UNIT 3 INTRODUCTION TO WIRELESS AND MOBILE NETWORKS

Structure **Page Nos.**

3.0 INTRODUCTION SYSTEMS

Communication Systems enables two or more person to communicate each other irrespective of their geographic location distance. This is only because of communication technology which provide such seamless service to their customers. Therefore, this communication service has tremendously grown among people in the past few years as it has eliminated the obstacle caused by geographic distance between people. Now there are modes of this communication system through which this service can be provided. The first one is the wired communication system and the other one is wireless communication system. Please note that in this chapter, the terms "wireless" and "cellular" are used interchangeably. Both are used in view of mobility. Moreover, in all diagrams, a dotted line represents a wireless link whereas a solid line represents a wired communication link.

3.1.1 Wired Communication System

The **Wired Communication System** depends solely on wires as e all the users (or communicators) are connected to each other through wires. The typical example (Figure 1) of such wired communication system can be a Local Area Network (LAN) where people are communicating and linked with each other through wires. Wire can be a cable wire, optical wire or any other type of wire.

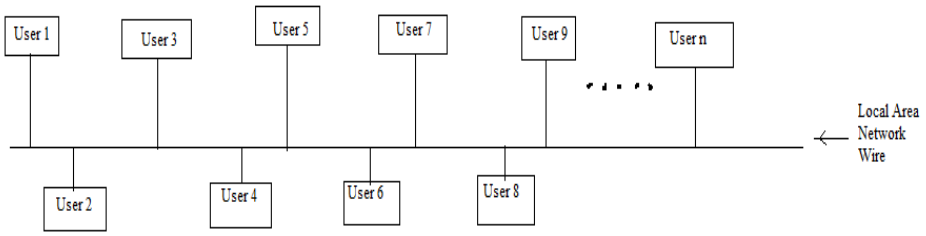


Figure 1: Wired Communication Systems

Following are the **pros of Wired Communication System**:-

- Wired technology has good data transfer speed.
- It is more secure as compared to wireless technology as the data transfer takes place in wired medium.

The **cons of Wired Communication System** are:-

- The position of a user becomes fixed due to attachment with a wire.
- As some wires are underground, it is difficult to perform their maintenance as one have to dig the ground to repair it.

3.1.2 Wireless Communication System

In **Wireless Communication System**, communication medium is the space and not the wires. Each user communicates with each other through a wireless link. This link can be a radio link which typically works on Radio Frequency (RF) concept. The typical example of a wireless communication system can be a mobile system (Figure 2) like Global System for Mobile Communication (GSM) OR Code Division Multiple Access (CDMA) in which the communication signals travel through air medium.

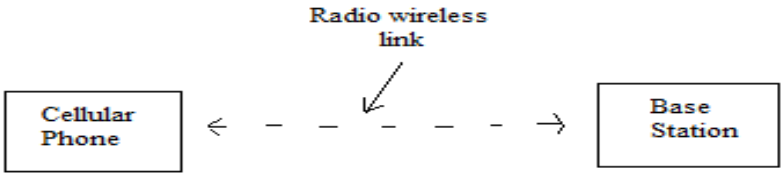


Figure 2: Wireless Communication System

Following are the **pros of Wireless Communication System**:-

- Wireless network provides mobility to its users.
- Users are free from wires and this reduces their effort to manage and maintain them.

The **cons of Wireless Communication System** are:-

- The technology is less secure as the whole communication takes place in an open wireless medium
- The data transfer speed is low as compared to wired technology.
- The quality of network and signals depend on the weather condition as rainy season deviate the signals in air which degrades the performance of a wireless network.

Modes of Wireless Communication System in small distance

Despite of cons of wireless network, this technology usage is increasing day by day and reaching to every people due to its advantage of getting people free form wires and providing them mobility. Therefore, our focus we will be on Wireless Technology. Now, we will discuss the two modes in which a wireless technology works.

- **Access Point (AP) Wireless Communication System :-**

  The first mode is called **Access Point (AP) Wireless Communication System.** In this Access Point (AP) wireless communication system (Figure 3), the data transfer takes place from source (User 1) to destination (User 2) through an Access Point. This access point can be a modem or a switch etc. This access point decides the path for data transfer to follow, data transfer speed, calculates the shortest path etc from source (User 1) to destination (User 2). No two users or more users can communicate directly or without an access point in this mode. The example of Access Point (AP) wireless technology is a wireless LAN network where r a modem decides the path and transfers the data form User 1 to User 2.

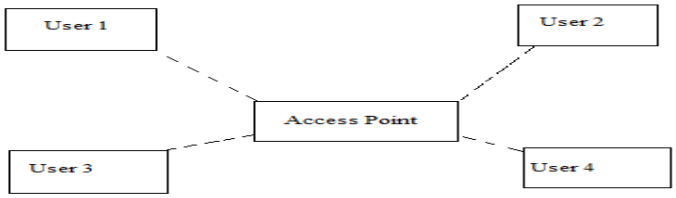


Figure 3: Access Point (AP) Wreless Communication System

- **Ad-hoc wireless Communication System :-**

  The second mode is Ad-hoc wireless communication system mode. In this mode (Figure 4), the data transfer takes place directly from source (User 1) to destination (User 2). There is no need of access point in this type of mode. Every user in this network mode communicates directly with each other. Such types of network are temporary and its establishment is very quick as compared to access point mode. These networks are successful where there is a requirement of temporary network only for few days.

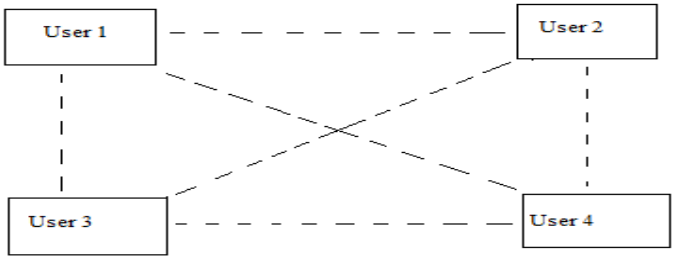


Figure 4: Ad-hoc Wireless Communication System

3.1 OBJECTIVES

After going through this unit you will be able to:

- define the wired and wireless communication systems;
- discuss the various wireless communication systems;

- define the wireless generations;
- define the Global System Mobile (GSM);
- define Code Division Multiple Access (CDMA); and
- define cellular system design fundamental.

