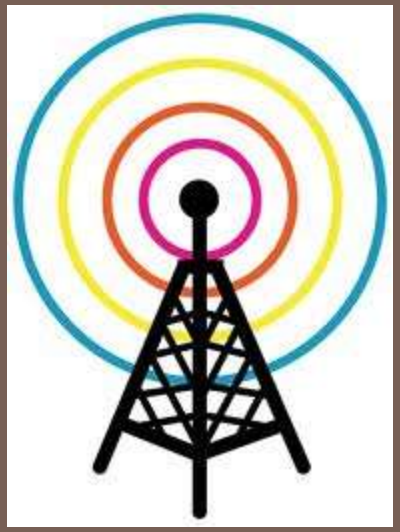
CELLULAR NETWORK



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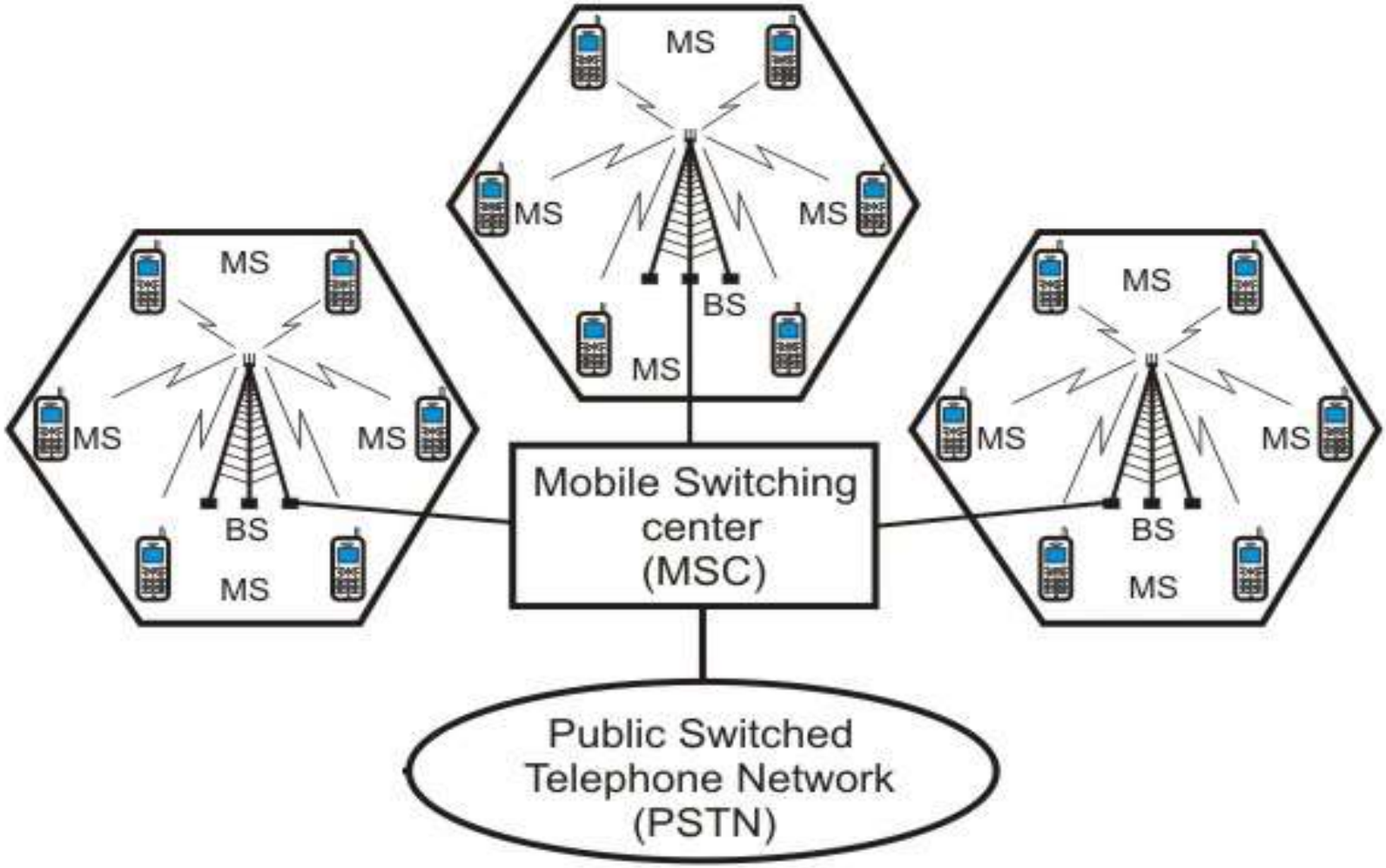
What is cellular network ?

- A cellular network is a radio network distributed over land areas called cells, each served by at least one fixed-location transceiver known as a cell site or base station.
- When joined together these cells provide radio coverage over a wide geographic area.
- This enables a large number of portable transceivers to communicate with each other and with fixed transceivers and telephones anywhere in the network, via base stations, even if some of the transceivers are moving through more than one cell during transmission.

Basic concepts



Basic components

- **Mobile station (MS)** : Mobile handsets which is used by user to communicate with other users.
- **Base Stations (BS):** Each cell contains an antenna, which is controlled by a small office.
- **Mobile Switching Center (MSC**): Each base station is controlled by a switching office, called mobile switching center.
- **Public switched telephone network** (**PSTN**): The public switched telephone network (PSTN) is the network of the world's public circuit switched telephone networks.

