Aim

To study and analyse various parameters of pre-existing networks like 3G, 4G and implement them, in future networks like 5G using Radio Resourse Management

Overview

Wireless Communication

Wireless communication technology is a modern alternative to traditional wired networking that does not rely on cables to connect various digital devices together.

Wireless communication revolution is bringing fundamental changes to data networking, telecommunication and is making integrated networks a reality by freeing a user from a cord, personal communication networks, wireless LANs, mobile radio networks and cellular systems, harbor the promise of fully distributed mobile computing and communication, anytime, anywhere.

Operation of Wireless Networks

Wireless Networks operate using radio frequency (RF) technology. When an RF current is supplied to an antenna, an EM field is created which propagates through space.

The corner stone of a wireless network is an access point(AP). The primary job of an access point is to broadcast a wireless signal that the wireless network can detect and 'tune' into. Since wireless networks are usually connected to wired ones, an access point also often serves as a link to the resources available on the wired network such as internet connection.

Some of the advantages of wireless communication network includes :

- Feasibility
- Mobility
- Easy setup
- Expandable
- Security
- Cost

Traffic growth and strategies to accommodate the future traffic demands

Over the last few years, a remarkable growth of data-enabled devices has been observed, which has led to an increase of the mobile data traffic. The amount of data carried by mobile networks moved from 10 gigabytes per month in 2010 to 3.7 exabytes per month in 2015. This outstanding growth has been caused by cellular network advances, moving from the 3 Generation (3G) to the 4 Generation (4G) of mobile systems; by the massive increase of smart devices and by the emergence of new type of applications, such as social networks, whose number of users grows notably day by day. Such numbers are continuously growing, and the prediction is that global mobile data traffic will increase approximately by eight times between 2015 and 2020 Smart devices are forecasted to generate 98% of the mobile data traffic by 2020, indicating that devices using wireless data connection are becoming more popular year by year. To increase the network capacity and accommodate the future traffic demands, the strategies that must be considered are:

- Using larger frequency bands
- Enhancing the spectral efficiency
- Increasing the cell density

The frequencies ranging from 3 to 30 GHz, also known as centimeter-wave frequencies, have the most attractive propagation characteristics. However, using this frequency range has limited potential because the spectrum is scarce and expensive, making it insufficient to deal with t
he future traffic growth. On the other hand, higher frequency bands ranging from 30 upto 300 GHz, also referred as millimeter-wave frequencies, have been considered as an option to increase the network capacity. Research shows that there is potential for using such bands. However, given the different propagation conditions compared to the traditional centimeter-wave frequencies, large antenna arrays and beamforming techniques are required to overcome the
pathloss. Orthogonal Frequency Division Multiplexing (OFDM) might not be the most suitable modulation for millimeter-wave. This modulation is very appropriate for bandwidth limited systems to multiplex users in frequency. However, since a large amount of spectrum is available in the millimeter-wave frequencies, users can be multiplexed in time.

To enhance the spectral efficiency, the most common and used approach is to exploit Multiple Input Multiple Output (MIMO) antenna technology. This technique allows to overcome the effects of the signal multipath and fading in systems with limited bandwidth that require high throughput. The main drawback of such technology is that, as the number of device antennas grows, the constraints in terms of space and cost increase. Thus, it is unlikely that future devices will be equipped with a large number of antennas. Another option that could be considered is the emerging Full Duplex (FD) technology. It allows a device to transmit and receive simultaneously in the same frequency band, thus, theoretically, doubling the throughput compared to conventional Half Duplex (HD) systems. Currently, the main concern about FD technology is the cancellation of the Self-Interference(SI) power, which refers to the interference generated by the transmitted signal at the receiver end of the same node. The SI power must be highly attenuated in order to have an operational FD transceiver.

Increasing the cell density has been positioned as the other key solution to deal with the expected mobile traffic growth. It is achieved by deploying a large number of low-power base stations in scenarios with high traffic density, while traditional macro cell base stations provide basic service coverage. A massive deployment of small cells is fundamental for moving towards the desired increase in network capacity.

Evolution of cellular technology

The past few decades have shown a great advancement in the field of mobile communication. With the increase in the demand of mobile communication and with increased number of mobile subscribers telecommunication companies are working hard to bring new technologies into existence with better features so as to meet up to the user requirement.

Cellular technologies have come a long way starting as 1st generation then 2nd Generation likewise 3rd generation and now 4th generation system is also introduced, in which each new generation brings a new technology and more high data rates than the previous one.

The *1st generation* system commonly known as 1G technology was introduced in the early 1980s. It was basically analog-based communication technology which only provided analog voice services and no data services and it supported the data transmission rate of upto 2.4kbps.

The *2nd Generation (2G)* mobile telephone networks were the next stage in the development of wireless systems after 1G, which introduced the mobile phone system that was completely digitalized. The 2G system provided data transmission rate of up to 64kbps which was quite better than 1G, it supported both voice and data transmission that is the facility of message sending was available moreover it also provided enhanced calling features like caller ID.

Then the *3rd generation* came into existence with significant features as they supported much higher data transmission rates of upto 2Mbps and offered increased capacity, which made them suitable for high-speed data applications as well as for the traditional voice calls which also supported global roaming. The benefits of higher data rates and greater bandwidth meant that 3G mobile phones offered subscribers a wide range of data services, such as mobile Internet access and multimedia applications. Compared to earlier mobile phones a 3G handset provided many new features such as TV streaming, multimedia, videoconferencing and many more.

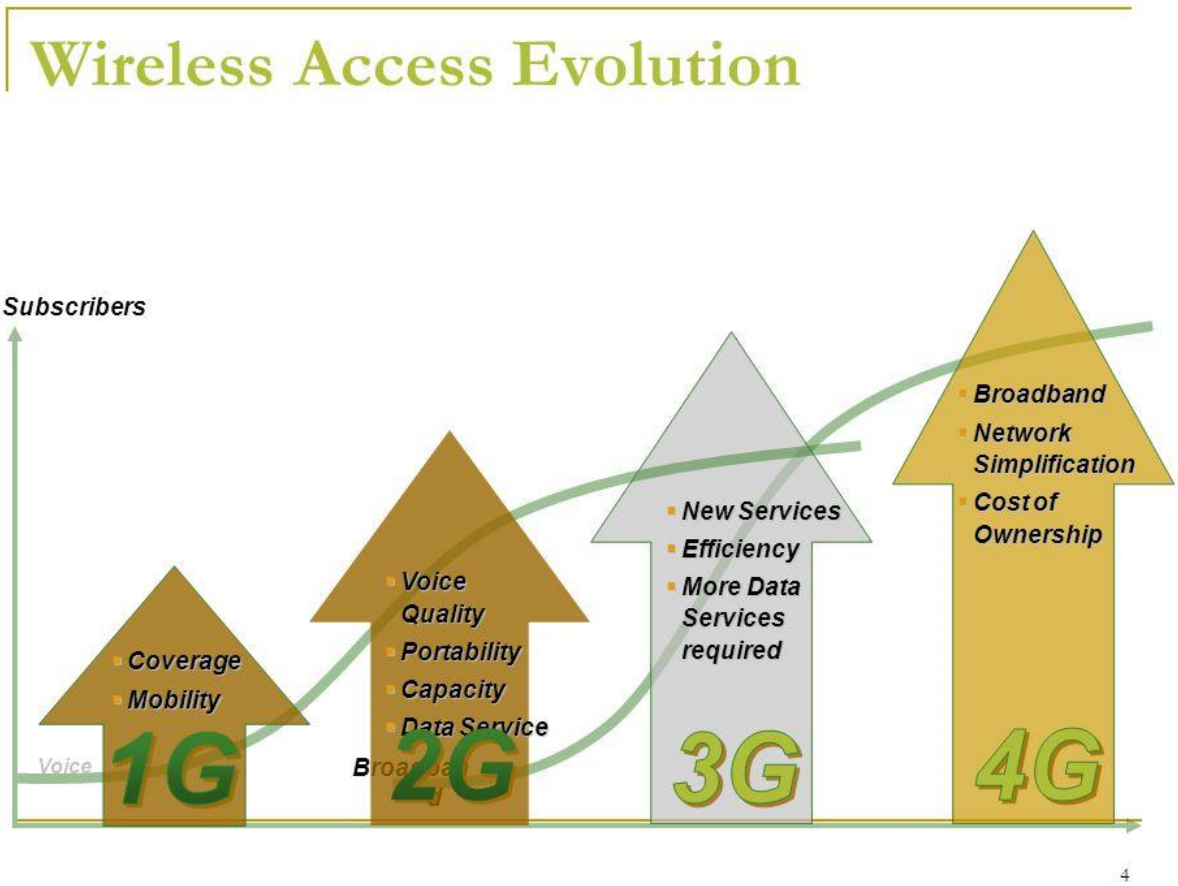
The *4G/LTE (Fourth Generation / Long Term Evolution)* is the next stage in mobile communication network development. In addition to the usual voice and other services of 3G, provides mobile ultra broadband Internet access. It provides the data rate of upto 1Gbps if the user is stationary and about 100Mbps if the user is mobile. Priorities for this standard include better reception, with less dropped data, IP interoperability for seamless mobile internet and faster information exchanges. The 4G enhancement promises to bring the wireless experience to an entirely new level with impressive user applications, such as sophisticated graphical user interfaces, high-end gaming, high definition video and high-performance imaging.

Motivation

Since we know that bandwidth is a scarce and costly resource and number of users are increasing day by day so in order to get a efficient networking system, with increasing demands , we wanted to bridge the gap between both. Two major trends are behind the race to 5G: the explosive growth in demand for wireless broadband that can carry video and other content-rich services, and the Internet of Things (IoT), where large numbers of smart devices communicate over the Internet. To achieve these objectives, 5G will provide extreme broadband speed, ultralow latency, and Ultra reliable web connectivity.
5G networks and devices will require substantially different architectures, radio access technology, and physical layer algorithms. Dense networks of small cells will complement macro base stations, operating at millimeter wave technologies and employing massive MIMO antenna arrays. And the processing components within network equipment and user devices will become more integrated and adaptive.

Goals

- To understand different kinds of networks (1G,2G,3G,4G) and there evolution.
- To understand different parameters and aspects of Radio resource management.
- Study of RRM in basic networks like 2G,3G and more.
- Learning MATLAB.
- Using MATLAB for basic communication programs and resource management in communication networks with the help of communication toolbox.
- Using all the learnt techniques in resource management for 5G.
- Research leading to the greater efficiency of 5G.
- Providing good grade of service for the network.
- Expanding all of the above mentioned aspects to further networks beyond 5G.
- To reduce transmission power and efficient bandwidth use



CHAPTER 2

SYSTEM ARCHITECTURE OF CELLULAR NETWORKS

First Generation (1G) – Analog System:

1G refers to the first-generation of wireless telephone technology, mobile telecommunications. These are the analog telecommunications standards that were introduced in the 1980s and continued until being replaced by 2G digital telecommunications. The main difference between two succeeding mobile telephone systems, 1G and 2G, is that the radio signals that 1G networks use are analog, while 2G networks are digital. Although both systems use digital signaling to connect the radio towers (which listen to the handsets) to the rest of the telephone system, the voice itself during a call is encoded to digital signals in 2G whereas 1G is only modulated to higher frequency, typically 150 MHz and up. Mobile radio telephones were used for military communications in the early 20th century. Car-based telephones were first introduced in the mid-1940s. This system used a single large transmitter on top of a tall building. A single channel was used for sending and receiving. To talk, the user pushed a button that enabled transmission and disabled reception. Due to this, these became known as "push-to-talk" systems in the 1950s. Although these systems are quite old, taxis and police cars use this technology. To allow users to talk and listen at the same time, IMTS (Improved Mobile Telephone System) was introduced in the 1960s. It used two channels (one for sending, one for receiving – thus there was no need for push-to-talk). IMTS used 23 channels from 150 MHz to 450 MHz. First-generation cellular networks were introduced in the 1980s. This started with the Advanced Mobile Phone Service (AMPS) that was invented at Bell Labs and first installed in1982. The key idea of 1G cellular networks is that the geographical area is divided into cells (typically 10-25km), each served by a "base station." Cells are small so that frequency reuse can be exploited in nearby (but not adjacent) cells. This allows many more users to be supported in a given area. For example, as compared to IMTS, AMPS can support 5 to 10 times more users in the same100-mile area by dividing the area into 20 smaller cells that reuse the same frequency ranges. In addition, smaller cells also require less powerful and cheaper, smaller devices to transmit and receive information. Actually, the first generation wireless mobile communication system is not digital technology, but analog cellular telephone system which was used for voice service only during the early 1980s. This Advanced Mobile Phone System (AMPS) was a frequency modulated analog mobile radio system using Frequency Division Multiple Access (FDMA) with 30kHzchannels occupying the 824MHz − 894MHz frequency band and a first commercial cellular system deployed until the early 1990‟s. The first commercially automated cellular network (the 1G generation) was launched in Japan by NTT (Nippon Telegraph and Telephone) in 1979 . The first 1G network launched in the USA was Chicago based Ameritech in 1983 using the Motorola Dyna TAC mobile phone. Each phone has a 32-bit serial number and 10 digit phone number in its PROM (Programmable Read-only Memory). When a phone is turned on, it scans for control signals from base stations. It sends this information to the BS with strongest control signal and the BS passes this information to MTS (Master Switching Station) as a packet. The subscriber initiates a call by keying in a phone number and pressing the send key. The MTS verifies the number and authorizes the user. MTS issues a message to the user’s cellphone indicating send and receive traffic channels. MTS sends a ringing signal to the called party. Party answers the call and MTS establishes the circuit and initiates billing information. Either party hangs up; MTS releases the circuit, frees the channels, and completes billing.

Security Issues with 1G:

Analog cellular phones are insecure. Anyone with an all-band radio receiver can listen into the conversation. Many scandals have been reported in this area. There are also thefts of airtime. Basically, a thief uses an all-band radio receiver that is connected to a computer. This computer can record the 32-bit serial numbers and phone numbers of subscribers when calling (recall that this information is sent as a packet). The thieves can collect a large database by driving around and can then go into business by reprogramming stolen phones and reselling them.

Paging Networks:

Paging networks are one of the oldest wireless technologies. They support one-way and two way alphanumeric messages between callers and pagers (beepers). The callers typically calla beeper company and leave a phone number and possibly a short message. Paging networks are being integrated with PDAs (personal digital assistants) like Palm Pilots.

Characteristics of Paging Networks:

Paging networks have been around for a while and were among the first wireless networks used for sending numeric and alphanumeric messages to external devices carried by mobile workers. These are specialized wireless networks for broadcasting a message to a specific pager to call back a specific number. The paging network provider (paging operator), such as Skytel, runs a paging control center which receives paging requests from regular phones, cellular phones, or other pagers and routes them to their destination pagers. The paging BTSs (Base Transceiver Stations) are connected to the paging control center through leased lines or wireless links such as satellites or wireless local loops.

The paging networks come in two flavors: one-way paging networks and two-way paging networks. The two-way paging networks allow pre-defined messages to be sent back by the receiver of the message. The commercial paging operators can establish a network that meets subscriber’s requirements and supports a wide range of paging devices. The paging devices can be equipped with sophisticated features such as priority paging, group paging, voice paging, voice prompts, and remote transmitter control.

