1

Overview of Mobile Networks

1.1 Introduction

Mobile networks are differentiated from each other with the word ‘generation,’ such as ‘first generation,’ ‘second generation,’ etc. This is quite correct because there is a big ‘generation gap’ between the technologies.

The first-generation mobile systems were the analogue (or semi-analogue) systems, which came in the early 1980s, also called NMTs (Nordic Mobile Telephones). They offered mainly speech and related services and were highly incompatible with each other. Thus, their main limitations were the limited amount of services offered and their incompatible nature.

An increase in the necessity for a system that catered to mobile communication needs and also offered increased compatibility with other systems, resulted in the birth of the second-generation mobile systems. International bodies played a key role in evolving a system that would provide better services and was more transparent and compatible with networks globally. But, unfortunately, the second-generation network standards could not fulfil the dream of having just one set of standards for networks globally. The standards in Europe differed from the standards in Japan and that of the Americas and so on. Of all the standards, the GSM went all the way in fulfilling the technical and the commercial expectations.

But, again, none of the standards in the second generation was able to fulfil the globalisation dream of the standardisation bodies. This would be fulfilled by the third-generation mobile systems. Also, it is expected that the third-generation systems will be predominantly data traffic oriented as compared with the second-generation networks that were carrying predominantly voice traffic.

The major standardisation bodies that play an important role in defining the specifications for the mobile technology are:

- ITU (International Telecommunication Union): The ITU with headquarters in Geneva, Switzerland is an international organisation within the United Nations, where governments and the private sector coordinate global telecom networks and services. The ITU-T is one of the three sectors of ITU, which produces the quality standards covering all the fields of telecommunications.
- ETSI (European Telecommunication Standard Institute): This body was primarily responsible for the development of the specifications for the GSM. Due to the technical and commercial success of the GSM, this body will also play an important role in
the development of the third-generation mobile systems. ETSI mainly develops the telecommunication standards throughout Europe and beyond.

- **ARIB (Alliance of Radio Industries and Business):** This body is predominant in the Australasian region and is playing an important role in the development of the third-generation mobile systems. ARIB basically serves as a standards developing organisation for radio technology.

- **ANSI (American National Standard Institute):** ANSI currently provides a forum for over 270 ANSI-accredited standards developers representing approximately 200 distinct organisations in the private and public sectors. This body has been responsible for the standards development for the American networks.

- **3GPP (Third Generation Partnership Project):** This body was created to maintain the complete control of the Specification design and process for the third-generation networks. The result of the 3GPP work is a complete set of specifications that will maintain the global nature of the 3G networks.

- **5GPPP (Fifth Generation Public Private Partnership):** This is driven by the EU (European Commission) and ICT Industry under the EU’s Horizon 2020 initiative. More than 30 members are part of this consortium including Industry bodies, SMEs, research bodies, etc.

### 1.2 Mobile Network Evolution

Mobile network evolution has been categorised into ‘generations’ as shown in Figure 1.1. A brief overview on each generation is given below.

#### 1.2.1 First-generation System (Analogue System)

The first-generation mobile system started in the 1980s was based on analogue transmission techniques. At that time, there was no worldwide (not even Europe-wide) coordination for the development of the technical standards for the system. Nordic counties deployed NMTs, while UK and Ireland went for a Total Access Communication System or TACS, and so on. Roaming was not possible and efficient use of the frequency spectrum was not there.

**Figure 1.1** Evolution of mobile networks.
1.2.2 Second-generation System (Digital System)

By the mid-1980s, the European commission started a series of activities to liberalise the communications sector, including mobile communication. This resulted in the creation of ETSI, which inherited all the standardisation activities in Europe. This saw the birth of the first specifications and the network based on the digital technology; it was called the Global System for Mobile Communication or GSM. Since the first networks at the beginning of 1991, GSM has gradually evolved to meet the requirements of data traffic and many more services than the original networks that were capable of handling mainly voice traffic.

- GSM (Global System for Mobile communication): The main elements of this system are the mobile, BTS (Base Transceiver Station) and BSC (Base Station Controllers) in the BSS (Base Station Subsystem) and the MSC (Mobile Switching Centre), VLR (Visitor Location Register), HLR (Home Location Register), AC (Authentication Centre), EIR (Equipment Identity Register) in the NSS (Network Switching Subsystem). This network can provide all the basic services such as speech and the data services up to 9.6 kbps, e.g. fax, etc. This GSM network also has an extension to the fixed telephony networks.

- GSM and VAS (Value Added Services): The next advancement in the GSM system was the addition of two platforms, the ‘Voice Mail System’ (VMS) and the ‘Short Message Service Centre’ (SMSC). The SMS proved to be incredibly commercially successful so much so that in some networks, the SMS traffic constitutes a major part of the total traffic of the network. Along with the VAS, IN (INtelligent services) also made its mark in the GSM system, with its advantage of giving the operators the chance to create a whole range of new services. Fraud management and ‘pre-paid’ services are the result of the IN service.

- GSM and GPRS (General Packet Radio Services): As the requirement for sending data on the air-interface increased, new elements such as SGSN (Serving GPRS Support Node) and GGSN (Gateway GPRS Support Node) were added to the existing GSM system. These elements made it possible to send the packet data on the air-interface. This part of the network handling the packet data is also called the packet core network. In addition to the SGSN and GGSN, it also contains the IP routers, firewall servers and the DNS (Domain Name Server). This enables wireless access to the Internet and the bit rate reaching to 150 kbps in optimum conditions.

- GSM and EDGE (Enhanced Data rates in GSM Environment): Now that both the voice and data traffic were moving on the system, the need to increase the data rate was felt. This was done by using more sophisticated coding methods over the Internet and thus increasing the data rate up to 384 kbps.

1.2.3 Third-generation Networks (WCDMA in UMTS)

In EDGE, very high movement of the data was possible, but still, the packet transfer on the air-interface behaves like a circuit switch call. Thus, part of this packet connection efficiency is lost in the circuit switch environment. Moreover, the standards for developing the networks till the second generation were different for different parts of the world. Hence, it was decided to have a network that provides services independent of the technology platform and whose network design standards are the same globally.
Thus, 3G was born. In Europe, it was called UMTS (Universal Terrestrial Mobile System), which is ETSI driven. IMT-2000 is the ITU-T name for the third-generation system while cdma2000 is the name of the American 3G variant. WCDMA is the air-interface technology for the UMTS. The main components include BS (Base Station) or Node B, RNC (Radio Network Controller) apart from WMSC (Wideband CDMA Mobile Switching Centre) and SGSN/GGSN. This platform offers many services that are based on the Internet, along with video phoning, imaging, etc.

