Unit 3- Wired LANs-IEEE standards, wireless LANs-Bluetooth, Cellular Telephony

IEEE STANDARDS

In 1985, the Computer Society of the IEEE started a project, called **Project 802**, to set standards to enable intercommunication among equipment from a variety of manufacturers. Project 802 does not seek to replace any part of the OSI or the Internet model. Instead, it is a way of specifying functions of the physical layer and the data link layer of major LAN protocols. The standard was adopted by the American National Standards Institute (ANSI). In 1987, the International Organization for Standardization (ISO) also approved it as an international standard under the designation ISO 8802.

Wired LANs

STANDARD ETHERNET

The original Ethernet was created in 1976 at Xerox's Palo Alto Research Center (PARC). Since then, it has gone through four generations: Standard Ethernet (10 Mbps), Fast Ethernet (100 Mbps), Gigabit Ethernet (l Gbps), and Ten-Gigabit Ethernet (l0 Gbps).

Ethernet

Ethernet is a set of technologies and protocols that are used primarily in LANs. It was first standardized in 1980s - IEEE 802.3 standard. IEEE 802.3 defines the physical layer and the medium access control (MAC) sub-layer of the data link layer for wired Ethernet networks.

Ethernet is classified into two categories: classic Ethernet and switched Ethernet.

Classic Ethernet is the original form of Ethernet that provides data rates between 3 to 10 Mbps. The varieties are commonly referred as 10BASE-X. Here, 10 is the maximum throughput, i.e. 10 Mbps, BASE denoted use of baseband transmission, and X is the type of medium used. Most varieties of classic Ethernet have become obsolete in present communication scenario.

A switched Ethernet uses switches to connect to the stations in the LAN. It replaces the repeaters used in classic Ethernet and allows full bandwidth utilization.

IEEE 802.3 Popular Versions

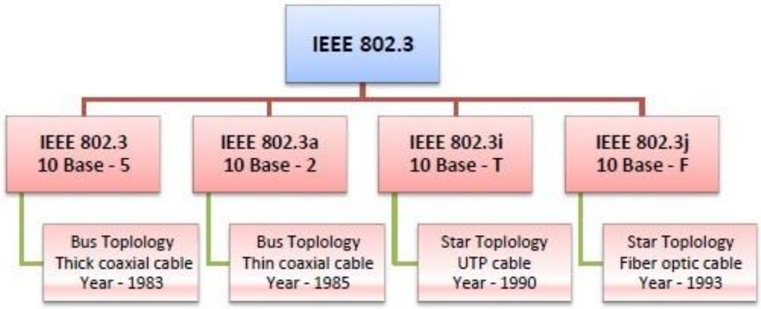
There are a number of versions of IEEE 802.3 protocol. The most popular ones are -

IEEE 802.3: This was the original standard given for 10BASE-5. It used a **thick single coaxial cable** .Here, 10 is the maximum throughput, i.e. 10 Mbps, BASE denoted use of baseband transmission, and 5 refers to the maximum segment length of 500m.

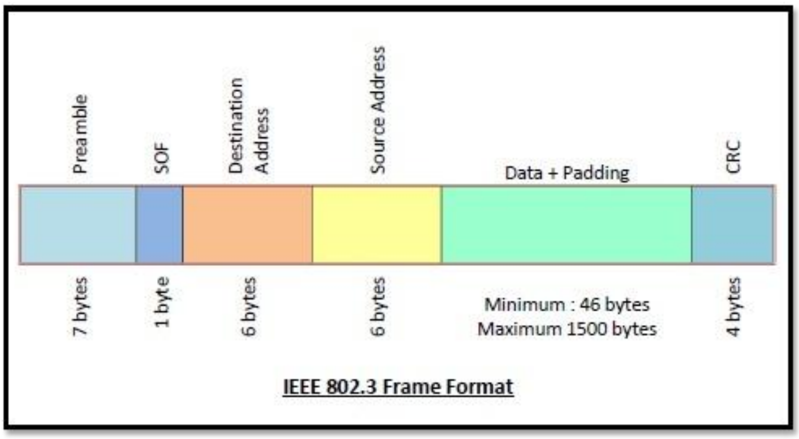
IEEE 802.3a: This gave the standard for thin coax (10BASE-2), which is a thinner variety where the segments of coaxial cables are connected by BNC connectors. The 2 refers to the maximum segment length of about 200m (185m to be precise).