3.2 WIRELESS COMMUNICATION SYSTEMS

The technology has grown tremendously and the consequence of which is modern wireless communication that has helped in eradicating the disadvantages of the typical wireless communication systems such as paging system and cordless telephone system. The examples of modern wireless communication systems are Cellular Mobile System, Bluetooth, and Wireless Local Area Network (WLAN). Below given are the few examples of Wireless Communication Systems which we will discuss in brief:-

3.2.1 Paging System

Paging systems are the systems which broadcasts the messages to its user for performing any action. Such message can be a service message in which a user can subscribe to a missed call alert service, caller tune service, internet service or any other such service. This message is broadcast to the users in a service area using same base stations. Coverage of a paging system can be of a range of 2 to 5 km or it can cover a wide area using wide area paging systems.

3.2.2 Cordless Telephone System

Cordless Telephone system consists of a landline telephone which is a fixed port (Figure 5). This landline is connected to the telephone exchange called Public Switched Telephone Network (PSTN). The landline telephone has a wireless (or cordless) handset which is connected to the landline telephone through a radio link. Therefore, through this cordless system, the user has the freedom to move while on a call. But this has a range or distance limitation which is around few tens of meters only.

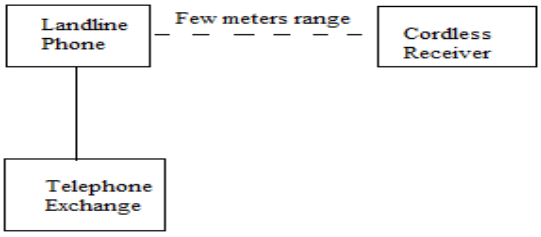


Figure 5: Cordless Telephone System

3.2.3 Cellular Mobile System

Cellular Mobile Systems eradicates the distance limitation imposed by a cordless telephone system. In this mobile system (Figure 6), a user can easily move from one place to another while on a call without getting disconnected from call. The user is constantly connected to the called user through radio links. As the user passes from one area (or cell) to another area (or another cell), the Base Station Controller (BSC) of one cell informs Base Station Controller (BSC) of other cell about the call transfer. Every cell has at least one BSC. Further all these BSC are connected to Mobile Switching Center (MSC). And finally all MSC are connected to PSTN.

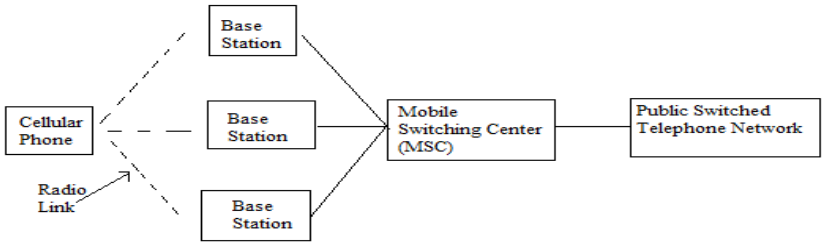


Figure 6: Cellular Mobile System

3.2.4 Bluetooth

As discussed above, Bluetooth works on ad-hoc mode in which the network is formed quickly and is of temporary basis. Bluetooth technology is created by a telecom company called Ericsson in 1994. It was developed in order to connect two devices without wires. The range in which Bluetooth technology works is of 10 meters (or 30 feet approx) only. The name "Bluetooth" is after tenth-century king Harald I of Denmark and parts of Norway who united Danish tribes into a single kingdom. The implication is that Bluetooth does the same with communications protocols, uniting them into one universal standard.

Bluetooth works on 2.4 GHz ISM band (Industrial, Scientific and Medical band) which divides the data into parts and sends it on up to 79 bands. It uses Frequency Hopping Spread Spectrum (FHSS) with Time Division Duplexing (TDD) technique at the rate of 1600 hops/sec. Moreover, the modulation technique employed is Guassian Frequency Shift Keying (GFSK) which was the only available modulation technique at the time of Bluetooth. Data rate is around 128 Mbps (Mega Bits per Second) and can support up to 8 devices simultaneously in Master-Slave mode. Bluetooth has versions started from version 1.0 to version 4.0.

3.2.5 Wireless Local Area Network (WLAN)

WLAN is a local area network but the end point at which the user gets the service is a wireless end. As you can see in below Figure 7, the user is connected to Access Point through a wireless link. The Access point is further connected to a LAN line which is wired. Therefore, in WLAN, only the last end is wireless and rest is wired network.

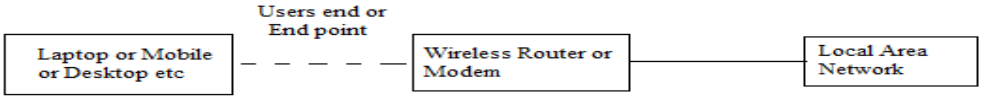
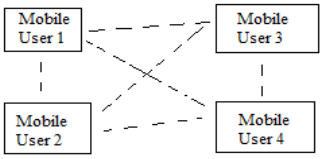


Figure 7: Wireless Local Area Network

WALN technology works on IEEE 802.11 standard. Components of 802.11 are Basic Service Set (BSS), Extended Service Set (ESS), Access Point (AP) and Distribution Systems (DS). We will now discuss these components in brief.
Basic Service Set (BSS) – BSS contains one or more mobile user (Figure 8 & 9). BSS can work in two modes. One is independent mode in which all users are connected to each other directly. The other mode is infrastructure mode in which all users communicate through an Access Point (AP).

Access Point – An AP can be a modem, router or a switch through which users communicate with each other. When a network employs this component, that network is called infrastructure mode. All the data passes through this AP.



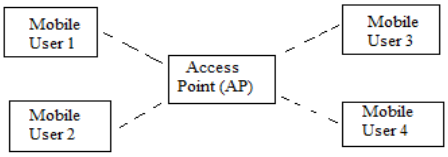


Figure 8: BSS Without Acess Point (AP) **Figure 9: BSS With Acess Point(AP)**

Extended Service Set (ESS) - All separate BSS (either in independent mode or in infrastructure mode) when connected to each other is called an Extended Service Set (Figure 10).

Distribution System (DS) – Distribution system connects AP of different ESS. This increases network coverage as all the users of different BSS will be connected with each other through DS (Figure 10). All the links connecting APs to DS can be wireless or wired.

