Technology Digest

Bulletin of telecom technology

Issue, April 2018

This is the first part of the series of Technology Digest on the topic **"Evolution of Mobile Communications"**.

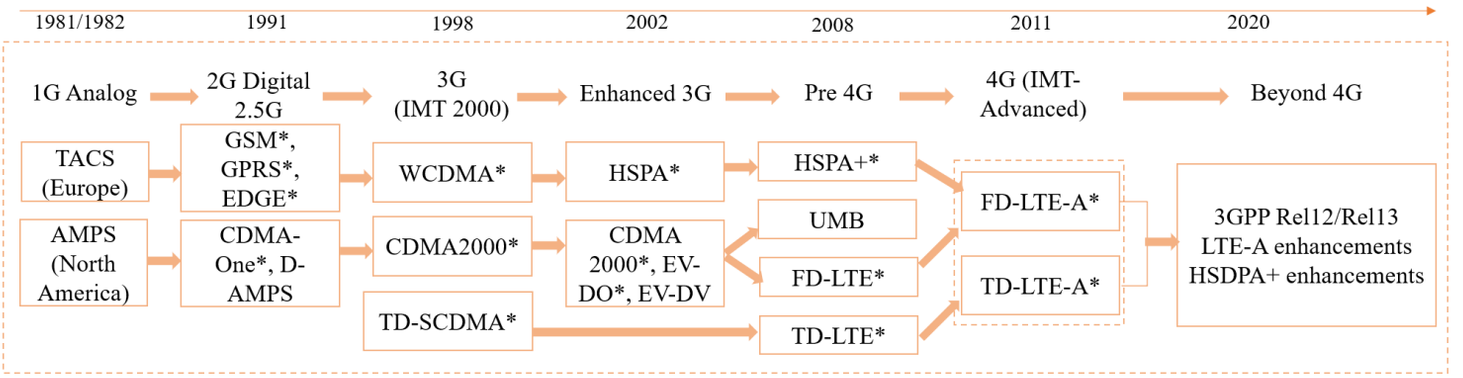
Telecom Regulatory Authority of India

Evolution of Mobile Communications (1G, 2G and 3G) – Part I

Mobile communications systems revolutionized the way people communicate. Any radio telephone capable of operating while moving at any speed, battery operated and small enough to be carried by a person comes under the mobile communication systems. Mobile telephones offer full-duplex transmission. These are one-to-one systems that permit two simultaneous transmissions.

Since the commercial introduction of Advanced Mobile Phone System (AMPS) service in 1983, mobile communication systems have witnessed an explosive growth. The most important breakthrough was the cellular concept. The advent of cellular operation brought frequency reuse capabilities. Advances in wireless access, digital signal processing, integrated circuits, increased battery life, etc led to exponential growth of personal communication services. Cellular telephones began as a simple two-way analog communication system using frequency modulation for voice and frequency-shift keying for transporting control and signaling information. Other cellular systems are a digital cellular system, cordless telephony, satellite mobile, and paging.

In this issue



* Technologies adopted in India

Figure 1 : Evolution path of Mobile Communication

Multiple Access Schemes

Before we venture in time to look at the past, present and future of mobile technology, let's take a look at different multiple access schemes.

Requirements for a multiple access scheme

In any cellular system it is necessary for it to be able have a scheme whereby it can handle multiple users at any given time. There are many ways of doing this, and as cellular technology has advanced, different techniques have been used.

There are a number of requirements that any multiple access scheme must be able to meet:

- Ability to handle several users without mutual interference.
- Ability to be able to maximize the spectrum efficiency

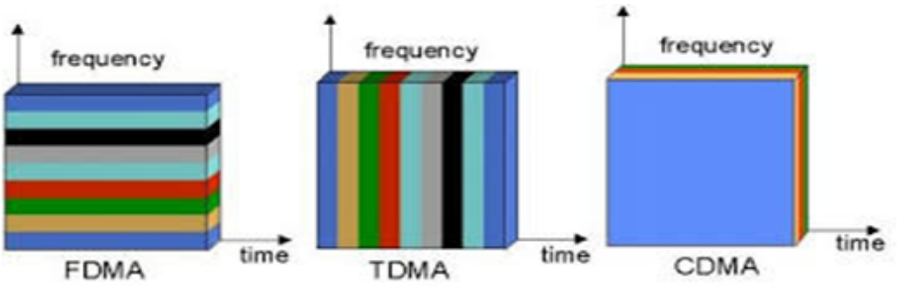


Figure 2: Multiple Access Schemes

- Must be robust, enabling ease of handover between cells.

