Evolution of Technologies, Standards, and Deployment of 2G–5G Networks

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INTRODUCTION

The fourth and fifth generation wireless mobile systems, commonly known as 4G and 5G, are expected to provide global roaming across different types of wireless and mobile networks, for instance, from satellite to mobile networks and to Wireless Local Area Networks (WLANs). 4G is an all IP-based mobile network using different radio access technologies providing seamless roaming and providing connection always via the best available network [1]. The vision of 4G wireless/mobile systems is the provision of broadband access, seamless global roaming, and Internet/data/voice everywhere, utilizing for each the most "appropriate" always best connected technology [2]. These systems are about integrating terminals, networks, and applications to satisfy increasing user demands ([3], [4]). 4G systems are expected to offer a speed of over 100 Mbps in stationary mode and an average of 20 Mbps for mobile stations reducing the download time of graphics and multimedia components by more than 10 times compared to currently available 2 Mbps on *3G* systems.

The fifth generation communication system is envisioned as the real wireless network, capable of supporting wireless world wide web (*wwww*) applications in 2010 to 2015 time frame. There are two views of 5G systems: evolutionary and revolutionary. In the evolutionary view the 5G (or beyond 4G) systems will be capable of supporting wwww allowing a highly flexible network such as a Dynamic Adhoc Wireless Network (*DAWN*). In this view advanced technologies including intelligent antenna and flexible modulation are keys to optimize the adhoc wireless networks. In revolutionary view 5G systems should be an intelligent technology capable of interconnecting the entire world without limits. An example application could be a robot with built-in wireless communication with artificial intelligence.

The 4G system is still predominantly a research and development initiative based upon 3G, which is struggling to meet its performance goals. The challenges for development of 4G systems depend upon the evolution of different underlying technologies, standards, and deployment. We present an overall vision of the 4G features, framework, and integration of mobile communication. First we explain the evolutionary process from *2G* to *5G* in light of used technologies and business demands. Next we discuss the architectural developments for 2G-5G systems, followed by the discussion on standards and services. Finally we address the market demands and discuss the development of terminals for these systems.

2G–5G NETWORKS: EVOLUTION

The first generation of *mobile phones* was analog systems that emerged in the early 1980s [5]. The second generation of digital mobile phones appeared in the 1990s along with the first digital mobile networks. During the second generation, the mobile telecommunications industry experienced exponential growth in terms of both subscribers and value-added services. Second generation networks allow limited data support in the range of 9.6 kbps to 19.2 kbps. Traditional phone networks are used mainly for voice transmission, and are essentially circuit-switched networks.

2.5G networks, such as General Packet Radio Service (*GPRS*), are an extension of 2G networks, in that they use circuit switching for voice and packet switching for data transmission resulting in its popularity since packet switching utilizes bandwidth much more efficiently. In this system, each user's packets compete for available bandwidth, and users are billed only for the amount of data transmitted.

3G networks were proposed to eliminate many problems faced by 2G and 2.5G networks, especially the low speeds and incompatible technologies such as Time Division Multiple Access (*TDMA*) [5] and Code Division Multiple Access (*CDMA*) [6] in different countries. Expectations for 3G included increased

bandwidth; 128 Kbps for mobile stations; and 2 Mbps for fixed applications [7]. In theory, 3G should work over North American as well as European and Asian wireless air interfaces. In reality, the outlook for 3G is not very certain. Part of the problem is that network providers in Europe and North America currently maintain separate standards' bodies (*3GPP* for Europe and Asia; *3GPP2* for North America). The standards' bodies have not resolved the differences in air interface technologies. There is also a concern that in many countries 3G will never be deployed due to its cost and poor performance. Although it is possible that some of the weaknesses at physical layer will still exist in 4G systems, an integration of services at the upper layer is expected.

The evolution of mobile networks is strongly influenced by business challenges and the direction mobile system industry takes. It also relates to the radio access spectrum and the control restrictions over it that varies from country to country. However, as major technical advances are being standardized it becomes more complex for industry alone to choose a suitable evolutionary path. Many mobile system standards for Wide Area Networks (WANs) already exist, including the popular ones such as Universal Mobile Telecommunications Systems (*UMTS*), CDMA, and *CDMA-2000* (1X/3X). In addition there are evolving standards for Personal Area Networks (PANs), such as *Bluetooth* wireless, and for WLANs, such as IEEE 802.11.

