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Information – Anyone, Anywhere, Anytime: Evolution of Mobile Network Systems

A Report of the
Mobile Computing Service Practice

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Prelude – a brief note on mobile computing

The next phase of the Internet revolution is here. Wireless Data is the promise to bring about an information communications revolution that will connect anybody, anywhere to any information, instantly! The content distribution boundaries are fading out. The convergence of technologies is creating extraordinary opportunities for organizations to break down the boundaries between people and information. Convergence of Internet and Wireless technologies has made mobile computing the technology that will deliver. Mobile wireless technologies are going to act as glue towards bringing together the wired and wireless to share and distribute information seamlessly across each other's areas of reference.

Impact: Like any new technology, the Mobile Computing world has also generated a lot of excitement and hype. Given this scenario, it is important that the basic principles and concepts behind these technologies are well understood and realistically applied to a solution in order to generate the maximum possible benefit for the organization investing in this technology.

Wireless technologies have simply been popular owing to their contribution in enhancing the user experience to instantly connect anytime and from anywhere. These technologies are enhancing themselves constantly to make available more and more high-speed data rates to consumers on their mobile devices. A true convergence is likely once the quality of information exchange and the speed rates are capable of matching up to those of fixed networks.

Implementation of a wireless solution enables an organization to create, access, process, store and exchange information without the constraint of a single location. This improves the quality, accessibility, efficiency and, therefore, effectiveness of the information. Mobile computing can be achieved by a combination of hardware, systems, middleware and application software and some mode of communication. This has been made possible in recent times due to the evolution of extremely powerful but small computing devices such as cell phones and PDAs, and subsequently, relevant software and communication infrastructures.

So why is mobile computing needed? Today, a lot of business happens while people are in the field; a lot of time is spent travelling and the customer constantly demands more focussed services. Hence, it can be understood that wherever business needs to happen outside the corporate walls, there is an opportunity for Mobile Computing. It could also be effectively applied to other fields such as tele-medicine, safety engineering, disaster management, e-governance, etc. In other words, the term Mobile Computing can be defined as describing the use of computing devices — which usually interact in some fashion with a central information system — while away from the normal, fixed workplace. People are more mobile these days; there is a need to be in touch with co-workers, decision-makers, and consumers; moreover, smarter devices such as information appliances are entering the market and the customer is becoming more and more demanding. All these factors are promoting the use of mobile computing as a viable technology to serve these requirements of the market. Hence, Mobile Computing enables a mobile person to create, access, process, store and communicate information without being constrained by a fixed location.

Enabling Wireless Technologies: First Generation mobile communication technologies such as AMPS, ETACS, NMT were designed for specific business purposes of voice communications. Different bandwidths and protocols made it difficult to enlarge the network for digital processing.

Emergence of new technologies such as D-AMPS, C-CDMA, GSM, GPRS and availability of larger bandwidth at high frequency ranges has made it possible to transmit data over the air and has made mobile computing a possibility. Protocols such as WAP, HDML, SMS, i-Mode, Bluetooth, etc., have enabled organizations to implement solutions that can be provided for users on the move.

While telecom infrastructures have made it possible to have online transactions, device manufacturers have come up with small versions of computing devices, the size of a pocket book, that could run small applications and carry personalized information. With operating systems such as PalmOS, WinCE, EPOC, it has been possible for the people on the move to carry basic information such as a personal calendar, emails, appointments, etc., on a small device, which can later be synchronized with the PC when they get back home or to the office.

Emergence of these devices and technologies have led to a huge potential to develop applications in varied segments, be it banking, airlines, stocks, advertisements, insurance, gaming, gambling, CRM, Location-Based Services, etc. Anything and everything that was available to a user on the Internet has the potential to be m-enabled for the user on the move. In addition, the technology has provided an avenue to launch services that can match the unique needs of a mobile person. This has led to tremendous IT investment opportunities for organizations to develop a variety of solutions, right from stacks, to utilities, to accessories, to portals, to services. Online transactions on the move have enabled the efficiency and effectiveness of any business process. Keeping this in mind, it is important to understand all these aspects of Mobile Computing technologies in the right perspective, in order to have a proper overall strategy towards absorbing these technologies in an organization.

Issues: The key issue facing mobile application developers is to minimize on investment, but at the same time, to cater to potentially all possible users, who could be using a variety of technologies and devices, while keeping the constraints of the technology in mind. Messaging and Push technologies that are going to get refined in future will add to the complexity of implementation of the solutions. Thus, it is important that the end requirement and future investment planning is done at the onset of implementation, to have a clear roadmap for rolling out any wireless solution.

Challenges: Despite the excitement that the mobile computing environment generates, there are some basic roadblocks that still need to be crossed. For example, due to the nature of the devices themselves, resources are scarce. These devices are prone to damage, loss or theft. Performance and reliability are a cause for concern. Besides, there hasn't been any breakthrough yet in the battery technology that could sustain these devices for an extended period of time. Hence, it is important that the solutions developed for these environments have a definite focus. They take the network, device, security, market and the industry into proper consideration and provide for the special needs of the target user.