1.2.4 Fourth-generation Networks (LTE)
Further advancements to mobile networks technology led to LTE or Long Term Evolution – a technology referred to as 4G. First proposed by NTT DoCoMo, the main aim of LTE was to increase the speed and capacity while reducing latency of the mobile networks. The mobile networks become simpler in architecture while moving towards an ALL-IP system. The air-interface used in LTE is OFDM (Orthogonal Frequency Division Multiplexing). Key elements include base stations called eNodeB, and Core elements include MME, P-GW and S-GW.

1.2.5 Fifth-generation Networks
5G or fifth-generation networks will probably be the networks for which technology evolution will occur. The new elements in 5G Radio would be NR or New Radio and a network that will be a truly convergent network that would include 4G LTE, Non-3GPP access technologies, Wi-Fi and core including NFV, SDN, Internet of Things (IoT), Cloud. 5G networks are expected to launch in 2019/2020, connecting billions of devices, a multifold increase in data, a latency as low as 1 ms and data rates as high as 100 Mbps.

1.3 Information Theory

1.3.1 Multiple Access Techniques
The basic concept of multiple access is to permit the transmitting station to transmit to the receiving station without any interference. Sending the carriers separated by frequency, time, and code can achieve this.

1.3.1.1 Frequency Division Multiple Access (FDMA)
This is the most traditional technique in radio communications, relying on the separation of the frequencies between the carriers. All that is required is that all the transmitters should be transmitting on different frequencies and that their modulation does not cause the carrier bandwidths to overlap. There should be as many as possible users that should be utilising the frequencies. This multiple access method is used in the first-generation or the analogue cellular networks. The advantage of the FDMA system is that transmission can be without coordination or synchronisation. The constraint in the FDMA system is the availability of the frequency.
1.3.1.2 Time Division Multiple Access (TDMA)
As the mobile communication moved on from first to second generation, the FDMA was not considered an effective way for frequency utilisation. Thus, to utilise already scarce frequency resources, TDMA was used. Thus, as shown in the Figure 1.2, many users can use the same frequency as each frequency can be divided into small slots of time called time slots, which are generated continuously. Thus, many users can log on to the same frequency.

1.3.1.3 Code Division Multiple Access (CDMA)
By utilising the spread spectrum technique, CDMA combines modulation and multiple access to achieve a certain degree of information efficiency and protection. Initially developed for the military applications, it gradually developed into a system that promised better bandwidth and service quality in an environment of spectral congestion and interference. In this technology, every user is assigned a separate code(s) depending upon the transaction. One user may have several codes in certain conditions. Thus, separation is not based on frequency or time, but on the basis of codes. These codes are nothing but very long sequences of bits having a higher bit rate than the original information. The major advantage of using the CDMA is that there is no plan for frequency re-use, the number of channels is greater, there is optimum utilisation of bandwidth, and the confidentiality of the information is well protected.

1.3.1.4 Orthogonal Frequency Division Multiple Access
FDM or frequency division multiplexing is a technique in which many signals are combined on single communication channels wherein each of these subchannels has a different frequency within the main channel. Due to this multiplexing, a high bandwidth channel that is complex in nature is produced. A demultiplexer at the receiver is used to separate the channels. The subchannel signal transmission is done at maximum speed. Now orthogonality is applied to FDM. Orthogonality signifies that the subcarriers are at 90° with respect to each other. This is possible by assigning the subcarrier frequencies to these channels. The application of orthogonality not only results in reduction of cross-talk between these carriers but also negates the presence of a guard band, while at the same time, higher spectrum efficiency is utilised.

1.3.2 Modulations
1.3.2.1 Gaussian Minimum Phase Shift Keying (GMSK)
GMSK is the modulation method for signals in GSM. This is a special kind of modulation method derived from minimum phase shift keying (MSK). This falls under the
frequency modulation scheme. The main disadvantage of MSK is that it has a relatively wide spectrum of operation, but as in GSM, the frequency is scarce, hence GMSK was chosen to be the modulation method as it utilises the limited frequency resources better. GMSK modulation works with two frequencies and is able to shift easily between the two. The major advantage of GMSK is that it does not contain any amplitude modulation portion and the required bandwidth of the transmission frequency is 200 kHz, which is an acceptable bandwidth by GSM standards. This is the modulation scheme used in GSM and GPRS networks.

1.3.2.2 Octagonal Phase Shift Keying (8-PSK)

The reason behind the enhancement of the data in the 2.5-generation networks such as the GPRS/EGPRS is the introduction of octagonal phase shift keying or 8-PSK. In this scheme, the modulated signal is able to carry three bits per modulated symbol over the radio path as compared with one bit in the GMSK modulated path. But, this increase in data throughput is at the cost of the decrease in the sensitivity of the radio signal. Thereby the highest data rates being provided within a limited coverage. This is the modulation scheme used in the EGPRS/EDGE networks.

1.3.2.3 Quadrature Phase Shift Keying (QPSK)

To demodulate the output of the frequency modulation, phase shift keying or PSK has been used as a preferred modulation scheme. In PSK, the phase of the transmitted waveform is changed instead of its frequency. In PSK, the number of phase changes is two while a step forward is the assumption that the number of phase changes is more than two, i.e. four, which is the case with QPSK. This enables the carrier to carry four bits instead of two, effectively doubling the capacity of the carrier. For this reason, QPSK is the modulation scheme chosen in WCDMA.

1.3.2.4 Quadrature Amplitude Modulation (QAM) and Discrete Fourier Transformation (DFT) in OFDM

QAM and DFT are modulation techniques used in OFDM. In the QAM method, the input data stream is encoded using QAM symbols. A QAM symbol block is inputted in the parallel to serial converter. This result is an in-phase signal. These signals are then transmitted over the radio channel and demultiplexed at the receiver. These QAM signals are filtered and recovered at the receiver using the parallel to serial converter and QAM demodulator. This system requires a narrower bandwidth, i.e. better spectral efficiency than most of the other systems. However, this is not the most spectrally efficient system as there is frequency spillage due to adjacent frequency sub-bands (in subchannels). This leads to the need for some amount of guard band and increased spacing between the sub-bands – leading to lower spectral efficiency. In the DFT modulation, though the fundamental QAM is used, the only difference is the addition of FFT. An inverse FFT is applied to the output of the QAM encoder resulting in complex time domain samples.

1.3.3 OSI Reference Model

The basic idea behind the development of the Open System Interconnection (OSI) Reference Model by the ITU was to separate the various parts that form a
communication system. This was possible by layering and modularisation of the functions that were performed by various layers (parts of the communication system). Although initially developed for communication between the computers, this model is being extensively used in the telecommunication field, especially in mobile communication.