The current trend in mobile systems is to support the high bit rate data services at the downlink via High Speed Downlink Packet Access (HSDPA). It provides a smooth evolutionary path for UMTS networks to higher data rates in the same way as Enhanced Data rates for Global Evolution (*EDGE*) do in Global Systems for Mobile communication (*GSM*). HSPDA uses shared channels that allow different users to access the channel resources in packet domain. It provides an efficient means to share spectrum that provides support for high data rate packet transport on the downlink, which is well adapted to urban environment and indoor applications. Initially, the peak data rates of 10 Mbps may be achieved using HSPDA. The next target is to reach 30 Mbps with the help of antenna array processing technologies followed by the enhancements in air interface design to allow even higher data rates.

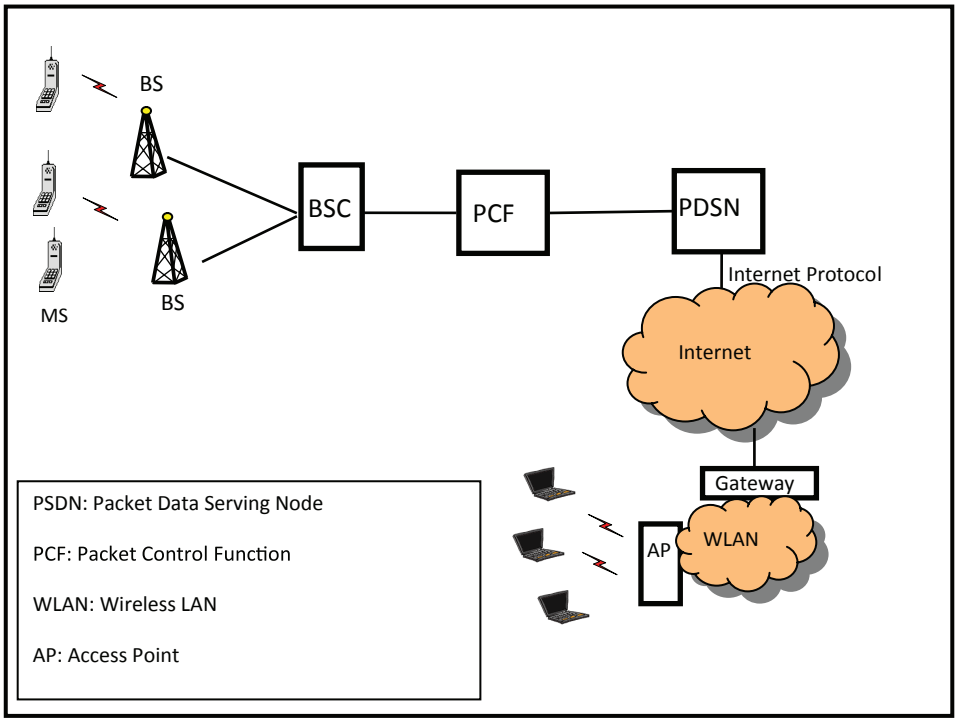
Another recent development is a new framework for mobile networks that is expected to provide multimedia support ([8], [9]) for IP telecommunication services, called IP Multimedia Subsystems (IMS) [10]. Real-time rich multimedia communication mixing telecommunication and data services could happen due to IMS in wireline broadband networks. However, mobile carriers cannot offer their customers the freedom to mix multimedia components (text, pictures, audio, voice, video) within one call. Today a two party voice call cannot be extended to a multiparty audio and video conference. IMS overcomes such limitations and makes these scenarios possible.

The future of mobile systems is largely dependent upon the development and evolution of 4G systems, multimedia networking, and to some extent, *photonic networks*. It is expected that initially the 4G mobile systems will be used independent from other technologies. With gradual growth of high speed data support to multimegabits per second, an integrations of services will happen. In addition, developments in photonic switching might allow mobile communication on a completely photonic network using Wavelength Division Multiplexing (*WDM*) on photonic switches and routers. The evolutionary view of 4G systems to 5G include a support of wireless world wide web allowing highly flexible and reconfigurable dynamic ad hoc networks.