Like any new and emerging technology, the mobile computing market is itself going through its own evolutionary process. New communication media, data access protocols, devices, operating systems and middleware are emerging from time to time. The basic issue that all these technologies are looking at is the nature of the medium itself. Ubiquity and accessibility become important to any service in the mobile arena. The problems of battery life, security of information as well as of the device itself are still being addressed and technologies are still evolving.

While all these issues remain to be addressed, it cannot be denied that the technology has immense potential to enable a customer to have enhanced experience in terms of accessing valuable information while he/she is playing golf, relaxing on a beach, waiting for a meeting, travelling in a train, and many more scenarios. Investments in research and development to improve the underlying technologies is only going to accelerate more investments in providing customers specialized services while they are on the move.

Future Watch: Future 3G technologies such as EDGE, UMTS, IVRS, and Broadband will enable a larger amount of data that can be exchanged while on the move and will determine the path the wired and wireless computing field will take. These will create the need for convergence of digital appliances, assimilation of the technologies, fading of content distribution boundaries and therefore, the need to provide a common framework for organizations to meet these challenges. It isn't tough anymore to imagine the near future where the small machine in the pocket will replace a variety of appliances that a person needs to carry — mobile phones, personal computer, driver licence, credit card, remote control, security device, smart cash, etc. — all combined in a single device.

To Summarize: Mobile Computing is a versatile technology that has created the necessity for organizations to review their existing business processes and realign them to a mobile workforce and customer base, in order to improve operational efficiency, communication, and customer service, with a view to reduce the overall business cycles. It provides the IT solution providers with immense opportunity to strategize and implement solutions that will eventually be of benefit to the organization.

It is very difficult to cover all these aspects of Wireless Technologies in one single Technology Review Report. TCS Mobile Computing Service Practice will bring out a series of Reports on these aspects, including Mobile Network Systems, Wireless Network Security, Wireless Protocols, Mobile Computing Devices, Wireless Application Architectures and Wireless Applications of the future.

This report, the first in this series, looks at the evolution of the mobile networks and tries to understand the future evolution path that these network technologies will take.

1 Introduction

The backbone of the Mobile Wireless revolution comprises the underlying communication technologies that are driving the information bandwidth available to consumers on the move. What once started out as a medium to exchange phone calls while on the move, has evolved into a realistic medium over which people, companies and organizations can exchange valuable data. Already, initiatives such as SMS, WAP, Wi-Fi, Bluetooth, i-Mode, etc., have exploited the data capability of wireless networks to deliver value-added services to the customers.

While currently it is necessary to connect to the wireless networks from one's mobile devices, technological innovation is looking towards an "always on" phenomenon. The greater the focus towards data-centric networks, the greater will be the shift from the circuit-switched services towards packet-switched networks. In other words, consumers will not have to shell out money for the airtime they use, but for the data they exchange over the wireless medium.

There has been an evolutionary change in mobile communications systems every decade. The first-generation in the 1980s and second-generation cellular systems in the 1990s have been used mainly for voice transmission and to support circuit-switched services. 1G systems were analog technologies-based; however, 2G systems are digital systems such as the GSM, cdmaOne and PDC. These systems operate nationwide or internationally, and are today's mainstream systems. The data rates for users in the air links of these systems are limited to a few Kbps. International Mobile Telecommunications 2000 (IMT-2000), the third-generation cellular systems, aim to provide 2 Mbps (indoor) and 144 kbps (outdoor) of data rates over wireless communication channels. However, demands for higher access speeds for multimedia communications will be unlimited. In the years to come, users and businesses will be free of space and time restrictions. Advanced personal communication devices will lead people to be truly a global entity. Key to the future generations (4G and 5G) of mobile communications are multimedia communications, wireless access to broadband fixed networks, and seamless roaming among different systems.

The technologies are taking their own logical evolutionary process and the following sections briefly discuss these.

2 First Generation Mobile Networks

Mobility to users on phones came about in the late 70s and early 80s when mobile phones came into the market. The technology was voice-centric and catered to putting the telephones on the move (hence the term mobile phones). Various analog techniques came into the market. Some of them are listed below:

- AMPS (Advanced Mobile Phone Service) in Asia and North America
- NMT (Nordic Mobile Telephone) in Sweden, Norway, Finland
- ETACS (Extended Total Access Communication System) in the UK
- NTT (Nippon Telegraph and Telephone) in Japan

These mobile phones worked—and still work—on the concept of cells, where the geographical spread was divided into small sectors, each called a cell, hence the term cell phones, to optimize and reuse frequencies in order to have a wider subscription base. A region is divided into different hexagonal regions with the same frequency being allocated to non-adjacent cells, thus reusing the frequency bands available. Low power transmitters in the cell phones prevent interference across cells.

All these networks, based on analog modulation technologies, had their inherent limitations in terms of limitations of the number of channels, proliferation of incompatible standards in different countries and regions, etc. This restricted the expansion plans of these technologies and thus, was costly to implement. Hence, most of the users of the first generation mobile phones were restricted to big corporate and business users only.