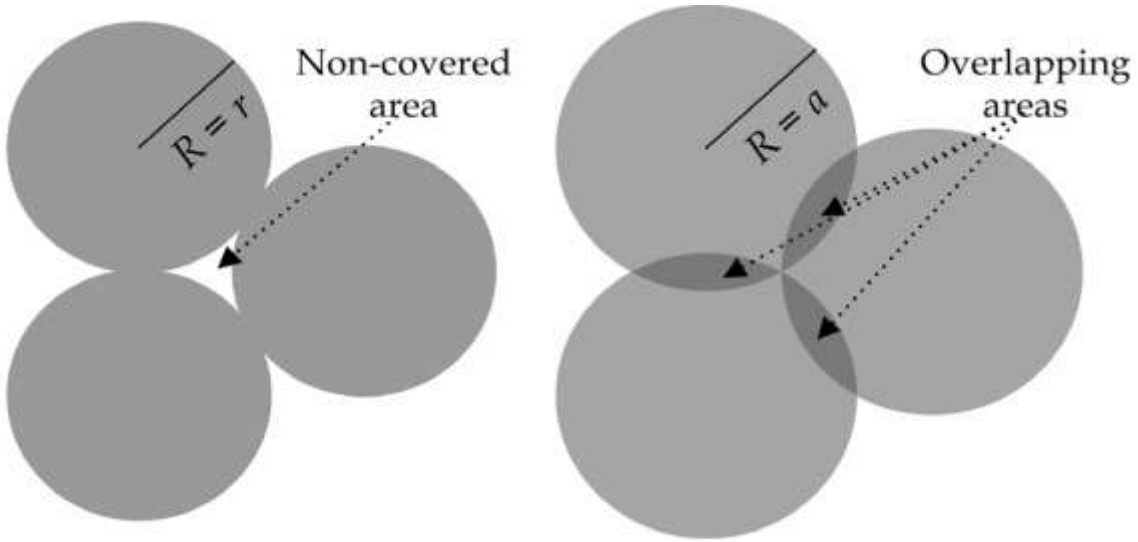
Why cells are hexagonal ?

Some criteria for the cell shapes

1. Geometric shape
2. Area without overlap
3. Area of the cell

Some eligible shapes

- Square
- Equilateral triangl
- Circle
- Hexagon



Area comparisons

The area of an equilateral triangle to a circle approx = 17.77%

The area of a square to a circle approx = 63.7%

The area of a hexagon to a circle approx = **83%**

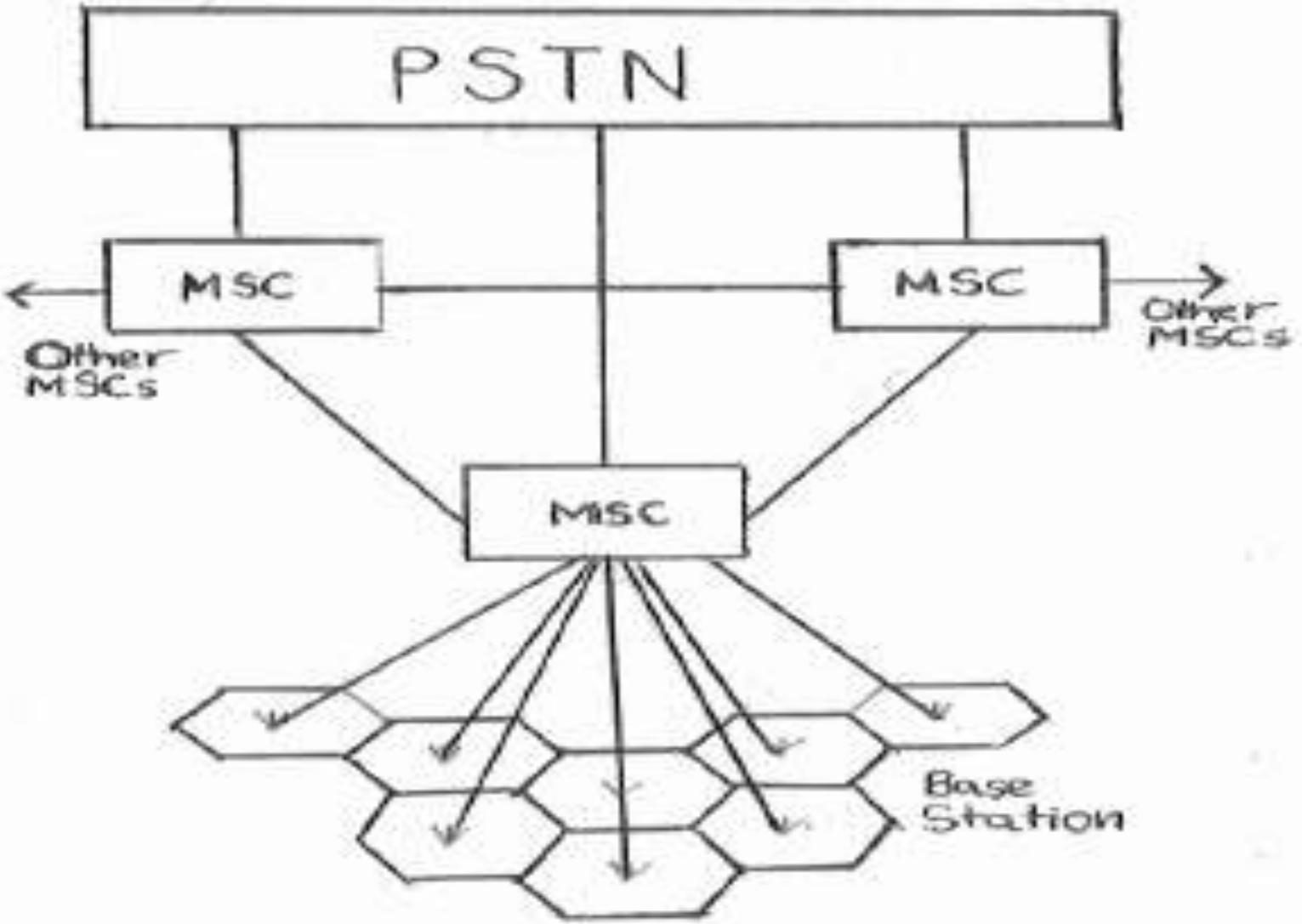
- ✓ It means hexagon has the highest coverage area after a circle.
- ✓ Thus hexagon satisfies all the conditions which is why the shape of a cell is hexagonal in cellular network.