Network Architecture

The basic architecture of wireless mobile system consists of a mobile phone connected to the wired world via a single hop wireless connection to a base station (BS), which is responsible for carrying the calls within its region called cell (Figure 1). Due to limited coverage provided by a BS, the mobile hosts change their connecting base stations as they move from one cell to another. A hand-off (later referred to as "horizontal handoff" in this article) occurs when a mobile system changes its BS. The mobile station communicates via the BS using one of the wireless frequency sharing technologies such as FDMA, TDMA, CDMA, and so forth. Each BS is connected to a mobile switching center (MSC) through fixed links, and each MSC is connected to others via Public Switched Telephone Network (*PSTN*). The MSC is a local switching exchange that handles switching of mobile user from one BS to another. It also locates the current cell location of a mobile user via a Home Location Register (HLR) that stores current location of each mobile that belongs to the MSC. In addition, the MSC contains a visitor

Figure 1. Wireless mobile system network architecture



locations register (VLR) with information of visiting mobiles from other cells. The MSC is responsible for determining the current location of a target mobile using HLR and VLR by communicating with other MSCs. The source MSC initiates a call setup message to MSC covering target area for this purpose.

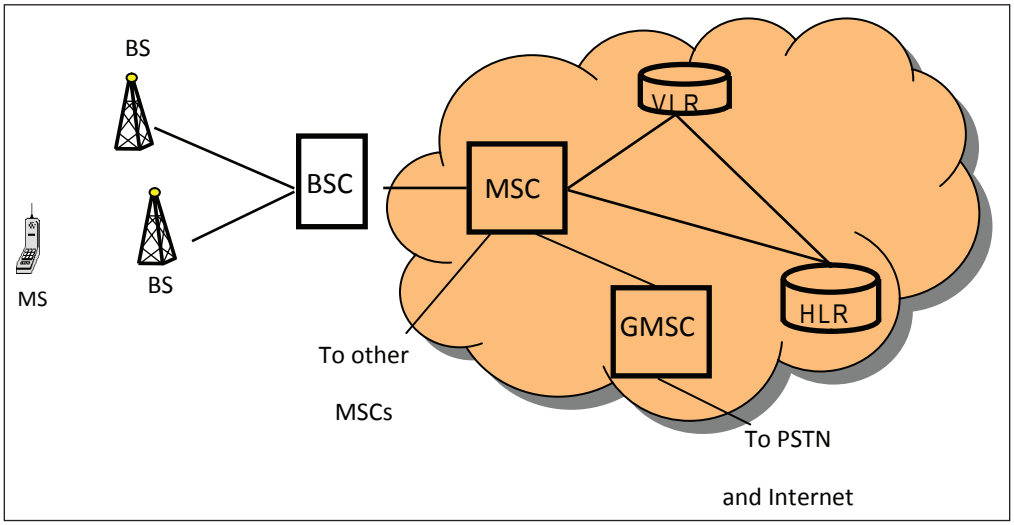
The first generation cellular implementation consisted of analog systems in 450–900 MHz frequency range using frequency shift keying for signaling and Frequency Division Multiple Access (FDMA) for spectrum sharing. The second generation implementations consist of TDMA/CDMA implementations with 900, 1800 MHz frequencies. These systems are called GSM for Europe and IS-136 for US. The respective 2.5G implementations are called GPRS and *CDPD* followed by 3G implementations.

Third generation mobile systems are intended to provide a global mobility with a wide range of services including voice calls, paging, messaging, Internet, and broadband data. IMT-2000 defines the standard applicable for North America. In Europe, the equivalent UMTS standardization is in progress. In 1998, a Third Generation Partnership Project (3GPP) was formed to unify and continue the technical specification work. Later, the Third Generation Partnership Project 2 (3GPP2) was formed for technical development of CDMA-2000 technology.

3G mobile offers access to broadband multimedia services, which is expected to become all IP based in future 4G systems ([11], [12]). However, current 3G networks are not based on IP; rather they are an evolution from existing 2G networks. Work is going on to provide 3G support and Quality of Service (QoS) in IP and mobility protocols. The situation gets more complex when we consider the WLAN research and when we expect it to become mobile. It is expected that WLANs will be installed in trains, trucks, and buildings. In addition, it may just be formed on an ad-hoc basis (like *ad-hoc networks* [13–15]) between random collections of devices that happen to come within radio range of one another (Figure 2).

