Wireless Communications

(Unit-2 &3)

CELLULAR MOBILE SYSTEMS

SPECTRUM ALLOCATION

- Spectrum allocation is one of the major problem that is facing by the radio communication industry. In setting the allocation policy, the FCC (Federal Communication Commission) seeks systems which need minimal bandwidth but provides high usage and consumer satisfaction.

- A mobile telephone system would operate within a limited assigned frequency band and would serve an almost unlimited number of users in unlimited areas.

CELLULAR MOBILE SYSTEMS

- Following are the major approaches in spectrum allocation:-

1) Single sideband, which divides the allocated frequency band into maximum numbers of channels.

2) Cellular, which reuses the allocated frequency in different geographical area.

3) Spread spectrum of frequency hoped, which Generates many code over a wide frequency band.

- In the past, 33 channels were allocated to three mobile telephone systems.

EM Spectrum for Telecom

Orderly use of frequency spectra reduces interference

- International Telecommunications Union (ITU) for worldwide coordination
- Federal Communications Commission (FCC) in the US
- European Conference for Posts and Telecommunications (CEPT) and European Telecommunication Standards Institue (ETSI) in Europe
- License spectrum is allocated for proprietary use, e.g., cellular communication
- Unlicensed spectrum is available for general use (with restrictions), e.g., 2.4 GHz ISM band

FREQUENCY ALLOCATION IN INDIA

- For any type of radio link, frequency is allocated by TRAI (TELEPHONE REGULATORY AUTHORITY OF INDIA)to the operator. This frequency allocation is different for different services. Like TRAI each country has a authority, who works co-ordination of FCC or like other international organization.

▪Most spectra licensed; 3G license is very expensive; FCC is a mighty sector.

▪Infrared, ISM band, and amateur radio band are license-free

EM Spectrum for Telecom

- In 1980 FCC assigned frequencies in two band A and B of 20 MHz groups.

BAND	MOBILE	BASE	TWO SYSTEMS/ MARKET
A	824-835 845-846.5	869-880 890-891.5	NON WIRELINE
B	835-845 846.5-849	880-890 891.5-894	WIRE LINE

- On July 24,1986, an addition 5 MHz was allocated to each band.

The Technology: Radio Spectrum

Radio Spectrum: from 30 KHz to 3 GHz
AM radio: 540KHz – 1800 KHz
FM radio: 88 MHz – 108 MHz
Cellular (e.g. AMPS): 824 – 849, 869 – 894 MHz
Cellular (e.g. GSM): 890 – 915, 935 – 960 MHz
PCS frequencies: 1800 – 2200 MHz
Microwaves: from 3 GHz to 300 GHz
Infrared Spectrum: from 300 GHz to 300 THz

The Technology: Radio Spectrum

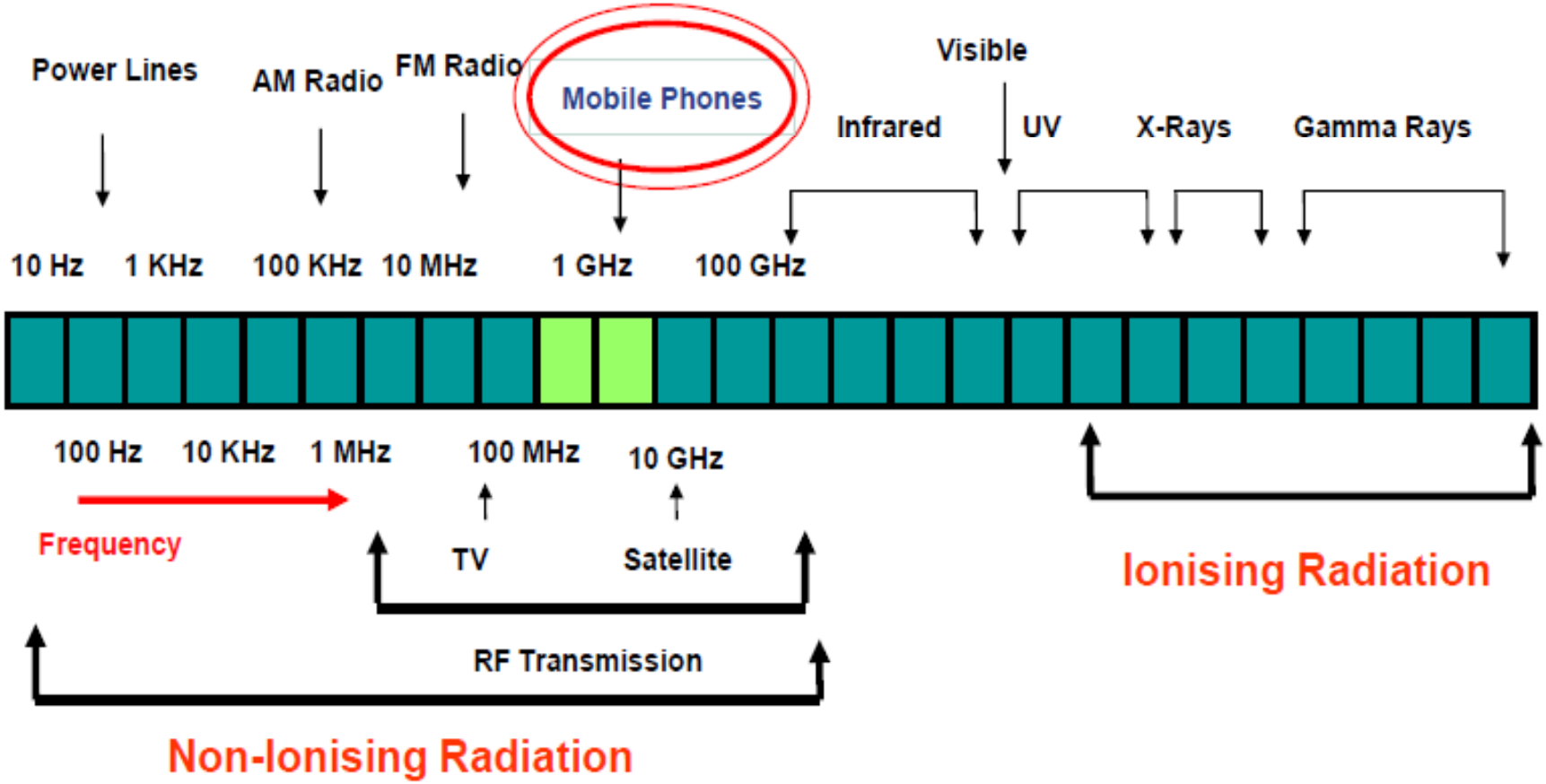
Spectrum for 2G services-

- **822-844 MHz paired with 869-889 MHz, presently being deployed for CDMA based 2 G networks in the country**
- **890-915 MHz paired with 935-960 MHz, presently being deployed for GSM based 2G networks**
- **1710-1785 MHz paired with 1805-1880 MHz, presently partially being deployed for GSM based 2G network**