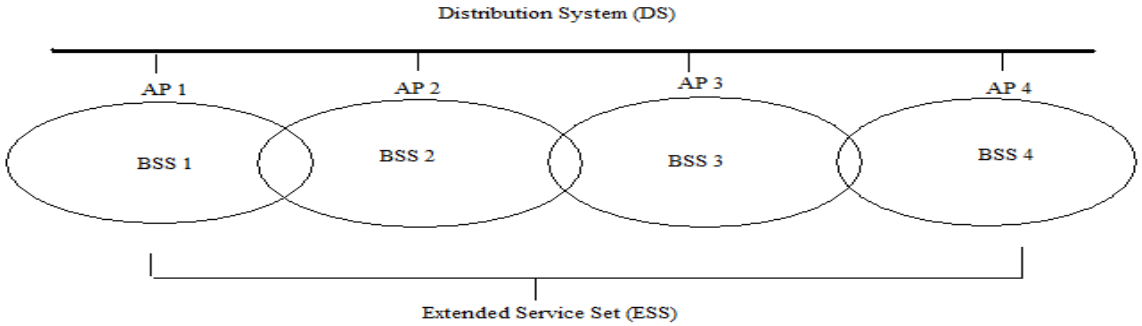


Figure 10: Extended Service Set (ESS) and Distribution Systems(DS)

☞ Check Your Progress 1

1. **State True or False**

   a) Wired communication systems are less secure than wireless communication system. ☐

   b) Wireless communication systems are easy to set up. ☐

   c) Data transfer speed is less in wireless communication system. ☐

   d) Ad-hoc wireless communication system uses an access point for users to get connected to each other. ☐

   e) In Wireless Local Area Network (WLAN), each point is a wireless point. ☐

   f) Basic Service Set (BSS) provides the ability for all Access Point (APs) to get connected to each other. ☐

2. Discuss about Bluetooth Technology?

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3. Explain how Cordless Telephone System works?

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3.3 WIRELESS GENERATIONS

Cellular Mobile System has come a long way as at present scenario, every person carries a cellular phone in his/her hand. This tremendous growth has established the growth of cellular technology. From a cordless phone which gave mobility to users but only of short distance in meters to a basic phone which has overcome the disadvantage of short range cordless phone. And now today, a basic cellular phone is converted to a smart multimedia cellular phone which is used not only for making calls but is used to click pictures, listen songs, record voice, checking mails etc. In this section, we will draw your attention towards the emerging generations of a wireless cellular phone.

Before starting with generations, we will discuss the two channel access technologies - Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) which are used in these generations.

Frequency Division Multiple Access (FDMA) allocates individual frequency channel to an individual user at a time. Each user gets a frequency channel whenever the user demands for it. Any other user cannot use the same frequency channel until the assigned channel is given back by the user to the pool of freely available frequency channel.
Time Division Multiple Access (TDMA) divides an individual frequency channel into number of time slots. These time slots are then allocated to users on demand. Unlike FDMA, one or more user can share the same frequency channel. Each slot is used either for transmitting or receiving signals. Therefore, the data transmission is non-continuous in nature which makes the hand-off simpler. Consecutive slots are used to transmit the data.

3.3.1 First Generation (1G) –

First Generation also called 1G is based on analog Frequency Modulation (FM) and Frequency Division Multiple Access (FDMA). 1G uses circuit switched technology and came in 1980. According to this generation, each user has allocated with a dedicated frequency channel. Moreover, this generation made solely to provide voice services to its users. It was not intended for any data services. These lacked features in 1G were the biggest reason behind the rise of Second Generation (2G).

3.3.2 Second Generation (2G) –

Second Generation provides the voice as well as data services to its users. Unlike 1G, no user has allocated dedicated frequency channel. 2G uses digital modulation technique and multiple access techniques like Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA). 2G came in 1990 and uses circuit switched technology. Every user in 2G uses a time-sharing frequency channel. In this generation, there are 3 TDMA standards which are – Global System Mobile (GSM), Interim Standard 136 (IS 136) and Pacific Digital Cellular (PDC) and one CDMA standard called 2G CDMA or Interim Standard 95 (IS 95) CDMA.

- *Global System Mobile (GSM)* – For every 200 KHz radio channel, there are 8 times slotted users. 2G TDMA standard GSM is used in countries like Europe, Australia, Asia and South America. It is also used in India

- *Interim Standard 136 (IS 136)* - For every 30 KHz radio channel, there are 3 times slotted users. 2G TDMA standard IS 136 is used in countries like Australia, North America and South America. IS 136 is also known as US Digital Cellular (USDC) or North American Digital Cellular (NADC).
- *Pacific Digital Cellular (PDC)* – This is a Japanese standard and is very similar to IS 136 with around 50 million users
- *2G CDMA or Interim Standard 95 (IS 95) CDMA* – For every 1.25 MHz channel, there are up to 64 users which are orthogonally coded. This standard is also known as CDMAOne and is used in Australia, Korea North America, Japan, China and South America.

3.3.3 Evolution to Mid of Second Generation (2.5G) –

After the second generation comes 2.5G and introduced in the year 2000. 2.5G is intended for faster data rates which are required for supporting modern internet applications. Existing 2G equipment is modified (both hardware and software) to support 2.5G services for enhanced data rates. Enhanced rata rates are provided for services such as web browsing, mobile commerce, e-mail services and location based mobile services. 2.5G also supports web browsing technology like Wireless Application Protocol (WAP).

2.5 provides three TDMA upgrades which are as follows-

- *High Speed Circuit Switched Data (HSCSD)* – As the name suggests, this TDMA upgrade is a circuit switched technology and provides higher data speed rates as compared to 2G. This technology upgrade is the first attempt to provide better data rates for GSM. Rather than allocating a single time slot to a single user, the higher data rates are provided to users by providing consecutive time slots. This technology also takes care of error control coding algorithm.
- *General packet Radio Service (GPRS)* – Unlike HSCSD, this TDMA upgrade is a packet based technology. GPRS supports more users as compared to HSCSD. It uses 2G TDMA modulation format but redefines air interface for better packet data access. It is more suitable for non real time applications like retrieval of email, faxes and asymmetric web browsing. Installation of internet gateway and new routers at base station is mandatory for using this technology.
- *Enhanced Data rates for GSM Evolution (EDGE)* – EDGE provides better data rates than GPRS by using new digital modulation technique called 8-PSK (Phase Shift Keying).This is implemented by upgrading hardware and software at base station. This technology is also called as Enhanced GPRS. Nine different air interface formats are defined by EDGE known as Multiple modulation and Coding Schemes (MCS) with error control protection.

