Mobile Computing

Unit-I

Mobile Physical Layer

* **Introduction**

- Communication, knowledge sharing, commerce & entertainment. This coverage is called Information and Communication Technologies (ICT).
- The first wireless n/w was commissioned in Germany in 1958. It was called A. Metz & used analog technology at 160 MHz. Only outgoing calls were possible in this n/w.
- Commerical service of GSM started in mid 1991.

* **Review of Generation of Mobile Services:**

- 0G = Mobile Radio Telephone (Pre-cellular Systems)
- 1G (AMPS) : Analog telecommunications standards introduced in 1980's
  : Able to transfer calls from one site to next during a conversation as the user is moving.
- ~~2G~~ : ~~Digital N/ws~~ : Uses FDMA for Modulation
- 2G (GSM) : Digital N/w - uses digitized technology in 1991
  : uses combination of TDMA & FDMA technologies. Data is transacted over ~~circuits~~ Circuits (this technology called circuit switched data / CSD)
  : Text messages, picture messages & Multi media messages
  : Faster phone to n/w signalling, less battery consumption, clear voice, reduce noise.
- 2.5G (GPRS) : High data rate from 56 kbit/s to 115 kbit/s.
  : voice digitized over circuit, data is packetized
  : Used for wireless Application Protocol (WAP) access.
- 2.75G (EDGE) : Extended version of GSM, data rates upto 384 kbit/s.
- 3G (UMTS, CDMA2000, HSPA) : Uses spread spectrum techniques for media access & encoding
  : ~~Both~~ voice (circuit switched) & data use packets, thus pkt switched n/w
  : Speed upto 1.8 / 3.6 / 7.2 & 14.0 Mbps.
- 4G (LTE) : Provide mobile ultra-broadband Internet access.
  : Extension of 3G with more ~~bbb~~ BW & services (BW - Bandwidth)
  : IP telephony, HD-mobile TV, video conferencing, 3D TV &, cloud computing etc.
  : 4G LTE - 100 Mbps download & 50 Mbps upload
  : WiMax - 128 Mbps download & 56 Mbps upload

* Comparison of 1G, 2G, 3G & 4G

Parameter	1G	2G	3G	4G
Technologies	AMPS, NTT, TACS	DAMPS, GSM, GPRS, CDMA	CDMA2000, WCDMA/HSPA+	LTE, LTE advanced
Data speed rates	2.4 to 14.4 Kbps	14.4 Kbps	3.1 Mbps	100 Mbps
Services	Analog voice	Digital voice + Simple Data	Mobile Broadband	- Faster & Better - Richer content - More connections
Evolution	Seamless Mobile Connectivity	Increased voice capacity delivering mobile to masses	optimized for enabling mobile broadband services & better connectivity	Faster & better mobile broadband experiences
Introduction Year	1980s	1990s (1991 - 1993)	2000-1	2009
First commercialization Location	USA	Finland	Japan	South Korea
Multiple Access	FDMA	FDMA / TDMA	CDMA	CDMA
Switching Type	Circuit Switching	Voice - Circuit Switched Data - Packet Switched	Pkt switching except air interface	Packet Switching
Bandwidth	Analog	25 MHz	25 MHz	100 MHz
Band Type	Narrowband	Narrowband	Wide band	Ultra wide band
Carrier Frequency	30 KHz	200 KHz	5 MHz	15 MHz
Applications	Voice calls	Voice calls, SMS, Browsing	Vide conferencing, Mobile TV, GPS	High Speed Apps, Mobile TV, Wearable Devices

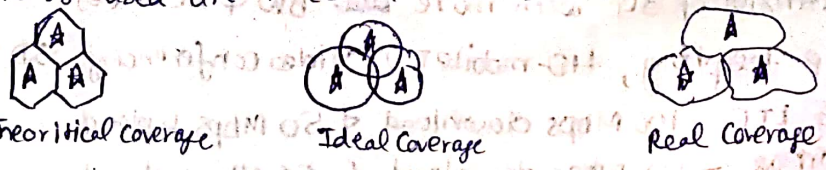
* Overview of Wireless Telephony & ~~Cellular Concepts~~

- Wireless telephony is the provision of telephone services to phones which may move around freely rather than stay fixed in one location.
- The mobile phones connect to a base station & satellite phones are connected to orbiting satellites. Both n/ws are interconnected to PSTN so that any phone in the world can be dialed.

* The Cellular Concept

- Cell: A cell is the basic geographic unit of a cellular system. The (area covered) coverage area of Mobile Base station. So, for every cell there is a base station.
- Cluster: A cluster is a group of cells. No channels are reused within cluster. Most commonly used are 7-cell & 4-cell clusters to cover an area.

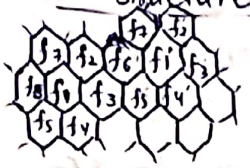
Cell Fundamentals:



Theoritical coverage Ideal Coverage Real Coverage

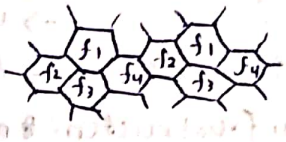
- Coverage area of cells is called footprint.
- Frequency Reuse: In a given coverage area, there are several cells that use same set of frequencies & interference b/w signals from these channels (called co-channel) is called co-channel interference.

- Cell structure for 7 cell



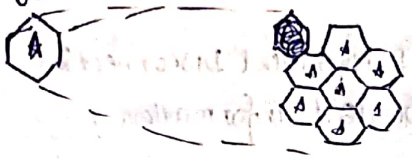
$f_1 = f_1'$, $f_2 = f_2'$ ... are co-channel cells

- Cell structure for 4 cell

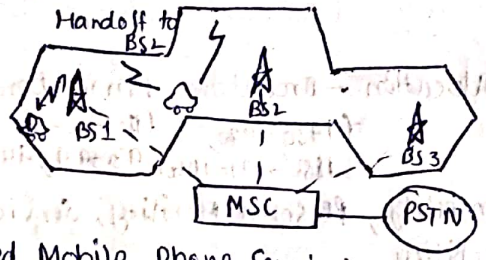


- Advantages of cell structures: High no. of users, less power needed, BS deals with inference locally

- Cell splitting :- Macro cell into micro cells



- Handoff Process : It occurs when mobile telephone n/w transfers a call from radio channel to radio channel as a mobile crosses adjacent cells.



- AMPS (Advanced Mobile Phone Service)
  - → 800 MHz to 900 MHz frequency band
  - → 30 KHz bandwidth
  - → Frequency modulation for radio transmission
  - → Limitations: # Low calling capacity
    # Limited spectrum
    # Minimal privacy

- Narrowband AMPS (NAMPS)
  - → Uses frequency division to get 3 channels in AMPS 30 kHz single channel bandwidth which increases possibility of interference due to reduced bandwidth.

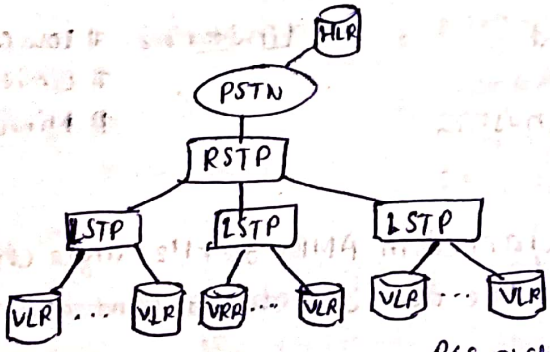
- Cellular System Components
  - → Public switched Telephone N/w (PSTN)
  - → Mobile Telephone Switching office (MTSO) (holds MSC (Mobile Switching Center))
  - → Cell site with antenna system
  - → Mobile Subscriber Unit (MSU)

- TDMA
  - → Provides 3 to 6 time channel in same BW as AMPS but using digital signals
  - → all transmissions digital
  - → 3 callers per full rate channel / 6 callers per half rate channel
  - → 800 MHz to 1900 MHz blocks of spectrum used.

- Extended TDMA
  - → Claims a capacity of 15 times that of analog cellular system by compressing quiet time during conversations.

- Fixed Wireless Access (FWA)
  - → Radio based local exchange service in which telephone service provided by common carries
  - → Employ TDMA or CDMA access technology

- Wireless Communication N/w Types:
  - → Cellular
  - → Wireless WAN
  - → Wireless LAN
  - → Paging
- Existing N/w infrastructure is not capable for providing adequate support for a mobile wireless computing environment:
  - → Limited Bandwidth
  - → Limited Geographical Coverage
  - → Heterogeneity
  - → Unreliability
  - → Mobile Host Protocols
  - → Frequent or Intermittent Disconnection
  - → High Bandwidth variability
  - → Locn Dependent Information
- PCS (Personal Communication System)
  - → Completely digital
  - → Operating at 1900 MHz frequency range
  - → Can be used internationally
  - → Key issues in PCS: # spectrum Allocation – Broadband, Narrowband, Unlicensed (1910-1930 MHz) (1930-1990, 1850-1910 MHz), (901-902, 930-931, 940-941 MHz)
    - # Mobility – Terminal mobility, Personal Mobility, Service Profile Management, Service mobility



PCS architecture

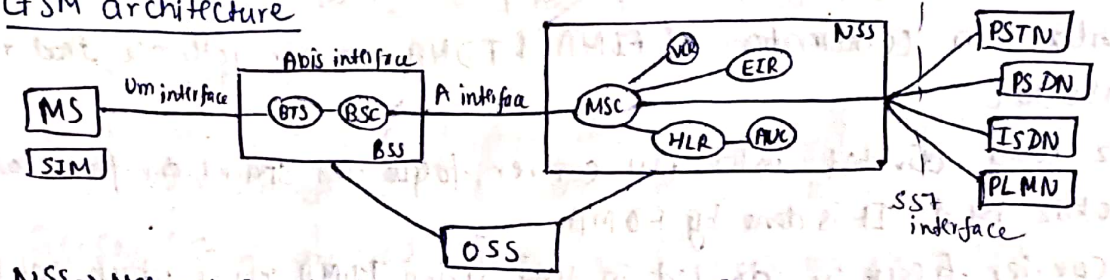
- Heterogenous PCS (HPCS)
  - → In HPCS, service area of different PCS systems may overlap or not. If overlapping, integration can increase system capacity. If no overlapping, can extend coverage service area.
  - → Basic requirement of HPCS is downward compatibility.
  - → Depending on n/w & radio technologies, 3 types of integration are considered:
    - # SRSN (Similar Radio Technology, Same N/w Technology)
    - # DRSN (Different " ", Same N/w ")
    - # DRDN (" " ", Different N/w ")
- Distributed N/w architecture / Intelligent N/w
  - → To provide a ubiquitous PCS, it is essential to integrate different telecommunication n/ws & systems. With the convergence of fixed n/ws & mobile n/ws becoming more & more popular, IN concept can be utilized to provide necessary n/w funcns for their integration.

- Cellular Systems : In a cellular system, covering area of an operator is divided into cells. A cell corresponds to the covering area of one transmitter or a small collection of transmitters. The size of cell is determined by the transmitter's power.

- Types of cells :
  (i) Macrocells (ii) Microcells (iii) Selective cells (instead of 360° coverage, say 120° coverage)
  (iv) Umbrella cells (covers several microcells)

* The GSM (Global System for Mobile Communication)

- GSM architecture



NSS → Network & Switching Subsystem
OSS → Operation & Support Subsystem
BSS → Base Station Subsystem
MS → Mobile Station

BSS { BTS – Base Transceiver Station / Base Station
BSC – Base Station Controller

NSS { MSC – Mobile Services Switching Center
HLR – Home Location Register
VLR – Visitor Location Register
AUC – Authentication Center
EIR – Equipment Identity Register

- GSM Functions : In GSM, five main func^{n} can be defined.
  (i) Transmission
  (ii) Radio Resource (RR) management : Includes channel assignment, change & release, handover, frequency hopping, power-level control, discontinuous transmission & reception, timing advance
  (iii) Mobility Management (MM) management : Includes location management, authentication & security
  (iv) Communication Management (CM) : Responsible for Call Control (CC), supplementary service management, Short Message Service management
  (v) Operation, Administration & Maintenance (OAM)

