Sub. Code : CS8601

Mobile Computing

ANNA University - CBCS Scheme - Regulation 2017 - SEM VI - (CSE)

- Simplified & Conceptual Approach
- 2 Marks Questions With Answers
- Chapterwise Solved AU Questions June 2016 To May 2019
- Solved AU Question Papers June 2016 To May 2019
- Solved Model Question Paper (As Per New Syllabus)

first edition : jan. 2020
second edition : jan. 2023

Price : ₹ 450/-
ISBN 978-93-89420-50-0

TECHNICAL PUBLICATIONS
SINCE 1993
An Up-Thrust for Knowledge

V. Jeyasri Arokiamary

SUBJECT CODE : CS8601

Strictly As Per Revised Syllabus of

ANNA UNIVERSITY

Choice Based Credit System (CBCS)

Semester - VI (CSE)

MOBILE COMPUTING

V. Jeyasri Arokiamary

M.E., PGDBA, MISTE,

Formerly Associate Professor, Department of ECE,

Kumaraguru College of Technology,

Coimbatore - 641 006.

Tamilnadu

TECHNICAL PUBLICATIONS

SINCE 1993 An Up-Thrust for Knowledge

MOBILE COMPUTING

Subject Code : CS8601

Semester - VI (Computer Science & Engineering)

Published by :

TECHNICAL PUBLICATIONS
SINCE 1993
An Up-Thrust for Knowledge

Amit Residency, Office No.1, 412, Shaniwar Peth,
Pune - 411030, M.S. INDIA, Ph.: +91-020-24495496/97
Email : info@technicalpublications.in Website : www.technicalpublications.in

Printer :
Yogiraj Printers & Binders
Sr.No. 10\1A,
Ghule Industrial Estate, Nanded Village Road,
Tal-Haveli, Dist-Pune - 411041.

ISBN 978-93-89420-50-0

9 789389 420500

AU 17

9789389420500 [2]

PREFACE

The Lord will perfect that which concerneth me.

Psalm 138 : 8

The importance of **Mobile Computing** is well known in various engineering fields. Overwhelming response to my books on various subjects inspired me to write this book. The book is structured to cover the key aspects of the subject **Mobile Computing**.

The book uses plain, lucid language to explain fundamentals of this subject. The book provides logical method of explaining various complicated concepts and stepwise methods to explain the important topics. Each chapter is well supported with necessary illustrations, practical examples and solved problems. All the chapters in the book are arranged in a proper sequence that permits each topic to build upon earlier studies. All care has been taken to make students comfortable in understanding the basic concepts of the subject.

The book not only covers the entire scope of the subject but explains the philosophy of the subject. This makes the understanding of this subject more clear and makes it more interesting. The book will be very useful not only to the students but also to the subject teachers. The students have to omit nothing and possibly have to cover nothing more.

I wish to express my profound thanks to all those who helped in making this book a reality. Much needed moral support and encouragement was provided on numerous occasions by my whole family. I wish to thank the Publisher and the entire team of Technical Publications who have taken immense pain to get this book in time with quality printing.

Any suggestion for the improvement of the book will be acknowledged and well appreciated.

Dedicated to Lord Jesus Christ.

Author

D. Jeyasri Arokiamary

SYLLABUS

Mobile Computing [CS8601]

Unit - I : INTRODUCTION

Introduction to Mobile Computing – Applications of Mobile Computing- Generations of Mobile Communication Technologies- Multiplexing – Spread spectrum -MAC Protocols – SDMA- TDMA- FDMA- CDMA

Unit - II : MOBILE TELECOMMUNICATION SYSTEM

Introduction to Cellular Systems - GSM – Services & Architecture – Protocols – Connection Establishment – Frequency Allocation – Routing – Mobility Management – Security – GPRS- UMTS – Architecture – Handover - Security

Unit - III : MOBILE NETWORK LAYER

Mobile IP – DHCP – AdHoc– Proactive protocol-DSDV, Reactive Routing Protocols – DSR, AODV , Hybrid routing –ZRP, Multicast Routing- ODMRP, Vehicular Ad Hoc networks (VANET) –MANET Vs VANET – Security.

Unit - IV : MOBILE TRANSPORT AND APPLICATION LAYER

Mobile TCP– WAP – Architecture – WDP – WTLS – WTP –WSP – WAE – WTA Architecture – WML

Unit - V : MOBILE PLATFORMS AND APPLICATIONS

Mobile Device Operating Systems – Special Constraints & Requirements – Commercial Mobile Operating Systems – Software Development Kit: iOS, Android, BlackBerry, Windows Phone – MCommerce – Structure – Pros & Cons – Mobile Payment System – Security Issues

TABLE OF CONTENTS

Unit I

Introduction

Syllabus

Mobile Computing - Mobile Computing Vs wireless Networking - Mobile Computing Applications - Characteristics of Mobile computing - Structure of Mobile Computing Application. MAC Protocols - Wireless MAC Issues - Fixed Assignment Schemes - Random Assignment Schemes - Reservation Based Schemes.

Contents

1.1 Introduction to Mobile Computing

AU : June-16, Dec.-17

It is the computation made over physical mobility. Mobile computing system permits the user to perform a task from a distant place from the device. The mobile computing is also known by different names according to its role in that context few examples are listed below.

1) Virtual home environment

It is denoted as " VHE". It is possible under VHE to operate a device like heater in a person's home though he is away from his place. He has a virtually available feeling at his home.

2) Nomadic computing

The entire mobile computing environment is nomadic in nature and it moves with the roaming user. It is possible for both remote and local services.

3) Wearable computer

The wearable computers are used like wearable accessories like shoes, clothes etc. by human beings. A person can wear it provided these computers have extra attributes than conventional mobile computers. Actually the wearable computers are those which can be adorned by a person like an accessory hat, shoe etc.

1.2 Examples of the Cellular Radio Communication

AU : Dec.-16

1. Cellular telephone system.
2. Cordless Telephone (CT) system.
3. Paging system.

These examples are given below.

Example 1 : Cellular telephone system

The cellular telephone system mainly helps to connect a Public Switched Telephone Network (PSTN) and any distant/near user provided the user is available within the corresponding radio range. (A basic cellular system is given below.) The mobile switching center or Mobile Telephone Switching Office (MTSO) connects the mobile units (called parties) to the PSTN. Every cell of the particular geographical area has its own base station with a transceiver, an antena, and also a control circuitry.

The base stations are capable of handling many full duplex cellular communications. The mobile switching center can handle atleast 5000 telephonic conversation at a time and 1,00,000 cellular users/subscribers in a network. The cellular communication is made possible between mobile units and the base stations with the help of Common Air Interface (CAI) which specifies four channels.

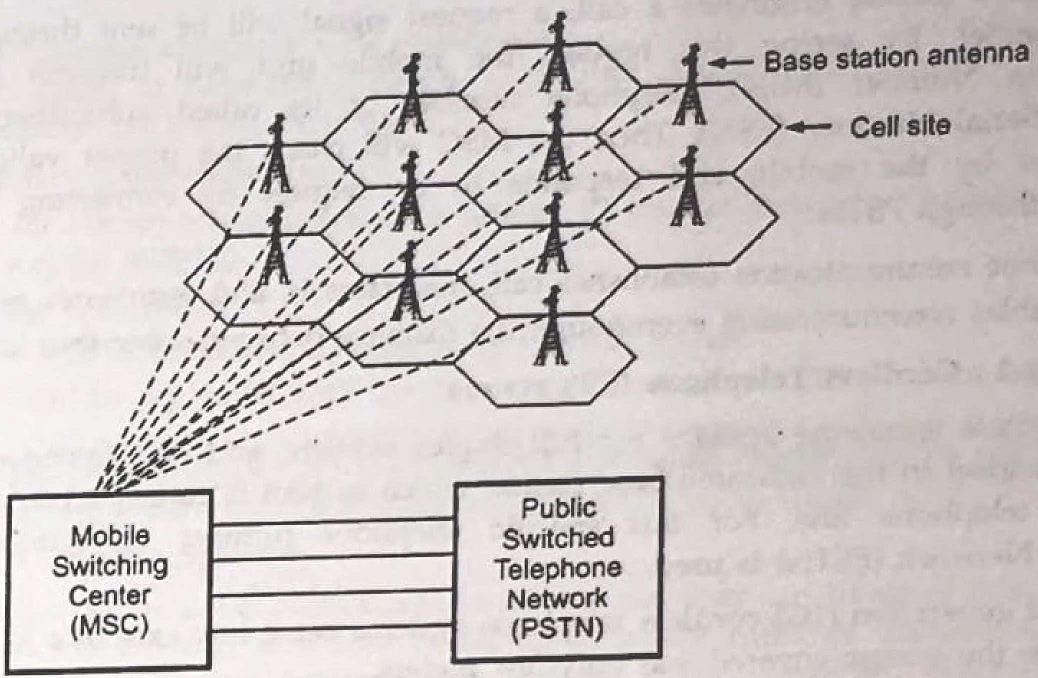


Fig. 1.2.2 Cellular system

They are :

1. Forward Control Channels (FCC)
2. Reverse Control Channels (RCC)
3. Forward Voice Channels (FVC) and
4. Reverse Voice Channels (RVC).

The control channels mentioned here are also termed as setup channels. They will have calls that are in progress but they usually send and receive data messages carrying call initiation and requests for services.

The Forward Control Channels (FCC) are also termed as "BEACONS" since they continuously broadcast the traffic requests for the mobile units within the cellular system. As soon as the cell phone is switched on it scans the control channels searching for the strongest signal of a base station. When the call progresses the mobile switching center adjusts the power transmitted (P_T) of the mobile unit and alters the channel of the mobile unit and also the base station so as to maintain the call quality eventhough the mobile unit is non-stationary.

The call in progress continues irrespective of the frequency changes from one base to another base station. Such a call continued process without termination is called as 'Hand off' technique. As the mobile moves and the signal strength reduces when it is away from its base station of cell, the next base station of the neighbouring cell where the mobile enters in will take charge of the call. A relay like process thus takes place within several base stations of the entire cellular system simply to sustain the call developed between two subscribers.

Whenever a mobile originates a call, a request signal will be sent through reverse control channel. By seeing this request the mobile unit will transmit its Mobile Identification Number (MIN), telephone number of its called subscriber, and the Electronic Serial Number (ESN). Then the MSC will check the proper validity of the signals sent by the mobile and responds to its request by connecting the called subscriber through PSTN.

The mobile communication establishes call, maintains it, and terminates as the call is over. It enables communication eventhough the distance between subscriber is large.

Example 2 : Cordless Telephone (CT) system

The cordless telephone systems are full duplex systems and it is intended to link a portable handset to the dedicated base station which in turn is connected to a particular dedicated telephone line. For this specific telephone number on Public Switched Telephone Network (PSTN) is used.

The first generation (1G) cordless telephone systems came into existance in 1980's. But the distance the system covered was only few meters.

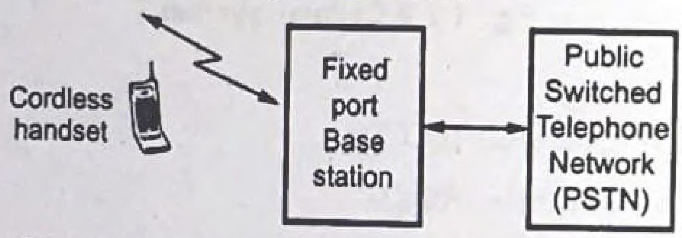


Fig. 1.2.3 Cordless Telephone (CT) system

Later the second generation (2G) cordless systems the distance was not a problem and the subscribers used cordless systems in mobile environment also. The system was good only if the subscriber availability was within the coverage of base station.

The cordless system also work together with paging system such that the roaming subscriber can first be paged and he or she can respond to it with the help of cordless telephone. In the simple cordless system shown above it illustrates that the cordless handset is linked to PSTN through the base station (fixed port). The cordless handset has a wireless link with its dedicated base station. The cordless systems are divided into two namely Analog CT and Digital CT.

In the early days these cordless systems were analog (Analog CT). They provided analog voice transmissions and enabled mobility within a limited distances. But they had many demerits such as

i) Poor call qualities

ii) Interference

These problems urged the need for digital cordless (Digital CT) systems. They provided better voice quality similar to wired telephone system.

Example for digital cordless system is

CT2 / Common Air Interface (CAI)

Some of the main criteria of CT2 system are

i) Voice signal is digitized through 32 kb/sec Adaptive Differential Pulse Code Modulation (ADPCM) technique.

ii) Bit stream compression facility.

iii) Final bit stream transmission at a rate of 72 kb/sec through Gaussian Frequency Shift Keying (GFSK).

iv) Immune to errors.

v) Supports data transmissions effectively upto 32 kb/sec.

vi) Traffic can be separated with the Time Division Duplex (TDD) access technique.

Note This CT2 standard does not provide for the mobility status and the later version CT2 + standard was used for this purpose.

Example 3 : Paging Systems

The paging systems are communication systems and they can transmit brief messages to subscribers. The message sent may be an alphanumeric message, numeric message or even a voice data. Paging systems also include news headlines, faxes and stock quotations. It may be sent to a particular paging subscriber through the paging system access number with a modem or a telephone keypad. Such a message is called as page.

In a technique called 'simulcasting' the wide paging systems sends a page from each base station simultaneously.

The important performance metrics used in decision-making process under hand off situations (mobility management) are listed below.

1. Probability of call blocking
2. Probability of call dropping.
3. Probability of call completion.
4. Handoff delay.
5. Rate of handoff.
6. Probability of an incomplete handoff.
7. Probability of handoff blocking.
8. Interruption time duration.
9. Handoff probability.

Strategies used to calculate the instant of handoff are :

1. Relative signal strength method.
2. Relative signal strength with hysteris method.
3. Relative signal strength with threshold method.
4. Prediction techniques.

In a wide area paging system a paging control center is available that connects the PSTN to different paging terminals.

Thus paging systems enable communication with subscribers irrespective of their roaming state. But the system requires large transmitter powers in the order of kilowatts and uses only low data rates for providing proper coverage.

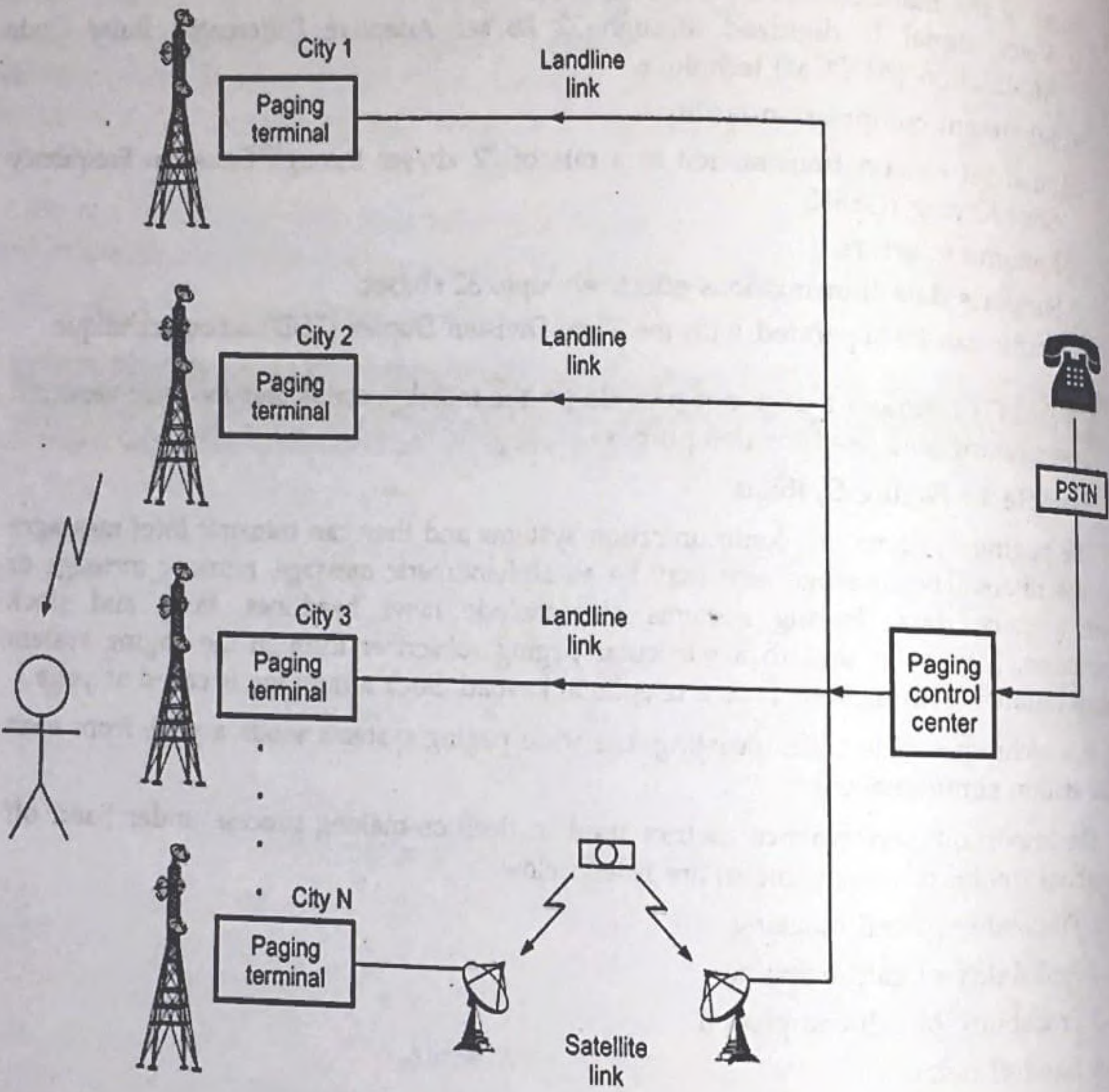


Fig. 1.2.4 Wide area paging system

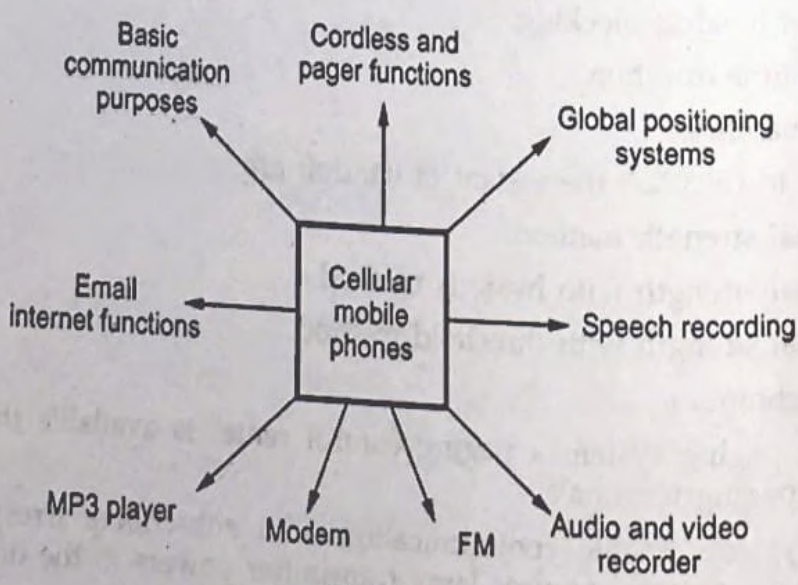


Fig. 1.2.5

There are several functionalities possible with cellular mobile phones as shown above which includes the pager functions too. It is helpful in sending short messages which are highly used by subscribers. The short message or page is sent to a subscriber wherever he is, and it is the main advantage of these system in spite of low data rates and large transmitter power requirements.

1.2.1 Cellular Mobile Communication

Important terminologies

1. **Cell :** It is smallest geographical area considered for cellular mobile communication.
2. **Base station (BS) :** Base station provides functionalities between mobile unit and Mobile Switching Center (MSC). The base station is located in each cell and it links the subscriber mobile unit with the MSC.
3. **Cell splitting :** In high cellular traffic regions, a larger cell is divided into smaller cells to have complete radio coverage.
4. **Handoff :** When mobile unit moves from one cell to another cell the call in progress will be handed over form one base transceiver to the base transceiver of the new cell where the mobile unit enters so that the call in progress is not disturbed and such a process is called as "Handoff".
5. **Cell sectoring :** A cell can be divided into many sectors. For example, from 3 sectors to 6 sectors in a hexagonal cell. The directional antenna should focus on each sector.
6. **Umbrella cell pattern :** A single large cell (Macro cell) consists of many small cells (Micro cells) and there will be interaction between the micro and macro cells.
7. **Control channel :** They are used for necessary exchange of information related to setting up and establishing cell base stations and the mobile units.
8. **Traffic channels :** They are used for carrying data or voice connections between different users.
9. **Frequency reuse :** It is a concept followed in cellular communication for efficient spectrum utilization. The same carrier frequency is reused by many cells in a cellular cluster and it is known as 'frequency reuse' scheme.
10. **Fading :** Fading is an effect in mobile radio propogation. It is common in multipath mobile signalling environment.
11. **Mobile Telecommunication Switching Office/Mobile Switching Center (MTSO/MSC) :** It is the main unit that connects the base transceiver station and the Public Switched Telephone Network (PSTN) in mobile communication.

11. Parameters for cells

Cell radius	→ 0.1 - 1 km.
Delay spread (average value)	→ 10 - 100 nsec.
Max bit rate	→ 1 Mb/sec.
Transmission power (P_T)	→ 0.1 - 1 watt.

12. Parameters for macro cells

Cell radius	→ 1 - 20 km.
Delay spread (average value)	→ 0.1 - 10 μsec.
Max bit rate	→ 0.3 Mb/sec.
Transmission power (P_T)	→ 1 - 10 watt.

13. Page

It is a brief message that is broadcast over an entire service area, generally in a simulcast type by many base stations at a time.

14. Forward channel

It is a radio channel used for transmission of information from base station to the mobile unit.

15. Reverse channel

It is a radio channel used for transmission of information from mobile unit to the base station.

16. Simplex systems

These are the communication systems that provide only one way communication.

17. Subscriber

A mobile phone user who pays subscription charges for using a cellular mobile communication system.

18. Mobile station

Mobile station is mainly intended for use while in movement at any location. It can be hand-held personal units that is portable or installed in moving vehicles.

19. Full duplex systems

The transmission and reception is typically on two different channels (FDD) even though new cordless systems are using TDD scheme. It is a communication system that allows two way communication simultaneously.

20. Half duplex systems

The communication systems that allow two way communication by using same radio channel for both transmission and reception. The user can transmit or receive at any time.

21. Transceiver

It is a device used for both transmitting and receiving radio signals.

22. Roamer

It is a mobile station that operates in a service area other that the subscribed service area.

23. PSTN

It is the public switched telephone network to which the Mobile Telephone Switching Center (MTSO) is connected.

1.2.2 Trends in Cellular Radio and Personal Communications

With the help of digital signal processing, RF technology, network intelligence the personal wireless systems have developed worldwide and provide many number of services to subscribers in their unique way. The Personal Communication Services (PCS) initiated in the United Kingdom and the frequency spectrum allotted was in the range 1800 MHz. It focussed on developing Personal Communication Networking (PCN).

The advantage of PCN is that the subscriber can receive or make a call irrespective of the roaming status. The Personal Communication Systems (PCS) includes several network features and provides more personalization, than the available cellular systems.

Then the indoor wireless networking got all the importance due to the better network connectivity within the building premises. One such standard is HIPERLAN compatible with indoor wireless standard and it was developed by European Telecommunications Standard Institute (ETSI).

An important worldwide standard known as Future Public Land Mobile Telephone System (FPLMTS) or International Mobile Telecommunication 2000 (IMT-2000) emerged in the year 1995 and it was developed by International Telecommunications Union (ITU). This IMT-2000 is a third generation (3G) standard and some of its advantages are

i) Global compatibility.

ii) Integrate paging, cordless and the cellular mobile system and LEO satellites as a single mobile system.

iii) Supports multi-function.

It is an excellent digital mobile radio system accepted worldwide. The satellite mobile systems incorporates good paging systems, data collection, global roaming and emergency communications. One such example is network of LEO satellites.

The fundamental technological developments has thus helped the wireless personal communication systems to grow rapidly and the demand it has is also high. The wireless networking will surely improve further to meet more requirements and additional features in wireless personal communication field.

Mobile Computing :

It is a real computation over physical mobility. It allows the user to execute a task/job even from a distant place. This mobile computing environment is also known by several names like,

- Virtual home environment.
- Nomadic computing etc.

1.3 Mobile Computing-Structural View

AU : June-16, Dec.-16,17, May-18,19

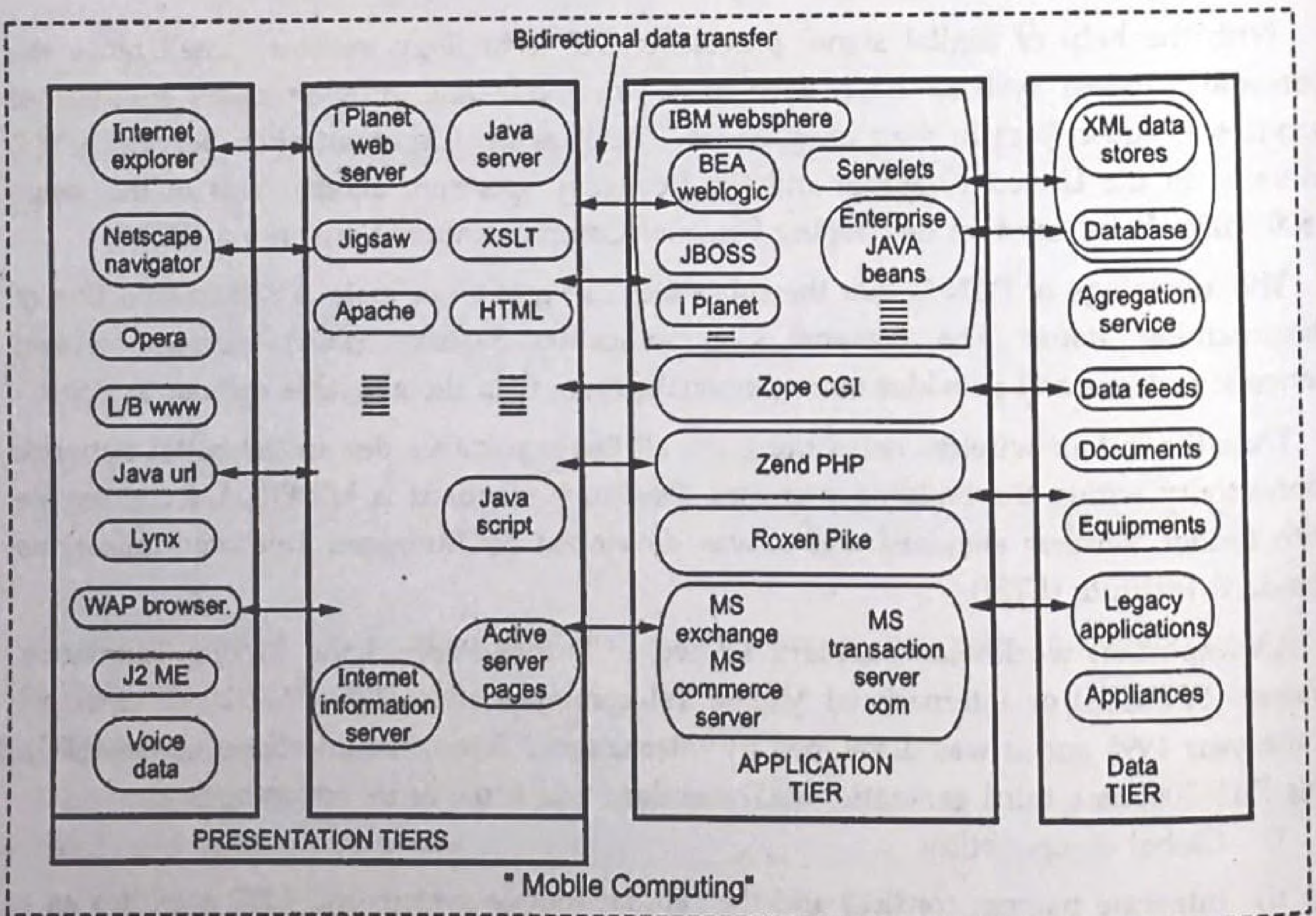
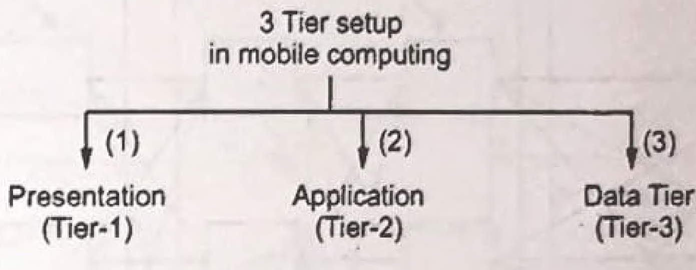


Fig. 1.3.1 Architecture of mobile computing

The three tier structure depicted is used mainly for mobile environment. They are presentation tier, data tier and application tier.



The presentation layer is concerned about user interaction. Its applications run on the client devices. This layer also includes web browsers, and the customized client programs.

The application tier is also known as middle tier which is like an "engine" to the automobile. It plays a vital role in wireless LAN applications. It performs the processing of user input, obtaining information and then making decisions. This layer includes technology like Java, "NET" services, cold fusion web logic, iplanet, 'Z end' etc. It is database independent.

The middleware also covers a wide range of software systems, mobile application support etc. The two independent open objects can be connected through this middleware as a software gateway.

There are many classifications available under middleware.

1.3.1 Mobile Computing

The mobile computing architecture is given in figure shown above. They are simple and efficient. One example of this network is three-tier architecture as in the diagram. It mainly consists of user interface (tier-1), access network, middle tier (tier-2) are data tier (tier-3). (See Fig. 1.3.2 on next page).

The first layer is the user interface or a presentation tier.

a. Message-oriented middleware are (MOM).

b. Transaction processing middleware (TP).

c. Communication middleware (CM).

d. Database middleware (DM).

e. Distributed object and components (DOC).

f. Transcoding middleware (TM).

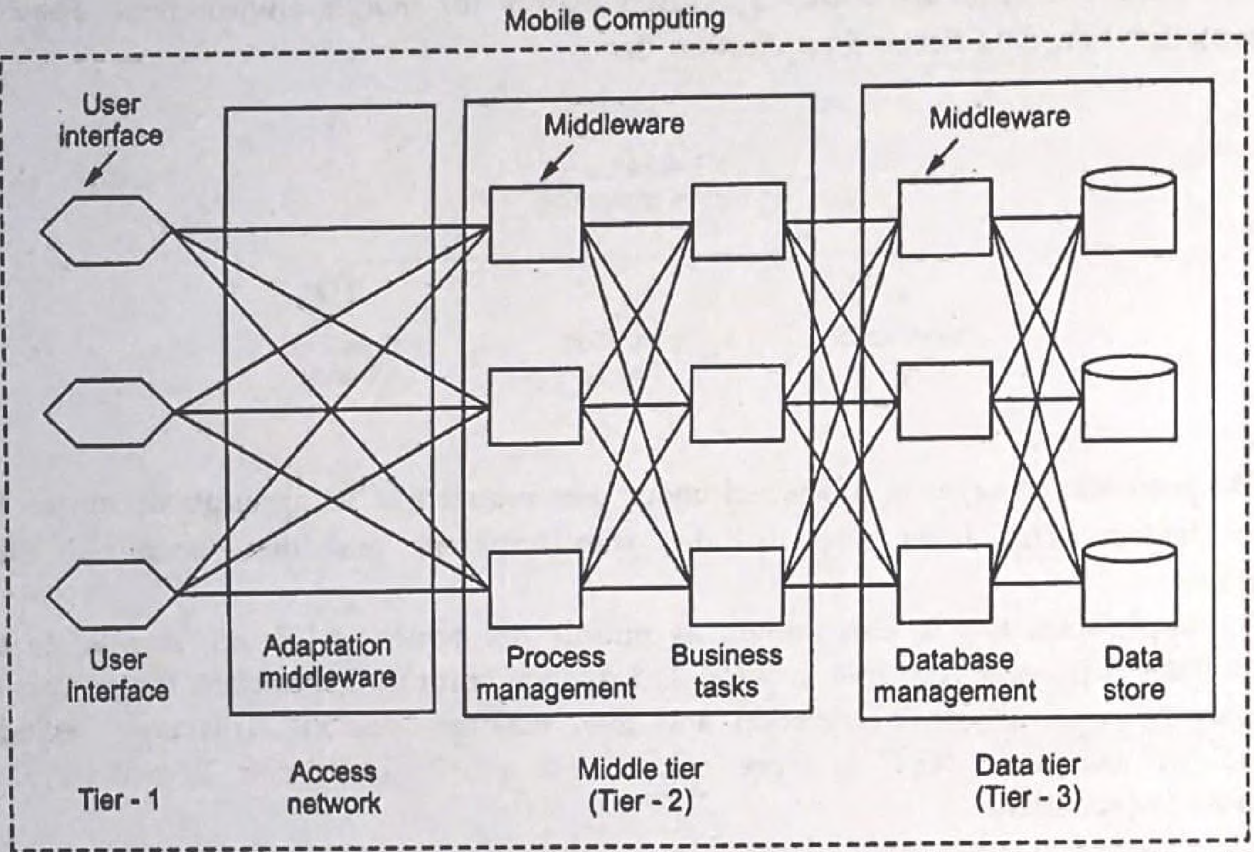


Fig. 1.3.2 An example for mobile computing - "Three tier architecture"

1.3.2.1 Message-Oriented Middleware (MOM)

The message oriented middleware is generally asynchronous, peer to peer which works in a subscribe method. One or many objects may subscribe to a particular event. When an event occurs it will be subscribed or published by asynchronous loosely coupled object. The MOM monitors the occurrence of events. The Request/Response scheme is more flexible with MOM method. Hence the message oriented middle is more appropriate for event driven applications. An example for MOM under Java is known as Java Message Service (JMS).

1.3.2.2 Transaction Processing Middleware (TP)

It is suited for developing transaction based distributed applications.

The number of client requests are properly mapped to different application tasks through application service routines. (See Fig. 1.3.3 on next page).

In an ideal TP system, the device for input and output can be different. The transaction processing is independent of database architecture. The TP middleware helps to reduce the resources by multiplexing technique, which in turn may reduce the response time.

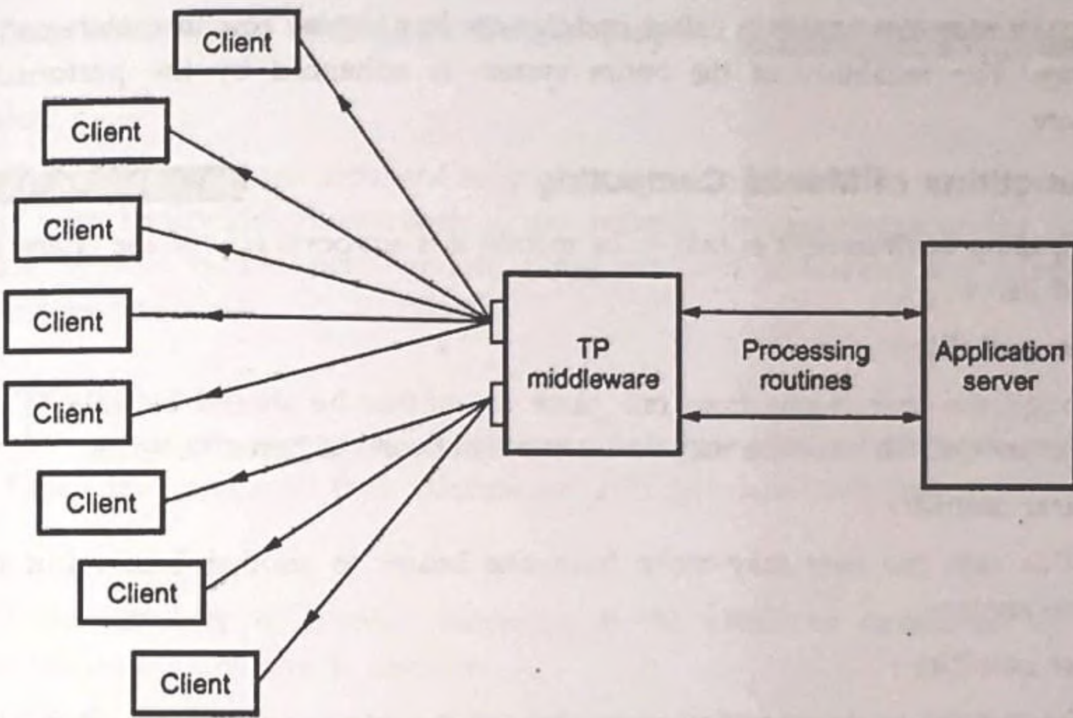


Fig. 1.3.3 Transaction processing (TP) middleware

1.3.2.3 Database Middleware (DM)

The database middleware is responsible for maintaining the entire data involved in communication. In data tier their are database management and data store facilities. User interface can interact with data tier through access network and middle tier.

1.3.2.4 Communication Middleware (CM)

It is used to connect one application to another application through communication middleware. In telecommunication field there are numerous elements in the core and the user interface is via the telnet. The communication between nodes are finally established.

1.3.2.5 Distributed Object and Components (DOC)

The Common Object Request Broker Architecture termed as CORBA is on of the best example for distributed objects and components. Many network programming tasks like framing, error handling etc. are simplified using CORBA. Many number of clients can be handled with high reliability and hit rates.

1.3.2.6 Transcoding Middleware (TM)

To attend the request or need of the user/client, the transcoding middleware is used to transform one format of data to another format. Actually content adaptation is done by transcoding to meet the requirement of each device.

The application tier or the so called middleware has to play role in mobile computing architecture. The reliability of the entire system is enhanced by the performance of middleware.

1.4 Functions of Mobile Computing

AU : June-16, Dec.-16

A computing environment is said to be mobile if it supports few of the characteristics mentioned below.

1. **User mobility :**

   Though the user roams from one place to another he should be able to use the same service. This service may be a remote network or home network.

2. **Bearer mobility :**

   In this case the user may move from one bearer to another bearer but use the same service.

3. **Host mobility :**

   In host mobility the user device can be either a server or a client. If it is a host mobility the mobility of that IP should be given more care. But if it is server or host mobility, some complexities will change.

4. **Service mobility :**

   Though the user changes from one service to another service it should remain enabled and if a user is sending a mail and he refers some information in his PC stored file for adding in his mail he should be allowed to do so.

1.5 Mobile Computing Vs Wireless Networking

AU : May-17,18, Dec.-16,17

- Mobile computing denotes collecting information and computational services in its mobile environment.
- But the wireless networking provides fundamental communication infrastructure.
- The mobile computing is based on the wireless networking environment and enables accessing data in mobile status.
- Wireless networking needs low investments and low setup time for setting up a network.
- Wireless local area network, Personal area network, Ad-hoc networks are some of the types of wireless networks.
- The wireless networks are of two types namely,
  i) Extension of the wired networks and ii) Ad-hoc networks.
- An Ad-hoc networks needs no infrastructure.
- It is based on the multi-hop wireless communications.
- On the other hand an example of wireless network is Wireless LAN (WLAN).

1.6 Characteristics of Mobile Computing

AU : June-16, Dec.-16, May-18

Adaptation :

In mobile computing environment adaptation refers to bandwidth management. It has to adjust with bandwidth fluctuations if any without the knowledge of the subscriber. There are several factors like handoff, noise etc. that influences the adaptation of computing environment.

Personalization :

In mobile computing scenerio the services can be personalized using the subscriber's profile. Hence they can avail their information with their handheld devices.

Ubiquity :

The word ubiquity in mobile computing is the ability of subscriber to compute informations from anywhere at anytime.

For example a sales representative can do his transactions from anywhere.

Location Awareness :

In mobile computing a handheld device equiped with Global Positioning System (GPS) can track the position of subscriber and inform it to the tracking station.

There are several applications that provide value added services by informing position-based services.

Some of the important applications are traffic control, emergency services where the computing environment dynamically monitor and the location informations to reduce congestion.

Broadcast :

In mobile computing environment data is efficiently transmitted to several subscribers simultaneously. For example a common advertising information is being sent to many users at a time.

1.7 Applications of Mobile Computing

AU : June-16, May-17,18, Dec.-17

Mobile computing provides several aplications and they are user friendly. Some of the applications include;

i) Vehicular mobile computing :

Vehicles will include weather forecasting, road conditions, along with news, music etc. Mobile computing enables many user friendly facilities. For personal system communications GSM phones might be available offering the voice and data connectivity with 384 kbits per second.

Mobile computing will be useful in emergency situations in wirelessly contacting the nearest hospitals and help in patient assistance etc.

ii) Business environments :

Mobile computing is useful where a simple device is represented by sensors transmitting state information. Also pagers, mobile, phones with full colour graphic delay will be useful in business applications. The PDA's, Palmtop/pocket computer etc are user friendly as it simplifies several calculations.

Thus mobile computing is useful in different fields and many applications are made possible.

1.8 Generation of Mobile Communication Technology AU : Dec.-16,17

The different generations 1G, 2G, 3G, 4G etc of cellular communication standards has evolved in different time periods.

The evolution of these standards made a remarkable developments in cellular mobile communication.

Evolution of Mobile Communication AU : Dec.-16

The wireless communication has developed worldwide from the year 1897 by means of radio and the development of the technology is due to revolution in the fields like

i) RF circuit fabrication

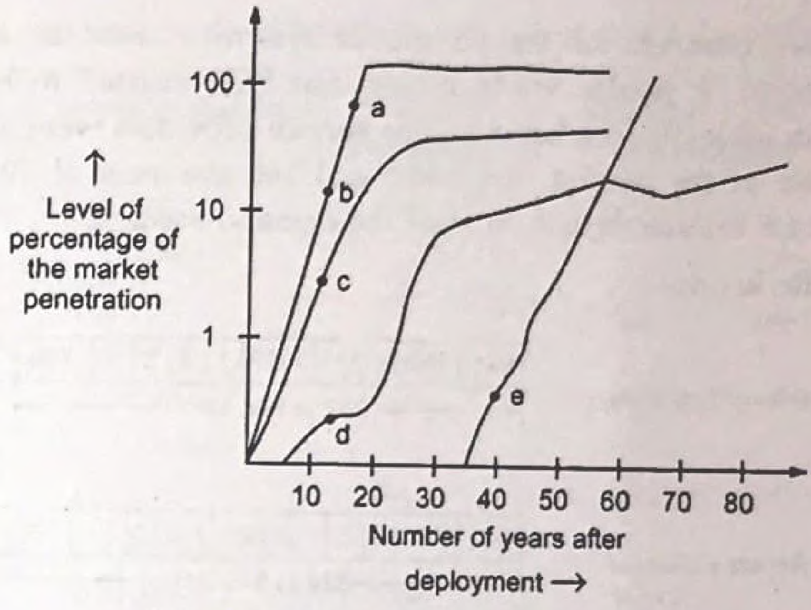
ii) Large scale circuit integration

iii) Digital circuit design

iv) Miniaturization technologies.

The impact of development of mobile communication is personal communication services. The cellular concepts emerged appreciably and slowly developed by Bell Laboratories in the period between 1960 and 1970. An exponential growth of wireless communication was observed. While comparing wireless technologies with other communications the penetration of wireless application is more in our day-to-day life. The cellular as well as personal communication services have revolutionized the communication field.

The drastic growth of mobile communication is compared here with other technologies in a graph.



a - Video cassette recorder - 1979 Year of introduction
b - Television - 1946
c - Automobile - 1900
d - Telephone - 1877
e - Mobile telephones - 1946

Fig. 1.2.1

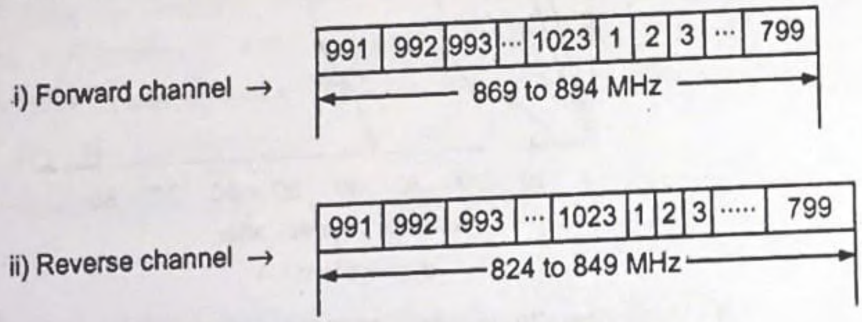
The cellular mobile communication technology emerged slowly and developed worldwide. At the same time it has penetrated into the market for long time with high demand than other technologies. It has an appreciable growth rate as seen in the graph.

In the year 1934 the police radio systems used the Amplitude Modulation (AM) systems for transmission purposes. In early cellular the major problem faced was vehicular ignition noise. It is also interesting that in 1960's the majority of mobile users were not linked through PSTN and they were not capable to dial the telephone numbers directly. In the year 1995 the number of mobile users in US was 37 % of the total population. The growth of cellular mobile users was approximately from 25000 to 25 million and this took roughly one decade. (From 1984 to 1993).

The number of consumers in wireless communications increases every year worldwide.

In early days the FM push-to-talk telephone systems were popular. In the period of 1940 this system used frequency of 120 kHz, such that only one person can talk at a time. It was known as half duplex mode. But the FCC increased the number of channels in each market and at the same time it does not need an extra spectrum allocation. It was possible with new technologies enabling reducation in bandwidth from 120 kHz to 60 kHz. Later automatic channel trunking was also possible and it was named as Improved Mobile Telephone Service (IMTS). With this IMTS full duplex mode was brought in. In the year 1968 AT and T Bell Laboratories recommended the concepts of the cellular mobile communication to the respective FCC and in the year 1983 FCC assigned 666 duplex channels for the US mobile systems named as Advanced Mobile Phone System (AMPS). It is also worth noting that FCC insisted to have 'duopoly' in each city. That is in each city/market only two service providers were allowed to have a healthy competition in the market. An additional 166 channels of 10 MHz frequency were permitted in US cellular system to meet the demand scenario.

US cellular radio service :



Some of the main problems the cellular mobile system faced are

i) Interference

ii) Less encryption techniques

iii) Spectrum inefficiency.

In the year 1991 the US Digital Cellular (USDC) system was implemented and this USDC Standard or Electronic Industry Association Interim Standard IS-54 enabled the main advantage of replacing few single user analog channels with that of the digital channels.

Comparing AMPS with USDC system the digital USDC provided more capacity to the cellular mobile world. It was due to the reasons, the USDC applied the techniques mentioned below.

i) $\frac{\pi}{4}$ differential quadrature phase shift keying.

ii) Speech coding.

iii) Time division multiple access.

Later a better cellular mobile system using Code Division Multiple Access (CDMA) was developed by the Qualcomm, Inc which was then standardized by the respective Telecommunications Industry Association (TIA) and the system was named as Interim Standard (IS-95).

The IS-95 allowed many number of mobile users by Direct Sequence Spread Spectrum (DSSS) technique. The CDMA cellular phone systems were independent of interference problems and provided better call quality than the first generation (1G) AMPS cellular system.

Some of the mobile standards of North America, Japan and Europe are listed below.

	Mobile standard	Year of introduction	Multiple access / Modulation	Bandwidth of channel
1) North America	a) AMPS (Cellular)	1983	FDMA / FM	30 kHz
	b) USDC (Cellular)	1991	TDMA / $\frac{\pi}{4}$ DQPSK	30 kHz
	c) CDPD (Cellular)	1993	(FH/Packet) / GMSK	30 kHz
	d) IS-95 (Cellular/PCS)	1993	CDMA (QPSK/BPSK)	1.25 MHz
2) Japan	a) JTACS (Cellular)	1988	FDMA / FM	25 kHz
	b) PDC (Cellular)	1993	TDMA / $\frac{\pi}{4}$ – DQPSK	25 kHz
	c) NTT (Cellular)	1979	FDMA/FM	25 kHz
	d) PHS (Cordless)	1993	TDMA / $\frac{\pi}{4}$ – DQPSK	300 kHz
3) Europe	a) ETACS (Cellular)	1985	FDMA / FM	25 kHz
	b) GSM (Celluar/PCS)	1990	TDMA / GMSK	200 kHz
	c) CT2 (Cordless)	1989	FDMA / GFSK	100 kHz
	d) DECT (Cordless)	1993	TDMA / GFSK	1.728 MHz

AMPS - Analog Mobile Phone System.

USDC - US Digital Cellular.

CDPD - Cellular Digital Packet Data.

IS-95 - Interim Standard-95.

JTACS - Japanese Total Access Cellular Systems.

PDC - Pacific Digital Cellular.

NTT - Nippon Telephone and Telegraph Company.

PHS - Personal Handy Phone System.

ETACS - European Total Access Cellular System.

GSM - Global System for Mobile.

CT2 - Cordless Telephone. (CT2)

DECT. - Digital European Cordless Telephone.

In the examples of cellular, cordless and PCS systems each one of them has unique advantages and facilities with respect to mobile comunication technology. Thus the transition from analog mobile phones to digital mobile phones was made along a number of years and today digital cellular telephony is very popular worldwide due to its several technical advantages, including cellular coverage capability.

The second generation (2G) cellular systems provide more facilities and attractive features than first generation (1G) systems. The 1G systems relied on analog transmissions, particularly or FDMA/FDD and the analog FM techniques. But the 2G standards rely on digital formats including TDMA/FDD and the CDMA/FDD multiple accessing techniques. (FDD - Frequency division duplexing).

Some of the important advantages of 2G standards are listed below :

a. Error correction and encryption :

While comparing to analog 1G standards the digitised 2G standards are less prone to errors. Even if any error is detected it is simpler to correct the errors under digital systems. Also encryption and decryption techniques related to security issues are possible only with digital systems. In 2G standards they provide

i) Better speech quality.

ii) High speed data applications.

iii) Efficient spectrum usage and compatible with TDMA access schemes.

iv) Supports multiple users.

b. TDMA and CDMA-Multiple access techniques :

In 2G systems TDMA and CDMA techniques are applied. In rare cases their combination with FDMA scheme is also used.

The TDMA technique is used by 2G standards that includes Global system for mobile (GSM), Interim standard-54 (IS - 54) and Digital European cordless standard (DECT). Here the spectral band is sub divided into many time slots and they form TDMA frames. Thus every subscriber will be assigned time slots in which transmission would take place. Cellular traffic congestion is highly minimized with this technology. The TDMA schemes use half duplex method. Other TDMA features include,

- Good Synchronization.
- For better operations it possesses guard intervals.

- Efficient spectrum utilization.
- Operates with faster data rates.

With CDMA technique every subscriber is assigned a n-bit code, and it guarantees high degree of security than other access techniques. The transmission of several users is differentiated by a code word which has been assigned to every subscriber. Thus TDMA and CDMA in 2G standards provide less design complexity, more security, faster speeds of transmissions and high reliability etc., than 1G systems.

A simple comparison with respect to growth of number of mobile users as the technology moves from 1G to 2G is shown in the following chart. There is a better reception for GSM - 2G standard as a high number of users were observed in the year 2001.

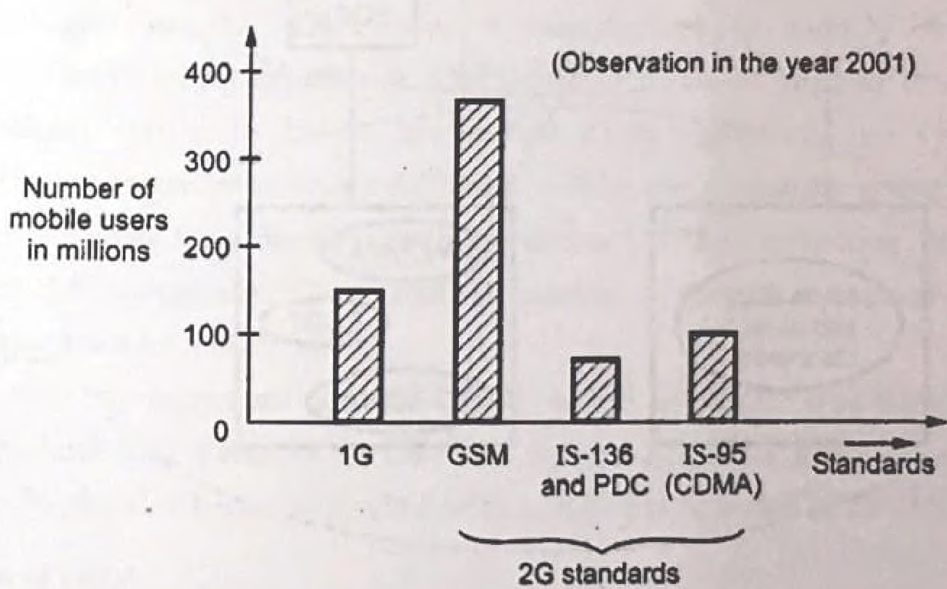


Fig. 1.8.1 Growth of number of users Vs growth of technology

In this chapter we will discuss some of the important 2G and 3G mobile standards and networks in detail.

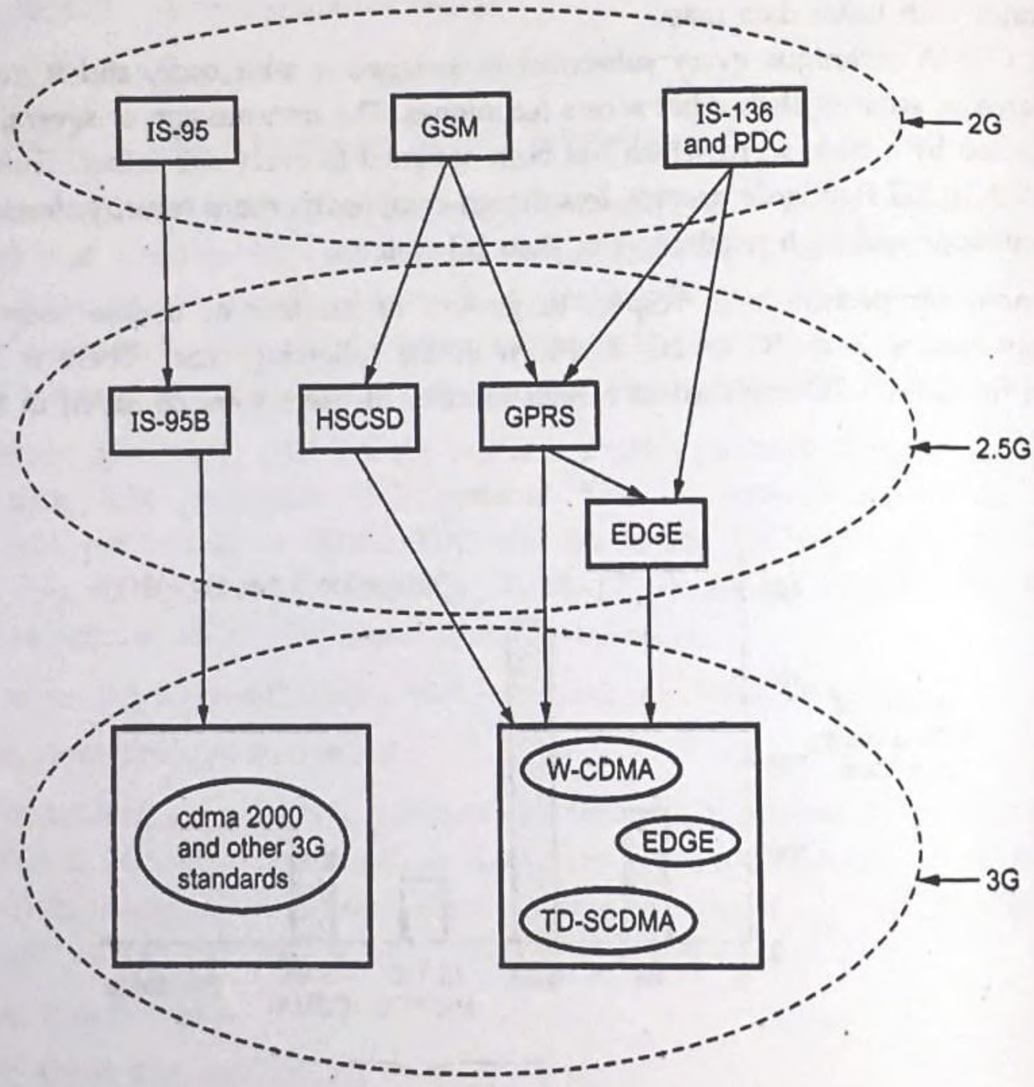


Fig. 1.8.2 Some of the 2G to 3G technology mobile standards-path upgrade view

1.8.1 Organization of 2G and 3G Standards

Second generation (2G) standards include :

I)

a) TDMA standards like

1) Interim standards 136 (IS - 136)

2) Global system for mobile (GSM)

3) Pacific digital cellular (PDC)

b) CDMA standards like

1) IS - 95 (cdma one).

II) Importance of 2.5 standards

1) HSCSD
2) GPRS
3) EDGE
4) IS - 95B (cdma two)

III) Third generation (3G) standards include :

1) IMT 2000 and UMTS
2) cdma 2000

1.8.1.1 Second Generation (2G) Technologies

1) Interim standard 136 (IS - 136)

The analog mobile phone system (AMPS) was not suitable to support high traffic and demands for high capacity. There was a requirement to modify and add new technologies so that this first generation AMPS system could be applied to meet the high demand of cellular traffic. In 1980's, the limited states digital cellular system (USDC) came into existance to accommodate multiusers within the frequency spectrum allocated. The USDC system used time division multiple access (TDMA) technique and compatible with usage of AMPS channels. The system is capable of providing capacity of six times more when compared to AMPS system.

It allowed dual mode system and the USDC/AMPS technique was later standardized as Interim standard and denoted as (IS - 54) by the EIA/TIA association in the year 1990. This IS - 54 standard was upgraded with additional features as IS-136.

1.8.1.2 Features of USDC

- The USDC system uses frequency reuse technique.
- USDC shares same frequencies with minimized interference.
- USDC supports three full-rate or six-half rate subscribers on every AMPS channel.
- It provides high cellular capacity.
- It accommodates many users.
- There was a smooth transition from analog cellular systems to digital cellular system, by which USDC became popular. Since USDC was installed in North America it was also called North American Digital Cellular Standard (NADC).

The IS - 136 system operates with both the AMPS and USDC standards in dual mode. Thus with a single phone, roaming between these two was possible.

The IS - 136 supports multiple USDC subscribers on every AMPS channel. It used the same frequency and adequate channel spacing as that of the AMPS.

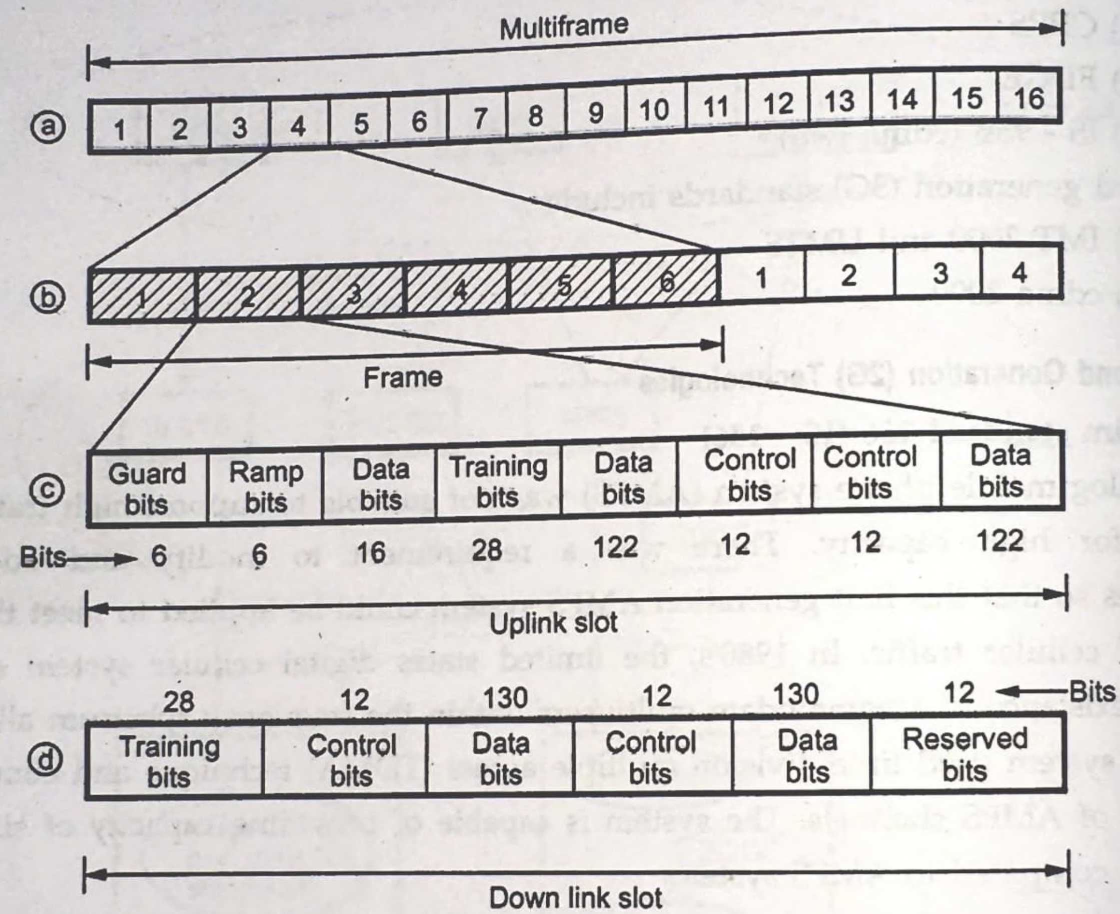


Fig. 1.8.3 Structures of IS - 136 standards

a. Multiframe.

b. Frame.

c. Uplink slot.

d. Downlink slot.

This IS - 136 standard operates in the frequency of 800 MHz band which could be upgraded even upto 1900 MHz band and was planned to bring out many user services by this frequency spectrum upgradation. IS - 136 also has some similarities with 2G GSM standard to an extent. It includes coding scheme, interleaving and convolution etc.

A simple air interface structure of IS - 136 is shown above. It consists of a multiframe, and in a frame the slots used for up and down links are also seen. Their individual fields including guard bits, control bits, training bits, data bits and so on are also shown. There is a reserved bits field which was assigned in downlink slot with 12 bits for downlink purpose.

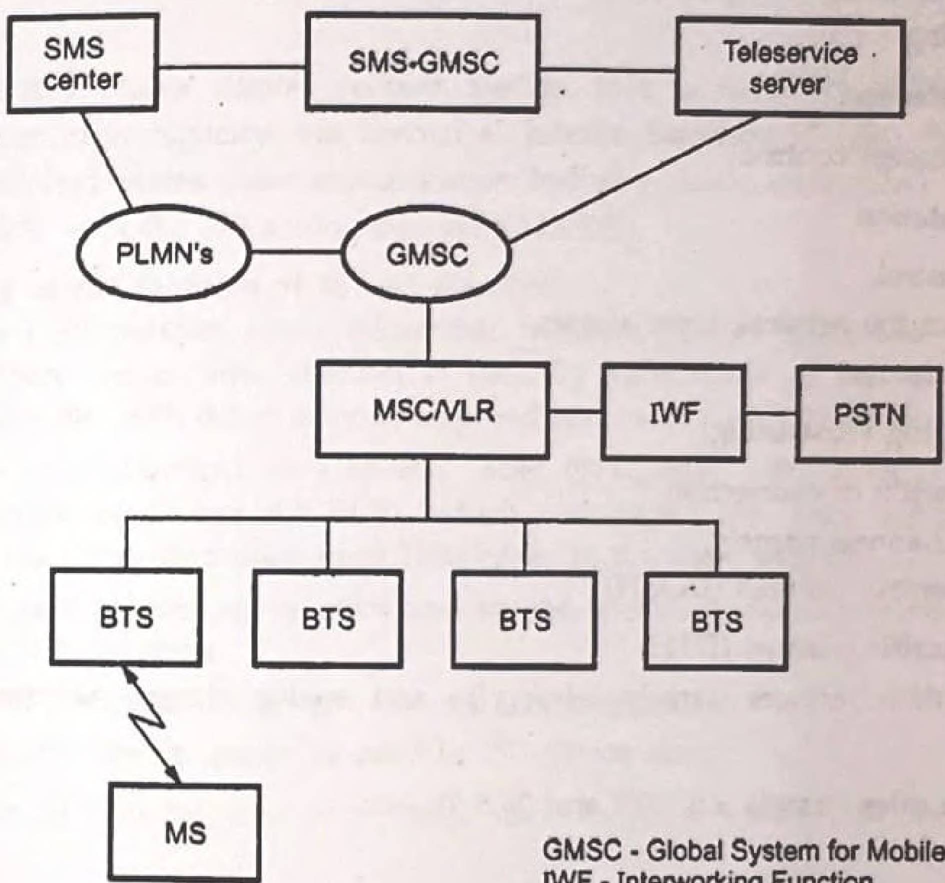


Fig. 1.8.4 Network architecture of IS - 136

Many digital control channels were created with IS - 54 and its upgraded so called standard is IS - 136 whose network architecture is shown here. It is also known as D-AMPS and also in a way it is compatible with 1G, AMPS system.

The network architecture of IS - 136 resembles the structure of GSM.

1.8.1.3 Features of IS - 136

- It operates in 800 - 1900 MHz frequency band.
- Its channel bandwidth is 30 kHz.
- The TDMA frame with 40 msec in 6 time slots is being used in it.
- Six time slots : (Channel data rates)

  1^{st} time slot - Half rate channel.

  2^{nd}, 5^{th} time slots - Full rate channel.

  2^{nd}, 3^{rd}, 5^{th}, 6^{th} time slots - Double rate channel.

- The data link layer of IS - 136 provides,
  i) Addressing
  ii) Error detection
  iii) Media access control.
  iv) Segmentation
  v) Flow control.
- On the other hand the network layer allows,
  i) Establishments
  ii) Maintaining (Sustaining)
  iii) Termination of connection.
- It possesses the channels namely,
  i) Digital control channel (DCCH)
  ii) Digital traffic channel (DTH)
- It provides the data services namely teleservice and analog circuit switched data service.
- It uses three data rates namely 9.6, 19.2 and 28.8 kb/sec.

Teleservices :

E.g. : 1) SMS through the DCCH channels.

2) Operator services.

Analog circuit switched data services :

E.g. 1) It is capable of providing data rate of 9.6 kb/sec.

Note :

Several enhancements of GSM system are adopted effectively in IS - 136 standard.

1.8.2 Interim Standard 95 (IS - 95)

Introduction :

The code division multiple access (CDMA) scheme came into existence in 1989 and it proved that it is a best technique suitable for digital cellular system by various tests. In CDMA, the main advantages are,

i) It can tolerate interference with spread spectrum technique.

ii) It provides high security.

iii) It helps in achieving high capacity land mobile communication systems.

The spread spectrum technology was mainly used in CDMA for enhancing security of data transmitted. Thus in applications where high security is in demand this technique can be opted. CDMA has several advantages when compared to FDMA and TDMA.

A united States digital cellular system that is based on CDMA technique that guarantees high capacity was known as Interim Standard 95 (IS - 95) and standardized by the United States Telecommunication Industry Association (TIA). IS - 95 standard is compatible with the US analog systems (AMPS).

Some of the features of IS - 95 standard :

i) IS - 95 permits every subscriber within a cell to make use of a radio channel where same radio channel is used by subscribers of adjacent cells too. This is possible with direct sequence spread spectrum (DSSS) technique.

ii) IS - 95 standard uses speech coder Qualcomm 9600 b/sec, Code Exited Linear Predictive Coder (QCELP), which can detect the voice activities and also can reduce the data rates upto 1200 b/sec in the silent periods.

iii) It uses specific modulation and spread spectrum techniques in its forward as well as reverse links.

iv) It is compatible with IS - 41 networking standard.

Channels and frequencies used in IS - 95 standard :

In the IS - 95 the frequency range used for its forwards link operation is 869 - 894 MHz.

For reverse link operation the frequency range used is 824 - 849 MHz.

A version of IS - 95 (PCS) is designed to use the operating frequency in the range 1800 - 2000 MHz band.

For cellular band operations the forward and reverse channel pair is IS-95 are separated by a frequency of 45 MHz.

The total spreading factor of user data in IS - 95 is 128 (chip rate of 1.228 M Chips/Sec.) The spreading process is different for forward and reverse links. They are given below :

1.8.3 Protocol Architecture of IS - 95 Standard

In the cdma One standard's protocol architecture the lower two layers and the corresponding layers of OSI model are shown below :

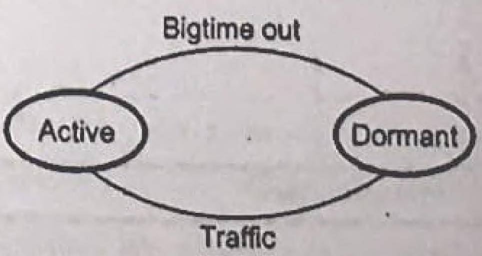


Fig. 1.8.5 MAC states in cdma One (IS - 95) standard

The functions of layer 1 are

i) Frequency use

ii) Radio transmission

The functions of layer 1 are related to

i) Effective delivery of voice and the data packets.

Under layer 2, the medium access control (MAC) sublayer takes care of the channel management. This MAC sublayer follows a finite state machine that is two states.

The status of packet data in transmissions is shown as a finite state machine of two cycles, and each transmission different state machine is maintained

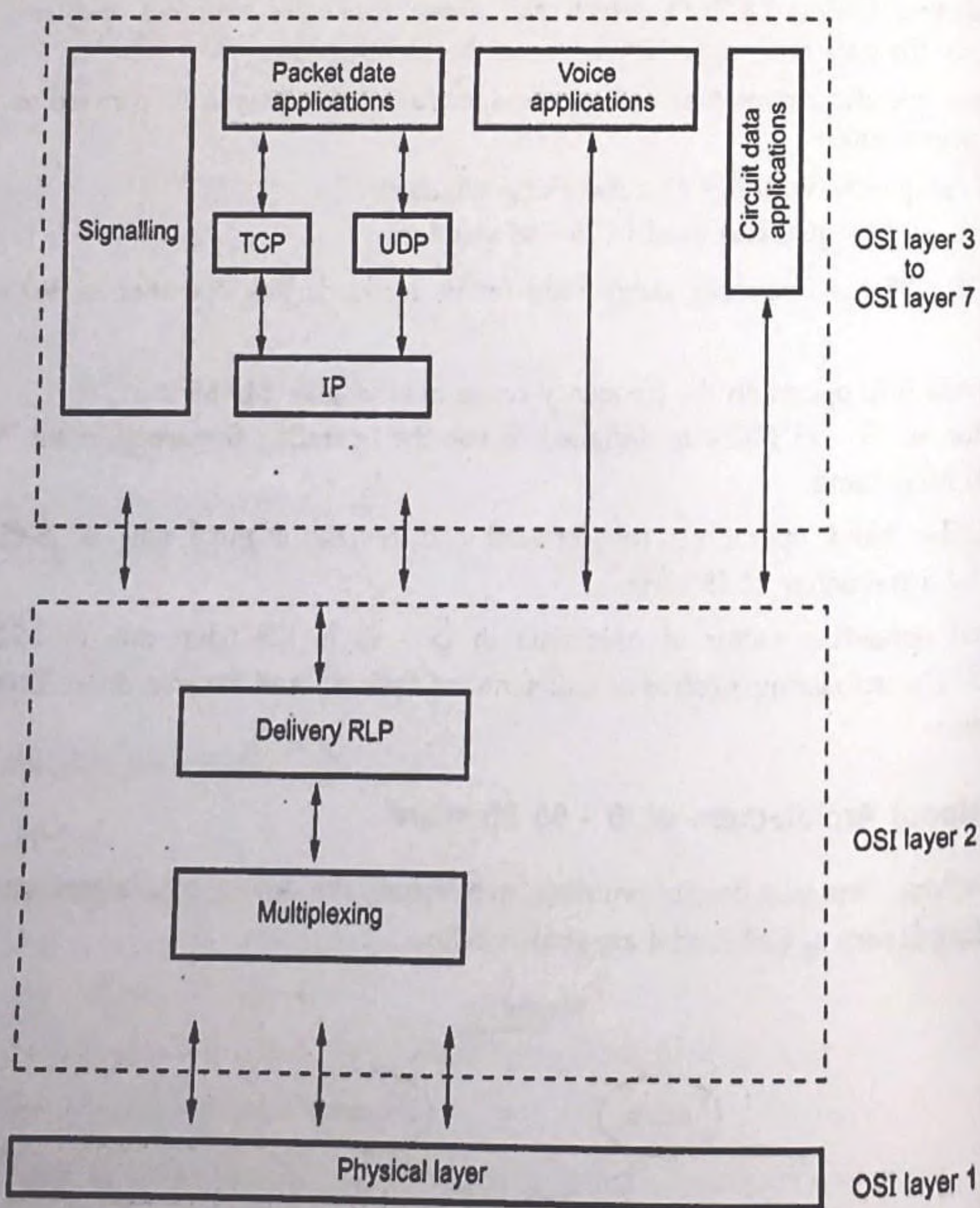


Fig. 1.8.6 'Protocol architecture' of IS - 95 (cdma One) - standard

Whenever mobile station (MS) is idle it is considered as "big time period".

In the active state the channels are assigned to the mobile. In dormant state the mobile units do not maintain any sequence of channels. Since they do not maintain any sequence in channels there is no strict mechanism for transmitting user data when it is in dormant state.

After the idle period (that is MS is idle) or bit period the mobile channels go to the dormant state. Thus the data from various sources are being multiplexed at first and then handed over for transmission.

Important terms related to channels of IS - 95 are detailed below :

The forward channels are known as downlink channels. They carry the data traffic from the base stations to mobile stations effectively. It consists of 64 channels. The respective logical channels are differentiated from one another by using various CDMA spreading codes and it is called as orthogonal code or walsh function (0 to 63).

Some of the dedicated and common control traffic channels are as follows.

1.8.3.1 Sync Channel

It is an optional channel used to send synchronization information to mobile stations. It is present in many cases and it is not considered in rate cells. The mobile channel will operate at a data rate of 1200 b/sec .

1.8.3.2 Paging Channel

It is also an optional channel. There are four types of messages sent through this forward CDMA channel. They are

i) Paging

ii) Overhead

iii) Order

iv) Channel assignment

Upto seven paging channels are used and it operates at one of the data rates namely 2400, 4800 or 9600 b/sec.

