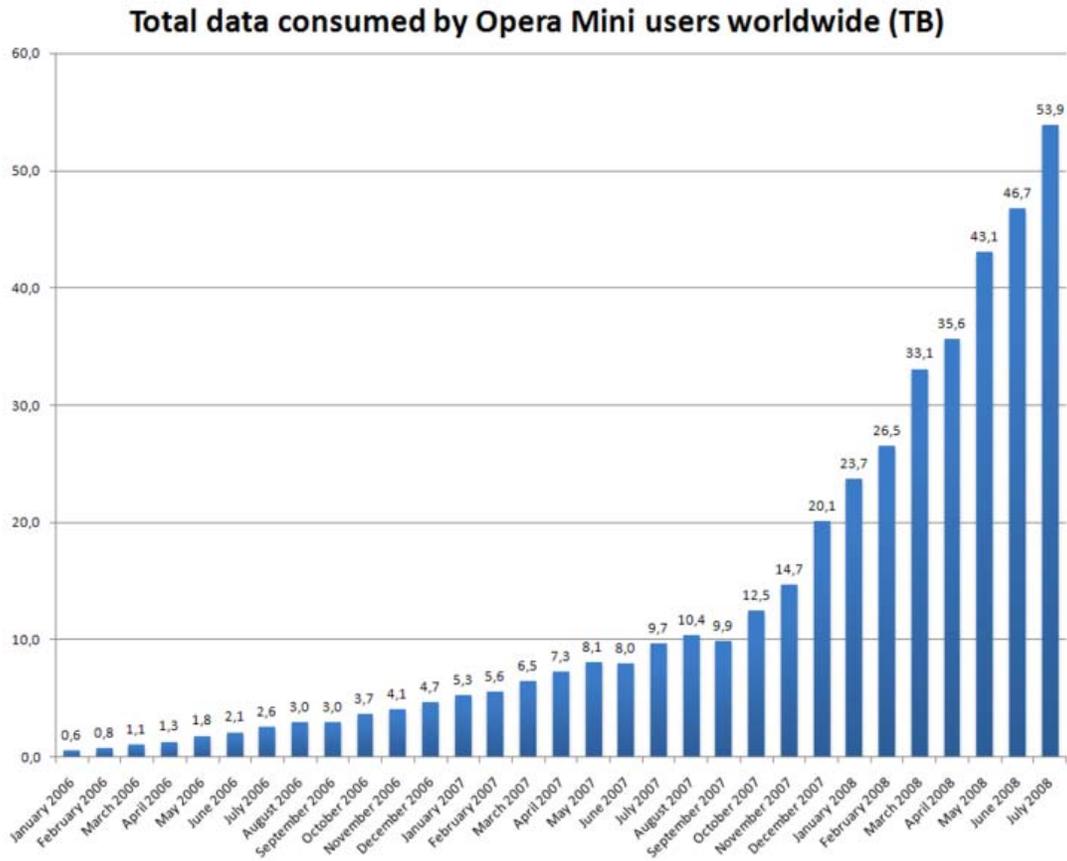
Total data consumed by Opera Mini users worldwide from 2006 to mid-2008 in TB

The development of standards is one approach being implemented to improve the interoperability, usability, and accessibility issues surrounding mobile web usage.

The Mobile Web Initiative (MWI) is a new initiative set up by the W3C to develop best practices and technologies relevant to the Mobile Web. The goal of the initiative is to make browsing the Web from mobile devices more reliable and accessible. The main aim is to evolve standards of data formats from Internet providers that are tailored to the specifications of particular mobile devices. The W3C has published guidelines for mobile content, and is actively addressing the problem of device diversity by establishing a technology to support a repository of device descriptions.

W3C is also developing a validating scheme to assess the readiness of content for the mobile web, through its *mobileOK Scheme*, which will help content developers to quickly determine if their content is web-ready. The W3C guidelines and mobile OK approach have not been immune from criticism. This puts the emphasis on Adaptation, which is now seen as the key process in achieving the ubiquitous web, when combined with a device description repository.
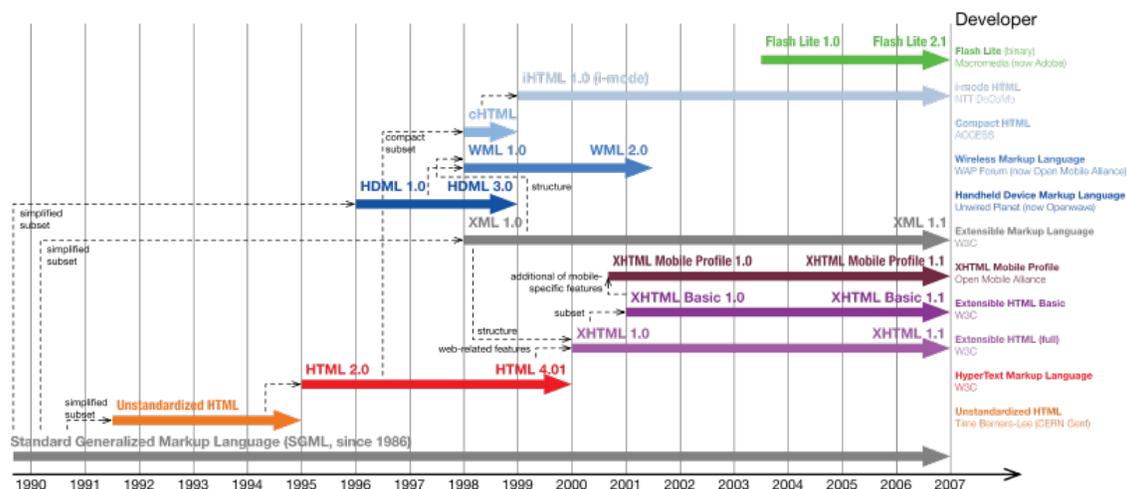
mTLD, the registry for .mobi, has released a free testing tool called the MobiReady Report to analyze the mobile readiness of website. It does a free page analysis and gives a Mobi Ready score. This report tests the mobile-readiness of the site using industry best practices and standards.

Other standards for the mobile web are being documented and explored for particular applications by interested industry groups, such as the use of the mobile web for the purpose of education and training.

Development

The first access to the mobile web was commercially offered in Finland in 1996 on the Nokia 9000 Communicator phone via the Sonera and Radiolinja networks. This was access to the real internet. The first commercial launch of a mobile-specific browser-based web service was in 1999 in Japan when i-mode was launched by NTT DoCoMo.

Evolution of mobile web standards

The Mobile Web primarily utilises lightweight pages written in Extensible Hypertext Markup Language (XHTML) or Wireless Markup Language (WML) to deliver content to mobile devices. Many new mobile browsers are moving beyond these limitations by supporting a wider range of Web formats, including variants of HTML commonly found on the desktop Web.

Top-level domain

The .mobi sponsored top-level domain was launched specifically for the mobile Internet by a consortium of companies including Google, Microsoft, Nokia, Samsung, and Vodafone. By forcing sites to comply with mobile web standards, .mobi tries to ensure

visitors a consistent and optimized experience on their mobile device. However, this domain has been criticized by several big names, including Tim Berners-Lee of the W3C, who claims that it breaks the device independence of the web: 1

It is fundamentally useful to be able to quote the URI for some information and then look up that URI in an entirely different context. For example, I may want to look up a restaurant on my laptop, bookmark it, and then, when I only have my phone, check the bookmark to have a look at the evening menu. Or, my travel agent may send me a pointer to my itinerary for a business trip. I may view the itinerary from my office on a large screen and want to see the map, or I may view it at the airport from my phone when all I want is the gate number. Dividing the Web into information destined for different devices, or different classes of user, or different classes of information, breaks the Web in a fundamental way. I urge ICANN not to create the ".mobi" top level domain.

Seven mass media

Since the first ringing tone was sold on the mobile phone in Finland in 1998, the mobile has emerged as the seventh of the mass media. Today a wide range of paid media content is consumed on mobile phones ranging from 9.3 billion dollars of music and 5 billion dollars of videogaming to horoscopes, virtual gifts, jokes, news, adult entertainment, etc. Also like on all other media, advertising appeared onto mobile when a free news service launched in Finland sponsored by ads in 2000. In 2005, The Crazy Frog ringtone became the first mobile ringtone to cross over into the mainstream music charts, beating Coldplay for the Number 1 spot on the UK charts.

Advertising

Advertisers are increasingly using the mobile Web as platform to reach consumers. The total value of advertising on mobile was 2.2 billion dollars in 2007. A recent study by the Online Publishers Association reports that about one-in-ten mobile Web users said they have made a purchase based on a mobile Web ad, while 23% said they have visited a Web site, 13% said they have requested more information about a product or service and 11% said they have gone to a store to check out a product.

Limitations
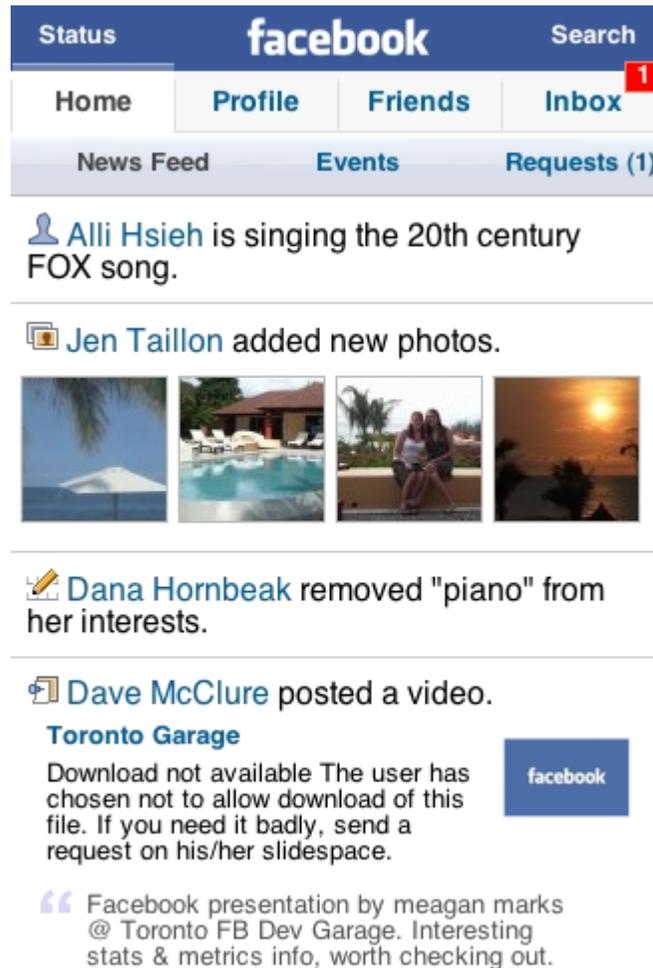
Social network service mobile graphical user interface (Facebook)

Though Internet access "on the go" provides advantages to many, such as the ability to communicate by email with others and obtain information anywhere, the web, accessed from mobile devices, has a large number of limitations, which may vary, depending on the device. However, newer smartphones such as the iPhone and those using the Android operating system overcome some of these restrictions. Some problems which may be encountered include:

- **Small screen size** – This makes it difficult or impossible to see text and graphics dependent on the standard size of a desktop computer screen.
- **Lack of windows** – On a desktop computer, the ability to open more than one window at a time allows for multi-tasking and for easy revert to a previous page. Historically on mobile web, only one page can be displayed at a time, and pages can only be viewed in the sequence they were originally accessed. However, there are apps for the iPhone (e.g. Oceanus), as well as browsers such as Opera Mini for

Java ME, allowing multiple windows, but sometimes a limited number, and not multiple windows in the same screen.

- **Navigation** – Most mobile devices do not use a mouselike pointer, but rather simply an up and down function for scrolling, thereby limiting the flexibility in navigation.
- **Lack of Javascript and cookies** – Most devices do not support client-side scripting and storage of cookies (smartphones excluded), which are now widely used in most Web sites for enhancing user experience, facilitating the validation of data entered by the page visitor, etc. This also results in web analytics tools not being suitable for uniquely identifying visitors using mobile devices.
- **Types of pages accessible** – Many sites that can be accessed on a desktop cannot on a mobile device. Many devices cannot access pages with a secured connection, Flash or other similar software, PDFs, or video sites, although recently this has been changing.
- **Speed** – On most mobile devices, the speed of service is very slow, often slower than dial-up Internet access.
- **Broken pages** – On many devices, a single page as viewed on a desktop is broken into segments, which are each treated as a separate page. Paired with the slow speed, navigation between these pages is slow.
- **Compressed pages** – Many pages, in their conversion to mobile format, are squeezed into an order different from how they would customarily be viewed on a desktop computer.
- **Size of messages** – Many devices have limits on the number of characters that can be sent in an email message.
- **Cost** – the access and bandwidth charges levied by cellphone networks can be high if there is no flat fee per month.
- **Location of mobile user**:
    - if advertisements reach phone users in private locations, users find them more distressful (Banerjee & Dholakia, 2008)
    - if the user is abroad the flat fee per month usually does not apply
- **Situation in which ad reaches user** – When advertisements reach users in work-related situations, they may be considered more intrusive than in leisure situations (Banerjee & Dholakia, 2008)

The inability of mobile web applications to access the local capabilities on the mobile device can limit their ability to provide the same features as native applications. The OMTP BONDI activity is acting as a catalyst to enable a set of JavaScript APIs which can access local capabilities in a secure way on the mobile device. Specifications and a reference implementation have been produced. Security is a key aspect in this provision in order to protect users from malicious web applications and widgets.

In addition to the limitations of the device itself there are limitations that should be made known to users concerning the interference these devices cause in other electromagnetic technology.

The convergence of the Internet and phone, in particular has caused hospitals to increase their mobile phone exclusion zones. A study by Erik van Lieshout and colleagues (Academic Medical Centre, University of Amsterdam) has found that the General Packet Radio Service (GPRS) used in modern phones can affect machines from up to 3 meters away. The Universal Mobile Telecommunications System (UMTS) signals, used in 3G networks, have a smaller exclusion zone of just a few centimeters. Not surprisingly, the worst offenders in hospitals are the doctors (New Scientist, 15 September 2007, pg.5).

Vulnerability to Mobile viruses

As more complex features are added to phones, they become more vulnerable to viruses which exploit weaknesses in these features. Even text messages can be used in attacks by worms and viruses. Advanced phones capable of e-mail can be susceptible to viruses that can multiply by sending messages through a phone's address book.

A virus may allow unauthorized users to access a phone to find passwords or corporate data stored on the device. Moreover, they can be used to commandeer the phone to make calls or send messages at the owner's expense.

Mobile phones used to have proprietary operating system unique only to the manufacturer which had the beneficial effect of making it harder to design a mass attack. However, the rise of software platforms and operating systems shared by many manufacturers such as Java, Microsoft operating systems, Linux, or Symbian OS, may increase the spread of viruses in the future.