MSC databases

- Home location register database (HLR) - stores information about each subscriber that belongs to it
- Visitor location register database (VLR) - maintains information about currently physically in the region
- Authentication center database - used for authentication activities, holds encryption keys
- Equipment identity register database (EIR) – keeps track of the type of equipment that exists at the mobile station

Connections between MS,BS,MSC and PSTN

- The service coverage area of a cellular network is divided into many smaller areas, referred to as cells, each of which is served by a base station (BS).
- The BS is fixed, and it is connected to the mobile telephone switching office (MTSO), also known as the mobile switching center(MSC).
- An MTSO is in charge of a cluster of BSs and it is, in turn,connected to the PSTN.
- MSs such as cell phones are able to communicate with wireline phones in the PSTN.
- Both BSs and MSs are equipped with a transceiver.


PSTN
MSC
MSC
MSC
Other MSCs
Other MSCs
Base Station

How a call is made ?

Two types of channels are available between mobile station and base station

1. **Control channels** : used to exchange information having to do with setting up and maintaining calls
2. **Traffic channels** : carry voice or data connection between users

- Both voice and control channels are further divided into forward (or downlink) and reverse (or uplink).

- A **forward channel** is used to carry traffic from the **BS to the MS.**

- A **reverse channel** is used to carry traffic from the **MS to the BS**.

At transmitting end

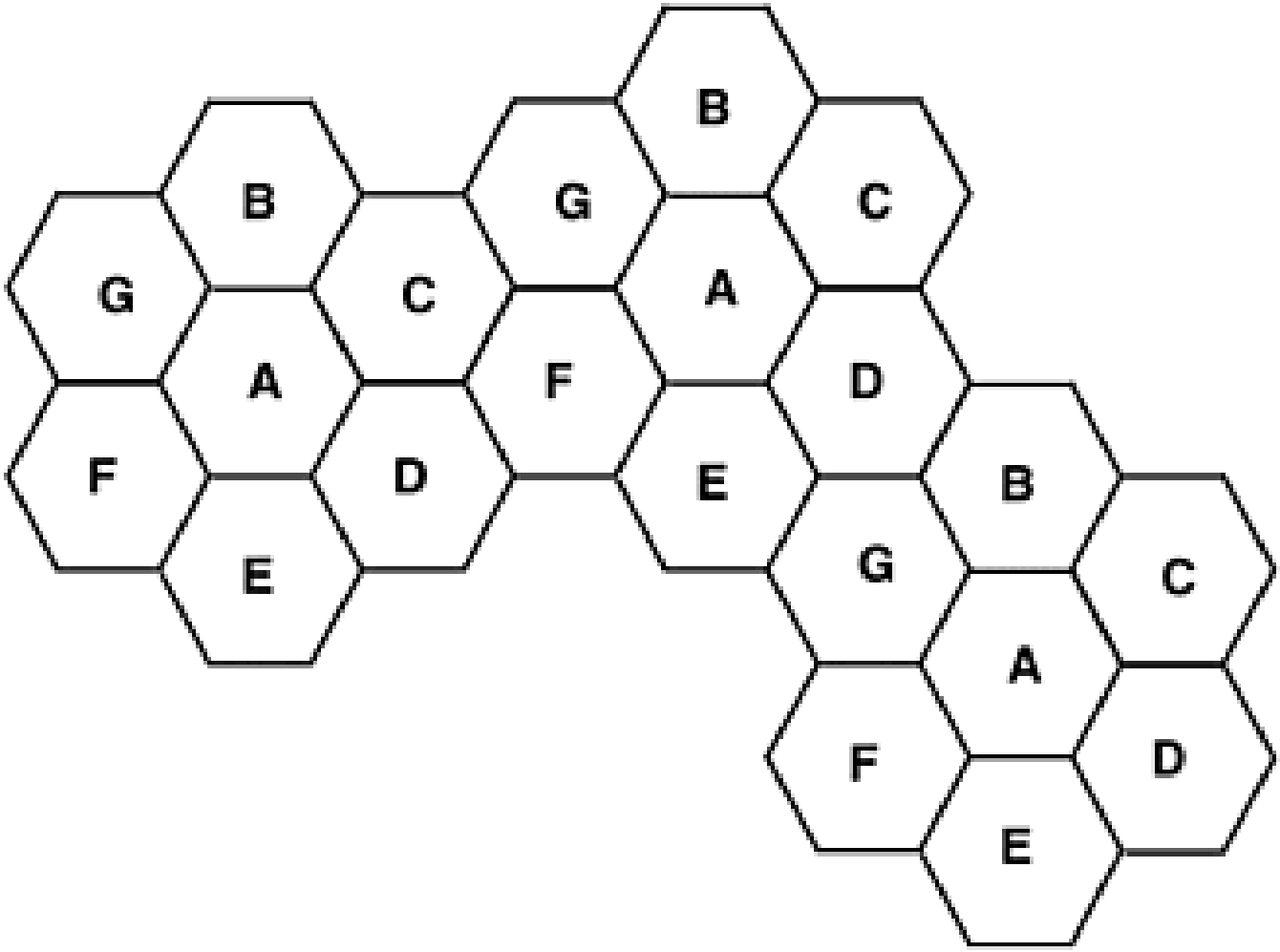
- A caller enters a 10-digit code (phone number) and presses the call button.
- The MS scans the band to select a free channel and sends a strong signal to send the number entered to BS.
- The BS relays the number to the MSC.
- The MSC in turn dispatches the request to all the base stations in the cellular system.
- The Mobile Identification Number (MIN) is then broadcast over all the forward control channels throughout the cellular system. It is known as paging.
- The MS responds by identifying itself over the reverse control channel.
- The BS relays the acknowledgement sent by the mobile and informs the MSC about the handshake.
- The MSC assigns an unused voice channel to the call and call is established.