IEEE 802.3i: This gave the standard for twisted pair (10BASE-T) that uses unshielded twisted pair (UTP) copper wires as physical layer medium. The further variations were given by IEEE 802.3u for 100BASE-TX, 100BASE-T4 and 100BASE-FX.

IEEE 802.3j: This gave the standard for Ethernet over Fiber (10BASE-F) that uses fiber optic cables as medium of transmission.



Frame Format of Classic Ethernet and IEEE 802.3



The main fields of a frame of classic Ethernet are -
Preamble: It is the starting field that provides alert and timing pulse for transmission. In case of classic Ethernet it is an 8 byte field and in case of IEEE 802.3 it is of 7 bytes.
Start of Frame Delimiter: It is a 1 byte field in a IEEE 802.3 frame that contains an alternating pattern of ones and zeros ending with two ones.
Destination Address: It is a 6 byte field containing physical address of destination stations.
Source Address: It is a 6 byte field containing the physical address of the sending station.

06:01 :02:01:2C:4B → **Ethernet Address format**

6 bytes =12 hex digits =48 bits

Length: It a 7 bytes field that stores the number of bytes in the data field.
Data: This is a variable sized field carries the data from the upper layers. The maximum size of data field is 1500 bytes.
Padding: This is added to the data to bring its length to the minimum requirement of 46 bytes.
CRC: CRC stands for cyclic redundancy check. It contains the error detection information

Wireless LANs

Bluetooth

Bluetooth is a wireless LAN technology designed to connect devices of different functions such as telephones, notebooks, computers (desktop and laptop), cameras, printers, coffee makers, and

so on. A Bluetooth LAN is an ad hoc network, which means that the network is formed spontaneously. The devices (gadgets) find each other and make a network called a piconet.
A Bluetooth LAN can even be connected to the Internet if one of the gadgets has this capability. A Bluetooth LAN, by nature, cannot be large.
Bluetooth technology has several applications.

- Peripheral devices such as a wireless mouse or keyboard can communicate with the computer through this technology.
- Monitoring devices can communicate with sensor devices in a small health care center.
- Home security devices can use this technology to connect different sensors to the main security controller.
- Conference attendees can synchronize their laptop computers at a conference.

Today, Bluetooth technology is the implementation of a protocol defined by the IEEE 802.15 standard. The standard defines a wireless personal-area network (PAN) operable in an area the size of a room or a hall.

Architecture

Bluetooth defines two types of networks: piconet and scatternet.

Piconets

A Bluetooth network is called a piconet, or a small net. A piconet can have up to **eight stations**, one of which is called the primary; the rest are called secondaries.
All the secondary stations synchronize their clocks and hopping sequence with the primary.
Note that a piconet can have only one primary station. The communication between the primary and the secondary can be one-to-one or one-to-many.
An additional eighth secondary can be in the *parked state*. A secondary in a parked state is synchronized with the primary, but cannot take part in communication until it is moved from the parked state.(Only eight stations can be active in a piconet. Activating a station from the parked state means that an active station must go to the parked state.)

Scatternet

Piconets can be combined to form what is called a *scatternet*. A secondary station in one piconet can be the primary in another piconet. This station can receive messages from the primary in the first piconet (as a secondary) and, acting as a primary, deliver them to secondaries in the second piconet.
A station can be a member of two piconets.
A Bluetooth device has a built-in short-range radio transmitter. (The current data rate is 1 Mbps with a 2.4-GHz bandwidth. This means that there is a possibility of interference between the IEEE 802.11b wireless LANs and Bluetooth LANs.)