Bluetooth is a feature now found in many higher-end phones, and the virus Caribe hijacked this function, making Bluetooth phones infect other Bluetooth phones running the Symbian OS. In early November 2004, several web sites began offering a specific piece of software promising ringtones and screensavers for certain phones. Those who downloaded the software found that it turned each icon on the phone's screen into a skull-and-crossbones and disabled their phones, so they could no longer send or receive text messages or access contact lists or calendars. The virus has since been dubbed "Skulls" by security experts. The Commwarrior-A virus was identified in March 2005, and it attempts to replicate itself through MMS to others on the phone's contact list. Like Cabir, Commwarrior-A also tries to communicate via Bluetooth wireless connections with other devices, which can eventually lead to draining the battery. The virus requires user intervention for propagation however.
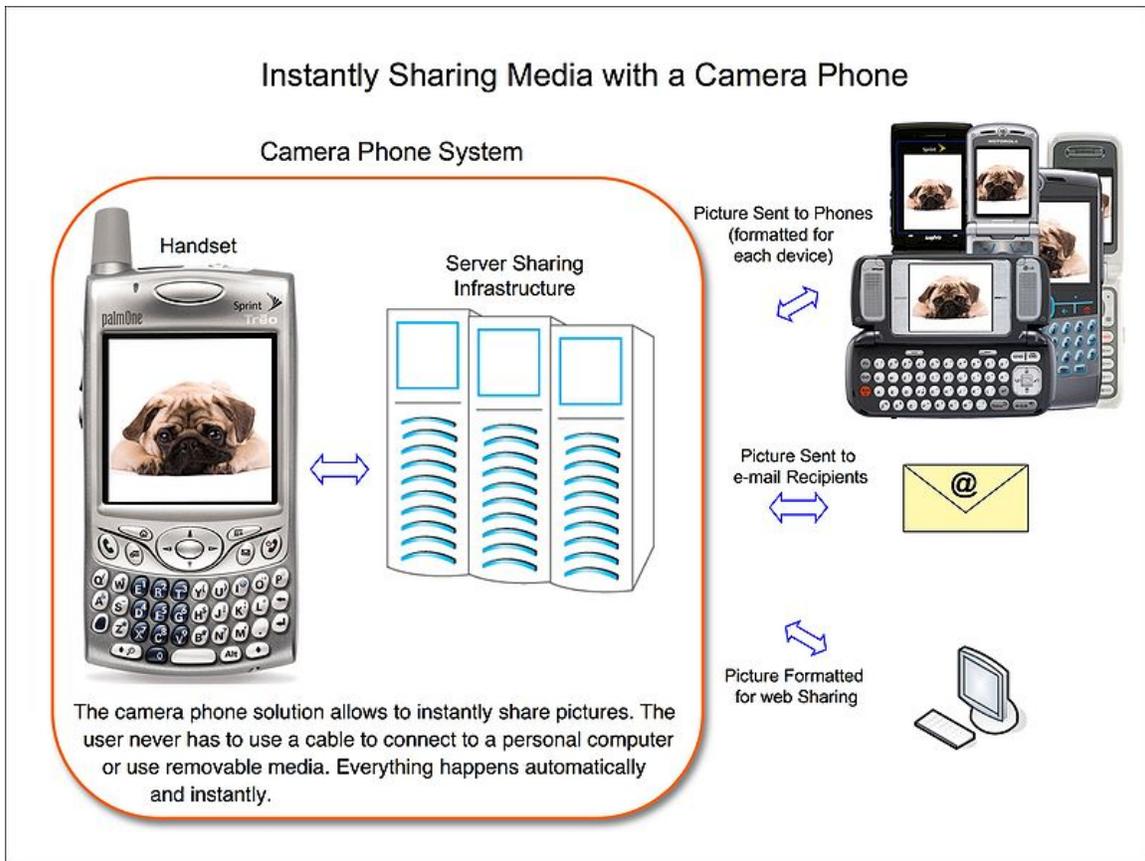
Bluetooth phones are also subject to bluejacking, which although not a virus, does allow for the transmission of unwanted messages from anonymous Bluetooth users.

Chapter 4

Camera Phone

A Sony Ericsson K800i **camera phone**

The camera phone instantly sharing media

A **camera phone** is a mobile phone which is able to capture either still photographs or video. Since early in the 21st century the majority of cameras and of mobile phones in use are camera phones.

Most camera phones are simpler than separate digital cameras. Their usual fixed focus lenses and smaller sensors limit their performance in poor lighting. Having no physical shutter, most have a long shutter lag and no flash or optical zoom. Many lack a USB connection, removable memory card, or other way of transferring their pictures more quickly than by the phone's inherent communication feature.

Some of the more expensive camera phones have only a few of these technical disadvantages, which apply most acutely in low light conditions and in any case have not inhibited their widespread use. Most model lines improve in these regards every year or two. Most, including Droid Incredible and iPhone, use a menu choice to start an application program to activate the camera. A few, such as the BlackBerry Storm2 and Droid X, have a separate camera button for quickness and convenience. Some are designed to resemble separate low-end digital compact cameras in appearance and to some extent in features and picture quality, and are branded as both mobile phones and cameras, including certain Sony phones.

The principal advantages of camera phones are cost and compactness; indeed for a user who carries a mobile phone anyway, the additional size and cost are negligible. Smart phones that are camera phones may run mobile applications to add capabilities such as geotagging. A few high end phones can use their touch screen to direct their camera to focus on a particular object in the field of view, giving even an inexperienced user a degree of focus control exceeded only by seasoned photographers using manual focus.

History

The camera phone, like many complex systems, is the result of converging and enabling technologies. There are dozens of relevant patents dating back as far as 1956. Compared to digital cameras of the 1990s, a consumer-viable camera in a mobile phone would require far less power and a higher level of camera electronics integration to permit the miniaturization. The CMOS active pixel image sensor "camera-on-a-chip" developed by Dr. Eric Fossum and his team in the early 1990s achieved the first step of realizing the modern camera phone as described in a March 1995 Business Week article. While the first camera phones, as successfully marketed by J-Phone in Japan, used CCD sensors and not CMOS sensors, more than 90% of camera phones sold today use CMOS image sensor technology.

Over the years there have been many videophones and cameras that include communications technologies. None of them had focused on the integration with the wireless Internet which would allow instant media sharing with anyone anywhere. Such experiments included, for example, a device that was known as the Apple Videophone/PDA in 1995. There were several digital cameras with cellular phone transmission capability shown by companies such as Kodak, Olympus in the early 1990s. There was also a digital camera with cellular phone designed by Shosaku Kawashima of Canon in Japan in May 1997.
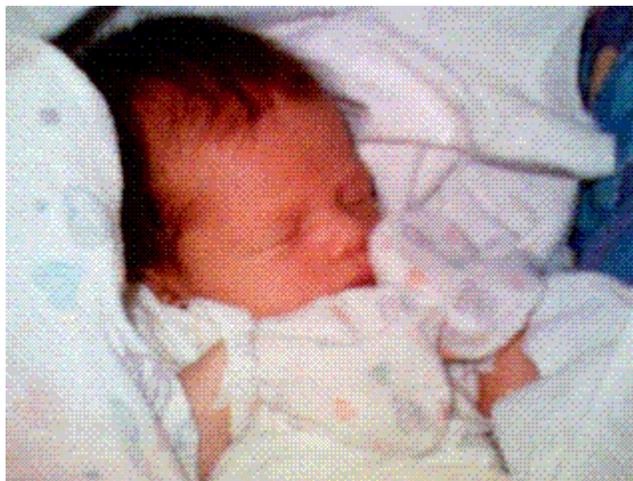
June 11, 1997, Santa Cruz, California: Image taken by Philippe Kahn after his daughter's birth.

On June 11, 1997, Philippe Kahn instantly shared the first pictures from the maternity ward where his daughter Sophie was born, with more than 2,000 family, friends and associates around the world. A sharing infrastructure and an integrated cell-phone and camera combo augured the birth of instant visual communications.. Kahn's picture is the first publicly known and shared picture.

In Japan, two competing projects were run by Sharp and Kyocera in 1997. Both had cell phones with integrated cameras. However, the Kyocera system was designed as a peer-to-peer video-phone as opposed to the Sharp project which was initially focused on sharing instant pictures. That was made possible when the Sharp devices was coupled to the Sha-mail infrastructure designed in collaboration with American technologist, Kahn. The Kyocera team was led by Mr. Kazumi Saburi.

The first commercial camera phone complete with infrastructure was the J-SH04, made by Sharp Corporation, had an integrated CCD sensor, with the Sha-Mail (Picture-Mail in Japanese) infrastructure developed in collaboration with Kahn's LightSurf venture, and marketed from 2001 by J-Phone in Japan today owned by Softbank. The first commercial deployment in North America of camera phones was in 2004. The Sprint wireless carriers deployed over one million camera phone manufactured by Sanyo and launched by the PictureMail infrastructure (Sha-Mail in English) developed and managed by LightSurf.

Camera phones can share pictures almost instantly and automatically via a sharing infrastructure integrated with the carrier network, thus negating the need for connecting cables or removable media to transfer pictures. Some camera phones use CMOS image sensors, due largely to reduced power consumption compared to CCD type cameras, which are also used. The lower power consumption prevents the camera from quickly depleting the phone's battery. Images are usually saved in the JPEG file format, and the wireless infrastructure manages the sharing. The sharing infrastructure is critical and explains the early successes of J-Phone and DoCoMo in Japan as well as Sprint and other carriers in the United States and the widespread success worldwide.

In 2006, Thuraya released the first satellite phone with an integrated camera. The Thuraya SG-2520 is manufactured by a Korean company called APSI and runs Windows CE.

The camera feature proved popular right from the start, as J-Phone in Japan had more than half of its subscribers using cameraphones in two years. The world soon followed. By 2003, more cameraphones were sold worldwide than stand-alone digital cameras. In 2004, Nokia became the world's most sold digital camera brand. In 2006, half of the world's mobile phones had a built-in camera. In 2008, Nokia sold more cameraphones than Kodak sells film based simple cameras, and thus Nokia is now even the biggest manufacturer of any kind of camera. As a direct result of the rapid popularity of cameraphones, two of the four giant cameramakers, Minolta and Konica have quit the camera business altogether. At the end of 2008, the world installed base of cameraphones was 1.9 billion.

Major manufacturers include Toshiba, Sharp, Nokia, Sanyo, Samsung, Motorola, Siemens, Sony Ericsson, and LG Electronics. The resolution is typically in the megapixel range.

Major manufacturers of cameras for phones include Toshiba, ST Micro, Sharp, Omnivision, and Aptina.

External camera

During 2003 as camera phones were gaining popularity in Europe some phones without cameras had support for MMS and external cameras that could be connected with a small cable or directly to the data port at the base of the phone. The external cameras were comparable in quality to those fitted on regular camera phones at the time, typically offering VGA resolution.

Phones that supported extra cameras include the Siemens SL55 and Nokia Series 40 phones such as the Nokia 6810. Unfortunately these cameras are not compatible with more recent phones.

These external cameras never proved very popular although they were stocked in various shops at the time.

Social impact

Personal photography allows people to capture and construct personal and group memory, maintain social relationships as well as expressing their identity. Camera phones provide the same opportunities, yet these functions are altered and allow for a different user experience. As mobile phones are constantly carried, camera phones allow for capturing moments at any time. Mobile communication also allows for immediate transmission of content (for example via Multimedia Messaging Services), which cannot be reversed or regulated.

While phones have been found useful by tourists and for other common civilian purposes, as they are cheap, convenient, and portable; they have also posed controversy, as they enable secret photography. A user may pretend to be simply talking on the phone or browsing the internet, drawing no suspicion while photographing a person or place illegally or against that person's wishes.

As a network-connected device, megapixel camera phones are playing significant roles in crime prevention, journalism and business applications as well as individual uses. They can also be used for activities such as voyeurism, invasion of privacy, and copyright infringement. Because they can be used to share media almost immediately, they are a potent personal content creation tool. On January 17, 2007, New York City Mayor Michael Bloomberg announced a plan to encourage people to use their camera-phones to capture crimes happening in progress or dangerous situations and send them to

emergency responders. Through the program, people will be able to send their images or video directly to 911.

Enforcing bans on camera phones has proven nearly impossible. They are small and numerous and their use is easy to hide or disguise, making it hard for law enforcement and security personnel to detect or stop use.

From time to time, organizations and places have prohibited or restricted the use of camera phones and other cameras because of the privacy, security, and copyright issues they pose. Such places include the Pentagon, federal and state courts, museums, schools, theaters, and local fitness clubs. Saudi Arabia, in April 2004, banned the sale of camera phones nationwide for a time before reallowing their sale in December 2004 (although pilgrims on the Hajj were allowed to bring in camera phones). In South Korea and Japan, all camera phones sold in the country must make a clearly audible sound whenever a picture is taken: These laws are intended to reduce the number of up-skirt photos taken.

There is the occasional anecdote of camera phones linked to industrial espionage and the activities of paparazzi, as well as some hacking into wireless operators' network.

Camera phones have also been used to discreetly take photographs in museums, performance halls, and other places where photography is prohibited. However, as sharing can be instantaneous, even if the action is discovered, it is too late, as the image is already out of reach, unlike a photo taken by a digital camera that only stores images locally for later transfer.

In Ireland the annual "RTE 60 second short award" was won by 15 year old Laura Gaynor who made her winning cartoon,"Piece of Cake" on her Sony Ericsson C510 camera phone.

Notable events involving camera phones

- The 2004 Indian Ocean earthquake was the first global news event where the majority of the first day news footage was no longer provided by professional news crews, but rather by citizen journalists, using primarily camera phones.
- On November 17, 2006, During a performance at the Laugh Factory comedy club, comedian Michael Richards was recorded responding to hecklers with racial slurs by a member of the audience using a camera phone. The video was widely circulated in television and internet news broadcasts.
- On December 30, 2006, the execution of former Iraqi dictator Saddam Hussein was recorded by a video camera phone, and made widely available on the Internet. A guard was arrested a few days later.
- Camera phone video and photographs taken in the immediate aftermath of the 7 July 2005 London bombings were featured worldwide. CNN executive Jonathan Klein predicts camera phone footage will be increasingly used by news organizations.
- Camera phone digital images helped to spread the 2009 Iranian election protests.

- Camera phones recorded the BART Police shooting of Oscar Grant.

Camera as an interaction device

The cameras of smartphones are used as input devices in numerous research projects and commercial applications. A commercially successful example is the use of QR Codes attached to physical objects. QR Codes can be sensed by the phone using its camera and provide an according link to related digital content, usually a URL. Another approach is using camera images to recognize objects. Content based image analysis is used to recognize physical objects such as advertisement posters to provide information about the object. Hybrid approaches use a combination of unobstrusive visual markers and image analysis. An example is to estimate the pose of the camera phone to create a real-time overlay for a 3D paper globe. On recent camera phones it is even feasible to provide an augmented reality overlay for 2D objects and to recognize multiple objects on the phone using a stripped down object recognition algorithm as well as using GPS and compass. Auto-geotagging can show where a picture is taken, promoting interactions and allowing a photo to be mapped with others for comparison.

Chapter 5

Subscriber Identity Module

A mini-SIM card next to its electrical contacts in a Nokia 6233.

A **subscriber identity module** (**SIM**) on a removable **SIM card** securely stores the service-subscriber key (IMSI) used to identify a subscriber on mobile telephony devices (such as mobile phones and computers). The SIM card allows users to change phones by simply removing the SIM card from one mobile phone and inserting it into another mobile phone or broadband telephony device.

A SIM card contains its unique serial number, internationally unique number of the mobile user (IMSI), security authentication and ciphering information, temporary

information related to the local network, a list of the services the user has access to and two passwords (PIN for usual use and PUK for unlocking).

SIM cards are available in three standard sizes. The first is the size of a credit card (85.60 mm × 53.98 mm x 0.76 mm). The newer, most popular miniature version has the same thickness but a length of 25 mm and a width of 15 mm, and has one of its corners truncated (chamfered) to prevent misinsertion. The newest incarnation known as the 3FF or micro-SIM has dimensions of 15 mm × 12 mm. Most cards of the two smaller sizes are supplied as a full-sized card with the smaller card held in place by a few plastic links; it can easily be broken off to be used in a device that uses the smaller SIM.

The first SIM card was made in 1991 by Munich smart card maker Giesecke & Devrient, who sold the first 300 SIM cards to Finnish wireless network operator Radiolinja.

Smart card technology
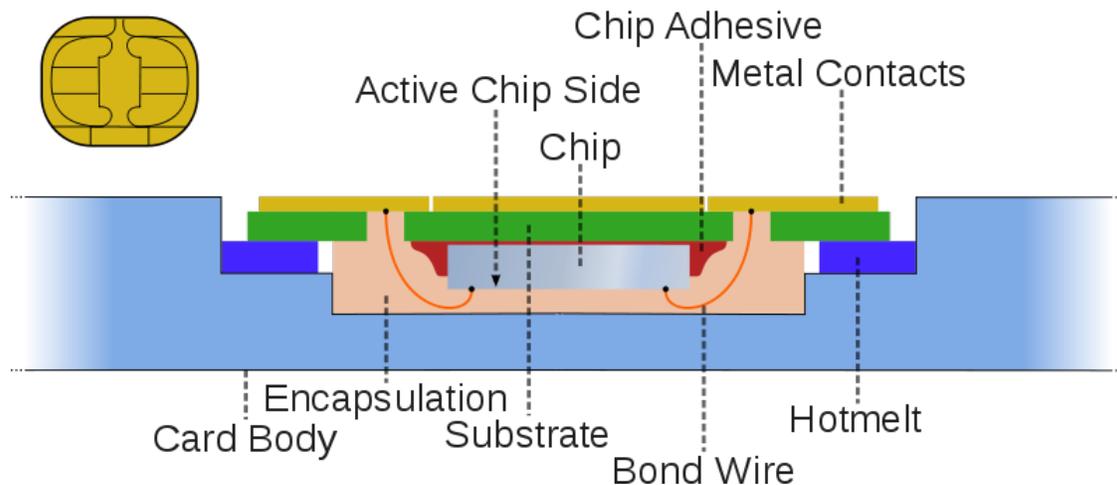
SIM chip structure and packaging

There are three operating voltages for SIM cards: 5 V, 3 V and 1.8 V (ISO/IEC 7816-3 classes A, B and C respectively). The operating voltage of the majority of SIM cards launched before 1998 was 5 V. SIM cards produced subsequently are compatible with 3 V and 5 V or with 1.8 V and 3 V.