FDMA - Frequency Division Multiple Access

FDMA is the most straightforward of the multiple access schemes that have been used. As a subscriber comes onto the system, or swaps from one cell to the next, the network allocates a channel or frequency to each one. In this way the different subscribers are allocated a different slot and access to the network. As different frequencies are used, the system is naturally termed Frequency Division Multiple Access. This scheme was used by all analogue systems.

TDMA - Time Division Multiple Access

The second system came about with the transition to digital schemes for cellular technology. Here digital data could be split up in time and sent as bursts when required. As speech was digitised it could be sent in short data bursts, any small delay caused by sending the data in bursts would be short and not noticed. In this way it became possible to organise the system so that a given number of slots were available on a give transmission. Each subscriber would then be allocated a different time slot in which they could transmit or receive data. As different time slots are used for each subscriber to gain access to the system, it is known as time division multiple access. Obviously this only allows a certain number of users access to the system. Beyond this another channel may be used, so systems that use TDMA may also have elements of FDMA operation as well.

CDMA - Code Division Multiple Access

The scheme has been likened to being in a room filled with people all speaking different languages. Even though the noise level is very high, it is still possible to understand someone speaking in your own language. With CDMA different spreading or chip codes are used. When generating a direct sequence spread spectrum, the data to be transmitted is multiplied with spreading or chip code. This widens the spectrum of the signal, but it can only be decided in the receiver if it is again multiplied with the same spreading code. All signals that use different spreading codes are not seen, and are discarded in the process. Thus in the presence of a variety of signals it is possible to receive only the required one.

In this way the base station allocates different codes to different users and when it receives the signal it will use one code to receive the signal from one mobile, and another spreading code to receive the signal from a second mobile. In this way the same frequency channel can be used to serve a number of different mobiles.

First Generation (Analog)

First-generation mobile systems used circuit switched analog transmission to carry low-quality voice traffic. In 1979, the first cellular system in the world became operational by Nippon Telephone and Telegraph (NTT) in Tokyo, Japan. In the United States, the Advanced Mobile Phone System (AMPS) was launched in 1982. The two most popular analog systems were Nordic Mobile Telephones (NMT) and Total Access Communication Systems (TACS). All the standards in 1G use frequency modulation techniques for voice signals and all the handover decisions were taken at the Base Stations. The spectrum within the cell was divided into a number of channels and every call is allotted a dedicated pair of channels.

Network Standards

The first generation of mobile communication technology consists of multiple standards such as AMPS, NMT, TACS among others.

1. **AMPS:** It is based on FDMA to allow multiple user access in a cell. Cell-sizes were not fixed under this standard and an eight-mile radius was used in urban areas and a twenty-five-mile radius in rural areas. With the increase in a number of users, new cells were added and with the addition of new cells the frequency plans needed to be reworked to

Figure 3: 1G Handset Communication

avoid interference related issues. There were security issues too with this and impersonation was easy if someone was able to get hold of another person's serial code.

2. **NMT:** NMT was based on analog technology and was developed in two versions; NMT 450 and NMT 900. The numbers indicate the frequency bands used. This standard specified billing and roaming but its specifications lacked in security as the traffic was not encrypted. The cell sizes in an NMT network range from 2 km to 30 km. NMT used full duplex transmission, allowing for simultaneous reception and transmission of voice.