At receiving end

- All the idle mobile stations continuously listens to the paging signal to detect messages directed at them.
- When a call is placed to a mobile station, a packet is sent to the receiver’s home MSC to find out where it is.
- A packet is sent to the base station in its current cell, which then sends a broadcast on the paging channel.
- The receiver MS responds on the control channel.
- In response, a voice channel is assigned and ringing starts at the MS.

Frequency reuse

- Cellular telephone systems rely on an intelligent allocation and reuse of channels.
- Each base station is given a group of radio channels to be used within a cell.
- Base stations in neighbouring cells are assigned completely different set of channel frequencies.
- By limiting the coverage areas, called *footprints, within cell boundaries, the same set of channels may be used to cover different cells separated from one another by a distance large enough to keep interference level within tolerable limits*



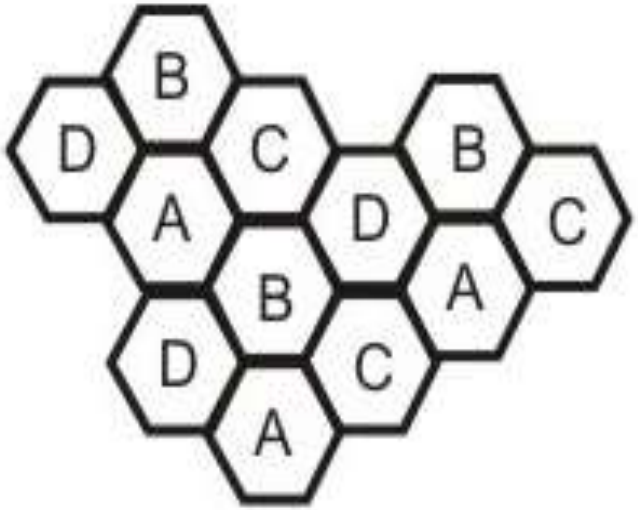
frequency reuse

- The closest distance between the centres of two cells using the same frequency is determined by **reuse distance**.

$$D = R\sqrt{3N},$$

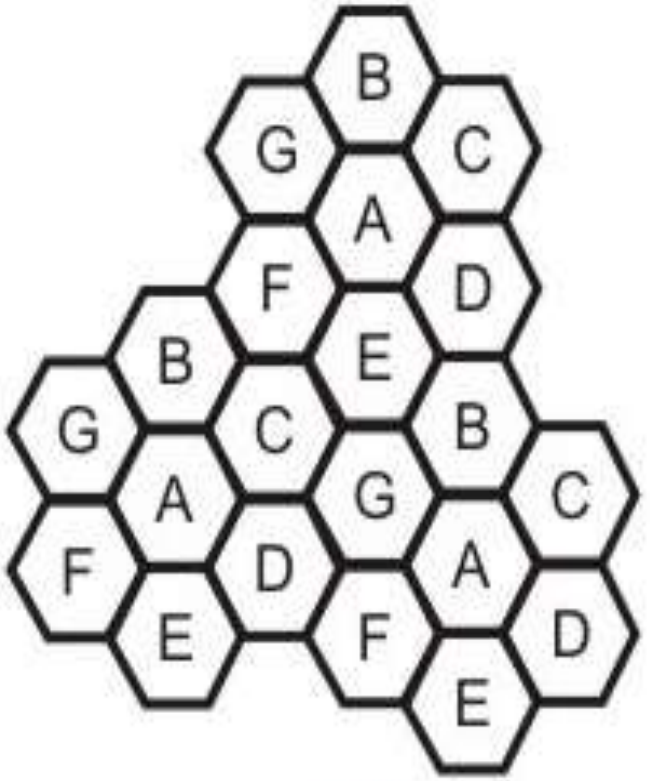
where *R* is the cell radius and *N* is the number of cells per cluster.

- Fraction of total available channels assigned to each cell within a cluster is 1/N which is called **reuse factor**.
- If there are a total of *M* channels allocated for cellular communications and if the coverage area consists of *N* cells, there are a total of *MN/7* channels available in the coverage area for concurrent use based on the seven-cell reuse pattern.



(a)

reuse factor of **1/4**

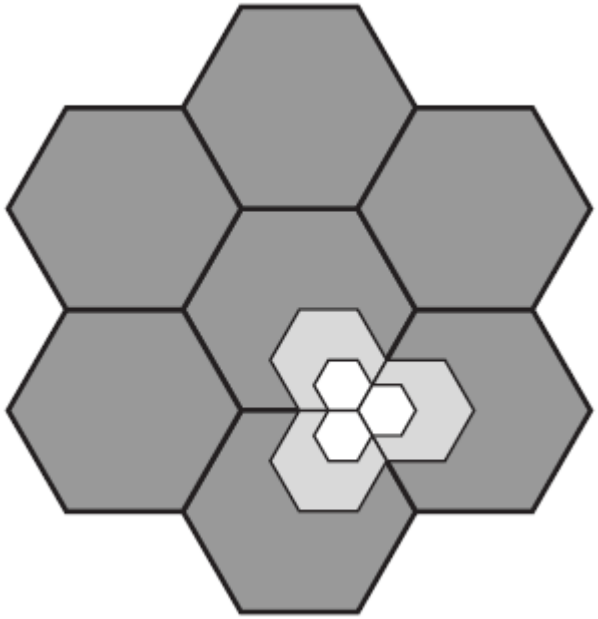


(b)