1.8.3.3 Pilot Channel

The pilot channel gives the timings related information to be mobile station with respect to forward CDMA channels and it compares the signal strengths of base stations.

The data rate is 19.2 kb/sec and the channel is a stream of 0's without discontinuity.

1.8.3.4 Traffic Channel

The traffic channels are used to carry the user data at data rates of 1200, 2400, 4800 or 9600 b/sec. These traffic channels are actually spread by a PN sequence code (long code) and it helps to differentiate mobile stations.

All the channels are properly coded and then interleaved except the pilot channel.

1.8.3.5 Reverse CDMA Channels

The reverse CDMA channels are also known as uplink channel. The main types of reverse CDMA channels are,

i) Access channels

ii) Traffic channels.

i) Access channels :

The access channels are used by the mobile stations for call initiation and to provide responses to paging messages mentioned previously. These access channels can be upto 32 channels and they operate at a data rate of 4800 b/sec.

ii) Traffic channel :

The traffic channels are intended for carrying user data. Four data rates possible with which these channels can operate are 1200, 2400, 4800 and 9600 b/sec. Also the pay load of traffic channels are from a variable rate vocoder unit with the output date rates mentioned above.

The forward and reverse CDMA channels are discussed in much more detail in the following chapter.

1.8.4 Forward Link

In forward link each mobile unit in a particular cell is assigned different spreading sequence providing enough separations between signals of different users. This holds good, even for the situation where there are no multipath of problems.

The user data stream is also encoded, interleaved and spread by one of 64 orthogonal spreading sequences known as walsh functions.

All the signals of a cell are first scrambled by applying a pseudorandom sequence (length 2^{15} chips) because many users make use of the same spreading sequence in different cells. Due to proper scrambling of signals in a cell the orthogonality of entire forward channel subscribers is well preserved.

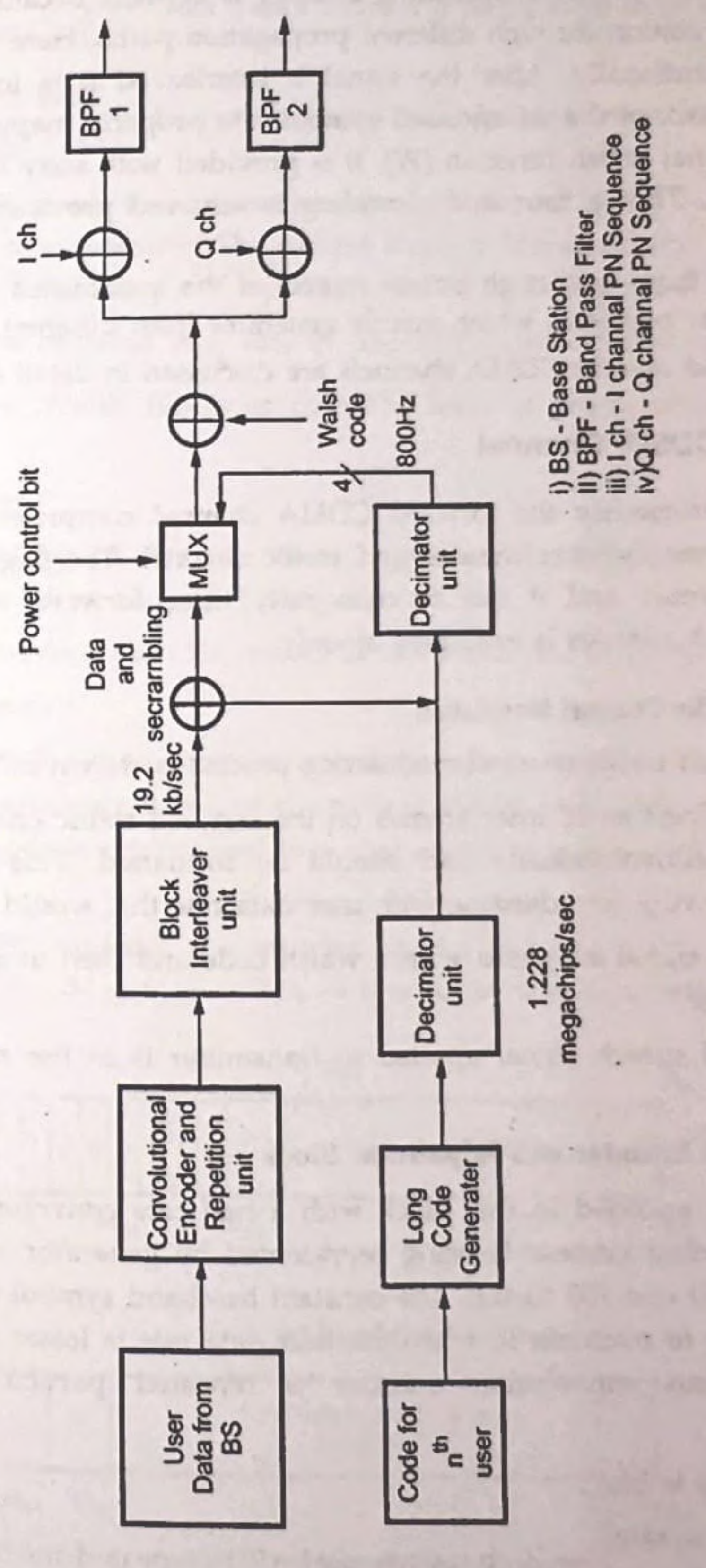


Fig. 1.8.7 IS-95 forward CDMA channel modulation

In the reverse link a special spreading strategy is applied, because the mobile signals arrive at the base station through different propagation paths. Here the user data stream is encoded convolutionally. After the signal is interleaved it is followed by mapping function. Every block of the six encoded symbols are properly mapped to corresponding sixty four orthogonal walsh function (W). It is provided with sixty four - ary orthogonal signalling method. Thus a four fold spreading is achieved providing a rate of 1.228 M chips/sec.

In reverse link there is enough power control of the transmitted signal. This leads to minimizing near-far problems which mainly generates from different received powers.

The forward and reverse CDMA channels are discussed in detail in next section.

1.8.5 Forward CDMA Channel

As discussed previously the forward CDMA channel comprises of synchronization channel, pilot channel, paging channel and traffic channel. The paging channels can be upto seven in number and it can be upto sixty three forward traffic channels. The functionality of each channel is explained already.

1.8.5.1 Forward Traffic Channel Modulation

The basic forward traffic channel modulation process is shown in the diagram below.

The data is grouped as 20 msec frames on the forward traffic channel. The user data has to be coded convolutionally and should be formatted. This process has to be followed by interleaving for adjusting with user data rate that would change.

This interleaved signal is spread with a walsh code and then in a sequence at a rate of 1.228 M chips/sec.

The data rate of speech signal applied to transmitter is in the range of 1200 b/sec and 9600 b/sec.

1) Convolutional Encoder and Repetition Block :

The user data is encoded in this block with a half rate convolutional encoder with length 9. This encoding process is being represented by generator vectors say G_1 and G_0 that is 561 (octal) and 753 (octal). The constant baseband symbol rate is 19.2 kb/sec and in order to maintain it, when the user data rate is lesser than 960 b/sec, the symbol coming from convolution encoder is repeated particularly before block interleaving process.

Repetition concept is like ;

1) $\left.\begin{array}{l}\text{If information rate}\\ \text{is 4800 b / sec}\end{array}\right\} \rightarrow$ Each code symbol will be repeated one time.

2) If information rate is 2400 b / sec $\rightarrow$ Each code symbol will be repeated three times

3) If information rate is 1200 b / sec $\rightarrow$ Each code symbol will repeated seven times

This repetition will result in constant rate (coded rate) of 19,200 symbols/sec for all the information data rates possible. The second block in the schematic namely the block interleaver follows this encoding and repetition circuit. In IS - 95 if the signal is encoded at a $\frac{1}{2}$ rate and if it is encoded in $\frac{1}{3}$ rate in respective forward and reverse link and it has to be mapped to Walsh functions then the level of interference will be greatly reduced.

2) Block Interleaver :

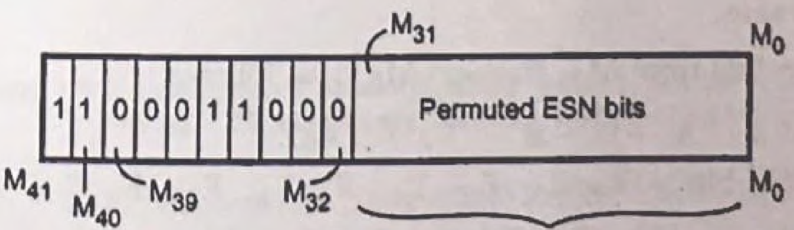
It is primarily a 24 by 16 array in its arrangement. This block interleaving is done after convolutional encoding and repetition processes.

The IS - 95 standard uses variable rate CELP code at a rate of 1.2 to 14.4 kb/sec.

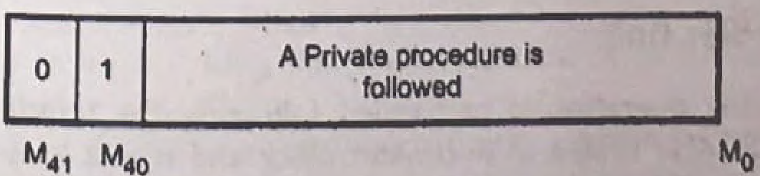
3) Long PN Sequence :

In forward channel for data scrambling purpose direct sequence is being used. For each user a long PN sequence is assigned and it is a long code with time period $2^{42} - 1$ chips. This long PN code is represented in a characteristics polynomial and it is denoted as P(x).

The private long PN sequence is mentioned as M_{41} and M_{40} will be set to 0, 1, and M_{39} through M_0 as M_{39} M_{38} M_{37} .... M_0 $\rightarrow$ It is set by a private method.



(a) Public code mask



(b) Private code mask

Fig. 1.8.8 Long PN code mask formats in IS - 95 standard

$$P(x) = x^{42} + x^{35} + x^{33} + x^{31} + x^{27} + x^{26} + x^{25} + x^{21} + x^{19} + x^{18} + x^{17} + x^{16} + x^{10} + x^{7} + x^{6} + x^{5} + x^{3} + x^{2} + x^{1} + 1.$$

In this assignment of a long sequence to each user, each PN chip of this long sequence is produced using modulo-2 inner product of the 42 bit mask and the state vector of the PN sequence generator.

The first state of the generator is defined mainly whenever the output of the sequence generator becomes 1 following the 41 consecutive '0' output bits. (Since it is considered as 0 to 41 (42 bits)).

In this case in the MSB we have the bit as '1'.

There are two types of masks that can be used in this entire procedure. They are,

1) Private mask

2) Public mask

The private mask in long code generation is for mobile station's identification number purpose (MIN).

The public mask in long code generation is for mobile stations electronic serial number (ESN).

It is important to note that all the CDMA calls are initiated with the help of public mask. After authentication process there will be transition from public to private mask.

There two masks are specified as follows.

i) Public long PN code is specified with M_{41} (M stands for masking) through M_{32} as,

$M_{41}\ M_{40}\ M_{39}\ M_{38}\ ....\ M_{32} = 1\ 1\ 0\ 0\ 0\ 1\ 1\ 0\ 0\ 0$

and

$M_{31}\ M_{30}\ M_{29}\ M_{28}\ .....\ M_0$ → It is set to a permutation of the respective mobile station's ESN bits value.

This permutation bits from M_{31} through M_0 is as follows :

Let ESN bits = $(E_{31}, E_{30}, E_{29}, E_{28}\ .....\ E_2, E_1, E_0)$

The permuted ESN bits = $(E_0, E_{31}, E_{22}, E_{13}, E_4, E_{26}, E_{17}, E_8, E_{30}, E_{21}, E_{12}, E_3, E_{25}, E_{16}, E_7, E_{29}, E_{20}, E_{11}, E_2, E_{24}, E_{15}, E_6, E_{28}, E_{19}, E_{10}, E_1, E_{23}, E_{14}, E_5, E_{27}, E_{18}, E_9)$

1.8.6 Data Scrambler Unit

The data scrambling operation is performed following the interleaving process. The PN sequence of 1.228 MHz is sent to decimator block and it will keep out the chip 1 out of the every sixty-four PN chips. Also these PN chips are consecutive. For performing data scrambling operation modulo-2 addition of the two blocks namely interleaver and decimator outputs [19.2 kb/sec and 1.228 M chips/sec] is employed as available in the block diagram of CDMA channel modulation process.

Power control subchannel :

At the base station receiver end, a unique power level is tried to be maintained for all the subscribers in IS - 95 standard so as to reduce bit error rate (BER level). For every mobile station the signal strength and interference is being measured and it is attended and responded by its base station reverse traffic channel receiver unit.

It is also worth noting that for about every 1.25 msec the power control updated results are transmitted by the base station because in real time mobile environment the signal strength and interference varies continuously.

The necessary power controlling instructions are transmitted to every user on the forward control subchannel which commands the mobile unit to increase or decrease its power level in steps of 1 dB. For example a '0' will be sent in power control subchannel to the user in case if low power levels of received signal is observed. On the other hand a '1' will be sent to the user in power control subchannel if the received signal is very high, and by seeing this '1' the mobile is commanded to reduce transmitted power. The power controlling bits are sent after the data scrambling process.

Orthogonal Covering :

The orthogonal covering process follows the data scrambling and is done in the

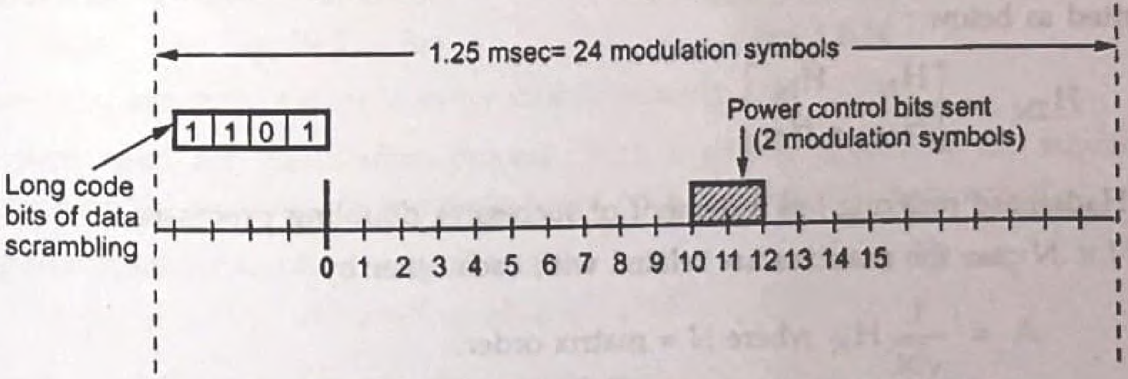


Fig. 1.8.9 Example of random power control bit position in IS - 95 standards forward traffic channel

forward link in IS - 95. The channels transmitted (traffic channels) on forward CDMA channel is spread with a Walsh function (n) at a rate of 1.228 Mchips/sec which is maintained as fixed. The length of binary sequence in Walsh functions is 64 and they are exactly orthogonal to each other. This is meant for orthogonal channelization function for all the subscribers that is in the forward link. C onsider a subscriber is spread using this Walsh function 'n' is allocated channel number n where n is in the range 0 to 63.

For every period of 52.083 μsec the walsh binary sequence gets repeated and it is equal to single coded data symbol. It can be simply said as "the data symbol is actually spread by the 64 Walsh chips (c)."

The Walsh matrix is also known as Hadamard matrix (H) and the 64 Hadamard matrix in this case is generated by recursive process.

1.8.7 Walsh Hadamard Transform

The 1 dimensional (ID) Walsh Hadamard transform can be

given as $$H(u) = \frac{1}{N} \sum_{x=0}^{(N-1)} f(x) (-1)^{\sum_{i=0}^{n-1} b_i(x) b_i(a)} \quad \ldots.$$

in which case $N = 2^n$ and u will take values between 0 to N – 1.

In a 2D case, this transform becomes

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

The Hadamard matrix is of a lowest order. Considering N = 2, (2 × 2 matrix) can be given as

$$H_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

Supply H, will be as $H_1 = 0$.

If H_N represents the matrix of order N then it can be denoted as H_{2N} and represented as below :

$$H_{2N} = \begin{bmatrix} H_N & H_N \\ H_N & -H_N \end{bmatrix}$$

The Hadamard ordering has a demerit of successive doubling processes.

For N × N case the matrixes are related with each other by

$$A = \frac{1}{\sqrt{N}} H_N \text{ where } N = \text{matrix order.}$$

Summarizing Hadamard matrix or Walsh function matrix, we write

$$H_1 = 0$$

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

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

$$H_{2N} = \begin{bmatrix} H_N & H_N \\ H_N & -H_N \end{bmatrix}$$

Using these matrices and by recursive procedure 64 by 64 Walsh matrix can be generated. In IS - 95 standards orthogonal covering we consider 64 by 64 Walsh matrix which corresponds to the channel number 'n'.

The channel number n = 0 corresponds to the pilot channel and from n = 1 onwards is assigned for other channels since n = 0 is assigned to pilot channel, it is a 'blank' walsh code in this case, which contains quadrature pseudo noise sequence code. Also the channel number 32 (n = 32) is assigned for the important synchronization channel.

1.8.8 Quadrature Modulation

From the block diagram of CDMA channel modulation process we consider the quadrature modulation module that cares about quardature (Q channel) and In-phase (I-channel) related modulation here for simplicity .

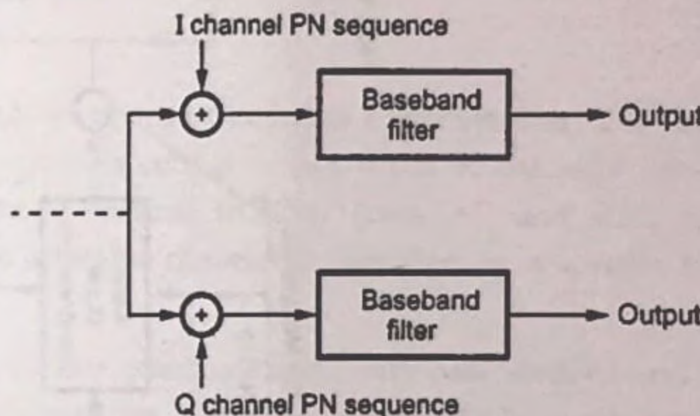


Fig. 1.8.10

A simple and short binary PN sequence, with a time period of $2^{15}-1$ chips is applied for acquisition and synchronization at every mobile receiver end.

It is then used for modulation process. Such a shorter spreading bit sequence is known as pilot PN sequence. It is mainly based on a characteristic polynomial.

The polynomial for in-phase modulation is,

$$P_I(x) = x^{15} + x^{13} + x^9 + x^8 + x^7 + x^5 + 1$$

and polynomials for quadrature modulation is,

$$P_Q(x) = x^{15} + x^{12} + x^{11} + x^{10} + x^9 + x^6 + x^5 + x^4 + x^3 + 1$$

Using these polynomials, the PN binary sequences using i(n) and q(n) are generated using linear recursion procedure.

I	Q	Phase
0	0	$\pi/4$
1	0	$3\pi/4$
1	1	$-3\pi/4$
0	1	$-\pi/4$

Table 1.8.1 Mapping of I and Q in forward CDMA channels

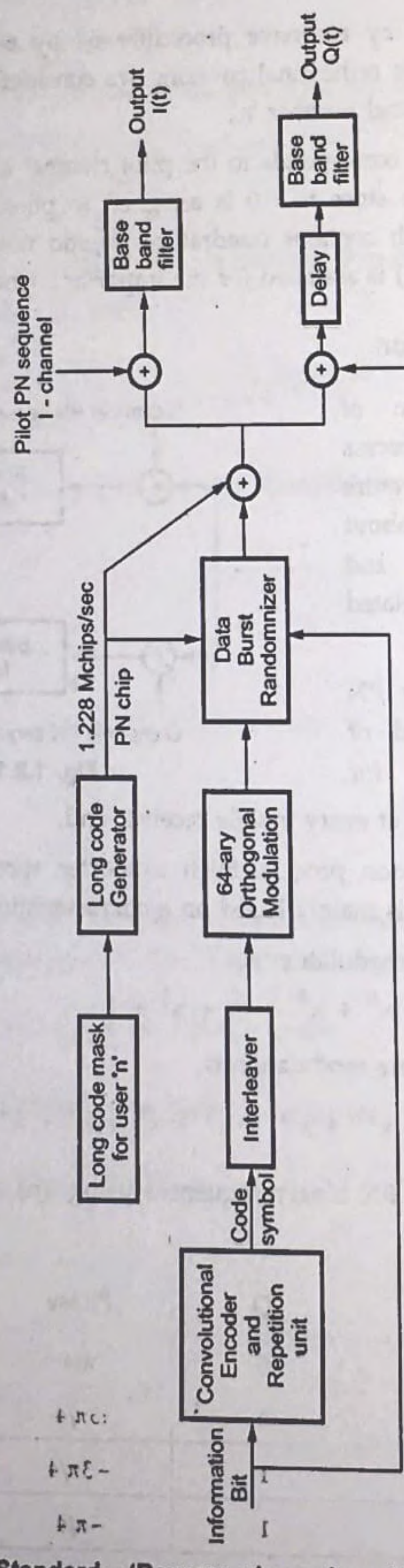


Fig. 1.8.11 IS - 95 Standard - 'Reverse channel modulation process for an user'

1.8.9 Reverse CDMA Channels

In IS - 95 the reverse CDMA channel modulation scheme is shown in the diagram shown below. The data is grouped into 20 msec frames on reverse channel. An ordered sequence of operations are carried as the data is transmitted on the reverse channel.

The operations are

1) Convolutional encoding

2) Block Interleaving

3) Applying 64-ary orthogonal modulation.

4) Spreading before transmission.

Generally the user data in the respective reverse channel is transmitted at 1200, 2400, 4800, 9600 b/sec. The reverse CDMA channels consist of two types of channels namely access channels (AC's) and reverse traffic channel (RTC's). These AC and RTC have same frequency assignment. The access or traffic channel is identified by a specific long code.

Access channel (AC) : It is used to initiate communication with base stations and for responding to the paging channel informations. Thus AC is effectively used by the mobile. The AC operates at fixed data rate (4800 b/sec).

Reverse traffic channel (RTC) : It is intended for having reverse traffic to carry signals in these channels. Also the RTC operates at a variable rate.

Note : The reverse CDMA channel can contain upto 32 AC's for a paging channel.

1.8.10 Convolutional Encoder and Symbol Repetition Unit

In IS - 95 standard this block has boundary length of 9. This coder uses three generator vectors as G_0, G_1 and G_2 that is 557, 663, 771 (all in octal) values. The signal is convolutionally encoded and then symbol repetition takes place. The repetition process is done before interleaving operation and when the rate is lesser that 9600 b/sec. After the repetition operation the output symbol rate of coder block is kept fixed at 28.8 kb/sec. It is followed by interleaving operation.

Having the characteristic polynimials P_I (x) and P_Q (x) the pilot pseudo noise (PN) sequences i(n) and q(n) can be produced with linear recursion operations. A modulo-2 addition is applied in determining this i(n) and q(n) sequences. The respective chip rates of pilot PN sequences will be 1.228 M chips/sec.

1.8.11 Block Interleaver Unit

The block interleaving is done in reverse CDMA channel and this process follows the encoding and repetition operations. The time span of block interleaver is 20 msec and it is an array consisting 32 × 18 matrix order is 32 rows and 18 columns. In this matrix the code symbols are being written by columns and they are read out by the matrix rows respectively.

1.8.11.1 Orthogonal Modulation

In reverse CDMA channel M-ary orthogonal modulation is used when M = 64. For a single Walsh function out of 64 possible Walsh functions is sent for each group of 6 coded dits. In the Walsh function totally 64 Walsh chips are being sent. The Walsh function number can be chosen by applying a formula relating six coded bits. Let the Walsh function number be W_n which can be given as

$$W_n = C_0 + 2C_1 + 4C_2 + 8C_3 + 16C_4 + 32C_5.$$

where $C_0, C_1 \ldots\ldots C_5 \rightarrow$ Six coded bits

$C_0 \rightarrow$ First coded bit out of six bits

and $C_5 \rightarrow$ Last coded bit out of six bits

$$\left.\begin{array}{l}\text{Walsh chip transmission}\\ \text{rate } (w_{tr})\end{array}\right\} = \frac{(28.8\ \text{kb/sec})\cdot(64\ \text{Walsh chips})}{\text{Six coded bits}}$$

$$w_{tr} = 307.2\ \text{kb/sec}$$

Note :

- In forward CDMA channels, the Walsh functions are used for spreading operation for denoting an user channel.
- On reverse CDMA channel the Walsh functions are applied for the purpose of data modulation.

1.8.11.2 Variables Data Rate Transmission

In the reverse CDMA channel various data rates are being transmitted. Whenever the data rate is about 9600 b/sec the interlever output bits will be transmitted. It is worth nothing then when the data rate is less than 9600 b/sec, the code symbol repetition process will produce redundancy. As shown in the table given below, when the rate is 4800 b/sec then only half of the inteleaver input bits would be transmitted.

Parameter involved	Data rate in b/sec			
User's data rate	1200	2400	4800	9600
Code rate	1/3	1/3	1/3	1/3
Bits in single walsh symbol	6	6	6	6
% of Tr duty cycle	12.5	25	50	100
PN chips/code symbol	42.67	42.67	42.67	42.67
PN chips/walsh symbol	256	256	256	256
PN chip rate in Mchips/sec	1.228	1.228	1.228	1.228
Walsh chip rate in kchips/sec	307.2	307.2	307.2	307.2

Table 1.8.2 Some of the reserve traffic channel modulation parameters list

The process that involves various data rates are shown in a simple diagram given below for reverse CDMA channel in IS - 95 standard.

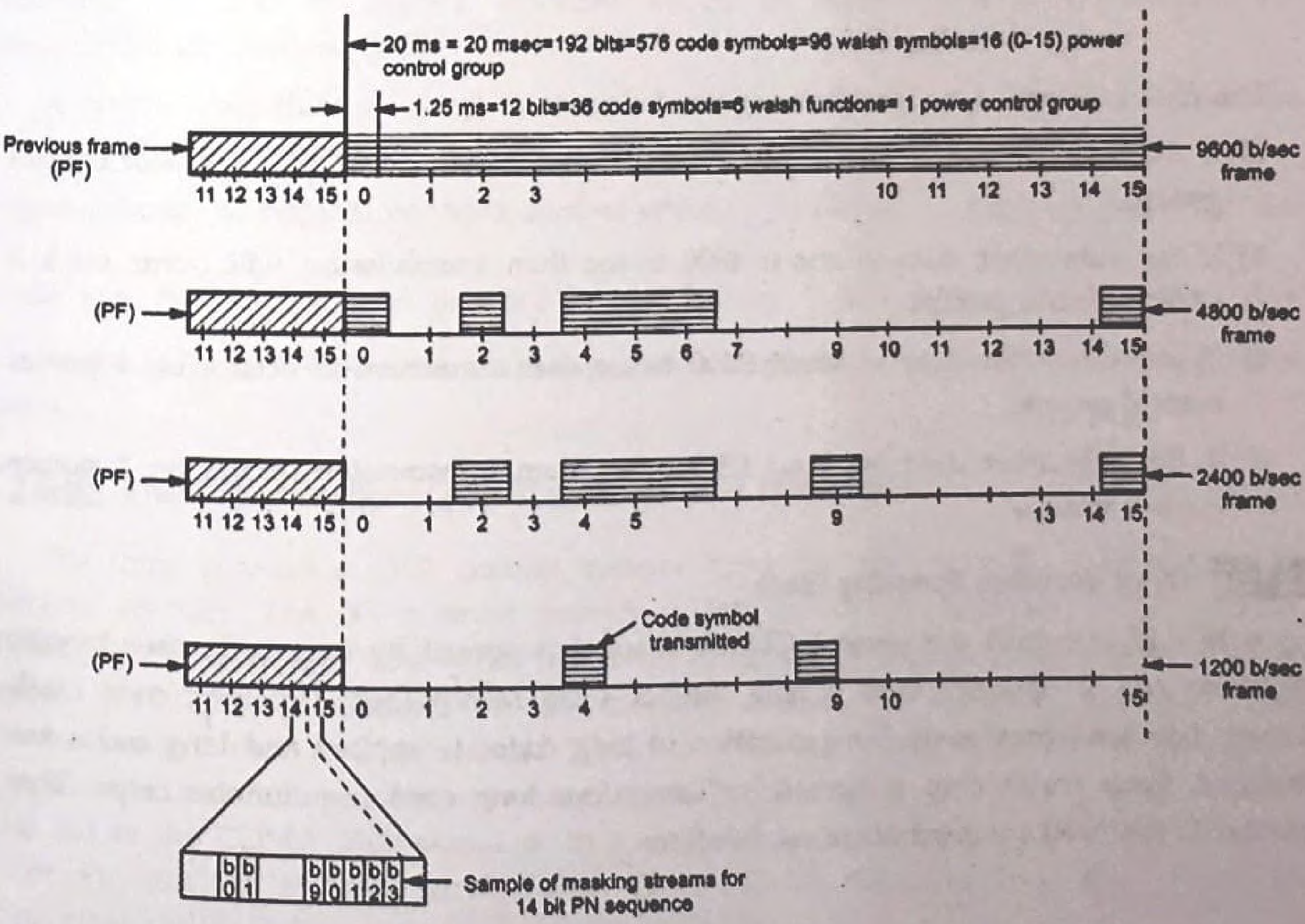


Fig. 1.8.12 Variable data rate transmission in IS - 95 in reverse CDMA channel

In this example the data is sent for every 20 msec frame duration and it is subdivided into sixteen power control groups as shown, in data rate 9600 b/sec. Each power control group is of 1.25 msec period. The power control group can be either gated on or gated off depending upon transmission requirement. Usually every repeated code symbol has to be transmitted only once. The mobile station will reduce PG Equivalent Isotropic Radiated Power (EIRP) and it may lead to reduction in interference to other mobile stations operating on same channel.

The 64 - ary orthogonal modulator is followed by data burst randomnizer block that is used to produce a masking bit pattern which consists of 0's and 1's which will mask the redundant data in random, generated code repetition procedure.

A block of bits say 14 bits taken from long code will decide the masking pattern. This masking is actually done to differentiate mobiles and to reduce interference.

The 14 bits from long PN code used for spreading is represented as,

$b_0\ b_1\ b_2\ b_3\ b_4 \ldots\ldots\ b_{13}$ (0– 13) = 14 bits.

Where bit $b_{13} \rightarrow$ latest bit and

$b_0 \rightarrow$ earliest bit.

The data randomnizer algorithm is given below :

a) If the subscriber data is 9600 b/sec transmission will occur on 16 power control groups.

b) If the subscriber data is about 4800 b/sec then transmission will occur on a 8 power control groups.

c) If the subscriber data is about 2400 b/sec then transmission occurs on 4 power control groups.

d) If the subscriber data is about 1200 b/sec then transmission occurs on 2 power control groups.

1.8.11.3 Direct Sequence Spreading Block

In IS - 95 standard the reverse CDMA channel is spread by long code pseudonoise sequence and it operates with a data rate of 1.228 Mchips/sec. The long code mask format discussed previously for generation of long codes is applied and long codes are obtained. Each walsh chip is spread by using four long code pseudonoise chips. This process is followed by quadrature modulation.

1.8.12 Quadrature Modulation

Before transmission of signal in IS - 95 reverse CDMA channel the traffic channel is spread by inphase and quadrature channels pilot pseudonoise sequences. These PN sequences are similar to the sequences applied in the forward CDMA channel procedures. The purpose of pilot sequences is to provide synchronization. The type of modulation in reverse CDMA channel is offset quadrature phase shift keying (OQPSK). Also a delay of 406.9 nsec (half a chip) is introduced in data spread by quadrature (Q) pilot pseudonoise sequence corresponding to inphase (I) pilot pseudonoise sequence. The purpose of introducing such delays is for improving,

i) Synchronization and

ii) Spectral shape.

According to the mapping table in forward CDMA channel for I and Q signal states, here the I and Q data are properly mapped into corresponding phase value.

Note : A variable rate speech coder (QCELP) is used in the IS - 95 standard the compatible with higher data rate channel. In order achieve good speech quallility the structure of IS-95 is slightly modified so as to make it flexible with personal communication systems (PCS).

A special procedure is opted to change the convolutional code rate on forward and reverse CDMA channels. That is by puncturing two symbols out of every six symbol representation of original encoded symbol stream $\left(\frac{1}{2}\right)$ we get a change of convolutional code rate from $\frac{1}{3}$ to $\frac{1}{2}$ on forward link and from $\frac{1}{2}$ to $\frac{3}{4}$ rate in case reverse link respectively. In IS - 95 standard a better system capacity is achieved with average data rates.

1.8.13 Third Generation (3G) Standards and Networks

The third generation (3G) cellular systems have the goal to fulfil the demands of several services. The 3G systems provide global mobile multimedia communication facilities in an attractive way. It has minimum performance quality equal to that of ISDN speed (144 kb/sec). Coming to the mobility services in microcell and macrocell environment it uses 384 kb/sec and 2 Mb/sec for the low mobility services mainly in picocellular and microcellular environments. The evolutions of 3G system for CDMA has led to the CDMA 2000 standard. In a similar way the evolution of 3G for IS - 136, GSM etc. has led to wide band CDMA (W - CDMA) standard. It is also known as Universal Mobile Telecommunication Service (UMTS).

The 3G systems guarantee an efficient wireless access with high performance quality. They adopt intelligent new protocols to meet the cellular needs of the modern world.

Some of the important characteristics of 3G systems are summarized below :

- 3G system supports packet-switched and circuit switched services like Internet traffic and voice services.
- It supports roaming.
- It provides backward compatability and inter operatibility.
- It supports symmetric and asymmetric traffic.
- It is compatible with running many servicess simultaneously in same terminal.
- It can create 'Virtual Home Environment' (VHE), that is creating a personalized set of services for a user and also when the user is in movement it can be maintained as such.

These 3G systems were standardized and it was initiated in the year 1992 by the International Telecommunication Union (ITU). As a result of this 3G standardization the International Mobile Telecommunication 2000 (IMT - 2000) was introduced which has different 3G standards in it.

Also a smooth beginning 3G standard with a better backward compatibility with 2G standards was the aim of IMT - 2000. The 3G systems tries to converge several applications including telephony, multimedia services and internet etc in an effective manner.

It is also worth noting that a combination of different networks like 3G, ATM, Ethernet and X.25 will serve effectively if used for a single multimedia session. The 3G data service requires novel protocols to serve better and it is sure that if efficient middle-ware protocols are used it will help 3G system to provide improved applications.

Some of the notable features of 3G system are

- Provision for multirate services.
- For a coherent uplink, user-dedicated pilot is allowed.
- Multiuser detection is possible.
- Intercarrier handover.

The ITU has mentioned that the minimum requirement for cellular system performance of a 3G system includes both the packet-switched data and circuit switched data.

Three popular data rates used are as follows :

i) For pedestrian environment the data rate is 384 kb/sec.

ii) For vehicular environment the data rate is 144 kb/sec.

iii) For fixed indoor and the picocell environment the data rate is 2 Mb/sec.

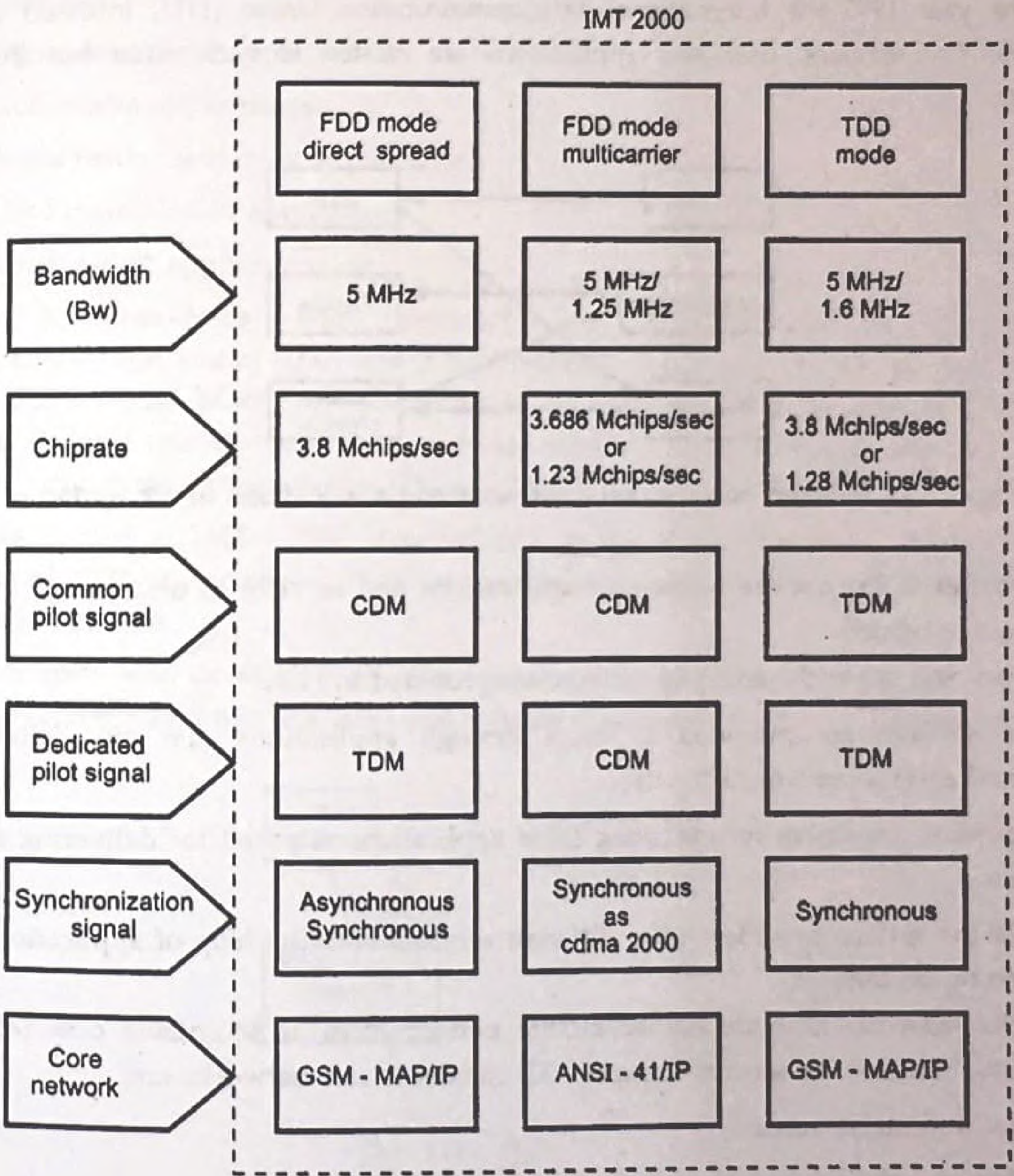


Fig. 1.8.13 Third generation (3G) standard systems

FDD - Frequency division multiplexing.

CDM - Code division mulltplexing.

TDD - Time division duplex.

TDM - Time division mulitiplexing

1.8.14 Relation between User, Services and Applications

In the year 1992 the International Telecommunication Union (ITU) initiated the 3G activities. The services, user and applications are related to each other but they are different.

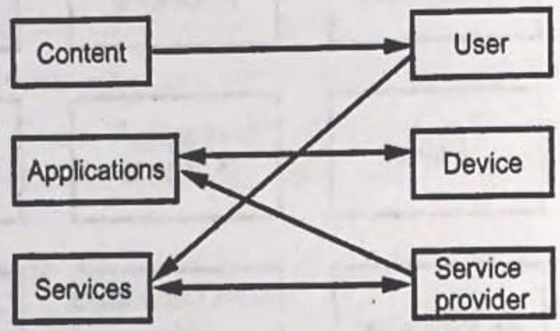


Fig. 1.8.14 Relation between services, user and applications in 3G systems

It is better to list out the terms user applications and services to understand in what way they are related.

- An user will subscribe and pay for services provided to him.
- These services are provided to users through applications that can deliver the required service content to the user.
- The devices are meant for executing these applications required for delivering service content.
- Finally the service providers offer different services with the help of applications that is running on devices.

The 3G networks provide higher mobile performances at acceptable cost ratios to subscribers. Some of the service classes of 3G standards and networks are,

i) Voice and audio service.

ii) Effective wireless messaging service.

iii) Switched data service.

iv) Medium multimedia service.

v) Interactive high multimedia service.

vi) High multimedia services etc.

By these services 3G offer services to meet high speeds, bandwidth requirements, faster internet services accesses, web browsing, better faxing and dial-up accesses with networking set-ups.

Also there are several applications possible with 3G along with advanced services mentioned above.

i) Mobile commerce applications.

ii) Multimedia applications.

iii) Multimedia messaging applications.

iv) Geolocation-based applications.

v) Broadcasting applications etc.

The 3G standards were initiated and standardized by International Telecommunication Union (ITU) and it was released in the year of 1990. A project titled 'Future Public Land Mobile Telecommunications System' (FPLMTS) was developed by ITU and its goal was to unite the worldwide wireless networks under one roof or one standard. This project proposed by ITU was later called as 'IMT-2000'.

It was named as IMT - 2000 standard due to the reason that it is operational at a data rate of 2000 kb/sec speed. Thus its operating frequency is 2000 MHz that is part of frequency spectrum.

IMT - 2000 was developed to combine several wireless technologies like wireless LANs (WLANs), fixed wireless links and satellite communications into one standard.

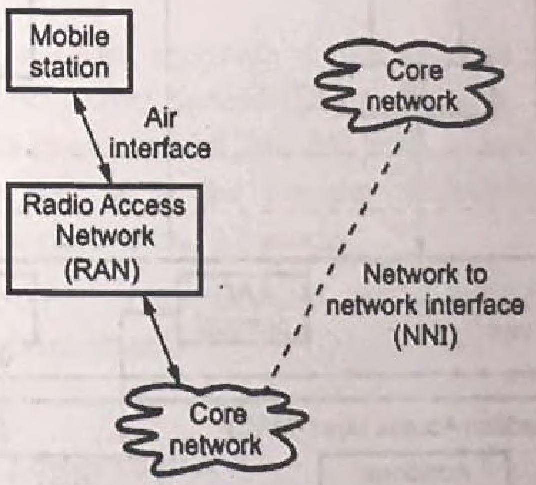


Fig. 1.8.15 IMT - 2000 Standard specification

In above Fig. 1.8.15 different components of IMT - 2000 standard specification are shown. The RAN block consists of a group of interconnected base station controllers and they are used to co-ordinate with a group of base stations. ITU decides for reuse of the available infrastructure and evolution of the 2G systems as per the demands of cellular market. The NNI shown here is meant for connecting dissimilar core networks with each other so as to provide enough roaming capabilities to the subscribers who belong to various networks respectively.

Some of the third generation cellular standards and networks are dealt in this section in detail.

The 3G systems we account for consideration are namely,

1) cdma 2000.

2) WCDMA.

1) cdma 2000 - 3G system : The cdma 2000 is a 3G standard. It has a smooth transition and a better backward compatability with 2G CDMA systems. The cdma-2000 can be used as an air interface. The protocol stack diagram of cdma 2000 consists of the important entities including signalling TCP, IP, UDP, high speed networks, voice and packet data related applications in top layers, link access control, medium access control layers correspond to layer 2 of OS2 and the fundamental physical layer that corresponds to layer 1 of OSI model.

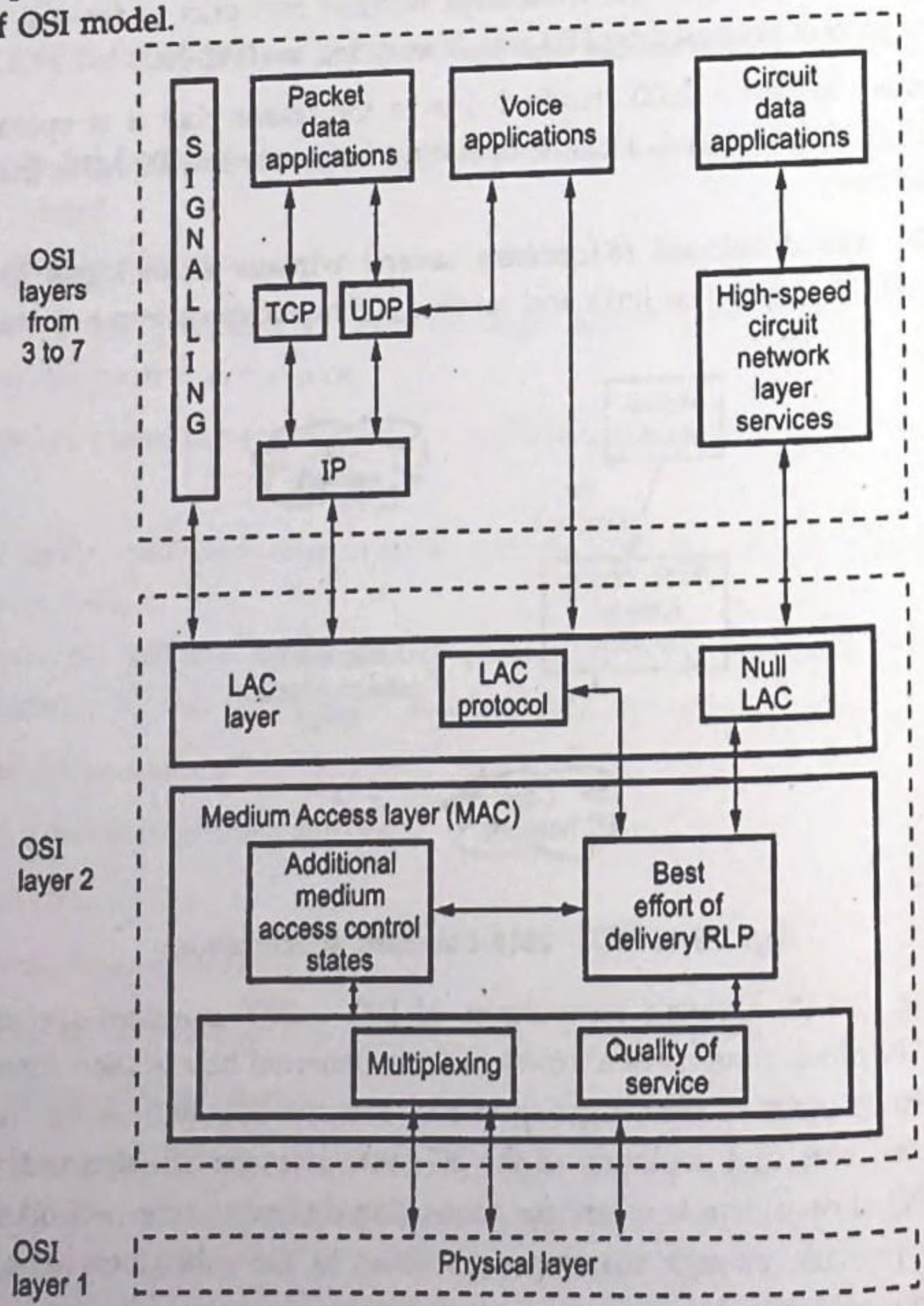


Fig. 1.8.16 3G - cdma 2000 protocol stack diagram

The terms used in protocol stack block diagram are,

i) TCP - Transport control protocol.

ii) UDP - User datagram protocol.

iii) IP - Internet protocol.

iv) LAC - Link access control.

v) MAC - Medium access control.

vi) QoS - Quality of service.

In second generation (2G) systems the IS - 95 family called as cdma one that is based on CDMA technique. Thus for 3G systems some hardware approaches are only required that will help to develop many service application under 3G which had a smooth upgradation from 2G to 3G. Thus 3G has backward compatability.

The cdma 2000 is thus an advancement of CDMA technology developed by the Qualcomm and meant for high data rate (HDR) packet standard. The standard also uses the adjacent three 1.25 MHz channels that can be used together for providing packet data throughputs and it will rely on vehicle speed, cell traffic loading and propagation environments.

Physical layer :

In the cdma 2000 physical layer, originally two spreading modes were made use of namely Multicarrier (MC) and Direct Spread (DS) techniques. There are two non direct spread modes in cdma 2000 known as 1X and 3X. That is under the 1X mode it uses a cdma one carrier whereas the 3X is the popular multicarrier system. The simplest version of the cdma 2000 standard is the 1X mode.

The uplink and downlink characteristics are summarized for the stake of understanding the future enhancements.

Uplink Characteristics :

i) Using open or closed power control :

The uplink is permitted to opt both the open loop power control and fast closed loop power control which is derived from 2G cdma one, and a good development is observed in CDMA technology in 3G systems.

ii) Pilot-based coherent detection :

In uplink performance of cdma 2000 is enhanced by the usage of Reverse Pilot Channel (R - PICH) and it provides a way for the base station to do the required coherent demodulation of the traffic received.

Downlink Characteristics :

Fast power control :

The closed-loop fast power control is used in cdma 2000. The power of the downlink traffic is measured by the mobile stations. Then according to the observation they give a 'power-up' or 'power-down' command to the base stations. A significant performance for high speed transfers is seen in a low-mobility environment.

Transmit diversity :

Transmit diversity is used at the base station, and it is required that diversity has to be applied at receiver end also to make the system effective. It can be applied for both direct spread and multicarrier approaches. In multicarrier method the basestation uses different antennas that are spatially separated for transmitting sub carrier. The signals that are originating from various antennas fade and are not dependable which leads to frequency diversity. Under direct spread approach the base station spreads the stream of data into two substreams and then they are transmitted with two antenna separately. To have better spreading of code, orthogonality between the two streams of data is maintained.

Synchronized base station operation :

Synchronization between the base stations is done, since it leads to faster handovers between the 2G and 3G systems that is cdma one and cdma 2000 respectively.

Pilot Signals :

There are two important pilot signals which are called as

i) Common Pilot

ii) Auxiliary Pilot.

A common code multiplexed pilot signal for all the users on the downlink is used. The information regarding multipath fading and channel conditions will be shared by the mobile nodes through these channels. The auxiliary pilot signals are basically optional and they are intended to support the smart antenna systems.

Common Characteristics

i) Turbo codes :

The cdma 2000 standard uses turbo codes for its coding for the supplemental channels. It is applied to increase robustness in case of high n-speed data service applications.

Double number of Walsh codes :

It is possible to use even upto 128 Walsh codes in cdma 2000 for variable spreading procedure. The carrier capacity is thus increased twice when compared to cdma one standard.

Independent data channels :

There are two types of physical data channels which are used. They are (i) fundamental channels (FCH's), (ii) supplemental channels (SCH's). They are coded separately and then interleaved. High data rate services are possible with the SCH's.

5 msec frame options :

The common frames have frame duration of 20 msec. A latency of 5 msec is also permitted for low latency type of transmission.

Chiprates with backward compatability :

The chiprates used in cdma 2000 are actually multiples of the chiprates used in cdma one standard. This is one of the simplified mode of chiprates adapted in cdma 2000 by its backward compatability.

1.8.15 Different Physical Channels in cdma 2000

The different channels disscussed under cdma 2000 are ;

i) Data traffic physical channel.

iii) Uplink physical channel.

iii) Downlink physical channel.

i) Data traffic physical channel

There are two data traffic channels namely supplemental and fundamental (SCH and FCH) channels and they are code-multiplexed in downlink and uplink. The encoding parameters and the modulation parameters are specified by the radio configuration (RC). There can be upto nine radio configurations where, the first two radio configurations are specified regarding backward compatability with the cdma one.

ii) Uplink (Reverse link) physical channel

* Reverse pilot channel (R-PICH)
* Reverse access channel (R-ACH)
* Reverse enhanced access channel (R-EACH)
* Reverse common control channel (R-CCCH)
* Reverse data traffic channel.

R-PICH :

Using this R-PICH channel the base station detects a mobile's transmission. It is an unmodulated spread spectrum signal channel. The R-PICH is used to send the power control signals to the respective base stations.

R-ACH :

For initiating communication, the mobile stations use R-ACH channels and it is done as a response to the paging messages.

R-EACH :

This channel is used to initiate communication with base stations, and it is used by mobile stations.

R-CCCH :

This signal is intented for conveying user and signalling informations to base station whenever the reverse traffic channels are not in use.

Along with these channels the reverse data traffic channels are also used. (Forward link) Physical channel :

iii) Downlink

The downlink physical channels are,

* Forward pilot channel (F-PICH)
* Forward auxiliary pilot channel (F-APICH)
* Transmit diversity pilot channel (F-TDPICH)
* Forward common control channel (F-CCCH)
* Forward sync channel (F-SYNCH)
* Forward paging channel (F-PCH)
* Forward broadcast channel (F-BCH)
* Forward quick paging channel (F-QPCH)
* Forward common power control channel (F-CPCCH)
* Forward common assignment channel (F-CACH)
* Forward data traffic channel.

i) F-PICH :

This channel is used to get the multipath fading and the channel conditions. This channel is shared by the mobile nodes to obtain the above mentioned information.

ii) F-APICH :

The number of these channels can be many. These F-APICH channels are used along with the smart antennas (array of antennas) in beam-forming applications. It was observed that the coverage of smart antennas are increased by the help of these channels. Each APICH channel is assigned a unique Walsh code under code multiplexed scheme in downlink.

F-TDPICH :

These channels are intended for synchronization by the mobile within a particular cell.

F-CCCH :

It is used to send high-layer messages (e.g. MAC layer) to the mobile units. The F-CCCH channel is used by the base station.

F-SYNCH :

This forward sync channel is used for providing initial synchronization related informations to the mobile stations.

Two types of forward sync channels are used.

1) Wideband sync channel.

2) Shared sync channel.

The wideband synchronization channel is compatible with both the non-overlay and overlay configurations. The shared synchronization channel is compatible with overlay configuration and it is used in both cdma 2000 and IS-95 channels.

F-PCH :

This channel is used by base stations. The channel is intended to transmit the mobile station specific messages and the overhead messages. Here also two types of channels are used.

Forward paging channel

1) Wideband paging channel

2) Shared paging channel

The wideband paging channel is compatible with both the overlay and non-overlay configurations. It is modulated across the 3G cdma 2000 wideband channel completely. The shared paging channel is compatible with overlay configuration of the 3G cdma 2000 standard over the 2G IS-95 standard. It is also used for both cdma 2000 and IS-95 channels.

F-BCH :

This channel is intended to transmit control information to the respective mobile stations effectively which have not been allotted a traffic channel.

F-QPCH :

This quick paging channel is used by the paging channel for providing control information to the mobile stations.

F-CPCCH :

The necessary power control information of uplink common control channels are conveyed by base stations using this channel.

F-CACH :

The quick assignments of reverse common control (uplink) channel is done by base station using this channel.

In addition to these channels the forward data traffic channels are also used in downlink (forward) physical channels in cdma 200 standard.

1.8.16 Data Link Control Layer (DLC) Issues - cdma 2000

The data link control (DLC) layer in cdma 2000 mainly uses a logical channel structure for having information exchange. So far we have discussed the physical layer aspects in cdma 2000. In general there are four protocol layers specified in cdma 2000. They are

1. Physical layer (Layer 1)
2. MAC sublayer (Layer 2)
3. LAC sublayer (Layer 2)
4. Upper layer (Layer 3)

1.8.16.1 W-CDMA (UMTS) - Third Generation Cellular System

The third generation cellular system, Universal Mobile Telecommunications System (UMTS) is an air interface and it was evolved in the year 1996, under European Telecommunications Standards Institute (ETSI). In third generation wireless telecommunications standards, UMTS is very popular due to its services and applications. The UMTS was submitted to International telecommunication union's IMT-2000 body by ETSI in the year 1998. The UMTS is also known as UMTS Terrestrial Radio Access (UTRA). The goal of UMTS was to provide high capacity cellular system. This UMTS (W-CDMA) technology has a smooth transition from 2G system so that it has a better backward compatability.

This 3G UMTS has the speciality such that any entertainment device, computers and telephone etc can access this wireless air interface network and can be connected to Internet from anywhere and at any time. The packet data rate supported by UMTS is upto 2.048 Mb/sec for single user. There are many other features for W-CDM such as,

i) It provides private and public network features.

ii) The W-CDMA needs allocation of 5 MHz frequency spectrum and it is a significant difference when compared to other standards.

iii) It has interoperability for all GSM, GPRS, IS-136 (PDC) and EDGE applications.

iv) It applies direct sequence spread spectrum chip rate more than 16 megachips/sec for single user.

v) This system provides atleast six times the spectrum efficiency than a GSM standard.

1.8.16.2 UMTS - An Overview

The European proposal for IMT-2000 is called as Universal Mobile Telecommunication System (UMTS). It made a big revolution in the third generation era. The group of special mobile (GSM) enhancement towards UMTS is often known as "EDGE" technology which stands for enhanced data rates are upto 384 kbits/sec using 200 kHz wide carrier with same frequencies as that of GSM. The basic structure of UMTS comprises of user equipment, radio network subsystem and core network. UMTS supports FDD and TDD modes. The FDD mode for UTRA uses the wideband CDMA (W-CDMA) with direct sequence spread spectrum (DSSS) scheme. Hence the up and downlinks under FDD uses different frequencies. The uplink carrier is around 1920 to 1980 MHz.

GSM also fits itself into ETSI and termed as global multimedia mobility (GMM). UMTS provides different services.

1. Real time services
2. Bearer services
3. Non real time services
4. Circuit and packet switched methods of transmissions.

1.8.16.3 UMTS - Architecture

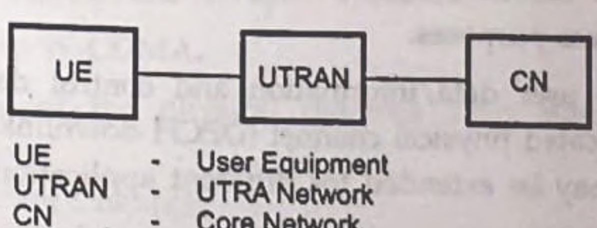


Fig. 1.8.17 UMTS - architecture - Basic block diagram

The UTRA network called as 'UTRAN' enables cell level mobilities and it has many radio network subsystems (RNS). The main functions of RNS is listed below.

1. Call handover control
2. Channel ciphering and deciphering
3. Radio resource management

In the architecture of UMTS, the user equipment (UE) is connected to core network 'CN' via UTRAN block.

Functions like

1. Gateways to other (external) networks

2. Inter system handover are handled by core network

There are two types of modes compatible with UTRA system.

a. UTRA FDD mode

b. UTRA TDD mode

The wideband CDMA namely W-CDMA is used for UTRA FDD and up and downlinks use separate frequencies. FDD mode can provide 250 channels (approx), for handling user traffic; (e.g. voice channel facility). Direct sequence spread spectrum (DS) coding is compatible and data rate of 2 Mbits/sec can be achieved here. Many logical and physical channels can be assigned. User data (from layer two and higher layer) is sent over uplink dedicated physical data channel (uplink DPDCH) and in UTRA, the FDD mode makes use of wideband CDMA (W-CDMA) along with direct sequence spreading (DSS). The mobile uplink frequency range is from1920 MHz to 1980 MHz and the downlink frequency used by base station is from 2110 MHz to 2170 MHz. It is possible to accommodate 250 channels approximately with this specified frequency spectrum range. Like GSM, in UTRA technology there are logical and physical channels available for the users. In uplink the uplink dedicated physical data channel (uplink DPDCH) is used to transport user data/information. The uplink dedicated physical control channel (uplink DPCCH) is used in transport layer to control data (like data used for controlling power).

The control data from mobile station is carried by physical random access channel (PRACH) for random access purposes.

In downlink case the user data/information and control data from layer one are carried by downlink dedicated physical channel (DPCH downlink). The chip rate may be 4.096 Mchip/sec and it may be extended for different applications in future upto 16.384 Mchip/sec.

The modulation scheme used is QPSK. CDMA technique which is compatible with UTRA has many features like,

i) Localization of mobile stations.

ii) Soft handovers.

iii) High degree of accuracy.

CDMA scheme has a drawback of "complex power control" during a "call progress".

1.8.16.4 UTRA - TDD Mode

The time division duplexing mode of the UTRA technology makes use of wideband TDMA/CDMA for the medium access and the up/down links uses the same frequency. The data rate is 2 Mbit/sec for about 120 channels (approx) in case of the user traffic. The direct sequence (DSS) type of spreading code is applied and the modulation scheme used is QPSK. In TDD the power controlling can be slower than the FDD because the number of power controlling cycles in one second are less. It is worth noting that the frame structures of FDD and TDD are same and hence both the schemes can coexist in necessary conditions.

The W-CDMA-UMTS is also called as UTRA-FDD. The physical layer of this standard can be related to be radio interface when observing one particular link between base station and a terminal. The air interface protocol structure of WCDMA is shown below.

The physical layer provides transfer services information to the next layer using various types of channels. While considering channels there are three important types of channels which have to be considered. They are

i) Logical channels

ii) Transport channels

iii) Physical channels

In the protocol structure block diagram all the three channels are shown. The logical channels are responsible for transfer of information between RLC and MAC layers. The physical channel clearly defines the required code and frequency ranges for both up and downlinks. The characteristics of the data/information is sent over the channel by transport channels. In the W-CDMA the physical layer provides services to the respective MAC layer through the transport channels.

Physical channels in W-CDMA.

In W-CDMA some of the physical channels carry information on the downlink channels as listed below.

- CPICH (Common Pilot Channel)
- SCH (Synchronization Channel)
- AICH (Acquisition Indication channel)
- PICH (Paging Indication Channel)
- CSICH (CPCH Status Indication Channel)
- CD/CA-ICH (Collision Detection/Channel)
- Assignment indication channel

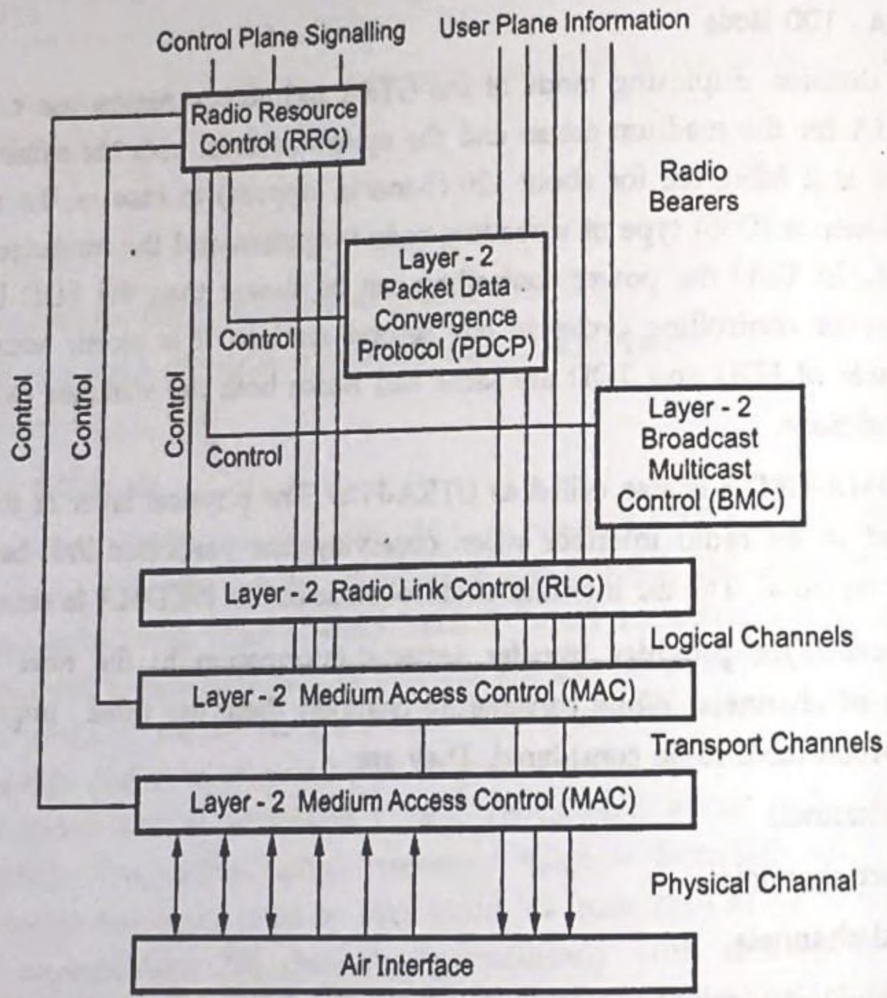


Fig. 1.8.18 Air interface protocol structure of W-CDMA(UMTS)

The first two channels CPICH and SCH have to be transmitted by every base station. The various transport channels are mapped on different physical channels. A few physical and transport channels are identical. Let this group be X.

On the other hand a few physical channels act as carriers for a portion of the transport channels. This group of channels let it be denoted as Y. A simple mapping of transport channels onto physical channels is shown below.

	Transport channel		Physical channels
Group X	RACH	→	PRACH (Physical Random Access Channel)
	BCH	→	PCCPCH (Primary Common Control Physical Channel
	DSCH	→	PDSCH (Physical Downlink Shared Channel)
	CPCH	→	PCPCH (Physical Common Packet Channel)
	PCH FACH	→	SCCPCH (Secondary Common Control Physical Channel)

Group Y	DCH	→	DPCCH (Dedicated Physical Control Channel)
		→	DPDCH (Dedicated Physical Data Channel)

Thus the transport channels are mapped onto the physical channels.

Then the important transmission characteristics of W-CDMA includes,

1) Identical characteristics of up and downlinks.

i) Radio frame structure of 10 msec.

ii) Spreading/channelization codes (OVSF codes)

iii) System frame number (SFN) of 12 bits.

iv) Chip rate of 3.84 Megachips/sec

v) Channel spacing of 5 MHz.

vi) Long code of 38400 chips.

2) Uplink channel characteristics.

In W-CDMA the uplink channel characteristics the main operations are

i) Spreading

ii) Scrambling

iii) Modulation

After spreading and scrambling it forms the CDMA signal.

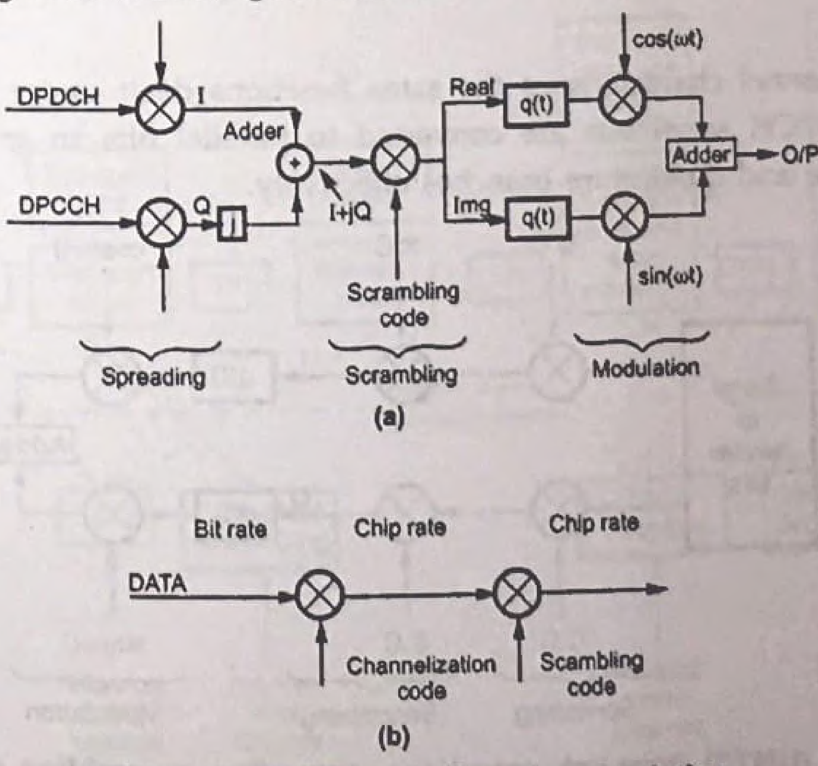


Fig. 1.8.19 Transmission characteristics

a) W-CDMA (UMTS) uplink spreading, scrambling and modulation operations
b) Spreading and scrambling

The Walsh codes are used in WCDMA. The spreading codes in WCDMA are known as orthogonal variable spreading factor (OVSF) codes. Then spreading factor can vary from 4 to 512. This standard uses 3.84 megachips/sec chip rate and maintained as constant. By using shorter spreading codes higher data rates and by using longer spreading codes lower data rates are obtained. Thus by decreasing spreading factor the data rate can be increased. But it will also reduce the number of cellular users which can be supported. The reason is fewer codes are only available in case of shorter spreading factor.

In case of demodulation pilot symbols are used. The channels DPCH, CCPCH and the PRACH carriers pilot symbols.

In spreading at the transmitter end, the channelization code is capable of identifying the physical data channels DPDCH and control channels (DPCCH) with the code length.

The process of scrambling follows the spreading. It uses gold code that has a pseudorandom characteristics. The long code has 10 msec frame and used at rake receiver in base station. The short code is used when the base station applies multiuser detection techniques.

In modulation combine Inphase-Quadrature, code multiplexing is used (i.e. dual channel QPSK scheme).

The transmission power can be reduced by having faster power control in the uplinks.

In downlink channel characteristics the same functions dealt under uplink are done and at first the DPCH serial bits are converted to parallel bits so as to have correct mapping in inphase and quadrature branches effectively.

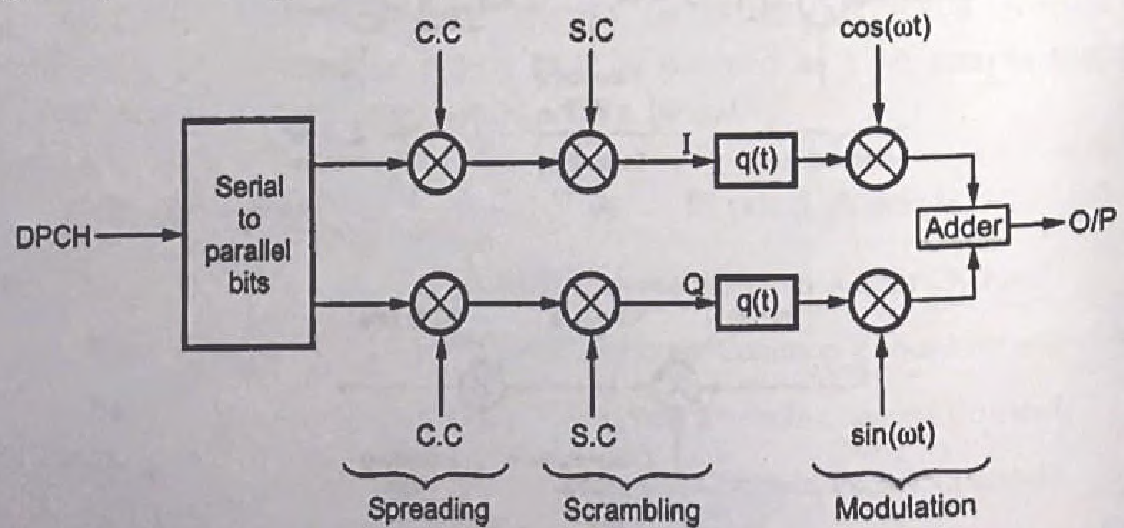


Fig. 1.8.20 WCDMA (UMTS) Downlink operations, spreading, scrambling and modulation

S.C - Scrambling code
C.C. - Channel code

In spreading that is based on OVSF codes operating limit is upto 512 chips. The scrambling uses gold codes for a time frame of 10 msec (i.e. 38400 chips). Under channels SCH, the primary and secondary SCH are used. The primary SCH consists of a code of 256 chips and in secondary SCH it can generate upto 64 various code words, for identifying common channels having continuous transmission. In modulation quadrature phase shift keying with relevant time-multiplexed data and control system are used.

Transport channels :

The main characteristics of information that the transport channels can provide is summarized below :

i) The shared information for up or downlink.

ii) The control information for up or downlink.

iii) Power control characteristics.

iv) Managing the collision risk.

v) Mobile station identification.

vi) Beam forming information.

vii) Data rate variation.

viii) Broadcast coverage area

- In entire cellular area or in a selected cell alone.

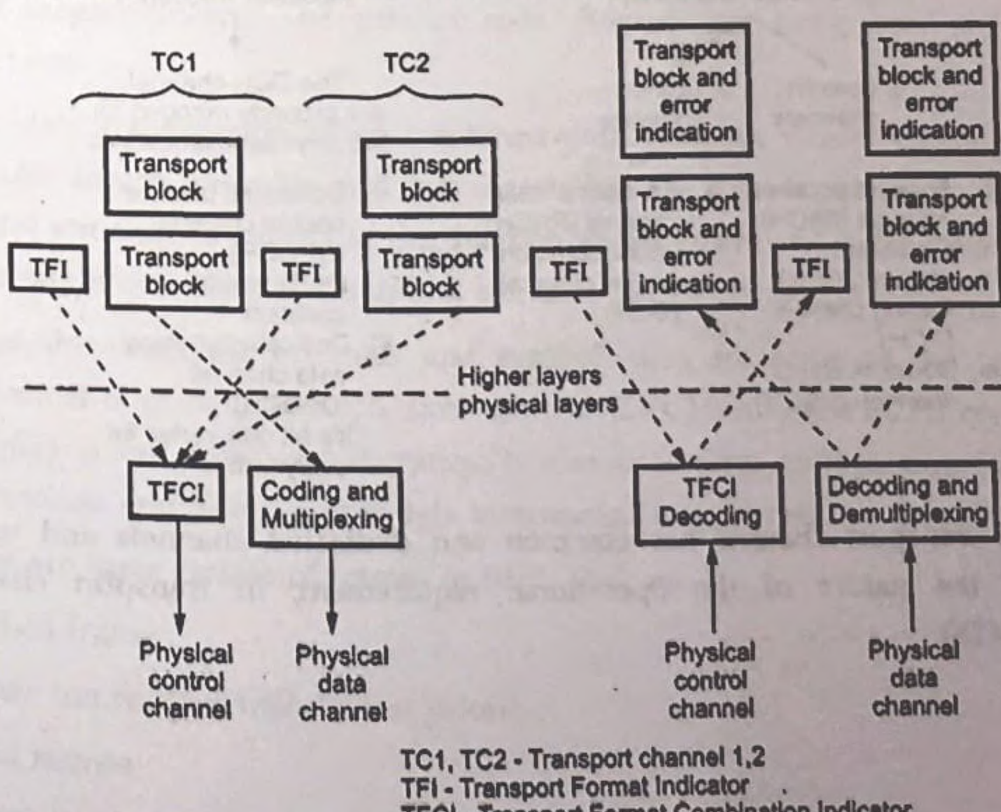


Fig. 1.8.21 Higher layers and physical layers (W-CDMA (UMTS))

The interaction between physical and higher layers are shown in the diagram. Every transport channel carries the transport format indicator (TFI). The physical layer does the function of combining all the TFI information from various transport channels to form the Transport Format Combination Indicator denoted as TFCI. This TFCI is useful as it informs the mobile equipment about availability of active transport channel, in the current frame.