Access Technology

In the first generation of mobile telecommunication, Frequency Division Multiple Access (FDMA) technique was used which allows a number of users to share the available frequency by segmenting the frequency block into smaller subcarriers and allocating those subcarriers on a per-user basis. In FDMA, each phone call is assigned to a specific uplink frequency channel and other downlink frequency channel. The channel, therefore, is closed to other conversations until the initial call is finished, or until it is handed-off to a different channel.

Second Generation

Second Generation or 2G technology was introduced in the early 1990s' as the first generation of digital radio technologies. Those circuit-switched data services were developed as a replacement for analog cellular networks. Specifically, through digital systems, the voice is taken through the handset and passes from an analog to digital converter so that what comes out is a series of bits (bitstream). Additionally, Second Generation technologies introduced services such as SMS (Short Message Services) and MMS (Multimedia Message Services) which are digitally encrypted.

Network Standards

The second generation of mobile communications technologies was developed mainly on four standards, namely, Global System for Mobile Communications (GSM), Interim Standard 136 (IS-136), Code Division Multiple Access – 1 (CDMA-1) or Interim Standard 95 (IS -95), and PDC (Personal Digital Cellular).

1. **GSM:** It is a standard developed by European Telecommunications Standards Institute (ETSI) designed to provide services such as voice mail, text messaging, international roaming, prepaid calling, SMS, etc. The early GSM systems used a 25MHz frequency spectrum in a 900MHz band. This spectrum is then divided into 124 carrier frequencies of 200 KHz each. A single 200 KHz channel was shared between eight users by allocating a unique time slot to each one of them. The cell radius in the GSM network varies depending upon the antenna height, antenna gains, propagation conditions, etc.
2. **CDMA One/IS-95:** It is a wireless interface protocol that was standardized in 1993 which supports up to 64 users that are orthogonally coded and simultaneously transmitted on each 1.25 MHz channel. All users share the same 1,250 kHz wide carrier, but unique digital codes are used to differentiate subscribers. The codes are shared by both the mobile station and the base station and are called "pseudo-random code sequences". Base stations in the system distinguish themselves from each other by transmitting different portions of the code at a given time.

Access Technology

In the second-generation telecom systems, multiple access is achieved by TDMA and CDMA techniques.

Evolved 2G Systems

Due to a demand of high efficiency and capacity in the second-generation networks, some enhancements have been done in the existing network architecture, which came to be known as 2.5G. It provided support for packet-switched data services in addition to circuit switched data service that 2G used to support. The major enhancements in 2.5G are as follows:

- Introduction of **General Packet Radio Service (GPRS)** into the GSM specifications. GPRS provides faster data rates by aggregating several time slots into a single bearer. It takes all eight timeslots from GSM (which is a TDMA system) in a 200 kHz bandwidth giving a theoretical data rate of 8 x14.4=115kbps. In practice though, it supports up to 56kbps and up to 4 timeslots.
- **Enhanced Data Rates for Global Evolution (EDGE)** also known as Enhanced GPRS is digital mobile phone technology that allows improved data transmission rates as a backward-compatible extension of GSM. It is

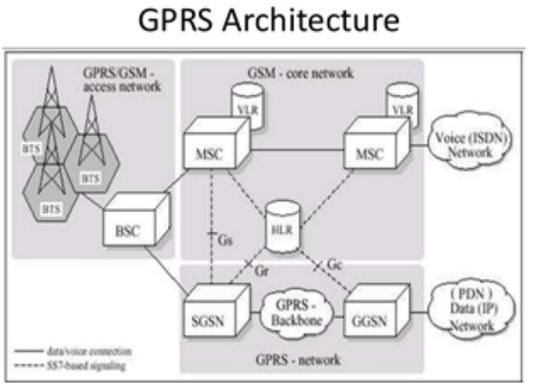


Figure 4: GPRS Architecture

BTS: Base Transceiver Station

BSC: Base Station Controller

MSC: Mobile Switching Centre

VLR: Visitor Location Register

HLR: Home Location Register

SGSN: Serving GPRS Support Node

GGSN: Gateway GPRS Support Node

considered a pre-3G radio technology. It is an evolution of the GPRS radio modulation to higher data rates within the same 200 kHz bandwidth used by GSM and GPRS. It adds the capability of 8- PSK (Phase Shift Keying) modulation to transmit 3bits per waveform (using 1 of 8 phrases) compared to the only 1bit per waveform using GMSK (Gaussian-filtered Minimum Shift Keying) modulation as used in GSM and GPRS.

