Wireless Communication

Unit-I

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Introduction To Wireless Communication System

* Evolution of Mobile Radio Communications

* Reasons for Developing a wireless mobile telephone system:

(i) Limited Service Capability

- primary disadvantage of a conventional mobile telephone System is that communications coverage area of each zone normally planned to be as large as possible which means that the transmitted power should be high as the federal specification allows.
- Call Drop if user moves from one zone to other & limited no. of active users to no. of channels assigned to particular frequency zone.

(ii) Poor Service Performance

- In conventional mobile telephone system, large no. of subscribers created a high blocking probability during busy hours.

(iii) Inefficient Frequency Specturm Utilization

- In conventional system, each channel can only serve one customer at a time in a whole area so the specturm not utilized efficiently.

* Three Approaches to achieve ideal mobile telephone system:

(i) SSB (Single Side Band) (ii) Cellular (reuse of allocated band)

(iii) Spread Specturm or frequency-hopped

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(UHF, EHF)
Microwave Transmission - 2GHz to 40GHz
Cell phones - 825 MHz to 845 MHz (approx)

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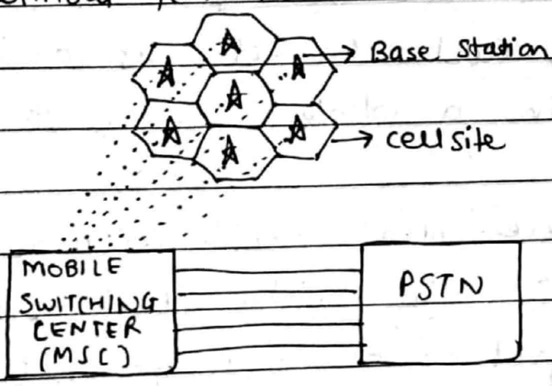
* Frequencies for Radio Transmission

- International Telecommunications Union (ITU), Geneva is responsible for worldwide coordination of telecommunication ~~satellites~~ activities (wired & wireless)
- ITU Radio Communication Sector (ITU-R) has split world into three regions:
  (i) Region 1 covers Europe, Middle East, former Sovient Union countries & Africa
  (ii) Region 2 covers Greenland, North & South America
  (iii) Region 3 covers fast east, Australia & New Zealand
- Within these regions, further regulations such as FCC (Federal Communication Commission) in US, or CEPT (Conference for Eurpean Posts & Telecommunications) in Europe etc.

* Examples of wireless Communication Systems

(i) Cellular Telephone Systems

- It mainly helps to connect a public switched telephone network (PSTN) & any distant/near user provided user is available within corresponding frequency range.
- The cellular communication is made possible b/w mobile units & base stations with help of common air interface (CAI), which specifies four channels:
  (a) Forward Control Channel (FCC)
  (b) Reverse Control Channel (RCC)
  (c) Forward voice Channel (FVC)
  (d) Reverse voice Channel (RVC)
- The call in progress continues irrespective of the frequency changes from one base station to another base station. Such a call continued process without termination is called "Hand off" Technique.



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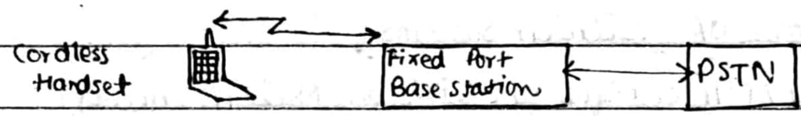
(ii) Cordless Telephone System (CT Systems)

- Full duplex systems intended to link a portable handset to the dedicated base station which in turn is connected to a particular dedicated telephone line



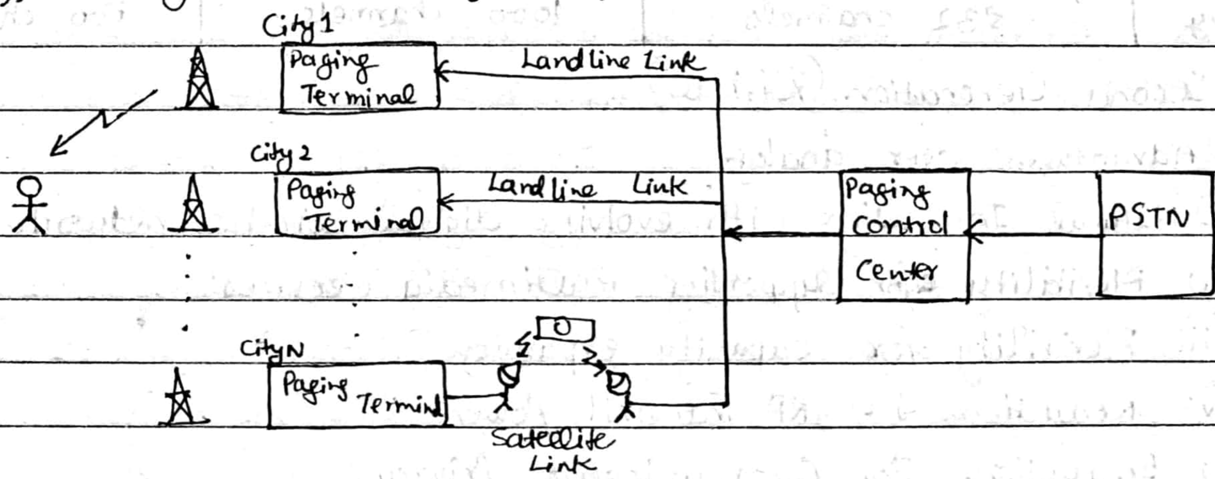
- 1G CT systems in 1980s which covered only few meters.
- 2G system, in mobile environment also.
- Analog & Digital CT

  Ex of Digital CT is CT2 / Common Air Interface (CAI)

(iii) Paging Systems

- Transmit brief messages to subscribers, message may be an alphanumeric, numeric message or even voice data. Such a message is called page
- In a technique called 'simultaneously', the wide paging systems send a page from each base station simultaneously.
- Performance metrics

  (a) Probability of call blocking (b) Probability of call dropping
  (c) Probability of call completion (d) Probability of incomplete handoff
  (e) Probability of handoff completion (f) Handoff probability
  (g) Handoff Delay (h) Rate of Handoff (i) Interruption Time Duration



- Strategies to calculate instant handoff:

  (a) Relative Signal Strength (b) Relative Signal Strength with Hysteresis method
  (c) Relative Signal Strength with threshold method (d) Prediction Techniques

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(300 to 3000 MHz)
↑
* UHF, SHF, EHF = Microwave frequency Range

Band	Frequency Range	Application
S	1.5 to 5.2 GHz	Cellular
C	3.9 to 6.2 GHz	Satellite
W	56 to 100 GHz	Further development in cellular

* Overview of Generation of Cellular Systems
  - 1G wireless systems used FDMA (Frequency Division Multiple Access)
  - 2G used TDMA (Time) & CDMA (Code)
  - 1G & 2G offer predominantly voice
  - 2.5 G standards : HSCSD, GPRS
  - 3G based on CDMA with 2Mbps transmission rate & support for multimedia

* First Generation (Analog)

Region / Parameter	America AMPS: Advanced Mobile Phone System	Europe ETACS: European Total Access Communication System	Japan NTT: Nippon Telephone & Telegraph
Multiple Access	FDMA	FDMA	FDMA
Duplexing	FDD (Frequency Division Duplex)	FDD	FDD
Forward Channel	869 - 894 MHz	935 - 960 MHz	870 - 885 MHz
Reverse Channel	824 - 849 MHz	890 - 915 MHz	925 - 940 MHz
Channel Capacity	30 kHz	25 KHz	25 kHz
Data Rate	10 kbps	8 kbps	0.3 kbps
Spectral Efficiency	0.33 bps/Hz	0.33 bps/Hz	0.012 bps/Hz
Capacity	832 channels	1000 channels	600 channels

* Second Generation (Digital)
  - Advantages over analog
    1. Natural Integration with evolving digital wireless network
    2. Flexibility for supporting multimedia services
    3. Flexibility for capacity expansion
    4. Reduction in RF Transmit Power
    5. Encryption For Communication Privacy
    6. Reduction in System Complexity

North America - Interim Standard-54 & IS-95 (IS-54)

Japan - PDC (Personal Digital Cellular)

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Europe { - GSM (Global Service for Mobile Communication)
- DCS 1800 (Digital Cellular System)

DQPSK - Differential Quadrature Phase Shift Keying
GMSK - Gaussian Filtered Minimum Shift Keying
OQPSK - Offset Quadrature Phase Shift Keying

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Region / Parameter	US IS-54	Europe GSM	Japan PDC	US - IS-95
Multiple Access	TDMA / FDD	TDMA / FDD	TDMA / FDD	CDMA
Modulation	$\frac{\pi}{4}$ DQPSK	GMSK	$\frac{\pi}{4}$ DQPSK	QPSK/OQPSK
Forward channel	869 - 894 MHz	935 - 960 MHz	810-826 MHz	869-894 MHz
Reverse channel	824 - 849 MHz	890 - 915 MHz	940 - 956 MHz	824 - 849 MHz
Channel ~~Capacity~~ Spacing	30 kHz	200 kHz	25 kHz	1.250 kHz
Data Chip Rate	48.6 Kbps	270.833 Kbps	42 Kbps	1.2288 Mcps
Speech Codec Rate	7.95 kbps	13.4 kbps	6.7 kbps	1.2/2.4/4.8/9.6 kbps

- SMS (Short Message Service) is one of the popular feature of GSM. It is a service that allows the subscribers to transmit short & real time messages to the other subscribers of the same network.

* Third Generation (3G)

- Standards: W-CDMA, TD-SCDMA
  Europe: IMT-2000 (wideband Direct Sequence CDMA, DS-CDMA)
  North America: CDMA-2000 (MultiCarrier CDMA, MC-CDMA)
  Both use FDD to support two way transmission with frequency isolation
- Features: ① Higher Transmission Rate ⓘⓘ Support for Multimedia Services
- Mobiles can be located anywhere within footprint of a base station. If every mobile transmits at same power level, signal received at cell-site receiver form the mobile(s) closet to it will be the strongest. This is known as "Near-Far Problem" & power levels needs to be controlled to smooth out near-far effect. Power control, rate allocation & service scheduling are radio resource management functions.
- 3G standard advantages:
  (i) Global Compatibility
  (ii) Integrate Paging, cordless & cellular mobile system & LEO satellites as a single mobile system
  (iii) Supports - Multifunction

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BS – ~~Mob~~ Base Station   Tx – Transmit
MS – Mobile ~~System~~ Station   Rx – Rece~~ive~~ Date __/__/____

* Comparison of Various Wireless Systems

S.No.	Service Type	Functionality	Operating frequency	Level of Infrastructure	Complexity	Hardware cost	Range
(i)	Paging System	BS : Tx only MS : Rx only	<1 GHz	High	BS : High MS : Low	BS: High MS: low	High
(ii)	Cordless Telephone System	Transceiver	1-3 GHz	Low	BS : Low MS : Medium	BS: Medium MS : Low	Low
(iii)	Cellular Phone Systems	Transceiver	<2 GHz	High	~~BS~~ High	BS : High MS: Medium	High

* Advantages of Wireless Communications:

(i) Mobility (ii) Easier Installation (iii) Cost Effective Installation
(iv) Increased Reliability (v) Disaster Recovery

* Cellular Mobile Communication : Important Terminologies

(i) Cell : Smallest geographical area considered for cellular mobile communication
(ii) Cell Splitting : In high traffic regions, a larger cell divided into smaller cells to have complete radio coverage.
(iii) Cell Sectoring : A cell can be divided into many ~~cells~~ sectors. The directional antenna should focus on each other
(iv) Umbrella Cell Pattern : A single large cell (macro cell) consists of many small cells (micro cells) & there will be interaction b/w micro & macro cells
(v) Base Station (BS) : Provide functionalities b/w mobile unit & mobile switching center (MSC) & located in each cell to link subscriber mobile unit with MSC.
(vi) Mobile Telecommunication Switching Office (MTSO) or Mobile Switching Center (MSC) : Main unit that connects base station & PSTN
(vii) Control Channel : Used for necessary exchange of information related to setting up & establishing cell BS & mobile units
(viii) Traffic Channel : Used for carrying data or voice connections b/w users
(ix) Forward Channel : Channel for transmission of information from BS ~~to~~ to MS
(x) Reverse Channel : Channel for transmission of information from MS to BS
(xi) Frequency Reuse : The same carrier frequency is used by many cells in a cellular cluster & is known as 'frequency reuse' scheme.

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Introduction To Personal Communication Services (PCS)

* PCS objective is to enable communication with a person at any time, at any place & in any form.
* Salient features of PCS :

(i) Multiple Environments
(ii) Multimedia service with High Quality
(iii) Multi User Types
(iv) Global Roaming Capability
(v) Single Personal Telecommunication No. (PTN)
(vi) Very High Capability
(vii) Universal Handset
(viii) Service Security

* PCS Architecture :

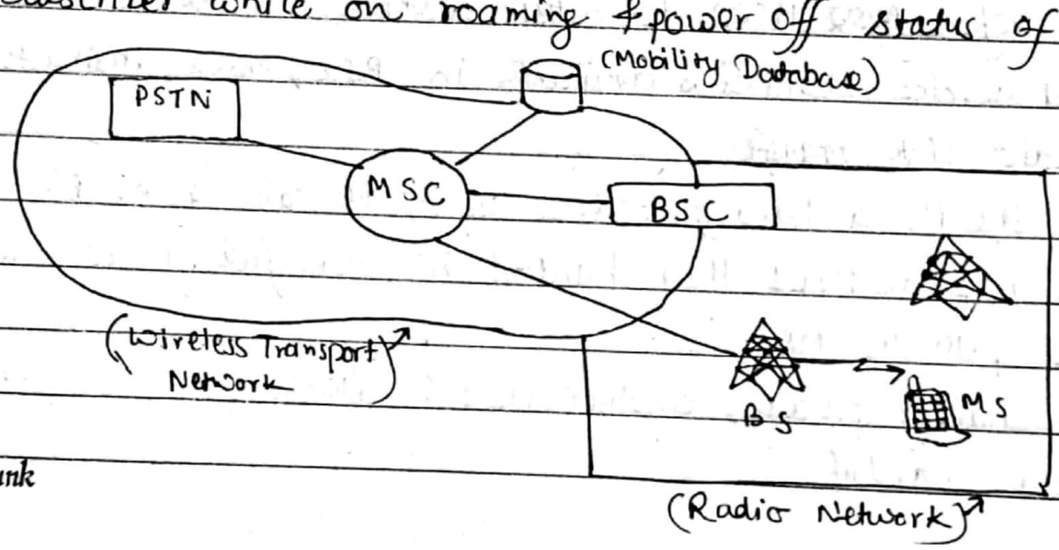
- Consists of two parts:

(i) Radio Network

PCS users carry Mobile Station (MS) or handset or mobile phone to communicate with BS in PCS network. The radio coverage of a BS is called cell. In GSM network, each cell is controlled by BSC (Base Station Controller) which are connected to MS through BS. The BSC are connected to MSC (Mobile Switching Center) by landlines.

(ii) Wireless ~~Network~~ Transport Network

An MSC is a telephone exchange configured specially for mobile applications. It interfaces with MSC (via BS) with PSTN. MSCs are also connected with mobility database to track location of MS & roaming management. The databases are HLR & VLR. HLR contains the authentication information like IMSI (International Mobile Subscriber Identity), identification information like name, address of subscriber, billing information like prepaid or postpaid, operator selection etc. VLR gives information about the location area of the subscriber while on roaming & power off status of the handset.



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* Mobility Management
- Handles function that arise due to mobility of subscriber
- Main objective of MM is location tracking & call setup
- Two aspects:

Ⓐ Hand off / Automatic Link Transfer

→ Engaged user MS connected to BS & if user moves to new area of other BS then radio link to old BS disconnected & to new BS established to continue connection

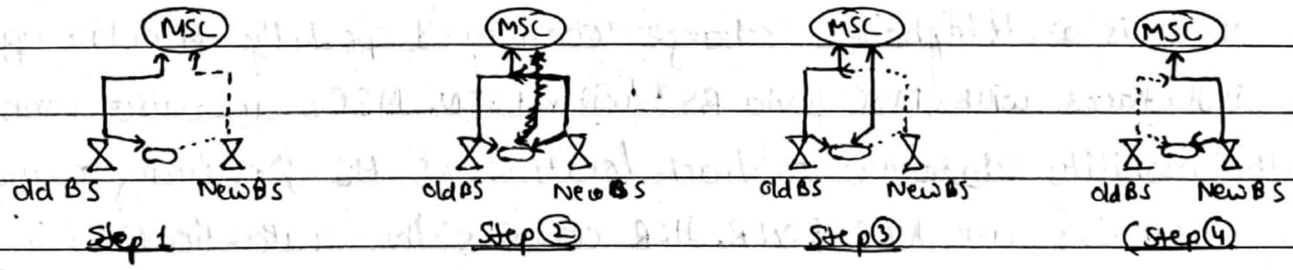
→ Two categories:

(i) Inter-BS Hand off / Inter Cell Handoff : (Actions taken as follows:)

ⓐ suspend conversation momentarily & initiate handoff procedure by picking a channel in new BS. Then, it resumes conversation in old BS

ⓑ when MSC receives that signal, it transfers information to new BS & setsup new conversation path to MS through that channel

ⓒ After MS transferred to new MS, it starts conversation channel with new BS & then disconnects link with old BS.



(ii) Inter System Handoff / Inter-MSC Handoff : (Action Taken as follows:)

ⓐ MSC1 requests MSC2 to perform handoff measurement on call in progress

ⓑ MSC 2 then selects a BS by interrogating signal quality & send info to MSC1

ⓒ MSC1 then asks ~~MSC2~~ MSC2 to setup a voice channel

ⓓ Assuming that a voice channel is available in BS2, MSC2 instructs MSC1 to start audio link transfer.

ⓔ MSC1 sends the MS a handoff order. Now, MS can access BS2 of MSC2. MSC2 informs MSC1 that handoff is successful. MSC1 then connects call path to MSC2

ⓕ In intersystem handoff process, another MSC is always in call path before & after handoff.

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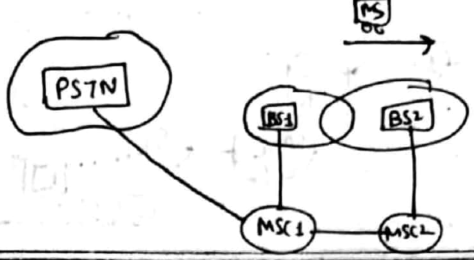

(Inter system Handoff)

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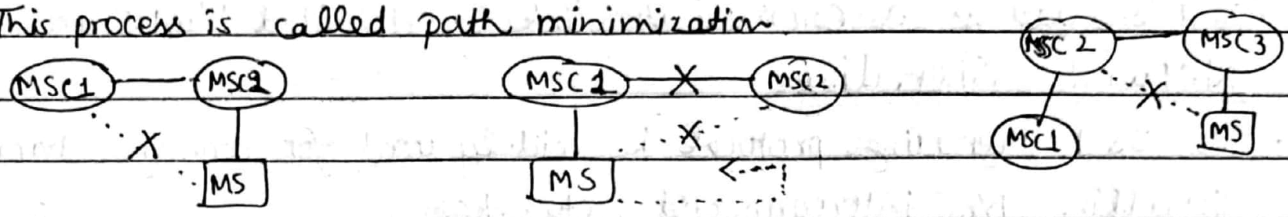
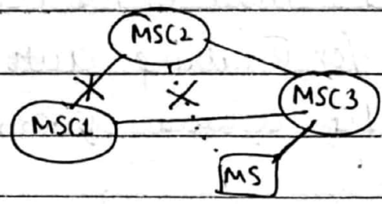
⇒ when MS moves to MSC3, MSC2 may be removed from the call path. The link b/w MSC 1 & MSC 2 is disconnected & MS connects to MSC 3 directly. This process is called path minimization.



ⓐ Handoff forward ⓑ Handoff backward ⓒ Handoff to third



ⓓ Path minimization

Ⓑ Roaming Management

→ Two operations:

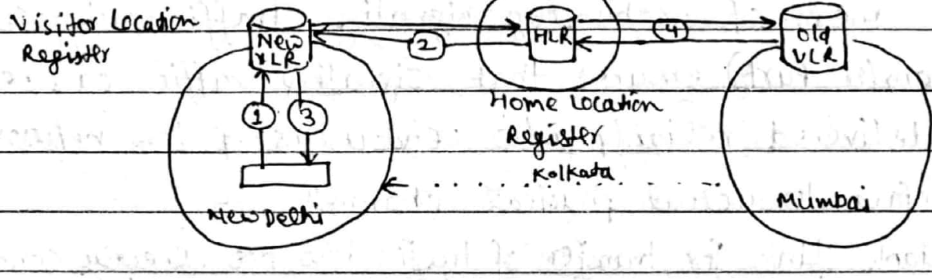
ⓘ Registration (location update): where MS informs system its current location

(Steps:) ① When MS enters new PCS network, it must register in VLR of new system

② The new VLR informs MS's HLR regarding current location & address of user. HLR sends ack. which includes MS's profile to new VLR.

③ New VLR informs MS about successful registration

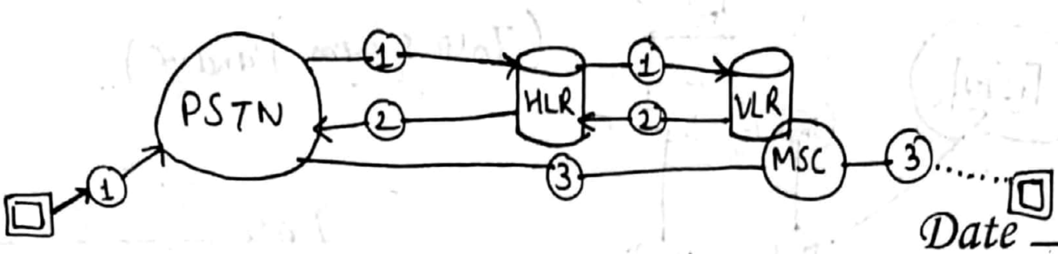
④ HLR sends a deregistration message to cancel location record of MS in old VLR. The old VLR acknowledges the ~~new~~ deregistration.



ⓘⓘ Location Tracking: Process during which a system locates MS. Location tracking is required when network attempts to deliver call to user.

(Steps: If call request approved by VLR then)

① If a wireless phone attempts to call a mobile subscriber, the call is forwarded to switch called originating switch in PSTN. The switch makes a query to HLR to find current VLR of MS. The HLR



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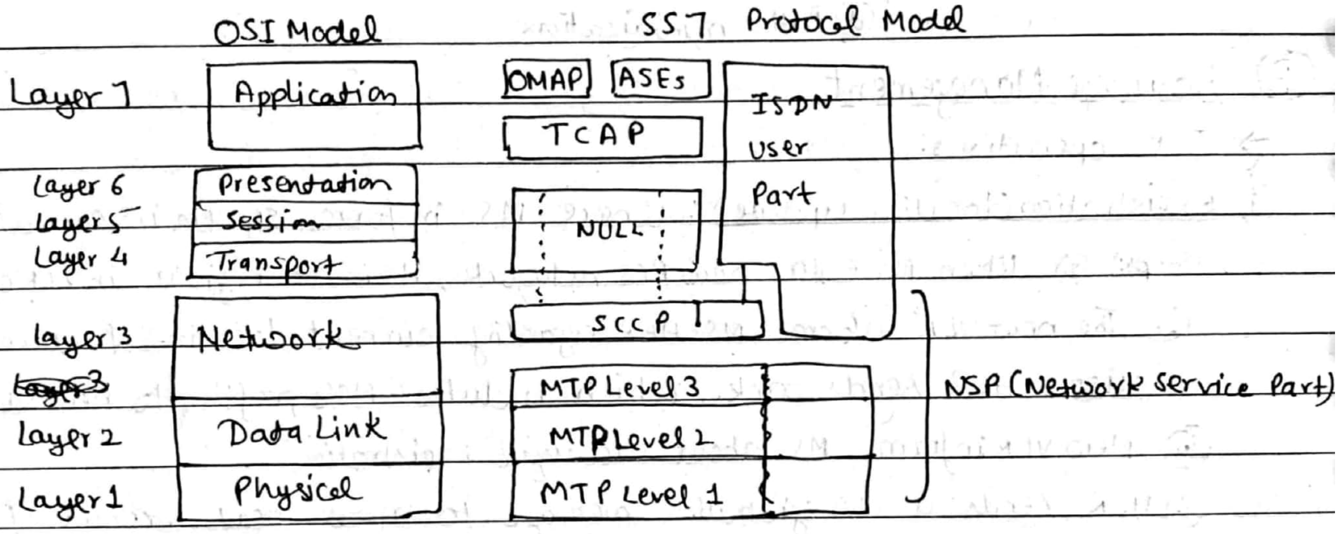
queries the VLR in which MS resides to get a communicable address.

(2.) The VLR returns the address to switch through HLR

(3.) Based on address a communication link is established b/w MS through visited MSC

* Networks Signaling

- The SS7 signaling protocol is widely used for common channel signalling b/w interconnected networks.
- SS7 is used to inter-connect most of the cellular MSCs throughout the US & is key factor for enabling autonomous registration & automated roaming in 1G cellular systems.
- SS7 architecture:



⇒ NSP provides ISDN nodes (Integrated Services Digital Network) with a highly reliable means of exchanging signaling traffic using connectionless service.

⇒ MTP (Message Transfer Part) ensures that signaling traffic can be transferred & delivered reliably b/w end-users & the network:

MTP1 – Interface to actual physical channel

MTP2 – Reliable link for transfer of traffic b/w two directly connected signaling points & flow of control b/w these points

MTP3 – Enhancement to addressing capabilities provided by MTP.

class 0 ≡ Basic Connection class
class 1 ≡ sequenced (MTP) connectionless class
class 2 ≡ Basic connection-oriented class
class 3 ≡ Flow Control connection-oriented class

classes provided by SSCP

Functional Diagram of Message Transfer Part

⇒ SCCP (Signaling Connection Control Part) provides ability to address global title messages, such as 800 numbers or non-billed numbers & uses local addressing based on SSNs (Subsystem ~~Netw~~ Numbers) to identify users at signaling node.

⇒ SS7 user part consists ISDN user part (ISUP), the transaction capabilities application part (TCAP) & the operation & maintenance & administration part (OMAP)

⇒ ISUP provides signaling functions for carrier and supplementary services for voice, data & video in an ISDN environment.

⇒ TCAP refers to application layer which invokes services of the SCCP & the MTP in a hierarchical format. & is concerned with remote applications

⇒ OMAP include monitoring, coordination, & control functions to ensure that trouble free communications are possible. It supports diagnostics are known throughout global network to determine loading & specific subnetwork behaviour.

- SS7 services

(i) Touchstar: This ~~kind of~~ service offered by the SS7 network is also known as CLASS & is a group of controlled services that provide its users with certain call management capabilities.

(ii) 800 Services: Provide toll free access to calling party to services & databases which is ~~provided by~~ offered by private parties.

(iii) Alternate Billing Service & Line Information Database (ADB/LIDB) These services use the CCS network to enable calling party to bill a call to personal number from any number.

- Advantages of Common Channel Signaling over Conventional Signaling

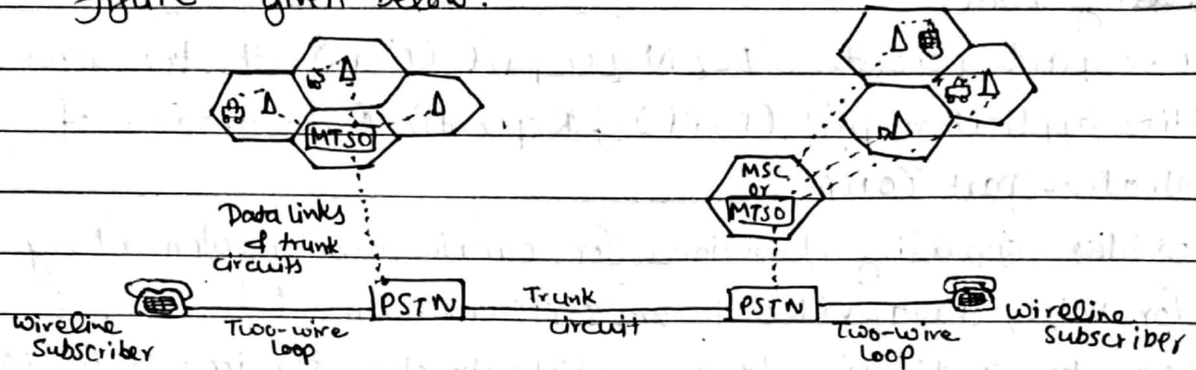
(i) Faster Call setup

(ii) Greater Trunking (or Queuing) Efficiency

(iii) Information Transfer

* A Basic Cellular System

- A simplified basic cellular system that includes all basic components necessary for cellular telephone communications is shown in the figure given below:



- A wireless radio network covering a set of cells in which two-way radio units such as cellular or PCS telephones can communicate.
- The radio network is defined by a set of BS which serves as central control for all users within that cell.
- Mobile users can communicate directly with the base stations & BS directly with MTSO or MSC.
- An MTSO controls channel assignment, call processing, call setup, & call termination.
- BS are distributed over area of system coverage & are managed & controlled by an on-site computerized cell-site controller that handles all cell-site control & switching functions.

* Multiple Access Techniques

- Multiple access is a signal transmission situation in which two or more users wish to simultaneously communicate with each other using the same propagation channel.
- Multiple access schemes are:
  1. Frequency Division Multiple Access (FDMA)
  2. Time Division Multiple Access (TDMA)
  3. Code Division Multiple Access (CDMA)
  4. Space Division Multiple Access (SDMA) (~~Not~~ used for wireless)

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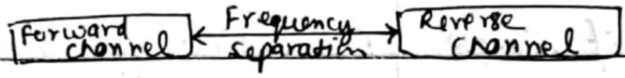
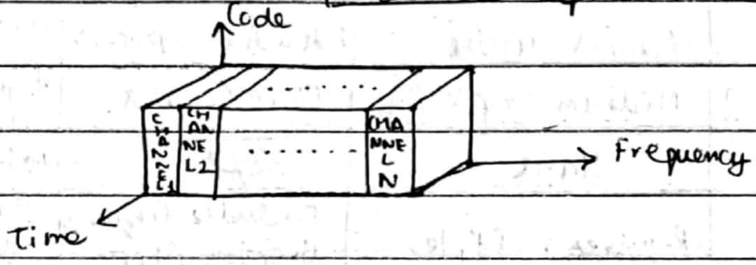
* FDMA

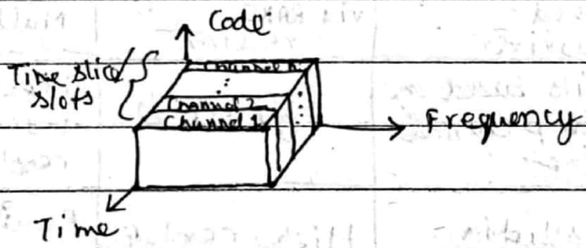
- The entire radio ~~frequency~~ spectrum is divided into many slices of frequency bands & each band/channel allocated to each user.
- In Frequency Division Duplexing (FDD), the duplex channel contains ~~The duplex~~ forward & reverse channels.