In general, 4G architecture includes three basic areas of connectivity ([16]–[19]); PANs (such as Bluetooth), WANs (such as IEEE 802.11), and cellular connectivity. Under this umbrella, 4G will provide a wide range of mobile devices that support global roaming ([20]–[23]). Each device will be able to interact with Internet-based information that will be modified on the fly for the network being used by the device at that moment (Figure 3).

Figure 2. Mobile system/WLAN integration



In 5G mobile IP, each cell phone is expected to have a permanent "home" IP address, along with a "care-of" address that represents its actual location. When a computer somewhere on the Internet needs to communicate with the cell phone, it first sends a packet to the phone's home address. A directory server on the home network forwards this to the care-of address via a tunnel, as in regular mobile IP. However, the directory server also sends a message to the computer informing it of the correct care-of address, so future packets can be sent directly. This should enable TCP sessions and HTTP downloads to be maintained as users move between different types of networks. Because of the many addresses and the multiple layers of subnetting, IPv6 is needed for this type of mobility. For instance, 128 bits (4 times more than current 32 bit IPv4 address) may be divided into four parts (I thru IV) for supporting different functions. The first 32-bit part (I) may be defined as the home address of a device while the second part (II) may be declared as the care-of ad-

Figure 3. Seamless connection of networks in 4G

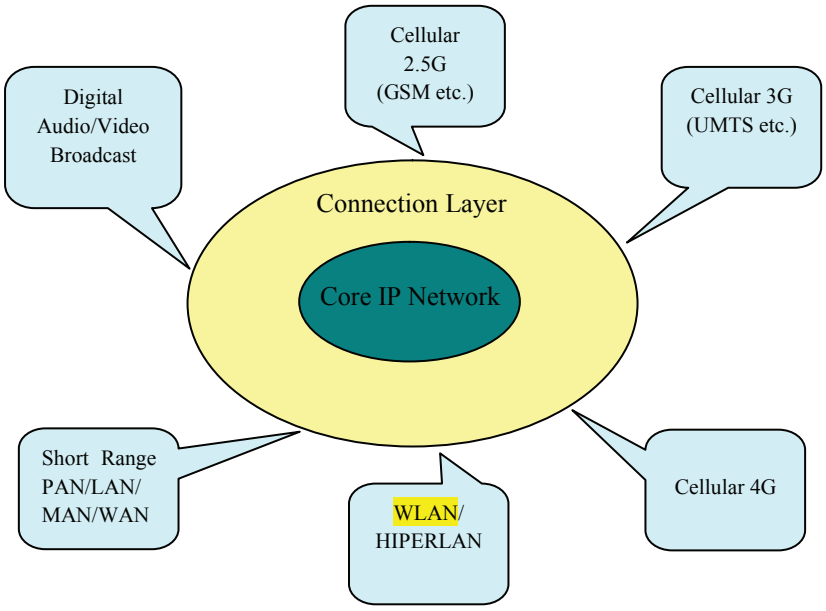


Table 1. Comparison of 1G–4G technologies

Technology/ Features	1G	2G/2.5G	3G	4G	5G
Start/ Deployment	1970/ 1984	1980/ 1999	1990/ 2002	2000/ 2010	**2010/ 2015**
Data Bandwidth	2 kbps	14.4–64 kbps	2 Mbps	200 Mbps to 1 Gbps for low mobility	**1 Gbps and higher**
Standards	AMPS	2G: TDMA, CDMA, GSM 2.5G: GPRS, EDGE, 1xRTT	WCDMA, CDMA-2000	Single unified standard	**Single unified standard**
Technology	Analog cellular technology	Digital cellular technology	Broad band-width CDMA, IP technology	Unified IP and seamless combination of broadband, LAN/WAN/ PAN and WLAN	**Unified IP and seamless combination of broadband, LAN/WAN/PAN/ WLAN and wwww**
Service	Mobile telephony (voice)	2G: Digital voice, short messaging 2.5G: Higher capacity packetized data	Integrated high quality audio, video and data	Dynamic information access, wearable devices	**Dynamic information access, wearable devices with AI capabilities**
Multiplexing	FDMA	TDMA, CDMA	CDMA	CDMA	**CDMA**
Switching	Circuit	2G: Circuit 2.5G: Circuit for access network & air interface; Packet for core network and data	Packet except circuit for air interface	All packet	**All packet**
Core Network	PSTN	PSTN	Packet network	Internet	**Internet**
Handoff	**Horizontal**	**Horizontal**	**Horizontal**	**Horizontal and Vertical**	**Horizontal and Vertical**

dress allowing communication between cell phones and personal computers. So once the communication path between cell and PC is established, care-of address will be used instead of home address, thus using the second part of IPv6 address.