reuse factor of **1/7**

Approaches to cope up with increasing demand

I. Adding new channels
II. Frequency borrowing – frequencies are taken from adjacent cells by congested cells
III. Cell splitting – cells in areas of high usage can be split into smaller cells
IV. Cell sectoring – cells are divided into a number of wedge-shaped sectors, each with their own set of Channels
V. Microcells – antennas move to



cell splitting

Multiple access methods

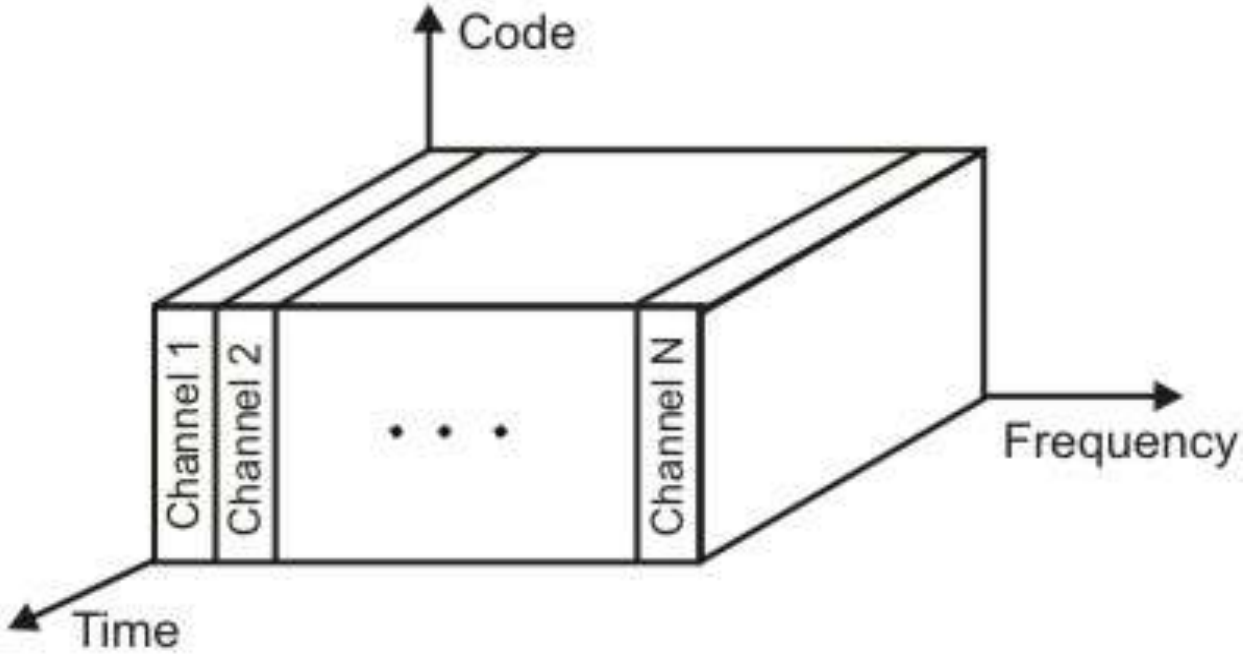
- Within a cell covered by a BS, there are multiple MSs that need to communicate with the BS. Those mobile stations must share the air interface in an orderly manner so that no MSs within the cell interfere with each other. The methods for MSs to share the air interface in an orderly manner are referred to as multiple access methods.