A W-SIM is a SIM card that incorporates core cellular technology in the card itself.

A *virtual SIM* is a mobile phone number provided by a mobile network operator that does not require a SIM card to terminate phone calls on a user's mobile phone.

Features added in later releases

The specification that standardized the micro-SIM form factor continues to evolve. Some features introduced recently include:

- a micro-SIM form factor
- allow for multiple simultaneous applications accessing the card through logical channels;
- introduce mutual authentication as a way to eliminate carrier spoofing by allowing the SIM card to authenticate the cell tower to which it is connecting;
- add a new PIN protection with hierarchical PIN management with a universal PIN, an application PIN and a local PIN; and
- expand the phonebook storage of the SIM card with entries for email, second name, and groups.

Card sizes
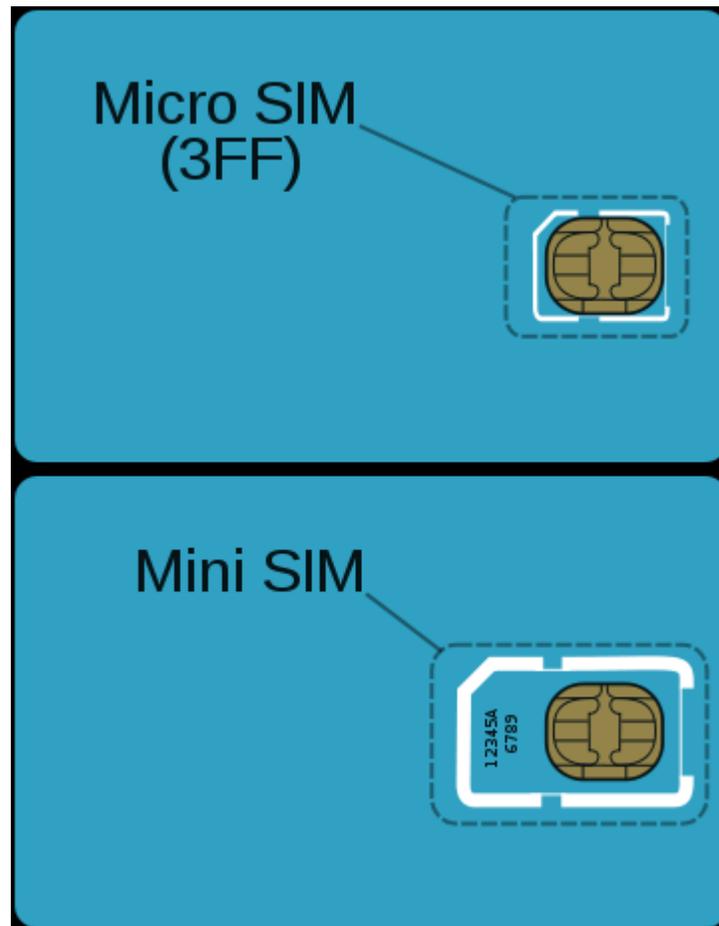
Micro-SIM and mini-SIM, as normally supplied in full-sized carrier cards

Micro-SIM with mini-SIM and full SIM brackets from Telia in Sweden

The memory film from a micro SIM card without the plastic backing plate

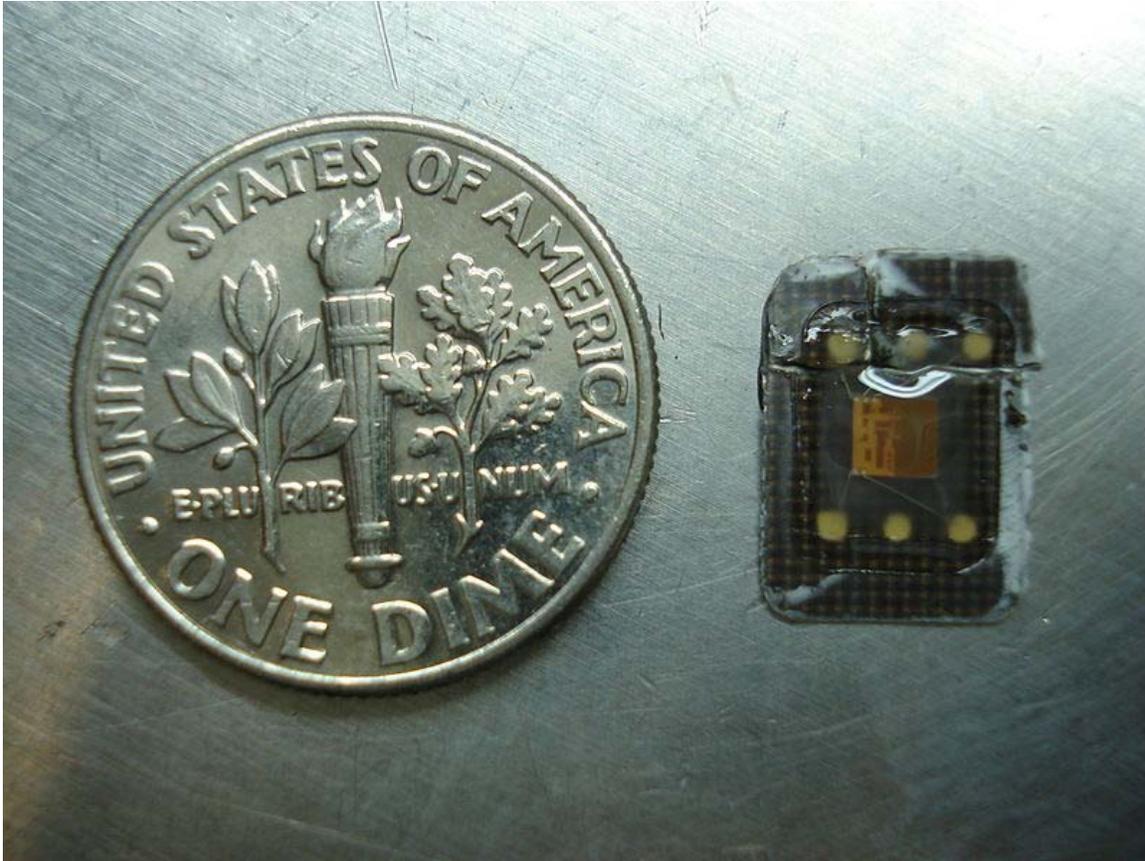SIM cards were first made the same size as a credit card (85.60 mm × 53.98 mm × 0.76 mm). The development of physically smaller mobile devices prompted the development of a smaller SIM card, the mini-SIM card. Mini-SIM cards have the same thickness as full-size cards, but their length and width are reduced to 25 mm × 15 mm.

The mini-SIM card has the same contact arrangement as the full-size SIM card and they are normally supplied within a full-size card carrier, attached by a number of linking pieces. This arrangement (defined in ISO/IEC 7810 as ID-1/000) allows for such a card to be used in a device requiring a full-size card, or to be used in a device requiring a mini-SIM card after cleanly breaking the scorings manufactured in the outline of a mini-SIM card.

Even smaller device sizes have prompted the development of a yet smaller card size, the *3FF card* or *micro-SIM*. Micro-SIM cards have the same thickness and contact arrangement again, but the length and width are further reduced to 15 mm × 12 mm. The specifications for the 3FF card or micro-SIM also include additional functionality beyond changing the physical card size.

SIM card sizes

SIM card	Standard reference	Length (mm)	Width (mm)	Thickness (mm)
Full-size	ISO/IEC 7810:2003, ID-1	85.60	53.98	0.76
Mini-SIM	ISO/IEC 7810:2003, ID-000	25.00	15.00	0.76
Micro-SIM	ETSI TS 102 221 V9.0.0, Mini-UICC	15.00	12.00	0.76

Development of the micro-SIM

The micro-SIM was developed by the European Telecommunications Standards Institute along with SCP, 3GPP (UTRAN/GERAN), 3GPP2 (CDMA2000), ARIB, GSMAssociaton (GSMA SCaG and GSMNA), GlobalPlatform, Liberty Alliance, and the Open Mobile Alliance (OMA) for the purpose of fitting into devices otherwise too small for a mini-SIM card.

The form factor was mentioned in the Dec 1998 3GPP SMG9 UMTS Working Party, which is the standards-setting body for GSM SIM cards, and the form factor was agreed upon in late 2003.

The micro-SIM was created with backwards compatibility in mind. The major issue with backwards compatibility was the contact area of the chip. Retaining the same contact area allows the micro-SIM to be compatible with the previous, larger SIM readers through the use of plastic cutout surrounds. The SIM was also designed to run at the same speed (5 MHz) as the previous version. The same size and positions of pins resulted in numerous "How-to" tutorials and YouTube video with detailed instructions how to cut usual SIM card to micro-SIM size with sharp knife or scissors. These tutorials became very popular among first owners of iPad 3G after its release on April 30, 2010 and iPhone 4 on June 24, 2010.

The chairman of EP SCP, Dr. Klaus Vedder, said

"With this decision, we can see that ETSI has responded to a market need from ETSI customers, but additionally there is a strong desire not to invalidate, overnight, the existing interface, nor reduce the performance of the cards. EP SCP expect to finalise the technical realisation for the third form factor at the next SCP plenary meeting, scheduled for February 2004."

Usage in mobile phone standards

SIM card for Thuraya satellite phone

The use of SIM cards is mandatory in GSM devices. The equivalent of a SIM in UMTS is called the Universal Integrated Circuit Card (UICC), which runs a USIM application, while the Removable User Identity Module (R-UIM) is more popular in CDMA-based devices e.g. CDMA2000. The UICC is still colloquially called a *SIM card*. Many CDMA-based standards do not include any removable card, and the service is bound to a unique identifier contained in the handset itself.

The satellite phone networks Iridium, Thuraya and Inmarsat's BGAN also use SIM cards. Sometimes these SIM cards work in regular GSM phones and also allow GSM customers to roam in satellite networks by using their own SIM card in a satellite phone.

The SIM card introduced a new and significant business opportunity of mobile telecoms operator/carrier business of the mobile virtual network operator (MVNO) which does not own or operate a cellular telecoms network, but which leases capacity from one of the network operators, and only provides a SIM card to its customers. MVNOs first appeared in Denmark, Hong Kong, Finland and the UK and today exist in over 50 countries including most of Europe, USA, Canada, Australia and parts of Asia and account for approximately 10% of all mobile phone subscribers around the world.

On some networks, the mobile phone is locked to its carrier SIM card e.g. on the GSM networks in the USA, the UK and Poland. This tends to happen only in countries where mobile phones are heavily subsidised, but even then not all countries and not all operators. In the US the phones are locked to the carrier, meaning that only specific carriers' SIM cards will work. In the UK, typically, most phones with subsidies are SIM-locked.

Phones sold with a contract are often locked (SIM-locked) to the network that provided the phone, since the phones are often subsidized in return for using provider for a minimum term (typically, 12 or 24 months). For example in the UK, a phone that would cost £250 without a contract might be offered free-of-charge with an 18 month contract commitment of £30 per month (£540 commitment in total).

A plethora of online and high-street (third-party) businesses now offer the ability to remove the SIM-lock from a phone, effectively making it possible to then use the phone on any network by inserting a different SIM card. Some of these resellers use wholeseller databases. This is a useful benefit for travellers that might want to put a local SIM card into their phone when they arrive in a country, in order to minimize roaming charges. In many countries, now it is possible to buy a pre-pay SIM card just by walking into a store, and these SIM-only deals are a cost effective way to stay in contact when travelling.

Phones sold as pre-pay often come with an operator subsidy, especially in competitive mobile markets like the UK. These phones are sold not just through mobile phone stores, but also supermarkets, catalogs, stationery outlets and online; thus the mobile companies are constantly competing to lower the price. Prepay phones come with a bundled SIM, which can be activated by the user in case the phone is bought up. The handsets are often SIM-locked to ensure that the user does not use another operator, allowing the original operator to eventually recoup its subsidy. However, because the units can be unlocked for a small fee (and even the operators themselves offer this service), units can be bought cheaply, separated from the original SIM card and sold on for a profit, perhaps in other markets, perhaps as contract phone. This is known in the industry as *box breaking*, and often harms the profits of the operator while allowing complicit sales staff and box breakers to reap the rewards. Note that, if a prepaid handset breaks, the SIM card (representing the prepaid account value, plus user's address book, history, etc) can typically be moved to another prepaid handset if the phone-network is the same. That is, the account is tied to the portable SIM card, not the handset, on prepaid phones. This is useful because by 2010, prepaid handsets cost less than the value a user might have stored in an account.

Mostly, GSM and 3G mobile handsets can easily be SIM-unlocked and used on any suitable network with any SIM card. A notable exception is the Apple iPhone, where in most markets Apple has gone to extreme lengths to lock-down their phones; thus they can only be used with the partner's network. This has led to a popular hack called the *jailbreak*, which allows custom software unapproved by Apple to run on the phone. Then software can be run to unlock the phone, which frees the iPhone from the partner network; thus any SIM card can be inserted. (Note that jailbreaking, in itself, does not

unlock the phone, and has other uses as well.) Apple and the hackers are locked in a war of escalation - described by Apple CEO Steve Jobs as "a game of cat and mouse" - with Apple constantly trying to close loopholes in their operating system, and the hackers finding new ways to jailbreak each version when it becomes available.

In countries where the phones are not subsidised e.g. Italy and Belgium, all phones are unlocked. Where the phone is not locked to its SIM card, the users can easily switch networks by simply replacing the SIM card of one network with that of another while using only one phone. This is typical, for example, among users who may want to optimise their telecoms traffic by different tariffs to different friends on different networks.

Dual SIM phones are now made by some mobile phone manufacturers, which save the user from carrying around a separate phone for every number. There are two types, the first, that allow one to switch between the SIMs, and the second, that allow both SIMs to be active simultaneously.

Operating systems

SIM operating systems come in two main types: native and Java Card. Native SIMs are based on proprietary, vendor specific software whereas the Java Card SIMs are based on standards, particularly Java Card which is a subset of the Java programming language specifically targeted at embedded devices. Java Card allows the SIM to contain programs that are hardware independent and interoperable.

Data

SIM cards store network-specific information used to authenticate and identify subscribers on the network. The most important of these are the ICC-ID, IMSI, Authentication Key (Ki), Local Area Identity (LAI) and Operator-Specific Emergency Number. The SIM also stores other carrier specific data such as the SMSC (Short Message Service Center) number, Service Provider Name (SPN), Service Dialing Numbers (SDN), Advice-Of-Charge parameters and Value Added Service (VAS) applications. (look to GSM 11.11)

Integrated circuit card identifier (ICC-ID)

Each SIM is internationally identified by its ICC-ID. ICC-IDs are stored in the SIM cards and are also engraved or printed on the SIM card body during a process called personalization. The ICC-ID is defined by the ITU-T recommendation E.118. According to E.118 the number is up to 19 digits long including a single check digit calculated using the Luhn algorithm. However, the GSM Phase 1 defined the ICC-ID length as 10 octets with operator-specific structure.

The number is composed of the following subparts:

Issuer identification number (IIN)

Maximum of seven digits:

- Major industry identifier (MII), 2 digits, 89 for telecommunication purposes.
- Country code, 1-3 digits, as defined by ITU-T recommendation E.164.
- Issuer identifier, 1-4 digits.

Individual account identification

- Individual account identification number. Its length is variable but every number under one IIN will have the same length.

Check digit

- Single digit calculated from the other digits using the Luhn algorithm.

Total size

With the GSM Phase 1 specification using 10 octets into which ICC-ID is stored as packed BCD, the data field has room for 20 digits.

In practice this means that on GSM SIM cards there are 20 digit (19+1) and 19 digit (18+1) ICC-IDs in use, depending upon issuer. However one issuer uses always same size of ICC-IDs.

To confuse matters more, SIM factories seem to have varying ways of delivering electronic copy of SIM personalization datasets. Some datasets are without the ICC-ID checksum digit, others are with the digit.

International mobile subscriber identity (IMSI)

SIM cards are identified on their individual operator networks by a unique IMSI. Mobile operators connect mobile phone calls and communicate with their market SIM cards using their IMSIs. The format is:

- The first 3 digits represent the Mobile Country Code (MCC).
- The next 2 or 3 digits represent the Mobile Network Code (MNC). 3 digit MNC codes are allowed by E.212 but are only implemented in some countries in North America, the Caribbean and Latin America.
- The next digits represent the mobile station identification number. Normally there will be 10 digits but would be fewer in the case of a 3 digit MNC or if national regulations indicate that the total length of the IMSI should be less than 15 digits.