The third part (III) of IPv6 address may be used for tunneling to establish a connection between wire line and wireless network. In this case an agent (a directory server) will use the mobile IP address to establish a channel to cell phones. The fourth and last part (IV) of IPv6 address may be used for local address for VPN sharing. Figure 4 illustrates the concept.

The goal of 4G and 5G is to replace the current proliferation of core mobile networks with a single worldwide core network standard, based on IPv6 for control, video, packet data, and voice. This will provide uniform video, voice, and data services to the mobile host, based entirely on IPv6. The objective is to offer seamless multimedia services to users accessing an all IP-based infrastructure through heterogeneous access technologies. IPv6 is assumed to act as an adhesive for providing global connectivity and mobility among networks.

Most of the wireless companies are looking forward to IPv6 because they will be able to introduce new services. The Japanese government is requiring all of Japan's ISPs to support IPv6 with its first 4G launch. Although the U.S. upgrade to IPv6 is less advanced, WLAN's advancement may provide a shortcut to 4G.

Standards

The role of standards is to facilitate interconnections between different types of telecommunication networks, provide interoperability over network and terminal interfaces, and enable free movement and trade of equipment. There are standard bodies in different countries that develop telecommunications standards based upon the government regulations, business

trends, and public demands. In addition, international standard organizations provide global standardizations. In the telecommunications area, International Telecommunications Union (ITU) and International Standards Organization (ISO) have been recognized as major international standards developers. Many popular telecommunications and networking standards are given by other international organizations such as Institute of Electrical and Electronics Engineers (IEEE) and Internet Engineering Taskforce (IETF). Among other organizations, the most well known are Telecommunications Industry Association (TIA) and American National Standards Institute (ANSI) in the U.S., European Telecommunication Standards Institute (ETSI), China Wireless Telecommunications Standards Group (CWTS), Japan's Association of Radio Industries and Businesses (ARIB) and Telecommunications Technology Committee (TTC), and Korea's Telecommunications Technology Association (TTA).

The ITU began its studies on global personal communications in 1985, resulting in a system referred to as International Mobile Telecommunications for the year 2000 (IMT-2000). Later, ITU Radio Communications Sector (ITU-R) and ITU-Telecommunications (ITU-T) groups were formed for radio communications and telecommunications standards, respectively. In Europe, the concepts of Universal Mobile Telecommunications System (UMTS) have been the subject of extensive research. In 1990, ETSI established an ad hoc group for UMTS that focused on the critical points to be studied for systems suitable for mobile users. Since 1998, ETSI's standardization of the 3G mobile system has been carried out in the 3G Partnership Project (3GPP) that focuses on the GSM-UMTS migration path. The 3GPP2 is an effort headed by ANSI for evolved IS-41 networks and related radio transmission technologies.

The standard organizations propose the mobile system standards that change as new technologies emerge, and the regulations and market demand change. The changing features and used technologies from first to fifth generation mobile systems are summarized in Table 1. It is noticeable that the fifth generation system not only provides a horizontal handoff like the previous systems but also provides a vertical handoff. While a global roaming may be provided by satellite systems, a regional roaming by 5G cellular systems, a local area roaming by WLANs, and a personal area roaming by wireless PANs, it will also be possible to roam vertically between these systems as well as support wwww services.

One technology (or its variation) that is expected to remain in future mobile system is CDMA, which is a use of *spread spectrum* technique by multiple transmitters to send signals simultaneously on the same frequency without interference to the same receiver. Other widely used multiple access techniques are TDMA and FDMA mostly associated with 3G and previous systems.

