SYLLABUS

Wireless Communication (3171004 / 3171608)

1. **Introduction to Wireless Communication System :**
   Evolution of mobile communications, Mobile Radio System around the world, Types of Wireless communication System, Comparison of Common wireless system, Trend in Cellular radio and personal communication. Second generation Cellular Networks, Third Generation (3G) Wireless Networks , Wireless Local Loop(WLL),Wireless Local Area network(WLAN), Bluetooth and Personal Area Networks.

2. **The Cellular Concept - System Design Fundamentals :**
   Cellular system, Hexagonal geometry cell and concept of frequency reuse,Channel Assignment Strategies Distance to frequency reuse ratio,Channel & co-channel interference reduction factor, S/I ratio consideration and calculation for Minimum Co-channel and adjacent interference, Handoff Strategies, Umbrella Cell Concept, Trunking and Grade of Service, Improving Coverage & Capacity in Cellular System-cell splitting, Cell sectorization, Repeaters, Micro cell zone concept, Channel antenna system design considerations.

3. **Mobile Radio Propagation Model, Small Scale Fading and Diversity :**
   Large scale path loss : - Free Space Propagation loss equation, Pathloss of NLOS and LOS systems, Reflection, Ray ground reflection model, Diffraction, Scattering, Link budget design, Max. Distance Coverage formula, Empirical formula for path loss, Indoor and outdoor propagation models, Small scale multipath propagation, Impulse model for multipath channel, Delay spread, Feher's delay spread, upper bound Small scale, Multipath Measurement parameters of multipath channels, Types of small scale Fading, Rayleigh and rician distribution, Statistical for models multipath fading channels and diversity techniques in brief.

4. **Multiple Access Techniques :**
   Introduction, Comparisons of multiple Access Strategies TDMA,CDMA, FDMA, OFDM , CSMA Protocols.

5. **Wireless Systems :**
   GSM system architecture, Radio interface, Protocols, Localization and calling, Handover, Authentication and security in GSM, GSM speech coding, Concept of spread spectrum, Architecture of IS-95 CDMA system, Air interface, CDMA forward channels, CDMA reverse channels, Soft handoff, CDMA features, Power control in CDMA, Performance of CDMA System, RAKE Receiver, CDMA2000 cellular technology, GPRS system architecture.

6. **Recent Trends :**
   Introduction to Wi-Fi, WiMAX, ZigBee Networks, Software Defined Radio, UWB Radio, Wireless Adhoc Network and Mobile Portability, Security issues and challenges in a Wireless network.

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1 Introduction to Wireless Communication System

Syllabus

Evolution of mobile communications, Mobile Radio System around the world, Types of Wireless communication System, Comparison of Common wireless system, Trend in Cellular radio and personal communication. Second generation Cellular Networks, Third Generation (3G) Wireless Networks , Wireless Local Loop(WLL),Wireless Local Area network(WLAN), Bluetooth and Personal Area Networks.

Contents

1.1 Evolution of Mobile Radio Communication

- In today's scenario the impact of cellular radio and Personal Communication Services (PCS) is enormous. Wireless communications is the fastest growing industry in history, due to enabling technologies which permit widespread deployment.
- It is necessary to understand the role of government regulatory agencies and service competitors in the evolution of new wireless systems, services, and technologies.
- As the radio spectrum usage is controlled by government, not by service providers, equipment manufacturers, researchers and entrepreneurs. Progressive involvement in technology development is vital for a government if it hopes to keep its own country competitive in the rapidly changing field of wireless personal communications.
- The wireless communications era was born in the 1970s with the development of highly reliable, miniature, solid-state radio frequency hardware. The recent exponential growth in cellular radio and personal communication systems throughout the world is directly attributable to new technologies of the 1970s, which are mature today.
- Fig. 1.1.1 shows how mobile telephony has penetrated our daily lives compared with other popular inventions of the 20th century.

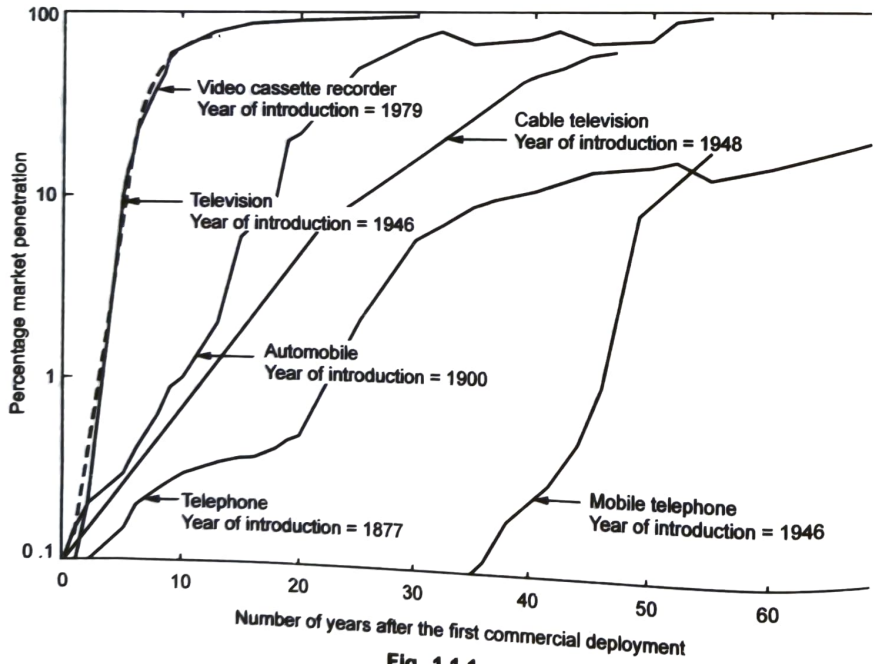


Fig. 1.1.1

- Fig. 1.1.1 shows that the first 35 years of mobile telephony there was little market penetration due to high cost and the technological challenges involved, but in the past decade, wireless communications has been accepted by consumers at rates comparable to television and the video cassette recorder.

1.2 Mobile Radio System Around the World

GTU : Winter 15

- Major Mobile Radio Standards In North America is summarized in Table. 1.2.1.

Standard	Type	Year of introduction	Multiple access	Frequency band	Modulation	Channel bandwidth
GSC	Paging	1970's	Simplex	Several	FSK	12.5 kHz
POCSAG	Paging	1970's	Simplex	Several	FSK	12.5 kHz
AMPS	Cellular	1983	FDMA	824-894 MHz	FM	30 kHz
NAMPS	Cellular	1992	FDMA	824-894 MHz	FM	10 kHz
USDC	Cellular	1991	TDMA	824-894 MHz	$\pi/4$ -DQPSK	30 kHz
CDPD	Cellular	1993	FH/Packet	824-894 MHz	GMSK	30 kHz
IS-95	Cellular /PCS	1993	CDMA	824-894 MHz 1.8-2.0 GHz	QPSK/BPSK	1.25 MHz
FLEX	Paging	1993	Simplex	Several	4-FSK	15 kHz
DCS-1900 (GSM)	PCS	1994	TDMA	1.85-1.99 GHz	GMSK	200 kHz
PACS	Cordless /PCS	1994	TDMA/FDMA	1.85-1.99 GHz	$\pi/4$ -DQPSK	300 kHz
MIRS	SMR/PCS	1994	TDMA	Several	16-QAM	25 kHz.

Table 1.2.1

- Major Mobile Radio Standards in Europe is summarised in table 1.2.2.