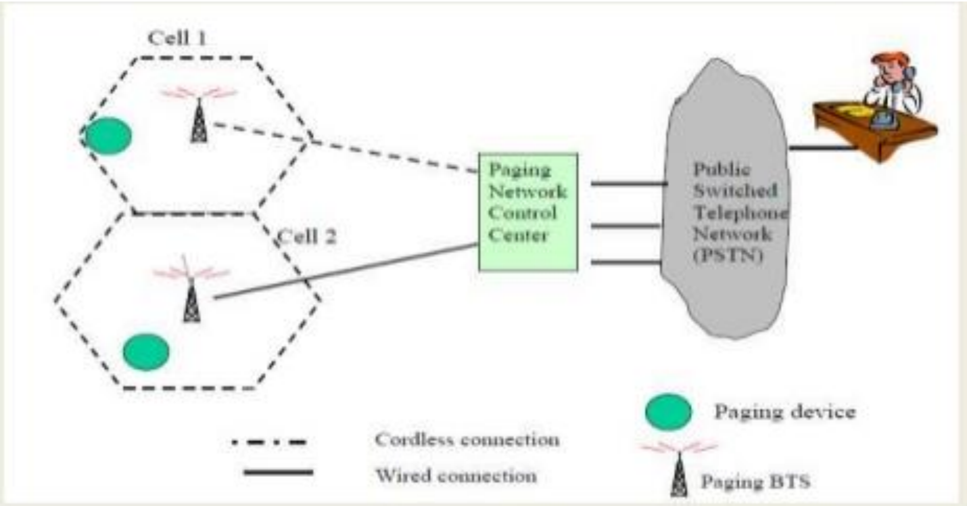


Fig: Conceptual view of paging

A few characteristics of the paging networks are follows:

1. Common applications are personal numeric messaging for call-back, alphanumeric messaging (dispatching and service), and two-way messaging (call dispatching with confirmation).

2. Capacity and speed includes 1200 bps for older and 6400 bps for newer systems. The paging networks are slower but have different design criteria for delivering the message within specific time periods.

3. Frequency bands used include 800 MHz for older paging networks and 901-941 MHz, with gaps, for newer networks.

4. Components of a paging network are a personal paging device, a paging computer/server at the paging operator’s site, and a paging transmitter. These networks may also use satellites for national coverage.

5. Coverage is 95% of the US, thanks to many local, regional and national paging network providers.

6. Communications protocols supported include FLEX and ReFLEX developed by Motorola for two-way paging. 7. Security is low and has not been considered a high priority.

The advantages of paging networks are:

1.Very inexpensive

2. Easy to operate for sender (from any telephone) and receiver.

3. Many options for users (numeric, alphanumeric, two-way, message storage).

4. Wide coverage at local, regional , national, and international levels Good building penetration.

The limitations of paging networks are follows:

1.Slow data transfer rate (1200 bps).

2.No acknowledgment (two-way paging costs extra).

3.Some of the available paging networks are overloaded, causing delays.

Drawbacks of 1G:

- Poor Voice Quality
- Poor Battery Life
- Large Phone Size
- No Security
- Limited Capacity
- Poor Handoff Reliability

Second Generation (2G) Network –Digital System:

Second Generation (2G) cellular networks, introduced in the late 1980s, are based on digital transmission. Digital transmissions offer several benefits over analog. Different approaches to 2G have been developed in the US and Europe. In the US, divergence happened because only one player (AMPS) existed in 1G. Because of this, several players emerged to compete in 2G.

IS-95: uses spread spectrum In Europe, exactly the reverse happened – there was a convergence because there were many (more than 5) incompatible 1G systems with no clear winner. This caused a major problem for the users (you could not use your telephones while traveling from England to France).European PTT (Post, Telephone and Telegraphic) sponsored development of the now very popular GSM that uses new frequency ranges and complete digital communication. 2G is short for second-generation wireless telephone technology. Second generation 2Gcellular telecom networks were commercially launched on the GSM standard in Finland by Radio linja in 1991. Three primary benefits of 2G networks over their predecessors were that phone conversations were digitally encrypted; 2G systems were significantly more efficient on the spectrum allowing for far greater mobile phone penetration levels; and 2G introduced data services for mobile, starting with SMS text messages. After 2G was launched, the previous mobile telephone systems were retrospectively dubbed 1G. While radio signals on 1G networks are analog, radio signals on 2G networks are digital. Both systems use digital signaling to connect the radio towers (which listen to the handsets) to the rest of the telephone system. 2G has been superseded by newer technologies such as 2.5G, 2.75G, 3G and 4G.however, 2G networks are still used in many parts of the world.The primary differences between first and second generation cellular networks are:

1.Digital traffic channels – first-generation systems are almost purely analog; second generation systems are digital.

2.Encryption – all second generation systems provide encryption to prevent eavesdropping.

3.Error detection and correction – second-generation digital traffic allows for detection and correction, giving clear voice reception.

4. Channel access – second-generation systems allow channels to be dynamically shared by a number of users

Capacity of 2G:

1.Digital voice data can be compressed and multiplexed much more effectively than analog voice encodings through the use of various codecs, allowing more calls to be packed into the same amount of radio bandwidth.

2. The digital systems were designed to emit less radio power from the handsets. This meant that cells had to be smaller, so more cells had to be placed in the same amount of space. This was made possible by cell towers and related equipment getting less expensive.

Advantages of 2G:

1.The lower power emissions helped address health concerns.

2. Going all-digital allowed for the introduction of digital data services, such as SMS and email.

3. Greatly reduced fraud: With analog systems it was possible to have two or more "cloned" handsets that had the same phone number.

4. Enhanced privacy: A key digital advantage not often mentioned is that digital cellular calls are much harder to eavesdrop on by use of radio scanners. While the security algorithms used have proved not to be as secure as initially advertised, 2G phones are immensely more private than 1G phones, which have no protection against eaves dropping.

Disadvantages of 2G:

1.In less populous areas, the weaker digital signal may not be sufficient to reach a cell tower. This tends to be a particular problem on 2G systems deployed on higher frequencies, but is mostly not a problem on 2G systems deployed on lower frequencies. National regulations differ greatly among countries which dictate where 2G can be deployed.

2.Analog has a smooth decay curve, digital a jagged steppy one. This can be both an advantage and a disadvantage. Under good conditions, digital will sound better. Under slightly worse conditions, analog will experience static, while digital has occasional dropouts. As conditions worsen, though, digital will start to completely fail, by dropping calls or being unintelligible, while analog slowly gets worse, generally holding a call longer and allowing at least a few words to get through.

3. While digital calls tend to be free of static and background noise, the lossy compression used by the codecs takes a toll; the range of sound that they convey is reduced. You will hear less of the tonality of some ones voice talking on a digital cell phone, but you will hear it more clearly.

GSM (Global System for Mobile Communications)–

The Popular 2G System: Although there are many competing technologies in the 2G cellular network landscape, GSM by far dominates the world today, with over 200 million users in over a hundred countries. GSM is very popular in Europe and is now gaining popularity in the US also. These networks operate at 9.6 Kbps and are based on international standards defined by the European Telecommunications Standards Institute (ETSI). Due to the popularity of GSM, let us look at GSM somewhat closely. GSM is completely designed from scratch (there is no backward compatibility with 1Gsystems such as AMPS). It can deliver data rate up to 9.6 Kbps by using 124 channels per cell; each channel can support 8 users through TDMA (maximum 992 users per cell, in practice about500). Some GSM channels are used for control signals for mobile units to locate the nearest base stations. In addition to voice, GSM phones provide data services for wireless users; i.e., you connect your GSM phone to your PC and it acts as a modem for email, fax, Internet browsing, etc. GSM also permits roaming between North American countries and European countries. To make it work, because of the frequency differences, you have to remove the user-specific SIM card from inside the American network's phone and place it into a European network's phone, or vice-versa. GSM's air interface is based on narrowband TDMA technology, where available frequency bands are divided into time slots, with each user having access to one time slot at regular intervals. Narrowband TDMA allows eight simultaneous communications on a single radio multiplexer and is designed to support 16 half-rate channels.

<u>GSM Network Architecture</u>: The architecture of GSM network defines several interfaces for multiple suppliers. The key players of this architecture are shown in Figure .

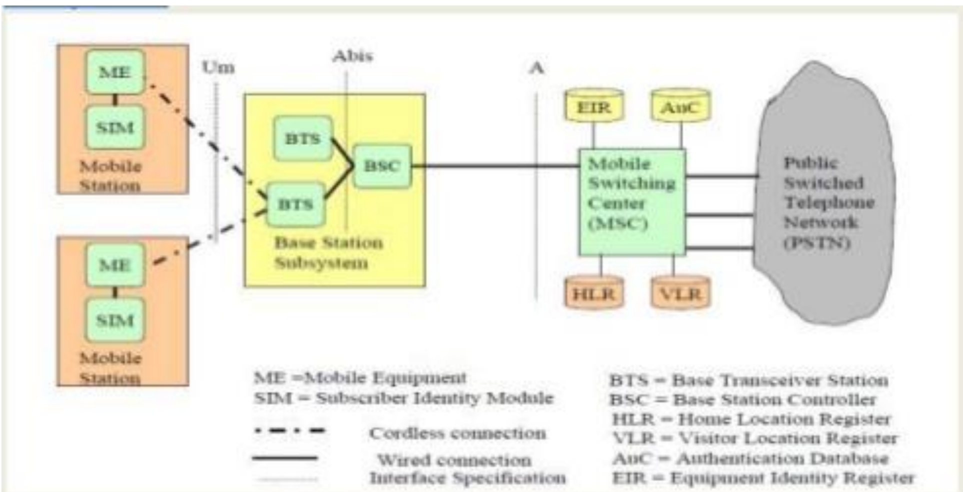


Fig: GSM Network Architecture

Mobile station (MS):

It represents the mobile user and communicates across the Um interface (air interface) with a base station transceiver in the same cell as the MS. The main part of MS is mobile equipment (ME) that represents physical terminals, such as a telephone or PDA. An ME includes a radio transceiver, a digital signal processor, and a subscriber identity module (SIM).GSM subscriber units are generic until SIM is inserted. SIMs are used to support roaming, as indicated previously.

Base Station Subsystem (BSS):

It consists of a base station controller (BSC) and one or more base transceiver stations (BTS). Each BTS defines a single cell and includes radio antenna, radio transceiver and a link to a base station controller (BSC). BSC reserves radio frequencies, manages handoff of mobile units from one cell to another within BSS, and controls paging. Mobile Switching Center (MSC): It is the nerve center of GSM. It provides links between cellular networks and public switched telecommunications networks. Specifically, an MSC controls handoffs between cells in different BSSs, authenticates users and validates accounts, and enables worldwide roaming of mobile users. To support these features, an MSC consists of the following databases:

1.Home location register (HLR) database – stores information about each subscriber that belongs to it.

2. Visitor location register (VLR) database – maintains information about subscribers physically in the region currently.

3.Authentication center database (AuC) – used for authentication activities and holds encryption keys.

4. Equipment identity register database (EIR) – keeps track of the type of equipment that exists at the mobile station. A number of control messages are exchanged between the key entities in the GSM architecture. These messages are used to support mobility and connection management. Figure shows the GSM Protocol Architecture. The protocols, as can be seen, follow the typical 7-layer model, where the lower layers provide transport over radio links (between the mobile station and BTSs) and wired packet-switching network (between BTSs and MSCs).

Protocols above the link layer of the GSM signaling protocol architecture provide specific functions such as the following:

1. Connection management connects end users (mobile stations) to the MSC or to other end users. These protocols, at layer 6 of the protocol stack, are used when you dial a number, for example, from your phone to another mobile or wired phone.

2. Mobility management provides location services and security controls. These protocols are supported at the layer 5 of the protocol stack.

3.Mobile application part (MAP) is used between HLR and VLR to provide updates as the users move around. These layer 4 protocols are used between an MSC and a BSC.

4.Radio resource management is used to control setup, termination and handoffs of radio channels. For example, all communications between your cellular phone and the base station are managed by using these layer 3 protocols.

5.BTS management is used for management of the base transceiver system also at layer 3 .

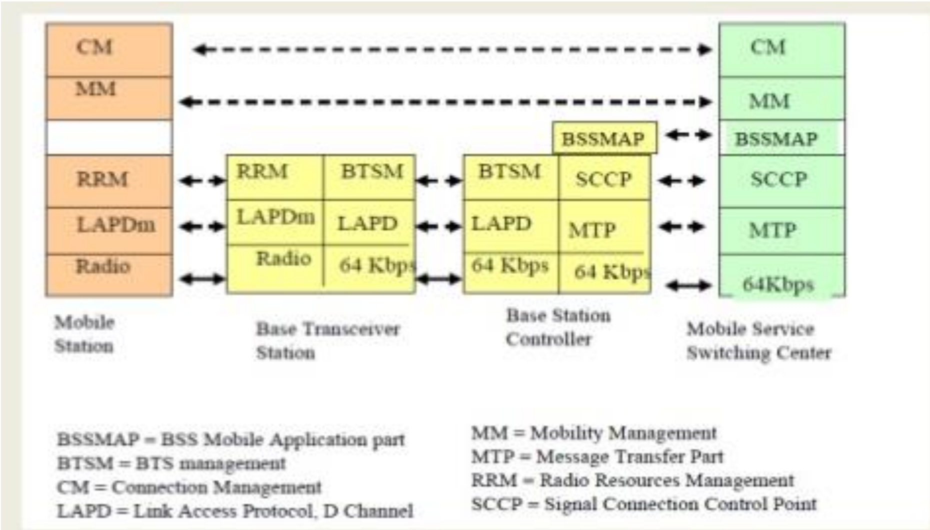


Fig: GSM Protocol

2G CDMA (IS-95):

While some systems have appeared, IS-95 is the best-known example of 2G with CDMA. Recall that in the case of CDMA, each user is assigned a unique code that differentiates one user from others. This is in contrast to TDMA where each user is assigned a time slot. There are several advantages of CDMA for cellular networks. The main advantage of CDMA is that many more users (up to 10 times more) can be supported as compared to TDMA. Although this leads to some complications, the advantage of supporting more users far outweighs the disadvantage of added complexity. The IS-95 cellular system has different structures for its forward (base station to mobile station) and backward links. The forward link consists of up to 64 logical CDMA channels, each occupying the same 1228 kHz bandwidth.

The forward channel supports different types of channels:

1. Traffic channels (channels 8 to 31 and 33 to 63) – these 55 channels are used to carry the user traffic (originally at 9.6 Kbps, revised at 14.4 Kbps).
2. Pilot (Channel 0) – used for signal strength comparison, among other things, to determine handoffs Synchronization (Channel 32) – a 1200 bps channel used to identify the cellular system (system time, protocol revision, etc.). Paging (channels 1 to 7) – messages for mobile stations All these channels use the same frequency band – the chipping code (a 64-bit code) is used to distinguish between users. Thus 64 users can theoretically use the same band by using different codes. This is in contrast to TDMA where the band has to be divided into slots – one slot per user. The voice and data traffic is encoded, assigned a chipping code, modulated and sent to its destination. The data in the reverse travels on the IS-95 reverse links. The reverse links consist of up to 94 logical CDMA channels, each occupying the 1228 kHz bandwidth. The reverse link supports up to 32 access channels and up to 62 traffic channels. The reverse links support many mobile unit-specific features to initiate calls, and to update location during handoffs. The overall architecture of 2G CDMA-based systems are

similar to the TDMA-based GSM systems (see Figure 4). The main difference is that the radio communication between the Base Station Subsystem and Mobile System uses CDMA instead of TDMA. Of course, the MSC now has to worry about handling soft handoffs, but the overall structure stays the same.

