Wired Medium and Wireless Medium

- **Wired Medium**

The information from source to destination is sent via wires/cables

- **Wireless Medium**

The information from source to destination is sent via wireless medium i.e. Electro magnetic waves or radio waves

Evolution to cellular networks

- Radio communication was invented by Nikola Tesla and Guglielmo Marconi: in 1893, Nikola Tesla made the first public demonstration of wireless (radio) telegraphy; Guglielmo Marconi conducted long-distance (over see) telegraphy 1897
- in 1940 the first walkie-talkie was used by the US military
- in 1947, John Bardeen and Walter Brattain from AT&T's Bell Labs invented the transistor (semiconductor device used to amplify and switch electronic signals)
- AT&T introduced commercial radio comm.: car phone – two way radio link to the local phone network
- in 1979 the first commercial cellular phone service was launched by the Nordic Mobile Telephone (in Finland, Sweden, Norway, Denmark

Origin of Wireless communication

- Wireless communications gained popularity in 1930's
  - Mainly used for public safety by police and other government organizations
  - Not connected to the PSTN (Public Switching Telephone Networks)
- First public mobile telephone service started in 1946 in United States
  - Using a single high power transmitter and large tower to cover an area of 50 km
- Mobile radio telephones were used for military communications in early 20th century
- Car-based telephones first introduced in mid 1940s
  - Single large transmitter on top of a tall building
  - Single channel used for sending and receiving
  - To talk, user pushed a button, enabled transmission and disabled reception
  - Became known as "push-to-talk" in 1950s
  - CB-radio, taxis, police cars use this technology
- IMTS (Improved Mobile Telephone System) introduced in 1960s
  - Used two channels (one for sending, one for receiving)
  - No need for push-to-talk
  - Used 23 channels from 150 MHz to 450 MHz

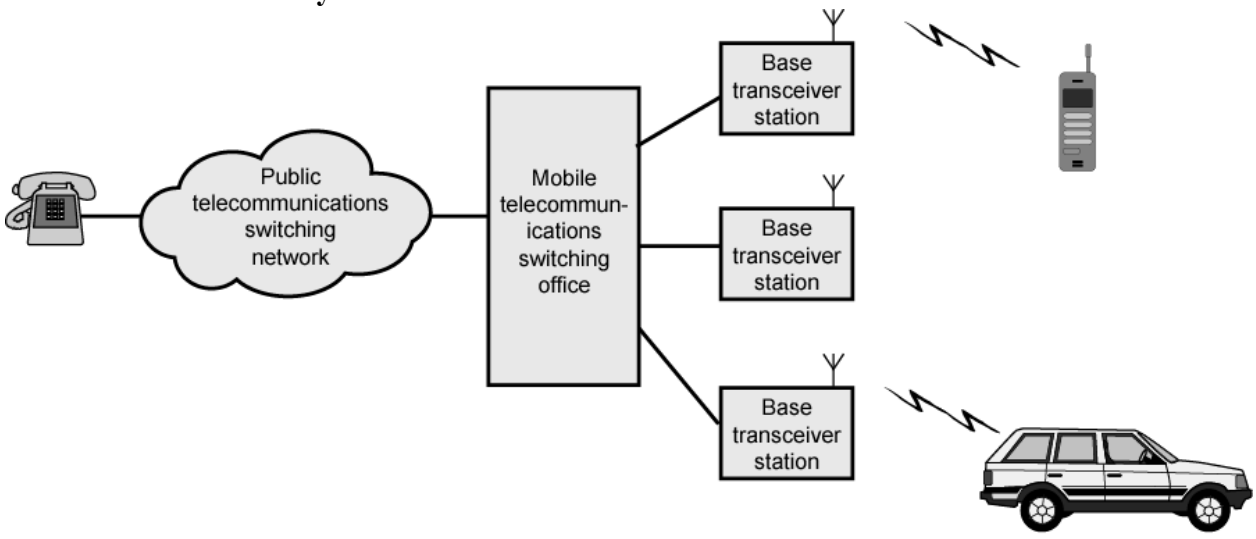
Several Types of Mobile Radio Systems

- Garage Door Controller [<100 MHz]
- Remote Controllers [TV/VCR/DISH][Infra-Red: 1-100 THz]
- Cordless Telephone [<100 MHz]
- Hand-Held Radio [Walki-Talki] [VHF-UHF:40-480 MHz]
- Pagers/Beepers [< 1 GHz]
- Cellular Mobile Telephone[<2 GHz]

First generation Network

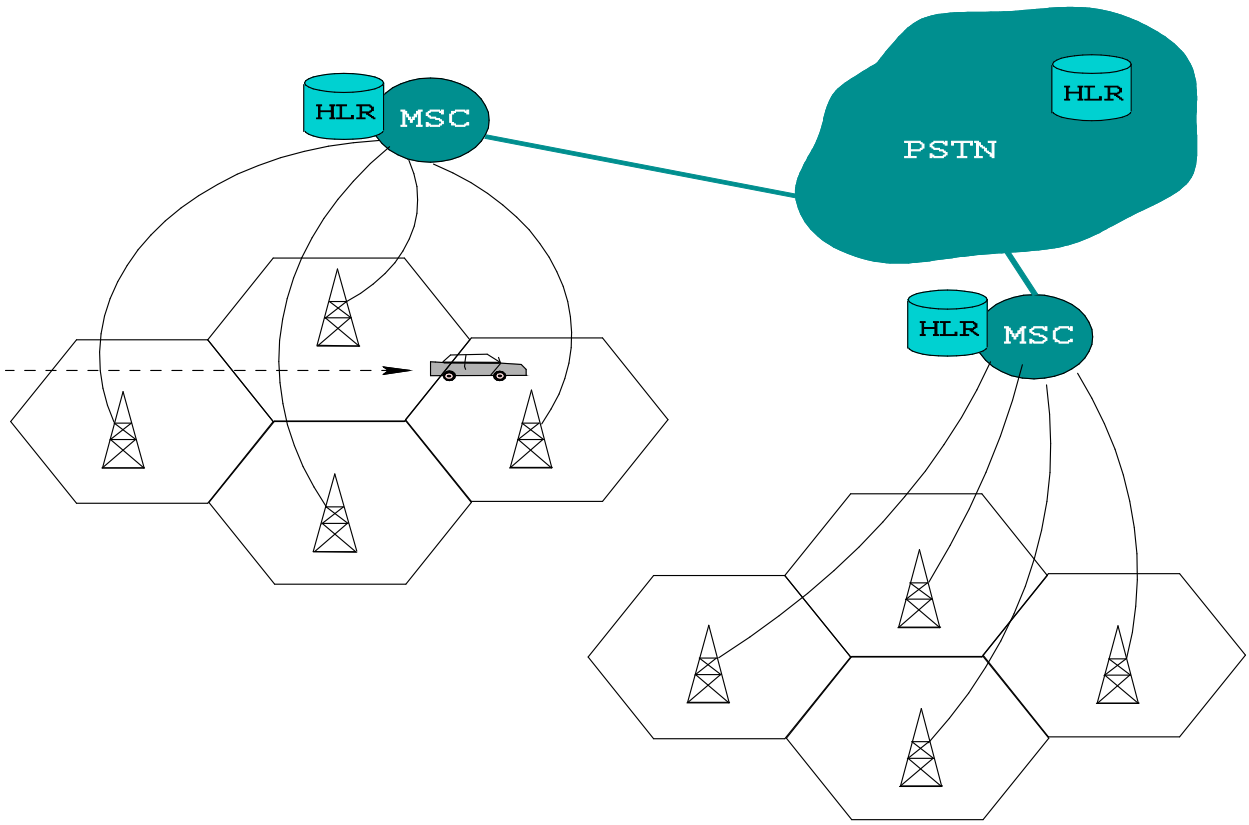
- Advanced Mobile Phone Service (AMPS) invented at Bell Labs and first installed in 1982
- Used in England (called TACS) and Japan (called MCS-L1)
- Key ideas:
  - Exclusively analog
  - Geographical area divided into cells (typically 10-25km)
  - Cells are small: Frequency reuse exploited in nearby (not adjacent) cells
  - As compared to IMTS, could use 5 to 10 times more users in same area by using frequency re-use (divide area into cells)
  - Smaller cells also required less powerful, cheaper,smaller devices

Overview of Cellular System



Overview of Cellular System

- The purpose of wireless networks is to provide wireless access to the fixed network (PSTN)



Cellular System

- The service area is divided into cells
  - Each cell is served by its own antenna
  - Each base station consists of a transmitter, a receiver, and control unit
  - Base station placed in the middle or at the border of the cell
  - Each base station is allocated a certain frequency band (frequency allocation

Components of a cellular System

- **BTS (Base Transceiver Station)** – main component of a cell and it connects the subscribers to the cellular network; for transmission/reception of information it uses several antennas spread across the cell
- **BSC (Basic Station Controller) –** it is an interface between BTSs and it is linked to BTSs by cable or microwave links; it routes calls between BTSs; it is also connected to the MSC
- **MSC (Mobile Switching Center)** – the coordinator of a cellular network, it is connected to several BSCs, it routes calls between BSCs; links the cellular network with other networks like PSTN through fiber optics, microwave or copper cable

Cellular Operation

- **Three basic devices**
  - A mobile station
  - A base transceiver
  - A Mobile Telecommunications Switching Office (MTSO)