1.3.3.1 Basic Function of the OSI Reference Model
Each layer shown in Figure 1.3 communicates with the layer above or below it. No two layers that lie above each other are dependent. The lower layer does not worry about the content of the information that it is receiving from the layer above. Thus, communication between adjacent layers is direct, while with the other layers it is indirect. Each node has the same reference model. When communicating with the other nodes, each layer can communicate with its counterpart in that node, e.g. physical layer with physical layer, transport layer with transport layer. This means that all the messages are exchanged at the same level/layer between two network elements and this is known as a peer-to-peer protocol. All the data exchange in a mobile network belongs to a peer-to-peer protocol.

1.3.3.2 Seven Layers of OSI Reference Model

1.3.3.2.1 Layer 1: Physical Layer
The physical layer is called so because of its ‘physical’ nature, i.e. it can be copper wire, an optical fibre cable, radio transmission or even a satellite connection. This layer is responsible for the actual transmission of data. This layer transmits the information that it receives from layer 2 without any changes except for the information needed to synchronise with the physical layer of the next node where the information is to be sent.

1.3.3.2.2 Layer 2: Data Link Layer
The function of this layer is to pack the data. The data packaging is based on a high-level data link control protocol. This layer combines the data into packets or frames and sends it to layer 1 or the physical layer for transmission. Layer 2 does the error detection and correction and forms an important part in the protocol testing as the information from layer 3 (data packet format) is sent to layer 2 to be framed into packets that can be transferred over layer 1.
1.3.3.2.3 Layer 3: Network Layer
This layer is responsible for giving all the information related to the path that a data packet has to take and the final destination it has to reach. Thus, this layer gives the routing information for the data packets.

1.3.3.2.4 Layer 4: Transport Layer
This layer is a boundary between the physical elements and logical elements in a network and provides a communication service to the higher layers. This layer checks the consistency of the message by performing end-to-end data control. This layer can perform error detection (but no error correction); it can cater for the reduced flow rate to enable retransmission of data. Thus, layer 4 provides flow control, error detection and multiplexing of the several transport connections on one network connection.

1.3.3.2.5 Layer 5: Session Layer
This layer enables synchronisation between two applications. Both nodes use layer 5, for coordination of the communication between them. This means that it does the application identification but not the management of the application.

1.3.3.2.6 Layer 6: Presentation Layer
This layer basically defines and prepares the data before it is sent to the application layer. This layer presents the data to both sides of the network in the same way. This layer is capable of identifying the type of the data and changes the length by compression or decompression depending upon the need, before sending it to the application layer.

1.3.3.2.7 Layer 7: Application Layer
The application layer itself does not contain any application but acts as an interface between the communication process (layers 1–6) and the application itself. Layer 1 is medium dependent while layer 7 is application dependent.

1.4 Second-generation Mobile Network

Of all the second-generation mobile systems, the Global System for Mobile communication or GSM is the most widely used. In this section we will briefly go through the important constituents of this system. The GSM system is divided into three major parts as shown in Figure 1.4: Base Station Subsystem or BSS, Network Subsystem or NSS and Network Management System or NMS.

1.4.1 Base Station Subsystem (BSS)
The BSS consists of the Base Transceiver Station or BTS, Base Station Controller or BSC and Transcoder Sub-Multiplexer (TCSM). The TCSM is sometimes physically located at the MSC, hence the BSC also has three standardised interfaces to the fixed network, namely A_{bis}, A and X.25.
1.4.1.1 **Base Transceiver Station (BTS)**
This manages the interface between the network and the mobile station. Hence, it performs the important function of acting as a hub for the whole of the network infrastructure. Mobile terminals are linked to the BTS through the air-interface. Transmission and reception at the BTS with the mobile is done via omnidirectional or directional antennas (usually having 120° sectors). The major functions of the base station are transmission of signals in the desired format, coding and decoding of the signals, countering the effects of multi-path transmission by using equalisation algorithms, encryption of the data streams, measurements of quality and received signal power, and operation and management of the base station equipment itself, etc.

1.4.1.2 **Base Station Controller (BSC)**
This controls the radio subsystem, especially the base stations. The major functions of the base station include the management functions of the radio resources and handover. It is also responsible for the control of the power transmitted. It manages the O&M and its signalling, security configurations and alarms.

1.4.2 **Network Subsystem (NSS)**
The NSS acts as an interface between the GSM network and the public networks PSTN/ISDN. The main components of the NSS are MSC, HLR, VLR, AUC, and EIR.

1.4.2.1 **Mobile Switching Centre (MSC)**
MSC or Switch as it is generally called, is the single most important element of the NSS as it is responsible for the switching functions that are necessary for the interconnection between the mobile users and that of mobile and the fixed network users. For this purpose, MSC makes use of the three major components of the NSS, i.e. HLR, VLR, and AUC.

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**Figure 1.4** GSM architecture.
1.4.2.2 Home Location Register (HLR)
HLR contains the information related to each mobile subscriber. Each subscriber mobile has some information that contains data such as the kind of subscription, services that the user can use, the subscriber’s current location, and the mobile equipment status. The database in the HLR remains intact and unchanged until the termination of the subscription.

1.4.2.3 Visitor Location Register (VLR)
VLR comes into action once the subscriber enters the coverage region. Unlike the HLR, VLR is dynamic in nature and interacts with the HLR when re-coding the data of a particular mobile subscriber. When the subscriber moves to another region, the database of the subscriber is also shifted to the VLR of the new region.

1.4.2.4 Authentication Centre (AUC)
The AUC or AC is responsible for policing actions in network. This has all the data that is required to protect the network against false subscribers and to protect the calls of regular subscribers. There are two major keys in the GSM standards, one is the encryption of the mobile users and other is the authentication of the mobile users. The encryption keys are held both in the mobile equipment and the AUC and the information is protected against unauthorised access.

1.4.2.5 Equipment Identity Register (EIR)
Each item of mobile equipment has its own personal identification, which is denoted by a number called the International Mobile Equipment Identity (IMEI). The number is installed during the manufacture of the equipment itself stating conformation to the GSM standards. Thus, whenever a call is made, the network would check the identity number and if this number is not found on the approved list of the authorised equipment, access is denied. The EIR contains this list of the authorised numbers and allows the IMEI to be verified.

1.4.3 Network Management System (NMS)
The main task of the NMS is to ensure that the running of the network is smooth. For this purpose, it has four major tasks to perform: network monitoring, network development, network measurements, and fault management. Once the network is up and running, the NMS takes over the responsibility of monitoring the performance of the network. If it sees some faults, it would generate the relevant alarms. Some of the faults may be corrected through the NMS itself (mostly software oriented) while for others, site visits would be required. NMS is also responsible for the collection of data and the analysis of its performance, thereby leading to accurate decisions related to the optimisation of the network. The capacity and the configuration of the NMS are dependent upon the size (both in terms of capacity and geographical area) and the technological needs of the network.