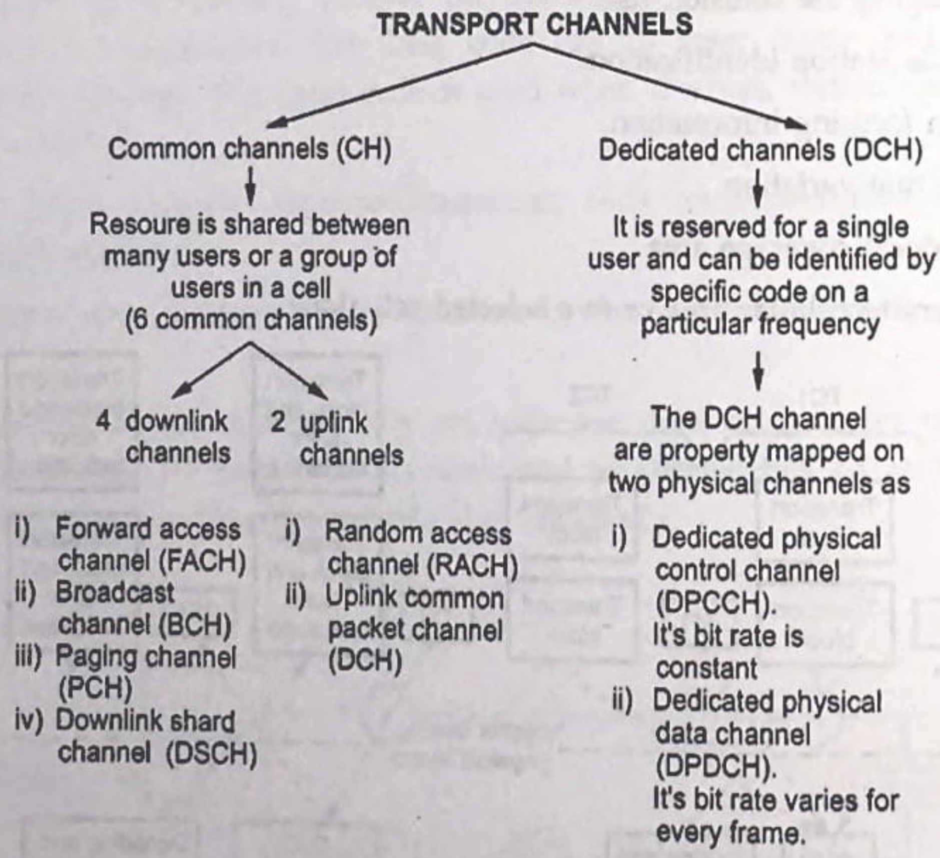
The TFI is added to each TC such that

{TFI + TC} is done where

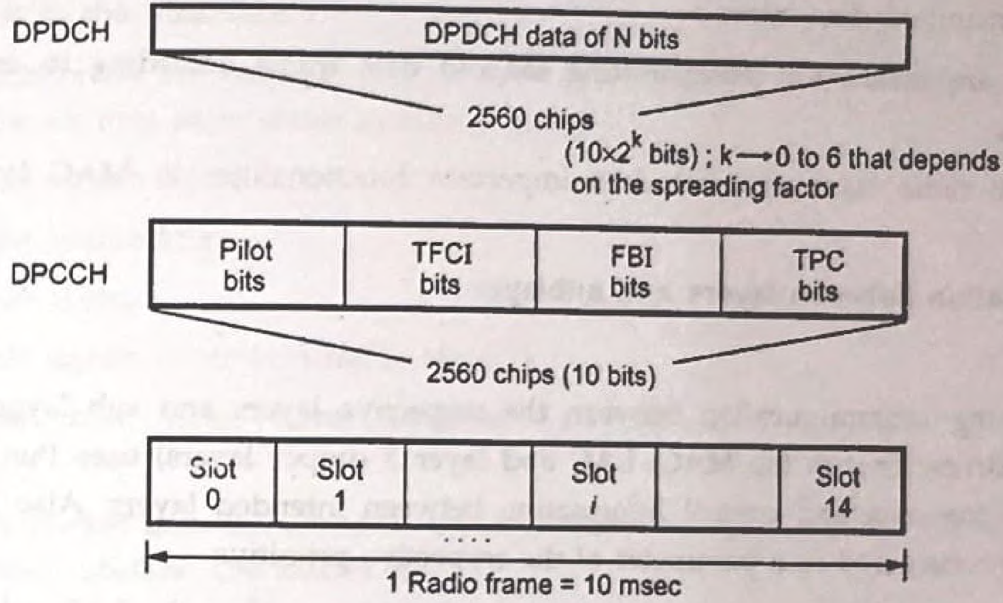
{TC} → Coding and multiplexing in bank of transport channels.

and {TFI} → Physical control channel (PCEH)

It is possible to divide the transport channels into common channel and dedicated channel for a specific operation.



Hence the transport channel has common and dedicated channels and uses them according to the nature of the operational requirement, in transport channels of W-CDMA(UMTS).



DPDCH - Dedicated Physical Data Channel
DPCCH - Dedicated Physical Control Channel

Fig. 1.8.22 The uplink DPDCH and DPCCH frame and slot structures

User data transmission :

In the user data transmission it makes use of slot structure of radio frame with 15 slots in 10 msec time period. The duration of a slot is about 2560 chips. It has a chip rate of 3.84 megachips/sec. The parallel code channels are being used for handling higher data rates.

The user data transmission when combined with Random Access Channel (RACH) has a particular future preamble and it is sent before the data transmission. The uplink frame and slot structure is shown in the diagram above where one radio frame period is 10 msec. For fast power control the uplink common packet channel is used.

In case of downlink the bit rates and symbol rates are same as the uplink. The downlink channel is of dedicated physical channel (DPCH) and (DPDCH) type. The bit rate in DPDCH is not fixed and it varies. It also uses time multiplexing for physical control information and also the user data information respectively.

Also there are three classes of frames in RLP. They are

i) New data frame :

They are transmitted with lowest priority.

ii) Control frames :

They are used to carry control information and it is given top priority.

iii) Retransmitted data frame :

They are meant for retransmitting the old data frame according to instructions given.

Thus the radio layer protocol does important functionalities in MAC layer under cdma 2000.

Communication between layers and sublayer

Structures :

Establishing communication between the respective layers and sub layers is done using primitives. That is the MAC, LAC and layer 3 (upper layers) uses the primitives for passing the data and control information between intended layers. Also the actual data unit is considered as a parameter of the respective primitive.

Consider that a PDU has to be sent from LAC sublayer. Now the LAC sublayer will invoke the service data unit (SDU) primitive to request the service from the MAC layer. There are four different primitives which are effectively used for communication. It is shown in the diagrams below for both the transmit and receive side.

E.g. : Transmit side :

i) Consider layer 3 wants to send a PDU. It makes a request for service from the next LAC sublayer by using the L2-data primitive as shown.

ii) If the SAR or LAC sublayer need to transmit a PDU i.e. from layer 3 then the LAC sublayer will invoke the SDU ready primitive thus requesting a service from respective MAC layer.

iii) In case if enough space is available for bearing data transfer function over physical channels then the MAC layer transmits the "Availability-Primitive" to express the event occured, as an indication to the service requester.

iv) Once the 'Availability-Primitive' is received, the LAC sublayer transmits MAC-Data primitive to that of the MAC, for requesting data transport service effectively.

On the other hand there are two important primitives which are used at receive end.

Receive side :

i) The MAC layer makes use of the MAC-Data primitive to the LAC sublayer.

ii) Once the processing is over, then it is informed to layer 3 as follows. The LAC sublayer sends a PDU using 'L2-Data primitive' to the layer 3 to express the reception of signalling data.

Upper layer in the structure :

The operation of the entire IS-2000 system is controlled effectively by the signalling entity. There are four main states available, namely,

i) Mobile station initialization

ii) Mobile station idle

iii) System access

iv) Mobile station control on traffic channel

All these four states have similarity with the IS-95 standard as backward compatability.

Also the packet data transmission involved has three modes when the mobile is in traffic channel substate. The modes are

a. Active mode

b. Control hold mode

c. Dormant mode

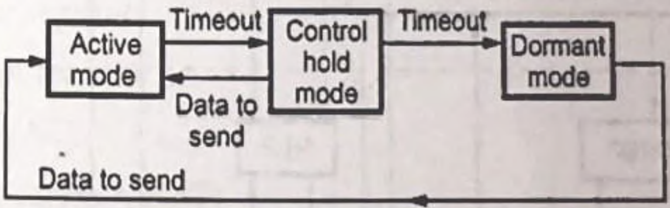


Fig. 1.8.23 Packet data transmission with three modes

In the active mode there is exchange of user packet data and the respective dedicated signalling data between base station (BTS) and the mobile station (MS). Then the control mode in packet data transmission helps to maintain the MAC control and the power control functions using dedicated control channel in the system.

Finally the dormant mode is mainly applied in 'mobile station idle state' to keep the information regarding user's packet data service registration (UPDR) and relevant connections. At any point a mobile is in any one of three modes or in a state of transition between these modes. In addition to this the signalling entity also keeps track of setup, maintenance etc. regarding a call. Thus the call processing functions are effectively handled by the signalling entity in the system.

Power control

It is very important to have proper power control in forward and receive end under cdma 2000 standard to improve accuracy and speed and finally system capacity. At the receive end the power control is mainly to reduce the differences in the power levels of signal that is received from many transmitters from base station. On the other hand in forward end power control is to reduce the differences in power levels of received powers present in same band that allows many users to exist on the system.

The main types of power control used are

i) Power control in reverse link

This type mainly makes sure that all the received link signals are at same power level (nearly). Hence interference can be minimized among all the mobile signals, in reverse link. By using open loop and closed loop setups the power control is implemented.

ii) Closed loop power control in forward link.

The closed loop power control is used in forward link and it is used to reduce the received power level from various transmitters at the mobile end. Then the EC/NO (Energy to noise) and the FER error rate of the signal received is measured by the mobile continuously with respect to the forward link.

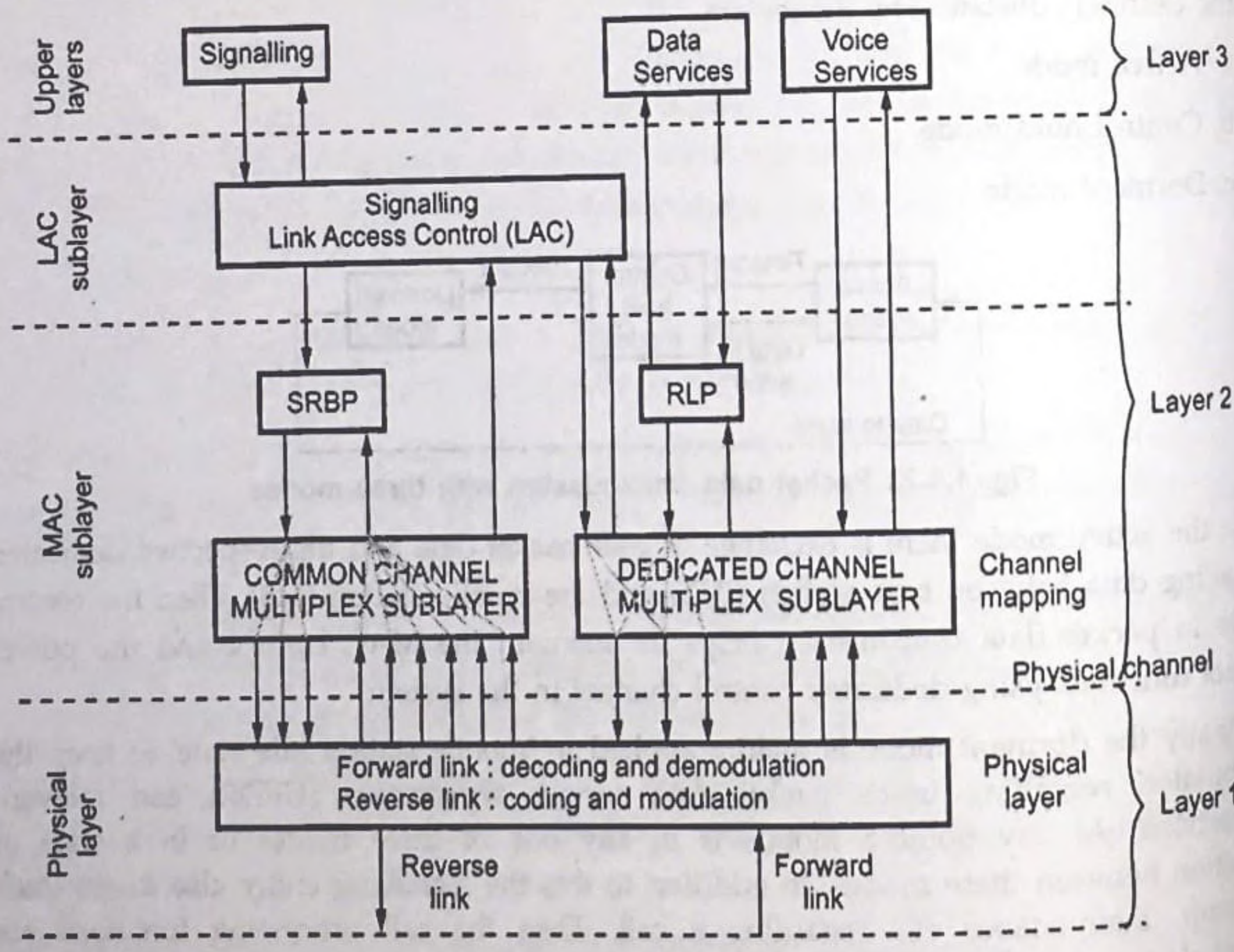


Fig. 1.8.24 Protocol architecture in IS-2000 (evolution of IS-95/cdma 2000) from the mobile perspective

The four entities of MAC layer Radio Link Protocol (RLP), Signalling Radio Burst Protocol (SRBP), dedicated channel multiplex sublayer and common channel multiplex sublayer is shown in the protocol architecture in IS-2000 (cdma 2000).

1.8.17 Network Architecture

A simple architecture that can support the cdma 2000 network is discussed here. The services that are provided by the cdma 2000 network are

i) Circuit switched voice service

ii) Circuit switched data service

iii) Packet switched data service

The entire network architecture can be expressed as two divisions. First the elements of the network, and second the two supporting functions that are capable of enhancing the network performance.

a) Elements of the network

When comparing cdma 2000 cdma one, six elements are similar in nature among them. They are

i) Base station controller

ii) Mobile switching centre

iii) Home location register

iv) Visitor location register

v) Access center (AC)

vi) Inter working function (IWF)

The BSC takes care of mobility management. The IWF makes circuit-switched data service. For packet switched data service in this standard, there are additional elements.

They are,

i) Authentication, authorization and accounting :

It is denoted as AAA. It is basically a server that can provide authentication, authorization and the accounting services for the respective PSDN that it enables packet data network connectivity effectively. The advantage of AAA is its effective authentication service. Also for each mobile station the AAA collects the data on its own usage of packet data service. Once authentication is completed the mobile station will be granted the necessary service for authorization.

ii) Packet data service node (PDSN)

This node enables the packet switched data service. The PSDN is mainly an Internet protocol (IP) router that can route the user data traffic to network like Internet. The packet switched traffic is effectively directed by PSDN between the packet switched network and mobile station.

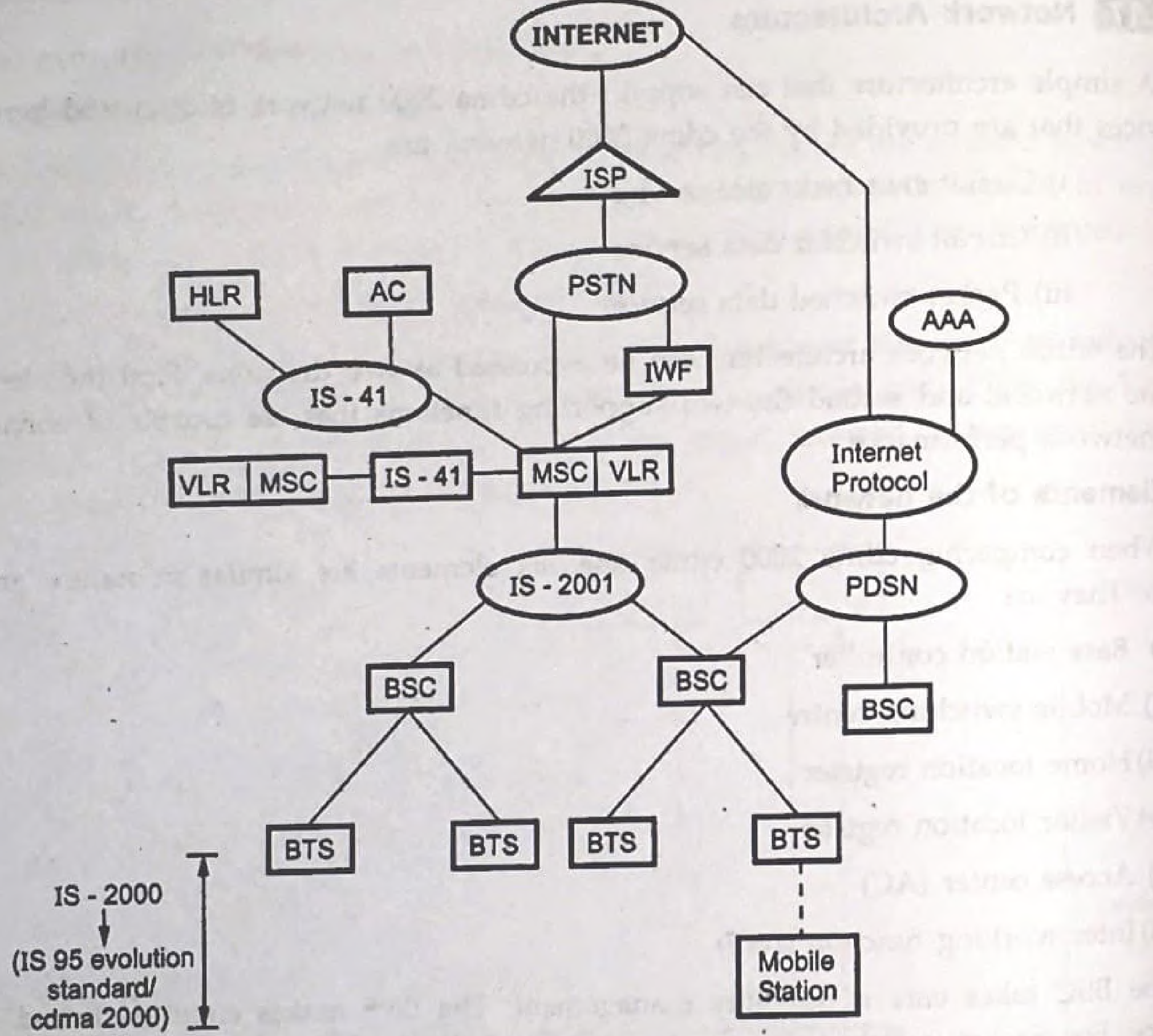


Fig. 1.8.25 A simple 3G wireless network

In addition to these elements of network there are two important functions associated in network architecture. They are

i) Mobile IP function

ii) Simple IP function

a. Mobile IP function

The network element that could support mobile IP are Home Agent (H) and Foreign Agent (FA).

The home agent together with FA is a router and the mobile IP function is provided by another rouler. This HA will reside on MS home IP network. Then the FA is also a router but resides in another PSDN so that it carries the name 'foreign agent'. Whenever a MS tries to visit the IP network this FA would receive packets sent by HA. Finally the FA delivers the packets to the respective MS.

b. Simple IP function

In the home PSDN, assume an MS that has an IP address 'M' whereas the server on the Internet has an IP address 'S'. With the help of these M and S addresses the IP packets will be effectively exchanged between servers and MS. These exchanges takes place in some PSDN node.

Thus these two functions enhances system performance in cdma 2000 network architecture.

The important issues of DLC is discussed now under layer 2.

The DLC layer 2 comprises of two sublayers.

LAC sublayer	} →Data link control layer (DLC)
MAC sublayer	

Medium Access Control (MAC) sublayer :

In MAC sublayer there are four important entities available. They are,

1) SRBP (Signalling Radio Burst Protocol) layer

2) Radio Link Protocol (RLP)

3) Common Channel Multiplex Sublayer

4) Dedicated Channel Multiplex Sublayer.

The SRBP (Signalling Radio Burst Protocol) layer is discussed here which is very important protocol layer under MAC (layer 2).

The SRBP can handle common-channel signalling with the help of radio burst techniques. This protocol layers performs in the common channel multiplex channel. SPBP performs many functions.

For example it controls the signalling messages which travels on common signalling channels in physical layer. Here six forward common signalling channels and three reverse common signalling channels are used. They are

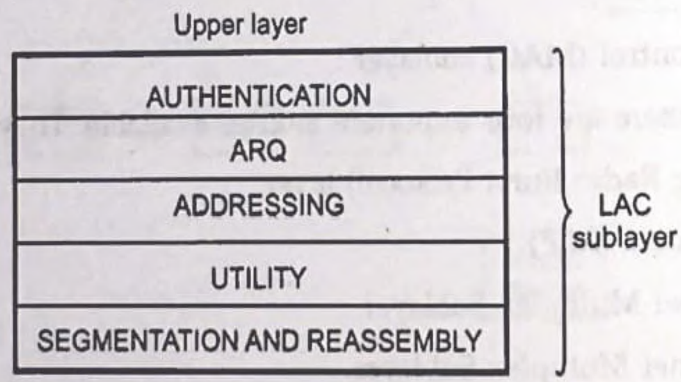
i) Forward channels - F-SYNCH
F-CPCCH
F-CCCH
F-PCH
F-CACH
F-BCCH

ii) Reverse channels - R-ACH
R-EACH
R-CCCH

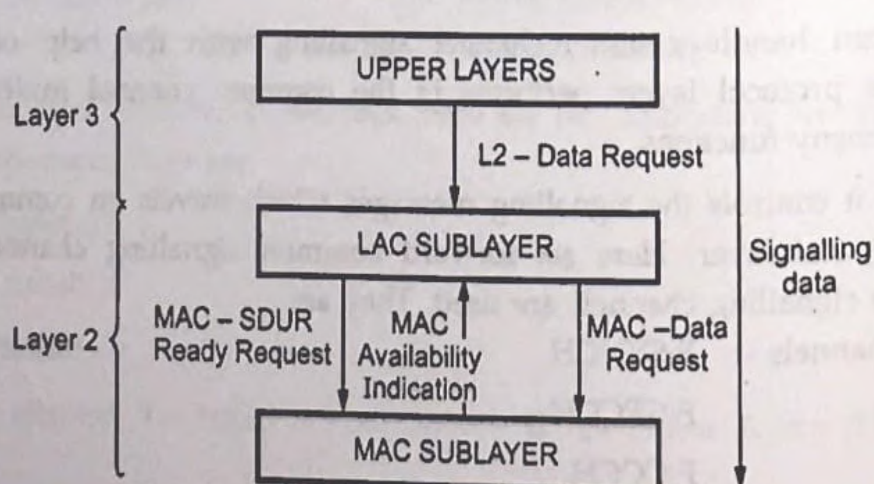
The SRBP layer is capable of computing few parameters such as randomization delay of each access to have transmission, power level of every successive access probe and also the reception of signalling messages effectively.

The SRBP is responsible to assemble SDU's (data units) for physical layer for transmitting on respective physical channels. It also receives SDU's which come from physical channels and sends them to link access control (LAC) sublayer. These are the functions of SRBP layer. Access modes in cdma 2000 are

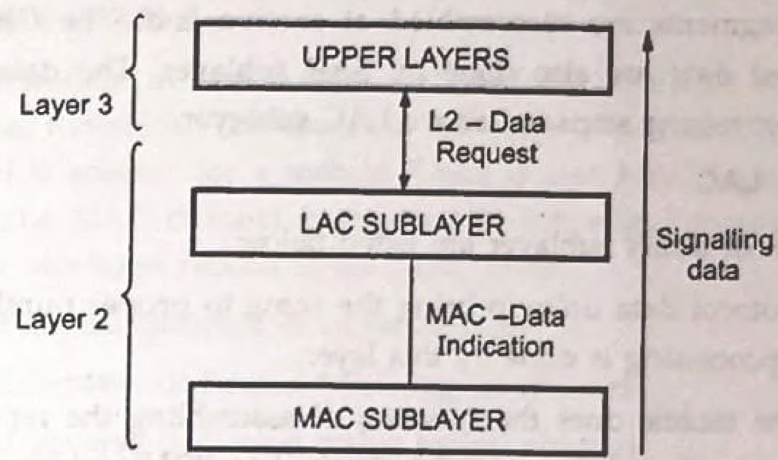
i) Basic access mode
ii) Reservation access mode
iii) Power controlled access mode
iv) Designated access mode.



(a)



(b)



(c)

a. Structure of LAC sublayer

b. Transmit side - Interaction of the primitives

c. Receive side - Interaction of the primitives

Fig. 1.8.26 MAC layer interaction with upper layers in cdma 2000

1.8.17.1 Sublayers

The structure of LAC sublayer is shown in the diagram above. The LAC sublayer provides the data link protocol. The protocol makes sure that signalling data that are being generated (that is from upper layers) is properly delivered across the air link. It also monitors the delivery of user packet data. While LAC and RLP handle the same data link protocols there is a significant difference between RLP and LAC.

The LAC makes a reliable delivery of the signalling data whereas the RLP makes a best effort in transport of packet data and it is not an assured delivery in RLP. This LAC is assumed as an interface between the upper layers and MAC layer.

LAC thus promises reliable data delivery. In LAC as in the diagram five sublayers are available.

Layer 1 in LAC - SAR

Layer 2 in LAC - Utility

Layer 3 in LAC - Addressing

Layer 4 in LAC - ARQ

Layer 5 in LAC - Authentication

1. Segmentation and reassembly (SAR) sublayer

In this sublayer the encapsulated PDU's are segmented into PDU fragments and it is done at transmit side. The cyclic redundancy check (CRC) is also computed by this SAR sublayer and it is added to the PDU's.

The same PDU fragments are reassembled at receive end. The CRC checking and validating the received data are also done by SAR sublayer. The data will be sent to other layer for next processing steps i.e. above LAC sublayer.

2. Utility sublayer in LAC

The main functions of utility sublayer are listed below

i) Padding the protocol data units to bring the same to proper number of bits which is required for processing is done by this layer.

ii) This layer at the mobile does the function of assembling the report fields related to radio environments and they may be attached to PDU's which is optional.

3. Addressing

This layer does the function of directing the PDU's to corresponding destination by providing relevant addressing.

4. ARQ sublayer

The ARQ sublayer is responsible for providing reliable delivery of the signalling data. The main concepts used in ARQ sublayer are,

i) Retransmission

ii) Providing positive/negative acknowledge

It is worth noting that the ARC sublayer in LAC is capable of delivering layer 3 PDU's in two modes namely, assured and unassured delivery.

In case of assured delivery the signalling data is sent repeatedly at regular intervals till it receives a positive ack. signal from the respective receiving LAC layer. But in unassured delivery type the LAC at transmitting end sends the signalling data properly but there is no acknowledge signal from the receiving LAC as in the case of assured delivery.

5. Authentication and addressing sublayers

This layer is capable of processing the addressing information like mobile ESN and MIN information when ever a mobile tries to access the network that is particularly for first time authentication.

But if the mobile access is permitted then there is no requirement of authentication existence and at the same time the dedicated traffic channels are assigned for the access made by the mobile to the network.

Logical channels in MAC

The logical channels in cdma 2000 standard are available for both forward and reverse directional functions. The channels are either a common type or dedicated type in which channel is specific for a mobile. There is also MAC logical channel and traffic logical channel. The MAC channel is assigned in active and control-hold states and it is intended to carry messages related to the MAC layer.

The important logical channels of cdma 2000 are

i) Forward/reverse dedicated MAC logical channel

ii) Forward/reverse dedicated traffic logical channel

iii) Forward/reverse common signaling channel

iv) Forward/reverse common traffic channel.

For forward or reverse the letter f/r can be used A simple tabulation expresses how to denote a logical channel in this standard.

1st letter	2nd letter	3rd letter
r - reverse f - forward	c - common d - dedicated to a particular mobile	m - MAC t - traffic s - signalling

For example if the logical channel is 'f/r - csch' then it is a forward/reverse dedicated signalling channel that is used for carrying the signalling information.

1.8.17.2 Radio Link Protocol (RLP) Layer

This RLP layer is intended to control the process of the user packet information/data which travels on the dedicated user channels. Different techniques are used to control the packet errors.

There are three main types of RLP. They are denoted as RLP1, RLP2 and RLP3, and they are used to implement the packet data service over the IS-95A standard traffic channels with specific data rates.

RLP1 → This service type helps to implement packet data service with the data rate of 14.4 or 9.6 kb/sec over the IS-95A standard traffic channels respectively.

RLP2 → This service type helps to implement packet data service over the IS-95B traffic channels (t-ch) and they are respective fundamental and supplemental code channels.

RLP3 → This service type helps to implement the above said packet data service with a data rate 2 Mb/sec (approx) over the cdma 2000 traffic channels in an efficient manner.

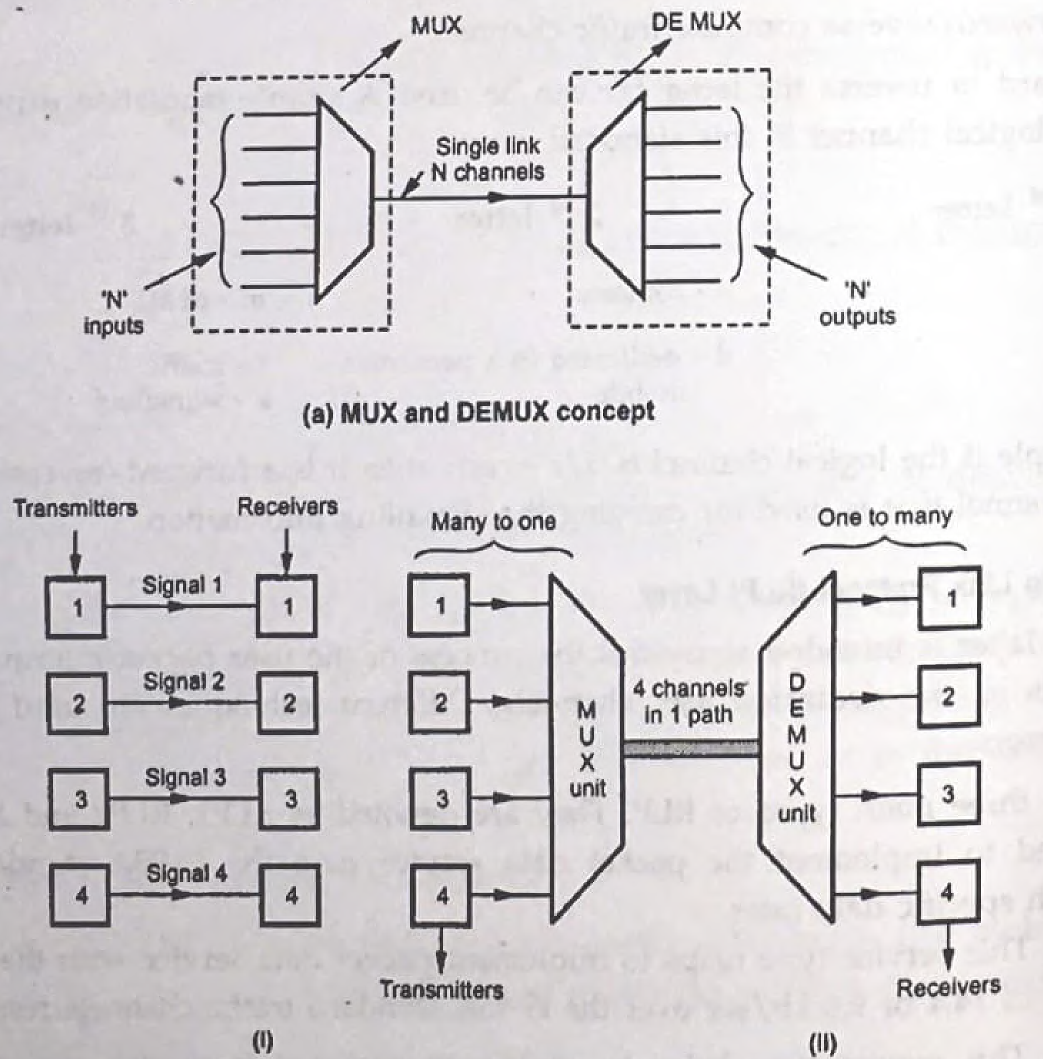
1.9 Multiplexing

AU : Dec.-16, May-17,18

Multiplexing is a technique used to accommodate more channels at a time so that each can have its own data/information which travel from transmitter to receiver. It is a concept of "many to one", and hence many channels are combined into a multiplexer (MUX) and sent as a single stream of data towards receiver. If a multiplexer (MUX) is used as transmitter it must be balanced with a demultiplexer circuit (DEMUX) at the receiver to receive the single stream of data and split them again into original set of channels which was the input to MUX unit.

Today the data traffic is highly voluminous and so the high capacity of data stream can be managed only by sharing the link (transmission link) between two devices.

The scheme of multiplexing is represented as block diagrams.



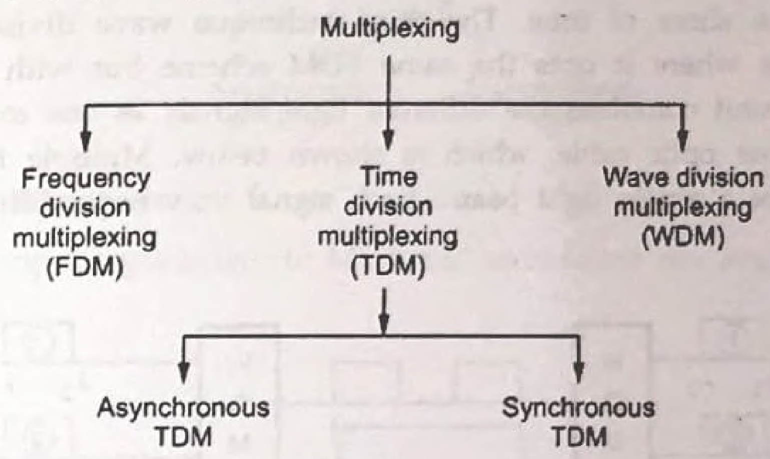
(b) Difference between multiplexing and conventional method of transmission

Fig. 1.9.1

In the field of communication the multiplexing technique is applied widely.

The data communicating devices like client server models today requires higher data rates and hence this technique is used to a greater extent.

1.9.1 Types of Multiplexing



Frequency division multiplexing :

The frequency division multiplexing concept (many to one) is shown in the diagram below.

Whenever the useful bandwidth exceeds the combined bandwidth of the signals to be transmitted, more number of channels are modulated with different carrier frequency and are sent as a signal stream from MUX unit. All these channels are transmitted as one channel and demultiplexer (DEMUX) differentiates it as the original individual channels at receiver side.

A guard band (unused bandwidth) is allowed to avoid overlapping of different channels. Four transmitted signals are merged as one signal by multiplier and sent as one complete signal and the signal is again divided by demultiplexer to get back four original signals.

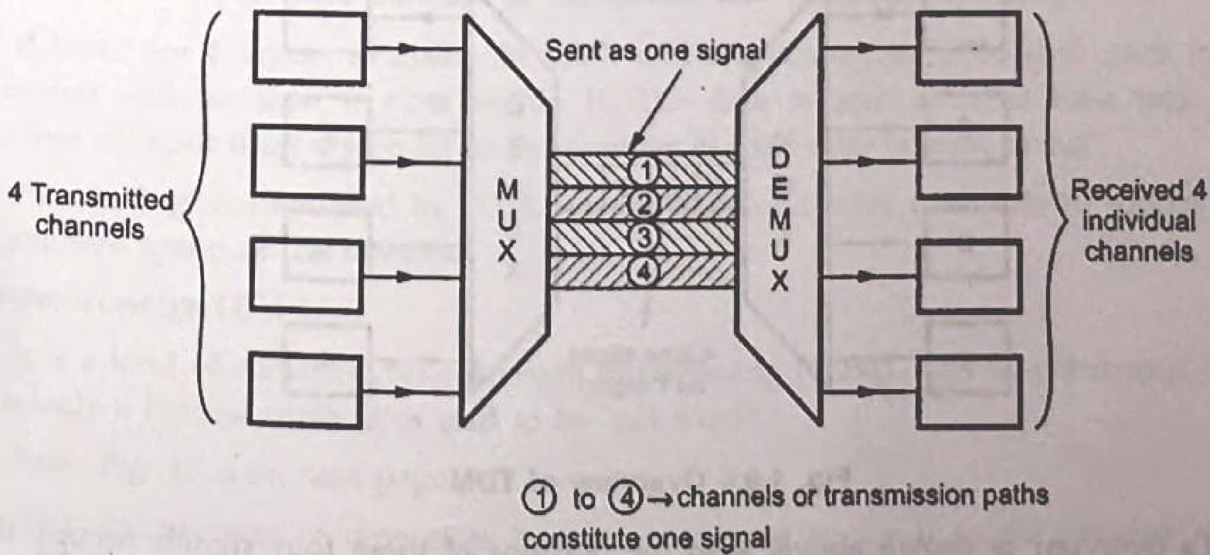


Fig. 1.9.2 Overview of FDM

In this FDM method it is like four different small links merged together as one main link by MUX and again split as 4 small links (channels) by DEMUX unit.

In FDM the channels are slices of frequencies f_1, f_2, f_3 etc whereas in TDM method the channels are the slices of time. The third technique wave division multiplexing (WDM) is a scheme where it opts the same FDM scheme but with respect to light signals. The WDM unit combines the different light signals as one main ray that can travel through a fiber optic cable, which is shown below. Multiple light sources are combined to produce a single light beam. Each signal may have different wavelength (λ).

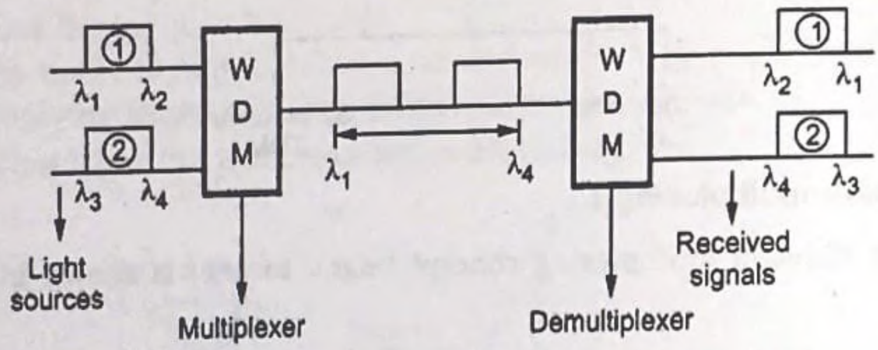


Fig. 1.9.3 Wave division multiplexing (WDM)

The demultiplexer at receiver gets the single light beam and splits it into original individual light sources for example 1 and 2 with λ_1 and λ_4 wavelengths.

Time division multiplexing (TDM) :

In TDM multiple transmission can occupy an individual link by subdividing the link and also interleaving its portions.

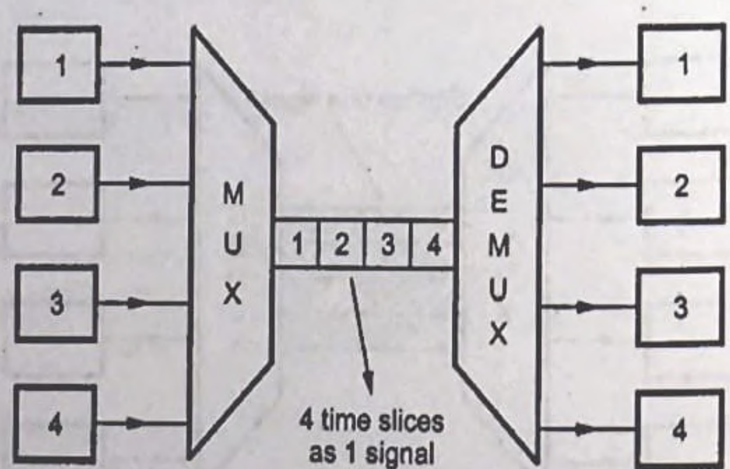
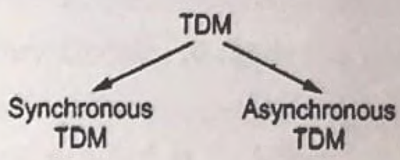


Fig. 1.9.4 Overview of TDM

TDM's overview is shown above. Also the portions of these four signals occupy the link sequentially during its journey towards demux.



Synchronous TDM scheme :

The multiple input signals sent to MUX and each frame has sequential slots for each signals.

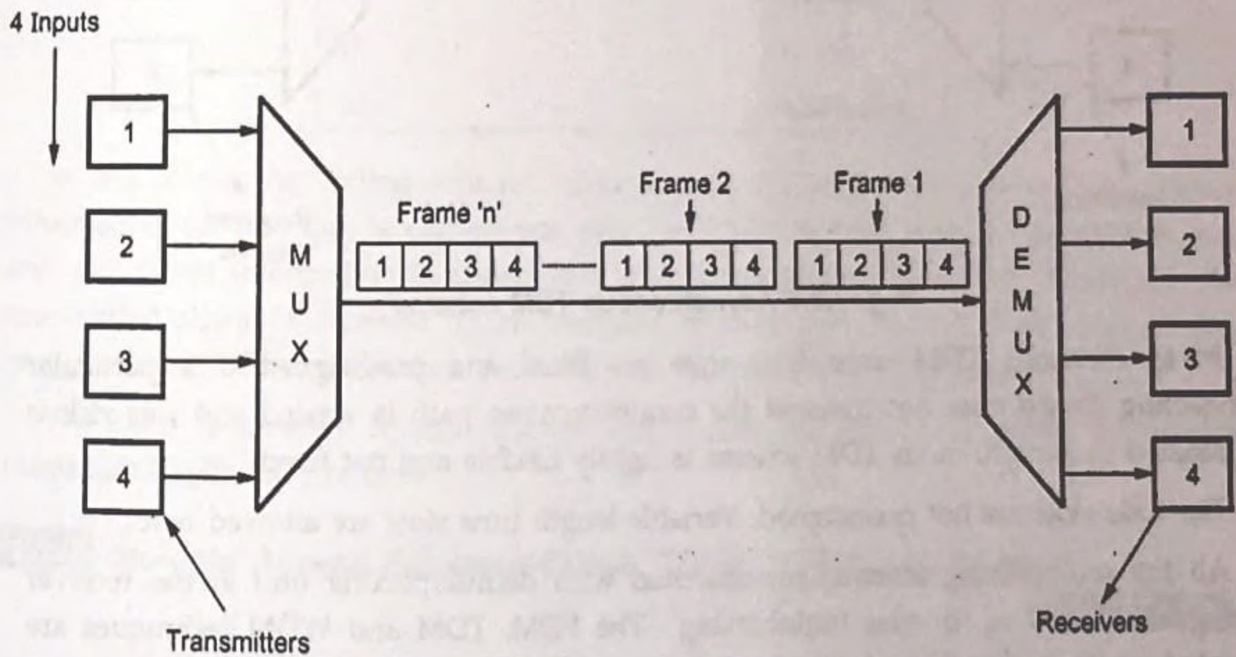


Fig. 1.9.5 Concept of multiplexer and demultiplexer units

If there are 4 inputs available to MUX under synchronous TDM then each frame is allocated with at least 4 slots within it. The data is sent at same data rate. Hence number of input lines are equal to the number of time slots in each frame.

'Bit stuffing' is permitted in TDM, where MUX unit adds extra bits to source stream to enhance speed of the devices.

Asynchronous TDM :

It is a kind of statistical time division multiplexing (TDM). This asynchronous method is mainly a flexible method or said to be "not fixed".

Refer Fig. 1.9.6 on next page.

Here the number of time slots in frame need not be equal to the number of input signals. The timeslots are three in frame for four number of input signals. The total speed of input can also be greater than that of the path. In general asynchronous TDM can handle more number of device than synchronous TDM.

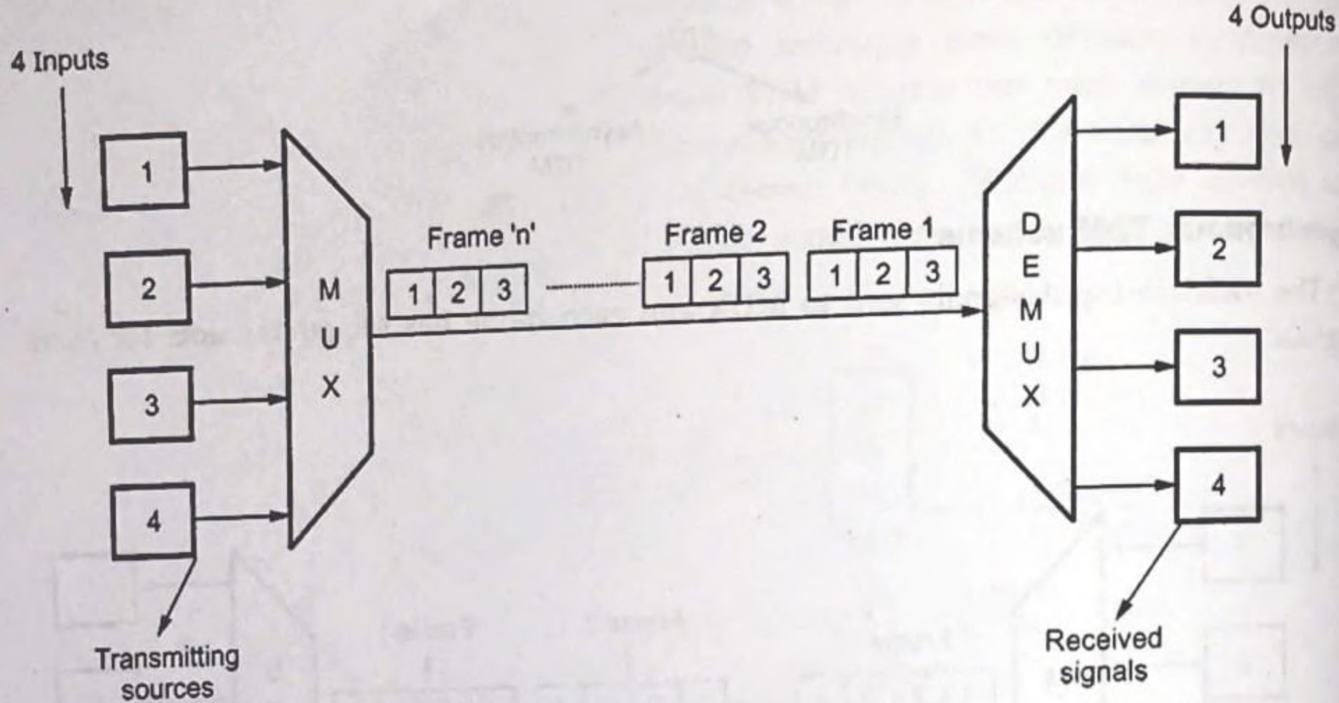


Fig. 1.9.6 Asynchronous TDM scheme

In synchronous TDM since time slots are fixed and preassigned if a particular connecting device does not transmit the communication path is wasted and this risk is eliminated in asynchronous TDM scheme is lightly flexible and not fixed.

The time slots are not preassigned. Variable length time slots are allowed here.

All the multiplexing schemes are matched with demultiplexing unit at the receiver and it also called as "inverse multiplexing". The FDM, TDM and WDM techniques are intented to do 'many to one' signal transmission and their corresponding demux units does the 'one to many' conversion to get back the original input signals or channels.

Frequency division multiplexing (FDM) :

It is the process where more information channel bandwidths are shifted in frequency with others available in turn to form a wider bandwidth containing information (data). The shifting or translating scheme is used mainly with bandwidths such that it avoids mutual interference.

Orthogonal concept in DAB :

Whenever the phase relationship of two sinusoidal signals (RF signals) is 90°, then the relationship between them is said to be orthogonal. They are also said to be in quadrature with each other. The subcarrier frequency spacing is in reciprocal of the symbol time period. In DAB modulation scheme the subcarriers that are successive have quadrature relationship with each other.

1.9.2 Scheme of Multiplexing

Coded Orthogonal Frequency Division Multiplexing (COFDM) :

In digital audio broadcasting the multiplexing scheme used is coded orthogonal frequency division multiplexing denoted as 'COFDM'.

C	-	Coding
O	-	Orthogonal modulation
F	-	Frequency
D	-	Division
M	-	Multiplexing

In the above the coding scheme refers to convolutional coding type. The original information or data that is carried out over multiplex is split into blocks (small units) and redundant information is added to it and hence generating a data 'overhead'. The transmitted signal is received by an intended receiver and the data both original data and overhead redundant bits are received with adequate synchronization.

The DAB technology is also efficient and it uses the viterbi algorithm which uses maximum likelihood principle.

1.9.3 Multiple Access Schemes-FDMA, TDMA, CDMA and SDMA

AU : Dec.-16

Introduction

With the multiplexing technique several users can share a particular medium with minimum interference. The efficiency of medium utility is high using this technique.

Multiplexing can be applied in four possible dimensions. They are namely

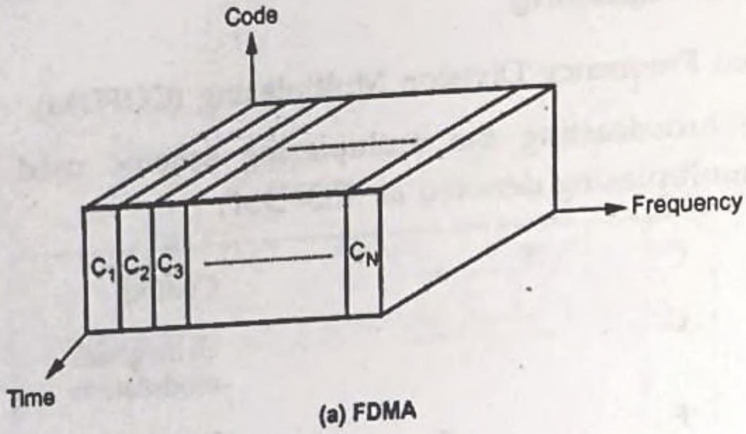
i) Frequency

ii) Time

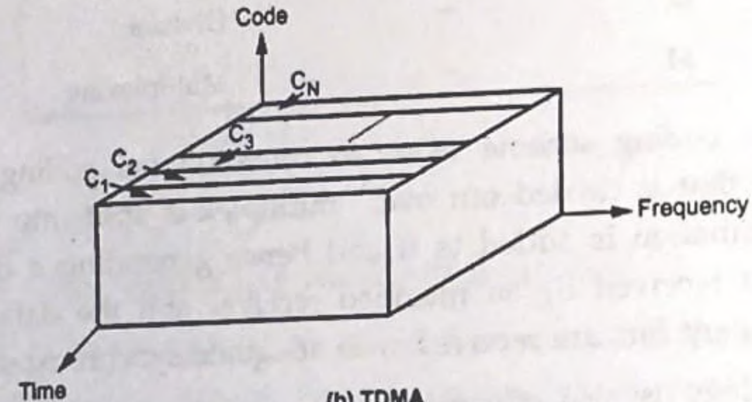
iii) Code and

iv) Space

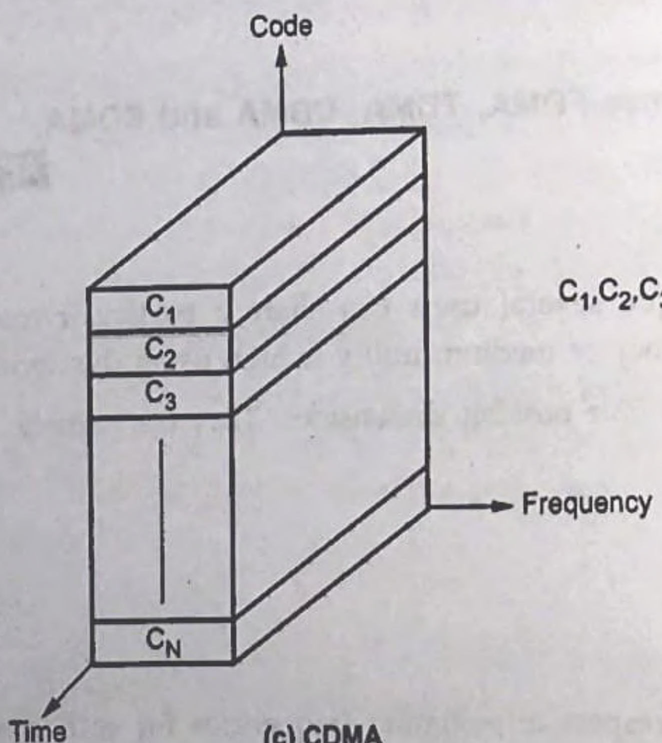
If multiplexing is done with respect to assigning frequencies for each channels it is known as frequency division multiplexing technique (FDMA). Similar to it if this technique is applied with respect to time or code or space then they are limited as TDMA, CDMA and SDMA correspondingly.



(a) FDMA



(b) TDMA



(c) CDMA

Fig. 1.9.7 Multiple access schemes

i) Frequency Division Multiple Access (FDMA)

In FDMA individual channels $(c_1, c_2, \ldots c_N)$ are assigned to individual subscriber/user as in Fig. 1.9.7 (a). A unique frequency band or a channel is allocated to each subscriber, and assignment of channels is done on demand basis. If there is a request for service a channels will be assigned to that user.

ii) Time Division Multiple Access (TDMA)

In TDMA systems the entire radio spectrum is split into time slots (slices) and each slot is allocated to individual user. The method used by TDMA system is also known as "buffer-and-burst" method. With TDMA only digital message/data and its modulation are used where as FDMA engages analog FM systems. The transmission of signals from several users is interlaced together into a frame structure which is then repeated continuously. A frame basically consists of the following.

1) Information message 2) Tail bits and 3) Pre-amble

In the TDMA/TDD technique, in a frame information half of the time slots are used only for forward link where as other half of time slots are used for reverse link channels. TDMA is popular because a single carrier frequency is divided as many time slices and they are used by a large number of subscribers by providing one time slice to one user.

One of the main advantages of TDMA scheme is simpler hand-off schemes.

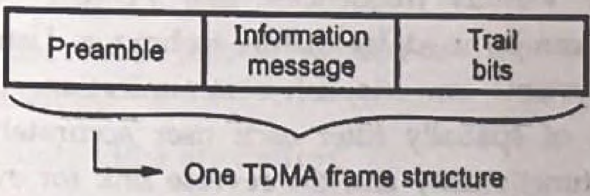


Fig. 1.9.8

iii) Code Division Multiple Access (CDMA)

In CDMA the narrow band message signal is multiplied with a larger bandwidth signal which is called as spreading signal. This spreading signal is a pseudo noise code sequence with chip rate greater than the message data rate. A pseudorandom code word of each user is orthogonal to the code words of other users.

As in Fig. 1.66 (c) there are 'N' no of channels available and these channels are allotted codes which are unique. Each channel has its own unique code word so that in CDMA interference problem is minimized.

In CDMA the stronger received mobile signal produces noise at the BS demodulators for weaker signals so that the weaker signal may not be received properly. It is called as near-far problem and by using proper power control methods it can be suppressed. In spite of this near far effect, CDMA posses the advantage of using same frequency by many users.

iv) Space Division Multiple Access (SDMA) :

In space division multiple access (SDMA) spot beam antennas are used to serve multiple users.

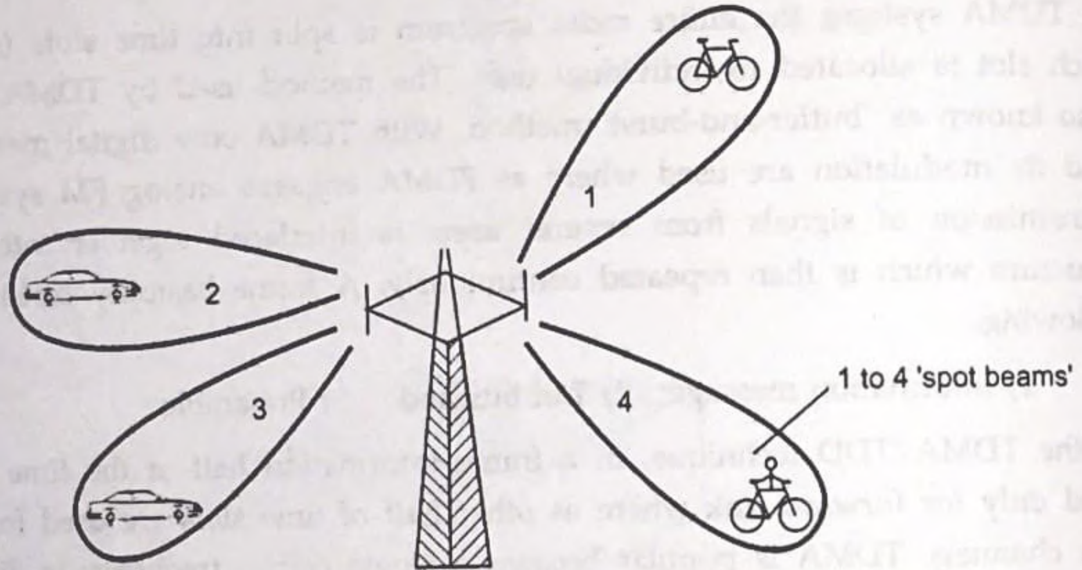


Fig. 1.9.9 SDMA spatially filtered antenna at base station serves multiple subscribers

The covered regions (with many users) will be served by a single frequency like TDMA/CDMA or various frequencies like FDMA. Sectorized antennas and adaptive antennas can be used for SDMA technique. Using the same channel, all the users in the systems can establish communication. The base station antenna should be capable of spatially filter each user accurately so that less power is enough for entire functionality and the reverse link for every user will be greatly improved.

Space Division Multiplexing

Assume there are n_i channels and in that consider three channels n_1, n_2 and n_3.

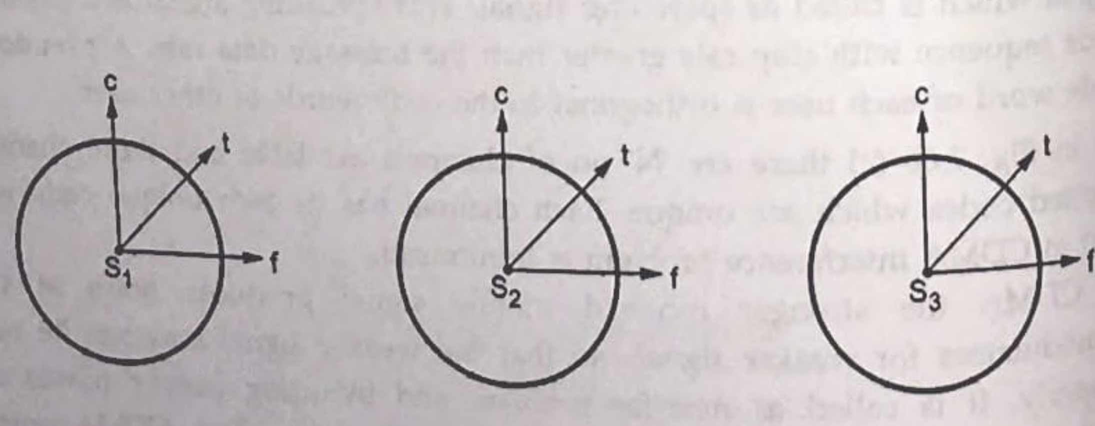


Fig. 1.9.10 Space division multiplexing

For these channels n_1, n_2 and n_3 three spaces S_1, S_2 and S_3 are allotted as shown here. In SDM multiplexing the interference will be very low but the space required to serve all the channels is high. If the number of channels are more total space used by this techniques will also be more.

All the access schemes can also be grouped as narrow band technique and wideband technique according to the method of bandwidth allocation.

1.9.4 Wideband system - Advantages

The transmission bandwidth of a single channel is larger than coherence bandwidth of the channel with wideband systems. Multipath fading does not affect wideband systems. The CDMA and TDMA system uses either time division duplexing TDD or frequency division duplexing FDD techniques.

1.9.5 Features of Three Multiple Access (FDMA, TDMA and CDMA) Techniques

1. FDMA

- The FDMA scheme can carry only one telephone circuit at same time.
- If a FDMA channels is not used at particular time, then it will be idle and any other user cannot use it.
- The base station and the mobile station transmit at a time without any break after the assignment of voice channel.
- The FDMA channel bandwidths are narrow.
- The FDMA cell site system cost are higher when compared to that of the TDMA system.
- This technique needs proper RF (radio frequency) filtering to reduce adjacent channel interference (ACI).
- The FDMA systems are less complex than TDMA schemes.
- Duplexers are used by FDMA mobile schemes.
- Synchronization and framing bits are required for FDMA systems since continuous transmission is taking place.

Note

In FDMA system use, same antenna at base station is shared by all channels and the power amplifiers are basically nonlinear. These affect the signal and "signal spreading" takes place in frequency domain which in turn generates intermodulation (IM) frequency. It is very important to reduce IM while dealing with FDMA schemes.

2. TDMA

It divides the radio spectrum into time slots. Each user is alloted one slot and only he can use it. There can be 'n' number of time slots according to the bandwidth. A delay can be used between forward and reverse channels.

- TDMA actually shares single carrier with many number of users.
- The data transmission is not continuous for TDMA users.
- TDMA uses different time slots for the transmission and reception.
- The transmission rates are very high in TDMA schemes and hence adaptive techniques are used.
- High synchronization is required in TDMA systems due to their burst transmission.
- Preamble is important in TDMA which bears synchronization and address information.
- The bandwidth is allotted to different users on demand basis.

3. CDMA

- The code division multiple access schemes provide individual code for each users. Multipath fading is reduced in CDMA.
- CDMA has to meet self-jamming problem.
- Near-far effect is a disadvantage in CDMA technique.
- Since each user is provided with a separate code, CDMA assures interference free communication.
- It uses frequency hopping (FHSS) or Direct Sequence Spread Spectrum (DSSS) methods for spread spectrum mechanisms.
- CDMA guarantees high degree of security than other schemes.
- The channel datarates are very high.

1.9.6 Comparison of SDMA, TDMA, FDMA and CDMA Techniques

Sr. No.	Approach	TDMA	FDMA	CDMA	SDMA
1.	Principle	Message sending time into disjoint time-slots, fixed pattern/demand driven.	Message is in different segments of frequency as disjoint subbands.	Spreads the spectrum using orthogonal codes.	Segment space into sectors/cells.

2.	Terminals	All the terminals are active for short time periods on same frequency.	Every terminal has its own frequency, which is uninterrupted.	All the terminals are active at same moment which is uninterrupted.	Only one terminal is active in one sector/one cell.
3.	Signal Separation	Synchronization is done in time domain.	Filtering in frequency domain is done.	Code plus special receivers arrangement.	Directed antennas/cell structure.
4.	Advantage	– Full digital in nature. – Flexible – Easy to establish.	– Robust – Easy establishment – Simple	– Flexible. – Soft handover – Less planning is enough.	– Simple. – Increases the capacity.
5.	Disadvantages	– Requires a guard space – Synchronization is difficult.	– Not flexible – Resources are limited.	– Receivers are complex in nature. – Needs more complicated power control for senders.	
6.	Application	Used in mobile networks.	Combined with TDMA/SDMA for hopping and reuse mechanisms.	– Integrated with TDMA/FDMA for application. – This is a complex scheme.	It is used only in combination with TDMA, FDMA (or) CDMA scheme for applications.
7.	Scheme	Time slices are used	Frequency slices are used.	Individual codes for each user.	Segments the space in each sector.

1.10 Spread Spectrum

AU : Dec.-17

This technique is used to increase the bandwidth of digital communication system. The input signal is fed into the channel encoder where a set of digital signals are generated from pseudonoise generator and added in modulator. These set of bits are called as pseudonoise signal. The signal is sent through channel. At the demodulator side the same pseudonoise code which was spread at transmitter is despread and the original data or information is extracted as output of channel decoder. The spreading code is also called as pseudocode or spreading sequence.

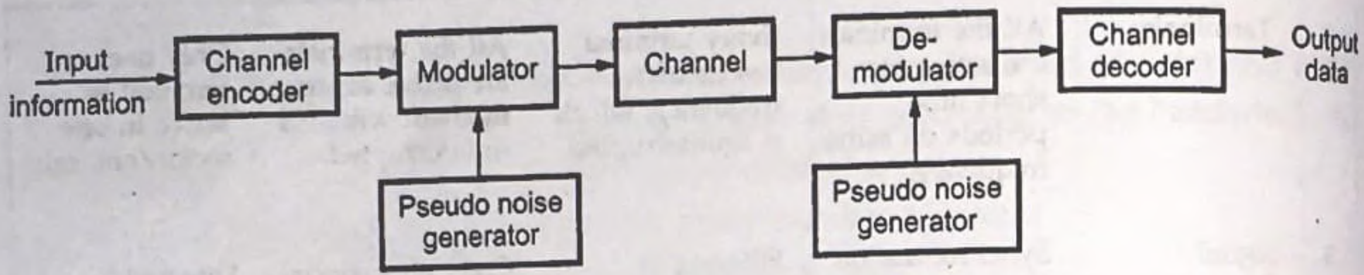


Fig. 1.10.1 Model of spread spectrum technique

The signal is spread over a larger bandwidth and it enables very high degree of security for signal transmission and reception. The direct sequence spread spectrum (DSSS) and frequency hopping spread spectrum (FHSS) are the two types of spread spectrum techniques used under spread spectrum. In direct sequence spread spectrum each bit to be transmitted is multiplied with a random set of bits and the digital information is transmitted. In frequency hopping spread spectrum the information (message) is divided into slices and transmitted at different frequency channels in random manner. The center frequency of the carrier signal is altered many times in a particular time period which is in accordance with a random set of channels. In both the DSSS and FHSS schemes the secrecy of data is maintained at cost of bandwidth. In the DSSS technique each bit cares only about its own random set of bits multiplied with it and it ignores the rest of other bits. The spread spectrum communication can be distinguished with three main elements.

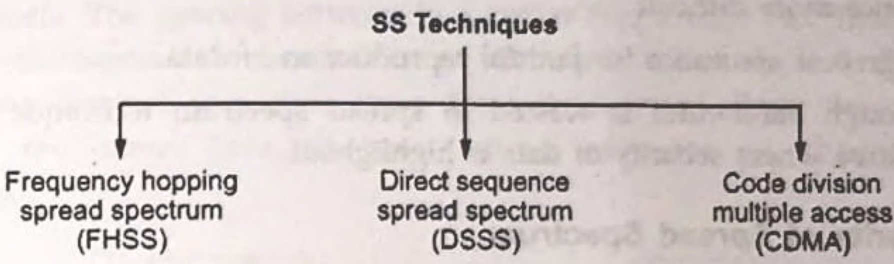
They are :

1. It requires larger bandwidth.
2. This bandwidth is spread with respect to code and not the data.
3. The receiver should synchronize properly to recover data. Hence it is possible for many users to access the same frequency (f) band simultaneously.

1.10.1 Advantages of Spread Spectrum (SS)

1. It reduces different kinds of noises.
2. It provides immunity from multipath distortion, and jamming problems.
3. This technique can be highly applied in cellular applications along with code division multiple access (CDMA) method of multiplexing.
4. The spread spectrum technique is used for hiding encrypting data signals.

All these three methods will be dealt in detail in this chapter. Earlier to it, it is better to understand the method of generation of spreading sequences (PN sequences), PN properties.



Spread Spectrum Sequence-Generation :

The pseudonoise signal is generated by pseudonoise code generator. This signal is actually a sequence of digits. The spreading technique involves XOR operation of input signal with the spreading sequence (sequence of digits). At the receiver side the spreading is removed by the same spreading code multiplication with necessary synchronization and the original signal is retrieved. The data rate and bandwidth saving is high.

The degree of redundancy is also good.

The pseudonoise is denoted as PN sequence. It should be same at transmitter and at receiver side. In the PN sequence is produced by PN generator and it will repeat itself in random nature.

The PN sequence is popular because of two important points. They are,

1) Unpredictability.

2) Randomness.

The randomness of the sequence is weighted by correlation properly and uniform distribution. The correlation properly is concerned with similarity of number of terms in sequences at various time shifts, and at the most difference is allowed. The uniform distribution of numbers is that the distribution of numbers in a sequence is uniform.

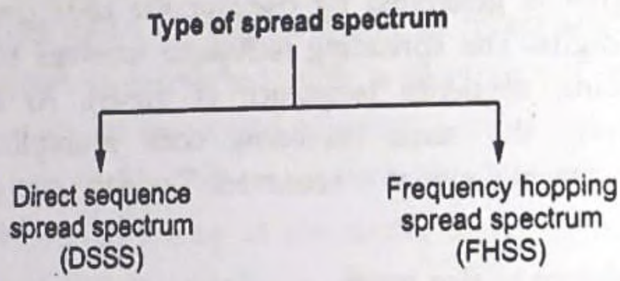
The **advantages** are many in this spread spectrum technique.

1. The vital reason for using this technique is highest security.
2. Then the problem of jamming is avoided.
3. In military application spread spectrum technique was mainly used to maintain high degree of security.
4. The message is transmitted at different frequencies from the transmitter and hence except the intended receiver a third party cannot receive the message or data.
5. Today not only in military applications but the commercial field also attracted towards spread spectrum techniques.
6. There are many advantages like hiding of information from the intruders.

7. Since wider bandwidth is used to spread information it makes the jamming and interference more difficult.
8. High degree of assurance for faithful reproduction of data.
9. Even though bandwidth is wasted in spread spectrum technique it is used in defence area where security of data is highlighted.

1.10.2 Demerits of Spread Spectrum

1. The main drawback of this technique is that bandwidth wastage.
2. This technique is not economical.



DSSS	FHSS
• Each bit of the information is multiplied with a sequence or stream of bits.	• Signal is transmitted over a random series of radio frequencies.
• The spreading code spreads this signal across a wider band width in direct proportion to number of bits used.	• Receiver has to hop between various frequencies to synchronize with message of transmitter.

For transmitting the signal under "Frequency Hopping" technique the message is sent over a series of random frequencies. At the receiver side hopping between two frequencies in synchronization with transmitter and finally picking up of message is done. An example of frequency hopping spread spectrum (FHSS) is shown in Fig.1.61.

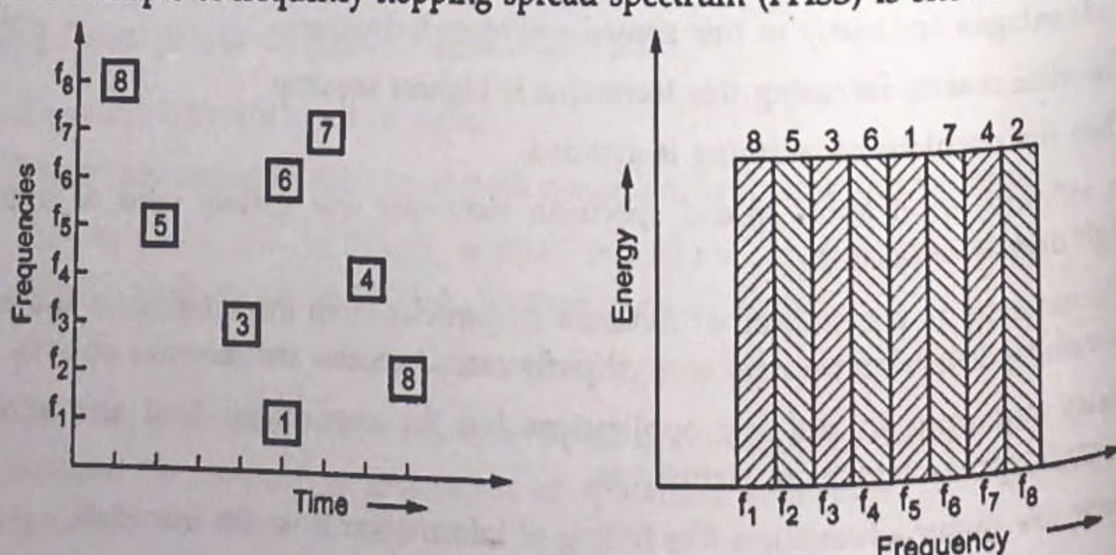


Fig. 1.10.2

Many channels are allocated for the FH signal. There are 2^i carrier frequencies which forms 2^j channels. The spacing between two carrier frequencies and hence the width of each channel corresponds to bandwidth of the input signal applied. The transmitter operates in one channel at a time for a fixed time period. Both the transmitter and receiver use the same code to tune into a sequence of channels in proper synchronization.