3 Second Generation Mobile Networks

The limitations of the First Generation Networks gave rise to the idea of investing in developing digital networks that can accommodate a larger number of subscribers in the same bandwidth, as well as provide for better voice quality. Different algorithms were used to divide available time slots amongst subscribers, thus increasing the potential capacity of the networks. Some examples of the Second Generation Networks are given below:

- D-AMPS (Digital Advanced Mobile Phone Service, also known as IS-54): Operates at 800MHz. Uses TDMA Standard — Exists mainly in USA
- N-CDMA (Narrow-band Code Division Multiple Access, also Known as IS-95): Operates at 800MHz
    - Characterized by high capacity and small cell radius
    - Uses Spread spectrum technology
    - Exists mainly in the USA
- GSM (Global System for Mobile Communications): First digital cellular system developed for compatibility throughout Europe. Operates at 900MHz range. Data rates vary according to switching type

Some of these topics are discussed later in this paper.

These technologies are still voice-centric. Digitization of signals was aimed at improving channel capacity and voice clarity rather than transmittal of data. However, the very fact that digitized information could be transmitted on these channels gave rise to the idea of exchanging information on top of voice over the same networks. This gave rise to the concept of Personal Communication Systems (PCS) that could shift the focus to data communications as well, although the prime focus remains voice. PCS operates in the

frequency band of 1850–1900 MHz and thus can accommodate a higher number of channels. This led to the evaluation of networks such as JS-008 (CDMA network at 1900 MHz in USA), E-NetZ (German network at 1900 MHz and GSM 1900 (Europe). More bandwidth was made available, hence a higher subscriber base could be achieved. Also, the focus slowly started shifting towards data communications over wireless, leading to protocols such as SMS, WAP, i-Mode, Wi-Fi, and Bluetooth, among others.

The three currently prevalent 2G networks, GSM, CDMA and CDPD, are discussed here to have a better understanding of the prevailing technologies.

3.1 Global System for Mobile Communications (GSM)

GSM networks are by far the most popular and widespread wireless communication media across the world, having a wide customer base in Europe and Asia-Pacific and command more than 50 percent of mobile customers.

GSM is based on narrow-band TDMA technology, where available frequency bands are divided into time slots. Each user is given access to one particular time slot separated by regular intervals. It allows eight simultaneous communications on a single 200KHz carrier and is designed to support 16 half-rate channels. Due to the widespread availability of GSM networks, a GSM mobile has the potential to seamlessly roam nationally and internationally.

GSM supports data services where users can send and receive data, at rates upto 9600 bps. A unique feature of GSM, not found in older analog systems, is the Short Message Service or SMS for short. SMS allows GSM users to exchange text-based messages upto a length of 160 characters over the wireless network.

While GSM networks are available in Europe at frequencies of 900 MHz and 1800 MHz, they are available in North America at 1900 MHz. Hence, these networks require Tri-band phones supporting all the three frequency bands to make the service support true global roaming.

A GSM network, as also other cellular networks, typically consists of 3 major components:

- Mobile Station (Consists of the Subscriber Identity Module – SIM, and the Mobile Equipment)
- Base Station Sub-System (Consists of the Base Stations and their controllers)
- Primary Network System (Consists of the Message switching centre, location information and authentication services)

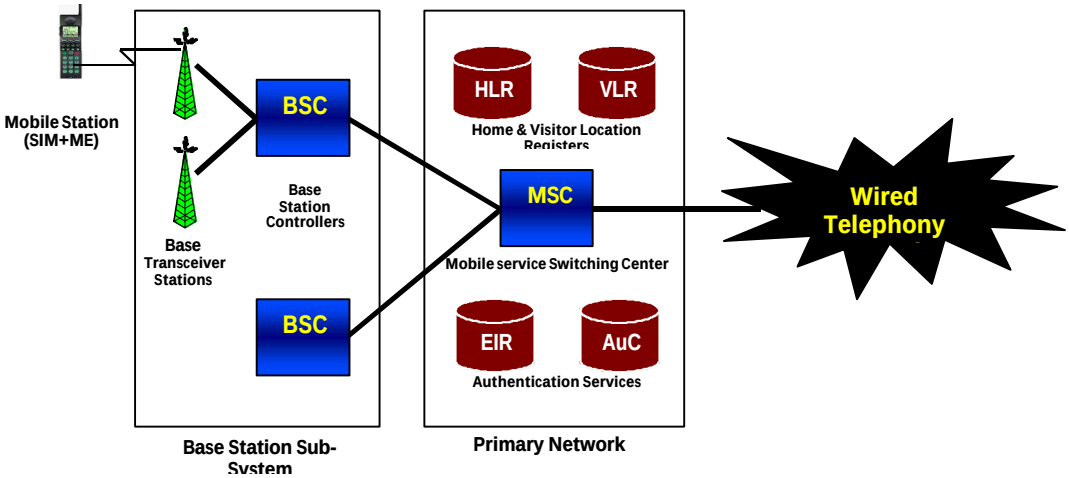


Figure 1: A GSM Network

Mobile Stations, i.e., the cell phones with SIM cards, are capable of talking to the transceiver stations, which in turn send the signals to the station controllers. Station controllers can decide whether the call is for within their sub-system and can route the call accordingly. Or else, the Station controllers pass on the information to the backend Message Switching Centre, which then decides, based on the location information of the recipient and authentication permissions, on where to route the call. The call can be routed to either some other sub-system within its own network or can be passed on to other wired or wireless networks. The location registers play an important role in facilitating the roaming feature across cells, cities, counties and national boundaries.