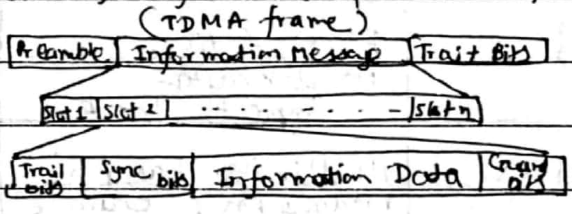




* TDMA

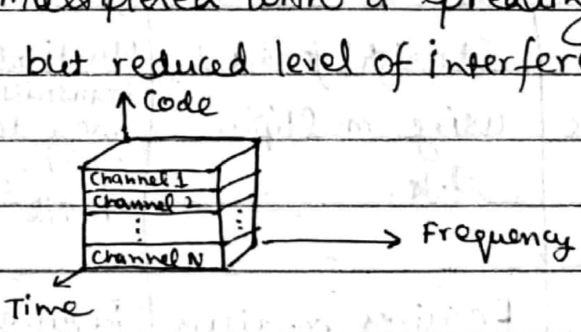
- Duplexing time (TDD) instead of frequency. Several user share time slots of the entire time available to access channel.
- Each TDD channel has individual time slots for forward & reverse time slots to have bidirectional communication.





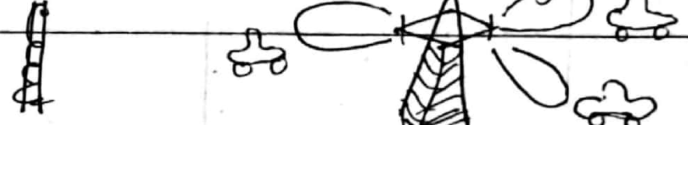
* CDMA

- Many users share same carrier frequency (f_c). The narrow band message signal is also multiplexed with a spreading signal of larger bandwidth.
- Near far problem but reduced level of interference.



* SDMA (for wireless)

- Capable of controlling radiated energy for each & every user in space, i.e., by spot beams a spatially filtered BS antenna serves different cellular user.



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* Comparison of Multiple Access Techniques Date __/__/____

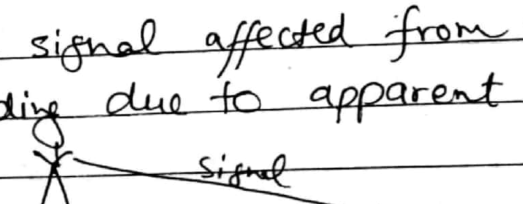
Parameter	FDMA	TDMA	CDMA	SDMA
Modulation	Relies on bandwidth efficient modulation	Relies on bandwidth efficient modulation	Simple Modulation	Transparent
Forward Error Correction	Increases power efficiency at expense of bandwidth efficiency	Increases power efficiency at expense of bandwidth efficiency	Can be implemented without affecting bandwidth efficiency	Transparent
Source Coding	Improves Efficiency	Improves Efficiency	Improves efficiency voice activation advantage	Transparent
System Complexity	Large no. of simple components	Reduced no. of channel units	Large no. of complex interacting components	Additional complexity related to antennas
User Terminal complexity	Simple	Medium complexity	More Complex.	Requires smart antennas
Handover	Hard	Hard	Soft	Potentially soft
Diversity	Requires multiple transmitters or receivers	Requires multiple transmitters or receivers can be frequency hopped	Includes frequency diversity when implemented with RAKE receiver	Simple antenna reduces space diversity orthogonal coding improves diversity with multiple transmit antenna
Multiple-access Interference	Limited by system planning	Limited by system planning	Dynamic power control	Limited by resolution of antenna
Fading	Flat-fading no diverdity simple to track	May need equencyselective may need equalizer	Frequency selective diversity via RAKE receiver	Reduced Multipath
Bandwidth	Hard limits based on modulation & channel spacing	Hard limits based on modulation & channel spacing	Soft Limits	Depends on antenna resolution
Synchronization	Low Resolution	Mid-resolution	High resolution	Requires Terminal Location
Flexibility	Fixed Data Rata	Data Rate variable in discrete steps	Can provide a variety of data rates without affecting signal in space	Transparent
Voice & Data Integration	Possibly, but may require revisions to system	Straight forward using multiple slots	Multicode transmission which may decrease efficiency of mobile terminal	Transparent
Evolution	Bandwidth to fit application	Requires medium initial bandwidth	Requires large bandwidth	Flexible, can be added as needed doesnot affect mobile

* 4G can be described as MAGIC - Mobile multimedia, Anytime anywhere, Global mobility support, Integrade wireless solⁿ & Customized personal service
* 4G technologies that meet requirements : WCDMA, CDMA2000, TD-CDMA & EDGE

Introduction To Wireless Channels & Diversity

* Two types of communication channels:
  (i) wired channels (ii) Radio or wireless channels
* The three basic propagation mechanisms (i.e, reflection, diffraction & Scattering) mainly responsible for multipath propagation
* Multipath propagation mainly produce three effects in wireless communications:
  (i) Multipath copies of signal may arrive at different phases
  (ii) Multipath propagation produce Inter Symbol Interference (ISI) 

  (iii) Multipath propagation produce short term or small scale fading.
* Fading
  - The strength (power) of received signal varies wrt time is known as fading.
  - Main causes are attenuation, changes in transmission medium, refraction, multipath propagation, rainfall, obstacles etc.
  - Basically two types:
  (i) Large Scale Fading (Long Term)
  → The local mean (average) power over time is known as long term fading.
  → Fading duration is very long as well as signal attenuation is large due to path loss for more duration.
(ii) Small Scale (Short Term) Fading
  → when signal strength (power) varied very fast over a short distance on the order of few wavelengths or over short time durations on the order of seconds is known as Small term fading.
→ Factors affecting small scale fading:
  (i) Multipath propagation (ii) Speed of surrounding obstacles
  (iii) Transmission bandwidth of signal
  (iv) Doppler shift (If there is a relative motion b/w transmitter & receiver then multipath signal affected from Doppler shift & produce short term fading due to apparent changes in frequency of signal)



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* Parameters of Mobile Multipath Channels

(i) Time Dispersion
- Mean excess relay
- RMS delay speed
- Excess delay speed

(ii) Coherence bandwidth

(iii) Doppler spread & coherence time

* Types of Small Scale Fading

(A) Based on multipath time delay ~~speed~~ Spread

(i) Flat fading: Properties: Bandwidth of signal < Bandwidth of Channel
Delay Spread < Symbol Time period

Demerits: Cause deep fades & more transmitter power required to receive signal with low bit error rates

(ii) Frequency Selective Fading: Properties:
Bandwidth of signal > Bandwidth of channel
Delay Spread > Symbol Time Period

(B) Based on Doppler Spread

(i) Fast Fading: Properties:
(a) Coherence time period < Symbol time period
(b) High Doppler spread
(c) Channel variations faster than baseband signal variations

(ii) Slow Fading: Properties:
(a) Coherence time period > Symbol time period
(b) Low Doppler spread
(c) Channel variations slower than baseband signal variations

* Fast fading Wireless Channel Modeling

- The multipath fading channel can be divided on the basis of the distribution function of the instantaneous power of the channel which depends on the radio environment.
- The types of fading multipath channel are as follows:

(i) Additive White Gaussian Noise (AWGN) Channel

→ In this channel, the received signal is degraded by thermal noise associated with physical channel itself & loses at transmitter & receiver. For terrestrial WC, not suitable for radio channels

(ii) Log-Normal Fading Channel

→ Due to trees, foliage, rainfall & atmospheric condition, the gradual change in local-mean power & this type of fading channel characterize by log-normal distribution funcn. The log-normal PDF is given by

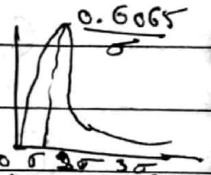
$$f_L(P_0) = \frac{1}{P_0 \sigma \sqrt{2\pi}} \exp\left[\frac{\ln(P_0) - m^2}{2\sigma^2}\right]$$

$\sigma \equiv$ RMS value of received signal
$m \equiv$ Mean of the received signal
$P_0 \equiv$ local mean power

(iii) Rayleigh Fading Channel

→ When there is no Line-of-Sight (LOS) path available b/w transmitter & receiver, received signals obey Rayleigh Distribution.

→ The PDF of Rayleigh Distribution is given by:



$$f_R(r) = \frac{1}{\sigma^2} \exp\left[\frac{-r^2}{2\sigma^2}\right], \text{ for } 0 \le r \le \infty$$

↳ amplitude of received signal

avg power of received signal → σ^2

$$= 0, \text{ for } r < 0$$

(iv) Two-ray Rayleigh fading Model

→ This model considers the multipath time delay factor

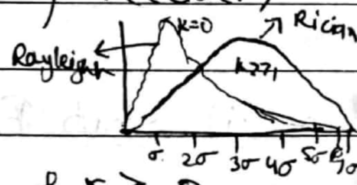
→ Impulse response $h(t) = \alpha_m \exp(j\phi_1)\delta(t) + \alpha_n \exp(j\phi_2)\delta(t-\tau)$

if $\alpha_n = 0$, $h(t) = \alpha_m \exp(j\phi_1)\delta(t)$

(iv) Rician Fading Channel

→ When direct LOS path is available b/w transmitter & receiver, the received signal obey Rician distribution

→ PDF of Rician Distribution is given by:



$$f_R(r) = \frac{r}{\sigma^2} \exp\left[-\frac{r^2+s^2}{2\sigma^2}\right] I_0\left[\frac{r^2}{\sigma^2}\right], \text{ for } s \ge 0 \;\&\; r \ge 0$$

$$= 0, \text{ for } r < 0$$

$s \equiv$ peak value of dominant Signal

$I_0() \equiv$ Modified Bessel funcn of the first kind & zero order

→ In terms of parameter k, Rician distribution:

$$k = \frac{\text{power in dominant path}}{\text{power in scattered path}} = \frac{s^2}{2\sigma^2}$$

→ If $s = 0$, then $k = 0$ & channel is Rayleigh

If $2\sigma^2 = 0$, then $k = \infty$ & channel is AWGN

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* BER (Bit Error Rate) Performance in Fading channels

- The slow flat fading channels changes very slowly when compared to modulation applied.
- Signal received, $s(t) = \underbrace{\alpha(t)}_{\text{channel gain}} \exp(-j \underbrace{\theta(t)}_{\text{channel phase shift}}) x(t) + \underbrace{n(t)}_{\text{Additive Gaussian Noise (AGN)}}$; $0 \le t \le T$
- Probability of error in slow flat-fading:

$$P(E) = \int_0^{\infty} P_e(x), q(x)\, dx \; ; \quad x = \alpha^2 \frac{(E_b)}{N_0}$$

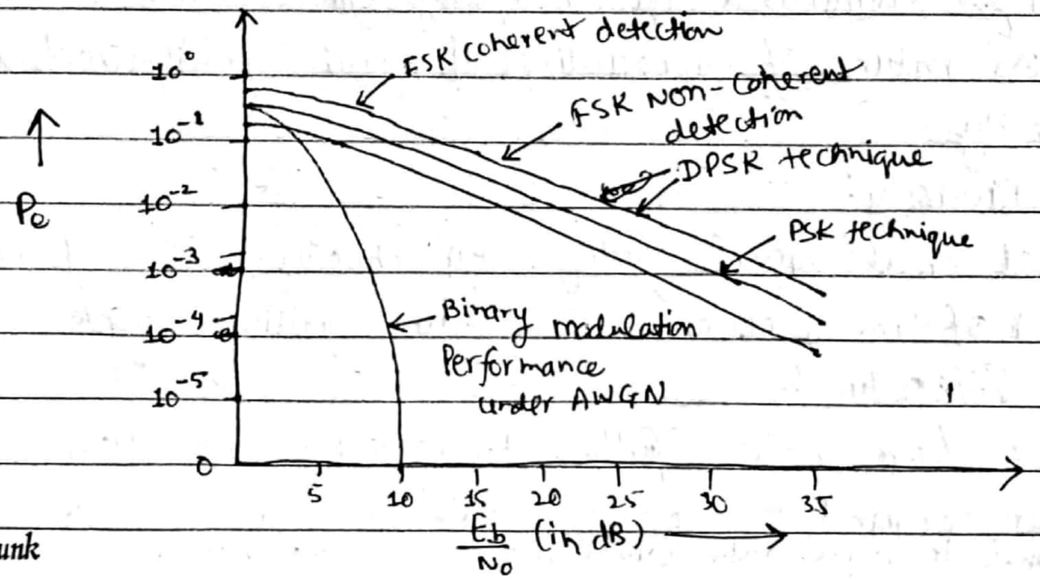
$E_b \rightarrow$ Average energy per bit
$N_0 \rightarrow$ Noise power density

- For Rayleigh fading channel case,

$$p(x) = \frac{1}{\Gamma} \exp\left(\frac{-x}{\Gamma}\right) ; \; x \geq 0 \quad , \Gamma = \frac{E_b}{N_0} \cdot \overline{\alpha^2}$$

$\overline{\alpha^2} \rightarrow$ instantaneous power value for unity gain fading channel

Probability of Error	Type of Modulation
$P(e), FSK = \frac{1}{2}\left[1 - \sqrt{\frac{\Gamma}{2+\Gamma}}\right]$	Coherent binary FSK
$P_e, PSK = \frac{1}{2}\left[1 - \sqrt{\frac{\Gamma}{1+\Gamma}}\right]$	Coherent binary PSK
$P_e, DPSK = \frac{1}{2(1+\Gamma)}$	Differential binary PSK
$P_e, NCFSK = \frac{1}{2+\Gamma}$	Non-coherent orthogonal binary FSK
For larger values of 'x', Pe is rewritten	
$P_e, FSK = \frac{1}{2\Gamma}$	Coherent FSK
$P_e, PSK = \frac{1}{4\Gamma}$	Coherent PSK
$P_e, DPSK = \frac{1}{2\Gamma}$	Differential PSK
$P_e, NCFSK = \frac{1}{\Gamma}$	Non-coherent orthogonal FSK



(BER performance of different digital modulation schemes under Rayleighs flat-fading channel compared to performance curves under AWGN)

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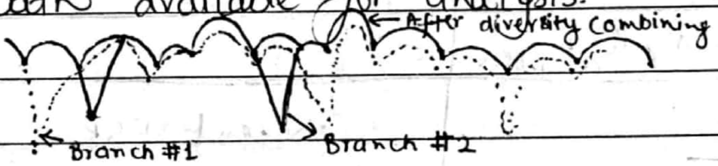
* Diversity
- The short-term multipath fading can be severly reduce transmission accuracy. Diversity is an effective way to combat channel fading.
- Diversity improves transmission performance by making use of more than one independently faded version of the transmitted signal.

* Diversity Modeling For Wireless Communications
- The diversity technique use the nature of the propagation path characteristics for improving the sensitivity of receivers. It will improve the wireless links at less costs. It doesnot require prior training because a training sequence is not needed by a transmitter like equalizer.
- Diversity technique finds a way of analyzing signal paths for multipath cellular environment.
- The simple concept of diversity is that even if a radio signal path experiences a deep fade, there will be another independent signal path available for analysis.



- Types of fading:
@ Small-Scale Fading: Mainly characterized by rapid amplitude fluctuations & deep fades of less wavelengths (λ)
ⓑ Large-Scale Fading: Generated by shadowing effects which is due to changes in both nature of surroundings & terrain profile involved.

- Types of Diversity
@ Microscopic Diversity:
To counteract small-signal fading. By choosing signal of higher strength most of time, receiver can reduce fading effects.
ⓑ Macroscopic Diversity:
To counteract large-scale fading. By choosing a BS that is not shadowed when compared to other BS, mobile unit can acquire a better signal to noise ratio (SNR) in its forward path.

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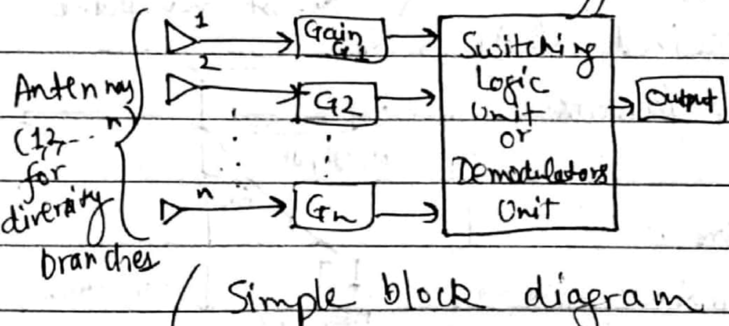
- Different Diversity Schemes

S.No.	Diversity Scheme	Advantages	Disadvantages
1.	Polarization Diversity	No space & extra bandwidth is required	(i) 3dB power is a must (ii) Two branch diversity scheme only possible
2.	Space Diversity	(i) Several diversity branches are allowed (ii) Also applicable to Macroscopic diversity (iii) No extra bandwidth or power is required	(i) Large hardware size is required (ii) Large antenna space is a must for microscopic diversity at BS
3.	Frequency Diversity	Several diversity branches are allowed	Relevant power level of frequency specturm are important
4.	Time Diversity	(i) Hardware is simple (ii) Several Diversity branches are allowed	(i) Larger buffer memory is a must when diversity frequency is small (ii) More frequency spectrum is necessary accn to no. of diversity branches
5.	Angle Diversity	Doppler Spread can be reduced	Diversity gain will depend on the no. of obstacles available around the terminal
6.	Path Diversity	(i) No space is required (ii) No extra bandwidth & power are required	The diversity gain will depend on delay status

* Each diversity technique is unique in its functionality but aims towards a common goal of reducing fading effects in multipath receiver circuit.

- Space Diversity Technique (Also called Antenna Diversity Scheme)
  → In this scheme, the ~~antenna~~ receiver config. is simple. Several no. of diversity branches are selectable. For producing diversity reception at each & every cell site, multiple base station receiving antennas are used effectively.



(Simple block diagram of space diversity technique)

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→ Space Diversity Combining Schemes

ⓐ Selective Diversity Combining:

⇒ The branches having strongest received signal will be selected, 'n' no. of demodulators are used & their gain can be adjusted to give mean signal to noise ratio (SNR) for every diversity branch

ⓑ Switched Combining Technique: Feedback Diversity

⇒ 'n' signals are scanned in a proper sequence & monitored to pick a signal in the sequence which is above present thershold value. Fading Reduction is less than other diversity techniques.

ⓒ Maximal Ratio Combining Technique:

⇒ all branch signals [N] are combined coherently with necessary weighting coefficients for every diversity branch signal, so that reduction of fading will be better leading to overall improvement of system performance

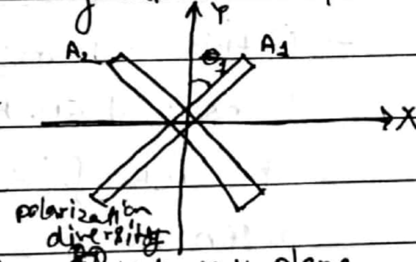
ⓓ Equal Gain Combiner Technique

⇒ all diversity branches are coherently added with same weighing factor & also cophases all diversity branches & finally adds them up.

- Polarization Diversity

→ Both horizontal & vertical polarization are involved.

→ In case, if a signal is transmitted by pair of polarized antennas & it is received by another pair of antennas then two uncorrelated fading signals will be received because of fading variations & different reflection coefficient.

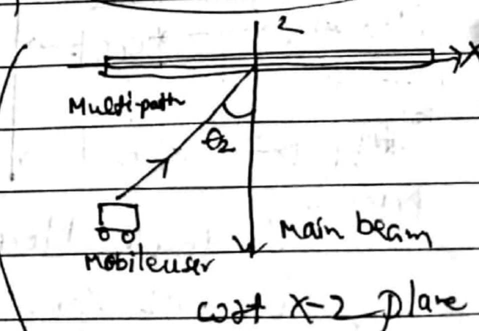


→ Let us assume that r_1 & r_2 possess independent Rayleigh distributions & phase angles ϕ_1 & ϕ_2, have independent uniform distribution values. The correlation coefficient of signals received at A_1 & A_2 can be determined by three factors:

(i) Polarization Angle

(ii) Cross polarization discrimination

(iii) Offset angle from that of the main beam direction of diversity antenna setup



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- Time Diversity

→ In this, the information is transmitted repeatedly at specific time spacings for several times; irrespective of fading conditions.

- Frequency Diversity

→ In this, the information is transmitted ~~repeate~~ on many carrier frequencies. The idea behind that is that if frequencies are separated by more than that of the coherence bandwidth of the mobile channel, these would be uncorrelated with each other & hence would not experience same fading status.

→ The fading variation independence factor between the separated frequency components is a main effect wrt land mobile communication & it is called as frequency diversity effect.

- Directional Diversity.

→ The received signals would arrive from different incident angles due to any one of the propagation mechanisms. ~~groun~~ By using selective directive antennas, the independent faded signals can be received.

- Path Diversity

→ In this, the signals are coherently combined. That is both the direct & delayed components are combined together. Thus, the diversity branches are generated only after signal reception, & this method is also known as Implicit diversity.

* Rake Receiver

- Also known as diversity receiver designed particularly for CDMA.
- 'RAKE' receiver collects all the delayed versions / shifted versions of the original signal.
- 'RAKE' receiver mainly makes use of the multiple correlations for signal reception in mobile communication.
- For obtaining an accurate estimate of the transmitted signal as a whole, rather than a single component, the multiple components are weighted after the 'N' correlators units.

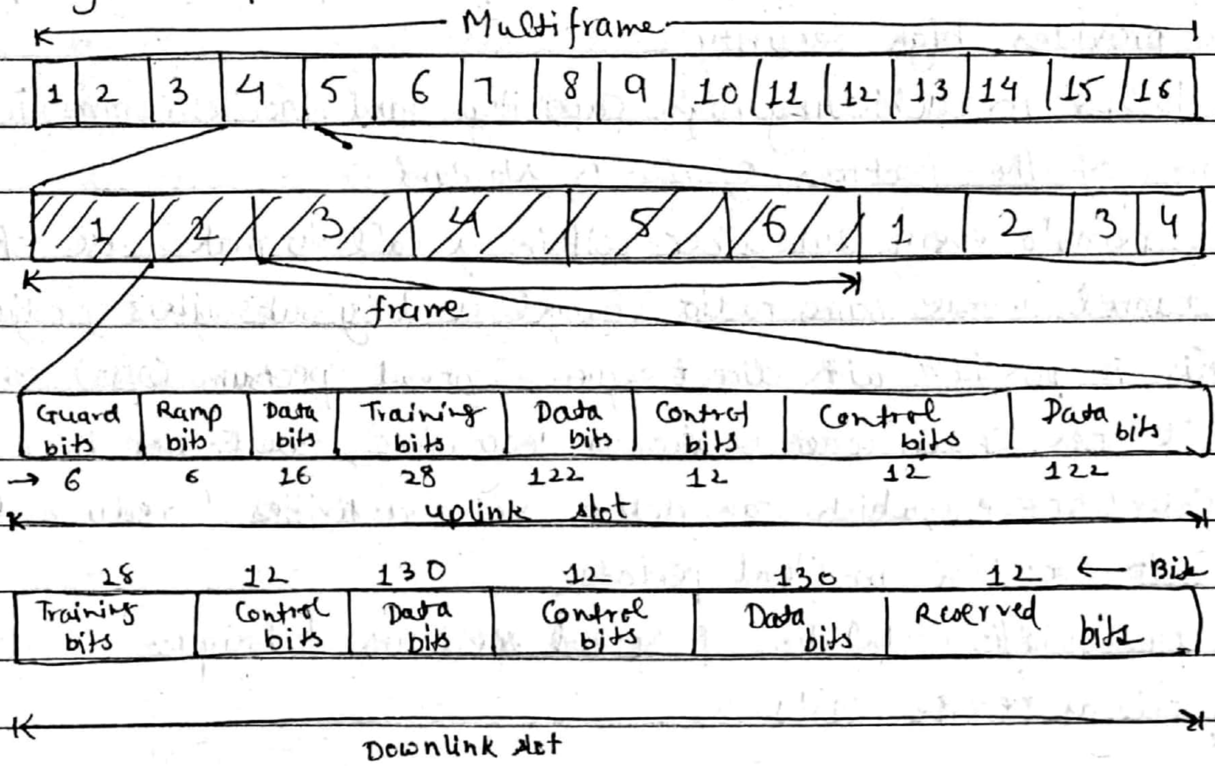
- Based on the output signal values, the detection of the bit decisions are done. A weighting state (network) provides a linear combination of the outputs from correlator for the bit decision purpose. If bit decisions are done wrt a single correlation, then probability of BER is higher.

* Wireless networks are flexible to change whereas fixed networks are very difficult to change. Main constraint with wireless networks is the bandwidth. The channel bandwidth for fixed networks can be increased for high traffic but cellular bandwidth provided to wireless networks can't be changed

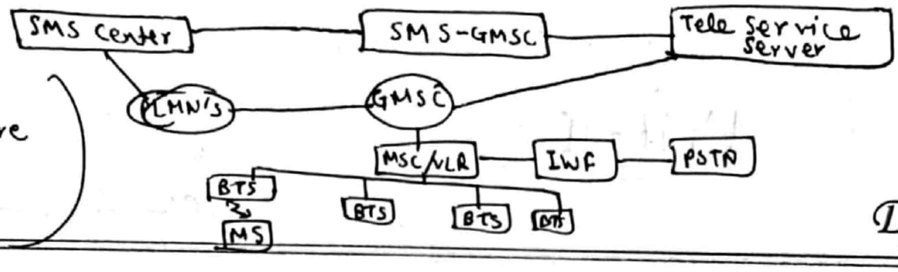
Unit-II

2G Networks

* 2G standards rely on digital formats including TDMA/FDD & CDMA/FDD.
* 2G standards provide:
  (a) better speech quality (b) High speed data applications
  (c) Efficient spectrum usage & compatible with TDMA access scheme
  (d) Supports multiple users
* TDMA schemes use half duplex.
* Interim Standard 136 (IS-136) (D-AMPS)
  - AMPS was not suitable to support high traffic and demands for high capacity. (in 1980's) USDC came into existance to accomodate multiuser within frequency spectrum allocated.
  - USDC/AMPS was standardized as IS-54.
  - Salient features of USDC
    (i) uses frequency reuse technique.
    (ii) shares same frequencies with minimized interference
    (iii) supports three full-rate or six half-rate subscribers on every AMPS channel
    (iv) provides high cellular capacity
    (v) accomodates many users
    (vi) also called North American Digital Cellular Standard (NADC)
  - IS-136 system operates with both AMPS & USDC standards in dual mode



Network Architecture of IS-136



GMSC : Global System for Mobile Center
IWF: Interworking Func^n
BTS: Base Transceiver Station
MS: Mobile Station
PLMN: Physical Layer Management Networks

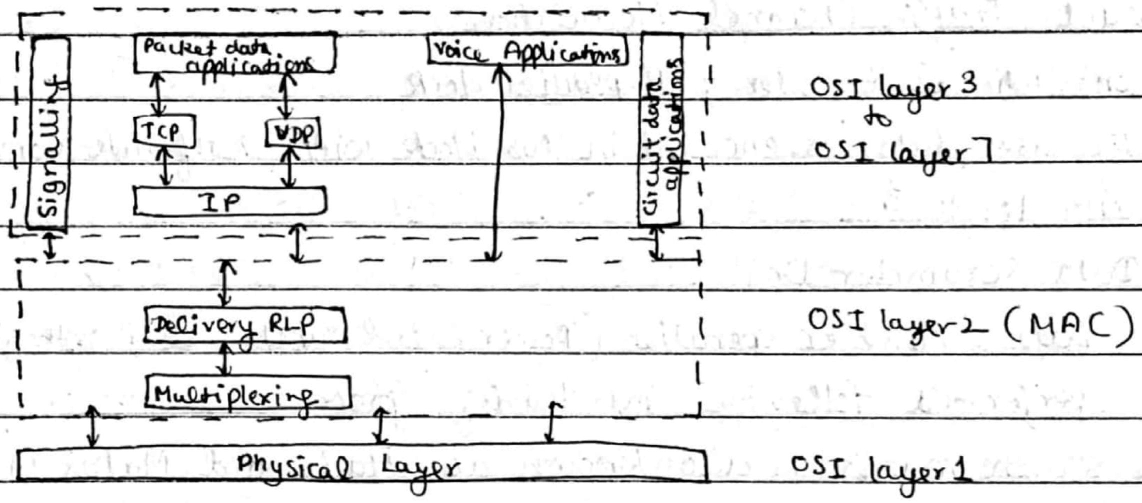
Date ___/___/______

- Salient Features of IS-136:
  (i) operates in 800-1900 MHz frequency band
  (ii) channel bandwidth is 30 kHz.
  (iii) TDMA frame with 40 msec in 6 time slots is being used in it.
  (iv) Six time slots: (Channel data rates)
    1st time slot - Half rate channel
    2nd, 5th time slots - Full rate channel.
    2nd, 3rd, 5th, 6th time slots - Double rate channel
  (v) data link layer of IS-136 provides:
    (a) Addressing (b) Error Detection (c) Media Access Control
    (d) Segmentation (e) Flow Control
  (vi) network layer provides:
    (a) Establishments (b) Maintaining (Sustaining) (c) Termination of Connection
  (vii) possesses channels namely:
    (a) Digital control channel (DCCH) (b) Digital Traffic channel (DTH)
  (viii) provides data services namely teleservice & analog circuit switched data service
  (ix) uses three data rates: 9.6, 19.2, 28.8 kb/sec

* Interim Standard 95 (IS-95) CDMA (Uses CDMA scheme)
- Advantages of CDMA:
  (i) can tolerate interference with spread spectrum technique
  (ii) provides high security
  (iii) helps in achieving high capacity land mobile communication systems
- Some of the features of IS-95 standard
  (i) It permits every subscriber within a call to make use of radio channel where same radio channel used by subscribers of adjacent cells too. This is possible with direct sequence spread spectrum (DSSS) technique
  (ii) It uses Speech coder Qualcomm 9600 b/sec, Code Excited Linear Predictive Coder (QCELP), which can detect voice activities & reduce data rates upto 1200 b/sec in silent periods.
  (iii) It uses specific modulation & spread spectrum techniques in its forward as well as reverse links.

