6-2-2 Mobile technologies

6-2-2-1 History

Commercial mobile cellular systems first became available in the early 1980's. These first systems were deployed, utilizing analog technology over circuit-switched networks. They had very limited features, poor voice quality, and limited radio coverage, although they have vastly improved over the last two decades and are still widely deployed around the world. In addition, data transfer was limited to 9600 baud.

In the early 1990's, the second generation of mobile cellular systems was introduced. Based upon digital technology and still utilizing the circuit-switched network, new features and services were introduced. Speech quality, although not equivalent to that of analog, was digitized through a low 8kbps bitrate vocoder that used Code Excited Linear Projection (CELP) technology. This has also been enhanced, over the past five years, to the extent that speech quality now exceeds that of the FM analog systems.

The immediate motivating factor for the third-generation communications systems is to increase system capacity. The overall number of users is exceeding the radio spectrum allocated to the second-generation; however, receiving and sending data are the essential building blocks to widespread mobile Internet access and to mobile data transfer, capabilities enabled with the third-generation. The third-generation is a generic term used for the next generation of mobile communications systems, often referred to simply as "3G." 3G mobile systems will provide enhanced services such as voice, text, and high-speed data, with 144kbps as an overall goal. The technology involved in the deployment of 3G systems and services is currently under development throughout the industry.

Attaining the goals of 3G will be an evolutionary migration from the installed 2G systems. Operators are phasing in new enhanced 2G capabilities, preparing for 3G services, and attempting to provide a seamless transition from existing digital systems, including full backwards compatibility. From a consumer perspective, this integration of system and service profiles, along with multi-mode terminals will mean worldwide roaming possibilities. 3G systems offer up to fifteen times the network capacity of analog networks. With the initial third-generation networks due to be launched in Japan in early 2001, and with European countries following in early 2002, 3G is already in sight. To enable third-generation capabilities, especially worldwide roaming, the radio interface specifications need to be defined and adopted, and complete interoperability needs to be finalized FM analog systems

6-2-2-2 First-Generation Mobile standards

The first generation of cellular wireless communications was based on analog technology and progressively became available to the consumer during the late 1970's and early 1980's. The most successful analog systems are based on the following standards, all of which are still in demand today:

Nordic Mobile Telephone (NMT) was the first commercially available analog system, introduced in Sweden and Norway in 1979.

Advanced Mobile Phone Service (AMPS) was launched in 1982. This has proven to be the most successful analog standard of all. AMPS networks are widely deployed and can be found on all continents.

Total Access Communications System (TACS) was originally specified for the United Kingdom and is based on AMPS. The original TACS specification was extended and is known as ETACS. ETACS is primarily deployed in Asia Pacific regions.

6-2-2-3 Second-Generation Mobile Standards

The second-generation (also known as 2G) introduced digital wireless standards that concentrated on improving voice quality, coverage, and capacity. The 2G standards were defined and designed to support voice and low-rate data-only Internet browsing was in its infancy during the definition stage. The world's four primary mobile digital wireless standards currently deployed around the world are GSM, TDMA (IS-136), CDMA (IS-95-B), and PDC, all supporting data rates up to 9.6kbps.

Global System for Mobile phone communications (GSM) was the first commercially available digital standard, introduced in 1992. GSM relies on circuit-switched data. The basic development of supporting data at low bit-rates (< 9.6 kbps) was introduced at the beginning of commercial services and has been predominantly used for e-mailing from laptop computers.

Time Division Multiple Access, originally IS-54 and now IS-136 (TDMA IS-136), is sometimes referred to as the "North American" digital standard; however, it is also deployed in Latin America, Asia Pacific, and Eastern Europe.

Personal Digital Communications (PDC) is the primary digital standard in Japan.

IS-95 is based on "narrowband" (referred to as narrowband because of the limited amount of information that can flow through these networks) Code Division Multiple Access (CDMA) technology. It has become popular in South Korea and North America.