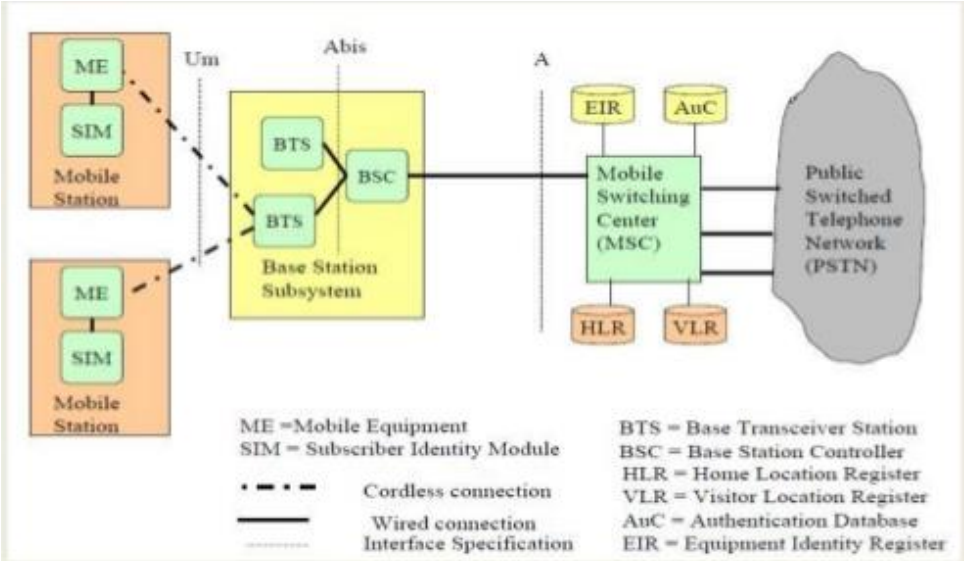


Fig: 2G CDMA (IS-95) Network Architecture

CDMA Versus TDMA:

There are conflicting performance claims for CDMA and TDMA. The debate is raging because hardware vendors have chosen sides and consequently the standardizing bodies have been lobbied hard. The primary motivation for this level of debate is that vendors want their selection to become the industry standard. Since both TDMA and CDMA have become TIA (Telecom Industry Association) standards – IS-54 and IS-95, respectively – the debate goes on to determine which standard is better. Technically speaking, CDMA has the following advantages over TDMA.
Network capacity: In CDMA, the same frequency can be reused in adjacent cells because the user signals differentiate from each other by a code. Thus frequency reuse can be very high and many more users (up to 10 times more) can be supported as compared to TDMA.

Privacy:Privacy is inherent in CDMA since spread spectrum modulates data to signals randomly (you cannot understand the signal unless you know the randomizing code).

Reliability and graceful degradation: CDMA-based networks only gradually degrade as more users access the system. This is in contrast to the sudden degradation of TDMA based systems. For example, if the channel is divided between ten users, then the eleventh user can get a busy signal in a TDMA system. This is not the case with CDMA because there is no hard division of channel capacity – CDMA can handle users as long as it can differentiate between them. In case of CDMA, the noise and interference increases gradually as more users are added because it becomes harder to differentiate between various codes.

Frequency diversity: CDMA uses spread spectrum, thus transmissions are spread over a larger frequency bandwidth. Consequently, frequency-dependent transmission impairments that occur in certain frequency ranges have less effect on the signal.

Environmental: Since existing cells can be upgraded to handle more users, the need for new cell towers decreases.
But, there are some drawbacks of CDMA cellular also:

Relatively immature: As compared to TDMA, CDMA is a relatively new technology but it is catching up fast. Self-jamming: CDMA works better if all mobile users are perfectly aligned on chip (code) boundaries. If this is not the case, then some interference can happen. This situation is better with TDMA and FDMA because time and frequency guard bands can be used to avoid the overlap.

Soft handoff:An advantage of CDMA is that it uses soft handoff (i.e., two cells can own a mobile user for a while before the handoff is complete). However, this requires that the mobile user acquires the new cell before it relinquishes the old – a more complex process than hard handoff used in FDMA and TDMA schemes. The main advantage of CDMA is that the frequency reuse can be very high and many more users can be supported in a cell as compared to TDMA. Although this leads to a soft handoff that is more complicated than the hard handoff used in TDMA, the advantage of supporting more users far outweighs the disadvantage of added complexity.

2.5G Networks (GPRS):

2.5 G wireless cellular networks have been developed as a transition path to 3G.Examples of these networks are GPRS and EDGE. These systems build packet-switching systems on top of existing 2G systems to improve data rates significantly. GPRS (General Packet Radio Service): GSM networks offer circuit-switched data services at 9.6 Kbps. Most GSM carriers are developing a service called General Packet Radio Service (GPRS), a 2.5G technology. GPRS can theoretically provide IP-based packet data speeds up to a maximum of 160 Kbps. However, typical GPRS networks operate at lower data rates. One proposed configuration is 80 Kbps maximum (56 Kbps typical) for the downlink and 20 Kbps maximum (14.4 Kbps typical) for the uplink. GPRS supports both IP and X.25 networking. GPRS can be added to GSM infrastructures quite readily. It takes advantage of existing200 kHz radio channels and does not require new radio spectrum. GPRS basically overlays a packet switching network on the existing circuit switched GSM network. This gives the user an option to use a packet-based data service. An architectural view of GPRS is presented in Figure .

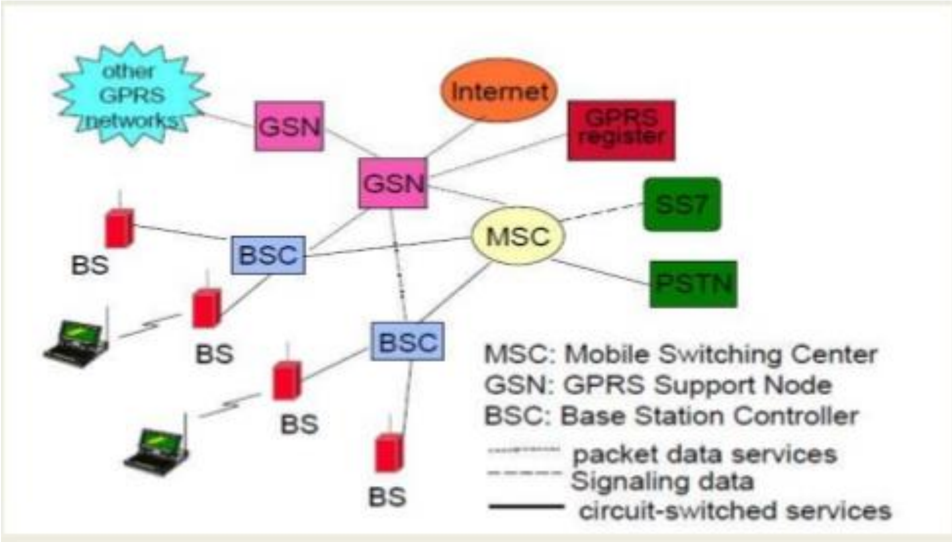


Fig: Architectural view of GPRS

The main component of a GPRS network is the GSN (GPRS Support Node) that receives the packet data and transfers it to the Internet or other GPRS networks. To provide GPRS services on top of GSM, the network operators need to add a few GSNs and make a software upgrade to BSCs and few other network elements. This quick upgrade capability has fueled the popularity of GPRS.

GPRS capability has been added to cell phones, and is also available in data-only devices such as PC card modems. Pricing is either flat rate or based on the volume of information communicated. GPRS is appealing because it offers higher data rates and also allows, because of packet services, constant "virtual" connections without the need to constantly "dial" into the network. The "always-on", higher capacity, GPRS networks are very suitable for Internet based content and packet-based data services. We can do Web browsing, email, and file transfer over a GPRS enabled phone. To use GPRS, users specifically need a mobile phone or terminal that supports GPRS (existing GSM phones do not support GPRS necessarily) and a subscription to a mobile telephone network that supports GPRS.

2.75G Networks (EDGE):

The phase after GPRS is called Enhanced Data Rates for GSM Evolution (EDGE).EDGE, generally considered a 3G technology, introduces new methods at the physical layer, including a new form of modulation (8 PSK) and different ways of encoding data to protect against errors. But the higher layer protocols stay the same. Thus EDGE can deliver maximum data rates up to 500 Kbps using the same GPRS infrastructure (practical throughputs may be only half the maximum rate).

EDGE has been designed to address some of the limitations of GPRS. For example, GPRS impacts a network's existing cell capacity because voice and GPRS calls both use the same network resources. The extent of the impact depends upon the number of timeslots, if any, that are reserved for exclusive use of GPRS. In addition, GPRS actual data rates are much lower than advertised. Specifically, achieving the theoretical maximum GPRS data transmission speed of 172.2 Kbps would require a single user taking over all eight timeslots without any error protection. Finally, GPRS is based on a modulation technique known as Gaussian minimum-shift keying (GMSK). EDGE is based on the eight-phase-shift keying (8 PSK) modulation that allows a much higher bit rate across the air interface. Since 8 PSK is also used in 3G, network operators need to incorporate it at some stage to make the transition to third generation mobile phone systems.

Third Generation Network (3G) –

Internet System: 3G or 3rd generation mobile telecommunications is a generation of standards for mobile phones and mobile telecommunication services fulfilling the International Mobile Telecommunications-2000 (IMT-2000) specifications by the International Telecommunication Union. Application services include wide-area wireless voice telephone, mobile Internet access, video calls and mobile TV, all in a mobile environment. The first pre-commercial 3G network was launched by NTT DoCoMo in Japan on 1998, branded as FOMA. India entered the 3G arena with the launch of 3G enabled Mobile and Data services by Government owned Mahanagar Telephone Nigam Ltd MTNL in Delhi and later in Mumbai. MTNL becomes the first 3G Mobile service provider in India. After MTNL, another state operator Bharat Sanchar Nigam Ltd. (BSNL) launched 3G services on 22 Feb 2009 in Chennai and later launched 3G as Nationwide. The auction of 3G wireless spectrum was announced in April 2010 and 3G Spectrum allocated to all private operators on 1 September 2010. The first Private-sector service provider that launched 3G services is Tata DoCoMo, on November 5, 2010. And the second is by Reliance Communications, December 13, 2010. Vodafone Launched their 3G by mid of March, 2011. Then, Bharti Airtel launched their 3Gservices on 24 January 2011 in Bangalore and also launched in Delhi & Jaipur on March 4, 2011(not GSM but only USB e stick). Aircel also launched 3G in Kolkata in the month of February. Idea also launched its 3G services in mid April. All the operators provide 3G services on the 2100 MHz band.

The private operators like IDEA and Reliance are increasing their 3G coverage as well as the number of subscribers. The third-generation (3G) vision is to create a unified global set of standards requirements that could lead to the commercial deployment of advanced multimedia wireless communications. The goal of 3G systems is to enable wireless service providers to offer services found on today's wire line networks. 3G is not one standard; it is a family of standards which can all work together. This is the main reason why there are too many terms and standards in the 3G space. The goal of 3G wireless systems was to provide wireless data service with data rates of144kbps to 384kbps in wide coverage areas, and 2Mbps in local coverage areas. Possible applications included wireless web-based access, E-mail, as well as video teleconferencing and multimedia services consisting of mixed voice and data streams. After ten years of development, IMT-2000 (International Mobile Telecommunications-2000) has accepted a new 3G standard from China, i.e. TD-SCDMA. Thus, there are new three 3G cellular network standards. They are CDMA2000 from America, WCDMA from Europe and TD-SCDMA from China. The best known example of 3G is the UMTS (Universal Mobile Telecommunications System) – an acronym used to describe a 3G system that originated in Europe and is being used elsewhere. In fact, several analysts claim that UMTS-3G. The overall idea is that UMTS users will be able to use 3G technology all over the world under different banners. This roaming ability to use devices on different networks will be made possible by satellite and land based networks. UMTS provides a consistent service environment even when roaming via “Virtual Home Environment” (VHE). A person roaming from his network to other UMTS operators experiences a consistent set of services, independent of the location or access mode (satellite or terrestrial).

Whatever the name, 3G is designed to raise the data rate to 2 megabits per second (2Mbps) – a much higher rate than 2G and 2.5G. Specifically, 3G systems offer between 144 Kbps to 384 Kbps for high-mobility and high coverage, and 2 Mbps for low-mobility and low coverage applications. In other words, 3G systems mandate data rates of 144 Kbps at driving speeds, 384 Kbps for outside stationary use or walking speeds, and 2 Mbps indoors. However, the indoor rate of 2 Mbps from 3G competes with high-speed 802.11 wireless LANs that offer data rates of 11 to 54 Mbps. The main attraction of 3G is the 384 Kbps data rate for outdoor use as an IP-based packet-switching service over wide areas. This service can support wireless Internet access over very wide geographical areas. 3G systems are based on packet switching instead of the older circuit-switching systems used in 2G. In 2G cellular networks, most data communication, apart from the Short Message Service (SMS), requires a circuit-switched connection in which a user must connect to a server to check email, for example. The main limitation of this approach is that the users have to be online even when they are not sending data, so they pay higher costs and network capacity is wasted. 3G networks use a connectionless (packet-switched) communications mechanism. Data are split into packets to which an address uniquely identifying the destination is appended. This mode of transmission, in which communication is broken into packets, allows the same data path to be shared among many users in the network. By breaking data into smaller packets that travel in parallel on different channels, the data rate can be increased significantly. For example, splitting a message into 6 packets can theoretically increase data rate six times (e.g. from 9.6Kbps to 56 Kbps, roughly). In addition, users can stay online throughout and yet not be charged for the time spent online. Rather, they only pay for the amount of data that they retrieve. This is in contrast to a circuit-switched network like the regular voice telephone network where the communication path is dedicated to the callers, thus blocking that path to other users for that period of time. This means that although a 3G handset is, in effect, permanently connected to the network, it only uses bandwidth when needed. 3G has evolved from 2G and is built on the success of GSM (GSM, GSM1800 andGSM1900). Dual-mode terminals ease migration from 2G to 3G. Although many options for 3G exist, the radio technology in 3G will likely be Wideband CDMA (Collision detect multiple access). This is similar to local area network technologies such as Ethernet. In the US, CDMA2000 will be used (this is similar to Wideband CDMA but backward compatible with IS-95).

MMS - The Main Driver for 3G: While different applications are being envisioned for 3G, MMS (Multimedia Message Service) is getting the most attention. From an end-user point of view, MMS is the same as SMS (Short Message Service) but with pictures. Let us examine the possible role of MMS in 3Gcellular networks. Several 3G cellular providers, such as Ericsson, are counting on MMS to drive the 3Gdevelopments because it is difficult to satisfy MMS requirements with 2G networks. Ericsson has an estimated 40% market share and more than 50% of the global subscriber base of MMS. Delivery of MMS services over 3G requires developments in handsets, infrastructure, content, and systems integration. Examples of the MMS applications include push messaging, automated data-generated graphics, picture messaging, cartoon delivery, and enhanced dating service including photos. Some operators such as the Telecom Italia Mobile are offering access to information on Italian football matches, TV program vignettes and Disney animated cards as part of its mobile multimedia services. Another MMS application uses the latest traffic-status information and knowledge of location to generate a map of the quickest route to a destination.