(iv) It is compatible with IS-41 networking standard Date __/__/____

- Channel & Frequencies used in IS-95
  - → Forward Link : 869-894 MHz → Reverse Link : 824-849 MHz
  - → For cellular operations, channel pair separated by frequency of 45MHz
  - → Total spreading factor is 128 (chip rate of 1.228 M chips/sec)
  - → A version of IS-95 (PCS) designed to use 1800-2000MHz band
- Protocol Architecture of IS-95 standard



- → Layer 1 functions : frequency use & radio transmission for effective delivery of voice & data packets
- → Layer 2 function : Channel management

- The forward channels are known as downlink channels. They carry data traffic from base station to mobile stations effectively. It consists of 64 channels. The respective logical channels are differentiated from one another by using various CDMA spreading codes & it is called as "Orthogonal code" or "Walsh Function" (0 to 63)
- Some of the dedicated & common ~~traffic~~ control traffic channels:

(i) Sync Channel
  → Optional channel to send synchronization info to ~~BS~~ MS & operate at 1200 b/sec data rate

(ii) Paging Channel
  → Optional channel to send four types of messages (Paging, Overhead, Order, Channel)
  → operates at 2400, 4800 or 9600 b/sec data rates

(iii) Pilot channel (stream of 0's without discontinuity)
  → Gives timing related info to MS wrt forward CDMA channels & compares signal strength of BS

Punk → Data Rate : 19.2 kb/sec

(iv) It is compatible with IS-41 networking standard Date __/__/____

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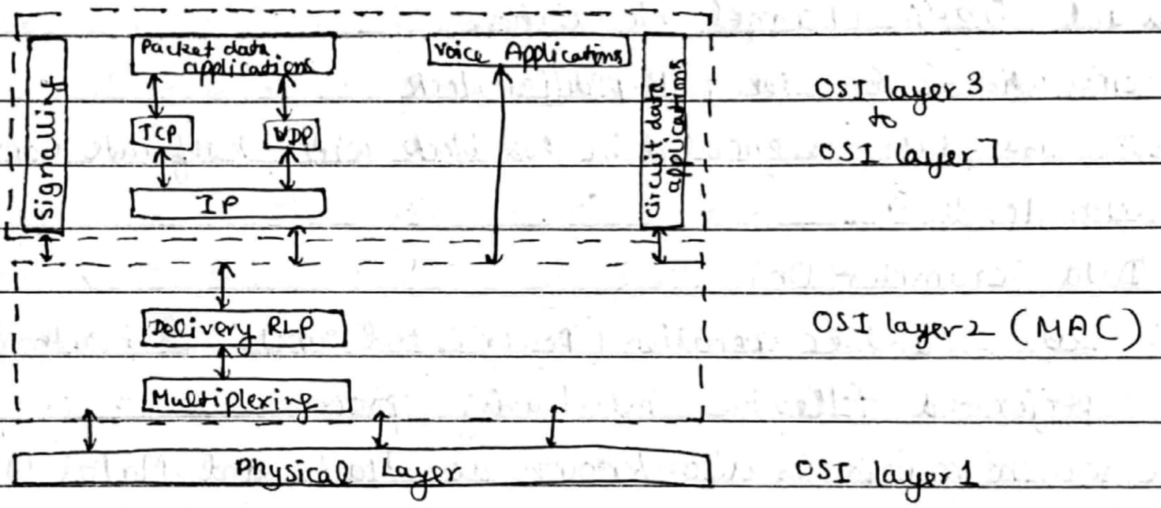

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Punk → Data Rate : 19.2 kb/sec

(iv) Traffic Channel

→ Used to carry user data at data rates 1200, 2400, 4800 or 9600 b/sec

- Forward CDMA channels

→ Comprises of synchronization channel, pilot channel, paging channel & traffic channel. The paging channels can be upto 7 in no. & it can be upto 63 forward traffic channels

- Forward Traffic Channel Modulation

① Convolutional Encoder & Repetition block

⇒ The user data is encoded in this block with half rate convolution encoder with length 9.

② Data Scrambler Unit

⇒ Data Scrambler operation (Power Control subchannel & orthogonal covering) performed following interleaving process

- The walsh matrix is also known as Hadamard Matrix (H) & the 64 Hadamard matrix is generated by recursive process

$$H(u) = \frac{1}{N}\sum_{x=0}^{N-1} f(x)\,(-1)^{\sum_{i=0}^{N-1} b_i(x)\,b_i(u)} \quad\Big|\quad H(u,v) = \frac{1}{N}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y)\,(-1)^{\sum_{i=0}^{N-1}[b_i(x)b_i(u) + b_i(y)+b_i(v)]}$$

Consider $N=2$ can be given under $H_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$

Supply H^4, will be as $H_1 = 0$

$$H_{2N} = \begin{bmatrix} H_N & H_N \\ H_N & -H_N \end{bmatrix} \qquad A = \frac{1}{\sqrt{N}} H_N .$$

$$H_1 = 0 \qquad H_2 = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix} \qquad H_4 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix}$$

- Reverse CDMA channels

→ Operations : ⓐ Convolutional Encoding ⓑ Block Interleaving ⓒ Supply 64-array orthogonal modulation ⓓ Spreading before transmission

→ Consists of two types of channels : Access Channels (AC's) & Reverse Traffic channels (RTC's)

① Access Channel

⇒ Used to initiate communication with BS & for responding to paging channel information & operates at 4800 b/sec data rate.

② RTC

⇒ Used for having reverse traffic to carry signals in these channels & operates at variable data rates (1200, 2400, 4800, 9600 b/sec)

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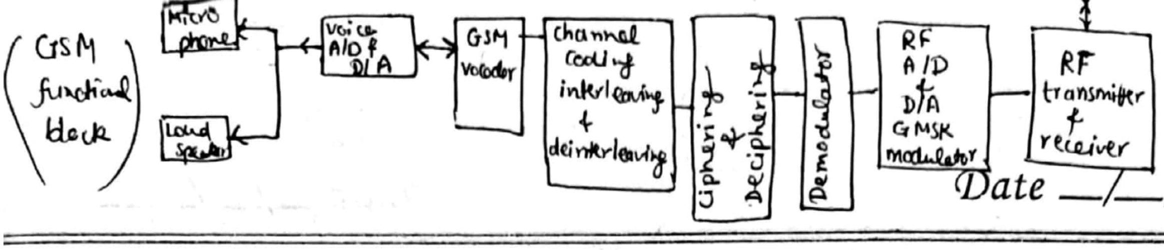
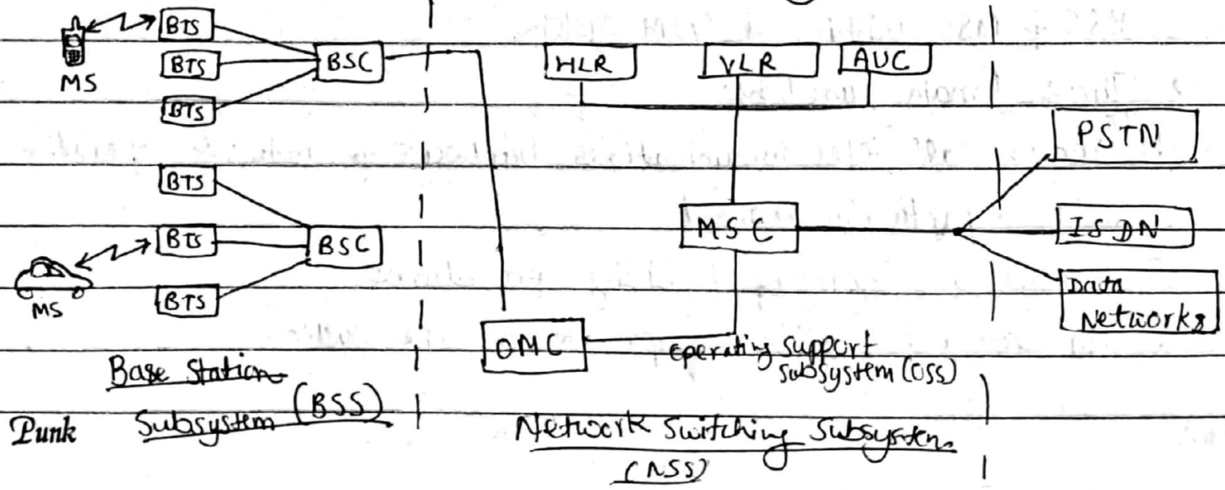


Date __/__/____

* GSM (Global System for Mobile)
  - was initially functioning in 900 MHz band of frequency & setting under ETSI.
  - main aim was to provide 'roaming facility' for subscribers & to follow ISDN guidelines.
  - deployed using 890 - 915 MHz for uplink & 935 - 960 MHz for downlink.
  - in US in the band of 1900 MHz & called PCS.
  - Channel coding is done with interleaving
  - Modulation & Demodulation are used for transmission & reception
  - Modulation scheme is Gaussian Minimum Shift keying digital modulation
  - Antenna is of MIMO (Multiple Input & Multiple Output) nature
  - User authentication is possible with GSM phones

* - GSM System Services
  → Follow ISDN guidelines & classified as either Teleservices or Data services. Teleservices include standard mobile telephony & mobile originated or base-originated traffic. Data services include computer-to-computer communication & packet switched traffic.
  → User services divided into three categories:
  (i) Telephone services ≡ Include Emergency Calling & facsimile
  (ii) Bearer Services or Data Services ≡ Include packet switched protocol & data rate from 300 bps to 9.6 kbps.
  (Limited to 1, 2, 3 layer of OSI model)
  (iii) Supplementary ISDN services ≡ Include call diversion, closed user groups & caller identification

* GSM System Architecture
  - Consist of three major interconnected subsystems: BSS, NSS & OSS



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- GSM Subsystems

(A) Base Station Subsystems (BSS)

→ provides & manages radio transmission path b/w MS & Mobile switching Center (MSC)

→ also manages radio interface b/w MS & all other subsystems of GSM

(i) ⇒ MS has two elements : Mobile equipment (ME) & Subscriber Identity Module (SIM)

User — [SIM / ME] — BSS

(ii) Two elements in BSS architecture :

⇒ Base Transceiver Station (BTS)

⇒ Base Station Controller (BSC)

(B) Network & Switching Subsystems (NSS)

→ handles GSM calls b/w external networks & the BSCs in the radio subsystem & is also responsible for managing & providing external access to several customer databases.

(i) Mobile Switching Center (MSC)

⇒ Controls traffic among ~~BSCs in~~ all of the BSCs

(ii) Three Databases

⇒ Home Location Register (HLR) [Subscriber info who resides in city]

⇒ Visitor Location Register (VLR) [Roaming Subscriber info]

⇒ Authentication Centre (AUC) [Handles authentication & encryption keys of each subscriber & contains EIR (Equipment Identity Register) to identify stolen or fraudulently altered phones]

(C) Operation Support Subsystem (OSS)

→ Supports one or several operation maintenance Centres (OMCs) which used to monitor & maintain performance of each MS, BS, BSC & MSC within a GSM system.

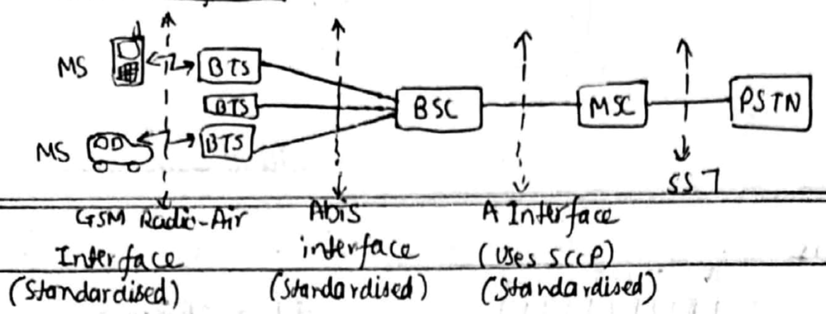
→ Three main functions:

(1.) To Maintain all telecommunications hardware & network operation with a particular market

(2.) Manage all charging & billing procedures

(3.) Manage all mobile equipments in the system

→ GSM Interfaces



- GSM Radio Subsystem

→ Since each radio channel consists of 8 time slots, there are a total of 1000 traffic channels within GSM. In practical implementation, a guard band of 100 kHz is provided at the upper & lower end of the GSM spectrum & only 124 channels are implemented.

→ GSM uses FDD & a combination of TDMA & FHMA schemes to provide multiple access to mobile users.

→ Forward Link : 935-960 MHz ; Reverse Link : 890-915 MHz

Forward & Reverse Channel pair separated by 45 MHz.

* GSM channel types

Logical channels →

- TCH (Traffic Channel)
  - → Speech
    - → Full Rate → 22.8 Kbps
    - → Half Rate → 11.4 Kbps
  - → Data
    - → Full Rate
      - 9.6 Kbps
      - 4.8 Kbps
      - 2.4 Kbps
    - → Half Rate
      - 4.8 Kbps
      - 2.4 kbps
- CCH (Control Channel)
  - → BCH (Broadcast)
    ⇒ Transmit data only in first time slot of certain GSM frames
    - → BCCH (Broadcast Control)
      ⇒ Broadcast cell information)
      ⇒ ~~Transmit data only in first time slot of certain GSM frames~~
    - → FCCH (Frequency Control)
      ⇒ Allow subscriber to synch its internal frequency standard
    - → SCH (Synchronization)
      ⇒ Allow frame synchronization
  - → CCCH (Common Control)
    - → PCH (Paging)
      ⇒ Provide paging signal from BS to MS in cell
    - → RACH (Random Access)
      ⇒ Reverse Link channel to acknowledge page & originate a call
    - → AGCH (Access Grant)
      ⇒ Forward Link communication
  - → DCCH (Dedicated Control)
    - → SDCCH (Standalone Dedicated Control)
      ⇒ carry data after connection before assignment
    - → SACCH (Slow Associated Control)
      ⇒ Send slow but regularly changing data
    - → FACCH (Fast Associated Control)
      ⇒ Carries urgent Messages

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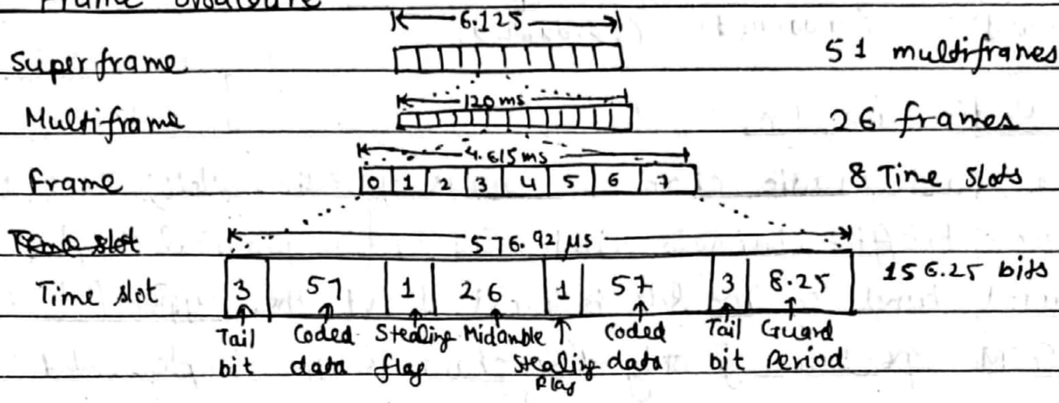
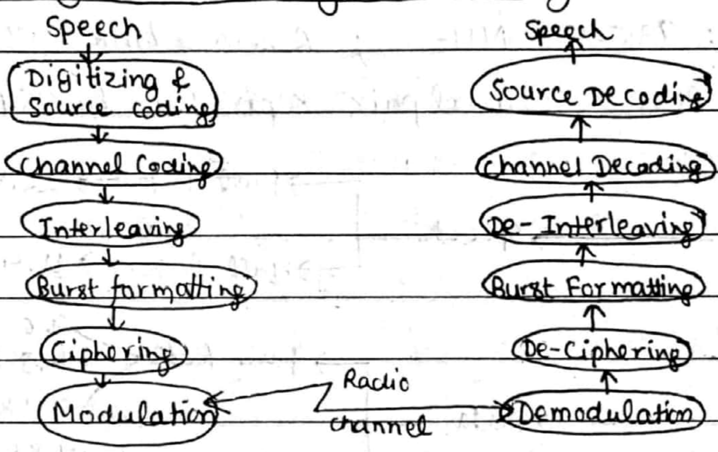
Date __/__/____

* GSM Frame Structure



* GSM voice Signal Processing and Coding



- Speech Coding

→ GSM speech coder based on residually excited linear predictive coder (RELP), which is enhanced by including a long-Term Predictor (LTP). The coder provide 260 bits for each 20ms blocks of speech, which yields a bit rate of 13 kbps.

→ By incorporating a voice activity detector (VAD) in speech coder, GSM system operate in Discontinuous Transmission Mode (DTX) which provides a longer subscriber battery life & reduces instantaneous radio interference since GSM transmitter is not active during silent periods.

- Channel Coding

→ The output bits of the speech coder are ordered in groups for error protection based upon their significance in contributing to speech quality.

→ Out of the total 260 bits in a frame, the most important 50 bits, called type Ia bits, have 3 parity check (CRC) bits added to them.

- Channel Coding for Data Channels

→ Based on handling 60 bits of user data at 5ms intervals.

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- Channel Coding for Control Channels
→ The five code uses the generator polynomial
$$G_5(x) = (x^{23}+1)(x^{17}+x^3+1) = x^{40}+x^{26}+x^{23}+x^{17}+x^3+1$$
- Interleaving
→ In order to minimize the effect of sudden fades on the received data, the total of 456 encoded within each 20ms speech frame or control message frame are broken into eight 57 bit sub-blocks.
- Ciphering
→ It modifies the content of the eight interleaved blocks through the ~~sense~~ use of encryption techniques known only to particular MS & BTS.
- Burst Formatting
→ It adds binary data to the ciphered blocks, in order to help synchronization and equalization of the received signal.
- Modulation
→ The modulation scheme used by GSM is 0.3 GMSK, where 0.3 describes 3dB bandwidth of the Gaussian pulse shaping filter with relation to the bit rate (eg $BT_s = 0.3$)
- Frequency Hoping
→ If users in a particular cell have severe multipath problems, the cell may be defined as a Hoping Cell by the network operator, in which case Slow Frequency Hoping may be implemented to combat the multipath or interference effects in that cell
- Equalization
→ It is performed at the receiver with the help of the training sequences transmitted in the midamble of every time slot.
- Demodulation
→ The portion of the transmitted forward channel signal which is of interest to a particular user is determined by the assigned TS & ARFCN.
- After demodulation, the binary information is deciphered, de-interleaved, channel decoded & speech decoded

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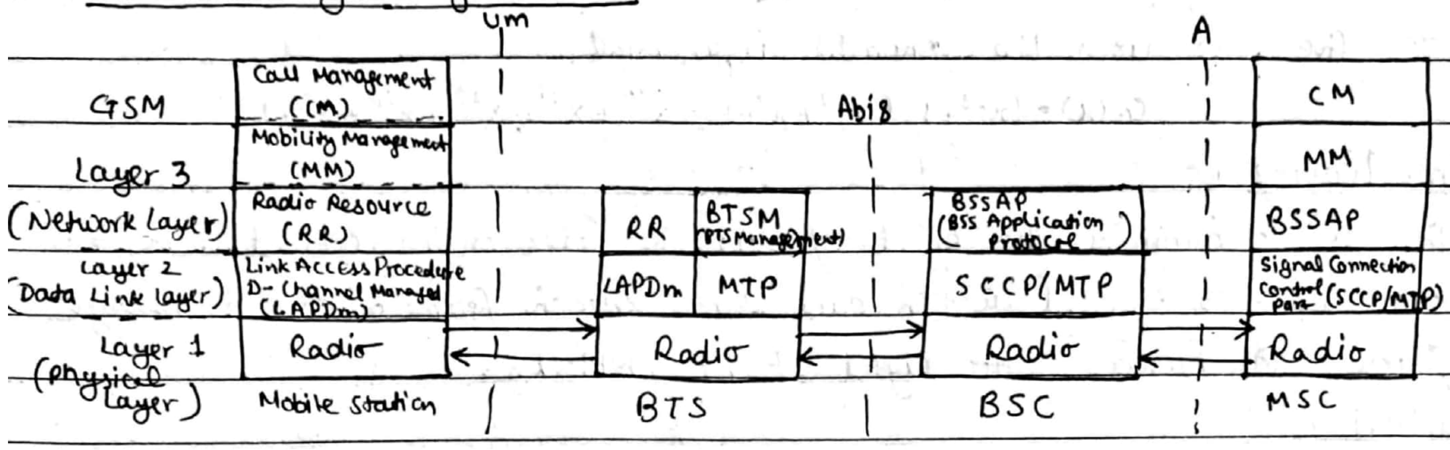
* Network Signaling in GSM



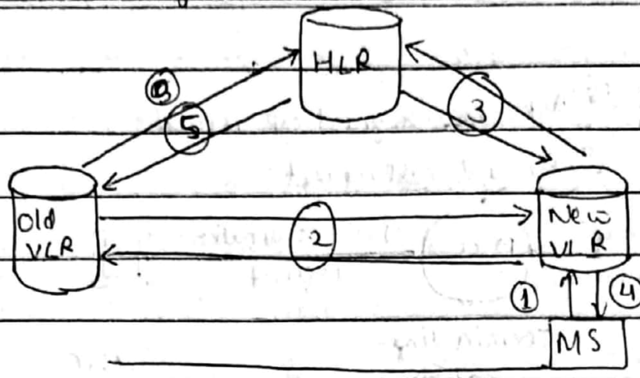
- MS-BTS : The physical layer b/w MS & BTS is called Um interface & performs functions (i.e. full or half duplex access, provides TDMA, FDMA & CDMA, framing of data)
  : The data link layer present b/w MS & BTS is called LAPDm & functions are i.e. (data flow control, acknowledged/unacknowledged data transmission, address & sequence number check, segmentation)
- CM : Supports call establishment, maintenance, termination
  Supports functioning of SMS
  Support DTMF (Dual Tone Multiple Frequency) Signaling.
- MM : Control the issue regarding mobility management, location updating & registration
- RRM (Radio Resource Management) : Manages radio resources such as frequency assignment, signal measurement
- BTS-BSC Signalling Protocols : The physical layer b/w BTS & BSC is called Abis interface whereas voice is coded by using 64 kbps PCM.
- BSC-MSC Signaling Protocols : Physical layer b/w BSC & MSC is called A interface. Data Link layer protocol b/w BSC & MSC is MTP (Message Transfer Protocol) & SSCP. MTP & SSCP are part of SS7 used by interface A.

* Mobility Management in GSM

- Mobility management funcⁿ handles the funcⁿ that arises due to mobility of the subscriber.
- Main objective of MM is location tracking & call setup.
- Registration process of MS moving from one VLR to another VLR.

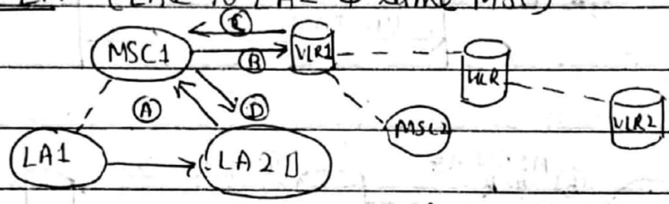
Punk

1. Listen BCCH periodically, If new location ~~change~~ area, registration message to new VLR using SDCCH
2. Old & new VLR communicate & perform authentication process
3. ~~If~~ New VLR sends registration message to HLR & if accepted, HLR provides info to new VLR
4. New VLR informs MS of successful registration
5. HLR sends a deregistration to old VLR. Old VLR cancels record of MS & sends ack to HLR.

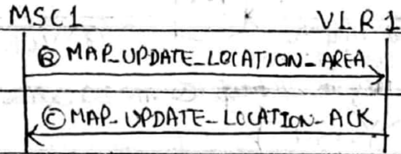


- **GSM Location Update** (Three Cases): Occurs when MS moves from one LA to another

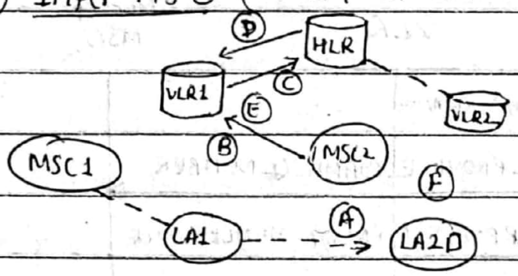
(i) **Inter-LA** (LA1 to LA2 & same MSC)



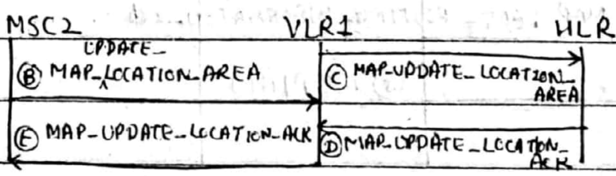
Ⓐ Request message MS to MSC
Ⓑ Forward Request
Ⓒ Update LAI field of VLR
Ⓓ ACK to MS



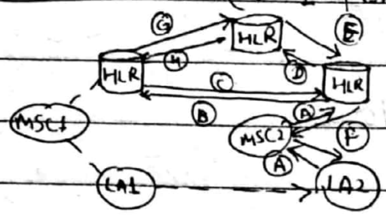
(ii) **Inter MSC** (LA1 to LA2 ~~are~~ & different MSC)



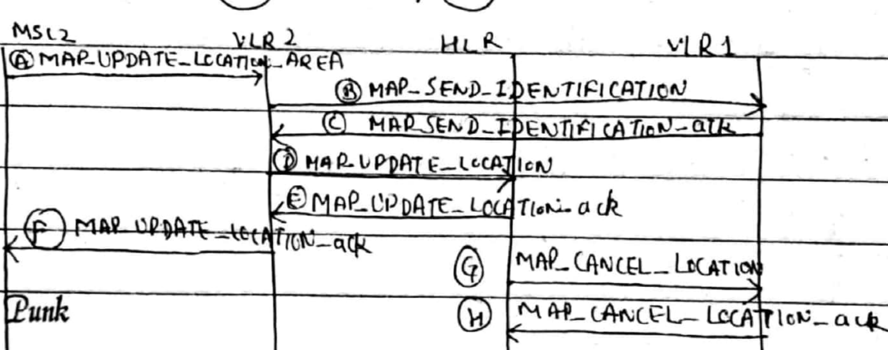
Ⓐ Request Message
Ⓑ Forward Request
Ⓒ Forward Request
Ⓓ Update & ACK
Ⓔ ~~ACK~~ MSC field in HLR updated & ACK to VLR
Ⓕ ACK to MS



(iii) **Inter VLR** (LA1 & LA2 to different VLR)



Ⓐ Update Request to VLR from MS
Ⓑ VLR2 identify previous VLR1
Ⓒ Identification message to HLR
Ⓓ VLR2 create VLR record for MS & sends registration message to update HLR
Ⓔ Obsolete Record of MS ~~d~~ in VLR1 deleted



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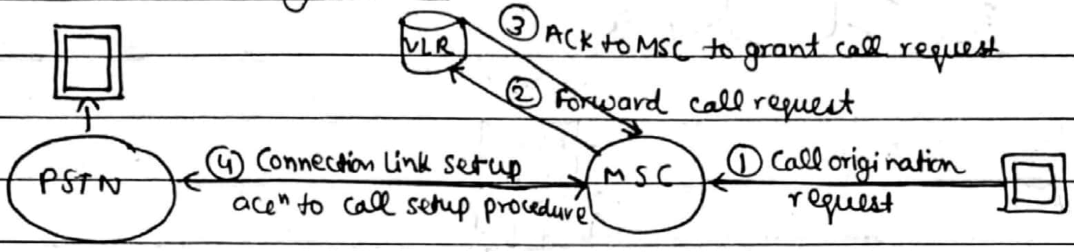
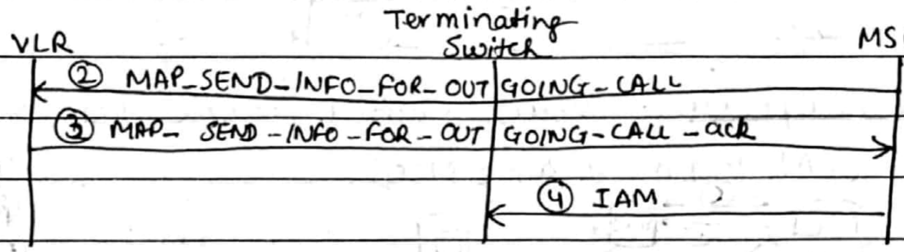
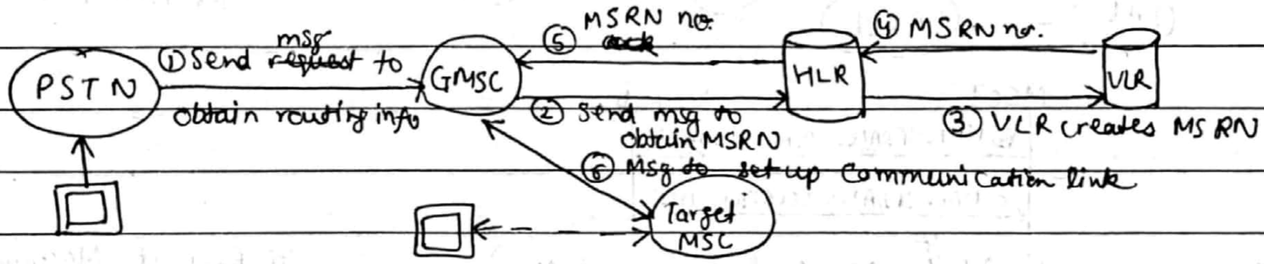
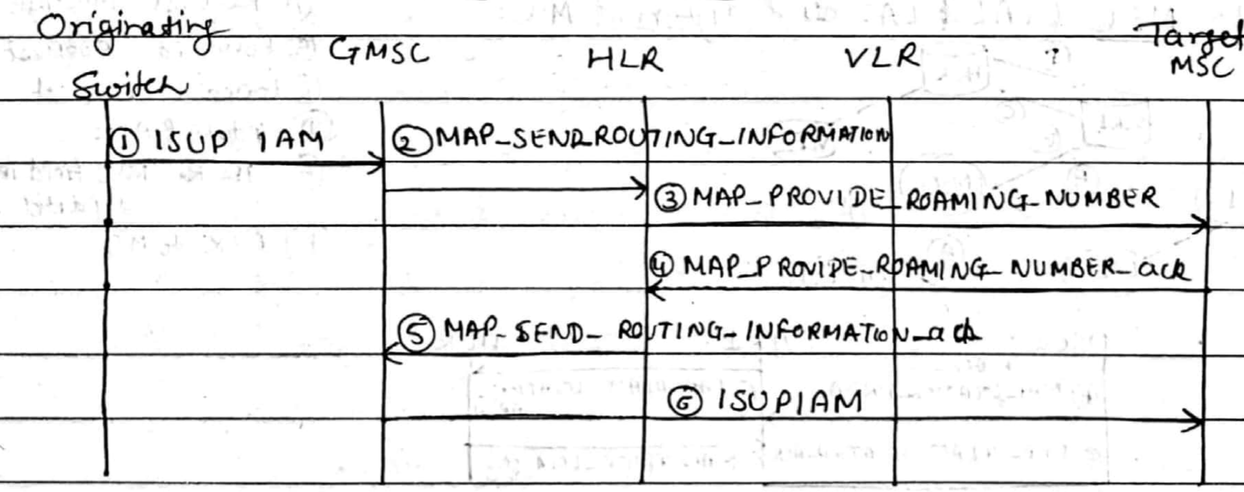
- GSM Call Origination





- GSM Call Termination





* Security in GSM
  - Confidentiality
  - Encryption
  - Authentication

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Spread Spectrum Systems

* Problems encountered by a communication system :

(i) In areas such as military communication, the information has to be secured & should not be allowed to interfere communication by any means.