Standard	Type	Year of Introduction	Multiple access	Frequency band	Modulation	Channel bandwidth
E-TACS	Cellular	1985	FDMA	900 MHz	FM	25 kHz
NMT-450	Cellular	1981	FDMA	450-470 MHz	FM	25 kHz
N'MT-900	Cellular	1986	FDMA	890-960 MHz	FM	12.5 kHz
GSM	Cellular/PCS	1990	TDMA	890-960MHz	GMSK	200 kHz
C-450	Cellular	1985	FDMA	450-465 MHz	FM	20 kHz /10 kHz

ERMES	Paging	1993	FDMA	Several	4-FSK	25 kHz
CT2	Cordless	1989	FDMA	864-868 MHz	GFSK	100 kHz
DECT	Cordless	1993	TDMA	1880-1900 MHz	GFSK	1.728 MHz
DCS 1800	Cordless/PCS	1993	TDMA	1710-1880 MHz	GMSK	200 kHz

Table 1.2.2

- Major Mobile Radio Standards in Japan are summarised in Table 1.2.3.

Standard	Type	Year of introduction	Multiple access	Frequency band	Modulation	Channel bandwidth
JTACS	Cellular	1988	FDMA	860-925 MHz	FM	25 kHz
PDC	CelluJar	1993	TDMA	810-1501 MHz	π/4-DQPSK	25 kHz
NTT	Cellular	1979	FDMA	400/800 MHz	FM	25 kHz
NTACS	Cellular	1993	FDMA	843-925 MHz	FM	12.5 kHz
NTT	Paging	1979	FDMA	280 MHz	FSK	12.5 kHz
NEC	Paging	1979	FDMA	Several	FSK	10 kHz
PHS	Cordless	1993	TDMA	1895 - 1907 MHz	π/4-DQPSK	300 kHz

Table 1.2.3

1.2.1 Terminology in Wireless Communication

- Important definitions in wireless communication are :

1. Base Station

- A fixed station in a mobile radio system used for radio communication with mobil stations. Base stations are located at the center or on the edge of a coverage regio and consist of radio channels and transmitter and receiver antennas mounted on t tower.

2. Control Channel

- Radio channels used for transmission of call setup, call request, call initiation an other beacon or control purposes.

3. Forward Channel

- Radio channel used for transmission of information from the base station to th mobile.

4. Full Duplex Systems

- Communication systems which allow simultaneous two-way communication Transmission and reception is typically on two different channels (FDD) althoug new cordless PCS systems are using TDD.

5. Half Duplex Systems

- Communication systems which allow two-way communication by using the same radio channel for both transmission and reception. At any given time, the user can only either transmit or receive information.

6. Handoff

- The process of transferring a mobile station from one channel or base station to another.

7. Mobile Station

- A station in the cellular radio service intended for use while in motion at unspecified locations. Mobile stations may be hand-held personal units (portables) or installed in vehicles (mobiles).

8. Mobile Switching Center

- Switching center which coordinates the routing of calls in a large service area. In a cellular radio system, the MSC connects the cellular base stations and the mobiles to the PSTN. An MSC is also called a Mobile Telephone Switching Office (MTSO).

9. Page

- A brief message which is broadcast over the entire service area, usually in a simulcast fashion by many base stations at the same time.

10. Reverse Channel

- Radio channel used for transmission of information from the mobile to base station.

11. Roamer

- A mobile station which operates in a service area (market) other than that from which service has been subscribed.

12. Simplex Systems

- Communication systems which provide only one-way communication.

13. Subscriber

- A user who pays subscription charges for using a mobile communications system.

14. Transceiver

- A device capable of simultaneously transmitting and receiving radio signals.

University Question

1. *Define the following terms regarding wireless communication :*
   I) Control channel 2) Half duplex channel 3) Base station 4) Mobile switching center
   5) Simplex systems 6) Full duplex systems 7) Reverse channel **GTU : Winter 15. Marks 7**

1.3 Types of Wireless Communication System

- Wireless communication channel specification involves allocating the finite resour in two steps :
  1. Finite resource is allocated for the two directions of transmission.
  2. Portion allocated for each direction is used to create multiple channels for th direction.
- These two steps of subdividing the finite resource are referred to as :
  1. Duplexing methods 2. Multiple access methods
- The multiple access methods refer to the method of creating multiple channels fo each transmission direction.
- There are three main types of multiple access methods :
  1. Frequency Division Multiple Access (FDMA)
  2. Time Division Multiple Access (TDMA)
  3. Code Division Multiple Access (CDMA)

1.3.1 Paging System

- Paging is a simplex mode of radio communication system, which can transmi alphanumeric messages to the paging receiver. A pager (receiver) is a small pocke sized, battery operated, display device.

1.3.1.1 Paging System Operation

- Fig. 1.3.1 shows paging system

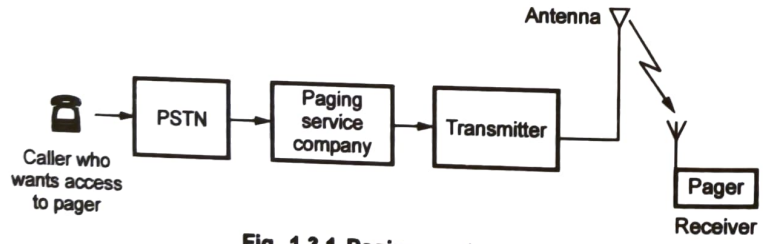


Fig. 1.3.1 Paging system

- To make a contact with pager, the caller has to call to paging company first and dictate the message to transmit. The paging company sends the message to the pager. The pager receives the message and gives an audio visual indication. The message can be retrieved from pager display.

1.3.1.2 Paging Formats

- Fig. 1.3.2 shows digital protocol for pager.

Preamble	Sych. packet	Address packet	Display Data

Fig. 1.3.2

- Preamble and synch packets are dotting sequence of clock pulses that helps for synchronization in receiver. Then address packets which contains the unique pager identification number and then the message to display are sent.
- Digital paging uses two protocol usually.
  1. POCSAG (Post Office Code Standard Advisory Group)
  2. FLEX
- POCSAG uses ASK - PSK two level modulation technique for transmitting data. The data rate of 2.4 kbps can be achieved.
- FLEX protocol was developed by motorola. It uses ASK-FSK two or four level modulation technique. The data rate from 1.6 kbps to 6.4 kbps can be supported. Also it uses Cyclic Redundancy Check (CRC) for error correction and detection.

1.3.2 Cordless Telephone System

- Cordless telephones are advanced form of ordinary telephones. Cordless phones operate in full-duplex mode, it requires two separate channels one for transmitting and receiving each. These channels must be widely separated in frequency band to avoid interference.
- Cordless phone uses analog FM either in 43 - 49 MHz or 900 MHz bands. Some cordless phone use digital spread-spectrum techniques.
- Now cordless telephones can automatically scan upto 25 channels and selects any one where better clarity is obtained. The base unit frequency and handset frequency must be widely separated as both frequencies are in use simultaneously. Usually 20 MHz separation is used in most cordless phones.
- To separate both transmit and receive frequencies a circuit called duplexer is used in base unit and in handset. Since the range of using cordless phones is short hence transmitting power required is very much less in the range of few micro watts.
- The antenna of 900 MHz cordless phones are much smaller and because of low power battery life is also longer also the cost is less. Hence cordless phones are very popular amongs user.

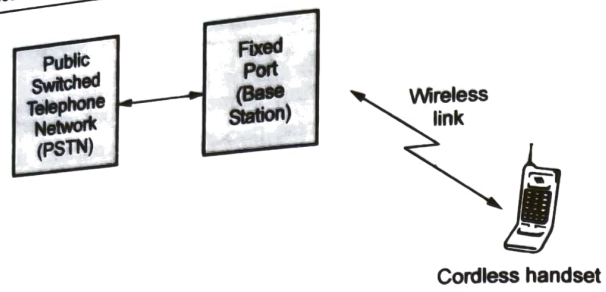


Fig. 1.3.3 Cordless telephone system

- Simple Fig. 1.3.3 shows working of cordless telephone system.