GSM is being enhanced to support roaming across other wireless networks. It is also the migration path most preferred by the GPRS initiative.

3.2 Code Division Multiple Access (CDMA)

CDMA technology, more prevalent in North America, was initially promoted by Qualcomm. This technology uses the Spread Spectrum concept of sharing a larger spectrum with multiple users, at the same time as assigning them unique digital codes. Operating in the 1900 MHz and 800 MHz bands, its main advantage lies in its ability to provide higher bandwidth while preventing interference due to the digital coding of signals.

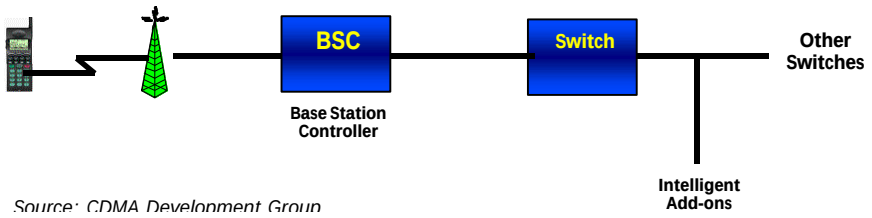


Figure 2: CDMA

The ability of CDMA to allow more calls to occupy the same space in the communication channel increases its capacity, and hence, provides a cost-effective solution to its users.

It can provide higher data rates of more than 64 Kbps due to its concept of frequency reuse and soft handoffs. Additionally, the cell planning is simpler. It is being promoted in a big way as a step towards 3G high bandwidth networks.

3.3 Cellular Digital Packet Data (CDPD)

While the above technologies were advancing, there was a concern amongst certain organizations that had already invested substantially in analog networks. There was a need to have a technology that could be put as an overlay over these existing networks and at the same time provide some digital services to their customers. CDPD is the solution most popular in North America. It is a packet data overlay that works on idle time in-between calls to transmit and receive information. It uses the concept that cell phones are not always used for voice communication, and hence the time slot can be exploited to provide a low-cost data transmittal facility to consumers. Its popularity comes mainly from its cost-effectiveness, as it uses existing networks, thus reducing the risk of technology obsolescence.

4 3G Wireless Networks

Now that the importance of data over wireless networks is well understood, research institutions and organizations have progressively started investing in developing high-speed data networks that can enhance the capacity, quality and rates at which data is currently available. These emerging technologies constitute what is known commonly as Third Generation Wireless networks, or simply 3G. These systems aim to provide an enhanced experience to the users in terms of receiving or sending voice, text or binary data.

With the advent of 3G networks, the wireless and the internet worlds are being brought together along with more real-time video and multimedia graphics, also made available over the wireless medium. This is to be achieved while enhancing the voice services as well, to match landline quality. True global roaming will be made possible, the underlying network technology, notwithstanding.

As mentioned above, the drive for 3G is the need for higher capacities and higher data rates. While higher capacities can basically be obtained by having a greater chunk of the spectrum or by using new evolved air interfaces, the data requirements can be served to a certain extent by overlaying 2.5G technologies on the existing networks. In many cases, it is possible to provide higher speed packet data by adding a few network elements and a software upgrade.

3G networks are concentrating on providing excellent service quality to customers both for voice and data, providing huge system capacity and high security of the information exchanged. The various technology initiatives that will enhance the user experience on these networks will be enhanced battery lives, flat mobile screens with higher resolutions, cameras, voice recognition and verification, biometrics and end-to-end encryption techniques.

4.1 2.5G Networks – A Step towards 3G

Before going ahead full-fledged into 3G network implementations, there are a few initiatives, popularly known as 2.5G networks, that are being taken to gradually migrate existing networks towards 3G. Some of these such as GPRS, HSCSD and EDGE will be discussed below. These initiatives aim to implement packet data services and increase the data rates over the existing GSM and TDMA networks.

4.1.1 General Packet Radio Service (GPRS)

The GPRS initiative aims at extending the existing 2G networks to have the capability of launching packet-based services while enhancing the data rates supported by these networks. Hence, GPRS is essentially an overlay on top of existing GSM and TDMA networks, which provides a telecom operator with the facility of reusing the radio spectrum across multiple users and hence enhancing the capacity of the network.

GPRS introduces a couple of network elements and a software upgrade to achieve its objectives. Its network elements, Serving GPRS Support Node (SGSN) and Gateway GPRS Support Node (GGSN), perform the tracking of packet-based mobile terminals, security and access control, interfacing with external packet data networks for exchange of packet-based data, etc.

The idea of this solution is to reuse frequencies across multiple users and hence optimize the use of frequency spectrums at all times. Thus, users can have the advantage of being connected all the time but paying only for the data exchanged between the mobile device and the network, with data transmission rates upto 144 Kbps, with GPRS implementation. This will facilitate the convergence of cellular and Internet service providers, leading to a very exciting new business model. Wireless application technologies, such as WAP, which are facing major bottlenecks, essentially due to the performance problems of the 2G networks, are expecting a big boost once GPRS networks are put into use.