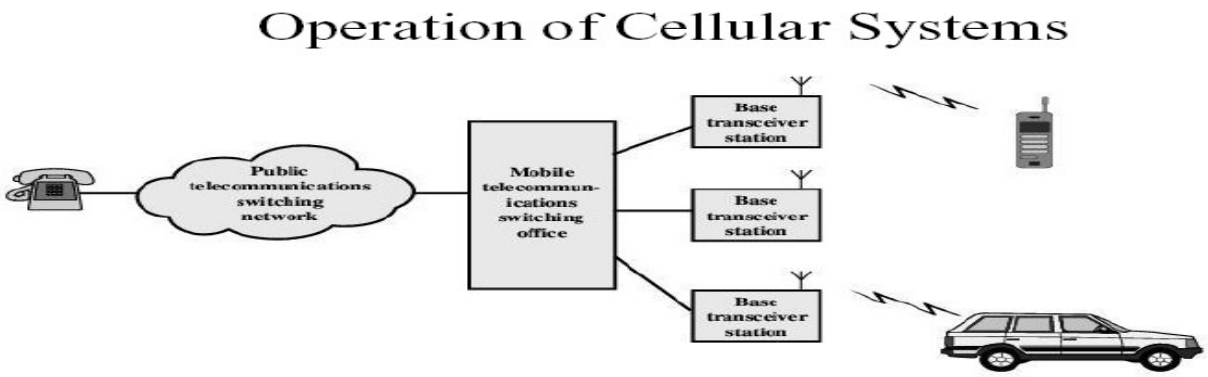


Figure 14.5 Overview of Cellular System

Operational Channels (2 week)

Four types of channels used in each cell that take active part during a mobile call:

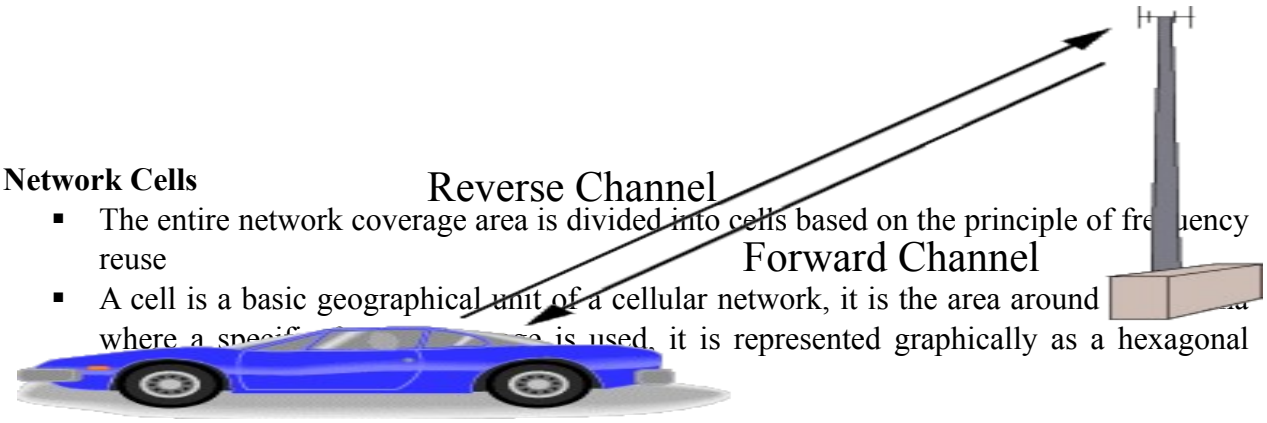
- Forward Voice Channel (FVC)
- Reverse Voice Channel (RVC)
- Forward Control Channel (FCC)

Reverse control channels (RCC)

- Four types of channels used in each cell that take active part during a mobile call:
- **Forward Voice Channel (FVC):** Used for the voice transmission from the BS to the MS.
- **Reverse Voice Channel (RVC):** Used for voice transmission from the MS to the BS.
- **Forward Control Channel (FCC):**
  - Setting up calls
  - Divert call to unused voice channels
  - Channels transmit and receive call initiation and service request messages.
  - **Reverse Control Channel (RCC):** This is used for the call control purpose from the MS to the BS. Control channels are usually monitored by mobiles.

Common Air Interface (CAI)

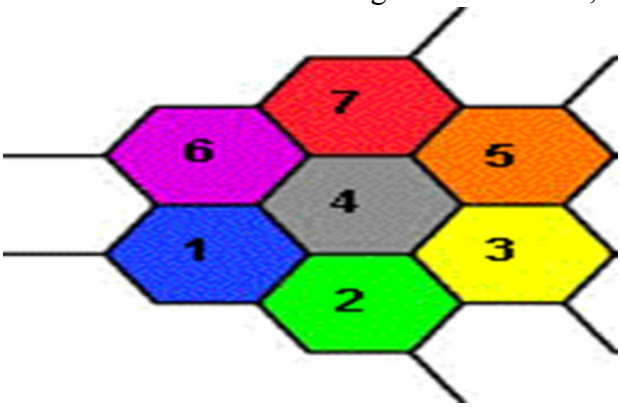
- A standard that defines Communication between a Base Station and Mobile
- Specifies Four Channels [Voice Channels and Control / Setup Channels]
  - FVC: Forward Voice Channel
  - RVC: Reverse Voice Channel
  - FCC: Forward Control Channel
  - RCC: Reverse Control Channel



Network Cells

- The entire network coverage area is divided into cells based on the principle of frequency reuse
- A cell is a basic geographical unit of a cellular network, it is the area around [illegible] where a specific [illegible] is used, it is represented graphically as a hexagonal

- When a subscriber moves to another cell, the antenna of the new cell takes over the signal transmission
- A cluster is a group of adjacent cells, usually 7 cells; no frequency reuse is done within a cluster
- The frequency spectrum is divided into sub bands and each sub band is used within one cell of the cluster
- In heavy traffic zones cells are smaller, while in isolated zones cells are larger
- Cell design (around 10 mile radius) Served by base station consisting of transmitter, receiver, and control unit.
- Base station (BS) antenna is placed in high places (churches, high rise buildings.
- Cells use low powered transmitters.
- Each cell is allocated a band of frequencies, and is served by its own antenna as well as a base station consisting of a transmitter, receiver and control unit



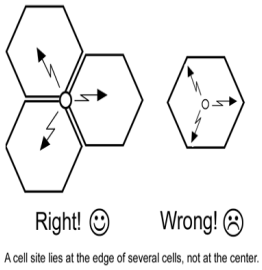
Why cells

- The cellular concept was a major breakthrough in solving the problem of spectral congestion and user capacity. It offered very high capacity in a limited spectrum allocation without any major technological changes.
- The cellular concept has the following system level ideas
  - Replacing a single, high power transmitter with many low power transmitters, each providing coverage to only a small area.
  - Neighboring cells are assigned different groups of channels in order to minimize interference.
  - The same set of channels is then reused at different geographical locations.

Cells

- A cell is an area covered by a transponder.

Cell Sectorization



- Cells can be divided into sectors to provide a sma ith in a cell, and therefore, more frequency reuse.
- **Cellular Area**: Cellular areas aren't really circular n the terrain and the interference that's present.

- **Cell Sectoring**
  - Cell divided into wedge shaped sectors
  - 3 – 6 sectors per cell
  - Each with own channel set
    - Subsets of cell's channels
  - Directional antennas

Types of cells

- **Macro cell –** their coverage is large (aprox. 6 miles in diameter); used in remote areas, high-power transmitters and receivers are used
- **Micro cell –** their coverage is small (half a mile in diameter) and are used in urban zones; low-powered transmitters and receivers are used to avoid interference with cells in another clusters
- **Pico cell –** covers areas such as building or a tunnel

Cell Footprint

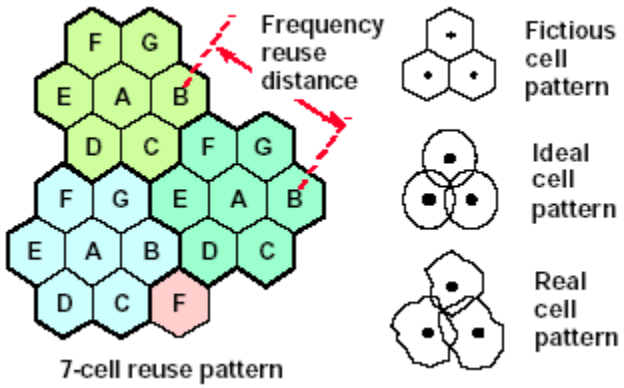
- The actual radio coverage of a cell is known as the cell footprint.
  - Irregular cell structure and irregular placing of the transmitter may be acceptable in the initial system design. However as traffic grows, where new cells and channels need to be added, it may lead to inability to reuse frequencies because of co-channel interference.
  - For systematic cell planning, a regular shape is assumed for the footprint.

Other cellular concepts

- **Handover :** Moving a call from one zone (from the transmitter-receiver from one zone) to another zone due to subscriber's mobility
- **Roaming :** Allowing the subscriber to send/receive calls outside the service provider's coverage area

Frequency Reuse

- Each cell is served by a base station that uses the assigned channel group.
- The power radiated by a base station is deliberately kept low, and antennas are located so as to achieve coverage within the particular cell.
- By limiting the coverage area within a cell, the same group of channels can be used to cover various cells that are separated from one another by distances large enough to keep the co channel interference level within tolerable limits.