In these three schemes (CDMA, TDMA, FDMA), receivers discriminate among various signals by the use of different codes, time slots, and frequency channels, respectively. Digital cellular systems is an extension of IS-95 standard and is the first CDMA-based digital cellular standard pioneered by Qualcomm. The brand name for IS-95 is cdmaOne. It is now being replaced by IS-2000 and is also known as CDMA-2000, which is a 3G mobile telecommunications standard from ITU's IMT-2000. CDMA-2000 is considered an incompatible competitor of the other major 3G standard *WCDMA*.

Due to its importance in future systems, let's now examine the different CDMA standards currently available. CDMA-2000 1x, also known as CDMA-2000 1xMC (multicarrier), is the core 3G CDMA-2000 technology. The designation multicarrier refers to the possibility of using up to three separate 1.25 MHz carriers for data transmission and is used to distinguish this from WCDMA.

WCDMA is the wideband implementation of the CDMA multiplexing scheme, which is a 3G mobile communications standard tied with the GSM standard. WCDMA is the technology behind UMTS.

CDMA-2000 1xRTT (Radio Transmission Technology) is the basic layer of CDMA-2000, which supports up to 144 Kbps packet data speeds. 1xRTT is considered mostly 2.5G technology, which is used to describe systems that provide faster services than 2G, but not quite as fast or advanced as newer 3G systems. CDMA-2000 1xEV (Evolution) is CDMA-2000 1x with High Data Rate (HDR) capability added. 1xEV is commonly separated into two phases, CDMA-2000 1xEV-DO and CDMA-2000 1xEV-DV. CDMA2000 1xEV-DO (Evolution-Data Only) supports data rates up to 2.4 Mbps. It is generally deployed separately from voice networks in its own spectrum. CDMA2000 1xEV-DV (Evolution-Data and Voice) supports circuit and packet data rates up to 5 Mbps. It fully integrates with 1xRTT voice networks. CDMA-2000 3x uses three separate 1.25 MHz carriers. This provides three times the capacity but also requires three times more bandwidth.

Network Services

Users relate to different systems with the help of available applications and services that are directly a function of available data rates. The key difference between the 2G and 3G is the data rate support enabling the latter to provide interactive video communication, among other services. A type of service that gained popularity in 2G systems is the messaging service known as Short Messaging Services (SMS), which is a text messaging service for 2G and later mobile phones. The messages in SMS cannot be longer than about 160 characters. An enhanced version of SMS known as Enhanced Messaging Service (EMS) supports the ability to send pictures, sounds, and animations. A newer type of messaging service, Multimedia Messaging Service (MMS), is likely to be very popular for 3G systems and beyond. MMS provides its users the ability to send and receive messages consisting of multimedia elements from person to person as well as the Internet, and serves as the e-mail client. MMS uses Wireless Application Protocol (*WAP*) technology and is powered by the well-known technologies, EDGE, GPRS, and UTMS (using WCDMA). The messages may include any combination of text, graphics, photographic images, speech, and music clips or video clips.

The most exciting extension of messaging services in MMS is a video message capability. For instance, a short 30 seconds video clip may be shot at a location, edited with appropriate audio being added and transmitted with ease using the mobile keys on the cellular phones. In addition, by using Synchronized Multimedia Integration Language (SMIL), small presentations can be made that incorporate audio and video along with still images, animations, and text to assemble full multimedia presentation by using a media editor.

With MMS, a new type of service Interfacing Multimedia Messaging Services (IMMS) is expected to emerge that integrates MMS and Mobile Instant Messaging (MIM) allowing the users to send messages in their MIM buddy list. This will bring full integration of state-of-the art mobile messaging services including MIM, MMS, and chat into all types of mobile devices.

A new term, "Mobile Decision Support (MDS)" has been coined recently for a unique set of services and applications that will provide instant access to information in support of real-time business and personal activities for vehicle based 3G systems. Some example services are navigation, emergency services, remote monitoring, business finder, e-mail, and voicemail. It is expected that MDS based services will generate a huge nonvoice traffic over the Net.

WAP is an open international standard for applications that use wireless communication on mobile phones. The primary language of WAP specification is Wireless Markup Language (WML), which is the primary content based on XML (a general purpose markup language to encode text including the details about its structure and appearance). The original intent in WAP was to provide mobile replacement of World Wide Web. However, due to performance limitations and costs it did not become quite popular as originally expected.