(ii) Sometimes a hostile transmitter can jam transmission. To avoid this the channel should be immune to any external interference.

(iii) Even in non-military communications an unintentional interference is caused by a user who is transmitting its information through a channel which is already being used.

- These problems can be solved using a technique called Spread Spectrum Modulation.

* How is Spread Spectrum Signal (SS signal) different from Normal Signal?

- SS signal occupies a larger bandwidth than that of a normal signal
- The S.S signal invariably uses some kind of coding
- SS signal is "pseudorandom" in nature. This makes it appear like "random noise". Therefore, normal receiver can't demodulate the SS signal

* Applications of SS Modulation Technique :

(i) In combating the intentional interference (jamming)

(ii) In rejecting the unintentional interference from some other user

(iii) To avoid the self interference due to multipath propagation

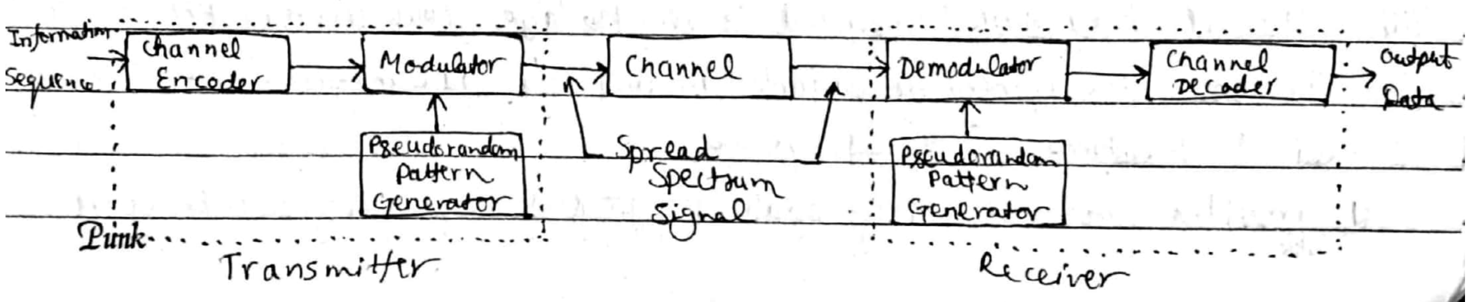
(iv) In low probability of intercept (LPI) signals

(v) In obtaining the message privacy

* SS Modulation Techniques

- Average Type Systems
  - Direct Sequence Spread Spectrum (DS-SS) system
- Avoidance Type Systems
  - Frequency Hopping
  - Time Hopping
  - Chirp
  - Hybrid Models

* SS Digital Communication System model



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* A pseudo-noise (PN) sequence may be defined as a coded sequence of 1s & 0s with certain auto-correlation properties
* The maximum length sequence is a type of cyclic code which represents a commonly used periodic PN sequence. The maximum length sequence at the generator output will always be periodic with a period of

$N = 2^m - 1$ m = length of shift register

* Properties of Max Length Sequence:
  1. Balance property (In each period of a maximum length sequence, the no. of 1s is always one more than no. of 0s)
  2. Run property (Among the runs (subsequence) of 1s & 0s in each period of maximum length sequence, one half the runs of each kind are of length one, one fourth are of length two, one eighth are of length three & so on)
  3. Correlation property (Auto-correlation of a maximum length sequence is periodic & binary valued)
* An externally generated interfering signal is called as a jamming signal & such an intentional interference is called jamming.
* DS-SS technique can be used ~~for~~ in practice for transmission of signal over a bandpass channel (ex- satellite channel). For such an application, the coherent binary phase shift keying (BPSK) is used in transmitter & receiver

- Advantages of DS-SS system
  1. very high discrimination against multipath signals so interference caused by multipath reception is minimized successfully
  2. performance in noise is superior to other system such as FHSS system
  3. Combats intentional interference (jamming) most effectively
- Drawbacks of DS-SS system
  1. with serial search system, acquisation time is too large & thus slow system
  2. Sequence generated by PN code generator output must have a high rate
  3. Channel bandwidth required is very ~~too~~ large (But less than FH-SS system)
  4. Synchronization affected by variable distance b/w transmitter & receiver.
- Salient Features of DS-SS System
  1. provides good security against potential jamming or interception

② Extremely effective against narrowband jamming signals
③ Narrowband communications can coexist with DS-SS signals
④ Not very effective against broad band interference

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* FH-SS (Frequency Hoped) System

- In this, the data is used to modulate carrier. The data modulated carrier is then randomly hoped from one frequency to the other. Because of this, spectrum of transmitted signal is spreaded sequentially rather than instantaneously.
- Uses MFSK (M-ary Frequency Shift Keying) Modulation technique.
- Two types :- Slow FH (Symbol Rate (R_s) of MFSK = ~~integral~~ integer multiple of hop rate (R_H))
  Fast FH (Hop Rate (R_H) = ~~integral~~ integer multiple of symbole rate of MFSK (R_s))
- Two Most important application:
  ⓘ Wireless local area network (WLAN) Standard for wi-fi
  ⓘⓘ Wireless personal area network (WPAN) Standard for Bluetooth

IEEE 802.11 — FHSS in wifi → Later presented as Bluetooth
↓ Improved
802.11a & 802.11b (Removed FHSS)

- Bluetooth LAN is an Ad hoc network & is implemented using IEEE802.1
- Bluetooth defines following two networks:
  ⓘ Piconets (A bluetooth network with atmost 8 station (1 master & other slaves)
  ⓘⓘ Scatternet (Piconets are combined to form a scatternet)

* Applications of Spread Spectrum Techniques.

ⓘ For combating intentional interference (jamming)
ⓘⓘ For reducing unintentional interference
ⓘⓘⓘ For suppressing the interference due to multipath reception
ⓘⓥ In the "low probability of intercept" (LPI) application
ⓥ Used in mobile communication ~~as~~ because fading doesn't affect entire spectrum
ⓥⓘ Secured communication due to PN sequence
ⓥⓘⓘ Used in RADAR & other navigation system due to very precise measurement of time delays.
ⓥⓘⓘⓘ CDMA (Code Division Multiple Access)

* Difference b/w Multiple Access & Multiplexing

ⓘ In multiple access the users will share the remote communication channels such as a satellite or radio channel. However, in multiplexing the channel such as telephone channel is shared by users confined to a local site.

(ii) In a multiplexed System, the requirements of users are generally fixed. But in a multiple access system, the requirements of a user change dynamically with time. Hence, dynamic channel allocation is required to be provided.

* Cellular Code Division Multiple Access (CDMA) Systems

- Principle:

(i) In CDMA, each user is given a unique code sequence or signature sequence. This sequence allows the user to spread info signal across assigned frequency band

(ii) At the receiver, the signal is recovered by using same code sequence. At the receiver the signals from various users are separated by checking cross-correlation of the received signal with each possible user signature sequence.

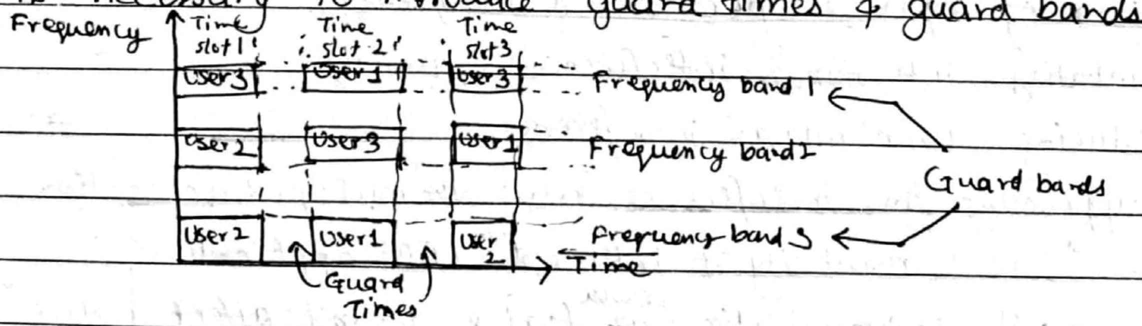
(iii) In CDMA, the users access the channel in random ~~order~~ manner. Hence the signals transmitted by multiple users will completely overlap both in time & in frequency.

(iv) CDMA signals are spread in frequency. Therefore, the demodulation & separation of these signals at the receiver can be achieved by using the pseudorandom code sequence.

(v) CDMA is also called as "Spread Spectrum Multiple Access (SSMA)"

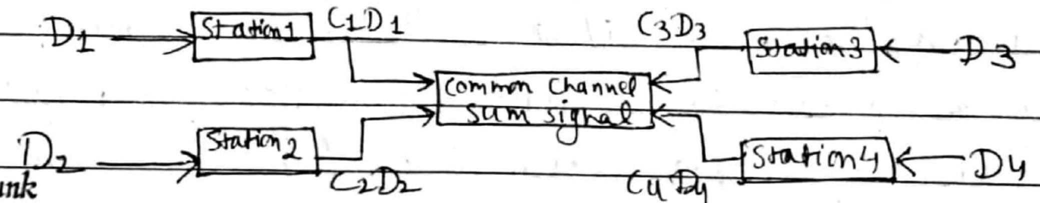
(vi) CDMA doesn't need any synchronization, however, code sequence or signature waveforms are required. In CDMA, one channel carries all the transmissions simultaneously.

(vii) In CDMA, as bandwidth as well as time of channel are being shared by users, it is necessary to introduce guard times & guard bands.



- Idea of CDMA:

Let us assume that there are four stations 1, 2, 3, 4 & data D_1, D_2, D_3, D_4 from these stations respectively. Let code assigned be C_1, C_2, C_3, C_4 respectively: (These codes are orthogonal, i.e., $C_m \times C_n = 0$) & any code multiplied by itself gives 4 (no. of stations)) → Properties of Chip



→ Each station receives sum signal. If 2 & 3 are talking, then 3 will multiply sum signal by C_2. At 3, multiplication takes place as:

$$\text{Sum Signal} \times C_2 = (C_1D_1 + C_2D_2 + C_3D_3 + C_4D_4) \times C_2$$
$$= 0 + 4D_2 + 0 + 0$$

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- Concept of chip

→ In CDMA, each station is assigned a code. It is a sequence of nos. called as a chip. These codes are called orthogonal sequences

- Data Representation:

→ The encoding rules are as under:

(i) A bit 0 is encoded as -1

(ii) A bit 1 is encoded as +1

(iii) If a station is silent & no signal is to be transmitted, then this is encoded as 0.

- CDMA Services:

(1) Voice Services
(2) Data Services
(3) Circuit Switched Data
(4) Packet Switched Data
(5) Message Services
(6) CDMA radio
(7) CDMA radio channel
(8) Location based Services

- Power Control:

→ Power Control is used to maintain the minimum necessary transmitted power for reliable communication.

→ Power control is essential in cellular systems for high system capacity & satisfactory transmission quality by

(i) limiting interference among users in different cells using the same frequency channel (i.e., co-channel interference) and

(ii) alleviating the near-far effect which reduces interference among users in the same or different cells using adjacent frequency channels.

→ "Near Far Effect" is a condition in which a nearby transmitter captures the receiver of the mobile or base station so that the latter is unable to detect the signal of a second transmitter located farther away. The near far effect can be ~~ep~~ equalized through power control.

→ The two types of power control are:

(i) Open Loop Power Control

In this, the transmitter estimates the channel condition (gain) & adjusts its transmission power accordingly.

→ Each station receives sum signal. If 2 & 3 are talking, then 3 will multiply sum signal by C_2. At 3, multiplication takes place as:

Sum Signal $\times C_2 = (C_1D_1 + C_2D_2 + C_3D_3 + C_4D_4) \times C_2$

$= 0 + 4D_2 + 0 + 0$

Date __/__/____

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→ The two types of power control are:

(i) Open Loop Power Control

In this, the transmitter estimates the channel condition (gain) & adjusts its transmission power accordingly.

Punk

(ii) Closed Loop Power Control (suffers from feedback delay)

In this, the ~~recei~~ receiver estimates
(a) the received power level,
(b) the received signal to interference ratio, or
(c) the transmission error rate, compares the measurement with the target desired value & sends info for power control adjustment to transmitter.

- Effects of Multipath Propagation on Code Division Multiple Access (CDMA)

RAKE Receiver

→ CDMA receivers can combine all delayed versions of the transmitted signal and provide better signal to noise ratio (SNR) at destination side. By using a specific correlation receiver unit, the 'RAKE' receiver collects all delayed versions/shifted versions of the original signal.

→ Each & every correlator unit is capable of searching a particular range of time delays & is termed as 'search window'. The RAKE receiver is also known as "diversity receiver" designed particularly for CDMA technique.

→ The 'RAKE receiver' mainly makes use of the multiple correlations for the signal reception in mobile communication.

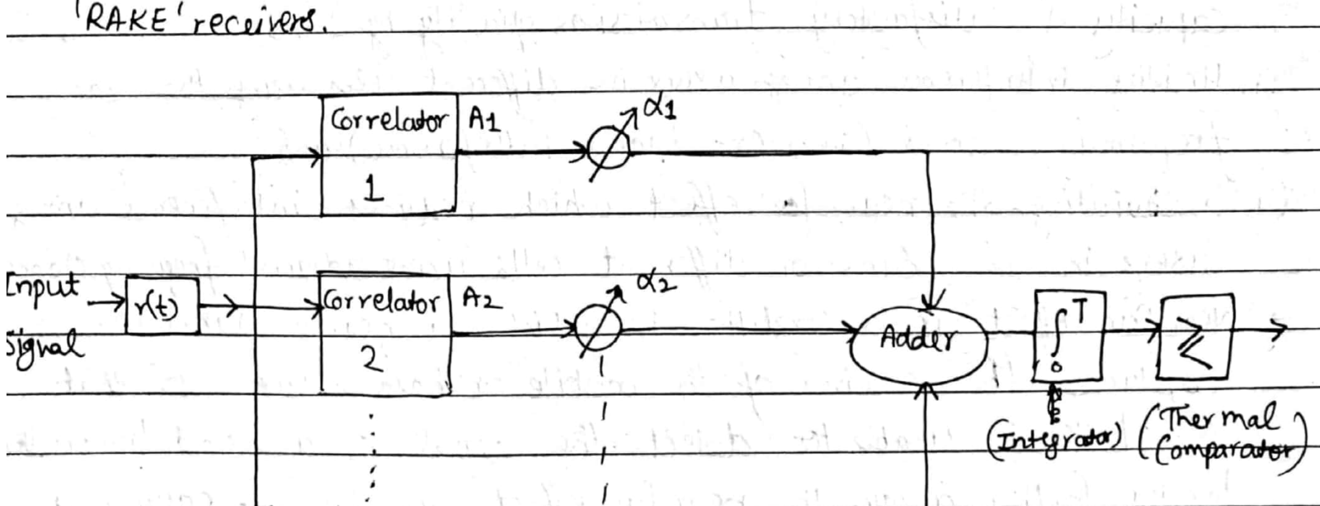
→ The general ~~overall~~ signal can be represented as 'A′' & is given as under:

$$A' = \sum_{n=1}^{N} \alpha_n \cdot A_n$$

$\alpha_n \rightarrow$ weighting factor

$A_n \rightarrow$ output of n^{th} correlator

→ For having a better performance to produce efficient signal reception, selection of weighting ~~factor~~ coefficients, which is based on output values (actual output) of correlator, is an important criteria in the 'RAKE' receivers.



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* Performance Comparison of FDMA, TDMA & CDMA

S.NO.	FDMA	TDMA	CDMA
1.	Overall bandwidth is shared among many stations.	Time sharing takes place.	Sharing of bandwidth & time both takes place.
2.	Due to non-linearity of devices inter modulation products are generated b/w adjacent channels.	Due to incorrect synchronization, there can be an interference b/w the adjacent time slots.	Both type of interferences will be present
3.	Synchronization is not necessary.	Synchronization is essential.	Synchronization is not necessary.
4.	Codeword is not required.	Codeword is not required.	Codewords are required.
5.	Guard bands b/w adjacent channels are necessary.	Guard times b/w adjacent time slots are necessary	Guard bands & Guard time both are necessary.

Wireless Communication

Unit-III

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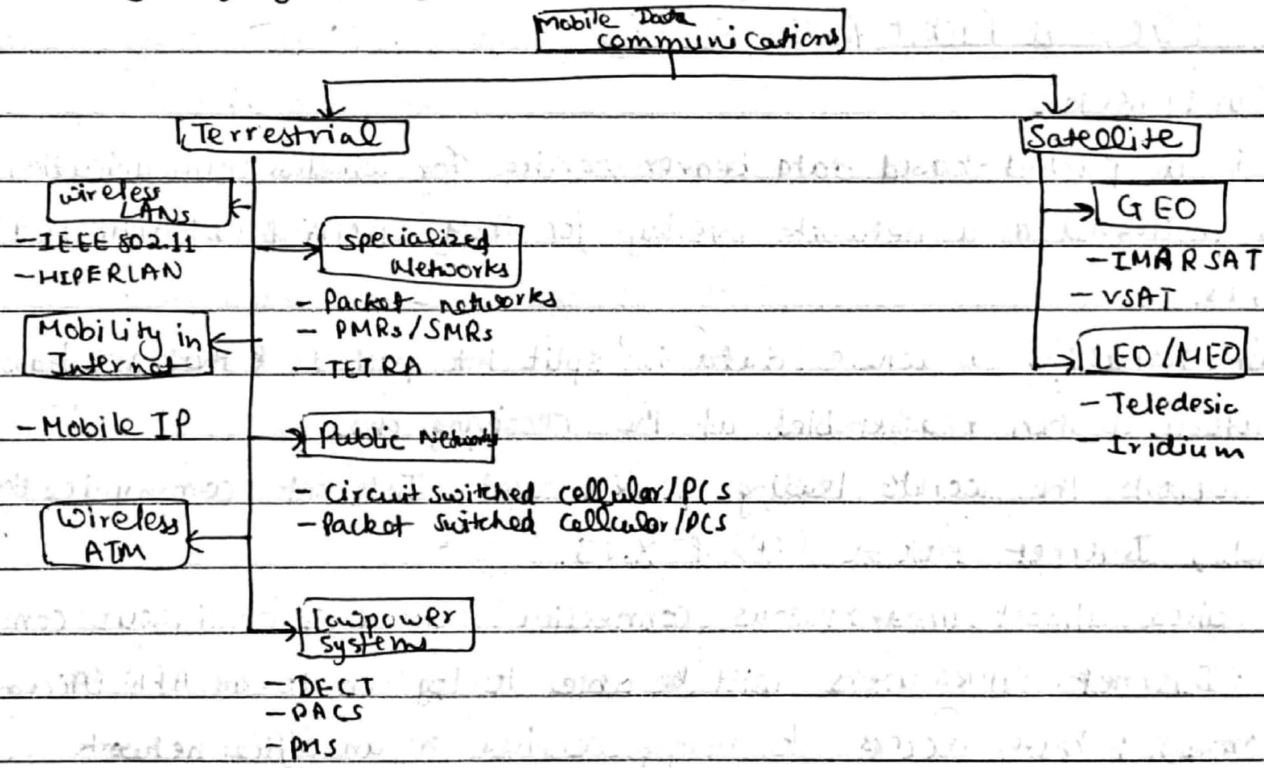
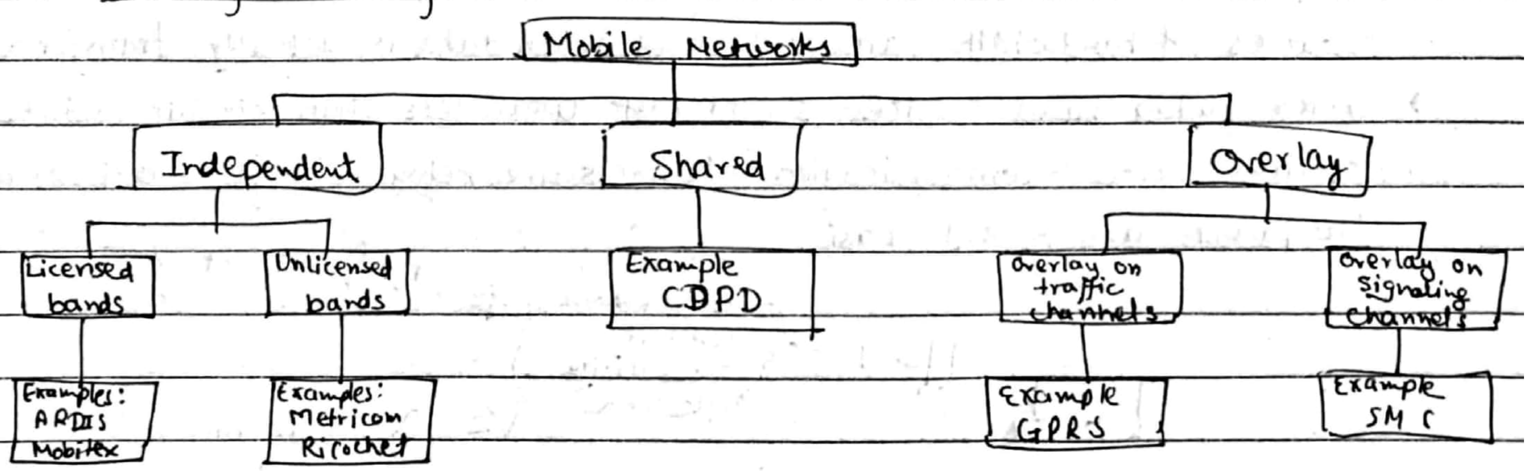
2.5 G Mobile Data Networks

* **Introduction To Mobile Data Networks**

- Applications: (i) Paging & short message services (SMS) (ii) e-mail & internet/intranet access (iii) Database access & file transfer (iv) Fleet management & dispatch (v) Inventory control (vi) Credit card authorization from remote or mobile location (vii) Field services (viii) Intelligent highways, i.e., automatic toll collection (ix) Data inputs, i.e., hospital patient charts & auto rental returns
- Range of Systems of Mobile Data Networks:



- Classification of Mobile Networks



→ Independent Networks have their own spectrum that is not coordinated with any other service & their own infrastructure that is not shared with any other service.

→ Shared Mobile data Networks share the spectrum & part of infrastructure with an already existing voice-oriented analog service. The services operate in the same radio channels used for analog service but they have their own air-interface & MAC protocols.

→ Overlay networks means that the data service will not only make use of spectrum allocated for another service but also the MAC frames & air interface of an existing voice-oriented digital cellular system.

* GPRS (General Packet Radio Services)

- Basic Fundamentals

→ GPRS is a packet-based data bearer service for wireless communication that is delivered as a network overlay for GSM, CDMA & TDMA (ANSI-136) networks.

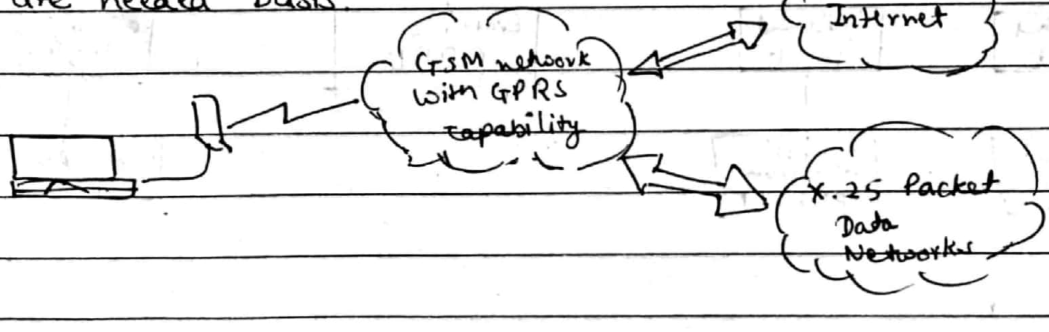
→ Packet switching is where data is split into packets that are transmitted separately & then reassembled at the receiving end.

→ GPRS supports the world's leading packet-based Internet communication protocols, Internet Protocol (IP) & X.25.

→ GPRS gives almost instantaneous connection set-up & continuous connection to the Internet. GPRS users will be able to log on to an APN (Access Point Name) & have access to many services or an office network.

→ A physical end-to-end connection is not required because network resources & bandwidth are only used when data is actually transferred.

→ GPRS packet-based services should cost users less than circuit-switched services since communication channels are being shared & are on a 'as-packets-are-needed' basis.



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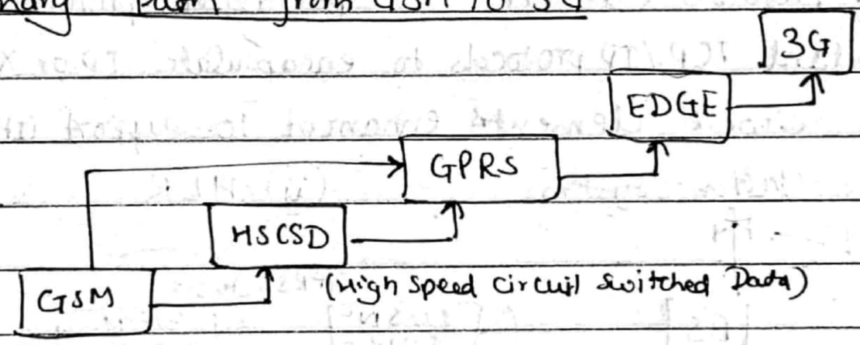
- Salient Differences of GPRS from GSM

(i) Higher bandwidth & therefore data speeds
(ii) Immediate & continuous connection to the Internet - always on-line
(iii) New text & visual data & content services
(iv) Packet-switching rather than circuit switching
(v) Different mediation, rating & billing requirements
(vi) Support for leading Internet Communication protocols - Internet protocol (IP) & X.25
(vii) Additional components & protocols to GSM network - the key elements are SGSN (servicing GPRS support node), GGSN (Gateway GPRS support node) & a charging gateway
(viii) Different devices → from laptops or hand helds to GPRS capable phones, PCs & modems
(viii) First important step on path to 3G.

- Evolutionary Path from GSM to 3G



- Applications: (i) Chat (ii) Information services such as text or graphics (iii) Still images (iv) Moving images (v) web browsing (vi) Document sharing & remote collaborative working (vii) Audio reports (viii) Job dispatch (ix) Corporate email (x) LAN applications (xi) Internet email (xii) Vehicle positioning (xiii) File Transfer

- Challenges: (i) Availability (ii) Security & Roaming (iii) Limited cell capability (iv) IP mediation (v) Creating compatible & comparable data records (vi) Limited speeds (vii) ~~Transmi~~ Transit Delays.

* GPRS working

- The key elements in a GPRS network are:

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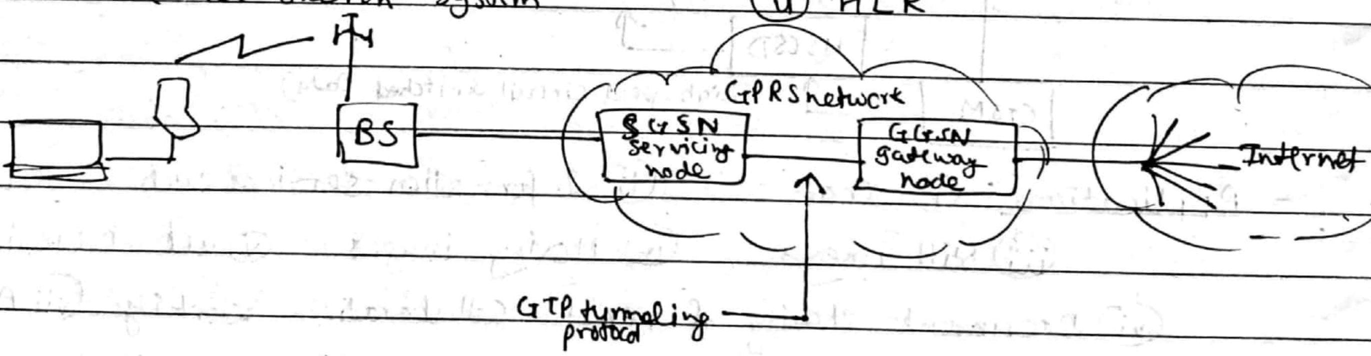
(i) SGSN : The node within the GSM infrastructure that sends & receives packet data to & from the mobile stations & keeps track of the mobiles within its service area. SGSNs send queries to HLRs (Home location Registers) to obtain data profile of GPRS subscribers & detects new GPRS mobile stations in a given service area. It performs the functions include mobility management, (tracking a mobile location), user verification & collection of billing data.