7-cell reuse pattern

Cellular Concept

- Let T = total number of duplex channels

K cells = size of cell cluster (typically 4, 7,12, 21)

N = T/K = number of channels per cell

- For a specific geographic area, if clusters are replicated M times, then total number of channels

– system capacity = M x T

– Choice of K determines distance between cells using the same frequencies – termed co-channel cells

– K depends on how much interference can be tolerated by mobile stations and path loss

Frequency reuse

- Each color/letter uses the same frequency band

Cellular Design Reuse Pattern

- Example: cell cluster size K = 7, frequency reuse factor = 1/7, assume T = 490 total channels, N = T/K = 70 channels per cell
- Assume T = 490 total channels,
- K = 7, N = 70 channels/cell
- Clusters are replicated M=3
- times
- System capacity = 3x490 = 1470 total channels

Cluster Size

- From geometry of grid of hexagons only

certain values of K are possible if replicating

cluster without gaps

- K = i2 + ij + j2 where i and j are non-negative

integers

Cellular Concepts (Co-Channel Cells)

- To find co-channel neighbours of a cell, move i cells perpendicular to the hexagon boundary, turn 60 degrees counter clockwise, and move j cells (example: i=2, j=2, K=12)
- In order to maximize capacity, Co-channel cells are placed as far apart as possible for a given cluster size
- The relationship among the distance between the Co-channel cells, D, the cluster size K and the cell radius R is given as;

$$D/R = \sqrt{3K}$$

Setting up a call process

- When powered on, the phone does not have a frequency/ time slot/ode assigned to it yet; so it scans for the control channel of the BTS and picks the strongest signal

- then it sends a message (including its identification number) to the BTS to indicate its presence
- the BTS sends an acknowledgement message back to the cell phone
- the phone then registers with the BTS and informs the BTS of its exact location
- after the phone is registered to the BTS, the BTS assigns a channel to the phone and the phone is ready to receive or make calls

Setting up a call

- The subscriber dials the receiver's number and sends it to the BTS
- the BTS sends to its BSC the ID, location and number of the caller and also the number of the receiver
- the BSC forwards this information to its MSC
- the MSC routes the call to the receiver's MSC which is then sent to the receiver's BSC and then to its BTS
- the communication with the receiver's cell phone is established

Receiving a call process

- When the receiver' phone is in an idle state it listens for the control channel of its BTS
- If there is an incoming call the BSC and BTS sends a message to the cells in the area where the receiver's phone is located
- The phone monitors its message and compares the number from the message with its own
- If the numbers matches the cell phone sends an acknowledgement to the BTS
- After authentication, the communication is established between the caller and the receiver

Mobility Management in a cell

Handover / Handoff

- Occurs as a mobile moves into a different cell during an existing call, or when going from one cellular system into another.
    - It must be user transparent, successful and not too frequent.
    - Not only involves identifying a new BS, but also requires that the voice and control signals be allocated to channels associated with the new BS

Handover / Handoff

- Once a particular signal level P min is specified as the minimum usable signal for acceptable voice quality at the BS receiver, a slightly stronger signal level PHO is used as a threshold at which a handover is made.

$$P_{HO} = P_{\min} + \Delta$$

Handover indicator

- Each BS constantly monitors the signal strengths of all of its reverse voice channels to determine the relative location of each mobile user with respect to the BS. This information is forwarded to the MSC who makes decisions regarding handover.
- Mobile assisted handover (MAHO) : The mobile station measures the received power from surrounding BSs and continually reports the results of these measurements to the serving BS.

Practical handover

- High speed users and low speed users have vastly different dwell times which might cause a high number of handover requests for high speed users. This will result in interference and traffic management problem.
- The Umbrella Cell approach will help to solve this problems. High speed users are serviced by large (macro) cells, while low speed users are handled by small (micro) cells.

First-Generation Cellular

- 1st generation cellular networks are purely analog cellular systems.
- The transmission of data is sent via a continuously variable signal
- Advanced Mobile Phone Service (AMPS) invented at Bell Labs and first installed in 1982
- Used in England (called TACS) and Japan (called MCS-L1)
- Key ideas:
    - Exclusively analog
    - Geographical area divided into cells (typically 10-25km)
    - Cells are small: Frequency reuse exploited in nearby (not adjacent) cells
    - As compared to IMTS, could use 5 to 10 times more users in same area by using frequency re-use (divide area into cells)
    - Smaller cells also required less powerful, cheaper smaller devices

First Generation

- Analog
- Frequency Division Multiple Access (FDMA)
    - Multiple users are provided access to a system by dividing the spectrum up into frequency bands.
    - Different users use different frequency bands.
- AMPS standard.
    - 30 kHz voice channels

First Generation

- Two 25-MHz bands are allocated to AMPS
    - One from BS to mobile unit (869–894 MHz)
    - Other from mobile to base station (824–849 MHz)
- Bands is split in two to encourage competition
    - In each market two operators can be accommodated
- Operator is allocated only 12.5 MHz in each direction
- Channels spaced 30 kHz apart
    - Total of 416 channels per operator
- Twenty-one channels allocated for control
- 395 to carry calls

Second Generation Cellular

- 2nd generation cellular networks refer to digital cellular and PC wireless systems.
- voice and low speed data services.
- They consist of digital traffic channels, perform encryption, error detection & correction
- Users share channels dynamically
- Based on digital transmission

- Different approaches in US and Europe
- US: divergence
  - Only one player (AMPS) in 1G
  - Became several players in 2G due to competition
  - Survivors
    - IS-54 and IS-135: backward compatible with AMPS frequency allocation (dual mode - analog and digital)
    - IS-95: uses spread spectrum
- Europe: Convergence
  - 5 incompatible 1G systems (no clear winner)
  - European PTT development of GSM (uses new frequency and completely digital communication)

Four popular standards for 2G

1- Global System for Mobile (GSM)

- Eight time-slotted users for each 200 kHz radio channel.
- Deployed widely in Europe, Asia, Australia, South America, and some parts of the U.S. in the PCS band of spectrum.
- GSM uses SIM (Subscriber Identity Module) cards that can be transferred from phone-to-phone. Phones for other types of technologies must be programmed.
- T-Mobile, AT&T, and Cingular in the U.S.

2-Interim Standard 136 (IS-136)

- Also called North American Digital Cellular (NADC)
- Three time-slotted users per 30 kHz channel
- Popular in North America, South America, and Australia.
- Cingular and AT&T in the U.S. Both companies have larger areas for their TDMA networks

3- Pacific Digital Cellular (PDC)

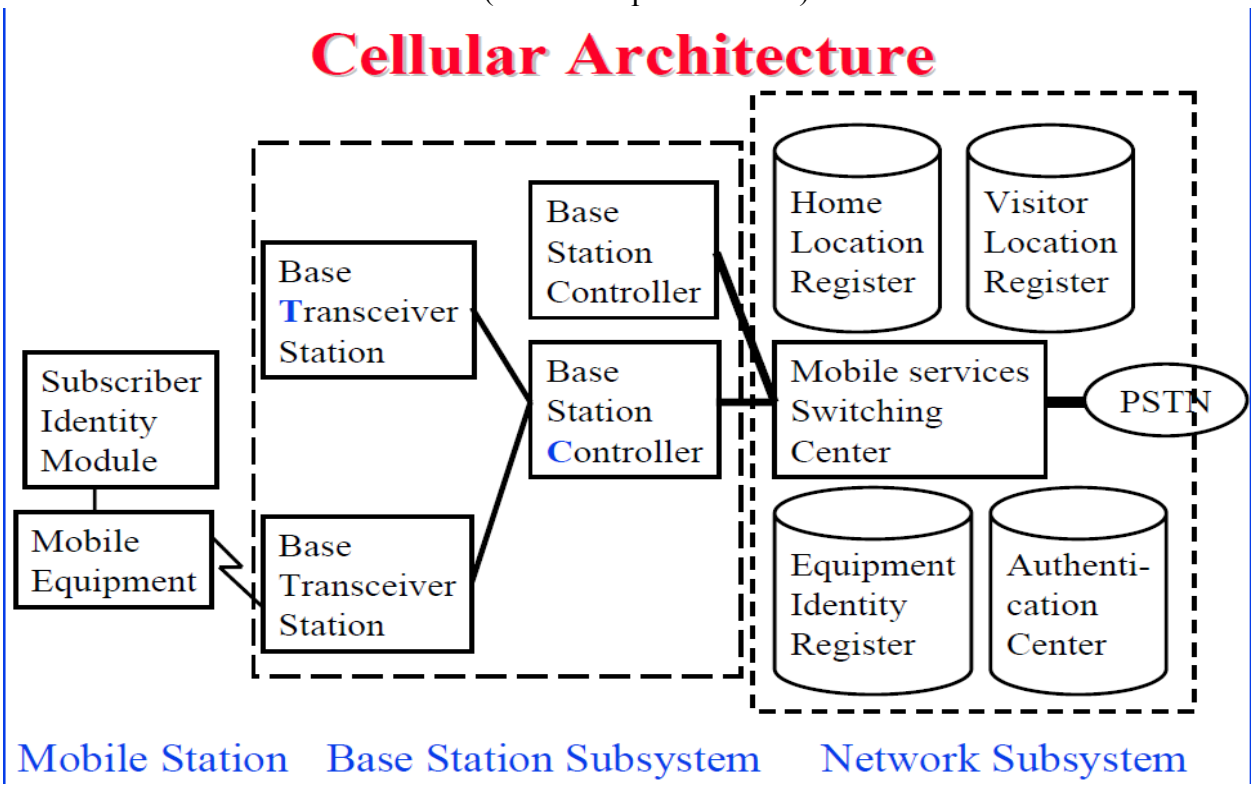
- Japanese standard
- Similar to IS-136

4- Interim Standard 95 (IS-95)

- CDMA
- Also known as cdmaOne
- 64 users in a 1.25 MHz channel.
- Can be used in 800 MHz and 1900 MHz bands.
- Sprint and Verizon in the U.S.
  - Digital modulation

- TDMA/FDD or CDMA/FDD
  - Time Division Multiple Access (TDMA) – 3 popular standards use this.
    - Signal is digitized.
    - Users occupy different time slots.

- Example from wired telephone: Each user needs to send an 8-bit block of digitized voice every 125 microseconds (8000 times per second).
  - Requirement is for 64 kbps.
  - One type of channel can support a data rate of 1.544 Mbps (a "T1" telephone circuit).