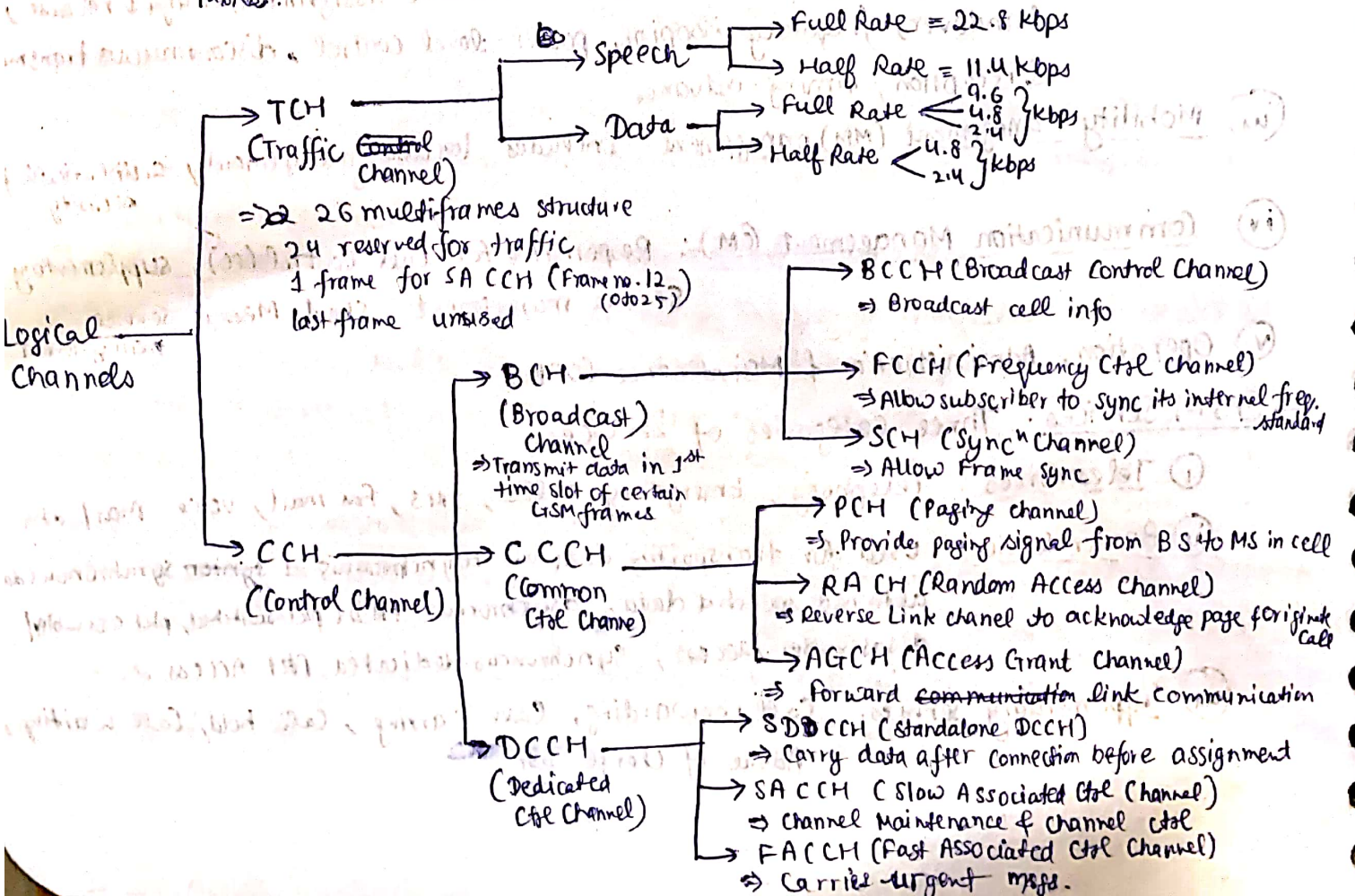
- GSM Services : Three categories of services :
  (i) Teleservices : Telephony, Emergency calls, SMS, Fax mail, Voice Mail etc.
  (ii) Bearer services : Used for transporting data ex- Asynchronous & synchronous data, alternate speech & data, asychronous PAD (pkt-switched, pkt assembler/disassembler) access, synchronous dedicated Pkt Access etc.
  (iii) Supplementary services : Call Forwarding, Call Barring, Call hold, Call waiting, Advice of charge etc.

* Air Interface

- The radio interface is the interface b/w the mobile station & the fixed infrastructure.
- Air interface is central interface of every mobile ~~station~~ system. It is the interface to which a customer is exposed.
- Two frequency bands, of 25 MHz each one, have been allocated for GSM system:
  - (i) 890-915 MHz band for uplink (MS to BS)
  - (ii) 935-960 MHz band for downlink (BS to MS)
- Um is the air interface of GSM which provides physical link b/w mobile & n/w.
- GSM utilizes a combination of FDMA & TDMA on air interface that results in 2D structure.
- 25 MHz band divided into 124 carrier frequencies spaced one from eachother by 200kHz band. It is done by FDMA.
- Each carrier frequency divided in time using TDMA scheme which splits radio channel with width 200kHz into 8 bursts (0.577 ms × 8 = 4.615 ms). Each of eight bursts, that form a TDMA frame, are then assigned to single user.

* Channel Structure

- A chanel corresponds to recurrence of one burst every frame. In GSM two types of channels: (i) Traffic channels used to transport speech & data information
  (ii) Control channels used for n/w management msgs & some channel maintenance tasks.



* GPRS (General Packet Radio Service)

- It applies a pkt radio principle to transfer user data pkts in an efficient way b/w MS & external pkt data n/ws.
- Pkts can be directly routed from GPRS MS to pkt switched n/ws. N/ws based on IP & X.25 n/w are supported in current version of GPRS.
- GPRS pkt transmission offers a more user-friendly billing than that offered by circuit switched services.
- It improves utilization of radio resources, offers volume-based billing, higher transfer rates, shorter access times, & simplifies access to pkt data n/ws.

- Key components of GPRS -

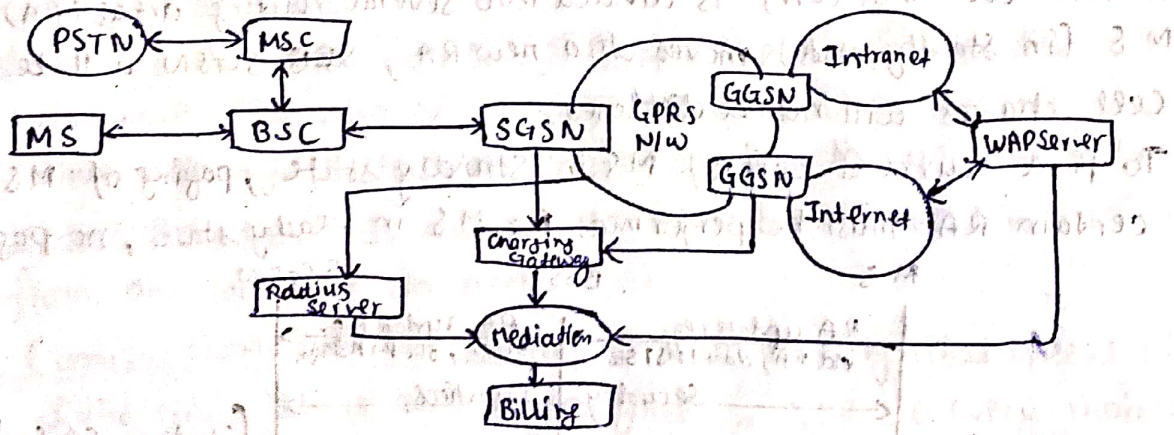
(i) SGSN (Servicing GPRS Support Node): Responsible for delivery of data pkts from & to the MS within its service area.

(ii) GGSN (Gateway GPRS Support Node): Acts as an interface to external networks for several SGSNs; an SGSN may route its pkts over different GGSNs to reach different pkt data networks.

(iii) Charging Gateway: Interface b/w charging gateway & functionality & billing system.

(iv) GTP (GPRS Tunnelling Protocol): A specialized protocol that operates over top of IP & X.25 protocols.

→ In addition, GBSM n/w nodes such as MSC, VLR, HLR, BSS enhanced to support GPRS.

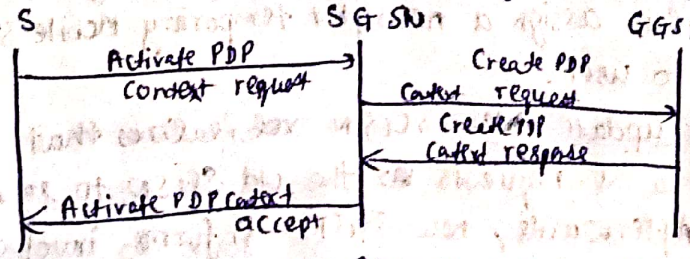


GPRS Architecture

- Services:

(i) Bearer services & Supplementary services

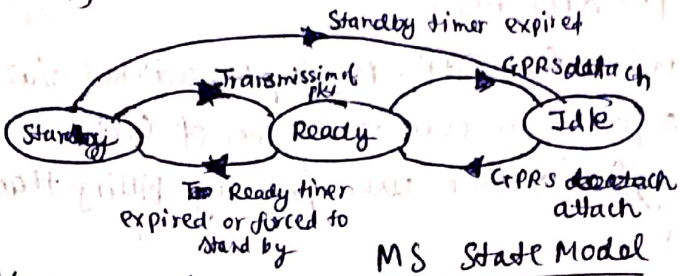
(ii) QOS → GPRS allows defining QOS profiles using parameters: service precedence, reliability, delay, & throughput.



PDP (Pkt Data Protocol) Context Activation

(iii) Simultaneous Usage of Pkt switched & Circuit Switched Services

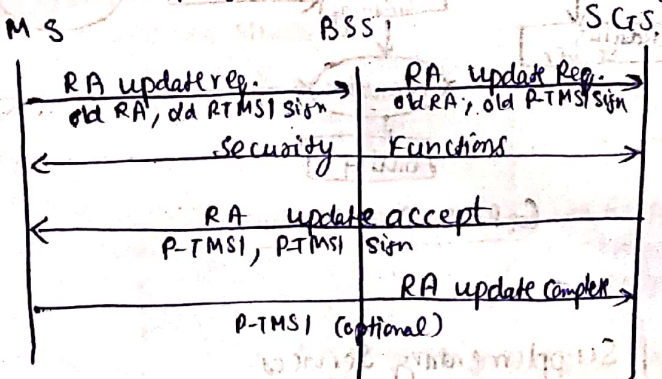
(iv) Session Management, Mobility Management & Routing (PDP context)



MS State Model

* Location Management

- Main task of loc^n management is to keep track of user's current loc^n so that incoming pkts can be routed to his or her MS.
- For this purpose, MS frequently sends loc^n update msg to its current SGSN.
- A MS can be in one of three states (Standby, Ready, Idle) depending on its current traffic amount; the loc^n update frequency is dependent on state of MS.
- In Idle, MS not reachable. ∴ performing a GPRS attach, MS gets into ready state & deatach from n/w to fall back in IDLE state.
  Standy state reached when MS doesn't send any pkts for longer time & Ready timer (started at GPRS attach) expires.
- MS in ready state informs its SGSN of every movement to a new cell.
- ~~MS in Standby state~~
- A GSM Loc^n Area (LA) is divided into several routing areas (RA). When MS (in Standby state) moves to a new RA, SGSN will be informed, cell changes will not be disclosed.
- To find current cell of MS in Standby state, paging of MS within a certain RA must be performed. For MS in ready state, no paging necessary.



(Intra SGSN RA update)

- Two scenarios of MS moving into new RA

(i) Intra-SGSN routing area update: SGSN has already stored necessary user profile & can assign a new pkt temporary Mobile Subscriber Identity (P-TMSI) to user.

(ii) Inter-SGSN RA update: New SGSN realizes that MS has changed to its area & requests the old SGSN to send PDP contexts of user. Afterwards, new SGSN informs involved GGSNs about

User's new routing context. Combined RA/LA update: MS sends a "RA update req." to SGSN. The parameter "update type" is used to indicate that LA update is needed. The msg is then forwarded to VLR, which performs LA update.

- GPRS mobility management consists of two levels: Micro mobility management tracks the current RA or cell of MS. It is performed by SGSN. Macro mobility management keeps track of MS' current SGSN & stores it in HLR, VLR & GGSN.

- HLR-VLR

- HLR (Home Location Register) – It is mobile operator database which includes details of subscribers such as phone number, current n/w location, billing details, number status. These details are accessible by MSC & VLR.
- VLR (Visitor Location Register) – It supports roaming functions for users outside coverage area of their own HLR. It contains same data as HLR with updates in n/w location. VLR can locate in which n/w the no. is currently roaming.
- The main difference b/w HLR & VLR is that HLR has permanent data & VLR changes ~~all~~ data all time & is temporary.

- Mobility Management

- It is one of the major func^{n}s of GSM & GPRS n/w that allows mobile phones to work. The aim of mobility management is to track where subscriber are & thus allowing calls, SMS & other services to be delivered to them.
- Loc^n Update Procedure – It allows MS to inform cellular n/w when it moves from one loc^n area to next.
- TMSI (Tempory Mobile Subscriber Identity) – It is identity that is sent b/w mobile & the n/w. It is randomly assigned by VLR to every mobile in the area, the moment it is switched on. This no. is local to a loc^n area, hence it is updated each time mobile moves to a new geographical area.
- Roaming – It is ability for a cellular customers to make & receive calls, send or receive data or access other services when travelling outside geographical coverage area or home n/w by means of using a visited n/w.

- Handoffs

- It is the transition for a user from one base station to adjacent B.S. as the users moves around. This is an important process which prevents dropping of calls as user moves from one geographical loc^n to another.

• Types of Handoff:

→ Hard Handoff: In this, link to prior BS is terminated as user is transferred to new cell's BS. Hence MS is linked to not more than one BS at a time.

→ Soft Handoff: It is used in CDMA. It refers to overlapping of BS coverage ~~area~~ zones. In this MS transceive signals from more than one BS at a time.
Hence soft handoff in CDMA, all repeaters use same frequency channel for each mobile set. Each set is identity is based on a code.

• Types of GSM Handover

→ Intra-BTS Handover
→ Inter-BTS-Intra BSC handover
→ Inter BSC handover
→ Inter MSC handover

* Channel Allocation in Cellular Systems

- Three major categories for assigning channels to cells or base stations:
  (i) Fixed Channel Allocation (ii) Dynamical channel Allocation
  (iii) Hybrid channel allocation

- Fixed Channel Allocation (FCA)

→ FCA systems allocate specific channels to specific cells. This allocation is static & can't be changed.
→ For efficient operation, FCA systems typically allocate channels in a manner that maximizes frequency reuse.
→ In Non-uniform spatially traffic, the available channels are not used efficiently.

- Dynamical Channel Allocation (DCA)

→ It attempts to alleviate the problem mentioned for FCA systems when offered traffic is non-uniform. No set rel^n ship exists b/w channels & cells.
→ Channels are part of a pool of resources. Whenever a channel is needed by a cell, it is allocated, under constraint that frequency reuse requirements can't be violated.
→ Two ~~to do~~ problems:
  (i) A degree of randomness leads to fact that frequency reuse is often not maximized.
  (ii) Involve complex algos. for deciding which available channel is most efficient.