Third Generation

The ever-growing needs of subscribers and the several technological advances that existed in the early 2000s led the market to the development of the third-generation technology which focused on the improvement of voice services with some data capabilities. Those systems were developed with the aim of offering high-speed data and multimedia connectivity to subscribers. The International Telecommunication Union (ITU) has defined 3G systems as being capable of supporting high-speed data ranges of 144 kbps to greater than 2 Mbps.

Network Standard

The third generation of mobile technologies focused on the improvement of voice services, higher bandwidths and the support of multimedia services which are mainly developed on two technology standards: Universal Mobile Telecommunication System (UMTS) and CDMA-2000.

1. **UMTS:** It is a third-generation successor of second-generationGSM-based cellular technologies including GPRS and EDGE, which is managed by 3GPP (Third Generation Partnership Programme). UMTS is also referred to as WCDMA as it uses Wideband CDMA (W-CDMA) to carry the radio transmissions. It employs a 5 MHz channel bandwidth. Using this bandwidth, it has the capacity to carry over 100 simultaneous voice calls, or it can carry data at speeds up to 2 Mbps in its original format. In FDD, the transmission and reception of signals are achieved simultaneously using two different frequencies. For the FDD scheme to operate satisfactorily there is a guard band between transmission and reception frequencies to enable the receiver not to be unduly affected by the transmitter signal.

   TDD uses only a single frequency for full duplex transmission control that shares the channel between transmission and reception, spacing them apart by multiplexing the two signals on a time basis. It is used with data transmissions (data or digitized voice), transmitting a short burst of data in each direction. As the transmission periods are relatively short no time delay is noticed on voice transmissions resulting from the time delays introduced by using TDD.

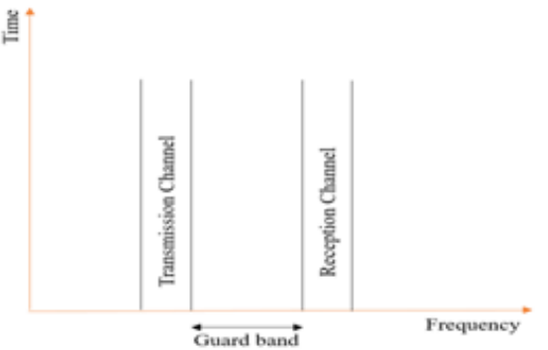


Figure 5: Frequency Division Duplex (FDD)

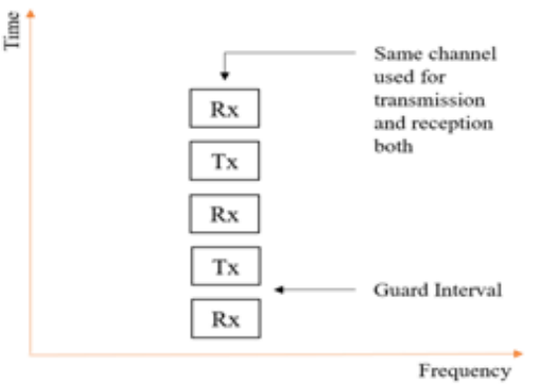


Figure 6: Time Division Duplex (TDD)

2. **CDMA-2000:** It is a third-generation (3G) standard developed by the International Telecommunication Union (ITU). Data communication speeds ranging from 114 Kbps to 2 Mbps are supported by this standard.CDMA-2000 denotes a family of standards that represent the successive revolutionary

stages of the underlying technology, namely, CDMA2000 1x, CDMA2000 1x EV-DO (EVolution Data Optimized), and CDMA2000 1x EV-DV (EVolution Data and Voice).