Second generation

Cellular Architecture (Cont)

- Base station controller (BSC) and Base transceiver station (BTS)
- One BTS per cell.
- One BSC can control multiple BTS.
  - Allocates radio channels among BTSs.
  - Manages call handoffs between BTSs.
  - Controls handset power levels
- Mobile Switching Center (MSC) connects to PSTN and switches calls between BSCs. Provides mobile registration, location, authentication. Contains Equipment Identity Register.

Second Generation

Cellular Architecture (Cont)

- Home Location Register (HLR) and Visitor Location Register (VLR) provide call routing and roaming
- VLR+HLR+MSC functions are generally in one equipment
- Equipment Identity Register (EIR) contains a list of all valid mobiles.
- Authentication Center (AuC) stores the secret keys of all SIM cards.
- Each handset has a International Mobile Equipment Identity (IMEI) number.

Differences Between First and Second Generation Systems

- Digital traffic channels – first-generation systems are almost purely analog; second-generation systems are digital
- Encryption – all second generation systems provide encryption to prevent eavesdropping
- Error detection and correction – second-generation digital traffic allows for detection and correction, giving clear voice reception

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

First Generation Systems

- Advanced Mobile Phone Service (AMPS) invented at Bell Labs and first installed in 1982
    - Advanced Mobile Phone Service (AMPS) is a standard system for analog signal cellular telephone service in the United States and is also used in other countries. It is based on the initial electromagnetic radiation spectrum allocation for cellular service by the Federal Communications Commission (FCC) in 1970. Introduced by AT&T in 1983, AMPS became one of the most widely deployed cellular system in the United States

Cellular Terms/Concepts used in AMPS

- Users are Mobile
    - Must transfer call from one region to another
- Low powered, handheld transmitters
    - Must be relatively close to a receiver (<20 miles)
- Frequencies are reused in other cells
- In band signaling
- Paging
- Frequency Modulation
    - Helps remove noise.

First Generation Analog

- Original cellular telephone networks
- Analog traffic channels
- Early 1980s in North America
- Advanced Mobile Phone Service (AMPS)
    - AT&T
- Also common in South America, Australia, and China

Spectral Allocation In North America

- Two 25-MHz bands are allocated to AMPS
    - One from BS to mobile unit (869–894 MHz)
    - Other from mobile to base station (824–849 MHz)
- Bands is split in two to encourage competition
    - In each market two operators can be accommodated
- Operator is allocated only 12.5 MHz in each direction
- Channels spaced 30 kHz apart
    - Total of 416 channels per operator
- Twenty-one channels allocated for control
- 395 to carry calls

AMPS

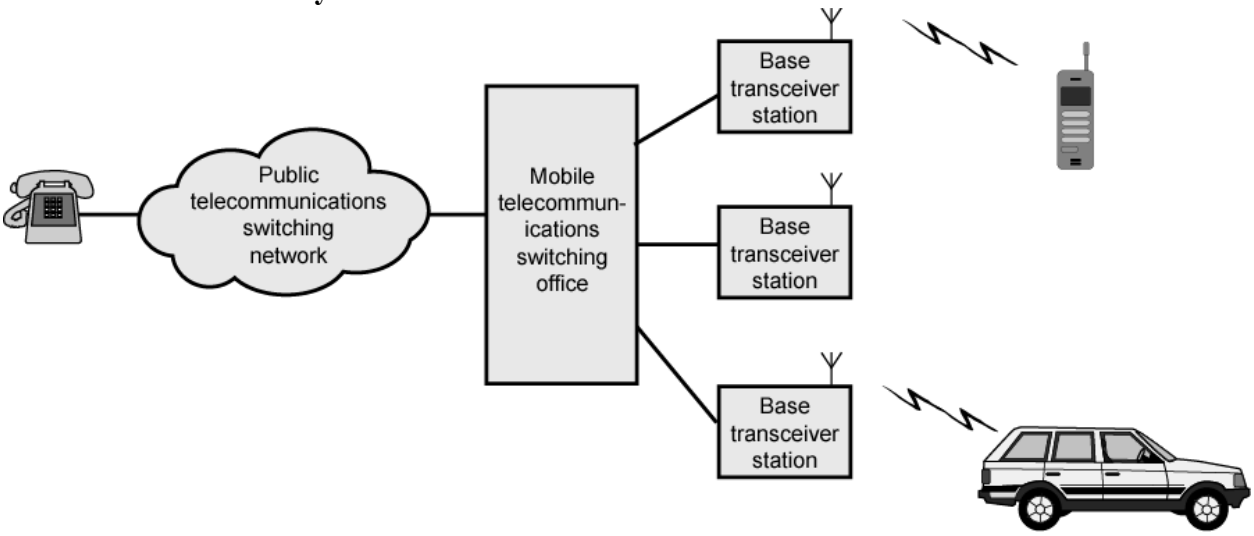
- Originally 40 MHz of spectrum separated into two bands of 20 MHz each (A and B band). Later expanded to 25 MHz each –

- FDD used with 45 MHz separation in uplink and downlink – prevents self interference. • AMPS uses 30 kHz radio channels between mobile station and base stations • Two service providers in area are each allocated 25 MHZ => 12.5 MHz for each direction => 416 pairs of channels: split into 395 voice channels + 21 control channels for signaling •

Spectral Allocation In North America

- Control channels are 10 kbps data channels
- Conversation channels carry analog using frequency modulation
- Control information also sent on conversation channels in bursts as data
- Number of channels inadequate for most major markets
- For AMPS, frequency reuse is exploited

Overview of Cellular System



Operation

- AMPS-capable phone has numeric assignment module (NAM) in read-only memory
  - NAM contains number of phone
    - Assigned by service provider
  - Serial number of phone
    - Assigned by the manufacturer
  - When phone turned on, transmits serial number and phone number to MTSO
  - MTSO has database of mobile units reported stolen
    - Uses serial number to lock out stolen units
  - MTSO uses phone number for billing
  - If phone is used in remote city, service is still billed to user's local service provider

AMPS Control Channels

- 21 full-duplex 30-kHz control channels
  - Data are transmitted in frames
- Control information can be transmitted over voice channel during conversation
  - Mobile unit or the base station inserts burst of data
    - Turn off voice FM transmission for about 100 ms
    - Replacing it with an FSK-encoded message

- Used to exchange urgent messages
  - Change power level
  - Handoff

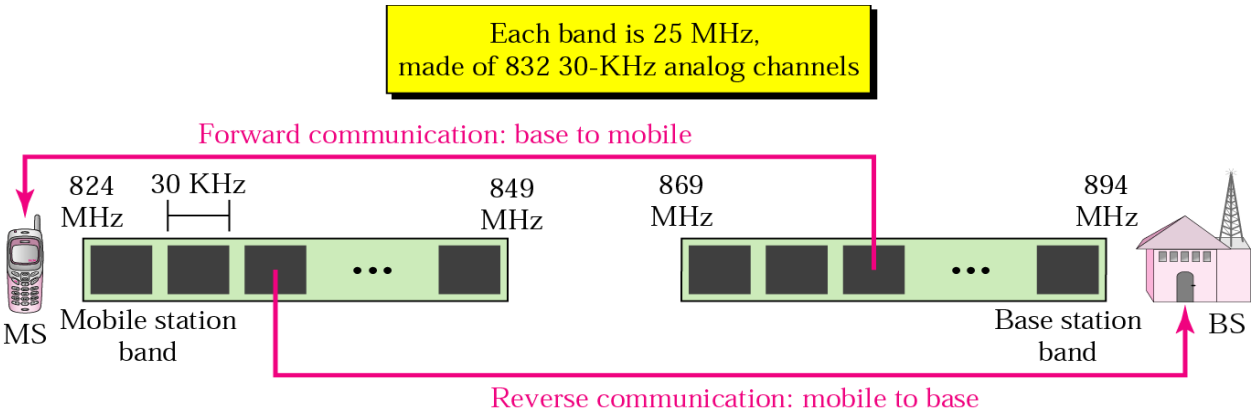
Call Sequence

1. Subscriber initiates call by keying in number and presses send
2. MTSO validates telephone number and checks user authorized to place call
   - Some service providers require a PIN to counter theft
3. MTSO issues message to user's phone indicating traffic channels to use
4. MTSO sends ringing signal to called party
   - All operations, 2 through 4, occur within 10 s of initiating call
5. When called party answers, MTSO establishes circuit and initiates billing information
6. When one party hangs up MTSO releases circuit, frees radio channels, and completes billing information