IEEE 802.11 versus 3G Cellular:

Although 3G cellular networks are getting a great deal of attention, the 802.11 WLANs are proving to be a tough competitor to 3G. In the very best case, 3G networks are supposed to deliver around 2 Mbps in an office environment. This is in no way competition for 802.11 networks that can deliver from 11 Mbps to 54 Mbps. For data applications such as Web browsing, remote database access and software downloads, 802.11 is far superior to 3G. In addition to slower data rates, Web browsing on cellular phones requires use of special protocols such as Wireless Application Protocol (WAP) and markup languages such as Wireless Markup Language (WML). In short, viewing Web pages with 3G is inherently inferior to doing so with 802.11 LANs. But 3G cellular networks are well suited for applications like instant messaging (IM), Short Messaging Service (SMS), or Multimedia Messaging Service (MMS). However, IM is not straightforward – you cannot send messages from IM to someone using MMS or SMS on a digital phone without a special gateway between the SMS/MMS servers and IM clients. A very attractive alternative to 3G are the 802.11 hotspots that connect 802.11 LANs to wired networks at airports, Internet cafes, shopping malls and coffee shops. While 802.11 hotspots have far less range than 3G, they are much cheaper to set up. In addition, anyone can set up a hotspot but only a telephone carrier or corporation can afford 3Gbase station. In short, 802.11 WLANs are easier to install and cost far less than setting up a 3Gnetwork. In addition, 3G's fastest data rate of 2 Mbps is slow compared to the slowest data rate of 802.11's 11 Mbps. As 802.11 WLANs move toward 54 Mbps, it is apparent that 3G cannot compete with the data rate of WLAN. Another difficulty is that the WLAN industry is growing at a stellar rate while 3G deployments have been slowed down considerably due to infrastructure costs. In some sense, the growth of WLANs is coming at 3G's expense. In reality, many of the3G providers including T-Mobile, AT&T, and Verizon have made announcements about deploying WLAN services as their 3G plans are delayed. But the limitations of 802.11 should be also noted. 3G cellular phone network cells can transmit from 5 to 6 miles in diameter. Compare this to 802.11 access points which range only between 300 to 900 feet. Thus you will need millions of 802.11 based access points to cover a metropolitan area. Due to this, "hybrid wireless networks" that support hot spots and are connected through 3G or other networks make more sense. The success of 802.11 versus 3G is also leading to interesting new developments. For example, Cisco has announced an 802.11 telephone that supports Voice Over IP (VOIP) over WLANs. This not good news for 3G. Many MMS applications for 3G are being built on top of existing popular services by adding images and audio to basic text services. As 3G makes higher bandwidth applications possible, more applications will be developed.

WCDMA-3G

3G wireless service has been designed to provide high data speeds, always-on data access, and greater voice capacity. Listed below are a few notable points −

- The high data speeds, measured in Mbps, enable full motion video, high-speed internet access and video-conferencing.

- 3G technology standards include UMTS, based on WCDMA technology (quite often the two terms are used interchangeably) and CDMA2000, which is the outgrowth of the earlier CDMA 2G technology.
- UMTS standard is generally preferred by countries that use GSM network. CDMA2000 has various types, including 1xRTT, 1xEV-DO and 1xEV-DV. The data rates they offer range from 144 kbps to more than 2 mbps.

Sub-systems of 3G Network

A GSM system is basically designed as a combination of three major subsystems −

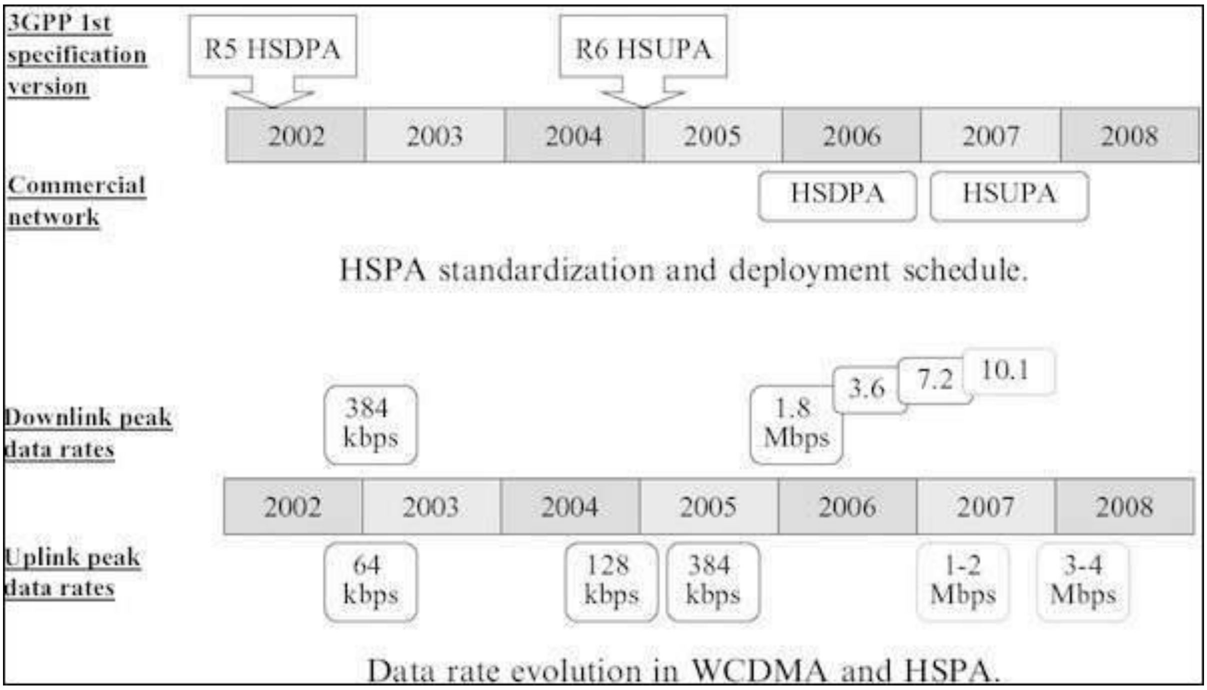
- **Network Subsystem (NSS)** − MSC/VLR, HLR, AuC, SMSC, EIR, MGW. Common for both 2G & 3G Network.
- **UTRAN** − RNC & RBS.
- Operation and maintenance Support Subsystem (OSS).

There are three dominant interfaces, namely,

- **IuCS** − Between RNC and MSC for speech & Circuit data;
- **IuPS** − Between RNC & SGSN for packet data;
- **Uu interface** − Between the RNC and MS.

Let's look at the standardization and deployment schedule of HSPA in brief −

- High-speed downlink packet access (HSDPA) was standardized as part of 3GPP Release 5 with the first specification version in March 2002.
- High-speed uplink packet access (HSUPA) was part of 3GPP Release 6 with the first specification version in December 2004.
- HSDPA and HSUPA together are called High-Speed Packet Access’ (HSPA).
- The first commercial HSDPA networks were available at the end of 2005 and the commercial HSUPA networks were available on 2007.
- The HSDPA peak data rate available in the terminals is initially 1.8Mbps and will increase to 3.6 and 7.2 Mbps during 2006 and 2007, and later on 10Mbps and beyond 10Mbps.
- The HSUPA peak data rate in the initial phase was 1–2 Mbps and the second phase was 3–4Mbps.



HSPA is deployed over the WCDMA network on the same carrier or - for high capacity and high speed solution - using another carrier, see figure above. In both cases, WCDMA and HSPA can share all the network elements in the core network and the radio network comprising base stations, radio network controller (RNC), Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN). WCDMA and HSPA also share the site base station antennas and antenna cables.

The upgrade WCDMA HSPA requires new software and potentially new equipment in the base station and RNC to support the rate and higher data capacity. Because of the shared infrastructure between WCDMA and HSPA, the cost of the upgrade WCDMA HSPA is very low compared to the construction of a new stand-alone data network.

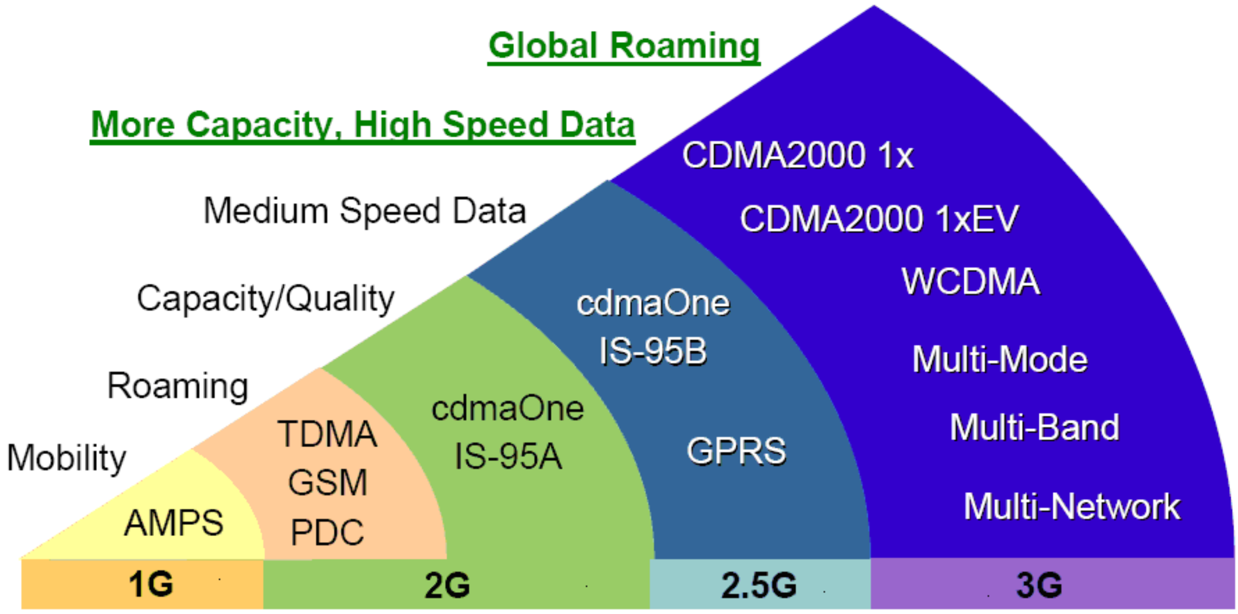


Fig: 1G to 3G journey

Fourth Generation (4G Networks) –

Integration System: In telecommunications, 4G is the fourth generation of cellular wireless standards. It is a successor to the 3G and 2G families of standards. In 2009, the ITU-R organization specified the IMT-Advanced (International Mobile Telecommunications Advanced) requirements for 4Gstandards, setting peak speed requirements for 4G service at 100 Mbit/sec for high mobility communication (such as from trains and cars) and 1 Gbit/sec for low mobility communication (such as pedestrians and stationary users). One of the key technologies for 4G and beyond is called Open Wireless Architecture (OWA), supporting multiple wireless air interfaces in an open architecture platform. A 4G system is expected to provide a comprehensive and secure all-IP based mobile broadband solution to laptop computer wireless modems, smartphones, and other mobile devices. Facilities such as ultra-broadband Internet access, IP telephony, gaming services, and streamed multimedia may be provided to users. In mid 1990s, the ITU-R organization specified the IMT-2000 specifications for what standards that should be considered 3G systems. In 2008, ITU-R specified the IMT-Advanced (International Mobile Telecommunications Advanced) requirements for 4Gsystems. IMT-Advanced compliant versions of LTE and Wi MAX are under development and called "LTE Advanced" and "Wireless MAN-Advanced" respectively. On December 6, 2010, ITU recognized that current versions of LTE, Wi Max and other evolved 3G technologies that do not fulfill "IMT-Advanced" requirements could nevertheless be considered "4G", provided they represent forerunners to IMT-Advanced and "a substantial level of improvement in performance and capabilities with respect to the initial third generation systems now deployed." In all suggestions for 4G, the CDMA spread spectrum radio technology used in 3G systems and IS-95 is abandoned and replaced by OFDMA and other frequency-domain equalization schemes. This is combined with MIMO (Multiple In Multiple Out), e.g. , multiple antennas, dynamic channel allocation and channel-dependent scheduling. The 4G mobile system is an all IP-based network system. The features of 4G may be summarized with one word- integration. 4G technology should integrate different current existing and future wireless network technologies (e.g. OFDM, MC-CDMA, LAS-CDMA and Network-LMDS) to ensure freedom of movement and seamless roaming from one technology to another. These will provide multimedia applications to mobile users by accessing different technologies in a continuous and always best connection possible. 4G networks can integrate several radio access networks with fixed internet networks as the backbone. A core interface sits in between core network and radio access networks, and a collection of radio interfaces is used for communication between the radio access networks and mobile users. This kind of integration combines multiple radio access interfaces into a single network to provide seamless roaming/handoff and the best connected services.

	3G	4G
Major Requirement Driving Architecture	Predominantly voice driven-data was always add on	Converged data and voice over IP
Network architecture	Wide area cell based	Hybrid–integration of wireless LAN and wide area
Speed	384 Kbps to 2 Mbps	20 to 100 Mbps in mobile mode
Frequency Band	1800-2400 MHz	Higher frequency bands (2-8 GHz)
Switching Design Basis	Circuit and Packet	All digital with packetized voice
Access Technologies	W-CDMA,	OFDM and MC-CDMA (Multi Carrier CDMA)
Component Design	Optimized antenna design, multi-band adapters	Smarter Antennas, software multilane and wideband radios
IP	A number of air link protocols, including IP 5.0	All IP (IP6.0)

Figure (8): Comparison of 3G and 4G.

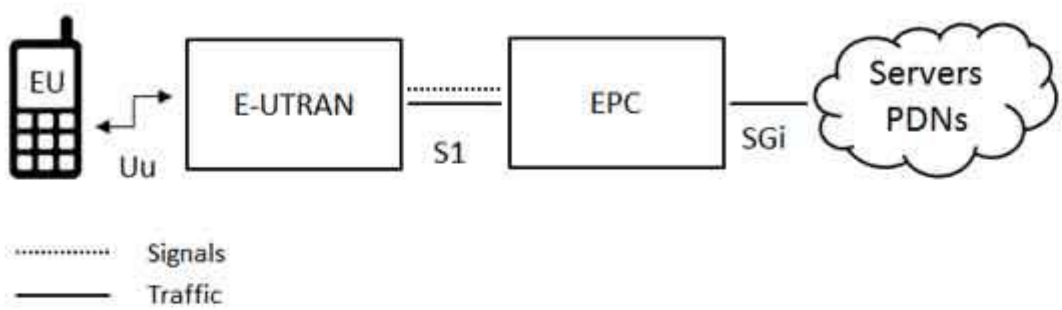
The wireless telecommunications industry as a whole has early assumed the term 4G as a short hand way to describe those advanced cellular technologies that, among other things, are based on or employ wide channel OFDMA and SC-FDE technologies, MIMO transmission and an all-IP based architecture. Mobile-Wi MAX, first release LTE, IEEE 802.20 as well as Flash-OFDM meets these early assumptions, and have been considered as 4G candidate systems, but do not yet meet the more recent ITU-R IMT-Advanced requirements.

4G Architecture

The high-level network architecture of LTE is comprised of following three main components:

- The User Equipment (UE).
- The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN).
- The Evolved Packet Core (EPC).