Bluetooth Layers

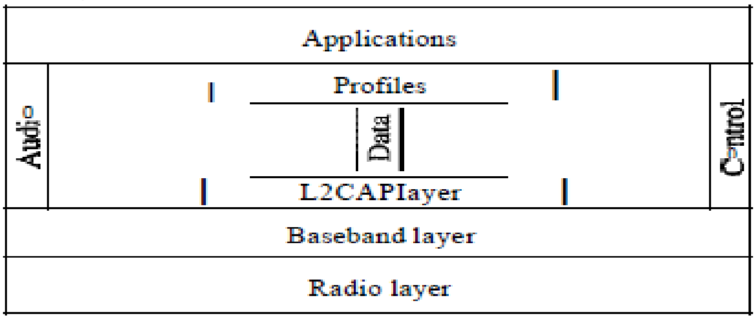
Radio Layer

The radio layer is roughly equivalent to the physical layer of the Internet model.
Bluetooth uses the frequency-hopping spread spectrum (FHSS) method in the physical layer to avoid interference from other devices or other networks. Bluetooth hops 1600 times per second, (i.e., each device changes its modulation frequency 1600 times per second.)

Baseband Layer

The baseband layer is roughly equivalent to the MAC sublayer in LANs.
The **access method** is TDMA.

The primary and secondary communicate with each other using time slots. The length of a time slot is exactly the same as the dwell time, 625 µs. This means that during the time that one frequency is used, a sender sends a frame to a secondary, or a secondary sends a frame to the primary.



The communication is only between the primary and a secondary (secondaries cannot communicate directly with one another).

TDMA

Bluetooth uses a form of TDMA that is called TDD-TDMA (timedivision duplex TDMA). TDD-TDMA is a kind of half-duplex communication in which the secondary and receiver send and receive data, but not at the same time (halfduplex); the communication for each direction uses different hops.

Single-Secondary Communication : If the piconet has only one secondary, the TDMA operation is very simple. The time is divided into slots of 625 µs. The primary uses even numbered slots (0, 2, 4, ...); the secondary uses odd-numbered slots (1, 3, 5, ...).

TDD-TDMA allows the primary and the secondary to communicate in half-duplex mode.

Multiple-Secondary Communication If there is more than one secondary in the piconet

- the primary uses the even-numbered slots, but a secondary sends in the next odd-numbered slot if the packet in the previous slot was addressed to it.
- All secondaries listen on even-numbered slots, but only one secondary sends in any odd-numbered slot.

We can elaborate the process as follows

1. In slot 0, the primary sends a frame to secondary 1.
2. In slot 1, only secondary 1 sends a frame to the primary because the previous frame was addressed to secondary 1; other secondaries are silent.
3. In slot 2, the primary sends a frame to secondary 2.
4. In slot 3, only secondary 2 sends a frame to the primary because the previous frame was addressed to secondary 2; other secondaries are silent.
5. The cycle continues.

Links

Two types of links can be created between a primary and a secondary**: SCQ links and ACL links**.

SCQ*:** A synchronous connection-oriented (SCQ) link is used when avoiding latency (delay in data delivery) is more important than integrity (error-free delivery). That is a fast delivery more important than error free communication in certain applications like real time communications. If a packet is damaged, it is never retransmitted.*** SCQ is used for **real-time audio** where avoiding delay is all-important. A secondary can create up to **three SCQ links** with the primary, sending digitized audio at 64 kbps in each link.

<u>ACL</u>: An asynchronous connectionless link (ACL) is used when data integrity is more important than avoiding latency. In this type of link, if a payload encapsulated in the frame is corrupted, it is **retransmitted**. ACL can use one, three, or more slots and can achieve a maximum data rate of **721 kbps**.

<u>Frame Format</u>

A frame in the baseband layer can be one of three types: one-slot, three-slot, or five-slot.

A slot is 625 μs. However, in a one-slot frame exchange, 259 μs is needed for hopping and control mechanisms. This means that a one-slot frame can last only 625 - 259, or 366 μs. With a 1-MHz bandwidth and 1 bit/Hz, the size of a one-slot frame is 366 bits.