6-2-2-4 High-speed Circuit-switched Data (HSCSD)

High-speed Circuit-switched Data (HSCSD) provides access to four channels simultaneously; theoretically providing four times the bandwidth of a standard circuit-switched data transmission of 14.4kbps.The HSCSD is based on circuit switching and is implemented on GSM Infrastructure (Fig-1).

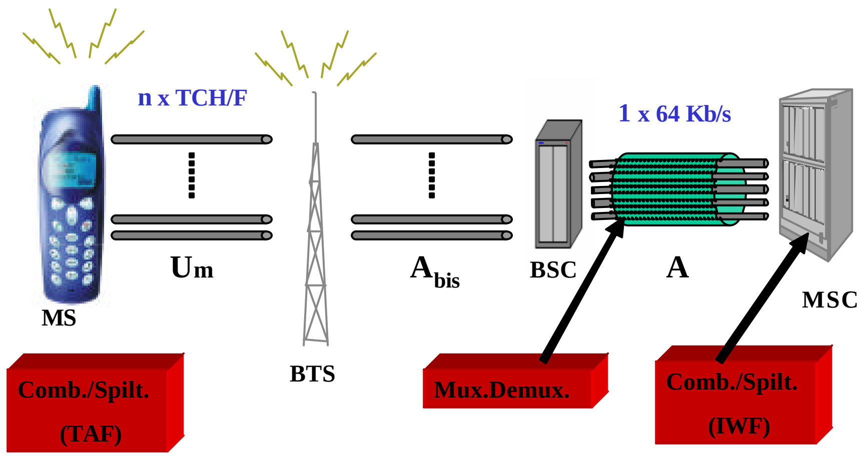

Fig.1- HSCSD Structure

6-2-2-5 Enhanced Second-Generation Mobile Standards

Enhanced second-generation (sometimes referred to as 2.5G or 2+G) builds upon the second-generation standards by providing increased bit-rates and bringing limited data capability. Data rates range from 57kbps to 171kbps.

General Packet Radio System (GPRS):

General Packet Radio System (GPRS) is an evolutionary path for GSM and IS-136 TDMA to UWC-136. It is a standard from the European Telecommunications Standards Institute (ETSI) on packet data in GSM systems. The Telecommunications Industry Association (TIA), as the packet-data SDO for TDMA-136 systems, has also accepted GPRS. GPRS supports theoretical data rates up to 171kbps by utilizing all eight channels simultaneously. This data rate is roughly three times faster than today's fixed telecommunication networks and about ten times as fast as current circuit-switched data services on GSM networks. GPRS is a universal packet-switched data service in GSM. It involves overlaying a packet-based air interface on the existing circuit-switched GSM network. Packet switching means that GPRS radio resources are used only when users are actually sending or receiving data. Using GPRS, the information is split into separate but related packets before being transmitted and subsequently reassembled at the receiving end. GPRS is a non-voice-added service that allows information to be sent and received across multiple mobile telephone networks. It supplements today's circuit-switched data and short messaging service. GPRS uses packet data technology, a fundamental change from circuit-switched technology, to transfer information. It also facilitates instant connection capability, sometimes referred to as "always connected." Immediacy is one of the key advantages of GPRS. Immediacy enables time-critical application services.

GPRS (General Packet Radio Service) is a packet data communications system integrated with the GSM cellular telephone system. Standardized by ETSI in December 1997, GPRS products are currently under development by GSM equipment vendors. GPRS is a large, complex system that merges cellular telephone radio transmission technology and Internet information delivery protocols. Initial implementations of GPRS will operate within the framework of present GSM technology. It is also anticipated that GPRS will be adapted for use in North American TDMA cellular systems and enhanced TDMA cellular systems (EDGE).The GPRS specification admits considerable flexibility in the design of network elements and in network operation. The values assigned to a large set of parameters influence many performance characteristics including the relationship of GPRS data transmissions to GSM telephone traffic, the relationship of uplink data traffic to downlink data traffic, and the proportion of resources devoted to signaling and user data.