- Hybrid Channel Allocation Schemes

(i) Channel Borrowing : Channels are assigned to cells just as in fixed allocation schemes. If a cell needs a channel in excess of channels previously assigned to it, that cell may borrow a channel from one of its neighbouring cells given that a channel is available & use of this channel won't violate frequency reuse requirements.
Major Problem is that when a cell becomes a channel from a neighbouring cell, other nearby cells are prohibited from using borrowed channel because of co-channel interference which can lead to call blocking over time.
Two extensions : Borrowing with Channel Ordering (BCO) & Borrowing with Directional Channel Locking (BDCL).

(ii) BDCL : Two distinctive characteristics:
(a) Ratio of fixed to dynamic channels varies with traffic load.
(b) Nominal channels are ordered such that the first nominal channel of a cell has highest priority of being applied to call within the cell.

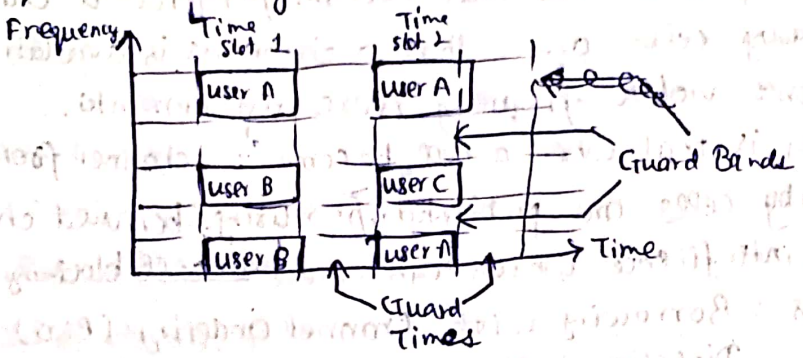
(iii) BDCL : Channels are locked in nearby cells that are affected by borrowing. This differs from BCO in which a borrowed channel is locked in every cell within the reuse distance. Benefit is that more channels are available in the presence of borrowing & subsequent call blocking is reduced.
Disadvantage : Borrowed channels are only locked in nearby cells that are attacked by the borrowing.

(iv) Dynamic Channel Reassignment (DCR) : Where a DCA scheme allocate a channel to an initiate call or handover, a DCR system switches a cell's channel (that is currently being used) to another channel which is closer to optimum acc^n to frequency reuse or other cost criteria. DCR is equivalent to DCA.

* CDMA (Code Division Multiple Access)

- CDMA is digital wireless technology that uses spread spectrum techniques. It provides channel access to multiple users simultaneously. Only one channel carries transmission from all users simultaneously.
- Each user is given a unique code sequence or signature sequence which allows the user to spread info signal across frequency band. The signal is recovered using same code sequence.
- Signals from multiple users will completely overlap both in time & in frequency as users access channel in random manner.

- CDMA doesn't need synchronization, however, code sequence or signature waveforms are required.
- In CDMA, as bandwidth as well as time of channel are being shared by users, it is necessary to introduce guard bands & guard times.



- Advantages: Dropouts in CDMA occur only if MS is at least twice as far from the BS
- Disadvantages: Locks international roaming, changing handset is not easy as the n/w info is stored in phone unlike GSM which stores info in SIM card.

Mobile Computing Architecture

- It is an umbrella term used to describe technologies that enable people to access n/w services any place, any time & any where.
- Applications:
  → Vehicles → Emergencies → Business → Credit Card Verification
  → Replacement of Wired N/Ws → Infotainment

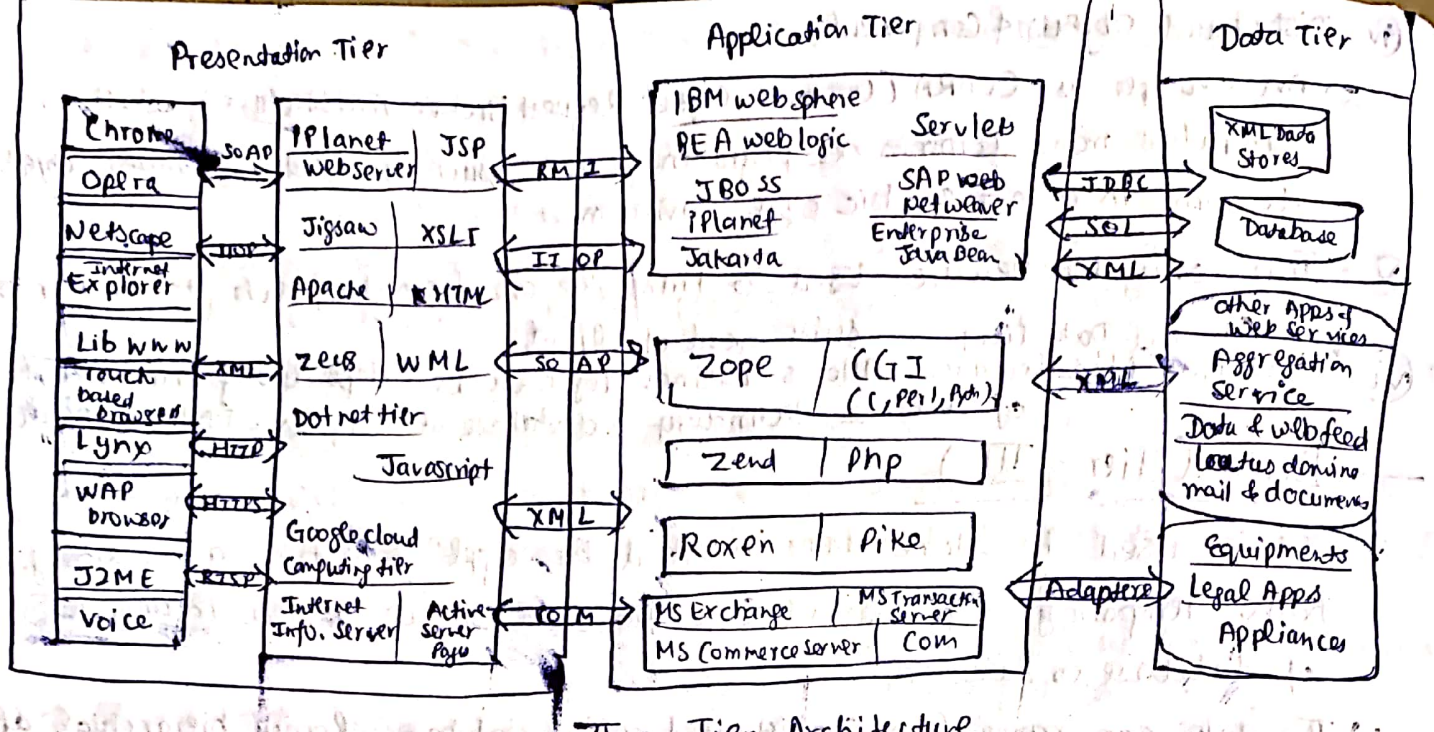
Issues in Mobile Computing

→ Technical Issues: # Portable Computer # Small Storage Capacity
Small User Interface # Low Power Consumption

→ Due to its nomadic nature, it is not easy to monitor proper usage.
→ Hacking, piracy, malicious destruction, fraud are some of the problems experienced by mobile computing
→ Issues with unauthorized access to data & info by hackers
→ Problem of identity theft is very difficult to eradicate.
→ Credential verification is also a big problem in mobile computing.

Three-Tier Architecture for Mobile Computing

Three tiers :- Presentation
Application
Data



Three Tier Architecture

– Presentation (Tier-I)

→ This is the user facing system in the 1st tier. This is layer of agent app^n's & systems. These app^n's run on client device & offer all user interfaces. This tier is responsible for presenting the information to the end user.

→ 'Presentation Tier' includes web browsers, WAP browsers & customized client programs. A mobile computing agent needs to be context aware & device independent.

– Application Tier (Tier-II)

→ It performs the business logic of processing user input, obtaining data, & making decisions. In certain cases, it do transcoding of data for appropriate rendering in Presentation ~~Layer~~ Tier.

→ It includes technologies like JSP, NET services, Php etc.

→ Func^n's related to decisions on rendering, n/w management, security, data store access etc are implemented using different middleware s/w. A middleware framework is defined as a layer of s/w which sits in middle b/w OS & user facing s/w.

→ Middleware Categories:

(i) Message-Oriented Middleware: Loosely connects different app^n through async. exchange of msgs.

(ii) Transaction-Processing Middleware: Provides tools & an environment for developing transaction based distributed app^n.

(iii) Communication Middleware: Connect one app^n to another through some communication middleware like Connecting one app^n to another through Telnet

(iv) Distributed Objects & Components:
→ An example is COBRA (Common Object Request Broker Architecture) which simplifies many common n/w programming tasks such as object registration, object location in a net centric appl^n environment.

(v) Transcoding Middleware: Used to transcode one format of data to another to suite need of client.

(vi) Database Middleware (Part of Data Tier): Allows business logic to be independent & transparent of database technology & database vendor. Ex- JDBC, ODBC etc.

— Data (Tier - III)

→ It is used to store data needed by appl^n & acts as a repository for both temporary & permanent data. The data can be stored in any form of database or datastore.

→ The data can range from sophisticated rel^{n}al database, legacy hierarchial dB, to even simple text-files. The data can also be stored in XML format for interoperability with other systems & datasources.

→ Database middleware run b/w appl^n program & database.

* Design Considerations for Mobile Computing

- The mobile computing (MC) environment needs to be context independent as well as context sensitive. Context information is the info^n related to the surrounding environment of an actor in the environment.
- In MC Environment, context data is captured so that decisions can be made about how to adapt content or behaviour to suite context.
- There are many ways in which context can be adapted:

① Content with Context Awareness: Build each appl^n with context awareness. There are different services for different client context (devices), for example, website can be designed in different ways for laptops, mobiles, PDAs etc., i.e., display & UI is different in each of them.

② Content switch on Context: Another way is to provide intelligence for the adaptation of content within the service. This adaptation happens & transparent to the client. In this, service is same for Internet, PDA & WAP. All access website through same portal url. An intelligent piece of code identifies what type of device or context it is.

③ Content Transcoding on Context: Another way is to provide a middleware platform that performs the adaptation of the content based on context & behaviour of device. The platform is intelligent enough to identify the context either from HTTP or additional customized parameter. In this, service may be in html or xml, the platform transcodes code from HTML or XML to html & wml on the fly.

- Different types of context that can enhance the usability, reliability & security of the service:

→ Client Context Manager : Three aspects of context management are:
ⓐ Context Sensing ⓑ Context Representation ⓒ Context Interpretation

→ CC/PP
→ W3C has proposed standard for context info. This standard is called Composite Capabilities / Preference Profiles (CC/PP) for describing device capabilities & user preferences.

→ Policy Manager : Responsible for controlling policies related to mobility

→ Semantic Web : Facilities to put machine understandable data on the web are becoming a necessity. The semantic web is targeted to address this need.

→ Security Manager : Provide a secure connection b/w client device & origin server. (Aspects of security : Confidentiality, Integrity, Availability, Non-Repudiation, Trust)

→ Platform for Privacy Preference Project (P3P) : Emerging standard defined by W3C which enables websites to express their privacy practices in a standardized form so that they can be retrived & interpreted by user agents.

→ Adaptability Manager : Responsible for adapting content, behaviour & other aspects acc^n to context & policy.

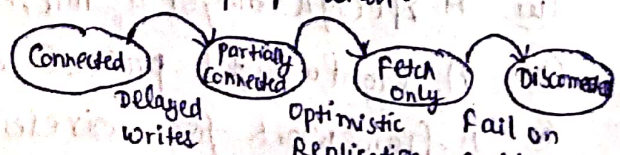
→ Content Adaptation & Transcoding : Spatial Transcoding, Temporal Transcoding, Color transcoding, Code transcoding, Object or semantic transcoding

→ Content Rating & Filtering
→ Seamless Communication
→ Content Aggregation
→ Autonomous Computing
→ Content Aware Systems
→ GPS

→ Making Existing Appl^n Mobile-Enabled : This can be achieved by:
ⓘ enhance existing appl^n
ⓘⓘ Rent an appl^n from ASP
ⓘⓘⓘ Write a new appl^n
ⓘⓥ Buy a packaged sol^n
ⓥ Bridge the gap through middleware

* Mobile File Systems

- Mobile File systems allow mobile users to run applications that access shared files over a mobile ~~Internet~~ n/w..
- Appl^n's behave same regardless of where user is located
- Adaptability is the main goal of Mobile file systems.
- Characteristics of Mobile File Systems:
  → Provide location transparency
  → Provide Cache Consistency
  → Provide Scalability
- Modes of Operation:



- Code Distributed File System is used in which files are grouped into volumes which are replicated on Code servers.

* Mobile Databases

- Mobile Database is a database that is transportable, portable & physically detached from corporate database server but has capability to communicate with those servers from remote sites allowing sharing of data.
- With mobile database, users can access corporate data on their laptop, PDAs at remote sites. Corporate database server & DBMS in mobile database environment deals with storing corporate data & providing corporate appl^n's.
- Two issues with mobile database are management of mobile database & communication b/w mobile & corporate database.
- Examples of Mobile database : SQL server Express (Microsoft), DB2 Enery where (Oracle) (Proprietory)

* WAP (Wireless Application Protocol)

- WAP is the defacto worldwide standard for providing Internet communications & advanced services on digital mobile devices, such as handheld phones, pagers & other wireless devices. This protocol is an open, global specification that allows users of the referenced digital devices to securely access & interact with Internet, Intranet, & extranet appl^n's & services.
- WAP is designed in a layered format so that it can be extensible, flexible & scalable.