Authentication key (K_i)

The K_i is a 128-bit value used in authenticating the SIMs on the mobile network. Each SIM holds a unique K_i assigned to it by the operator during the personalization process. The K_i is also stored on a database (known as Authentication Center or AuC) on the carrier's network.

The SIM card is designed not to allow the K_i to be obtained using the smart-card interface. Instead, the SIM card provides a function, *Run GSM Algorithm*, that allows the phone to pass data to the SIM card to be signed with the K_i. This, by design, makes usage of the SIM card mandatory unless the K_i can be extracted from the SIM card, or the carrier is willing to reveal the K_i. In practice, the GSM cryptographic algorithm for computing SRES_2 (see step 4, below) from the K_i has certain vulnerabilities which can allow the extraction of the K_i from a SIM card and the making of a duplicate SIM card.

Authentication process

1. When the Mobile Equipment starts up, it obtains the International Mobile Subscriber Identity (IMSI) from the SIM card, and passes this to the mobile operator requesting access and authentication. The Mobile Equipment may have to pass a PIN to the SIM card before the SIM card will reveal this information.
2. The operator network searches its database for the incoming IMSI and its associated K_i.
3. The operator network then generates a Random Number (RAND, which is a nonce) and signs it with the K_i associated with the IMSI (and stored on the SIM card), computing another number known as Signed Response 1 (SRES_1).
4. The operator network then sends the RAND to the Mobile Equipment, which passes it to the SIM card. The SIM card signs it with its K_i, producing SRES_2 which it gives to the Mobile Equipment along with encryption key K_c. The Mobile Equipment passes SRES_2 on to the operator network.
5. The operator network then compares its computed SRES_1 with the computed SRES_2 that the Mobile Equipment returned. If the two numbers match the SIM is authenticated and the Mobile Equipment is granted access to the operator's network. K_c is used to encrypt all further communications between the Mobile Equipment and the network.

Location area identity

The SIM stores network state information, which is received from the Location Area Identity (LAI). Operator networks are divided into Location Areas, each having a unique LAI number. When the device changes locations, it stores the new LAI to the SIM and sends it back to the operator network with its new location. If the device is power cycled, it will take data off the SIM, and search for the previous LAI. This saves time by avoiding having to search the whole list of frequencies that the telephone normally would.

SMS messages and contacts

Most SIM cards will orthogonally store a number of SMS messages and phone book contacts. The contacts are stored in simple 'Name and number' pairs - entries containing multiple phone numbers and additional phone numbers will usually not be stored on the SIM card. When a user tries to copy such entries to a SIM the handset's software will break them up into multiple entries, discarding any information that isn't a phone number. The number of contacts and messages stored depends on the SIM; early models would store as few as 5 messages and 20 contacts while modern SIM cards can usually store over 250 contacts.

Universal subscriber identity module

A 64K UICC in its larger carrier card

A Universal Subscriber Identity Module is an application for UMTS mobile telephony running on a UICC smart card which is inserted in a 3G mobile phone. There is a common misconception to call the UICC itself a USIM, but the USIM is merely a logical entity on the physical card.

It stores user subscriber information, authentication information and provides storage space for text messages and phone book contacts. The phone book on a UICC has been greatly enhanced.

For authentication purposes, the USIM stores a long-term pre-shared secret key K, which is shared with the Authentication Center (AuC) in the network. The USIM also verifies a sequence number that must be within a range using a window mechanism to avoid replay attacks, and is in charge of generating the session keys CK and IK to be used in the confidentiality and integrity algorithms of the KASUMI block cipher in UMTS.

The equivalent of USIM on GSM networks is SIM, and on CDMA networks it is CSIM.

Japan

Japan's 2G PDC system (which will be completely shut down by 2012; SoftBank Mobile has already shut down PDC from March 31, 2010) also specifies a SIM, but this has never been implemented commercially. The specification of the interface between the Mobile Equipment and the SIM is given in the RCR STD-27 annex 4. The Subscriber Identity Module Expert Group was a committee of specialists assembled by the European Telecommunications Standards Institute (ETSI) to draw up the specifications (GSM 11.11) for interfacing between smart cards and mobile telephones. In 1994, the name SIMEG was changed to SMG9.

Japan's current and next generation cellular systems are based on W-CDMA (UMTS) and CDMA2000 and all use SIM cards.

KDDI's au IC-CardNTT DoCoMo's FOMA Card

Finland

In July 2005, the Finnish government announced that a *Citizen Certificate*, a government-guaranteed electronic identity included in a SIM card, would be made available to every individual resident in Finland before the end of 2005, allowing mobile phone users to access e-services on the move. The Citizen Certificate has been described as "basically an e-ID card that will be compatible with several hardware devices, such as mobile phones, PDAs, personal computers, digital TV sets, and public web kiosks". It is based on open standards and secured public key infrastructure (PKI).

Chapter 6

4G

4G refers to the fourth generation of cellular wireless standards. It is a successor to 3G and 2G families of standards. A 4G system is expected to provide a comprehensive and secure all-IP based solution where facilities such as ultra-broadband (giga-bit speed) Internet access, IP telephony, gaming services, and streamed multimedia may be provided to users.

Pre-4G technologies such as mobile WiMAX and first-release 3G Long term evolution (LTE) have been available on the market since 2006 and 2009 respectively, and are often branded as 4G. Current versions of these technologies do however not fulfill the ITU-R requirements on 4G systems, stating data rates approximately up to 1 Gbit/s.

In all suggestions for 4G, the CDMA spread spectrum radio technology used in 3G systems and IS-95 is abandoned and replaced by frequency-domain equalization schemes, for example multi-carrier transmission such as OFDMA. This is combined with MIMO (Multiple In Multiple Out) i.e., multiple antennas, dynamic channel allocation and channel-dependent scheduling.

Background

The nomenclature of the generations generally refers to a change in the fundamental nature of the service, non-backwards compatible transmission technology, and new frequency bands. The first was the move from 1981 analog (1G) to digital (2G) transmission in 1992. This was followed, in 2002, by 3G multi-media support, spread spectrum transmission and at least 200 kbit/s, soon expected to be followed by 4G, which refers to all-IP packet-switched networks, mobile ultra-broadband (gigabit speed) access and multi-carrier transmission.

Requirements

An IMT-Advanced cellular system must have target peak data rates of up to approximately 100 Mbit/s for high mobility such as mobile access and up to approximately 1 Gbit/s for low mobility such as nomadic/local wireless access, according to the ITU requirements. Scalable bandwidths up to at least 40 MHz should be provided.

4G Predecessors and candidate systems

3GPP Long Term Evolution (LTE)

Telia-branded Samsung LTE modem

The pre-4G technology 3GPP Long Term Evolution (LTE) is often branded "4G", but the first LTE release does not fully comply with the IMT-Advanced requirements. LTE has a theoretical net bit rate capacity of up to 100 Mbit/s in the downlink and 50 Mbit/s in the uplink if a 20 MHz channel is used — and more if Multiple-input multiple-output (MIMO), i.e. antenna arrays, are used.

The world's first publicly available LTE-service was opened in the two Scandinavian capitals Stockholm (Ericsson system) and Oslo (a Huawei system) on the 14 December 2009, and branded 4G. The user terminals were manufactured by Samsung. The two largest major mobile carriers in the United States and several worldwide carriers have announced plans to convert their networks to LTE beginning in 2011.

The physical radio interface was at an early stage named *High Speed OFDM Packet Access* (HSOPA), now named Evolved UMTS Terrestrial Radio Access (E-UTRA).

The first LTE USB dongles do not support any other radio interface.

LTE Advanced

LTE Advanced (Long-term-evolution Advanced) is a candidate for IMT-Advanced standard, formally submitted by the 3GPP organization to ITU-T in the fall 2009, and expected to be released in 2012. The target of 3GPP LTE Advanced is to reach and surpass the ITU requirements. LTE Advanced should be compatible with first release LTE equipment, and should share frequency bands with first release LTE.

Mobile WiMAX (IEEE 802.16e)

The Mobile WiMAX (IEEE 802.16e-2005) mobile wireless broadband access (MWBA) standard (also known as WiBro in South Korea) is sometimes branded 4G, and offers peak data rates of 128 Mbit/s downlink and 56 Mbit/s uplink over 20 MHz wide channels.

The world's first commercial mobile WiMAX service was opened by KT in Seoul, South Korea on 30 June 2006.

Sprint Nextel has begun using Mobile WiMAX, as of September 29, 2008 branded as a "4G" network even though current version does not fulfill the IMT Advanced requirments on 4G systems.

IEEE 802.16m

The IEEE 802.16m evolution of 802.16e is under development, with the objective to fulfill the IMT-Advanced criteria of 1 Gbit/s for stationary reception and 100 Mbit/s for mobile reception.

UMB (formerly EV-DO Rev. C)

UMB (Ultra Mobile Broadband) was the brand name for a discontinued 4G project within the 3GPP2 standardization group to improve the CDMA2000 mobile phone standard for next generation applications and requirements. In November 2008, Qualcomm, UMB's lead sponsor, announced it was ending development of the

technology, favouring LTE instead. The objective was to achieve data speeds over 275 Mbit/s downstream and over 75 Mbit/s upstream.

Flash-OFDM

At an early stage the Flash-OFDM system was expected to be further developed into a 4G standard.

iBurst and MBWA (IEEE 802.20) systems

The iBurst system (or or HC-SDMA, High Capacity Spatial Division Multiple Access) was at an early stage considered as a 4G predecessor. It was later further developed into the Mobile Broadband Wireless Access (MBWA) system, also known as IEEE 802.20.

Objective and approach

Objectives

4G is being developed to accommodate the quality of service (QoS) and rate requirements set by further development of existing 3G applications like mobile broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV, but also new services like HDTV. 4G may allow roaming with wireless local area networks, and may interact with digital video broadcasting systems.

The 4G working group has defined the following as objectives of the 4G wireless communication standard:

- Flexible channel bandwidth, between 5 and 20 MHz, optionally up to 40 MHz.
- A nominal data rate of 100 Mbit/s while the client physically moves at high speeds relative to the station, and 1 Gbit/s while client and station are in relatively fixed positions as defined by the ITU-R,
- A data rate of at least 100 Mbit/s between any two points in the world,
- Peak link spectral efficiency of 15 bit/s/Hz in the downlink, and 6.75 bit/s/Hz in the uplink (meaning that 1 Gbit/s in the downlink should be possible over less than 67 MHz bandwidth)
- System spectral efficiency of up to 3 bit/s/Hz/cell in the downlink and 2.25 bit/s/Hz/cell for indoor usage.
- Smooth handoff across heterogeneous networks,
- Seamless connectivity and global roaming across multiple networks,
- High quality of service for next generation multimedia support (real time audio, high speed data, HDTV video content, mobile TV, etc.)
- Interoperability with existing wireless standards,
- An all IP, packet switched network.
- Femtocells (home nodes connected to fixed Internet broadband infrastructure)

Approaches

Consideration points

- Coverage, radio environment, spectrum, services, business models and deployment types, users.

Principal technologies

- Physical layer transmission techniques
  - MIMO: To attain ultra high spectral efficiency by means of spatial processing including multi-antenna and multi-user MIMO
  - *Frequency-domain-equalization*, for example *Multi-carrier modulation (OFDM) or* single-carrier frequency-domain-equalization *(SC-FDE) in the downlink: To exploit the frequency selective channel property without complex equalization.*
  - Frequency-domain statistical multiplexing, for example (OFDMA) or (Single-carrier FDMA) (SC-FDMA, a.k.a. Linearly precoded OFDMA, LP-OFDMA) in the uplink: Variable bit rate by assigning different sub-channels to different users based on the channel conditions
  - Turbo principle error-correcting codes: To minimize the required SNR at the reception side
- Channel-dependent scheduling: To utilize the time-varying channel.
- Link adaptation: Adaptive modulation and error-correcting codes
- Relaying, including fixed relay networks (FRNs), and the cooperative relaying concept, known as multi-mode protocol

4G features

The 4G system was originally envisioned by the Defense Advanced Research Projects Agency (DARPA). The DARPA selected the distributed architecture, end-to-end Internet protocol (IP), and believed at an early stage in peer-to-peer networking in which every mobile device would be both a transceiver and a router for other devices in the network eliminating the spoke-and-hub weakness of 2G and 3G cellular systems.

4G systems not only provide telecommunications services, but also data and multimedia services. Not only does 4G provide the aforementioned, it allows mobility, thus one can take their Internet connection on the road and never have to worry about finding a hotspot.

Some candidate systems suggest having an open Internet platform.

Components

Access schemes

As the wireless standards evolved, the access techniques used also exhibited increase in efficiency, capacity and scalability. The first generation wireless standards used plain TDMA and FDMA. In the wireless channels, TDMA proved to be less efficient in handling the high data rate channels as it requires large guard periods to alleviate the multipath impact. Similarly, FDMA consumed more bandwidth for guard to avoid inter carrier interference. So in second generation systems, one set of standard used the combination of FDMA and TDMA and the other set introduced an access scheme called CDMA. Usage of CDMA increased the system capacity, but as a theoretical drawback placed a soft limit on it rather than the hard limit (i.e. a CDMA network setup does not inherently reject new clients when it approaches its limits, resulting in a denial of service to all clients when the network overloads; though this outcome is avoided in practical implementations by admission control of circuit switched or fixed bitrate communication services). Data rate is also increased as this access scheme (providing the network is not reaching its capacity) is efficient enough to handle the multipath channel. This enabled the third generation systems, such as IS-2000, UMTS, HSXPA, 1xEV-DO, TD-CDMA and TD-SCDMA, to use CDMA as the access scheme. However, the issue with CDMA is that it suffers from poor spectral flexibility and computationally intensive time-domain equalization (high number of multiplications per second) for wideband channels.

Recently, new access schemes like Orthogonal FDMA (OFDMA), Single Carrier FDMA (SC-FDMA), Interleaved FDMA and Multi-carrier CDMA (MC-CDMA) are gaining more importance for the next generation systems. These are based on efficient FFT algorithms and frequency domain equalization, resulting in a lower number of multiplications per second. They also make it possible to control the bandwidth and form the spectrum in a flexible way. However, they require advanced dynamic channel allocation and traffic adaptive scheduling.

WiMax is using OFDMA in the downlink and in the uplink. For the next generation UMTS, OFDMA is used for the downlink. By contrast, IFDMA is being considered for the uplink since OFDMA contributes more to the PAPR related issues and results in nonlinear operation of amplifiers. IFDMA provides less power fluctuation and thus avoids amplifier issues. Similarly, MC-CDMA is in the proposal for the IEEE 802.20 standard. These access schemes offer the same efficiencies as older technologies like CDMA. Apart from this, scalability and higher data rates can be achieved.

The other important advantage of the above mentioned access techniques is that they require less complexity for equalization at the receiver. This is an added advantage especially in the MIMO environments since the spatial multiplexing transmission of MIMO systems inherently requires high complexity equalization at the receiver.

In addition to improvements in these multiplexing systems, improved modulation techniques are being used. Whereas earlier standards largely used Phase-shift keying,

more efficient systems such as 64QAM are being proposed for use with the 3GPP Long Term Evolution standards.

IPv6 support

Unlike 3G, which is based on two parallel infrastructures consisting of circuit switched and packet switched network nodes respectively, 4G will be based on packet switching *only*. This will require low-latency data transmission.

By the time that 4G is deployed, the process of IPv4 address exhaustion is expected to be in its final stages. Therefore, in the context of 4G, IPv6 support is essential in order to support a large number of wireless-enabled devices. By increasing the number of IP addresses, IPv6 removes the need for Network Address Translation (NAT), a method of sharing a limited number of addresses among a larger group of devices, although NAT will still be required to communicate with devices that are on existing IPv4 networks.

As of June 2009, Verizon has posted specifications that require any 4G devices on its network to support IPv6.

Advanced Antenna Systems

The performance of radio communications depends on an antenna system, termed smart or intelligent antenna. Recently, multiple antenna technologies are emerging to achieve the goal of 4G systems such as high rate, high reliability, and long range communications. In the early 1990s, to cater for the growing data rate needs of data communication, many transmission schemes were proposed. One technology, spatial multiplexing, gained importance for its bandwidth conservation and power efficiency. Spatial multiplexing involves deploying multiple antennas at the transmitter and at the receiver. Independent streams can then be transmitted simultaneously from all the antennas. This technology, called MIMO (as a branch of intelligent antenna), multiplies the base data rate by (the smaller of) the number of transmit antennas or the number of receive antennas. Apart from this, the reliability in transmitting high speed data in the fading channel can be improved by using more antennas at the transmitter or at the receiver. This is called *transmit* or *receive diversity*. Both transmit/receive diversity and transmit spatial multiplexing are categorized into the space-time coding techniques, which does not necessarily require the channel knowledge at the transmitter. The other category is closed-loop multiple antenna technologies, which require channel knowledge at the transmitter.