Spectrum for 3G services-

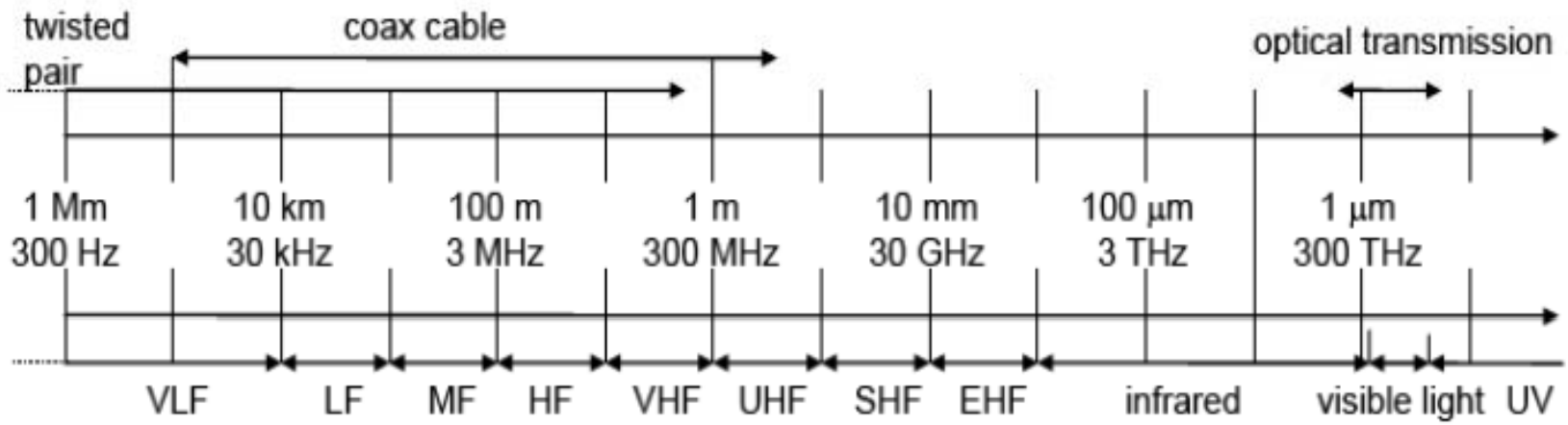
- 450-470 MHz
- 1900-1910 MHz paired with 1980-1990 MHz
- 1920-1980 MHz paired with 2110-2170 MHz

EM Spectrum for Telecom



As you move towards the higher side of the spectrum, the electromagnetic energy & penetration power goes on increasing

EM Spectrum for Telecom



VLF = Very Low Frequency

LF = Low Frequency

MF = Medium Frequency

HF = High Frequency

VHF = Very High Frequency

UHF = Ultra High Frequency

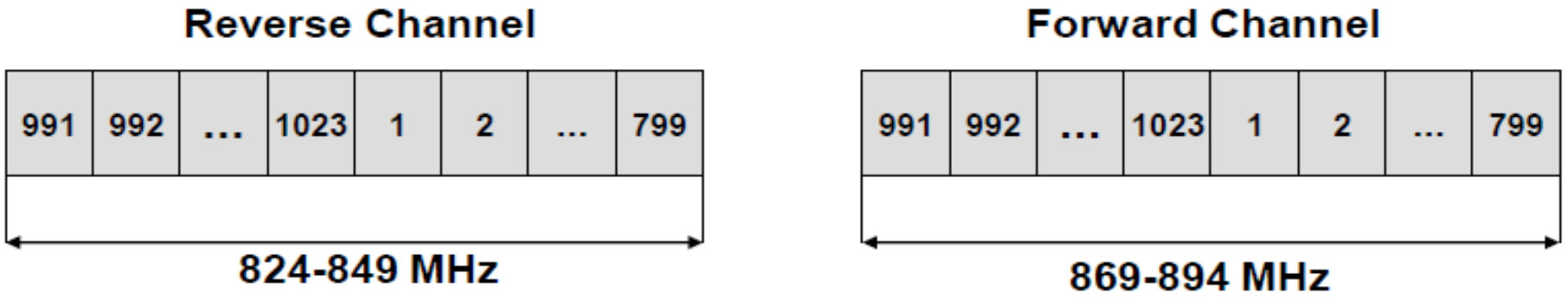
SHF = Super High Frequency

EHF = Extra High Frequency

UV = Ultraviolet Light

$\lambda = c/f$; wave length λ, speed of light $c \cong 3 \times 10^8 m/s$, frequency f

Example - Frequency Spectrum Allocation in U.S. Cellular Radio Service



Channel Number		Center Frequency (MHz)
Reverse Channel	1 <=N <= 799	0.030N + 825.0
	991 <= N <= 1023	0.030(N-1023) + 825.0
Forward Channel	1 <=N <= 799	0.030N + 870.0
	991 <= N <= 1023	0.030(N-1023) + 870.0

(Channels 800-990 are unused)

Channel bandwidth is 45 MHz

FREQUENCY SPECTRUM UTILIZATION

In a cellular phone system , the frequency utilization measurement X is the defined as maximum number of customers that could be served by one channel at busy hour.