3.3.4 Third Generation (3G) –

3G is designed to provide higher data rates with much available wider bandwidth. It uses packet switched technology and users uses smaller bandwidth. This generation allows the identification of user's location. The 3G technology provides the services like transparent roaming, communication using Voice Over Internet Protocol (VOIP), receives live music, interactive live web sessions, better network capacity, multi mega-bit internet access, readily available internet access and simultaneous exchange of voice and data packets using a single cellular mobile.

The above discussed Wireless generations are compared below in the form of a comparison Table 1.

Table 1: Comparison between Wireless Generations – 1G, 2G, 2.5G and 3G

	1G	2G	2.5G	3G
Introduced in year	1980	1990	2000	After 2004
Communication Method	Circuit Switched	Circuit Switched	Both Packet and Circuit Switched	Packet Switched
Modulation Technique	Analog Frequency Modulation	Digital Modulation	Digital Modulation and Shift Keying	Digital Modulation and Shift Keying
Services	Voice service only	Both Voice and Data services	Both Voice and Data services with faster data rates	Both Voice and Data services with faster data rates
Channel Assignment	Dedicated Frequency Channel	Dynamic Channel Assignment	Dynamic Channel Assignment	Dynamic Channel Assignment
Standards	-	3 TDMA Standards – GSM, PDC, IS 136 and 1 CDMA Standard	3 TDMA Standards – HSCSD, GPRS and EDGE	EDGE and W-CDMA

3.4 INTRODUCTION TO CELLULAR MOBILE SYSTEMS - GSM

Now a day, everyone is dependent on a cellular phone (called mobile) to get connected to other person. This connectivity among users is wireless in nature. Such communication is furnished by the standards like GSM (Global System Mobile), CDMA (Code Division Multiple Access) etc. This wireless link is called the Radio Link. All the communication between users takes place through this radio link and in open wireless medium called the Common Air Interface (CAI). The concept of Global System for Mobile Communication (GSM) was introduced in 1990 by the European country. From then, this standard accepted widely and utilized by several countries.

GSM network consists of several components which are as follows:

Mobile Station (MS) - This is the device which is used by the GSM user and is portable, small, light-weight and hand-held device.

Base Transceiver Station (BTS) - It is the cell tower which is located on the roof by the service providers to provide network to its users. A BTS is connected to MS by wireless radio links.

Base Station Controller (BSC) - This controls one or more BTS and is connected to them. This connectivity is through wires. BTS and BSC together called Base Station (BS).

Mobile Switching Centre (MSC) – A MSC is connected to number of BSC and manages the call routing process.

Authentication Centre (AuC) – Authentication Centre is responsible for authenticating a legitimate user (subscriber) and also provides 128-bit authentication key to user. Home Location Register (HLR) – This is a database which stores the user's information and its location information. This provides user an IMSI (International Mobile Subscriber Identity) number to identify its user. In other words, the area to which a subscriber belongs is saved in HLR.

Visitor Location Register (VLR) – This database contains the information about subscriber who visited the area of a particular MSC and stores the IMSI (Internationl mobile subscriber indentity) number temporarily.

Operation Maintenance Centers (OMC) – The operation of each MS, BTS, BSC and MSC is monitored and maintained by this centre.

Subscriber Identity Module (SIM) – This is a removable 16k or 32k chip (or a small smart card) which a service provider provides to its subscriber. It is used in MS to access the GSM services like calling, messaging etc.

Public Networks – This consists of networks like PSTN (Public Switched Telephone Network), Data Network, ISDN (Integrated Services digital Network) to which MSC is connected.

Below given Figure 11 is the architecture of GSM containing all the above described components. GSM communication operates on 900 MHz/1800 MHz standards and uses techniques like FDD (Frequency Division Duplexing) and TDMA (Time Division Multiple Access).

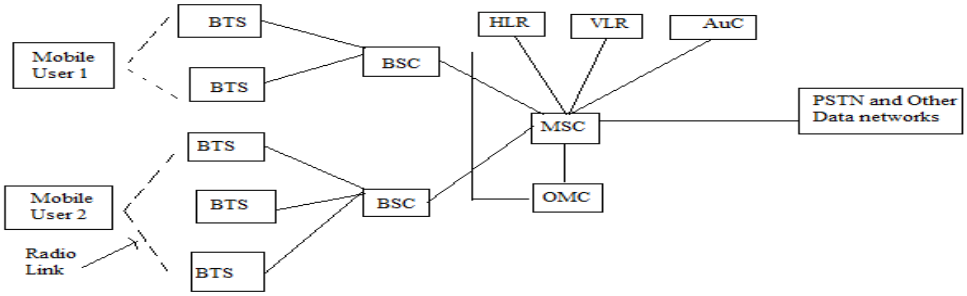

Figure 11: Global System Mobile (GSM) Architecture

Several generations like 1G (First Generation), 2G (Second Generation), 3G (Third Generation) in GSM has evolved during the past years. Even though the GSM network is utilized by almost every country these days but this standard has some vulnerabilities which are exploited by an intruder to get the access into the network or disturb its operation. The radio link between the MS and BTS is the most crucial point where an intruder takes advantage. Such vulnerabilities are listed below.

Vulnerabilities in GSM Communication

The GSM standard has some principles of security like subscriber identity confidentiality, use of a SIM as security module, subscriber identity authentication, use of triplets and stream ciphering of user traffic & user control data. An intruder takes an unfair advantage between a legitimate subscriber and the wireless radio link and breaches the security principles of GSM. This breach of principle is due to the

Following vulnerabilities present in GSM network:-

- *Wireless Radio Link* – All the communication is taking place through the medium of air. An intruder can easily intercept the communication between two subscribers or between a subscriber and its connected BTS.
- *Insecure A3/A5/A8 Algorithm* – GSM standard uses three algorithms. A3 algorithm is used for authenticating the subscriber through a 128-bit authentication key. A5 algorithm is used for encryption and decryption process and A8 algorithm is used for generating random keys. Many intruder attacks these three algorithms to know about the whole procedure. Every service provider keeps these algorithms confidential. But most of the intruder's targets the algorithm of GSM.
- *One-way Authentication* - In GSM network, only a BTS can authenticate a subscriber but a subscriber cannot authenticate a BTS. The problem arises when an intruder compromises a BTS and imposes attack through this BTS on legitimate subscriber.
- *Cloning of SIM Card* – An intruder can clone (or make a copy of a SIM card) by just deriving a 128-bit authentication key from the legitimate subscriber's SIM card. This results in misusing the SIM for fraudulent purpose.
- *No Integrity of Data* - In GSM standard, the authentication and confidentiality of a subscriber is maintained but there is no security provided for integrity of the data. An intruder can easily change the data with some fake data.