Software-Defined Radio (SDR)

SDR is one form of open wireless architecture (OWA). Since 4G is a collection of wireless standards, the final form of a 4G device will constitute various standards. This can be efficiently realized using SDR technology, which is categorized to the area of the radio convergence.

History of 4G and pre-4G technologies

- In 2002, the strategic vision for 4G — which ITU designated as IMT-Advanced — was laid out.
- In 2005, OFDMA transmission technology is chosen as candidate for the HSOPA downlink, later renamed 3GPP Long Term Evolution (LTE) air interface E-UTRA.
- In November 2005, KT demonstrated mobile WiMAX service in Busan, South Korea.
- In June 2006, KT started the world's first commercial mobile WiMAX service in Seoul, South Korea.
- In mid-2006, Sprint Nextel announced that it would invest about US$5 billion in a WiMAX technology buildout over the next few years ($5.4 billion in real terms). Since that time Sprint has faced many setbacks, that have resulted in steep quarterly losses. On May 7, 2008, Sprint, Imagine, Google, Intel, Comcast, Bright House, and Time Warner announced a pooling of an average of 120 MHz of spectrum; Sprint merged its Xohm WiMAX division with Clearwire to form a company which will take the name Clear.
- In February 2007, the Japanese company NTT DoCoMo tested a 4G communication system prototype with 4x4 MIMO called VSF-OFCDM at 100 Mbit/s while moving, and 1 Gbit/s while stationary. NTT DoCoMo completed a trial in which they reached a maximum packet transmission rate of approximately 5 Gbit/s in the downlink with 12x12 MIMO using a 100 MHz frequency bandwidth while moving at 10 km/h, and is planning on releasing the first commercial network in 2010.
- In September 2007, NTT Docomo demonstrated e-UTRA data rates of 200 Mbit/s with power consumption below 100 mW during the test.
- In January 2008, a U.S. Federal Communications Commission (FCC) spectrum auction for the 700 MHz former analog TV frequencies began. As a result, the biggest share of the spectrum went to Verizon Wireless and the next biggest to AT&T. Both of these companies have stated their intention of supporting LTE.
- In January 2008, EU commissioner Viviane Reding suggested re-allocation of 500–800 MHz spectrum for wireless communication, including WiMAX.
- February 15, 2008 - Skyworks Solutions released a front-end module for e-UTRAN.
- In April 2008, LG and Nortel demonstrated e-UTRA data rates of 50 Mbit/s while travelling at 110 km/h.
- In 2008, ITU-R established the detailed performance requirements of IMT-Advanced, by issuing a Circular Letter calling for candidate Radio Access Technologies (RATs) for IMT-Advanced.
- April 2008, just after receiving the circular letter, the 3GPP organized a workshop on IMT-Advanced where it was decided that LTE-Advanced, an evolution of current LTE standard, will meet or even exceed IMT-Advanced requirements following the ITU-R agenda.
- On 3 March 2009, Lithuanian's LRTC announcing the first operational "4G" mobile WiMAX network in Baltic states.

- In December 2009, Sprint began advertising "4G" service in selected cities in the United States, despite average download speeds of only 3-6Mbps with peak speeds of 10Mbps (not available in all markets).
- On December 14, 2009, the first commercial LTE deployment was in the Scandinavian capitals Stockholm and Oslo by the Swedish-Finnish network operator TeliaSonera and its Norwegian brandname NetCom (Norway). TeliaSonera branded the network "4G". The modem devices on offer were manufactured by Samsung (dongle GT-B3710), and the network infrastructure created by Huawei (in Oslo) and Ericsson (in Stockholm). TeliaSonera plans to roll out nationwide LTE across Sweden, Norway and Finland. TeliaSonera used spectral bandwidth of 10 MHz, and single-in-single-out, which should provide physical layer net bitrates of up to 50 Mbit/s downlink and 25 Mbit/s in the uplink. Introductory tests showed a TCP throughput of 42.8 Mbit/s downlink and 5.3 Mbit/s uplink in Stockholm.
- On 25 February 2010, Estonia's EMT opened LTE "4G" network working in test regime.
- On 5 June 2010, Sprint Nextel released the first 4G Smartphone, the HTC Evo 4G.
- On July 2010, Uzbekistan's MTS deployed LTE in Tashkent.
- On 25 August 2010, Latvia's LMT opened LTE "4G" network working in test regime 50% of territory.

Deployment plans

In May 2005, Digiweb, an Irish fixed and wireless broadband company, announced that they have received a mobile communications license from the Irish Telecoms regulator, ComReg. This service will be issued the mobile code *088* in Ireland and will be used for the provision of 4G Mobile communications. Digiweb launched a mobile broadband network using FLASH-OFDM technology at 872 MHz.

On September 20, 2007, Verizon Wireless announced that it plans a joint effort with the Vodafone Group to transition its networks to the 4G standard LTE. On December 9, 2008, Verizon Wireless announced that they intend to build and begin to roll out an LTE network by the end of 2009. Since then, Verizon Wireless has said that they will start their rollout by the end of 2010.

On July 7, 2008, South Korea announced plans to spend 60 billion won, or US$58,000,000, on developing 4G and even 5G technologies, with the goal of having the highest mobile phone market share by 2012, and the hope of an international standard.

Telus and Bell Canada, the major Canadian cdmaOne and EV-DO carriers, have announced that they will be cooperating towards building a fourth generation (4G) LTE wireless broadband network in Canada. As a transitional measure, they are implementing 3G UMTS that went live in November 2009.

Sprint offers a 3G/4G connection plan, currently available in select cities in the United States. It delivers rates up to 10 Mbit/s.

In the United Kingdom, Telefónica O2 is to use Slough as a guinea pig in testing the 4G network and has called upon Huawei to install LTE technology in six masts across the town to allow people to talk to each other via HD video conferencing and play PlayStation games while on the move.

Verizon Wireless has announced that it plans to augment its CDMA2000-based EV-DO 3G network in the United States with LTE. AT&T, along with Verizon Wireless has chosen to migrate toward LTE from 2G/GSM and 3G/HSPA by 2011.

The U.S. FCC is exploring the possibility of deployment and operation of a nationwide 4G public safety network which would allow first responders to seamlessly communicate between agencies and across geographies, regardless of devices. In June 2010 the FCC released a comprehensive white paper which indicates that the 10 MHz of dedicated spectrum currently allocated from the 700 MHz spectrum for public safety will provide adequate capacity and performance necessary for normal communications as well as serious emergency situations.

TeliaSonera started deploying LTE (branded "4G") in Stockholm and Oslo November 2009 (as seen above), and in several Swedish, Norwegian, and Finnish cities during 2010. In June 2010, Swedish television companies used 4G to broadcast live television from the Swedish Crown Princess' Royal Wedding.

Beyond 4G research

A major issue in 4G systems is to make the high bit rates available in a larger portion of the cell, especially to users in an exposed position in between several basestations. In current research, this issue is addressed by macro-diversity techniques, also known as group cooperative relay, and also by beam-division multiple access.

Pervasive networks are an amorphous and at present entirely hypothetical concept where the user can be simultaneously connected to several wireless access technologies and can seamlessly move between them. These access technologies can be Wi-Fi, UMTS, EDGE, or any other future access technology. Included in this concept is also smart-radio (also known as cognitive radio technology) to efficiently manage spectrum use and transmission power as well as the use of mesh routing protocols to create a pervasive network.

4G wireless standards

In September 2009, the technology proposals have been submitted to ITU-R as 4G candidates. Basically all proposals are based on two technologies:

- LTE Advanced standardized by the 3GPP
- 802.16m standardized by the IEEE (i.e. WiMAX)

First set of 3GPP requirements on LTE Advanced has been approved in June 2008. LTE Advanced will be standardized in 2010 as part of the Release 10 of the 3GPP specification. LTE Advanced will be fully built on the existing LTE specification Release 10 and not be defined as a new specification series. A summary of the technologies that have been studied as the basis for LTE Advanced is included in a technical report.

Chapter 7

Mobile Phone Radiation and Health

A Greenfield-type tower used in base stations for mobile telephony

The effect mobile phone radiation has on human health is the subject of recent interest and study, as a result of the enormous increase in mobile phone usage throughout the world (as of June 2009, there were more than 4.3 billion users worldwide). Mobile phones use electromagnetic radiation in the microwave range, which some believe may be harmful to human health. A large body of research exists, both epidemiological and experimental, in non-human animals and in humans, that shows overall no evidence for
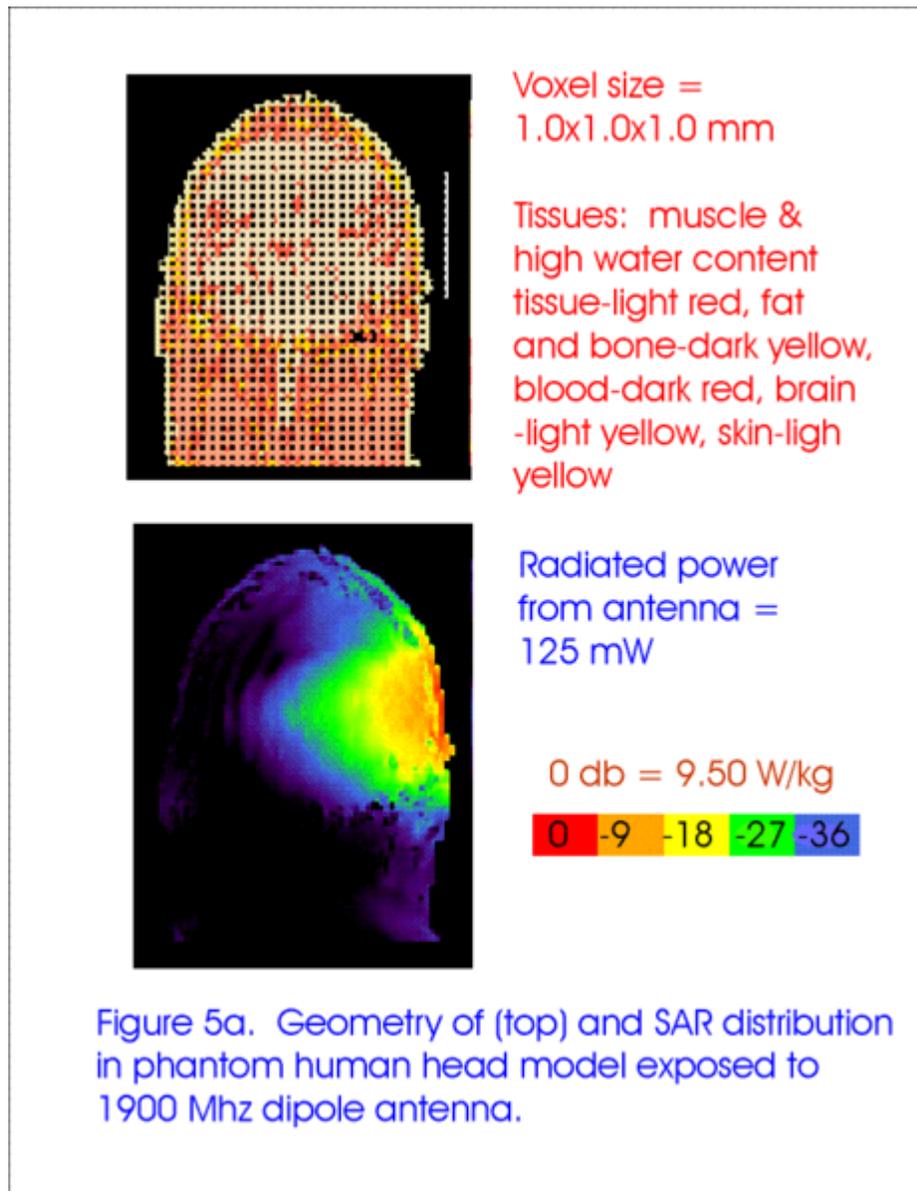
harmful effects. Other digital wireless systems, such as data communication networks, produce similar radiation.

The World Health Organization, based upon the consensus view of the scientific and medical communities, has stated that cancer is unlikely to be caused by cellular phones or their base stations and that reviews have found no convincing evidence for other health effects. The WHO expects to make recommendations about mobile phones in 2010. Some national radiation advisory authorities have recommended measures to minimize exposure to their citizens as a precautionary approach.

Effects

Many scientific studies have investigated possible health effects of mobile phone radiations. These studies are occasionally reviewed by some scientific committees to assess overall risks. A recent assessment was published in 2007 by the European Commission Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). It concludes that the three lines of evidence, *viz.* animal, *in vitro*, and epidemiological studies, indicate that "exposure to RF fields is unlikely to lead to an increase in cancer in humans."

Radiation absorption

Figure 5a. Geometry of (top) and SAR distribution in phantom human head model exposed to 1900 Mhz dipole antenna.

Calculated specific absorbed radiation (SAR) distribution in an anatomical model of head next to a 125 mW dipole antenna. Peak SAR is 9.5 W/kg averaged over a 1 mg cube. (*USAF/AFRL*).

Part of the radio waves emitted by a mobile telephone handset are absorbed by the human head. The radio waves emitted by a GSM handset can have a peak power of 2 watts, and a US analogue phone had a maximum transmit power of 3.6 watts. Other digital mobile technologies, such as CDMA2000 and D-AMPS, use lower output power, typically below 1 watt, UVA. The maximum power output from a mobile phone is regulated by the mobile phone standard and by the regulatory agencies in each country. In most systems the cellphone and the base station check reception quality and signal strength and the

power level is increased or decreased automatically, within a certain span, to accommodate different situations, such as inside or outside of buildings and vehicles. The rate at which radiation is absorbed by the human body is measured by the Specific Absorption Rate (SAR), and its maximum levels for modern handsets have been set by governmental regulating agencies in many countries. In the USA, the Federal Communications Commission (FCC) has set a SAR limit of 1.6 W/kg, averaged over a volume of 1 gram of tissue, for the head. In Europe, the limit is 2 W/kg, averaged over a volume of 10 grams of tissue. SAR values are heavily dependent on the size of the averaging volume. Without information about the averaging volume used, comparisons between different measurements cannot be made. Thus, the European 10-gram ratings should be compared among themselves, and the American 1-gram ratings should only be compared among themselves. SAR data for specific mobile phones, along with other useful information, can be found directly on manufacturers' websites, as well as on third party web sites.

Thermal effects

One well-understood effect of microwave radiation is dielectric heating, in which any dielectric material (such as living tissue) is heated by rotations of polar molecules induced by the electromagnetic field. In the case of a person using a cell phone, most of the heating effect will occur at the surface of the head, causing its temperature to increase by a fraction of a degree. In this case, the level of temperature increase is an order of magnitude less than that obtained during the exposure of the head to direct sunlight. The brain's blood circulation is capable of disposing of excess heat by increasing local blood flow. However, the cornea of the eye does not have this temperature regulation mechanism and exposure of 2–3 hours duration has been reported to produce cataracts in rabbits' eyes at SAR values from 100-140W/kg, which produced lenticular temperatures of 41°C. There were no cataracts detected in the eyes of monkeys exposed under similar conditions. Premature cataracts have not been linked with cell phone use, possibly because of the lower power output of mobile phones.

Non-thermal effects

The communications protocols used by mobile phones often result in low-frequency pulsing of the carrier signal. Whether these modulations have biological significance has been subject to debate.

Some researchers have argued that so-called "non-thermal effects" could be reinterpreted as a normal cellular response to an increase in temperature. The German biophysicist Roland Glaser, for example, has argued that there are several thermoreceptor molecules in cells, and that they activate a cascade of second and third messenger systems, gene expression mechanisms and production of heat shock proteins in order to defend the cell against metabolic cell stress caused by heat. The increases in temperature that cause these changes are too small to be detected by studies such as REFLEX, which base their whole argument on the apparent stability of thermal equilibrium in their cell cultures.

Other researchers believe the stress proteins are unrelated to thermal effects, since they occur for both extremely low frequencies (ELF) and radio frequencies (RF), which have very different energy levels.