A three-slot frame occupies three slots.

A device that uses a three-slot frame remains at the same hop (at the same carrier frequency) for three slots.

<u>Access code.</u> This 72-bit field contains **synchronization bits and the identifier** of the primary to distinguish the frame of one piconet from another.

<u>Header</u>. This 54-bit field is a repeated 18-bit pattern. Each pattern has the following subfields:

- <u>Address.</u> The 3-bit address subfield can define up to seven secondaries. If the address is zero, it is used for broadcast communication from the primary to all secondaries.
- <u>Type.</u> The 4-bit type subfield defines the type of data coming from the upper layers.
- <u>F.</u> This 1-bit subfield is for flow control. When set (1), it indicates that the device is unable to receive more frames (buffer is full).
- <u>A.</u> This I-bit subfield is for acknowledgment. (**Bluetooth uses Stop-and-Wait ARQ**; 1 bit is sufficient for acknowledgment.
- <u>S.</u> This 1-bit subfield holds a sequence number.
- <u>HEC.</u> The 8-bit header error correction subfield use **checksum** to detect errors in each 18-bit header section.

The header has three identical 18-bit sections. The receiver compares these three sections, bit by bit. If each of the corresponding bits is the same, the bit is accepted; if not, the majority opinion rules. This is a form of forward error correction (for the header only). This double error control is needed because the nature of the communication, via air, is very noisy.

There is no retransmission in this sublayer.

<u>Payload.</u> This subfield can be 0 to 2740 bits long. It contains data or control information corning from the upper layers.

Access code(72 bits)	Header(54 bits)	Payload (0 to 2740 bits)

<u>The Logical Link Control and Adaptation Protocol (L2CAP)</u>

It is used for data exchange on an ACL link; SCQ channels do not use L2CAP.

The L2CAP has specific duties: multiplexing, segmentation and reassembly, quality of service (QoS), and group management.

Multiplexing

At the sender site, it accepts data from one of the upper-layer protocols, frames them, and delivers them to the baseband layer. At the receiver site, it accepts a frame from the baseband layer, extracts the data, and delivers them to the appropriate protocol layer. It creates a kind of virtual channel.

Segmentation and Reassembly

The L2CAP divides the large packets from the upper layer into segments and adds extra information to define the location of the segments in the original packet. The L2CAP segments the packet at the source and reassembles them at the destination.

QoS

Bluetooth allows the stations to define a quality-of-service level. If no quality-of-service level is defined, Bluetooth defaults to *best-effort service* (it will do its best under the circumstances.

Group Management

Another functionality of L2CAP is to allow devices to create a type of logical addressing between themselves. This is similar to multicasting. For example, two or three secondary devices can be part of a multicast group to receive data from the primary.

Other Upper Layers

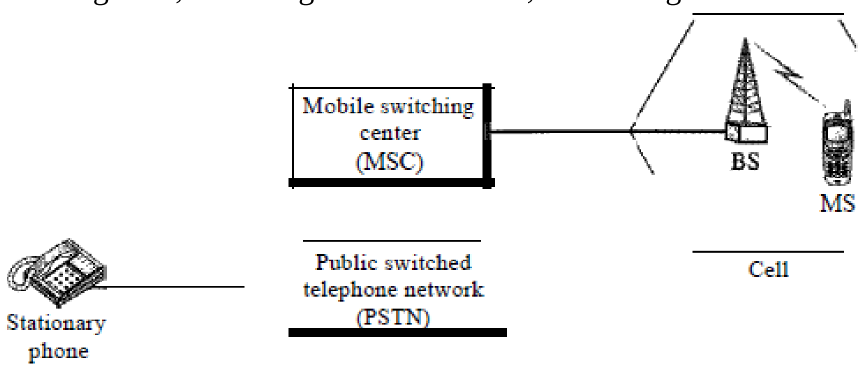
Bluetooth defines several protocols for the upper layers that use the services ofL2CAP; these protocols are specific for each purpose.