Although WAP never became popular, a popular WAP-like service called i-mode has recently been developed in Japan that allows Web browsing and several other well designed services for the mobile phones. i-mode is based upon Compact HTML (C-HTML) as an alternate to WML, and is compatible with HTML allowing the C-HTML Web sites to be viewed and edited using standard Web browsers and tools.

Terminals

A mobile phone system is used as a basic terminal for communication. Also called a wireless phone, handset, cellular mobile or cell phone, is a mobile communications system that uses a combination of radio wave transmission and conventional telephone switching to permit telephone communication to and from mobile users within a specified area. A 2.5G/3G terminal may consist of a mobile phone, a computer/laptop, a television, a pager, a video-conferencing center, a newspaper, a diary, or even a credit card. Often these terminals may require a compatible 3G card and specialized hardware to provide the desired functionality.

The terminal design considerations are influenced by the potential applications and bandwidth requirements. However, there are standards for mobile stations specifications as well, for instance, in IMT-2000. The actual mobile design varies based mainly upon the multiple available standards, speeds, displays, and operating systems. There are numerous smartphone operating systems tailored to specific products by well-known companies such as Palm, Nokia, Sony, Ericsson, Siemens, Alcatel, Motorola, Samsung, Sanyo, Panasonic, Mitsubishi, LG, Sharp, Casio, NEC, NTT DoCoMo,

KDDI, and so on. The key capability in most of the supported products being the camera, video clips, keyboards, touchscreen, voice recognition, WiFi (IEEE 802.11b WLAN), and Bluetooth wireless.

The future trends in wireless terminals include the influences of new technology such as software radio, wireless socket (WiFi), portability, and new design/display concepts. The newer smartphones are expected to have the functionalities of a Pocket PC with features such as Pocket Outlook, Pocket Internet Explorer, Windows Media Player, and MSN Messenger. These newer services will obviously make the communication in fourth generation systems much easier. However, the biggest challenge remains the integration and convergence of the technologies at the lower layers.

CONCLUSION

The current and future trends in mobile systems are considered, including the evolutionary path starting from first generation mobile phone systems and continuing to the development of fifth generation systems. The evolution of network design, architecture, standards, services, and terminals is discussed.

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Web Sites

Third Generation Partnership Project (3GPP), http://www.3gpp.org

Third Generation Partnership Project 2, 3GPP2, http://www.3gpp2.org

Wireless Application Protocol (WAP) Forum, http://www.wapforum.org

Global Systems for Mobile Communication (GSM) Association, http://www.gsmworld.com.

European Telecommunications Standards Institute (ETSI), http://www.etsi.org

International Telecommunications Union (ITU), http://www.itu.org

Code Division Multiple Access (CDMA) Development Group, http://www.cdg.org

Internet Engineering Taskforce (IETF), http://www.ietf.org

Institute of Electrical and Electronics Engineers (IEEE), http://www.ieee.org

American National Standards Institute (ANSI), http://www.ansi.org

Telecommunication Standards Institute (TIA), http://www.tiaonline.org

Association of Radio Industries and Businesses (ARIB), http://www.arib.or.jp

China Wireless Telecommunication Standards (CWTS) group, http://www.cwts.org

International Standards Organization (ISO), http://www.iso.org

Telecommunications Technology Association (TTA), http://www.tta.or.kr

S.L. Huang, IT Discussion Posting, http://www.daniweb.com/forums/thread35959.html

KEY TERMS

1G: Old-fashioned analog mobile phone systems capable of handling very limited or no data at all.

2G: Second generation voice-centric mobile phones and services with limited data rates ranging from 9.6 kbps to 19.2 kbps.

2.5G: Interim hardware and software mobile solutions between 2G and 3G with voice and data capabilities and data rates ranging from 56 kbps to 170 kbps.

3G: A long awaited digital mobile systems with a maximum data rate of 2 Mbps under stationary conditions and 384 kbps under mobile conditions. This technology is capable of handling streaming video two way voice over IP and Internet connectivity with support for high quality graphics.

3GPP: Third Generation Partnership Project. 3GPP is an industry body set up to develop a 3G standard based upon wideband CDMA (WCDMA).

3GPP2: Third Generation Partnership Project 2. 3GPP2 is an industry standard set up to develop a 3G standard based upon CDMA-2000.

3.5G: Interim systems between 3G and 4G allowing a downlink data rate upto 14 Mbps. Sometimes it is also called as High Speed Downlink Packet Access (HSDPA).