Blood-brain barrier effects

Swedish researchers from Lund University (Salford, Brun, Perrson, Eberhardt, and Malmgren) have studied the effects of microwave radiation on the rat brain. They found a leakage of albumin into the brain via a permeated blood-brain barrier. This confirms earlier work on the blood-brain barrier by Allan Frey, Oscar and Hawkins, and Albert and Kerns. Other groups have not confirmed these findings in cell or animal studies.

Cancer

In 2006 a large Danish study about the connection between mobile phone use and cancer incidence was published. It followed over 420,000 Danish citizens for 20 years and showed no increased risk of cancer. The German Federal Office for Radiation Protection (BfS) considers this report inconclusive.

The following studies of long time exposure have been published:

- The 13 nation INTERPHONE project - the largest study of its kind ever undertaken - has now been published and did not find a solid link with mobile phones and brain tumours.

The *International Journal of Epidemiology* published a combined data analysis from a multi national population-based case-control study of glioma and meningioma, the most common types of brain tumour.

The authors reported the following conclusion:

Overall, no increase in risk of glioma or meningioma was observed with use of mobile phones. There were suggestions of an increased risk of glioma at the highest exposure levels, but biases and error prevent a causal interpretation. The possible effects of long-term heavy use of mobile phones require further investigation.

In the press release accompanying the release of the paper, Dr Christopher Wild, Director of the International Agency for Research on Cancer (IARC) said:

An increased risk of brain cancer is not established from the data from Interphone. However, observations at the highest level of cumulative call time and the changing patterns of mobile phone use since the period studied by Interphone, particularly in young people, mean that further investigation of mobile phone use and brain cancer risk is merited.

A number of independent health and government authorities have commented on this important study including The Australian Centre for Radiofrequency Bioeffects Research (ACRBR) which said in a statement that:

Until now there have been concerns that mobile phones were causing increases in brain tumours. Interphone is both large and rigorous enough to address this claim, and it has not provided any convincing scientific evidence of an association between mobile phone use and the development of glioma or meningioma. While the study demonstrates some weak evidence of an association with the highest tenth of cumulative call time (but only in those who started mobile phone use most recently), the authors conclude that biases and errors limit the strength of any conclusions in this group. It now seems clear that if there was an effect of mobile phone use on brain tumour risks in adults, this is likely to be too small to be detectable by even a large multinational study of the size of Interphone.

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)which said in a statement that:

On the basis of current understanding of the relationship between brain cancer and use of mobile phones, including the recently published data from the INTERPHONE study, ARPANSA:

concludes that currently available data do not warrant any general recommendation to limit use of mobile phones in the adult population,

continues to inform those concerned about potential health effects that they may limit their exposure by reducing call time, by making calls where reception is good, by using hands-free devices or speaker options, or by texting; and

recommends that, due to the lack of any data relating to children and long term use of mobile phones, parents encourage their children to limit their exposure by reducing call time, by making calls where reception is good, by using hands-free devices or speaker options, or by texting.

The Cancer Council Australia said in a statement that it cautiously welcomed the results of the largest international study to date into mobile phone use, which has found no evidence that normal use of mobile phones, for a period up to 12 years, can cause brain cancer.

Chief Executive Officer, Professor Ian Olver, said findings from the Interphone study, conducted across 13 countries including Australia, were consistent with other research that had failed to find a link between mobile phones and cancer.

This supports previous research showing mobile phones don't damage cell DNA, meaning they can't cause the type of genetic mutations that develop into cancer," Professor Olver said.

However, it has been suggested that electromagnetic fields associated with mobile phones may play a role in speeding up the development of an existing cancer. The Interphone study found no evidence to support this theory.

- A Danish study (2004) that took place over 10 years found no evidence to support a link. However, this study has been criticized for collecting data from subscriptions and not necessarily from actual users. It is known that some subscribers do not use the phones themselves but provide them for family members to use. That this happens is supported by the observation that only 61% of a small sample of the subscribers reported use of mobile phones when responding to a questionnaire.

- A Swedish study (2005) that draws the conclusion that "the data do not support the hypothesis that mobile phone use is related to an increased risk of glioma or meningioma."

- A British study (2005) that draws the conclusion that "The study suggests that there is no substantial risk of acoustic neuroma in the first decade after starting mobile phone use. However, an increase in risk after longer term use or after a longer lag period could not be ruled out."

- A German study (2006) that states "In conclusion, no overall increased risk of glioma or meningioma was observed among these cellular phone users; however, for long-term cellular phone users, results need to be confirmed before firm conclusions can be drawn."

- A joint study conducted in northern Europe that draws the conclusion that "Although our results overall do not indicate an increased risk of glioma in relation to mobile phone use, the possible risk in the most heavily exposed part of the brain with long-term use needs to be explored further before firm conclusions can be drawn."

Other studies on cancer and mobile phones are:

- A Swedish scientific team at the Karolinska Institute conducted an epidemiological study (2004) that suggested that regular use of a mobile phone over a decade or more was associated with an increased risk of acoustic neuroma, a type of benign brain tumor. The increase was not noted in those who had used phones for fewer than 10 years.

- The INTERPHONE study group from Japan published the results of a study of brain tumour risk and mobile phone use. They used a new approach: determining the SAR inside a tumour by calculating the radio frequency field absorption in the exact tumour location. Cases examined included glioma, meninigioma, and pituitary adenoma. They reported that the overall odds ratio (OR) was not

increased and that there was no significant trend towards an increasing OR in relation to exposure, as measured by SAR.

In 2007, Dr. Lennart Hardell, from Örebro University in Sweden, reviewed published epidemiological papers (2 cohort studies and 16 case-control studies) and found that:

- Cell phone users had an increased risk of malignant gliomas.
- Link between cell phone use and a higher rate of acoustic neuromas.
- Tumors are more likely to occur on the side of the head that the cell handset is used.
- One hour of cell phone use per day significantly increases tumor risk after ten years or more.

In a February 2008 update on the status of the INTERPHONE study IARC stated that the long term findings '…could either be causal or artifactual, related to differential recall between cases and controls.'

- A self-published and non-peer reviewed meta-study by Dr. Vini Khurana, an Australian neurosurgeon, presented what it termed "increasing body of evidence ... for a link between mobile phone usage and certain brain tumours" and that it "is anticipated that this danger has far broader public health ramifications than asbestos and smoking". This was criticised as '…an unbalanced analysis of the literature, which is also selective in support of the author's claims.'

A publication titled "Public health implications of wireless technologies" cites that Lennart Hardell found age is a significant factor. The report repeated the finding that the use of cell phones before age 20 increased the risk of brain tumors by 5.2, compared to 1.4 for all ages. A review by Hardell et al. concluded that current mobile phones are not safe for long-term exposure.

In a time trends study in Europe, conducted by the Institute of Cancer Epidemiology in Copenhagen, no significant increase in brain tumors among cell phone users was found between the years of 1998 and 2003. "The lack of a trend change in incidence from 1998 to 2003 suggests that the induction period relating mobile phone use to brain tumors exceeds 5–10 years, the increased risk in this population is too small to be observed, the increased risk is restricted to subgroups of brain tumors or mobile phone users, or there is no increased risk."

Cognitive effects

A 2009 study examined the effects of exposure to radiofrequency radiation (RFR) emitted by standard GSM cell phones on the cognitive functions of humans. The study confirmed longer (slower) response times to a spatial working memory task when exposed to RFR from a standard GSM cellular phone placed next to the head of male subjects, and showed that longer duration of exposure to RFR may increase the effects on performance. Right-handed subjects exposed to RFR on the left side of their head on

average had significantly longer response times when compared to exposure to the right side and sham-exposure.

Electromagnetic hypersensitivity

Some users of mobile handsets have reported feeling several unspecific symptoms during and after its use; ranging from burning and tingling sensations in the skin of the head and extremities, fatigue, sleep disturbances, dizziness, loss of mental attention, reaction times and memory retentiveness, headaches, malaise, tachycardia (heart palpitations), to disturbances of the digestive system. Reports have noted that all of these symptoms can also be attributed to stress and that current research cannot separate the symptoms from nocebo effects.

Genotoxic effects

A large early 2009 meta-study of 101 scientific publications on genotoxicity of RF electromagnetic fields shows that 49 report a genotoxic effect and 42 do not. Research published in 2004 by a team at the University of Athens had a reduction in reproductive capacity in fruit flies exposed to 6 minutes of 900 MHz pulsed radiation for five days. Subsequent research, again conducted on fruit flies, was published in 2007, with the same exposure pattern but conducted at both 900 MHz and 1800 MHz, and had similar changes in reproductive capacity with no significant difference between the two frequencies. Following additional tests published in a third article, the authors stated they thought their research suggested the changes were "…due to degeneration of large numbers of egg chambers after DNA fragmentation of their constituent cells …". Australian research conducted in 2009 by subjecting in vitro samples of human spermatozoa to radio-frequency radiation at 1.8 GHz and specific absorption rates (SAR) of 0.4 to 27.5 W/kg showed a correlation between increasing SAR and decreased motility and vitality in sperm, increased oxidative stress and 8-Oxo-2'-deoxyguanosine markers, stimulating DNA base adduct formation and increased DNA fragmentation.

In 1995, in the journal *Bioelectromagnetics*, Henry Lai and Narenda P. Singh reported damaged DNA after two hours of microwave radiation at levels deemed safe according to government standards. Later, in December 2004, a pan-European study named REFLEX (Risk Evaluation of Potential Environmental Hazards from Low Energy Electromagnetic Field (EMF) Exposure Using Sensitive in vitro Methods), involving 12 collaborating laboratories in several countries showed some compelling evidence of DNA damage of cells in in-vitro cultures, when exposed between 0.3 to 2 watts/kg, whole-sample average. There were indications, but not rigorous evidence of other cell changes, including damage to chromosomes, alterations in the activity of certain genes and a boosted rate of cell division. Reviews of in vitro genotoxicity studies have generally concluded that RF is not genotoxic and that studies reporting positive effects had experimental deficiences.

Sleep and EEG effects

Sleep, EEG and waking rCBF have been studied in relation to RF exposure for a decade now, and the majority of papers published to date have found some form of effect. While a Finnish study failed to find any effect on sleep or other cognitive function from pulsed RF exposure, most other papers have found significant effects on sleep. Two of these papers found the effect was only present when the exposure was pulsed (amplitude modulated), and one early paper actually found that sleep quality (measured by the amount of participants' broken sleep) actually improved.

While some papers were inconclusive or inconsistent, a number of studies have now demonstrated reversible EEG and rCBF alterations from exposure to pulsed RF exposure. German research from 2006 found that statistically significant EEG changes could be consistently found, but only in a relatively low proportion of study participants (12 - 30%).

Health hazards of base stations

Another area of concern is the radiation emitted by the fixed infrastructure used in mobile telephony, such as base stations and their antennas, which provide the link to and from mobile phones. This is because, in contrast to mobile handsets, it is emitted continuously and is more powerful at close quarters. On the other hand, field intensities drop rapidly with distance away from the base of the antenna because of the attenuation of power with the square of distance. Base station emissions must comply with safety guidelines. Some countries however (such as South Africa for example) have no health regulations governing the placement of base stations.

Several surveys have found increases of symptoms depending upon proximity to electromagnetic sources such as mobile phone base stations.

A 2002 survey study by Santini *et al.* in France found a variety of self-reported symptoms for people who reported that they were living within 300 metres (984 ft) of GSM cell towers in rural areas, or within 100 m (328 ft) of base stations in urban areas. Fatigue, headache, sleep disruption and loss of memory were among the symptoms reported. Similar results have been obtained with GSM cell towers in Spain, Egypt, Poland and Austria. No major studies have been reported in which health effects did not occur on actual populations living near mobile base stations. However, there are significant challenges in conducting studies of populations near base stations, especially in assessment of individual exposure. Self-report studies can also be vulnerable to the nocebo effect.

A study conducted at the University of Essex and another in Switzerland concluded that mobile phone masts were unlikely to be causing these short term effects in a group of volunteers who complained of such symptoms. The Essex study has been criticised as being skewed due to drop-outs of test subjects, although these criticisms were answered by the authors.

As technology progresses and data demands have increased on the mobile network, towns and cities have seen the number of towers increase sharply, including 3G towers which work with larger bandwidths. Many measurements and experiments have shown that transmitter power levels are relatively low - in modern 2G antennas, in the range of 20 to 100 W, with the 3G towers causing less radiation than the already present 2G network. An average radiation power output of 3 W is used. The use of 'micro-cell geometries' (large numbers of transmitters in an area but with each individual transmitter running very low power) inside cities has decreased the amount of radiated power even further. The radiation exposure from these antennas, while generally low level, is continuous.

Experts consulted by France consider it is mandatory that main antenna axis not to be directly in front of a living place at a distance shorter than 100 meters. This recommendation was modified in 2003 to say that antennas located within a 100-metre radius of primary schools or childcare facilities should be better integrated into the cityscape and was not included in a 2005 expert report.

Occupational health hazards

Telecommunication workers who spend time at a short distance from the active equipment, for the purposes of testing, maintenance, installation, etcetera, may be at risk of much greater exposure than the general population. Many times base stations are not turned off during maintenance, but the power being sent through to the antennas is cut off, so that the workers do not have to work near live antennas.

A variety of studies over the past 50 years have been done on workers exposed to high RF radiation levels; studies including radar laboratory workers, military radar workers, electrical workers, and amateur radio operators. Most of these studies found no increase in cancer rates over the general population or a control group. Many positive results could have been attributed to other work environment conditions, and many negative results of reduced cancer rates also occurred.

Safety standards and licensing

In order to protect the population living around base stations and users of mobile handsets, governments and regulatory bodies adopt safety standards, which translate to limits on exposure levels below a certain value. There are many proposed national and international standards, but that of the International Commission for Non-Ionizing Radiation Protection (ICNIRP) is the most respected one, and has been adopted so far by more than 80 countries. For radio stations, ICNIRP proposes two safety levels: one for occupational exposure, another one for the general population. Currently there are efforts underway to harmonise the different standards in existence.

Radio base licensing procedures have been established in the majority of urban spaces regulated either at municipal/county, provincial/state or national level. Mobile telephone

service providers are, in many regions, required to obtain construction licenses, provide certification of antenna emission levels and assure compliance to ICNIRP standards and/or to other environmental legislation.

Many governmental bodies also require that competing telecommunication companies try to achieve sharing of towers so as to decrease environmental and cosmetic impact. This issue is an influential factor of rejection of installation of new antennas and towers in communities.

The safety standards in the U.S. are set by the Federal Communications Commission (FCC). The FCC has based its standards primarily on those standards established by the Institute of Electrical and Electronics Engineers (IEEE), specifically Subcommittee 4 of the "International Committee on Electromagnetic Safety".

Switzerland has set safety limits lower than the ICNIRP limits for certain "sensitive areas" (classrooms, for example).

In the Courts

In the USA, a small number of personal injury lawsuits have been filed by individuals against cellphone manufacturers, such as Motorola, NEC, Siemens and Nokia, on the basis of allegations of causation of brain cancer and death. In US federal court, expert testimony relating to science must be first evaluated by a judge, in a Daubert hearing, to be relevant and valid before it is admissible as evidence. In one case against Motorola, the plaintiffs alleged that the use of wireless handheld telephones could cause brain cancer, and that the use of Motorola phones caused one plaintiff's cancer. The judge ruled that no sufficiently reliable and relevant scientific evidence in support of either general or specific causation was proffered by the plaintiffs; accepted a motion to exclude the testimony of the plaintiffs' experts; and denied a motion to exclude the testimony of the defendants' experts.

French High Court ruling against telecom company

In February 2009 the telecom company Bouygues Telecom was ordered to take down a mobile phone mast due to uncertainty about its effect on health. Residents in the commune Charbonnières in the Rhône department had sued the company claiming adverse health effects from the radiation emitted by the 19 meter tall antenna. The milestone ruling by the Versailles Court of Appeal reversed the burden of proof which is usual in such cases by emphasizing the extreme divergence between different countries in assessing safe limits for such radiation. The court stated that, "Considering that, while the reality of the risk remains hypothetical, it becomes clear from reading the contributions and scientific publications produced in debate and the divergent legislative positions taken in various countries, that uncertainty over the harmlessness of exposure to the waves emitted by relay antennas persists and can be considered serious and reasonable".