(ii) GGSN : The node that interfaces to external public data networks (PDNs) such as Internet & X.25. It maintains routing information necessary to tunnel PDUs to SGSNs. Other functions include network & subscriber screening & address mapping

(iii) Charging Gateway : An interface b/w charging gateway functionality & billing system. It makes log entry whenever there is network activity. Main functions are collection of GPRS nodes, intermediate data record storage, buffering & transfer of data records to mediation / billing systems.

(iv) GPRS Tunnelling Protocol (GTP) : A specialized protocol that operates over top of standard TCP / IP protocols to encapsulate IP or X.25 packets.

- In addition, two network elements enhanced to support GPRS:
  (i) BSS (Base station System) (ii) HLR



GPRS Network

* GPRS Architecture

- Charging Gateway : It is a single logical interface b/w charging gateway functionality & the billing system. Its functionality can be either a separate centralized network element or a distributed resident in SGSN & GGSN

- GPRS Tunnelling Protocol (GTP):
  It is the protocol that tunnels the PDU through IP backbone by adding routing information. Functions of GTP :

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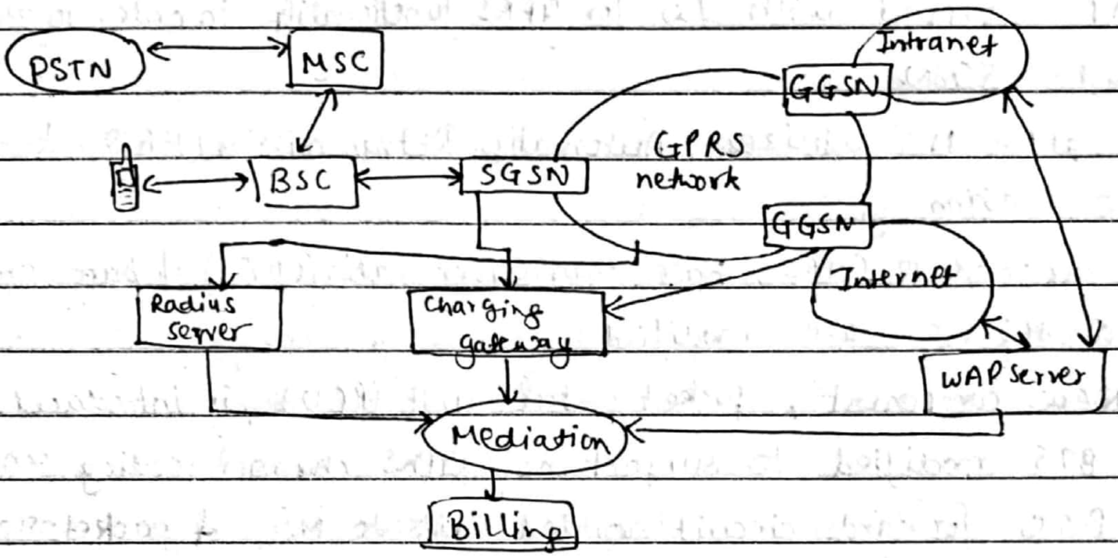
ⓐ CDR transfer mechanism b/w GPRS nodes & charging gateway functionality (CGF)
ⓑ Redirection of CDR transfer to another CGF
ⓒ Ability to detect communication failures b/w CDR handling GPRS network elements
ⓓ Ability to prevent duplicate CDRs that arise during redudancy operations
ⓔ Ability to advertise CDR transfer capability



GPRS architecture

- Additional GPRS network protocols.
  i. Sub-Network Dependent Convergence Protocol (SNDCP)
  ii. Logical Link Control (LLC)
  iii. Base Station System GPRS Protocol (BSSGP)
  iv. GPRS Mobility Management (GMM)
  v. Network Service
  vi. BSSAP+
- Data Transmission in a GPRS network

  Although a user experiences a continuous connection, a network connection needs to be opened & closed for each transaction.

  Steps:

ⓐ Network Access
  - User Registration
  - Authentication
  - Call Admission Control (CAC) (Determines network resources for QOS requested)

ⓑ Routing & Data Transfer

Types of data :- forwarded, Tunnelled, Compressed, Encrypted

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© Mobility Management

* GPRS Network Nodes

1. Mobile Station
   - consists of mobile terminal (MT) & terminal equipment (TE)
   - MT communicates with BSS over the air
   - MT equipped with s/w for GPRS functionality in order to establish links to the SGSN.
   - GPRS MS utilizes Automatic Retransmission (ARQ) to retransmit error frames
2. Base Station System
   - To accomodate GPRS, Base transceiver station (BTS) & base station controller (BSC) on the BSS are modified
   - New component, packet control unit (PCU), is introduced.
   - BTS modified to support new GPRS channel coding schemes
   - BSC forward circuit switched calls to MSC & packet-switched data (through PCU) to SGSN.
3. A Serving GSN (SGSN)
   - Role of SGSN equivalent to MSC/VLR in current GSM network
4. A Gateway GSN (GGSN)
   - GGSN is primarily provisioned by router, which supports traditional gateway functionaly : ⓐ Publishing subscriber addresses
     ⓑ Mapping addresses ⓒ Routing & tunneling packets
     ⓓ Screening Messages ⓔ Counting packets
5. HLR & VLR
   - New fields in the MS record introduced in HLR & accessed by SGSN & GGSN using IMSI as index key & used to map MS to one/more GGSNs
   - In MSC/VLR, new field, SGSN number, is added to indicate SGSN currently servicing the MS.

* Enhanced Data Rates for GSM Evolution (EDGE)

- EDGE or Enhanced GPRS (EGPRS) is a digital mobile phone technology that allows to increase data transmission rates & improve data transmission reliability. It is generally classified as 2.75G

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network technology. Around since 2003

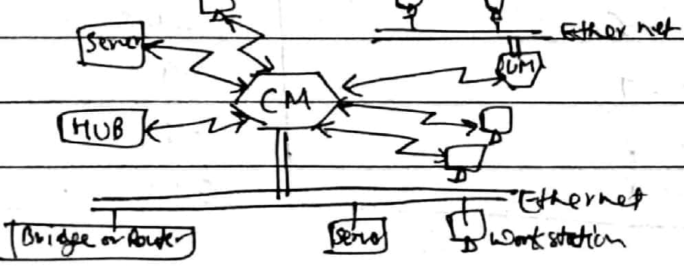
- High speed data applications such as video services & other multimedia benefit from EGPRS increased data capacity.
- On March 14, 2007, Ericsson announced plans for EDGE Evolution that permits 1 Mbits/sec peak speeds & latencies down to 100 ms.
- Technology
  → EDGE implemented as a bolt-on enhancement to 2G & 2.5G GSN & GPRS networks, making it easier for existing GSM carriers to upgrade to it.
  → EDGE is a superset to GPRS & can function on any network with GPRS deployed.
  → Although EDGE requires no h/w or s/w changes to be made to GSM core networks, base stations must be modified to support EDGE.
- Transmission Techniques
  → In addition to Gaussian Minimum Shift Keying (GMSK), EDGE uses 8 Phase Shift Keying (8PSK) for upper five of its nine modulation & coding schemes.
  → EDGE produces a 3-bit word for every change in carrier phase which effectively triples gross data rate offered by GSM & uses a rate adaptation algorithm.
  → It introduces a new technology not found in GPRS, Incremental Redudancy, which instead of retransmitting distributed packets sends more redudancy information to be combined in the receiver.
  → EDGE can carry data speeds upto 236.8 kbits/s for 4 timeslots.

Coding & Modulation Scheme (MCS)	Speed (kbit/s)	Modulation
MCS-1	8.8	GMSK
MCS-2	11.2	GMSK
MCS-3	14.8	GMSK
MCS-4	17.6	GMSK
MCS-5	22.4	8-PSK
MCS-6	29.6	8-PSK
MCS-7	44.8	8-PSK
MCS-8	54.4	8-PSK
MCS-9	59.2	8-PSK

- Classification
  → Class 3 & below EDGE not clearly considered 3G & class 4 & above EDGE conventionally considered as 3G. So, EDGE generally classified 2.75G
- EDGE Evolution
  → latencies reduced by lowering Transmission Time Interval by half (20ms to 10ms)
  → Bit rates increased using dual carriers & higher order modulation & "Turbo Codes" to improve error correction.
- Networks
  → EDGE is actively supported by GSM operators.

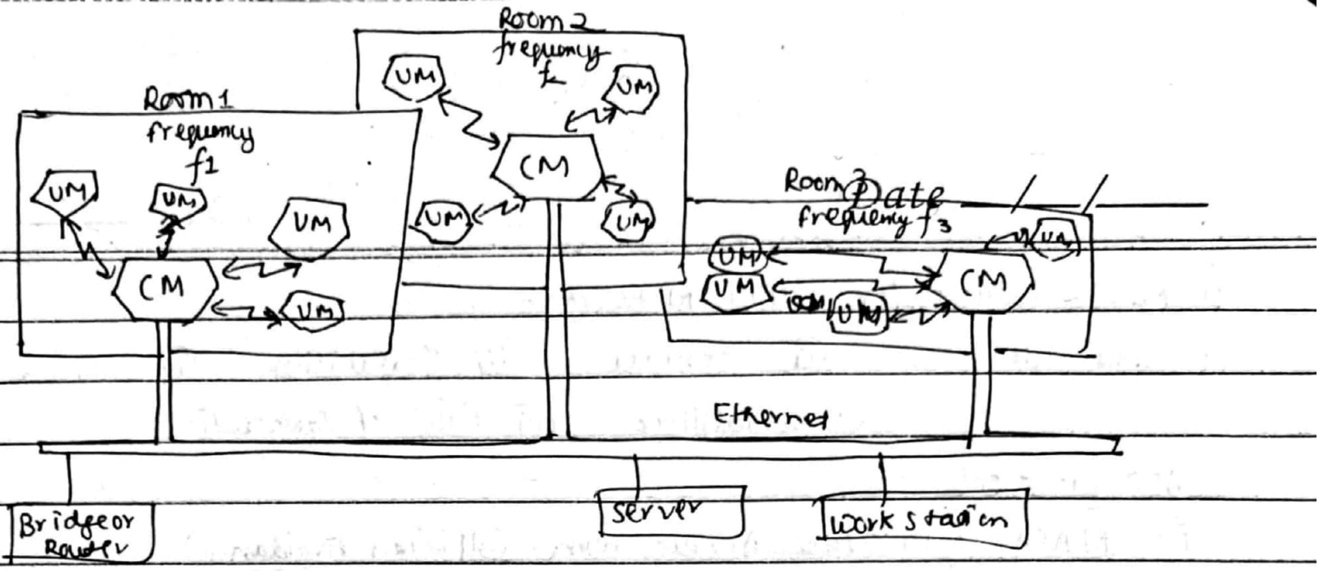
* Wireless LAN (WLAN)

- WLAN is a technology which uses radio frequency to transmit & receive data over the air, providing all the features & benefits traditional LANs but without limitations of a cable.
- It is a data communication system providing wireless peer-to-peer (PC-PC / PC-Hub / Printer-Hub) & point-to-point (LAN-to-LAN) connection within a building or campus
- Standard 802.11 b with bandwidth 11 Mbps & 2.4 GHz operating frequency. 802.11 a (successor of 802.11b) with bandwidth 54Mbps
- Salient features & ~~Drawbacks~~
  (a) Advantages: (i) Easy Deployment (ii) LAN extension (iii) Easy Access (iv) WLAN mobility (v) Cost Effective (vi) Smart working (vii) Increased Productivity
  (b) Disadvantages: (i) Limited Bandwidth (ii) Incompatibility (iii) Inference (iv) Black or dead spots (v) less security (vi) Need of backbone network
- WLAN Technology
  (a) Spread Spectrum (b) Narrowband Technology (c) Infrared Technology
- Applications
  (a) LAN extension (b) Nomadic access
  (c) Cross building interconnection (d) Adhoc networks

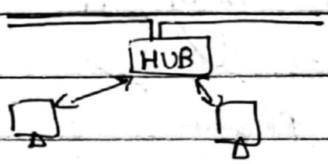


CM – Control module
UM – User module

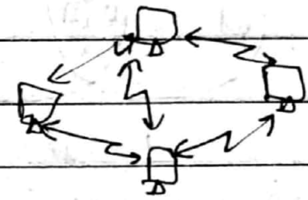
(Single Cell WLAN)



Multiple - cell W LAN



Nomadic Access



Adhoc access

- WLAN Requirements

(i) High thoroughput (ii) Large no. of nodes (Few 100s)

(iii) wired connection to backbone LAN (iv) service area ≥ 100 – 300 m

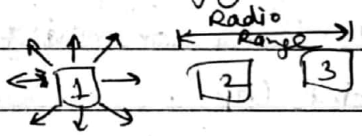
(v) Longer Battery Life (vi) Robustness & security

(vii) Licence-free operation (viii) Allocated Network Operation

(ix) Roaming Facility (x) Dynamic Configuration

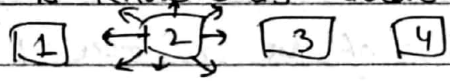
- Problems Associated with WLAN

(i) Hidden Station Problem



- Station 1 is transmitting to Station 2. If Station 3 senses medium to see if anyone is transmitting, it will not hear station 1 since it is out of range. Therefore, station 3 will come to wrong conclusion that no one is transmitti & so it can transmit to station 2. If station 3 starts transmitting, it wi create an interference at station-2 & will wipe out the frames from station 1
- This problem in which a station is not able to detect a potential competitor which is too far away is known as hidden station problem.

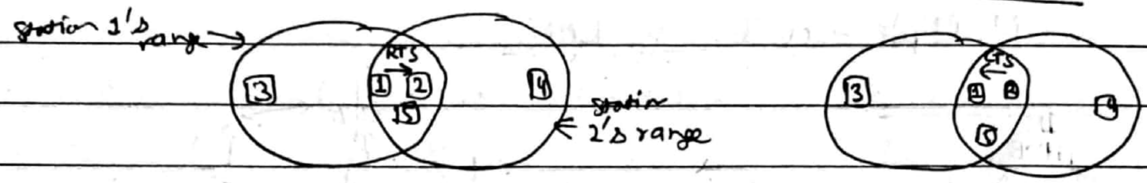
(ii) Exposed Station Problem



- Station-2 is transmitting to station-1. If station 3 senses medium, since station-2 comes in range with station-3 so station-3 will sense the transmission going on. Therefore it will falsely decide that it must not transmit to station-4. This problem is known as exposed Station problem.

- Design Issues for WLAN Networks
  - (i) Bandwidth (ii) Mobility (iii) Scalability (iv) Security
  - (v) Reliability (vi) Ease of Installation
- WLAN protocols
  - (i) MACA (Multiple Access with Collision Avoidance)

RTS – Request To Send
CTS – Clear To Send



Request   Response

(ii) MACAW (MACA for wireless) :- MACA fine tuned for improvement in performance. ACK frame, CSMA & (back off algorithm ~~data added~~ for each data stream rather than for each station.

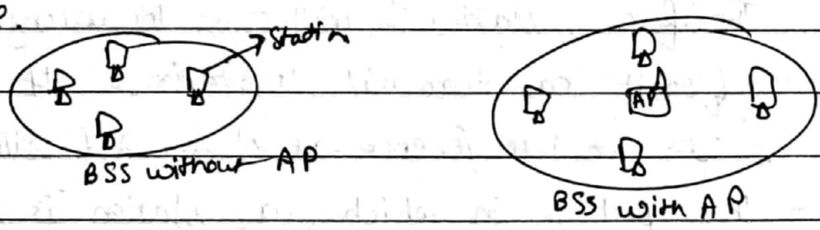
* WLAN (IEEE 802.11) : Covers physical & data layers

- IEEE defines two types of services:
  - (i) Basic Service Set (BSS) (ii) Extended Service Set (ESS)

(i) BSS

→ Made of stationary or moving wireless stations & a central station called access point (AP).

→ Can be either without AP or with AP. Without AP can't send data to another BSS & hence known as a stand alone network or ad hoc ~~ad~~ architecture.

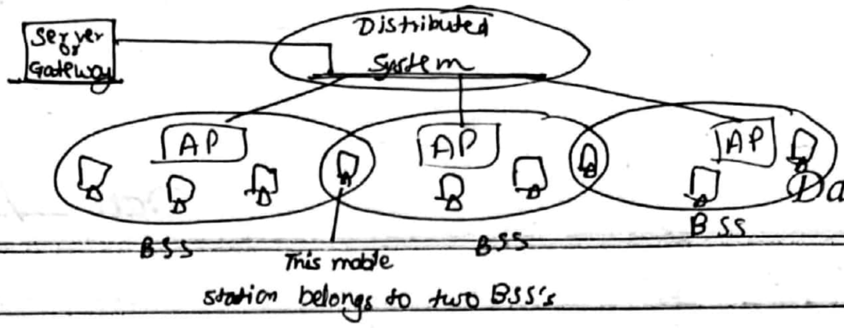


BSS without AP   BSS with AP

(ii) ESS

→ Consists of two or more BSSs with APs. BSSs in this system are connected to each other via a distribution system which is generally a WLAN.

→ ESS consists mobile stations & stationary or non moving stations.



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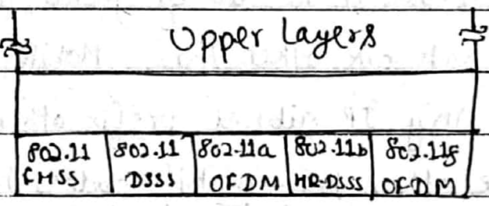
- Types of Stations in ESS
  - (i) No transition (stationary or moving only inside a BSS)
  - (ii) BSS transition (can move b/w BSS but not outside ESS)
  - (iii) ESS transition (can move b/w ESS)
- Physical Layer : IEEE has defined specification for converting bits to a signal in physical layer. One of them is in infra-red frequency & other five specifications are in RF range.

→ Five specification in RF range:

(i) FHSS - Frequency Hoped Spread Spectrum (802.11)
(ii) DSSS - Directed Sequence Spread Spectrum (802.11)
(iii) OFDM - Orthogonal Frequency Division Multiplexing (802.11a)
(iv) HR-DSSS - High Rate-DSSS (802.11b)
(v) OFDM (802.11g)



Physical layer

(i) FHSS → Frequency band - 2.4 GHz ISM band
Hops from one frequency to another & transmits for short period of time
Cycle repeats after N-hoppings.

(ii) DSSS → Frequency Band - 2.4 GHz ISM band
Each bit converted into chip code (time required same as original bit
N bits in each chip code then data rate N times equal to original
Uses PSK

(iii) OFDM → Principle same as FDM & type of modulation used is PSK & QAM. Data rates are 18 Mbps (PSK) & 54 Mbps (QAM)

(iv) HR-DSSS → Uses 2.4 GHz ISM band & uses complementary code keying (CCK) which encodes 4 or 8 bits of original data into one CCK symbol.

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* Mobile IP

- It is ~~an~~ the underlying technology for support of various mobile data and wireless networking applications

- Terms used in Mobile IP

(i) Agent Advertisement: An advertisement message constructed by attaching a special extension to router advertisement message

(ii) Binding: Association of home address of mobile node with a care-of address for that mobile node

(iii) Care-of address: An IP address associated with a mobile node while visiting a foreign Link. (Mobile Node's Home agent registered address is called primary care-of address)

(iv) Correspondent Node: A peer with which mobile node is communicating

(v) Foreign agent: A router on a mobile node's visited network, which co-operates with the home agent to complete the delivery of ~~message~~ datagrams to the mobile node while it is away from home

(vi) Foreign network: Any network other than Mobile Node's Home Network

(vii) Foreign subnet prefix: Any IP subnet prefix other than mobile node's home subnet prefix.

(viii) Foreign Link: Any link other than mobile node's home Link.

(ix) Home address: An IP address ~~associated~~ that is assigned for an extended period of time to a mobile node.

(x) Home network: A network, possibly virtual, is having a network prefix matching that of a mobile Node's home address.

(xi) Home link: The link on which mobile node's home subnet prefix is defined

(xii) Home agent: A router on a mobile node's home link with which the mobile node has registered its current care-of-address.

(xiii) Tunnel: The path followed by datagram while it is encapsulated

- Mobile IP Routing Operation

(i) Mobile IP established visited network as foreign node & home network as home node

(ii) Mobile IP uses a tunneling protocol to allow messages from PDN (Packet Data Network) to the directed mobile node's IP address

(iii) Home & foreign agents advertise their services continuously;

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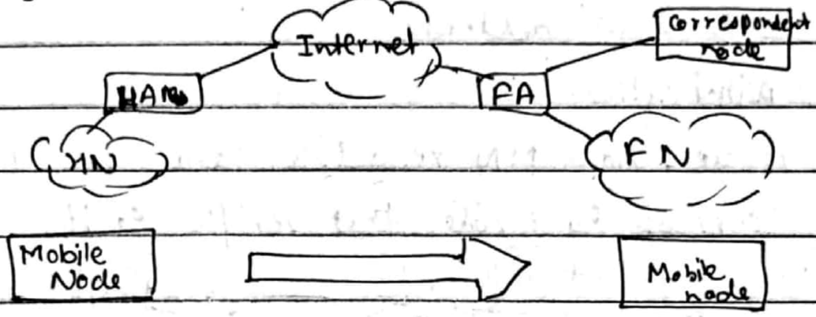
enabling Home agent to recognize new foreign agent & allow mobile node to register a new care-of address

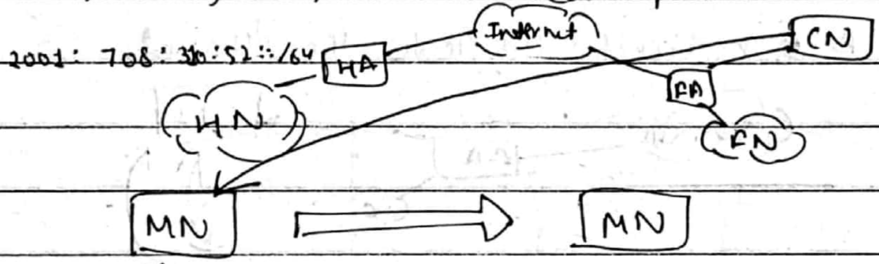


HA → Home agent
FA → Foreign agent
FN → Foreign network
HN → Home network

FA → IPv6 router with home agent functionality
HA → Regular IPv6 router

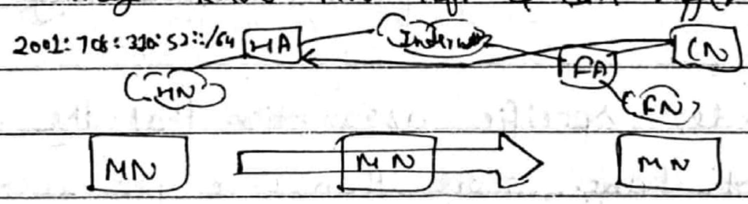
- Functionality in HN

(i) Home router sends router advertisements
(ii) MN receives its home address via neighbour discovery protocol
(iii) MN listens router advertisements or send Router Solicitation request to get or ensure network prefix
(iv) MN starts for task with correspondant node.



- Moving to foreign network

(i) Traffic b/w MN & CN is stalled
(ii) HN may know MN left & can buffer incoming traffic

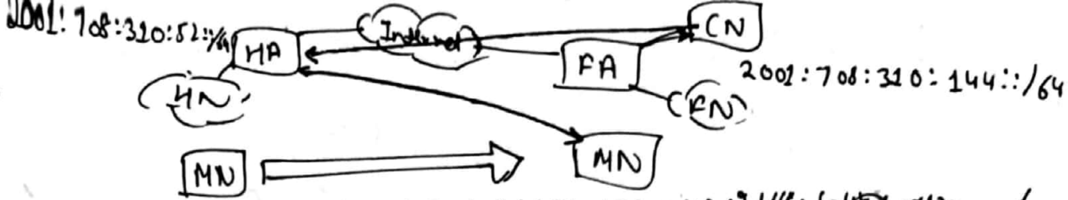


Home address:
2001: 708: 310: 52: 202: 2dff: fe4b: a120

(iii) MN uses lower layer mechanisms for detecting movement.
(iv) Router Solicitation message to get answer from routers in FN
(v) After entering FN, MN receives new network prefix from FN routers & constructs a new address for itself called care-of address.

- Functionality in FN

(i) MN inform HA about its new care-of address
(ii) MN sends message about its new care-of address & authentication



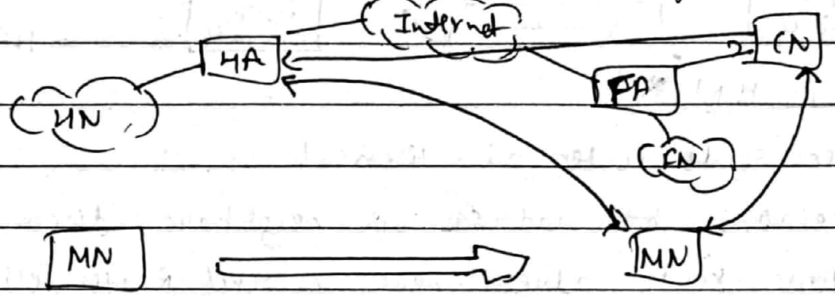
Home address : 2001:708:310:52:202:2dff:fe4b:a120
Care of address : 2001:708:310:144:202:2dff:fe4b:a120

info to home agent. This message is called binding update.

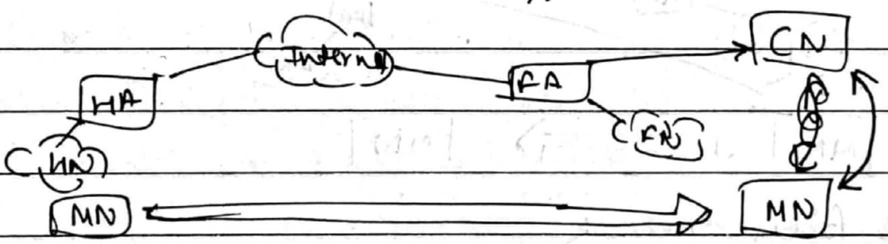
(iii) HA maintains register ~~for~~ of MN & updates its binding cache & performs tunneling to new address

- Mobile IP Route Optimization

(i) Binding update to recue, now MN recycles idea of binding update & send binding update to correspondant node that verifies it.



(ii) once verified the correspondent node doesnot need to send binding update ack. to MN, instead it just creates an IPv6-in-IPv6 tunnel to MN care-of address & redirects traffic to the tunnel.



- Limitations of Mobile IP

(i) It was designed to handle mobility of devices, but only relatively infrequent mobility.

(ii) It was designed under specific assumption that the attachment point would ~~be~~ not change more than once per second.

(iii) It should also point out that Mobile IP is intended to be used with devices that maintains a static IP ~~address~~ configuration.

(iv) ~~Since~~ It is much more difficult to use it with a device that obtains an IP address dynamically.