X= no. of customer/channel

(Conventional System)

EM Spectrum for Telecom-

(Reason for 800-MHZ)

30-100 MHz ----------Fixed Station Services
41-96 MHz------------TV Broadcasting
Vicinity of 100 MHz-------FM Broadcasting
118-136 MHz ----------Air to Ground System
Around 160 MHz----------Military Mobile Service
225-400 MHz-----------Military Aircrafts

So, no band was available between 30-400 MHz carrier portions as the service of this band had become much crowed. Above 10 GHz, due to severe propagation path loss, multipath fading and rain activity make the medium not suitable for mobile communication.
800 MHz was originally allocated to Educational TV channel.
Hence FCC(USA) allocated a 40 MHz system at 800 MHz to mobile Radio Cellular System.

PERFORMANCE CRITERIA

- There are three basic criteria to specify a cellular system

VOICE QUALITY:-

- Voice quality is complicated parameter for design engineers. Because it depends person to person and also all mobile users not uses a common equipment, so in this area designer cannot decide that how to build a system without knowing the voice quality that will satisfied the users.

- In Military, Air force communication, this is not a problem, Armed forces must use the assigned equipment.
- In general the voice quality depend upon the criteria, a set value x at which y percent of customer rate the system voice quality is good or excellent(from transmitter to receiver).

PERFORMANCE CRITERIA

- Generally following scaled used for circuit merits in respect of voice quality.

CIRCUIT MERIT	SCORE	QUALITY SCALE
CM1	1	NOTUNDERSTANDABLE(UNSATISFACTORY)
CM2	2	POOR (UNDERSTANDABLE BUT REPETITONS REQUD)
CM3	3	FAIR
CM4	4	GOOD
CM5	5	EXCELLENT

- If percentage of customers choosing CM4,CM5, the cost of system increases.
- The average circuit merits obtained from all the listeners is called mean opinion score usually MOS greater than equal to 4

PERFORMANCE CRITERIA

SERVICE QUALITY

- Following parameter are required to judge the service quality

1) **COVERAGE AREA:-** If a system serve as for as possible large area it is good, but it is not possible to serve 100 percent due to irregular geographical structure.

- Due to following regions, also full coverage of area is not possible.

a)The transmitted power must be very high to illuminate weak spots, which increases the cost.

PERFORMANCE CRITERIA

b)The higher the transmitted power, higher the interference.

Hence, a system that usually cover 90 percent area in flat parts, while 60 to 70 percent in hill parts is considered as good.

2)GRADE OF SERVICES:- The grade of service is very good or rather very good if number of block calls out of 100 is two or less than two in peak hour. However, the blocking probability at each cell site is different. To decrease the block calls or blocking probability requires a good system plan and sufficient number of radio channel as well as number of cell site.

PERFORMANCE CRITERIA

3) **DROPED CALLS:-** To measure the dropped calls, there is a parameter named call drop rate. If during **Q** calls ,Q-1 calls are completed than call drop rate is 1/Q, if Q-2 calls are completed than call drop rate is 2/Q.

As for as possible call drop rate must be low.

A high drop rate can be caused either

1. coverage problems or
2. handoff problems related to channel availability.

PERFORMANCE CRITERIA

SPECIAL FEATURES

A system may provide some extra features like:

voice mail service

automatic roaming

call waiting

live news

rail reservation facilities and navigation services.

But some time customer may not ready to pay the extra charges for such services.

Cellular Telephony

- Characterized by
  - High mobility provision
  - Wide-range
  - Two-way tether less voice communication
  - Handoff and roaming support
  - Integrated with sophisticated public switched telephone network (PSTN)
  - High transmit power requires at the handsets (~2W)

Cellular Telephony Systems

- Mobile users and handsets
  - Very complex circuitry and design
- Base stations
  - Provides gateway functionality between wireless and wireline links
  - ~1 million dollar
- Mobile switching centers
  - Connect cellular system to the terrestrial telephone network