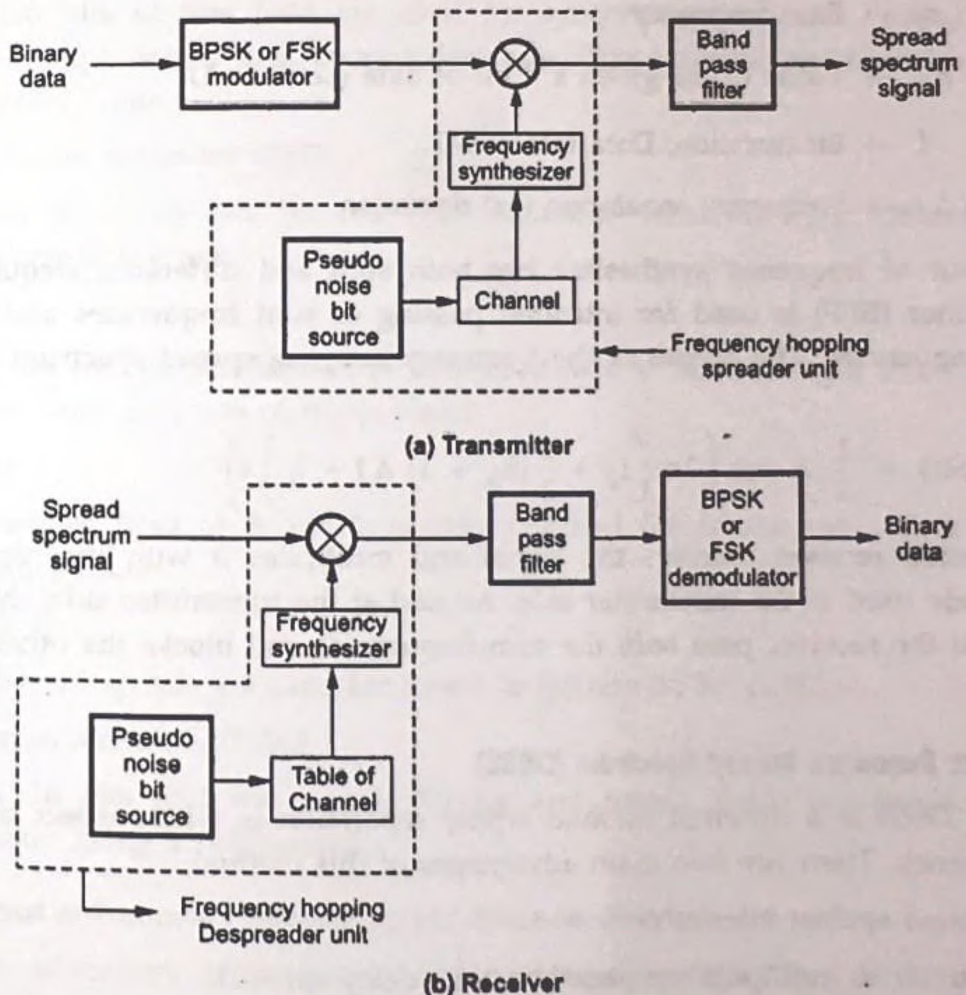


Fig. 1.10.3 Frequency hopping spread spectrum (FHSS) system

The frequency hopping spread spectrum method use the principle of calculating product of 2 signals. The binary information are fed into a modulator or transmitter using some digital to analog encoding scheme such as frequency shift or binary phase shift keying techniques. A table of frequencies is maintained to which the pseudonoise code or PN sequence or pseudonoise number source serves as an index. This helps to form the spreading code sequence. Each and every 'j' bit of this PN sequence source specifies one of the "2^j" carrier frequencies. At the successive time interval a carrier frequency (f_c) will be selected.

We can define the frequency shift keying (FSK) input to the frequency hopping spread spectrum system as

$$S_d(t) = A \cos (2\pi\ (f_0 + 0.5\ (b_k + 1)\Delta f)\ t)$$

$$\text{for } kT < t < (k+1)\,T$$

Where $A \rightarrow$ Amplitude of signal

$f_0 \rightarrow$ Base frequency

$b_k \rightarrow$ Value of the given k^{th} bit of data (i.e. 0 or 1)

$T \rightarrow$ Bit duration; Data rate = 1/T.

$\Delta f \rightarrow$ Frequency separation (or) deviation

The output of frequency synthesizer has both sum and difference frequencies. The band pass filter (BPF) is used for intended passing of sum frequencies and blocks the difference frequencies. The output of the frequency hopping spread spectrum synthesizer is,

$$S(t) = \frac{1}{2} A \cos \left(2\pi \left(f_0 + \frac{1}{2} (b_k + 1)\ \Delta f + f_k \right) t \right)$$

The intended receiver receives the signal and multiplies it with the replica of the spreading code used at the transmitter side. As said at the transmitter side, the bandpass filter (BPF) at the receiver pass only the sum frequencies and blocks the other difference frequencies.

1.10.2.1 Direct Sequence Spread Spectrum (DSSS)

This type DSSS is a different method where separation is with respect to code and not the frequency. There are two main advantages of this method.

1. Robustness against interference.
2. Insensitivity to multipath propagation (time delay spread).

The 802.11 IEEE standard uses this scheme for transmission and reception. The format of an IEEE 802.11 standard physical frame using DSSS schemes.

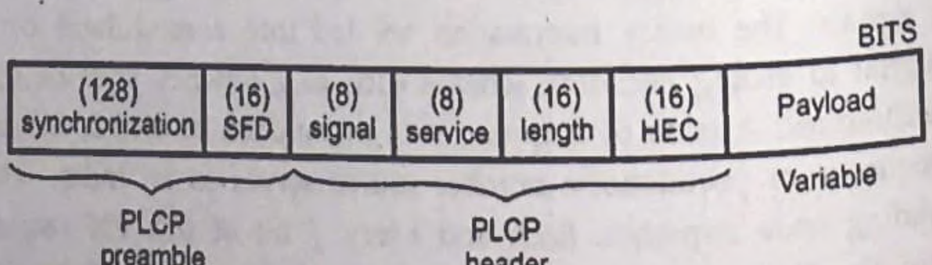


Fig. 1.10.4 Format of IEEE 802.11 standard physical frame using direct sequence spread spectrum

The format of DSSS shows that is has seven fields in total. Also it basically has two parts first is the PLCP (that is preamble and header) and second is payload part (MAC data). The payload part uses 1 to 2 Mbits/s for transmission and the first part PLCP uses 1 Mbits/s for the same. The seven fields of the direct sequence spread spectrum format has their own distinct functions. They are listed below.

1. **Synchronization :**

   The 128 bits of this field are used for synchronization, gain setting, frequency offset compensation and energy detection. The synchronization field consists of scrambled 1 bits.

2. **Start frame delimiter (SFD) :**

   If consists of 16 bits in this field which is used for synchronization at the beginning of a frame.

3. **Signal :**

   There are two values defined for this third field which has eight bits and this field indicates the data rate of the payload.

4. **Service :**

   This service field of 8 bits is mainly reserved for future use and it indicates a complaint frame.

5. **Length :**

   In this field 16 bits are used for length indication of the payload.

6. **Header error check (HEC) :**

   It has 16 bits and the signal. Service and length fields are protected by this checksum using a polynomial.

1.10.2.2 Format of Frequency Hopping Spread Spectrum (FHSS)

The main advantage of frequency hopping spread spectrum is that it allows for the coexistence of multiple network in a particular same area by separating different networks using various hopping sequence. This standard defines 79 hopping channels for North America and 23 for Japan. The hopping pattern selection is achieved by using a pseudorandom hopping pattern.

These are some of the examples of hopping sequences used in different countries. When dealing with modulation shift keying techniques FHSS PHY is compatible with gaussian frequency shift keying technique (GFSK). For example for a 1 Mbits/s a two level GFSK is used and for a 2 Mbits/s a four level GFSK is used. In frequency hopping spread spectrum the frame consists of two basic parts the PLPC part (that is preamble and header) and the payload as second part. The format consists of six fields. Each field has its own specific function. They are listed below.

1. **Synchronization :**

   It is the first part of PLCP preamble and it has 80 bits, usually with bit pattern as 010101... This field is concerned with synchronization of the receivers.

2. **Start frame delimiter :**

   It consists of 16 bits which indicates the start of the frame and hence helps synchronization of frames. This is the second part of PLCP preamble.

3. **PLCP-PDU length word (PLW) :**

   The first field of PLCP leader indicates the length of the payload in bytes which includes 32 bit CRC at the tail end of the payload. The PLW can range from 0 to 4,095. This field consists of 12 bits.

4. **PLCP signalling field(PSF) :**

   It consists of 4 bits. It is used to indicate data rate of the payload.

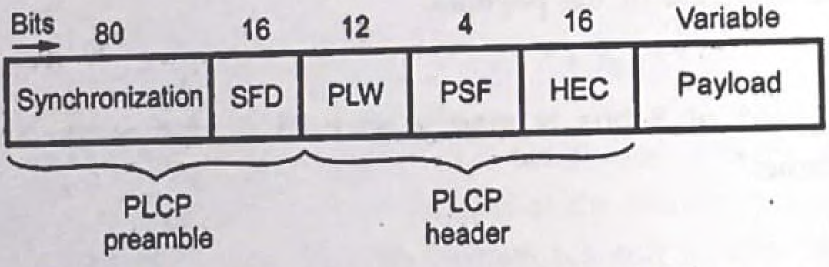


Fig. 1.10.5 Format of 802.11 standard physical layer used with frequency hopping spread spectrum

5. **Header error check (HEC) :**

   The PLCP header is safeguarded by a 16 bit checksum with generator polynomial as $g(x) = \left(x^{16} + x^{12} + x^{5} + 1\right)$. The HEC field thus consists of 16 bits.

1.10.3 Special Features of Spread Spectrum Systems

1. Reduced interference problems in communication.
2. Secured transmission and reception.
3. For signal hiding low density power spectra is used.
4. High resolution ranging is achieved.
5. Code division multiplexing for CDMA applications.
6. Cost of implementation is less.
7. Anti jamming capability.
8. Integrated components (IC) are available for related designing process.

9. As the number of RF channels increases [number of simultaneous users increases]. The degradation of system performance is acceptable.
10. Increased capacity.
11. Efficient spectrum utility.
12. Direct spread spectrum sequence (DSSS) is very much useful in defence area where high degree of security is required.
13. Frequency hopping spread spectrum (FHSS) is useful in many application areas like cellular mobile communication and spectrum bandwidth is completely used.

1.10.4 Spread Spectrum-Graphical Analysis

In communication system the information is modulated and transmitted. The transmission power is spread over the entire band. It is shown in the graph below.

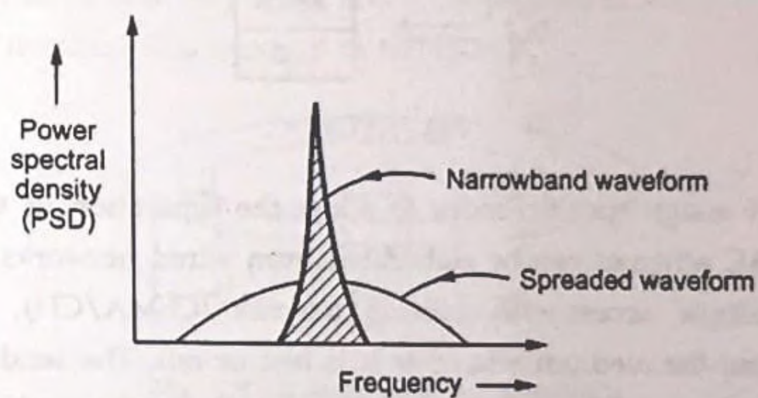


Fig. 1.10.6 Narrowband and spread spectrum waveforms

This spread spectrum techniques, due to the stretching of signal, occupies a larger bandwidth. On one side wastage of bandwidth may not be appreciable but in terms of defence, and military application security is more important than bandwidth economy criteria and this technique is well suited in defence area.

1.11 Medium Access Control (MAC)

AU : Dec.-16,18, May-17,19

The medium access control (MAC) algorithms perform several mechanisms for regulating user access to a physical medium. It provides traffic regulations in data communications. From the open system interconnect (OSI) model the MAC belong to the layer 2 called as data link control layer (DLC). The layer 2 has two subdivisions namely logical link control (LLC) and MAC layer. In multiplexing schemes used for wireless data transmissions MAC layer provides regulations for the data traffic.

With MAC layer access to physical medium is done using time division multiplexing (TDM), code division multiplexing (CDM), space division multiplexing (SDM), or frequency division multiplexing (FDM) schemes.

The MAC layer establishes, maintains, and also releases the channels for next higher layers by methods of activating and deactivating the channels used. The logical channels can be multiplexed on to the physical channels by the MAC layer. Thus MAC performs important function for cellular wireless networks.

1.11.1 Motivation for a Specialized MAC

For the wireless domain their are many medium access control (MAC) algorithms are used. The MAC comprises mechanisms that can regulate user access to required medium using a multiple access scheme either TDM, FDM, CDM or SDM. The MAC resembles traffic regulations in the highway/multiplexing. MAC belongs to the layer 2, (OSI) the data link control layer (DLC). This layer 2 is subdivided into logical link control (LLC), and MAC.

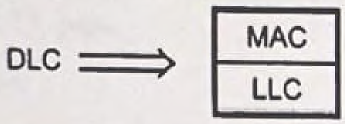


Fig. 1.11.1

MAC with CDM assign specific codes to allow the separation of various users in a code space. The MAC schemes can be elaborated from wired networks say, for example, the carrier sense multiple access with collision detection (CSMA/CD).

A sender can sense the medium wheather it is free or not. The sender will wait if the medium is busy. In case sender detects a collision signal in its sending process then it will send a jamming signal. In case of wireless network the strength of signal will get reduced in proportion to the square of the distance. In wireless environment there is a chance of several obstacles.

1.11.2 Hidden and Exposed Terminal

Consider a sender 1 use a carrier sense and detects an idle medium. As the sending procedure starts assume there occurs collision, due to sender 2. Such a situation dealt in hidden and exposed terminal.

In the example shown below the terminal A starts to send towards B. The terminal C wants to send information to B and it senses the medium. If the medium appears to be free (carrier sense fails), C starts sending and it leads to collision at junction of B.

The terminal A cannot realize this collision taken place and it continues with its own transmission.

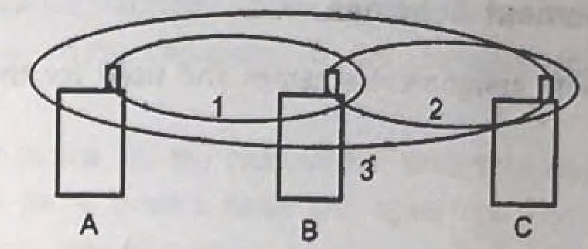


Fig. 1.11.2 Hidden and exposed terminals

The terminal A is hidden for C and C is hidden for A. In other case consider B sends to A and C wants to send data to other mobile that is not in interference ranges of A and C. Now the C senses carrier and finds that the carrier is busy. The terminal C postpones the transmission until it detects the medium as idle. If there is a collision at B it does not affect A since it is very weak and it propagates to A.

In this case the terminal C is exposed to terminal B.

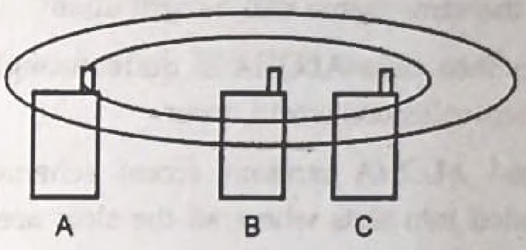


Fig. 1.11.3 Near and far terminals

In near and far terminal case, assume the terminals A and B are sending with same amount of transmission power. The signal strength reduces in proportion to square of the distance involved. For example, B's signal would drown out A's signal and hence terminal C cannot receive the A's signal. If C acts as bare station and coordinating medium accessing job. Then terminal B would drown out terminal A on the physical layer.

The wireless network using CDM has the problem of near/far effect. The signals arrives at the receiver with approximately uniform strength.

On the other hand if a person is closer to one but talks to a third person standing away from him will speak loudly to the third person to overcome the speech of the person close to him. The method of using codes (CDM) helps in reducing interference in wireless environment.

Also an accurate power control is required to receive all the senders with same strength at the receiver end.

1.11.3 Random Assignment Schemes

There are several random assignment schemes and used for the MAC protocols. They include,

- ALOHA
- Slotted ALOHA
- CSMA
- CSMA/CD and CSMA/CA

I) ALOHA schemes :

ALOHA in communication is a random assignment scheme. The basic ALOHA also known as pure ALOHA protocol is used for it.

Consider that a communication node need to send data simply start to transmit. The pure ALOHA scheme does not check wheather the channel is busy. Once if a frame of data is received at the destination end then next frame will be sent or otherwise if the frame is not received then the same frame will be sent again.

If there is no congestion then pure ALOHA is quite enough. But if there are several senders need to transmit then collisions world occur.

For this situation slotted ALOHA random access scheme holds good. In slotted ALOHA entire time is divided into slots where all the slots are of equal size. The packet size is kept with a restriction. Consider a node wants to transmit it can do its job only at beginning of the time slot. Beacon signals are made use of for marking the slots beginning.

Note If there are many stations want to send data the slotted ALOHA is not a much suitable scheme.

II) CSMA schemes :

A Carrier Sense Multiple Access (CSMA) is a random assignment scheme. In this technique a node first senses wheather the medium is free and then it starts to transmit.

There are two methods of CSMA namely,

- CSMA/Collision Detection (CD)
- CSMA/Collision Avoidance (CA)

In CSMA/CD random access technique, if the sender wants to transmit data it first senses the channel and finds whether it is free. Though the transmitting channel is sending data collision may occur in the channel. A destination node only can find any corrupted frame. Hence a retransmission may be required and channel is not utilized properly.

But a collision avoidance random access scheme is a much better technique than CSMA/CD scheme in avoiding collisions, in the channel, when there is a chance of collision occurance.

In CSMA/CA a node waits till the channel becomes free and then starts to transmit. If the medium is sensed to be busy a node will again wait for a particular time till the channel becomes free. Here any two nodes would not send data simultaneously.

1.11.4 Reservation-Based Schemes

A simple reservation-based scheme is Ready To Send (RTS)/Clear-To-Send (CTS). When a node need to transmit data it sends an RTS packet to receiver side before transmission getting started. At the destination the receiver transmits a CTS packet only then data transfer starts. If some other node wants to transmit packets it has to first sense a CTS packet. It makes sure that transmitting node has completed its transmission.

In the case of contension-based MAC protocol when a node need to transfer data it sends message for reserving the medium by just using a control message.

Some of the example schemes of RTS/CTS based medium access control (MAC) protocols includes,

- MACA
- MACAW
- S-MAC protocols.

1.11.4.1 MACA Scheme

The MACA protocol is nothing but multiple/access collision avoidance protocol. The hidden or exposed problem in MAC is avoided using MACA. It can also regulate transmitter's power. If a node makes use of MACA scheme it sends a request signal to the RTS to the destination (receiver).

All other sender's get this information and hence they will get out of their transmissions. If the receiver is free it will now responding with that of a CTS.

Eventhough MACA is a collision avoidance protocol there may be a collision occurance during the transmission of an RTS packet.

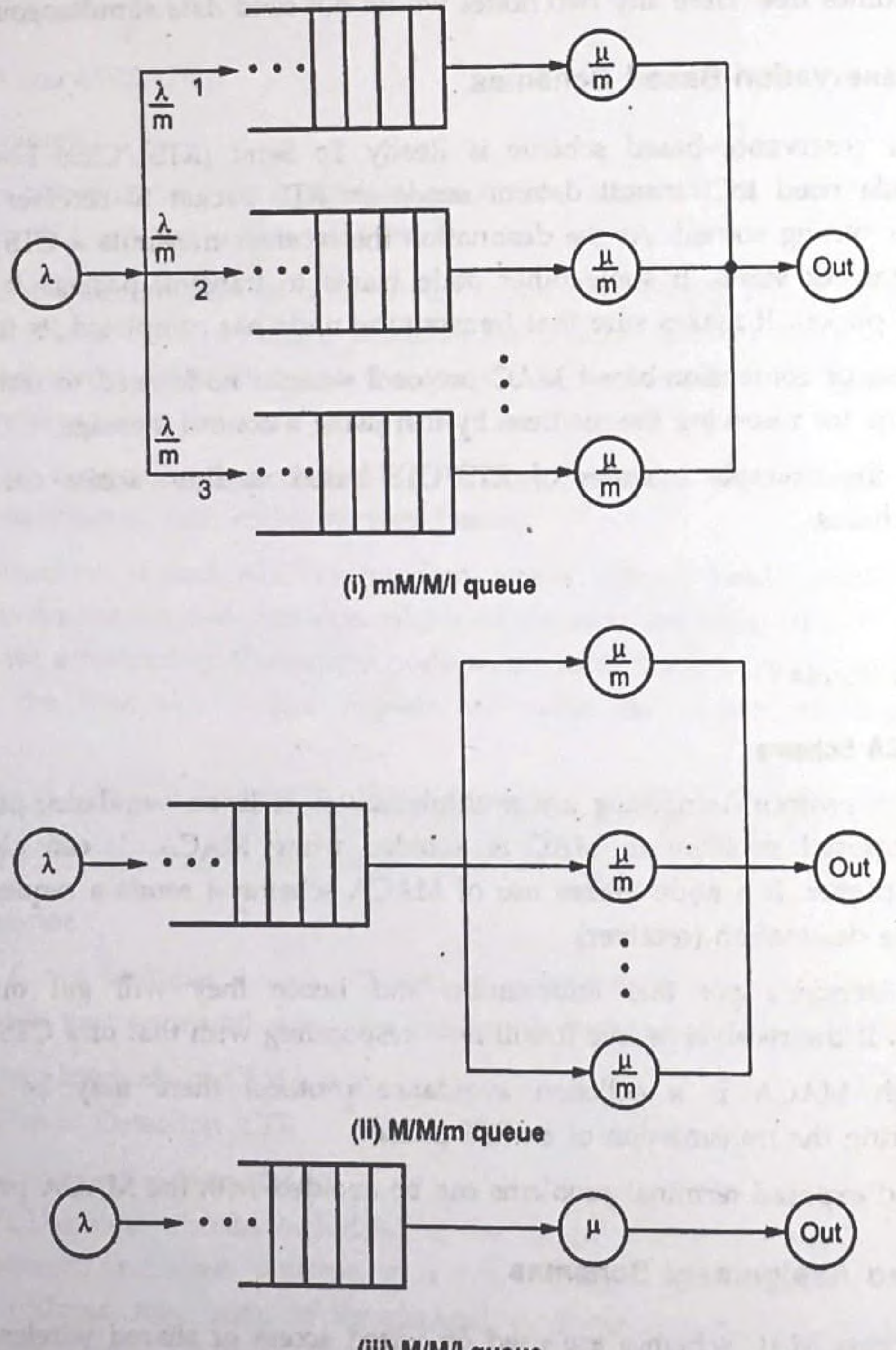
Hidden and exposed terminal problems can be avoided with the MACA protocols.

1.11.5 Fixed Assignment Schemes

Random access MAC schemes are used on wired access or shared wireless links. As the buffers are full packets are lost and they are run out of space. Here retransmissions are done for packet recovery as in the case of TCP.

To reduce the probability of packet loss enhanced schemes are used where the senders adjust their rate of sending in the process. A simple TDM/FDM sharing schemes are shown here. Consider M/M/I, M/M/M and a mM/M/I queues where m-times slower servers are applied. A link in shared in different links.

Example (i) mM/M/I quence :



(i) mM/M/I queue

(ii) M/M/m queue

(iii) M/M/I queue

Fig.1.11.4 Comparing different types of sharing a network link

In the three types of sharing a link the first two are used to model a TDM/FDM type of sharing. In third type it is particularly used for to model a packet bared multiplexing.

This third type of M/M/I queue is also used in another fixed based assignment scheme like SDM technique.

Considering telephony applications, TDM is used where entire time is divided into time slots. But when data traffic is handled, TDM or FDM is used and 'm' could take a value as 1. The entire bandwidth is assigned to a file transfer when others are kept in quence. In FDM when frequency is fixed dividing the link capacity in many servers (m) holds good for data transfer in the network.

When m = 1 and as one file transfer is completed then the entire capacity is allocated to next file transfer that is in queue with high priority. Thus MAC fixed assignment schemes are useful in handling packet data transfer.

1.11.6 MAC Protocols for Ad Hoc Networks

In recent years wireless network nodes became popular and as the applications using Internet is high. Sometimes an user may be interested in using a laptop computer without making routing functions via global Internet. For such cases Internet protocols will not be required. Thus the mobile computer users can be allowed to set up a short lived network with wireless communication devices, for a particular moment. This network is known as ad-hoc network. It is independent of infrastructure. Thus even when there is no infrastructure available an ad-hoc network can be formed.

The wireless computing devices are able to communicate with each other in ad-hoc networking, it is possible even there is no,

- Routers or
- Base stations or
- Internet service providers

The ad-hoc network and mobile ad-hoc network (MANET) are discussed in chapter 4.

The Medium Access Control (MAC) protocols provide a way to nodes in order to access the wireless medium with collision free status. With MAC layer protocol a group of subscribers can share the communication medium effectively. In Adhoc network distributed management protocols at MAC layer is required due to the infrastructure less wireless network. This is because of absence of centralized controller. The MAC layer is sub layer of Data link layer which takes care of data transfer between nodes. In mobile Adhoc Networks (MANET) due to lack of centralized control there are difficulties such as,

i) Network partitioning ii) Bit errors

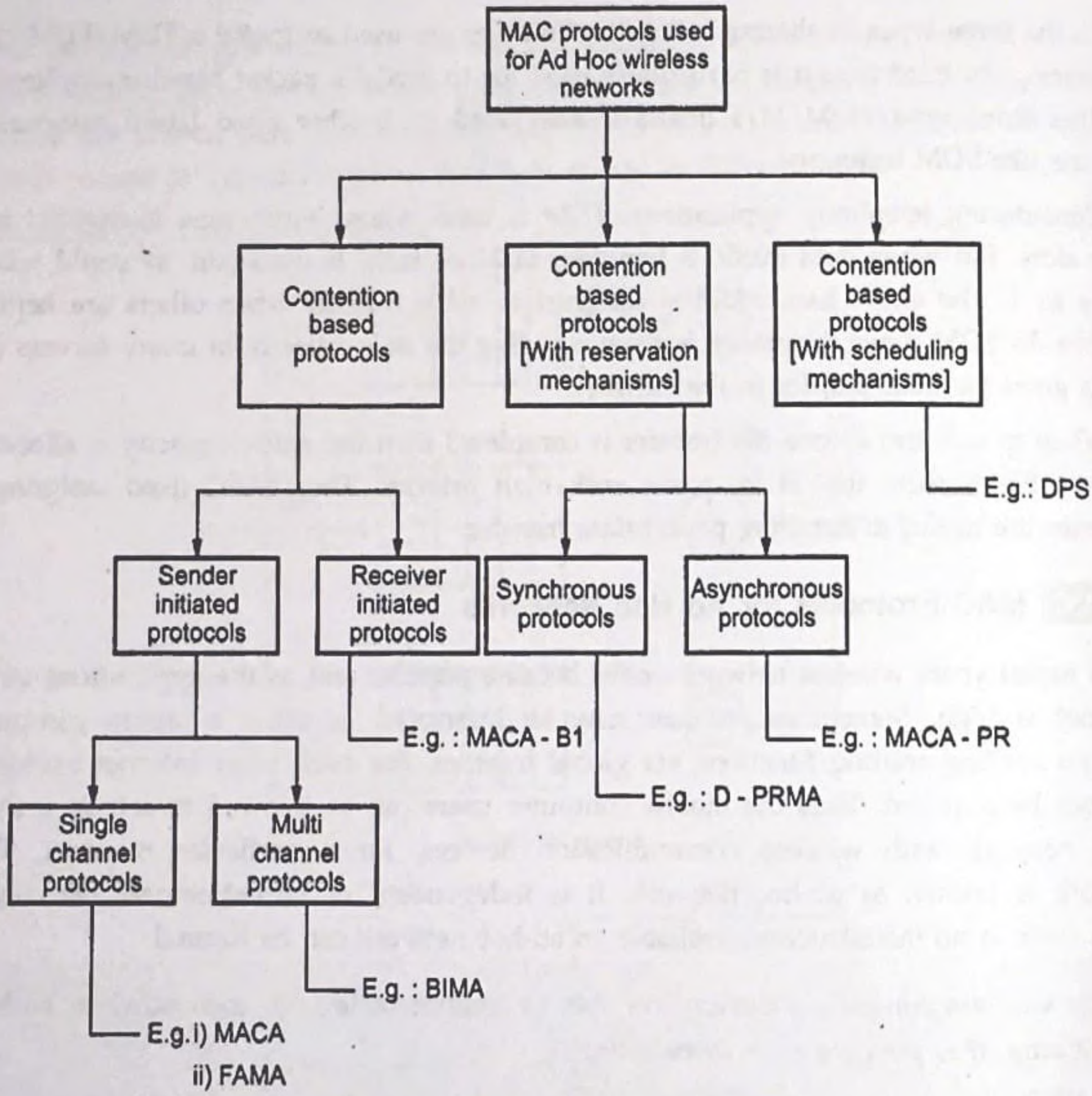


Fig. 1.11.5 Types of MAC Protocols

iii) Inefficient bandwidth utilization.

iv) Collisions due to hidden and exposed terminals.

v) And even loss of network connectivity etc.

Some of the functions and responsibilities of MAC layer are error corrections concerned with physcal layer physical addressing, framing, flow control. It also cares about addering problems caused due to unreliable time varying radio channel and node mobilities.

A maximum channel utilization and minimum interference is achieved and allows many simultaneous users to share a common medium. For the Adhoc networks various protocols are involved in design of MAC protocols. The Adhoc network MAC protocols are classified into three types. They are :

i) Contention based protocols,

ii) Contention based protocols with reservation mechanism and

iii) Contention based protocols with scheduling mechanism.

Each of these types are useful in Adhoc networking. For example in contention based protocols MACA uses two signalling packets. They are request-to-send (RTS) packet and clear-to-send (CTS) packet. For transmitting a data packet a RTS packet is sent in prior to it to the receiver. If the receiver is ready to receive, as the RTS is received receiver will transmit a CTS packet to transmitter for clearance. After receiving CTS packet without errors the transmitter will send the actual data packet.

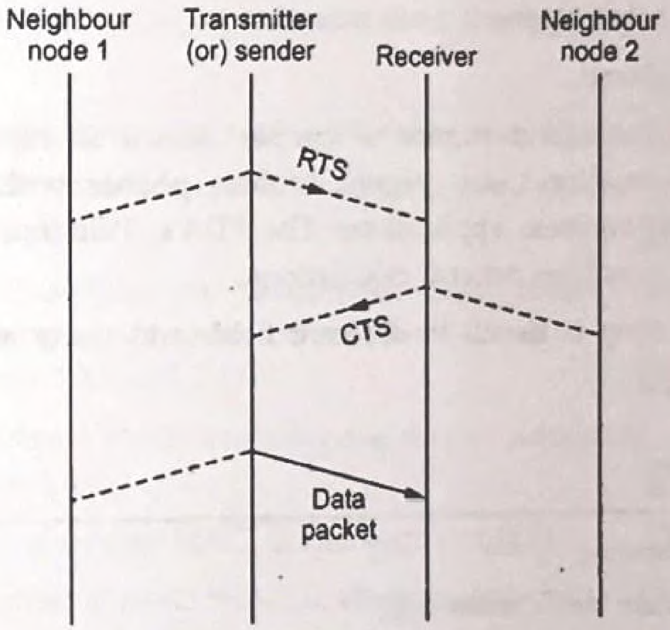


Fig. 3 A packet transmission scenario in MACA

The neighbour nodes also watch the transmission of RTS packet by sender and waits for its own transmission. A sendor sends a RTS to receiver. If CTS is not received by sender for a particular time in that waiting period it can also transmit packet to other node till that waiting period is completed. In MACA hidden and exposed terminal problem is solved. Whenever a collision is detected then the node doubles its own maximum back off window.

In addition to MACA there are other protocols are used in MANET.

Note : The Multiplex Access Collision Avoidance - By Invitation (MACA-B1) protocol is a receiver - initiated protocol. It reduces the number of packet exchanges. Here receiver requests the sender to transmit a packet instead of waiting for a packet everytime. For this Ready to Receive (RTR) packet is sent by sender instead of RTS packet.

Likewise three different protocols of MAC are applied in MANET and networks transmission efficiency is increased.

1.12 Applications of Mobile Computing

AU : Dec.-16

Mobile computing provides several aplications and they are user friendly. Some of the applications include;

i) Vehicular mobile computing :

Vehicles will include weather forecasting, road conditions, along with news, music etc. Mobile computing enables many user friendly facilities. For personal system communications GSM phones might be available offering the voice and data connectivity with 384 kbits per second.

Mobile computing will be useful in emergency situations in wirelessly contacting the nearest hospitals and help in patient assistance etc.

ii) Business environments :

Mobile computing is useful where a simple device is represented by sensors transmitting state information. Also pagers, mobile, phones with full colour graphic delay will be useful in business applications. The PDA's, Palmtop/pocket computer etc are user friendly as it simplifies several calculations.

Thus mobile computing is useful in different fields and many applications are made possible.

Review Questions

1. *Define mobile computing.*
2. *Write a short note on mobile networking.*
3. *List any two mobile computing application.*
4. *Give two characteristics of mobile computing.*
5. *Comment on MAC protocol.*
6. *Write a short note on fixed assignment schemes.*
7. *What is virtual home environment ?*
8. *What are the three tier setup in mobile computing ?*
9. *Mention three applications of mobile computing.*
10. *Explain the structure of mobile computing.*
11. *Explain the MAC protocols in detail.*
12. *Define mobile computing. Explain its characteristics and applications.*
13. *Explain the fixed assignment schemes and random assignment schemes.*
14. *Write short notes on,*

    i) Mobile computing environment and ii) MAC protocols.

University Questions with Answers

Part - A

Q.1 *List the advantages of mobile computing.* **(Refer sections 1.1, 1.7)** **AU : June-16, Marks 2**

Q.2 *Explain hidden and exposed terminal problems in infrastructure - less network.* **(Refer section 1.11.2)** **AU : June-16, Marks 2**

Q.3 *What are the different random assignment scheme in MAC ?* **(Refer section 1.11.3)** **AU : Dec.-16, Marks 2**

Q.4 *Differentiate mobile computing and wireless networking.* **(Refer section 1.5)** **AU : May-17, Marks 2**

Q.5 *List some random assignment scheme.* **(Refer section 1.11.3)** **AU : May-17, Marks 2**

Q.6 *List out the differences between mobile computing and wireless networking.* **(Refer section 1.5)** **AU : Dec.-17, Marks 2**

Q.7 *"MAC protool designed for infrastructure based wireless network may not work satisfactory in infrastructure-less environment." - Justify.* **(Refer sections 1.8.3 and 1.11)** **AU : Dec.-17, Marks 2**

Q.8 *Distinguish between mobile computing and wireless networking.* **(Refer section 1.5)** **AU : May-18, Marks 2**

Q.9 *List the issues of wireless MAC.* **(Refer section 1.11.1)** **AU : May-18, Marks 2**

Q.10 *State the objectives of MAC Protocols.* **(Refer section 1.11)** **AU : Dec.-18, Marks 2**

Q.11 *What do you mean by mobile computing ?* **(Refer section 1.1)** **AU : May-19, Marks 2**

Q.12 *Give some examples of reservation based schemes in MAC protocols.* **(Refer section 1.11.4)** **AU : May-19, Marks 2**

Part - B

Q.13 *Explain the characteristics of Mobile computing.* **(Refer section 1.6)** **AU : June-16, Marks 8**

Q.14 *Explain the structure of Mobile Computing Application.* **(Refer sections 1.3, 1.3.1)** **AU : June-16, Marks 8**

Q.15 *Explain the various taxonomy of MAC protocols in detail.* **(Refer section 1.11)** **AU : June-16, Marks 16**

Q.16 *Differentiate between FDMA, TDMA and CDMA.* **(Refer section 1.9.6)** **AU : Dec.-16, Marks 16**

Q.17	*Explain the distinguishing features of various generations of wireless networks.* **(Refer section 1.8)**	**AU : Dec.-16, Marks 8**
Q.18	*Describe the applications of mobile computing.* **(Refer section 1.12)**	**AU : Dec.-16, Marks 8**
Q.19	*Explain the wireless MAC issues in detail.* **(Refer section 1.11.1)**	**AU : May-17, Marks 8**
Q.20	*Explain fixed assignment scheme with a neat diagram.* **(Refer section 1.11.5)**	**AU : May-17, Marks 8**
Q.21	*Explain hidden and exposed terminal problem in infrastructure-less network.* **(Refer section 1.11.2)**	**AU : Dec.-17, Marks 8**
Q.22	*Describe architecture of mobile computing.* **(Refer section 1.3.1)**	**AU : Dec.-17, Marks 8**
Q.23	*What are the fixed assignment schemes of MAC protocol ? Explain their mehanism in detail. Compare and contrast them.* **(Refer section 1.11.5)**	**AU : Dec.-17, Marks 16**
Q.24	*Discuss in detail the structure of a mobile computing application.* **(Refer section 1.3)**	**AU : May-18, Marks 6**
Q.25	*List the characteristics of mobile systems.* **(Refer section 1.6)**	**AU : May-18, Marks 6**
Q.26	*What is CSMA ? What are the categories of CSMA ? Explain their working with advantages and disadvantages.* **(Refer section 1.11.3)**	**AU : May-18, Marks 7**
Q.27	*Describe the various random assignment schemes that are used in MAC protocol.* **(Refer section 1.11.3)**	**AU : Dec.-18, Marks 8**
Q.28	*Discuss the various Reservation Based schemes in MAC protocol.* **(Refer sections 1.11.4)**	**AU : Dec.-18, Marks 5**
Q.29	*Explain in detail about hidden terminal problem and exposed terminal problem.* **(Refer section 1.11.2)**	**AU : Dec.-18, Marks 13**
Q.30	*Describe the characteristics of mobile computing.* **(Refer section 1.6)**	**AU : May-19, Marks 5**
Q.31	*Explain the structure of mobile computing application with an illustrative example.* **(Refer section 1.3.1)**	**AU : May-19, Marks 8**
Q.32	*Summarize the functions of Fixed-assignment schemes in MAC protocols.* **(Refer section 1.11.5)**	**AU : May-19, Marks 8**

□□□

Unit II Mobile Telecommunication System

Syllabus

Introduction to Cellular Systems - GSM – Services & Architecture – Protocols – Connection Establishment – Frequency Allocation – Routing – Mobility Management – Security – GPRS-UMTS – Architecture – Handover - Security.

Contents

2.1 Introduction to Cellular System

Mobile communication refers to the conversation established between two users at two different places with their hand held equipment. Initially the focus of mobile communication was towards voice but later it also dealt with data. Today cellular phones provide many services. That include electronic mail, internet access, short message service, electronic address book, games, calculator. Further research is in process to attract people towards commercial product.

The size of the cellular phone is such that subscribers can handle it easily wherever they roam. The frequency range for mobile transmission includes 825 to 845 MHz range as its comfortable range. The information and technology field is greatly revolutionized due to the arrival of cellular phones.

The first generation digital cellular wireless network was the Advanced Mobile Phone System (AMPS). It provided 19.2 kbps data rate.

The second generation wireless systems are the popular Global System for Mobile communications (GSM), Personal Communication Service (PCS) and it provided 9.6 kbps data rate to deliver the data, with dedicated channels.

2.2 Evolution of Mobile Communication

- The wireless communication has developed worldwide from the year 1897 by means of radio and the development of the technology is due to revolution in the fields like

i) RF circuit fabrication

ii) Large scale circuit integration

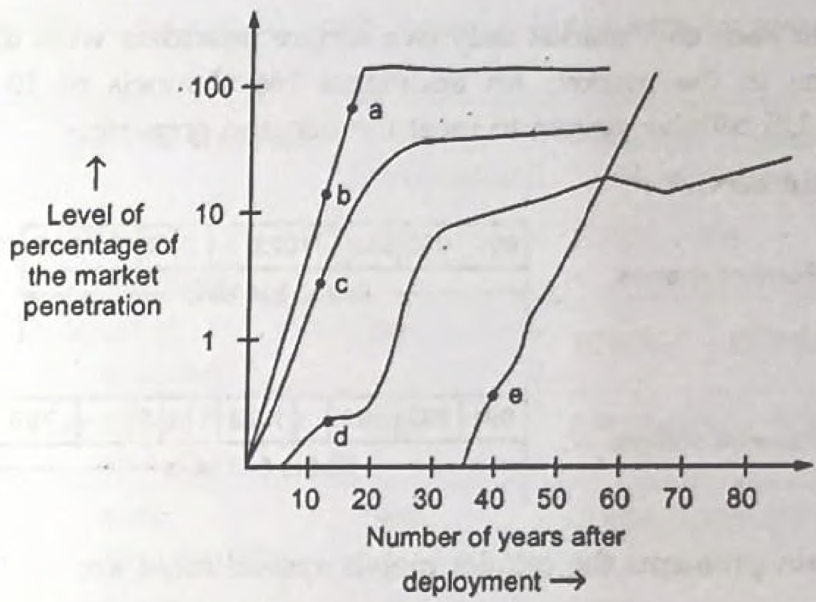
iii) Digital circuit design

iv) Miniaturization technologies.

The impact of development of mobile communication is personal communication services. The cellular concepts emerged appreciably and slowly developed by Bell Laboratories in the period between 1960 and 1970. An exponential growth of wireless communication was observed. While comparing wireless technologies with other communications the penetration of wireless application is more in our day-to-day life. the cellular as well as personal communication services have revolutionized the communication field.

The drastic growth of mobile communication is compared here with some of other technologies in a graph.

The cellular mobile communication technology emerged slowly and developed worldwide. At the same time it has penetrated into the market for long time with high demand than other technologies. It has an appreciable growth rate as seen in the graph.



a - Video cassette recorder - 1979 Year of introduction
b - Television - 1946
c - Automobile - 1900
d - Telephone - 1877
e - Mobile telephones - 1946

Fig. 2.2.1

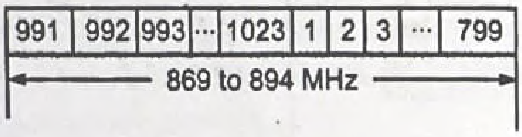
In the year 1934 the police radio systems used the Amplitude Modulation (AM) systems for transmission purposes. In early cellular the major problem faced was vehicular ignition noise. It is also interesting that in 1960's the majority of mobile users were not linked through PSTN and they were not capable to dial the telephone numbers directly. In the year 1995 the number of mobile users in US was 37 % of the total population. The growth of cellular mobile users was approximately from 25000 to 25 million and this took roughly one decade. (From 1984 to 1993).

The number of consumers in wireless communications increases every year worldwide.

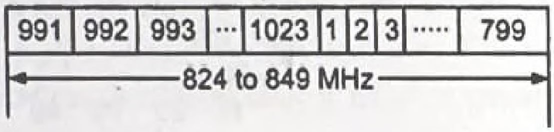
In early days the FM push-to-talk telephone systems were popular. In the period of 1940 this system used frequency of 120 kHz, such that only one person can talk at a time. It was known as half duplex mode. But the FCC increased the number of channels in each market and at the same time it does not need an extra spectrum allocation. It was possible with new technologies enabling reducation in bandwidth from 120 kHz to 60 kHz. Later automatic channel trunking was also possible and it was named as Improved Mobile Telephone Service (IMTS). With this IMTS full duplex mode was brought in. In the year 1968 AT and T Bell Laboratories recommended the concepts of the cellular mobile communication to the respective FCC and in the year 1983 FCC assigned 666 duplex channels for the US mobile systems named as Advanced Mobile Phone System (AMPS). It is also worthnothing that FCC insisted to have 'duopoly' in each city. That is in each city/market only two service providers were allowed to have a healthy competition in the market. An additional 166 channels of 10 MHz frequency were permitted in US cellular system to meet the demand scenario.

US cellular radio service :

i) Forward channel →



ii) Reverse channel →



Some of the main problems the cellular mobile system faced are

i) Interference

ii) Less encyption techniques

iii) Spectrum inefficiency.

In the year 1991 the US Digital Cellular (USDC) system was implemented and this USDC Standard or Electronic Industry Association Interim Standard IS-54 enabled the main advantage of replacing few single user analog channels with that of the digital channels.

Comparing AMPS with USDC system the digital USDC provided more capacity to the cellular mobile world. It was due to the reasons, the USDC applied the techniques mentioned below.

i) $\frac{\pi}{4}$ differential quadrature phase shift keying.

ii) Speech coding.

iii) Time division multiple access.

Later a better cellular mobile system using Code Division Multiple Access (CDMA) was developed by the Qualcomm, Inc which was then standardized by the respective Telecommunications Industry Association (TIA) and the sytem was named as Interim Standard (IS-95).

The IS-95 allowed many number of mobile users by Direct Sequence Spread Spectrum (DSSS) technique. The CDMA cellular phone systems were independent of interference problems and provided better call quality than the first generation (1G) AMPS cellular system.

Some of the mobile standards of North America, Japan and Europe are listed below.

	Mobile standard	Year of introduction	Multiple access / Modulation	Bandwidth of channel
1) North America	a) AMPS (Cellular)	1983	FDMA / FM	30 kHz
	b) USDC (Cellular)	1991	TDMA / $\frac{\pi}{4}$ DQPSK	30 kHz
	c) CDPD (Cellular)	1993	(FH/Packet) / GMSK	30 kHz
	d) IS-95 (Cellular/PCS)	1993	CDMA (QPSK/BPSK)	1.25 MHz
2) Japan	a) JTACS (Cellular)	1988	FDMA / FM	25 kHz
	b) PDC (Cellular)	1993	TDMA / $\frac{\pi}{4}$ - DQPSK	25 kHz
	c) NTT (Cellular)	1979	FDMA/FM	25 kHz
	d) PHS (Cordless)	1993	TDMA / $\frac{\pi}{4}$ - DQPSK	300 kHz
3) Europe	a) ETACS (Cellular)	1985	FDMA / FM	25 kHz
	b) GSM (Celluar/PCS)	1990	TDMA / GMSK	200 kHz
	c) CT2 (Cordless)	1989	FDMA / GFSK	100 kHz
	d) DECT (Cordless)	1993	TDMA / GFSK	1.728 MHz

AMPS - Analog Mobile Phone System.

USDC - US Digital Cellular.

CDPD - Cellular Digital Packet Data.

IS-95 - Interim Standard-95.

JTACS - Japanese Total Access Cellular Systems.

PDC - Pacific Digital Cellular.

NTT - Nippon Telephone and Telegraph Company.

PHS - Personal Handy Phone System.

ETACS - European Total Access Cellular System.

GSM - Global System for Mobile.

CT2 - Cordless Telephone. (CT2)

DECT - Digital European Cordless Telephone.

In the examples of cellular, cordless and PCS systems each one of them has unique advantages and facilities with respect to mobile comunication technology. Thus the transition from analog mobile phones to digital mobile phones was made along a number of years and today digital cellular telephony is very popular worldwide due to its several technical advantages, including cellular coverage capability.

Examples of the cellular radio communication.

1. Cellular telephone system.
2. Cordless Telephone (CT) system.
3. Paging system.

These examples are given below.

Example 1 : Cellular telephone system

The cellular telephone system mainly helps to connect a Public Switched Telephone Network (PSTN) and any distant/near user provided the user is available within the corresponding radio range. (A basic cellular system is given below.) The mobile switching center or Mobile Telephone Switching Office (MTSO) connects the mobile units (called parties) to the PSTN. Every cell of the particular geographical area has its own base station with a transceiver, an antena, and also a control circuitry.

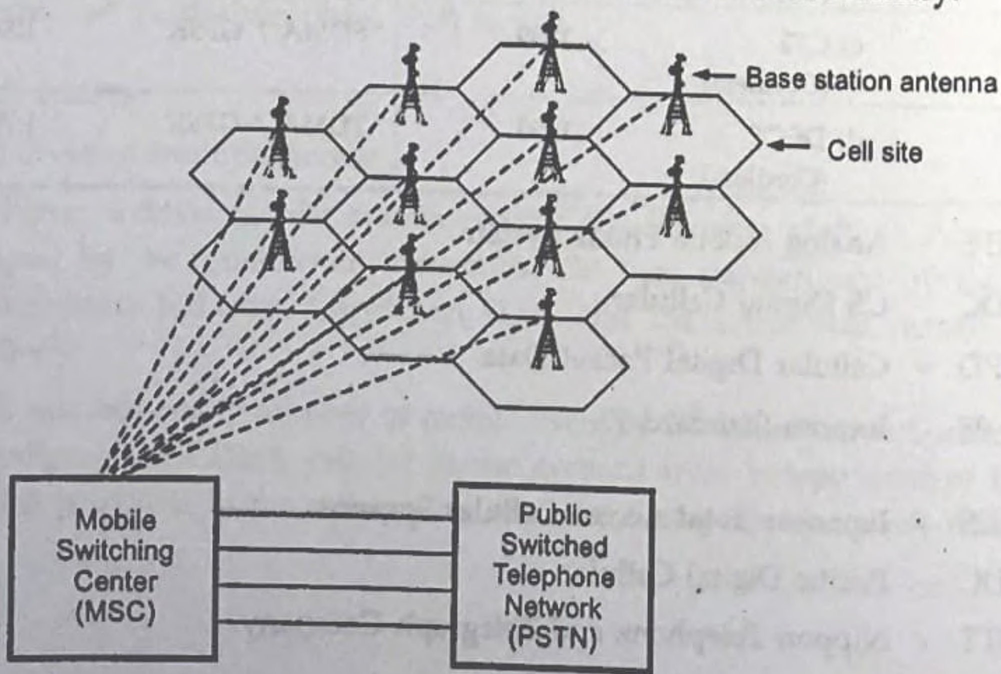


Fig. 2.2.2 Cellular system

The base stations are capable of handling many full duplex cellular communications. The mobile switching center can handle atleast 5000 telephonic conversation at a time and 1,00,000 cellular users/subscribers in a network. The cellular communication is made possible between mobile units and the base stations with the help of Common Air Interface (CAI) which specifies four channels.

They are :

1. Forward Control Channels (FCC)
2. Reverse Control Channels (RCC)
3. Forward Voice Channels (FVC) and
4. Reverse Voice Channels (RVC).

The control channels mentioned here are also termed as setup channels. They will have calls that are in progress but they usually send and receive data messages carrying call initiation and requests for services.

The Forward Control Channels (FCC) are also termed as "BEACONS" since they continuously broadcast the traffic requests for the mobile units within the cellular system. As soon as the cell phone is switched on it scans the control channels searching for the strongest signal of a base station. When the call progresses the mobile switching center adjusts the power transmitted (P_T) of the mobile unit and alters the channel of the mobile unit and also the base station so as to maintain the call quality eventhough the mobile unit is non-stationary.

The call in progress continues irrespective of the frequency changes from one base to another base station. Such a call continued process without termination is called as 'Hand off' technique. As the mobile moves and the signal strength reduces when it is away from its base station of cell, the next base station of the neighbouring cell where the mobile enters in will take charge of the call. A relay like process thus takes place within several base stations of the entire cellular system simply to sustain the call developed between two subscribers.

Whenever a mobile originates a call, a request signal will be sent through reverse control channel. By seeing this request the mobile unit will transmit its Mobile Identification Number (MIN), telephone number of its called subscriber, and the Electronic Serial Number (ESN). Then the MSC will check the proper validity of the signals sent by the mobile and responds to its request by connecting the called subscriber through PSTN.

The mobile communication establishes call, maintains it, and terminates as the call is over. It enables communication eventhough the distance between subscriber is large.

Example 2 : Cordless Telephone (CT) system

The cordless telephone systems are full duple systems and it is intended to link a portable handset to the dedicated base station which in turn is connected to a particular dedicated telephone line. For this specific telephone number on Public Switched Telephone Network (PSTN) is used.

The first generation (1G) cordless telephone systems came into existance in 1980's. But the distance the system covered was only few meters.

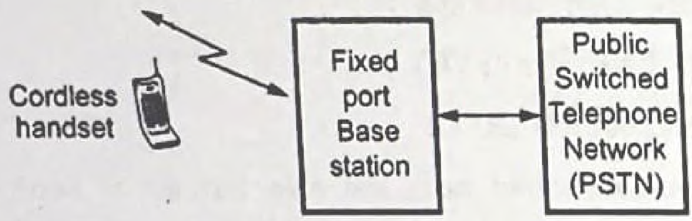


Fig. 2.2.3 Cordless Telephone (CT) system

Later the second generation (2G) cordless systems the distance was not a problem and the subscribers used cordless systems in mobile environment also. The system was good only if the subscriber availability was within the coverage of base station.

The cordless system also work together with paging system such that the roaming subscriber can first be paged and he or she can respond to it with the help of cordless telephone. In the simple cordless system shown above it illustrates that the cordless handset is linked to PSTN through the base station (fixed port). The cordless handset has a wireless link with its dedicated base station. The cordless systems are divided into two namely Analog CT and Digital CT.

In the early days these cordless systems were analog (Analog CT). They provided analog voice transmissions and enabled mobility within a limited distances. But they had many demerits such as

i) Poor call qualities

ii) Interference

These problems urged the need for digital cordless (Digital CT) systems. They provided better voice quality similar to wired telephone system.

Example for digital cordless system is

CT2 / Common Air Interface (CAI)

Some of the main criteria of CT2 system are

i) Voice signal is digitized through 32 kb/sec Adaptive Differential Pulse Code Modulation (ADPCM) technique.

ii) Bit stream compression facility.

iii) Final bit stream transmission at a rate of 72 kb/sec through Gaussian Frequency Shift Keying (GFSK).

iv) Immune to errors.

v) Supports data transmissions effectively upto 32 kb/sec.

vi) Traffic can be separated with the Time Division Duplex (TDD) access technique.

Note :

This CT2 standard does not provide for the mobility status and the later version CT2 + standard was used for this purpose.

Example 3 : Paging Systems

The paging systems are communication systems and they can transmit brief messages to subscribers. The message sent may be an alphanumeric message, numeric message or even a voice data. Paging systems also include news headlines, faxes and stock quotations. It may be sent to a particular paging subscriber through the paging system access number with a modem or a telephone keypad. Such a message is called as page.

In a technique called 'simulcasting' the wide paging systems sends a page from each base station simultaneously.

The important performance metrics used in decision-making process under hand off situations (mobility management) are listed below.

1. Probability of call blocking
2. Probability of call dropping.
3. Probability of call completion.
4. Handoff delay.
5. Rate of handoff.
6. Probability of an incomplete handoff.
7. Probability of handoff blocking.
8. Interruption time duration.
9. Handoff probability.

Strategies used to calculate the instant of handoff are :

1. Relative signal strength method.
2. Relative signal strength with hysteris method.
3. Relative signal strength with threshold method.
4. Prediction techniques.

In a wide area paging system a paging control center is available that connects the PSTN to different paging terminals.

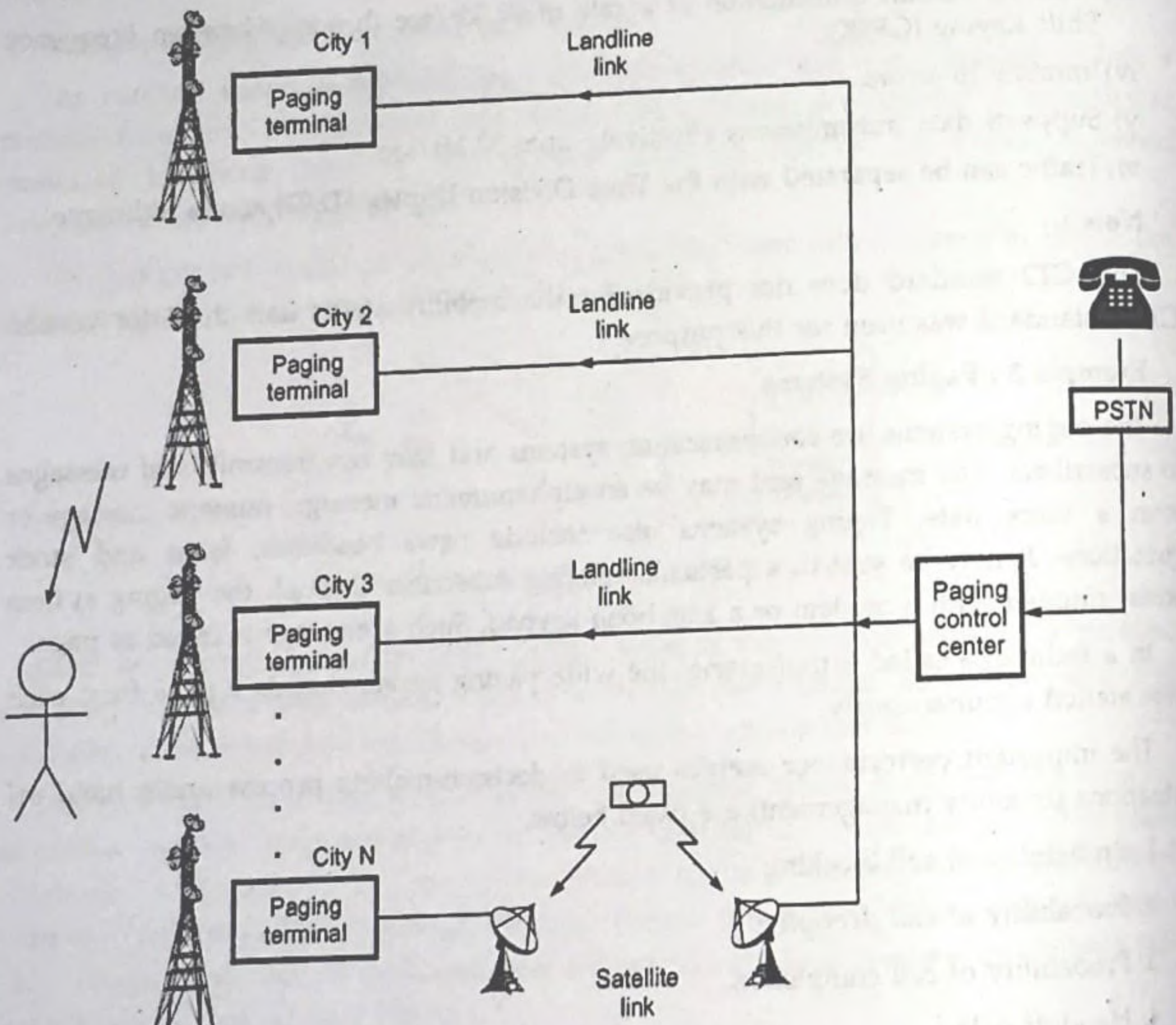


Fig. 2.2.4 Wide area paging system

Thus paging systems enable communication with subscribers irrespective of their roaming state. But the system requires large transmitter powers in the order of kilowatts and uses only low data rates for providing proper coverage.

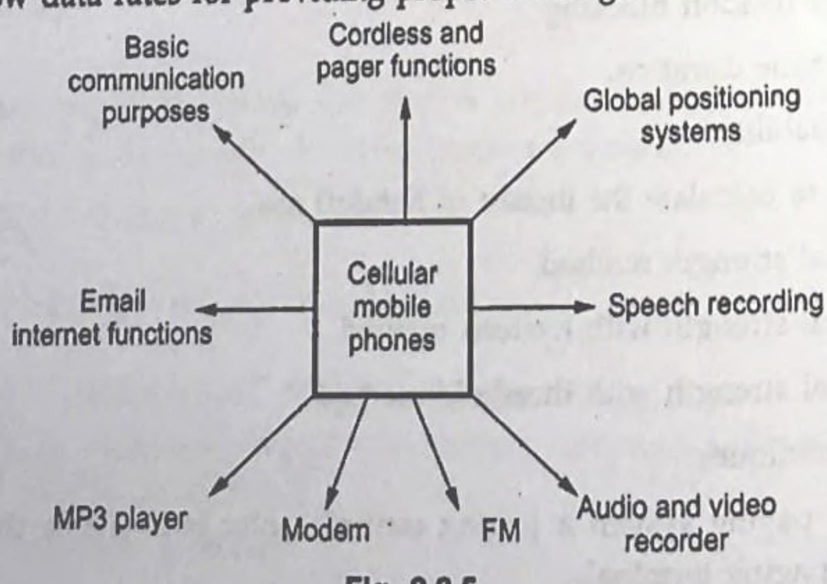


Fig. 2.2.5

There are several functionalities possible with cellular mobile phones as shown above which includes the pager functions too. It is helpful in sending short messages which are highly used by subscribers. The short message or page is sent to a subscriber wherever he is, and it is the main advantage of these system in spite of low data rates and large transmitter power requirements.

2.3 Cellular Mobile Communication

Important terminologies

1. **Cell :** It is smallest geographical area considered for cellular mobile communication.
2. **Base station (BS) :** Base station provides functionalities between mobile unit and Mobile Switching Center (MSC). The base station is located in each cell and it links the subscriber mobile unit with the MSC.
3. **Cell splitting :** In high cellular traffic regions, a larger cell is divided into smaller cells to have complete radio coverage.
4. **Handoff :** When mobile unit moves from one cell to another cell the call in progress will be handed over form one base transceiver to the base transceiver of the new cell where the mobile unit enters so that the call in progress is not disturbed and such a process is called as "Handoff".
5. **Cell sectoring :** A cell can be divided into many sectors. For example, from 3 sectors to 6 sectors in a hexagonal cell. The directional antenna should focus on each sector.
6. **Umbrella cell pattern :** A single large cell (Macro cell) consists of many small cells (Micro cells) and there will be interaction between the micro and macro cells.
7. **Control channel :** They are used for necessary exchange of information related to setting up and establishing cell base stations and the mobile units.
8. **Traffic channels :** They are used for carrying data or voice connections between different users.
9. **Frequency reuse :** It is a concept followed in cellular communication for efficient spectrum utilization. The same carrier frequency is reused by many cells in a cellular cluster and it is known as 'frequency reuse' scheme.
10. **Fading :** Fading is an effect in mobile radio propogation. It is common in multipath mobile signalling environment.
11. **Mobile Telecommunication Switching Office/Mobile Switching Center (MTSO/MSC) :** It is the main unit that connects the base transceiver station and the Public Switched Telephone Network (PSTN) in mobile communication.

Parameters for micro cells

Cell radius	→ 0.1 - 1 km.
Delay spread (average value)	→ 10 - 100 nsec.
Max bit rate	→ 1 Mb/sec.
Transmission power (P_T)	→ 0.1 - 1 watt.

Parameters for macro cells

Cell radius	→ 1 - 20 km.
Delay spread (average value)	→ 0.1 - 10 μsec.
Max bit rate	→ 0.3 Mb/sec.
Transmission power (P_T)	→ 1 - 10 watt.

Page

It is a brief message that is broadcast over an entire service area, generally in a simulcast type by many base stations at a time.

Forward channel

It is a radio channel used for transmission of information from base station to the mobile unit.

Reverse channel

It is a radio channel used for transmission of information from mobile unit to the base station.

Simplex systems

These are the communication systems that provide only one way communication.

Subscriber

A mobile phone user who pays subscription charges for using a cellular mobile communication system.

Mobile station

Mobile station is mainly intended for use while in movement at any location. It can be hand-held personal units that is portable or installed in moving vehicles.

Full duplex systems

The transmission and reception is typically on two different channels (FDD) even though new cordless systems are using TDD scheme. It is a communication system that allows two way communication simultaneously.

Half duplex systems

The communication systems that allow two way communication by using same radio channel for both transmission and reception. The user can transmit or receive at any time.

Transceiver

It is a device used for both transmitting and receiving radio signals.

Roamer

It is a mobile station that operates in a service area other that the subscribed service area.

PSTN

It is the public switched telephone network to which the Mobile Telephone Switching Center (MTSO) is connected.

Trends in cellular radio and personal communications

With the help of digital signal processing, RF technology, network intelligence the personal wireless systems have developed worldwide and provide many number of services to subscribers in their unique way. The Perseonal Communication Services (PCS) initiated in the United Kingdom and the frequency spectrum allotted was in the range 1800 MHz. It focussed on developing Personal Communication Networking (PCN).

The advantage of PCN is that the subscriber can receive or make a call irrespective of the roaming status. The Personal Communication Systems (PCS) includes several network features and provides more personalization, than the available cellular systems.

Then the indoor wireless networking got all the importance due to the better network connectivity within the building premises. One such standard is HIPERLAN compatible with indoor wireless standard and it was developed by European Telecommunications Standard Institute (ETSI).

An important worldwide standard known as Future Public Land Mobile Telephone System (FPLMTS) or International Mobile Telecommunication 2000 (INT-2000) emerged in the year 1995 and it was developed by International Telecommunications Union (ITU). This IMT-2000 is a third generation (3G) standard and some of its advantages are

i) Global compatibility.

ii) Integrate paging, cordless and the cellular mobile system and LEO satellites as a single mobile system.

iii) Supports multi-function.

It is an excellent digital mobile radio system accepted worldwide. The satellite mobile systems incorporates good paging systems, data collection, global roaming and emergency communications. One such example is network of LEO satellites.

The fundamental technological developments has thus helped the wireless personal communication systems to grow rapidly and the demand it has is also high. The wireless networking will surely improve further to meet more requirements and additional features in wireless personal communication field.

2.4 Cellular Concepts

Some of the important cellular concepts are discussed in detail.

a) Frequency reuse

b) Channel assignment

c) Handoff

d) Interference and system capacity

e) Tracking and Grade of Service (GoS)

f) Improving coverage and capacity.

2.4.1 Frequency Reuse Concept

In a cellular radio system channel allocation and reuse schemes are very important because it leads to bandwidth saving. In cellular mobile communication each channel is assigned with a group of channels. But a group of channel allocated for one cell will be different from the group of channels allocated for its neighbouring cell. Every cell is provided with its own base station and each base station is designed to provide accurate coverage within its cellular region. Hence the ultimate aim is to improve better performance with lesser number of radio channels.

The design process involved in allocating and reuse of radio channels is also called as frequency reuse technique. While planning the number of channels required for a geographical region the 'foot-print' (Radio coverage of a cellular area) of the cell has to be known. The number of hexagonal cells required will be planned and then channels will be assigned for every cell.

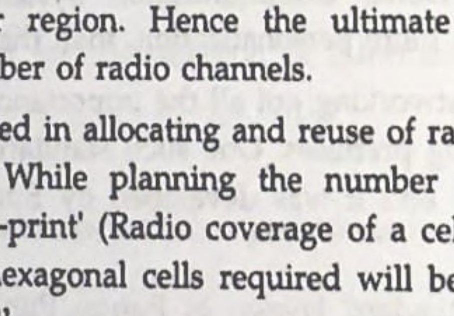


Fig. 2.4.1 Frequency reuse (N = 7)

In this example a cellular cluster N = 7 pattern is shown. The cells with same number uses same set of frequencies.

Consider a cellular region with 'N' cluster 's' number of duplex channels available for use then the measure capacity 'C' is given as,

$$C = k.MN$$

Where $k \rightarrow$ The group of channels alloted for each cell and $k < s$.

$M \rightarrow$ Cluster N is replicated 'M' times.

If the total number of duplex channels 's' are divided equally to all the cells then total number of available channels will be,

$$s = kN$$

Where $N \rightarrow$ Cluster size.

Substituting for 's' then the measure of cellular capacity is,

$$C = Ms$$

Where, M represents the number of times the cluster is replicated within the system.

The frequency reuse factor is another important parameter that is denoted as,

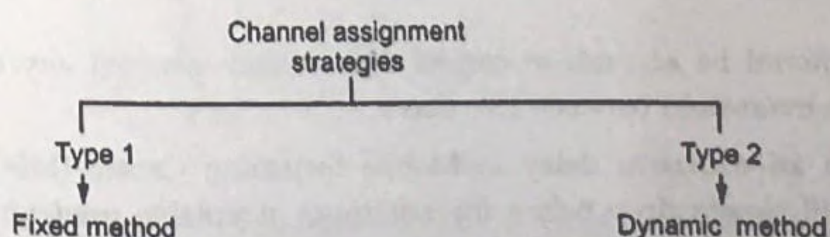
$$f = \frac{1}{N}$$

It is inversely proportional to the cluster N because $\frac{1}{N}$ of the available channels are only assigned to each cell within the cluster.

2.4.2 Channel Assignment

The channel assignment strategies play a vital role in utilization of available radio frequency spectrum. It is better to implement frequency reuse concepts in cellular environment for reducing bandwidth usage, and to meet the traffic demands effectively.

The channel assignments should be done carefully such that all the users must be served completely. The decisions made for assigning channel impacts directly the peformance of the entire system.



Type 1 : Fixed channel assignment

In this scheme each cell will be allocated a fixed number of voice channels. If a call request is made it can be served only if there is any unused channel available.

In case if there is no unused channels then the call will be blocked and cannot be served. But there is an approach allowed in fixed channel assignments called as "borrowing strategy" in which a particular cell in need of channels for serving its calls then it can borrow channels from its neighbouring cell. Now the cell accepts the channels is called as "acceptor cell" and the cell that donates channel to the needy cell is known as "donor cell". Hence the fixed channel assignment scheme is not much flexible with users.

Type 2 : Dynamic channel assignment

In this method the voice channels are not assigned to the cells permanently. But they are assigned according to the rising traffic needs of the cells. If there is high traffic then more channels will be allocated to that cell and if the cellular traffic is low then the cell will be attended with less number of channels. Whenever a call request is made the Base Station (BS) within the cell will request the Mobile Switching Center (MSC) to allocate channel for the cell. Hence channel allocation will take place as per the need of the cell.

Both the fixed and dynamic channel assignments are supervised by the MSC. The MSC monitors and make sure that the channel assignment scheme does not disturb any call that is in progress.

2.4.3 Handoff Technique

When mobile conversation is in progress, the mobile switching center should transfer/connect the call from the current base station$_1$ (BS_1) to next base station$_2$ (BS_2) as the mobile user enters the next cell. As the user leaves the cell$_1$ (at the border of cell$_1$) the signal strength decreases and when it travels towards the cell$_2$ the corresponding BS_2 follows the call progress and now the signal strength grows with respect to BS_2.

Such a proper call progress in spite of the mobile status of the user is known as handoff.

The handoff should be accurate at correct time instant to avoid any call termination when there is a conversation between two users.

But if there is an excessive delay at Mobile Switching Center (MSC) in assigning handoff, signal will slowly drop below the minimum acceptable predetermined level so as to enable channel in active status may result in a improper handoff.

This minimum acceptable level refers to 'acceptable audio quality' level at the Base Station (BS) receiver side.

A stronger signal that is slightly stronger than this acceptable audio quality is used as threshold and handoff has to be made at this threshold level (Δ). The 'Δ' level should be optimum and it must not be large or small from the desired level. The 'Δ' is given as,

$$\Delta = P_{R.H.} - P_{R.M.}$$

Where, $P_{R.H.}$ → Received handoff signal power.

$P_{R.M.}$ → Received minimum usable signal power.

If there is excessive delay introduced by MSC in allocating required hand off's then signal will drop below the optimum level as in the above example where mobile user travels from $cell_1$ to $cell_2$ (from point a to point b).

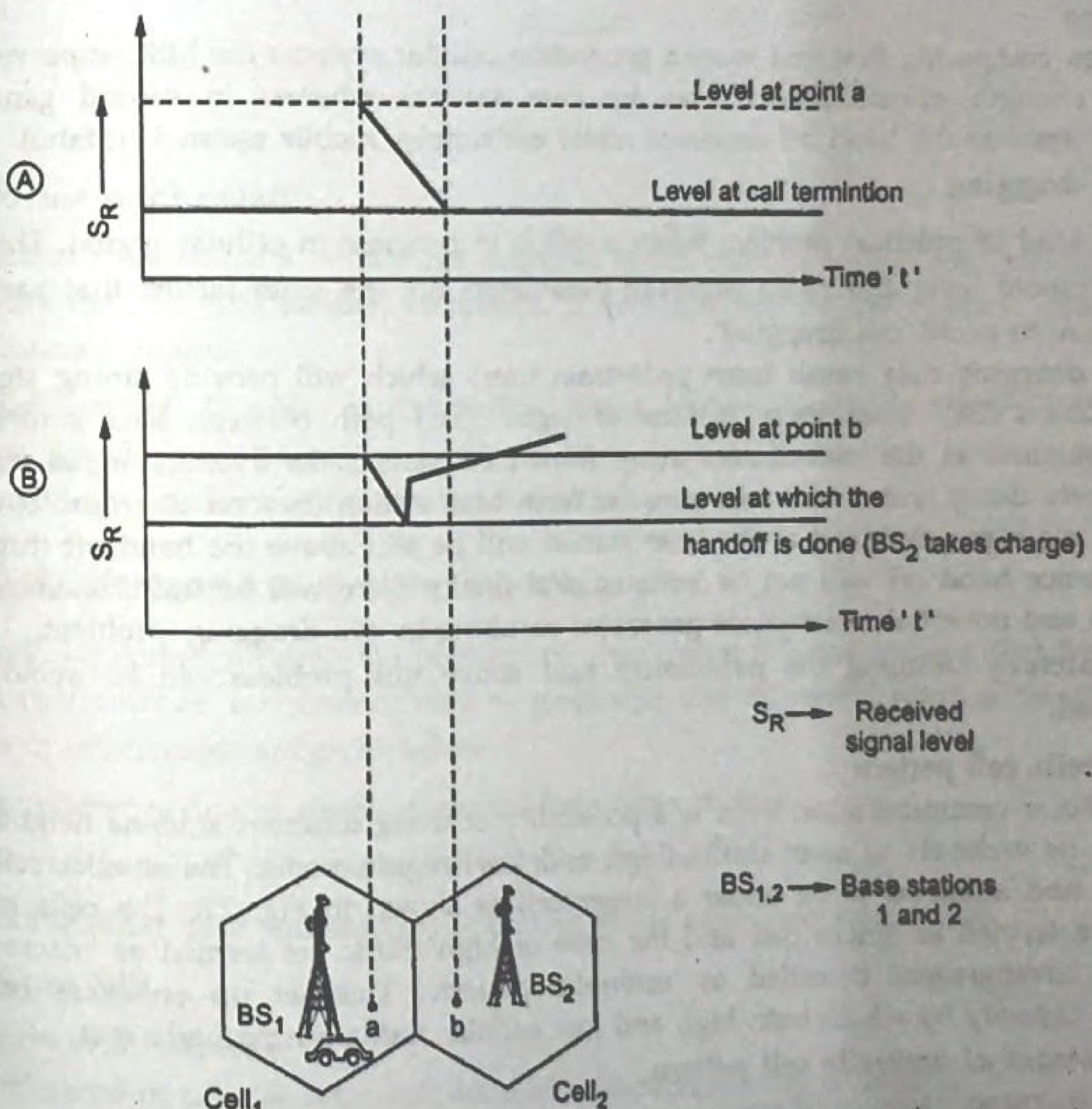


Fig. 2.4.2 Handoff technique : Mobile subscriber moves from a to b
(A) → Improper handoff due to excessive delay in MSC
(B) → Proper handoff from $cell_1$ to $cell_2$

Dwell time

It is important to note that as the mobile is moving from the serving Base Station (BS) there will be drop in the signal level. Therefore the base station usually monitors and measures the signal level before initiating a handoff for continuing the call progress.

The time period for which a particular call is maintained/sustained in a cellular region is known as "dwell time". There are many factor available that influences the 'dwell time' parameter, they are,

1. Interference.
2. Propagation.
3. The distance/range between the base station and the subscriber.

Maho

When comparing first and second generation cellular systems the MSC supervises the signal strength measurements done by base stations whereas in second generation cellular systems the hand off decisions made are simply "mobile assisted" (Maho).