The evolved packet core communicates with packet data networks in the outside world such as the internet, private corporate networks or the IP multimedia subsystem. The interfaces between the different parts of the system are denoted Uu, S1 and SGi as shown below:



The User Equipment (UE)

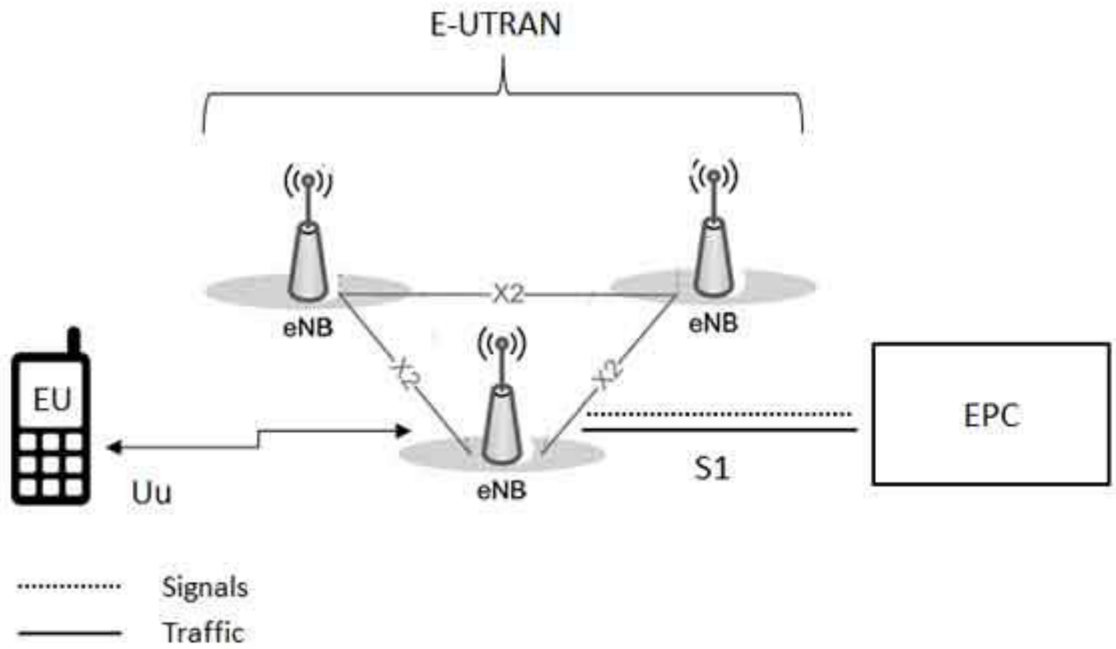
The internal architecture of the user equipment for LTE is identical to the one used by UMTS and GSM which is actually a Mobile Equipment (ME). The mobile equipment comprised of the following important modules:

- **Mobile Termination (MT)** : This handles all the communication functions.
- **Terminal Equipment (TE)** : This terminates the data streams.
- **Universal Integrated Circuit Card (UICC)** : This is also known as the SIM card for LTE equipments. It runs an application known as the Universal Subscriber Identity Module (USIM).

A **USIM** stores user-specific data very similar to 3G SIM card. This keeps information about the user's phone number, home network identity and security keys etc.

The E-UTRAN (The access network)

The architecture of evolved UMTS Terrestrial Radio Access Network (E-UTRAN) has been illustrated below.



The E-UTRAN handles the radio communications between the mobile and the evolved packet core and just has one component, the evolved base stations, called **eNodeB** or **eNB**. Each eNB is a base station that controls the mobiles in one or more cells. The base station that is communicating with a mobile is known as its serving eNB.

LTE Mobile communicates with just one base station and one cell at a time and there are following two main functions supported by eNB:

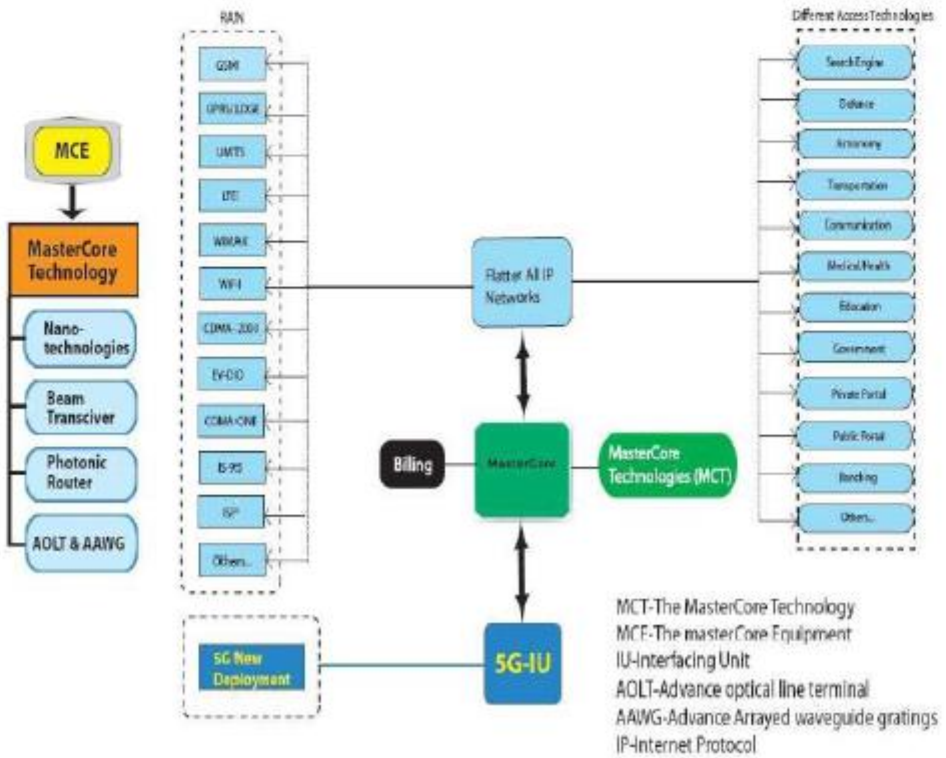
- The eBN sends and receives radio transmissions to all the mobiles using the analogue and digital signal processing functions of the LTE air interface.
- The eNB controls the low-level operation of all its mobiles, by sending them signalling messages such as handover commands.

Each eBN connects with the EPC by means of the S1 interface and it can also be connected to nearby base stations by the X2 interface, which is mainly used for signalling and packet forwarding during handover.

A home eNB (HeNB) is a base station that has been purchased by a user to provide femtocell coverage within the home. A home eNB belongs to a closed subscriber group (CSG) and can only be accessed by mobiles with a USIM that also belongs to the closed subscriber group.

The Evolved Packet Core (EPC) (The core network)

The architecture of Evolved Packet Core (EPC) has been illustrated below. There are few more components which have not been shown in the diagram to keep it simple. These components are like the Earthquake and Tsunami Warning System (ETWS), the Equipment Identity Register (EIR) and Policy Control and Charging Rules Function (PCRF).



Below is a brief description of each of the components shown in the above architecture:

- The Home Subscriber Server (HSS) component has been carried forward from UMTS and GSM and is a central database that contains information about all the network operator's subscribers.
- The Packet Data Network (PDN) Gateway (P-GW) communicates with the outside world ie. packet data networks PDN, using SGi interface. Each packet data network is identified by an access point name (APN). The PDN gateway has the same role as the GPRS support node (GGSN) and the serving GPRS support node (SGSN) with UMTS and GSM.
- The serving gateway (S-GW) acts as a router, and forwards data between the base station and the PDN gateway.
- The mobility management entity (MME) controls the high-level operation of the mobile by means of signalling messages and Home Subscriber Server (HSS).
- The Policy Control and Charging Rules Function (PCRF) is a component which is not shown in the above diagram but it is responsible for policy control decision-making, as well as for controlling the flow-based charging

functionalities in the Policy Control Enforcement Function (PCEF), which resides in the P-GW.

The interface between the serving and PDN gateways is known as S5/S8. This has two slightly different implementations, namely S5 if the two devices are in the same network, and S8 if they are in different networks.

Fifth Generation (5G Network):

5G (5th generation mobile networks or 5th generation wireless systems) is the next major phase of mobile telecommunications standards beyond the current 4G LTE (Long-Term Evolution) standards. 5G technology needs to be specified, developed, and deployed by a variety of industry players including network equipment vendors, network operators, semiconductor vendors, and device manufacturers. The scope of 5G will range from mobile phones to next-generation automobiles.

By providing higher bandwidth capacity than current 4G–supporting broadband, 5G will enable a higher density of mobile broadband users and support ultra reliable device-to-device and massive machine-type communications.

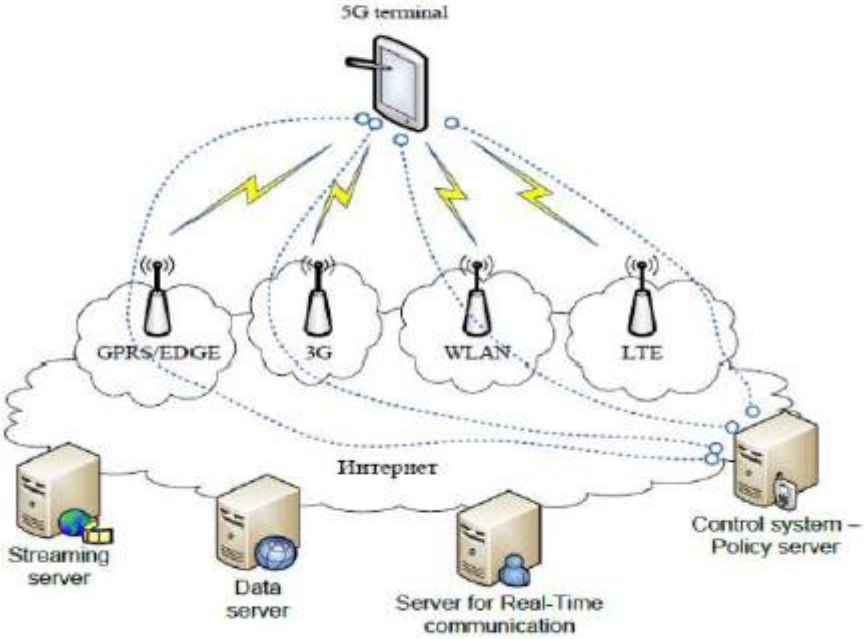
5G is also advanced in terms of −

- High increased peak bit rate
- Larger data volume per unit area (i.e. high system spectral efficiency)
- High capacity to allow more devices connectivity concurrently and instantaneously
- Lower battery consumption
- Better connectivity irrespective of the geographic region, in which you are
- Larger number of supporting devices
- Lower cost of infrastructural development
- Higher reliability of the communications

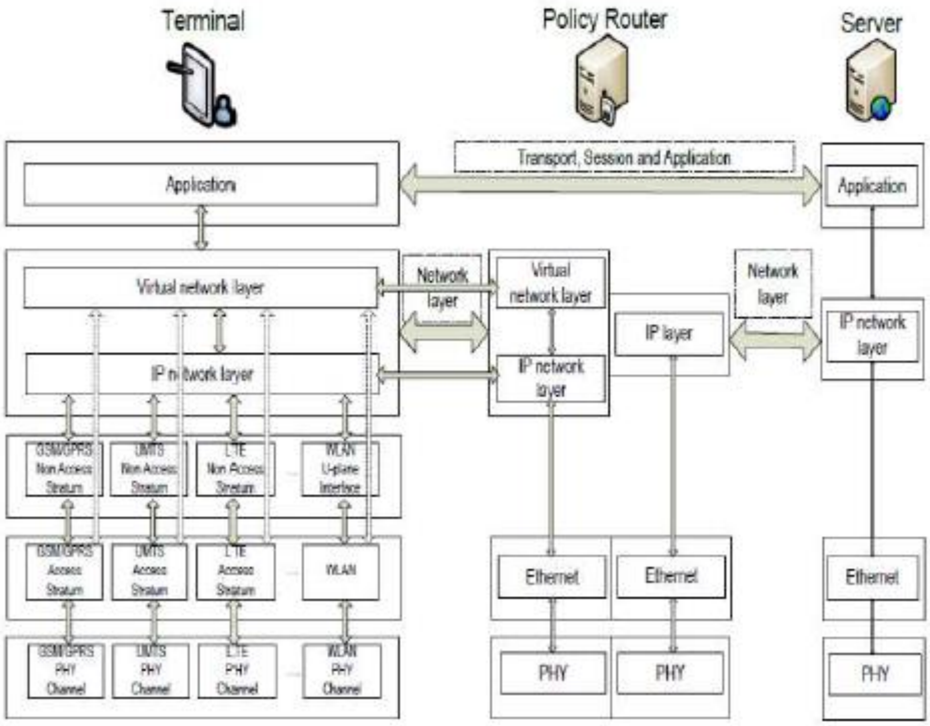
With the wide range of bandwidth radio channels, it is able to support the speed up to 10 Gbps, the 5G WiFi technology will offer contiguous and consistent coverage − “wider area mobility in true sense.”

Architecture of 5G is highly advanced, its network elements and various terminals are characteristically upgraded to afford a new situation. Likewise, service providers can implement the advance technology to adopt the value-added services easily.

The system model of 5G is entirely IP based model designed for the wireless and mobile networks.

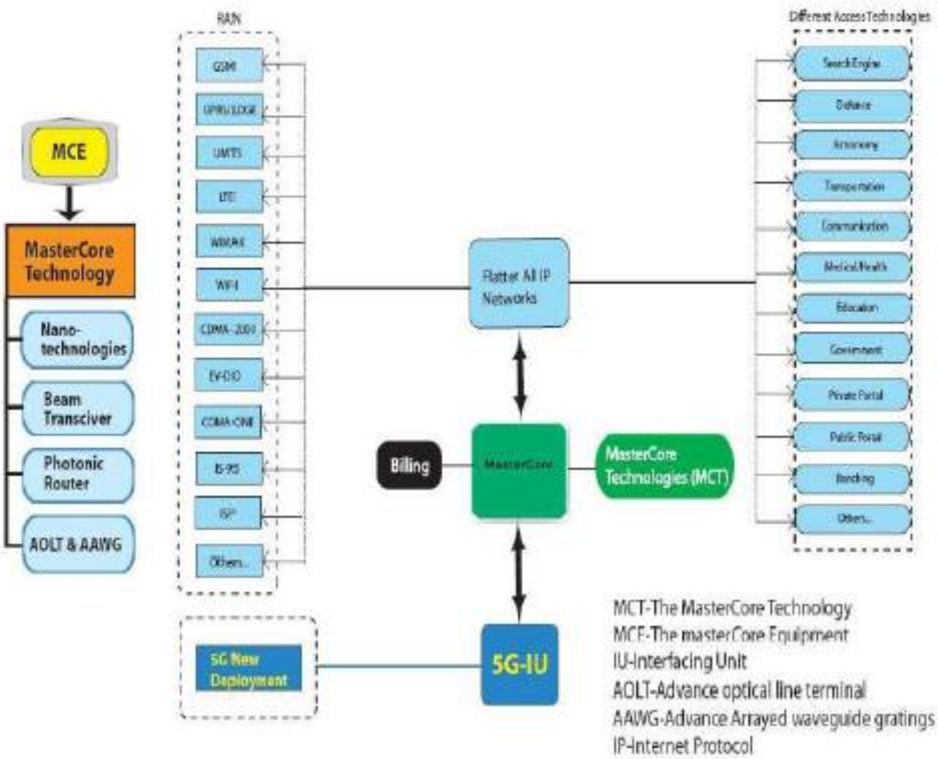


The system comprising of a main user terminal and then a number of independent and autonomous radio access technologies. Each of the radio technologies is considered as the IP link for the outside internet world. The IP technology is designed exclusively to ensure sufficient control data for appropriate routing of IP packets related to a certain application connections i.e. sessions between client applications and servers somewhere on the Internet. Moreover, to make accessible routing of packets should be fixed in accordance with the given policies of the user (as shown in the image given below).