The current trend shows that GPRS is going to go strong and will be a major player until 2005, after which the 3G networks are expected to start picking up.

4.1.2 High-Speed Circuit Switched Data (HSCSD)

This initiative within the GSM networks does not talk about changing to packet-switched networks, but enhancing the data rates of the circuit-switched networks to upto 57.6 Kbps. It is being achieved by adding together consecutive GSM time slots to enhance the capacity. This network implementation will be most suited for applications that have continuous streaming of data since the network continues to be circuit-switched. The problems with this implementation consist of its complex handover mechanism while roaming and its potential conflict with GPRS. Hence, the solution may be seen implemented mostly in isolated pockets.

4.1.3 Enhanced Data for Global Evolution (EDGE)

This initiative is the next step closer to the 3G wireless network experience manifested by enhancing the existing GSM and GPRS implementation and providing users with data speeds as high as 384 Kbps. It reuses the existing GSM/GPRS network elements and cell

plans but increases the data rates by increasing the data capacity of a GSM time slot and aggregating time slots together. This is done by incorporating add-in modules to existing networks, which implement complex modulation techniques.

The advantage with this implementation is its backward-compatibility with existing GSM and GPRS networks, thus providing a better, gradual migration path for operators, device manufacturers, infrastructure vendors and consumers.

4.2 Migration Path towards 3G Wireless Systems

Soon, a greater demand to remove the distinction between fixed and mobile networks will become apparent. Access to the Internet and Intranets, Teleworking, and the advent of the Virtual Office, are concepts which will become more commonplace in the near future. For the third generation communications system, the challenge will be the globalization and convergence of office and home applications and services with the help of new communications tools.

However, the situation is not that simple. The variety of communication systems in the market today, as discussed above, across different geographical locations, with their own economic, political, regulatory and social issues, make it difficult to bring all the players together to one single convergence point. There are large investments involved already and it is extremely difficult — if not impossible — to develop standards right from scratch. Keeping this in mind, it has been recognized that a standard should be developed that accommodates the backward-compatibility of existing networks, while at the same time defining a common framework under which these networks can evolve. This will be an evolution from each of the regional second generation systems — wireless and wireline — and will satisfy market demands for global roaming, service portability and multimedia, allowing for differentiation of services and products. Some of these initiatives are discussed below.

4.2.1 International Mobile Telecommunications Systems (IMT2000)

IMT2000 is a standardizing initiative where each of the regional third generation systems, which fulfills a defined basic set of requirements, can become an IMT2000 family member. The International Telecommunication Union (ITU) is responsible for developing the framework standardization that will ensure inter-working between all the IMT2000 family members. It will also include seamless co-existence with wireline networks, with the goal of fixed-mobile convergence in the future. The family of standards concept, the support of broadband services, together with wireless Intelligent Networks (IN)-based services will be major components for the development of a set of third generation requirements.

COMPONENTS OF IMT2000: The IMT2000 system is expected to be more than just an improved cellular system. The vision is to provide a universal communications system by converging all types of networks, including satellite systems, macrocell-microcell-picocell terrestrial cellular systems, unlicensed cordless systems and wireless access systems. The timescale for developing individual subsystems and strategies will not be the same for every region, or even for every country within that region – each will have its own evolution strategy.

A couple of these initiatives are mentioned below.

4.2.2 Universal Mobile Telecommunications System (UMTS)

UMTS stands for Universal Mobile Telecommunications System. It is a part of the International Telecommunications Union's IMT2000 vision of a global family of third-generation mobile communications systems. UMTS is expected to play a key role in creating the future mass market for high-quality wireless multimedia communications that is estimated at around 2 billion users worldwide by the year 2010. UMTS builds on today's significant investments in second generation mobile systems. It has the support of several hundred network operators, manufacturers and equipment vendors worldwide. It is one of the major new third generation mobile communications systems being developed within the framework which has been defined by the ITU and is known as IMT2000.

UMTS aims at enabling tomorrow's wireless Information Society, delivering high-value broadband information, commerce and entertainment services to mobile users via fixed, wireless and satellite networks. It will speed convergence between telecommunications, IT, media and content industries to deliver new services and create fresh revenue-generating opportunities. UMTS will deliver low-cost, high-capacity mobile communications offering data rates up to 2Mbps with global roaming and other advanced capabilities

UMTS services are expected to be launched commercially in 2001. The licenses have already been awarded in several European countries. UMTS experimental systems are already undergoing field trials with leading vendors worldwide.

UMTS will deliver pictures, graphics, video communications and other wide-band information, as well as voice and data, direct to people who are on the move. UMTS will build on and extend the capability of today's mobile technologies (such as digital cellular and cordless) by providing increased capacity, data capability and a far greater range of services using an innovative radio access scheme and an enhanced, evolving core network.