1.4.4 Interfaces and Signalling in GSM
As can be seen from Figure 1.4, there are some interfaces and signalling involved in the GSM system. Here, we will briefly discuss interfaces and some signalling.
1.4.4.1 Interfaces
1.4.4.1.1 Air Interface

The air interface is the central interface and most important interface in every mobile system. The importance of this interface arises from the fact that this is the only interface that the mobile subscriber is exposed to and that the quality of this interface is a critical factor for the success of the mobile network. The quality of this air interface primarily depends upon the efficient usage of the frequency spectrum that is assigned to it.

In the FDMA system, one specific frequency is allocated to one user engaged in a call. When there are numerous calls, the network tends to get overloaded leading to failure of the system. In a full rate (FR) system, 8 time slots (TSs) are mapped on every frequency while in the half rate (HR) system, 16 TSs are mapped on every frequency. In the TDMA system, only impulse-like signals are sent periodically, unlike the FDMA system where signals are assigned permanently. Thus, by combining the advantages of both techniques, TDMA allows seven other channels to be served on the same frequency (FR). GSM uses the GMSK modulation technique.

For the FR system:
Every impulse on frequency is called a burst. Every burst corresponds to a TS.

1 TDMA frame = 8 bursts
Uplink frequency band = 890–915 MHz
Downlink frequency band = 935–960 MHz

Frequency division multiplexing divides each of the frequency ranges into 124 channels of 200 kHz width. Since this is required for both transmission and reception, 124 duplex communication channels are produced.

Now, channel bit rate = $D$ per unit time.
As one TDMA frame has 8 bursts, hence each burst has a bit rate $d = D/8$.
This means that each TS is of 577 $\mu$s duration. Thus, one frame has a duration of 4.615 ms.

There are many kinds of frames in the air-interface such as Multiframe, Superframe, and Hyperframes as shown in Table 1.1. Each frame has a duration of 577 $\mu$s and carries a communication channel in which a message element called a packet is transmitted periodically.

The physical channel of the TDMA frames carry logical channels that transport user data and signalling information. Thus, there are traffic channels and signalling channels in the TDMA frame. The traffic channels (TCH) either transmit data or voice signal and can be HR or FR. HR provides a bit rate for coded speech of 6.5 kbps and FR has double

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<th>Table 1.1</th>
<th>GSM frame hierarchy.</th>
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<td>Multiframe$_{(51)}$ = 51 TDMA frames</td>
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<tr>
<td>Multiframe$_{(26)}$ = 26 TDMA frames</td>
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<tr>
<td>Superframe$_{(51)}$ = 51 multiframes</td>
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<tr>
<td>Superframe$_{(26)}$ = 26 multiframes</td>
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<tr>
<td>Hyperframe = 2048 superframes</td>
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capacity, i.e. 13 kbps. The signalling channels may contain information such as broadcast channels (e.g. BCCH, SCH, FCH); common control channels (e.g. AGCH, PCH, RACH); dedicated channels (e.g. DCCH, SDCCH); and associated channels (e.g. FACCH, SACCH, SDCCH).

1.4.4.1.2 A_{bis} Interface
The A_{bis} interface is the interface between the BTS and the BSC. It is a PCM interface, i.e. defined by the 2 Mbps PCM link. Thus, it has a transmission rate of 2.048 Mbps, having 32 channels of 64 kbps each. As the traffic channel is 13 kbps on the air-interface, while A_{bis} is 64 kbps, hence multiplexing and transcoding do conversion from 64 kbps on the A_{bis} interface to 13 kbps on the air-interface. Four channels are multiplexed into one PCM channel while traffic channels are transcoded up to 64 kbps. TCSMs are usually located at the MSC to save the transmission costs but can also be located at the BSC site. LAPD signalling along with the TRX management (TRXM), common channel management (CCM), radio link management (RLM), and dedicated channel management (DCM) form a part of this interface.

1.4.4.1.3 A Interface
The A interface is present between the TCSM and MSC or physically between the MSC and BSC (generally, TCSMs are physically located at the MSC). This interface consists of one or more PCM links each having a capacity of 2048 Mbps. There are two parts of the A interface: one from the BTS to the TRAU where the transmitted payload is compressed; and the other between the TRAU and MSC where all the data is uncompressed. The TRAU is typically located between the MSC and BSC and should be taken into consideration when dealing with this interface. SS7 signalling is present on the A interface.

1.4.4.2 Signalling
1.4.4.2.1 LAPD_{m}
This stands for ‘modified Link Access Protocol for D-Channel’. This is a modified and optimised version of the LAPD signalling for the GSM air-interface. The frame structure consists of 23 bytes and is present in three formats A-, B- and A_{bis}. Both the A- and B-formats are used for both the uplink and downlink, while the A_{bis} is only used for the downlink.

1.4.4.2.2 SS7
This provides the basis of all the signalling traffic on all of the NSS interfaces. SS7 or Signalling system No. 7 is a signalling standard developed by the ITU. This provides the protocols by which the network elements in the mobile (and telephone) networks can exchange information. It is used between the BSC and MSC. It is capable of managing the signalling information in complex networks. It is used for call set up and call management, features such as roaming, authentication, call forwarding, etc. It is not allocated permanently and is required only for the call set up and call release function. It is also known as Common Channel Signalling No. 7 or CCS#7.

1.4.4.2.3 X.25
This links the BSC to the O&M centre. It is an ITU-developed signalling protocol, allowing communication between remote devices. This is a packet switched data
network protocol that allows both data and control information flow between the host and the network. By utilising connection-oriented services, it makes sure that the packets are transferred in order.

1.5 Third-generation Mobile Networks

Third-generation mobile networks are designed for multimedia communication, thereby enhancing image and video quality, and increasing data rates within public and private networks. In the standardisation forums, WCDMA technology emerged as the most widely adopted third-generation air-interface. The specification was created by the 3GPP and the name WCDMA is widely used for both the FDD and TDD operations. 3G networks consist of two major parts: the Radio Access Network (RAN); and the Core Network (CN), as shown in Figure 1.5. RAN consists of both the radio and transmission parts.

1.5.1 Radio Access Network (RAN)

The main network elements in this part of the network are the base station (BS) and the radio network controller (RNC). The major functions include management of the radio resources and telecommunication management.