1.3.3 Cellular Telephone System

- A basic cellular system consists of three parts :
  1. A mobile unit
  2. A cell site
  3. A Mobile Telephone Switching Office (MTSO)
- Fig. 1.3.4 shows the basic cellular system.

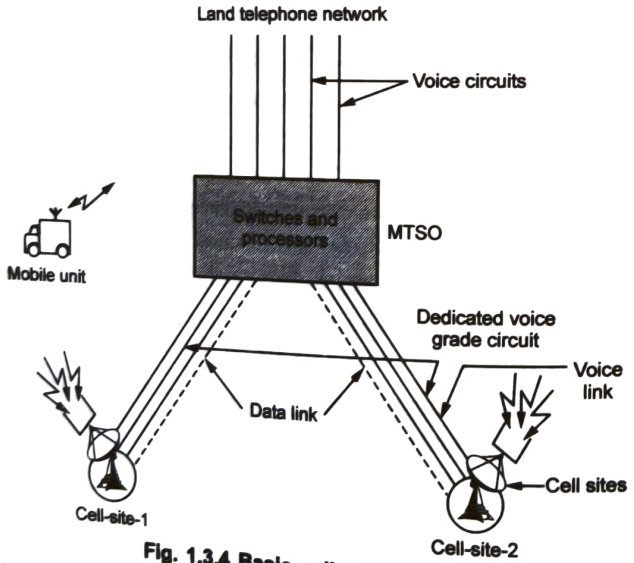


Fig. 1.3.4 Basic cellular system

1. Mobile Unit :

- A mobile telephone unit contains a control unit a transreceiver and an antenna system.

2. Cell Site :

- The cell site provides interface between the MTSO and the mobile units. It has a control unit, radio, cabinets, antennas a power plant and data terminals.
- Mobile unit is a transreceiver. It moves in any of the all sites.

3. MTSO :

- The switching office and central co-ordinating element for all cell sites, contains the cellular processes and cellular switch. It interfaces with telephone company zone offices; controls call processing and handle billing activity.
- MTSO provides coordination amongst the all sites and processor. It also performs the functions of overall administration. It also handles call processing and billing activities.

1.3.4 Comparison of Common Wireless System

- Comparison of common wireless system is given

Service	Coverage range	Required infrastructure	Complexity	Hardware cost	Carrier frequency
Paging system	High	High	Low	Low	< 1 GHz
Cordless phone	Low	Low	Moderate	Low	< 100 MHz
Cellular phone	High	High	High	Moderate	< 1 GHz

1.4 First Generation (1G) Cellular Network

GTU : Summer 16

- The first analog, voice oriented cellular telephone system launched during 1970s and 1980s is referred to as first generation or 1G cellular technology.
- The first generation cellular system used analog frequency modulation schemes for transmission with two isolated bands downlink (from base station to mobile) and uplink (from mobile to base station) transmission. It uses Frequency Division Multiplexing (FDM) to increase system capacity.
- Different 1G cellular technologies are :
  1. Advanced Mobile Phone System (AMPS)
  2. Total Access Communication System (TACS)
  3. Nordic Mobile Telephone (NMT - 450)
  4. Nippon Telegraph and Telephone (NTT)
  5. Japanese TACS (JTACS)
- Table 1.4.1 summarizes different 1G analog cellular systems.

Standard	Forward band (MHz)	Reverse band (MHz)	Channel spacing (kHz)	Region	Comments
AMPS	824 - 849	869 - 894	30	United States	Also in Australia, Southeast Asia, Africa
TACS	890 - 915	935 - 960	25	EU	Later, bands were allocated to GSM
E-TACS	872 - 905	917 - 950	25	UK	
NMT 450	453 - 457.5	463 - 467.5	25	EU	
NMT 900	890 - 915	935 - 960	12.5	EU	Freq. overlapping; also in Africa and southeast Asia
C-450	450 - 455.74	460 - 465.74	10	Germany, Portugal	
RMTS	450 - 455	460 - 465	25	Italy	
Radiocom 2000	192.5 - 199.5	200.5 - 207.5	12.5	France	
	215.5 - 233.5	207.5 - 215.5			
	165.2 - 168.4	169.8 - 173			
	414.8 - 418	424.8 - 428			
NTT	925 - 940	870 - 885	25/6.25	Japan	First band is nationwide, others regional
	915 - 918.5	860 - 863.5	6.25		
	922 - 925	867 - 870	6.25		
JTACS/NTACS	915 - 925	860 - 870	25/12.5	Japan	All are regional
	898 - 901	843 - 846	25/12.5		
	918.5 - 922	863.5 - 867	12.5		

Table 1.4.1 Existing 1G analog cellular systems

1.4.1 AMPS

- Due to increasing demand of mobile users, the available channels are not enough to accomodate new users. The solution can not be simply to assign new frequencies as the spectrum space for new approach to mobile telephony was needed. Hence a system called Advanced Mobile Telephone System (AMPS) was deployed in 1983 in Chicago.

- AMPS uses cellular concept based on many repeaters. The cellular radio technology was more efficient and can provide high quality mobile service to maximum subscribers.
- A total 40 MHz of spectrum bandwidth is 800 MHz band was allocated to AMPS. The AMPS uses seven cells reuse pattern with provisions for sectoring and cell splitting to increase capacity. There are many repeaters responsible for coverage in a cell. The cell shapes are hexagonal ideally as shown in Fig. 1.4.1.

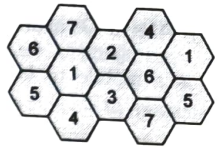


Fig. 1.4.1 Cell structure

- All the cell sites are interconnected by fiber optics or microwave link to Mobile Telephone Switching Office (MTSO) or Mobile Switching Center (MSC). All the calls are routed through cell center and MTSO. No mobile users are directly connected.
- Each cell site transmitter operates at comparatively low power frequency reuse is possible after some distance. The available bandwidth is divided amongs the cells.

1.4.2 Cellular Carriers and Frequencies

- Each carrier has 395 duplex voice channels and 21 control channels to setup calls and administer housekeeping activities like registration and paging. For voice modulation narrowband analog FM is used with maximum frequency deviation of 12 kHz and channel spacing of 30 kHz.
- Two carriers are used known as A and B carrier. A represents non-wireline carrier and B is for wire line carrier. Each carriers are assigned 832 frequencies (790 voice and 42 data). A pair of frequency is used to create one channel. Transmission from base to mobile is called as **forward channel** and transmission from mobile to base is called as **reverse channel**.
- In North American system, reverse channel transmission uses frequency in range of 824 MHz to 849 MHz and forward channel transmission uses frequency in the range of 869 MHz to 894 MHz.

1.4.3 Channel Allocation

- The control channels are used to allocate voice channels to the user. After dialling a telephone number and then pressing send button, the phone scans all the control channel frequencies for a strongest signal. The cell phone transmits its corresponding control channel and once the call is established the cell sites assigns it a clear voice channel.

- During conversation, the adjacent cell monitors the signal strength, when signal strength is greater in an adjacent cell, the call is transferred to that cell. This process is called **handoff**. Thus handoff requires a change in frequency for mobile phone.

1.4.4 AMPS Operation for Mobile Originated Calls

- It is a mobile to land call. If a mobile subscriber wants to make a call, there is exchange of several messages over the control channels such as :
  1. Handshaking operations
  2. Signaling operations
  3. Service requests
- Fig. 1.4.2 shows steps involved in mobile originated calls.