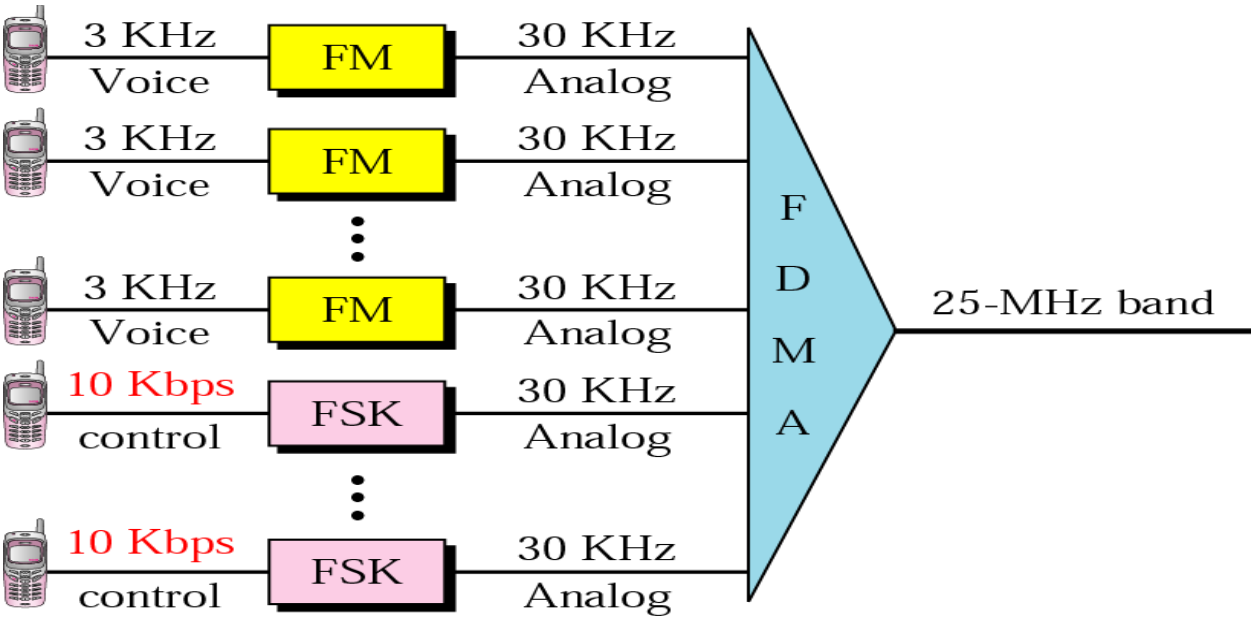
AMPS System Identifiers (ID codes)

Notation	Name	Size (bits)	Description
MIN	Mobile Identifier	34	Directory number assigned by operating company to a subscriber
ESN	Electronic serial number	32	Assigned by manufacturer to a mobile station
SID	System identifier	15	Assigned by regulators to a geographical service area
SCC	Station class mark	4	Indicates capabilities of a mobile station
SAT	Supervisory audio tone	One of three sine wave signals	Assigned by operating company to each base station
DCC	Digital color code	2	Assigned by operating company to each base station

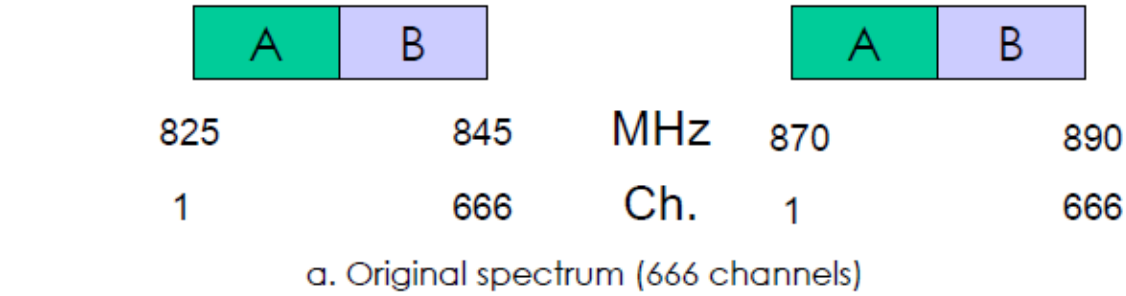
Cellular bands for AMPS



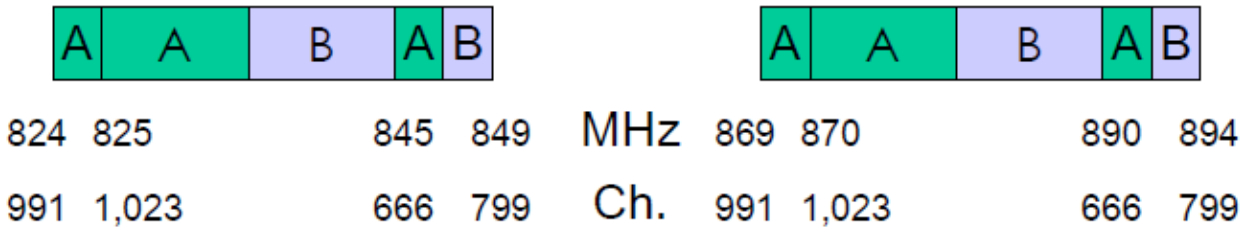
Cellular bands for AMPS



AMPS Frequency Allocation and Channels



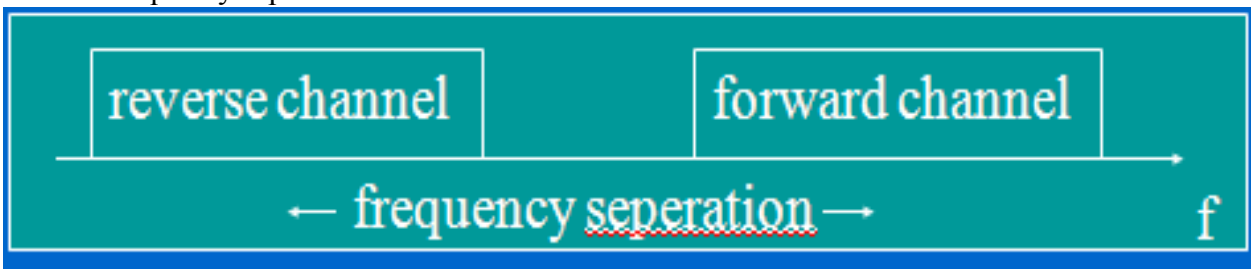
a. Original spectrum (666 channels)



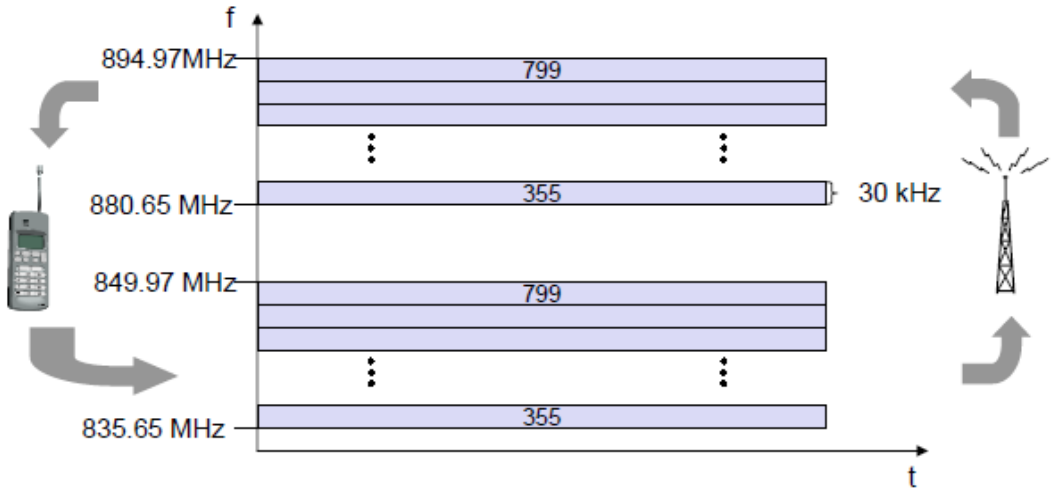
b. Expanded spectrum (832 channels)

Frequency division duplexing (FDD)

- Two bands of frequencies for every user
- Forward band
- Reverse band
- Duplexer needed
- Frequency separation between forward band and reverse band is constant



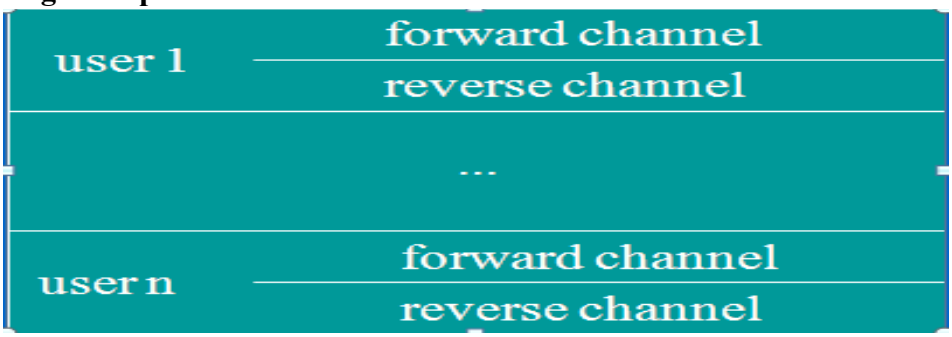
FDD/FDMA – AMPS



$f(c)_{uplink} = 825{,}000 + 30 \times (\text{channel number})$ KHz

$f(c)_{downlink} = f(c)_{uplink} + 45{,}000$ KHz

Logical separation FDMA/FDD



Multiple Access Techniques in use

Cellular System	Multiple Access Technique
Advanced Mobile Phone System (AMPS)	FDMA/FDD
Global System for Mobile (GSM)	TDMA/FDD
US Digital Cellular (USDC)	TDMA/FDD
Digital European Cordless Telephone (DECT)	FDMA/TDD
US Narrowband Spread Spectrum (IS-95)	CDMA/FDD

Radio Transmission

- Frequency Bands and Physical Channels: – The original system covered a bandwidth of 40 MHz – The band for forward transmission is 870 - 890 MHz – The reverse transmission is 825 - 845 MHz – An AMPS physical channel is 30 kHz – Total number of channel (per direction) is 20 MHz/30 kHz = 666 – The carrier frequency corresponding to channel C is – f(C) = 825 MHz + 30 C kHz (reverse direction) – f(C) = 870 MHz + 30 C kHz (forward direction)

Frequency Bands and Physical Channels

- AMPS spectrum is divided into two equal regions labeled A and B – Two cellular operating licenses (corresponding to bands A and B) in each geographical area. – There are 1,466 operating licenses in the USA. – All systems operating in A-band (416 channels) have the same odd SIDs (least significant bit = 1) – Among the 832 AMPS channels, there are 42 control channels (21 channels for each band) from 313 - 354 – All other channels (up to 395 channels) are traffic channels