1.5.1.1 Base Station (BS)

The BS in 3G is also known as Node B. The BS is an important entity as an interface between the network and the WCDMA air-interface. As in second-generation networks, transmission and reception of the signals from the BS is done through omnidirectional or directional antennas. The main functions of the BS include channel coding, interleaving, rate adaptation, spreading, etc., along with the processing of the air-interface.

Figure 1.5 Third-generation system (WCDMA).
1.5.1.2 Radio Network Controller (RNC)
This acts as an interface between the BS and the CN. RNC is responsible for control of the radio resources. And, unlike in GSM, the RNC in conjunction with the BS would be able to handle all the radio resource functions without the involvement of the CN. The major functions of the RNC involve load and congestion control of the cells, admission control and code allocation, routing of the data between the Iub and Iur interfaces, etc.

1.5.2 Core Network (CN)
The CN in 3G networks, consist of two domains: a circuit switched (CS) domain; and a packet switched (PS) domain. The CS part handles the real-time traffic and the PS part handles the non-real-time traffic. Both these domains are connected to the other networks, e.g. CS to the PSTN and PS to the public IP network. The protocol design of the UE and UTRAN is based on the new WCDMA technology but the CN definitions have been adopted from the GSM specifications. Major elements of the CN are WMSC/VLR, HLR, MGW (Media Gateway) on the CS side and SGSN (Serving GPRS Support Node) and GGSN (Gateway GPRS Support Node) on the PS side.

1.5.2.1 WCDMA Mobile Switching Centre (WMSC) and VLR (Visitor Location Register)
The switch and database are responsible for call control activities. WMSC is used for the CS transactions and the VLR function holds information on the subscriber visiting the region, which includes the mobile’s location within the region.

1.5.2.2 Gateway Mobile Switching Centre (GMSC)
This is the interface between the mobile network and the external CS networks. This establishes the call connections that are coming in and going out of the network. It also finds the correct WMSC/VLR for the call path connection.

1.5.2.3 Home Location Register (HLR)
This is the database that contains all the information related to the mobile user and the kind of services subscribed to. A new database entry is done when a new user is added to the system and this entry is kept until the user is subscribed to the network. It also stores the UE location in the system.

1.5.2.4 Serving GPRS Support Node (SGSN)
The SGSN maintains an interface between the RAN and the PS domain of the network. This is mainly responsible for mobility management issues like the registration and update of the UE, paging related activities, and security issues for the PS network.

1.5.2.5 Gateway GPRS Support Node (GGSN)
This acts as an interface between the 3G network and the external PS networks. Its functions are similar to the GMSC in the CS domain of CN, but for the PS domain.

1.5.2.6 Network Management System in 3G Networks
As the network technology evolved from 2G to 3G, so did the network management systems. The NMS in 3G systems will be capable of managing packet switched data...
also, as against voice and circuit switched data in 2G systems. The management systems in 3G would be more efficient, i.e. more work would be possible from the NMS rather than visiting the sites. These systems would be able to optimise and improve the system quality in a more efficient way. The management systems are also expected to handle both the multi-technology, i.e. 2G to 3G, and multi-vendor environments.

1.5.3 Interfaces and Signalling in 3G Networks

As seen from Figure 1.5, there are some interfaces and signalling involved in 3G systems. Here, we will briefly discuss interfaces and some signalling.

1.5.3.1 Interfaces
1.5.3.1.1 Uu/WCDMA Air-Interface

Uu or the WCDMA air-interface is the most important interface in 3G networks. The Uu interface works on WCDMA principles wherein all the users are assigned one code, which varies with the transaction. As shown in Figure 1.2, each user uses a separate spreading code. Unlike with GSM, here every user uses the same frequency band. There are three variants of the CDMA, which are direct sequence WCDMA frequency division duplex (DS-WCDMA-FDD), direct sequence WCDMA time division duplex (DS-WCDMA-TDD), and multi-carrier WCDMA (MC-WCDMA). In the initial phase of the WCDMA network rollouts, the FDD variant would be used. Initially, ‘wideband’ was introduced because the Euro-Japanese CDMA version used a wider bandwidth than the American version of CDMA.

1.5.3.1.2 Frequency Bands in WCDMA-FDD

The air-interface transmission directions are separated at different frequencies and a duplex distance of 190 MHz (Figure 1.6). The uplink frequency band is 1920–1980 MHz and the downlink is from 2110 to 2170 MHz. There are several bandwidths defined for
the WCDMA system, e.g. 5, 10 and 20 MHz. However, 5 MHz is the one that is currently being used in network development. Though the bandwidth is 5 MHz, the effective bandwidth would be 3.84 MHz, as the guard band would take in 0.6 MHz from either side (i.e. 1.2 MHz in total makes up the guard band).

1.5.3.1.3 Iub Interface
This is the interface that connects the BS to the RNC. This is standardised as an open interface unlike in the GSM where the interface between the BTS and BSC was not an open one. This consists of common signalling links and traffic termination points. Each of these traffic termination points is controlled by dedicated signalling links. One traffic termination point is capable of controlling more than one cell. Iub interface signalling consists of a Node B Application Part (NBAP), which has two important constituents, i.e. a Common NBAP (C-NBAP) and Dedicated NBAP (D-NBAP), which are used for common and dedicated signalling links, respectively.

1.5.3.1.4 Iur Interface
This is a unique interface in WCDMA networks. Iur is an interface between the RNC and RNC. There was no such interface in the GSM network, i.e. between the BSC and BSC. This interface was designed for supporting the inter-RNC soft-handover functionality. This interface also supports the mobility between the RNC, both the common and dedicated channel traffic and resource management (e.g. transfer of the cell measurements between the cells). The signalling protocol used for this interface is the Radio Network Subsystem Application Part (RNSAP).

1.5.3.1.5 Iu Interface
This interface connects the RAN to the CN. It is an open interface and handles the switching, routing and control functions for both the CS and PS traffic. Thus, the interface that connects the RAN to the CS part of the CN is called the Iu-cs interface while the one that connects the RAN to the PS part of the CN is called the Iu-ps interface.

1.5.3.2 Signalling
The signalling in the third-generation’s WCDMA networks is in three planes: the transport plane; the control plane; and the user plane. This is because the 3G network is understood in three layers that contain data flows. These three layers are transport, control and user plane layers as shown in Figure 1.7.