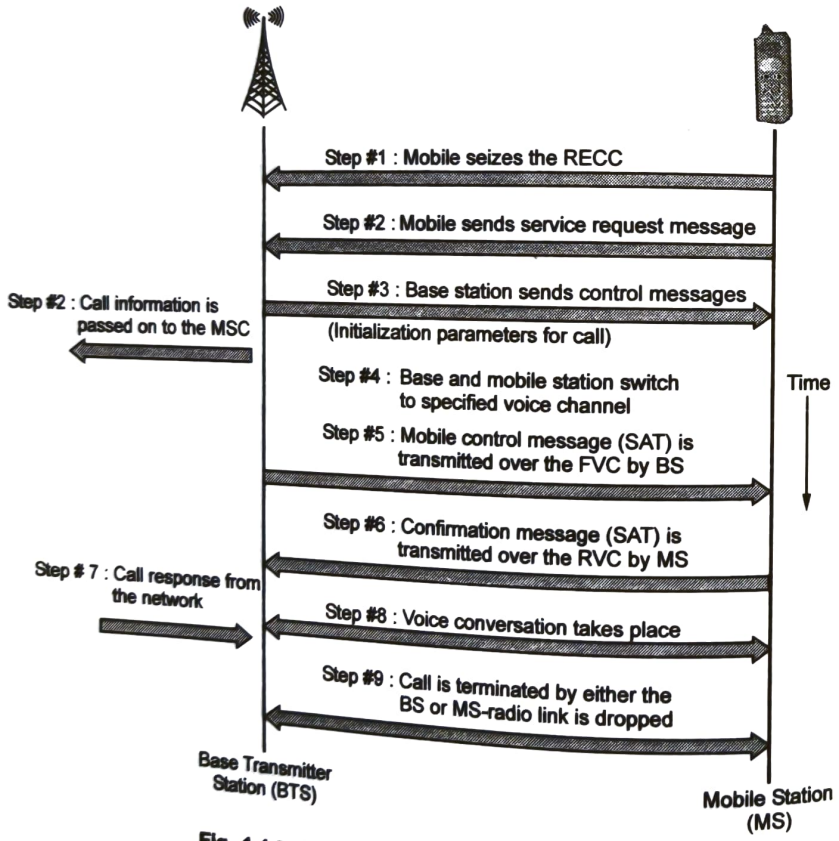


Fig. 1.4.2 AMPS mobile originated calls

Step 1 : Mobile seizes to Reverse Control Channel (RECC).

Step 2 : Once mobile seizes the RECC, it starts transmitting service request message to base station over RECC.

Step 3 : On granting the service request it sends initial voice channel designation message.

Step 4 : Base and mobile stations switched their communication to the voice channel specified.

Step 5 : The base station sends a mobile control message over Forward Voice Channel (FVC) with Supervisory Audio Tones (SAT).

Step 6 : Mobile station sends transmits confirmation message (SAT) over Reverse Voice Channel (RVC).

Step 7 : Mobile station awaits completion of call with response from network.

Step 8 : Voice conversation takes place.

Step 9 : Either base station sends a release order message or mobile sends a signalling tone at which point the BS and MS drop the voice channel radio link.

1.4.5 AMPS Operation for Mobile Terminated Calls

- The mobile terminated calls are land-to-mobile and mobile-to-mobile calls. Various phases involved in mobile terminated calls are
  1. Paging
  2. ID information exchange
  3. Signaling
  4. Control messages
- Fig. 1.4.3 shows steps involved in mobile terminated calls.

Step 1 : The Main Switching Centre (MSC) sends ID of Mobile Station (MS) to Base Station (BS).

Step 2 : The Base Station (BS) transmits a paging message along with ID information ESN, MIN, SID.

Step 3 : The Mobile Station (MS) responds to the page by returning ID over Reverse Control Channel (RECC).

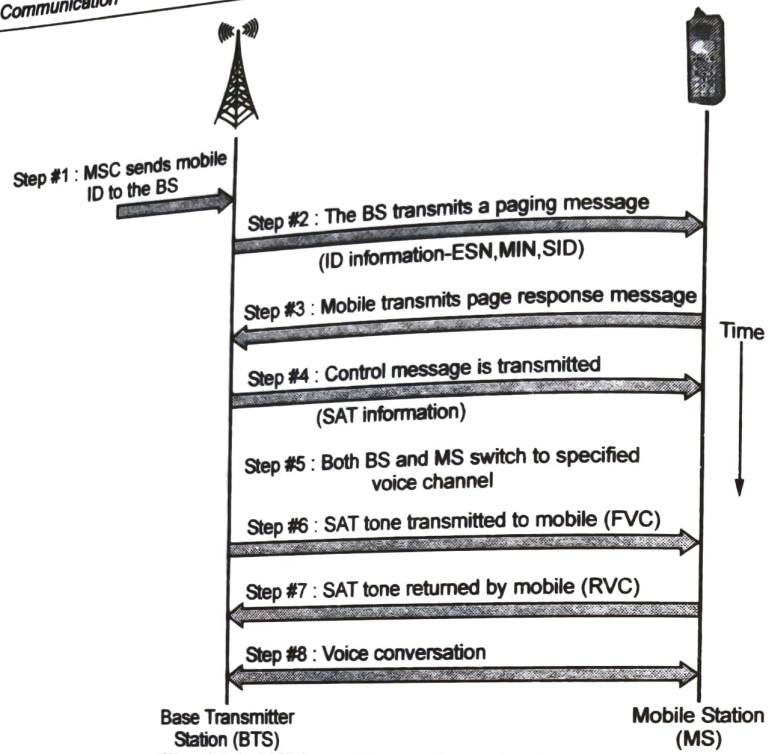


Fig. 1.4.3 AMPS mobile terminated calls

Step 4 : Control message is sent by Base Station (BS) over Forward Control Channel (FOCC).

Step 5 : Both Base Station (BS) and Mobile Station (MS) switch to voice channel.

Step 6 : Supervisory Audio Tones (SAT) transmitted to Mobile Station (MS) over Forward Voice Channel (FVC).

Step 7 : Supervisory Audio Tones (SAT) returned by Mobile Station (MS) over Reverse Voice Channel (RVC).

Step 8 : After last handshake signal, the traffic channel is opened to conversation between Base Station (BS) and Mobile Station (MS).

1.4.6 AMPS Hand-off Operation

- The hand-off operations occur in a cellular system when Mobile Station (MS) to another cell.
- The hand-off operation in AMPS involves following :
  1. Handshaking operations
  2. Signal strength measurements
  3. MSC operations during hand-off
  4. Confirmation messages.

- Fig. 1.4.4 illustrates various control messages sequence of hand-off operation in AMPS system.