GPRS offers packet-switched connections to data networks via mobile technology. It is designed to allow faster and easier Internet access with continuous connectivity, and enables applications including multimedia messaging, wireless corporate intranet, remote control and maintenance of appliances. It is also considered part of the migration to third generation (3G) Mobile network (Fig.2).

The advantages of GPRS technology allows users to stay connected to the Internet by using packet switching technology providing faster downloads as no time is spent attempting to access a dial-up connection. A user favorite information and entertainment sites are always available via GPRS without having to maintain a continuous phone call [8]. Not only does Vodafone's GPRS service greatly enhance your WAP experience, it also lets you stay permanently connected to the mobile Internet without running up a huge phone bill. This is because with GPRS, you are only charged for the amount of information you send and receive, not the length of time you use your phone. This means that once switch on your GPRS phone in the morning and connect to the mobile Internet, you can stay on all day - you don't need to connect and disconnect to the Net each time you want to access a service. This is known as being "always on" because your GPRS phone is always ready for you to use the mobile Internet, saving you time and hassle.

The "always on" capability of GPRS means that you don't need to worry about your mobile Internet session being interrupted by phone calls either. With Vodafone's GPRS service, you can simply pause your browsing session, take the call, and then carry on reading the page you were on already. It's another handy timesaving function of GPRS that enhances your enjoyment of WAP.

GPRS is a packet-based wireless communication service that, promises data rates from 56 up to 114 Kbps and continuous connection to the Internet for mobile phone and computer users GPRS is based on "regular" GSM (with the same modulation) and will complement existing services such circuit-switched cellular phone connections such as SMS or cell broadcast. Voice over Ip over GPRS is also explored.

In theory, GPRS packet-based service should cost users less than circuit-switched services since communication channels are being used on a shared-use, as-packets-are-needed basis rather than dedicated only to one user at a time. It should also be easier to make applications available to mobile users and Wap or i-mode should far more attractive for the user. In addition to the Internet Protocol GPRS supports X.25, a packet-based protocol that is used mainly in Europe.

Operator should deploy GPRS very fast as most of the interoperability test between the network and the Handset are now finished (September'00) and because GPRS is mainly a software upgrade for the BTS, BSC and servers. GPRS data speeds are expected to reach 100 Kbps.

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Fig.2 – GPRS Structure

Enhanced Data rates for GSM Evolution (EDGE)

Another GSM 2.5G packet technology, Enhanced Data rates for GSM Evolution (EDGE), will boost data rates to 384 Kbps if/when deployed(Fig.3).

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Fig.3- EDGE Structure

6-2-2-6 Third-Generation Mobile Standards

Third-generation systems will provide wide-area coverage at 384kbps and local area coverage up to 2Mbps. The primary motivation for the development of third-generation wireless communications is the ability to supplement standardized 2G and 2G+ services with wideband services. Essentially, this offers voice plus data capability.

The existing array of incompatible second-generation technologies, together with the restricted amount of information that can be transferred over these narrowband systems, prompted the ITU to work towards defining a new global standard for the next-generation broadband mobile telecommunication systems. Known as IMT-2000 (International Mobile Telecommunications-2000), the project was started to attain authorship of a set of globally harmonized standards for broadband mobile communications. The first set of IMT-2000 recommendations was recently approved by the ITU.

IMT-2000 is the term used by the International Telecommunications Union for this set of globally harmonized standards. The initiative was to define the goal of accessing the global telecommunication infrastructure through both satellite and terrestrial mobile systems. IMT-2000 has reflected the explosion of mobile usage and the need for future high-speed data communications, with wideband mobile submissions. IMT-2000 is a flexible standard that allows operators around the world the freedom of radio access methods and of core networks so that they can openly implement and evolve their systems. How they do it depends on regulations and market requirements.