Precaution

Precautionary principle

In 2000, the World Health Organization (WHO) recommended that the precautionary principle could be voluntarily adopted in this case. It follows the recommendations of the European Community for environmental risks. According to the WHO, the "precautionary principle" is "a risk management policy applied in circumstances with a high degree of scientific uncertainty, reflecting the need to take action for a potentially serious risk without awaiting the results of scientific research." Other less stringent recommended approaches are prudent avoidance principle and as low as reasonably practicable. Although all of these are problematic in application, due to the widespread use and economic importance of wireless telecommunication systems in modern civilization, there is an increased popularity of such measures in the general public, though also evidence that such approaches may increase concern. They involve recommendations such as the minimization of cellphone usage, the limitation of use by at-risk population (such as children), the adoption of cellphones and microcells with as low as reasonably practicable levels of radiation, the wider use of hands-free and earphone technologies such as Bluetooth headsets, the adoption of maximal standards of exposure, RF field intensity and distance of base stations antennas from human habitations, and so forth.

Precautionary Measures and health advisories

Some national radiation advisory authorities, including those of Austria, France, Germany, and Sweden, have recommended measures to minimize exposure to their citizens. Examples of the recommendations are:

- Use hands-free to decrease the radiation to the head.
- Keep the mobile phone away from the body.
- Do not use telephone in a car without an external antenna.

The use of "hands-free" was not recommended by the British Consumers' Association in a statement in November 2000 as they believed that exposure was increased. However, measurements for the (then) UK Department of Trade and Industry and others for the French l'Agence française de sécurité sanitaire environnementale showed substantial reductions. In 2005 Professor Lawrie Challis and others said clipping a ferrite bead onto hands-free kits stops the radio waves travelling up the wire and into the head.

Chapter 8

Mobile Phones on Aircraft

Mobile phones on aircraft are strictly regulated as concerns exist that mobile phones pose a danger to the aircraft and passengers. It is thought they could adversely affect the navigational instruments in the cockpit and so such devices must be turned off while the aircraft is airborne.

The use of mobile phones and similar devices has been banned by regulatory bodies such as the United States' Federal Aviation Administration and others across the world. Many reasons have been given and tests have been performed to try and identify any possible interference that may arise from their usage in–flight. The general conclusions are that *any risk that may cause aircraft failure and passenger deaths is too high* until testing confirms that the risks have been dealt with or do not exist.

The major problems are that the mobile phones or other electronic devices may interfere with aircraft systems or computers due to poor or missing shielding and so cause a catastrophic failure of the control mechanisms. There have been few instances where a definite link between device use and system failures have been proven and in those cases where a correlation has been shown it has tended to be where shielding was in fact not present, of bad quality or had been compromised.

Since the regulations were imposed by the various international bodies there have been advances in equipment and systems which have allowed the gradual introduction of safe in-flight communications via mobile phones and such devices. These systems are being implemented by an increasing number of airlines and carriers as each is tested by the authority responsible for air-safety and deemed to be fit for use.

Mobile phone usage issues

Electromagnetic interference

Some level of electromagnetic interference to aircraft systems is theoretically possible from active radio transmitters such as mobile phones, small walkie–talkies or radio remote–controlled toys and also from unintentional emitters such as ordinary radio receivers, computers and virtually any non–trivial electronic device.

There are some reports that indicate this and some that refute it:

Boeing performed extensive tests as reported in AeroMagazine's *Interference from Electronic Devices* in response to reports by flight crews of anomalies that they believed to be caused by electronic devices. The flight crews had apparently confirmed the effect by switching the "suspect" devices on and off and watching the effects. Despite this and despite the fact that Boeing in many cases was able to purchase the actual offending device from the passenger and use it in extensive testing Boeing was never able to reproduce any of the anomalies. The report concludes:

As a result of these and other investigations, Boeing has not been able to find a definite correlation between PEDs and the associated reported airplane anomalies.

ABC News *20/20* aired a report in December 2007 trying to get to the bottom of the ban on cell phone usage in aircraft. They interviewed one of the authors of the IEEE Spectrum report cited below but also noted that this study was not designed to actually detect interference–only that cellphones which are not switched off. The report concludes that the primary reason for the ban on cell phone use in flight is that neither the FAA nor the FCC are willing to spend the money to perform conclusive safety tests. They have left this up to the airlines who do not see any return on investment made in paying for such tests. According to the *20/20* website ABC News consultant and veteran airline pilot John J. Nance states categorically:

There's little reason to worry about cell phones interfering with an airplane's navigational equipment. Nance says an airplane's electronic systems are "all heavily shielded. That means that stray signals cannot get into those systems."

A NASA publication details the fifty most recent reports to the Aviation Safety Reporting System (ASRS) regarding "avionics problems that may result from the influence of passenger electronic devices." The nature of these reports varies widely. Some merely describe passengers' interactions with flight crews when asked to stop using an electronic device. Other reports amount to crews reporting an anomaly experienced at the same time a passenger was witnessed using a mobile phone which indicates only a weak correlation and not causality. However a few reports state that anomalies were observed to appear and disappear as the suspect device was turned on and off which would indicate a high degree of correlation.

A NASA report from 2001 summarizes "14 years of incidents reported by pilots to the ASRS" of interference caused, or suspected to be caused, by passengers electronic devices. Mobile phones were the most frequently identified source of interference with laptop computers a close second. In no cases were the affected avionics found to be defective upon later testing. Degrees of correlation or confidence were not among the data summarized in the report.

A 2003 study involved three months of testing with RF spectrum analyzers and other instruments aboard regular commercial flights. The report found that on a typical flight at

least one mobile phone is likely to be left on throughout the flight and that a mobile phone in use produces a far stronger signal than one that is simply left switched on. In the authors' words:

There is no smoking gun to this story: there is no definitive instance of an air accident known to have been caused by a passenger's use of an electronic device. Nonetheless, although it is impossible to say that such use has contributed to air accidents in the past, the data also make it impossible to rule it out completely. More important, the data support a conclusion that continued use of portable RF-emitting devices such as cellphones will, in all likelihood, someday cause an accident by interfering with critical cockpit instruments such as GPS receivers. This much is certain: there exists a greater potential for problems than was previously believed.

A 2000 study by the British Civil Aviation Authority concluded that:

interference levels produced by a portable telephone, used near the flight deck or avionics equipment bay, will exceed demonstrated susceptibility levels for equipment qualified to standards published prior to July 1984. Since equipment qualified to these standards are installed in older aircraft, and can be installed (and is known to be installed) in newly built aircraft, current policy for restricting the use of portable telephones on all aircraft will need to remain in force.. …For safety reasons, the Regulatory Authorities should continue to prohibit the use of portable telephones by passengers on aircraft whilst the engines are running.

A report from BBC news comments that "most of the evidence is circumstantial and anecdotal. There is no absolute proof mobile phones are hazardous." It also quotes Dan Hawkes the head of avionic systems at the Civil Aviation Authority (CAA):

There's an industry consensus, throughout the world, that mobile phones are a potential hazard to aircraft and must be switched off. A typical aircraft these days could have anything up to 15 or more radio systems on board. The signals that a mobile phone gives out could penetrate into equipment, and could affect the operation of the computer. The computer may shut down, which would affect the aircraft's navigation, which in turn would affect the signals sent to the auto pilot, and the way the aircraft is automatically flown. The aircraft might go off course, and even might change height.

Whether interference from small battery-powered devices should have any influence on electronic systems that should be designed to fly through lightning storms without failing is often disputed by critics of the ban. An article by Tekla S. Perry and Linda Geppert, then editors of *IEEE Spectrum*, offers an explanation: "While a brand new aircraft may indeed be completely immune from such interference, shielding and other mechanisms that normally protect the avionics do degrade over time, after thousands of takeoffs, landings, and pressurization cycles and various maintentance procedures. Similarly, the shielding in passengers' devices also degrades due to the passage of time and, in some cases, repair procedures."

While certainly not a rigorous scientific study the Discovery Channel television program MythBusters examined the "myth" that mobile phones are banned aboard aircraft to force passengers to use the airline's inflight phones. They concluded that this is "busted". Their tests caused no interference to a small airplane's avionics but did to unshielded equipment. They concluded that interference could occur aboard an aircraft if the shielding was not working correctly.

Conclusions

The cost of an accident, should one occur, could be extremely high in terms of human life and the risk is completely avoidable in that no one absolutely needs to use their mobile phone in flight. The regulatory agencies and aviation industry take the position that any increased risk is unacceptable if it is avoidable.

Some mobile phone systems such as GSM may cause an irritating buzz, explained in the TDMA article, which could disrupt communications from the pilot to ground. The high speed of air travel may make interference more likely than it would otherwise be. The maximum speed of travel in a mobile phone system is limited by several factors; frequency changes, rate of change of timing offset, etc. and the speed of an airplane often exceeds these as, typically, mobile phones are designed for use in a fast car which means the phone will fail to register to the network and retry registration repeatedly.

Other factors

Social resistance to mobile phone use on flights

People may prefer a ban on mobile phone use in flight as it prevents undue amounts of noise from cellphone chatter. For several reasons people tend to talk more loudly into mobile phones than they do when talking in person.

One reason is people subconsciously rely on hearing their own voice to modulate their own speech volume. Mobile phones do not introduce adequate sidetone, a reduced volume "copy" of that person's speech, back into the earpiece. Landline phones have done this for a long time and is also the cause of the "echo" effect on many cordless phones. Another reason is that the conversation in the phone may demand more mental processing power. This is because mobile phones sound different from normal speech due to audio data compression or background noise.

Whatever the reason is the net effect is that the person is less aware of the people around them. Also the high level of background noise on an airplane would invariably force people to talk more loudly into their cell phones. Finally a more obvious problem is that passengers will tend to talk more if they have a larger potential audience i.e. anyone that they can reach via phone. In other words it is expected that mobile phone conversations will be longer and louder than current passenger conversations.

AT&T has suggested that in-flight mobile phone restrictions should remain in place in the interests of reducing the nuisance to other passengers caused by someone talking loudly on a phone next to them.

Competition for airlines' in-flight phone service

Skeptics of the ban believe that the airlines support the ban because they do not want passengers to have an alternative to the in-flight phone service such as GTE's Airphone. These services are much more expensive than mobile phone services. They also provide extremely slow data rates at a similarly high price. In general the airlines have had little success in selling these services and the in-flight phone equipment has disappeared from most U.S. domestic flights.

It could be easy to believe that the airlines support a continued ban on mobile phone use so as to force customers to use the in-flight phone service with comments such as those made by Andy Plews a spokesman for UAL's United Airlines. "We don't believe it's a good safety issue"..."We'd like people to use the air phones."

Current status

Emirates Airline

On 20 March 2008, Emirates Airline flights began allowing in-flight voice calls on some commercial airline flights.

The approval by EASA of these systems has established that GSM phones on certified aircraft types are considered safe to use when installed with an on-board cellular picocell.

Europe

AeroMobile and OnAir allow the use of personal electronics devices aboard flights. The services are most prevalent in Europe and are licensed to specific airlines for use.

Malaysia Airlines

Malaysia Airlines flights are installed with AeroMobile systems to enable in flight voice calls and text messages.

Mobile phones on corporate jets

Falcon 2000 on 2 April 2009 implemented a new concept designated SafeCell when it commenced flying.

United States

To protect the integrity of the electronic control and navigation equipment aboard large airliners in commercial service the use of cellphones designed for terrestrial service is forbidden. The FCC did, however, allocate spectra in the 450 MHz and 800 MHz frequency bands for use by equipment designed and tested as "safe for air-to-ground service" and these systems use widely separated ground stations. In the 450 MHz band co-channel assignments are at least 497 miles apart and in the 800 MHz band only specific sites were authorized by the FCC. The 450 MHz service is limited to "general aviation" users, in corporate jets mostly, while the 800 MHz spectrum can be used by airliners as well as for general aviation. The 450 MHz spectrum is named AGRAS while the 800 MHz service is under review following an auction of the spectrum in 2006.

Regulations and practices

Mobile phones are portable electronic devices and, as such, are banned from use in civilian airplanes by the Federal Aviation Agency unless the operator of a commercial aircraft or pilot of a private aircraft determines that it could not cause interference to avionics in the aircraft.

The FAA in **14 C.F.R § 91.21** bans the use of *all* portable electronic devices (with a few odd exceptions) for all flights operated by an airline or those flights under Instrument flight rules (IFR). It does allow that the airline (or for privately operated aircraft the pilot) can make an exception to this rule if the operator deems that device safe. This effectively gives the airline, or pilot, the final word as to what devices may be used aboard an aircraft as far as the FAA is concerned although the FCC restriction still applies.

- Note that for aircraft operated by an airline the pilot is not considered the "operator" and cannot legally allow exceptions to the airline's restrictions although the pilot may dictate *additional* restrictions.

No U.S. airlines have approved the use of mobile phones while in flight.

The FAA in **Advisory Circular 91.21-1A** *recommends* that aircraft operators blanket ban all intentional transmitters and mentions specifically CB radios, remote control devices and cellular phones. While Advisory Circulars are not legally binding air carriers rarely ignore the official written advice from the FAA.

This Advisory Circular has since been superseded by AC 91.21.1B.

Federal Avaiation Regulation (FAR) 91.21 states that the Pilot In Command of an aircraft that is NOT IFR, and NOT Part 121 (Commercial Air Carriers), can allow usage of "Portable Electronic Devices". However to take the attitude that "The FAA doesn't say I can't do it" is incorrect, particularly in the category of radiotelephone communications governed by the FCC. FCC regulations, and specifically **Title 47 Part 22.925 (Oct 1, 2006 revision)**, states "Cellular telephones installed in or carried aboard airplanes,

balloons or any other type of aircraft must not be operated while such aircraft are airborne (not touching the ground). When an aircraft leaves the ground, all cellular telephones on board that aircraft must be turned off.".

The use of cell phones aboard airborne planes is banned by the FCC in **47 C.F.R. § 22.925**: "The use of cellular telephones while this aircraft is airborne is prohibited by FCC rules.... The use of cellular telephones while this aircraft is on the ground is subject to FAA regulations." This ban applies to phones that use the 800 MHz spectrum. Personal Communications Services (PCS) phones that use the 1900 MHz spectrum are governed under **FCC 47CFR24** and their use in aircraft is not restricted by the FCC whether on the ground or in flight.

Cell tower channel re-use

The U.S. Federal Communications Commission (FCC) currently prohibits the use of mobile telephones aboard *any* aircraft in flight. The reason given is that mobile phone systems depend on channel reuse and operating a phone at altitude may violate the fundamental assumptions that allow channel reuse to work.

The FCC is also concerned that the use, or even non-use, of a powered cell phone could cause disruption to the cell systems' towers and has banned their use.

Mobile telephones are intentionally designed with a low power output. A tower is the center of a "cell" and due to attenuation with distance (inverse square law) cell phone transmissions can usually be received only weakly by towers in adjacent cells and not at all in cells farther away (non-adjacent cells). This allows the channel used by any given phone to be reused by other phones in non-adjacent cells. This principle allows tens or hundreds of thousands of people to use their phones at the same time in a given metropolitan area while using only a limited number of channels.

Channel reuse works because a mobile phone on the ground will only have one "closest" tower that can possibly use a particular group of frequencies, CDMA codes, or time slots. The software that manages the system assumes that the signal from a phone on a particular tower can, on other towers, only be "heard" at greatly reduced signal strength. The frequency, code, or time slot used by the phone can therefore be reused by other phones on other towers.

In the old analog cell system a channel was simply a frequency pair: There were seven groups of 35 channels each and no two adjacent cells used the same channel groups. Modern CDMA and TDMA systems are more complex: A channel in TDMA is a frequency pair, and a time slot, and a channel in CDMA is a spread spectrum key but the principle of channel reuse still applies.

If a mobile phone is operated from an aircraft in flight above a city these assumptions ares no longer valid because the towers of numerous different cells may be about equidistant from the phone. Multiple towers might assume that the phone is under their

control and the phone could be assigned a free channel by one tower but could also be heard on other towers using the same channel group. The channel might already be in use on those other towers and could cause interference with existing calls. It is also possible that the software controlling the towers could crash. Even if the software can cope with hearing the same phone on multiple non-adjacent towers the result at best is an overall decrease in system capacity.

An additional concern is the output power of the mobile handset. Because the towers might be miles below the aircraft the phone might have to transmit at its maximum power to be received. This will increase the risk of interference with electronic equipment on the aircraft.

Recent and future changes

In flight technology

Airlines have installed technologies to allow phones to be connected within the airplane as it flies. Such systems were tested on flying scheduled flights from 2006 and in 2008 several airlines started to allow in-flight use of mobile phones. These changes have been attributed to strong demand by frequent fliers. A few airlines that are installing the equipment are also considering the issue of "phone-free zones" and "quiet time" on long flights.