Advantages of GSM:

- GSM is already used worldwide with millions of subscribers.
- International roaming allows subscriber to use a single mobile phone throughout Western Europe. CDMA works in Asia, but not in France, Germany, the U.K. and other popular European destinations.
- GSM is mature which started in the mid-80s which is more stable network with robust features. CDMA is still building its network.
    i) GSM's maturity means engineers cut their teeth for the technology to create an unconscious preference.
- The availability of Subscriber Identity Modules, which are smart cards that provide secure data encryption which gives GSM mobile commerce advantages.

Disadvantages of GSM:

- Lack of access to American market.

☞ Check Your Progress 2

1. **State True or False**

    i) Enhanced Data rates for Gsm Evolution (EDGE) provides better data rates than General Packet Radio Service (GPRS). ☐

    ii) Global System Mobile (GSM) arrived in 2.5 G. ☐

    iii) Home Location Register (HLR) and Visitor Location Register (VLR) are the components of Mobile Switching Center (MSC). ☐

    iv) 2G provides data services only. ☐

    v) Interim Standard 136 (IS 136) is introduced in 3G. ☐

2. Compare 1G, 2G, 2.5G and 3G generations.

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3. Explain GSM architecture with a diagram.

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3.5 CODE DIVISION MULTIPLE ACCESS (CDMA)

Code Division Multiple Access (CDMA) started in 1993 when the first CDMA standard IS-95 issued. In 1995, CDMA technology put into commercialization in Hong Kong and America on large scale. In April, 2001, China Unicom began to construct CDMA networks—the largest in the world. At present, CDMA commercial networks are established in about 40 countries or area which is approximately 20% of all users in the world.

Code Division Multiple Access is a multiple access based technology which provides 1.25 MHz bandwidth per carrier. Its reuse factor is 1 (Figure 12) where as GSM reuse factor is 7, CDMA is available on operating frequency 450, 800, 1900 MHz. It provides inherently superior receive sensitivity (approx. -121 dB). In CDMA, there is a tradeoff between Capacity, Coverage and Quality. It uses precise power control algorithms which minimizes interference. It has multiple diversities like it receives spatial diversity through two receive antennas, path diversity through rake receivers, frequency diversity through spread spectrum and time diversity through interleaving. In CDMA, each user has a unique PN (Pseudo Noise) code. Each user transmits its information to other users by spreading with unique code. CDMA technology uses Direct Sequence Spread Spectrum (DSSS) Unlike other cellular technologies like GSM, each user is separated by a code not by time slot and frequency slot. Moreover, each user share the same bandwidth as the PN code separates and isolates each user and therefore prevents form interference.

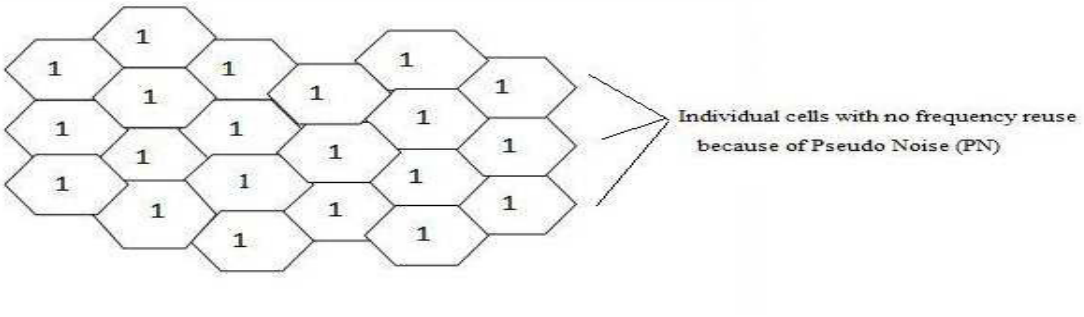

Figure 12: Code Division Multiple Access (CDMA) Frequency Allocation

CDMA technology can be used for implementing WLL (Wireless Local Loop). Existing landline operators can extend their network with WLL. Cellular operators can capitalize on their current network to deliver residential service with WLL. New service providers can quickly deploy non-traditional WLL solutions to rapidly meet a community's telephony needs.

Advantages of CDMA include:

- Increased cellular communications security.
- Provides simultaneous conversations.
- Increased efficiency so that the carrier can serve more subscribers.
- Smaller phones.
- Low power requirements and little cell-to-cell coordination needed by operators.
- Extended reach - beneficial to rural users situated far from cells.
- Uses Direct Sequence Spread Spectrum (DSSS) technology
- Provides soft & softer handoff of a user crossing between cellular region
- Uses rake receiver
- Provides high quality voice to its users
- Has power control
- Gives better coverage area network
- Has a very simple network planning of cells
- Provides smooth migration to 3G and the operator's benefit is protected.

Disadvantages of CDMA include:

- Due to its proprietary nature, all of CDMA's flaws are not known to the engineering community.
- CDMA is relatively new, and the network is not as mature as GSM.
- CDMA cannot offer international roaming, a large GSM advantage.
- Higher spectrum requirement.

☞ Check Your Progress 3

1. Explain how frequencies are allocated in Code Division Multiple Access (CDMA)?

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2. List all advantages and disadvantages of Code Division Multiple Access (CDMA).

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3.6 CELLULAR SYSTEM DESIGN FUNDAMENTAL

This section discusses about the basic fundamentals of cellular systems which are important in designing a cellular system. Such fundamentals concepts are frequency reuse, hand-off and signal strength threshold, Interference, and Coverage & Capacity improvements. We will discuss these basics of cellular design fundamentals one by one

3.6.1 Frequency Reuse

GSM technology involves the concept of frequency reuse. As the name suggests, the given frequencies are used again and again in different cells so as to serve more users at a time. A geographic area is divided into large hexagonal cells (not in practice) and then the frequencies are allotted to each cell. Each cluster has total of 7 small hexagonal cells (Figure 13). In this, each of the cell in cluster uses different frequencies so as to avoid interference and reuses them in cell in different clusters in order to provide service to all users. Each large cell has frequency starting from 1 to 7. The smaller inner most of each large cell is allotted the frequency 1 and then frequency 2 to its small cell which is at the top of the inner most (or central) small cell. Now, the next frequency is 3 which is clock wise next and so on.