The transport plane is a means to provide connection between a UE and network (i.e. air-interface). It contains three layers: physical; data; and network. The physical layer is the WCDMA layer (TDD/FDD), while the data layer is responsible for setting-up/maintaining/deleting the radio link, protection, error corrections, etc. The data layer also controls the physical layer. The network layer basically contains functions that are required for the transport control plane. The control plane contains signalling related to the services that are handled by the network. The Iub interface is maintained by NBAP; in the Iu interface it is RNAPA while in Iur it is RNSAP. For signalling between the application and the destination on the physical layer, user plane signalling is utilised, e.g. on the Uu interface it is DPDCH.
1.6 Fourth-generation Mobile Networks

The fourth-generation or 4G networks are the next generation networks beyond 3G, promising a data rate of 100 Mbps. This fully IP-based integrated system technology provides a comprehensive IP solution where users can experience voice, data, and multimedia – anytime and anywhere. Long Term Evolution or LTE is the most famous 4G technology and is based on 3GPP Release 8 (December 2008). So, what is the fundamental motivation behind the development of 4G technology? The motivation is the need for higher rates beyond that of HSPA, high QoS and low latency. To achieve this, the LTE system is a whole packet switch system that has low complexity (even in architecture) that provides higher QoS and data rates. The network has Access Network and the Evolved Packet System (EPS). EPS is a pure IP-based system with Internet Protocol that will carry both real time services and data. The air-interface technology used in LTE is. The architecture in LTE as shown in Figure 1.8 is quite simplified with Access Network consisting of BSs called eNodeB and a CN consisting of EPS.

1.6.1 Access Network

The Access Network consists of Evolved UMTS Terrestrial Radio Access Network (E-UTRAN). E-UTRAN performs functions such as: connection mobility control, radio resource management, dynamic resource controller, radio bearer control, eNodeB measurement configuration and provisioning. There are two interfaces to E-UTRAN – one towards the other BS called X2 and the other towards EPC called S1.

1.6.1.1 eNodeB

Evolved NodeB or eNodeB is the enhanced base station based on 3GPP standards, providing the RRM and LTE air-interface for the Access Network. Each eNodeB that controls the UEs in one or more cells is called the serving eNodeB. There are two
fundamental functions performed by eNodeB – performing the low-level operations of UEs connected to it (e.g. handover) and sending the radio transmissions to all UEs connected to it.

1.6.2 Evolved Packet Core Network

The evolved packet core has a few network elements. The key ones discussed include the Mobility Management Entity (MME), Serving Gateway (S-GW), Packet data network gateway (P-GW) and Home Subscriber Server (HSS).

1.6.2.1 Mobility Management Entity (MME)

The MME is the entity that interfaces with the access network. Key functions include load sharing, MME pooling, paging, bearer activations/deactivations, congestion management, etc. On the EPC side, it is responsible for attaching the UE to the S-GW. Both the signalling and control plane functioning are functions handled by the MME. The interaction between the LTE and 2G/3G network also happens through the MME.

1.6.2.2 Serving Gateway (S-GW)

The S-GW connects the data between eNodeB and the P-GW. It also supports the handovers between eNodeBs and also between LTE and 2G/3G technologies.

1.6.2.3 Packet Data Network Gateway (P-GW)

The P-GW’s main function is connecting the UE to the external packet data networks using the SGi interface. This is similar to GGSN in the EPGRS networks. Multiple Packet Data Networks (PDNs) can be accesses by the one UE using connectivity to multiple PDNs.

1.6.2.4 Home Subscriber Server (HSS)

The HSS is similar to ones used in GSM and UMTS networks. It is a central database that has information – both user related and subscription related – about the network operator’s subscribers.
1.6.3 Interfaces and Signalling

Though there are few interfaces in the LTE network, we will discuss the two most visible interfaces: X2 and S1.

1.6.3.1 X2

This is the interface between two eNodeBs. There are two components of the X2 interface: X2-UP and X2-CP, for user plane and control plane, respectively. X2-UP tunnels the packets between eNodeBs using the tunnelling protocol, GTP-U (over UDP or IP). In the case of X2-CP, the transport layer is defined between the two eNodeBs using the SCTP interface over the IP. Some of the functions performed by X2-CP include general management, error handling, intra-LTE mobility support, handover cancellation, etc.

1.6.3.2 S1

This is the interface between E-UTRAN and MME. As usual, there are two components: user plane and control plane, i.e. S1-UP and S1-CP. S1-UP is responsible for transferring the data packets (non-guaranteed delivery) between the eNodeB and S-GW. As in the case of X1, the transport network player is built on IP transport and GTP-U. S1-CP is responsible for controlling many UEs through the SCTP or Stream Control Transmission Protocol. It is also responsible for the handover signalling procedure, paging procedure, etc.

1.7 Fifth-generation Networks

Also called 5G networks, these are designed and are currently in the process of being standardised. Till 4G, we were talking about the technology, but in 5G we speak about a networked society. Almost in all of the technologies – from 1G to 4G, the lead was in Europe, but for the first time, we will see 5G expected to be launched in Asia (e.g. in Korea and Japan). Some of the key attributes of the 5G network will be:

- Data rates: 1–10 Gbps
- Latency: 1–10 ms
- Reliability: 99.99%
- Operating frequency range: apart from regular frequency in the sub-GHz range, it will also operate in the range of 6–100 GHz

As mentioned before, in a few years from now, there will be a fully networked society – 5G along with IoT and Cloud are key elements that will make it happen. To reach this stage, there are a few challenges associated with the 5G technology: apart from catering to data rates and latency, the other key challenges are to be able to cater to 1000 times higher data, a 100 times higher number of connected devices, 10 times less energy consumption and, of course, higher battery life up to 10 years. The devices in the 5G networks will not just be UEs but also sensors and other devices that will support making a totally networked society.

LTE will have advancements in technology leading to LTE-evolved and later on to full 5G networks. Fully evolved 5G networks are expected to be up and running by 2020. As shown in Figure 1.9, New Radio technology called NR (as defined in 3GPP) will be the
hallmark of the 5G radio network. These networks will be compatible with the legacy mobile and PSTN network apart from Wi-Fi. Also, M2M (and later IoT), Cloud, applications, transport networks will be an integral part of the ecosystem.

1.8 Supporting Technologies

As we move into advanced technology environments, it is good to know about some of the technologies both in wired and wireless domains that would help network planning engineers in their understanding of networks.

1.8.1 ADSL2+

Digital Subscriber Line or DSL is a common technology used for bringing broadband to homes. Various types of DSL include SDSL, ADSL, and ADSL2+. SDSL and ADSL are symmetric and asymmetric digital subscriber lines, respectively – the major difference being that the bandwidth can be allocated to the user in ADSL. In the former, both the upload and download speed is the same while in latter the speeds are different (or asymmetric); the download speed is higher than upload in ADSL. The major advantage that ADSL has is the ability to have the DSL and a telephone unit on the same two wires and they can be used simultaneously. This is because ADSL does not take up the entire bandwidth. SDSL uses the whole bandwidth and leaves no room for a telephone unit. The bandwidth for the telephone is allocated to the upload speed and explains the much higher bandwidth despite using the same two wires. ADSL is standardised technology. If the number of downstream channels is doubled, it becomes ADSL2+, leading to data transport.
rates as high as 24 Mbps downstream and up to 1.4 Mbps upstream (depending on the distance from the digital subscriber line access multiplexer or DSLAM to the customer premises). ITU G.992.5 defines the standard for ADSL2+.