The Master Core Technology

As shown in the Figure given below, the 5G Master Core is convergence point for the other technologies, which have their own impact on existing wireless network. Interestingly, its design facilitates Master Core to get operated into parallel multimode including all IP network mode and 5G network mode. In this mode (as shown in the image given below), it controls all network technologies of RAN and Different Access Networks (DAT). Since, the technology is compatible and manages all the new deployments (based on 5G), it is more efficient, less complicated, and more powerful.



5G technology is adorned with many as well as distinct features, which applicability is useful for a wide range people.

Applications of 5G

Some of the significant applications are −

- It will make unified global standard for all.
- Network availability will be everywhere and will facilitate people to use their computer and such kind of mobile devices anywhere anytime.
- Because of the IPv6 technology, visiting care of mobile IP address will be assigned as per the connected network and geographical position.
- Its application will make world real Wi Fi zone.
- Its cognitive radio technology will facilitate different version of radio technologies to share the same spectrum efficiently.
- Its application will facilitate people to avail radio signal at higher altitude as well.

Important Advantages of 5G

There are several advantages of 5G technology, some of the advantages have been shown in the above *Ericsson* image, and many others are described below −

- High resolution and bi-directional large bandwidth shaping.
- Technology to gather all networks on one platform.
- More effective and efficient.
- Technology to facilitate subscriber supervision tools for the quick action.
- Most likely, will provide a huge broadcasting data (in Gigabit), which will support more than 60,000 connections.
- Easily manageable with the previous generations.
- Technological sound to support heterogeneous services (including private network).
- Possible to provide uniform, uninterrupted, and consistent connectivity across the world.

COMPARISON OF 1G TO 5G TECHNOLOGIES

Technology	1G	2G/2.5G	3G	4G	5G
Deployment	1970/1984	1980/1999	1990/2002	2000/2010	2014/2015
Bandwidth	2kbps	14-64kbps	2mbps	200mbps	>1gbps
Technology	Analog cellular	Digital cellular	Broadbandwidth/ cdma/ip technology	Unified ip & seamless combo of LAN/WAN/WLAN/PAN	4G+WWWW
Service	Mobile telephony	Digital voice,short messaging	Integrated high quality audio, video & data	Dynamic information access, variable devices	Dynamic information access, variable devices with AI capabilities
Multiplexing	FDMA	TDMA/CDMA	CDMA	CDMA	CDMA
Switching	Circuit	Circuit/circuit for access network& air interface	Packet except for air interface	All packet	All packet
Core network	PSTN	PSTN	Packet network	Internet	Internet
Handoff	Horizontal	Horizontal	Horizontal	Horizontal& Vertical	Horizontal& Vertical

Though, 5G technology is researched and conceptualized to solve all radio signal problems and hardship of mobile world, but because of some security reason and lack of technological advancement in most of the geographic regions, it has following shortcomings −

- Technology is still under process and research on its viability is going on.
- The speed, this technology is claiming seems difficult to achieve (in future, it might be) because of the incompetent technological support in most parts of the world.
- Many of the old devices would not be competent to 5G, hence, all of them need to be replaced with new one — expensive deal.
- Developing infrastructure needs high cost.
- Security and privacy issue yet to be solved.

CHAPTER 3

INTRODUCTION TO MATLAB, SIMULINK, AND THE COMMUNICATION TOOLBOX

Matlab is a computing environment specially designed for matrix computations. It is widely used for the study of a variety of applications, including circuits, signal processing, control systems, communications, image processing, symbolic mathematics, statistics, neural networks, wavelets, and system identification. Its large library of built-in functions and toolboxes, as well as its graphical capabilities, make it a valuable tool for electrical engineering education and research.

Matlab has an interactive mode in which user commands are interpreted immediately as they are typed. Alternatively, a program (called a script) can be written in advance using a text editor, saved as a file, and then executed in Matlab.

Matrix Manipulation

The basic objects manipulated by Matlab are two-dimensional matrices (though recent versions can process multidimensional matrices). Recall that a vector is a special case of a matrix that has only one row or one column. In this course, we will define a vector as a column vector, which corresponds to a single column of a matrix, e.g., an N ×1 matrix with N rows and one column. A row vector is obtained from a column vector by using the transpose operator.

You will find that Matlab is extremely powerful when performing matrix manipulations because many scalar operations operate in parallel for all elements of a matrix. This almost eliminates the need for iterative loops employed in most conventional programming languages. For example, in order to generate s (n) sin(2 n / 1000) for n = 1, . . . , 1000:

In C,

```
for (n = 1; n <= 1000; n + +)
{
s(n) = sin(2*pi* n/1000)
}
```

In Matlab, we could use a for loop as follows:

```
for n = 1 : 1000,
s(n) = sin(2*pi*n/1000);
end
```

However, it is much simpler to write:

```
s = sin(2∗pi ∗ (1 : 1000) /1000);
```

Since Matlab programs are interpreted (not compiled), for loops and while loops are inefficient. They should be avoided whenever possible.

Graphical Plotting

Matlab supports graphical plotting on the computer screen and to a printer. The command for plotting on the screen is **plot**, which can be used in several formats as follows.

```
>> plot(y) % Plots vector y versus its index.
>> plot(x, y) % Plots vector y versus vector x.
>> plot(x, y '<line type>') % Plots vector y versus vector x with the specified <line type>.
```

Possible line types include line, point, and color specifications. The command plot can also take on other forms depending on its argument list. Please refer to the on-line help for a detailed discussion of this command.

A number of commands are used to help generate the desired plot. These include: **axis, hold, title, xlabel, ylabel, text, gtext** , etc. Some of these will be needed for this lab – please refer to the on- line help for details on these commands. Use the **print** command to obtain a high-quality hard copy of the current screen plot.

Obtaining Help

There are two main ways of obtaining help. The first way is by invoking the help command on the Matlab command window to provide you with a list of topics for which help is available. By using help <topic> where topic is the name of a toolbox or function, you will receive either a list of functions available in the toolbox, or an explanation of the function itself, respectively.

The second method of obtaining on -line help is by reading the manuals that are installed on the system in PDF format. You can use a web browser with the Adobe Acrobat Reader plug-in to view these manuals.

Simulink

Simulink is a program for simulating signals and dynamic systems. As an extension of Matlab, Simulink adds many features specific to the simulation of dynamic systems while retaining all of Matlab’s general purpose functionality.

Simulink has two phases of use: *model definition* and *model analysis*. A typical session starts by either defining a new model or by recalling a previously defined model, and then proceeds to analyze that model. In order to facilitate the model definition, Simulink has a large class of windows called block diagram windows. In these windows, models are created and edited principally by mouse-driven commands. An important part of mastering Simulink is to become familiar with manipulations of various model components in these windows.

After you define a model, you can analyze it either by choosing options from the Simulink menus or by entering commands in the Matlab command window. The progress of an ongoing simulation can be viewed while it is running, and the final results can be made available in the Matlab workspace when the simulation is complete

Pre-work Tasks

Please read the following topics using the on-line help documents (or a book on Matlab).

Command mode
operation. On-line help.

Script editing and execution.

Command language: constants, expressions, assignments, m-files, function calls, function definitions, and comments.

Matlab commands: diary, echo, type, !, pause, quit, who, and whos.

Predefined variables: ans, i, j, and pi.

Built-in operators for vector manipulation: :(range selector), ’(transpose), +, −, *, /, ˆ,.*, ./, and .ˆ .

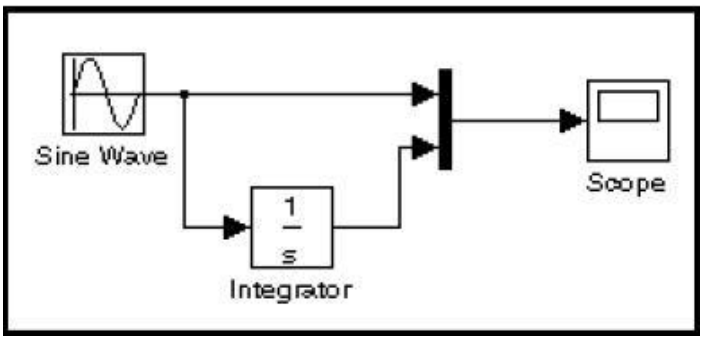
Language constructs: for, while, end, if, and break.

Commands to generate graphical plots: plot, bar, stairs, title, xlabel, ylabel, text, gtext, hold, axis, grid, clg, and print.

Built-in functions: abs, angle, clear, conj, cos, exp, imag, real, sin, rem, round, ceiling, floor, fix, fliplr, flipud.

Simulink

Now we describe how to construct a simple model using Simulink software, and how to simulate that model. The basic techniques you use to construct and simulate this simple model are the same as those for more complex models. The model described in this section integrates a sine wave and displays the result along with the original wave. When completed, the block diagram of the model should look similar to this:

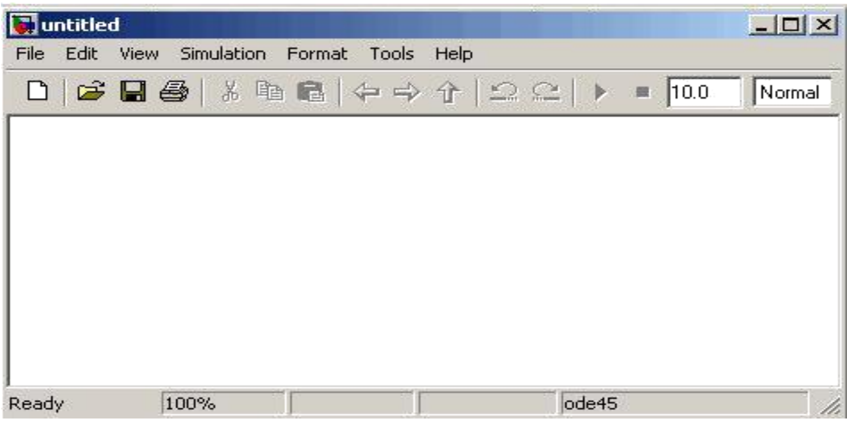


Follow these steps to construct the model:

Click the Simulink icon  in the MATLAB toolbar to enter simulink or click the MATLAB **Start** button, then select **Simulink > Library Browser.**

The Library Browser appears. It displays a tree-structured view of the Simulink block libraries installed on your system. You build models by copying blocks from the Library Browser into a model window.

Select **File > New > Model** in the Simulink Library Browser to construct a new model. An empty model window appears as shown below.

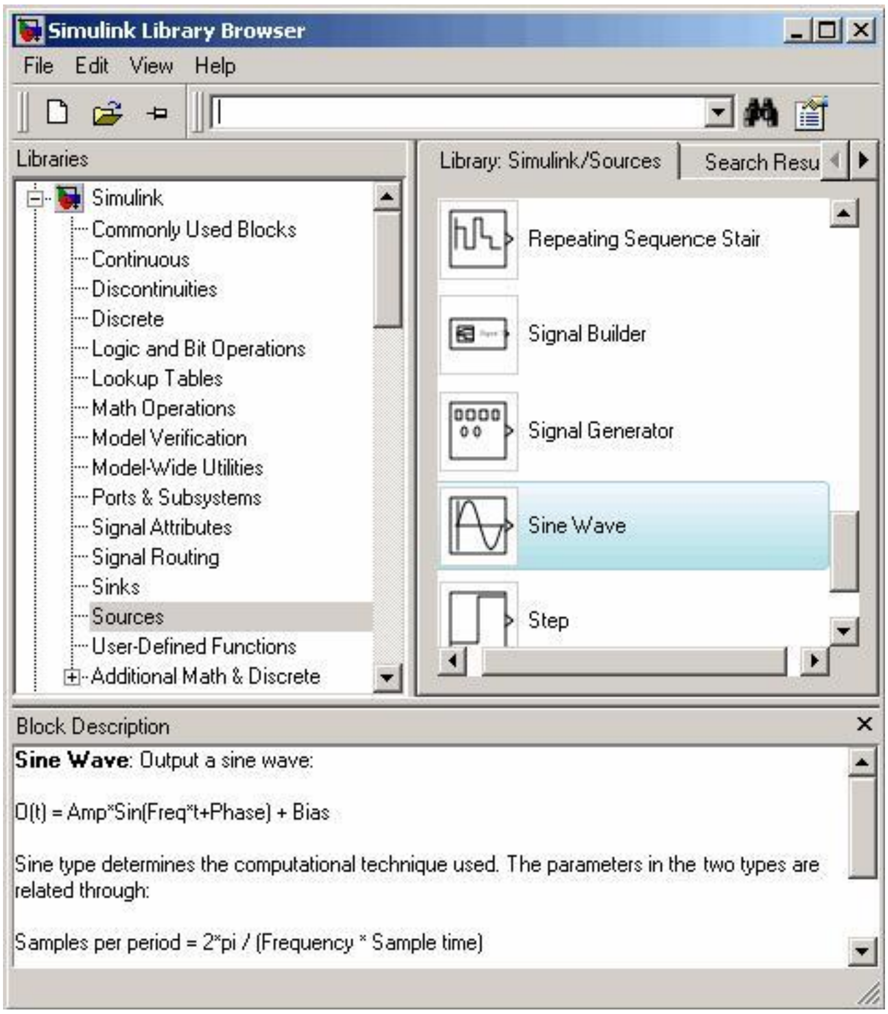


To construct a model, you first copy blocks from the Simulink Library Browser to the model window. To create the simple model in this section, you need four blocks:

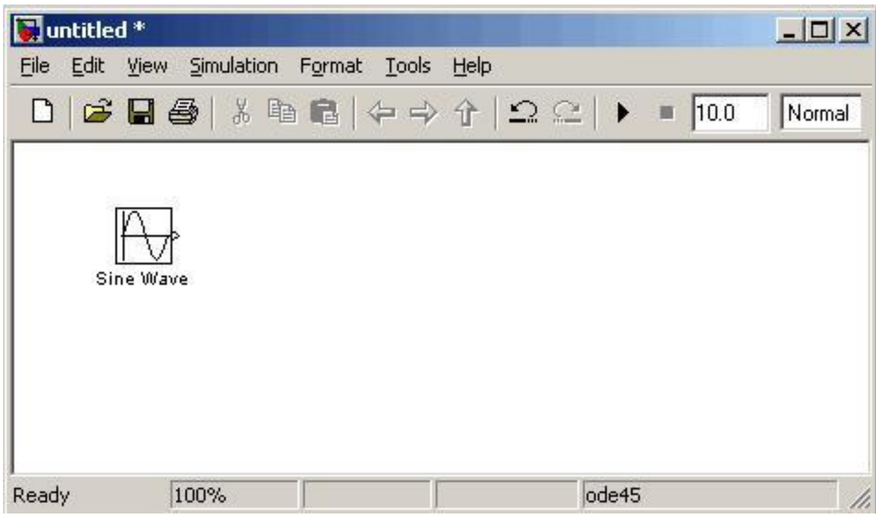
- **Sine Wave** — To generate an input signal for the model
- **Integrator** — To process the input signal
- **Scope** — To visualize the signals in the model
- **Mux** — To multiplex the input signal and processed signal into a

single scope To add blocks to your model:

- Select the **Sources** library in the Simulink Library Browser. The Simulink Library Browser displays the Sources library.

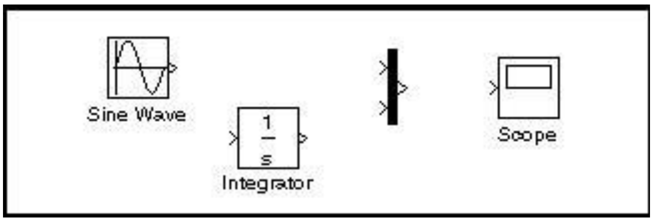


Select the **Sine Wave** block in the Simulink Library Browser, then drag it to the model window. A copy of the Sine Wave block appears in the model window.