Future changes

A few U.S. airlines have announced plans to allow mobile phones to be used on aircraft pending approval by the FCC and the FAA. The method is similar to that used in some cars on the German ICE train and the aircraft will contain a device known as a picocell. The picocell will act as a miniature mobile telephone tower communicating with mobile phones within the aircraft and relaying the signals to either satellites or a terrestrial-based system. The picocell will be designed and maintained for full compatibility with the rest of the on-board avionics. Communication between the picocell and the rest of the telephone network will be on separate frequencies that do not interfere with either the cellular system or the aircraft's avionics much like the on–board phone systems already aboard many commercial aircraft. Since the picocell's antennas within the aircraft would be very close to the passengers and inside the aircraft's metal shell both the picocell's and the phones' output power could be reduced to very low levels reducing the chance for interference. Such systems have been tested on a few flights within the United States under a waiver from the FCC.

ARINC and Telenor have formed a joint venture company to offer such a service on board commercial aircraft. The mobile phone calls are routed via satellite to the ground network and an on-board EMI screening system stops the cellphones contacting the ground network.

These systems are comparatively easy to implement for customers in most of the world where GSM phones operating on either of just two bands are the norm. The multitude of incompatible mobile phone systems in the United States and other countries makes the situation more difficult — it is not clear if the onboard repeaters will be compatible with all of the different cell-phone protocols (TDMA, GSM, CDMA, iDen) and their respective providers.

On 30 August 2006 the Irish low-cost airline Ryanair announced it will introduce a facility to allow passengers to use their mobile phones in-flight. This service as started on the 19th February 2009 with 20 of their Dublin based aircraft.

As of mid April 2007 Qantas teamed up with Panasonic Avionics Corporation and AeroMobile to commence a three month trial that would "enable customers to send and receive e-mails, access the Internet and send and receive text messages from their own mobile phone"

On 18 October 2007 Ofcom published proposals for the technical and authorisational approach that would be adopted to allow this for European GSM users on the 1800Mz band on UK registered aircraft. and on 26 March 2008 Ofcom approved the use of mobile phone-supporting picocells aboard aircraft in the United Kingdom. Airline companies will have to equip the aircraft with picocells and apply for licences.

Chapter 9

Mobile Phones and Driving Safety

Mobile phone use while driving is common, but dangerous. Because of this, some jurisdictions have made the use of a cell phone while driving illegal. Others have enacted laws to ban handheld mobile phone use, but allow use of a handsfree device. In some cases restrictions are only directed to minors or those who are newly qualified license holders.

Increased risk

Distracted driving fatalities caused by cell phone use and texting soared in the space of three years, according to new U.S. government research. Text messaging alone caused more than 16,000 deaths in car accidents from 2001 to 2007, the researchers estimated. But auto deaths involving cell phones and texting while driving rose 28 percent in just three years, from 4,572 in 2005 to 5,870 in 2008.

The Société de l'assurance automobile du Québec (SAAQ) conducted a study in 2003. Questionnaires were sent to 175,000 drivers and analysis was done on the 36,078 who responded. The questionnaire asked about driving habits, risk exposure, collisions over the past 24 months, socio-demographic information, and cell phone use. Questionnaires were supported with data from cell phone companies and police crash records. The study found that the overall relative risk (RR) of having an accident for cell phone users when compared to non-cell phone users averaged 1.38 across all groups. When adjusted for kilometers driven per year and other crash risk exposures, RR was 1.11 for men and 1.21 for women. They also found that increased cell phone use correlated with an increase in RR. When the same data were reanalyzed using a Bayesian approach, the calculated RR of 0.78 for those making less than 1 call/day and 2.27 for those with more than 7 calls/day was similar to cohort analysis.

When the data were reanalyzed using case-crossover analysis, RR was calculated at a much higher 5.13. The authors expressed concern that misclassification of phone calls due to reporting errors of the exact time of the collisions was a major source of bias with all case-crossover analysis of this issue.

Means and standard errors (in parentheses) for the Alcohol, Base line, and Cell-Phone conditions

	Alcohol	Base line	Cell Phone
Total Accidents	0	0	3
Brake Onset Time (msec)	888 (51)	943 (58)	1022 (61)
Braking Force (% of maximum)	69.6 (3.6)	56.4 (2.5)	55.2 (2.9)
Speed (MPH)	52.8 (.08)	54.9 (.08)	53.2 (.07)
Following Distance (meters)	26.5 (1.7)	27.3 (1.3)	28.5 (1.6)
½ Recovery Time	5.4 (0.3)	5.4 (0.3)	6.2 (0.4)

Simulation study comparisons with alcohol

A 2003 study by the University of Utah psychology department measured response time, following distance, and driving speed of a control group, subjects at the legal BAC limit of 0.08%, and subjects involved in cell phone conversations. Data from the report are listed to the right.

It should be noted that the data of this study was adjusted to reflect socially accepted results. As the study notes; "... this is the third in a series of studies that we have conducted evaluating the effects of cell phone use on driving using the car following procedure. Across these three studies, 120 participants performed in both baseline and cell phone conditions. Two of the participants in our studies were involved in an accident in baseline conditions, whereas 10 participants were involved in an accident when they were conversing on a cell phone." However zero (0) drunk drivers had accidents in any of

the tests. When results of this study are taken at face value it suggests that it is actually safer to drive drunk than sober.

From the report:

- Forty adults (25 men, 15 women), recruited via advertisements in local newspapers, participated in the Institutional Review Board approved study.
- Of the 40 participants, 78% owned a cell phone, and 87% of the cell phone owners reported that they have used a cell phone while driving.
- The experiment lasted approximately 10 hr (across the three days of the study)
- A PatrolSim high-fidelity driving simulator, ... manufactured by GEISIM, was used in the study.
- The cell phone was manufactured by LG Electronics Inc. (Model TP1100). For hands-free conditions, a Plantronics M135 headset (with earpiece and boom microphone) was attached to the cell phone.
- ... the participant's task was to follow the intermittently braking pace car driving in the right-hand lane of the highway.
- Initially both the participant's car and the pace car were driving at about 62 miles/hr (mph) with a following distance of 40 m
- In the alcohol session, participants drank a mixture of orange juice and vodka (40% alcohol by volume) calculated to achieve a blood alcohol concentration of 0.08% wt/vol.
- Participants drove in the 15-min car-following scenario while legally intoxicated. Average blood alcohol concentration before driving was 0.081% wt/vol and after driving was 0.078% wt/vol.
- In the cell phone session, three counterbalanced conditions, each 15 min in duration, were included: single-task baseline driving, driving while conversing on a handheld cell phone, and driving while conversing on a hands-free cell phone.
- In both cell phone conditions, the participant and a research assistant engaged in naturalistic conversations
- We used a multivariate analysis of variance (MANOVA) followed by planned contrasts to provide an overall assessment of driver performance in each of the experimental conditions.
- We performed an initial comparison of participants driving while using a handheld cell phone versus a hands-free cell phone. Both handheld and hands-free cell phone conversations impaired driving. However, there were no significant differences in the impairments caused by these two modes of cellular communication
- Drivers in the cell-phone condition exhibited a sluggish behavior (i.e., slower reactions) which they attempted to compensate for by increasing their following distance. Drivers in the alcohol condition exhibited a more aggressive driving style, in which they followed closer, necessitating braking with greater force.

- By contrast, when participants were intoxicated, neither accident rates, nor reaction time to vehicles braking in front of the participant, nor recovery of lost speed following braking differed significantly from baseline. Overall, drivers in the alcohol condition exhibited a more aggressive driving style.
- Most importantly, our study found that accident rates in the alcohol condition did not differ from baseline; however, the increase in hard braking and the increased frequency of TTC values below 4 s are predictive of increased accident rates over the long run
- No accidents were observed in the alcohol sessions of our study. Nevertheless, alcohol clearly increases the risk of accidents in real-world settings.
- Two of the participants in our studies were involved in an accident in baseline conditions
- One factor that may have contributed to the absence of accidents in the alcohol condition of our study is that the alcohol and driving portion of the study was conducted during the daytime (between 9:00 a.m. and noon).
- We compared the cell phone driver with the drunk driver for two reasons. First, there are now clear societal norms associated with intoxicated driving, and laws in the United States expressly prohibit driving with a blood alcohol level at or above 0.08%. Logical consistency would seem to dictate that any activity that leads to impairments in driving equal to or greater than the drunk driving standard should be avoided
- Support for this study was provided through a grant from the Federal Aviation Administration.

After controlling for driving difficulty and time on task, the study concluded that cell phone drivers exhibited greater impairment than intoxicated drivers.

Meta-analysis

A 2005 review by the Hawaiian legislature entitled "Cell Phone Use and Motor Vehicle Collisions: A Review of the Studies" contains an analysis of studies on cell phone/motor vehicle accident causality.

Meta-analysis by the Canadian Automobile Association and the University of Illinois found that response time while using both hands-free and hand-held phones was approximately 0.5 standard deviations higher than normal driving (i.e., an average driver, while talking on a cell phone, has response times of a driver in roughly the 40th percentile).

Arguments from increase in mobile subscription

In the US, the number of cell phone subscribers has increased by 1,262.4% between the years 1985-2008. In approximately the same period the number of crashes has fallen by 0.9% (1995–2009) and the number of fatal crashes fallen by 6.2%. It has been argued that

these statistics contradict the claims that mobile use impairs driving performance. Similarly, a 2010 study from the Highway Loss Data Institute published in February 2010 reviewed auto claims from three key states along with Washington D.C. prior to cell phone bans while driving and then after. The study found no reduction in crashes, despite a 41% to 76% reduction in the use of cell phones while driving after the ban was enacted.

These statistics, while compelling, ignore other salient factors. For example, many mobile phone subscribers will not drive or be eligible to drive, and mobile ownership may have increased while usage at the wheel has declined. It should also be remembered that correlation does not imply causation. In addition, improvements in car design during the same period almost certainly have reduced the chances of a crash proving fatal.

As a percentage of distraction-related accidents

Driver inattention is estimated to be a factor in between 20 to 50 percent of all police-reported crashes. Driver distraction, a sub-category of inattention, has been estimated to be a contributing factor in 8 to 13 percent of all crashes. Of distraction-related accidents, cell phone use may range from 1.5 to 5 percent of contributing factors. However, large percentages of unknowns in each of those categories may cause inaccuracies in these estimations. A 2001 study sponsored by The American Automobile Association recorded "Unknown Driver Attention Status" for 41.5 percent of crashes, and "Unknown Distraction" in 8.6 percent of all distraction related accidents. According to NHTSA, "There is clearly inadequate reporting of crashes".

Currently, "Outside person, object, event" (commonly known as rubbernecking) is the most reported cause of distraction-related accidents, followed by "Adjusting radio/cassette/CD". "Using/dialing cell phone" is eighth.

Handsfree device

Hands-free car kit

Driving while using a handsfree cellular device is not safer than using a hand held cell phone, as concluded by case-crossover studies. epidemiological, simulation, and meta-analysis. The increased "cognitive workload" involved in holding a conversation, not the use of hands, causes the increased risk. One notable exception to that conclusion is a study by headset manufacturer Plantronics, which found 71 percent of the test subjects steered more accurately, 100 percent had faster brake reaction times, and 92 percent maintained a more consistent speed when using a headset versus handheld.

The consistency of increased crash risk between hands-free and hand held cell phone use is at odds with legislation in many locations that prohibits hand held cell phone use but allows hands-free. Nevertheless, dialing a cell phone is more distracting than talking on a cell phone, and hands-free devices that offer voice-dialing may reduce or eliminate that increased risk.

Comparisons with passenger conversation

The scientific literature is mixed on the dangers of talking on a cell phone versus those of talking with a passenger. The common conception is that passengers are able to better regulate conversation based on the perceived level of danger, therefore the risk is negligible. A study by a University of South Carolina psychology researcher featured in the journal, Experimental Psychology, found that planning to speak and speaking put far more demands on the brain's resources than listening. Measurement of attention levels showed that subjects were four times more distracted while preparing to speak or speaking than when they were listening. The Accident Research Unit at the University of Nottingham found that the number of utterances was usually higher for mobile calls when compared to blindfolded and non-blindfolded passengers across various driving conditions. The number of questions asked averaged slightly higher for mobile phone conversations, although results were not constant across road types and largely influenced by a large number of questions on the urban roads.

A 2004 University of Utah simulation study that compared passenger and cell-phone conversations concluded that the driver performs better when conversing with a passenger because the traffic and driving task become part of the conversation. Drivers holding conversations on cell phones were four times more likely to miss the highway exit than those with passengers, and drivers conversing with passengers showed no statistically significant difference from lone drivers in the simulator. A study led by Andrew Parkes at the Transport Research Laboratory, also with a driving simulator, concluded that hands-free phone conversations impair driving performance more than other common in-vehicle distractions such as passenger conversations.

In contrast, the University of Illinois meta-analysis concluded that passenger conversations were just as costly to driving performance as cell phone ones. AAA ranks passengers as the third most reported cause of distraction-related accidents at 11 percent, compared to 1.5 percent for cellular telephones. A simulation study funded by the American Transportation Research Board concluded that driving events that require urgent responses may be influenced by in-vehicle conversations, and that there is little practical evidence that passengers adjusted their conversations to changes in the traffic. It concluded that drivers' training should address the hazards of both mobile phone and passenger conversations.

Texting

The scientific literature on the dangers of driving while sending a text message from a mobile phone, or *texting while driving*, is limited. A simulation study at the Monash

University Accident Research Centre has provided strong evidence that both retrieving and, in particular, sending text messages has a detrimental effect on a number of critical driving tasks. Specifically, negative effects were seen in detecting and responding correctly to road signs, detecting hazards, time spent with eyes off the road, and (only for sending text messages) lateral position. Surprisingly, mean speed, speed variability, lateral position when receiving text messages, and following distance showed no difference. A separate, yet unreleased simulation study at the University of Utah found a sixfold increase in distraction-related accidents when texting.

The low number of scientific studies may be indicative of a general assumption that if talking on a mobile phone increases risk, then texting also increases risk, and probably more so. Market research by Pinger, a company selling a voice-based alternative to texting reported that 89% of U.S. adults think that text messaging while driving is "distracting, dangerous and should be outlawed." The AAA Foundation for Traffic Safety has released polling data that show that 87% of people consider texting and e-mailing while driving a "very serious" safety threat, almost equivalent to the 90% of those polled who consider drunk driving a threat. Despite the acknowledgement of the dangers of texting behind the wheel, about half of drivers 16 to 24 say they have texted while driving, compared with 22 percent of drivers 35 to 44.

Texting while driving received greater attention in the late 2000s, corresponding to a rise in the number of text messages being sent. Over a year approximately 2,000 teens die from texting while driving. The 2008 Will Smith movie *Seven Pounds* deals with Smith's character committing suicide in order to donate his organs to help save the lives of seven people to make up for the seven people he killed in a car accident because he was receiving a text message while he was driving. Texting while driving attracted interest in the media after several highly publicized car crashes were caused by texting drivers, including a May 2009 incident involving a Boston trolley car driver who crashed while texting his girlfriend. Texting was blamed in the 2008 Chatsworth train collision which killed 25 passengers. Investigations revealed that the engineer of that train had sent 45 text messages while operating.

On July 27, 2009, the Virginia Tech Transportation Institute released preliminary findings of their study of driver distraction in commercial vehicles. Two studies, comprising about 200 long-haul trucks driving 3 million combined miles, used video cameras to observe the drivers and road; researchers observed "4,452 safety-critical events, which includes crashes, near crashes, crash-relevant conflicts, and unintended lane deviations." 81% of the safety critical events had some type of driver distraction. Text messaging had the greatest relative risk, with drivers being 23 times more likely to experience a safety-critical event when texting. The study also found that drivers typically take their eyes off the forward roadway for an average of four out of six seconds when texting, and an average of 4.6 out of the six seconds surrounding safety-critical events.

Legislation

A sign along Bellaire Boulevard in Southside Place, Texas states that using mobile phones while driving is prohibited from 7:30 AM to 9:30 AM and from 2:00 PM to 4:15 PM

Accidents involving a driver being distracted by talking on a mobile phone have begun to be prosecuted as negligence similar to driving while intoxicated. In the United Kingdom, from 27 February 2007, motorists who are caught using a hand-held mobile phone while driving will have three penalty points added to their license in addition to the fine of £60. This increase was introduced to try to stem the increase in drivers ignoring the law. Israel, Japan, Portugal and Singapore prohibit all mobile phone use while driving,

including use of hands-free devices. New Zealand bans hand held cellphone use from 1 November 2009. Many states in the United States have banned texting on cell phones while driving. Illinois became the 17th American state to enforce this law. As of July 2010, 30 states had banned texting while driving, with Kentucky becoming the most recent addition on July 15.