What is a Decibel- dB

- Decibel is the unit used to express relative differences in signal strength. – It is expressed as the base 10 logarithm of the ratio of the powers of two signals: – dB = 10 log (P2/P1) – Logarithms are useful as the unit of measurement because • signal power tends to span several orders of magnitude • signal attenuation losses and gains can be expressed in terms of subtraction and addition

AMPS Logical Channels

Name	Notation	Use	Topology
Reverse Control Channel (1 per sector per cell)	RECC	Signalling	(Random Access) Many-to-one
Reverse Voice Channel (Associated Control Channel)	RVC	Traffic (Signalling)	Dedicated One-to-One
Forward Control Channel	FOCC	Signalling	Broadcast One –to-Many
Forward Voice Channel (Associated Control Channel)	FVC	Traffic (Signalling)	Dedicated One-to-One

Introduction to 2G networks

- Development driven by the need to improve speech quality, system capacity, coverage and security
- First System that use digital transmission
- Examples of Second Generation (2G) cellular systems ...
    - Digital AMPS (D-AMPS) in the US,
    - Personal Digital Communication (PDC) in Japan,
    - Intrim Standard `94 (IS-94) in Korea and the US
    - Global System for Mobile Communication (GSM)

Introduction of GSM

- GSM stands for Global System for Mobile Communications
- Standard developed by European Telecommunications Standards Institute(ETSI).
- First deployed in Finland in July 1991
- Mobilink started operations as a first GSM cellular service in Pakistan
- Presently more than 1 billion mobile subscriber of GSM in more than 210 countries.
- GSM make use of narrow band Time division multiple access (TDMA) for transmitting signals.
- GSM provides basic to advanced voice and data services including roaming service.

Why GSM???

- Early 1980s there was analog technologies
    - Advance mobile phone services (AMPS) in North America
    - Total Access Communication System(TACS) in UK
    - Nordic Mobile telephone (NMT) in Northern Europe and North Atlantic
- Problems in 1G
    - Each Country developed their own system due to which system worked only within the boundaries of each country

- System Capacity was not grown in cost efficient manner as then umber of user increase

Positive of GSM…..

- Improved spectrum efficiency
- International roaming
- Low-cost mobile sets and base stations (BSs)
- High-quality speech
- Compatibility with Integrated Services Digital Network (ISDN) and other telephone company services

Year	Milestone
1982	**GSM formed**
1986	**Field test**
1987	**TDMA chosen as access method**
1988	**Memorandum of understating signed**
1989	**Validation of GSM system**
1990	**Pre operation system**
1991	**Commercial system startup**
1992	**Coverage of larger cities / airports**
1993	**Coverage of main roads**
1995	**Coverage of rural areas**

GSM Milestones

1996	**June: 133 networks in 81 countries operational.**
1997	**July: 200 networks in 109 countries operational, around 44 million subscribers worldwide.**
1999	**Wireless Application Protocol (WAP) came into existence and became operational in 130 countries with 260 million subscribers.**
2000	**General Packet Radio Service (GPRS) came into existence.**
2001	**As of May 2001, over 550 million people were subscribers to mobile telecommunications.**

The GSM network

- **Switching system(SS)**

Switching system is responsible for performing call processing and subscriber related functions**.**

- **Base station System(BSS)**

All radio-related functions are performed in the BSS, which consists of base station controllers (BSCs) and the base transceiver stations (BTSs).

- **Operation and support system(OSS)**

The functional entity from which the network operator monitors and controls the system. OSS offer the customer cost-effective support for centralized, regional, and local operational and maintenance activities that are required for a GSM network.

Switching System(SS)

The Switching system include the following component

- **Mobile Switching Centre MSC**
  - the core switching entity in the network.
  - Is connected to the radio access network (RAN);
  - the RAN is formed by the BSCs and BTSs within the Public Land Mobile Network (PLMN).
  - all calls to and from the user are controlled by the MSC.
  - A GSM network has one or more MSCs, geographically distributed.
- **Home Location Register (HLR)**
  - A database used for storage and management of subscriptions.
  - data about subscribers, including a subscriber's service profile, location information, and activity status.
  - When an individual buys a subscription, he or she is registered in the HLR of that operator.
- **Visitor Location Register (VLR)**
  - A database that contains temporary information about subscribers that is needed by the MSC in order to service visiting subscribers.
  - The VLR is always integrated with the MSC.
  - For roaming user, VLR connected to that MSC will request data about the mobile station from the HLR through MSC
- **Authentication Centre (AUC)**
  - Provides authentication and encryption parameters that verify the user's identity and ensure the confidentiality of each call.
  - The AUC protects network operators from different types of fraud found in today's cellular world.
- **Equipment Identity Register (EIR)**
  - A database that contains information about the identity of mobile equipment that prevents calls from stolen, unauthorized, or defective mobile stations.
  - The AUC and EIR are implemented as stand-alone nodes or as a combined AUC/EIR node.

Base Station System (BSS)

A Bastion Station System include the following component.

- **Base Station Controller (BSC)**
  - provides all the control functions and physical links between the MSC and BTS.

- It is a high-capacity switch that provides functions such as handover, cell configuration data, and control of radio frequency (RF) power levels in base transceiver stations.
- A number of BSCs are served by an MSC.

- **Base Transceiver Station (BTS)**
  - handles the radio interface to the mobile station.
  - The BTS is the radio equipment (transceivers and antennas) needed to service each cell in the network.

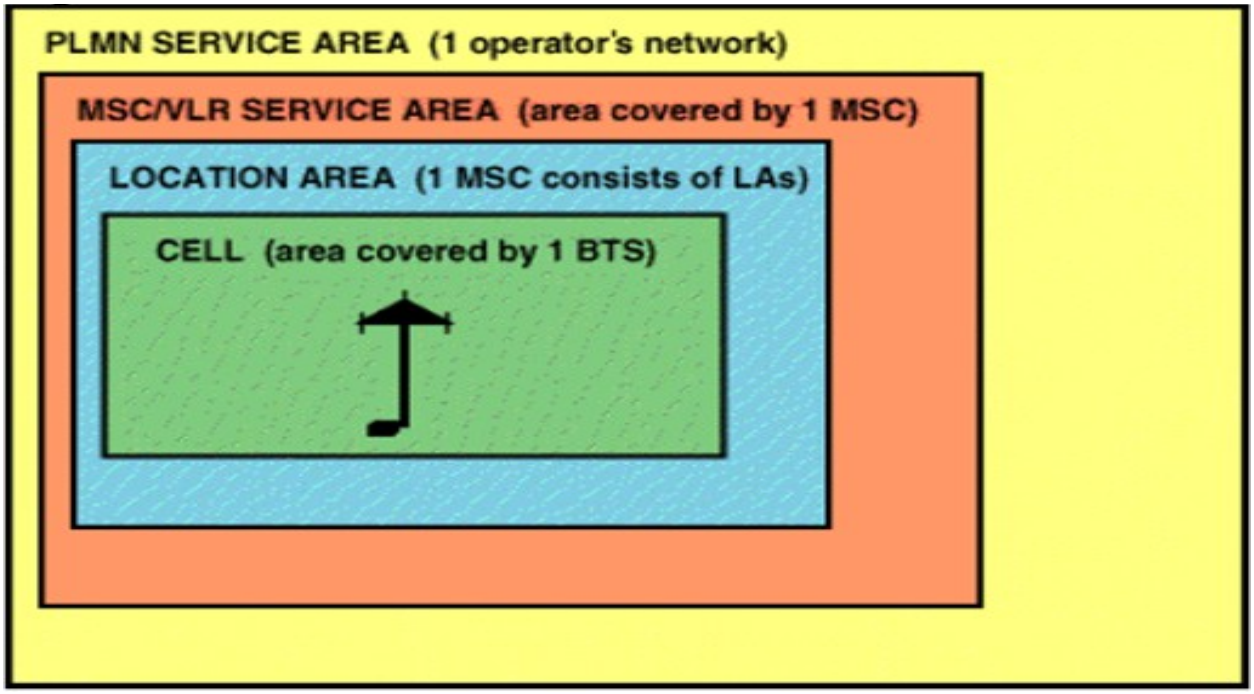
A group of BTSs are controlled by a BSC

Operation and Support System (OSS)

- The OSS is an element within the overall GSM network architecture that is connected to components of the SS and the BSC. It is used to control and monitor the overall GSM network and it is also used to control the traffic load of the BSS. It must be noted that as the number of BS increases with the scaling of the subscriber population some of the maintenance tasks are transferred to the BTS, allowing savings in the cost of ownership of the system.

GSM Network Areas

- GSM network is made up of geographic areas.



GSM Network Areas

- **Cell**
  - The Cell is the area given radio coverage by one BTS
  - The GSM Network identifies each cell via cell global identity (CGI) number, assigned to each cell.
- **Location Area (LA)**
  - Group of cell

- It is the area in which the subscriber is paged.
- Each LA is served by one or more BSC but only by a single MSC.
- Each LA is assigned a location area identity(LAI)

- **MSC/VLR Service Areas**
  - A MSC/VLR service area represents the part of the GSM network that is covered by one MSC and which is reachable, as it is registered in the VLR of the MSC
- **PLMN Network Areas**

The PLMN service area is an area served by one network operator.

GSM specifications

- **Uplink frequency band**— 933 to 960 MHz (Basic 900 MHz only)
- **Download Frequency band** — 890 to 915MHz (basic 900 MHz only).
- **duplex distance**—80 MHz.
- **channel bandwidth -- 2**00 kHz.
- **modulation**—Gaussian minimum shift keying (GMSK).
- **transmission rate—**over-the-air bit rate of 270 kbps.
- **access method—**time division multiple access (TDMA)
- **speech coder—**GSM uses linear predictive coding (LPC). Speech is encoded at 13 kbps.