— WAP Environment

→ wireless communication environment is constrained because :

(i) Less Bandwidth (ii) More Latency
(iii) Less Connection Stability (iv) Less predictable environment

→ ~~other funda~~ As a result, protocols that provide wireless applicability must be tolerant of these types~~of~~ of problems. Other fundamental limitations for handheld, wireless devices include:

(i) Life of battery (ii) Less powerful CPUs (iii) Less memory
(iv) Restricted power consumption (v) Smaller Displays (vi) Different I/P devices
(vii) Lack of mouse

— Key Elements in WAP Specifications

(i) Definition of WAP programming Model
(ii) Wireless Markup Language (WML)
(iii) A specification for a microbrowser
(iv) A lightweight protocol stack
(v) A framework for wireless telephony

- WAP Programming Model / WAP architecture

→ WAP architecture describes:

(i) WAP Client (Also known as WAE User agent)

It is a component of the WAP terminal which consists of a microbrowser & WAP protocol stack in order to handle execution of all requests & responses going through WAP layered structure.

Two primary standards are supported by microbrowser:

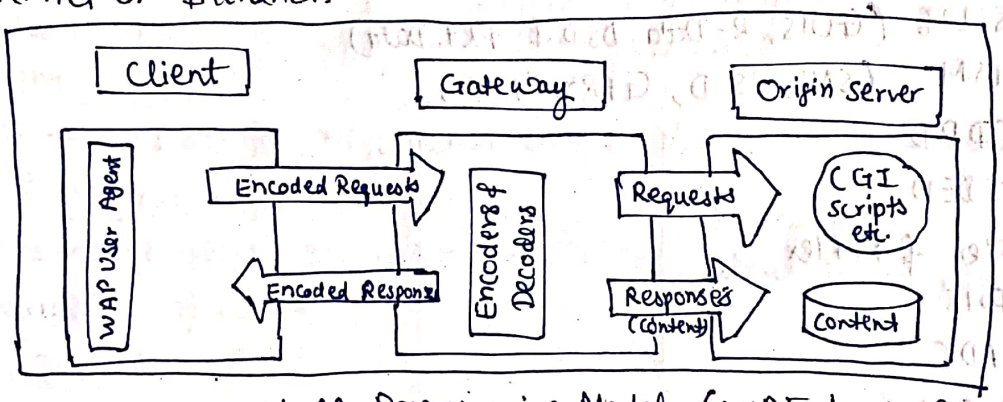
ⓐ Encoded WML ⓑ Compiled WML script

(ii) WAP Gateway

The gateway works as a WAP proxy. It receives requests from client, transforms an HTTP message & sends it (based on URL) to addressed web server.

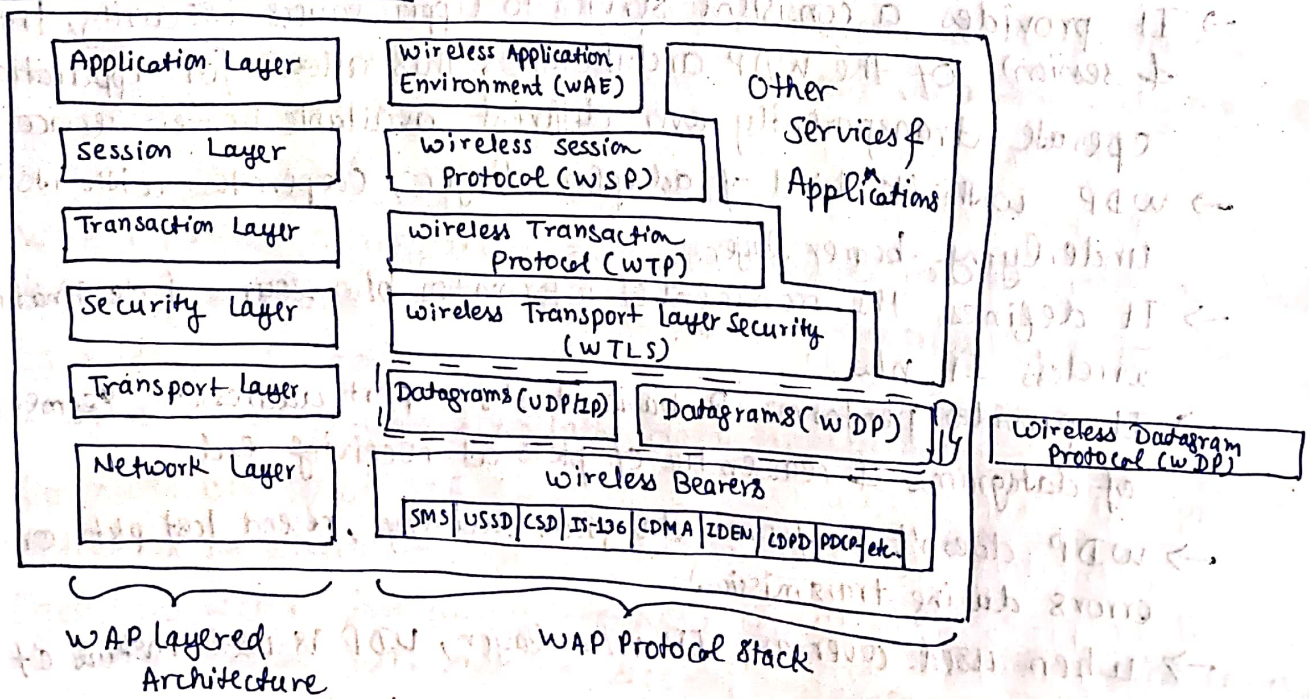
(iii) Origin Server

The client's microbrowser requests WML pages. These WML pages are stored on the origin server, which might be a web server, connected via the Internet or Intranet.



WAP Programming Model (WAE logical Model)

* WAP Protocol Stack



WAP Protocol Stack

- WAP protocol stack is divided into 5 layers:-

(i) Appen layer → Wireless Application Environment (WAE)
It contains device specifications, WML, WML script

(ii) Session layer → wireless session Protocol (WSP)
It provides fast connection specifications & reconnection

(iii) Transaction layer → wireless Transaction Protocol (WTP)
It runs on top of UDP & is part of TCP/IP

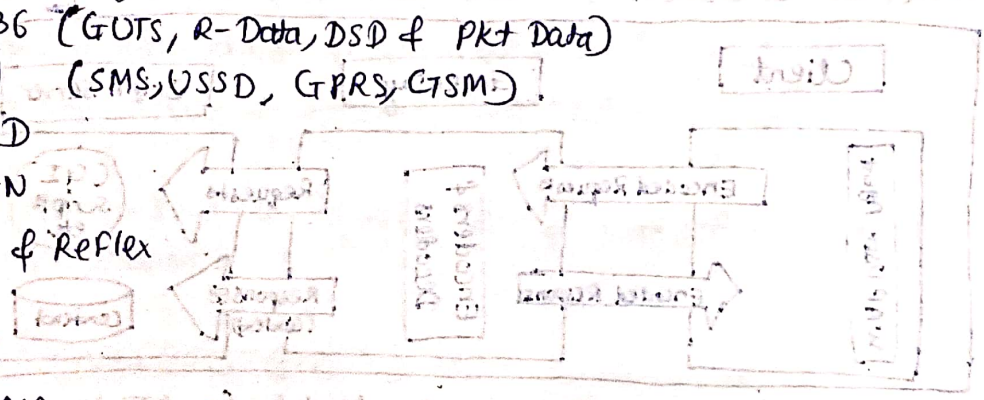
(iv) Security layer → Wireless Transport Layer security (WTLS)
It incorporates security features such as data integrity checks, privacy, authentication services etc.

(v) Transport Layer → wireless Datagram Protocol (WDP)
It presents consistent data format to higher layers or WAP protocol stack.

- The Bearer Layer

→ The bearer layer is a bearer service, such as:

(i) IS-136 (GUTS, R-Data, DSD & Pkt Data)
(ii) GSM (SMS, USSD, GPRS, CSM)
(iii) CDPD
(iv) IDEN
(v) Flex & Reflex
(vi) PHS
(vii) PDC
(viii) CDMA



- Wireless Datagram Protocol (WDP)

→ It provides a consistent service to upper layers (security, transaction, & session) of the WAP architecture. This allows for applications to operate transparently over different available bearer services.

→ WDP with its kind of adaption layer, cooperates with its underlying bearer layer.

→ It defines the movement of information blw source & destination over wireless IP n/w.

→ It ~~provides~~ performs 3 basic tasks: port addressing, segmentation of datagrams & reassembly of pkts at receiving end.

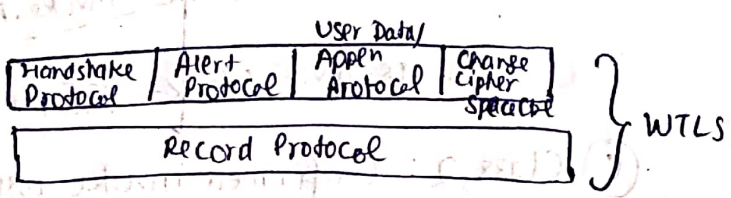
→ WDP doesn't (confirm datagram delivery, resend lost pkts or correct errors during transmission)

→ When used over an IP n/w layer, UDP is used instead of WDP

– Wireless Transport Layer Security (WTLS)

→ It is a the security protocol to ensure secure transactions on WAP terminal.
→ WTLS is based upon the industry-standard Transport Layer Security (TLS), formely known as Secure Socket Layer (SSL).
→ It provides transport layer security b/w a WAP client & WAP gateway/proxy.
→ It ensures data integrity, privacy, authentication & DOS protection.
→ WAP gateway automatically & transparently manages wireless security with minimals overhead.
→ It provides end-to-end security which & appln security which includes security facilities for en/decryption, strong authentication, integrity & management.

→ WTLS protocols:



(i) Record Protocol
It is the interface to upper layer & to lower layer.

(ii) Handshake Protocol
It is responsible for negotiation process b/w client & server

(iii) Alert Protocol
For providing alert msgs which contain info about severity of msg & description of alert.

(iv) User Data Protocol
Consist of payload which WAP client intends to send

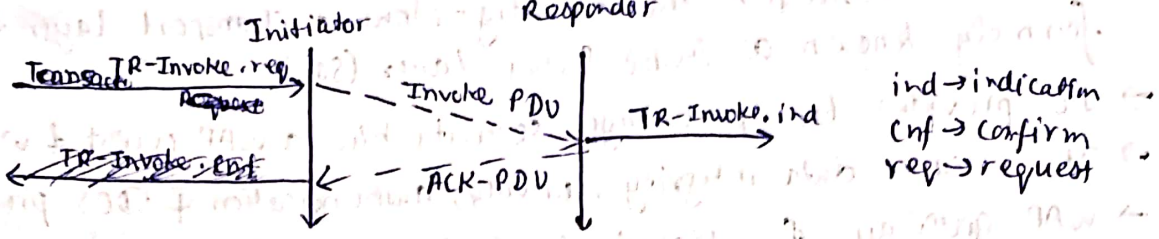
(v) Change Cipher Spec Protocol
Change cipher spec is sent by client or server to notify the other partner that subsequent records will be sent under the newly negotiated cipher specs & keys.

– Wireless Transaction Protocol (WTP)

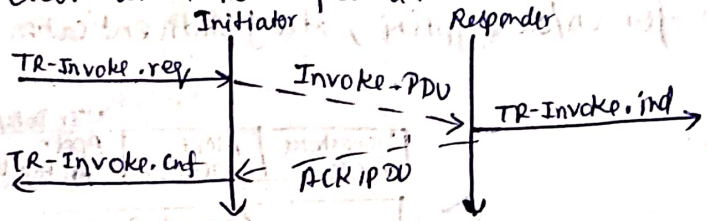
→ WTP provides a mechanism especially designed for WAP terminals. This technology allows more subscribers on the same n/w, due to reduced bandwidth utilization.
→ WTP provides unreliable & reliable data transfer based on request/reply paradigm.
→ It runs on top of UDP & performs many of the same tasks as TCP optimized for wireless devices.
→ Each transaction has unique identifiers, acknowledgements, duplicated removed & retransmission. WTP has no security mechanisms.
→ WTP supports retransmission of lost pkts, selective retransmission, segmentation & re-assembly, port no. addressing & data flow ctrl.

→ WTP Transaction Classes: 3 types of operation:

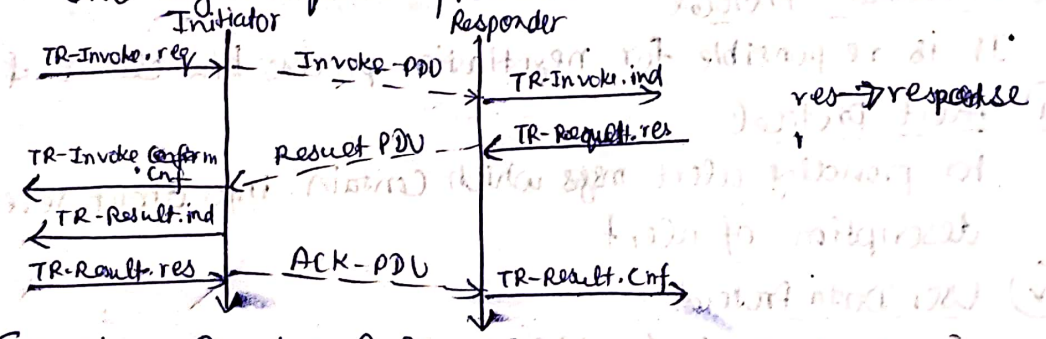
Ⓐ Class 0 : Unconfirmed invoke msg with no result msg.
This is a datagram that can be sent within context of existing WSP session.