Cell dragging

It is kind of practical problem when a call is in progress in cellular region. The hand offs threshold level and radio coverage parameters are the main factors that has to be taken care to avoid 'cell dragging'.

Cell dragging may result from pedestrain users which will provide strong signal to Base Station (BS) when there is Line of Sight (LoS) path between base station and subscriber and as the user moves away from base station the average signal strength will slowly decay and as the user goes far from base station (beyond the radio coverage of cell), the signal received at the base station will be still above the hand off threshold level. Hence hand off will not be initiated and finally there will be traffic management problem and potential interference generated resulting in 'cell dragging' problem.

By carefully designig the parameters said above this problem can be avoided or minimized.

Umbrella cell pattern

In cellular communication there is a possibility of using different antenna heights and different powerlevels to meet traffic (high and low) requirements. The smaller cells are grouped and assumed to be under a larger cell as shown in Fig. 2.8. The cells of low traffic are termed as 'micro cell' and the cells of high traffic are termed as 'macro cell'. Such an arrangement is called as 'umbrella pattern'. This set up enhances cellular coverage capacity by which both high and low cellular traffic are properly met.

Advantages of umbrella cell pattern

1. Increases radio coverage.
2. Reduces number of handoff's.
3. Provides more number of channels.
4. Less MSC intervention.

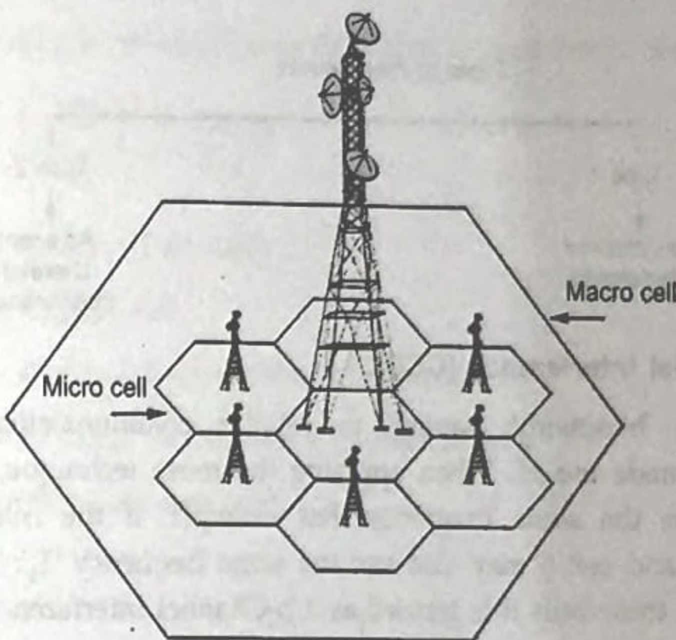


Fig. 2.4.3

Hard and soft handoff

Different base stations handle the required radio communication job, which is the main idea used in hard handoff technique. It does not refer to the physical changes in the channels assigned.

In soft handoff it refers to the ability of the Mobile Switching Center (MSC) for selecting among various received signals from base stations. This selecting/turning ability is the main idea behind soft handoff technique.

2.4.4 Interference and System Capacity

In cellular communication the problem of interference is a major issue that limits the system performance. Interference may be generated due to several reasons. Some of the sources of interference are given below.

i) Interference due to signal generated from other mobile.

ii) A call that is in progress in the neighbouring cell..

iii) Some other Base Stations (BS) operating in the same frequency range.

iv) Cross talk.

Effects of interference :

- Interference in cellular zone will definitely degrade the signal quality.
- In some extreme cases interference may lead to blocked calls status.
- Interference is a bottleneck that limits the capacity of cellular systems.

Types of interferences

- Type 1
  - Co - channel interference
- Type 2
  - Adjacent channel interference

Type 1 : Co-Channel Interference (CCI) :

To increase the 'bandwidth saving' in cellular communication the concept of frequency reuse is made use of. When applying the reuse technique, in a cellular zone many cells may use the same frequency. For example, if the $cell_1$ in a zone uses frequency 'f_1' cell 5 and cell 6 may also use the same frequency 'f_1'. Then if there is an interference between these cells it is termed as 'Co-Channel Interference (CCI)'

Solution to reduce co-channel interference :

The CCI degrades the system performance and it has to be reduced or minimized. For this the co-channel cells should be physically separated by a definite range/distance so that interference will not take place during signal propagation.

Analysis :

The co-channel interference will be independent of the power transmitted and dependent on the distance between the two centers of the closest cells (D) and the radius of the cell (R) if and only if the size of each cell in the cellular zone is same (approx) and the BTS transmitts the same power (P).

Thus if there is enough isolation of radio frequency (r_f) between the cells, co-channel interfence may not occur.

If 'Q' is the 'co-channel reuse ratio' parameter it is given as,

$$Q = \frac{D}{R}$$

$$Q = \sqrt{3N}$$

Where N is the size of the cluster. There should be an acceptable trade off between Q and N to have minimum tolerable co-channel interference.

Some co-channel reuse ratio values.

Co-channel reuse ratio (Q)	Cluster size (N)
3	3
6	12
6.24	13

For a particular cellular coverage area the signal to interference ratio is given as,

$$\frac{S}{I} = \frac{\left(\sqrt{3N}\right)^n}{i_o} = \frac{(D/R)^n}{i_o}$$

Where, R → Radius of the cell.

N → Cluster size.

D → Distance between the cell centers.

i_o → Number of interfering co-channel cells.

and n → Path loss exponent.

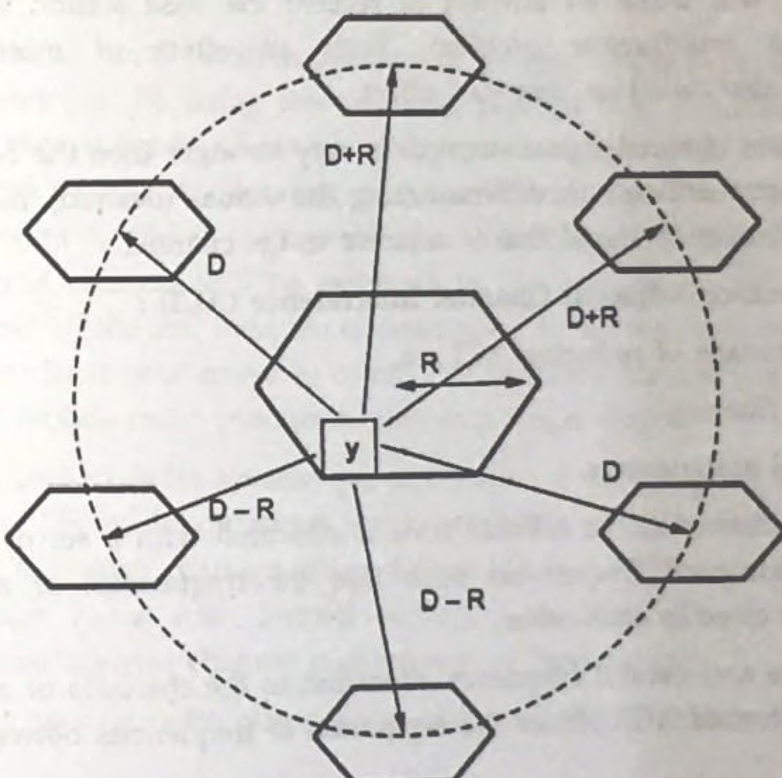


Fig. 2.4.4 Co-channel interference in seven cell reuse cellular pattern

Consider a seven cell reuse pattern, N = 7 and assuming that a mobile user is at the cell boundary as shown in Fig. 2.4.4. It is denoted as 'y'.

The mobile user is at a distance say 'D - R' from two closest neighbouring cells and the other cells are at distances. D, D + R as in the Fig. 2.4.4. If the path loss exponent 'n' is 4 (assume) the signal to interference ratio for worst case is approximated as given below.

$$\text{Signal to interference ratio} = \frac{S}{I} = \frac{R^{-4}}{2(D-R)^{-4} + 2(D+R)^{-4} + 2D^{-4}}$$

It is evident that the co-channel interference necessitates the measurements of link performance and which in turn enables the required frequency reuse plan. If frequency reuse scheme is carefully planned and implemented in the design of cellular communication the overall capacity of the system can be enhanced.

Type 2 : Adjacent Channel Interference (ACI) :

Adjacent Channel Interference (ACI) is a kind of interference arising due to signals that are adjacent in frequency. This interference is due to imperfect receiver side filters which permits nearby signal frequencies to mix/leak with the actual passband.

Near-far effect :

If an user is transmitting in a range that is very close to another subscriber's receiver then the receiver will make an attempt to receive the base station signal which will result in serious interference problem. Such an effect of interference due to distance/range is also called as "near-far" effect.

When an adjacent channel signal strength is very stronger then the base station of the cell will find it very difficult in differentiating the actual (desired) mobile user signal from the strong 'bleedover' signal that is adjacent to the channel.

Solutions to Reduce Adjacent Channel Interference (ACI) :

The important means of reducing ACI are,

i) Proper filtering.

ii) Channel assignments.

Every cell in a cluster in the cellular zone is allocated with a set of channels. These channels can be assigned frequencies such that the frequencies of adjacent channel should not be very close to each other.

Such an effective and careful frequency allocation to the channels of a cell will help a lot to reduce the effect of ACI. Hence the separation of frequencies between the channels is very important.

There is another complexity involved with ACI. The frequency reuse principle will help to save bandwidth. But at the same time if the channels that are very close uses the (reuse) same frequencies then there will be serious Adjacent Channel Interference (ACI) effect.

Consider two mobile users namely 1 and 2. If mobile 1 is 15 times closer to the base station when compared to mobile 2 and its energy spreads out, then the signal to adjacent channel interference ratio of the weak mobile 2 will be,

$$\frac{S}{I} = (15)^{-n}$$

Where n $\rightarrow$ Path loss exponent factor.

Note : It is always better to have six channel separations allowed in the frequency assignments to the channels of a cell to maintain the effect of ACI to an acceptable level.

2.4.5 Trunking and Grade of Service (GoS)

In cellular mobile communication the two important aspects that has to be considered with more care are,

1) Trunking
2) Grade of Service (GoS)

These aspects have to be well planned so that it will lead to a better system performance.

2.4.5.1 Trunking

The 'trunking' deals with accommodation of larger number of mobile users in minimum radio spectrum. By using this trunking concept it is possible to allow many users to share smaller number of mobile channels in a cell. It is done by assigning channels on demand basis and allocating a channel from a pool of channels available. That is if an user want to access a channel for establishing a cell then from the pool of channels the required channel will be assigned to the user. Once the call progress is terminated at the end of the call then the channel used so far will return to the pool and will be ready for any next new access to come. The trunking concept finds application in telephone circuitry, mobile radio communication in a larger way.

For designing truncked radio system that is capable of handling a particular capacity at a 'grade of service'. Some fundamental points regarding trunking theory is required. It was developed by a Danish mathematician Erlang. In the 19^{th} century the concept of accommodating large users with limited servers was dealt. The amount of traffic intensity that is carried by one channel is expressed as "one Erlang".

For example, if a mobile radio channel was occupied for 15 minutes of an hour then it is said as

$$\text{Traffic intensity} = \frac{1}{4} = 0.25 \text{ Erlangs}$$

Thus trunking is a main concept used to improve system efficiency. Also the term grade of service is closely linked with representation of grade of service.

2.4.5.2 Grade of Service (GoS)

The Grade of Service (GoS) is another important measure that express the ability of mobile user to access a trunked system mainly in the busiest hour of the day. The busiest hour of day is statistically studied and considered as 4 pm to 6 pm on the Thursday and Friday of a week. The busiest hour is also decided with respect to customer demand in particular hours.

The linked system's performance is defined by its grade of service. Only if the trunked system permits its user to access if even in the busiest hour then such a trunked system is said to be an ideal system. To meet out an appropriate GoS, the estimation of maximum capacity required for allocating enough number of radio channels in the design is a must. The GoS is also a measure of congestion that is specified as the probability of delaying a call beyond a time limit. The call request rate multiplied with holding time has to be equal to the traffic intensity which is offered by an user. If the traffic intensity in Erlangs generated by user is T_u then,

$$T_u = \lambda \cdot H$$

Where, $\lambda \rightarrow$ Average number of the call requests/unit time for an user.

$H \rightarrow$ Average call duration.

In case if the traffic is distributed equally among all the channels then the traffic intensity for a single channel. A_c in the trunked system 'C' will be,

$$A_c = NA_u/C$$

Where, $N \rightarrow$ Number of users in a trunked system with an unspecified number of channels in it.

Then there are two category of trunking system is available namely,

1) Trunking system with no queuing for the call requests.

2) Trunking system with queue provision for holding calls that are blocked.

This is given in the tree classification as shown in Fig. 2.4.5.

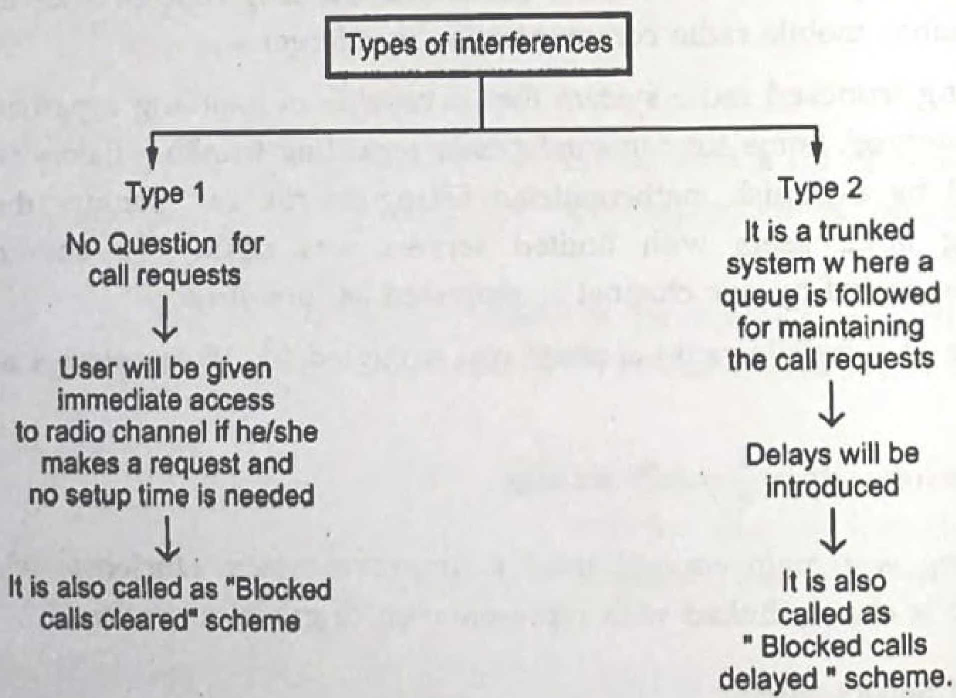


Fig. 2.4.5

The GoS parameter will be different for the various cellular systems. For example, the AMPS cellular system is mainly designed for GoS of 2% blocking status, which implies that 2 calls out of 100 calls allotted will be blocked.

The two broad classes of the trunked radio system is also called as Lost Call Cleared (LCC) and Lost Call Delayed (LCD) systems.

In Lost Call Cleared (LCC) system queuing is allowed for the call requests made. If a user wants service it will be served in case of availability of channel within a minimum time. Otherwise the call will be blocked if there is no channel available to assign. The grade of service is described by Erlang B formulae expressing the probability of an user experiencing blocked call status in the lost call cleared system.

In the second lost call delayed system the queues are made use to hold the call requests which were initially blocked. In this type if a user makes a call request it will served if channel is available or if the channel is not available at that moment the call will be delayed till the channel becomes available. It is determined by Erlang C formula. The grade of service in this system will express the probability of the delaying time for a call. There is large number of users available in the second type.

Thus in trunked system there are lost call cleared (no queues used) and lost call delayed (queues used) and the second type of trunking system is widely used.

Summary of some important terms related to trunking theory are as follows :

1.	GoS	The grade of service is a measure of congestion which is a probability of a call which is being blocked.
2.	Request rate	It represents the average number of the call requests made in a unit time and it is denoted by λ/sec.
3.	Load	The available traffic density across the complete trunked radio system.
4.	Setup time	It represents the time needed to allocate a trunked channel for an user who have made request.
5.	Holding time	It represents the average time duration taken for a call and it is denoted by 'H'.

2.4.6 Improving Coverage Capacity and Capacity in Cellular Systems

To increase the coverage area in a cellular system it is very important to assign more number of radio channels to a cell so as to meet the mobile traffic.

More number of channels, higher will be the coverage range (distance) in the cell thus leading to a higher coverage capacity.

For enhancing the cellular coverage capacity there are many techniques available and some important cellular techniques are discussed below in detail.

i) Cell splitting

ii) Cell sectoring

iii) Micro zone method

iv) Repeaters for extending range

2.4.6.1 Cell Splitting

Cell splitting is a technique of subdividing the congested (high traffic) cell into smaller sized cells. The parent cell which was originally congested is called as "macro cells" and the smaller cells are called as micro cells". The main objective of "cell splitting process" is to increases the cellular capacity of the system where frequency reuse technique can be efficiently implemented.

For example, a congested cell is subdivided into smaller cells shown in Fig. 2.4.6. Each smaller (micro) cell has a base station antenna exclusively and the micro cell radius will be half the radius value of the macro cell.

The transmit power (P_t) will be less for the micro cells. Assuming P_{r-o} as the received power at old cell boundary and P_{r-N} as the received power at new cell boundary.

$$P_{r-o} \propto P_{t_l} \cdot R^{-n}$$

$$P_{r-N} \propto P_{tN} \cdot \left(\frac{R}{2}\right)^{-n}$$

Where, P_{t_l} $\rightarrow$ Transmit power of larger (parent) cell.

P_{tN} $\rightarrow$ Transmit power of smaller (new) cell.

n $\rightarrow$ Path loss exponent.

$R; \frac{R}{2}$ $\rightarrow$ Radii of the larger and smaller cells.

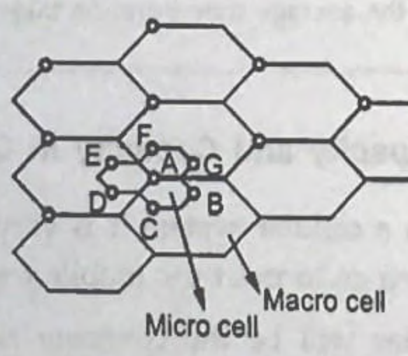


Fig. 2.4.6 Cell splitting

In cell splitting process generally the larger are dedicated to high speed traffic.

The reason for this is the number of 'hand offs' will be less in larger cell and call progress will be smoothly continued in larger cells.

Also the channels in old cells have to be broken into two groups due to following points.

i) If larger transmit power is used for all the available cells then some of the channels used by smaller cells may not be completely separated by co-channel cells. This may lead to interference.

ii) In case if smaller transmit power is used for the available cells then there is chance of 'unserved' problem. That is some parts of the larger cells would be left out as 'unserved'. This is also not acceptable.

Hence the channels of the macro/larger cell has to be divided into two groups. The larger cells for high speed traffic and micro/smaller cells for low speed traffic regions.

Antenna down tilting :

The process of an antenna down tilting is done mainly to focus the energy radiated from the Base Station (BS) towards the ground and not towards the horizon so that radio coverage of new micro cells will be properly limited.

2.4.6.2 Cell Sectoring

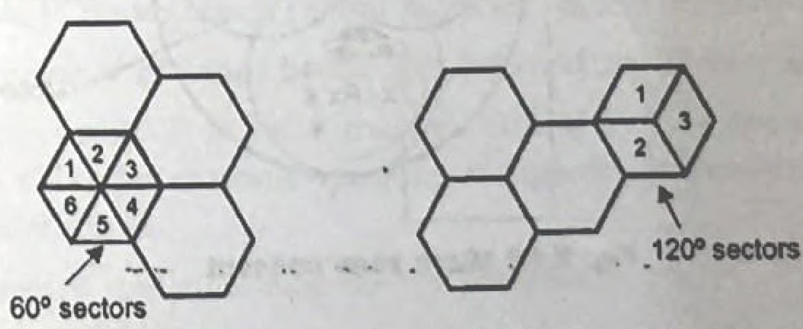
The cell sectoring is again a technique to increase the capacity but it keeps the radius of cell as constant. The size of clusters in cellular region may be reduced because the cell sectoring increases the Signal to Interference Ratio (SIR) value.

The method of decreasing the co-channel interference value and enhancing the system performance by using the directional antennas is known as "cell sectoring".

Sectors :

A cell in the cellular region is generally divided into 120° sectors or 60° sectors. If the sectoring is 120° a cell of hexagon type consists of three (3) sectors and if the sectoring is 60° sectoring the hexagonal type cell consists of six (6) sectors as shown in Fig. 2.4.7.

If cell sectoring is employed then the channel used in a cell will be divided into groups i.e. called as sectored groups and they are used only within a sector.



(a) 60° sectoring (b) 120° sectoring

Fig. 2.4.7 Cell sectoring

For example, in a seven cell reuse pattern with 120° sectoring, the possible number of interferers in the first tier will be only two. It means that only two cells of the six co-channel cells get interfered and it is better to apply cell sectoring in the design aspects of mobile communication to increase cellular capacity with less interference.

2.4.6.3 Micro Zone Method

Micro cell zone principle :

One of the problem associated with cell sectoring is that "requirement of more number of handoffs" thereby increased load status at the switching and control link components of the cellular mobile system.

There is another new concept known as 'micro zone concept' to minimize this problem.

In Fig. 2.4.8 there are three zones 1 to 3 shown with T/R set up. But they are connected to a single Base Station (BS) so that they are sharing the same equipment. For establishing connection between these three zones with the common base station microwave link, coaxial cable or fiber optic cable are used. Such an arrangement of several cellular zones with one base station constitues a cell.

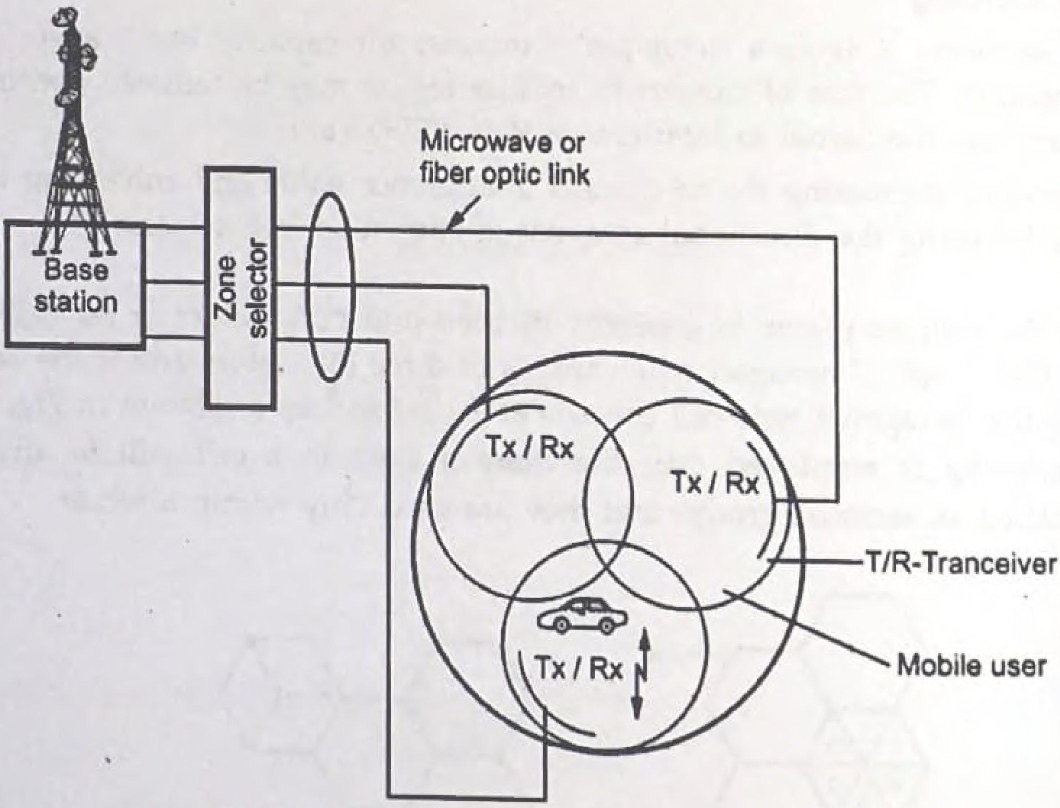


Fig. 2.4.8 Micro zone concept

Within the cell when a mobile user roams from one zone say 1 to another zone 2 then zone 1 will have strongest signal with respect to the base station.

In this micro cell zone concept the antennas are placed at the edges of each zone such that when the user moves from one zone to another zone the signal strength does not reduce like other methods. The number of hand offs are less when compared to cell sectoring method when a cell is in progress.

The merits of this technique are listed below.

Advantages of micro zone cell concept :

i) When the mobile user travels from one zone to another zone within the same, cell the same channel is still maintained for the call progress.

ii) Since low power transmitters are used in each zone apart from control base station the effect of interference is highly reduced.

iii) Improved signal quality is possible.

iv) Reduced number of hand offs when a call is in progress.

Application :

i) It is used in urban traffic (or) in highways traffic conditions.

2.5 Personal Communication

The personal communication services are many that has taken wireless technologies to greater heights. This chapter covers several Personal Communication Services (PCS) with examples. In wireless technologies some of the low power PCS systems are DECT, CT-2, handyphones etc.

Important issues related PCS design :

1. Percentage of area in a service region can provide specific service quality.
2. Depending on user intensity radio channel availability has to be planned.
3. Complexities in PCS is connected in planning weight, battery size and operating time period.
4. Complexity of PCS also affects control functions needed for network interaction.
5. Privacy and security provided by the encryption facility of the radio link.
6. Circuit quality involved in radio channels should include speech distortion and transmission delay for channels operating at a particular threshold error ratio and for error-free channels.

Some of the personal communication services are dealt below.

1. Cordless telephone system.
2. Personal handyphone system.
3. Personal Digital Cellular (PDC) telecommunication system.
4. Personal Access Control (PACS)

2.5.1 Cordless Telephone System

In home or office buildings, residential neighbourhoods and other places where people spend their time, they require a personal communicating device for communicating with other end people. These needs were slowly served by new low-power voice and data personal communications with longer battery life in usage and these are served partially by cordless telephones, wireless PBX using CT-2, DCT-900/DECT/CT-3 etc.

For high data rates in office buildings special technologies were applied like Wireless Local Area Network (WLAN) or data PCS with data rates more than a megabit per second.

The cordless telephones were mainly designed to provide limited coverage within residence campus and large buildings by eliminating cord between handset and the base unit. The speed and voice quality must be taken in cordless phones such that they should be capable of competing with wireline telephones.

These cordless telephone systems are full duplex systems and it uses radio for connecting a portable handset to the base station intended to it, which is connected to a telephone line with a particular number on Public Switched Telephone Network (PSTN).

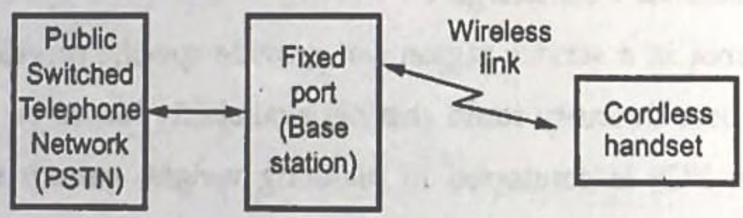


Fig. 2.5.1 Cordless telephone system

Early in first generation cordless telephones were used only in home (in-door) environment. But in second generation cordless telephones allowed subscribers to use them in outdoor environments also. The cordless telephones provided only less range of mobility.

When compared to wireline telephone systems cordless telephone should possess specific characteristics to meet out design issues and it can be designed as analog Cordless Telephones or Digital Cordless Telephones (CT-2, DECT etc.) and there must be few important features it has to possess.

- It should have wireline telephone circuit quality so as to reduce speech distortion and transmission delay.
- It should be of less complexity, to reduce d.c. power handling.
- It should minimize transmitter power to reduce weight, minimize cost, increase wage time etc.

Hence its design should have,

i) Less user channels per megahertz.

ii) Less user channels in single base unit on average.

iii) Several base units per area.

iv) Shorter transmission range.

v) Less complexity when dealing with other networks.

2.5.2 Personal Handyphone System (PHS)

The Personal Handyphone System (PHS) is mainly a Japanese air interface standard that was developed by 'Research and Development Center" for Radio Systems (RCR).

Some of the expected advantages of PHS were,

i) PHS was expected to promote personal and multimedia communication as its media.

ii) To provide interconnection of many PHS networks.

iii) To have interregional roaming facility.

iv) Base stations has to be developed such that several PHS operators can share it.

PHS use Time Division Multiple Access (TDMA) and Time Division Duplexing (TDD) techniques, where four duplex radio channels are provided on every channel. In general PHS is capable of supporting seventy-seven radio channels with 300 kHz wide each.

The range of an area that can be covered by PHS is upto 100 to 500 m and this region is called as micro cellular system to attain higher system capacity. Advantage of using such micro cells are reduced transmission power for better battery life and less cost.

The Fig. 2.5.2 shown expresses the concept of PHS. PHS can be used as handset of a cordless phone in indoor or outdoor modes namely private or public modes. Whenever a PHS terminal has to be used as a public mode then it has to have another 10 digit user number.

PHS makes use of dynamic channel assignment. Some of the features of PHS are :

i) Provides high capacity to micro cellular regions.

ii) High security.

iii) Enhanced voice quality.

iv) Longer call operating time (≡ 5 hours) and standby time (≡ 17 days) because of small call size.

v) Multimedia service capability.

vi) Simple spectrum management.

PHS system structure

PHS is a system that enables the option of using a handset of a digitized cordless phone both in indoor or outdoor environments. In PHS system the main elements are base station or Cell Station (CS) and an element called Personal Station (PS).

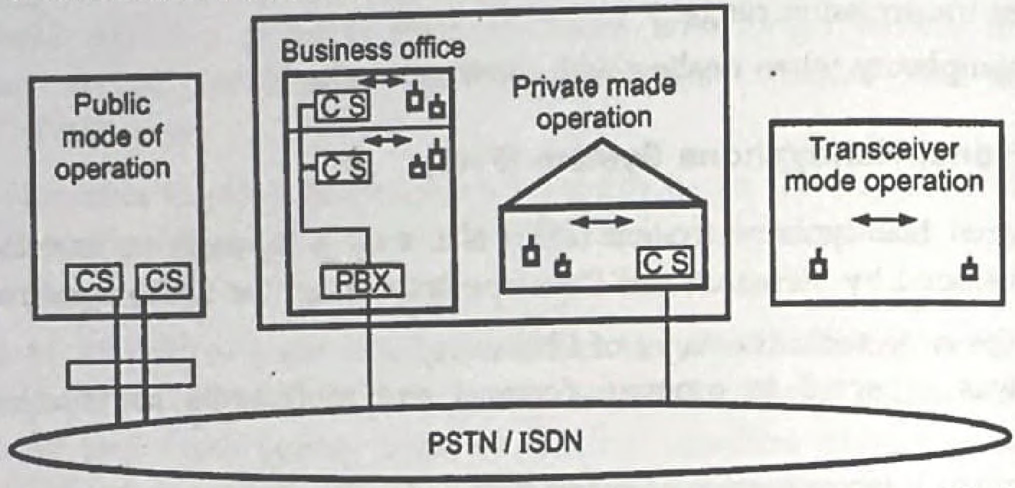


Fig. 2.5.2 System concept of personal handyphone system (PHS)

The Fig. 2.5.2 comprises of following main units.

i) PHS terminals.

ii) A parent mode (private-mode operation) for a digitized cordless phone.

iii) Cell Station (CS).

iv) Antenna elements.

In private mode PHS a PBX or a parent mode at home is linked to the Public Switched Telephone Network (PSTN). When PHS is used outside the home or building that is in public mode as said previously the PHS terminal should posses an extra 10 digit subscriber number. Each of the Cell Station (CS) is connected to the ISDN. It is also worth noting that under transceiver mode a direct communication between PHS terminals is possible. Hence out of the three modes private, public or transceiver a subscriber can opt for any one mode.

2.5.3 Personal Digital Cellular (PDC) System

It is a standard developed in the year 1991 in Japan for providing enough capacity in high cellular traffic region. It is also termed as Japanese Digital Cellular standard (JDC) and it is like interim standard 54 with less dissimilarities.

Features of PDC standard

i) It has no backword compatability with analog systems. But at the same time PDC offers interconnectivity with other existing analog cellular systems.

ii) PDC standard is assigned a bandwidth of 80 MHz in Japan.

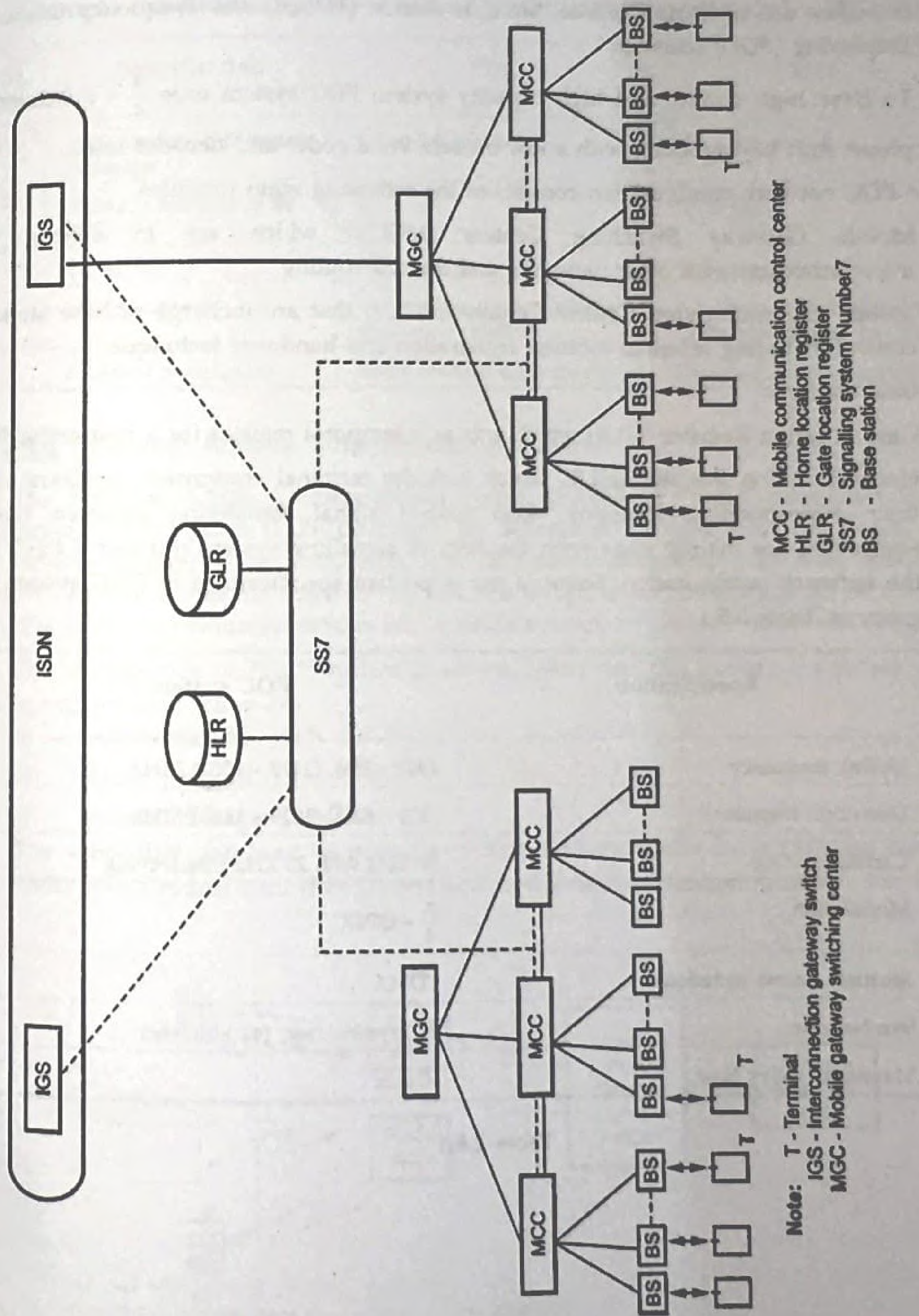


Fig. 2.5.3 PDC System_ Network Configuration

iii) PDC applies Mobile Assisted Hand Off (MAHO) technique for having hand offs and supports a four-cell reuse pattern.

iv) It makes use of Time Division Multiple Access (TDMA) and Frequency Division Duplexing (FDD) schemes.

v) To have high quality and high capacity system PDC system uses $\frac{\pi}{4}$ - quadrature phase shift keying along with a low bit rate voice coder and decoder units.

The PDC network configuration consists of the following main modules.

a) Mobile Gateway Switching Centers (MGC's) which are in control of interconnection with other networks and the call routing.

b) Mobile Communication Control Centers (MCC's) that are incharge of base station control including terminal location registration and handover technique.

c) Base stations.

d) Gate Location Register (GLR) which acts as a temporal register for a roaming call.

e) Home Location Register (HLR) which includes terminal equipment numbers and their corresponding locations. Also control signal transfering between these equipment are mainly done with the help of signalling system number 7 (SS7) in the network configuration. Some of the important specifications of PDC system is given in Table 2.5.1.

Sr. No.	Specification	PDC system
1.	Uplink frequency	(940 - 956), (1477 - 1501) MHz
2.	Downlink frequency	(810 - 826), (1429 - 1453) MHz
3.	Carrier spacing	50 kHz with 25 kHz interleaving
4.	Modulation	$\frac{\pi}{4}$ - QPSK
5.	Muitiple access technique	TDMA
6.	Symbol rate	21 ksymbol/sec, (42 kbit/sec)
7.	Maximum delay time	10 μsec

Table 2.5.1

A simple comparison between PHS and PDC systems are tabulated as follows.

Sr. No.	Specification	PDC	PHS
1.	Base station/cell station coverage	1.5 to 5.0 km radius	100 - 300 m radius
2.	Relative number of BS (CS)	1	40 to 120
3.	Handover	Fast handover	Slow handover
4.	Voice codec	Vector Sum Excited Linear Prediction (VSELP)	Adaptive Differential Pulse Code Modulation (ADPCM)
5.	Channel assignment	Fixed channel assignment	Dynamic channel assignment

2.5.4 Personal Access Communication System

The Personal Access Communication System (PACS) is a third generation Personal Communication System (PCS) developed by Bellcore in the year 1992. the PACS system is capable of supporting data, voice and also video information for both indoor and micro cell use the main objective of PACS is to focus on integrating all forms of the wirelss local loop communications into a single system, to establish wireless connectivity.

The architecture of PACS system is shown below and this system comprises of four main components. They are

a) Subscriber Unit (SU)

b) Radio Ports (RP)

c) Access Manager (AM)

The subscriber unit may be portable or fixed and the Radio Ports (RP) are connected to Radio Port Control Unit (RPCU) and also to the Access Manager (AM).

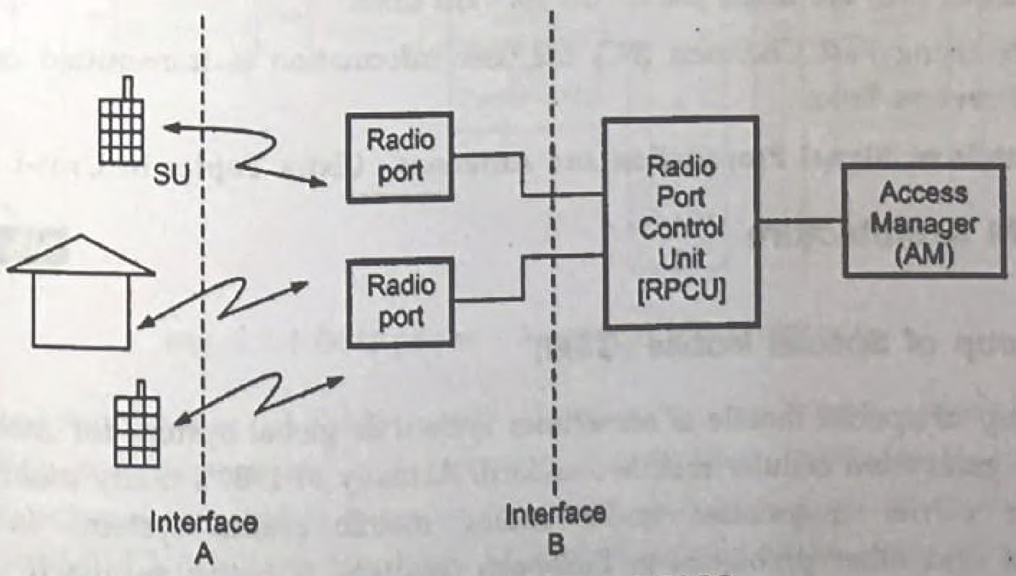


Fig. 2.5.4 Architecture of PACS

The air interface 'A' is used to provide connection between radio port and subscriber unit. The interface 'B' is intended to provide required protocols to connect the subscribers unit via radio ports to that of the RPCU and links the RPCU with its radio ports with the help of Embedded Operations Channel (EOC) available within the interface.

In the PACS system more number of Radio Frequency (RF) channels are Frequency Division Multiplexed (FDM) channels or time division multiplexed channels and the frequency separation is upto 80 MHz.

Features of PACS :

i) Wireless Access Communication System (WACS) uses 32 kb/sec. Adaptive Differential Pulse Code Modulation (ADPCM) coding scheme for speech encoding process. ADPCM allows the voice signal to be encoded with a bit rate of 32 kb/sec. which is half the 64 kbps PCM rate (standard rate).

ii) PACS system makes use of $\frac{\pi}{4}$ – differential phase shift keying scheme.

iii) PACS is compatible with Frequency Division Duplexing (FDD) or Time Division Duplexing (TDD) since PACS is a TDMA based technology.

iv) PACS uses adaptive power control to reduce power consumption and to minimize co-channel interference (CCI) problem.

v) PACS provides the following channels for messge transfer operation.

a) System Broadcasting Channel (SBC's) are mainly used on forward links to transmit paging information. SBC of 32 kbp/sec. can provide system and alerting information for about 80,000 users.

b) For synchronizing each subscriber unit synchronization channel (SYN) and Slow Channel (SC) are made use on the forward links.

c) Only using Fast Channels (FC) the user information is transmitted on forward and reverse links.

Fundamentals of Signal Propagation and Antennas : (Extra Topics in Unit-I to Know)

2.6 GSM Architecture

AU : Dec.-18

2.6.1 Group of Special Mobile (GSM)

The group of special mobile is sometimes known as global system for mobile and it is a second generation cellular mobile standard. Actually in 1980's many mobile systems with closer carrier frequencies under analog mobile phone systems faced many interferences and other problems, in European counters. A better approach which is a second generation digital system is the global system for mobile with acronym 'GSM'. In the age before GSM European countries used various cellular mobile standards which were not much efficient. GSM was initially functioning in 900 MHz band of frequency. The group of special mobile committee was a functioning group of CEPT. In the year of 1992 GSM modified its name to "Global system for mobile communications". The standards setting for GSM was under European Technical Standards Institute (ETSI).

In European countries GSM was first marketed in the year 1991. After two years other countries also evinced interest in this digital standard used for cellular communications technology.

The main aim of GSM was to provide 'roaming facility' for subscribers and to follow ISDN guidelines. It provides voice services that are compatible with ISDN standards.

GSM lies under second generation systems, that replaced first generation analog systems. Considering satellite uplink and downlinks, GSM was deployed using 890-915 MHz for uplinks and 935 to 960 MHz for downlink transmissions. GSM system used in United States in the band of 1900 MHz was called as Personal Communications Services (PCS). There are many GSM solutions known as GSM 900, GSM 1800 etc.

GSM phone - functional block diagram

The global system for mobile (Group of Special Mobile) GSM phone functional block diagram is shown above. The transceiver antenna system receives or transmits RF signal. The analog to digital conversion and digital to analog conversions are done in opposite directions depending upon transmission or reception. Microphone and loudspeakers are used in similar two directional ends.

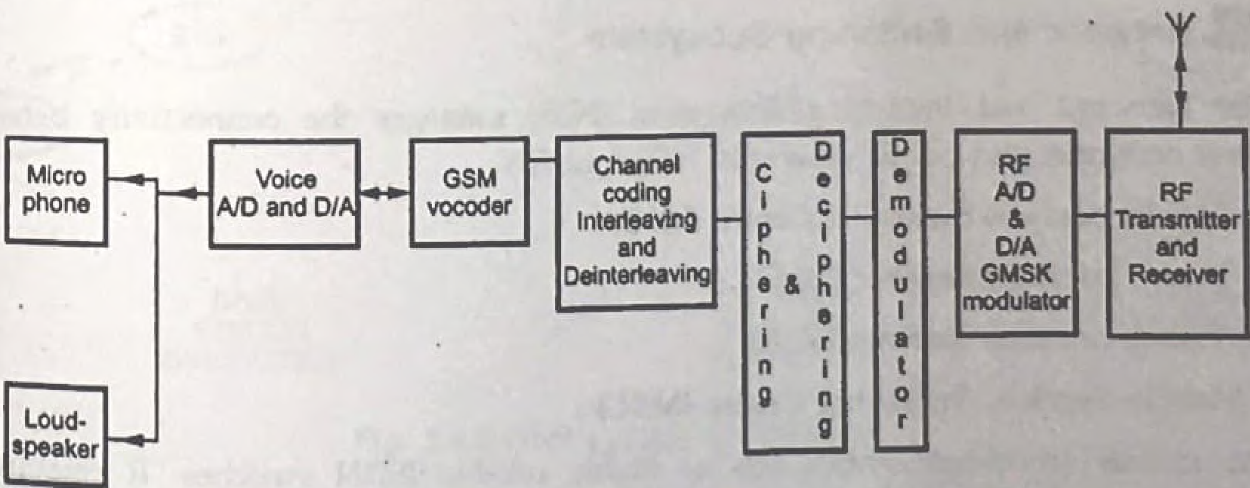


Fig. 2.6.1 GSM phone - functional block diagram

The channel coding is done with interleaving technique. Modulation and demodulation for transmission and reception. Equalization technique is also applied. Modulation scheme adopted is gaussian minimum shift keying digital modulation. The antenna is of MIMO (Multiple Input and Multiple Output) nature. User authentication is possible with GSM phones.

Depending upon the services provided by this standard there are six important category/examples.

1) Transactional service - Shopping - Booking	2) Travelling related services - Roaming - Weather	3) Personal service - Health monitoring - Budgeting
4) Mobile office - E-mail - Modem - Fax	5) Fun - Gambling - Online games	6) Security services - Emergency calls - Alarm provisions

There are three subtopics which are important under GSM.

(1) GSM Architecture
(2) GSM Services
(3) GSM Protocols

In GSM architecture, the subsystems are

i) Network and Switching Subsystem (NSS)

ii) Radio Subsystem (RSS)

iii) Operation Support Subsystem (OSS)

2.6.2 Network and Switching Subsystem

The Network and Switching Subsystem (NSS) manages the connectivity between wireless networks and public networks. NSS contains

i) Mobile Services Switching Centre (MSC)

ii) Home Location Register (HLR)

iii) Visitor Location Register (VLR)

i) Mobile Services Switching Centre (MSC) :

The mobile switching centres acts as highly reliable ISDN switches. It establishes connections between BSC's and all other MSC's. A single MSC can manage many BSC's of a particular region. A typical gateway MSC is termed as GMSC and it has additional fixed networks like PSTN and ISDN.

ii) Home Location Register (HLR) :

The home location register is very important database used in GSM standard in the sense it consists of all user related information.

It consists of mobile subscriber ISDN number, the related services and authentication key facilities. The information regarding users (subscribers) are linked to it. HLR also involves itself with charging and accounting details of subscribers.

iii) Visitor Location Register (VLR) :

VLR is responsible for any visitors or new users entering the network. Whenever a new Mobile Subscriber (MS) enters the Local Area (LA) then visitor location register VLR has to take immediate action so that it copies all related information about that new user.

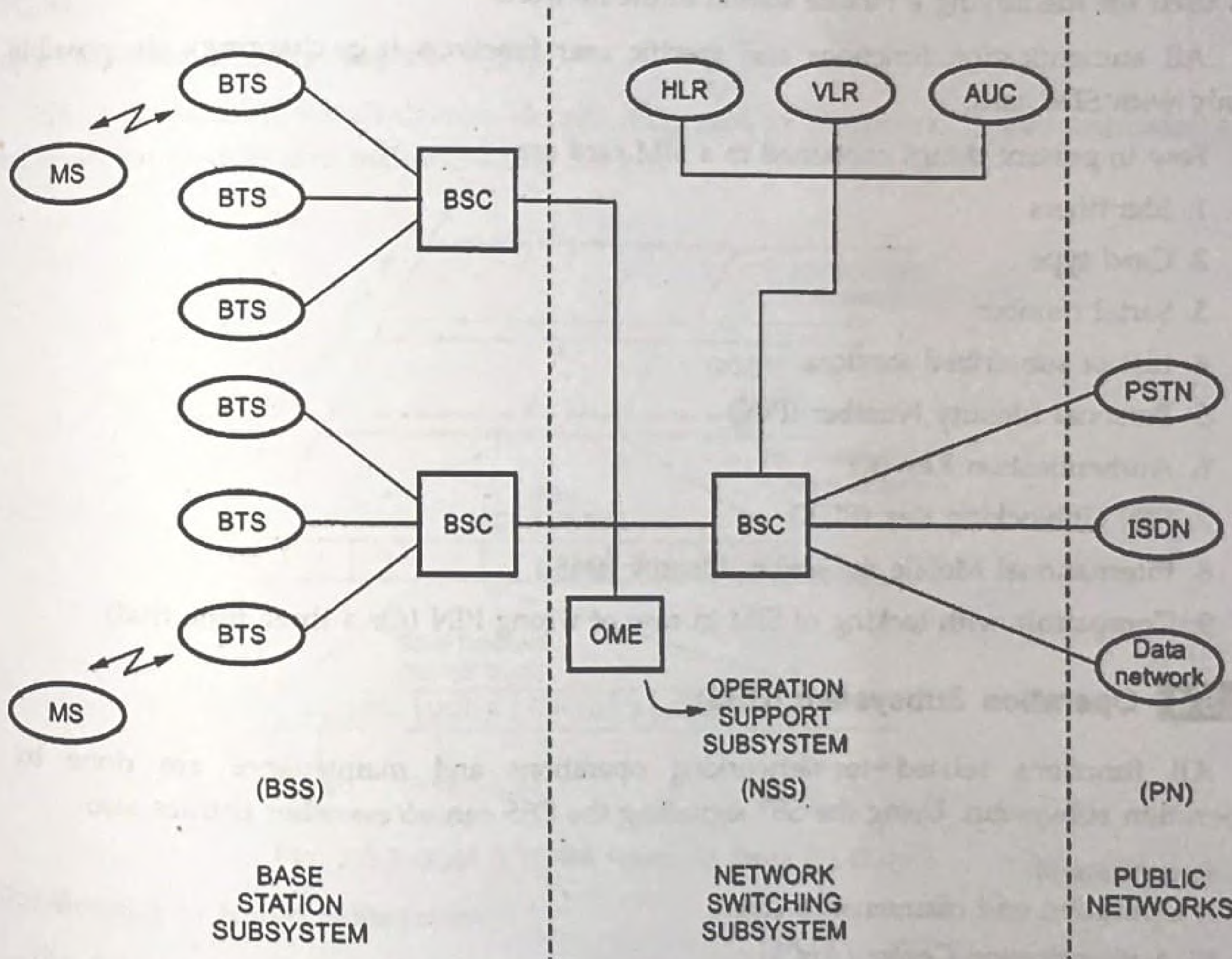


Fig. 2.6.2 GSM system architecture

2.6.3 Radio Subsystem (RSS)

In GSM architecture the radio subsystem 'RSS' consists of two main parts.

i) Mobile stations ii) Base station subsystem

In a GSM network, it has many Base Station Subsystems (BSS's) where each one is controlled by a base station controller called 'BSC'. It is equipped to perform all functions which are important to maintain an individual mobile station. The BSS unit also consists of many base transceiver stations BTS's.

The base station controller can manage many BTS's. It can reserve many radio frequencies, handing over functions from one base transceiver station to another base transceiver station. It can also perform paging operation of MS. The multiplexing of many radio channels onto a fixed network is possible.

The subscriber identity module termed as 'SIM' with all user related information are available with Mobile Station (MS). The International Mobile Equipment Identity (IMEI) is used for identifying a mobile station in the network.

All authentication functions and specific user functions (e.g. charging) are possible only with SIM card.

Few important things contained in a SIM card are

1. Identifiers
2. Card type
3. Serial number
4. List of subscribed services
5. Personal Identity Number (PIN)
6. Authentication Key (K)
7. PIN Unblocking Key (PUK)
8. International Mobile Subscriber Identity (IMSI)
9. Compatible with locking of SIM in case of wrong PIN (for a three time trial).

2.6.4 Operation Subsystem (OSS)

All functions related to networking operations and maintenance are done by operation subsystem. Using the SS7 signalling the OSS can access other entities also.

It consists of

i) Operation and maintenance centre

ii) Authentication Centre (AuC)

iii) Equipment Identity Register (EIR)

i) Operation and Maintenance Centre (OMC)

The functions managed by the operation and maintenance systems are

1) Traffic monitoring
2) Subscriber and security management including billing
3) Status of network entities in a report form.

OMC is subjected to the concept of TMN Telecommunication Management Network, which is standardized by ITU-T. OMC monitors and maintains each MS, BSC, BS and MSC within entire GSM system.

It is also responsible for integrity and performance of each subscriber equipment within the system.

ii) Authentication Centre (AuC)

The user identification, protection of all user information are taken care of by authentication centre. It can also be kept safe as a part of Home Location Register (HLR).

iii) Equipment Identity Register (EIR)

EIR is responsible for all devices identification used in a network. It also maintains a list of stolen devices and malfunctioning devices.

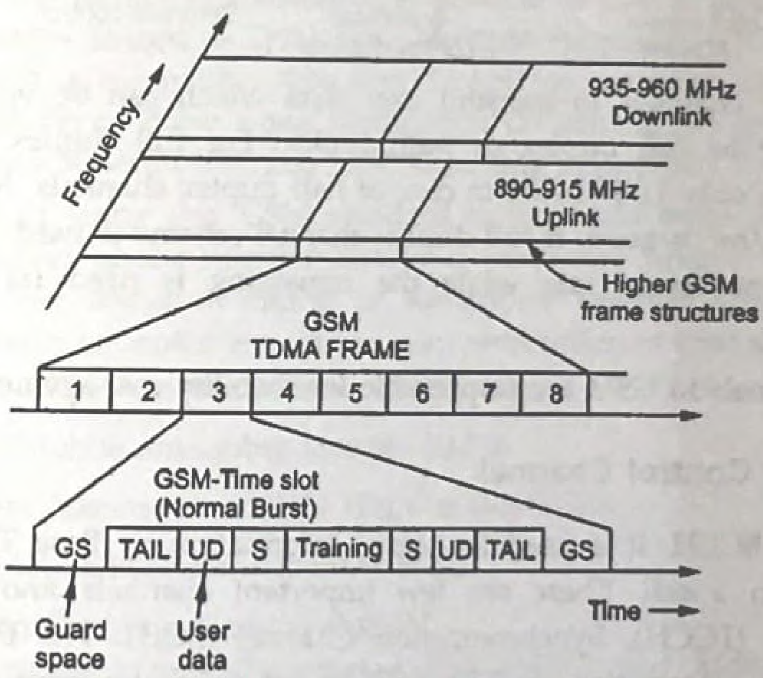


Fig. 2.6.3 GSM i) TDMA frame ii) Slots iii) Bursts

Significance of Radio Subsystem :

The frequency band used for uplink or (forward link) was 890-915 MHz and for downlink (Reverse link) was 935-960 MHz. The original frequency band for GSM was 25 MHz. The forward and reverse frequency bands are generally split into channels each with 200 kHz wide and they are known as Absolute Radio Frequency Channel Numbers (ARFCN's). It denotes forward and reverse channel pair and it is separated in the frequency of 45 MHz. TDMA concept can be used for time sharing to cover all subscribers.

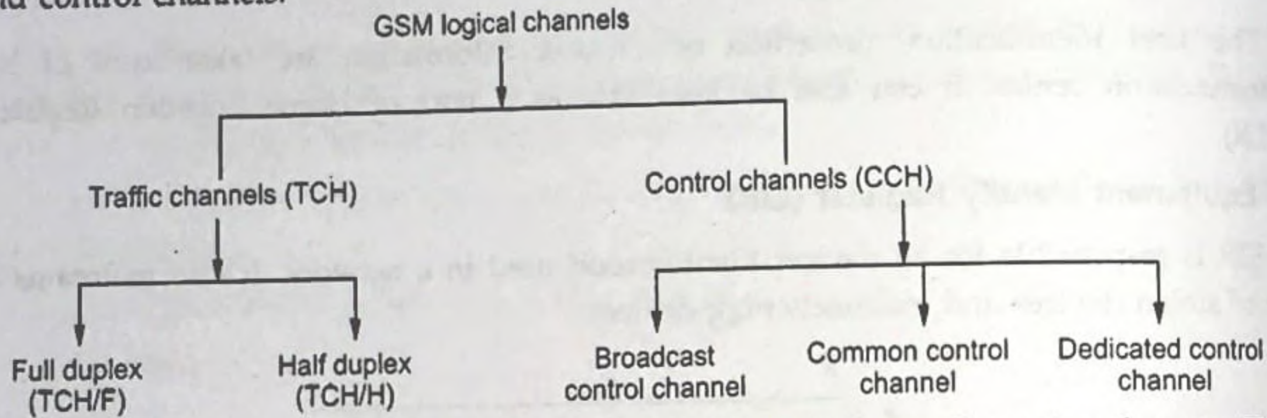
Data can be transmitted as portions known as burst. It (time slot) will contain user and signalling information. The middle of the time slot of the GSM frame has the

Training Sequence (TS) which is used to adapt the needed parameters of the receiver, and to select the strongest signal in multipath propagation environment.

2.7 Channels

AU : Dec.-18

GSM has different types of logical channels and they are separated as traffic channels and control channels.



GSM uses traffic channels to transmit user data which can be voice, fax etc. This traffic channel may be full duplex or half duplex. For full duplex the data rate is 22.8 kb/sec and it is only 11.4 kb/sec in case of half duplex channels. For GSM standard a data rate of 13 kb/sec is good. If full duplex channel scheme is used 13 kb/sec is used for actual data transmission rate while the remaining is used for error correction purposes.

The control channels in GSM are responsible for mobility management.

2.7.1 Broadcast Control Channel

It is denoted as BCCH. It is used for signal information by Base Transceiver Station (BTS) to all MS, in a cell. There are few important channels known as Frequency Correction Channel (FCCH), Synchronization Channel (SCH). The FCCH is used for frequency correction information by BTS. SCH is helpful to transmit information about time synchronization. Basically FCCH and SCH are subchannels of BCCH.

The Common Control Channel (CCCH) is related to information transferring with respect to connection setup between BS and MS, (exchanged whenever required). Whenever a call has to be setup the MS seeks help of Random Access Channel (RACH) for sending data to base transceiver station. All channels described so far are unidirectional. The dedicated control channels are bidirectional.

The Dedicated Control Channels (DCCH) maintain a low data rate using Stand Alone Dedicated Control Channel (SDCCH) till the MS establishes TCH with the BTS. Signalling to MS regarding usage of TCH or SDCCH for connection setups BTS makes use of Access Grant Channel (AGCH), under common control channels. In DCCH there are SACCH and FACCH. The TCH and SDCCH has Slow Associated dedicated Control

Channel (SACCH) and this channel is used for exchanging system information like signal power level and channel quality.

The channels (FACCH) are used for exchanging large amount of data in less period of time. Out of the three layers in GSM architecture the network layer plays a vital role in the sense it contains Radio Resource management (RR), Mobility Management (MM) and Call Management (CM).

The functions like call set, call maintenance and releasing radio channels are taken care by RR. Then registration, identification, authentication updating location, providing Temporary Mobile Subscriber Identity (TMSI replaces IMSI) are done by Mobility Management (MM). Finally the Call Management (CM) consists of three entities known as

a) Call Control (CC) b) Short Message Services (SMS)

c) Supplementary Services (SS)

Point to point connection establishment is possible in CM. It also provides functions to send in band tones known as Dual Tone Multiple Frequency (DTMF) over the entire GSM network. GSM is compatible with four 16 kbit/sec channels into a single channel of 64 kbit/sec and hence Pulse Code Modulation (PCM) can be applied for GSM. For signalling operations between BSC and MSC signalling system No. 7 (SS7) is used.

The advantage of using this GSM standard is its world wide localization of users facility. The particular phone number alloted is same and unique world wide and is quite a complex free design Roaming of subscribers between two providers in one country or in different countries is possible even with different providers.

To find or locate a MS the main features required are listed below :

i) International Mobile Subscriber Identity (IMSI)

ii) Mobile Station International ISDN Number (MSISDN)

iii) Temporary Mobile Subscriber Identity (TMSI)

iv) Mobile Station Roaming Number (MSRN)

Two opposite terms Mobile Terminated Call (MTC) and Mobile Originated Call (MOC) work very accurately in this network. MTC works in a situation where the calling station is outside the GSM network. MOC suits it to an environment when a call is purely initiated i.e. when MS transmits a request signal for a new connection in the GSM network.

The flow of messages for MTC and MOC under GSM are unique in nature.

In GSM network the movement of mobile station is around 250 km/hr. As the cell size is small (few kms) the faster will be the coverage done by MS.

When the mobile station moves out of the coverage range of Base Transceiver Station (BTS) handover is a must or when traffic is very high in a cell the handover is very important.

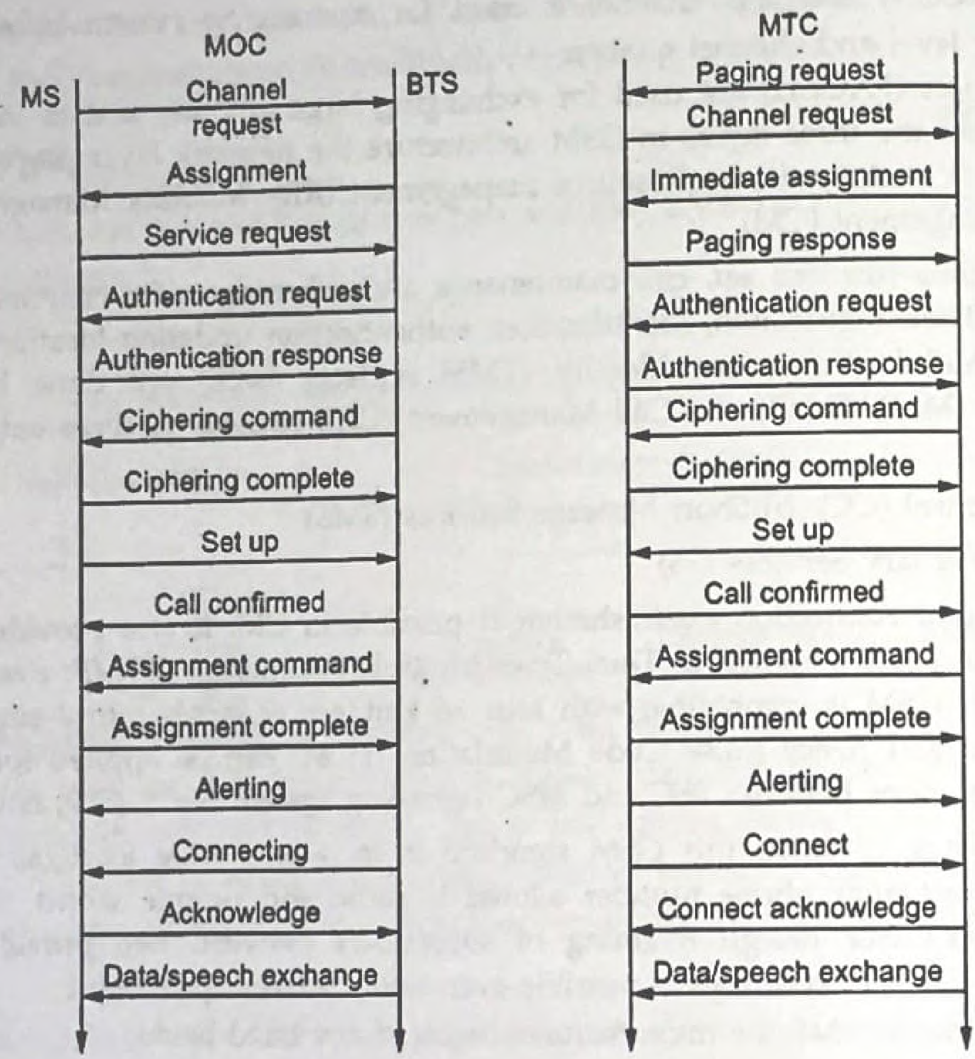


Fig. 2.7.1 Flow of message in MOC and MTC

1) In Intracell handover the base station may decide to change carrier frequency while narrow band interference is high which disturbs transmission.
2) In the second case though the mobile station enters another cell it is still in the proper control of BSC of cell. In this case the BSC will change handover at the new carrier frequency of that new cell.
3) In case 3, GSM has to provide some handover functions between the cells those are controlled by different BSC's. This is because the BSC's can control only limited number of cells in a network. Then the handovers has to be controlled overall by the MSC.
4) In fourth case in Inter MSC handover, the handovers may be required between different MSC's.

2.8 Mobility Management

AU : Dec.-18

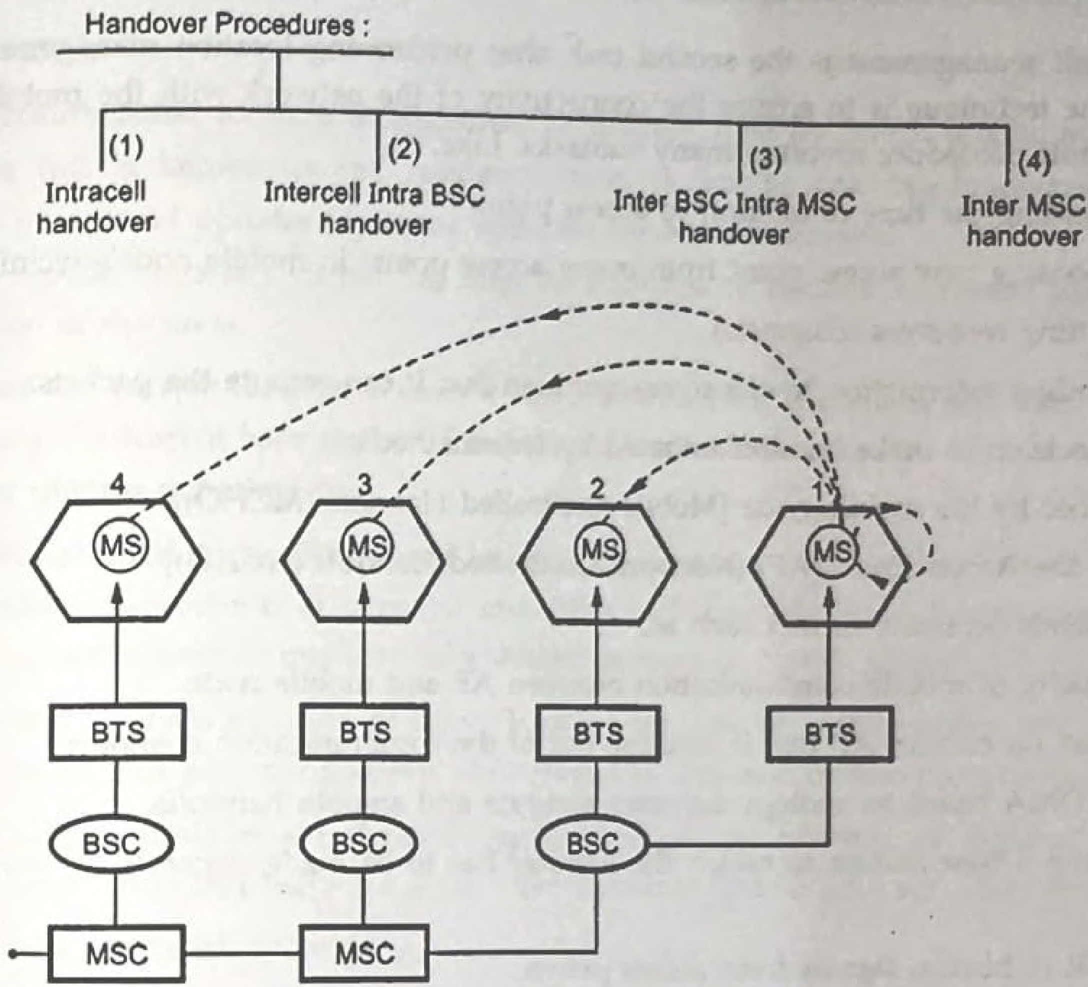


Fig. 2.7.2 Handover procedures

In mobile communication the mobile node changes its own physical location (i.e. address) in very less time. The mobility of user has to be strictly supervised so that it is easier to continue call communication smoothly. The methods of managing the mobility is hence very important. In such a procedure of mobility management there are two important types known as,

i) Location management. ii) Hand off management.

The location management procedure has two operations i.e. search and update.

Search operation : It is invoked by a node which needs connection establishment with that of a mobile node.

Update operation : It is also called as registration operation that is it gives information about the node's current location. The search operation is supported by the update operation. The search overhead (Cost) mainly depends on granularity and currency of the location information. Also organization of the location databases, location registrars is important because it stores the location related informations of the nodes.

Handoff management is the second task after performing location management. The aim of the technique is to ensure the connectivity of the network with the mobile node. The handoff procedure involves many subtasks. Like,

i) Deciding the time of handoff to access point.

ii) Choosing new access point from many access points in mobile node's vicinity.

iii) Getting resources (channels)

iv) Sending information to old access point so that it can reroute the packets.

The decision to make handoff initiated by two methods,

i) Either by the mobile node [Mobile Controlled Handoff (MCHO)].

ii) By the Access Point (AP) [Network Controlled Handoff (NCHO)]

It depends on many factors such as,

a) Quality of mobile communication between AP and mobile node.

b) Load on current AP that is running out of the communication channels.

The CDMA based technology assumes accurate and smooth handoffs.

Selecting a base station to which the handoff has to be made depends on few factors like,

i) SNR of beacon signals from access points.

ii) Mobile node's region may move in very short time intervals.

iii) Availability of the resources at the access point.

The main resources that has to be acquired in new cell are uplink and downlink channels.

Location management	- It assists in establishing new connections.
Handoff management.	- It ensures the connectivity of the mobile node with the network.

Both the operations completes mobility management.

Location management principles : The location management schemes uses many databases known as location registrars for maintaining the locations and other related information like service profile and preferences. One of the simple location management scheme which uses single location registrar is known as Home Location Registrar (HLR). It maintains location information of all mobile nodes in the network.

As a whole simple location management scheme performs both search and update functions.

Design Issues :

To perform better location management an average time for which mobile node stays within a cell is known as cell residency time. It has be calculated accurately. The periodic time-based updates (dynamic updates) has to be monitored.

- As a mobile node is switched on then its HLR has to notified to ensure the current position of the node.
- To find the current location of mobile node first its HLR is notified and then the HLR contacts the current base station of cell where the node is available.

Dynamic update schemes :

The Registration Areas (RA) based location updates is a static update scheme. It does not include measurements of dynamic mobilities of the mobile node. Boundaries of RAs found with the aggregate mobility information patterns of mobile nodes.

The static boundaries leads to many location updates of mobile nodes two adjacent RAs. These type of ping-pong effects are avoided in dynamic update procedures.

The periodic updates are dynamic updates. They are example of dynamic update scheme. Apart from this there are some more dynamic update schemes. They are ;

i) Movement-based updates.

ii) Distance-based updates.

Both the methods are dynamic location update schemes.

Note : To avoid roaming mobile node's location very often the technique known as per-user location caching can be used. For efficient implementation of the caching scheme the two parameters to consider are,

i) Location at which registrars has to be informed for caching.

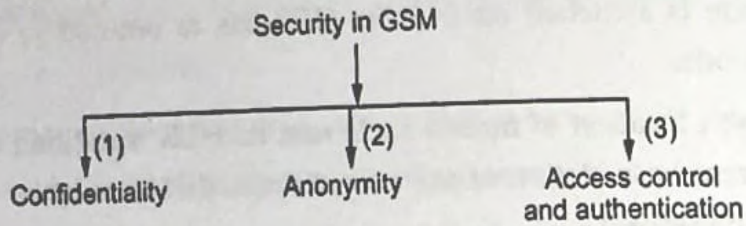
ii) At what time the location information has to be cached ?

The location information can be replicated. Partial replication is done under two organizations of location registrars. They are hierarchical and flat organization.

These location management procedures ensures the current location of the node. It is followed by the second task handoff procedure. Hence in mobility management both location and handoff management are done.

2.9 Security in GSM

The degree of security in GSM is higher with respect confidentiality information in Subscriber Identity Module (SIM) and Authentication Centre (AuC). Any unauthorised trial will be disabled and a PIN is maintained in this aspect.



1) Confidentiality :

To maintain confidentiality encryption and decryption techniques are used. The information about user (subscriber) is encrypted. Only an authorized person can decrypt it.

2) Encryption :

All information that are user related are encrypted. This ensures more privacy from the point of subscribers. If authentication process is over the base transceiver station and mobile station can work with proper encryption by using cipher key say 'K_c'. The Subscriber Identity Module (SIM), MS and the network calculate the same key 'K_c' which is based on a particular random value and the key itself is not transmitted. The cipher key 'K_c' is not generated using an individual key 'K_i', but generated using some random value with a particular algorithm intended for this purpose. The Base Transceiver Station (BTS) and the Mobile Station (MS) can encrypt at one end and decrypt at the other end. For example cipher key of 64 bits, is used.