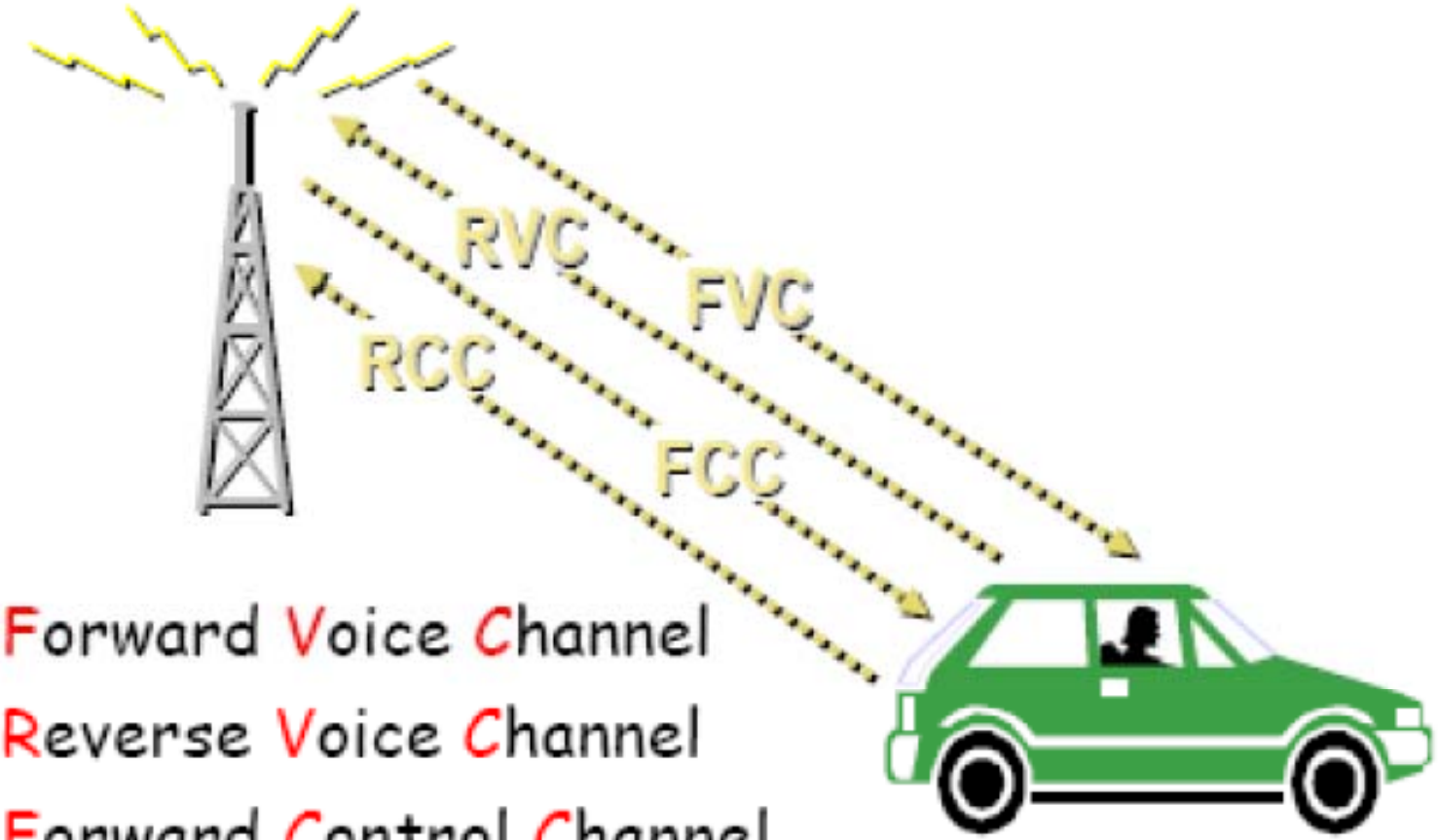
Cellular Telephone Systems

- A cellular telephone system provides a wireless connection to the PSTN for any user location within the radio range of the system.
- Cellular system accommodate a large no. of users over a large geographical area, within a limited frequency spectrum .
- Cellular radio systems provide high quality service that is often comparable to that of the landline telephone systems.
- High capacity is achieved by limiting the coverage of each base station transmitter to a small geographical area called a cell so that the same radio channels may be reused by another base station located some distance away. A sophisticated switching technique called a handoff enables a call to proceed uninterrupted when the user moves from one cell to another.

Mobile Comms. - Components

- **Mobile Base Station (MBS): – includes**
  - an antenna,
  - a controller,
  - a number of receivers
- **Mobile telecommunications switching office (MTSO)**
  - connects calls between mobile units
- **Channels between mobile unit and MBS**
  - Control channels: to exchange information related to setting up and maintaining calls
  - Traffic channels: to carry voice or data connection between users

Base Station - Mobile Network



Forward Voice Channel

Reverse Voice Channel

Forward Control Channel

Reverse Control Channel

Cellular Systems

Control channels are used for initiating mobile calls.

Control channels are often called setup channels because they are involved for setting up call and moving it to an unused voice channel.

Control channels transmits and receive data messages that carry call initiation and service request s and monitored by mobile phones when they do not have a call in progress.

Forward channels act as beacons which continually broadcast all the traffic requests for all mobile systems.

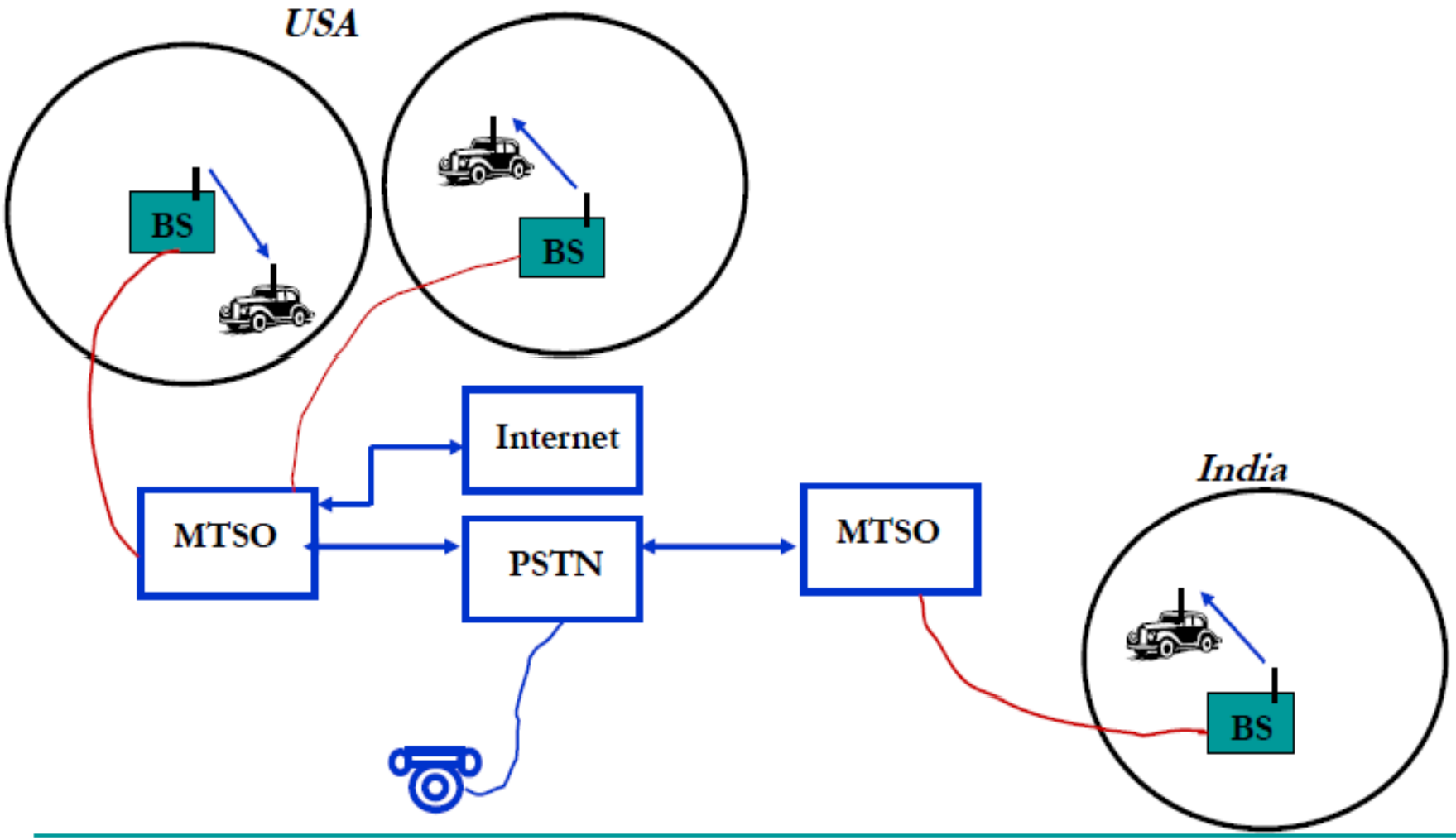
Cellular Topology

- Cellular network:
  - Series of overlapping hexagonal cells in a honeycomb pattern
- Cellular network components
  - Base Station: Transmitter, Receiver, Controller, Antenna
  - Cell: Base station's span of coverage
  - Mobile Switching Center: Contains all of the control and switching elements to connect the caller to the receiver, even as the receiver moves from one cell to another