Ⓑ Class 1: Confirmed invoke msg with no result msg.
This is used for data push, where no response from the destination is expected.



Ⓒ Class 2: Confirmed invoke msg with result msg.
One single request produces a single reply



– Wireless Session Protocol (WSP)

→ WSP establishes a reliable session b/w client & the server, which is the WAP gateway/proxy & releases the session in an orderly manner.

→ WSP is open standard for maintaining high level session. It provides shared state b/w client & server used to optimize content transfer.

→ WSP has following features for context exchange b/w client & server:
(i) Session Management (ii) Content Encoding (iii) Capability Negotiation

→ WSP defines two protocols:

(i) Connection-mode session services over a transaction service / Connection-oriented WSP

Used for long-lived connections. A session state is maintained. There is reliability for data sent over a connection-mode session.

It provides facilities:
Ⓐ Session Management Facility
Ⓑ Exception Reporting Facility
Ⓒ Method Invocation Facility
Ⓓ Push facility
Ⓔ Confirmed Push facility
Ⓕ Session Resume facility

(ii) Non-confirmed, connectionless services over a datagram transport service / Connectionless WSP

Suitable when appl^n do not need reliable delivery of data & do not care about confirmation. Can be used without actually having established a connection.

Offers unreliable transport of WSP primitives, both pull (request & response) & push (single msg) transfer.

- Wireless Application Environment (WAE)

→ This layer contains similar www func^{n}s & mobile phone technologies. It includes a microbrowser environment that contains functionality such as WML, WML-Script & Wireless Telephony Application (WTA).

→ WTA enables the user to interact with mobile-phone features & other user agents not specified by WAE.

→ WAE includes different user agents to execute different services.

→ Primary objective of WAE is to provide an interoperable environment to build services in wireless space. Content is transported using standard protocols in www domain & optimized HTML like protocols in wireless domain.

→ WAE architecture allows all content & services to be hosted on standard web browser.

→ Major elements of WAE model include:

① User agent : Browser or client program

② Content Generators : These are appl^{n}s on origin server that extract standard content in response to requests from user's agents.

③ Standard Content Encoding : Allows WAE user to navigate web content

④ Wireless Telephony Appl^n (WTA) : Extensions for calls telephony feature ctrl.

* Applications of WAP

- Accessing the internet from mobile devices
- Games can be played from mobile devices over wireless devices
- Online banking via mobile phones
- Providing weather & traffic alerts
- Email, voicemail on mobile devices
- Location based services like mapping vehicle location information

Unit - II

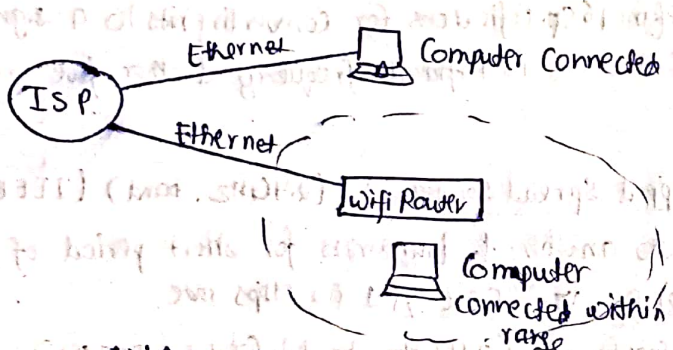
Mobile Data Link Layer

* Wireless LAN Overview

- A wireless LAN (WLAN) is a wireless n/w that links two or more devices using wireless communication within a limited area such as home, school, office etc. This enables users to move around within a local coverage area & still be connected to the n/w.

- Advantages:
  - → People can access n/w whenever they want & aren't limited by length of cable.
  - → Setting up of WLAN is done with wireless Router.
  - → Router can handle more than one connections at same time.

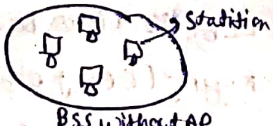
- Disadvantages:
  - → WLAN use radio waves. Hence, special care is needed for encryption
  - → Reliability issues are there due to interference from other devices.
  - → Router has fixed range. To extend range, more routers are required.



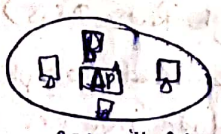
WLAN architecture

* IEEE 802.11

- Covers physical & data link layers.
- It defines two types of services:
  - (i) Basic Service Set (BSS)
  - (ii) ESS (Extended Service Set)
- BSS :→ Made of stationary or mobile wireless stations & an optional central base station called access point.
  - → Can be either without AP or with AP. Without AP can't send data to another BSS & hence known as standalone n/w or adhoc n/w

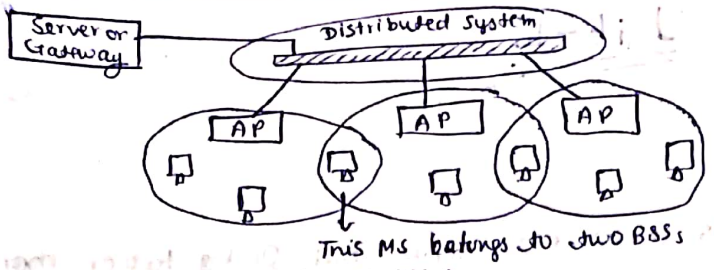


BSS without AP
Adhoc N/W

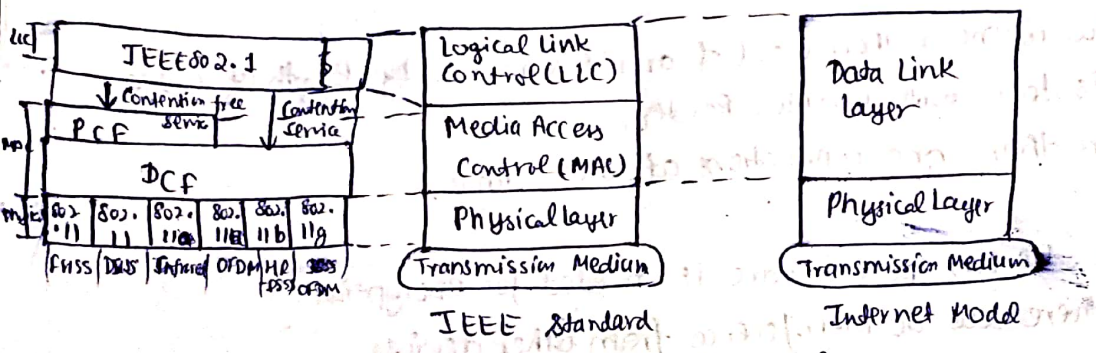


BSS with AP
or
Infrastructure N/W

- ESS :→ Consists of two or more BSSs with AP. BSSs in this system are connected to each other via a distributed system which is generally a WLAN.
  - → The distributed system connects the APs in the BSSs.



- Type of Stations in ESS (based on Mobility)
  - (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)



LLC & MAC layer

- Physical Layer :→ IEEE has defined 6 specifications for converting bits to a signal in physical layer. One of them is in infrared frequency & other five are in RF range.

→ Six specifications are:

(i) FHSS (Frequency Hopped Spread Spectrum) (2.4 GHz band) (IEEE 802.11)

Hops from frequency to another & transmits for short period of time. Cycle repeats after N-hopping. Uses FSK, 1 & 2 Mbps rate

(ii) DSSS (Direct Sequence Spread Spectrum) (2.4 GHz band) (IEEE 802.11)

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, 1 & 2 Mbps rate.

(iii) Infrared (Infrared Band) (IEEE 802.11)

Uses Pulse position Modulation (PPM). Mapped sequences converted to optical signals (4 to 16 bits or 2 to 4 bit sequence). 1 & 2 Mbps rate.

(iv) OFDM (Orthogonal Frequency Division Multiplexing) (IEEE 802.11a) (5.725 GHz band)

principle same as FDM & type of modulation is PSK & QAM. Comm Data rates are 18 Mbps (PSK) & 54 Mbps (QAM).

(v) HR-DSSS (High Rate DSSS) (IEEE 802.11b) (2.4 GHz Band)

Uses Complementary Code Keying (CCK) which encodes 4 or 8 bits of original data into one CCK symbol.

(vi) OFDM (IEEE 802.11g) (2.4 GHz Band)

This new specification defines forward error correction & backward compatible with 802.11b

MAC (Media Access Control) Layer

→ Media Access Control (also known as Medium Access Control) is a sublayer of the Data Link Layer specified in 7 layer OSI model.

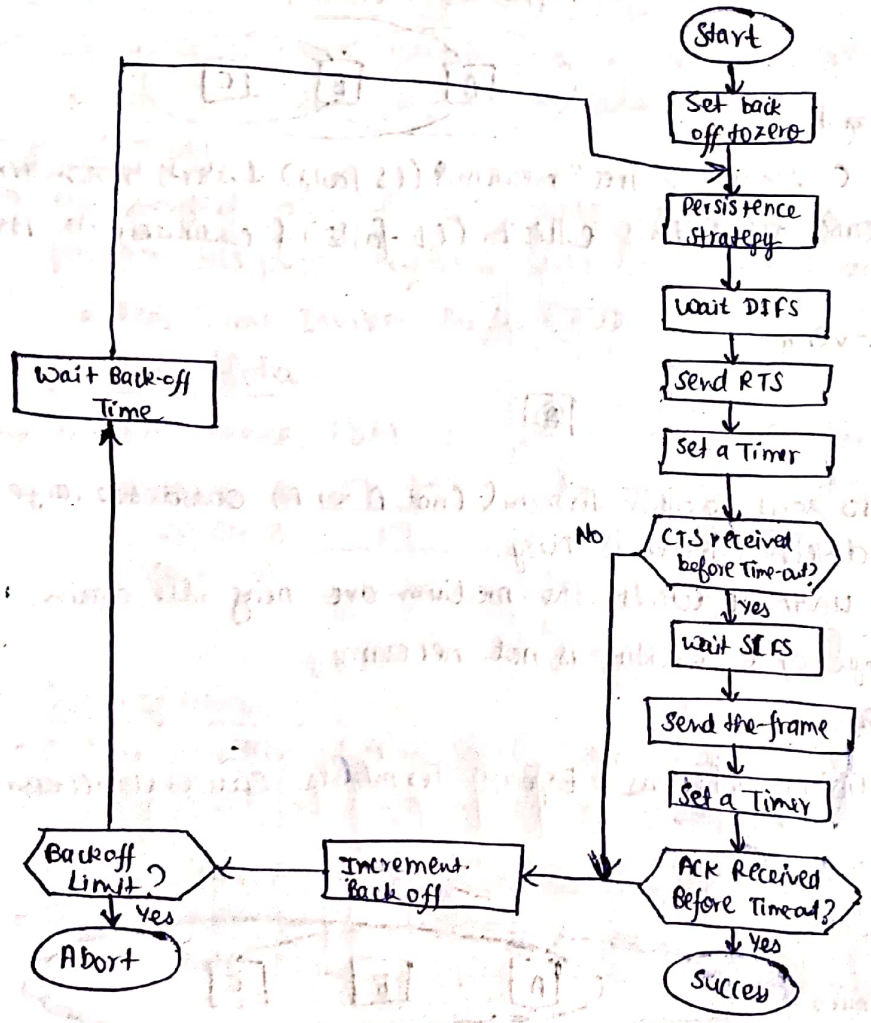
→ The hardware that implements MAC is referred to as a Medium Access Controller.

→ It acts as an interface b/w Logical Link Control (LLC) sublayer of the n/w's Physical layer.

→ It emulates a full-duplex logical communication ~~link~~ channel in a multi-point n/w. The channel may provide unicast, multicast or broadcast communication service.

→ IEEE 802.11 defines two MAC sublayers : The Distributed Coordination Func^n (DCF) & Point Coordination function (PCF).

→ DCF uses CSMA/CA as access method.



CSMA/CA flow chart

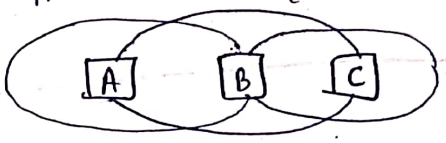
→ PCF is an optional access method that can be implemented in the infrastructure n/w (not in an adhoc n/w). It can be implemented on top of DCF & is used mostly for time sensitive transmission.

→ PCF has a centralized, contention-free polling access method the AP performs polling for stations that are capable of being polled.

→ Due to priority of PCF over DCF, stations that only use DCF may not gain access to medium. To prevent this, a repetition interval has been designed to cover both contention-free (PCF) & contention-based (DCF) traffic.

* Motivation for a Specialised MAC

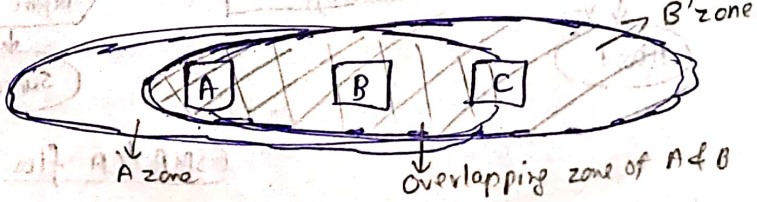
- One of the most popular MAC schemes for wired n/ws is CSMA/CD. In this:
  - → Sender listens to the medium to check if its free.
  - → If busy medium, sender waits ~~to check if~~ until its free.
  - ↳ If medium found free, sender starts transmitting data & continues to listen to the medium.
  - → when sender detects collision, it stops at once & sends a jamming signal.
- This scheme fails for wireless n/w because:
  - → it is ~~intended for~~ interested in only in collisions that can occur in receivers & not in sender.
  - → signal in wireless n/w decreases as it travels larger distance
  - → A sender may apply CS & CD but collisions happen at receiver (Hidden & Exposed Terminals).