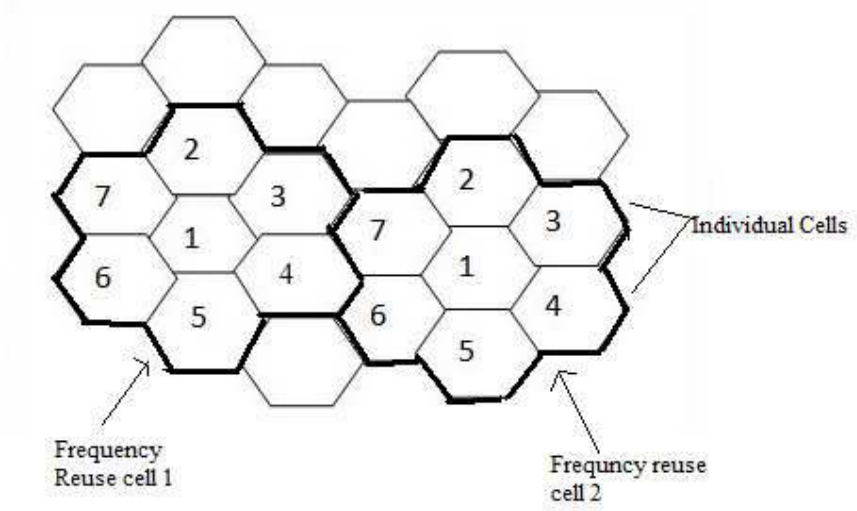

Figure 13: Frequency Reuse Concept

This is the way how the frequencies are reused in order to serve more and more users. Moreover, the reason of dividing the area into hexagonal cells than dividing it into triangle, circle or rectangle is that the hexagon has largest area for a given radius. Also the area of unit is proportional to number of base stations which is equal to the proportional to setup cost of base stations and the number of neighbors to a single unit is a way of hand-off which equals to the proportional to base station networking and control complexity.

3.6.2 Hand-off and Signal Strength

Hand-off is a way to transfer a user's calls one from one cell to another. It is also known as "Hand-over" of a user from one base station to another. There are two types of hand-offs. One is *Hard hand-off* in which the channel in the existing cell which the user is about to leave is released first and only then the channel in the target cell is engaged. Therefore, the connection to the existing cell is broken before or 'as' the connection to the target is made—for this reason such handovers are also known as *break-before-make*. Hard handovers are intended to be instantaneous in order to minimize the disruption to the call. When the mobile is between base stations, then the mobile can switch with any of the base stations, so the base stations bounce the link with the mobile back and forth. This is called *ping-ponging*.

A *soft handoff* is one in which the channel in the existing cell is retained and used for a while in parallel with the channel in the target cell. In this case the connection to the target is established before the connection to the existing is broken, hence this handover is called *make-before-break*. The interval, during which the two connections are used in parallel, may be brief or substantial. Soft handovers may involve using

connections to more than two cells: connections to three, four or more cells can be maintained by one phone at the same time. When a call is in a state of soft handover, the signal of the best of all used channels can be used for the call at a given moment or all the signals can be combined to produce a clearer copy of the signal. The latter is more advantageous, and when such combining is performed both in the downlink (forward link) and the uplink (reverse link) the handover is termed as *softer*. Softer handovers are possible when the cells involved in the handovers have a single cell site.

The question arises here is when to make a handoff or a handover? The answer to this question is based on the *signal strength* and the *minimum threshold value* of the strength required. Consider a simple scenario in which a user is moving from A place to B place. The user is on call. Now as the user is moving, the cell phone is constantly linked with the base station with the full signal strength. As the user moves away from the existing base station, gradually the signal strength keeps on decreasing with the distance. Now the point will come where the strength becomes so low that the minimum threshold value which is maintaining the links with existing base station has reached zero level. And this threshold value is increasing in correspondence with the new or target base station which is enough to maintain the call through the radio links.

3.6.3 Interference

Interference is the disturbance caused in the medium to degrade the quality of service. The reason behind this interference can be a call in neighboring cells, base stations operating on same frequency, or any other mobile in the same cell. Such interference is the consequence of cross talk where a caller gets connected to another unintended called party. In cellular system, interference can be a *Co-Channel Interference* or *Adjacent Channel Interference.*

Co-Channel Interference is caused due to the frequency reuse phenomenon as the base stations which are operating at the same frequency causes interference. As described above the concept of frequency reuse, each cell has base station which is operating on a frequency. This interference degrades the receiver performance as the signal arrives from both intended transmitter and undesired transmitter which are operating on same frequency.

Adjacent Channel Interference is caused by extraneous power from a signal in an adjacent channel and is caused due to the base stations which are operating at adjacent frequencies. The reason behind this interference can be inadequate filtering, improper tuning or poor frequency control. This can be handled by applying the technologies like proper channel assignment and careful filtering.

3.6.4 Coverage and Capacity Improvements

The cellular system constantly needs improvements in order to better service (in terms of signal strength- coverage and readily available service - capacity) to its users. This can be achieved by two technologies – *Cell Splitting* and *Cell Sectoring* for capacity improvements and *Repeaters* for coverage improvement.

Cell Splitting – Just like the name, this technology splits a single cell into number of small cells. One cell may be divided into three smaller cells so that the capacity of users can be handled easily and all users get served simultaneously. Moreover, the all splitted cell (as shown in red color in Figure 14) has its own base stations.

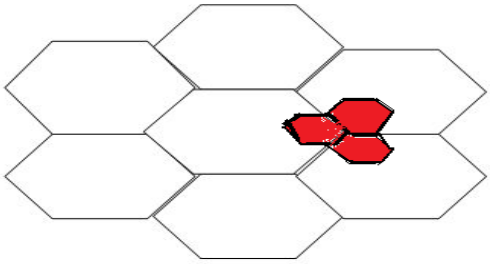

Figure 14: Cell Spelitting

As the number of base station has increased, the transmitted power of base station is reduced. This is because of the reason of small coverage area which is the region of splitted cell. This is done to handle varynig mobility. faster user are handle by larger sells and slow moving users are dealt by small cells.