Third Generation (3G) Mobile Services

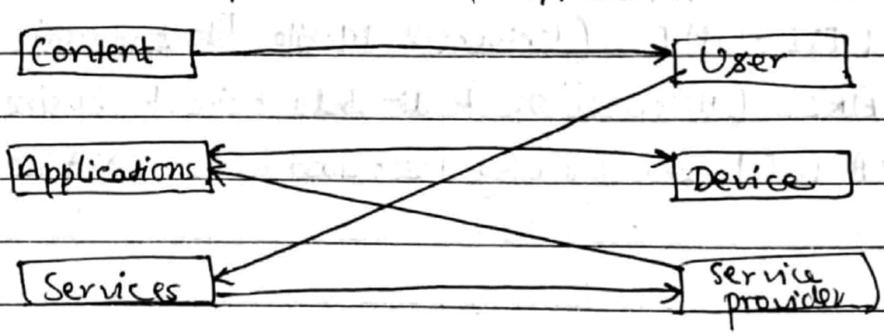
* Introduction To ~~International Mobile Telecommunications 2000~~ 3G Mobile service (IMT2000) vision

- W-CDMA (wide band CDMA) is also known as Universal Mobile Telecommunication Service (UMTS).
- Important Characteristics of 3G System:
  1. supports packet switched & circuit switched services like Internet traffic & voice services
  2. supports roaming
  3. provides backward compatibility & inter operatibility
  4. supports symmetric & asymmetric traffic
  5. ~~Important~~ Compatible with running many services simultaneously in same terminal
  6. can create 'Virtual Home Environment' (VHE) that is Creating a personalized set of services for user & also when user is in movement, it can be maintained as such

IMT 2000

	FDD mode direct spread	FDD mode multicarrier	TDD mode
Bandwidth (BW)	5 MHz	5 MHz / 1.25 MHz	5MHz / 1.6 MHz
Chiprate	3.8 Mchips/sec	3.686 or 1.23 Mchips/sec	3.8 or 1.28 Mchips/sec
Common pilot signal	CDM	CDM	TDM
Dedicated pilot signal	TDM	CDM	TDM
Synchronization Signal	Asynchronous Synchronous	Synchronous as CDMA2000	Synchronous
Core network	GSM-MAP/IP	ANSI-41/IP	GSM-MAP/IP

- Three popular data rates:
  1. for pedestrian environment, data rate is 384 kb/sec
  2. for vehicular environment, data rate is 144 kb/sec
  3. for fixed indoor & picocell environment, data rate is 2Mb/sec
- Rel^n b/w User, Services & Applications



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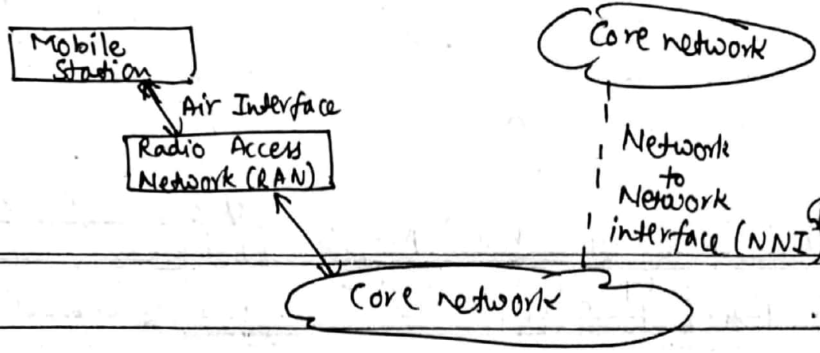

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IMT-2000 Standard Specification

* International Mobile Telecommunications - 2000 (IMT-2000)

- IMT-2000, better known as 3G, is a family of standards for mobile communications defined by the International Telecommunication Union (ITU), which includes EDGE, UMTS & CDMA 2000 as well as DECT & WiMAX
- Services include wide-area wireless voice telephone, video calls & wireless data, all in a mobile environment.
- 3G networks enable network operators to offer users a wide range of more advanced services while achieving greater network capacity through improved spectral efficiency.
- IMT 2000 is a standard name used for all 3G systems
- Vision:
  (i) Common worldwide spectrum
  (ii) Multiple radio environment (LAN, satellite, cordless, cellular)
  (iii) worldwide roaming capability
  (iv) High quality, enhanced security & performance
  (v) Small Terminal for worldwide use.
  (vi) Integration of satellite & terrestrial system
- Services Provided:
  (i) Higher bearer rate capabilities
  (ii) 2Mbps for fixed environment
  (iii) 384 kbps for indoor & outdoor pedestrian environment
  (iv) 144 kbps for vehicular environment
- Standardization Work
  (i) Europe - ETSI - UMTS (Universal Mobile Telecommunication System)
  (ii) Japan - ARIB (Associate of Radio Industries & Business) - WCDMA
  (iii) USA - TIA (Telecom Industry Association) - CDMA 2000

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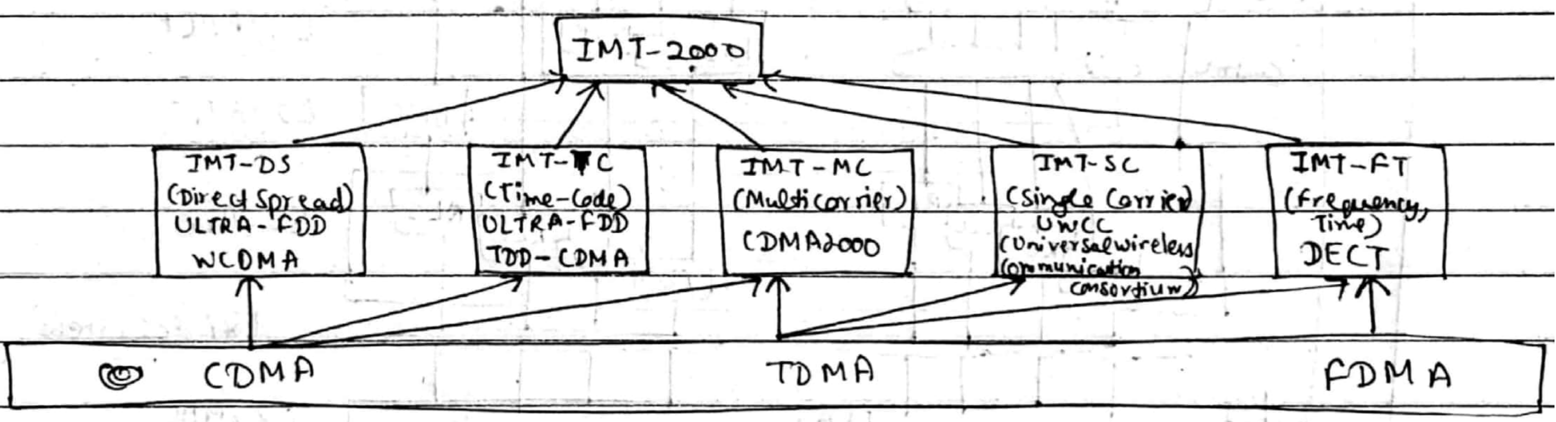
- Salient Features of IMT-2000
  1. Greater degree of security. 3G networks use KASUMI block crypto instead of older AS/1 stream cipher. End-To-End Security
  2. Data rates - 384 kbps, 144 kbps & 2Mbps
- Applications of IMT-2000
  (i) Mobile TV (ii) Video-on demand (iii) Video conferencing (iv) Tele-medicine (v) Location-based services
- IMT 2000 Family : ITU standardized five groups of 3G radio access technology:
  (i) IMT-DS (ii) IMT-TC (iii) IMT-SC (iv) IMT-FT (v) IMT-MC



- Compatibility requirements:
  (i) Direct upgrades (ii) Roaming (iii) Handover

* Wideband Code Division Multiple Access (WCDMA)

- WCDMA is one of the main technologies for implementation of 3G Cellular systems.
- Salient features:
  1. Different Types of Physical Channels
  2. Short & Long Data Packets
  3. DS-CDMA (Direct-Access CDMA)
  4. Chipping rate of 3.84 Mchips/s & QPSK modulation for forward & reverse link frequencies
  5. Compatibility with CDMA 2000 systems
  6. User-plane: Two sub layer protocols for user plane are PDCP (Packet data convergence protocol) & BMC (broadcast & multicast control protocol). These are controlled by RRC (Radio Resource Control) at network layer & are linked to

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RLC (Radio Link Control) at data link layer.

(vii) Multi-rate transmission.

(viii) Key features of WCDMA processing units:

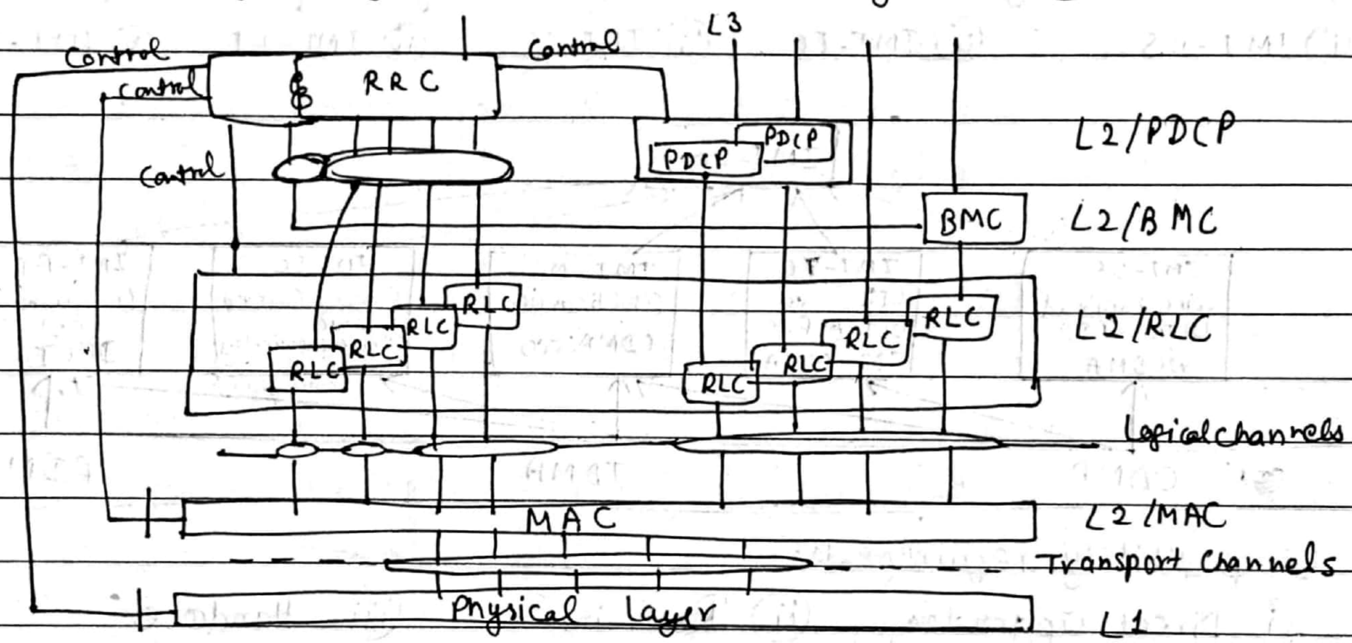
(a) Asynchronous base stations (b) Chipping rate of 3.84MHz

(c) Multi-rate transmission of signals by spread factor control (d) Use of variable data rates

- Protocol Architecture

→ Consists of 3 layers :

(i) L1 - Physical layer (ii) L2 - Datalink layer (iii) L3 - Network layer



→ Logical Channels : MAC layer provides data transfer services on logical channel

- Logical control channel
- Logical traffic channel

⇒ Logical Control Channel

(i) Broadcast Control Channel (BCCH)

(ii) Paging Control Channel (PCCH) → Down link channel

B/w MS & N/w: (iii) Common control channel. (CCCH)

(iii) Dedicated Control Channel (DCCH)

B/w MS: (iv) ODMA Common Control Channel (OCCCH) → Bidirectional channel

(v) ODMA Dedicated Control Channel (ODCCH)

⇒ Logical Traffic Channel

(i) Dedicated Traffic Channel (DTCH)

(ii) ODMA Dedicated Traffic Channel (ODTCH)

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→ Transport Channel : It is defined by how & with what characteristics data is transferred over the air interface

Two types:

(i) Dedicated channels

(ii) Common channels

- (a) Broadcast channel (BCH)
- (b) Forward Access Channel (FACH)

} → Downlink channel

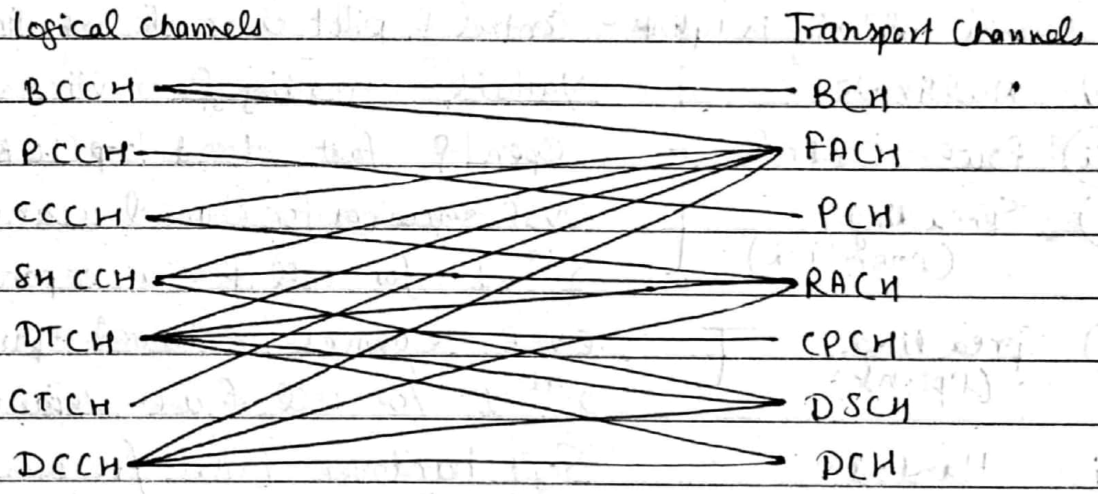
- (c) Random Access Channel (RACH)
- (d) Common Packet Channel (CPCH)

} → Uplink channel

- (e) Downlink shared channel (DSCH)
- (f) Paging Channel (PCH)

} → Downlink channel

→ Mapping b/w logical & Transport Channels



→ Physical Channels : Transport channels are mapped on the physical channels. Physical channels are merged in physical layer which consists of radio frame & time slot.
- 2 uplink channel
- 1 downlink channel

⇒ Uplink Physical Channels
- Uplink Dedicated Physical Data Channel (DPDCH) & Dedicated Physical Control Channel (DPCCH) — Uplink / Uplink / Uplink
- Physical random access channel (PRACH) & physical common packet channel (PCPCH)

(i) DPDCH (ii) DPCCH (iii) PRACH (iv) PCPCH

⇒ Downlink channels

(i) Downlink Dedicated Physical Channel (DPCH) (ii) Primary Downlink Shared Channel (DSCH)

(iii) Primary & Secondary Common Pilot Channel (CPICH) (iv) Primary & Secondary Common Control physical channel (CCPCH)

(v) Synchronization Channel (SCH)

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- WCDMA Parameters

(i) Channel Bandwidth - 5MHz
(ii) Duplex mode - FDD & TDD
(iii) Downlink RF channel Structure - Direct speed
(iv) Chip Rate - 3.84Mcps
(v) Frame length - 10ms
(vi) Spreading modulation - Balanced QPSK (downlink), Dual-channel QPSK (uplink)
(vii) Data modulation - QPSK (downlink) BPSK (uplink)
(viii) Channel Coding - Convolutional & turbo codes
(ix) Coherent Detection - User dedicated time multiplexed pilot (downlink & uplink), common pilot in the downlink
(x) Channel multiplexing in downlink - Data & control channels are multiplexed
(xi) Channel multiplexing in uplink - Control & pilot channels are time multiplexed
(xii) Multirate - Variable spreading & multicode
(xiii) Power Control - Open & fast closed loop (1.6 KHz)
(xiv) Spreading (Downlink) - OVSF sequences for channel separation Gold sequences $2^{18}-1$ for cell & user separation
(xv) Spreading (Uplink) - OVSF sequences for channel separation Gold sequences $2^{41}-1$ for cell & user separation
(xvi) Handover - Soft handover Inter-frequency handover
(xvii) ~~Mult~~ Spreading factor - 4-256 (uplink), 4-512 (downlink)

* CDMA2000

- It has a smooth transition and a better backward compatibility with 2G CDMA systems.
- It is an advancement of CDMA technology developed by Qualcomm & meant for high data rate (HDR) packet standard.
- In CDMA 2000 physical layer, originally two spreading modes, MC (Multicarrier) & DS (Direct Spread) techniques. There are two non direct modes in CDMA 2000 known as 1X & 3X. Under 1X mode it uses CDMA one carrier whereas 3X is the popular multicarrier system

Punk

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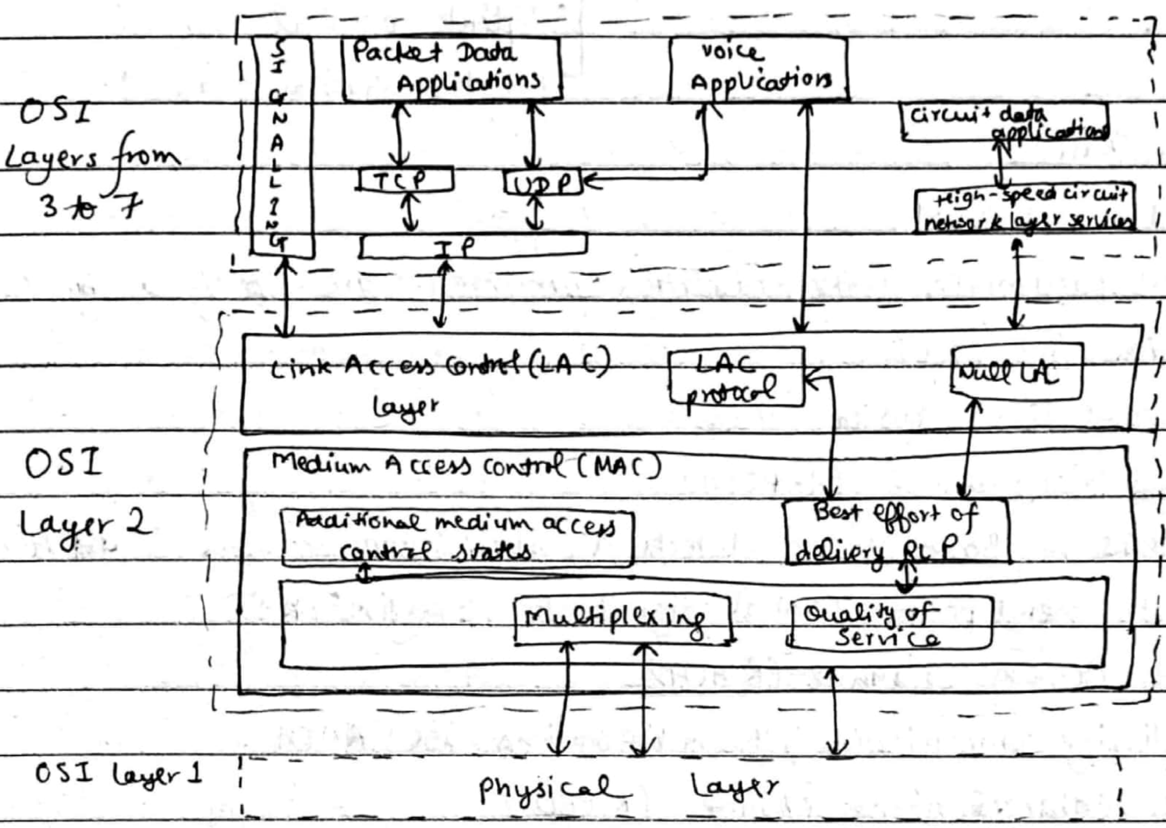
- The simplest version of CDMA 2000 standard is 1x mode.



- Uplink Characteristics
  (i) Using open or closed power control
  (ii) pilot based coherent detection
- Downlink characteristics
  (i) Fast power control
  (ii) Transmit diversity
  (iii) Synchronized based station operation
  (iv) Pilot signals
    - Common Pilot → for all users
    - Auxilary Pilot → To support smart antenna systems
- Common Characteristics
  (i) Turbo Codes for coding supplemental channels, increases robustness
  (ii) → Double no. of walsh codes ⇒ 128 walsh codes
  (iii) → Independent data channels
    - Fundamental channels (FCHs)
    - Supplemental channels (SCHs)

→ 5msec frame options
→ Chip rates with backward compatibility

Date __/__/____

- WCDMA Parameters

(i) Channel Bandwidth - 5MHz

(ii) Duplex mode - FDD & TDD

(iii) Downlink RF channel structure - Direct speed

(iv) Chip Rate - 3.84Mcps

(v) Frame length - 10ms

(vi) Spreading modulation - Balanced QPSK (downlink)
Dual-channel QPSK (uplink)

(vii) Data modulation - QPSK (downlink) BPSK (uplink)

(viii) Channel Coding - Convolutional & turbo codes

(ix) Coherent Detection - User dedicated time multiplexed pilot (downlink & uplink), common pilot in the downlink

(x) Channel multiplexing in downlink - Data & control channels are multiplexed

(xi) Channel multiplexing in uplink - Control & pilot channels are time multiplexed

(xii) Multirate - Variable spreading & multicode

(xiii) Power Control - Open & fast closed loop (1.6 KHz)

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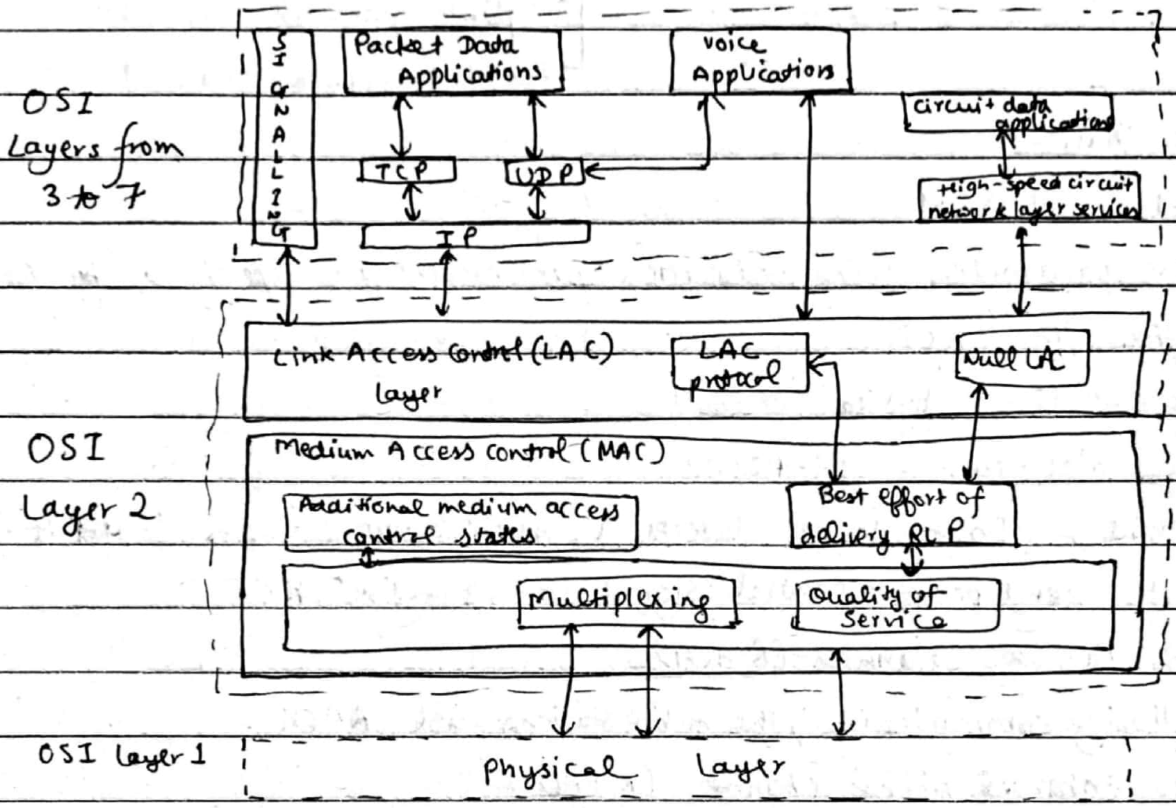

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Date __/__/____

* Different physical channels in CDMA2000
  - Data traffic physical channel
  - Uplink physical channel
  - Downlink physical channel

(i) Data Traffic Channels

(a) FCH (b) SCH

The encoding parameters & the modulation parameters are specified by the radio configuration (RC).

(ii) Uplink (Reverse link) physical channel

(a) Reverse Pilot Channel (R-PICH)

Using this, Base station (BS) detects a mobile's transmission & it is used to send power control signals to respective BS.

(b) Reverse Access Channel (R-ACH)

For initiating communication, the mobile stations use RACH.

(c) Reverse Enhanced Access Channel (R-EACH)

Used to initiate communication with BS & used by MS

(d) Reverse Common Control Channel (R-CCCH)

Intended for conveying user & signalling info to BS wherever reverse traffic channels not in use.

(e) Reverse Data Traffic Channels

(iii) Downlink Physical Channel

(a) Forward pilot channel (F-PICH)

Used to get multipath fading & channel conditions

(b) Forward Auxilary Pilot channel (F-APICH)

Used along with smart antennas in beam-forming applications

(c) Forward Transmit Diversity pilot Channel (F-TDPICH)

Intended for synchronization by mobile within a particular cell.

(d) Forward Common Control channel (F-CCH)

Used to send high-layer messages to mobile units.

(e) Forward Sync Channel (F-SYNCH)

Used for providing initial synchronization related info to MS.

Two types
- Wideband Sync Channel (For overlay & non overlay config)
- Shared Sync Channel (For overlay config)

Punk

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(f) Forward Paging Channel (F-PCH) < Wideband paging channel / Shared paging channel

Intended to transmit MS specific messages & overhead messages

(g) ~~FCB~~ Forward Broadcast Channel (F-BCH)

Intended to transmit control info to respective MS effectively which have not been allocated a traffic channel

(h) Forward Quick Paging Channel (F-QPCH)

Used by paging channel for providing control info to MS

(i) Forward Common Power Control Channel (F-CPCCH)

Necessary power control info of uplink CCH are conveyed by BS using this channel

(j) Forward Common Assignment Channel (F-CACH)

For quick assignments of reverse common control (uplink) channel by BS.

(k) Forward data traffic channel

- Data Link Control layer (DLC) Issues

It mainly uses a logical channel structure for having info exchange. There are four protocol layers specified in CDMA 2000:

(i) Physical layer (Layer 1) (ii) MAC Layer (Layer 2)

(iii) LAC layer (Layer 2) (iv) Upper layer (Layer 3)

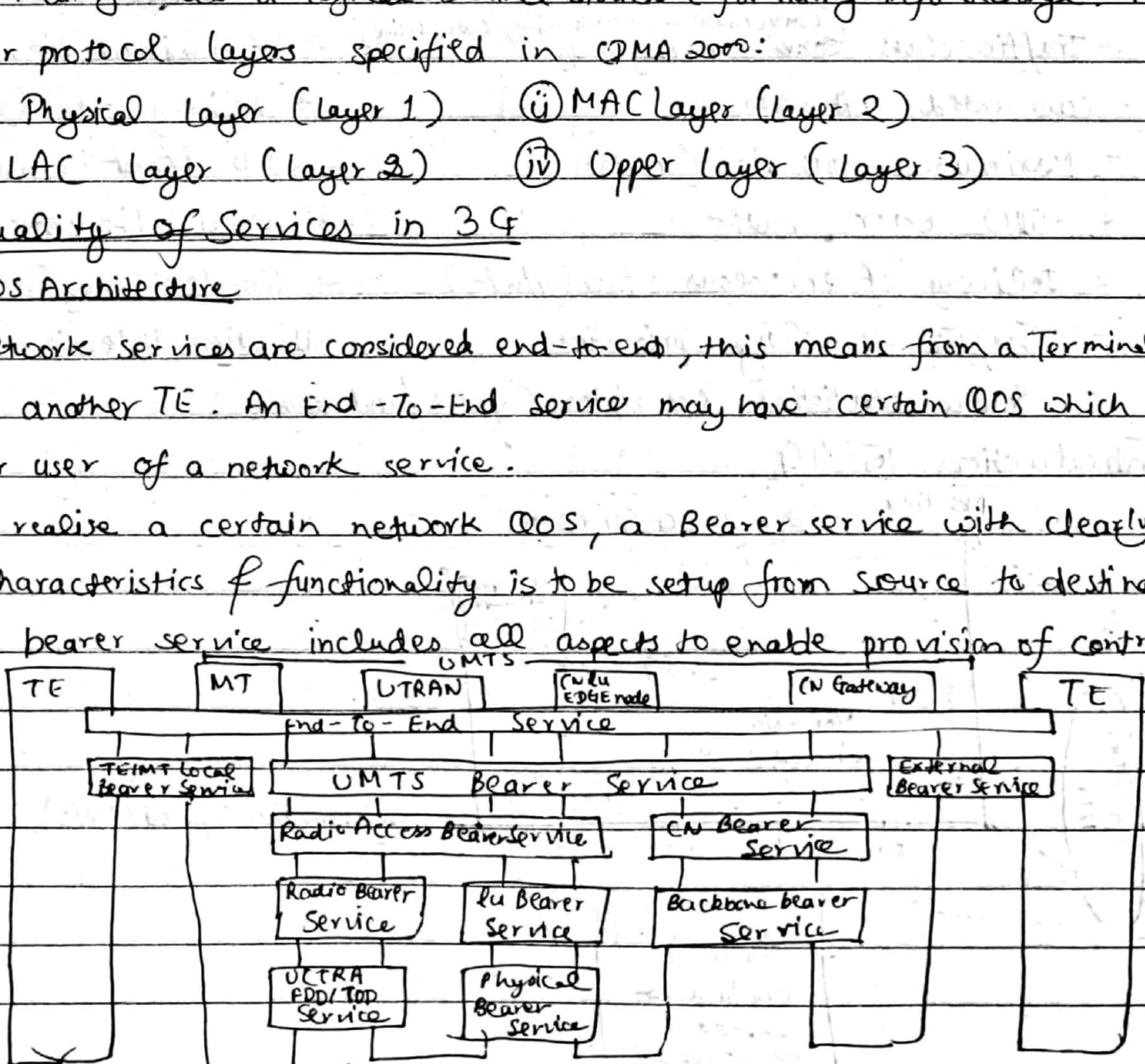
* Quality of Services in 3G

(i) QOS Architecture

→ Network services are considered end-to-end, this means from a Terminal equipment (TE) to another TE. An End-To-End service may have certain QOS which is provided for user of a network service.