The recent IMT-2000 recommendation highlights five distinct mobile/terrestrial radio interface standards:

1. IMT-MC: CDMA Multi-carrier (known as cdma2000 or IS-2000).
2. IMT-DS: CDMA Direct Spread (known as Wideband CMDA or WCDMA-FDD). This standard is intended for applications in public macro-cell and micro-cell environments. The Frequency Division Duplex (FDD) mode is used for symmetrical applications, i.e., those requiring the same amount of radio resources in the uplink as in the downlink. This standard is well supported by Japan's ARIB and GSM network operators and vendors.
3. IMT-TC: CDMA TDD (WCDMA-TDD). Time Division Duplex (TDD) targets public micro-cell and pico-cell environments, and, due to severe interference-related considerations, is intended primarily for indoor use. This standard is optimized for symmetrical and asymmetrical applications with high data rates.
4. IMT-SC: TDMA Single Carrier (known as UWC-136 and EDGE). UWC-136 (Universal Wireless Communications) and EDGE (Enhanced Data Rates for GSM Evolution) will provide extended data services, with no changes to channel structure, frequency, or bandwidth. IMT-SC is the evolutionary path for GSM and TDMA-136, achieved by building upon enhanced versions of GSM and TDMA-136 technology. EDGE is a radio-based high-speed mobile data standard with aggregate transmission speeds of up to 384kbps when all eight timeslots are used.
5. IMT-FT: TDMA Multi-carrier (well known as DECT, Digital Enhanced Cordless Telecommunication).

The IMT-2000 recommendations encompass three CDMA and two TDMA radio air interface standards.

Wideband Code Division Multiple Access (WCDMA) should not be confused with narrowband CDMA; they are completely different protocols. WCDMA is a younger technology, defined specifically to deliver high-speed data services and Internet-based packet-data at 3G data rates. WCDMA supports both packet and circuit-switched communications, such as Internet access and landline telephone services; however, WCDMA was defined with no requirements on second-generation backward compatibility.

WCDMA makes very efficient use of the available radio spectrum. No frequency planning is needed, since one-cell re-use is applied. Using techniques such as adaptive antenna arrays, hierarchical cell structures, and coherent demodulation, network capacity can be increased. In addition, circuit and packet-switched services can be combined on the same channel, allowing true multimedia services with multiple packet or circuit connections on a single terminal. WCDMA capacity is approximately double that of narrowband CDMA. The wider bandwidth and the use of both coherent demodulation and fast power control in the uplinks and the downlinks allow a lower receiver threshold. WCDMA uses a network protocol structure (signaling) similar to that of GSM; therefore, it will be able to use the existing GSM network as the core network infrastructure.

In CDMA2000, a range of RF channel bandwidths are supported: 1.25, 3.75, 7.5, 11.25, and 15MHz. This range allows for support of a range of data rates as well as a high number of users.

In order to support higher bandwidth channels, CDMA2000 has defined two configuration options: Direct Spread (DS) and Multi-carrier (MC). The DS option is similar to IS-95B and uses the entire bandwidth to spread the data for radio transmissions. In the MC option, user data is encoded as a single stream and de-multiplexed into multiple streams. Each stream carries part of the user data using a different carrier frequency signal, hence the name Multi-carrier. The receiver will multiplex the received signals together before demodulation is carried out. Both the DS and MC options are available in the forward link only. The reverse link supports only the DS option.

WCDMA is a code-division multiple access technology which separates each user's voice or data information by multiplying the information by pseudo-random bits called "chips". The pseudo-random bit sequences have a rate of 3.84 Mcps (millions of chips per second), resulting in the narrowband information bits of the user being spread across a much wider bandwidth of approximately 5 MHz. For this reason, CDMA technology is sometimes referred to as “spread spectrum.”