CDMA2000 1X which is also standardized as IS-2000 supports circuit-switched voice and has the capability to provide up to and sometimes beyond 35 simultaneous calls per sector and as such it doubles the capacity of the original IS-95 networks. It also enables the transmission and reception of data at rates up to 153 kbps in both directions.

CDMA2000 1x EV-DO only carries data, but at speeds up to 3.1Mbps in the forward direction and 1.8 Mbps in the reverse direction, the speed in the reverse link being upgraded as part of Release A of the standard.

Evolved 3G Systems

Due to the convergence of Internet and Wireless Communications, a tremendous growth has been observed in mobile network services. Also, 3G Systems had some limitations related to coverage and access speed, power consumption, the complexity of the system, etc. This led the industry to find ways to update the already existing air interface standards and replace them with improved versions. This was done with the deployment of the updated versions of W-CDMA and CDMA 2000, High-Speed Packet Access (HSPA) and 1xEV-DO.

HSPA (also known as 3.5G) is the evolved version of W-CDMA which consists of two individual technology standards, i.e., High-Speed Downlink Packet Access (HSDPA) and High-Speed Uplink Packet Access (HSUPA).

- **HSDPA:** It is an upgrade to the original 3G UMTS cellular system that provides much greater download speeds for data. Using HSDPA, peak user data rates of 10 Mbps within the 5 MHz channel bandwidth offered under 3G UMTS can be achieved. It improves the overall network packet data capacity, improves the spectral efficiency and enables networks to achieve a lower delivery cost per bit along with higher data speeds as well as shorter service response times and better availability of services to users.
- **HSUPA:** HSUPA is the companion technology to HSDPA, applied to the uplink from the User Equipment (UE) to the NodeB or base station and provides a considerable increase in speed for users in the uplink. It allows peak uplink raw data rates of 5.74 Mbps. To facilitate the improved performance, the Hybrid ARQ (Automatic Repeat reQuest)

COMPARISON BETWEEN 1G, 2G AND 3GBASED ON DIFFERENT PARAMETERS

Technology	1G	2G/2.5G	3G
Start/development	1970/1984	1980/1999	2000/2010
Data Bandwidth	2 Kbps	14.4-64 Kbps	2 Mbps
Standards	AMPS	2G: TDMA, CDMS, GSM 2.5: GPRS, EDGE	WCDMA, CDMA – 2000
Technology	Analog Cellular Technology	Digital Cellular Technology	Broad bandwidth CDMA, IP technology
Service	Mobile Telephony (Voice)	2G; Digital Voice, SMS 2.5G: Higher capacity packetized data	Integrated Higher Quality audio, video and data
Multiplexing	FDMA	TDMA, CDMA	CDMA
Switching	Circuit	2G; Circuit 2.5G: Circuit for access network and air interface: packet for core network and data	Packet except circuit for air interface
Core Network	PSTN	PSTN	Packet network
Handoff	Horizontal	Horizontal	Horizontal
Note	During 1G wireless phones were used for voice only.	2g allowed multiple users to use a single channel via multiplexing. In 2.5G multimedia services and streaming grew. Phones started supporting web browsers.	3G had multimedia services support along with streaming. Universal access and portability across different device types was made possible.

used for HSDPA is also employed for the uplink, HSUPA. To reduce latency, fast packet scheduling has been adopted for the uplink as for the downlink with a slightly different variation.

Conclusion

From early 1970s when 1G was introduced till date, we have come a long way from basic wireline to analog systems to digital technologies. But due to ever increasing demand and expectations of the consumers the telecom sector is trying its best to improve the technologies further and make available a higher data rate to the consumers.

Not only we seek betterment in voice and data communication but we also want to implement projects like Internet of Things. Thus we are in search of better communication technologies. Hence 4G and 5G were introduced. In part 2 of Technology Digest we will take a look at the present and future mobile communication generations.

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Published by: Telecom Regulatory Authority of India
Editorial responsibility: TD Division, TRAI
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