GSM PLMN

- PLMN stand for public land mobile network
- Is a network that is established and operated by an administration or by a recognized operating agency (ROA) for the specific purpose of providing land mobile telecommunication service to public.
- A PLMN is identified by Mobile Country Code(MCC) and the Mobile Network Code(MNC)
- Each operator has its own PLMN
- PLMNs interconnected with other PLMNs and public switched telephone network (PSTN) for telephone communication or with Internet service provider (ISP) for data and internet access of which link are defined as interconnect links between provider.

Objective of GSM PLMN

- To provide the subscriber a wide range of services and facilities, both voice and non voice, that are compatible with those offered by existing networks (e.g., PSTN, ISDN)
- To introduce a mobile service that is compatible with ISDN
- To provide certain services and facilities exclusive to mobile situations
- To provide facilities for automatic roaming, locating, and updating of mobile subscribers
- To provide for efficient use of the frequency spectrum
- To give access to the GSM network for a mobile subscriber in a country that operates the GSM system
- To provide service to a wide range of MSs, including vehicle-mounted stations, portable stations, and handheld stations
- To allow for a low-cost infrastructure and terminal and to keep cost of service low

GSM PLMN Services

The basic telecommunication services provided by the GSM PLMN are divided into three main groups

1. **Teleservices or telephony services**

The abilities of a Bearer Service are used by a Teleservice to transport data. These services are further divided in the following ways:

Voice Calls

The most basic Teleservice supported by GSM is telephony. This includes full-rate speech at 13 kbps and emergency calls, where the nearest emergency-service provider is notified by dialing three digits.

Videotext and Facsmile

Another group of teleservices includes Videotext access, Teletex transmission, Facsimile alternate speech and facsimile Group 3, Automatic facsimile Group, 3 etc.

Short Text Messages

Short Messaging Service (SMS) service is a text messaging service that allows sending and receiving text messages on your GSM mobile phone. In addition to simple text messages, other text data including news, sports, financial, language, cell broadcast and location-based data can also be transmitted.

2.Bearer Services

- Data services or Bearer Services are used through a GSM phone. to receive and send data is the essential building block leading to widespread mobile Internet access and mobile data transfer. GSM currently has a data transfer rate of 9.6k. New developments that will push up data transfer rates for GSM users are HSCSD (high speed circuit switched data) and GPRS (general packet radio service) are now available.

3. Supplementary services

Supplementary services are additional services that are provided in addition to teleservices and bearer services. These services include caller identification, call forwarding, call waiting, multi-party conversations, and barring of outgoing (international) calls, among others. Following are the supplementary services

- Conferencing
- Call Waiting
- Call Hold
- Call Forwarding
- Call Barring

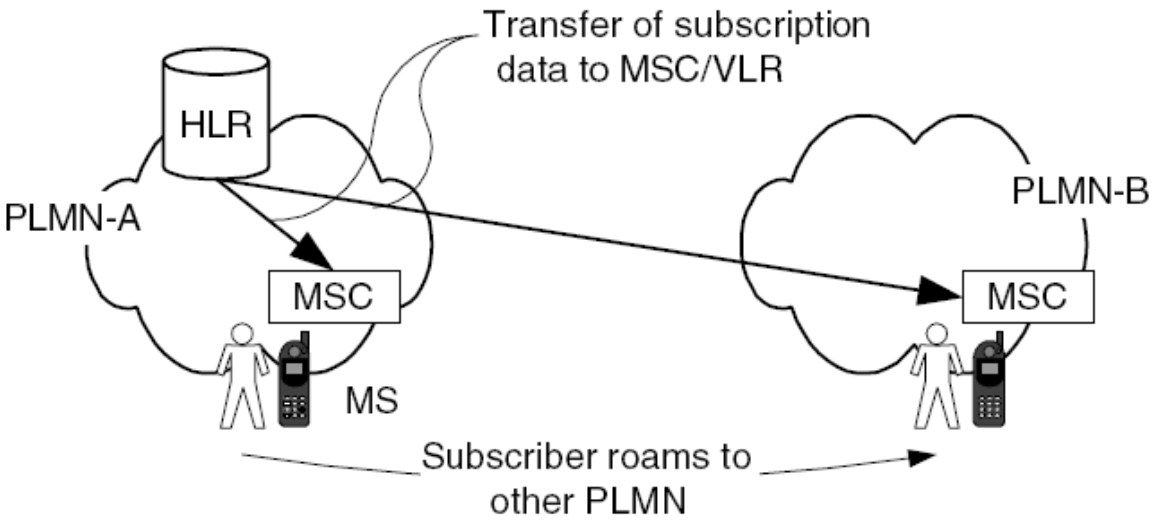
Number Identification :

Following supplementary services related to number identification:

- Calling Line Identification Presentation
- Calling Line Identification Restriction :
- Connected Line Identification Presentation
- Connected Line Identification Restriction
- Malicious Call Identification
- Advice of Charge (AoC)
- Closed User Groups (CUGs)
- Unstructured supplementary services data (USSD)

GSM Mobility

- Roaming with GSM is made possible through the separation of switching capability and subscription data.
- A GSM subscriber has her subscription data permanently registered in the HLR in his/her HPLMN.
- The GSM operator is responsible for provisioning this data in the HLR. The MSC and GMSC in a PLMN, on the other hand, are not specific for one subscriber group.



Mobile Station

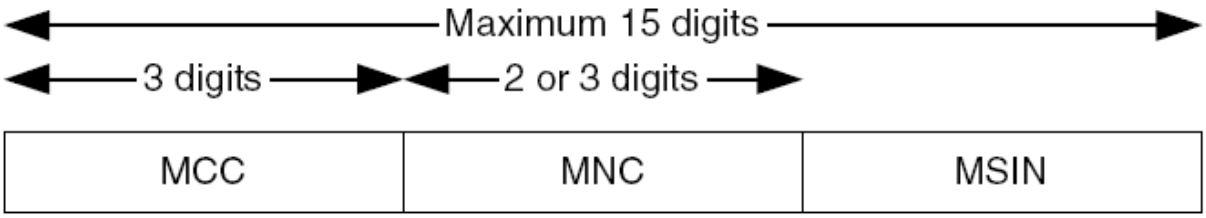
- Mobile Equipment (ME)
- Subscriber Identification Module (SIM)
    - this is the chip embedded in the SIM card that identifies a subscriber of a GSM network;
    - When the SIM card is inserted in the ME, the subscriber may register with a GSM network.
    - The ME is now effectively personalized for this GSM subscriber;
    - The SIM card contains information such as IMSI, advice of charge parameters, operator-specific emergency number, etc.

Identifiers in the GSM Network

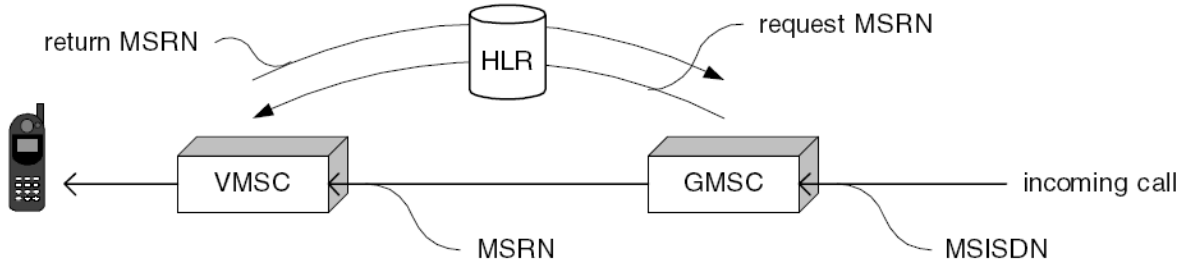
- GSM uses several identifiers for
    - the routing of calls,
    - identifying subscribers (e.g. for charging),
    - locating the HLR, identifying equipment, etc.

IMSI

- International Mobile Subscriber Identity (IMSI)
    - It is embedded on the SIM card and is used to identify a subscriber.
    - The IMSI is also contained in the subscription data in the HLR.
    - *roaming charging* – a VPLMN uses the IMSI to send billing records to the HPLMN of a subscriber.

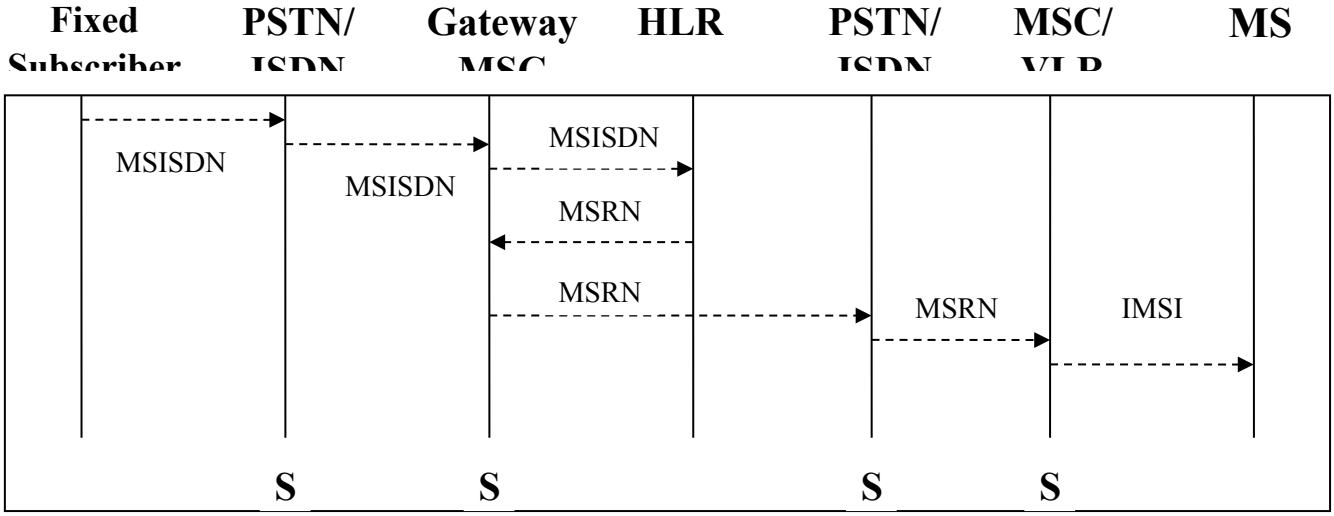


- **International Mobile Equipment Identifier**
  - Each ME has a unique IMEI which is hard-coded in the ME and cannot be modified.
  - (IMEI) is used to identify the ME.
- **Mobile Station Roaming Number**
  - (MSRN) is used in the GSM network for routing a call to a MS.
  - The MSRN is allocated to a subscriber during MT call handling and is released when the call to that subscriber is established.
  - Each MSC in a PLMN has a (limited) range of MSRNs allocated to it.