Time Division Multiple Access

One approach to reducing the number of confusing options to the end user and to improve the overall functionality of time-division cellular technology is to combine TDMA and CDMA radio air interface technology into one system. This combined approach, referred to as TD-CDMA, would retain some of the fundamental GSM-TDMA design parameters, such as frame and time-slot structure, which are key factors for interoperability and evolution. At the same time, the CDMA technology would add better interference averaging and frequency diversity. The combined approach would also merge the excellent spectral efficiency of CDMA, while retaining the robustness, planning principles, and well understood characteristics of TDMA-based GSM.

In addition to the improvements of data throughput and interworking, 3G will provide an additional spectrum for the operators. The increase in 3G spectrum efficiency will also provide the operator with more throughput over limited resources. The transition from the existing 2G networks to

3G capabilities will evolve over time. Dual-mode terminals will attempt to provide seamless hand-over and roaming capabilities.

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6-2-2-7 Evolution to 3G Wireless Technology

Initial coverage

Initially, 3G wireless technology will be deployed as "islands" in business areas where more capacity and advanced services are demanded. A complete evolution to 3G wireless technology is mandated by the end of 2000 in Japan (mostly due to capacity requirements) and by the end of 2001 in Europe. NTT DoCoMo is deploying 3G wireless services in Japan in the third quarter of 2000. In contrast, there is no similar mandate in North America and it is more likely that competition will drive the deployment of 3G wireless technology in that region. For example,
Nextel Communications has announced that it will be deploying 3G wireless services in North America during the fourth quarter of 2000.The implementation of 3G wireless systems raises several critical issues, such as the successful backward compatibility to air interfaces as well as to deployed infrastructures.

Interworking with 2G and 2G+ Wireless Networks

The existence of legacy networks in most regions of the world highlights the challenge that communications equipment manufacturers face when implementing next-generation wireless technology. Compatibility and interworking between the new 3G wireless systems and the old legacy networks must be achieved in order to ensure the acceptance of new 3G wireless technology by service providers and end-users.
The existing core technology used in mobile networks is based on traditional circuit-switched technology for delivery of voice services. However, this traditional technology is inefficient for the delivery of multimedia services. The core switches for next-generation of mobile networks will be based on packet-switched technology which is better suited for data and multimedia services.
Second generation GSM networks consist of BTS, BSC, MSC/VLR and HLR/AuC/EIR network elements. The interfaces between BTS, BSC and MSC/VLR elements are circuit-switched PCM. PRS technology adds a

parallel packet-switched core network. The 2G+ network consists of SC with packet interfaces to SGSN, GGSN, HLR/AuC/EIR. The interfaces between BSC and GSN network elements are either Frame Relay and/or ATM so as to provide reliable transport with Quality of Service (QoS).RNC network elements. The 3G Core Network consists of the same entities as GSM and GPRS: G MSC/VLR, GMSC, HLR/AuC/EIR, 3G-SGSN, and GGSN. IP technology is used end-to-end or multimedia applications and ATM 3G wireless technology introduces new Radio Access network (RAN) consisting of Node B and echnology is used to provide reliable transport with QoS. 3G wireless solutions allow for the possibility of having an integrated network for circuit-switched nd packet-switched services by utilizing ATM technology. The BSC may evolve into an RNC by sing add-on cards or additional hardware that is co-located. The carrier frequency (5Mhz) and
the bands (2.5 to 5Ghz) are different for 3G wireless technology compared to 2G/2G+ wireless technology. Evolution of BSC to RNC requires support for new protocols such as PDCP, RRC,RANAP, RNSAP and NBAP. Therefore, BTS' evolution into Node B may prove to be difficult andmay represent significant capital expenditure on the part of network operators. SC evolution depends on the selection of a fixed network to carry the requested services. If an TM network is chosen, then ATM protocols will have to be supported in 3G MSC along with interworking between ATM and existing PSTN/ISDN networks.