Cell Sectoring – As the name suggests, a single cell is divided into small sectors at angle of 120 degree or 60 degree. When a cell is sectored into six small cells, this sectoring is called 60 degree sectoring. When a cell is sectored into three small cells, this sectoring is called 120 degree sectoring (Figure 15 & 16). This is an another way of improving capacity of a particular cell. Moreover, 120 degree sectoring reduces co-channel interference as the antennas used in the technology are directional antennas and not omni-directional antenna. Directional antenna signals are directed in a particular direction where as an Omni-directional antenna signals are directed in all directions equally.

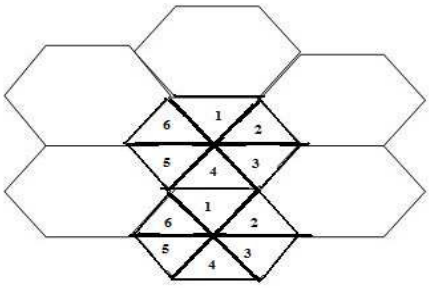

Figure 15: Cell 60 Degree Sectoring

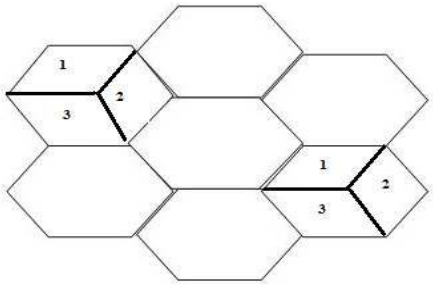

Figure 16: Cell 120 Degree Sectoring

Repeaters – This technology is employed in order to improve coverage of a cellular site. Radio repeaters are used to provide extended range at the places where the signals face obstacle and are difficult to reach like in buildings, basements etc. As repeaters are bi-directional and has range extension capability, the signal reaches the target places easily.

☞ Check Your Progress 4

1. **State True or False**

   i) Total of 8 small cells are needed to make a one large cell in order to reuse the frequency. ☐

   ii) Threshold level decreases as the user moves away from existing base stations. ☐

   iii) Hard Hand-off relies on the concept of break before make. ☐

iv) Adjacent Channel Interference is caused due to frequency reuse concept. ☐

v) Both Cell Splitting and Cell Sectoring are the solution for coverage improvement. ☐

2. Explain the difference between Adjacent Channel Interference and Co-Channel Interference?

……

……

……

3. What is Cell Sectoring? State its type?

……

……

……

3.7 SUMMARY

This completes our discussion on the Wireless Communication Networks which includes Independent Mode and Ad-hoc Mode. Further, we discussed various wireless communication systems such as Paging System, Cordless Telephone Systems, Cellular Mobile Systems, Global System Mobile (GSM), and Code Division Multiple Access (CDMA). Also, we discussed the various wireless generations from 1G (First Generation), 2G, 2.5G and 3G and compared these with each other in the form of a table. At the end of a unit, various cellular design fundamental have been discussed which covers concepts like frequency reuse, hand-offs, Coverage and Capacity improvements and Interference.
The information given on various topics can be supplemented with additional reading. However, wireless technology is very popular and useful these days and provides mobility to the users flying regularly from one place o another.

3.8 SUGGESTED READING

1. Rappaport, Theodore S. 2005. *Wireless communication – Principles and Practice. Second Edition,* Pearson Prentice Hall of India (PHI)

2. Smith, Richard Keith. 2006. *Mobile and Wireless Communications: An Introduction*. Tata McGraw-Hill Publication

3. Palanivelu and Nakkeeran. 2009. *"Wireless and Mobile Communication"* PHI Learning Pvt. Ltd

4. Schiller, Jochen H. 2003. ***Mobile** Communication*. Addison- Wesley Publications

5. Schwartz, Mischa. 2005. *Mobile and Wireless Communications,* Press Syndicate of the University of Cambridge

6. Vijay K. Garg, etl. Wireless Communication , Pearson

7. www.wikipedia.org

8. Stallings, William. 2009 *Wireless Communications and Networks*, Pearson Education India

3.9 SOLUTIONS / ANSWERS

☞ Check Your Progress 1

1. i) False
   ii) True
   iii) True
   iv) False
   v) False
   vi) False

2. Bluetooth works on ad-hoc mode in which the network is formed quickly and is of temporary basis. Bluetooth technology is created by a telecom company called Ericsson in 1994. It was developed in order to connect two devices without wires. The range in which Bluetooth technology works is of 10 meters (or 30 feet approx) only. The name "Bluetooth" is after tenth-century king Harald I of Denmark and parts of Norway who united Danish tribes into a single kingdom. The implication is that Bluetooth does the same with communications protocols, uniting them into one universal standard.

   Bluetooth works on 2.4 GHz ISM band (Industrial, Secientific and Medical band) which divides the data into parts and sends it on up to 79 bands. It uses Frequency Hopping Spread Spectrum (FHSS) with Time Division Duplexing (TDD) technique at the rate of 1600 hops/sec. Moreover, the modulation technique employed is Guassian Frequency Shift Keying (GFSK) which was the only available modulation technique at the time of Bluetooth. Data rate is around 128 Mbps (Mega Bits per Second) and can support up to 8 devices simultaneously in Master-Slave mode. Bluetooth has versions started from version 1.0 to version 4.0.

3. Cordless Telephone system consists of a landline telephone which is a fixed port. This landline is connected to the telephone exchange called Public Switched Telephone Network (PSTN). The landline telephone has a wireless (or cordless) handset which is connected to the landline telephone through a radio link. Therefore, through this cordless system, the user has the freedom to move while on a call. But this has a range or distance limitation which is around few tens of meters only.

☞ Check Your Progress 2

1. i) True
   ii) False
   iii) True
   iv) False
   iv) False.

2. Comparison between 1G, 2G, 2.5G and 3G

	1G	2G	2.5G	3G
Introduced in year	1980	1990	2000	After 2004
Communication Method	Circuit Switched	Circuit Switched	Both Packet and Circuit Switched	Packet Switched
Modulation Technique	Analog Frequency Modulation	Digital Modulation	Digital Modulation and Shift Keying	Digital Modulation and Shift Keying
Services	Voice service only	Both Voice and Data services	Both Voice and Data services with faster data rates	Both Voice and Data services with faster data rates
Channel Assignment	Dedicated Frequency Channel	Dynamic Channel Assignment	Dynamic Channel Assignment	Dynamic Channel Assignment
Standards	-	3 TDMA Standards – GSM, PDC, IS 136 and 1 CDMA Standard	3 TDMA Standards – HSCSD, GPRS and EDGE	EDGE and W-CDMA

3. GSM network consists of several components which are as follows:

Mobile Station (MS) - This is the device which is used by the GSM user and is portable, small, light-weight and hand-held.