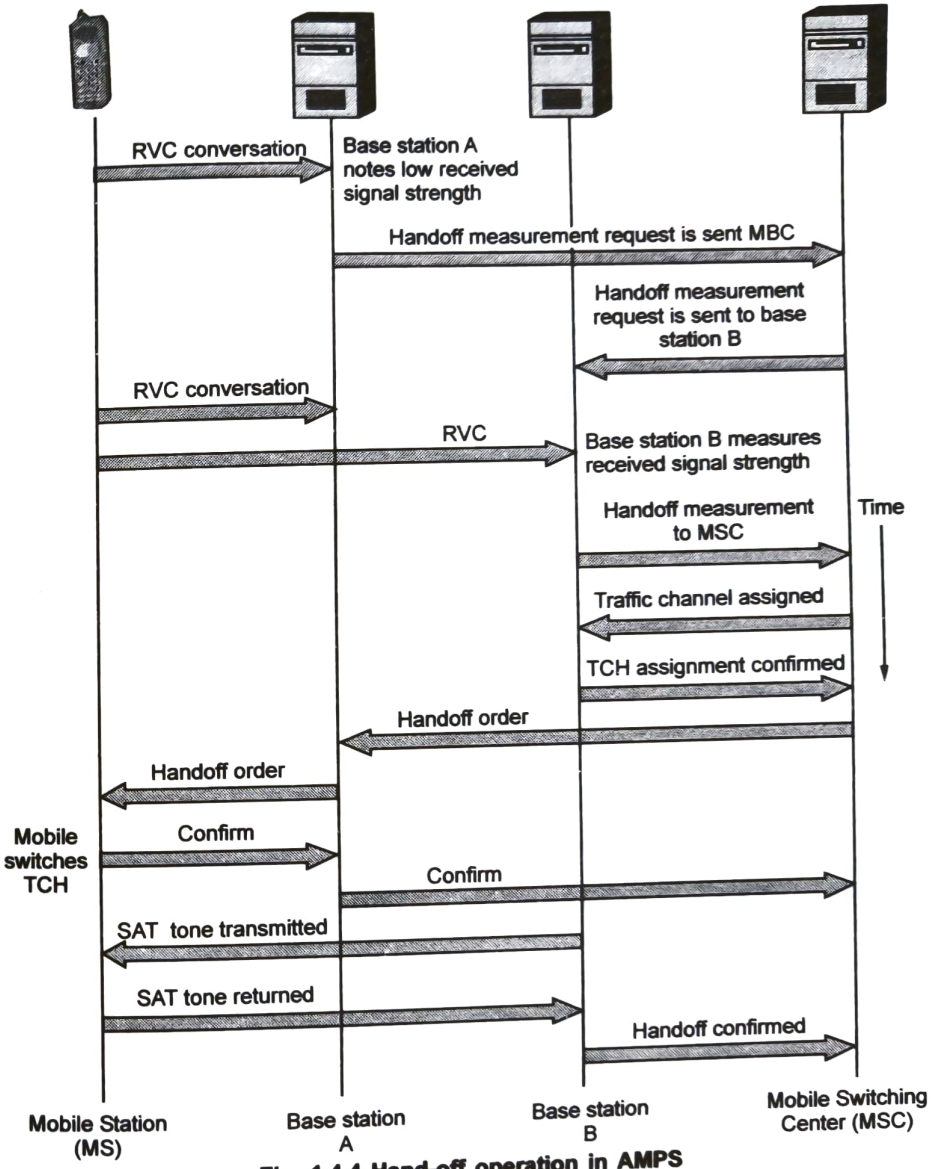


Fig. 1.4.4 Hand-off operation in AMPS

University Question

1. *Describe evolution of 1G mobile phone systems.* **GTU : Summer 16, Marks 4**

1.5 Second Generation (2G) Cellular System

GTU : Summer 16

- 2G standards rely on digital formats TDMA/FDD and CDMA/FDD multiple access techniques (FDD - Frequency Division Duplexing). 2G cellular systems provide more facilities and attractive features than 1G systems.
- Features of 2G cellular systems are :
  1. Better speech quality.
  2. High speed data application.
  3. Efficient spectrum utilization.
  4. Supports multiple users.
- Different 2G cellular technologies are :

A] TDMA :

1. Interim Standard - 136 (IS - 136)
2. Global System for Mobile (GSM)
3. Pacific Digital Cellular (PDC).

B] CDMA :

1. Interim Standard - 95 (CDMA - one)

- Table 1.5.1 summarizes major 2G digital cellular standards.

System	GSM	IS-54	JOC	IS-95
Region	Europe / Asia	United States	Japan	United States/Asia
Access method	TDMA/FDD	TDMA/FDD	TDMA/FDD	CDMA/FDD
Modulation scheme	GMSK	$\pi/4$ - DQPSK	$\pi/4$ - DQPSK	SQPSK/QPSK
Frequency band (MHz)	935 - 960	869 - 894	810 - 826	869 - 894
	890 - 915	824 - 849	940 - 956	824 - 849
			1,477 - 1,489	
			1,429 - 1,441	
			1,501 - 1,513	
			1,453 - 1,465	
Carrier spacing (kHz)	200	30	25	1,250
Bearer channels/carrier	8	3	3	Variable
Channel bit rate (kbps)	270.833	48.6	42	1,228.8
Speech coding	13 kbps	8 kbps	8 kbps	1 - 8 kbps (variable)
Frame-duration (ms)	4.615	40	20	20

Table 1.5.1 2G digital cellular standards

University Question

1. *Describe evolution of 2G mobile phone systems.* GTU : Summer 16, Marks 3

1.6 2.5 Generation (2.5G) Cellular System

- 2.5G is an upgradation of existing 2G cellular system without any additional frequency spectrum and change in technology.
- Different 2.5G cellular system standards include :
  1. CDPD (Cellular Digital Packet Data)
  2. HSCSD (High Speed Circuit Switched Data)
  3. GPRS (General Packet Radio Service).

1.6.1 Mobile Data Services

- Various mobile data services technologies are : ARDIS, Mobitex, CDPD, TETRA, GPRS and Metricom. Table 1.6.1 compares different parameters of these technologies.

System	ARDIS	Mobitex	CDPD	TETRA	GPRS	Metricom
Frequency band (MHz)	800 bands 45 kHz sep.	935 - 940 896 - 961	869 - 894 824 - 849	380 - 383 390 - 393	890 - 915 935 - 960	902 - 928 ISM bands
Channel bit rate (kbps)	19.2	8.0	19.2	36	200	100
RF channel spacing	25 kHz	12.5 kHz	30 kHz	25 kHz	200 kHz	160 kHz
Channel access / Multiuser access	FDMA / DSMA	FDMA / Dynamic S-ALOHA	FDMA / DSMA	FDMA / DSMA	FDMA / TDMA / Reservn.	FHSS / BTMA
Modulation technique	4-FSK	GMSK	GMSK	$\pi/4$-QPSK	GMSK	GMSK

Table 1.6.1

1.7 Third Generation (3G) Cellular System

GTU : Summer 16

- 3G is a cellular system that supports higher data services, advanced multimedi services and global roaming. The 3G system ensures an efficient wireless access wit high performance quality by using intelligent new protocols.
- Different 3G cellular system standards include :
  1. IMT 2000 and UMTS 2. CDMA 2000.

University Question

1. *Describe evolution of 3G mobile phone systems.* GTU : Summer 16, Marks 3

1.8 Fourth Generation (4G) Cellular System

GTU : Summer 16

- The goal of 4G cellular system is convergence of wireless mobile with wireless acces communication technologies. A new converged system will be an improvement i bandwidth efficiency, dynamic bandwidth allocation, quality of service and security.
- The 4G cellular system will require an all IP architecture and connectivity for an one, any where and at all the time. The expected data rate is above 20 Mbps whic can match wireless ATM speed.

1.8.1 Characteristics of 4G

1. Fully converged services

- A wide range of services will be available to the mobile user conveniently and securely via the 4G Core Network. Personal communications, information systems and entertainment will seem to be merged into a seamless pool of content.

2. Ubiquitous mobile access

- 4G aims to provide access to multimedia services anytime anywhere. Devices will not simply rely on cellular reception. Improved radio access technology as well as integration of all types of communication networks allows for virtually constant connectivity to the 4G core backbone. Mobile handsets will be intelligent and software-reconfigurable on the fly to allow them to interface with different types of networks on the move. Also, there will be full cross compatibility on a world-wide scale since each type of network has a gateway to the IP backbone.

3. Software dependency

- Advanced software systems are employed for all purposes - network operation, service provision, interfacing and integration, etc. Not only the Core Network but the mobile devices will be highly intelligent as well as re-configurable via software.