The evolution of SGSN and GGSN to 3G nodes is relatively easier. Enhancements to GTP protocol and support for new RANAP protocol are necessary to support 3G wireless systems.ATM protocols need to be incorporated to transport the services. The HLR databases evolve into3G-HLR by adding 3G wireless user profiles. The VLR database must also be updated accordingly. The EIR database needs to change to accommodate new equipment that will be deployed for 3G wireless systems. Finally, global roaming requires compatibility to existing deployment and graceful fallback to an available level when requested services are not available in the region. Towards this end, the Operator Harmonization Group (OHG) is working closely with 3G Partnership Projects (3GPP and 3GPP2) to come up with global standards for 3G wireless protocols. Although 3G is still in the early stages of rollout, good overviews of the key aspects of WCDMA networks are becoming increasingly available, which are well suited for engineers, managers, and industry executives looking to gain a higher-level understanding of these new technologies.
However, there is still some confusion surrounding the terminology used in reference to WCDMA (3G, UTRA, UMTS, etc), which this paper aims

to clarify. By exploring experiences with 2G CDMA and GSM technology, as well as reviewing the basic features of WCDMA and comparing it to 2G, lessons can be learned and applied to WCDMA with great effect – particularly when attention is focused on the WCDMA radio link and the key radio-related parameters, which require tuning before a WCDMA system can be commercially launched.

WCDMA (Wideband Code Division Multiple Access) is the air-interface technology forming the basis of UTRA. The term "Wideband" is used to differentiate WCDMA from the 2G CDMA based technology - pioneered by Qualcomm - called cdmaOne or IS-95 CDMA. WCDMA uses a bandwidth over three times wider than cdmaOne.

UTRA (Universal Terrestrial Radio Access) is the third generation (3G) radio network technology specified by the 3rd Generation Partnership Project (**3GPP**), a joint standardization project consisting of standardization bodies from Europe, Japan, Korea, the USA, and China. UTRA has two modes, **UTRA-FDD** (Frequency Division Duplex) and **UTRA-TDD** (Time Division Duplex). UTRA-FDD is based on a harmonized version of WCDMA technology agreed to by the various members of 3GPP. UTRA-TDD is likely to experience further harmonization related to the TD-SCDMA standard proposed by the Chinese standards body CWTS.

UTRA Release-99, Release 4 and Release 5

Release-99, the first release of a global, harmonized UTRA standard by the 3GPP was ompleted in 1999. In September 2000, yearly releases were discontinued in favor of contentbased releases. As a result, UTRA Release 2000 was split into Release 4 and Release 5, with planned completion dates of March 2001 and December 2001 respectively. Release 4 contains relatively minor adjustments to Release-99, whereas Release 5 is likely to nclude more substantial modifications such as data rates up to 10 MBps on the downlink. Other ey features planned post-Release-99 will focus on harmonization of the UTRA-TDD standardwith the TDD mode from CWTS, and interconnectivity of UTRA-FDD and IS-41 -based core networks.

UMTS (Universal Mobile Telephone System) is an ETSI (European Telecommunications tandards Institute) term for third generation (3G) wireless technology designed to provide eamless global coverage through interoperability of terrestrial and non-terrestrial (e.g. satellite) etworks. The term UTRA was originally of UMTS, and in this context, UTRA stands for UMTS used by ETSI to refer to the terrestrial radio component

Terrestrial Radio Access. The Terrestrial Radio Access component of UMTS was submitted to the 3GPP by ETSI as an input into the CDMA harmonization process.

IMT-2000 provides a framework for a single global 3G standard which is the result of
harmonization efforts of manufacturers and operators around the world. IMT-2000 is a multimode tandard, which provides compatibility across multiple core network and air-interface standards. UTRA-FDD represents one component of the IMT-2000 framework, which also includes

cdma2000 (a CDMA-based technology specified by **3GPP2**) and other air-interface
technologies. Within the IMT-2000 framework, UTRA-FDD is referred to as **IMT-DS** (Direct pread) because it is a direct-spread CDMA technology, and cdma2000 is referred to as **IMTMC** Multi-Carrier) because it offers a wideband mode using more than one carrier. TD-SCDMA submitted by China's CWTS) and UTRA-TDD form yet another component of IMT-2000.