4.2.3 cdma2000

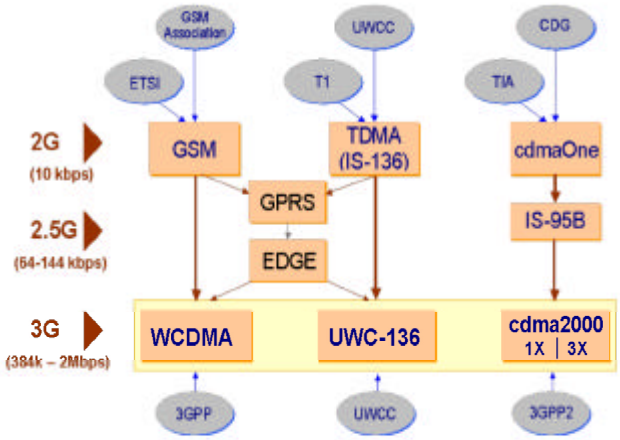
cdma2000 is another 3G standard for the delivery of high bandwidth data and high capacity voice services. The evolution of the cdma2000 standard will enable mobile systems to offer data throughputs of 2Mbps and beyond.

The higher bandwidth that cdma2000 provides will deliver the full potential of 3G. For example, it also allows simultaneous access to several voice, video and data services at once. cdma2000 is fully compliant with IMT2000 requirements for 3G. cdma2000 will be implemented in the existing frequency bands of CDMA and TDMA at 800 and 1900 MHz, as well as the new spectrum at 2GHz in Japan.

4.3 3G Evolution Path

A variety of technologies/standards exists across different parts of the world, and therefore, so do the number of paths that can be taken. The figure below shows in brief the individual paths each of these technologies is taking towards adapting to the 3G network systems. Since different network systems are at different stages of evolution

towards 3G, the table below tries to summarize these evolution paths and the time-line at which they can be expected to come up in the market.



Courtesy: www.itu.int

Figure 3: Adapting to the 3G Network Systems

Note: Not all of these standards have been discussed in this report. Only the most popular and predominant technologies have been covered above.

Standard Name	Other Names (Aliases)	Upgrade Path For	Expected Availability
Code Division Multiple Access (CDMA)	IS-95, IS-95A, cdmaOne	N/A	Current
Global System for Mobile Communications (GSM)	N/A	N/A	Current
1XRTT	G3G-MC-CDMA-1X, also called 2.5 step for CDMA	CDMA	End of 2001
General Packet Radio System (GPRS)	Also called 2.5G for GSM	GSM and probably TDMA	2001
Enhanced Data for GSM Efficiency (EDGE)	Also called 2.5G for GSM & TDMA	GSM and TDMA	End of 2001

Standard Name	Other Names (Aliases)	Upgrade Path For	Expected Availability
Wideband CDMA (WCDMA)	WCDMA, FDD Mode 1 (Direct Sequence), G3G-DS-CDMA	GSM and TDMA, and in rare cases CDMA	2002 Europe, later for North America depending upon spectrum availability
cdma2000	3XRTT, FDD Mode 2 (Multicarrier), G3G-MC-CDMA-3X	CDMA	2003
High Data Rate (HDR)	HDR	Not a true 3G upgrade; a network extension using a CDMA base system	End of 2001

Source: www.wirelessdevnet.com

Some of the migration paths are discussed below, for the most predominant networks.

4.3.1 GSM and TDMA to 3G

GSM and TDMA systems have more or less the same set of options for migrating to 3G. The path to 3G is not as simple in the case of GSM/TDMA as in the case of CDMA. The main evolutionary standards are GPRS, EDGE and, finally, W-CDMA. Vendors are positioning each of these standards as a step to the next, but operators are not so sure. For operators moving from GSM to GPRS to EDGE and then to WCDMA, they'll have to make investments 3 times which won't be pleasing to anyone. At this time, there seem to be four basic options that GSM and TDMA operators are considering:

- Install GPRS, then move straight to WCDMA
- Install EDGE, then move straight to WCDMA
- Install GPRS, then move to EDGE, then to WCDMA or
- Install EDGE, skip move to WCDMA, and wait for the next generation (4G).

A lot will depend on the returns on investment these operators will get after rolling out the services. The time taken to move along towards 3G will depend a lot on market considerations.

4.3.2 CDMA To 3G

While GSM and TDMA operators have multiple choices ahead for progressing to the next-generation networks, CDMA operators have a single path that truly builds upon itself. Currently, all North American CDMA networks are based on IS-95 (cdmaOne) which can be set up to provide data rates upto 14.4 kbps. The next step is to have a

software upgrade from IS-95A to IS-95B, which provides additional voice efficiencies giving additional capacity, and allows for up to 84-Kbps packet data. While this migration does not need any additional hardware, however, most operators may decide not to move to IS-95B because of two reasons.

1. IS-95A in itself is relatively new and carriers have just launched their IS-95A data services.

2. By the time IS-95B becomes available, 1XRTT will be ready.

Source: The Yankee Group, 2000

Figure 4: Evolution of CDMA to 3G

4.3.3 Cost Considerations

In the shorter term, TDMA and GSM have a much more cost-effective upgrade option by means of moving to GPRS to be in a position to provide data services. As mentioned earlier, an upgrade to GPRS doesn't require substantial investments and existing GSM/ TDMA service providers can upgrade to GPRS at a small percentage of their initial 2G investments. The IS-95 upgrade path to 1xRTT is comparatively costly. It should also be noted that IS-95A in itself has also not been in existence for long. However, in the final run to truly 3G networks, GSM/TDMA operators may have to incur much higher investments, as shown in the table below.