3) Authentication :

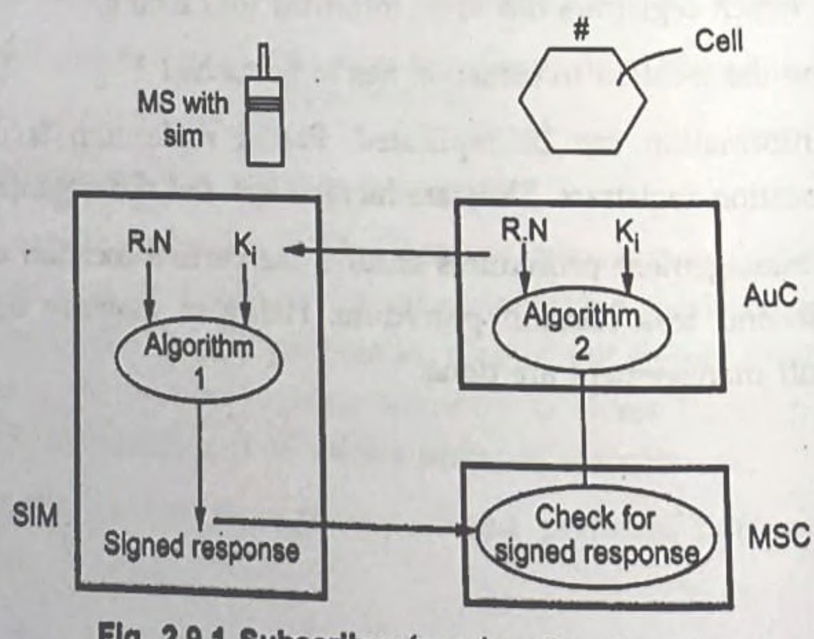


Fig. 2.9.1 Subscriber (user) authentication

Users can opt for any type of service that a GSM network can offer. The authentication is based on the SIM card that stores user related information. A Random Number (R.N) and Authentication Key (K_i) along with the specific algorithm is used for developing user authentication.

The access control generates a Random Number (R.N) and the SIM provides a signed response where Authentication Centre (AuC) does the basic generation of random values Random Number (R.N), signed response and secret key 'K_c'. Ultimately this is sent to Home Location Register (HLR). The visitor location register VLR sends random number R.N to the SIM where the subscriber and network does the same type of functions. When both match, the VLR will accept the subscriber (new) or simply it will reject it and hence higher user authentication is made possible in GSM networks.

Comparison of IS136, IS95 and GSM standards [2G standards].

Parameter	IS136	IS95	GSM
Year	1991	1993	1990
Type of access	TDMA	CDMA	TDMA
Spacing between forward and reverse channels	45 MHz	45 MHz	45 MHz
Bandwidth of channel	30 kHz	1250 kHz	200 kHz
Maximum power of mobile unit	3 W	0.2 W	20 W
Number of users per channels	3	35	8
Base station transmission band	869 MHz to 894 MHz	869 MHz to 894 MHz	935 to 960 MHz
Carrier signal bit rate	48.9 kbps	9.6 kbps	270.8 kbps
Bit rate of speech code	8 kbps	8/4/2/1 kbps	13 kbps
Frame size	40 msec	20 msec	4.6 msec

Table 2.9.1 Comparison of second generation mobile telephone systems

2.10 Mobile Number Portability (MNP)

The mobile number portability is related to routing of the mobile calls or sending messages (MMS or SMS) to a mobile number as it is ported. A central database (CDB) of the ported numbers is available. The network operator should copy the CDB status and has to decide which network should send a call to. This procedure is termed as All Call Query (ACQ) which is an efficient method with better scalability. The MNP systems follows the ACQ/CDB method for making call routing.

In case of decentralised model of the MNP a Flexible Number Register (FNR) can be used for managing database of ported in or ported out numbers for call routing procedures. Service providers uses HLR query services to findout the correct network of the cellular number whenever it routes messages and also voice calls to MNP enabled region.

The MNP provides more flexibility to the mobile users to change their service providers when required without changing their mobile number. The mobile gets attached to new service provider and the same number is used when the user is in roaming status.

The user can stay with his/her same cellular technology (GSM or CDMA). The MNP facility is allowed for both prepaid and postpaid users.

To port a number it would take sever working days (approx). The cost involved will be collected by the new service provider from the mobile user. One the service provider is changed it is expected to retain with this new provider atleast for three months period.

2.10.1 Tele-services in GSM

GSM provides voice-oriented tele-services. It comprises of encrypted voice transmission, data communication as PSTN, message services. The main goal of GSM is to provide high quality digital voice transmission. In GSM it offers emergency numbers. For an user the same number can be given and it can be used in entire Europe.

GSM provides simple short messaging services known as SMS where upto 160 characters transmission of message is possible. An extension of SMS, Enhanced Message Service (EMS) is allowed in which larger Message transmission upto 760 characters is permitted. Also next to EMS there is Multimedia Message Service (MMS) is provided by GSM. Here it offers larger picture transmission (GIF, JPG etc). Short video clippings can be sent.

A non-voice teleservice of GSM is group 3 fax service. In this fax data is sent as digital data. Using a transparent bearer service, fax data and fax signalling is done.

GSM hence provides many teleservices in the wireless network.

Note To increase the market value the MNP technique helps more by providing flexibility to mobile users.

2.11 General Packet Radio Service (GPRS) AU : June-16,17, Dec.-16

The General Packet Radio Service (GPRS) provides efficient packet mode of data transfer. GPRS is popular because it provides a cost effective packet services supporting internet applications.

GPRS allows other services like,

- Unicast
- Multicast and
- Broadcast

The important concepts of GPRS are :

i) The GSM system is capable of allocation time slots [from one to eight] in a time division multiplexing access frame for the GPRS radio channels.

ii) Demand based time slot allocation.

iii) Depending on a coding technique it is possible to have data rate up to 150 kbps with GPRS.

iv) The maximum data rate is not limited by GPRS.

v) GPRS is independent of the characteristics of radio channel.

vi) GPRS is dependent on type of the radio channel.

vii) GPRS supports point-to-point packet transfer service.

viii) With GPRS it is possible to maintain a virtual circuit within GSM network in case of change of the cells.

Security services provided by GPRS :

1. Access control
2. Authentication
3. User information confidentiality
4. User identity security

Reliability classes possible in GPRS (as per ETSI) :

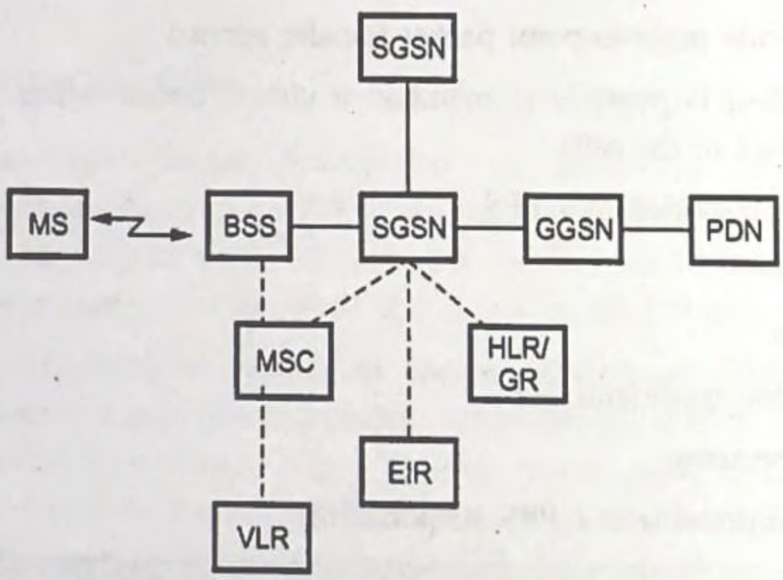
Reliability Class	Service Data Unit (SDU)	SDU Probability	Duplicate SDU Probability
1	10^{-2}	10^{-2}	10^{-5}
2	10^{-4}	10^{-6}	10^{-5}
3	10^{-9}	10^{-9}	10^{-9}

GPRS provides many services without restricting data rates of transmission. The service precedence namely high, low, normal, reliability class, throughput and delay are determined by QoS profile. The delay in GPRS is mainly due to transmission delay and channel access delay in the network and GPRS does not append additional delay. Many security services like user authentication, access control, user information confidentiality, user identity confidentiality are enabled with GPRS. There are also two important network elements available that plays a vital role in performance of GPRS.

They are GPRS support nodes called as GSN. There are many interfaces available for flexibility and system efficiency. The gateway GPRS support node acts between GPRS network and external Packet Data Networks (PDN). The CGSN is connected to other external networks like X.25 standard.

The General Packet Radio Service (GPRS) facilitates packet mode transfer for specific applications. This scheme involves a fully packet oriented data transmission.

For GPRS the GSM scheme allots between one and eight time slots within a TDMA frame structure. Demand assignment of time slots is possible and hence flexibility is high with GPRS. Fixed and preassigning of TDMA time slots is not a must. Point to point packet transfer service is allowed in GPRS which enables maintaining circuits in GSM network. A data rate of 150 kb/sec is generally met. The GPRS concept is not dependent on channel characteristics.



SGSN - Serving GPRS support node.
HIR - Home location register.
VLR - Visitor location register.
GR - GPRS register.
GGSN - Gateway GPRS support node.
PDN - Packet data network
EIR - Equipment Identity Register

Fig. 2.11.1 'GPRS'-General packet radio service architecture

The data packets are transmitted from the PDN through the SGSN and GGSN which is directed to MS finally via BSS. The proper procedures of mobility management are also met. For data encryption purpose, a temporal identifier Temporal Logical Link Identity (TLLI) and a Ciphering Key Sequence Number (CKSN) are used. In GPRS transmission plane protocol structure, using the GPRS Tunnelling Protocol (GTP) all data transfer are done within GPRS (between GSN's). The reliable protocol TCP or

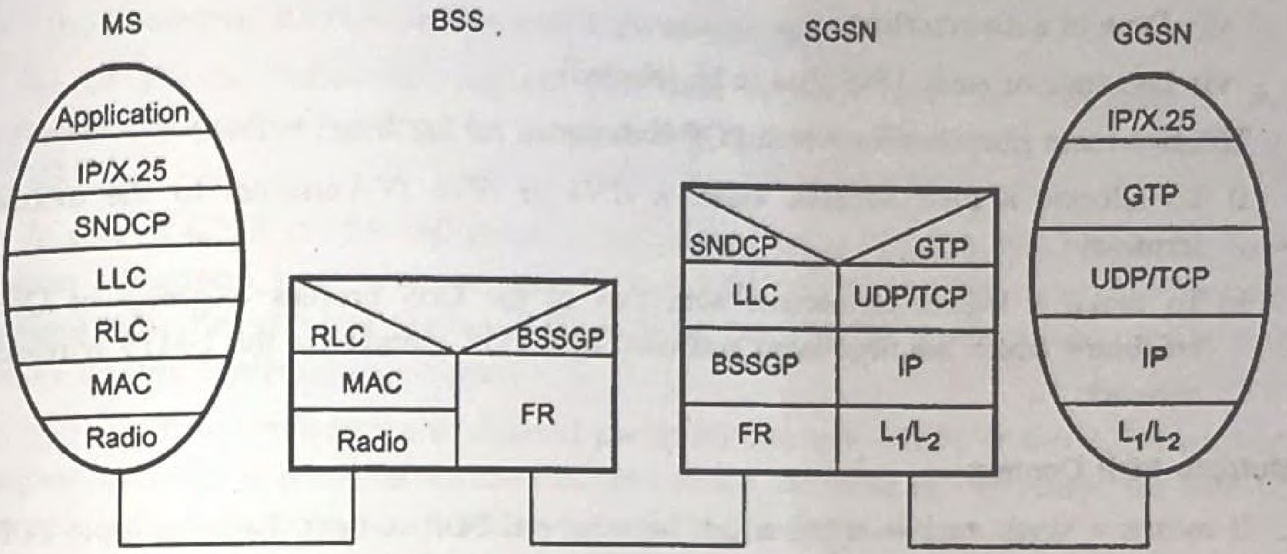


Fig. 2.11.2 GPRS - Transmission plane protocol-reference

non-reliable protocol namely UDP are two different protocols where any one of them can be used GTP. To adopt different characteristics of underlying networks in the system. Subnetwork Dependent Convergence Protocol (SNDCP) utilized between MS and SGSN.

Mainly the routing and QoS informations are sent with the help of Base Station Subsystem GPRS Protocol (BSSGP). Medium Access Control (MAC) with proper signalling procedures for radio channels and mapping the LLC frames with that of GSM channels and radio link protocol namely RLC facilitates reliable link.

The GPRS is an optimum and better system for transmission of packet-oriented data transmission.

2.11.1 PDP Context Procedure

The Packet Data Protocol (PDP) context provides a packet data connection with which Utran Equipment (UE) and the wireless network can exchange their IP packets. The usage of the packets data connections are restricted to particular services. They are accessed through access points. The PDP context is very important for UMTS packet data architecture.

To establish an end to end connection the PDP context has a record of the parameters that consists of required information.

Some of them are ;

i) PDP type.

ii) Address type of PDP.

iii) Quality of service (QoS) profile request.

iv) QoS parameters negotiable with network.

v) Type of authentication.

vi) Dynamic or static DNS (has to be selected)

The two main purposes for which PDP is designed for are listed below.

i) To allocate a PDP address, either a IPV4 or IPV6 (V-Versions) to the mobile terminal.

ii) To make a logical connection with that of the QoS profiles a group of QoS attributes which are negotiated and used by a PDP context via the UMTS wireless network.

Multiple PDP Context

It means a single mobile terminal can have several PDP context. Each multiple PDP contexts can have different QoS profiles at same time. The primary PDP context will be activated first. In case of multiple PDP context each context has many PDP address and different APN.

The multiple PDP contexts has two sub classifications like ;

(i) Multiple primary PDP contexts which can provide connectoins to the different PDN's.

(ii) Secondary PDP contexts to offer connections to same PDN with varius QoS.

Through many PDP's are available in multiple PDP context each one of them has unique PDP address. They allow simultaneous connections to many PDN's like internet for a single application. Each PDP context has its own QoS progile RAB (Radio Access Bearer), GTP tunnel, and NSAPI (Network Layer Service Access Point Identifier.) Each PDC in multiple PDP are independent of each other.

Note A secondary PDP context is associated with primary PDP context. The PDP address (i.e. IP addr) and its Access Point (AP) can be reused from the primary context. Both the primary and secondary PDP context can offer connection to same PDN with their own QoS.

2.11.2 Combined RA / LA Update Procedures

In General Packet Radio Service (GPRS) network the combined Routing Area/Location Area (RA/LA) update procedure is been used. The Mobile Station (MS) sends the routing area update request message to new SGSN.

For both the UMTS and GPRS systems the update types are namely,

(i) RA update. (ii) Periodic RA update.

(iii) Combined RA/LA update.

(iv) Combined RA/LA update with IMSI attachment.

In UMTS the 'follow on request' parameter is been used for indicating if the connection should be retained for any pending uplink traffic. This is not available in GPRS.

In case of GPRS it adds cell global identity information (RA, LA etc.) before the base station subsystem pass the messages to the SGSN. In GPRS the timer mechanisms ensures wheather Mobile Station (MS) initiates inter SGSN routing area update just before current updating procedures.

The old SGSN will forward buffered packet data to new SGSN. If the SGSN context request message is not received then the old SGSN continues its procedure. (In case of security fail). But the next step will be followed (In case of security success).

In RA/LA updates the new SGSN sends SGSN context acknowledge. Message to old SGSN that invalids SGSN-VLR (Visitor Location Register) association in the old mobility management context.

Then the new SGSN sends the update PDP context request message to GGSNs. As the message is received the GGSN PDP contexts are then modified.

Now the SGSN issues the update location information to inform HLR (Home Location Register) about the change of MS.

The old SGSN and HLR will exchange their cancel location message pair.

Then the HLR will insert the subscriber data to new SGSN.

For every PDP context that is active, extra tasks are been performed by SGSN.

Then location update (LA) will follow. A lookup table is maintained. Referring it the SGSN translates RA identity into VLR number and then sends the location update request message to VLR. It updates or creates the SGSN-VLR association.

Now the systematic GSM location update procedure is followed.

The new SGSN transmits routing area update accepting message to mobile station.

Then routing area complete message is sent by MS to new SGSN. If required reallocation complete message will follow it.

Note In GPRS during RA update packet forwarding is done between new and older SGSN.

2.12 Universal Mobile Telecommunication System (UMTS)

AU : June-16, Dec.-16,17, May-18

2.12.1 W-CDMA (UMTS) – Third Generation Cellular System

The third generation cellular system, Universal Mobile Telecommunications System (UMTS) is an air interface and it was evolved in the year 1996, under European Telecommunications Standards Institute (ETSI). In third generation wireless telecommunications standards, UMTS is very popular due to its services and applications. The UMTS was submitted to International telecommunication union's IMT-2000 body by ETSI in the year 1998. The UMTS is also known as UMTS Terrestrial Radio Access (UTRA). The goal of UMTS was to provide high capacity cellular system. This UMTS (W-CDMA) technology has a smooth transition from 2G system so that it has a better backward compatability.

This 3G UMTS has the speciality such that any entertainment device, computers and telephone etc can access this wireless air interface network and can be connected to internet from anywhere and at any time. The packet data rate supported by UMTS is upto 2.048 Mb/sec for single user. There are many other features for W-CDM such as,

i) It provides private and public network features.

ii) The W-CDMA needs allocation of 5 MHz frequency spectrum and it is a significant difference when compared to other standards.

iii) It has interoperability for all GSM, GPRS, IS-136 (PDC) and EDGE applications.

iv) It applies direct sequence spread spectrum chip rate more than 16 megachips/sec for single user.

v) This system provides atleast six times the spectrum efficiency than a GSM standard.

2.12.1.1 UMTS - An Overview

The European proposal for IMT-2000 is called as Universal Mobile Telecommunication System (UMTS). It made a big revolution in the third generation era. The group of special mobile (GSM) enhancement towards UMTS is often known as "EDGE" technology which stands for enhanced data rates are upto 384 kbits/sec using 200 kHz wide carrier with same frequencies as that of GSM. The basic structure of UMTS comprises of user equipment, radio network subsystem and core network. UMTS supports FDD and TDD modes. The FDD mode for UTRA uses the wideband CDMA (W-CDMA) with direct sequence spread spectrum (DSSS) scheme. Hence the up and downlinks under FDD uses different frequencies. The uplink carrier is around 1920 to 1980 MHz.

GSM also fits itself into ETSI and termed as global multimedia mobility (GMM). UMTS provides different services.

1. Real time services
2. Bearer services
3. Non real time services
4. Circuit and packet switched methods of transmissions.

2.12.1.2 UMTS - Architecture

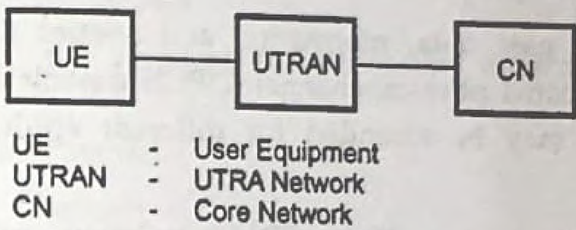


Fig. 2.12.1 UMTS - architecture - Basic block diagram

The UTRA network called as 'UTRAN' enables cell level mobilities and it has many radio network subsystems (RNS). The main functions of RNS is listed below.

1. Call handover control
2. Channel ciphering and deciphering
3. Radio resource management

In the architecture of UMTS, the user equipment (UE) is connected to core network 'CN' via UTRAN block.

Functions like,

1. Gateways to other (external) networks
2. Inter system handover are handled by core network

There are two types of modes compatible with UTRA system.

a. UTRA FDD mode

b. UTRA TDD mode

The wideband CDMA namely W-CDMA is used for UTRA FDD and up and downlinks use separate frequencies. FDD mode can provide 250 channels (approx), for handling user traffic; (e.g. voice channel facility). Direct sequence spread spectrum (DS) coding is compatible and data rate of 2 Mbits/sec can be achieved here. Many logical and physical channels can be assigned. User data (from layer two and higher layer) is sent over uplink dedicated physical data channel (uplink DPDCH) and in UTRA, the FDD mode makes use of wideband CDMA (W-CDMA) along with Direct Sequence Spreading (DSS). The mobile uplink frequency range is from 1920 MHz to 1980 MHz and the downlink frequency used by base station is from 2110 MHz to 2170 MHz. It is possible to accommodate 250 channels approximately with this specified frequency spectrum range. Like GSM, in UTRA technology there are logical and physical channels available for the users. In uplink the uplink dedicated physical data channel (uplink DPDCH) is used to transport user data/information. The uplink dedicated physical control channel (uplink DPCCH) is used in transport layer to control data (like data used for controlling power).

The control data from mobile station is carried by physical random access channel (PRACH) for random access purposes.

In downlink case the user data/information and control data from layer one are carried by downlink dedicated physical channel (DPCH downlink). The chip rate may be 4.096 Mchip/sec and it may be extended for different applications in future upto 16.384 Mchip/sec.

The modulation scheme used is QPSK. CDMA technique which is compatible with UTRA has many features like,

i) Localization of mobile stations.

ii) Soft handovers.

iii) High degree of accuracy.

CDMA scheme has a drawback of "complex power control" during a "call progress".

2.12.1.3 UTRA - TDD Mode

The time division duplexing mode of the UTRA technology makes use of wideband TDMA/CDMA for the medium access and the up/down links uses the same frequency. The data rate is 2 Mbit/sec for about 120 channels (approx) in case of the user traffic. The direct sequence (DSS) type of spreading code is applied and the modulation scheme used is QPSK. In TDD the power controlling can be slower than the FDD because the number of power controlling cycles in one second are less. It is worth noting that the frame structures of FDD and TDD are same and hence both the schemes can coexist in necessary conditions.

The W-CDMA-UMTS is also called as UTRA-FDD. The physical layer of this standard can be related to be radio interface when observing one particular link between base station and a terminal. The air interface protocol structure of WCDMA is shown below.

The physical layer provides transfer services information to the next layer using various types of channels. While considering channels there are three important types of channels which have to be considered. They are

i) Logical channels

ii) Transport channels

iii) Physical channels

2.12.2 Protocol Structure of W-CDMA (UMTS)

In the protocol structure block diagram all the three channels are shown. The **logical channels** are responsible for transfer of information between RLC and MAC layers. The physical channel clearly defines the required code and frequency ranges for both up and downlinks. The characteristics of the data/information is sent over the channel by transport channels. In the W-CDMA the physical layer provides services to the respective MAC layer through the transport channels.

i) Physical Channels in W-CDMA

In W-CDMA some of the physical channels carry information on the downlink channels as listed below.

- CPICH (Common Pilot Channel)
- SCH (Synchronization Channel)
- AICH (Acquisition Indication channel)
- PICH (Paging Indication Channel)
- CSICH (CPCH Status Indication Channel)
- CD/CA-ICH (Collision Detection/Channel)
- Assignment indication channel

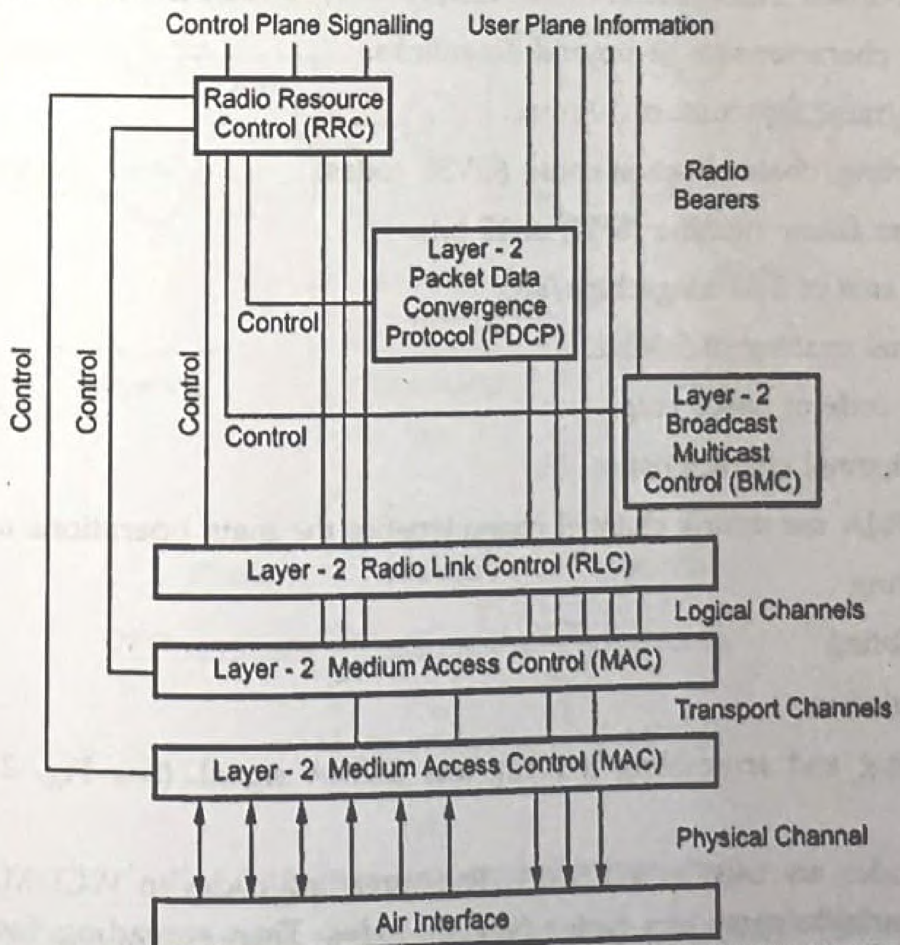


Fig. 2.12.2 Air interface protocol structure of W-CDMA (UMTS)

The first two channels CPICH and SCH have to be transmitted by every base station. The various transport channels are mapped on different physical channels. A few physical and transport channels are identical. Let this group be X.

On the other hand a few physical channels act as carriers for a portion of the transport channels. This group of channels let it be denoted as Y. A simple mapping of transport channels onto physical channels is shown below.

	Transport channel		Physical channels
Group X	RACH	→	PRACH (Physical Random Access Channel)
	BCH	→	PCCPCH (Primary Common Control Physical Channel
	DSCH	→	PDSCH (Physical Downlink Shared Channel)
	CPCH	→	PCPCH (Physical Common Packet Channel)
	PCH FACH	→	SCCPCH (Secondary Common Control Physical Channel)
Group Y	DCH	→	DPCCH (Dedicated Physical Control Channel)
		→	DPDCH (Dedicated Physical Data Channel)

Thus the transport channels are mapped onto the physical channels.

Then the important transmission characteristics of W-CDMA includes,

1) Identical characteristics of up and downlinks.

   i) Radio frame structure of 10 msec.

   ii) Spreading/channelization codes (OVSF codes)

   iii) System frame number (SFN) of 12 bits.

   iv) Chip rate of 3.84 Megachips/sec

   v) Channel spacing of 5 MHz.

   vi) Long code of 38400 chips.

2) Uplink channel characteristics.

   In W-CDMA the uplink channel characteristics the main operations are

   i) Spreading

   ii) Scrambling

   iii) Modulation

After spreading and scrambling it forms the CDMA signal. (See Fig. 2.12.3 on next page).

The Walsh codes are used in WCDMA. The spreading codes in WCDMA are known as orthogonal variable spreading factor (OVSF) codes. Then spreading factor can vary from 4 to 512. This standard uses 3.84 megachips/sec chip rate and maintained as constant. By using shorter spreading codes higher data rates and by using longer spreading codes lower data rates are obtained. Thus by decreasing spreading factor the data rate can be increased. But it will also reduce the number of cellular users which can be supported. The reason is fewer codes are only available in case of shorter spreading factor.

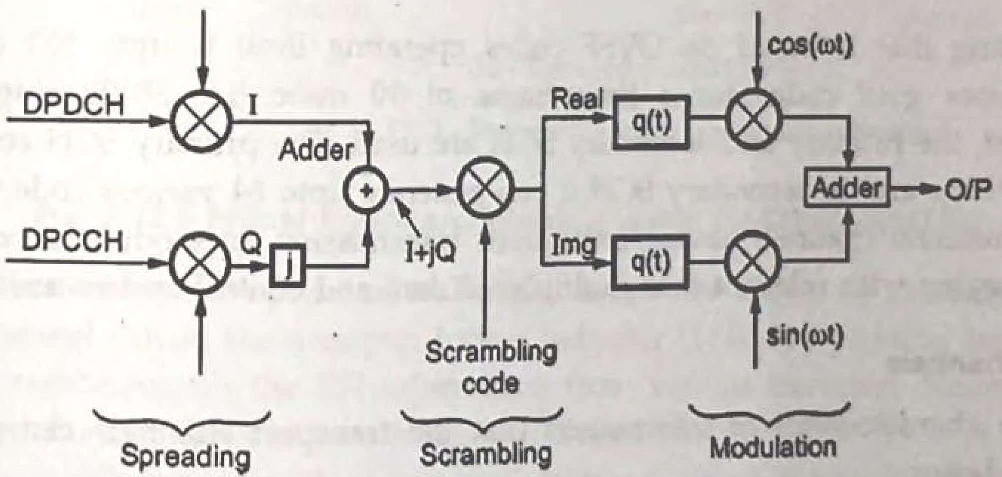
In case of demodulation pilot symbols are used. The channels DPCH, CCPCH and the PRACH carriers pilot symbols.

In spreading at the transmitter end, the channelization code is capable of identifying the physical data channels DPDCH and control channels (DPCCH) with the code length.

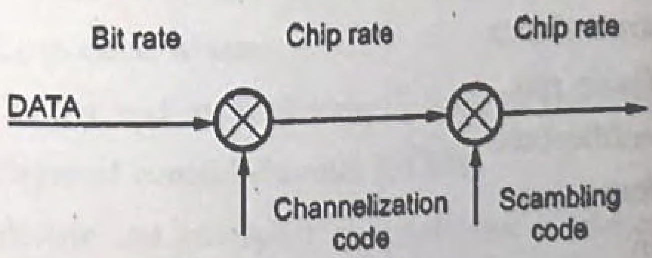
The process of scrambling follows the spreading. It uses gold code that has a pseudorandom characteristics. The long code has 10 msec frame and used at rake receiver in base station. The short code is used when the base station applies multiuser detection techniques.

In modulation combine Inphase-Quadrature, code multiplexing is used (i.e. dual channel QPSK scheme).

The transmission power can be reduced by having faster power control in the uplinks.



(a)



(b)

Fig. 2.12.3 Transmission characteristics

a) W-CDMA (UMTS) uplink spreading, scrambling and modulation operations
b) Spreading and scrambling

In downlink channel characteristics the same functions dealt under uplink are done and at first the DPCH serial bits are converted to parallel bits so as to have correct mapping in inphase and quadrature branches effectively.

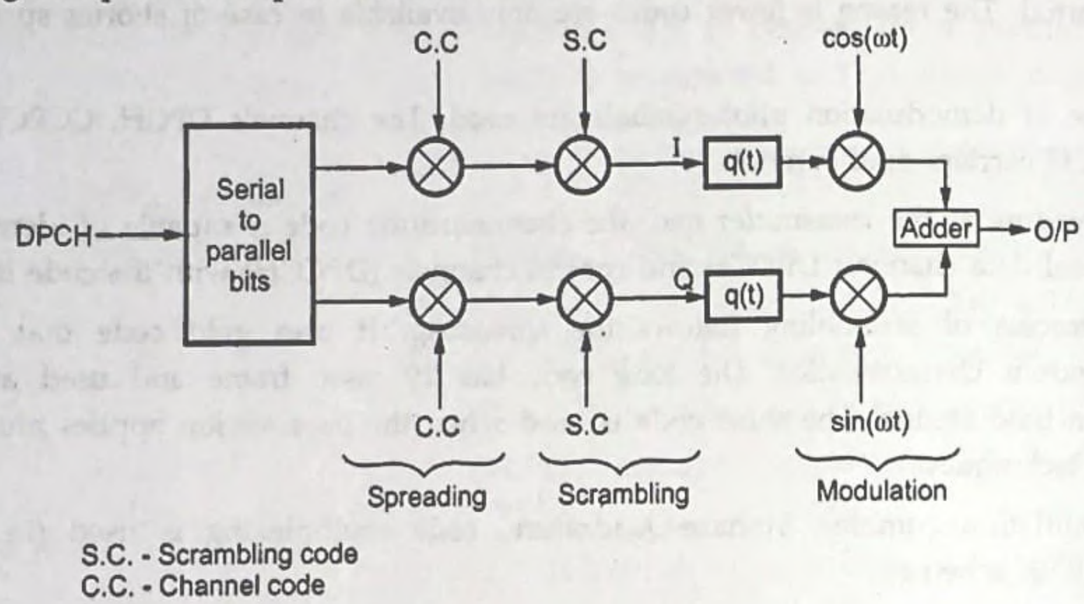


Fig. 2.12.4 WCDMA (UMTS) Downlink operations, spreading, scrambling and modulation

In spreading that is based on OVSF codes operating limit is upto 512 chips. The scrambling uses gold codes for a time frame of 10 msec (i.e. 38400 chips). Under channels SCH, the primary and secondary SCH are used. The primary SCH consists of a code of 256 chips and in secondary SCH it can generate upto 64 various code words, for identifying common channels having continuous transmission. In modulation quadrature phase shift keying with relevant time-multiplexed data and control system are used.

Transport Channels

The main characteristics of information that the transport channels can provide is summarized below :

i) The shared information for up or downlink.

ii) The control information for up or downlink.

iii) Power control characteristics.

iv) Managing the collision risk.

v) Mobile station identification.

vi) Beam forming information.

vii) Data rate variation.

viii) Broadcast coverage area

- In entire cellular area or in a selected cell alone.

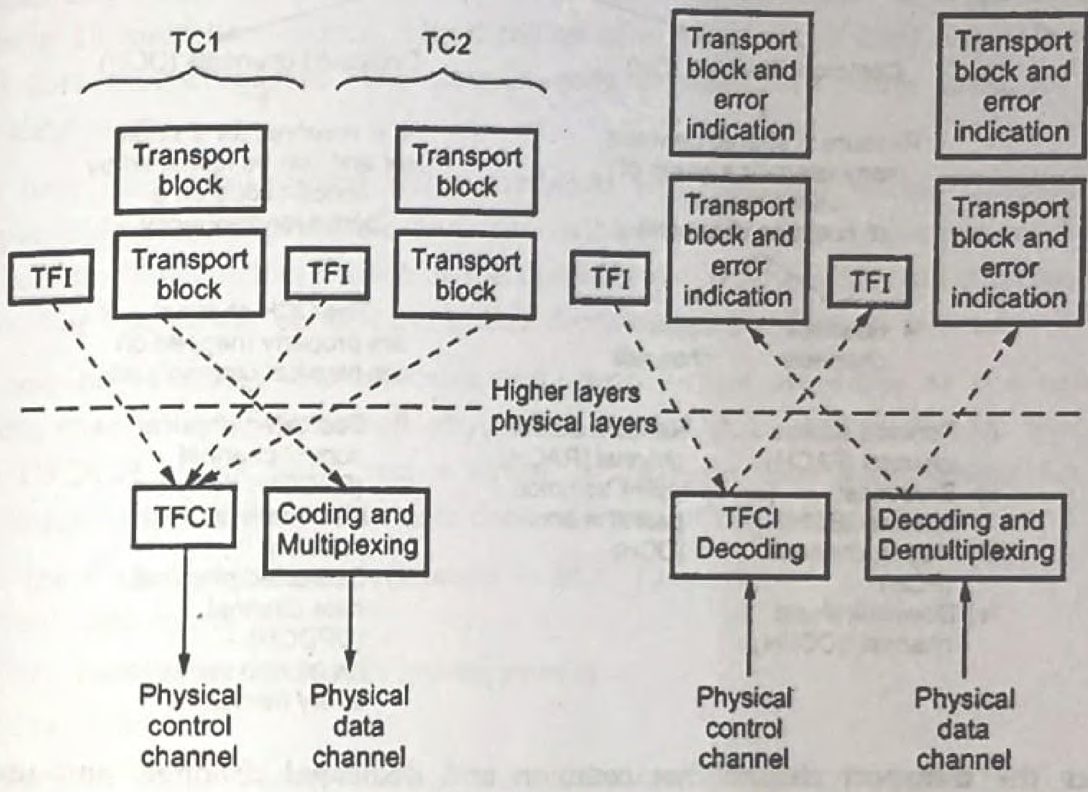


Fig. 2.12.5 Higher layers and physical layers (W-CDMA (UMTS))

The interaction between physical and higher layers are shown in the diagram. Every transport channel carries the transport format indicator (TFI). The physical layer does the function of combining all the TFI information from various transport channels to form the Transport Format Combination Indicator denoted as TFCI. This TFCI is useful as it informs the mobile equipment about availability of active transport channel, in the current frame.

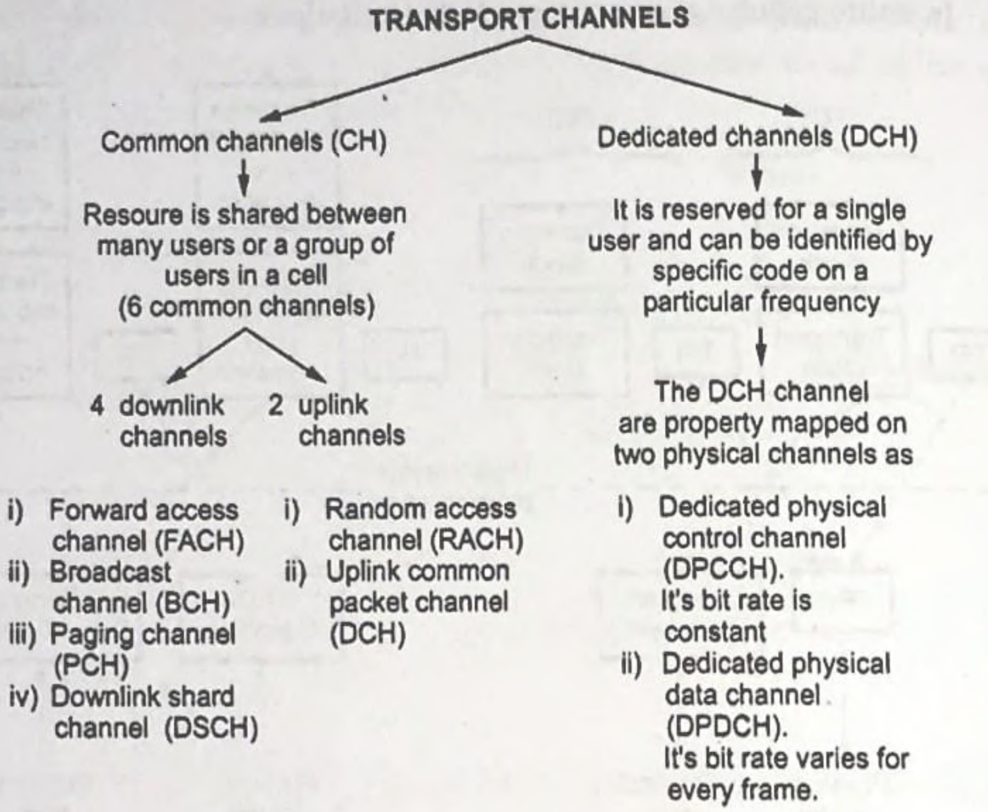
The TFI is added to each TC such that

{TFI + TC} is done where

{TC} → Coding and multiplexing in bank of transport channels.

and {TFI} → Physical control channel (PCEH)

It is possible to divide the transport channels into common channel and dedicated channel for a specific operation.



Hence the transport channel has common and dedicated channels and uses them according to the nature of the operational requirement, in transport channels of W-CDMA(UMTS).

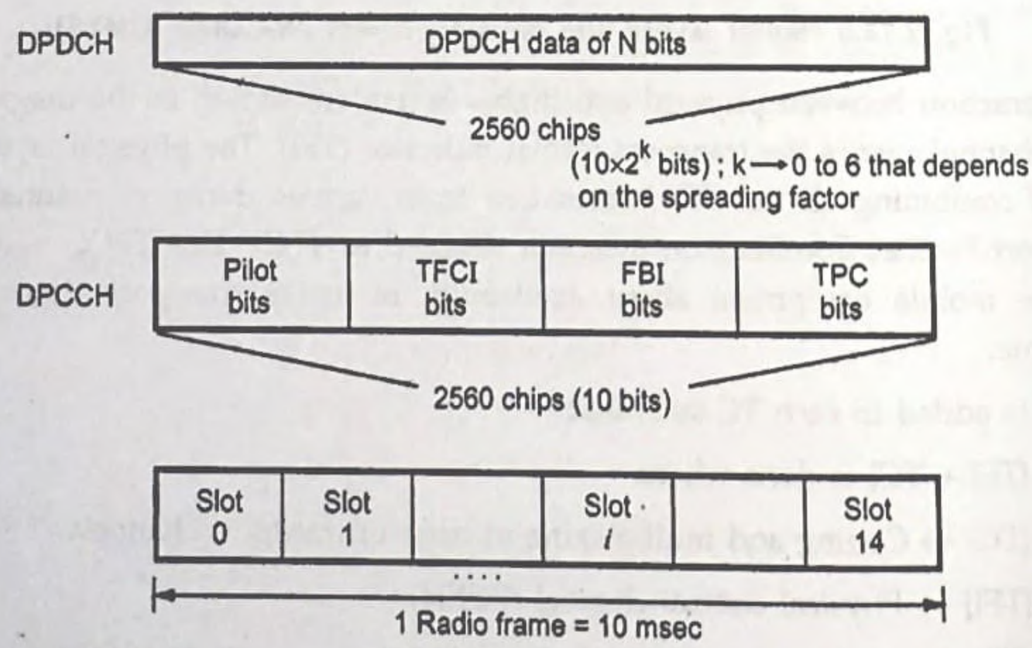


Fig. 2.12.6 The uplink DPDCH and DPCCH frame and slot structures

User Data Transmission

In the user data transmission it makes use of slot structure of radio frame with 15 slots in 10 msec time period. The duration of a slot is about 2560 chips. It has a chip rate of 3.84 megachips/sec. The parallel code channels are being used for handling higher data rates.

The user data transmission when combined with Random Access Channel (RACH) has a particular future preamble and it is sent before the data transmission. The uplink frame and slot structure is shown in the diagram above where one radio frame period is 10 msec. For fast power control the uplink common packet channel is used.

In case of downlink the bit rates and symbol rates are same as the uplink. The downlink channel is of dedicated physical channel (DPCH) and (DPDCH) type. The bit rate in DPDCH is not fixed and it varies. It also uses time multiplexing for physical control information and also the user data information respectively.

Also there are three classes of frames in RLP. They are

i) New data frame :

They are transmitted with lowest priority.

ii) Control frames :

They are used to carry control information and it is given top priority.

iii) Retransmitted data frame :

They are meant for retransmitting the old data frame according to instructions given.

2.12.3 Communication between Layers and Sublayer

Structures :

Establishing communication between the respective layers and sub layers is done using primitives. The MAC, LAC and layer 3 (upper layers) uses the primitives for passing the data and control information between intended layers. Also the actual data unit is considered as a parameter of the respective primitive.

Consider that a PDU has to be sent from LAC sublayer. Now the LAC sublayer will invoke the service data unit (SDU) primitive to request the service from the MAC layer. There are four different primitives which are effectively used for communication. It is shown in the diagrams below for both the transmit and receive side.

E.g. : Transmit side :

i) Consider layer 3 wants to send a PDU. It makes a request for service from the next LAC sublayer by using the L2-data primitive as shown.

ii) If the SAR or LAC sublayer need to transmit a PDU i.e. from layer 3 then the LAC sublayer will invoke the SDU ready primitive thus requesting a service from respective MAC layer.

iii) In case if enough space is available for bearing data transfer function over physical channels then the MAC layer transmits the "Availability-Primitive" to express the event occured, as an indication to the service requester.

iv) Once the 'Availability-Primitive' is received, the LAC sublayer transmits MAC-Data primitive to that of the MAC, for requesting data transport service effectively.

On the other hand there are two important primitives which are used at receive end.

Receive side :

i) The MAC layer makes use of the MAC-Data primitive to the LAC sublayer.

ii) Once the processing is over, then it is informed to layer 3 as follows. The LAC sublayer sends a PDU using 'L2-Data primitive' to the layer 3 to express the reception of signalling data.

Upper layer in the structure :

The operation of the entire IS-2000 system is controlled effectively by the signalling entity. There are four main states available, namely,

i) Mobile station initialization

ii) Mobile station idle

iii) System access

iv) Mobile station control on traffic channel

All these four states have similarity with the IS-95 standard as backward compatability.

Also the packet data transmission involved has three modes when the mobile is in traffic channel substate. The modes are

a. Active mode b. Control hold mode c. Dormant mode

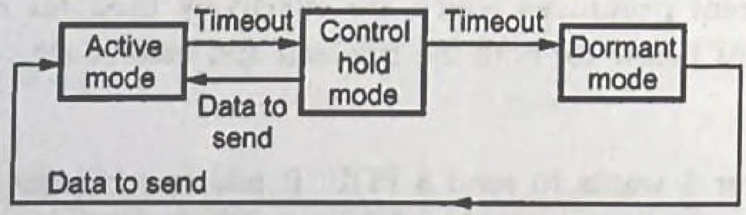


Fig. 2.12.7 Packet data transmission with three modes

In the active mode there is exchange of user packet data and the respective dedicated signalling data between base station (BTS) and the mobile station (MS). Then the control mode in packet data transmission helps to maintain the MAC control and the power control functions using dedicated control channel in the system.

Finally the dormant mode is mainly applied in 'mobile station idle state' to keep the information regarding user's packet data service registration (UPDR) and relevant connections. At any point a mobile is in any one of three modes or in a state of transition between these modes. In addition to this the signalling entity also keeps track of setup, maintenance etc. regarding a call. Thus the call processing functions are effectively handled by the signalling entity in the system.

Power Control

It is very important to have proper power control in forward and receive end under cdma 2000 standard to improve accuracy and speed and finally system capacity. At the receive end the power control is mainly to reduce the differences in the power levels of signal that is received from many transmitters from base station. On the other hand in forward end power control is to reduce the differences in power levels of received powers present in same band that allows many users to exist on the system.

The main types of power control used are

i) Power control in reverse link

This type mainly makes sure that all the received link signals are at same power level (nearly). Hence interference can be minimized among all the mobile signals, in reverse link. By using open loop and closed loop setups the power control is implemented.

ii) Closed loop power control in forward link

The closed loop power control is used in forward link and it is used to reduce the received power level from various transmitters at the mobile end. Then the EC/NO (Energy to noise) and the FER error rate of the signal received is measured by the mobile continuously with respect to the forward link.

The four entities of MAC layer Radio Link Protocol (RLP), Signalling Radio Burst Protocol (SRBP), dedicated channel multiplex sublayer and common channel multiplex sublayer is shown in the protocol architecture in IS-2000 (cdma 2000).

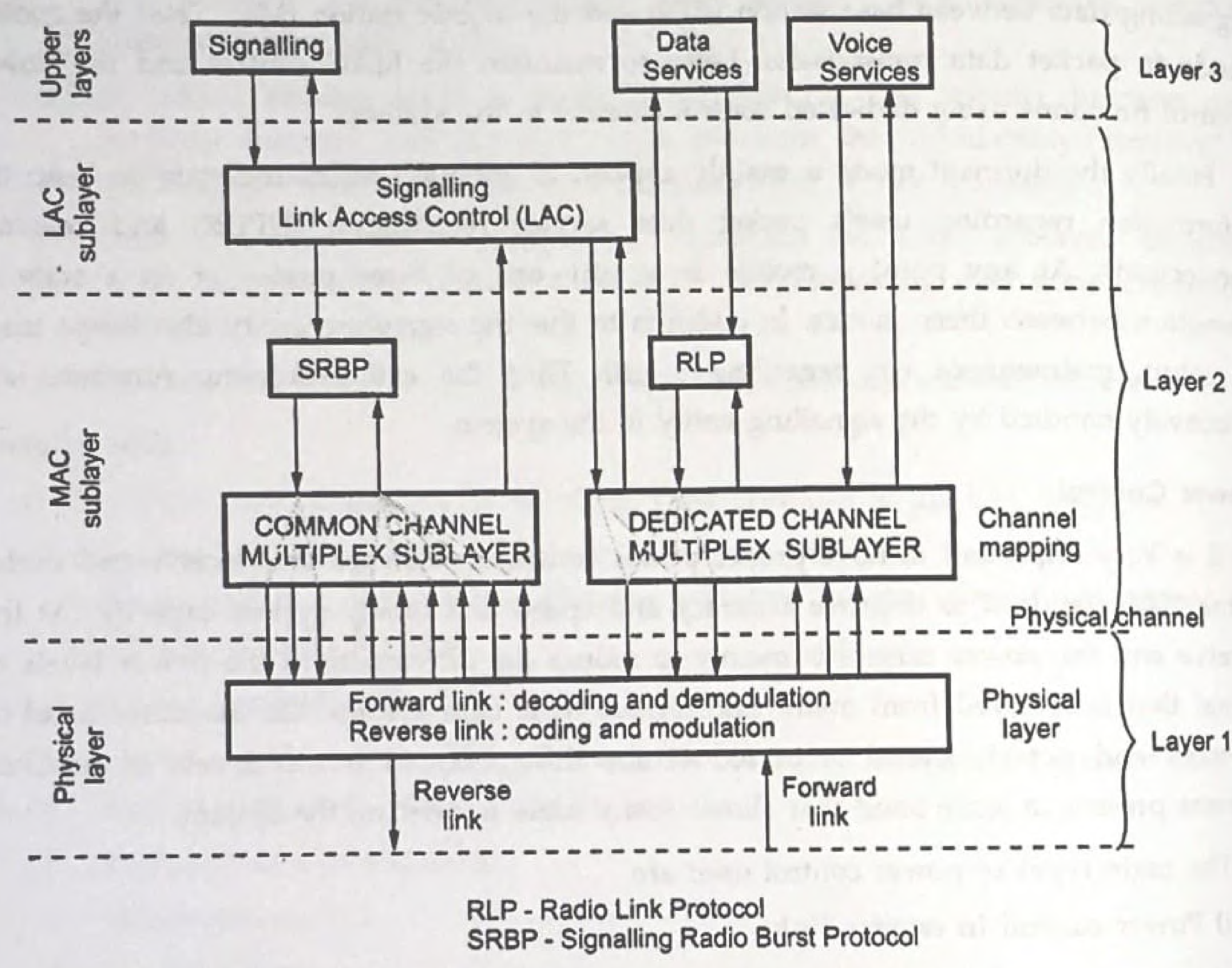


Fig. 2.12.8 Protocol architecture in IS-2000 (evolution of IS-95/cdma 2000) from the mobile perspective

2.13 Comparison of Cellular Networks and Adhoc Networks

AU : May-19

The cellular wireless networks like GSM, CDMA are infrastructure type. The cellular network consists of a main central entity say base station and other mobile devices are mobile subscribers. Any communication between mobile devices and Mobile Transceiver Station (MTS) takes place through the base station. Depending upon the range both macrocell and microcell works with its base station.

But in Ad-hoc networks it operates without any infrastructure. They are self organising multihop networks. There is no central entity like cellular networks.

The mesh networks and WSN networks are few examples of Ad-hoc networks. A simple comparison of cellular networks with the Ad-hoc networks is tabulated below.

Parameter Specification	Cellular Networks	Ad-hoc Networks
Topology	Star type	Mesh type
Bandwidth mechanism	Allocation is guaranteed	Allocation is based on the shared channels
Routing	Routing is centralized	Decentralized
Number of hops	Single hop type	Multiple hops
Switching type	Circuit switching	Packet switching
Cost	Higher cost involved	Lower cost
Time	Take more time for deployment	It does not take more time for deployment
Network Maintenance	It needs periodic maintenance	Since the nodes are self organising maintenance is easier
Frequency re-use	Static frequency re-use is applied	Using a carrier sense mechanism a dynamic frequency re-use is applied.
Call drop problem	Lower call drops	Higher call drops

Thus cellular networks differs from Ad-hoc networks in several aspects respectively.

Review Questions

1. *Define cell and cell shape.*
2. *Give two examples for personal communication.*
3. *Write a short note on PDA.*
4. *What are the advantages of cordless telephone ?*
5. *Define frequency reuse.*
6. *What is known as channel assignment ?*
7. *Define handoff principle.*
8. *What are the types of handoff ?*
9. *What is known as grade of service ?*
10. *How can we improve the cellular capacity ?*
11. *Calculate the wavelength of signal for a PCS and cellular mobile system with ranges as 2.6 GHz and 845 MHz.*
12. *What are the merits of frequency reuse ?*
13. *What are the demerits of non-hexagon cell shape ?*
14. *Define soft handoff.*
15. *What is known as improper handoff ?*

16. *What is known as tracking ?*
17. *Compare mobile radio systems with conventional telephone systems with atleast two points.*
18. *What is a PDC system ?*
19. *What is mobility management ?*
20. *Write a note on GPRS ?*
21. *Explain the architecture of UMTS standard ?*
22. *Explain GPRS with a neat sketch.*
23. *What are the advantages of 3G standard ?*
24. *Explain the security issues in GSM ?*
25. *What is known as mobile number portability ? Explain*
22. *What are the advantages of UMTS standard ?*
23. *How security is achieved in CDMA cellular communication ? Explain one 3G cellular standard ?*
24. *Explain how handoffs are implemented in GSM ?*
25. *What are the services provided in GSM ? Explain.*

University Questions with Answers

Part A

Q.1 *State the purpose of Home Location Register (HLR).* **(Refer section 2.6.2)** **AU : Dec.-18, Marks 2**

Q.2 *List the subsystems of GSM.* **(Refer section 2.6)** **AU : Dec.-18, Marks 2**

Q.3 *Differentiate cellular and Adhoc networks.* **(Refer section 2.13)** **AU : May-18, Marks 2**

Q.4 *Identify the services offered by GPRS.* **(Refer section 2.11)** **AU : May-19, Marks 2**

Q.5 *List out the advantages of UMTS networks over 2G networks.* **(Refer section 2.12)** **AU : May-19, Marks 2**

Part B

Q.6 *Describe about the system architecture of Global System for Mobile Communication.* **(Refer section 2.6.1)** **AU : Dec.-18, Marks 13**

Q.7 *What is UMTS ? Describe the function of HLR and VLR in call routing and roaming.* **(Refer section 2.12)** **AU : Dec.-18, Marks 13**

Q.8 *Outline the services offered by GSM.* **(Refer section 2.10.1)**

Q.9 *Analyze the important features associated with security in GSM.* **(Refer section 2.9)** **AU : May-19, Marks 13**

Q.10 *Draw and explain the architecture of GPRS. List its advantages and limitations.* **(Refer section 2.11)** **AU : May-18, Marks 13**

Unit III Mobile Network Layer

Syllabus

Global System for Mobile Communication (GSM) - General Packet Radio Service (GPRS) - Universal Mobile Telecommunication System (UMTS).

Contents

3.1 Mobile Internet Protocol (Mobile IP) - An Overview

AU : Dec.18, May-19

Whenever the user is connected to an application(s) across the Internet it is said to be in mobile status. The routers actually uses the IP address in IP datagram to do the routing function. The network portion of an IP address helps routers to send datagram from source computer to network where the target computer is attached (connected) with. Mobile IP can also deal with dynamic IP addresses.

Terminologies related to mobile IP :

- **Home address :** The IP address on the network is known as home address.
- **Home network :** A mobile node is designated to a network which is called as home network.
- **Foreign agent :** The router on the foreign network is called as foreign agent.
- **Foreign network :** Whenever the mobile node moves the attachment point to another network then it is called as foreign network.

Home agent :

The mobile node that communicates with the router of its home network is called as a "home agent".

Care of address : It is the address that is used to identify the location of foreign agent.

The mobile IP is explained with an example in next chapter.

Mobile IP

The 'MOBILE IP' is similar to the handoff or roaming situation in cellular mobile network. The handoff technique helps the user to continue conversation inspite of his mobility. Likewise the user who is connected through Internet and his point of attachment changes dynamically. But all the connections established are maintained without any disturbances though his underlying network properties change. Basically the IP address changes from one network to another network. It holds good if the user is static in his particular network. The 'MOBILE IP' enhances the efficiency of network and friendly with the users.

Inspite of mobility the user finds the connections are still available by this technique.

This chapter deals with mechanisms that are developed for the network layer to support mobility status. Example for this is 'Mobile IP'.

Also the mobility, portability of the equipment is supported 'Dynamic Host Configuration Protocol' (). It is also deals at the end of this chapter.

Some of the design goals and assumptions regarding mobile IP is given below.

3.1.1 Goals and Assumptions and Requirements of Mobile IP

Assume an user is moving from his home network to which his computer is configured at. As soon as he leaves his home network he may not receive any packet and he has to reconnect the computer (wired or wireless). If routing mechanisms are considered carefully the above problem can be solved easily. The goal of Mobile IP is to enable packet transmission efficiently without any packet loss.

Consider a host computer which sends an IP packet with the header containing destination address along with other fields.

The destination address determines the receiver of the data packet and relating physical subnet.

For example, the destination address will be 129.13.43.99. It shows that the receiver has to be connected to the physical subnet with network prefix as 129.13.43. At this moment the routers in internet look at the destination address of the packets incoming and it forwards them with respect to the look-up tables. For the sake of simplicity the prefixes alone are stored on which further optimizations shall be applied.

If the receiver is reachable within the physical subnet it will get the packets. Once it moves outside the subnet then it will receive the packets or packets cannot reach it. Thus a host requires the " Topologically Correct Address". Thus to achieve the goals of Mobile IP the entire system should be designed properly.

3.1.2 Quick Solution

Moving to a location that is completely a new IP address is assigned. It is difficult to find a mobile host on internet platform that has changed the address.

he IP address with regard to present location is dynamically adapted (Dynamic DNS). But if the mobile is moving frequently this approach also may not be useful. The domain name system (DNS) uses caching for improving scalability. It does not present consistent views of name and address.

A better approach is to design proper routing. The routers are 'brains' of the entire Internet system. The changes in routing will not be allowed by service providers or the system administrators. Only to compromise with mobile status it may be allowed but at the cost of poor stability of the system.

The ultimate goal towards mobile IP is to provide correct topological address and to enable packet transactions in spite of moving hosts from their home networks.

Some of the requirements of mobile IP includes

i) Compatibility

ii) Transparency

iii) Scalability

iv) Efficiency and

v) Security

Summary of goal of mobile IP

* To support end-system mobility the entire system should have.

1) Efficiency

2) Maintaining scalability

3) Compatibility with the existing Internet protocols and other related applications.

3.1.3 Entities and Terminologies

i) Mobile Node (MN) :

A mobile node (MN) is a router or an end-system that is capable of changing its point of connection to the internet with the help of mobile IP. Mobile need not be smaller devices. For example a router onboard of an aircraft is a mobile node.

ii) Home Network :

A home network is nothing but a subnet to which a mobile node belongs to (with corresponding IP address). Within the home network there is no need of mobile IP.

iii) Correspondent Node (CN) :

For a mobile node atleast one partner is required. The correspondent node (CN) acts as partner for MN and CN can be mobile or a fixed node.

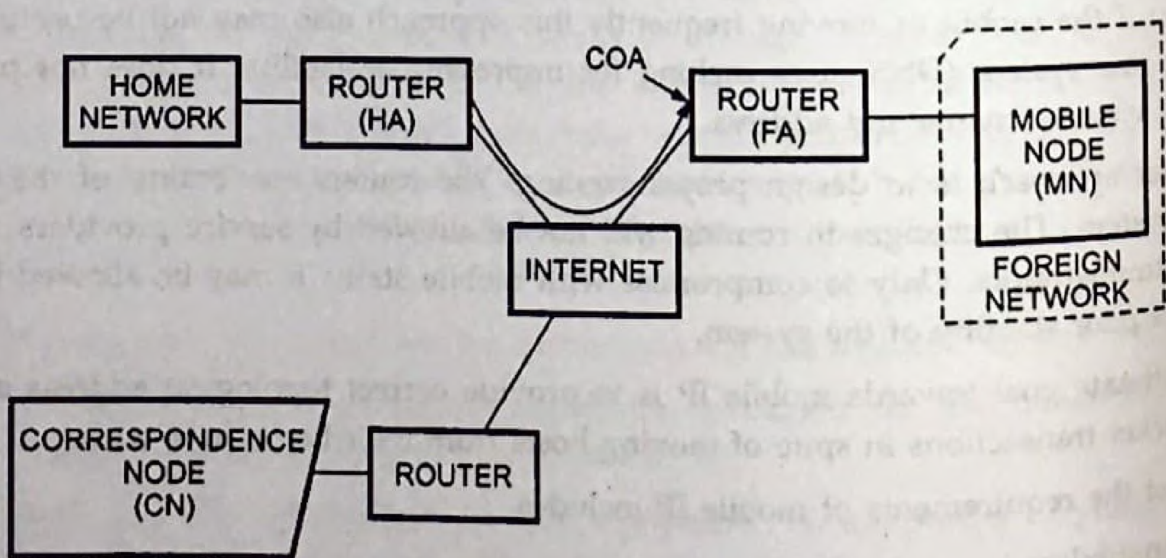


Fig. 3.1.1 Mobile IP network

iv) Foreign Network (FN) :

The foreign network is a current subnet to which the mobile node visits. It is completely different from home network.

v) Foreign Agent (FA) :

The FA provides many services to the mobile node during its visit to that the foreign network. This FA can act as default router for the mobile node.

vi) Care-of Address (COA) :

The current location of MN is defined by care-of address (with respect to IP). The packets sent to that of the MN are delivered to COA and they are not delivered directly to the MN's IP address. The address at which the packets finally exit is known as tunnel. The COA express the tunnel endpoint.

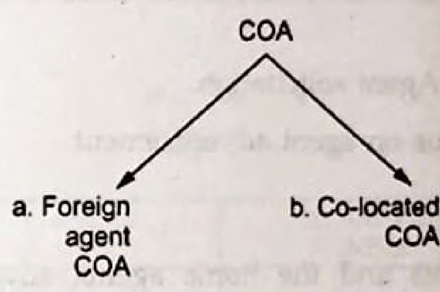


Fig. 3.1.2

a. Foreign agent COA :

The COA may be an IP address of foreign agent (FA). It can be located at FA.

b. Co-located COA :

The COA will be co-located if the mobile node (MN) has acquired an extra IP address that acts as COA. This address may be topologically correct. Here the tunnel end point will be at the MN.

Note :

The co-located addresses can be acquired using the services like dynamic host configuration protocol (DHCP).

vii) Home Agent (HA) :

It is located in home network and it provides several services for the MN. Only at HA the tunnel for packets towards MN will start.

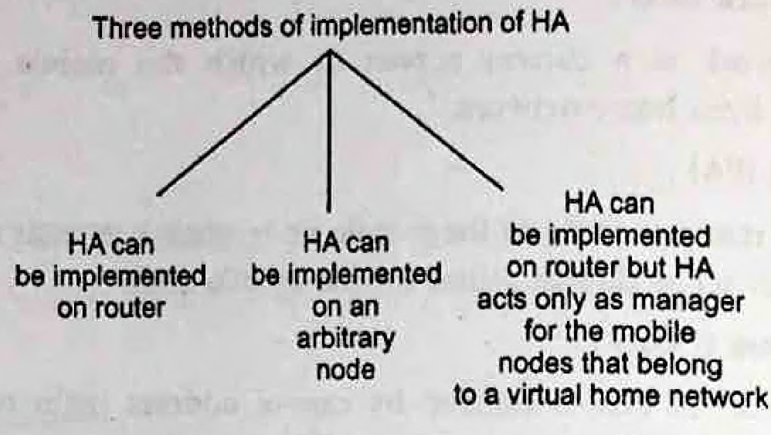


Fig. 3.1.3

3.1.4 Agent Discovery

To find a foreign agent from MN's point of view is a complex task. The two discovery methods are :

1) Agent advertisement 2) Agent solicitation.

In this chapter we shall focus on agent advertisement.

1) Agent advertisement

Generally the foreign agents and the home agents advertise about their presence through periodical 'agent advertisement messages.' They are seen as 'beacon broadcast' into subnets. For this the Internet Control Message Protocol (ICMP) messages as per RFC 1256 are made use allowing some extensions for mobility status. An example of agent advertisement according to RFC 1256 is with some extension is shown in below diagram.

The upper part of it represents ICMP packet where as the lower part is the mobility extension. Some of the fields are not shown here. Some of the fields namely type, code, lifetime, addresses, preference levels, lengths etc. are shown respectively.

The mobile nodes (MN) has to be reached with correct link layer's address. The 'Time to live' (TTL) field of the packet will be set to 1, for all the advertisements so as to avoid the forwarding process.

The respective fields in the ICMP are usually defined as above in Fig. 3.4. The type filed is set to a value 9, next the code is set to 0, when the agent routes the traffic from the non-mobile nodes.

The foreign agents are required to send their packets form the mobile nodes and the number of addresses are available in addresses.

The length of time for which this advertisements are valid is called as 'Lifetime'.

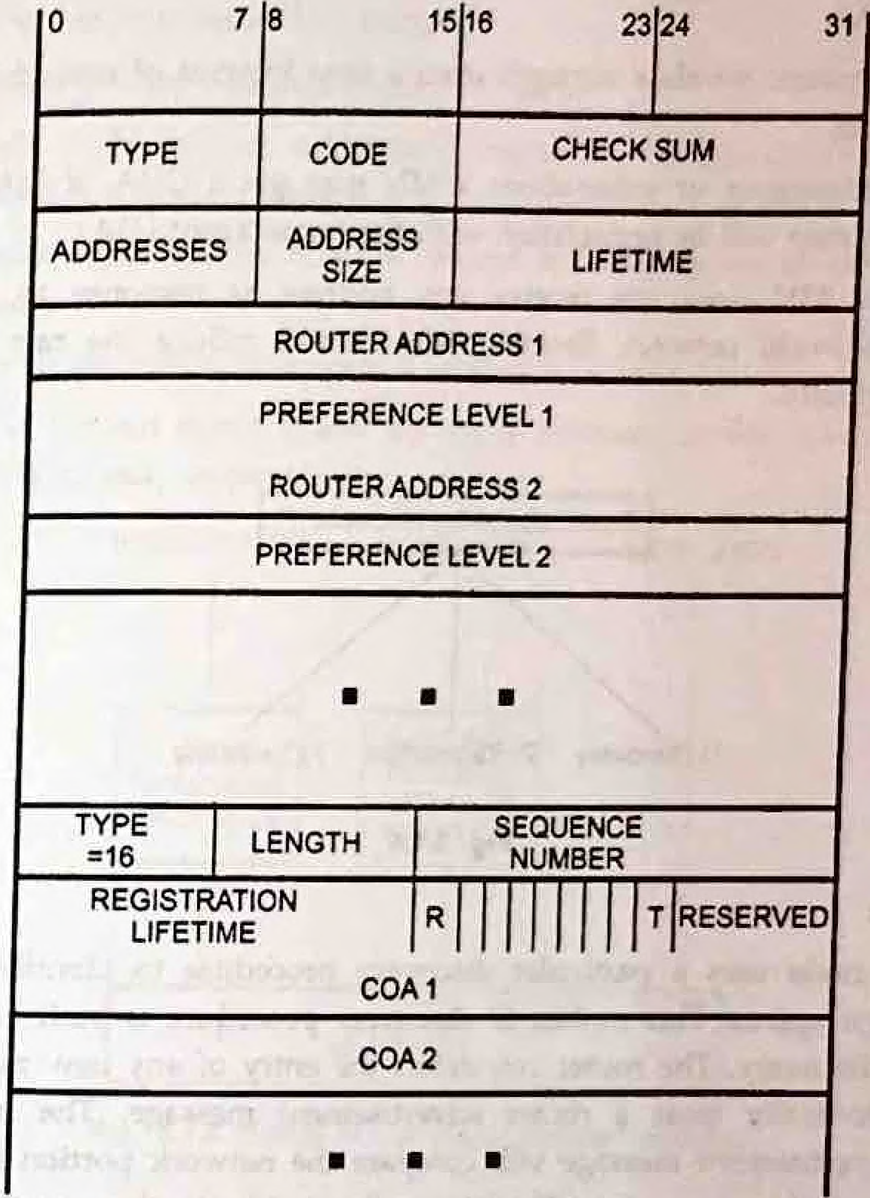


Fig. 3.1.4 Agent advertisement packet

Preference levels are available for each address helps the node to select the router that is interested to receive a new node (NN).

Agent advertisement is one of the main method in agent discovery.

The second one is agent solicitation.

2) Agent Solicitation

In case if there is agent advertisements presents and if mobile node (MN) did not receive any COA then the MN should send an agent solicitation message.

But it is important to monitor that these agent solicitation messages do not flood the network. A mobile node can send three solicitation messages (one per second) as soon as it enters a new network. Basically the solicitation messages are sent by MN to search a foreign agent (FA).

For a highly dynamic wireless network even a time interval of second between these messages is too long.

By these advertisements or solicitations a MN may get a COA. If MN is in foreign network then next step will be registration with the home agent (HA).

Note : If the MN does not receive any address as response to its solicitation messages then to avoid network flooding MN should reduce the rate of solicitation messages exponentially.

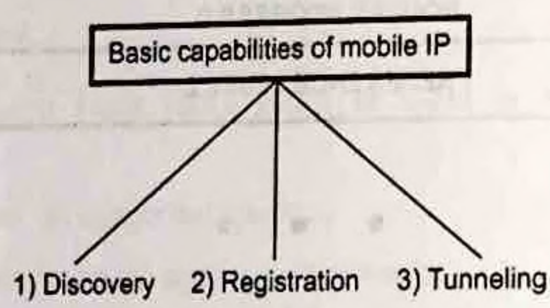


Fig. 3.1.5

i) Discovery :

Each mobile node uses a particular discovery procedure to identify the respective home and foreign agents. This mobile IP discovery procedure is built on the top of an existing router discovery. The router can detect the entry of any new mobile node. The router will periodically issue a router advertisement message. The mobile node by noticing this advertisement message will compare the network portion of the router IP address with network portion of its IP address allocated by the home network.

ii) Registration :

If a mobile node obtains an address (care-of-address) from the distant network (foreign) then it should be registered with the home agent. The mobile node sends a request for registration to its home agent along with care-of-address information. Whenever the home agent receives the registration request information the routing table is updated and it sends back the registration reply to the mobile node. Registration thus is done to inform the home agent about its address.

- **Authentication**

It is a part of registration phase. The mobile host has to be authenticated. A digital signature is generated using the MD5 hashing algorithm and 128 bit secret key. The mobile node and the home agent will share a common key for security purpose and this key is not known by any third party or intruders. A triplet (home address, registration life time and care-of-address) is maintained at the home agent at the end of registration. This is known as binding the mobile node.

The registration process has four important steps.

1. The mobile node sends a registration request to foreign agent for forwarding its service from the foreign agent.
2. This request from mobile node is relayed to home agent of mobile node by the foreign node.
3. The home agent rejects or accepts it and reply is sent.
4. Finally the foreign agent relays the reply message to the corresponding mobile node which actually requested it.

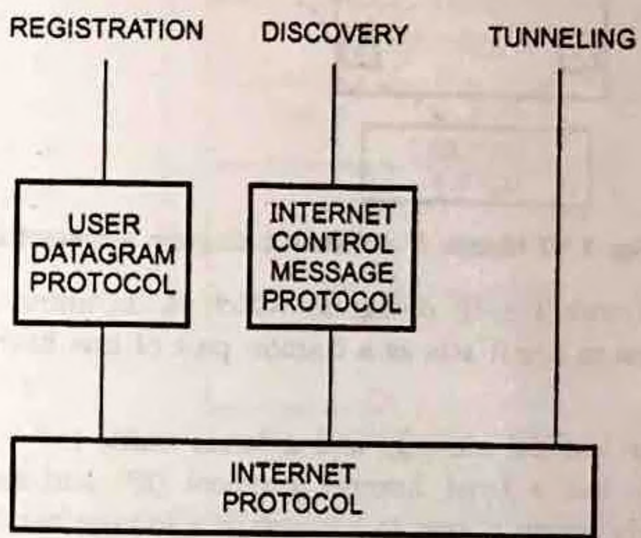


Fig. 3.1.6 Mobile IP - protocol support concept

3.1.5 Mobile IP - Schematic Architecture

Mobile Internet Protocol is denoted as mobile IP. A schematic diagram of it is shown in Fig. 3.1.7. The connectivity in the network is represented as links.

Case study

The server 'A' (say) wants to send an IP datagram to a node X. The home address of X is known to A. The server A does not know whether X is in its home network or not. A sends packet to X with home address of X as its destination Internet protocol address in the IP header. The IP datagram then routed to X's home network area.

At the X's home location network the IP datagram is intercepted by the available home agent. The home agent also discovers that 'X' is a foreign network. Then the home agent encapsulates the full datagram inside a new IP datagram.

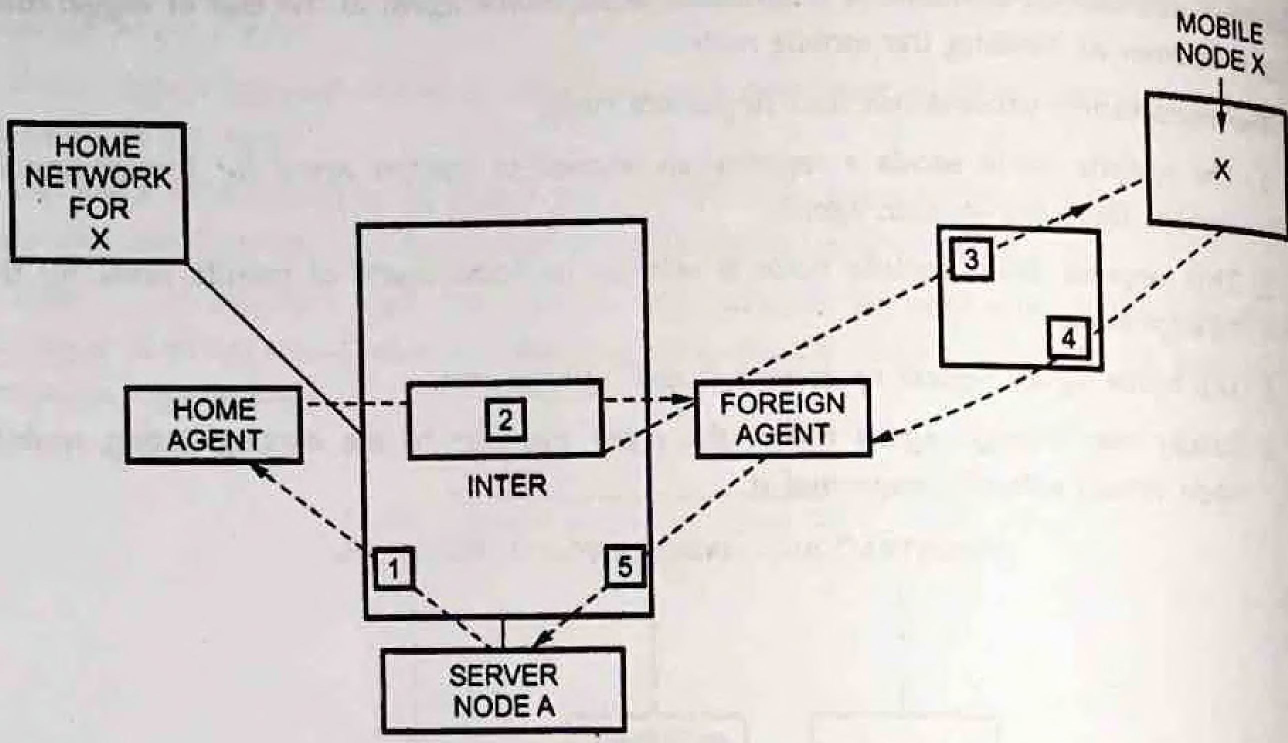


Fig. 3.1.7 Mobile IP schematic diagram architecture

At the distant network the IP datagram which is incoming is intercepted by the foreign agent. The foreign agent acts as a counter part of this home agent in the foreign network.