1.8.2 VDSL2

Very-high-bit-rate DSL is a DSL technology that provides faster data transmission than ADSL. The data transmission rates go up to 52 Mbps downstream and 16 Mbps upstream in twisted cable and up to 85 Mbps upstream and downstream in coaxial cables. This is based on recommendation ITU-T G.993.1. VDSL2 can offer data rates up to 100 Mbps in both uplink and downlink directions. ITU-T G.993.2 is the standard for VDSL2. It has enabled operators and carriers to upgrade the xDSL infrastructure in a way to deploy triple play – voice, data and high-definition TV.

1.8.3 FTTN

FTTN or Fibre to the Node takes fibre optic cables into neighbourhoods. The end user is then connected to this node through the coaxial cable or twisted pair wiring. This permits the user to have access to high speed internet by the usage of protocols such as DOCSIS (Data Over Cable Services Interface Specifications) and data rates varying with the type of protocol used and the distance from the cabinet. Cross talk is the most effective means to reduce the speed of the network. Vectoring is a technique based on the noise cancellation on a ADSL/VDSL line resulting in significant increase in the speeds attainable on such networks. The speed can be doubled in short lines while diminishing speed in longer lines where cross talk is weaker anyway. Vectoring technology measures and cancels interference across hundreds of lines over the full frequency spectrum they occupy. The interference is processed by subdividing the spectrum into narrow frequency bands, known as tones, and processing each tone independently. All copper lines deploying vectoring technology are processed simultaneously and the results are used in real time to develop antiphase compensation signals for each line, based on the actual signals transmitted on other lines in the bundle.

In FTTN, data is sent over the FTTN and then to the home over vector VDSL2 lines. The only requirement is that all the lines should be under the control of a single operator – no sub local loop unbundling. Cross talk elimination is not possible if lines belong to multiple operators and terminate on different nodes.

1.8.4 V+

Some key features of V+ include delivering speeds of more than 200 Mbps and up to 500 m. It also extends the frequency range used by VDSL2 17a to 35 MHz to achieve these higher speeds. V+ can be mixed with existing VDSL2 17a deployments to fill the gap between VDSL2 17a vectoring (100 Mbps aggregate at 700 m) and G.fast (500 Mbps+ aggregate at 100 m). It offers longer reach (higher bit rates beyond 250 m) and higher density (100–200 subscribers).
1.8.5 GPON

Passive Optical Network or PON is a technology where point to multipoint architecture is implemented by using the unpowered fibre splitters to enable single optical fibres to serve multiple end point customers without providing individual fibres between the hub and customer. It works on wavelength division multiplexing (WDM), using one wavelength for upstream and one for downstream traffic on a single mode fibre. GPON or Gigabit Passive Optical Network is an enhancement of APON/ BPON supporting higher rates, enhanced security, and choice of layer 2 protocol (ATM, GEM, Ethernet).

1.8.6 GEPON

This is another standard of PON, known as Gigabit Ethernet Passive Optical Network or GEPON. Also called Ethernet PON, it uses Ethernet to send data. It uses 1 Gbps upstream and downstream data rates. BPON is based on ATM, GPON uses native Ethernet and GEPON supports ATM, Ethernet and WDM using a superset multi-protocol layer. A couple of other differences between GPON and GEPON are operational speed (1 Gbps asymmetrical in GPON vs. 2.5 Gbps symmetrical in GEPON) and protocol support for transport of data packets. GEPON is highly flexible and scalable. A broadcast method is used in the downstream and a TDMA (Time Division Multiple Access) protocol is used in the upstream.

1.8.7 G.Fast

The G.Fast acronym comes from Fast access to subscriber terminals with the G coming from the G series of ITU recommendations. It is a DSL standard for local loops smaller than 500 m. The technology uses time division duplexing unlike ADSL and VDSL that use frequency division duplexing. The main limitation in the system performance is due to the cross-talk phenomenon thereby making vectoring mandatory in the G.Fast systems. The latest developments make it possible to deliver 100 Mbps using G.Fast.

1.8.8 XG-PON1

Due to ever increasing demand on GPON, with requirements leading to higher line rates, optical extensions, and affordable migration conditions, the next generation GPON called XG-PON was developed. XG-PON, a 10Gb capable passive optical network is based on ITU-T G.987. Asymmetric XG-PON is called XG-PON1 (10 Gbps upstream and 2.5 Gbps downstream) while symmetric XG-PON is called XG-PON2 (10 Gbps upstream). It uses TDMA in uplink and TDM in downlink as multiplexing schemes. However, the network operator needs to make significant investments to deploy XG-PON. (Note, the X in XG stands for the Roman numeral 10.)

1.8.9 XGS-PON

XGS-PON is the next generation development of PON with similarity to XG-PON but it is symmetrical in nature. The standard at the ITU aims to match GPON capacity for residential services and to add 6 Gbps of symmetrical capacity for new services. It is expected to have 10 Gbps in downstream and 10 Gbps in upstream directions.
1.8.10 NGPON2

Considering XG-PON where the capacity of the system increases fourfold (2.5–10 Gbps) versus investments needed, the solution, NGPON2 (Next Generation PON2), is actually relatively simple. The technology uses the time and wavelength division multiplexing technique and makes multiple NGPON1 systems work together. It provides a capacity of from 40 to 80 Gbps in downstream and 10–20 Gbps in upstream directions. It can coexist with the GPON and XG-PON1 systems.

1.8.11 NB-IoT

This is a Low Power Wide Area (LPWA) technology that is being developed for the IoT – to provide connectivity to devices in indoor locations in 3GPP release 13. This is not based on LTE but DSSS (Direct Sequence Spread Spectrum) modulations. Apart from coverage, the technology also focuses on long battery life, and a high number of devices connected in a small area. The standards for this are being developed. Some key applications are: smart metering, smart cities, in-building automation, etc. One negative aspect of NB-IoT is that it is difficult to deploy as it is not a part of LTE. Hence, it would need a side band using different software leading to an increase in cost or deployment will happen in a deprecated GSP spectrum.