- **Mobile Station Integrated Services Digital Network Number (MSISDN Number)**
  - The MSISDN is used to identify the subscriber when, among other things, establishing a call to that subscriber or sending an SMS to that subscriber.
  - The MSISDN is not stored on the subscriber's SIM card and is normally not available in the MS.
  - The MSISDN is provisioned in the HLR, as part of the subscriber's profile, and is sent to MSC during registration.

Call Routing in GSM



GPRS

GPRS is an enhancement over the GSM and adds some nodes in the network to provide the packet switched services. These network nodes are called GSNs (GPRS Support Nodes) and are responsible for the routing and delivery of the data packets to and from the MS and external packet data networks (PDN).

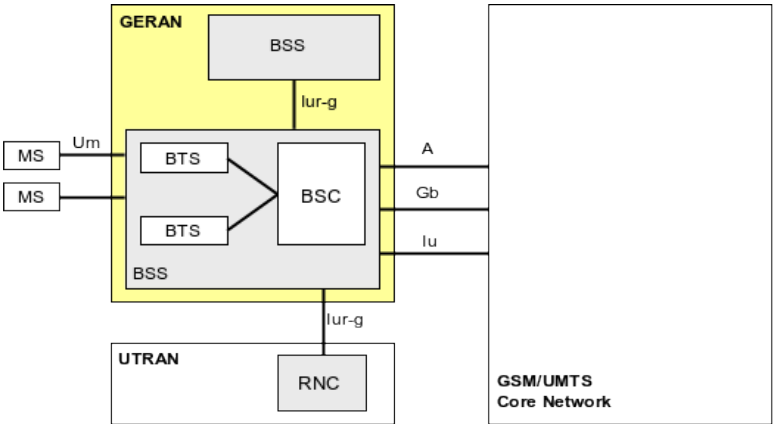
Introduction to GPRS

- Goals of GPRS:
  - Efficient bandwidth usage for bursty data traffic (e.g. Internet)
  - Higher data rates
  - New charging models
- Initially specified by ETSI
- A lot of releases (R97, R98, R99, R4 etc.)
- Specifications handed over to 3GPP
- A lot of specifications considered in this overview:
  - Release 5 (Ganz) / 6 (most recent TS at 3GPP)

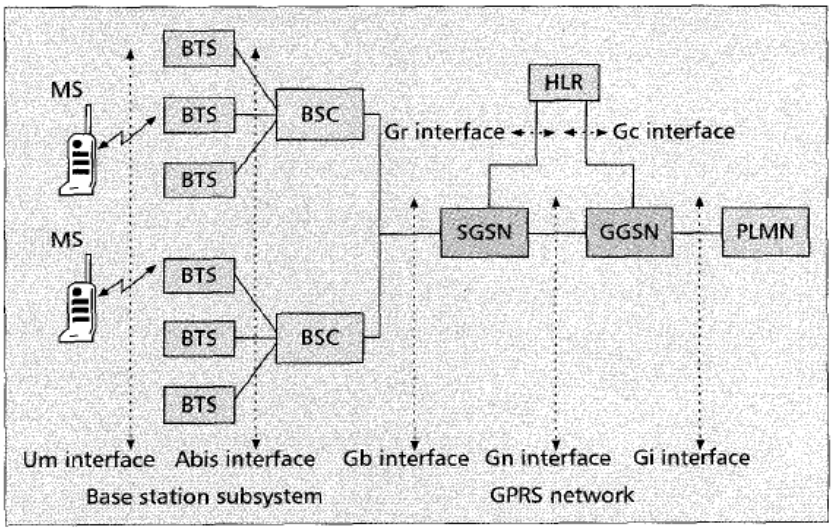
GPRS Release 5/6

- Two modes determined by generation of core network:
  - 2G core => A/Gb
  - 3G core => Iu
- Iu interface added in rel. 5 to align with UMTS

GERAN Reference Architecture



GPRS Architecture



A/Gb mode

- Class A: MS can operate simultaneous packet switched and circuit switched services
- Class B: MS can operate either one at one time
    - Most common for handsets today
- Class C: MS can operate only packet switched services
    - E.g. expansion cards for laptops

Iu mode

- CS/PS mode: Same as Class A in A/Gb mode
- PS mode: MS can only operate packet switched services
- CS mode: MS can only operate circuit switched services

Control Channels

- Packet Common Control Channel (PCCCH)
    - When allocated in a cell, GPRS related mobiles camp on it
    - Divded into
        - Random Access (PRACH): MS initiate packet transfer or respond to paging messages
        - Paging (PPCH): to page an MS prior to packet transfer
        - Access Grant (PAGCH): send resource assignment to MS prior to packet transfer
        - Packet Notification (PNCH): used to send a PTM-Multicast notification to group of MS
- Packet Dedicated Control Channel (PDCCH)
        - Slow Associated Control Channel (SACCH)
            - Radio measurements, power control and data
            - SMS transfer during calls
        - Fast Associated Control Channel (FACCH)
            - For one Traffic Channel (TCH)
            - Carry Ack
        - Stand-alone Dedicated Control Channel (SDCCH)

        - is used in the GSM system to provide a reliable connection for signalling and Short Message Service.
- Packet Broadcast Control Channel (PBCCH)
    - Frequency correction channels
        - Allows the MS to synchronize their Local Oscillator (LO) to the Base Station LO, using frequency offset estimation and correction.
    - Synchronization channel (MS freq. vs. BS)
    - Broadcast control channel for general information on the base station

Mobility

- A mobile station has three states in GPRS system:
    - Idle
    - Standby
    - Active
- The operation of GPRS is partly independent of the GSM network. However, some procedures share the network elements with current GSM functions.
- Data is transmitted between a mobile station and the GPRS network only when the mobile station is in the active state.
- In the active state, the SGSN knows the cell location of the mobile station.
- In the standby state, the location of the station is known only as to which routing area it is in.
- In the idle state, the mobile station does not have a logical GPRS context activated or any Packet-Switched Public Data Network (PSPDZ) addresses allocated, The MS can receive only those multicast messages that can be received by any GPRS mobile station.

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GPRS Air Interface

- Master slave concept
    - One PDCH acts as Master
    - Master holds all PCCCH channels
    - The rest of channels act as Slaves
- Capacity on demand
    - PDCH(s) are increased or decreased according to demand
    - Load supervision is done in MAC Layer

Uplink Data Transfer (from power point)

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QoS Support

- Assumes that IP multimedia applications are able to
    - Define their requirements
    - Negotiate their capabilities
    - Identify and select available media components
- GPRS specifies signaling that enable support for various traffic streams
    - Constant/variable bit rate
    - Connection oriented/connection less
    - Etc.

QoS Profile for GPRS Bearers

- 4 parameters:

    - Service precedence
        - 3 classes
    - Reliability parameter
        - 3 classes
    - Delay parameters
        - 4 classes
    - Throughput parameter
        - Maximum and mean bit rates
- QoS profile is included in Packet Data Protocol (PDP) context
- Negotiation managed through PDP procedures (activation, modification and deactivation)

Service Types

- Point-to-Point
    - Internet access by user
- Point-to-Multipoint
    - Delivery of information (e.g. news) to multiple locations or interactive conference applications

GPRS BSS

- A software upgrade is required in the existing Base Transceiver Site (BTS).
- The Base Station Controller (BSC) also requires a software upgrade, and the installation of a new piece of hardware called a packet control unit (PCU).
- The PCU directs the data traffic to the GPRS network and can be a separate hardware element associated with BSC.
- The PCU provides a physical and logical data interface out of BSS for packet data traffic.

Registration of a Mobile Node

A mobile station must register itself with GPRS network.

- GPRS attach
    - The device sends message to the new SGSN containing the last assigned Temporary Mobile Subscriber Id (TMSI), location area information, etc.
    - The new SGSN queries the old SGSN for the identity of this mobile device.
    - Then the new SGSN requests more information from the mobile device to authenticate itself against the new SGSN
- GPRS detach
    - GPRS detach can be initiated by the MS or the network.

Session Management

- After Successful attach, when it wishes to begin a packet data, it must activate Packet Data Protocol (PDP) address.This address is unique only for a particular session. It consists of,
    - PDP type
    - PDP address assigned to MS
    - Requested QoS
- Once PDP Context is activated, a two-way tunnel is established between the device current SGSN and the corresponding GGSN.

- GGSN hides the mobility from onward
- PDP-Address allocation:
    - Static:Assigned by network operator of User's home PLMN.
    - Dynamic:Assigned by Corresponding GGSN.

PDP Context Activation(from powerpoint)