X intends to respond to the message and it sends traffic to 'A'. In this example A is not mobile. Hence A has a fixed Internet protocol (IP) address. For routing X's IP datagram to A, each datagram is sent to a router in a foreign network, and this router is a foreign agent.

The IP datagram from X to A then travels across the network using A's address (IP) as its destination address.

3.1.6 Tunneling and Encapsulation

3.1.6.1 Tunneling

It establishes a virual pipe for the packets available between a tunnel entry and endpoint. The packets that enters the tunnel will be forwarded and they will leave it with no change. Thus tunneling is sending a packet via a tunnel and it is achieved by 'Encapsulation'.

In the tunneling operation of mobile - IP, IP - within - IP encapsulation (embedding) mechanism is applied. For this a new IP header called as tunnel header is added by home agent. Therefore the home agents address is the tunnel source IP address itself.

Note : Shaded fields in the IP encapsulation represents the fields that are carried directly from inner IP header to that of the outer IP header portion.

3.1.6.2 Encapsulation

It refers to a mechanism of arranging a packet header and data. Putting them together in the data part of the new packet. On the otherhand taking or eliminating data part of another packet is called as decapsulation.

Note : Whenever a packet is sent from higher protocol layer to the lower protocol layer these two operations encapsulation and decapsulation are taking place.

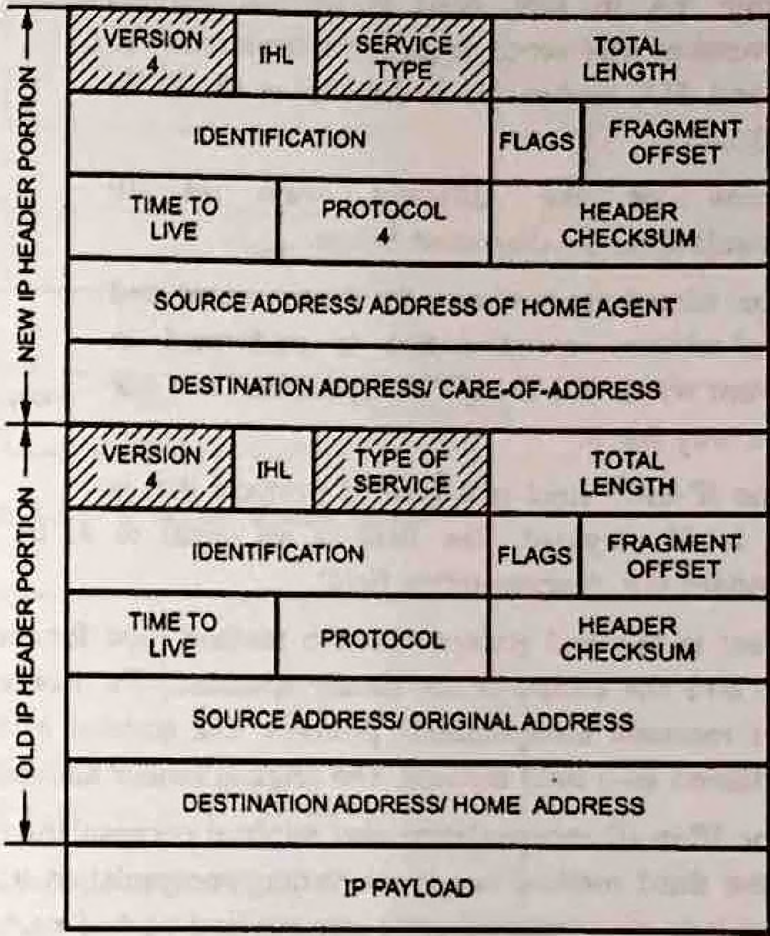


Fig. 3.1.8 IP encapsulation in mobile IP

For registration MN sends a request to foreign agent and FA replies to MN as shown. The registration request to HA is sent through FA and reply from HA to MN also goes

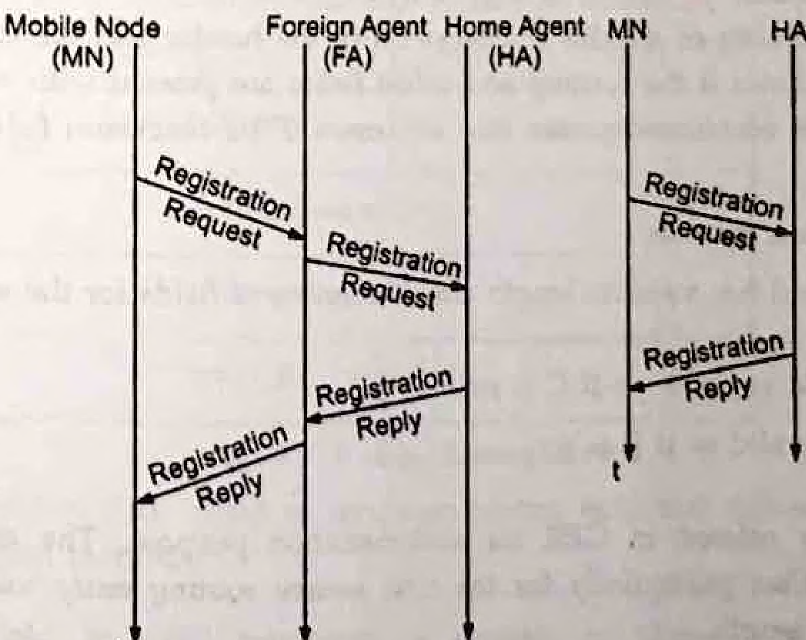


Fig. 3.1.9 Registration of mobile node through HA or FA

through FA to MN. Next is without the FA intervention MN sends request for registration to HA and HA replies for it directly as shown in Fig. 3.1.10.

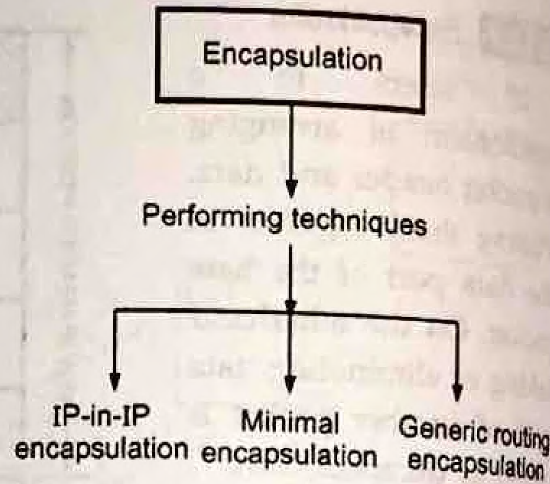


Fig. 3.1.10

Some of the different ways of IP encapsulations are discussed below.

For tunneling between the home agent and care-of-address encapsulation is performed in different ways. An IP-in-IP encapsulation is a one of the way for it.

The IP-in-IP field is a type of protocol that is used in IP payload. The field is set equal to 4. In IP-in-IP there are many fields redundant (eg. fragmentation field).

Next is minimal encapsulation, a method used for mobile IP. Here both tunnel entry point and the endpoint are clearly specified. The header field consists of the value 55 under minimal encapsulation protocol. The address of MN is needed here. A bit 'S' is maintained as a field content. The original sender address of the CN is included.

The IP-in-IP encapsulation and minimal encapsulation methods works only for the IP and the third method is generic routing encapsulation (GRE), it permits encapsulation of the packets of a protocol suite into payload part of packet of some other protocol suite. Simple procedure of it is shown below. The original data, header and GRE header forms the new data. The header of second protocol suite will be put in the front end.

The minimal value of header is only 4 bytes for GRE. The C bit field is set, if the checksum field consists of a valid IP checksum of the header and the payload data. The R bit is set that shows if the routing and offset fields are present with valid information. Similarly the C bit mentioned earlier also expresses if the checksum field is present with valid information.

IP encapsulation formats :

The routing field has variable length and it consists of fields for the source routing.

Checksum field is valid $\Rightarrow$ If C is set
Offset field is valid $\Rightarrow$ If R is set

A key field is offered in GRE for authentication purpose. The offset in bytes is represented by offset particularly for the first source routing entry value. The routing field has variable length.

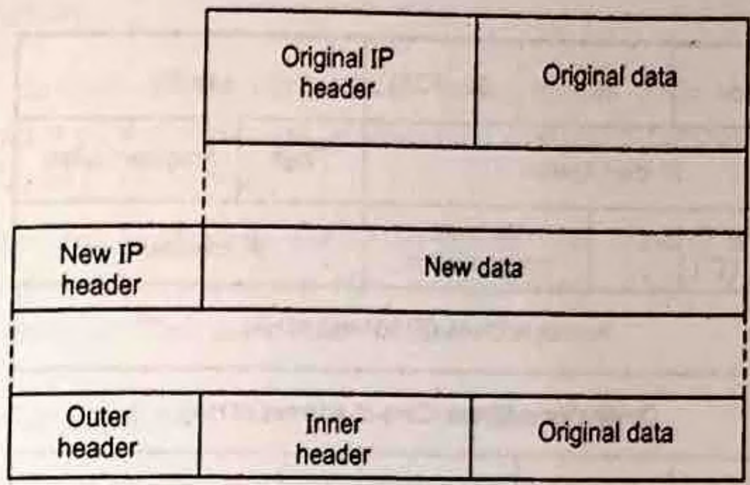


Fig. 3.1.11 IP encapsulation format

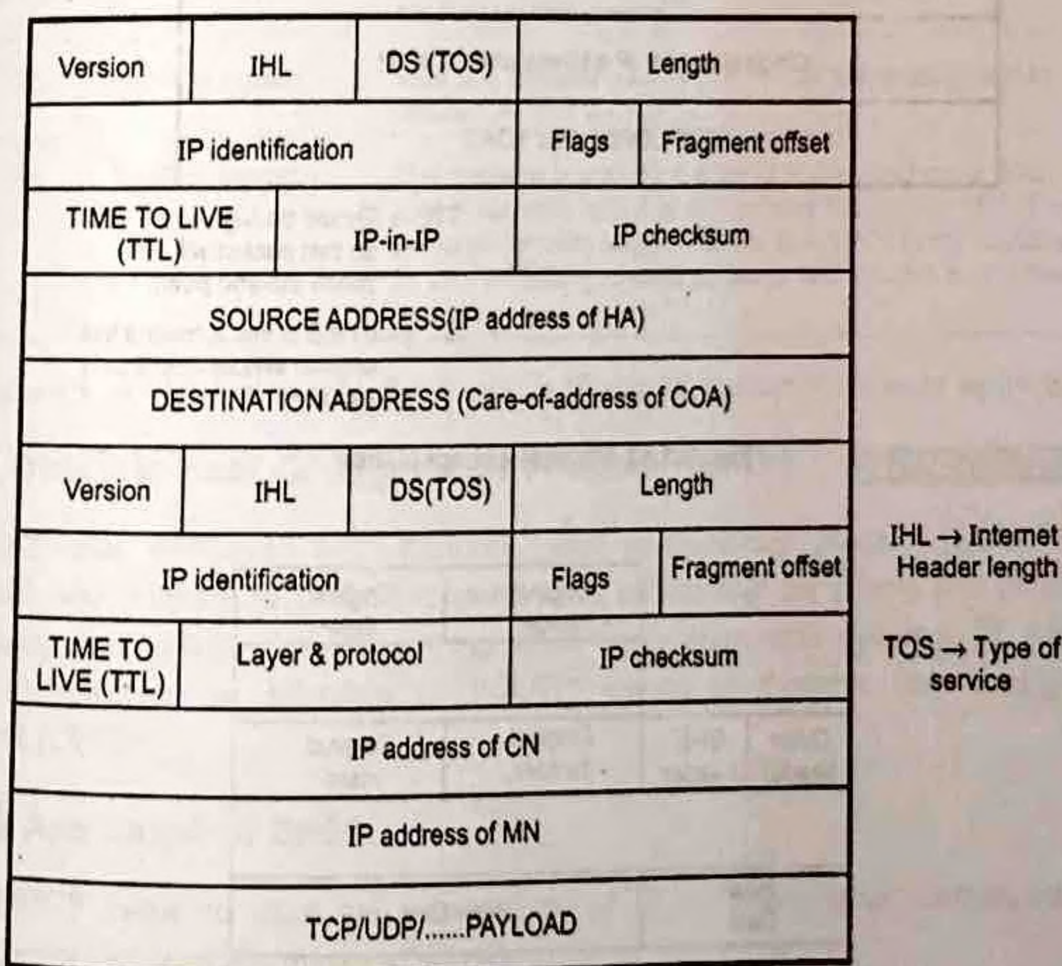


Fig. 3.1.12 IP-in-IP encapsulation

There is a field in GRE called as recursion control field that differentiates GRE from other encapsulation methods.

Recursion field in GRE represents a counter to show number of recursive encapsulations that are allowed.

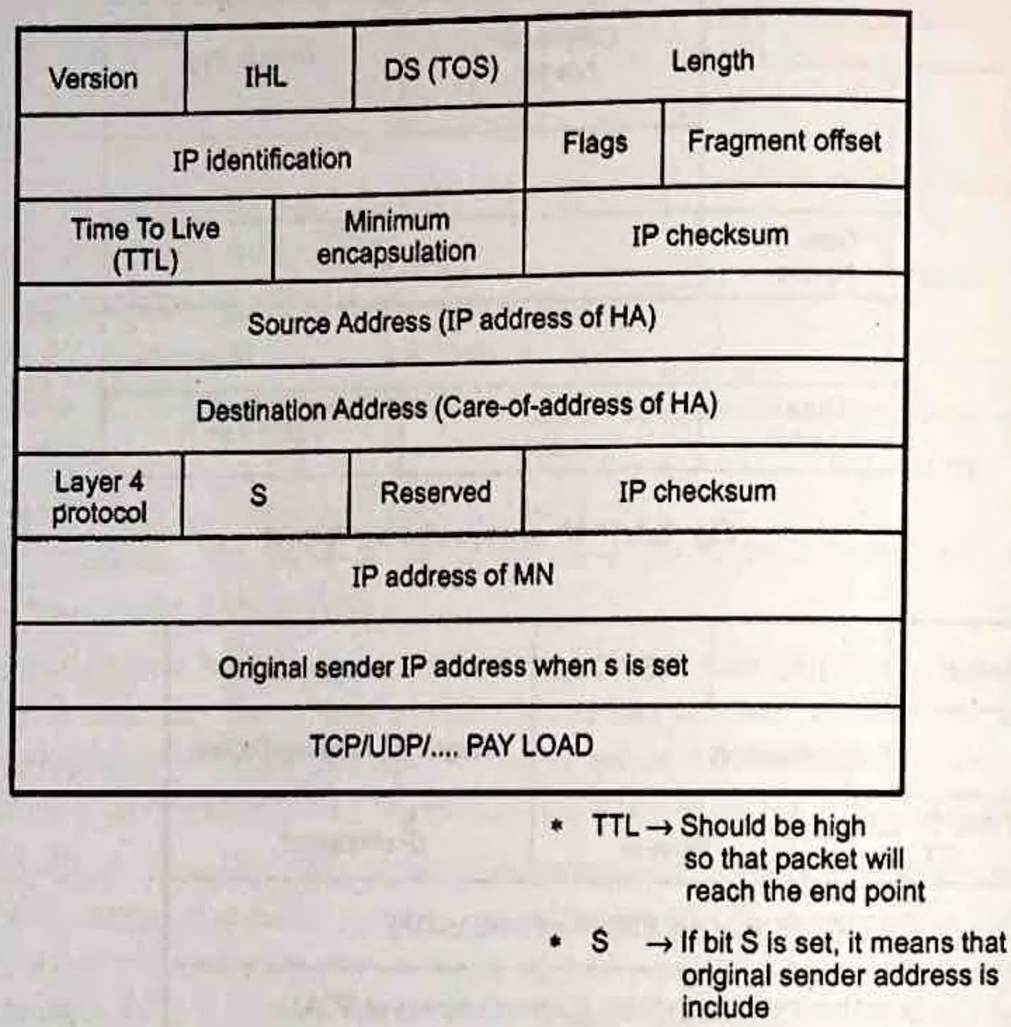


Fig. 3.1.13 Minimal encapsulation

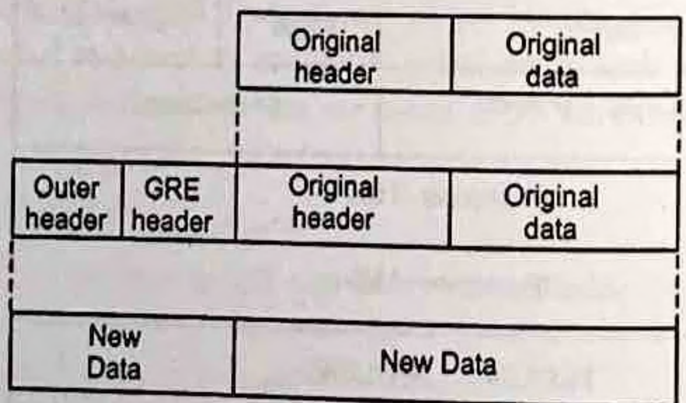


Fig. 3.1.14 Generic routing encapsulation (GRE)

The reserved field has to be ignored or zero on reception. For GRE the version field is zero.

3.1.7 Optimization

In mobile IP protocol all the data packets to the mobile node should go through home agent. Because of this there will be unwanted overheads between HA and CN in network so that latency will increase.

Thus it is important to optimize the routes in network. For this the CN has to be informed about current location of the MN. An optimized mobile IP protocol requires four additional messages. They are tabulated below.

Sr. No.	Message required	Description
1)	Binding request	If a node wants know about mobile node (MN) it sends a request to home agent (HA).
2)	Binding ACK	On request the node will return this message after getting binding update message.
3)	Binding update	This is a message sent by HA to CN mentioning correct location of MN.
4)	Binding warning	The message is sent by a node if it decapsulates a data packet for MN, and it is not present FA for the MN. The message contains target address and MN's home address. In turn a binding update message will be sent to the node by HA.

These are the four messages that a mobile IP should contain if it has to optimized.

3.2 Dynamic Host Configuration Protocol (DHCP) AU : May-18, Dec.-18

DHCP was developed from protocol called as Bootstrap protocol (BOOTP). This standard was released in 1985. It supports static information for clients that includes IP addresses. To manage dynamic configuration information and dynamic IP addresses IETF standardized an extension to 'BOOTP' known as dynamic host configuration protocol (DHCP).

3.2.1 Application of DHCP

1. DHCP helps to drag the management of IP addresses from distributed client servers to centrally managed servers.
2. In the sites with more TCP/IP clients, DHCP yields support to manage large number of clients effectively.
3. DHCP is useful in sites with fewer TCP/IP addresses than the number of clients.
4. In sites that needs frequent movement from host to host with different locations DHCP is used.

5. DHCP is used in sites where laptop computers have to move among different networks within a particular site.
6. It is used for diskless clients.

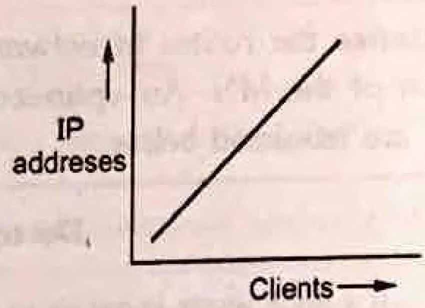


Fig. 3.2.1 Client Vs number of IP addresses

As the number of clients grows up the need for IP addresses is more. There is a chance of scarcity of IP addresses availability. This scarcity can be minimized with the help of DHCP. There are two ways possible.

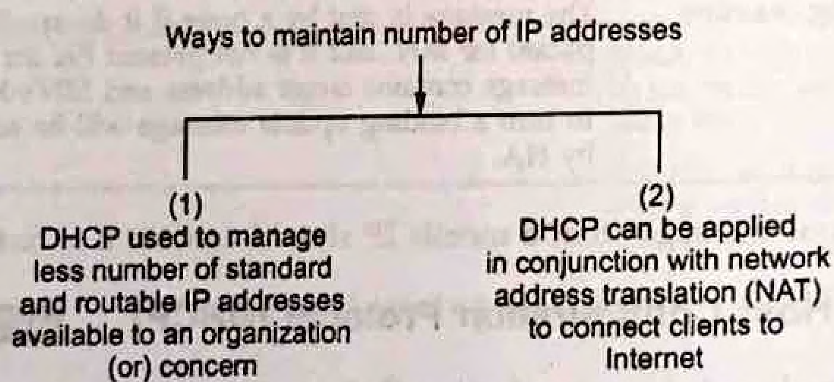


Fig. 3.2.2

By using these methods accessible IP addresses are made easy to some extent in networking.

The dynamic host configuration protocol was developed from Bootstrap protocol (BOOTP). The BOOTP is client server protocol which was designed to furnish four information. The problems associated with BOOTP are given below.

Problems with BOOTP

When a node (computer) is attached to TCP/IP Internet (connection established) should be aware of these above said four information.

1. Its subnet mask
2. Internet protocol (IP) address.
3. Internet protocol (IP) address of a router.
4. Internet protocol (IP) address of a name server.

Actually this Bootstrap protocol (BOOTP) is not a dynamic configuration protocol. Whenever a client requests IP address the server machine with BOOTP searches a table which matches physical address of client with Internet protocol (IP) address. This link between client and IP address is predetermined.

BOOTP cannot address a few problems like

1. If a host moves from a physical network to another network.
2. If a host seeks a temporary Internet protocol (IP) address.

There are critical situation where BOOTP cannot decide what to do next.

3.2.2 Significance of Dynamic Host Configuration Protocol

But Dynamic host configuration protocol DHCP provides dynamic configuration. It is an extension to the BOOTP and compatible with it. If a host is running BOOTP client it can also request a configuration (example : static configuration) from a DHCP server node. The advantages of DHCP are;

1) Whenever a host moves from one network to another network or to connect or disconnect with a network.

2) DHCP also provides temporary IP address for a particular predetermined time period.

3.2.2.1 Components of Dynamic Host Configuration Protocol

The dynamic host configuration protocol (DHCP) is built on a client-server model. It has designated server hosts allocating the network addresses and delivering configuration parameters to the dynamically configured hosts. The term 'client' refers to host that request initialization parameters and the term 'server' refers to a host that can provide initialization parameters through dynamic host configuration protocol. The DHCP mainly provides configuration parameters to the Internet hosts. It consists of two components.

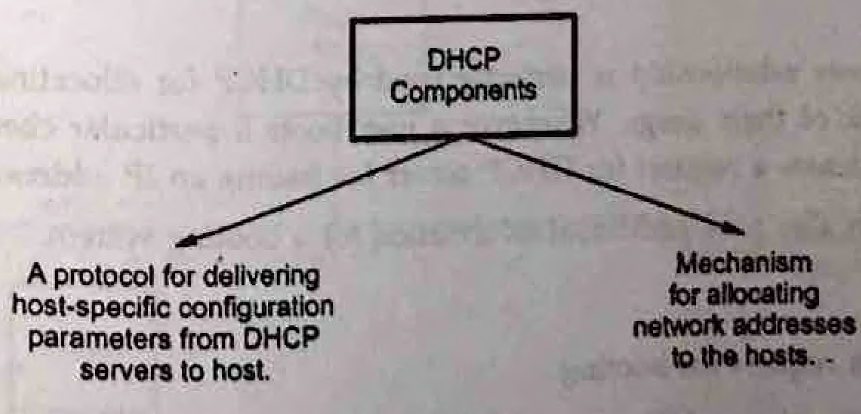


Fig. 3.2.3

The DHCP supports three important mechanisms for the IP address allocation.

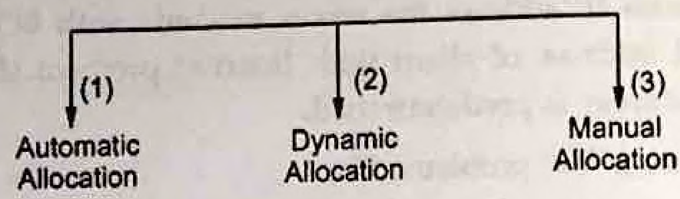


Fig. 3.2.4

1) Automatic allocation is also possible, wherein the DHCP assigns permanent IP address to a particular client.

2) With the dynamic allocation DHCP assigns IP address to a client for a particular period of time.

3) In the manual allocation a client's IP address is assigned by network administrator, where the DHCP is used to inform the address assigned to the client.

Note : Whenever permanent IP address pool is not required and if temporary IP addresses are enough for a set of clients in this case it is better to have dynamic allocation mechanism.

Only in dynamic allocation method automatic reuse of an address is done.

Importance of DHCP

DHCP is a widely used protocol for configuring hosts like PC's, printers and workstations. The DHCP servers allocates mainly IP addresses from a pool of IP addresses to a set of clients with the help of network administrator as discussed so far. Hence dynamic host configuration protocol which was created by Internet Engineering Task Force (IETF) streamlines the efficiency of the network connectivity that is used by mobile IP protocols.

The DHCP protocol is used by three different agents as we know server, client and relay agent. This DHCP server is actually a central server configured on a site's network that can provide DHCP services. The client (software program) interacts with DHCP server.

The client/server relationship is perfectly used by DHCP for allocating IP addresses and keeping track of their usage. Whenever a user boots a particular client system and that system broadcasts a request for DHCP server for issuing an IP address.

The DHCP can also pass additional information for a booting system.

Sequence :

1. Client issues request for booting.
2. Server receives the packet.

3. Compares it with database of possible parameters.

The IP address may be of static or dynamic type.

Static IP address : It is permanently assigned to the client.

Dynamic IP address : It is not assigned to the client till it gets booted and address given by the server.

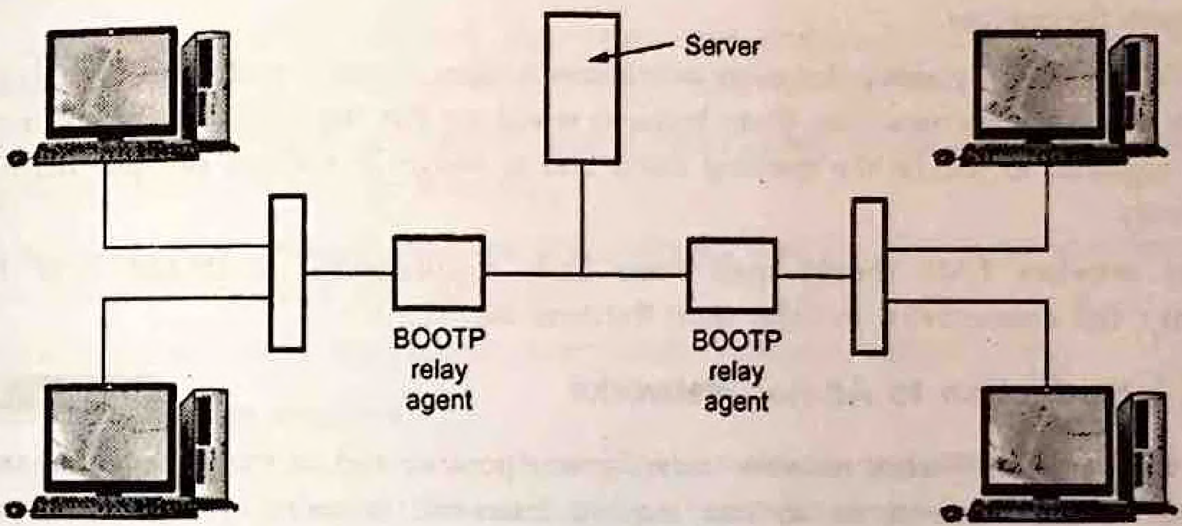


Fig. 3.2.5 DHCP - Clinet/server environment

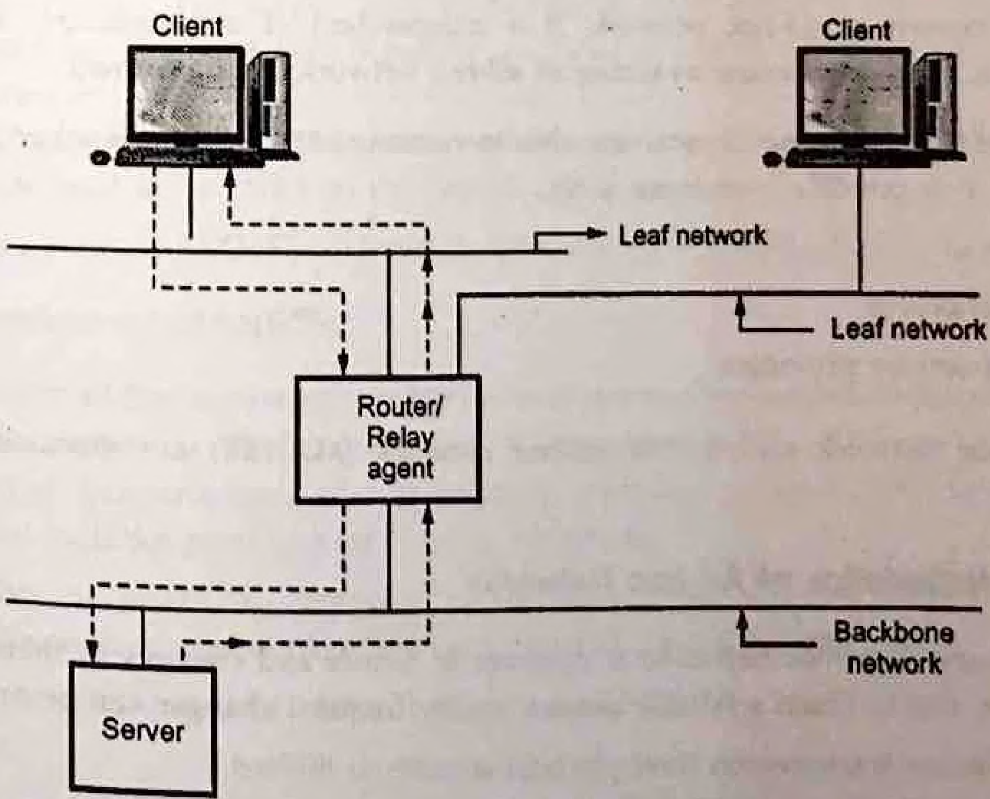


Fig. 3.2.6 DHCP - Client/server interaction sample

Hence the dynamic host configuration (DHCP) protocol is considered as "a protocol of choice".

Note : The DHCP responds to a particular period of time (server responds with IP address) which is also known as "lease" for which period the client makes use of the address assigned to it.

With this client/server interaction setup DHCP enables computers on a network to configure themselves.

DHCP makes it possible for users of wireless devices to move within an organization that is with various networks. (from home to work) for this the DHCP client and server work together to handle the roaming status and to assign IP address on new networks efficiently.

The wireless LAN should meet some basic requirements. It should have high capacity, full connectivity, to cover short distances etc.

3.3 Introduction to Ad-hoc Networks

AU : May - 19

In recent years wireless network nodes became popular and as the applications using Internet is high. Sometimes an user may be interested in using a laptop computer without making routing functions via global Internet. For such cases Internet protocols will not be required. Thus the mobile computer users can be allowed to set up a short lived network with wireless communication devices, for a particular moment. This network is known as ad-hoc network. It is independent of infrastructure. Thus even when there is no infrastructure available an ad-hoc network can be formed.

The wireless computing devices are able to communicate with each other in ad-hoc networking, it is possible even there is no,

* Routers or
* Base stations or
* Internet service providers

The ad-hoc network and mobile ad-hoc network (MANET) are discussed in this chapter.

3.3.1 Characteristics of Ad-hoc Networks

- The topology of ad-hoc networks is dynamic in nature and changes in their topology is possible. But to attain a reliable output quality frequent changes can be avoided.
- Due to wireless transmission their physical security is limited.
- The capacity of these network is lower when compared with wired networks.

- They experience higher loss rates, higher delays and also the jitter than the fixed type of networks.
- They use either exhaustible power supplies or batteries for getting energy. In network design it is very important to consider power saving.
- In a perfect 'ad-hoc network' it has all the seven layers from physical layer to application layer.
- In designing an ad-hoc network their exists high complexity with physical layer setups but in case of mobile networks it will be taken care by their base stations.
- The informations related to network destiny, link failures, nodes distributions has to be clearly defined for ad-hoc networks.
- To obtain a better network structure it is important that the MAC layer and network layer should collaborate with each other.
- The ad-hoc network is independent of any central control or infrastructure.

The ad-hoc networks provides;

- Instant infrastructure in case of sudden meetings, unplanned interpersonal communications etc. Planned infrastructures are not required.
- Remote area networking : In parsely populated areas where infrastructure setup is difficult ad-hoc networks can be established.
- Effective system : The ad-hoc packet oriented network setup is less expensive and also effective. These ad-hoc networks provides a better solution for application specific cases.

A working group at IETF under ad-hoc networks focused on mobile ad-hoc networking termed as 'MANET' in the year of 2002.

A relation between MANET and mobile IP is shown in the Fig. 3.4.3.

3.4 Overview of MANET's

The "mobile ad-hoc networks" MANETs have many advantages and one of the most important advantage is its "Infrastructure independent" nature. The ad-hoc networks does not need infrastructure's that is required for other wireless networks. The term infrastructure includes need of base stations, routers etc.

The ad-hoc networks are composed of the equal nodes that can communicate with each other through wireless links. Their is no central control for their work.

The important features of ad-hoc networks and MANET's are discussed in detail in this chapter.

The term MANET describes mobile, wireless, distributed multihop networks that could operate independent of infrastructure. A MANET network is composed of mobile, autonomous, wireless nodes that could be connected at network edges to that of the fixed wired Internet. Initially MANET is developed due to military requirements where infrastructure less, line of sight operations are required.

Salient features of MANET includes

1) Network size

It refers to the geographical coverage area that could be covered by the network. The number of nodes for a given geographical area represent network density.

2) Connectivity

It refers to many issues. One such is the number of neighbouring nodes that could link to them directly. This link may be bidirectional. Connectivity also refers to link capacity between any two nodes.

3) Network topology

The user mobility can affect the network topology. Due to it the network protocols has to adapt to topology changes. Conversely when nodes are inoperative due to dead batteries their will be rapid changes in topology.

4) User traffic

The design of MANET is thick related with user traffic. It includes some conditions like,

- Does the user traffic consist of bursty, shorter packets without periodic delays ?
- Does it contain longer packets sent periodically with fixed time bounds ?
- Or is it a combination of these two situations ?

5) Operational environment

It refers to terrain whether it is a urban, rural or maritime etc. Due to any one of this LOS may not exist.

6) Energy

In MANET there is no availability of fixed base stations. A low energy network approach is tried with battery operated store and forward nodes in the network.

If some nodes are not participating in network operations shutting them for some time can be done.

In addition to there issues cost involved in MANET designed is also high that has to be planned with a proper balance with network features.

Example for MANET

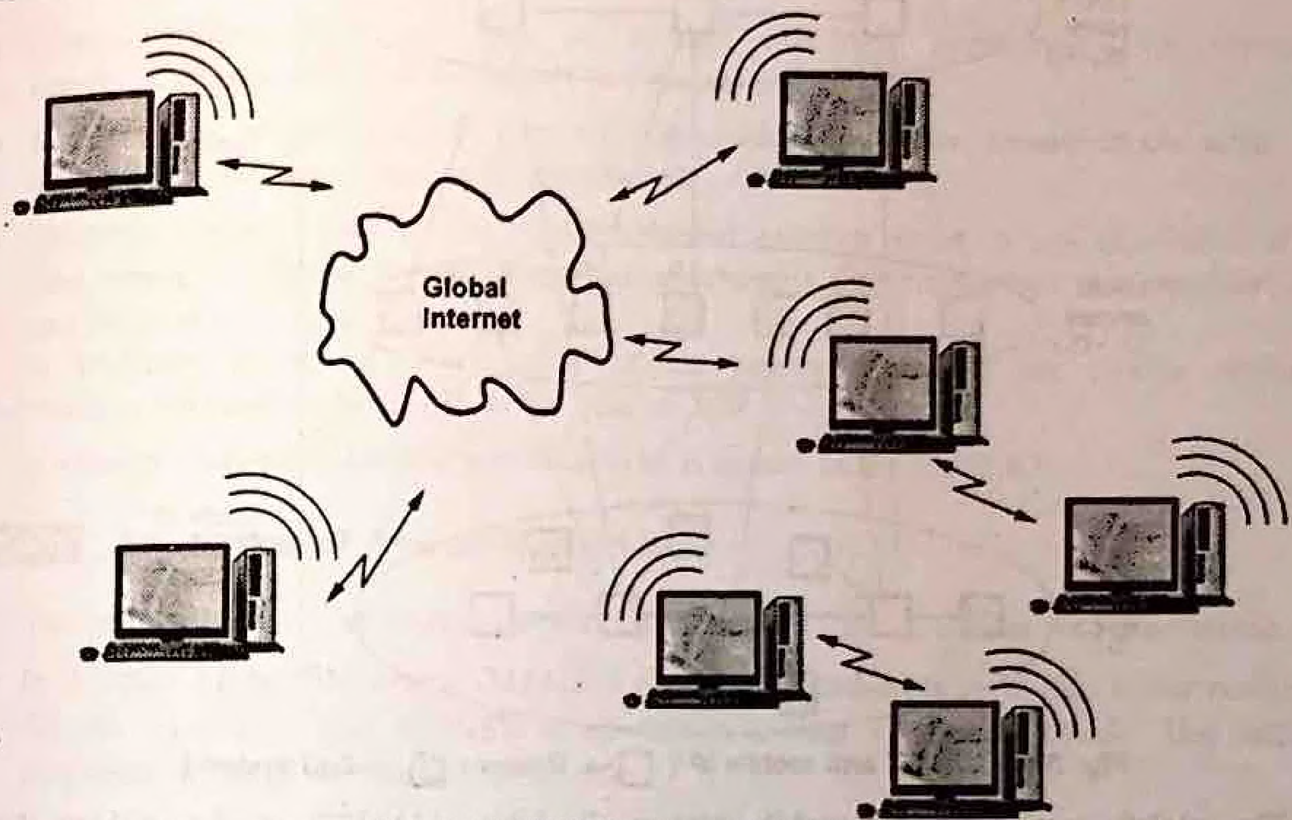


Fig. 3.4.1 MANET connected to Internet

An example of MANET connected to Internet is shown above. Individual nodes transmits and receives data with globalized Internet arrangement.

A simple ad-hoc network composed of nodes and the complexity involved with network setup are shown in following diagrams.

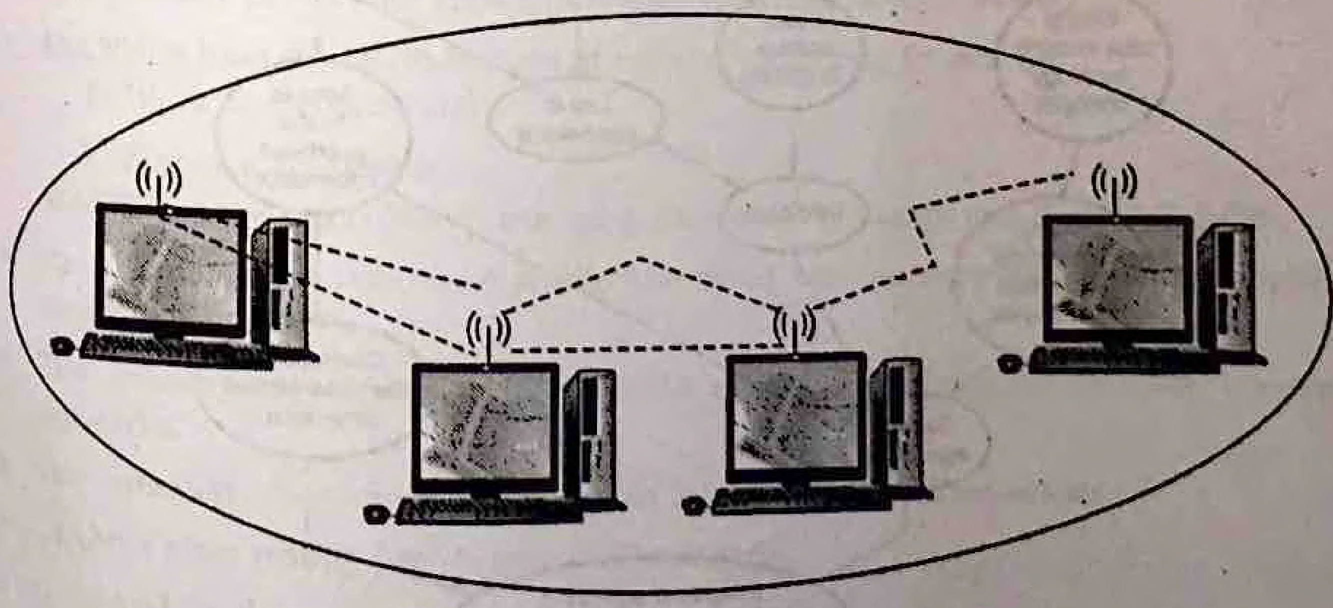


Fig. 3.4.2 Mobile ad-hoc network (MANET)

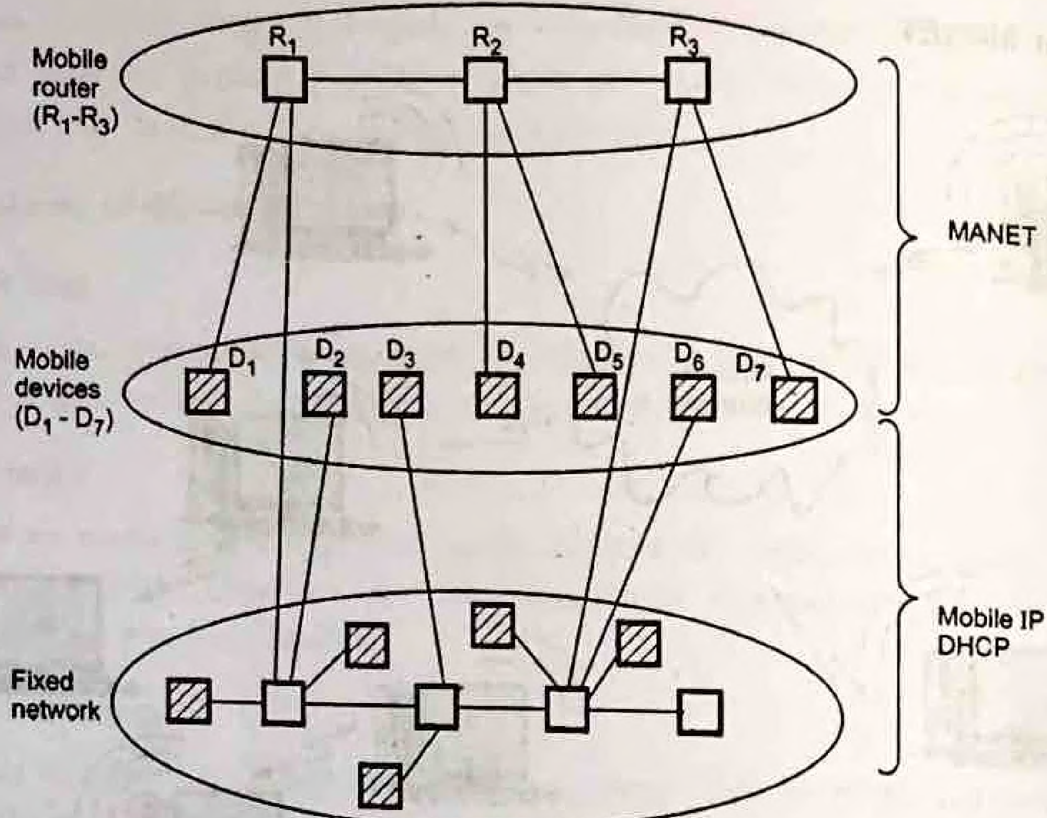


Fig. 3.4.3 MANET and mobile IP [□ → Router ; ▨ → End system]

The mobile router (I) and mobile devices (II) forms MANET as shown here. It's relation with fixed network is established.

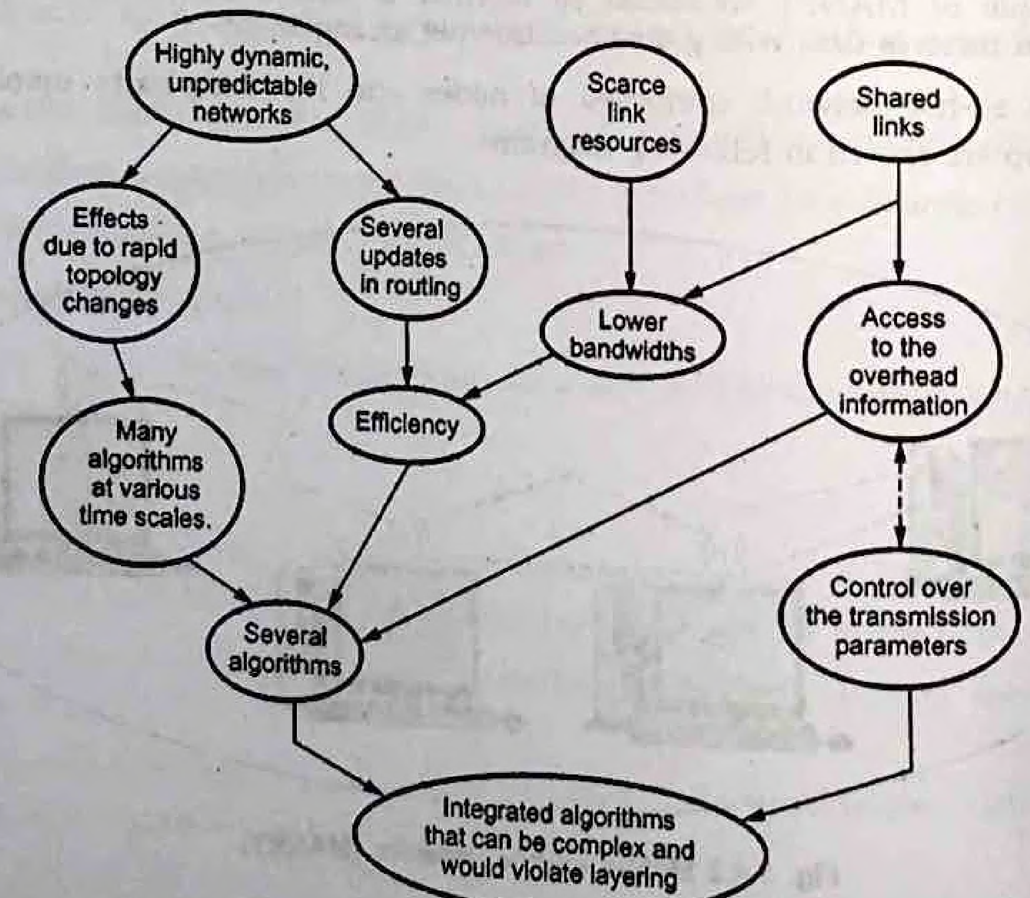


Fig. 3.4.4 Complexities in 'ad-hoc' network arrangement

3.5 Advantages of Ad-hoc Networks

- Instant infrastructure in case of sudden meetings, unplanned interpersonal communications etc. Planned infrastructures are not required.
- Remote area networking : In paresely populated areas where infrastructure setup is difficult ad-hoc networks can be established.
- Effective system : The ad-hoc packet oriented network setup is less expensive and also effective. These ad-hoc networks provides a better solution for application specific cases.

A working group at IETF under ad-hoc networks focused on mobile ad-hoc networking termed as 'MANET' in the year of 2002.

A relation between MANET and mobile IP is shown in the Fig. 3.4.3.

3.5.1 Properties of Ad-hoc Networks

- The protocol design of ad-hoc networks are different from the fixed wired networks.
- In Mobile Ad-hoc Network (MANET) their is no dedicated network infrastructure devices available. The MANET is an architectureless wireless network. The radio propagation range of MANET is limited.
- Because of its range limitation, for covering a short distance it has to undergo many hops.
- In few specific scenarios for communication with other networks outside some of the devices have network connections with the outside base stations (BTS) and these devices acts as gateways for ad-hoc networks.
- The gateway devices are known as weakly connected ad-hoc networks.
- MANET's have two main features of wireless computing known as
  1) Weak connectivity and
  2) Resource constraints.
- MANET's have difficulties in managing bandwidth efficiency and data availability.
- Data management policies of architecture based wireless network cannot be applied directly to MANET's.
- The gateways of MANET's are not reliable as the base stations of other wireless networks.
- The gateways communications only with local hosts at low frequencies.
- MANET's are mainly peer-to-peer (P2P) networks.
- In MANET's there is no pre-existing infrastructures.
- These networks has limited accesses to a base station.

- They have power limitations.
- Their is no centralized controlling mechanisms.

3.6 Routing in MANET

Routing is a complex task in ad-hoc networks. The destination node may be out of range with respect to source node which is transmitting data packets.

The purpose of routing is to find correct path between the source and destination for forwarding packets. If infrastructure is available in wireless networks routing will be an easier task because there the cells are defined. .

But in ad-hoc network independent of infrastructure routine is tough task.

Thus in ad-hoc networks,

- The traditional routing algorithms will not be suitable.
- Centralized approaches will not be appropriate.
- Several nodes in network should have routing capability.
- They have no connection and ad-hoc network between nodes and they experience fast changing environment.
- If the load is less a method called as "flooding" can be applied in ad-hoc networking. But flooding is not an efficient method. To avoid looping as packets are forwarded, a hop counter should be used because the knowledge of maximum number of hops is very important. Still this flooding technique is not much used for packet forwarding.

3.6.1 Fundamental Steps in Routing

i) Forwarding the packets to next hop. That is from an input interface to an output interface in a traditional wired network.

ii) While forwarding packets sender much check for following parameters.

a) Packet reaching the destination.

b) Minimize the number of hops/path length.

c) Minimize the delay.

d) Minimize the packet loss.

e) Minimize cost involved.

3.6.2 MANET Vs Traditional Routing

- In MANET's each node is a potential router whereas most of the nodes in traditional wired networks do not route the packets.

- In MANET the nodes transmit and receive their own packets and they also forward packets to other nodes.
- In MANET the topology is dynamic because of the mobile nodes but relatively it is static in case of traditional routing methods.
- The routing in MANET must consider the layer 2 and layer 3 informations whereas in traditional routing protocols they rely on layer 3 information only.
- In MANET the link layer informations includes the data about connectivity and interferences.

  Main issues to be addressed by routing protocol in MANET are,

  1) Routing discovery

  2) Data forwarding

  3) Route maintenance.

3.7 Types of MANET Routing

AU : June 16, May-18, 19

The MANET's routing protocols are classified as proactive (table-driven) and reactive (on-demand) types.

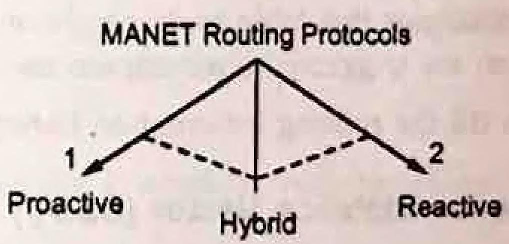


Fig. 3.7.1

These classification depends upon how they respond to any changes in network topology.

If a host is running a proactive protocol will react to topology change by propagating routing related informations to the neighbours. Such information transmission takes place whenever there is a change in link state is detected.

Two broader classification of routing protocols are unicast and multicast types.

1) Unicast routing protocols

a) Proactive protocols : Examples of the proactive (table-driven) protocols are

i) Destination sequenced Distance Vector (DSDV) protocol.

ii) Wireless Routing Protocol (WRP).

b) On-demand routing protocol : In this routing protocol routes are constructed according to the demand. It tries to find or maintain routes whenever necessary.

Examples of on-demand protocol are,

i) Dynamic Source Routing (DSR)

ii) Signal Stability based Adaptive Routing (SSA)

iii) Ad-hoc On-demand Distance vector Routing (AODV)

iv) Temporaly Ordered Routing Algorithm (TORA)

These protocols are reactive natured.

c) Hybrid routing protocol : A combination of reactive and proactive approach is also made. It is known as hybrid routing protocol.

Example of hybrid routing protocol proposal is Zone Routing Protocol (ZRP).

DSDV is like traditional distance vector routing technique. It is also called as "Bellman-Ford routing algorithm". The DSDV has few modified procedures to reduce routing loops.

Important operations of DSDV :

i) Each router in the network collects informations from all its neighbours.

ii) After gathering information node searches for a shortest path to route the packet.

iii) A new routing table is generated.

iv) Then the router will broadcast this table to its neighbours. Due to this function the other node (neighbours) are triggered to recompute their respective routing table.

v) This process continues till the routing information becomes stable.

3.7.1 Destination Sequence Distance Vector (DSDV)

Two important routing algorithms commonly used in MANET are,

a) Destination Sequence Distance Vector (DSDV)

b) Dynamic Source Routing (DSR)

In ad-hoc networks Destination distance vector (DVR) protocol was applied at first and then later the On-demand Distance Vector (AODV) protocol was used. The performance of DVR was not efficient, due to count-to-infinity problems. Because every node exchanges with its neighbour table at regular periods. Changes that takes place at a node in network slowly propagates and thus it is not a better protocol to apply.

Some features added to DVR algorithm is known as Destination Sequence Distance Vector (DSDV) routing algorithm. Two features appended with DVR are namely,

i) Sequence numbers

ii) Damping.

i) Sequence numbers

Every routing advertisement should come with sequence number. These sequence numbers helps to apply the advertisements in a proper order. It helps to avoid looping.

ii) Damping

If the transcient changes in network topology prolongs for negligible time then it may not degrade the performance of routing mechanisms. A node waits if changes are unstable and this waiting time will depend on the time taken between first and the best advertisement of routing path to a definite destination node.

3.7.2 Dynamic Source Routing (DSR)

In this routing the routing task is divided into two different problems. It was analyzed in the period 1996 to 2002.

- Route discovery : It is nothing but the node searches for a correct destination for transmitting packet and currently their may be no correct route available.
- Route maintenance : If node has discovered a correct node it starts forwarding packets through it. But if the node transmits packets for a long time then in that case it has to make sure wheather the route is held upright. Thus route maintenance is essential for making sure of packet delivery to the intended node.

Like token rings in fixed type of networks also this DSR can be used. The periodic routing updates are not applied in this method.

Routing mechanism in DSR

Whenever a node discovers a route it will broadcast a route request with two parameters namely,

1) Identifier

2) Destination address.

If a node receives a route request it has to do the following things.

- If the node had received the request that is identified by unique identifier the node will drop its request packet.
- Once the node recognizes its destination node's address it shows that request has reached its target.

If it does not recognize the node will append its address to the list and then broadcast the new updated route request in the network.

3.7.3 Ad hoc On Demand distance vector routing protocol (AODV)

AODV protocol is a reactive protocol which is contructed on a DSDV protocol. While a DSDV routing protocol maintains a complete list of routes. But, in an AODV protocol routes are created only on demand. The use of destination sequence numbers ensures a new route. Next hop routing model is essentially adopted in AODV. The routing table in a host points to the next destination. The desitination IP address of the packet received is cross checked with the routing table so as to forward the packet to the next destination.

The node awaits a reply after forwarding a RREQ. AODV uses the sequence numbers of the destination for determining the route. The RREQ is identified by the broadcast ID and IP address. The broadcast ID and IP address are cross checked based on th RREQ. If the RREQ is a mere repetition it is ignored or else a reverse path to the origin (O) is established. A reverse path is established along the intermediate nodes in there routing table based on the request. When an RREQ touches the destination a reply is sent in the reverse path to the original source (O).

In the Fig. 3.7.2 shown below the route discovery based on AODV is shown.

This shows the RREQ from the source and RREP along the reverese path.

From the origin to the destination adopting a hop by hop state each node registers only the next hop and not the entire route. The transmission of data packets from the origin can be done as and when the RREP is received.

Each node transmits a HELLO message along the route so as to maintain the route in AODV. If an HELLO message is not received, it indicates as disruption in the connectivity.

In case of disruption of a route, the origin may initiate once again a route discovery to the destination.

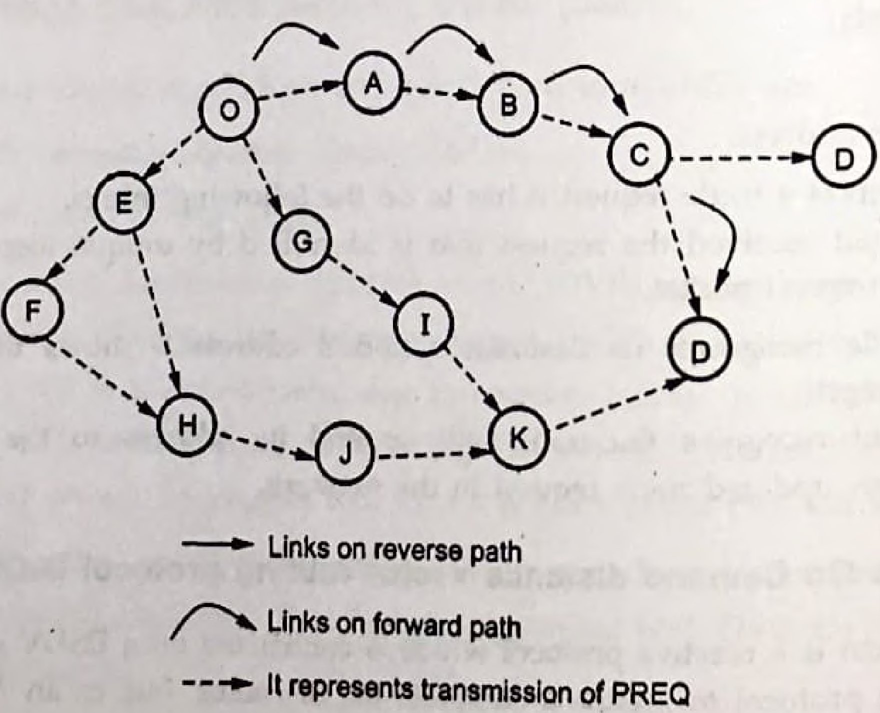


Fig. 3.7.2 Propagation of RREQ In AODV protocol - An example

Properties of AODV

A reactive routing approach is used to discover / maintain the route. This in turn reduces the number of routing messages.

HELLO messages are used to update the nodes routing table regarding next hop. Further AODV is bidirectional such that an RREP is sent along the reverse path based on the RREQ. However, due to the HELLO message there is an additional burden to the protocol.

3.7.4 Hybrid Routing

An efficient routing procedure can be achieved using a hybrid routing method which is a combination of proactive and reactive routing technique.

As each protocol has its own advntages beneficially using there strengths would be excellent.

If simultaneous usage of both protocols is not achieved then the efficiency is likely to be compromised. In order to strike a balance between both protocols (say X and Y), protocol X should be used locally while protocol Y should be globalised.

Scalability and adaptability in routing procedure is enabled by hybridization. This module basically contributes to framework tuning

3.7.4.1 Zone Routing Protocol (ZRP)

In the protocol the network is divided into a number of zones. Consider a zone z(m,n) where 'n' represents the node and 'm' denotes the radius, where a bunch of node operate at a maximum distance of 'm'.

$$Z(m, n) = \{i \mid H(n, i) \hat{u}\, m\}$$

Where, H(i,j) where i and j are different nodes and H(i,j) is the distance between the nodes.

The main components of the protocol's architecture are mentioned below.

1) Intra zone Routing Protocol (IARP)
2) Inter zone Routing Protocol (IERP)
3) Bordercast Resolution Protocol (BRP)
4) Neighbour Discovery Protocol (NDP)

The IARP covers the Routing zone which encompass the distance and routes of the nodes inside a zone. On the other hand the IERP uses selective flooding under the IARP.

Datagram are conveyed to the peripheral nodes by bordercasting (BRP). However, it is initially the NDP which initiates the neighbour discovery function.

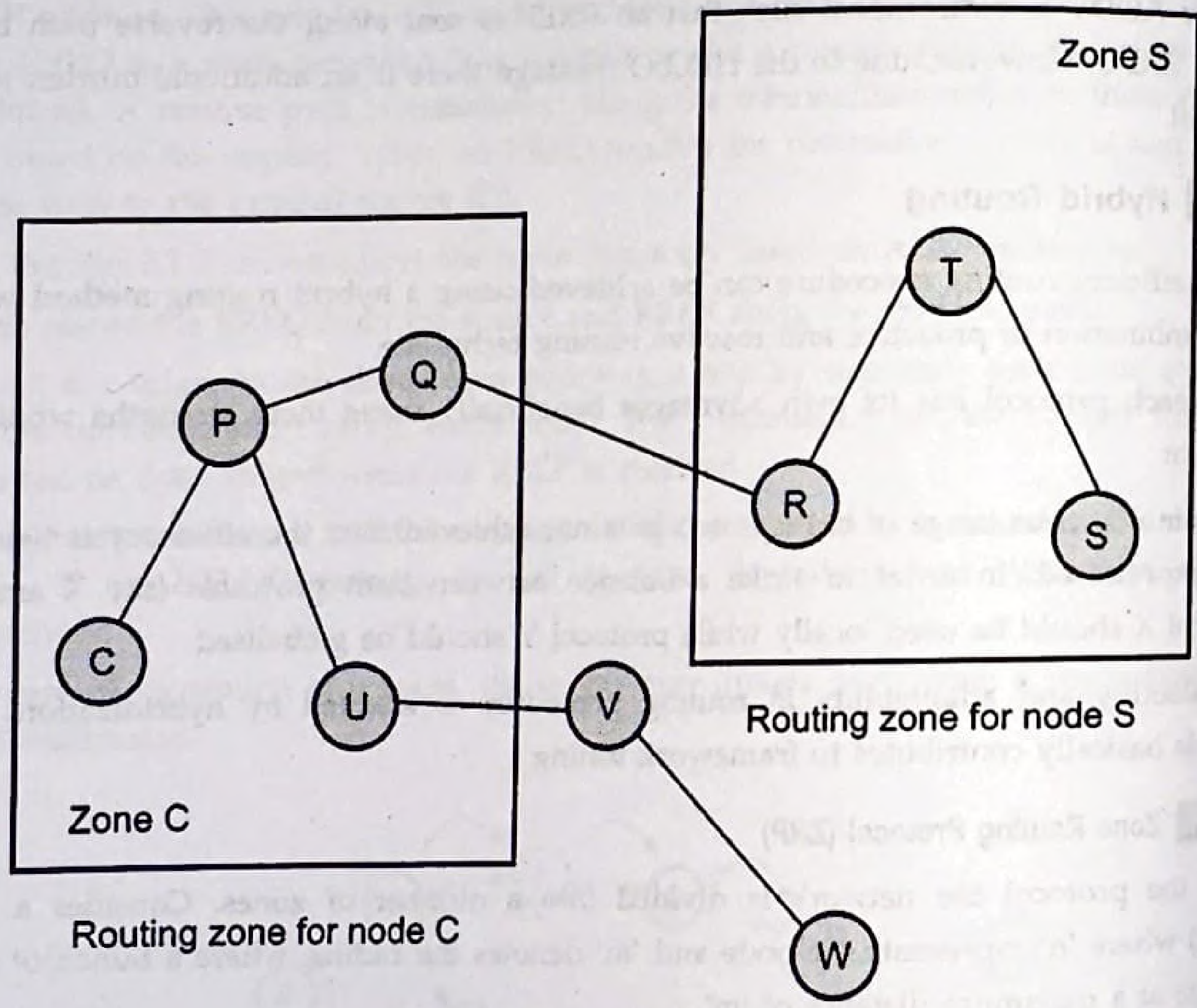


Fig. 3.7.3 Network with ZRP

Referring to the Fig. 3.7.3 shown above, a data packet is to be sent from node C to node S. We can see that node S is not within the zone and so a request is sent to the peripheral nodes Q and U. U forwards the request to the adjacent nodes and it is seen that S is along the routing zone of R and T. A reply is thus received from S and sent to C. Thus, IRP enables to maintain the routing information proactively within the zone and reactively beyond the specific zone.

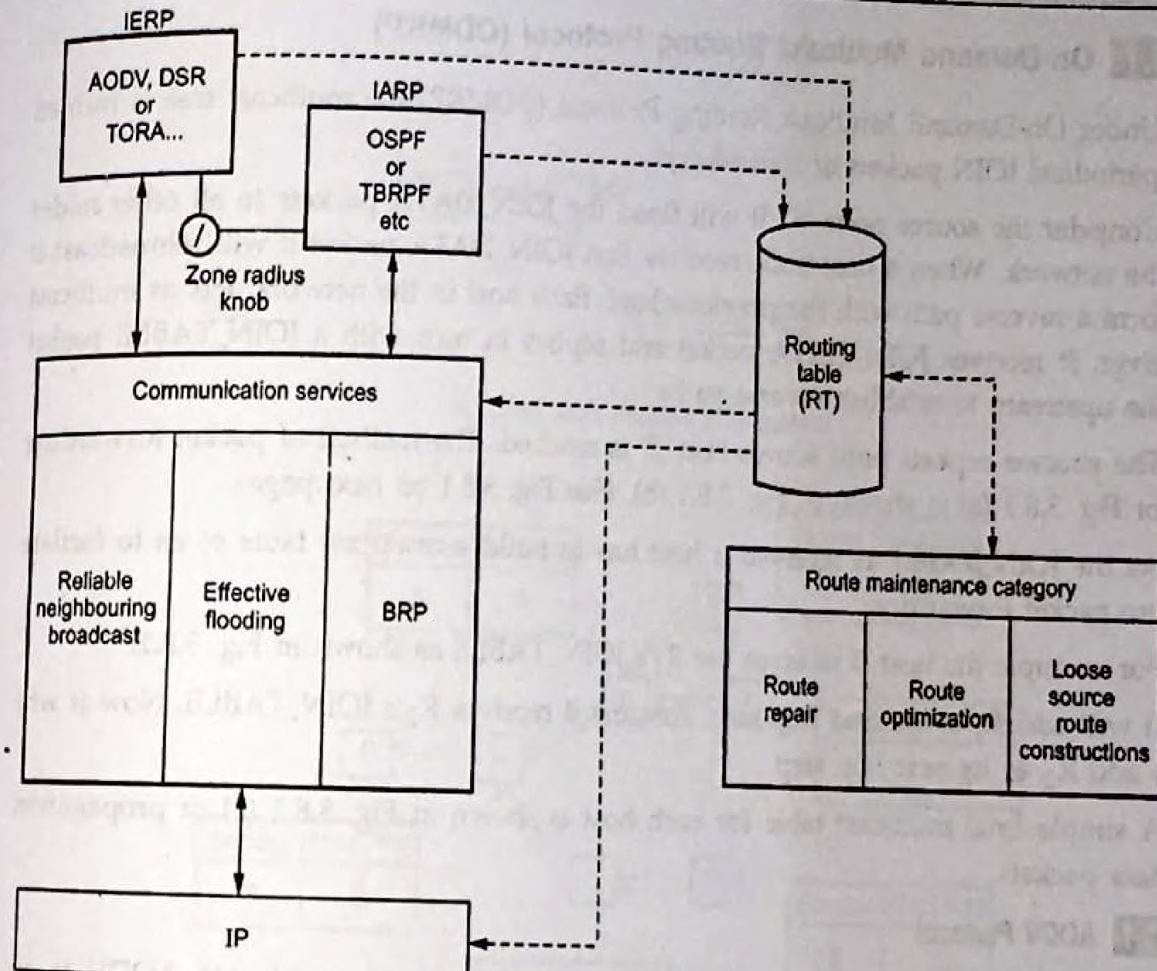


Fig. 3.7.4 Architecture of zone Routing Protocol [ZRP]

3.8 Multicast Routing

In multicasting protocols the two classification are

i) Source-based protocol

ii) Core-based protocol.

These classification is based on how multicast tree constructions are made. The source-based protocol attempts to maintain a per source multicast tree from every source host to the members in the corresponding multicast group. Thus there will be many multicast trees in the network.

In core-based protocol there will be one multicast tree that is rooted at core host. There are several applications served by multicasting. One such is video conferencing.

In MANET due to its host mobility, broadcasting nature of wireless environment, interference, applying multicasting is difficult than in the case of other wireless and wired networks.

3.8.1 On-Demand Multicast Routing Protocol (ODMRP)

Under On-Demand Multicast Routing Protocol (ODMRP) the multicast tree is formed by periodical JOIN packets of host source.

Consider the source node 'S'. It will flood the JOIN_DATA packets to all other nodes in the network. When a host node receives first JOIN_DATA packet it will rebroadcast it to form a reverse path with the previous host. Each host in the network acts as multicast receiver. It receives JOIN_DATA packet and replies in turn with a JOIN_TABLE packet to the upstream to establish reverse paths.

The process repeats until source host 'S' is reached. The method of packet forwarding is for Fig. 3.8.1 (a) is shown in Fig. 3.8.1 (b). (See Fig. 3.8.1 on next page).

As the JOIN_TABLE is received a host has to build a multicast table so as to facilate future packet forwarding.

For example the host B receives the R_1's JOIN_TABLE as shown in Fig. 3.8.1.

It will add R_1 as its next hop step. Assume B receives R_2's JOIN_TABLE. Now it will also add R_2 as its next hop step.

A simple final multicast table for each host is shown in Fig. 3.8.1 (c) in propagation of data packets.

3.8.1.1 AODV Ptotocol

The on-demand distance vector routing protocol known as multicast AODV is an extension of unicast AODV protocol. Here the multicast tree is updated whenever a new host joins the multicast group. For making process of tree updation easier the route request packet (RREQ) is being broadcast.

In case a host receives a RREQ and if the host is not a member of multicast group, then it will rebroadcast RREQ to the neighbouring members of the network.

But if the host is a member of multicast group and if this host receives a RREQ then it will give route reply (RREP) packet data to the sending host (S). Now the multicast table will be updated. By these processes forward path will be created.

If two RREQ's are received at a time then depending upon minimum number of hop count the one with minimum hop count will be selected.

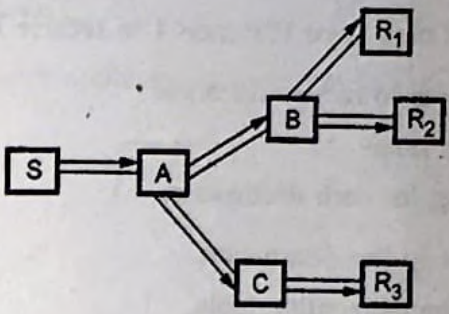
MACT

It is multicast activation (MACT) packet. The source S will unicast a MACT packet to the next hop step. On receiving a MACT packet the next hop will enable for source host (route with minimum hop count) and it leads to multicast tree.

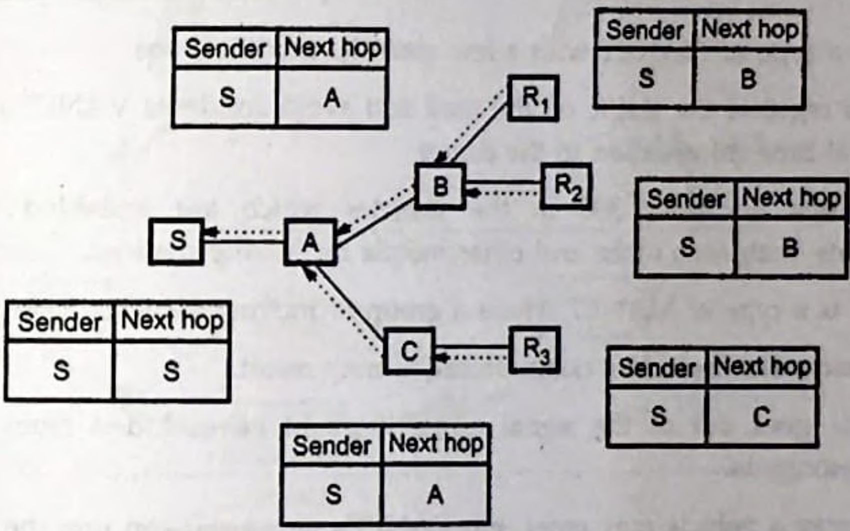
This procedure continues till a multicast meaber is reached successfully.

Distance vector algorithm design issues.

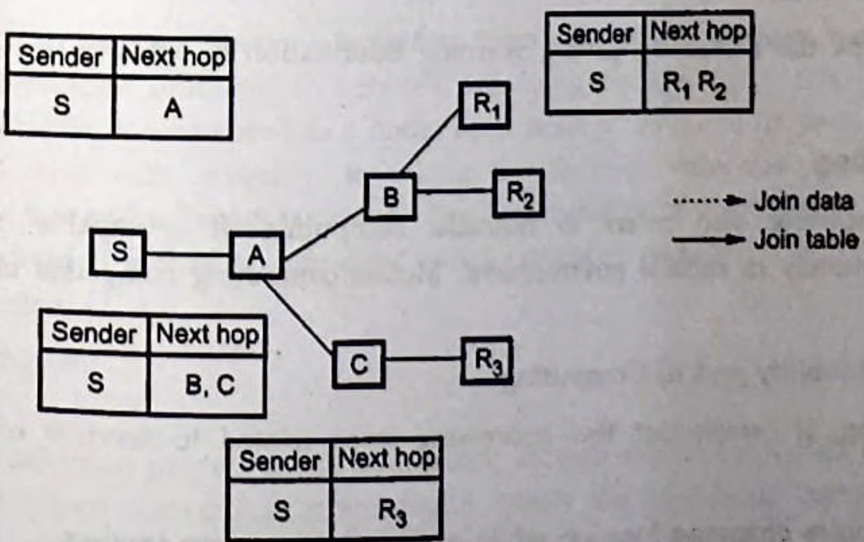
- The distance of each link in the network is a metric that has to be minimized.