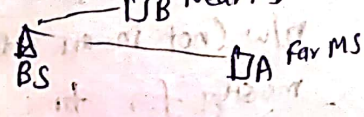
- Hidden Terminals
  - → A sends to B, C can't hear A
  - → C wants to send to B, C senses a "free" medium (CS fails) & starts transmitting
  - → Collision at B occurs, A can't detect this collision (CD fails) & continues with its transmission to B.
  - → A is "hidden" to C & vice-versa
- Exposed Terminals
  - ~~→ A sends to B, C can't~~
  - → B sends to A, C wants to send to other terminal (not A or B) outside the range.
  - → C senses the carrier & detects carrier is busy.
  - → C postpones its transmission until it detects the medium are being idle again.
  - → But A is outside radio range of C, waiting is not necessary.
  - → C is "exposed" to B.
- Hidden Terminals cause collisions whereas Exposed Terminals causes unnecessary delay.

* Near and Far Terminals

- A & B both are sending signals with same transmission power.



- Signal strength decreases proportional to square of distance. Hence BS is unable to receive A's ~~signal~~ transmission.



- This is the near far problem in CDMA. All signals must arrive at receiver at same strength otherwise the communication quality will be severly degraded.
- Precise power control is needed to receive all senders with same strength at the receiver.

- SDMA (Space Division Multiple Access)

→ It is used for allocating a separated space to users in wireless n/ws. A typical appln involves assigning an optimal base station to a mobile phone user.

→ The basis for SDMA algo is formed by cells & sectorized antennas which constitute the infrastructure implementing SDM (Space Division Multiplexing)

- FDMA (Frequency Division Multiple Access)

→ FDM (Frequency Division Multiplexing) describes schemes to subdivide the frequency dimension into several non-overlapping frequency bands.

→ FDMA is a method employed to permit several users to transmit simultaneously on one satellite transponder by assigning a specific frequency within the channel to each user. Each conversation gets its own, unique, radio channel.

- TDMA (Time Division Multiple Access)

→ It offers a more flexible scheme which comprises all technologies that allocated certain time slots for communication.

- Fixed TDM

→ The simplest algo for using TDM is allocating time slots for channels in fixed pattern. Assigning different slots for uplink & downlink using same frequency is called Time Division Duplex (TDD).

- Classical Aloha

→ In this scheme, TDM is applied without controlling medium access

Aloha

- Slotted Aloha

→ Introduction of time slots. All senders have to be synchronized, transmission can only start at beginning of a time slot.

Slotted Aloha

- CSMA (Carrier Sense Multiple Access)

→ sensing carrier before accessing medium

→ 1-persistent : Continuously listen carrier. If free, transmit immediately & if busy, wait until free.

→ Non-persistent: Checking carrier. If busy, pause CS for random amount of time & then try again

→ p-persistent: System nodes also Sense medium but only transmit with a probability of p, with station deferring to next slot with probability 1-p, i.e., access is slotted in addition.

– Demand Assigned Multiple Access / Reservation Aloha

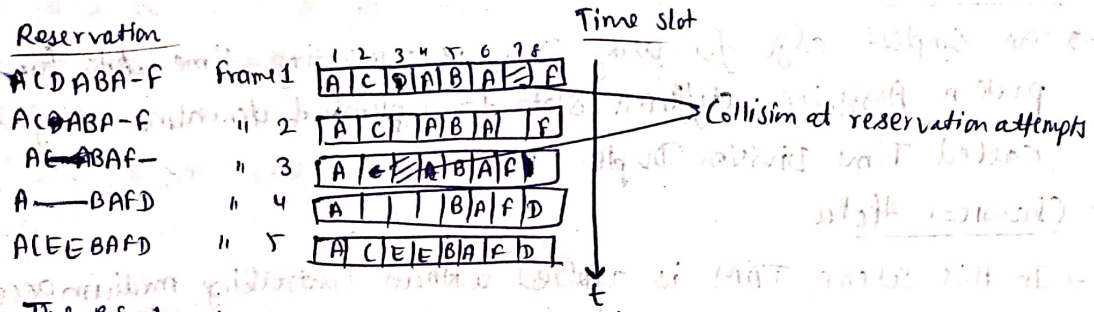
→ Channel efficiency for Aloha is 18% & for slotted Aloha is 36%. It can be increased to 80% by implementing reservation mechanisms & combinations with some (fixed) TDM patterns.

→ It is assumed that not all users will need simultaneous access to the same communication channels. DAMA assigns a pair of available channels based on requests issued from a user. Once call is completed, channels are returned to the pool for an assignment to another call.

→ DAMA is an explicit reservation scheme. Each transmission slot has to reserved explicitly.

– PRMA (Packet Reservation Multiple Access)

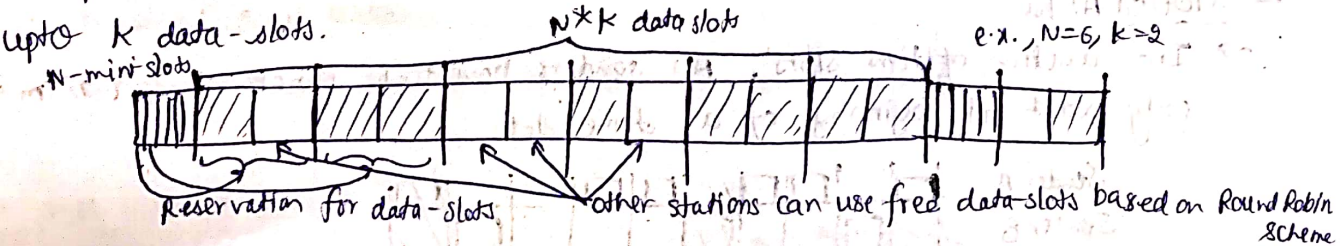
→ A kind of implicit reservation scheme where slots are reserved implicitly. The frame (certain no. of slots form a frame) is repeated in time, i.e., a fixed TDM pattern is applied. A "BS" now broadcasts the status of each slot to all mobile stations.



The BS broadcasts reservation status 'ACDABA-F' to all stations, here A for

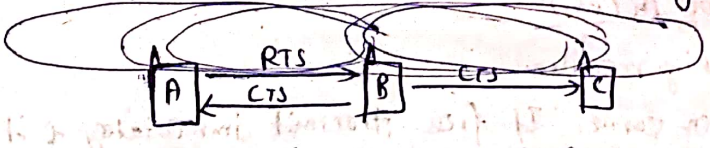
– Reservation TDMA

→ In a fixed TDM scheme, N mini-slots followed by N-k data-slots form a frame that is repeated. Each station is allotted to its own mini-slot & can use it to reserve upto k data-slots.



– Multiple Access With Collision Avoidance (MACA)

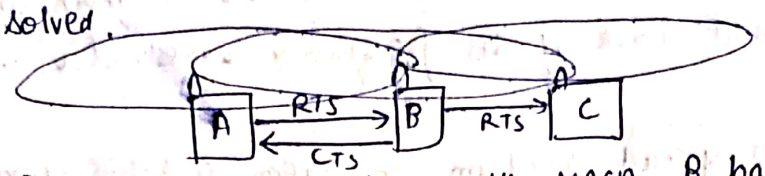
→ MACA is a simple scheme that solves hidden terminal problem. It uses random access aloha scheme but with dynamic reservation.



Hidden Terminal Soln

→ In this case, A & C both want to send to B which can cause collision (hidden terminal problem). With MACA, A doesn't start transmission at once but sends RTS first. B receives RTS that contain name of sender & receiver & length of future transmission. RTS is not heard by C & B triggers

acknowledgment called CTS which is heard by C & medium is reserved by A for duration of transmission. Hence, C is not allowed to send anything to B for the duration indicated in CTS. Hence, collision can't occur at B & hidden terminal problem is solved.



→ To solve exposed terminal problem: with MACA, B has to transmit RTS first containing name of receiver (A) & sender (B). C doesn't react to this msg as it is not receiver but A acknowledges using a CTS. C does not receive this CTS & concludes A is outside the detection range. C can start its transmission assuming it will not cause collision at A.

* Polling

- Polling schemes are used when one station wants to be heard by others. Polling is strictly centralized scheme with one master & several slave stations. The master can poll slaves acc^n to many schemes : round robin (only efficient if traffic patterns are similar & over all stations), randomly, acc^n to reservation etc.
- The master can also establish list of stations wishing to transmit during contention phase. After this phase, station polls each station on the list.
- Ex:- Randomly addressed polling
  - → BS signals readiness to all MS
  - → MS o RTS transmit random no without collision using CDMA or FDMA.
  - → The BS chooses one address for polling from list of all random nos.
  - → The BS acknowledges correct pkts & continues polling the next terminal.

* Inhibit Sense Multiple Access

- This scheme is used for pkt data transmission service.
- Cellular Digital Pkt Data (CDPD) in AMPS mobile phone system is also known as Digital Sense Multiple Access (DSMA).
- Here, BS only signals a busy medium via a busy tone (called BUSY/IDLE indicator) on the downlink.
- After the busy tone stops, accessing the uplink is not coordinated any further. The BS acknowledges successful transmissions; a MS detects a collision only via the missing +ve ack.
- In case of collisions, additional back-off & transmission mechanisms are implemented.

ISMA using Busy tone

* Spread Spectrum (SS)

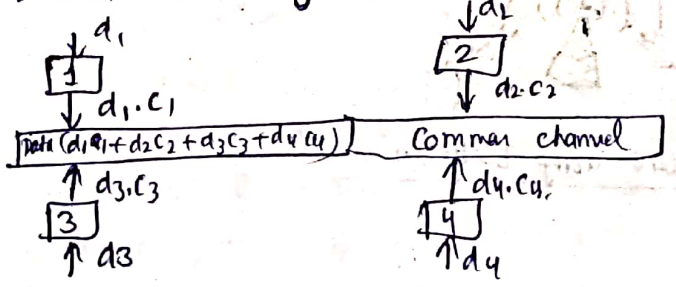
- Spread Spectrum is a form of wireless communication in which frequency of transmitted signal is deliberately varied. This results in much greater bandwidth than the signal would have if its frequency were not varied.
- Forms of SS:

(i) DSSS : It is a spread spectrum modulation technique used to reduce overall signal interference. In DSSS, a stream of info. to be transmitted is divided into small piece each of which is allocated to a frequency channel. A data signal at point of transmission is combined with higher data rate bit sequence (also known as chipping code) that divides data acc^n to spreading ratio. The redudant chipping code helps signal resist interference & also enables original data to be recovered if data bits are damaged during transmission.

(ii) FHSS (Frequency Hoped SS) : FHSS transmission is the repeated switching of frequencies during radio transmission to reduce interference. It is useful for countering eavsdropping or to obstruct jamming of telecommunication. In FHSS, transmitter hops b/w available narrowband frequencies in a pseudorandom sequence known to both seider & receiver. A short burst of data is transmitted on current narrowband channel, then transmitter & receiver tune to next frequency in the sequence for next burst of data. In most systems, transmitter will hop to new frequency more than twice per second.

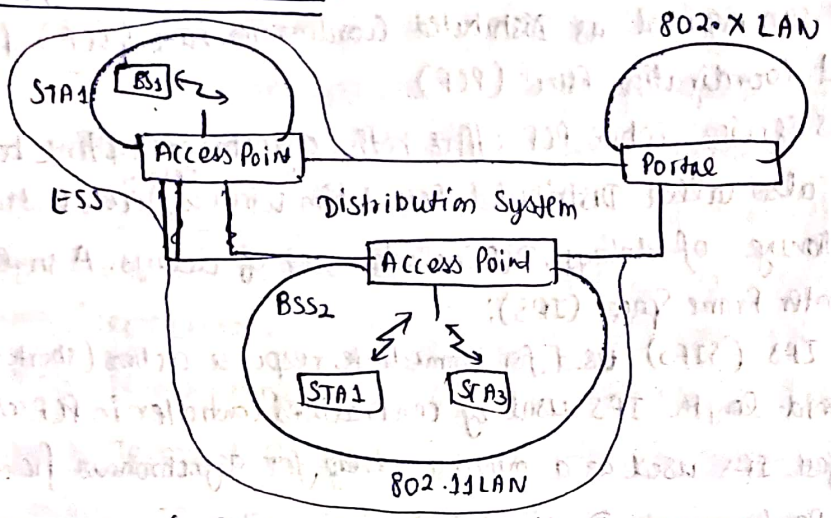
* Code Division Multiple Access (CDMA) (Already done in Unit I)

- Also called Direct Sequence Multiple Access (DSMA), it is a digital multiple access system which provide coded sequence to multiple users to access simultaneously.
- Primary feature is that only one channel carries transmissin from all users simultaneously. Each bit in the signal is replaced by a code to create high bandwidth signal. Codes are different for different users.
- Code assigned must satisfy two basic requirements:
  - → If code multiplied with itself, result should give high value, i.e., code should have a good autocorrelation.
  - → If code multiplied with another code, result should be 0 or low value, i.e., codes should be orthogonal to other codes.