Wireless WAN

Cellular Telephony

Cellular telephony is designed to provide communications between two moving units, called mobile stations (MSs), or between one mobile unit and one stationary unit, often called a land unit. A service provider must be able to locate and track a caller, assign a channel to the call, and transfer the channel from base station to base station as the caller moves out of range.

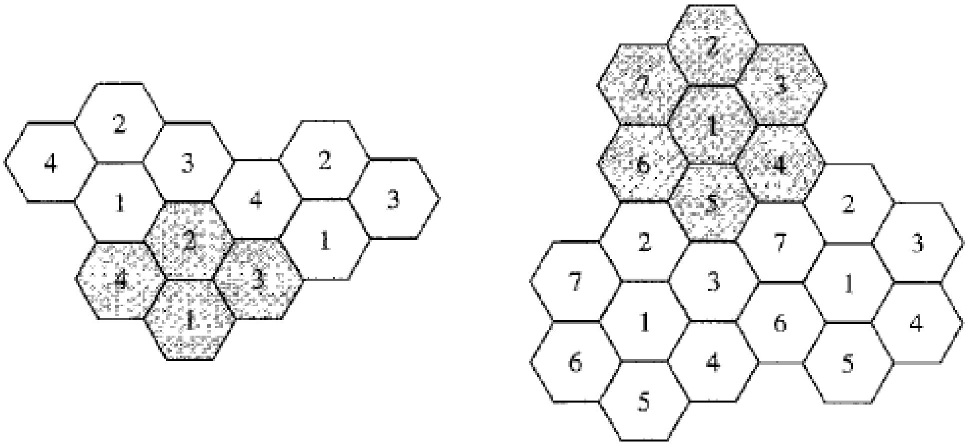
To make this tracking possible, **each cellular service area is divided into small regions called cells.** Each cell contains an antenna and is controlled by a solar or AC powered network station, called the **base station (BS)**. Each base station, in turn, is controlled by a switching office, called **a mobile switching centre (MSC)**. The MSC coordinates communication between all the base stations and the telephone central office. It is a computerized centre that is responsible for connecting calls, recording call information, and billing.



Cell size is optimized to prevent the interference of adjacent cell signals. The transmission power of each cell is kept low to prevent its signal from interfering with those of other cells.

1.1.1. Frequency Reuse Principle

In general, neighbouring cells cannot use the same set of frequencies for communication because it may create interference for the users located near the cell boundaries. However, the set of frequencies available is limited, and frequencies need to be reused. A frequency reuse pattern is a configuration of N cells, N being the **reuse factor,** in which each cell uses a unique set of frequencies. When the pattern is repeated, the frequencies can be reused. There are several different patterns.



a. Reuse factor of 4 b. Reuse factor of 7

The numbers in the cells define the pattern. The cells with the same number in a pattern can use the same set of frequencies. We call these cells the *reusing cells.*

1.1.2. Transmitting

To place a call from a mobile station, the caller enters a code of 7 or 10 digits (a phone number) and presses the send button. The mobile station then scans the band, seeking a setup channel with a strong signal, and sends the data (phone number) to the **closest base station** using that channel. The base station relays the data to the MSC. The MSC sends the data on to the telephone central office. If the called party is available, a connection is made and the result is relayed back to the MSC. At this point, the MSC assigns an unused voice channel to the call, and a connection is established. The mobile station automatically adjusts its tuning to the new channel, and communication can begin.

1.1.3. Receiving

When a mobile phone is called, the telephone central office sends the number to the MSC. The MSC searches for the location of the mobile station by sending query signals to each cell in a process called *paging.* Once the mobile station is found, the MSC transmits a ringing signal and, when the mobile station answers, assigns a voice channel to the call, allowing voice communication to begin.