1.8.12 LTE eMTC

eMTC stands for Enhanced Machine Type Communications. LTE eMTC is also known as LTE-M. MTC work started in 3GPP from release nine onwards, but significant progress was made in releases 12 and 13. LTE-M is more energy efficient because of its extended discontinuous repetition cycle (DRX). LTE-PSM from release 12 (power-saving mode) had a similar feature, but extended DRX was created specifically for LTE-M in release 13. A software upgrade to the LTE network and it is ready for MTC without any investment in antennas or other hardware. The data rates are higher than NB-IoT. Applications include wearables, energy management, utility, etc.

1.8.13 RFID

Radio frequency identification (RFID) refers to small electronic devices that contain a chip and antenna. The chip is capable of carrying 2 kB of data. This helps in providing unique identification for the object. The antenna enables the chips to transmit the information to the reader. The reader converts the information from the antenna signal into digital information and passes it on to computers for use. RFID systems use many different frequencies, but generally the most common are low frequency (around 125 kHz), high frequency (13.56 MHz) and ultra-high frequency or UHF (850–900 MHz). Microwave (2.45 GHz) is also used in some applications.

1.8.14 NFC

NFC is a short-range high frequency wireless communication technology that enables the exchange of data between devices over a distance of about 10 cm. NFC can be
considered a development of RFID. This operates at a frequency of 13.56 MHz. The standards and protocols of the NFC format are based on RFID standards outlined in ISO/IEC 14443, FeliCa, and the basis for parts of ISO/IEC 18092.

1.8.15 ZigBee

ZigBee is a wireless technology developed as an open global standard to address the unique needs of low-cost, low-power wireless M2M networks. The ZigBee standard operates on the IEEE 802.15.4 physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz. Sometimes, there is confusion between Bluetooth, Wi-Fi and ZigBee – both Bluetooth and Wi-Fi have been developed for the communication of large amounts of data with complex structures such as media files, software, etc. However, ZigBee has been developed looking into the needs of the communication of data with simple structures such as the data from sensors. The ZigBee protocol supports longer battery life, low latency, DSSS, approximately 65,000 nodes network apart from supporting multiple technologies (P2P, PMP, etc.).

1.8.16 Z-Wave

Z-Wave is a protocol used to communicate between devices that are used for home automation. Z-Wave is designed to provide reliable, low-latency transmission of small data packets at data rates up to 100 kb s⁻¹. The throughput is 40 kb s⁻¹ which is suitable for control and sensor applications with a communication distance of around 30 m. Communication between devices is possible even if they are not in line of sight with each other. Z-Wave is based on a proprietary design and a sole chip vendor.

1.8.17 LoRa

LoRa stands for Long Range Wide Area Networks. It targets key requirements in the IoT such as secure bidirectional communication, mobility and localisation services. This standard will provide seamless interoperability among smart things without the need for complex local installations and returns freedom to the user, developer, businesses enabling the roll out of the IoT. The communication between the end devices and gateways is spread out on different frequency channels and data rates. Data rates range from 0.3 to 50 kbs. The range is in the order of 15–20 km connecting millions of nodes with battery life of more than 10 years. In order to develop and promote the LoRa wireless system across the industry, the LoRa Alliance was set up.

1.8.18 SigFox

SigFox is a Low Power Wide Area Network. It is an operated network for the IoT. It is applicable for small messages and not for high bandwidth usage. The SigFox network operates on sub-GHz frequencies, on ISM bands: 868 MHz in Europe/ETSI and 902 MHz in the US/FCC. It uses an Ultra-Narrow Band (UNB) modulation, and with a 162 dB budget link SigFox enables long range communications, with much longer reach than GSM. The SigFox radio link uses unlicensed ISM radio bands. The exact
frequencies can vary according to national regulations, but in Europe the 868 MHz band is widely used while in the US, 915 MHz is used. Some key characteristics of SigFox are: 140 messages per object in a day, with a payload size for each message of 12 bytes. The wireless throughput is up to 100 bps.

1.8.19 Li-Fi

Li-Fi or Light Fidelity is visible light communication. As the name suggests, it is based on light communication (coming from Optical Wireless Communications). It uses visible light, infrared, and the near violet spectrum. Practically it uses common LEDs for data transfer (and photodetectors for data reception) that can reach to more than 200 Gbps. Unlike Wi-Fi, Li-Fi cannot pass through walls, hence lights need to be switched on even during the day if connectivity through Li-Fi is required.

A part of the ITS or Intelligent Transport Systems, Dedicated Short Range Communications or DSRC are data systems only operating in the ISM bands. One of the main applications is for vehicle road side assistance. This is one- or two-way wireless communication. Operating in the licensed frequency bands (FCC: 75 MHz of spectrum in the 5.9 GHz band; ETSI: 30 MHz of spectrum in the 5.9 GHz band), it provides a secure wireless interface required by active safety applications. It supports high speed, low latency, and short range wireless communications while being immune in extreme weather conditions. It supports both Vehicle-2-Vehicle (V2V) and Vehicle-2-Infrastructure (V2I) communications.

1.8.20 V2V and V2I

V2V and V2I communication, an application for DSRC, is part of vehicular transportation systems (VTS). VTS is developed as part of ITS. This technology will allow vehicles to ‘talk’ to each other or to support infrastructure. V2V is also known as VANET (vehicle ad-hoc networks) which is a part of MANET (mobile ad-hoc networks). These are essentially enhanced versions of the Wi-Fi systems with the exception that they are optimised for moving vehicles with a range of up to 800 m. Each vehicle will have a designated ID and is connected to GPS that can locate the position of the vehicle to within a couple of metres. The speed, direction, and size of the vehicle is transmitted at a speed of 10 s⁻¹ and receiving that same data from other V2V-equipped vehicles around. All information is then sent to onboard computers that will operate the electronic safety systems.

1.8.21 SRD

SRD or Short-Range Devices are radio devices that provide less interference to the other radio services due to less transmitted power. Some of the applications include CCTV cameras, LAN, remote controls, etc. As the power transmitted is in the range of 25–100 mW, the range of transmission is from a few metres to a few hundred metres, the user is free to operate such equipment but may require a licence in certain cases. This is based on ECC Recommendation 70–03.
1.8.22 RLAN

RLAN or Radio LAN is commonly called Wireless LAN or also Wi-Fi. It is used in home, office or small area public locations; it operates in 2.4 and 5 GHz frequency bands, based on IEEE802.11 standards.

1.8.23 PMR

PMR stands for professional mobile radio or private mobile radio. The most famous example is the TETRA (terrestrial trunked radio) systems that have been deployed with police/security agencies around the world. Some important features include point to multipoint, push to talk and close user group communications. Narrow band frequency modulation is used. In India, 3GPP band 27 is earmarked for police/PMRTS (public mobile radio trunking service).