4. Diverse user devices

- A defining feature of 4G will be the proliferation of a vast array of devices that are capable of accessing the 4G backbone. Wireless capabilities will be embedded into devices that we wouldn't even consider today. Not only personal devices like phones, PDAs, laptops, etc. but also sensors, embedded controllers and other specialised equipment. The point behind this is to allow them to autonomously communicate with each other. By building in sophisticated software, they will be able to automatically initiate timely actions. 2G enabled mobile person-to-person communications while 3G is opening the door to person-to-machine communication with mobile Internet. 4G introduces another dimension with machine-to-machine communication.

5. Autonomous networks

- While user devices are highly intelligent, the core network will also be very sophisticated. It will be capable of managing itself and dynamically adapting to changing network conditions and user preferences for seamless communication. Apart from evolved mobility management, connection control, hand-over mechanisms, etc, dynamic bandwidth allocation will make far more efficient use of the available radio spectrum.

1.8.2 Comparison of 1G, 2G, 3G and 4G System

Technology/Features	1G	2G/2.5G	3G	4G
Start/Deployment	1970/1984	1980/1999	1990/2002	2000/2010
Data bandwidth	2 kbps	14.4-64 kbps	2 Mbps	200 Mbps to 1 Gbps for low mobility
Standards	AMPS	2G : TDMA, CDMA, GSM 2.5G : GPRS EDGE , 1xRTT	WCDMA, CDMA-2000	Single unified standard
Technology	Analog cellular technology	Digital cellular technology	Broad bandwidth CDMA, IP technology	Unified IP and seamless combination of broadband LAN/WAN/ PAN and WLAN
Service	Mobile telephony (voice)	2G : Digital voice, short messaging 2.5G : Higher capacity packetized data	Integrated high quality audio, video and data	Dynamic information access wearable devices

Multiplexing	FDMA	TDMA, CDMA	CDMA	CDMA
Switching	Circuit	2G : Circuit 2.5G : Circuit for access network and air interface; packet for core network and data	Packet except circuit for air interface	All packet
Core network	PSTN	PSTN	Packet network	Internet

University Question

1. *What is the difference between 2G, 2.5G and 3G ? Describe GPRS architecture.*

GTU : Summer 16, Marks 7

1.9 Wireless Local Loop (WLL)

- Wireless Local Loop (WLL), is a term for providing wireless connections stationary or near stationary stations within a small service area.
- WLL is generally targeted at the last mile or from a point in the neighbourhood the user.

1.9.1 Advantages of Wireless Local Loop

1. Ease of installation as the digging is not required.
2. Quick installation of new links i.e. rapid provisioning.
3. The cost is not dependent on distance up to some limit.
4. Concentration of resources especially at the multiplexer to the high bandwid backbone.

1.9.2 WLL Architecture

- IS-54 architectural reference model for WLL is shown in Fig. 1.9.1.

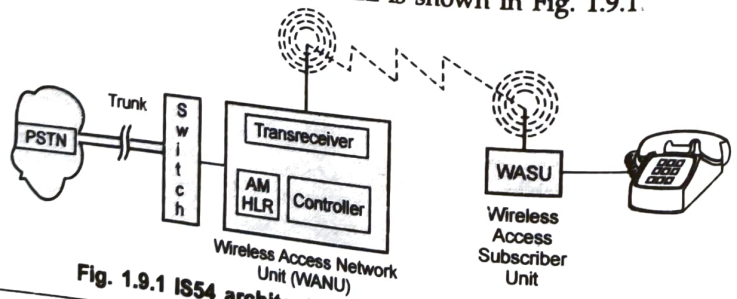


Fig. 1.9.1 IS54 architectural reference model for WLL

1.9.3 WLL Deployment Issues

- Various WLL deployment issues are :

1. Spectrum

- WLL spectrum can be accessed in two modes : licensed and unlicensed band.
- The licensed band spectrum has limited interference, but requires licensing.
- The unlicensed spectrum has more interference, but no licensing is needed. It is generally limited in power.

2. Service quality

- Users expecting service quality should to be the same as wireline telephone service.
- User expects high reliability.
- Every user expects low risk of fraud as there is threat of hijacking the link.

3. Network planning

- The WLL network should support very high penetration levels (for example >90%).
- WLL assumes that users are not moving (or rarely move).
- WLL antenna height is generally derived from user density.

1.9.4 WLL Technologies

- Existing WLL technologies are :
  1. Satellite based
  2. Cellular based
  3. Low Tier PCS or Microcellular based
  4. Fixed Wireless Access (FWA)

1. Satellite based

- Satellite based WLL technology is supported by satellite operators (Hughes Network Systems, Inmarsat International Circular Orbit (ICO), Iridium, Globestar, Odyssey, American Mobile Satellite Corporation (AMSC), Asia Cellular Satellite (ACeS), Thuraya etc.
- Among these some of these operators (such as Hughes) used terrestrial versions of their system.

2. Cellular based

- Cellular based WLL systems are used in rural and non dense population areas.

3. **Low Tier PCS or Microcellular based**
   - The low tier personal communication systems (PCS) are low power systems. Vario low tier PCS are PACS, PHS and DECT etc.
4. **Fixed Wireless Access (FWA)**
   Fixed wireless accesses are proprietary point-to-point links used for specific areas.

1.10 Wireless LAN (WLAN)

- A Wireless Local-Area Network (WLAN) provides the features and benefits traditional LAN technologies such as Ethernet and token ring without the limitatio of wires or cables.
- A WLAN system is different from a traditional wired LAN in many ways : T destination address is not equivalent to a physical location, WLANs deal with fixe portable and mobile stations and of course, the physical layers used here a fundamentally different from wired media.
- Wireless is a local area data network without any physical connectivity i.e. witho wires. WLAN is implemented as an extension to a wired LAN within a building campus.
- Wireless LAN is referred as Wireless Fidelity (Wi-Fi).

1.10.1 Design Goals of WLAN

1. Global, seamless operation.
2. Low power for battery use.
3. No special permissions or licenses needed to use the LAN.
4. Robust transmission technology.
5. Simplified spontaneous cooperation at meetings.
6. Easy to use for everyone, simple management.
7. Protection of investment in wired networks.
8. Security (no one should be able to read my data), privacy (no one should b able to collect user profiles), safety (low radiation).
9. Transparency concerning applications and higher layer protocols, but als location awareness if necessary.

1.10.2 Advantages and Disadvantages of WLAN

Advantages of WLAN

- WLAN offers following advantages :
  1. **Mobility :** WLAN offers wire-free access within operating range.
  2. **Low Implementation Costs :** WLAN are easy to setup, relocate, change and low cost.
  3. **Installation Speed and Simplicity :** Fast and simple installation of WLAN.
  4. **Network Expansion :** Easy expansion of WLAN possible.
  5. **Higher user to install base ratio :** Wireless environment offers a higher user to capacity ratio.
  6. **Reliability :** WLAN is more reliable than cable network.
  7. **Scalability :** WLAN can be configured in various topologies as per requirement.
  8. **Use of ISM band :** WLAN operates in unregulated ISM (Industrial Scientific and Medical).

Disadvantages of WLAN

1. Low bandwidth compared to wired networks (1-10 Mbit/s)
2. Many proprietary solutions, especially for higher bit-rates, standards take their time (e.g. IEEE 802.11)
3. Many national restrictions for wireless, long time to establish global solutions like, e.g. IMT-2000

1.10.3 Types of WLAN

- Various WLAN types are listed below :
  1. 802.11
  2. HyperLAN
  3. HomeRF
  4. Bluetooth
  5. MANET

1.10.4 Hidden and Exposed Station Problems in WLAN

- Hidden terminal problems are refers to the collision of a packet at a receiving node due to the simultaneous transmission of those nodes that are not in the direct transmission range of the sender, but are within the transmission range of the receiver.

- Collision occurs when both nodes transmit packets at the same time wit knowing about the transmission of each other.
- Fig. 1.10.1 shows the hidden and exposed terminal problems in WLAN.