4G: Planned evolution of 3G technology that is expected to provide support for data rates up to 100 Mbps allowing high quality and smooth video transmission.

5G: In an evolutionary view, it will be capable of supporting wwww allowing highly flexible dynamic

ad hoc wireless networks. In a revolutionary view, this intelligent technology is capable of interconnecting the entire world without limits.

Ad-hoc Networks: A self configuring mobile network of routers (and hosts) connected by wireless, in which the nodes may move freely and randomly resulting in a rapid and unpredictable change in network's wireless topology. It is also called a Mobile Ad-hoc NETwork (MANET).

Bluetooth: A wireless networking protocol designed to replace cable network technology for devices within 30 feet. Like IEEE 802.11b, Bluetooth also operates in unlicensed 2.4GHz spectrum, but it only supports data rates up to 1 Mbps.

CDPD: Cellular Digital Packet Data is a wireless standard providing two way data transmission at 19.2 kbps over existing cellular phone systems.

CDMA: Code Division Multiple Access, also known as CDMA-ONE or IS-95, is a spread spectrum communication technology that allows many users to communicate simultaneously using the same frequency spectrum. Communication between users are differentiated by using a unique code for each user. This method allows more users to share the spectrum at the same time than alternative technologies.

CDMA-2000: Sometimes also known as IS-136 and IMT-CDMA multicarrier (1X/3X) is an evolution of narrowband radio transmission technology known as CDMA-ONE (also called CDMA or IS-95) to third generation. 1X refers to the use of 1.25 Mhz channel while 3X refers to 5 Mhz channel.

DAWN: Advanced technologies including smart antenna and flexible modulation are keys to optimize this wireless version of reconfigurable ad hoc networks.

DSSS: In Direct Sequence Spread Spectrum, the data stream to be transmitted is divided into small pieces, each of which is allocated a frequency channel. Then the data signal is combined with a higher data rate bit sequence known as "chipping code" that divides the data according to a spreading ratio, thus allowing a resistance from interference during transmission.

EDGE: Enhanced Data rates for Global Evolution technology gives GSM and TDMA the capability to handle third generation mobile phone services with speeds up to 384 kbps. Since it uses the TDMA infrastructure, a smooth transition from TDMA based systems such as GSM to EDGE is expected.

FHSS: In Frequency Hopping Spread Spectrum, a broad slice of bandwidth spectrum is divided into many possible broadcast frequencies to be used by the transmitted signal.

GPRS: General Packet Radio Service provides data rates upto 115 kbps for wireless Internet and other types of data communications using packet data services.

GSM: Global Systems for Mobile Communication is a worldwide standard for digital wireless mobile phone systems. The standard was originated by the European Conference of Postal and Telecommunications Administrations (CEPT) who was responsible for the creation of ETSI. Currently, ETSI is responsible for the development of GSM standard.

Mobile Phones: Mobile communication systems that use radio communication and conventional telephone switching to allow communication to and from mobile users.

Photonic Networks: A network of computers made up using photonic devices based on optics. The devices include photonic switches, gateways, and routers.

PSTN: Public Switched Telephone Network is a regular voice telephone network.

Spread Spectrum: It is a form of wireless communication in which the frequency of the transmitted signal is deliberately varied over a wide range. This results in a higher bandwidth of the signal than the one without varied frequency.

TDMA: Time Division Multiple Access is a technology for sharing a medium by several users by dividing into different time slots transmitting at the same frequency.

UMTS: Universal Mobile Telecommunications System is the third generation mobile telephone standard in Europe that was proposed by ETSI.

WAP: Wireless Application Protocol defines the use of TCP/IP and Web browsing for mobile systems.

WCDMA: Wideband CDMA is a technology for wideband digital radio communications of multimedia and other capacity demanding applications. It is adopted by ITU under the name IMT-2000 direct spread.

WDM: Wavelength Division Multiplexing allows many independent signals to be transmitted simultaneously on one fiber with each signal located at a different wavelength. Routing and detection of these signals require devices that are wavelength selective, allowing for the transmission, recovery, or routing of specific wavelengths in photonic networks.

WWWW: A World Wide Wireless Web is capable of supporting a comprehensive wireless-based Web application that includes full graphics and multimedia capability at beyond 4G speeds.