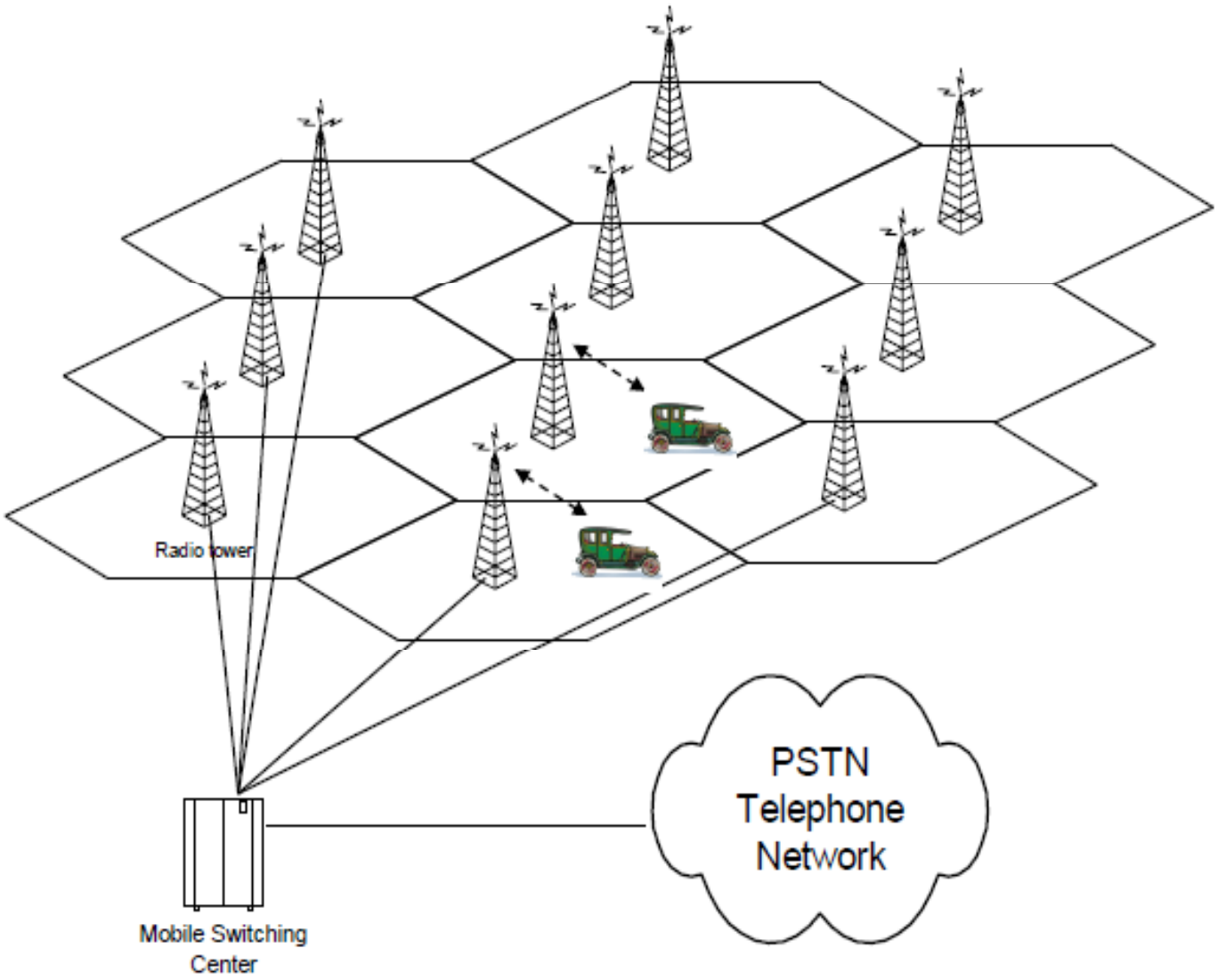
Cellular Telephone Systems

- Fig. shows a basic cellular system which consists of mobile stations ,base stations & a mobile telephone switching office(MTSO),since it is responsible for connecting all mobiles to the PSTN in a cellular system.
- Each mobile communicates via radio with one of the base stations & may be handed off to any no of base stations throughout the duration of call .
- The MS contains a transceiver, an antenna & control circuitry & may be mounted in a vehicle or used as a portable handheld unit.
- The BS consist of several transmitters & receivers which simultaneously handles full duplex comm. & generally have towers which support several transmitting & receiving antennas.
- The BS serves as a bridge between all mobile users in the cell & connects the simultaneous mobile calls via telephone lines or microwave links to the MSC.