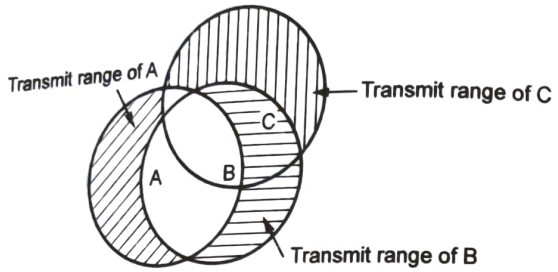


Fig. 1.10.1 Hidden and exposed terminal in WLAN

Hidden Terminal Problem

- Node B is within the range of nodes A and C, but A and C are not in each othe range. Let us consider the case where A is transmitting to B. Node C, being out A's range, cannot detect carrier signal and may therefore send packet to B, th causing a collision at B. This is referred to as the **hidden-terminal problem**, as nod A and C are hidden from each other.

Exposed Terminal Problem

- The exposed terminal problem refers to the inability of a node, which is blocked du to transmission by a nearby transmitting node, to transmit to another node. Let u now consider another case where B is transmitting to A. Since C is within B's rang it senses carrier signal and decides to defer its own transmission. However, this unnecessary because there is no way C's transmission can cause any collision receiver A. This is referred to as the **exposed-terminal problem**, since B bein exposed to C caused the latter to needlessly defer its transmission.

1.11 Bluetooth

- Bluetooth is an open specification (universal) for short-range wireless voice and dat communications. Bluetooth standardization began in 1998.
- Bluetooth is an always-on, short-range radio hook-up that resides on a microchip. was initially developed by Swedish mobile-phone maker Ericsson in 1994 as a wa to let laptop computers make calls over a mobile phone. Since then, severa thousand companies have signed on to make Bluetooth the low-power short-rang wireless standard for a wide range of devices.

- Sponsors of Bluetooth are : **Initial** : Ericsson, Nokia, IBM, Toshiba and Intel formed a Special Interest Group (SIG) to expand on the concept and to develop a standard under IEEE 802.15 WPAN.
- **Expanded :** In 1999 to include 3 Com, Lucent, Microsoft and Motorola also the first specification, v1.0b was released and then accepted as the IEEE 802.15 WPAN standard for 1 Mb/s networks. Thousands of companies are now adopters of Bluetooth.
- The Bluetooth standards are published by an industry consortium known as the Bluetooth SIG (Special Interest Group).
- The concept behind Bluetooth is to provide a universal short-range wireless capability. It uses the 2.4 GHz band, available globally for unlicensed low-power uses.
- Bluetooth is intended to support an openended list of applications including data, audio, graphics and even video.
- Bluetooth is the first popular technology for shortrange ad-hoc networking that is designed for integrated voice and data applications. Compared with WLANs, Bluetooth has a lower data rate, but it has an embedded mechanism to support voice applications.
- Unlike 3G cellular systems, Bluetooth is an inexpensive personal area ad-hoc network operating in unlicensed bands and owned by the user.

Bluetooth Applications

- The bluetooth SIG considers three application-based scenarios :
  1. Cable replacement
  2. Ad-hoc personal networks
  3. Integrated Access Points (APs) for data/voice

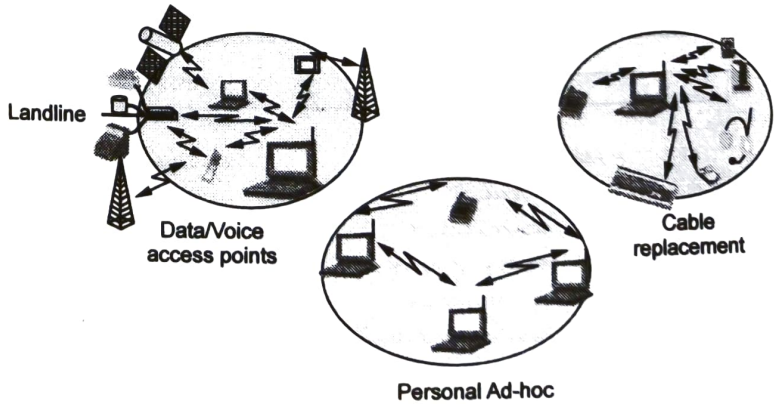


Fig. 1.11.1 Three application scenarios considered by Bluetooth

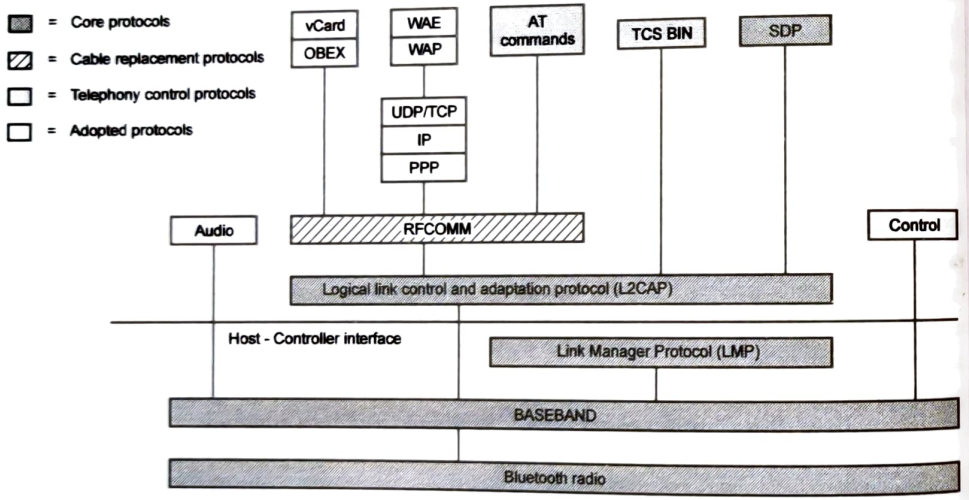
Bluetooth Standards Documents

- Bluetooth standards are divided into two groups :

1. **Core Specifications :** Describes the details of the various layers of the Bluetooth protocol architecture, from the radio interface to link control.
2. **Profile Specifications :** Are concerned with the use of Bluetooth technology to support various applications. Each profile specification discusses the use of the technology defined in the core specifications to implement a particular usage model. It includes a description of which aspects of the core specifications are mandatory, optional and not applicable.

1.11.1 Protocol Architecture

- Bluetooth is defined as a layered protocol architecture consisting of core protocols, cable replacement, telephony control protocols and adopted protocols as shown in Fig.1.11.2.



AT = Attention sequence
IP = Internet protocol
OBEX = Object exchange protocol
RFCOMM = Radio frequency communications
SDP = Service discovery protocol
TCP = Transmission control protocol
TCS BIN = Telephony control specification - binary
UDP = User datagram protocol
vCal = Virtual calender
vCard = Virtual card
WAE = Wireless application environment
WAP = Wireless application protocol

Fig.1.11.2 Bluetooth protocol stack

- The core protocols form a five-layer stack consisting of the following blocks :

1. Bluetooth Radio :

- It specifies the details of the air interface, including frequency, the use of frequency hopping, modulation scheme and transmit power.

2. BASEBAND :

- It is concerned with connection establishment within a piconet, addressing, packet format, timing and power control.

3. Link Manager Protocol (LMP) :

- LMP is Responsible for linking setup between Bluetooth devices and ongoing link management. (this includes security aspects such as authentication and encryption, plus the control and negotiation of baseband packet sized).

4. Logical Link Control and Adaptation Protocol (L2CAP) :

- The L2CAP adapts upper-layer protocols to the baseband layer. L2CAP provides both connectionless and connection-oriented services.