Handoff

During a conversation, if the mobile station moves from one cell to another then the signal may become weak. To solve this problem, the MSC monitors the level of the signal every few seconds. If the strength of the signal diminishes, the MSC seeks a new cell that can better accommodate the communication. The MSC then changes the channel carrying the call (hands the signal off from the old channel to a new one).

Hard Handoff : Early systems used a hard handoff. In a hard handoff, a mobile station only communicates with one base station. When the MS moves from one cell to another, communication must first be broken with the previous base station before communication can be established with the new one. This may create a rough transition.

Soft Handoff : New systems use a soft handoff. In this case, a mobile station can communicate with two base stations at the same time. This means that, during handoff, a mobile station may continue with the new base station before breaking off from the old one.

Roaming

Roaming means that a user can have access to communication or can be reached where there is coverage. A service provider usually has limited coverage. Neighbouring service providers can provide extended coverage through a roaming contract.

Cellular Telephony Generations

Since the introduction of first commercial mobile phone in 1983 by Motorola, mobile technology has come a long way. Be it technology, protocols, services offered or speed, the changes in mobile telephony have been recorded as generation of mobile communication. Here we will discuss the basic features of these generations that differentiate it from the previous generations.

1G - First Generation

This was the first generation of cell phone technology . The very first generation of commercial cellular network was introduced in the late 70's with fully implemented standards being established throughout the 80's. It was introduced in 1987 by Telecom (known today as Telstra), Australia received its first cellular mobile phone network utilising a 1G analog system. 1G is an **analog technology** and the phones generally had poor battery life and voice quality was large without much security, and would sometimes experience dropped calls . These are the analog telecommunications standards that were introduced in the 1980s and continued until being replaced by 2G digital telecommunications. The maximum speed of 1G is 2.4 Kbps .

Some characteristics of 1G communication are −

- Speeds up to 2.4 kbps
- Poor voice quality
- Large phones with limited battery life
- No data security

2G - Second Generation

Cell phones received their first major upgrade when they went from 1G to 2G. The main difference between the two mobile telephone systems (1G and 2G), is that the radio signals used by 1G network are analog, while 2G networks are **digital** . Main motive of this generation was to provide secure and reliable communication channel. It implemented the concept of CDMA and GSM . Provided small data service like sms and mms. Second generation 2G cellular telecom networks were commercially launched on the GSM standard in Finland by Radiolinja (now part of Elisa Oyj) in 1991. 2G capabilities are achieved by allowing multiple users on a single channel via multiplexing. During 2G Cellular phones are used for data also along with voice. The advance in technology from 1G to 2G introduced many of the fundamental services that we still use today, such as SMS, internal roaming , conference calls, call hold and billing based on services e.g. charges based on long distance calls and real time billing. The max speed of 2G with General Packet Radio Service (GPRS) is 50 Kbps or 1 Mbps with Enhanced

Data Rates for GSM Evolution (EDGE). Before making the major leap from 2G to 3G wireless networks, the lesser-known 2.5G and 2.75G was an interim standard that bridged the gap.

Some prominent characteristics of 2G communication are −

- Data speeds up to 64 kbps
- Text and multimedia messaging possible
- used GSM technology.
- Better quality than 1G

When **GPRS** technology was introduced, it enabled web browsing, e-mail services and fast upload/download speeds. 2G with GPRS is also referred as **2.5G**, a step short of next mobile generation.

3G - Third Generation

This generation set the standards for most of the wireless technology we have come to know and love. Web browsing, email, video downloading, picture sharing and other Smartphone technology were introduced in the third generation. Introduced commercially in 2001, the goals set out for third generation mobile communication were to facilitate greater voice and data capacity, support a wider range of applications, and increase data transmission at a lower cost .

The 3G standard utilises a new technology called UMTS as its core network architecture - Universal Mobile Telecommunications System. This network combines aspects of the 2G network with some new technology and protocols to deliver a significantly faster data rate. Based on a set of standards used for mobile devices and mobile telecommunications use services and networks that comply with the International Mobile Telecommunications-2000 (IMT-2000) specifications by the International Telecommunication Union. One of requirements set by IMT-2000 was that speed should be at least 200Kbps to call it as 3G service.