- The popular multiple access methods

1. FDMA
2. TDMA
3. CDMA

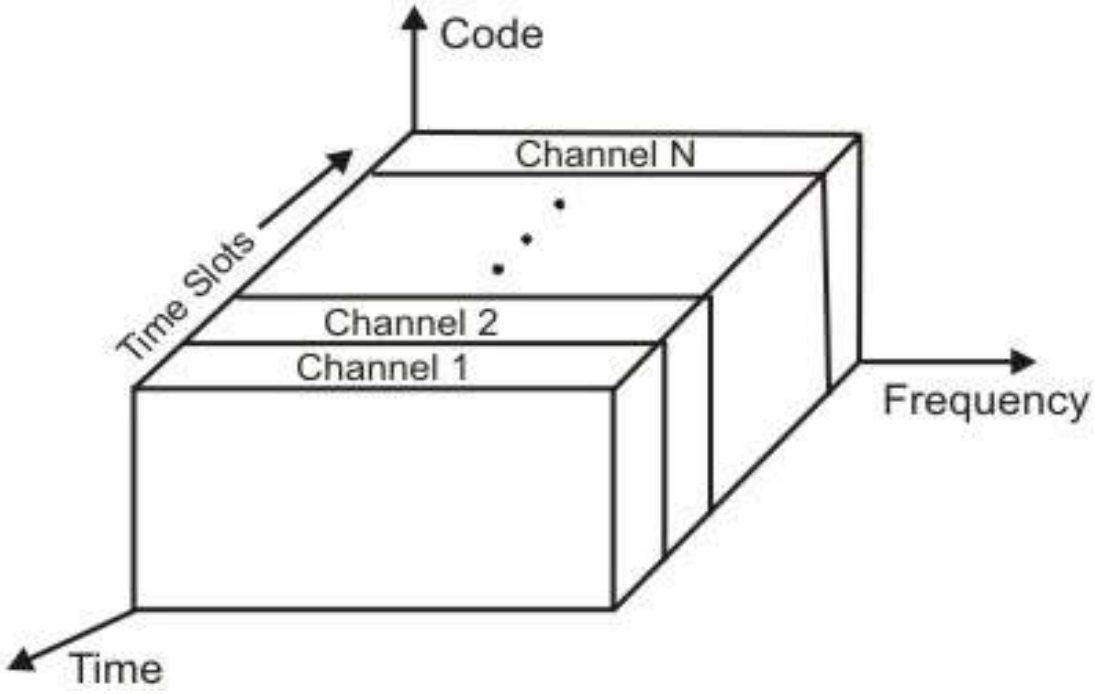
FDMA

- FDMA divides the frequency spectrum assigned to the BS into several frequency bands, as known as channels.
- These channels are well separated and do not interfere with each other.
- An MS can use the assigned channel(s) exclusively.



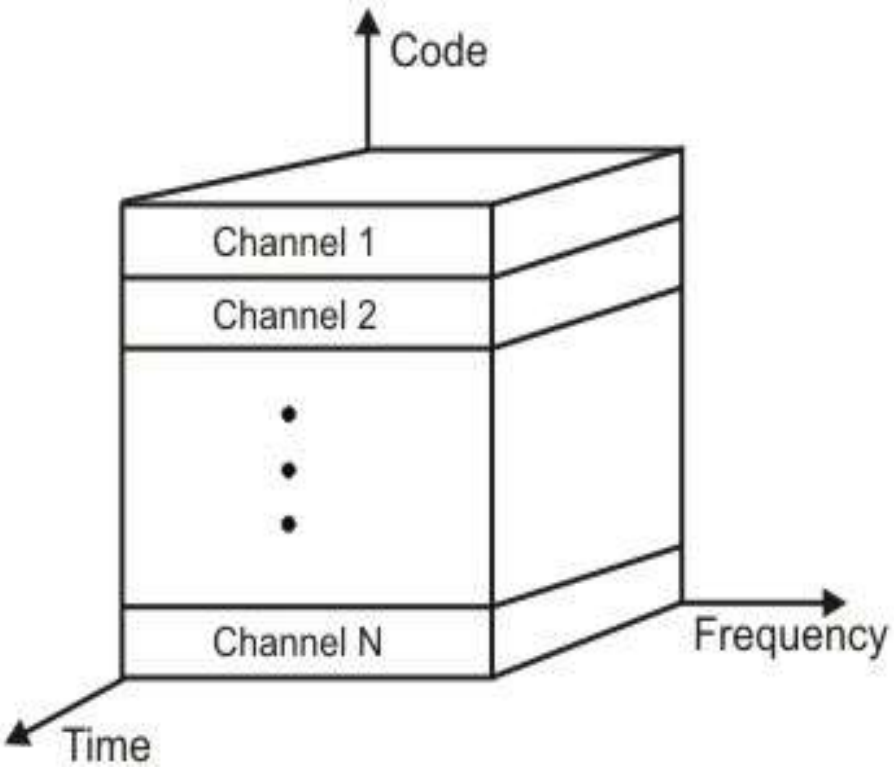
TDMA

- The bandwidth is timeshared
- In each time slot, only one MS is allowed to use the shared channel to transmit or receive.
- MSs take their turn transmitting or receiving in their allocated slots in a roundrobin fashion.



CDMA

- Data from all stations are transmitted simultaneously and are separated based on coding theory
- In case of CDMA, the transmission from different stations occupy the entire frequency band at the same time.
- Multiple simultaneous transmissions are separated by using coding theory.
- Each bit is assigned a unique m-bit code or chip sequence.



Location Management

Location management deals with how to keep track of an active mobile station within the cellular network. A mobile station is active if it is powered on. Since the exact location of a mobile station must be known to the network during a call,location management usually means how to track an active mobile station between two consecutive phone calls.

Two basic operations

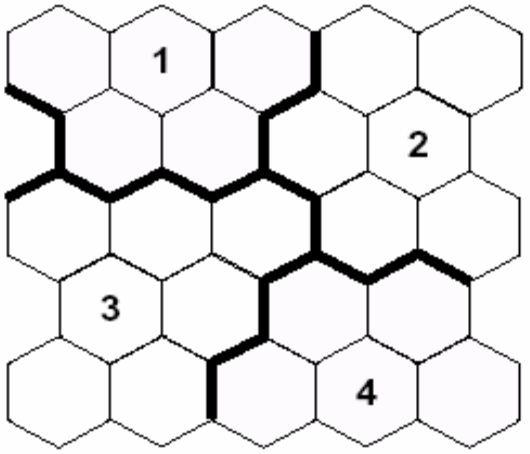
1. **Location Updating**: Informing the network of a devices location.
2. **Paging**: Polling a group of cells to determine the precise location of a device

Location update Schemes

A. Static location update schemes

Static schemes define the frequency and occurrence of location updates independently from any user characteristics.Such static mechanisms allow efficient implementation and low computational requirements due to the lack of independent user tracking and parameterization

I. Always update and never update
II. Location areas



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B. Dynamic location update schemes

Dynamic location update schemes allow per-user parameterization of the location update frequency. These account for the dynamic behavior of users and may result inlower location management costs than static schemes. Unlike static location management strategies, a location update may be performed from any cell in the network, taking into consideration the call arrival and mobility patterns of the user.