5. Service Discovery Protocol (SDP) :

- Device information, services and the characteristics of the services can be queried to enable the establishment of a connection between two or more Bluetooth devices.
- **RFCOMM** is the cable replacement protocol included in the Bluetooth specification. RFCOMM presents a virtual serial port that is designed to make a replacement of cable technologies as transparent as possible.
- RFCOMM provides for binary data transport and emulates EIA-232 control signals over the Bluetooth baseband layer. EIA-232 (formerly known as RS-232) is a widely used serial port interface standard.
- Bluetooth specifies a **telephony control protocol.** TCS BIN (telephony control specification-binary) is a bit oriented protocol that defines the call control signalling for the establishment of speech and data calls between Bluetooth devices.
- The **adopted protocols** are defined in specifications issued by other standards-making organizations and incorporated into the overall Bluetooth architecture.
- The Bluetooth strategy is to invent only necessary protocols and use existing standards whenever possible. Some of the adopted protocols are :
  1. PPP (point to point protocol)
  2. TCP/UDP/IP
  3. OBEX (object exchange protocol)
  4. WAE/WAP (wireless application environment and protocol).

1.11.2 Radio Specification

The Bluetooth radio specification is a document that gives the basic details of radio transmission for Bluetooth devices. Table 1.11.1 summarizes the key parameters.

Sr No.	Parameter	Typical Value
1.	Topology	Up to 7 simultaneous links in a logical star
2.	Modulation	GFSK
3.	Peak data rate	1 Mbps
4.	RF bandwidth	220 kHz (– 3dB), 1 MHz (– 20dB)
5.	RF band	2.4 GHz ISM band
6.	RF carriers	23/79
7.	Carrier spacing	1 MHz
8.	Transmit power	0.1 W
9.	Piconet access	FH-TDD-TDMA
10.	Frequency hop rate	1600 hops/s
11.	Scatternet access	FH-CDMA

Table 1.11.1 Bluetooth Radio and Baseband Parameters

- Bluetooth makes use of the 2.4 GHz band within the ISM band. In most countries, the bandwidth is sufficient to define 79 1 MHz physical channels.
- Power control is used to keep the devices from emitting any more RF power than necessary. The power control algorithm is implemented using the link management protocol between a master and the slaves in a piconet.
- One important aspect of the radio specifications is the definition of three classes of transmitters based on output power :

  I] **Class 1 :** Outputs 100 mW (+20 dBm) for maximum range, with a minimum of 1 mW (0 dBm). In this class power control is mandatory, ranging from 4 to 20 dBm. This mode provides the greatest distance.

  II] **Class 2 :** Outputs 2.4 mW (+4 dBm) at maximum, with a minimum of 250 μW (– 6 dBm). Power control is optional.

  III] **Class 3 :** Lowest power. Nominal output is 1 mW.

- Modulation for Bluetooth is Gaussian FSK, with a binary one represented by a positive frequency deviation and a binary zero represented by a negative frequency deviation from the centre frequency. The minimum deviation is 115 kHz.

1.12 Personal Area Network (PAN)

- A Personal Area Network (PAN) is a computer network used for communication among computer devices (including telephones and personal digital assistants) close to one person.
- The reach of a PAN is typically a few meters. PAN's can be used for communication among the personal devices themselves (intrapersonal communication), or for connecting to a higher level network and the Internet.
- Personal area networks may be wired with computer buses such as USB and FireWire. However, a Wireless Personal Area Network (WPAN) is made possible with network technologies such as Infrared (IrDA) and Bluetooth.

Fig. 1.12.1 Personal area network

1.12.1 Synchronization Protocols

- Synchronizers use different protocol layers for communication with other devices.
- Common popular synchronization protocols for synchronizing mobile applications are :
  1. Bluetooth
  2. IrDA

1.12.1.1 Bluetooth Protocol

- Bluetooth protocols are used for synchronization among mobile devices and Bluetooth-enabled PCs in a wireless personal area network.
- Fig. 1.12.2 shows synchronization between Bluetooth enabled computer and device.
- Bluetooth is a connection-oriented protocol using Bluetooth Object Exchange OBEX (a protocol for transport layer in Bluetooth).

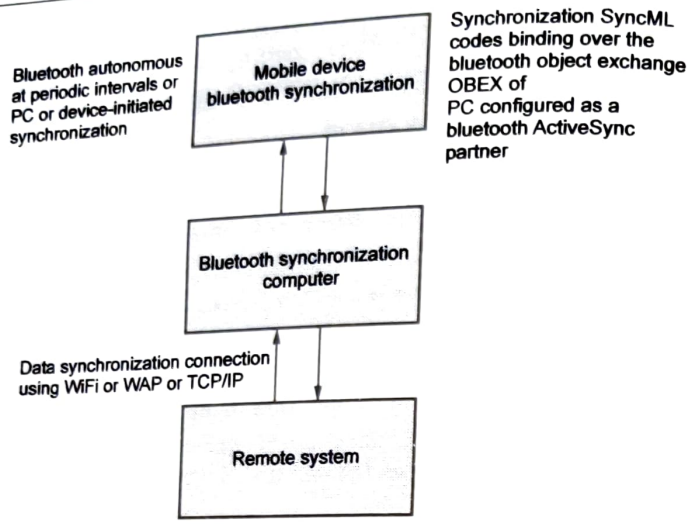


Fig. 1.12.2 Synchronization between bluetooth devices

- Bluetooth protocol is a self-discovery protocol. It discovers whether nearby personal area device a Bluetooth-protocol-based communicating device.
- A Bluetooth enabled device sets up an adhoc network with the Bluetooth enabled devices and computing systems.
- Bluetooth protocol synchronizes PIM data (calendar, email, business card, text messages, and phonebook) with the ActiveSync device or a device which is not Bluetooth enabled through the virtual COM port.

1.12.1.2 Infrared Data Association (IrDA) Protocol

- Infrared-based synchronization of mobile devices and computers within the same room.
- IrDA specifications include connection-oriented or connectionless protocols.
- IrDA specifies five levels of communication-
  1. minimum,
  2. access,
  3. index,
  4. sync, and
  5. SyncML (levels 1 to 5)

- IrDA synchronization can be used to synchronize PIM data (calendar, email, business card, text messages, etc.)

1.13 Short Questions and Answers

Q.1 Name the main parts of paging system.

Ans. : 1. Calling subscriber 2. Telephone network
3. Paging service company 4. Paging receiver

Q.2 Name the two main digital protocols used in paging system.

Ans. : 1. POCSAG 2. FLEX

Q.3 What is AMPS ?

Ans. : AMPS is a North American, first generation cellular radio implemented using analog FM.

Q.4 What is meant by half duplex ?

Ans. : **Half-duplex** is a two-way communication in which only one station can transmit at a time.

Q.5 What is mean by full-duplex ?

Ans. : **Full-duplex** is a two way communication in which both terminals can transmit simultaneously.

Q.6 What is MTSO ?

Ans. : Mobile Telephone Switching Office (MTSO) is the central co-ordinating office for the cell sites. It interfaces PSTN, controls call processing and handles billing activities.

Q.7 What is Bluetooth ?

Ans. : Bluetooth is a wireless technology standard used to exchange data over short distances. The data is exchanged from fixed and mobile devices by creating Personal Area Network with security at high level.

Q.8 What is the difference between WiFi and Bluetooth ?

Ans. : WiFi fall under WLAN category while Bluetooth fall under WPAN category. WLAN specifications are published under IEEE 802.11 and Bluetooth under IEEE 802.15 standards. Bluetooth is the standard for wireless personal area networks or WPAN. It allows high speed transmission of data over very short distances.

1.14 Multiple Choice Questions

Q.1 Bluetooth is the wireless technology for _____.

[a] local area network [b] personal area network
[c] both (a) and (b) [d] none of the mentioned **[Ans. : b]**