Cellular Phone Networks

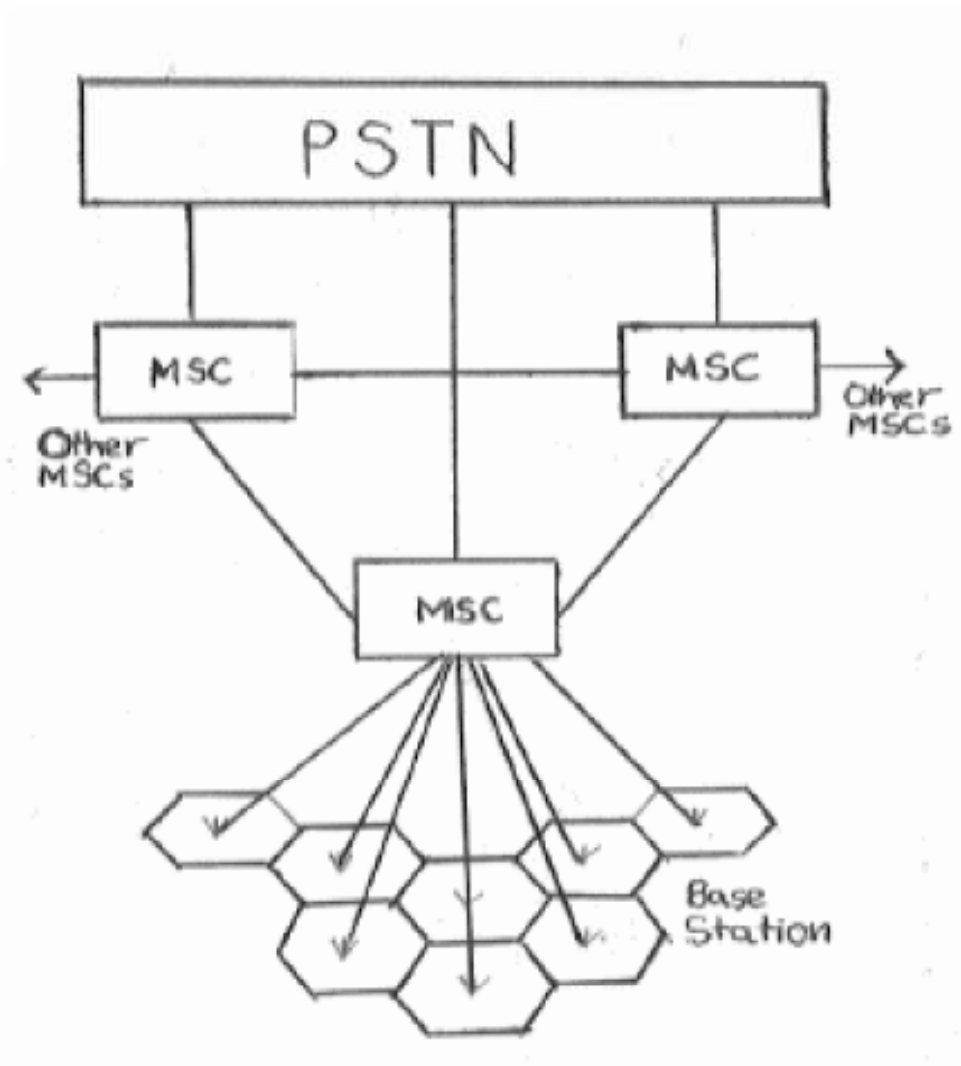


Cellular Telephony - Architecture



Cellular Networks

- All BSs within a cluster are connected to a **Mobile Switching Center(MSC)**.
- Each MSC of a cluster is then connected to the MSC of other clusters and a PSTN main switching center.
- The MSC stores information about the subscribers located within the cluster and is responsible for directing calls to them.



MTSO Controlled Call between Mobile Users

Steps:-

- Mobile unit initialization
- Mobile-originated call
- Paging
- Call accepted
- Ongoing call
- Handoff

Functions:-

- **Call blocking**
- **Call termination**
- **Call dropping**
- **Calls to/from fixed and remote mobile subscriber**

Making a Call

Scan Control Channels: Your cell phone needs to use the "closest" base station because that's the one with the strongest signal and the one that will give the best connection. To *find* the closest base station, your phone checks all the control channels and determines which has the strongest signal.(Depending upon the threshold power level),At this point it again scans the control channels in search of strongest base station signal.

The control channels are defined and standardized over the entire geographical area covered and typically make up of 5% of the total number of channels available in the system.

Choose Strongest: Your cell phone chooses the strongest signal and decides to use *that* one for placing the call.

Making a Call

Send Origination Message: Your cell phone now transmits a very short message (about 1/4 second) that contains the MIN (Mobile Identification Number, that is your cell phone number), its ESN (Electronic Serial Number), and the number you just dialed. It also sends the (SCM) station class mark which indicates what is the maximum transmitted power for a particular user.

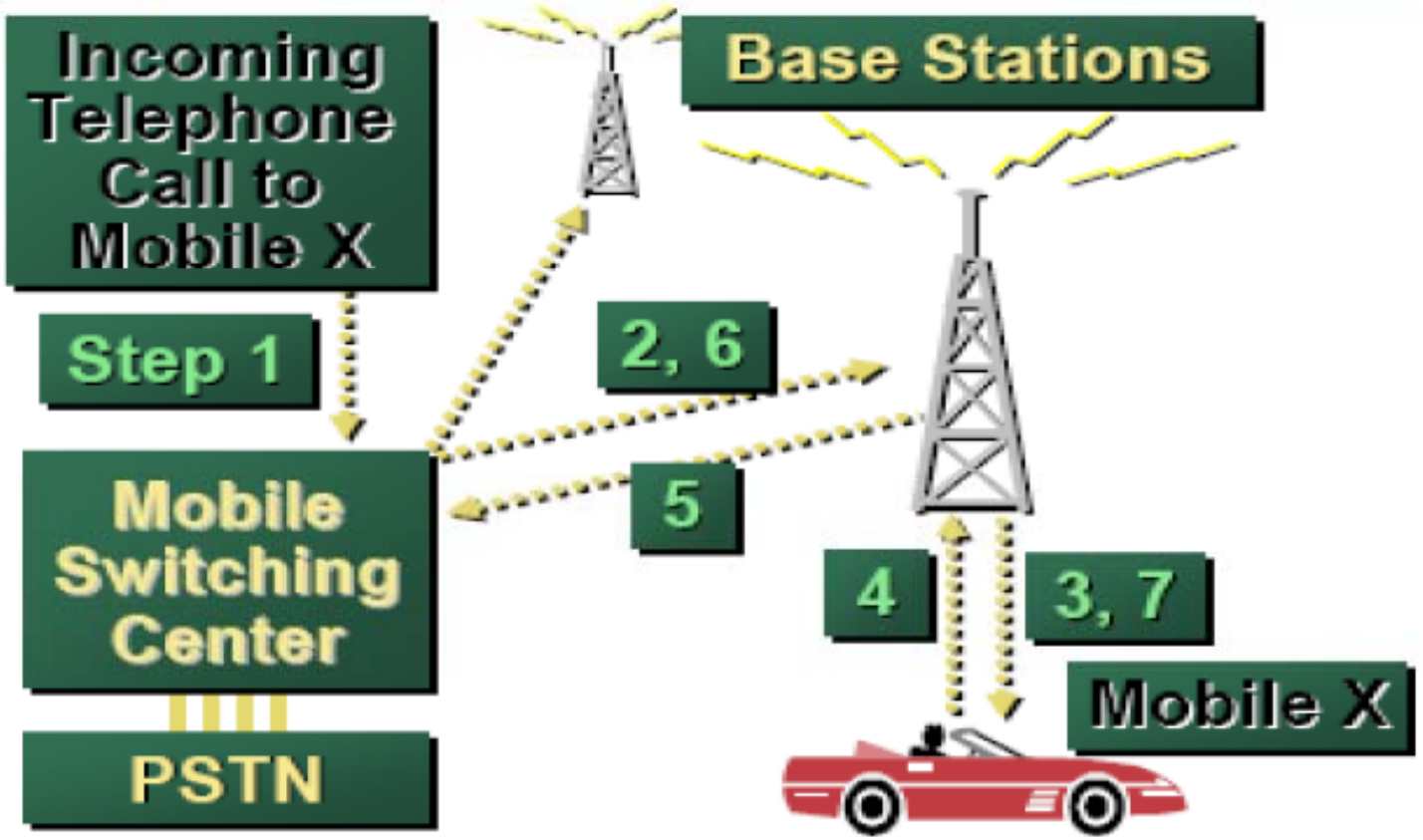
Get Channel Assignment: After the cellular service provider verifies that you are a valid, paying customer (based on the MIN and ESN your phone sent), the base station sends a Channel Assignment message to your phone (also a short 1/4-second burst). This message tells your phone where (that is, on which channel) the conversation will take place.