I. Thresold based
   a) Time based
   b) Movement based
   c) Distance based
II. Profile based

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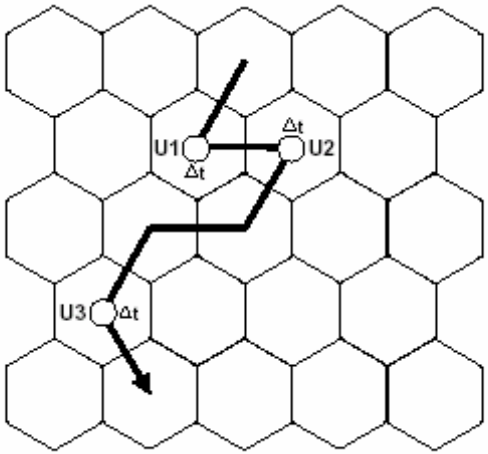
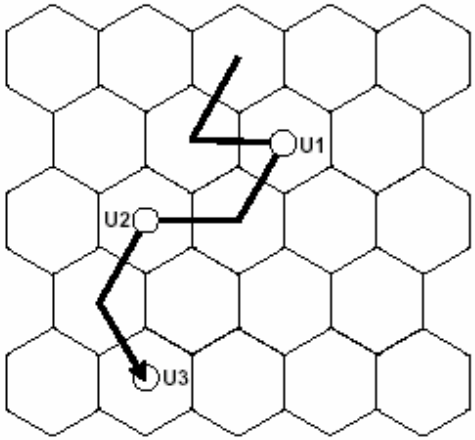
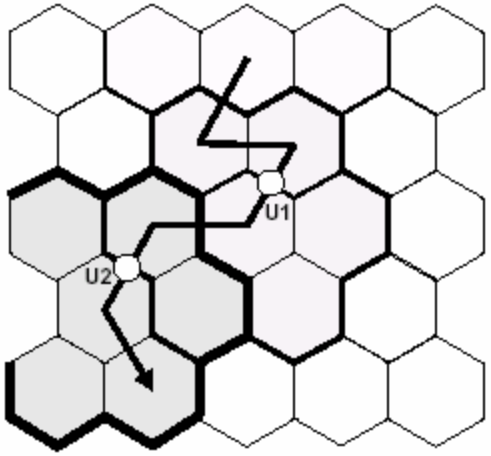


Time based



Movement based



Distance based

Paging schemes

While mobile devices perform updates according to their location update scheme, the network needs to be able to precisely determine the current cell location of a user to be able to route an incoming call. This requires the network to send a paging query to all cells where the mobile device may be located, to inform it of the incoming transmission.

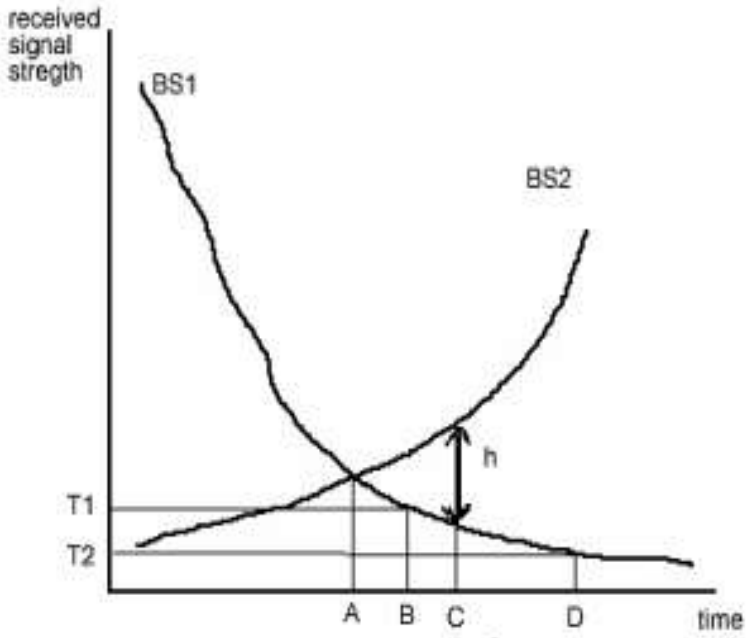
I. Simultaneous paging
II. Sequential paging
III. Intelligent paging

Handoff

Continuation of an active call is one of the most important quality measurements in the cellular systems. Handoff process enables a cellular system to provide such a facility by transferring an active call from one cell to another.

Handoff initiation

I. *Relative Signal Strength*
II. *Relative Signal Strength with Thresh*
III. *Relative Signal Strength with Hyster*
IV. *Relative Signal Strength with Hyster and Threshold*



Handoff decision protocols

I. Network controlled handoff (NCHO)
II. Mobile assisted handoff (MAHO)
III. Mobile controlled handoff (MCHO)

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Handoff types

1. **Hard handoff**

The hard handoff term is used when the communication channel is released first and the new channel is acquired later from the neighboring cell. Thus, there is a service
interruption when the handoff occurs reducing the quality of service. Hard handoff is used by the systems which use time division multiple access (TDMA) and frequency division multiple access (FDMA) such as GSM and General Packet Radio Service (GPRS).

2. **Soft handoff**

A soft handoff can establish multiple connections with neighboring cells. Soft handoff is used by the code division multiple access (CDMA) systems where the cells use same frequency band using different code words. Each MS maintains an active set where BSs are added when the RSS exceeds a given threshold and removed when RSS drops below another threshold value for a given amount of time specified by a timer. When a
presence or absence of a BS to the active set is encountered soft handoff occurs.

Channel assignment

- As the frequency spectrum is limited and mobile users are increasing so the main task of resource management is to serve the maximum number of possible calls through a limited number of channels. The available wireless bandwidth is divided into channels, where each channel is capable of supporting a communication session.