Technology	**2G**	**2.5G**	**2.5G**	**3G**
TDMA and GSM	1x	GPRS .28x	EDGE .51x	WCDMA GPRS Route: 1.2x EDGE Route: .90x

Technology	2G	2.5G	2.5G	3G
CDMA	1x	1XRTT .40x	–	cdma2000 .60x

Source: The Yankee Group, 2000

The cost equations for TDMA or GSM may vary depending on the exact path taken (EDGE, no EDGE, or only EDGE). CDMA has the unique advantage of having the same air interface in 2G as in 3G (same underlying technology).

4.4 3G: To Summarize

The third-generation systems will mainly have the following characteristics:

- A very high bit rate
- Enhanced communications
- Multimedia-enabling

Third-generation mobile communication will provide the mass-market with high quality, efficient, and easy-to-use wireless mobile multimedia services.

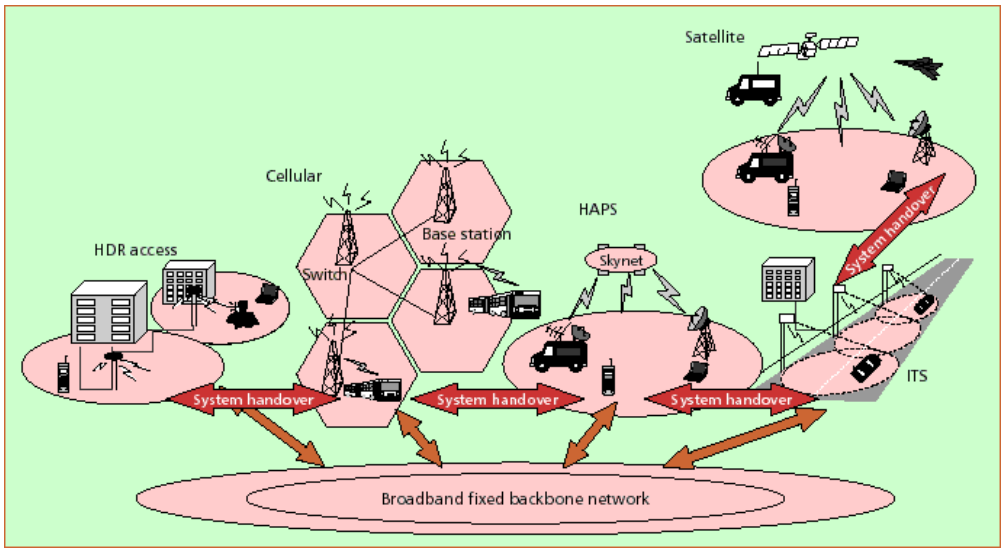
Third-generation systems will provide support for:

- High data rates: (minimum) 144 Kbps in all radio environments and 2 Mbps in low-mobility and indoor environments
- Symmetrical and asymmetrical data transmission. In fact, the data rate isn't the same, and doesn't have to be, when transmitting information from a server to a terminal or from a terminal, to a server
- Circuit-switched and packet-switched services, such as Internet Protocol (IP) traffic and real-time video
- Good voice quality (comparable to wireline quality)
- Greater capacity and improved spectrum efficiency
- Several simultaneous services to end-users and terminals, for multimedia services
- The seamless incorporation of second-generation cellular systems, in order not to have any discontinuity between the second- and the third-generation systems
- Global roaming between different IMT-2000 operational environments
- Economies of scale and an open global standard that meets the needs of the mass market

5 Moving towards 4G and 5G

Future generations of communication systems — termed as fourth (4G) and fifth generation (5G) — look beyond the cellular and telephony networks, but also at communication systems such as broadband wireless access systems, millimeter-wave LANs, intelligent transport systems (ITS), and high altitude stratospheric platform station (HAPS) systems. From the trends of mobile communication systems, it is evident that there is a demand to satisfy the requirements of high data rate, high mobility, and seamless coverage. Future systems will include several different systems — with different applicability — trying to coexist together. Some will have high performance in providing high data rates, others in service coverage or high mobility. In future systems, seamless roaming among these different systems will constitute a very important concept. This feature will be added to high data rate, high mobility, and connection broadband fixed networks.

The picture below gives a typical pictorial representation of how the future network systems will co-exist and interact with each other.



(*Source: www.comsoc.org*)

Figure 5: Co-existence and Interaction of Future Networks

Some of these components are summarized below.

5.1 4G-Cellular Systems

4G-cellular systems will not only be high-speed but also of high-capacity, with low bit cost and the ability to support the services of the next decade. In order to achieve high capacity with reasonable frequency bandwidth, the cell radius of 4G-cellular systems shall be shortened from that of present cellular systems. By constructing networks based on IP technology, the seamless connection between 4G, 3G, wireless LANs (WLANs), and fixed networks will be implemented.