Begin Conversation

Brief Outline of Cellular Process:

- Telephone call placed to mobile user
- Telephone call made by mobile user

Telephone call to mobile user



Telephone call to mobile user

Step 1 – The incoming telephone call to Mobile X is received at the MSC.

Step 2 – The MSC dispatches the request to all base stations in the cellular system.

Step 3 – The base stations broadcast the Mobile Identification Number (MIN), telephone number of Mobile X, as a paging message over the FCC throughout the cellular system.

Step 4 – The mobile receives the paging message sent by the base station it monitors and responds by identifying itself over the reverse control channel.

Step 5 – The base station relays the acknowledgement sent by the mobile and informs the MSC of the handshake.

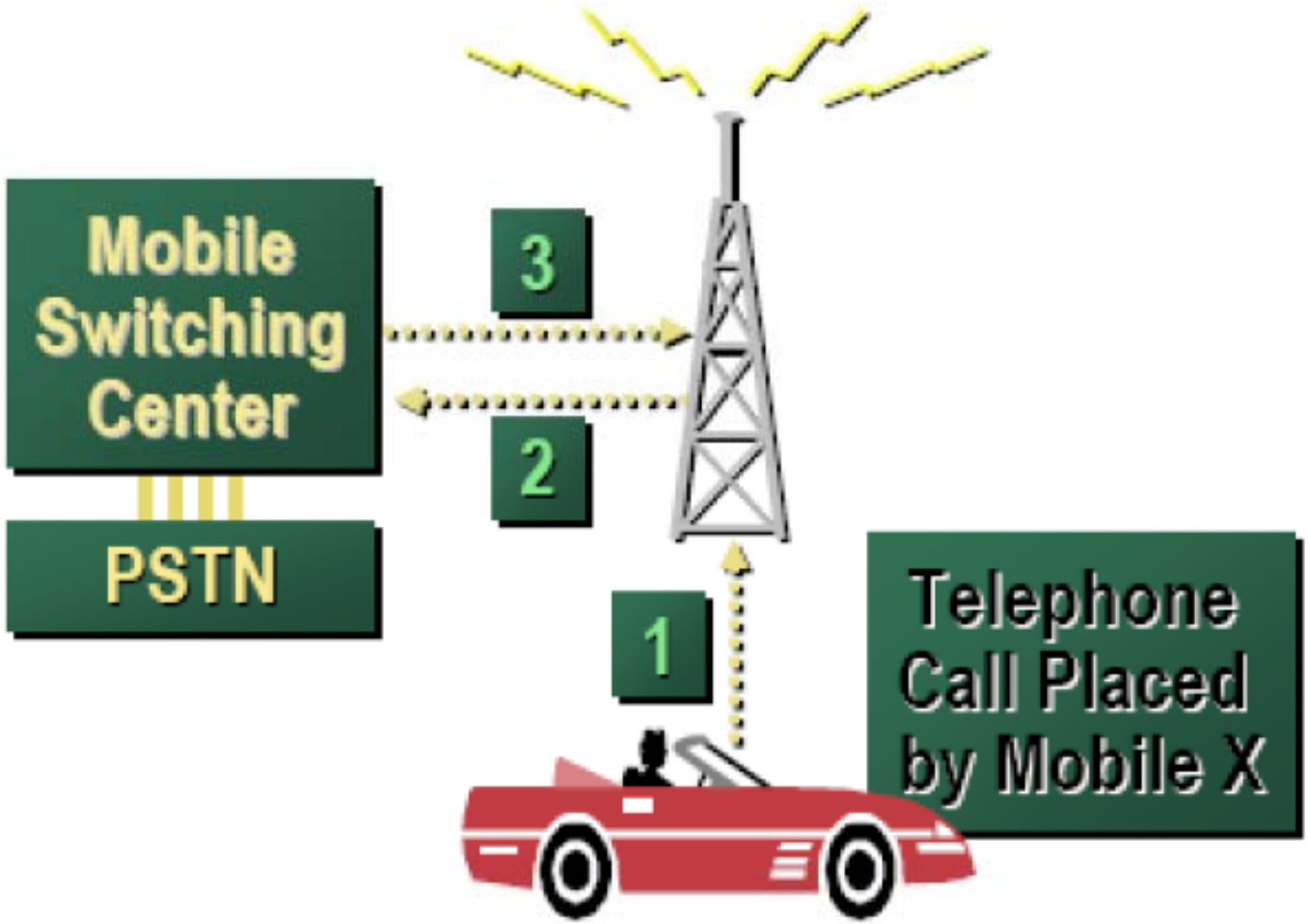
Step 6 – The MSC instructs the base station to move the call to an issued voice channel within in the cell.