→ To realise a certain network QOS, a Bearer service with clearly defined characteristics & functionality is to be setup from source to destination of se[rvice]

→ A bearer service includes all aspects to enable provision of contracted QO[S]



QOS Architecture

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(ii) There are four different QOS classes

(a) ~~Conversat~~ Conversational Class   (b) Streaming Class

(c) Interactive class   (d) Background class

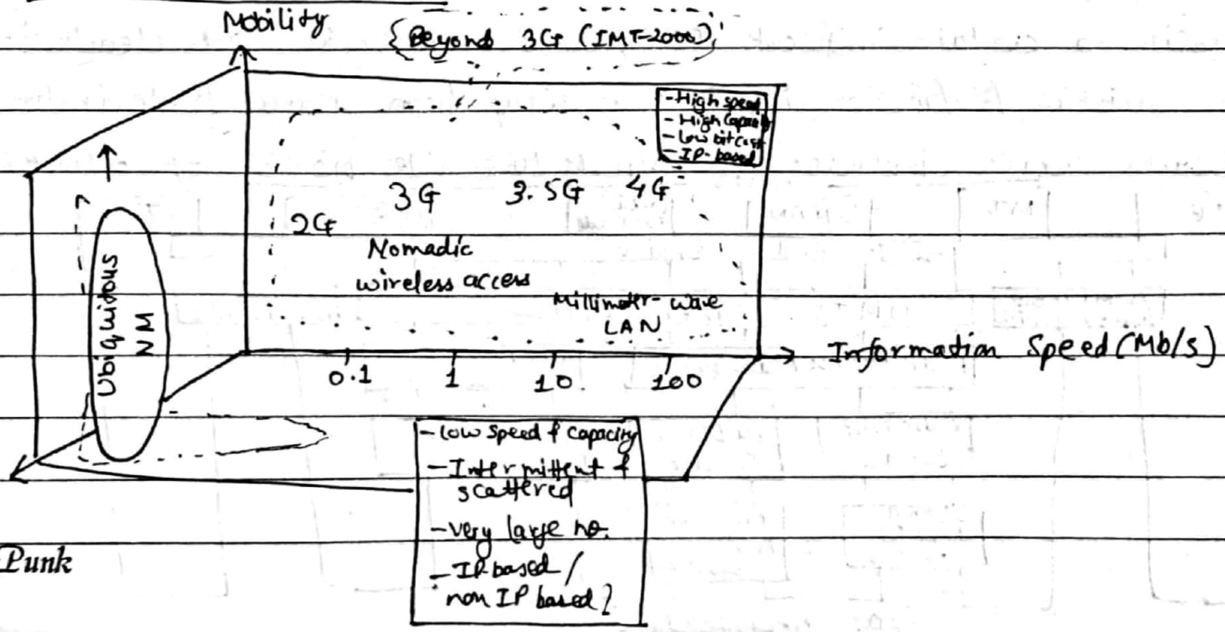
Traffic Class	Conversational Class Real Time	Streaming class Real Time	Interactive class ~~Real Time~~ Best Effort	Background class Best Effort
Fundamental Characterisition	- Preserve time relation (variation) b/w info entities of the stream - Conversational pattern (stringent & low delay)	- Preserve time relation (variation) b/w info entities of the stream	- Request response pattern - Preserve payload content	- Destination is not expecting the data within a certain time - Preserve payload content
Example of application	voice	streaming video	web browsing	Telemetry, emails

UMTS QOS Classes

(iii) List of UMTS Bearer Service Attributes

- Traffic class (~~Conv~~ Conversational, Streaming, Interactive, Background)
- Maximum bit rate (kbps)
- Guaranted bit rate
- Delivery order (y/n)
- Maximum SDU size (octets)
- SDU format information (bits)
- SDU error ratio
- Residual bit error ratio
- Delivery of erroneous SDUs (y/n/-)
- Transfer Delay (ms)
- Traffic Handling priorities
- Allocation / Retention Priority
- Source statistics descriptor (speech / unknown)

* Introduction To 4G



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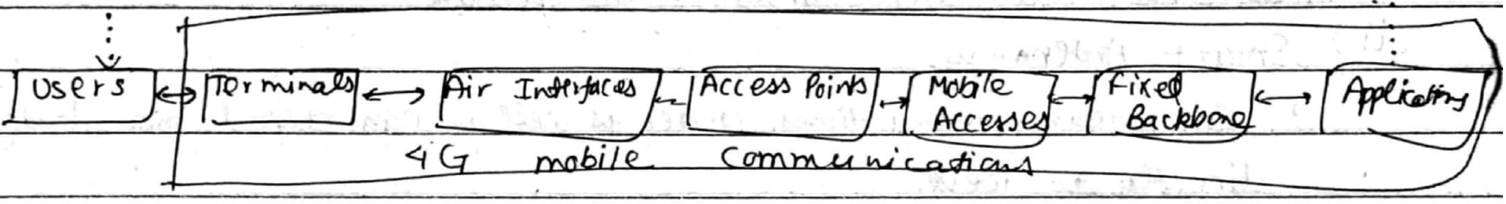
- 4G QOS:
  - → High speed transmission (peak 50-100 Mb/s, average 200 Mb/s)
  - → Larger capacity (~10 times greater than 3G systems)
  - → Next gen Internet support (IPv6, QOS)
  - → Seamless services
  - → Flexible network architecture
  - → Use of microwave band (3~6 GHz)
  - → Low system costs (1/10~1/100 of 3G systems)



- 4G vision:

Property	4G
Starting Time	2010-2012
Driven Technique	Intelligent S/W Auto Config
Representative Standard	OFDM, UWB
Radio Frequency	3GHz - 5GHz
Bandwidth	10 Mbps - 20Mbps
Multi-address Technique	FDMA, TDMA, CDMA
Cellular Coverage	Mini Area
Core networks	All-IP networks
Service Type	Multimedia Machine-to-Machine

- Barriers to Progress in 4G

Three paths : (i) Nobody makes conversion to 4G
↳ Incremental upgrades
(ii) Everyone makes conversion to 4G
↳ Cheap
(iii) Some of the players make conversion to 4G
↳ Equipment expensive

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– 4G Hardware

(i) Ultra Wideband networks

→ Ultra wideband technology or UWB is an advanced transmission technology that can be used in implementation of a 4G network.

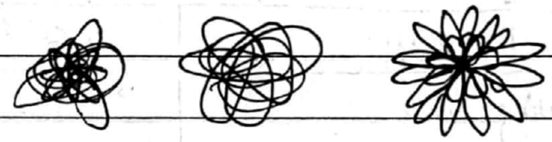
→ An UWB device works by emitting a series of short, low powered electrical pulses that are not directed at one particular freq but rather spread across entire spectrum.

→ UWB freq b/w 3.1 to 10.6 GHz. Pulse are called shaped noise as not flat but curves across spectrum.

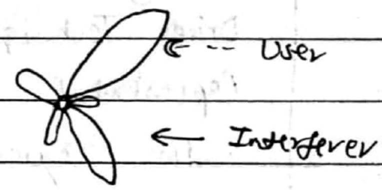
(ii) Smart Antennas

→ Can Hear many times louder as well as can respond more loudly & directly as well.

→ Two types : (a) Switched Beam antennas



(b) Adaptive ~~Smart~~ Array antennas



→ Advantages :

(a) Optimise available power (b) Increase base station range & coverage

(c) Reuse available spectrum (d) Increase bandwidth

(e) Lengthen battery life of wireless devices

– 4G Software

Multi-network functional device is a software defined radio

(i) Software defined radio

It is one that can be configured to any radio or frequency standard through use of software.

(ii) Packet Layer

It is a layer of abstraction that separates data being transmitted from the way that it is being transmitted.

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(iii) Packets :- Packets are:

Advantages

(a) more secure (b) more flexible (c) More reliable
(d) proven technology (e) easier to standardize (f) extensible

Disadvantages:

To use packet all cellular h/w will need to be upgraded or replaced.

Punk

Unit-IV

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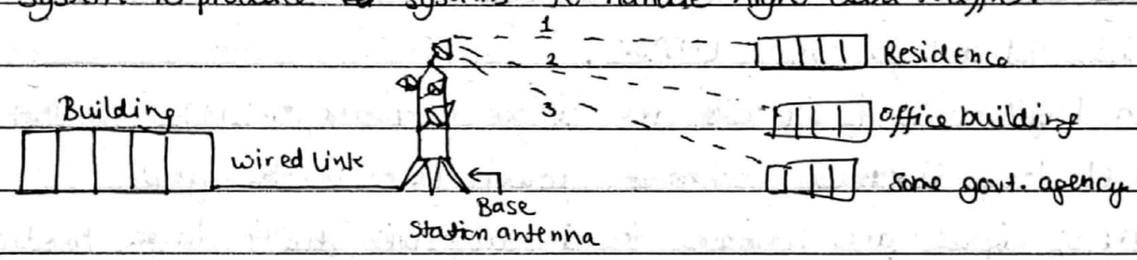
Wireless Local Loop (WLL)

* Wireless local loop

- Sometimes called radio in the loop (RITL) of fixed radio access (FRA), wireless local loop, is a system that connects subscribers to the PSTN using radio signals as a substitute for copper for all or part of the connection between subscriber and the switch.
- In WLL systems, there are two categories NWLL & BWLL. Narrowband WLL(NWLL) can be used to replace conventional telephone systems and the Broadband WLL(BWLL) can be used to produce higher speed data & voice services. Thus, WLL is the best system in local loop systems to handle high data traffic.



- The connectivity may be wireless loops in total or a hybrid of wired cables & WLLs
- An ideal WLL should have some main features:
  (i) It should have complete scalability to meet traffic requirements
  (ii) It should provide better QOS (Quality of Service)
  (iii) It should be compatible with other cellular technologies.
- Advantages of available in usage of WLL:-
  (i) Cost is comparitively less (ii) Less installation time
  (iii) Good scale of installation
- There are two types of WLL technologies available:
  (i) Local Multipoint Distribution Service (LMDS)
  (ii) Multichannel Multipoint Distribution Service (MMDS)

* LMDS

- The propagation characteristics are well defined, & reduce potential coverage area to one cell site. A frequency of 1.3 MHz bandwidth is alloted for this LMDS technique for delivering broadband services.
- The range of LMDS transmitter can be even upto 8 km in case of metropolitan regions.
- In LMDS, signals are being transmitted in broadcast or point-to-multipoint methods.

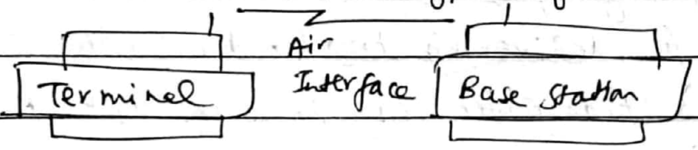
Punk

- The return path, i.e., from subscribers to BS, is of point-to-point transmission method.
- Advantages:
  (i) These systems can be deployed easily
  (ii) They are cost effective, Network management, maintenance & operation is possible
  (iii) The data rate of the system is relatively high
  (iv) The architecture is salable according to customer demands
- Main bottleneck with LMDS is that it requires large no. of Base stations due to its short range of operation from BS.

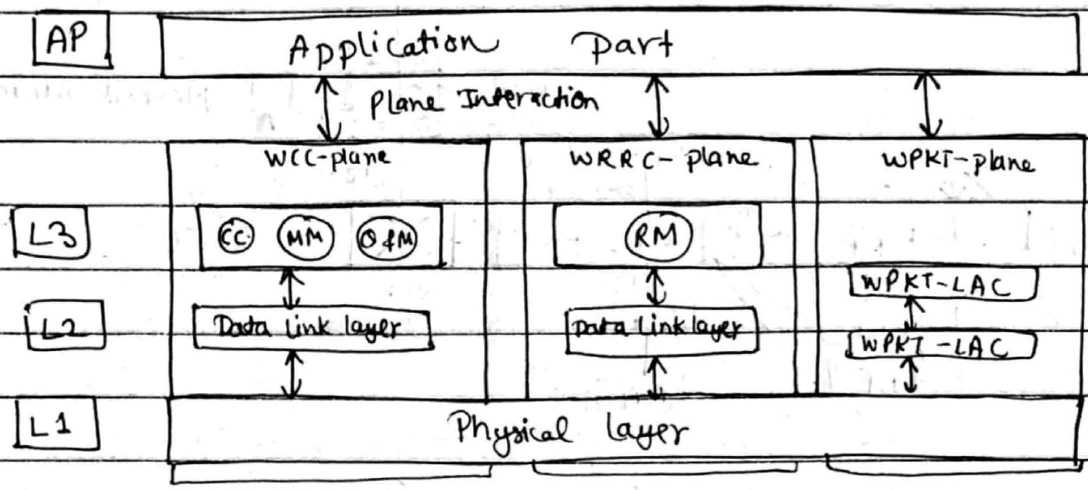
* MMDS
  - MMDS advantages over LMDS:
  (i) wavelengths (λ) of signals are larger compared to LMDS so that signals can travel long distances without power losses in the signal
  (ii) MMDS signals are immune to rain absorption due to large bandwidth of signal
  (iii) The cost involved in BS is lower in MMDS because it involves equipment that can be operated with low frequencies
  - Frequency range - 2.15 GHz to 2.68 GHz
  - Contraint regarding service area in km & transmitted power as the FCC did not allow power transmitted of BS serving & area which is more than 50 km.

* WLL user requirements
  - List of services that can be offered using WLL system:
  (i) voice service : 64 kb/s PCM, 32 kb/s ADPCM
  (ii) Voice band data service : 56 kb/s (facsimile, modem)
  (iii) Data service : 115 kb/s (Internet service, PC communication)
  (iv) ISDN services : 144 kb/s (2B+D)

* Air Interface
  - The radio interface of WLL system conforms to air interface standard. The standard allows two types of bandwidth (5 & 10 MHz).



- Basic Model of Radio Interface



→ The wireless protocol architecture consists of WLL radio resource control (WRRC) plane which is responsible for radio resource management (RM); call the WLL communication control plane (WCC) plane which is responsible for the bearer connection & call control (CC) and mobility management (MM) functions; & the WLL packet control (WPKT) plane, which supports radio transmission.

→ Each signaling plane has a general hierarchial structure pursuant to OSI model.

→ Physical layer Aspects: Modulation / Demodulation, channel encoding & decoding

→ Data link layer Aspects: Connectionless mode operation, data resending, & point to point data transfer b/w originating & terminating terminals, error control, & sequence control.

→ Network layer aspects: WRCC plane performs control procedure from power on to radio channel resource assignment, Provides Sync info control, System info control, random access control & RM & then performs internetworking with WCC plane

* WLL architecture

- WLL system includes: a WLL gateway switching system that connects radio system to PSTN; radio port controller (RPC), which provides concentration & control funcⁿ to no. of base stations called radio port (RP); & the radio interface unit (RIU), which are fixed units attached to the residential or commercial buildings. Also included are the radio port operation & maintenance unit (RPOM) which is responsible for maintaining & managing radio network elements & the internetworking function (IWF) unit

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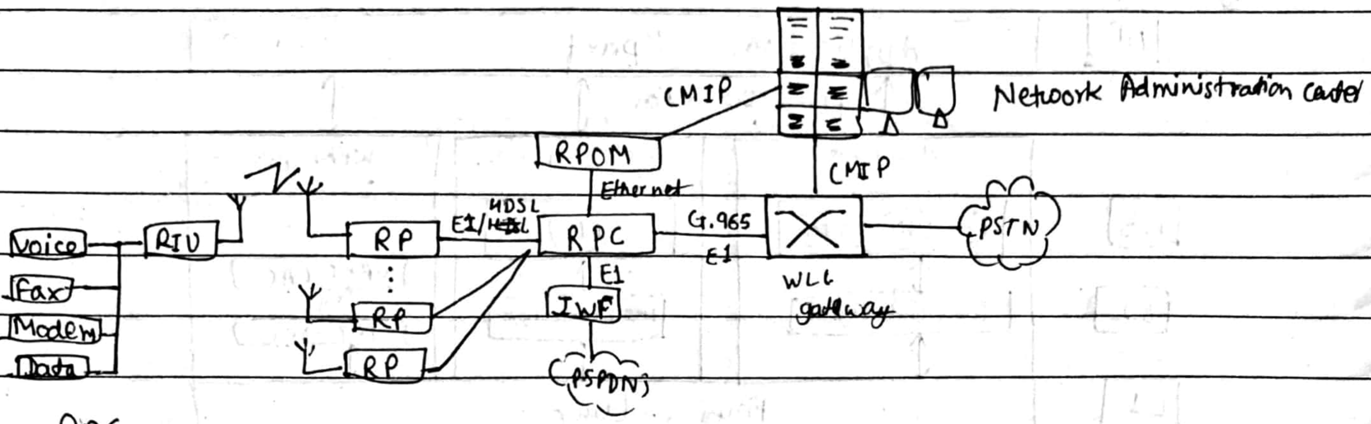
which is used as a gateway to data services & the ~~PSDN~~ public switched packet data network (PSPDN)



RPC

→ The RPC ~~internet~~ interworks with the RPOM for network management, with IWF for Internet services & PC communication & with WLL gateway switching system for accusing the PSTN & ISDN.

→ The RPC has the capability of local switching function to support calls within a RPC in case of failures.

→ A single rack RPC can accomodate upto 10,000 subscribers & a two rack RPC can accomodate upto 20,000 subscribers.

RP

→ The RP uses WCDMA based radio interface in 2.3GHz frequency range & accesses the RPC via an E1 / LAPD interface.

→ The RP provides coverage upto 8 km with line capacity of 80 channels

→ RP can provide high quality voice & data transmission, can be installed indoors or outdoors & can be operated unmanned via remote control.

RIU

→ RIU connects to RP via radio interface based on WCDMA method at 2.3 GHz.

→ on subscriber side, RIU can be connected to PSTN phones, ISDN phones, facsimile terminals, modems & PCs to provice services.

→ RIU can be configured to support 1, 2, 4, or 32 lines & distance b/w RP & RIU can be upto 8 km.

IWF

→ The IWF unit provides a gateway to external data networks, including internet, X.25 & frame relay networks.

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→ The IWF provides necessary functions to perform data & protocol conversion & inter-system interface matching when a WLL subscriber tries to ~~reach~~ search for database information of the PSPDN.

→ Modem pool module enables data transmission b/w subscriber PC & PSTN/PSPDN.

→ Direct internet access module connects subscriber's PC to Internet directly.

* WLL Technologies

- WLL systems are typically based on one of the following four technologies:

(i) Satellite-Based Systems

→ These provide telephony services for rural communities and isolated areas such as islands. They are designed for a Gaussian or Rician channel with K factor greater than 7 dB.

→ These can be of two types:

(a) Technology designed specially for WLL applications

(b) Technology piggybacked onto mobile satellite systems as an adjunct service

⇒ Of these, the former offer quality & grade of service comparable to wireline access, but it may be expensive. The latter promises to be less costly but, due to bandwidth restrictions may not offer quality & grade of service comparable to plain old telephone service (POTS)

Example of (a) is HNS ~~telephony~~ earth station (TES) technology which can make use of virtually any GEO C-band or Ku-band satellite.

→ There are many proposed system for mobile satellite service including the Inmarsat International Circular Orbit (ICO) system, Iridium, Globalstar, Odyssey, American Mobile Satellite Corporation (AMSC), Asia Cellular Satellite (ACeS) & Thuraya mobile satellite system. These systems are specialized to support low-cost mobile terminals primarily for low bit rate voice & data applications.

(ii) Cellular Based System

→ These provide high power, large range, median subscriber density, & median circuit quality WLL services. These are primarily used to expand basic telephony services. Typically, operate in 800-900 MHz, 1.8-1.9 GHz & sometimes at 450 MHz or 1.5 GHz.

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→ This approach offers both mobility & fixed access from same cellular platform.

→ Telecommunications Industry Association (TIA) group TR.45 is considering IS-136 (US Digital TDMA), IS-95 (CDMA) & PCS-1900 (GSM) based systems for WLL. These systems are all optimized for cellular telephony, i.e., for a Rayleigh Fading Channel with millisecond fade duration & with 5-10 ms of delay spread.

→ HNS E-TDMA system is a derivative of IS-136 modified specially for WLL. It is first cellular based system deployed for WLL & as a result, is mature in terms of features & capabilities it supports.

(iii) Low-Tier PCS or Microcellular-Based Systems

→ These provide low power, small range, high subscriber density, & high circuit quality WLL services. Typically operated at 800 MHz, 1.5 GHz, 1.8 GHz & 1.9 GHz

→ Compared with cellular based WLL, more stations are required to cover the same service area.

→ Low-tier systems such as PACS & PHS are designed to operate in a Rayleigh channel & can tolerate intermediate delays upto 500 ns. The basic user channel is typically 32 kbps, with aggregation possible for much higher user bandwidths.

→ The small range limits delay spread ~~improvements~~ impairment.

→ The ANSI standard PACS system was designed specially to support WLL, in addition to supporting limited mobility upto 40 mph.

→ In general such technologies were designed for indoor Rayleigh channel with delay spread less than 100 ns & picocellular coverage areas.

(iv) Fixed Wireless Access Systems

→ These are proprietary radio systems designed specially for fixed wireless application which may or may not be extensible to PCS or cordless.

→ The primary disadvantage of cellular approach is its limitation on toll-quality voice & signal transparency. The primary disadvantage of low tier PCS & microcellular approaches is their range. Non-standard & wireless access (FWA) technology can address these issues & become more efficient.

→ Such systems include Interdigital TDMA system, which is a Bellcore

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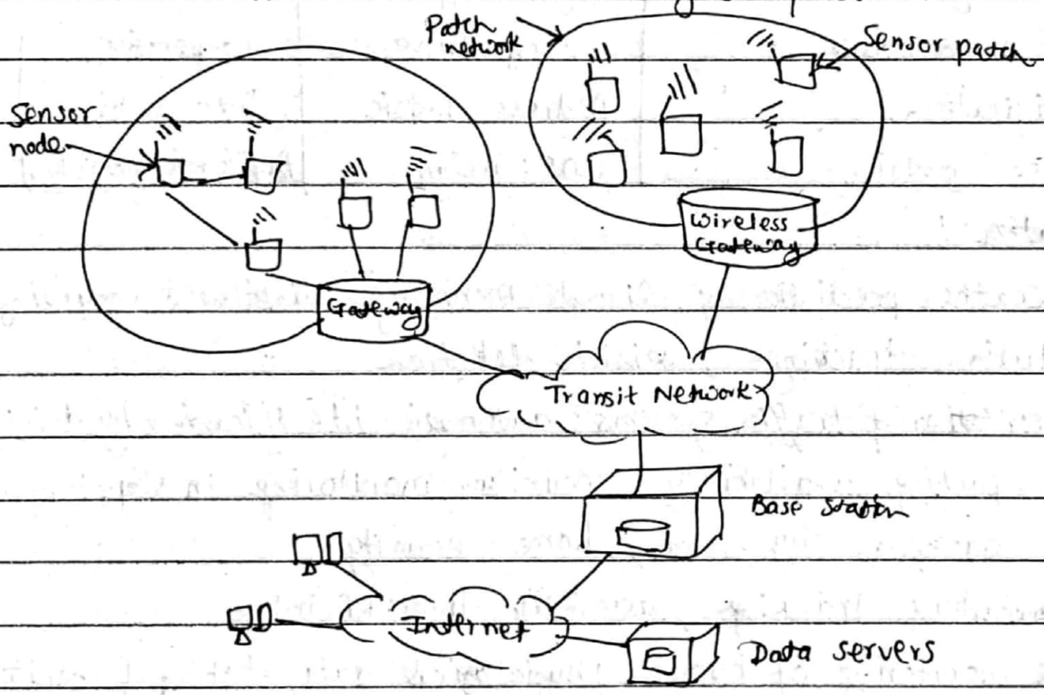
standard; the new broadband CDMA standard by Okidata, which is TR.45 interim standard from Joint Technical committee (JTC) ~~of the~~; & the Interdigital broadband CDMA technology, which is proprietary.

→ FWA system for zonal areas are designed to cover local telephone area directly from PSTN switches.

* Wireless Sensor Networks (WSNs)

- The technology required for WSNs is located b/w IEEE 802.15.1 or IEEE 802 of technology & the RFIDs. WSNs can be viewed as an extreme form of wireless ad hoc network with very low power devices.



A typical wireless sensor network

- The network consists of several 1000s or more tiny immobile sensors (also called motes) that are densely deployed in the service area on an ad-hoc basis to sense & transmit regularly some defined characteristics of surrounding environment.
- An associated BS collects ~~it & forward the~~ info forwarded by wireless sensor on a data-centric basis.

- On basis of mode of operation, two categories:

(i) Proactive WSNs: Sensor nodes ~~transmit~~ periodically switch on their transmitters, sense parameter & transmit data to network. In this way, proactive WSNs collects a snapshot of relevant parameters at regular interval of time & process the data for further use. Well suited for applications requiring periodic monitoring of data.

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(ii) Reactive WSNs: Sensor nodes react immediately to sudden & significant changes in value of a sensed parameter. Well suited for time critical applications.

— MANETs vs WSNs

S.No.	Parameter/feature	MANETs	WSNs
1.	Communication reliability	Unreliable	Unreliable
2.	Network configuration requirement	Self-configuration	Self-configuration
3.	Bandwidth requirement	Constrained	very constrained
4.	Energy requirement	Constrained	very constrained
5.	Node mobility	Typically mobile	Typically immobile
6.	Interaction among nodes	Competitive	Cooperative
7.	Nodes identification	Address centric	Data centric
8.	Performance metric	QoS: delay	Application specific QoS

— WSNs applications:

(i) Environment: weather prediction; climate monitoring, distributed computing, pollution tracking; seismic detection

(ii) Urban: Transportation & traffic systems; automatic identification by driving license, parking availability, security monitoring in shopping malls, parking garages, city streets, home security

(iii) Industry: Inventory tracking, assembly lines: RFID tags

(iv) Medical: Tele-monitoring of human physiological data, taking & monitoring doctors & patients inside a hospital & insurance cards, aids for visually handicapped.

(v) Military: To track & monitor movements of enemy troop or terrorists.

Wireless Personal Area Networks (WPAN)

* **WPAN**

- The term PAN (Personal Area Network) was introduced to denote a communication b/w proximal electronic devices by using the body as a conduit for information.
- The motivation for such a network comes from the fact that there is need for data exchange not only on large distances but also b/w devices carried by one person or surrounding the person at a conversational distance.
- PAN will cover the personal space surrounding the person within the distance that can be covered by the voice & have capacity in range of 10bps to 10 Mbps.
- WPAN represent an example of ad hoc networks which provide capability of establishing mutual on-demand wireless links with either little or no preconfiguration.

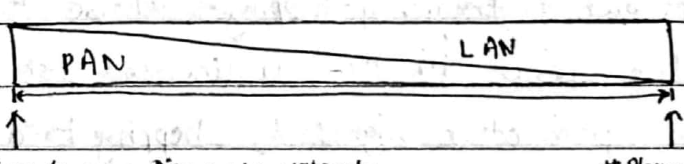
- • **PAN**

→ PAN is a network solution that enhances our personal environment, either work or private, by networking a variety of personal and wearable devices.

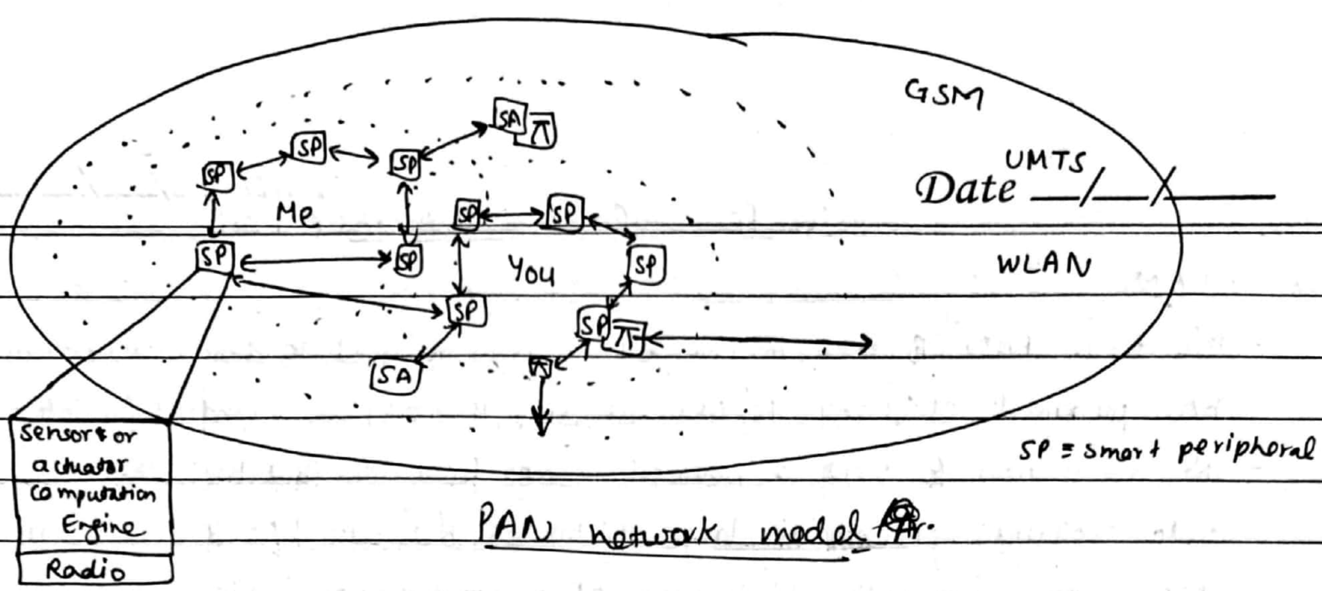
→ For the networking of proximate devices, PAN may use the wireless medium, the electric field of human body as conductor, the magnetic field and so on. In particular, when it uses the wireless medium, it is referred to as wireless PAN (WPAN).

→ The WPAN forms a wireless "bubble" around person, referred to as personal operating space (POS). Any time two WPAN-equipped devices get within approximately 10m of one another (i.e., their POSs intersect), they can form a spontaneous, just-in time, disposable connection.

→ WPAN is short range wireless technology which emphasizes low cost & low power consumption, usually at the expense of transmission speed range & max data rate.



# Spontaneous Disposable Networks	# Planned, fixed networks
# Lower cost & power	# Higher cost & power
# Shorter range	# Longer range
# 1-10Mbps peak speed	# 10-100



PAN network model

* Bluetooth Technology : IEEE 802.15

- Bluetooth technology lies under WLAN. The WPAN uses infrared rays & radio waves
- One of the PAN technology standard, known as Bluetooth, uses radio instead of infrared. The data rate is of 1 Mbps for a distance of 10 meters, approx.
- It is independent of line of sight technique. Therefore WPAN works in adhoc mode only.
- adhoc means spontaneous small area network. The new devices like Bluetooth or 802.11 IEEE standard uses this "adhoc" technique. Therefore Bluetooth deals with short range wireless technology. It provides low cost solⁿ. It also provides link b/w mobile computers, portable handheld devices, cellular phones etc. ~~The Blueto~~

* Bluetooth

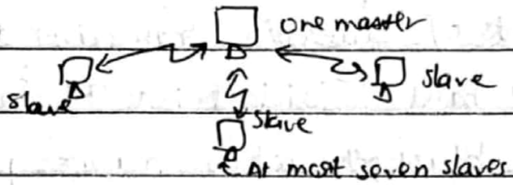
- Bluetooth is the name given to a new technology using short-range radio links, intended to replace the cable(s) connecting portable and/or fixed electronic devices.
- Its key features are robustness, low complexity, low power & low cost. Designed to operate in noisy frequency environment, Bluetooth radio uses a fast acknowledgement & frequency-hopping scheme to make link robust.
- Bluetooth modules operate in the unlicensed ISM band at 2.4 GHz & avoid interference from other signals by hopping to a new frequency after transmitting or receiving a packet.
- A Bluetooth LAN is an Ad hoc network. It is possible to connect the Bluetooth LAN to the Internet. This technology is implemented using the IEEE 802.15 standard.

- Architecture :

→ Bluetooth defines following two types of networks:

(i) Piconets

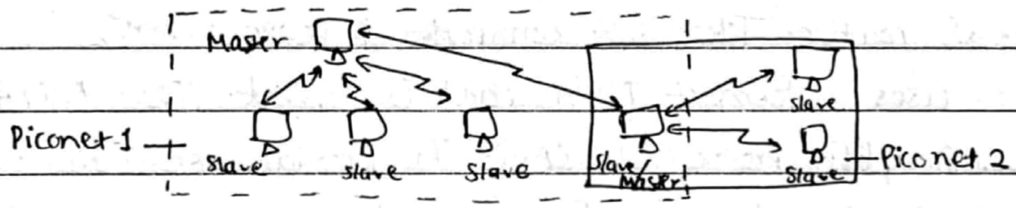
A bluetooth network is called piconet or small net. It can have atmost eight stations, one of them is called master & other slaves. All slaves are synchronized with master. A piconet can have only one master station. The communication b/w a master & slaves can be one-to-one or one-to-many.