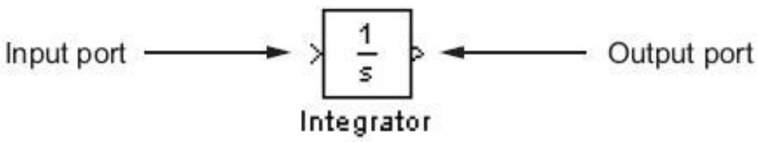
- Select the **Sinks** library in the Simulink Library Browser.
- Select the **Scope** block from the Sinks library, then drag it to the model window. A Scope block appears in the model window.
- Select the **Continuous** library in the Simulink Library Browser.
- Select the **Integrator** block from the Continuous library, then drag it to the model window. An Integrator block appears in the model window.
- Select the **Signal Routing** library in the Simulink Library Browser.
- Select the **Mux** block from the Sinks library, then drag it to the model window. A Mux block appears in the model window.

Before you connect the blocks in your model, you should arrange them logically to make the signal connections as straightforward as possible.



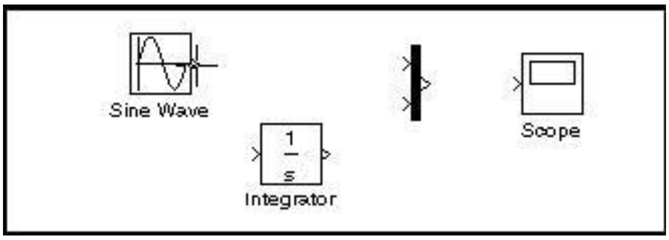
After adding blocks to the model window, you must connect them to represent the signal connections within the model. Notice that each block has angle brackets on one or both sides. These angle brackets represent input and output ports:

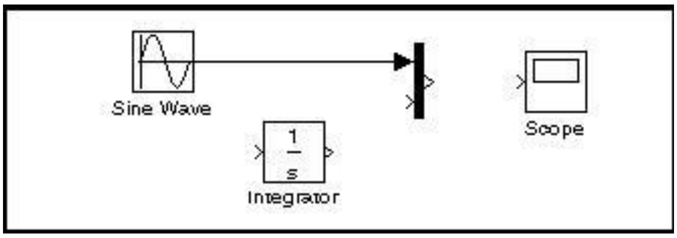
- The > symbol pointing into a block is an *input port*.
- The > symbol pointing out of a block is an *output por*



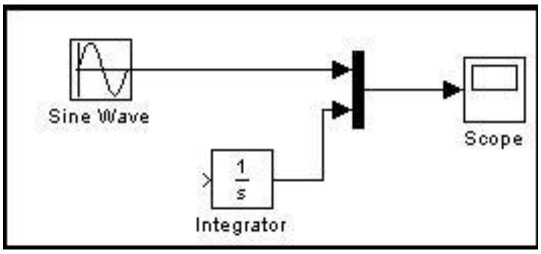
To draw a line between two blocks:

- Position the mouse pointer over the output port on the right side of the Sine Wave block. Note that the pointer changes to a cross hairs (+) shape while over the port.
- Drag a line from the output port to the top input port of the Mux block. Note that the line is dashed while you hold the mouse button down, and that the pointer changes to a double-lined cross hairs as it approaches the input port of the Mux block. Release the mouse button. The software connects the blocks with an arrow that indicates the direction of signal flow.



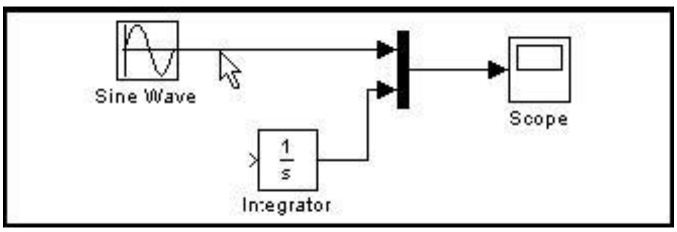


The model should look similar to the following figure after making other connections:

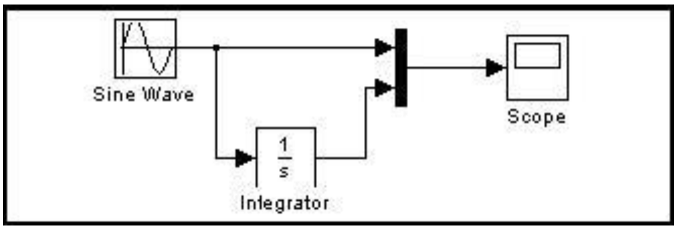


The model is almost complete. To finish the model, you must connect the Sine Wave block to the Integrator block. This final connection is somewhat different from the other three. Because the output port of the Sine Wave block already has a connection, you must connect this existing line to the input port of the Integrator block. The new line, called a *branch line*, carries the same signal that passes from the Sine Wave block to the Mux block. To weld a connection to an existing line:

- Position the mouse pointer *on the line* between the Sine Wave and the Mux block.



- Press and hold the **Ctrl** key, then drag a line to the Integrator block's input port. The software draws a line between the starting point and the input port of the Integrator block as shown below.



After you complete the model, you should save it for future use. To save the model:

- Select **File > Save** in the model window.
- Specify the location in which you want to save the model.
- Enter simple_model in the **File name** field.
- Click **Save**.

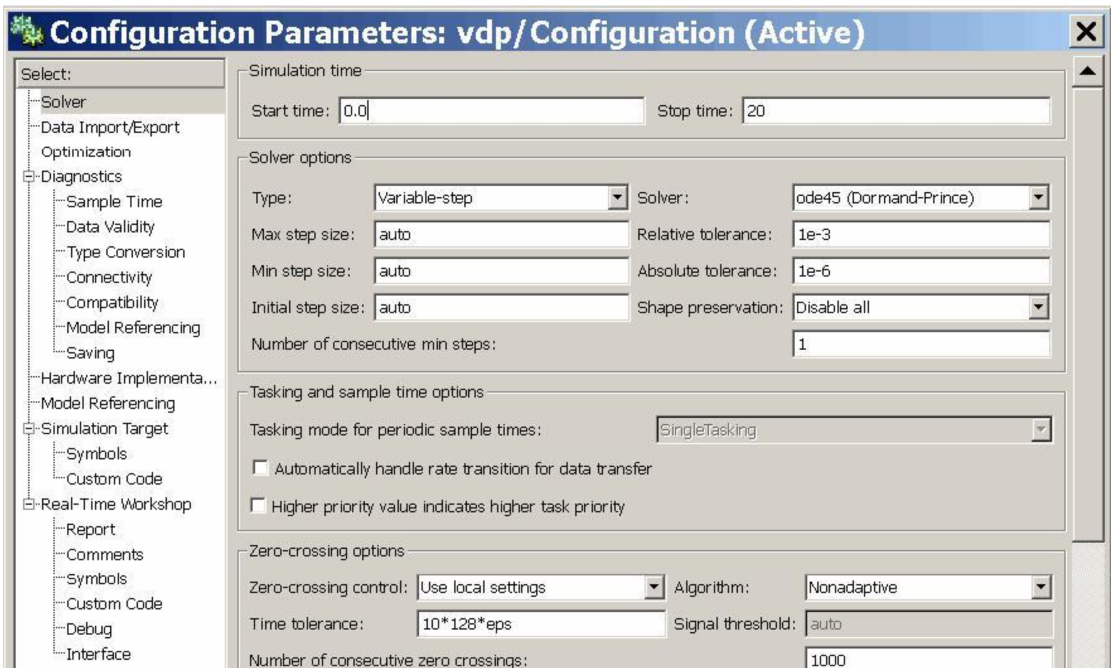
The software saves the model with the file name simple_model.mdl.

You can now simulate the system and visualize the results as follows.

Set simulation options such as the start and stop time, and the type of solver that Simulink software uses to solve the model at each time step. You specify these options using the Configuration Parameters dialog box.

To specify simulation options for the sample model:

- Select **Simulation > Configuration Parameters** in the model window. The software displays the Configuration Parameters dialog box.



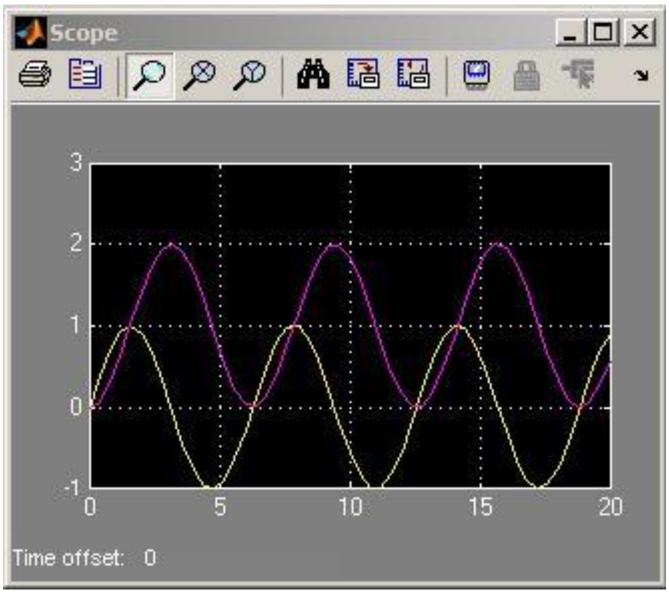
- Enter 20 in the **Stop time** field.
- Click **OK**.

Now you are ready to simulate your sample model and observe the simulation results. To run the simulation:

- Select **Simulation > Start** in the model window. The software runs the model, stopping when it reaches the stop time specified in the Configuration Parameters dialog box.
- On computers running the Microsoft® Windows® operating system, you can

  also click the **Start simulation** button  and **Stop simulation** button  in the model window toolbar to start and stop a simulation.

- Double-click the **Scope** block in the model window. The Scope window displays the simulation results.

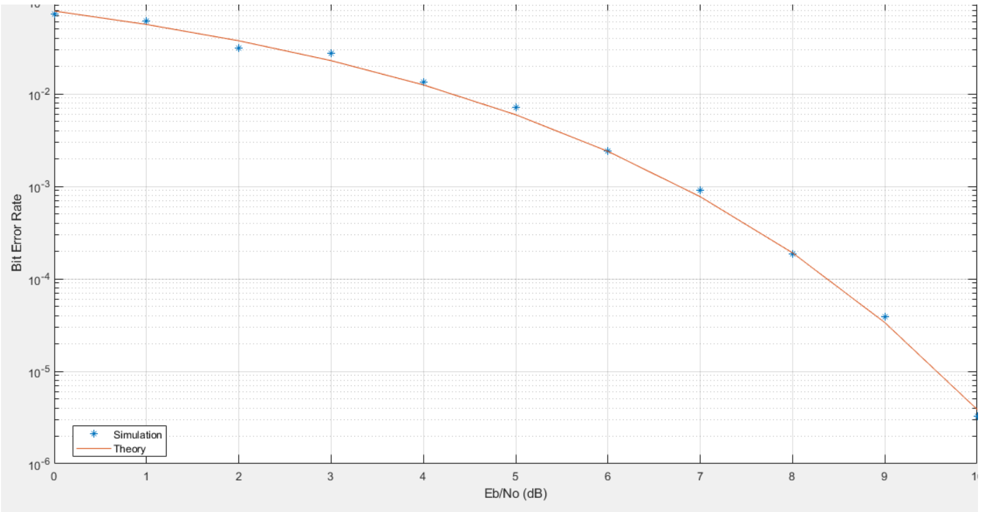


Using Communication Toolbox

Open the Communication Toolbox located in Blocksets&Toolboxes Comm Tbx Library. This shows all of the elements available to a communication system. Open several of the blocks in order to see what functions are available; for example, look at Modulation and Analog Modem. Within Analog Modem, there are several modulation techniques. Try experimenting with some of the blocks to familiarize yourself with what is available. If you need further help, there is an on -line tutorial in PDF form for the Communications Toolbox which provides descriptions of the available functions and blocks.

QPSK and OFDM

```
M = 4;
k = log2(M);
numSC = 128;
cpLen = 32;
maxBitErrors = 100;
maxNumBits = 1e7;
qpskMod = comm.QPSKModulator('BitInput',true);
qpskDemod = comm.QPSKDemodulator('BitOutput',true);
ofdmMod = comm.OFDMModulator('FFTLength',numSC,'CyclicPrefixLength',cpLen);
ofdmDemod =
comm.OFDMDemodulator('FFTLength',numSC,'CyclicPrefixLength',cpLen);
channel = comm.AWGNChannel('NoiseMethod','Variance', ...
    'VarianceSource','Input port');
errorRate = comm.ErrorRate('ResetInputPort',true);
 ofdmDims = info(ofdmMod)
numDC = ofdmDims.DataInputSize(1)
frameSize = [k*numDC 1];
EbNoVec = (0:10)';
snrVec = EbNoVec + 10*log10(k) + 10*log10(numDC/numSC);
berVec = zeros(length(EbNoVec),3);
errorStats = zeros(1,3);
for m = 1:length(EbNoVec)
    snr = snrVec(m);

    while errorStats(2) <= maxBitErrors && errorStats(3) <= maxNumBits
     dataIn = randi([0,1],frameSize);
    qpskTx = qpskMod(dataIn);
    txSig = ofdmMod(qpskTx);
    powerDB = 10*log10(var(txSig));
    noiseVar = 10.^(0.1*(powerDB-snr));
    rxSig = channel(txSig,noiseVar);
    qpskRx = ofdmDemod(rxSig);
    dataOut = qpskDemod(qpskRx);
   errorStats = errorRate(dataIn,dataOut,0);
    end

 berVec(m,:) = errorStats;
 errorStats = errorRate(dataIn,dataOut,1);
end
berTheory = berawgn(EbNoVec,'psk',M,'nondiff');
figure
semilogy(EbNoVec,berVec(:,1),'*')
hold on
semilogy(EbNoVec,berTheory)
legend('Simulation','Theory','Location','Best')
xlabel('Eb/No (dB)')
ylabel('Bit Error Rate')
grid on
hold on
```

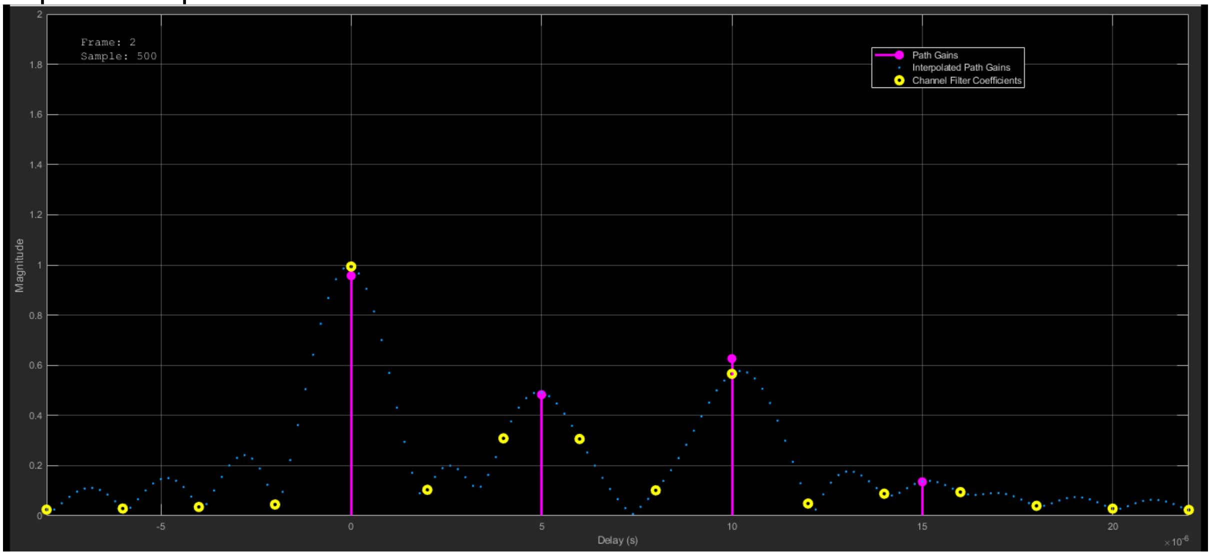


Bit Error Rate
10^-2
10^-3
10^-4
10^-5
10^-6
0
1
2
3
4
5
6
7
8
9
Eb/No (dB)
Simulation
Theory