Technique	TDMA	FDMA	CDMA
Principle	Segment time into time slots (disjoint)	Segment frequency into disjoint subbands	Orthogonal coding
Active Terminal	All active for short periods of time on same frequency	Every terminal has its own frequency	All terminals can be active at same band & at same time
Signal separation	Synchronization in time domain	Filtering in frequency domain	Code plus special receivers
Advantages	Digital, flexible	Simple, robust	Flexible, less planning required
Disadvantages	Synchronization difficult	Inflexible	Complex Receivers

* LAN System Architecture

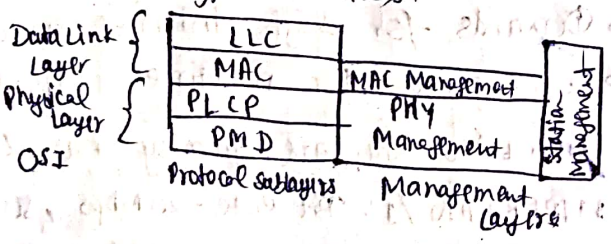


- Components of Architecture & wireless Part

→ Several nodes called stations (STA i) are connected to access points.
→ Stations & AP within same radio coverage form BSS.
→ BSS 1 & BSS 2 are connected via a distribution system.
→ Distribution system connects BSSs via AP to form single n/w & extends wireless coverage area. This area is called ESS & has its own identifier, ESSID.
→ ESSID is name of n/w & is used for separate different n/ws.

* LAN Protocol Architecture

- LLC → Logical Link Control
- MAC → Media Access Control
- PMD → Physical Medium Dependent Sublayer
- PLCP → Physical Layer Convergence Protocol



- MAC → It handles medium access, fragmentation of user data, encryption.
- PLCP → It provides carrier sense signal called clear channel assessment (CCA) & provides service access point (SAP).
- PMD → It handles modulation & encoding/decoding of signals
- MAC management → It supports association & reassociation of a station to an AP & roaming b/w different APs.
- PHY management → It includes channel tuning & maintenance.
- Station management → Interacts with both management layers & responsible for additional higher layer func's (Ex:- Ctrl of bridging & interaction with distribution system in case of an AP)

* MAC-Layer & Management

- MAC layer has to fulfil several tasks. It has to control medium access, it also offer support for roaming, authentication & power consumption.
- Basic services provided by MAC layer are mandatory asynchronous data service & an optional time-bounded service.
- Asynchronous service supports broadcast, multicast & pkt exchange is based on 'best-effort' model, i.e., no delay bounds can be given for transmission.
- MAC layer covers three functional areas: Reliable data delivery, access ctrl & security
- Three basic access mechanisms: Mandatory basic method based on CSMA/CA; optional method to avoid hidden terminal problem; a contention free polling method for time bounded service.
- First two methods are summarized as Distributed Coordination Func^n (DCF) & third method is called Point Coordination Func^n (PCF).
- DCF offers asynchronous service while PCF offers both asynchronous & time bounded service
- MAC mechanisms are also called Distributed Foundation Wireless Medium Access Control (DFWMAC).
- To ensure smooth functioning of delays, DCF includes set of delays. A single ~~set of~~ delay is known as Inter Frame Space (IFS):
  - → Short IFS: Shortest IFS (SIFS) used for immediate response actions (shortest waiting time)
  - → PCF-IFS: PIFS, a mid-length IFS used by centralized controller in PCF scheme (Slow SIFS & MIFS)
  - → DCF-IFS: DIFS, longest IFS used as a minimum delay for asynchronous frame (Longest Waiting Time)

* HiperLAN (High Performance Radio LAN)

- It is a WLAN standard. It is European alternative for IEEE 802.11 standards.
- It is defined by European Telecommunications Standard Institute (ETSI).
- In ETSI, standards are defined by BRAN project (Broadband Radio Access N/ws).
- Motivation for Hiper LAN
  - Massive growth in wireless & mobile communications
  - Demands for high internet speed access.
  - Emergence for multimedia applications.
- Hiper LAN standard family has 4 different versions:
  - HIPERLAN/1: Bit Rate - 20 Mbps, 50m Range, Frequency Range - 5 GHz
  - HIPERLAN/2: Bit Rate - 50 Mbps, Frequency Range - 5 GHz
  - HIPERACCESS: Bite Rate - 25 Mbps, Frequency Range - 11 to 66 GHz
  - HIPERLINK: Bit Rate - 155 Mbps, Short Range - Point-to-Point Technology

Bluetooth

* IEEE: 802.15

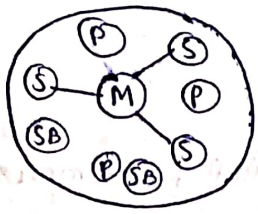
- It is a working group of Institute of Electrical & Electronics Engineer (IEEE) Standard committee which specifies wireless personal Area N/W (WPAN) standards.
- Bluetooth is well known & widely used specification that defines parameters for wireless communication among digital devices.
- The specification also allows for connection to the Internet.
- These WPAN n/ws are designed for inexpensively connecting low power devices located within 1m to 100 m of each other.
- IEEE 802.15 working group proposes two general categories:
  - TG4 (low rate: data speed of 20kbps to 250 kbps)
  - TG3 (High rate: data speed of 11 Mbps to 55 Mbps)

* Bluetooth Applications

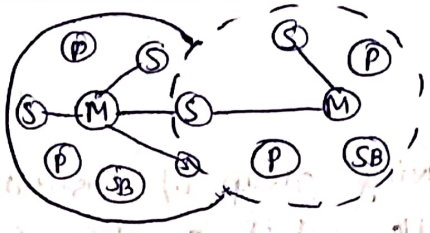
(i) Data & voice access points
(ii) Cable Replacement
(iii) Adhoc Networking

* Bluetooth Terms & Features - Bluetooth Architecture (Piconet & Scatternet)

- Bluetooth operates on 79 channels in the 2.4 GHz band with 1MHz carrier space. Each device performs frequency hopping with 1600 hops/second in a pseudo-random fashion.
- Piconet is a collection of Bluetooth devices which are synced to same hopping seq. One device in piconet acts as Master(M) & all others are slaves(S). Each piconet has a unique hopping pattern, the master determines the hopping pattern in piconet & slaves have to synchronize to this pattern.
- There are also parked (P) & stand-by devices (SB), which are additional devices. The parked devices can't actively participate in piconet but are known & can be reactivated within some milliseconds. The standby devices donot participate in piconet.
- Each piconet has exactly one master & upto 7 simultaneous slaves, more than 200 parked devices. If a parked device has to communicate then one of the slaves must switch to parked mode & allow parked device to come to active mode.
- Formation of Piconet
  - → The first steps involves a master sending its clock & device ID which is a 48-bit world wide unique identifier. All active devices are assigned a 3-bit active member address (AMA). All parked devices use an 8-bit parked member address (PMA). Devices in the standby donot any address.
  - → Forming groups of piconet called as the scatternet. Many piconets with overlapping coverage can exist simultaneously.



Piconet

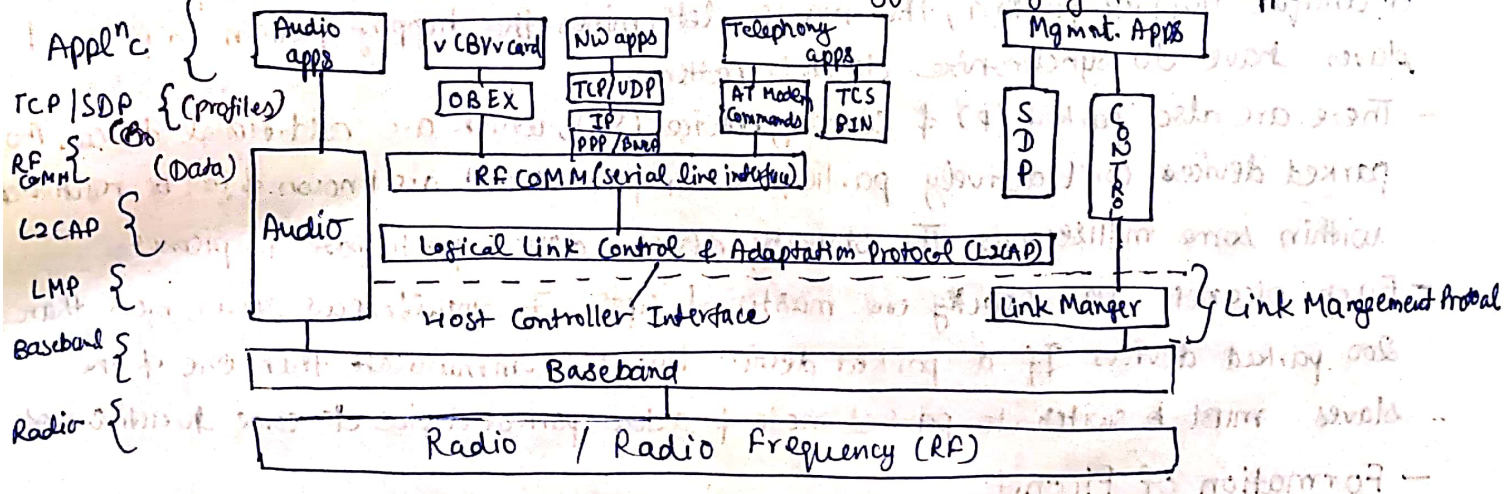


Scatternet

- If a device wants to participate in more than one piconet, it has to sync to the hopping sequence of the piconet it want to take part in.
- If a device acts as a slave in one piconet, then it starts syncing with the hopping seq. of piconet it wants to join. After sync^n, it acts as a slave to new piconet & no longer participates in older piconet.
- Before having one piconet, slaves inform the current master that it will be unavailable for certain amount of time. The remaining piconets continue to communicate as usual.
- Bluetooth applies FH-CDMA for separation of piconets.
- A master can also leave piconet & become slave in another piconet; but can't become master to another piconet. But as soon as master leaves piconet all traffic within piconet is suspended until master returns.

* Bluetooth Protocol Stack

- The Bluetooth protocol stack can be divided into:
  - (i) Core Specification: which describes protocols from physical layer to data link control together with management functions.
  - (ii) Profile Specification: which describes many protocols & func^{n}s needed to adapt the wireless Bluetooth technology to legacy & new applications.



- Core Protocols of Bluetooth

(i) Radio Layer

- Radio modem is specified in RF layer.
- Bluetooth must support voice & data. It uses 2.4 GHz ISM band license-free frequency for worldwide operation with some minor adaptations to national restrictions.
- Bluetooth transceivers use Gaussian FSK for modulation.

(ii) Baseband Layer

- Link ctrl & bit levels are specified by baseband layer.
- This layer performs frequency hopping for interference mitigation, medium access, defines the physical links & defines the pkt formats.
- The pkt consists of 3 fields:
  (A) access code (B) pkt Header (C) Payload
- Bluetooth offers two different types of links:
  (A) Synchronous Connection-Oriented Link (SCO) (B) Asynchronous Connectionless Link (ACL)
- SCO
  → Classical Telephony (i.e, voice) requires symmetrical, ckt-switched, point-to-point Connection
  → For this type of link, master reserves two consecutive slots at fixed intervals. A master can support upto 3 simultaneous SCO links to the same slave or different slaves. Similarly a slave supports upto 2 links from different masters or upto 3 links from same master.
  → Each SCO link carries voice at 64 kbps & no forward error correction (FEC); 2/3 FEC or 1/3 FEC can be selected. However voice data over an SCO is never retransmitted.
- ACL
  → Data appl^n's require symmetrical or asymmetrical, pkt-switched, point-to-multipoint transfer scenario with broadcast included (like web traffic)
  → Here master uses a polling scheme. The slave may only answer if it has been addressed in the preceding slot. Only one ACL link can exist b/w a master & a slave. For ACL's carrying data 1-slot, 3-slot & 5-slot pkts can be used.
  → Here data can be protected using a 2/3 FEC scheme.
  → Bluetooth offers a fast automatic repeat request (ARQ) scheme for reliable transmission.

(iii) Link Manager Protocol (LMP)

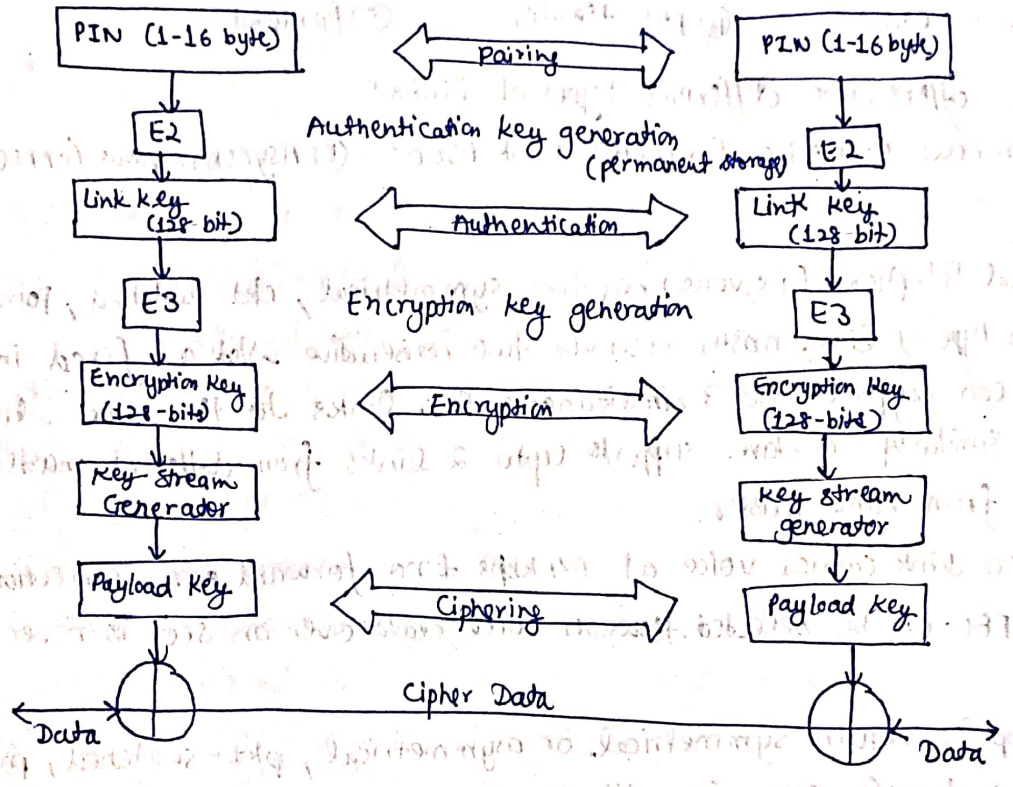
- This manages various aspects of the radio link b/w master & slave & the current parameter setting of the devices.
- LMP enhances baseband functionality.
- The func^n covered by LMP are:
  (a) Authentication, Pairing & Encryption (b) Synchronization
  (c) Capability Negotiation (d) QOS Negotiation
  (e) Power Control (f) Link Supervision
  (g) State & Transmission Mode Change

(iv) L2CAP

- L2CAP is a data link ctrl protocol offering logical channels b/w Bluetooth devices with QOS properties. It is available for ACL's only, the Audio appl^n using SCO's have to avail only the baseband layer only.