Base Transceiver Station (BTS) - It is the cell tower which is located on the roof by the service providers to provide network to its users. A BTS is connected to MS by wireless radio links.

Base Station Controller (BSC) - This controls one or more BTS and is connected to them. This connectivity is through wires. BTS and BSC together called Base Station (BS).

Mobile Switching Centre (MSC) – A MSC is connected to number of BSC and manages the call routing process.

Authentication Centre (AuC) – Authentication Centre is responsible for authenticating a legitimate user (subscriber) and also provides 128-bit authentication key to user.

Home Location Register (HLR) – This is a database which stores the user's information and its location information. This provides user an IMSI (International Mobile Subscriber Identity) number to identify its user. In other words, the area to which a subscriber belongs is saved in HLR.

Visitor Location Register (VLR) – This database contains the information about subscriber who visited the area of a particular MSC and stores the IMSI number temporarily.

Operation Maintenance Centers (OMC) – The operation of each MS, BTS, BSC and MSC is monitored and maintained by this centre.

Subscriber Identity Module (SIM) – This is a removable 16k or 32k chip (or a small smart card) which a service provider provides to its subscriber. It is used in MS to access the GSM services like calling, messaging etc.

Public Networks – This consists of networks like PSTN (Public Switched Telephone Network), Data Network, ISDN (Integrated Services digital Network) to which MSC is connected.

Below given Figure 11 is the architecture of GSM containing all the above described components. GSM communication operates on 900 MHz/1800 MHz standards and uses techniques like FDD (Frequency Division Duplexing) and TDMA (Time Division Multiple Access).

☞ Check Your Progress 3

1. Code Division Multiple Access is a multiple access based technology which provides 1.25 MHz bandwidth per carrier. It reuses factor 1 (Figure 12) where as GSM reuses factor of 7, CDMA is available on operating frequency 450, 800, 1900 MHz. It uses RUIM Card and provides inherently superior receive sensitivity (approx. -121 dB). In CDMA, there is a tradeoff between Capacity, Coverage and Quality. It uses precise power control algorithms which minimizes interference. It has multiple diversities like it receives spatial diversity through two receive antennas, path diversity through rake receivers, frequency diversity through spread spectrum and time diversity through interleaving. In CDMA, each user has a unique PN (Pseudo Noise) code. Each user transmits its information to other users by spreading with unique code. CDMA technology uses Direct Sequence Spread Spectrum (DSSS) is used. Unlike other cellular technologies like GSM, each user is separated by a code not by time slot and frequency slot. Moreover, each user share the same bandwidth as the PN code separates and isolates each user and therefore prevents form interference. User axis shows cumulative signal strength of all users.

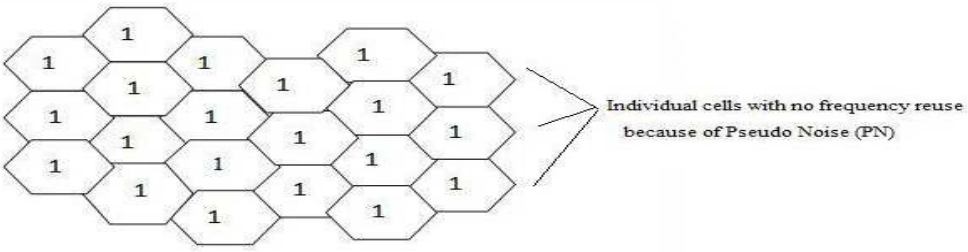

Figure 12: Code Division Multiple Access (CDMA) Frequency Allocation

2. Following are the advantages and disadvantages of CDMA -

   Advantages of CDMA include:

   - Increased cellular communications security.
   - Simultaneous conversations.
   - Increased efficiency, meaning that the carrier can serve more subscribers.
   - Smaller phones.
   - Low power requirements and little cell-to-cell coordination needed by operators.

- Extended reach - beneficial to rural users situated far from cells.
- Uses Direct Sequence Spread Spectrum (DSSS) technology
- Provides soft & softer handoff of a user crossing between cellular region
- Uses rake receiver
- Has a variable rate vocoder
- Provides high quality voice to its users
- Has power control
- Gives better coverage area network
- Has a very simple network planning of cells
- Provides smooth migration to 3G and the operator's benefit is protected.

Disadvantages of CDMA include:

- Due to its proprietary nature, all of CDMA's flaws are not known to the engineering community.
- CDMA is relatively new, and the network is not as mature as GSM.
- CDMA cannot offer international roaming, a large GSM advantage

☞ Check Your Progress 4

1. i) False
   ii) True
   iii) False
   iv) False
   iv) False.

2. *Co-Channel Interference* is caused due to the frequency reuse phenomenon as the base stations which are operating at the same frequency causes interference. As described above the concept of frequency reuse, each cells has base stations which are operating on frequencies. This interference degrades the receiver performance as the signal arrives from both intended transmitter and undesired transmitter which is operating on same frequency.

   Adjacent Channel Interference is caused by extraneous power from a signal in an adjacent channel and is caused due to the base stations which are operating at adjacent frequencies. The reason behind this interference can be inadequate filtering, improper tuning or poor frequency control. This can be handled by applying the technologies like proper channel assignment and careful filtering. Data Encryption Standard (DES) is a symmetric-key block cipher published by the National Institute of Standards and Technology (NIST) in 1977. DES has been the most widely used symmetric-key block cipher since its publication.

3. *Cell Sectoring* – As the name suggests, a single cell is divided into small sectors at angle of 120 degree or 60 degree. When a cell is sectored into three small cells, this sectoring is called 120 degree sectoring. When a cell is sectored into six small cells, this sectoring is called 60 degree sectoring (Figure 15 & 16). This is an another way of improving capacity of a particular cell. Moreover, 120 degree sectoring reduces co-channel interference as the antennas used in the technology are directional antennas and not omni-directional antenna.

Directional antenna signals are directed in the particular direction where as an Omni-directional antenna signals are directed in all directions equally.