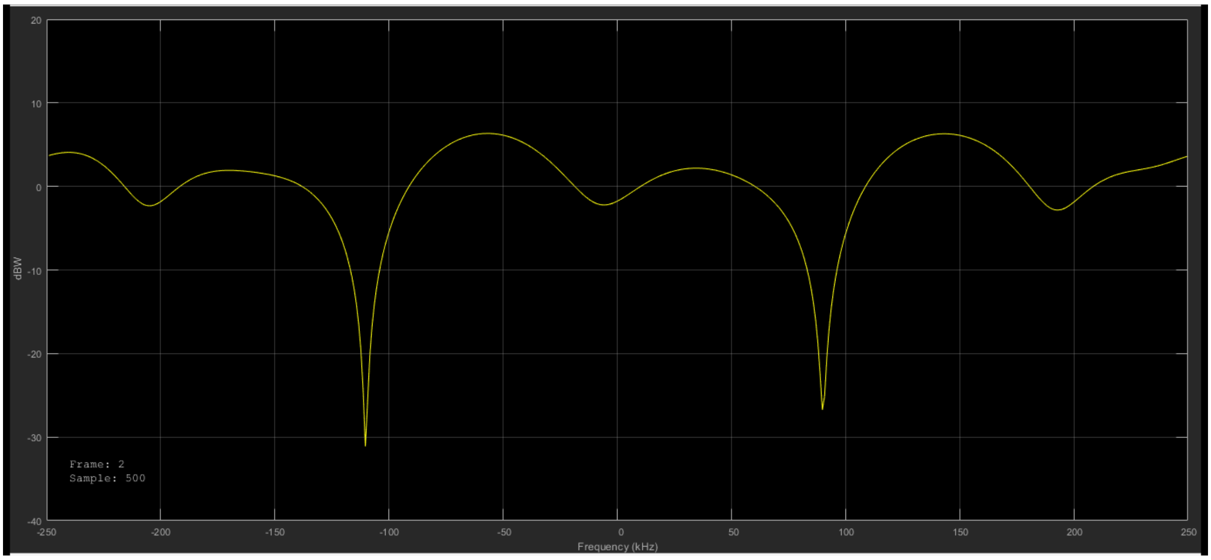
MULTIPATH FADING

```
sampleRate500KHz = 500e3;
sampleRate20KHz  = 20e3;
maxDopplerShift  = 200;
delayVector = (0:5:15)*1e-6;
gainVector  = [0 -3 -6 -9];
KFactor = 10;
specDopplerShift = 100;
rayChan = comm.RayleighChannel( ...
    'SampleRate',          sampleRate500KHz, ...
    'PathDelays',          delayVector, ...
    'AveragePathGains',    gainVector, ...
    'MaximumDopplerShift', maxDopplerShift, ...
    'RandomStream',        'mt19937ar with seed', ...
    'Seed',                10, ...
    'PathGainsOutputPort', true);
ricChan = comm.RicianChannel( ...
    'SampleRate',              sampleRate500KHz, ... 'PathDelays',              delayVector, .
'AveragePathGains',        gainVector, ..  'KFactor', KFactor, ..'DirectPathDopplerShift',
specDopplerShift, ...'MaximumDopplerShift',      maxDopplerShift, ...'RandomStream',
'mt19937ar with seed', ...  'Seed',            100, .. 'PathGainsOutputPort',      true);
qpskMod = comm.QPSKModulator( ... 'BitInput',    true, .. 'PhaseOffset', pi/4);
bitsPerFrame = 1000;
msg = randi([0 1],bitsPerFrame,1);
 modSignal = qpskMod(msg);
 rayChan(modSignal);
ricChan(modSignal);
release(rayChan);
release(ricChan);
rayChan.Visualization = 'Impulse and frequency responses';
rayChan.SamplesToDisplay = '100%';

numFrames = 2;

for i = 1:numFrames
    msg = randi([0 1],bitsPerFrame,1);
    modSignal = qpskMod(msg);
    rayChan(modSignal);
end
```

Impulse Response Plot



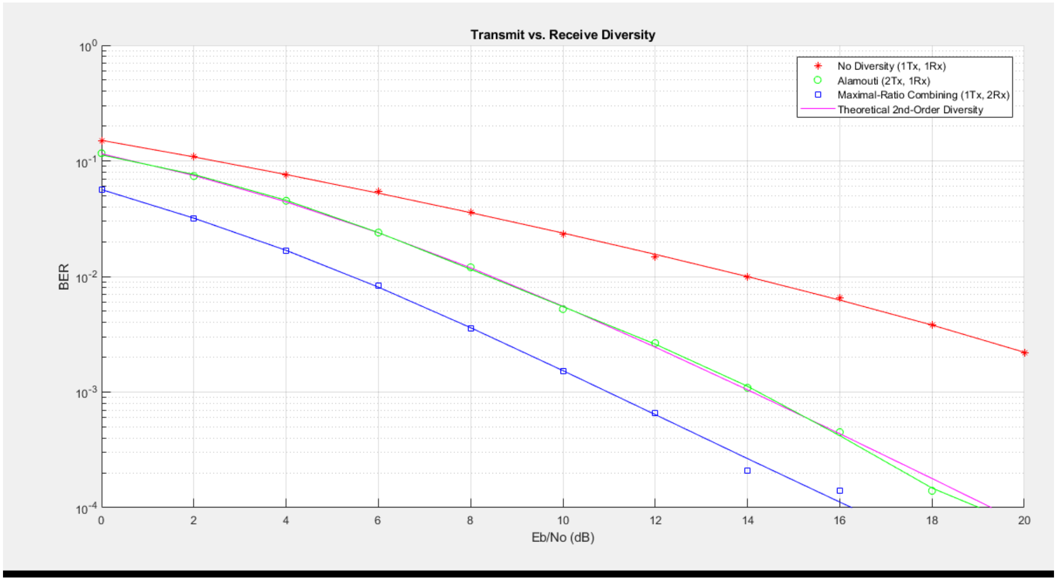
Frequency Response Plot



MIMO systems

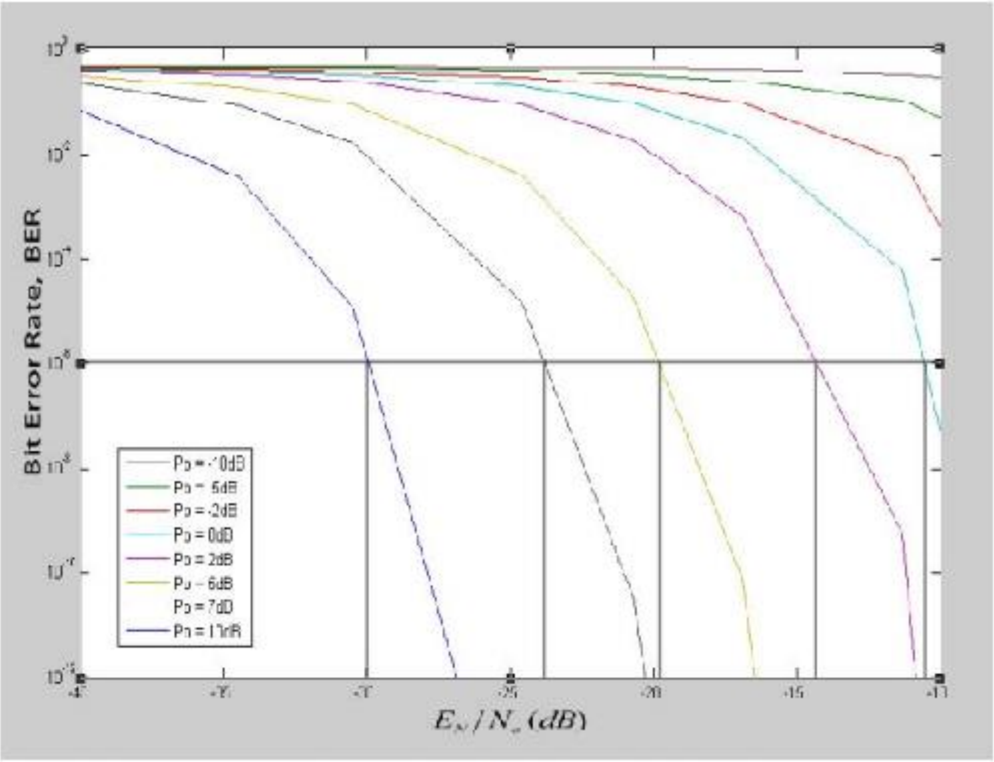
```
frmLen = 100;
numPackets = 1000;
EbNo = 0:2:20;
N = 2;
M = 2;
P = 2;
bpskMod = comm.BPSKModulator;
bpskDemod = comm.BPSKDemodulator('OutputDataType','double');
ostbcEnc = comm.OSTBCEncoder;
ostbcComb = comm.OSTBCCombiner;
awgn1Rx = comm.AWGNChannel(...
    'NoiseMethod', 'Signal to noise ratio (Eb/No)', ..   'SignalPower', 1);
awgn2Rx = clone(awgn1Rx);
errorCalc1 = comm.ErrorRate;
errorCalc2 = comm.ErrorRate;
errorCalc3 = comm.ErrorRate;
s = rng(55408);
H = zeros(frmLen, N, M);
ber_noDiver  = zeros(3,length(EbNo));
ber_Alamouti = zeros(3,length(EbNo));
ber_MaxRatio = zeros(3,length(EbNo));
ber_thy2     = zeros(1,length(EbNo));
fig = figure;
grid on;
ax = fig.CurrentAxes;
hold(ax,'on');

ax.YScale = 'log';
xlim(ax,[EbNo(1), EbNo(end)]);
ylim(ax,[1e-4 1]);
xlabel(ax,'Eb/No (dB)');
ylabel(ax,'BER');
fig.NumberTitle = 'off';
fig.Renderer = 'zbuffer';
fig.Name = 'Transmit vs. Receive Diversity';
title(ax,'Transmit vs. Receive Diversity');
set(fig, 'DefaultLegendAutoUpdate', 'off');
fig.Position = figposition([15 50 25 30]);
for idx = 1:length(EbNo)
    reset(errorCalc1);
    reset(errorCalc2);
    reset(errorCalc3);
    awgn1Rx.EbNo = EbNo(idx);
    awgn2Rx.EbNo = EbNo(idx);
    for packetIdx = 1:numPackets
        data = randi([0 P-1], frmLen, 1);
        modData = bpskMod(data);
        encData = ostbcEnc(modData);
        H(1:N:end, :, :) = (randn(frmLen/2, N, M) + ...1i*randn(frmLen/2, N, M))/sqrt(2);
       H(2:N:end, :, :) = H(1:N:end, :, :);
        H11 = H(:,1,1);
        H21 = H(:,:,1)/sqrt(2);
        H12 = squeeze(H(:,1,:));
```

```
        chanOut11 = H11 .* modData;
        chanOut21 = sum(H21.* encData, 2);
        chanOut12 = H12 .* repmat(modData, 1, 2);
        rxSig11 = awgn1Rx(chanOut11);
        rxSig21 = awgn1Rx(chanOut21);
        rxSig12 = awgn2Rx(chanOut12);
        decData = ostbcComb(rxSig21, H21);
        demod11 = bpskDemod(rxSig11.*conj(H11));
        demod21 = bpskDemod(decData);
        demod12 = bpskDemod(sum(rxSig12.*conj(H12), 2));
        ber_noDiver(:,idx)  = errorCalc1(data, demod11);
        ber_Alamouti(:,idx) = errorCalc2(data, demod21);
        ber_MaxRatio(:,idx) = errorCalc3(data, demod12);

    end
    ber_thy2(idx) = berfading(EbNo(idx), 'psk', 2, 2);
   semilogy(ax,EbNo(1:idx), ber_noDiver(1,1:idx), 'r*', ...
            EbNo(1:idx), ber_Alamouti(1,1:idx), 'go', ...
            EbNo(1:idx), ber_MaxRatio(1,1:idx), 'bs', ...
            EbNo(1:idx), ber_thy2(1:idx), 'm');
    legend(ax,'No Diversity (1Tx, 1Rx)', 'Alamouti (2Tx, 1Rx)',...
          'Maximal-Ratio Combining (1Tx, 2Rx)', ...
          'Theoretical 2nd-Order Diversity');

    drawnow;
end
fitBER11 = berfit(EbNo, ber_noDiver(1,:));
fitBER21 = berfit(EbNo, ber_Alamouti(1,:));
fitBER12 = berfit(EbNo, ber_MaxRatio(1,:));
semilogy(ax,EbNo, fitBER11, 'r', EbNo, fitBER21, 'g', EbNo, fitBER12, 'b');
hold(ax,'off');
 rng(s);
```



CDMA

```
clc
clear all
close all
N=1:3:25;
N0=10^-6;
Rb=10000;
L=8;
P0dB=[-10 -5 -2 0 2 5 7 10];
xliv
for s=1:length(P0dB)
 P0(s)=10.^(P0dB(s)./10);
end
Tb=1./Rb;
Eb=P0.*Tb;
SNR=Eb./N0;
M11=P0/N0;
M02=P0/N0^2;
M22=2*P0.^2/N0.^2;
Pdel=0.1*P0;
Ts=Tb/L;
for j=1:length(SNR)
 for i = 1:length(N)
 sMUI(i)=sqrt(((N(i)-1)/N(i))* Ts.^2*(M22(j)-M11(j).^2));
 end
 SMUI(:,j)=sMUI;
end
Smui=(SMUI.^2)./1000;
for k=1:length(Pdel);
 for l = 1:length(SNR);
 sICI(l)=sqrt((Pdel(k).*M02(l)).*Ts.^2);
 snoise(l)=sqrt(N(l).*(M02(k).*N0).*Ts);
 end
 SICI(:,k)=sICI;
 Snoise(:,k)=snoise;
end
SICI;
format long
for y=1:length(P0);
 for z = 1:length(P0)
 EN(z)=(N0*(M11(y).^2))./(((M22(z)-
(M11(z).^2))+M02(z).*(Pdel(z)+(N0./Ts))));
 end
 En(:,y)=EN;
 En1(:,y)=EN/N0;
 EndB(y)=10*log10(En1(y));
end
 BER=(1./2)*erfc(sqrt(En./N0));
semilogy(EndB,BER)
axis([-40 -10 10e-12 10e-0])
legend('Po=-10dB','Po=-5dB','Po=-
2dB','Po=0dB','Po=2dB','Po=5dB','Po=7dB','Po=10dB',8)
```


Bit Error Rate, BER
E_b / N_o (dB)