- L2CAP provides 3 different logical channels that are transported via the ACL b/w master & slave.
  (A) Connectionless (B) Connection-oriented (C) Signaling

- Bluetooth Security Architecture



* Bluetooth User Scenarios

- ~~Three~~ ~~There~~ Three in One phone: In office, your ~~fun~~ phone func^{n}s as intercom (no telephony charge)
  At home, it is used as cordless phone (fixed line charge)
  On the move, it func^{n}s as mobile phone (cellular charge)
- Headset: Connect headset to your PC through bluetooth. Mostly used in cars
- Cordless Desktop: Connect your desktop/laptop to printer, scanner & keyboard, mouse
- Internet Bridge: Use mobile device or laptop to surf internet by connecting through Bluetooth & sharing Internet.
- File Sharing: Share files b/w devices using Bluetooth.

Local Area Wireless Systems

* Wireless Private Automatic Branch Exchange (WPABX)

- These systems integrate wireless telephones with PBX switching system. Wireless PBX telephones communicates through wired BS to WPBX switching system. Most WPBX system have automatic switching call-transfer that allows wireless handsets to transfer their calls to other BS as they move through WPBX radio coverage area.
- WPABS systems work force is highly mobile in a relatively small area.

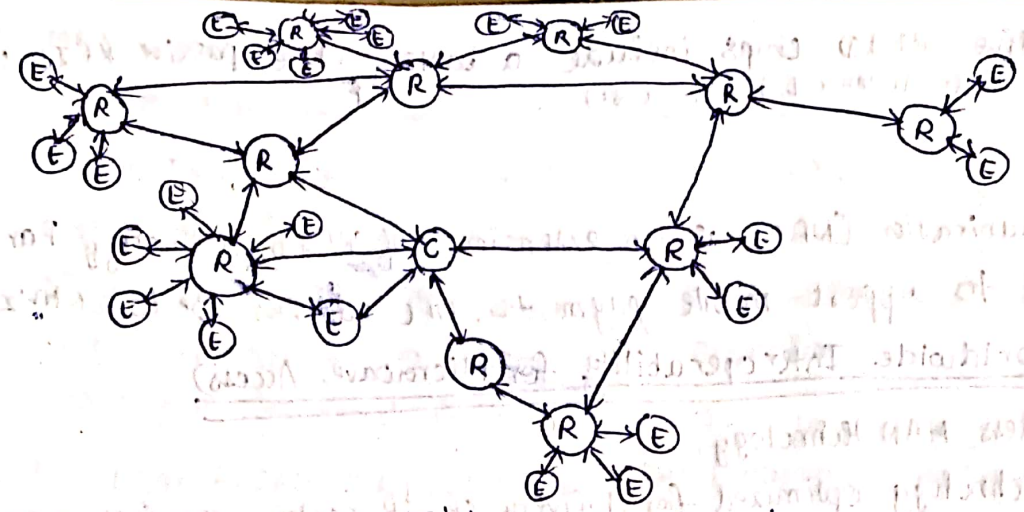
- A WPABX radio system allows for voice or data communications on either an analog or digital radio channel.
- WPABX contains freely configurable interface module (I/F) for wired (DE) & cordless (HS) terminals, which can be operated from a base station (BS).
- A central control unit (PABX-CPU) is provided to control all call handling & service feature control tasks, & a subordinate control unit (Mobile-CPU) for call setup & switch-off control of the cordless terminals (HS) in accordance with a set of assigned call numbers. The control units (PABX-CPU, Mobile-CPU) & the interface modules (I/F) are connected with each other through bus system (BUS).
- The users of PBX phone system can communicate within their company or organization & the outside world.
- A PBX also allows you to have more phones than physical phone lines (PTSN) & allows free calls blw users. It also provides feature like transfers, voicemail, call recording, interactive voice menus (IVRs) & ACD call queues.

* IrDA (Infrared Data Association)
- It is a non-profit organization whose goal is to develop specifications for infrared wireless communications. The association has been founded in 1993.
- It is an industry sponsored organization to create international standards for H/w & S/w used in infrared links.
- In this radio transmission, a focused ray of light in the infrared frequency spectrum is modulated with information & sent from transmitter to receiver over relatively short distance. IR (Infrared Radiation) is same technology used to control a TV set with remote control.
- Infrared data communication plays an important role in wireless data communication devices like laptops, PDAs, digital cameras, phones etc. other uses include sending document from notebook computer to printer, coordinating schedules & telephone books blw your devices
- Advantages of IrDA:
  → Point-to-Point Communication → Line-of-sight appln → Security
  → Low power consumption → Low cost.
- Disadvantages of IrDA:
  → Line-of-sight
  → one device at a time
- The IrDA protocol stack consists of IrPHY (layer-1), IrLAP (layer-2), IrLMP (layer-3) & other layers on top of IrLMP such as TinyIP, IrCOMM, OBEX (object exchange protocol), IrSimple etc.

Specifications	IrDA	WLAN	Bluetooth
IEEE standard	Infrared Data Association Standar	802.11a, 11b, 11g, 11n, 11ac, 11ad	802.15.1
Medium of communication	Infrared Light	RF waves	RF waves
Coverage Range	0 to 2 metres	20 to 100 meters	10 to 100 metres
N/w size	2 devices	Dozens of Devices	2 to 8 devices
LOS requirement	Yes	No	No
Max. data rate	16 Mbps	54 Mbps	3 Mbps
Power Consumption	Very Low	High	Low
Interference tolerance	Excellent	Bad	Good
Authentication, Authorization, encryption	Not Available	Available	Available

* ZigBee

- It is a low power, wireless n/w standard used to create PAN. ZigBee chips are integrated with radios or microcontrollers that have flash memory blw 60-256 kB.
- ZigBee n/w layer supports both star & tree n/ws & mesh n/wing. It is built on physical & MAC layer defined in 802.15.
- ZigBee includes 4 key components: n/w layer, appln layer, ZigBee Device Objects (ZDOs) & manufacturer defined appln objects ~~which~~ with allows for customization & favors ~~for to the~~ total integration.
- Applns include wireless light switches, traffic management systems, home energy monitors etc.
- ZigBee devices are used in smart energy, medical & in home automation.
  - → In smart energy applications zigbee products are used to monitor & control use of energy & water.
  - → In medical field it is used to connected unlimited no. of health monitoring devices & many more.
  - → In home automation it controls domestic lighting, such as switches, dimmers, occupancy sensors & load controllers.
- It has two bands of operation 868/915 MHz & 2450 MHz. 868/915 band provides about 20-40 kbps & 2450 MHz band provides about 250 kbps data rates. In addition to this uses zigbee end devices can go to sleep mode which saves battery consumption & it also takes care of security of the information owing to security layer.
- Zigbee n/w is comprised of coordinator (C), router (R) & end devices (E). Zigbee supports mesh-routing.



Zigbee N/w Example

- Zigbee IP consists of various protocol layers viz. physical layer (PHY), mac layer, n/w layer & appln layer. IEEE 802.15.4 standard defined zigbee PHY & MAC specifications. Zigbee alliance specifies n/w & appln layers.
- ZigBee is a low power spin off of Wifi. The manufactures which are members of the Alliance provide S/W, H/W & reference designs to anyone who wants to build appl's using Zigbee.

* RFID (Radio Frequency Identification)

- It is a form of wireless communication that uses electromagnetic fields to automatically identify an object, animal or person. It also tracks tags attached to objects. The tags contain electronically stored information.
- It is a system for tagging & identifying portable equipment, consumer products, & even living organisms using a special device called an RFID reader. RFID allows objects to be labeled & tracked as they move from place to place.
- An RFID system consist of 3 corresponds : a scanning antenna & transceiver (combined into one reader known as interrogator) & a transponder. Transponder are known as RFID tags which consists of a microchip, memory & antenna.
- RFID system comprise of different func's:
  - → Reading or Interrogating data in tag
  - → Filtering data
  - → Communicate with the tag with host computer
  - → Updating & entering customized data into the tag.
- Whenever a reader within range sends appropriate signals to an object, the associated RFID chips responds by sending whatever data it contains. The reader, in turn, displays these response data to an operator.
- RFID systems operate in any of four radio frequency ranges:
  - → 125 to 134.2 kHz
  - → 13.56 MHz
  - → 856 MHz to 960 MHz
  - → 2.45 GHz

- So-called active RFID chips include a battery while passive RFID chips do not. (Longer distance but more cost)

- NFC vs RFID

Near Field Communication (NFC) is an extension of RFID technology band being developed to support mobile payments. NFC utilizes the 13.56 MHz band.

* WiMAX (Worldwide Interoperability for Microwave Access)

- Based on wireless MAN technology.
- A wireless technology optimized for delivery of IP centric services over a wide area.
- A scalable wireless technology ~~optimized for delivery of IP centric services over a wide~~ for constructing alternative & complementary broadband nlws.
- A certification that denotes interoperability of equipments built to the IEEE 802.16 or compatible standard. The IEEE 802.16 working group develops standards that address two types of usage models:
  - → A fixed usage model (IEEE 802.16-2004)
  - → A portable usage model (IEEE 802.16e)
- WiMAX operate similar to WiFi but at higher speeds & over greater distances & for greater no. of users.
- It was designed to provide 30-40 Mbps (fixed & portable) but now, it aims at providing 1Gbps for fixed stations.
- It aims at providing about 15 Mbps capacity in a 3km cell coverage area.
- Why WiMAX?
  - → Satisfy a variety of access needs
  - → & support very high bandwidth sol^{n}s ~~which~~ where large spectrum deployments are desired.
  - → Help service providers meet many of the challenges they face due to increasing customer demands.
  - → Provide wide area coverage & QOS capabilities.
  - → Can be integrated into both wide-area & 3G mobile & wireless & wireline nlws allowing it to become part of a seamless anytime, anywhere broadband access sol^{n}.
- Two types of services:
  - → Non-line-of-sight
  - → Line-of-sight
- WiMAX physical layer (PHY) is based on orthogonal frequency division multiplexing, a scheme that offers good resistance to multipath, & allows WiMAX to operate in NLOS conditions.

- WiMAX Capabilities:
  - → very high peak data rates
  - → adaptive modulation & coding (AMC)
  - → Support for TDD & FDD
  - → WiMAX uses OFDM
  - → Flexible & Dynamic per User Resource Allocation
  - → Support for Advanced Antenna Techniques
  - → Link-Layer Retransmissions (support ARQ [Automatic ~~Repeat~~ Retransmission Request])
  - → IP based Architecture (WiMAX base station & WiMAX receiver)
  - → Backaul (Refers both to the connection from the access point back to the base station & to the connection from back station to the core n/w)
  - → Device / User authentication
  - → Protection of Control Msgs
  - → Scalable bandwidth & data rate support
  - → QOS security
  - → Support for mobility
  - → support for privacy
  - → Flexible key-Management Protocol
  - → Support for Fast Handover
- The design of WiMAX n/w is based on following major principles:
  - (i) Spectrum: Able to be deployed in both licensed & unlicensed spectra.
  - (ii) Topology: Support different Radio Access N/w (RAN) topologies.
  - (iii) Interworking: Independent RAN architecture to enable seamless integration & interworking with WiFi, 3G PP & 3GPP2 n/ws & existing IP operator core n/w.
  - (iv) IP Connectivity: Supports a mix of IPv4 & IPv6 n/w interconnects in clients & appln servers.
  - (v) Mobility Management: Possibility to extend the fixed access to mobility & broadband multimedia services delivery.

Feature	WiMax (802.16a)	WiFi (802.11b)	WiFi (802.11a/g)
Primary Appln	Broadband Wireless Access	Wireless LAN	Wireless LAN
Frequency Band	Licensed / Unlicensed 2 GHz to 11 GHz	2.4 GHz ISM	2.4 GHz ISM (g) 5 GHz U-UNII(a)
Channel Bandwidth	Adjustable 1.25MHz to 20MHz	25 MHz	20 MHz
Half/Full Duplex	Full	Half	Half
Radio Technology	OFDM (256-channels)	DSSS	OFDM (64-channels)
Bandwidth Efficiency	<= 5 bps/Hz	<=0.44 bps/Hz	<=2.7 bps/Hz
Modulation	BPSK, QPSK, 16-, 64-, 256-QAM	QPSK	BPSK, QPSK, 16-, 64- QAM
FEC	Convolutional Code Reed-Solomon	None	Convolutional Code
Encryption	Mandatory - 3DES optional - AES	Optional - RC4 (AES in 802.11i)	Optional RC4 (AES in 802.11i)
Mobility	Mobile WiMax (802.16e)	In development	In development
Mesh	Yes	Vendor Proprietary	Vendor Proprietary
Access Protocol	Request / Grant	CSMA / CA	CSMA / CA