3G has Multimedia services support along with streaming are more popular. In 3G, Universal access and portability across different device types are made possible (Telephones, PDA's, etc.). 3G increased the efficiency of frequency spectrum by improving how audio is compressed during a call, so more simultaneous calls can happen in the same frequency range. The UN's International Telecommunications Union IMT-2000 standard requires stationary speeds of 2Mbps and mobile speeds of 384kbps for a "true" 3G. The theoretical max speed for HSPA+ is 21.6 Mbps.

Like 2G, 3G evolved into 3.5G and 3.75G as more features were introduced in order to bring about 4G. A 3G phone cannot communicate through a 4G network , but newer generations of phones are practically always designed to be backward compatible, so a 4G phone can communicate through a 3G or even 2G network .

. Some of the characteristics of this generation are −

- Data speeds of 144 kbps to 2 Mbps
- High speed web browsing
- Running web based applications like video conferencing, multimedia e-mails, etc.
- Fast and easy transfer of audio and video files
- 3D gaming

4G - Fourth Generation

4G is a very different technology as compared to 3G and was made possible practically only because of the advancements in the technology in the last 10 years. Its purpose is to provide high speed , high quality and high capacity to users while improving security and lower the cost of voice and data services, multimedia and internet over IP. Potential and current applications include amended mobile web access, IP telephony , gaming services, high-definition mobile TV, video conferencing, 3D television, and cloud computing.

The key technologies that have made this possible are MIMO (Multiple Input Multiple Output) and OFDM (Orthogonal Frequency Division Multiplexing). The two important 4G standards are WiMAX (has now fizzled out) and LTE (has seen widespread deployment). LTE (Long Term Evolution) is a series of upgrades to existing UMTS technology and will be rolled out on Telstra's existing 1800MHz frequency band. The max speed of a 4G network when the device is moving is 100 Mbps or 1 Gbps for low mobility communication like when stationary or walking, latency reduced from around 300ms to less than 100ms, and significantly lower congestion. When 4G first became available, it was simply a little faster than 3G. 4G is not the same as 4G LTE which is very close to meeting the criteria of the standards. To download a new game or stream a TV show in HD, you can do it without buffering .

Newer generations of phones are usually designed to be backward-compatible , so a 4G phone can communicate through a 3G or even 2G network. All carriers seem to agree that OFDM is one of the chief indicators that a service can be legitimately marketed as being 4G. OFDM is a type of digital modulation in which a signal is split into several narrowband channels at different frequencies. There are a significant amount of infrastructure changes needed to be implemented by service providers in order to supply because voice calls in GSM , UMTS and CDMA2000 are circuit switched, so with the adoption of LTE, carriers will have to re-engineer their voice call network. And again, we have the fractional parts: 4.5G and 4.9G marking the transition of LTE (in the stage called LTE-Advanced Pro) getting us more MIMO, more D2D on the way to IMT-2020 and the requirements of 5G .
. Its major characteristics are −

- Speeds of 100 Mbps to 1 Gbps
- Mobile web access
- High definition mobile TV
- Cloud computing
- IP telephony

5G - Fifth Generation

5G is a generation currently under development , that's intended to improve on 4G. 5G promises significantly faster data rates, higher connection density, much lower latency, among other improvements. Some of the plans for 5G include device-to-device communication, better battery consumption, and improved overall wireless coverage. The max speed of 5G is aimed at being as fast as 35.46 Gbps , which is over 35 times faster than 4G.

Key technologies to look out for: Massive MIMO , Millimeter Wave Mobile Communications etc. Massive MIMO, milimetre wave, small cells, Li-Fi all the new technologies from the previous decade could be used to give 10Gb/s to a user, with an unseen low latency, and allow connections for at least 100 billion devices . Different estimations have been made for the date of commercial introduction of 5G networks. Next Generation Mobile Networks Alliance feel that 5G should be rolled out by 2020 to meet business and consumer demands.