Piconet

(ii) Scatternet

Piconets are combined to form a scatternet.



A slave in ~~Piconet 1~~ the first piconet can act as master in the second piconet. It will receive messages from master in first piconet by acting as a slave & then delivers the message to the slaves in the second piconet.

- Bluetooth Devices

→ Every bluetooth device consists of a built in short range radio transmitter. The data rate is 1 Mbps & bandwidth is 2.4 GHz.

→ The Bluetooth specification standard defines a short range (10-meter) radio link.

→ Devices carrying Bluetooth-enabled chips can easily transfer data at a rate of about 1Mbps within 10m (33 feet) of range through walls, clothing & luggage bags.

→ Each Bluetooth-enabled device contains a 1.5-inch square transceiver chip operating in the ISM (industrial, scientific, & medical) radio frequency band of 2.40 GHz to 2.48 GHz. This frequency is generally available worldwide for free without any licensing restrictions. The ISM band is divided into 79 channels with each carrying a bandwidth of 1 MHz.

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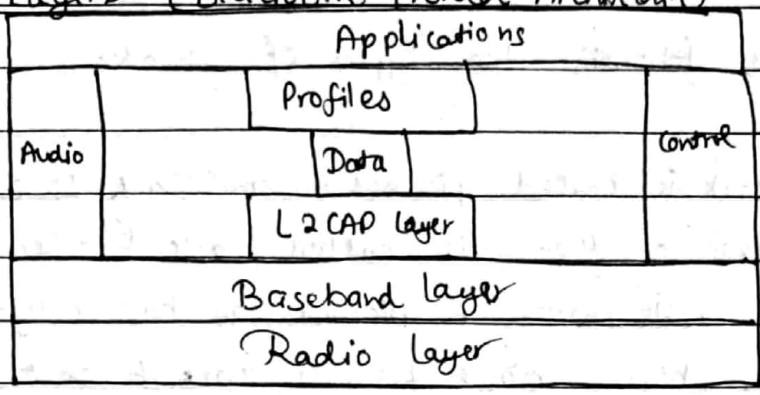
- Bluetooth Layers (Bluetooth Protocol Architecture)



(i) Radio: It defines requirements of Bluetooth transceiver device operating in the 2.4GHz ISM band. This band is divided into 79 channels of 1MHz each.

(ii) Baseband: Physical layer of Bluetooth which manages physical channels & links apart from other services like error correction, data widening, hop selection & Bluetooth security. The Baseband protocol is implemented as a link controller, which works with the link manager for carrying out link level routines like link connection & power control.

(iii) TDMA: Bluetooth uses a form of TDMA that is called TDD-TDMA.

(iv) Logical Link Control & Adaptation Protocol (L2CAP): It provides connection-oriented & connectionless data services to upper layer protocols with protocol multiplexing capability, segmentation & reassembly operation, & group abstractions. L2CAP permits higher-level protocols & applications to transmit & receive L2CAP data packets upto 64 kilobytes in length.

Bluetooth	WLAN IEEE 802.11 x
(i) Hop frequency is 1600 hops/second	(i) Hop frequency is 2.5 hops/second
(ii) Data transfer rate is 1 Mbps	(ii) Data transfer rate is 11 Mbps.
(iii) Transmission range is 10m.	(iii) Transmission range is 15-150 m indoor and 300 m outdoor
(iv) It uses lower transmission power	(iv) It uses more transmission power than Bluetooth
(v) It uses GFSK (Gaussian frequency Shift Keying) modulation technique	(v) It uses CCK (Complementary Code Keying) modulation technique.
(vi) Being a Standard for short time network ~~is for longer time network~~	(vi) Standard for LAN & for longer time network.
(vii) Used to connect devices that are in close proximity	(vii) It is a full LAN connectivity solⁿ designed to provide full network service at Ethernet data rate.

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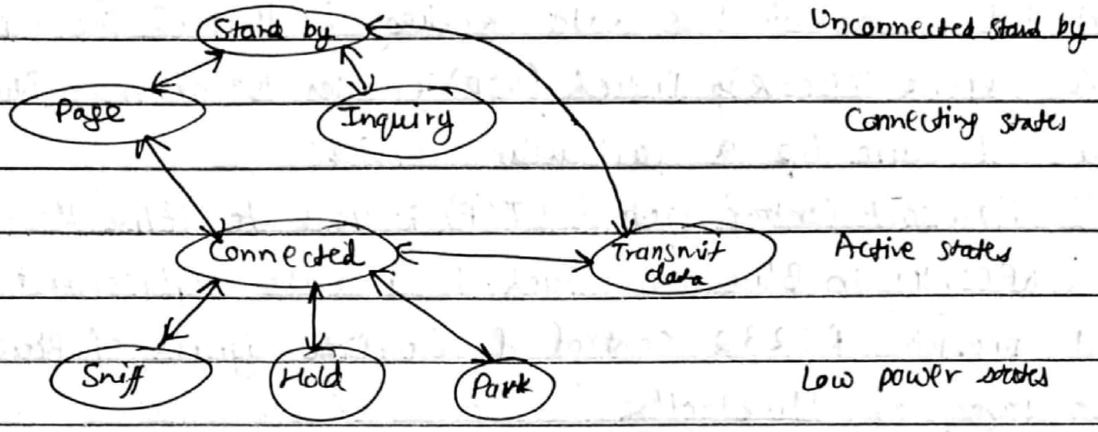
- Bluetooth Connection Mode Relationship

→ Four possible modes:

(i) Active mode (ii) Hold mode (iii) Sniff mode (iv) Park mode

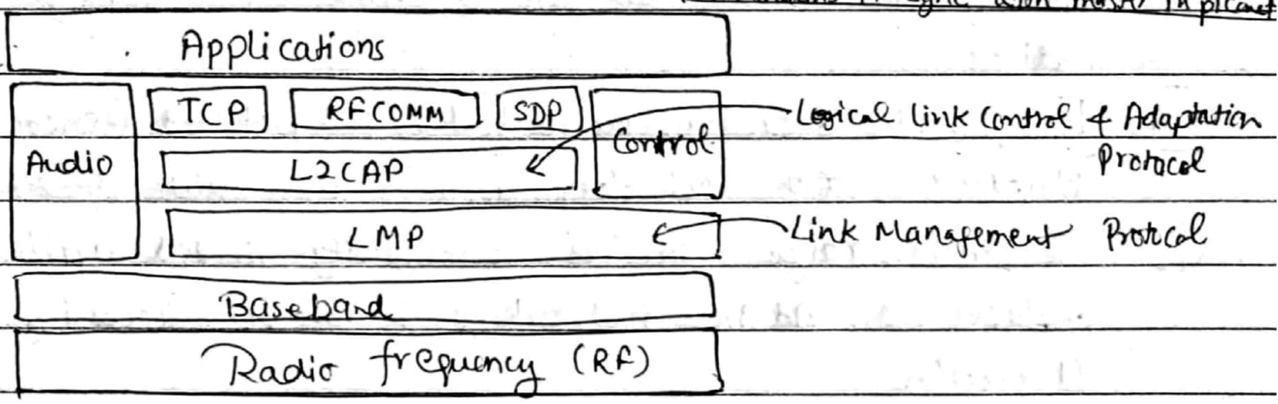


→ If a Bluetooth devices is in active mode, it transmits & receive packets, which may be of data or control packets. Each slave is assigned a bit address to differentiate it from a packed device.

→ The other three modes are mainly intended for saving power by reducing their own duty cycles.

→ When device is in hold mode, it has intermediate power efficiency which is achieved by making particular device inactive temporarily for short time intervals. The sniff mode is good in prolonging the battery life by minimizing unnecessary transmission of the poll packets. When a slave decides to be inactive for particular time period, it enters park mode which has large duration than others. ~~Communication b/w master & slave~~ Slave doesn't participate in data traffic but maintains its sync with master in picanet

* Bluetooth Protocol Stack Architecture



- In Bluetooth, protocol stack enables communication with many devices. It includes data & control signalling in Bluetooth.
- Radio modem is specified in RF layer.
- The link control & bit levels are specified by the baseband layer.

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- The link management protocol (LMP) is capable of configuring links with other devices. It provides power modes, traffic scheduling, packet format, state of units in piconet, authentication & encryption with L2CAP connection oriented & connectionless data services to that of the upper layer protocols.
- The Service Discovery Protocol (SDP) enables two or more Bluetooth devices in case of supporting a particular service.
- The Transport Control Protocol (TCP) is used to define the both call control.
- The RFCOMM in Bluetooth stack is a cable replacement protocol that will provide RS232 control & also data signals of Bluetooth baseband signal

* **Advantages of Bluetooth**

(i) Eliminates usage of cables linking computers to keyboards, mouse & printers.
(ii) Call home from a distant place to turn any appliances on & off, ~~set~~ ~~to~~ alarm etc.
(iii) Enables MP3 players in wireless fashion, to other machines.
(iv) To make calls from a wireless headset which is connected remotely to cellular
(v) It helps in monitoring remotely the home networks; air conditioners, ovens etc.
(vi) ~~It~~ The control is possible with Bluetooth upto 10 meters. It is developed such that it can be used by many users.
(vii) The piconet setup, i.e., 8 small devices can communicate in a small network helps to develop networking for a shorter range. Also, upto 10 piconets can be in a same coverage range of the Bluetooth radio.
(viii) To provide security, each link is protected & encoded & therefore, Bluetooth ~~tech~~ technology assures user authentication.
(ix) The short range wireless connectivity-oriented applications like cable replacement, Ad hoc networking & data-voice accessing are possible with Bluetooth.

* **WiMAX (IEEE: 802.16)**

- WiMAX is defined as Worldwide Interoperability for Microwave Access by the WiMAX forum, formed in 2001 June to promote conformance & interoperability of the IEEE 802.16 standard, officially known as Wireless MAN.

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- WiMAX aims to provide wireless data over long distances, in a variety of different ways, from point to point links to full mobile cellular type access.

- Uses: The bandwidth & reach of WiMAX make it suitable for following potential applications:
  1. Connecting Wi-Fi hotspots with each other & to other parts of the internet.
  2. Providing a wireless alternative to cable & DSL for last mile (last km) broadcast access.
  3. Providing high speed data & telecommunications services
  4. Providing a diverse source of Internet connectivity as part of a business continuity plan.
  5. Providing nomadic connectivity
- Broadband Access
  → In areas without pre-existing physical cable or telephone networks, WiMAX may be a viable alternative for broadband access that has been economically unavailable.
  → WiMAX access was used to assist with communications in Aceh, Indonesia after Tsunami in Dec 2004. WiMAX provided broadband acess that helped regenerate communication to & from Aech so that condition post-tsunami can be retrieved.
- Limitations:
  → In practice, you could deliver symmetrical speeds of 10 Mbps at 10 km but in urban environments, it is more likely that 30% of installations may be non-line-of-sight & therefore users may only receive 10 Mbps over 2 km.
  → There is no uniform global licensed spectrum for WiMAX.
    US ⇒ Around 2.5 GHz
    Asia ⇒ 3.3 GHz   elsewhere ⇒ 3.5, 2.3/2.5 or GHz

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* WiMAX vs wifi

- WiMAX is a long range (many km) system that uses licensed or unlicensed spectrum to deliver a point-to-point connection to the Internet from an ISP to an end user. Different 802.16 standards provide different types of access, from mobile to fixed.
- wi-fi is a short range (upto few 100s of m) system that uses unlicensed spectrum to provide access to a network, typically covering only the network operator's own property. Typically wi-fi is used by an end user to access their own network, which may or may not be connected to Internet. If WiMAX provides services analogous to a cell phone, wi-fi is more analogous to a cordless phone

* Introduction To Mobile Adhoc Networks (MANETS)

- Ad hoc networks consists of a collection of wireless nodes. These nodes are connected with each other to dynamically establish an Adhoc or on-the-fly network without any kind of support of any centralized infrastructure. In this kind of network, each mobile host works as a router which enables peer-to-peer as well as peer-to-remote wireless communications.
- An alternative way for mobile communication, in which mobile devices form a self-creating, self-organising and self-administering wireless network, called a mobile adhoc network.
- Features of Adhoc networks:

(i) Autonomous & infrastructureless
(ii) Multi-hop routing
(iii) Dynamic network topology
(iv) Device heterogeneity
(v) Energy constrained operation
(vi) ~~Variable~~ Bandwidth constraint variable capacity links
(vii) Limited physical security
(viii) Network Capability
(ix) Self-creation self-organization & self-administration

- Advantages of Adhoc networks:

(a) No infrastructure & lower cost
(b) Mobility (MANET Only)
(c) Decentralized & Robust
(d) Easy to build & spontaneous infrastructure

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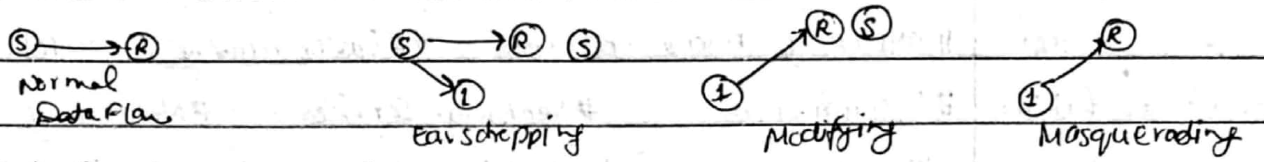
- Disadvantages of Adhoc networks

(a) Higher error rate (b) lower data rate (c) Dynamic topology & scalability

(d) Security (Eavsdropping, Traffic analysis, Masquerading, Replay, message modification, DoS)

$\underbrace{\text{Eavsdropping, Traffic analysis}}_{\text{Passive}}$ $\underbrace{\text{Masquerading, Replay, message modification, DoS}}_{\text{Active}}$



(e) Enery limitation (MANET only)

	Advantages	Disadvantages
Infrastructure	As ~~described earlier~~, The adhoc networks do not rely on any infrastructure. They work independently, are more robust, & it is cheaper to form ad hoc network. There is no installation, maintenance cost.	without any help from infrastructure, the nodes have to work harder. They have to hop the messages, secure their own resource from attackers, perform a routing table, etc.
Mobility	In ad hoc network, a node can move free theoritically. As long as this node can hop to a node inside network, it can also communicate with other nodes in network.	In practical, it is hard to form a network in which a node can move freely.
Scalability	Depend on routing algorithm, how adhoc networks can perform well.	A Table driven algo would not perform well, because there will be big overhead.
Routing	In the infrastructure networks, if the access point is defected, there will be no more communication in the affected cell.	Mobility & increased or decreased no. of nodes can force some routing algorithms to alter their routing table.
Security	Some attacks can cause malfunction. If one of participant is attacked & it doesn't work anymore, the network can relay the messages through other route (if alternative route is available)	Internal attacks may be possible via ad hoc transmissions. It means, the attacker can disguise itself as ad hoc participant. It can spy, modify, or delete the hopped messages.

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- Application of Adhoc networks

Application	Possible Scenarios / Services
Tactical Networks	#Military communication & operations #Automated battlefields
Emergency Services	#Search & rescue operations #Disaster recovery # Police & fire fighting
Commercial & civilian environments	#E-commerce #Vehicular Services #Network of visitors at airport #Sports, stadiums, trade fairs, shopping malls #Mobile offices etc.
Home & enterprise networking	#Home/office wireless networking # Conference, meeting rooms # PAN, personal networks (PN) #Network at construction sites
Education	#Universities & campus settings #virtual classrooms
Entertainment	#Multi-user games # wireless P2P networking # Robotic pets # Outdoor Internet Access # Theme parks
Sensor networks	# Home applications # Body area networks (BAN) # Data tracking of environment
Context Aware Services	#Follow-on services: Call forwarding etc. # Infotainment: Touristic info #Information Services: Location specific services, Time dependent services
Coverage extension	#Extending cellular network access # linking up with Internet, Intranet etc.

- Hidden-Node problem & exposed node problem in MANET

* Global Mobile Systems

- Communications satellites have operated using a geostationary orbit (GEO) lying about 36000 km above earth's surface. From this orbit, the satellite appears to be stationary (fixed) above a specific location from earth & therefore ensuring continuous, uninterrupted coverage to that particular location.
- The primary role of a geostationary communication satellite is to act as a wireless repeater station in space that operates in a broadcast mode & provides a microwave link b/w two remote locations on earth.
- To support a wide range of services & provide superior service quality comparable to that available from terrestrial wireless & wireline networks, constellations of satellites operating in low earth orbits (LEO) or medium earth orbits (MEO) are considered more suitable

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S.No.	Characteristic	Satellite Type GEO	MEO	LEO
1.	Altitude range	36,000 km	10,000-20,000 km	500-2000 km
2.	Satellite visibility	24 hours	2-4 hours	10-20 minutes
3.	Round-Trip Delay	500 ms	40-80 ms	5-10 ms
4.	Satellite Lifetime	20-30 year	10-15 years	4-8 years
5.	Satellite Constellation Cost	Low	Medium	High

- A no. of global mobile satellite systems are in various stages of development & deployment, with the first global mobile satellite service initiated in 1998. The four such systems that are in advanced stages of planning and/or early implemenentation are Iridium, Globalstar, ICO & Teledesic.
- To provide global coverage for mobile subscribers, LEO systems need to deploy a large no. of satellites; they must either support intersatellite links (Iridium, Teledesic) or use a large no. of ground stations (Globalstar).

* An Iridium System

- It can be termed as an extension of existing wireless systems to provide mobile services to remote & populated areas which are not covered by terrestrial cellular services.
- An Iridium system provides more capacity & better QOS & also provide emergency services in event that terrestrial cellular services are disabled in disaster situations.
- 66 LEOs in six orbital plane (11 in each plane, with uniform nominal spacing of 37.7°) are in operation. The satellites have circular orbits at an altitude of 783 km. Each iridium satellite uses a 48-beam antenna pattern & each beam which has a minimum diameter of 600 km, can be individually switched.
- Each satellite is equipped with two-way communication links.
- Only about 2/3 of beams will be active at given time because some beams will be switched off when satellites are in vicinity of poles, where beams tend to overlap, or when satellites are over countries or regions in which, iridium doesnot have regulatory arrangements to operate. The switching of beams is referred as a cell management.

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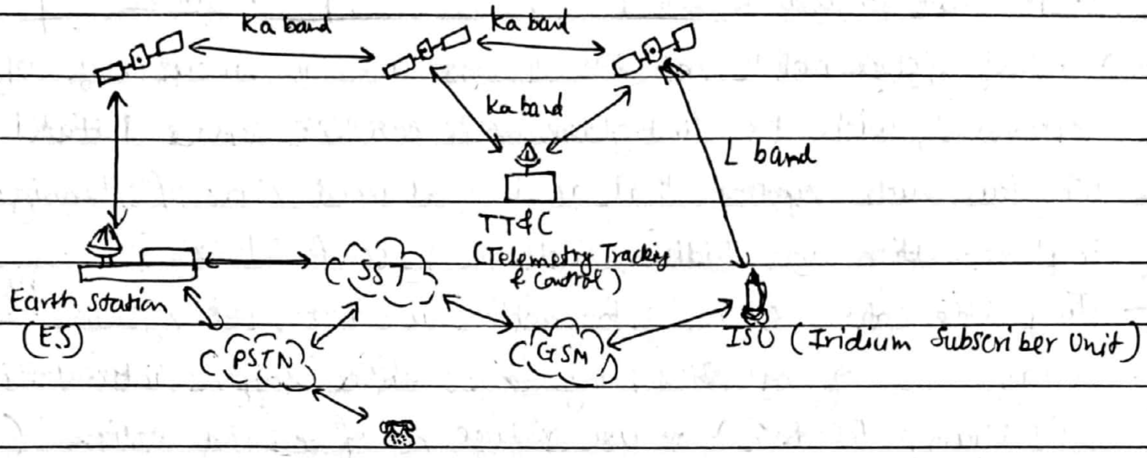
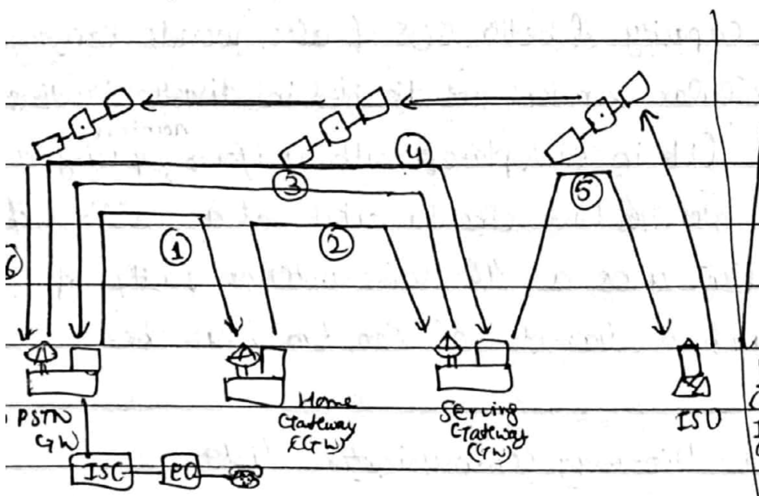
- Beams are equivalent to cells associated with terrestrial mobile system. Cell mangement or switching of beams to provide continuity of existing call is equivalent to handoff in terrestrial cellular mobile systems. This requirement of cell mangement is an additional complexity associated with LEO-based systems compared with MEO or GEO systems.

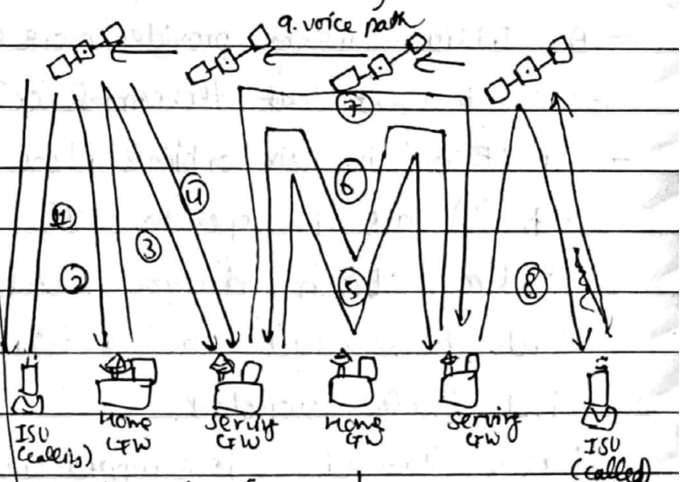


- Connections b/w Iridium satellites & PSTN are provided via gateways. The intersatellite links b/w neighbouring satellites provide flexibility for location of earth stations & remove requirement that an ES be continuously available within satellite footprint. The ISU would be a dual mode mobile station that will support both satellite & terrestrial mobile network interface standards.



1. PSTN GW sends ISU's MSISDN to home GW
2. Home GW queries serving GW for ISU location info
3. Serving GW routes a call to servicing GW
4. PSTN GW routes call to servicing GW
5. servicing GW alerts terminating ISU
6. Voice path after ISU answers

Call Flow Example PSTN-ISU



1. ISU acquires SV
2. Access to Home GW for authentication (calling)
3. Service transferred to GW (calling) after authentication
4. Setup request to servicing GW (calling)
5. Location query to servicing GW (called)
6. Location info to servicing GW (calling)
7. Route call to servicing GW (called)
8. Ring Alert ISU (called)
9. Establish voice path on answer

Call Flow Example ISU-ISU

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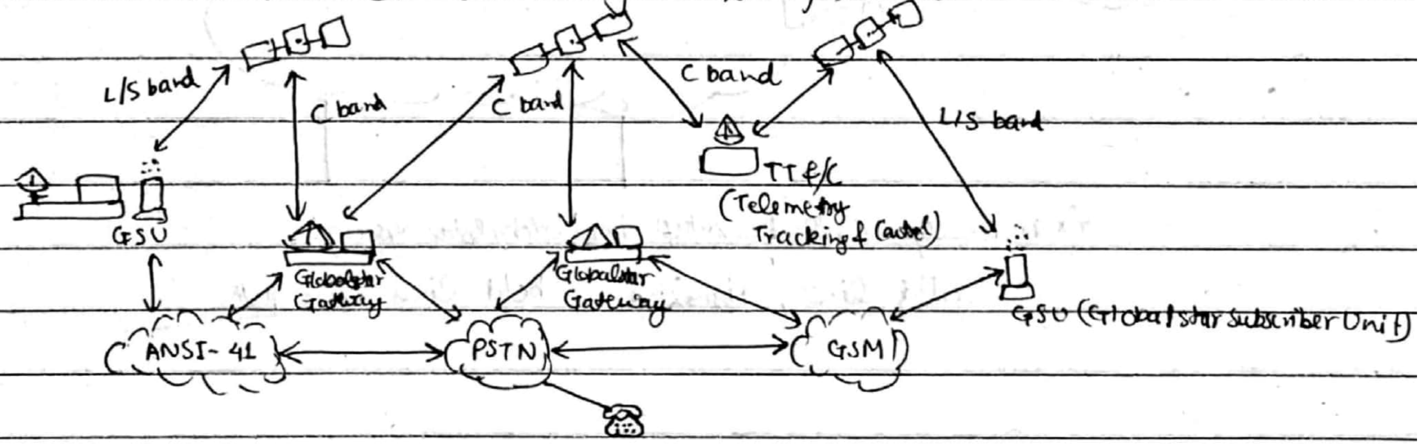
* The GLOBALSTAR System

- Based on a constellation of 48 LEO satellites at an altitude of 1414 km in 8 ~~orbital~~ planes inclined at 52°.
- Unlike Iridium system, Globalstar system does not use intersatellite links but rather depends on a large number of interconnected earth stations or gateways for efficient call routing and delivery over the terrestrial network.
- To provide telephone & messaging services to subscribers in locations that are not covered, or inadequately covered, by conventional wireline or wireless networks.
- Satellites provide only transponder functions making their design and operation less complex and perhaps more reliable. Each satellites supports a 16-beam antenna & Globalstar deploy path diversity.
- To provide the interface b/w ground segment (terrestrial networks) & space segment (Globalstar satellites), globalstar design destation equipped with three to five antennas that can track trajectories of the satellites.



- Globalstar uses two types of communication links: service links in the L/S band for communication b/w terminals & space vehicle & gateway links in C band for communication b/w earth stations and space vehicles.
- Globalstar uses CDMA for service links & FDMA/FDD for gateway links with QPSK modulation. CDMA provides increased ~~capa~~ capacity through its frequency reuse voice activity detection, & spectrum-sharing capabilities, and better performance through its support for multiplies diversity.
- Globalstar doesnot supports ISLs & supports a range of terminals including fixed (public call box PABX), mobile (automobiles), & handheld terminals.
- The following four versions of handheld terminals, with max ~~po~~ transmit power capability of 2W, will be used by Globalstar:

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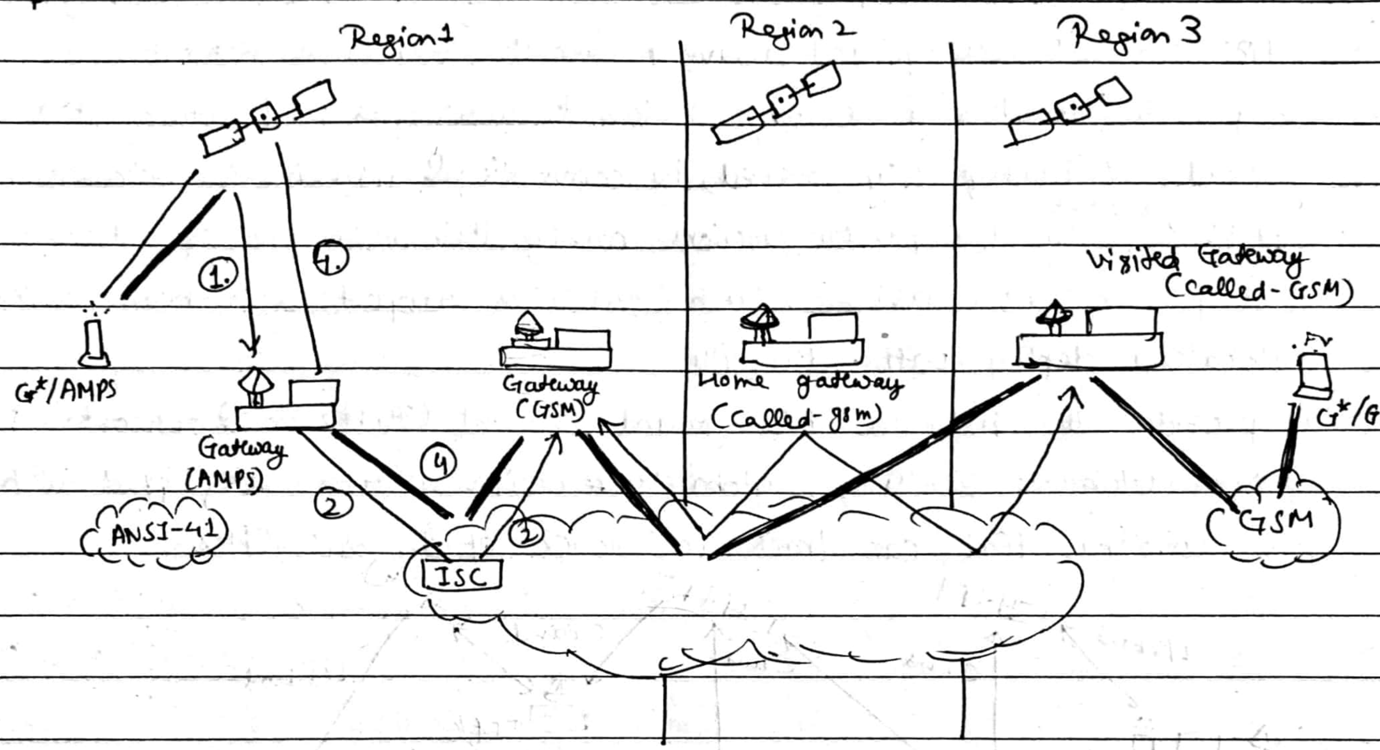
(i) single-mode : Globalstar
(ii) undual-mode : Globalstar / GSM
(iii) dual-mode : Globalstar / CDMA cellular
(iv) triple-mode : Globalstar / CDMA cellular / AMPS cellular



Example of called setup in Globalstar system:
solid lines, signaling , bold lines voice path.