5.2 Broadband Wireless Access Systems

Broadband wireless access systems using 5 GHz and millimeter-wave bands have been developed. Multimedia Mobile Access Communication (MMAC) Systems — devised in

Japan — are a high-performance wireless system to be used after IMT-2000, which allows any person to communicate “anytime, anyplace”. The MMAC will provide two categories of high-speed wireless access communications. The first will be serviced both outdoors and indoors. This is a broadband mobile communications system, which can transmit up to 30 Mbps using 5.2 GHz, which will operate starting in 2001. The second will provide ultra-high-speed WLANs indoors, which can transmit high-speed signals (up to 600 Mbps) using the millimeter-wave radio band (e.g., 60 GHz).

5.3 Intelligent Transport Systems

Intelligent Transport Systems (ITS) is a new transport system concept, which will comprise an advanced information and telecommunications network for users, roads, and vehicles. ITS is expected to contribute much to solving problems such as traffic accidents and congestion. Not merely solving such problems, ITS will also provide multimedia services for drivers and passengers. ITS will consist of different development areas, including advances in navigation systems, electronic toll collection system, assistance for safe driving, and so forth. The most important infrastructure will be a road-vehicle communications system, in which many base stations will be equipped along the trunk road in order to communicate with vehicles, and several control stations will manage these base stations.

5.4 High-Altitude Stratospheric Platform Station Systems

The HAPS system is very attractive for multimedia communications. It has the potential to become the third communications infrastructure after terrestrial and satellite communications. The platforms will keep their positions at about 20 km high in the stratosphere. By optical inter-communication links, they will make a mesh-like network in the sky. A broadband access link will be the link between the platform station and the user station. The frequency band of the access link is expected to use a millimeter-wave band. This system can support various types of user terminals, fixed terminals, portable terminals, and mobile terminals. The typical bit rate of the access link will be 25 Mbps for most fixed and portable terminals, while a several hundred megabits per second link can be made available for limited fixed terminals with larger antennae.

6 Conclusion

Mobile communications are clearly going to show major enhancements in terms of capabilities of mobile networks. The next generation of wireless services, besides improving the overall capacity, will create its own unique demands in terms of localization, personalization, etc., which will in turn, drive the development and continuous evolution of services and infrastructure. While development of 3G networks will continue and pick up pace in the near future, the 2nd generation networks will keep evolving in terms of continuous enhancements and towards convergence of existing 2G standards. The initial 3G solutions should coexist with the 2G networks while slowly evolving to all 3G networks. While 3G networks expect transparent roaming across all networks throughout the world, given the current investments and implementation of the 2nd generation systems, true roaming — consistent service availability, across networks, independent of networks — will take some time to implement. A lot will depend on the commercial proposition of each of the technologies and on how good an organization’s business models are to recover investments.

While technologies continue to establish themselves in the business world, research is already progressing towards the next generation of communication services. The future mobile communications systems are expected to provide a wide variety of services, from high-quality voice to high-definition video, through high-data-rate wireless channels anywhere in the world. High data rates require broad frequency bands, and sufficient broadband can be achieved in higher frequency bands such as microwave and millimeter-wave. These broadband wireless channels have to be connected to broadband fixed networks such as the Internet and local area networks. Future generations of systems will include not only cellular phones, but also many new types of communications systems. Future generations of mobile communications will talk about multimedia communications, wireless access to broadband fixed networks, and seamless roaming among different systems.

This report concludes by looking back at existing wireless technologies and summarizing the next generation wireless communication media in the following table. These technologies, indeed, have a long way to go. And exciting and amazing products are bound to emerge in the years to come.

	1980s	**1990s**	**2000s**	**2010s**	**2020s**
Generation	First	Second	Third	Fourth	Fifth
Keywords	Analog	Digital Personal	Global World Standards	High data rates High mobility IP-based	High data rates High mobility IP-based
Systems	Analog Cellular Analog Cordless	Digital Cellular GSM, IS-54, PDC Digital Cordless DECT, PHS Mobile Satellite Iridium, Inmarsat-M	IMT2000 (3G Cellular) Max Data Rate: 2Mbps	4G Cellular Broadband Access Mini Data Rate: 2 – 20 Mbps?	5G Cellular Broadband Access Mini Data Rate: 20 – 100 Mbps?

Source: www.comsoc.org

7 References

This report was compiled from various sources such as a wide range of articles, white papers, news items and analysis reports. In addition, a list of Websites, which provide much of the information summarised in this report, is presented below. There is an abundance of information at these sites and it is recommended that the readers take a look at them to gather more in-depth knowledge on any desired topic:

www.ieee.org

www.gsmworld.com

www.comsoc.org

www.qualcomm.com

www.etsi.org

www.lucent.com

www.wirelessdevnet.com

www.anywhereyougo.com

www.allnetdevices.com

www.itu.int

www.umts-forum.org

www.nokia.com

www.ericcson.com

www.wapforum.org

Preparing this report has benefitted from the collective wisdom of the members of the Mobile Computing Service Practice at TCS-Pune. The Group's brainstorming sessions and discussions helped in bringing together a coherent thought process while compiling this report.