- When mobile station want to communicate with another mobile user then it will send request for a channel to the base station. Depending on channel allocation algorithm either BS or MSC will allocates a channel to mobile station. Channel allocation is a process of allocating a channel to a call. While allocating a channel main focus is on selecting a channel frequency without violating the interference constraint so that the blocking of call is minimum.

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Various channel allocation schemes

1. **Fixed channel allocation (FCA)**

In fixed channel allocation fixed number of channels is assigned to particular cell. In this scheme, when all the channels assigned to the cell are busy then the calls will be blocked, so to improve the blocking probability borrowing scheme can be used along with fixed channel allocation scheme. In borrowing scheme, if there is a channel request and all the channels in particular cell is busy then the cell borrows some additional channels from any of the neighbouring cells. The disadvantage of this scheme is channel allocation become more complex

2. **Dynamic channel allocation**

Two types

a. Distributed dynamic channel allocation
b. Centralized dynamic channel allocation

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a. Distributed dynamic channel allocation

In the distributed dynamic channel allocation algorithm the total number of channels are divided into three equal size groups. Any cell in the cluster can acquire the channel group as long as no one of its adjacent cells is holding the same group. Thus no adjacent base station uses the same group. The same group can be used by the two base stations as long as the distance between these two base stations is the minimum reuse distance.

b. Centralized dynamic channel allocation

In Centralized dynamic channel allocation, a single central pool of all available channels is maintained from which a central computer allocates channels to various cells on demand, and the cells return the channels to the central pool. In this, the spectral efficiency is higher but such schemes have a high centralization overhead, as well as a there is single central computer the failure of this computer may cause a serious problem

3. Hybrid channel allocation

It is the combination of both fixed channel allocation and dynamic channel allocation schemes.

Evolution of Cellular Network

1G (First Generation):

- Advanced Mobile Phone Service (AMPS)
  - US trials 1978; deployed in Japan (’79) & US (’83)
  - 800 MHz band — two 20 MHz bands
  - TIA-553
  - Still widely used in US and many parts of the world
- Nordic Mobile Telephony (NMT)
  - Sweden, Norway, Demark & Finland
  - Launched 1981; now largely retired
  - 450 MHz; later at 900 MHz (NMT900)
- Total Access Communications System (TACS)
  - British design; similar to AMPS; deployed 1985
  - Some TACS-900 systems still in use in Europe

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2G (Second Generation):

D-AMPS: D-AMPS is essentially a digital version of AMPS and it is backward compatible with AMPS. It uses the same bands and channels and uses the frequency reuse factor of 1/7. 25 frames per second each of 1994 bits, divided in 6 slots shared by three channels. Each slot has 324 bits-159 data, 64 control, 101 error-correction. It uses both TDMA and FDMA medium access control techniques.

GSM: GSM (Global System for Mobile Communications) is a second generation, cellular, digital mobile phone system, and it is one of the world's main 2G wireless standards, having become widely established in Europe and many other countries of the world. GSM operates in the three main frequency bands of 900 MHz, 1800 MHz, and 1900 MHz, which are known respectively as GSM 900, GSM 1800 and GSM 1900. In the USA, GSM is also known as PCS (Personal Communication Service), and it operates in the 1900 MHz frequency band.

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In order to make the most efficient use of its available frequency bands, and to provide maximum traffic-carrying capacity, GSM networks employ a combination of FDMA (frequency division multiple access) and TDMA (time division multiple access). Although GSM was primarily developed as a voice communication system, with a reliance on circuit switching techniques, there is also a limited data handling capability available through the Short Message Service (SMS), allowing the phone-user to send and receive text messages. When handling calls, GSM networks also rely on a sophisticated process for authentication and security, including a number of other basic operating units such as the Home Location Register, Visitor Location Register, Equipment Identity Register and Authentication Centre, which together enable the network to perform checks on the identity and status of the subscriber and the phone. The SIM (Subscriber Identification Module) card is another essential element in the GSM operating system, and this card stores important data relevant to the phone and the user.

IS-95 CDMA: IS-95 is based on CDMA/DSSS and FDMA medium access control technique.

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3G (Third Generation):

3G - Third Generation mobile telephone networks are the latest stage in the development of wireless communications technology. Significant features of 3G systems are that they support much higher data transmission rates and offer increased capacity, which makes them suitable for high-speed data applications as well as for the traditional voice calls. In fact, 3G systems are designed to process data, and since voice signals are converted to digital data, this results in speech being dealt with in much the same way as any other form of data. Third Generation systems use packet-switching technology, which is more efficient and faster than the traditional circuit-switched systems, but they do require a somewhat different infrastructure to the 2G systems. The benefits of higher data rates and greater bandwidth mean that 3G mobile phones can offer subscribers a wide range of data services, such as mobile Internet access and multimedia applications. Compared to earlier mobile phones a 3G handset provides many new features, and the possibilities for new services are almost limitless, including many popular applications such as TV

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The main 3G technologies include UMTS and cdma2000™, with Europe settling on the UMTS with wideband CDMA (W-CDMA) as its chosen approach, whilst in the USA the cdmaOne networks will be upgraded to CDMA2000, a multi-carrier CDMA (MC-CDMA). It is generally accepted that CDMA is a superior transmission technology, when it is compared to the old techniques used in GSM/TDMA. WCDMA systems make more efficient use of the available spectrum, because the CDMA technique enables all base stations to use the same frequency. In the WCDMA system, the data is split into separate packets, which are then transmitted using packet switching technology, and the packets are reassembled in the correct sequence at the receiver end by using the code that is sent with each packet. WCDMA has a potential problem, caused by the fact that, as more users simultaneously communicate with a base station, then a phenomenon known as "cell breathing" can occur. This effect means that the users will compete for the finite power of the base station's transmitter, which can reduce the cell's range.

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Thank You