Telephone call to mobile user

Step 7 – The base station signals the mobile to change frequencies to an unused forward and reverse voice channel pair.
At the point another data message (alert) is transmitted over the forward voice channel to instruct the mobile to ring.

Now the call is in progress. The MSC adjusts the transmitted power of the mobile and changes the channel of the mobile end and base stations in order to maintain call quality. This is called *handoff.*

Telephone Call Placed by Mobile



Telephone Call Placed by Mobile

Step 1 – When a mobile originates a call, it sends the base station its telephone number (MIN), electronic serial number (ESN), and telephone number of called party. It also transmits a station class mark (SCM) which indicates what the maximum power level is for the particular user.

Step 2 – The cell base station receives the data and sends it to the MSC.

Step 3 – The MSC validates the request, makes connection to the called party through the PSTN and validates the base station and mobile user to move to an unused forward and reverse channel pair to allow the conversation to begin.

Roaming

- All cellular systems provide a service called roaming. This allows subscribers to operate in service areas other than the one from which service is subscribed.
- When a mobile enters a city or geographic area that is different from its home service area, it is registered as a roamer in the new service area.

- Registration
  - MSC polls for unregistered mobiles
  - Mobiles respond with MINs
  - MSC queries mobile's home for billing info

- Calls
  - MSC controls call, bills mobile's home

Roaming

- A wireless roaming network has five components that make it work:
  - A database for storing customer profile information such as features, dialing capabilities, and the home serving area identification. This is called the home location register (HLR).
  - A database of mobile numbers used by each switch on the network.
  - A signaling network for transmitting data messages between switches.
  - Routing specifications that direct the data messages to the appropriate destination.
  - Public long-distance connections for call delivery

Roaming

- A registration cycle keeps track of a phone as it travels around the network. It begins when a wireless user powers on their phone. The general steps for this process are:
- When the phone is powered on, it sends a data message to the cellsite. This data message contains the Mobile Identification Number (MIN or phone number) and the Electronic Serial Number (ESN). The cellsite forwards this information to the switch.
- The switch compares the MIN with a table of all MINs in the network. It will determine if the MIN belongs to a home customer, or to a visiting customer. In either case, the switch will request the subscriber's feature profile from the Home Location Register (HLR). The HLR for home customers may be integrated into the same switch or stored on a separate platform.

Roaming

- If the HLR is a separate platform, or if the customer is visiting from another system, the switch then sends a data message to the HLR across the signaling network. Routing specifications stored at Signaling Transfer Points (STPs) provide the necessary information to direct the message to the home location register.
- When the Home Location Register (HLR) receives the message, it checks the MIN & the ESN. If the numbers are valid, the HLR records the location of the phone and returns a message containing the subscriber's feature list and calling restrictions to the visited switch.
- Once the visited switch receives the return message, it creates a Visitor Location Register (VLR) to store information about the roamer, including the MIN, ESN, features, etc... This register will be used by the roamer as long as they are registered in the visited system.

Hand-over

- During a call, the base station would monitor the signal level from the mobile phone. When the mobile phone is moving into a new cell, the signal level will fall to a critical value causing the base station to inform the Mobile Switching Center(MSC) about this event. The MSC would instruct all the surrounding base stations to measure the mobile phone's signal level and transfer control to the base station receiving the strongest signal level. This is known as **hand-over** and occurs within **400ms**, so the phone user is hardly aware of a break.
- Registration is done again with the new base station. Location information stored in the MSC about this mobile telephone is updated. If the mobile telephone is moved into a cell belonging to a different cluster it would also have to register with the new MSC.

Other Events

Call Blocking:

During the mobile initiated if all the traffic channels assigned to the nearest BS are busy then a Busy tone is returned to the user.

Call Transmission:

When one of the two users hangs up or terminate the cell or switch off the mobile phone, the MTSO is informed and the traffic channels at the two BS are released. Generally it is choice of user, when he/she wants to terminate the call.

Call Drop:

During a connection due to interference or weak signal if BS cannot maintain the minimum required signal call will drop and informed to the MTSO.

Call to/from Fixed and Remote Subscriber:

The MSTO connects to the PSTN so MTSO can setup a connection between a mobile user in the area and a fixed subscriber via the telephone network.

Advanced Mobile Phone System (AMPS) (Analog Cellular System)

- **Used in North America**; **First -generation** analog cellular system, available since 1983; Developed by Bell Labs.
- **Adopts FDMA**
  - Voice channels are carried by different radio frequencies.
  - A total 50 MHz in 824-849 MHz & 869-894 MHz
  - Divided into 832 frequency channels: 416 downlinks and 416 uplinks(5% Control Channels)
  - Frequency Reuse: A frequency may be reused by cells in different clusters

AMPS (Advanced Mobile Phone System)

- Analog cell phone standard, established in 1983
- First used in Chicago
- Uses range of frequencies between 824Mhz and 894 MHz
- Pair of frequencies, one for transmit and one for receive create one channel
- Standard analog voice channel - 30kHz, comparable to a wired telephone

AMPS

- The scope of AMPS specification is limited to the air interface between subscriber equipment and base station radios. Signaling systems that link base stations to switches and switches to other switches are proprietary in North America
- A signaling standard for communications between mobile switches: IS-41, for roaming management

AMPS (Advanced Mobile Phone System)

- Transmit and receive frequencies are separated by 45 MHz
- Only operate in the 800 MHz band; therefore, not many features (like email, web browsing) offered

Digital Cellular- What does it offers from Analog?

- **Best quality compared with analogue system**
- **Improved bandwidth efficiency**
  - Reduced from 30 kHz to 10 kHz, and then to 5 kHz.
    This is achieved via 3-time-slot Time Division Multiple Access (TDMA) (i.e. three pairs of people using a 30 kHz radio channel simultaneously)
- **Use of micro-cellular technology to accommodate smaller and smaller cells particularly around the new frequency band of 2 GHz**
- **Improved frequency reuse**
- **Error detecting and Correcting techniques**