(a) Load_data packets propagation



(b) Load_table packets propagation



(c) Last multicast table

Fig. 3.8.1 On-demand multicast routing protocol

a) Distance of each link may have 'distance' 1 to reduce hop count.

b) The algorithm attempts to reduce distance.

- The routing table at each node
  a) Specifies the next hop for each destination.

  b) Specifies the distance to the destination.
- Neighbours can also exchange routing table.
  Information for finding a route (or a better route) to reach the destination.

3.9 Vehicular Ad-hoc Networks (VANET) AU : June-16, Dec.-17, May-17,18

- VANET is a type of MANET with a few essential modifications.
- In order to regulate the traffic on the road and avoid accidents VANET is designed to provide real time information to the driver.
- With a range of about 300 m the vehicles which are embeded with sensors communicate with each other and other mobile facilitating devices.
- A VANET is a type of MANET where a group of moving vehicles forms a network.
- In larger networks multi-hop communication may result.
- If a vehicle goes out of the signal range it might be excluded from the network where it belongs to.
- In similar way a vehicle may enter into VANET's range and can join the network.
- Geographical information can be disseminated by VANET and can assist the driver in the moving vehicle.
- VANET helps the driver by giving warning information in advance in the form of messages.

Mobile computing

Mobile computing also refers to nomadic computing. It is capable of compute information remotely in mobile environment. Mobile computing comprises of two main concepts.

They are i) Mobility and ii) Computing

In computing, it carries out few processing steps related to services on a remote system.

Mobility denotes changing location while communication is on process.

3.9.1 Architecture of VANET

The vehicular Adhoc network architecture is shown in Fig. 3.9.1.

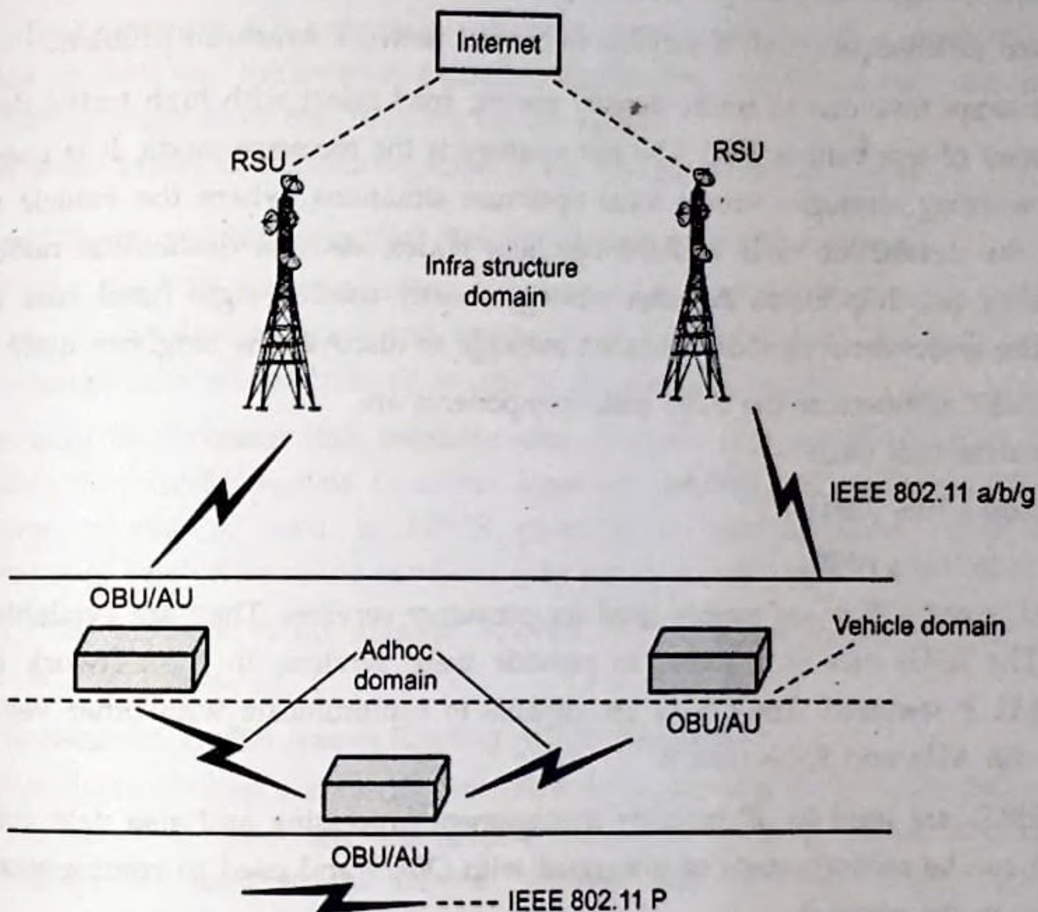


Fig. 3.9.1 VANET Architecture

The routing protocols obtain information from navigation services and basics street maps. The broadcast problems in network are being avoided with this protocol. Each and every vechicle is considered as a node. Each node is aware of its own position, with GPS devices and with multihop technique the farthest vehicular node select as a forwarder in the entire broadcast range. The functionality of these types of geographic protocols is divided is divided into three wider categories namely;

- Path selection
- Forwarding and
- Recovery

The path selection process is not mandatory. In case the protocol fails to find a road path then it selects forwarding strategy and selects the neighbour vechicular node to forward the packet data. There are two strategies used commonly for path selection known as,

- Dijkstra algorithm
- Next junction or intersection algorithm.

  The Dijkstra algorithm has problems like overhead and reduced availability.

  The next junction selection is suitable to control network overhead problem.

At the same time due to traffic density metric, road select with high traffic density is done instead of less vehicle load. The last strategy is the recovery mode. It is used when other forwarding strategies are in local optimum situations, where the vehicle node is closer to the destination node and the neighbor nodes, also the destination node is not reachable by one hop alone. Another strategy mostly used is right hand rule traverse graphs. The nodes send periodical beacon message to discover the neighbor node.

In VANET architecture the three main components are,

- Application unit (AU)
- On Board Units (OBUs)
- Road Side Units (RSUs)

The AU's and OBUs are mainly used for consumer services. They are available in the vehicle. The RSUs acts as a router to provide these services, in the network through IEEE 802.11 P standard. The OBU's are capable to communicate with other vehicles as well as with AU's and RSUs with it.

The OBU's are used for IP mobility management processing and also data collection. The AU's can be separate units or integrated with OBU's and used to communicate with the RSU's in the network.

Also dedicated short range communication [DSRC] is used to enable communication between vehicles. and the IEEE 802.11 P is made used among other RSU's and OBU's in the system. All these units together strive to provide services to user.

3.9.2 Routing Protocols in VANET

The VANET routing protocols are broadly classified as,

- Vehicle-to-vehicle based [V2V]
- Vehicle-to-infrastructure based [V2I]
- Combined hybrid V2V and V2I communication

The Vehicular Adhoc Network (VANET) enhances road safety and enhances the investment opportunities in many developing countries. VANET is developed as a part of Intelligent Transportation System (ITS). It provides innovative services that is related to several modes of transport.

- **V2V adhoc network :** It permits direct vehicular communication. It does not relay on fixed infrastructure supports. It is used to increase security dissemination and safety application.
- **V2I adhoc network :** It permits a vehicle to communicate with a roadside units. It focuses on data and information gathering application. For this, it may use single hop or multihop movement that depends on the range.

Under these broad classifications some of the routing protocols useful for VANET :

Grid-based Predictive Geographical Routing Protocol [GPGR Protocol]

- In VANET the V2V communication is a multi-hop communication among the vehicle that are wirelessly connected and has no fixed infrastructures. The data packet are sent through relay nodes from its source to the destination end.
- There may be frequent link breakage due to rapid changes in topology and few obstacles like traffic signals in urban areas on roadside. A maximum relay node selection criteria is used in GPGR protocol to manage these situations. The conventional MANET routing protocols may not be suitable for VANET scenario.
- The GPGR protocol could manage VANET with dynamic topology and the high speed in road traffic.

Intersection-based Traffic Aware Routing (iCAR) Protocol :

- The Intelligent Transportation System (ITS) applications are classified into one hop that are used to pass any information to nearby vehicles where the multihop applications are used in the Internet accesses. The vehicular density may cause transmission failures.
- This iCAR is mainly designed to improve the overall performed in urban. It utilizes both offline map data and real time traffic informations. iCAR is based on the vehicular density with average communication delay. It evenly distributes datapaclets in the network and avoids selection of high density roads as forwarding paths. Also before noting overall performance enhance ement link breakage rate must be checked.

Enhancement in Network Mobility Protocol [NEMO] :

- For accommodating Network Mobility (NEMO) in protocol MIPV6 the Internet Engineering Task Force (ITEF) requests for enhanced protocol such as NEMO basic mobility support protocol.
- An enhancement in NEMO is mainly to reduce vertical handoff latencies. Also V2V communication is used to initiate the required handoff processes. The vehicles does a relay like role with each other in this handoff processes with that of the fixed infrastructures. NEMO protocol could reduce the overall latency.

Evolving Graph Reliable Adhoc On-Demand Distance Vector Routing Protocol [EG- RAODV] :

- When the vehicles change their velocity in VANET the network topology is changed. It is not scheduled in advance. A graph theory helps to work with a dynamic changeable topology with the road and vehicle informations VANET dynamics can be assessed.
- A graph model is used in this protocol to design an efficient rotation protocol to design an efficient routing protocol for VANET.
- This EG-RAODV protocol is applicable to the networks where the topology dynamics are well predictable at different time periods.

Mobility Aware Zone-based Ant Colony Optimization Routing for VANET Protocol [MAZACORNET] :

- The Adhoc On-Demand multipath routing protocols like AOMDV, AODVM are enhanced versions of AODV protocol.
- These are reactive protocols. They result in traffic congestion and inefficient bandwidth utilization in the network.
- The developing MAZACORNET routing protocol is a hybrid algorithm. It divides the nodes into several zones which makes effective utilization of the radio bandwidth.
- This protocol applies reactive approach between the zones and proactive approach within a zone for finding routes. An advantage of this protocol is to reduce congestion in VANET.

3.9.3 Security in VANET

The VANET is vulnerable to many security attacks. This is because of the nature of its open access medium in the network. There are several threats and attacks posing a threat to driver confidentiality. The attackers can be classified into three classes namely,

- Insider Vs Outsider
- Active Vs Passive and
- Malicious Vs Rational attackers

Classification of Attacks on VANET :

- In VANET the vehicle itself is a required source of electricity and hence battery life is not a problem.
- The major threats on
  1. Confidentiality
  2. Integrity and
  3. Availability.

- In addition to this confidentiality and accountability are also a class of attack on VANET.

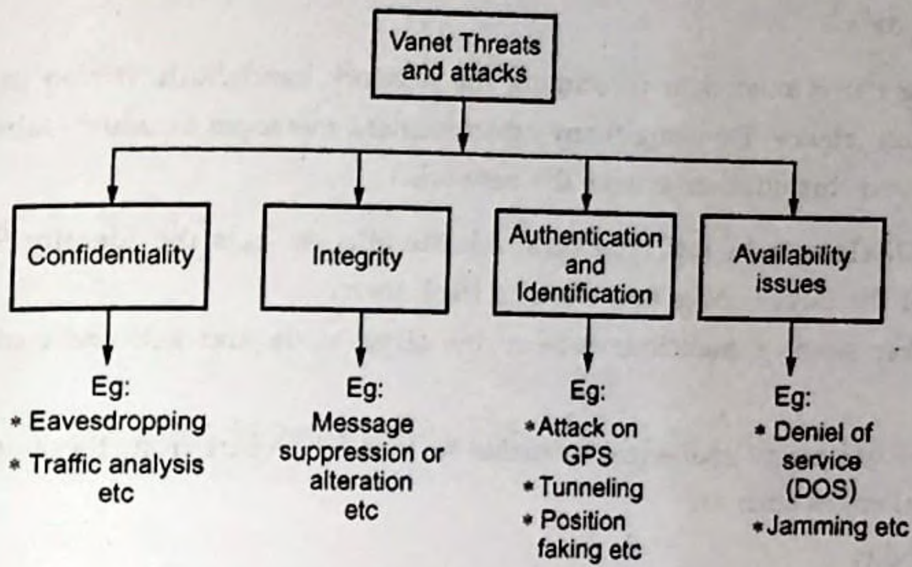


Fig. 3.9.2 Classification of Attacks of VANET

- Hence the VANET network are further classified as,
  1. Network attack
  2. Timing attack
  3. Social attack
  4. Monitoring attack and
  5. Application attack, etc.
- There are attackers such as Selfish Driver, Malicious attacker and Pranksters, etc. But each class of attacker makes different types of attacks.
- The Denial of Service [DOS] attacks targets to unavailability of networks. It can even prevent sending and receiving of messages to other vehicles from the network. If the attacker jams the network communication medium channel or it makes control of resources of a vehicle.
- **Sybil Attack :** Under this attack it includes sending multiple copies of messages to other vehicles so that it misguides the vehicle telling that there is a traffic jam ahead to it and it has to take another route.
- **Message Suppression Attack :** In this attack the attacker can choose some packets and drop it. Sometimes those packets may contain a critical required information. The goal of this attacker is to deny the collision and jamming information from reaching the knowledge of concerned authorities.

- **Alteration Attack :** This type of attack takes place where the attacker try to change or modify an existing data. It would delay the information transmission and also the content of data.
- **Spamming :** It is related to consuming the network bandwidth. It also increases the transmission latency. By using many advertisement messages in which subscribers are not interested this attacker attacks the network.
- **Identity Discloser :** In this type of attack the attacker gets the Identity Say ID and location of the target nodes and starts to track them.
  The attacker sends a malicious code to the target node and gets the required data from it.

Thus there are many challenges available to VANET. Apart from these attacks there are other challenges such as,

- Mobility
- Volatility
- Bootstrap
- Network scale, etc.

Security Requirements in VANET Networks :

An efficient VANET has to satisfy many security requirements. They have to be considered at the time of designing VANET's, so that it can withstand the attacks towards it. Some of the security needs include :

- Authentication
- Privacy
- Availability
- Integrity and
- Non-Repudiation method of identifying the attacks and preventing any crime in the VANET.

Hence all these security requirements done in VANET helps to prevent threats and attacks in the VANET to a greater extent possible.

3.10 MANET Vs VANET

AU : June-16, Dec.-16, 17, May-17, 18

MANET	VANET
It is mobile ad-hoc network.	It is vehicular ad-hoc network.
MANET has collection of mobile nodes.	VANET has collection of nodes where nodes refers to vehicles on roadside.
MANET is independent of infrastructure.	In VANET the vehicular nodes would communicate to network or nearest base station.
The nodes in MANET are random in nature.	Movement of nodes in VANET is restricted to road topology.
In MANET nodes may not experience random changes.	VANET experience random change in topology.

Security

Security is a critical issue as far as MANET is concerned. Preventing a deliberate attack on the network and blocking malicious content becomes all the more difficult nature of MANET. As the attack comes from within the network detection and prevention become cumbersome. Jamming the network and tying up the network with voluminous data overload could be easily done. Routing tables could be easily manipulated to convey misinformation so as to breach network security easily. Some of the major issues which cause serious security concern are discussed below :

Power supply : By spreading misinformation as mentioned above the network could be held up unnecessarily causing depletion in the battery backup.

Network boundary : The boundary cannot be demarcated as the mobile nodes take up the function of a router. Malicious content can be easily transmitted and using firewall becomes very difficult as it is impossible to judge the nature of the data flow.

Encryption : Encryption is rendered futile due to the limitations in computation. Without encryption the data remains exposed and vulnerable to attack.

Jamming : This could be easily done if a node is deliberately broadcasting misinformation and holding up data flow.

Security characteristics : The security characteristics of a network should ensure that it remains robust even in the eventuality of an attack.

Network sustainability : The flow of information should not be curtailed due to jamming.

Network authentication : Transmission must occur only between authenticated nodes and should be able to avoid decays.

Information security : Unauthorised access to the information must be strictly avoided.

Security issues are explained in the following chapter.

3.11 Security in MANET's

In recent years the mobile ad-hoc networks (MANET's) have attained tremendous attention due to its self configuration and self maintenance features. The aim of security solutions in MANETs is to provide security services like,

- Confidentiality
- Integrity
- Anonymity
- Availability to the mobile users.

Thus for security it is important to protect their protocol stack. The table shown below describe the security issues in each layer of protocol stack of MANET.

"In MANET the protection of the fundamental functionality to deliver data bits from one node to another node" is given top priority in providing security.

Sr. No.	Layer in protocol stack	Security issues in each layer
1.	Physical layer	Preventing the signal jamming deniel of service attacks.
2.	Data link layer	Protecting wireless MAC protocol and to provide link layer security support.
3.	Network layer	Protecting the ad-hoc routing and forwarding protocols.
4.	Transport layer	Securing and authenticating end-to-end communications through data encryption techniques.
5.	Application layer	Detection and prevention of viruses, worms, malicious codes etc.

Table 3.11.1 : Security issues in MANET

The multihop connectivity is provided in mobile ad-hoc networks in two different steps.

Step 1 : Ensuring single hop connectivity through the link layer protocols.

Example : Wireless Medium Access Control (MAC).

Step 2 : Extending connectivity to multiple hops through the network layer routing and data forwarding protocols.

Example : Ad-hoc routing.

There are two approaches for protecting MANET's namely proactive (prevents attacker in first place through cryptographic techniques) and reactive (detects security threats and react accordingly and it is posteriori natured) approaches.

The proactive approach is used for ensuring correctness of routing states whereas in the reactive approach is used for protect packet forwarding functions.

But as the number security features are increased there will be more computational complexity and it is also not economical.

3.11.1 Multifence Security Solution

In MANET multi-hop connectivity is provided through the distributed protocols in link and network layers. A better security approach is to have both proactive and reactive methods and all the three components should be encompased. The three components are

i) Prevention

ii) Detection

iii) Reaction.

The prevention component find the attacker by increasing the difficulty of entering the system. The detection and reaction components discovers only the occasional intrusions and take reactions so as to avoid pertaining adverse effects. The prevention component is achieved by secure ad-hoc routing protocols.

3.11.2 Network Layer Security

It is concerned with protecting network layer's functionalities for delivering packets through multihop ad-hoc forwarding method between mobile nodes. The proposals can be classified into two categories,

i) Secure ad-hoc routing protocols.

ii) Secure packet forwarding protocols.

3.11.3 Message Authentication Primitives

The messages are being transmitted between the nodes in the network. The content of these messages has to be authenticated and for security there are three cryptographic primitives are widely used. They are,

1) Message authentication codes

2) Digital signature

3) One-way HMAC key chain.

1) Message authentication codes

In this technique two node share a common secret symmetric key (k). They can generate and also check a message authenticator $h_k(\cdot)$ with help of a hash function 'h'.

A 'HMAC' could be verified by an intended receiver only ; the HMAC is a popular security primitive used for network layer.

2) Digital signature

It is based on asymmetric key cryptography. It includes signing or decrypting and the verifying or encrypting functions. It is not resilient against disk operating system attacks because an attacker may include false signatures and blocks verification process. If public key is known to all nodes then each node can verify digital signature such that digital signatures are more scalable to several receivers.

3) One-way HMAC key chain

There are many one-way cryptographic functions are available so that if output $\int(x)$ is given it not feasible to calculate input x value. Just by applying $\int(\cdot)$ in repeated manner on an initial input value then a chain of outputs can be found.

The computations incorporated in one-way key-chain-based authentication is less and an authenticator can verify larger number of receivers.

Notes

- Hash-chain based authentication need clock synchronization.
- Receivers should buffer a message for verifying when the key was revealed.
- A timer should be gauged carefully to monitor any second round of communication taking place due to key release.

Review Questions

1. *Define Mobile IP.*
2. *What are the goals of Mobile IP ?*
3. *Define node, home agent, home address in Mobile IP.*
4. *Mention the basic Capabilities of mobile IP.*
5. *Write a note on tunnelling in Mobile IP.*
6. *What is TCP ?*
7. *Define any two types of TCP.*
8. *What is DHCP ?*
9. *What are the advantages of TCP/IP ?*
10. *List any two improvements of TC*
11. *Explain mobile IP in detail.*
12. *Define mobile IP. Explain the routing mechanism in detail.*
13. *Explain the registration, discovery, tunnelling and encapsulation in Mobile IP in detail.*

14. *Explain DHCP in detail.*
15. *What is MANET ?*
16. *What are the advantages of MANET ?*
17. *List any three characteristics of ad-hoc networks ?*
18. *Mention any four advantages of MANET.*
19. *Write two properties of MANET.*
20. *What are the types of MANET routing protocols ?*
21. *What are the fundamental steps in routing ?*
22. *Write a note on VANET.*
23. *List any two security issues in MANET.*
24. *What is traditional routing ?*
25. *What is MANET ? Explain the characteristics and applications of MANET.*
26. *Discuss the routing in MANET in detail.*
27. *Explain traditional Vs MANET routing protocol in detail.*
28. *Write short note on : i) MANET ii) VANET and iii) Traditional routing*
29. *Explain vehicular ad-hoc networks in detail.*
30. *What are the applications of MANET ? Explain any one type of routing.*
31. *Explain MANET Vs VANET in detail.*
32. *What are the popular routing protocols used in MANET ? Explain.*
33. *Explain the characteristics of MANET. Comment on traditional routing protocols.*
34. *Explain the security issues in MANET in detail.*

University Questions with Answers

Part A

Q.1 *List the characterstics of MANETs.* **(Refer section 3.4 and 3.5.1)** AU : June-16, Marks 2

Q.2 *Compare MANET Vs. VANET.* **(Refer section 3.10)** AU : June-16, Marks 2

Q.3 *What is multicasting ?* **(Refer section 3.8)** AU : Dec.-16, Marks 2

Q.4 *Compare and contrast MANET Vs VANET.* **(Refer section 3.10)** AU : Dec.-16, Marks 2

Q.5 *List the applications of MANETs.* **(Refer section 3.6.2)** AU : May-17, Marks 2

Q.6 *Distinguish proactive and reactive protocols.* **(Refer section 3.7 and 3.7.3)** AU : May-17, Marks 2

Q.7 *What is the purpose of DHCP ?* **(Refer section 3.2)** AU : May-18, Marks 2

Q.8 *Compare VANET with MANET.* **(Refer section 3.10)** AU : May-18, Marks 2

Q.9 *What is the key mechanism in mobile IP ?* **(Refer section 3.1.4)** **AU : Dec.-18, Marks 2**

Q.10 *Mention two main design issues of MANET ?* **(Refer section 3.6)** **AU : Dec.-18, Marks 2**

Q.11 *What are the important steps in Destination-Sequenced Distance-Vector Routing (DSDV) ?* **(Refer section 3.7.1)** **AU : Dec.-18, Marks 2**

Q.12 *Identify the desirable features of Mobile IP.* **(Refer section 3.1.5)** **AU : May-19, Marks 2**

Q.13 *Why is routing in MANET so complex task ?* **(Refer section 3.6)** **AU : May-19, Marks 2**

Q.14 *Compare MANET versus VANET.* **(Refer section 3.10)** **AU : May-19, Marks 2**

Part B

Q.15 *Explain characteristics, applications of MANET.* **(Refer sections 3.4)** **AU : June-16, Marks 8**

Q.16 *Explain DSR routing protocols in detail.* **(Refer sections 3.7.2)** **AU : June-16, Marks 8**

Q.17 *Draw and explain the architecture of VANET.* **(Refer section 3.9.1)** **AU : June-16, Marks 8**

Q.18 *Explain the various Security and attacks on VANET.* **(Refer section 3.9.3)** **AU : June-16, Marks 8**

Q.19 *Explain the traditional routing protocols.* **(Refer sections 3.2 and 3.2.2)** **AU : Dec.-16, Marks 16**

Q.20 *What are multicast routing protocols ?* **(Refer section 3.8)** **AU : Dec.-16, Marks 8**

Q.21 *What are reactive and proactive protocols ? Specify its advantages and disadvantages.* **(Refer section 3.7 and 3.7.3)** **AU : Dec.-16, Marks 8**

Q.22 *Explain the design issues of MANET routing protocols in details.* **(Refer sections 3.6 and 3.6.1)** **AU : May-17, Marks 16**

Q.23 *Explain any two VANET routing protocol with an example.* **(Refer sections 3.9.2)** **AU : May-17, Marks 16**

Q.24 *Discuss route discovery and route maintenance mechanisms in DSR with illustrations. List its merits and demerits* **(Refer section 3.7.2)** **AU : Dec.-17, Marks 16**

Q.25 *Describe the architecture of VANET with the functionality of the components. Compare VANET with MANET.* **(Refer section 3.9.1)** **AU : Dec.-17, Marks 16**

Q.26 *Describe the architecture of VANET with a neat diagram.* **(Refer section 3.9.1)** **AU : May-18, Marks 13**

Q.27 *Explain the design issues in MANET and the applications of adhoc network..* **(Refer sections 3.6 and 3.6.1)** **AU : May-18, Marks 13**

Q.28 *Consider the network given below. Here 'S' is source node and 'D' is target node. Illustrate the process of route discovery, route reply, data delivery and route caching using DSR. Explain the approach.* **(Refer sections 3.7 and 3.7.2)** **AU : May-18, Marks 15**

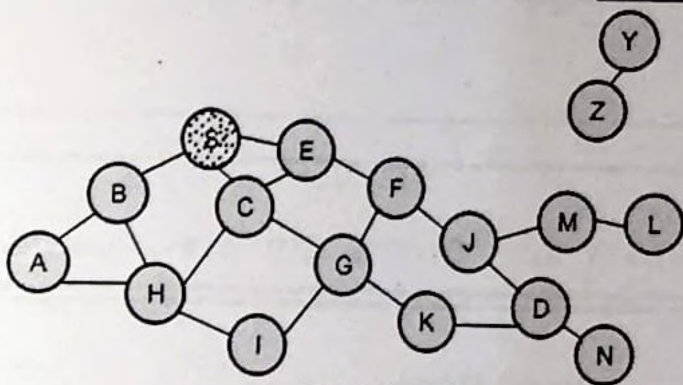


Fig. 3.1

Q.29 *Enumerate the processes involved in data packet delivery using mobile IP in adhoc networks.*
(Refer sections 3.1.5 and 3.1.6) **AU : May-18, Marks 15**

Q.30 *Explain mobile IP requirement and terminologies.*
(Refer sections 3.1.1, 3.1.2 and 3.1.3) **AU : Dec.-18, Marks 8**

Q.31 *Why the traditional IP cannot be used in the mobile network. In what way does mobile IP support mobile Hubs ?* **(Refer sections 3.1 and 3.1.2)** **AU : Dec.-18, Marks 5**

Q.32 *Illustrate DSR routing in detail and compare it with DSDV.*
(Refer sections 3.7, 3.7.1 and 3.7.2) **AU : Dec.-18, Marks13**

Q.33 *Explain the architecture of VANET and various security attacks on VANET.*
(Refer sections 3.9.1 and 3.9.1) **AU : Dec.-18, Marks 13**

Q.34 *With a neat diagram explain the packet delivery process between the correspondent node and the mobile node.*
(Refer sections 3.1.3 and 3.1.5) **AU : May-19, Marks 8**

Q.35 *Describe the characteristics and applications of Mobile Ad hoc networks.*
(Refer sections 3.3 and 3.3.1 and 3.4) **AU : May-19, Marks 13**

Q.36 *Summarize the two important classes of routing protocols for traditional networks.*
(Refer sections 3.6.2 and 3.7) **AU : May-19, Marks13**

Q.37 *Organize the steps involved in operation of Destination-Sequenced Distance-Vector Routing protocol. Illustrate with an example.*
(Refer sections 3.7 and 3.7.1) **AU : May-19, Marks 15**

□□□

Notes

Unit IV

Mobile Transport and Application Layer

Syllabus

Mobile TCP - WAP - Architecture - WDP - WTLS - WTP -WSP - WAE - WTA Architecture - WML

Contents

4.1 Overview of TCP/IP

AU : June-16, Dec.-18

To support mobility the Transmission Control Protocol (TCP) is applied for several applications.

Most of the applications rely on transport layer like TCP or UDP is user datagram protocol. There are two main functions of transport layer in internet namely checksumming and multiplexing or demultiplexing of data. TCP needs some special environments so as to be applied for mobile applications. UDP is connectionless and it does not guarantee reliable data delivery. But TCP offers connections between any two applications and it guarantees reliable data delivery.

4.2 Goals of TCP/IP

The transmission control protocol and Internet Protocol (IP) are the two important protocols and they are named as TCP/IP protocol suite. There are two important goals of TCP/IP.

i) The first goal in its design was to build and develop an interconnection of different networks that provide a universal communication services that is internetwork or Internet. The second goal is to interconnect various physical networks to form what actually appears to the users to be a larger network, and an interconnection of such networks forms an Internet. A node makes it possible to forward the data packets from one network to another network and it is called as a router. Since the routing function is a part of IP layer of TCP/IP protocol suite it is also called as IP router.

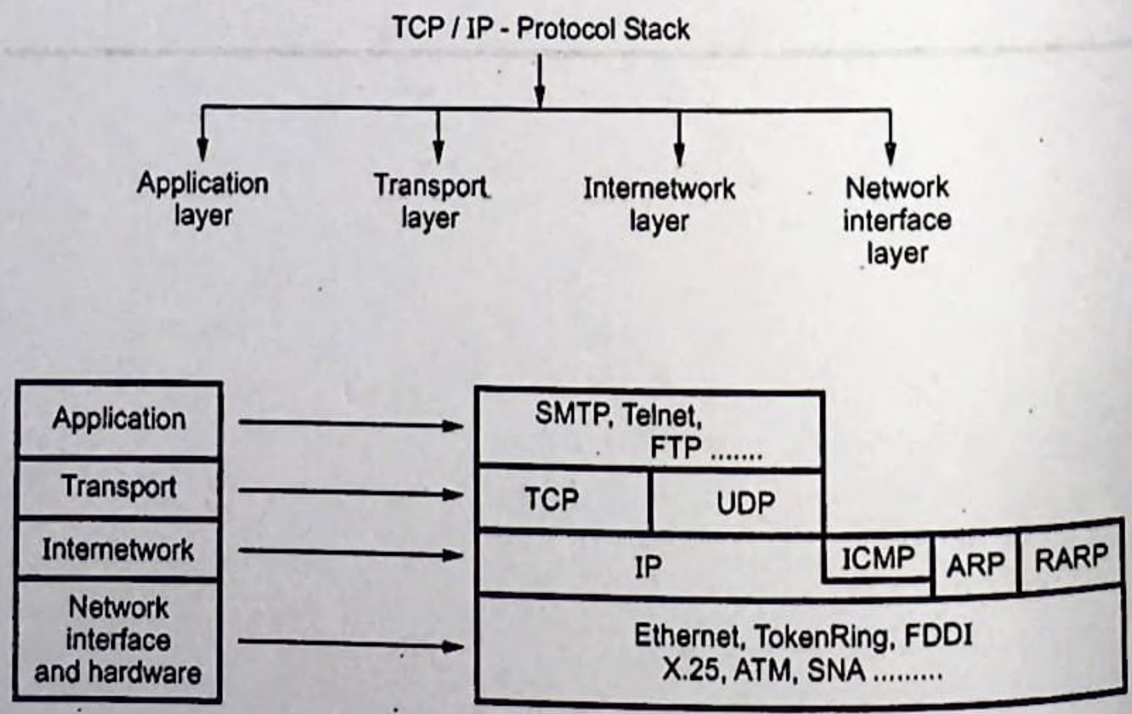


Fig. 4.2.1 TCP/IP-Architectural model

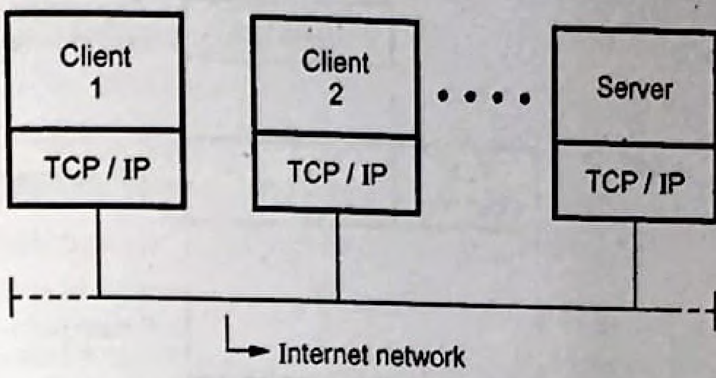


Fig. 4.2.2 Client server model - In TCP/IP

Each of the above four layers have different application functions like SMTP, Telnet etc. There are few important characteristics for the application protocols. They are :

i) TELNET

ii) FTP (File Transfer Protocol)

iii) SMTP (Simple Mail Transfer Protocol) etc.

For transport mechanism they use either TCP or UDP.

TCP is a peer-to-peer, connection oriented protocol, and there is no master-slave relation available.

Here server is an application available for the Internet users, and the client is a requester of that service. A client part is invoked to make a request by the user for his application and it inturn provides the service, using the TCP/IP as transport vehicle. 'Request' and 'Reply' signals are interchanged. A server is capable of attending several requests (multiple clients) simultaneously.

4.3 TCP/IP - Operation

Any 'communication' developed for data transmission may contain many networks and they are called as 'subnetworks'. Connecting the computer with the subnetwork is done by token ring. The blocks of data is then transferred from one host to another host by implementing Internet protocols (IP) in the end systems. Each entity in the network should have an unique address. Within each host, every process has its own address and it allows the transport protocol (TCP) to deliver data/information to each relevant process.

To control all the operations the user data and control data should be sent to the appropriate host. In this "sending of data" process usually a block of data is passed to TCP, and TCP will receive all the data first and then the entire block will be broken by TCP into smaller pieces for simplified processing. A control information known as 'TCP header' is appended along with each piece of data. Hence a 'TCP segment' is formed.

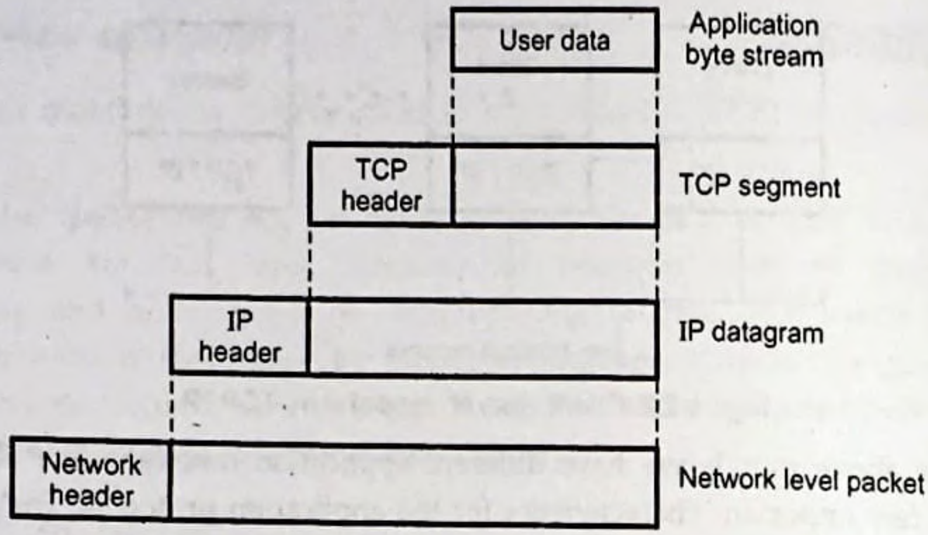


Fig. 4.3.1 Protocol data units - in TCP/IP protocol architecture

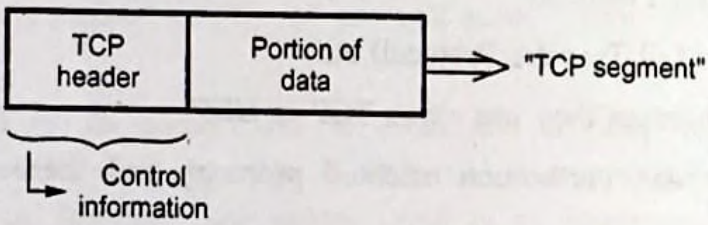


Fig. 4.3.2

Many items can be included within the TCP header like,

i) Destination port

ii) Checksum

iii) Sequence number.

When the TCP segments are handed over to Internet Protocol (IP) with necessary instructions, where to send those segments, the IP will append a IP header with relevant control information and the segment is now known as IP datagram.

These IP datagrams will be finally sent to network access layer and it is ready for transmission process towards first subnetwork in the network in the path to destination host.

The network access layer also appends its own header and now it has formed a frame/packet. The packet header includes important information like

i) Facilities requests (facility like priority) ii) Destination subnetwork address.

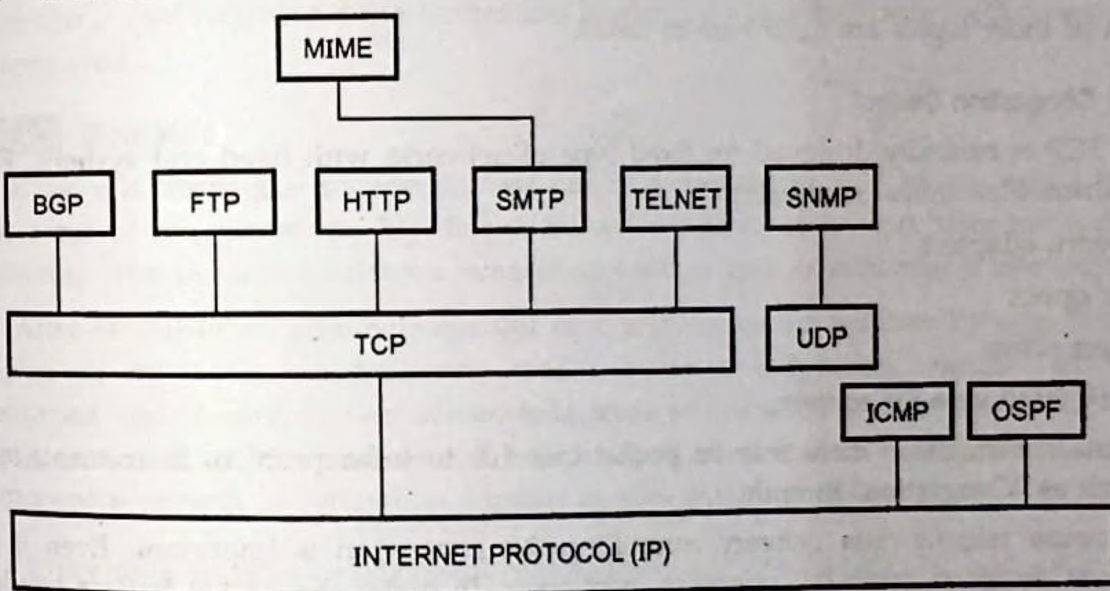
4.4 Applications of TCP/IP

There are many applications provided by TCP/IP protocol suite. Some of them are listed below.

1) **Simple Mail Transfer Protocol (SMTP) :** It provides an 'electronic mail' function. Also it is used for transferring messages between different hosts. The uses of SMTP includes mailing lists, forwarding and return receipts.

2) **File Transfer Protocol (FTP) :** The 'FTP' is mainly used for sending files from one system to another system which is available under an user command. FTP allows both binary and text natured file transfers.

3) **TELNET :** It enables remote log-on facility, by which user operates (log-on) as if he is connected to the system directly. There are two TELNET modules available. They are "User TELNET" and "Server TELNET". With a TCP connectivity the terminal data traffic takes place between these 'User TELNET' and 'Server TELNET'



TCP - Transmission control protocol; IP - Internet protocol
SNMP - Simple N/W management protocol ; UDP - User Datagram Protocol
and UDP length = (IP length – IP header length)
SMTP - Simple mail transfer protocol.
HTTP - Hypertext transfer protocol
FTP - File transfer protocol
BGP - Border gateway protocol
MIME - Multipurpose internet mail extension
ICMP - Internet control message protocol
OSPF - Open shortest path first

Fig. 4.4.1 Protocols in "TCP/IP" - Protocol suite

4.5 Types of TCP

AU : Dec. - 16, 18, May - 18, 19

There are several TCP techniques are available. It includes,

- Traditional TCP
- Indirect TCP

- Snooping TCP
- Mobile TCP
- Transaction-Oriented TCP

The Mobile TCP is one of the types of TCP Techniques.

4.5.1 Traditional TCP

In mobile environment TCP applies several mechanisms to improve efficiency. The topics to be discussed in traditional TCP are

i) Congestion control ii) Fast retransmit/Fast recovery

iii) Slow start iv) Implications on mobility.

Each of these topics are dealt here in detail.

4.5.1.1 Congestion Control

The TCP is basically designed for fixed type of networks with fixed end systems. For data transmission takes place using

- Network adapters
- Fiber optics
- Copper wires
- Special hardware for routers.

In data transmission there may be packet loss due to some problem in transmission path such as "Congestion" in node.

To ensure reliable data delivery controlling this congestion is important. Even if a network is designed carefully congestion may occur. In router the packet buffers would be filled and the router will be unable to forward packets.

Now the sum of input rates of the packets intended for an output link will be higher than output link capacity.

If there is a packet loss receiver unit will recognize it later by noticing a gap in packet stream. But upto the missing packet state the receiver sends acknowledge the sequence to the sender.

The sender by noticing a missing acknowledgement in the sequence of acknowledgement recognizes a packet loss occurance, due to congestion in path.

To avoid congestion now TCP reduces the rate of packet transmission drastically so that accumulation of packets gets slow down.

Note In heavy load TCP guarantees sharing of bandwidth. Also by using reliable hardware like special routers, network adapters and software the congestion in transmission path can be controlled.

4.5.1.2 Fast Retransmit / Fast Recovery

Two important features will lead to reduce congestion threshold. They are ;

1) Fast retransmit 2) Fast recovery.

If the sender receives acknowledgements continuously for same packet then sender assumes that the receiver has received packets upto acknowledged packet in the sequence. The gap in packet stream may be due to an error in transmission path or due to a severe congestion.

Once packet loss is noticed by sender it retransmits the missing packets before the allotted time expires. Such a behaviour is called as 'fast retransmit'.

If acknowledgements are received continuously it shows that there is no congestion and the sender would continue the same current congestion window. The sender always performs a 'fast recovery' from packet loss strategy. By this mechanism efficiency of TCP is improved.

4.5.1.3 Slow Start

If there is missing acknowledgement due to a packet loss TCP reacts fast. It may not come out of congestion quickly. But its behavior exhibits slow start after the congestion detection. The sender calculates a congestion window and its start size is one segment.

After arrival of an acknowledgement sender increases the window by one. Then after arrival of two acknowledgements, sender increases congestion window by two. It continues and if another two acknowledgments are received the congestion window is again increases by two and, now it will be equal to 4. Such a mechanism is called as exponential growth of congestion window in slow start technique.

Every time an acknowledgement coming back will take one Round Trip Time (RTT)

So far we noticed that congestion window was doubled every time. But the steps might be very large and hance doubling is not good. The exponential growth of congestion window stops at the congestion threshold.

Note As the congestion window reaches the congestion threshold level then after that if an acknowledgement is received then the window will be increased only by (linearly) and doubling the size is avoided.

4.5.1.4 Implications on Mobility

The mobility itself may induce packet loss. Always soft handover may not be possible from one system to another.

Fundamental design problem in TCP is if there is packet loss the cause for it cannot be distinguished easily. Sometime error control mechanism is misused for congestion control. But end result will be packet loss for both cases.

When using the mobile IP there may be some packet available in transit to the old agent (foreign agent) where as the mobile node is moving to a new foreign agent. So that there may be packet loss. Thus packet loss may also be induced by mobility from one node to another.

4.5.2 Indirect TCP

The traditional TCP had the problem of poor performance with wireless links. Also the TCP available within a fixed network cannot be altered. Due to these reasons the 'Indirect TCP' (I-TCP) emerged slowly. The I-TCP emerged slowly. The I-TCP segments the TCP connection into two parts namely,

1) Fixed part 2) Wireless part.

In the below diagram the mobile host is connected through a wireless link and an Access Point (AP) to the wired internet. The correspondent host resides here. The foreign agent can control the mobility of mobile host. Also it can handover the existing connection to next foreign agent whenever the mobile moves on.

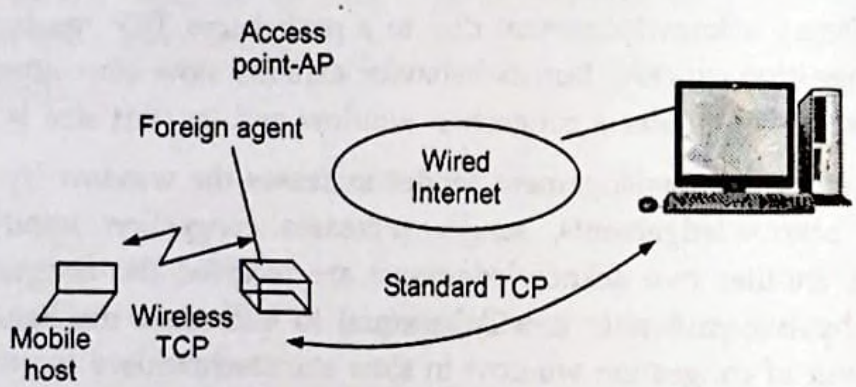


Fig. 4.5.1 Indirect TCP segments

If handover takes place I-TCP needs several actions to happen. The I-TCP has many advantages and they are listed below :

- The I-TCP does not need any changes in TCP protocol when used by hosts in fixed network. All optimizations for TCP works between correspondent host and foreign agent.
- Because of the strict partitioning into two connections in I-TCP the transmission errors if any would not propagate into fixed network.
- In I-TCP new mechanisms can be introduced between foreign agent and mobile host. It allows different tests to be applied.
- It is also possible to apply different transport layer protocol between mobile host and foreign agent. Compressed headers can also used in I-TCP.
- But with the technique of segmentation in I-TCP there are also same demerits. Some of the demerits are listed below :

- The correspondent node is not aware of partitioning done. A crashing access node may crash applications that runs on correspondent node and assumes a reliable end-to-end delivery.
- Increased handover latency creates problem.
- The foreign agent involved should be a trusted entity or otherwise their will be security problems.

4.5.3 Snooping TCP

Main drawback in I-TCP is the segmentation of single TCP connection into two connections. Because of this original end-to-end TCP semantic will be lost. But here the function of enhancement is buffering data closer to mobile host so as to perform local retransmission when there is a packet loss. A correct place for TCP enhancement is the foreign agent (in mobile IP terms) as shown below.

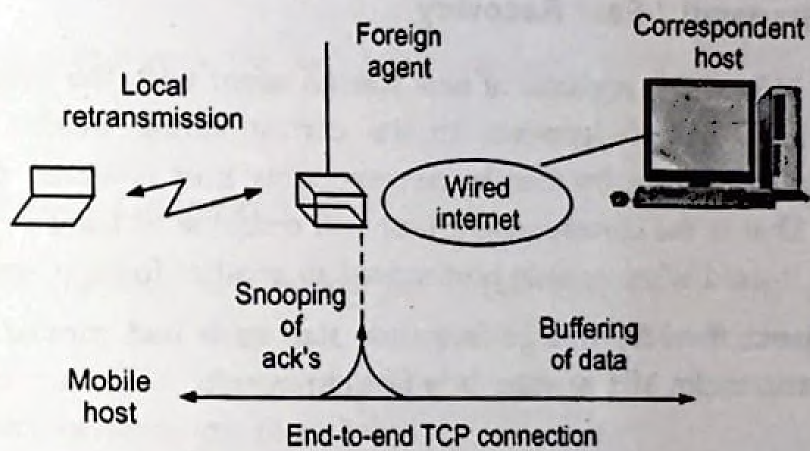


Fig. 4.5.1 Snooping TCP

As it is seen the foreign agent buffers packets with that of the destination mobile host. In addition to this, it also snoops the packet flow in two directions (as shown) and recognizes acknowledgements. By buffering packets to a foreign node there is a chance of local retransmission in case of packet losses in wireless link. Till receiveing acknowledgements from mobile host the foreign agent continues buffering process. If it does not receive acknowledgement then either packet or acknowledgement could be lost.

As an alternate it could receive a duplicate ACK but it also reflects that a packet has been lost. Now a faster retransmission is made by foreign agent and time outs will also be shorter. The foreign agent can filter any duplicate ACK's so that unwanted retransmissions are avoided.

Unnecessary traffic on wireless link can be avoided since the foreign agent is capable of discards duplicates of packets that was already transmitted and acknowledged.

With snooping TCP there are many advantages. Some of them are summarized below :

i) The end-to-end semantic of TCP is not changed.

ii) As soon as a mobile host reaches a new foreign agent a handover of state is not required.

iii) The correspondent host involved need not be changed.

iv) It does not account wheather the next foreign agent had applied enhancement or not.

4.5.3.1 Demerits of Snooping TCP

i) It does not differentiate the behavior of wireless links as in the case of I-TCP.

ii) Usage of negative acknowledges results in more number of mechanisms.

iii) Only if the encryption used above transport layer this snooping TCP can work or otherwise it will not work.

4.5.4 Fast Retransmit / Fast Recovery

As the Mobile Host (MH) registers at new foreign agent with the help of mobile IP it will send duplicate acknowledgements to the corresponding hosts. The idea is to transmit three duplicate Ack's. By this the corresponding host is forced to enter into fast retransmit mode. That is the correspondent host will continue to transmit with same rate (i.e. previous rate it used when mobile host moved to another foreign agent).

On the other hand the MH will go into slow start as it had moved to new foreign agent and it will also make MH to enter into fast retransmit.

4.5.4.1 Merits

- Simple design approach.
- Minor changes in mobile host's software is only required.

4.5.5 Transmission / Time-out Freezing

If connection problems exists MAC layer has noticed even before the connection was actually interrupted with respect to TCP. MAC layer does not decide that the disconnection is due to congestion. But the MAC layer informs TCP layer regarding upcoming loss of connections.

Thus as a result TCP stop transmission and it freezes the present state of the congestion window. Once the MAC layer knows about interruption at earlier stage it informs it to correspondent and mobile host.

On the other hand if connectivity is detected by MAC layer it informs TCP to resume its operation again which was stopped earlier.

4.5.5.1 Merits

- Resumes TCP connection in spite of longer interruptions.
- It is independent of ACK's and usage of sequence numbers.

4.5.5.2 Selective Retransmission

One of the important advantage of extension of TCP is the usage of 'selective retransmission'. The TCP-ACK's are cumulative, and they acknowledge the receipt of packets upto a particular packet. Now the sender retransmits all packets from the last packet onwards. This is 'go-back-n retransmission' method. The bandwidth is wasted due to sending many packets once again.

An alternate to this is selective retransmission. The TCP requests indirectly for selective retransmission. The receiver is capable of acknowledging single packets and the sender can determine in particular about which packet is to be retransmitted.

4.5.5.3 Merits

- Sender will retransmit only the packet that was lost.
- Bandwidth is saved.

4.5.6 Transaction - Oriented TCP

Consider an application is running on mobile host (MH). The MH sends short requests from time to the server. If the application that is running reliable packet transfer it would use TCP. Due to this several packets are required over the wireless links. The sequence of steps are given below.

- At first TCP use a three-way handshake for establishing connection.
- For transmission of request and closing connections through three-way handshake atleast 4 (1 + 3) additional packets are neeeded.

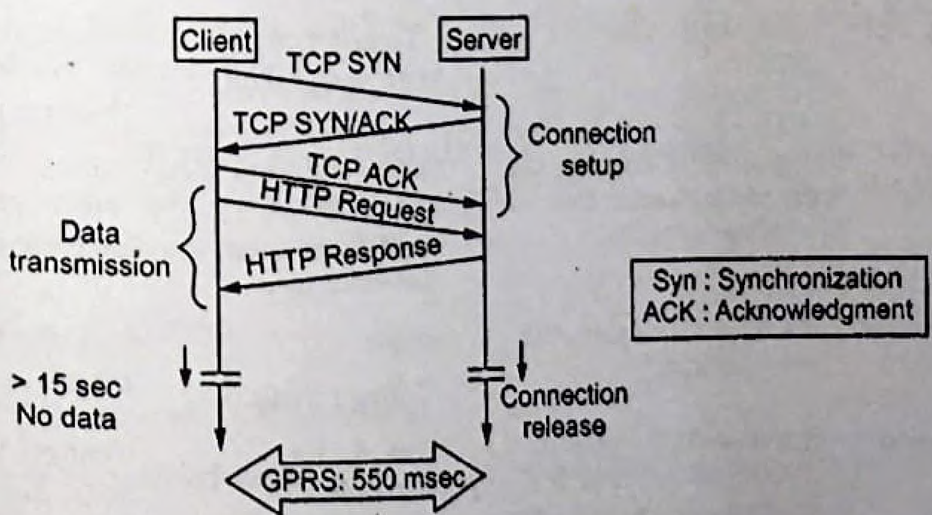


Fig. 4.5.2 TCP connection setup overhead.

- If there is a heavy traffic for a long time this requirement is minimum or otherwise it will be of waste to have more packets to handle less packet transmission.

In this example an overhead scenario is shown. The web services depend on HTTP and it need reliable transport system. TCP is used for this purpose in Internet.

The TCP connection has to established before a HTTP request is sent. Assume GPRS is used as wire area transport system.

There is an one-way delay equal to 550 msec. To set up a TCP connection it may take more than one second.

The Transaction-oriented TCP (T-TCP) emerged in this regard to provide more efficiency T-TCP can combine the packets for both connection establishment and release with that of the user data packets. By this approach the additional number of packets can be reduced. If there is seven additional packets required this T-TCP can reduce it upto two packets.

Merit

- Reduction in overhead.

Demerits

- Needs changes in mobile host and correspondent hosts.
- Has security problems.

Summary of the classical enhancements to the TCP are tabulated below regarding mobility scenario.

Sr. No	TCP approach	Mechanism involved	Merits	Demerits
1.	Indirect TCP (I-TCP)	It segments TCP connection into two.	Simple. Isolation of wireless link is possible.	Loss of the TCP semantics. Security problem.
2.	Snooping TCP (S-TCP)	Snooping of data and ACK's	Transparancy. MAC integration.	Inadequate isolation of the wireless links. Security problem.
3.	Mobile TCP (M-TCP)	Segments TCP connection, can choke sender through window sizes	End-to-end semantics is maintained. Handles frequent disconnections.	Poor isolation of wireless link. Security problem.
4	Fast retransmit fast recovery	It avoids slow-start after any roaming.	Simple. More efficient.	Not transparent. Mixed layers.
5.	Transmission time-out freezing	It freezes TCP states at disconnections, later it resumes after reconnection.	Work for long interruptions.	Changes in TCP. MAC dependent.

6.	Selective retransmission	Lost data only retransmitted.	Highly efficient.	Complex. Need more buffer spaces.
7.	Transaction-oriented TCP (T-TCP)	Combine connection setup/release.	Efficient for few applications.	Not transparent. Security problems

4.6 Mobile TCP

AU : June - 16

It is important to address the problem of occurrence of lengthy and frequent disconnections.

The mobile-TCP (M-TCP) has same goals as I-TCP and snooping TCP; to avoid the sender window from disconnection or shrinking if bit errors cause but not the congestion causes current problem.

- This Mobile-TCP aims to improve system throughput.
- M-TCP lower delay time.
- M-TCP maintains end-to-end semantics of TCP.

When there is frequent or lengthy disconnections in network then mobile-TCP may be suitable to compensate it and increases system throughput.

The M-TCP also segments TCP connection into two as I-TCP. But an unmodified TCP is used on standard host-supervisory host (SH) connection.

The M-TCP achieves low bit error rate, in case of wireless links.

The Supervisory Host (SH) supervises all the packets transmitted to Mobile Host (MH) and ACK's sent by MH's. In case ACK not received from MH then SH decides that the MH is disconnected. Now it sets the sender's window size as '0' and sender is now said to be in persistant mode.

The sender's state remain constant whatever be the time for which the receiver is disconnected. This is persistant mode.

An adapted TCP is used by wireless link and it is capable of recovering from packet losses. It does not use slow start. The M-TCP also needs a bandwidth manager to provide fair sharing over wireless links.

4.6.1 Merits of M-TCP

- Maintains end-to-end TCP semantics.
- It can avoid unwanted retransmissions in case of MH disconnections.
- Lost packets will be retransmitted automatically.

4.7 Improvement in TCP Performance

AU : June-16, Dec.-16, 17, May - 18

Consider a client and server program located at different points. The client program uses a temporary (ephemeral) port number and the server program uses permanent (well-known) port number. These port numbers are used for authorized identification.

Some permanent port used by the TCP are tabulated below.

Protocol	Port	Description
TELNET	23	Terminal network
Users	11	Active users
SMTP	25	Simple mail transfer protocol
RPC	111	Remote procedure call
DNS	53	Domain name server

Improved TCP services

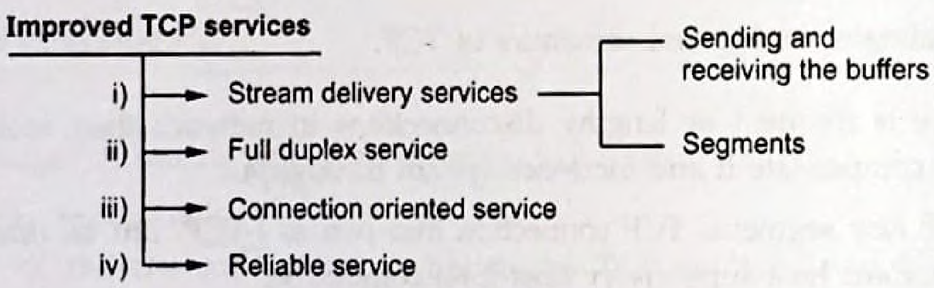


Fig. 4.7.1

i) Stream delivery service : TCP is also known as stream oriented protocol. An application program or process transmits a group of bytes to User Datagram Protocol (UDP) for delivery purposes. There may be several groups of data sent to UDP but the UDP considers only one group of data at a time.

TCP monitors the sending process and receiving process for an ordered sequence of bytes transmission and reception of the exact replica of the data stream. The data bytes are assumed to travel in a tube like structure.

Under sending and receiving processes TCP requires buffers for data storage. For each direction there is sending and receiving buffers available. For implementation of these buffers a circular array of 1 byte positions are considered. The buffer at the receiver end has to receive the corresponding data streams. If any bytes are empty it has to be filled by the data from the network.

Before transmitting data few points have to be noted such as : For TCP, the IP acts as a service provider and it has to send data/message in the form of ordered bytes. TCP has to get the data bytes and it groups them into packet form known as segments. A header information is appended along with this segment. The transmitter and receiver should be transparent with all the processes they adopt and they should be synchronous with each other for better reception of data streams. It is worth noting that the segments at transport layer need not be same and of fixed size.

ii) Full duplex service : The data flow which is possible at a time in both directions and it is known as full duplex service. Hence each TCP will have both transmitting and receiving buffer and the data segments are transmitted in both directions.

iii) Connection oriented service : TCP itself is a connection oriented protocol. When two processes (A and B) at different sites want to communicate a sequence as follows takes place.

- TCP of A informs the TCP of B and gets approval status from TCP of B.
- TCP of A and TCP of B exchanges data streams in both directions.
- If all data are sent and buffer is in empty condition the TCP's of A and B processes will destroy their buffers.

Such a kind of sending and receiving of data is highly improved with TCP/IP.

iv) Reliable service : TCP is a well known reliable transport protocol. The safe and accurate reception of data is arrived with help of this TCP protocol suite.

Also for smooth operation TCP uses four timers namely

a) Retransmission timer b) Persistence timer

c) Keep alive timer and d) Time-waited timer

TCP also takes care to avoid congestion in the network.

Some of the Internet examples in connection with TCP/IP protocol suite are shown here. Consider two networks namely 1 and 2 interconnected with the help of a router.

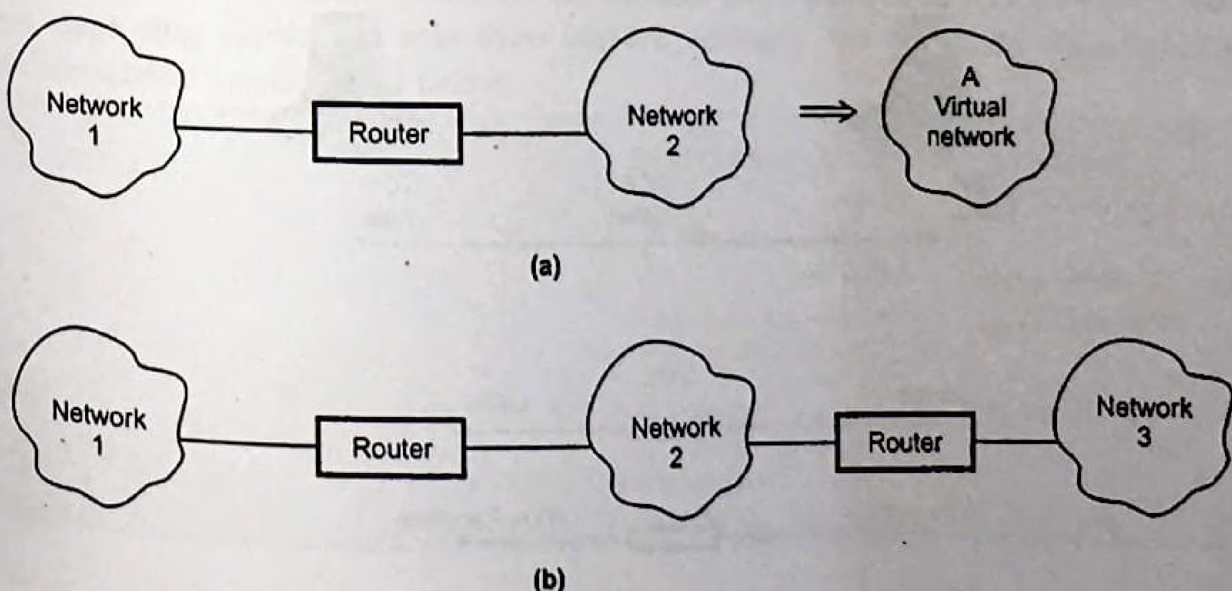


Fig. 4.7.2 Internet examples a) Two networks interconnected b) Multiple networks interconnected

The two interconnected set of networks in Fig. 4.7.2 (a) is seen as one logical network and a router enables communication between two networks. More than one router may be used in case of multiple networks interconnected. The router has few fundamental properties :

i) From the network point of view a router is a normal host.

ii) From user point of view the routers are invisible and they form one large internetwork.

The Internet protocol (IP) address comprises of two parts and the IP address = <network number><host number>. This network number is unique throughout the Internet and the host number is assigned by the organization that controls the network identified by the network number.

4.7.1 Adaptation of TCP Window

- A three-way handshake is required for connection establishment of first TCP session. The operation of connection is a systematic procedure.
- Using a SYN packet the local system communicates with the remote end.
- It sends an initial sequence number to the remote end.
- Receiving this at the receiving end, on ACK of the initial sequence number is sent back to local system as response of the remote system. Also an initial sequence number of the remote end is sent in response SYN packet.

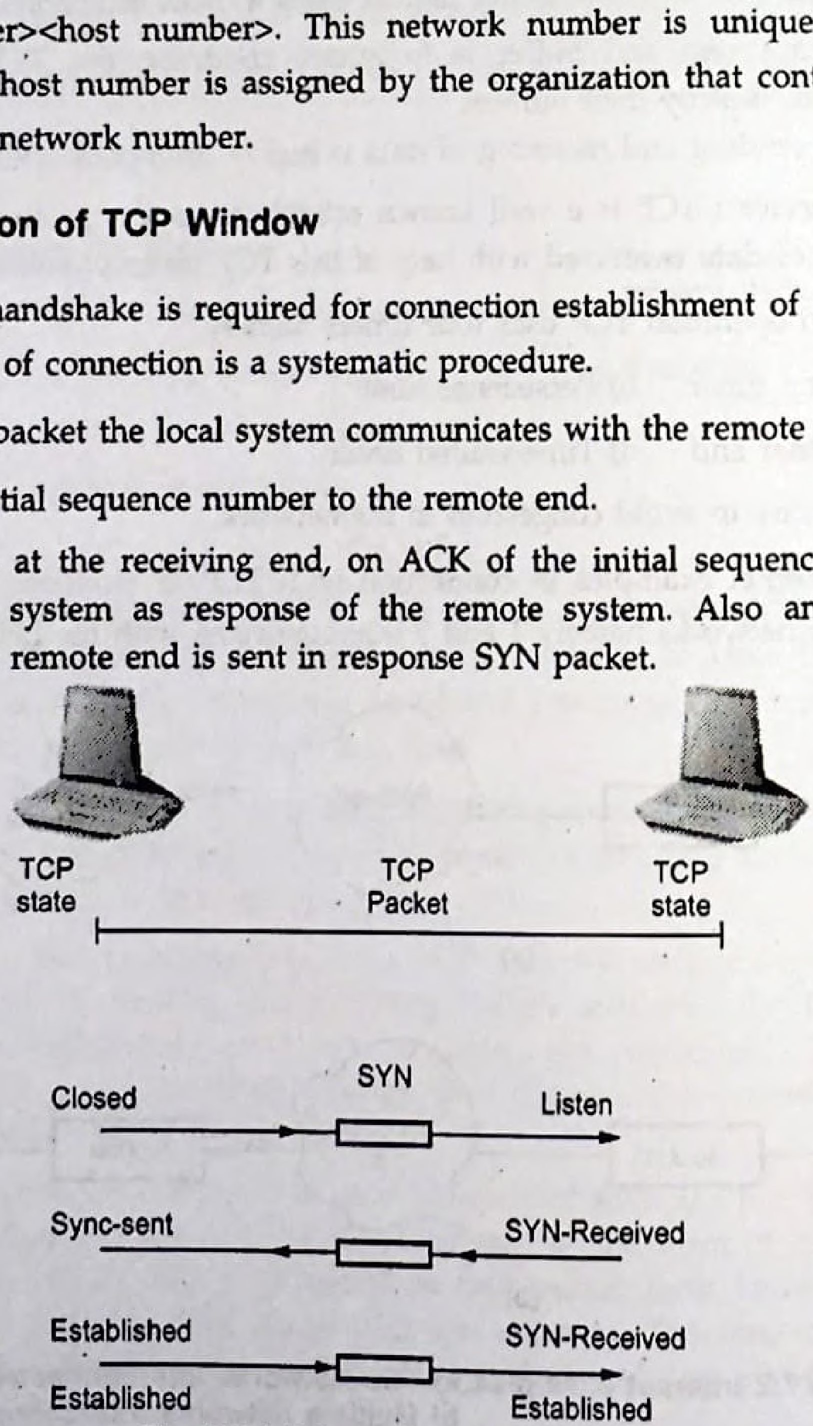


Fig. 4.7.3 Adaptation of TCP window

- The local end then responds with an ACK of this remote sequence number.
- It is important to note that before any data is sent this deals performance implications of this protocol is that the time taken for the two systems to synchronize is one and half round-trip times [RTTs]
- This has to be assured before every data transfer.
- As the connection has been established the two systems begins to transfer data. TCP is a sliding-window protocol. The flow control is mainly based upon the management of retransmission timeouts and the advertised window size. This is an attempt to optimize protocol performance within that of the observed delay and the loss parameters of the connection established. TCP is an adaptive flow-control protocol. In case of any data loss sensed by the sender the TCP flow rate gets reduced.
- Also the TCP flow rates will slowly increase again when the reliable retransmission is established.
- If there is no reliable flow then invariably reestablished flow rate will back off to an initial state and then the entire adaptive flow-control process will start again.
- TCP behaves adaptively for data transfer procedure.

4.8 TCP over 2.5G / 3G Wireless Networks

AU : Dec.-18

The 2.5G / 3G wireless networks are focused for transportation of Internet data. When deploying application over these wireless networks, the important characteristics to be considered are tabulated below.

Data rate	2.5G systems - 10 to 20 kbps (uplink) - 20 to 50 kbps (downlink) 3G system - 64 kbps (uplink) - 115 to 384 kbps (downlink) Periodic allocation of high - speed channels may be allotted.
Jitter	Wireless system generally suffer from delay spikes due to temporal loss of radio coverage blocking etc. In GSM it is 10 ms (approx.) and more.

Latency	GPRS provides average delay of < 2 sec with highest quality of service. Algorithms for error correction and protection (like FEC) are applied in wireless networks.
Packet loss	During handovers packets may be lost. The link level retransmission has reduced the loss rates in 2.5G/3G wireless systems.

The configuration parameters with respect to the above characteristics for adapting TCP to the wireless environment are;

i) Limited transmit (Useful when smaller amount of data are sent)

ii) Large windows (Large window should be supported).

iii) Large MTU (Maximum Transfer Unit). If the MTU is larger it will increase congestion window.

iv) Explicit Congestion Notification (ECN).

v) Selective Acknowledgment (SACK).

vi) Time stamp.

vii) No header compression.

The above recommended configuration parameters for 2.5G/3G networks are already used by the i-mode system. To have better efficiency in the above wireless networks all the parameters have to be considered.

4.9 Applications of TCP/IP

AU : June - 16

- Many of the real time applications are related to ICP/IP and some of them are detailed below.
- A simple mail transfer protocol (SMTP) used to exchange information across different systems.
- File transfer protocol (FTP) is used to send large data files.
- Post office protocol (POP) is used for email services.
- Internet message access protocol (IMAP) is used for retrieval of email informations.
- TELNET protocol is used for interactive sessions similar to the TCP platform.
- NET bios session service is used in TCP as session protocol respectively.

4.10 Wireless Application Protocol (WAP)

The wireless world of web development is tremendous as it changed the field of communication more brighter. The wireless application protocol forum popularly known as WAP forum was actually founded in the year 1997. The main objectives of this WAP forum was,

i) To bring diverse Internet contents like web pages, push services etc.

ii) To provide other data services like stock quotes to mobile terminals (PDA's) and digital cellular phone units.

iii) To provide better protocol suite to support world wide wireless communication, the Internet applications.

iv) To support wireless networks like CDPD, GSM, UMTS etc.

Many solutions were derived by the "WAP Forum" to meet these requirements they are :

a. **Scaleable :** The protocols and other services should be able to be in scale with the customer needs.

b. **Interoperable :** It allows the terminals and softwares from several vendors to communicate with many networks of different providers. Hence internetworks communication is made possible.

c. **Efficient :** To provide proper quality of service suitable to the requirements of wireless and the mobile networks.

d. **Reliable :** To provide predictable and consistent platforms for deployment of services.

e. **Secure :** It should have provisions to secure data and to preserve data integrity and devices.

WTA → Wireless Telephony Application

HTML → Hypertext Markup Language

WML → Wireless Markup Language

In the Fig. 4.10.1 it is evident that various scenarios are possible for integrating many WAP components into the existing fixed and wireless networks. It is shown as a part of the full figure. The other part of the figure is the fixed network which comprises of networks such as Public Switched Telephone Network (PSTN) and traditional Internet.

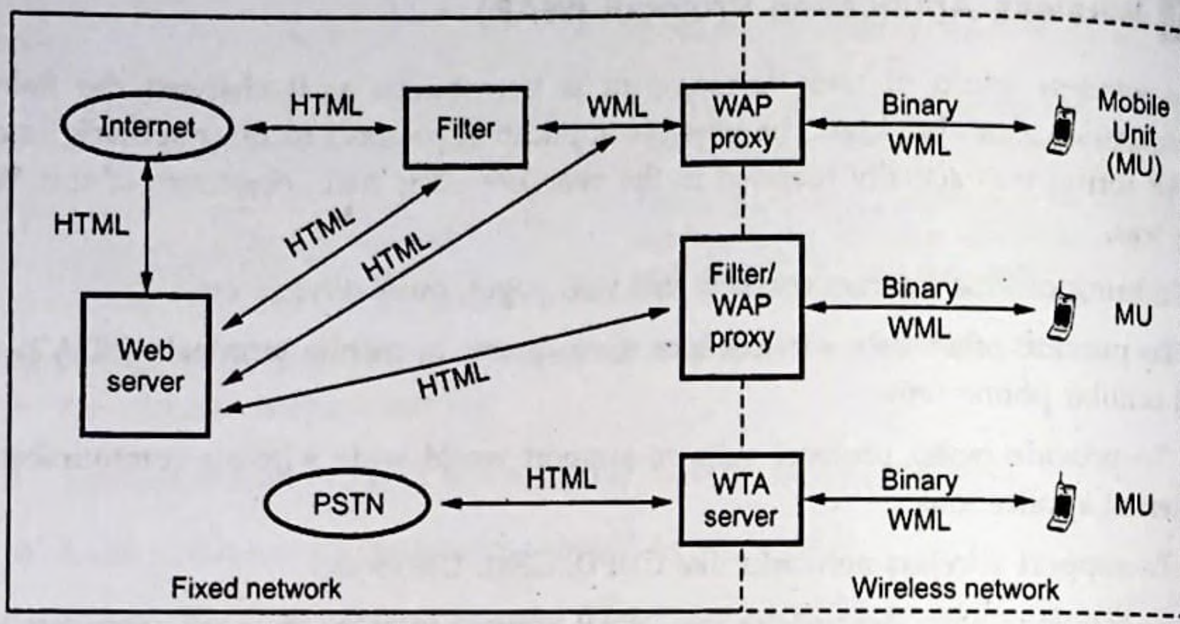


Fig. 4.10.1 Integration of various WAP components - An example

The protocols used and the services of the networks existing cannot be changed. The wireless networks provides WAP enabled wireless, mobile devices. There are special type of filters used to translate Hypertext Markup Language (HTML) into Wireless Markup Language (WML). The same function can also be done by gateways available between fixed and wireless network. Gateways can acts as proxies for accessing web. Finally the Wireless Telephony Application (WTA) translates the signalling of telephone networks into the WML events which can be displayed at handheld devices. Through the Wireless Application Environment (WAE) the wireless clients of various services, telephony and web are integrated.

The WAE forms the top layer in the layered architecture of Wireless Application Protocol (WAP). In this chapter the WAP is discussed in detail.

4.10.1 Wireless Application Environment (WAE)

In wireless network environment for the data is transmission the wireless handsets size, weight and portability are important bottlenecks and has to be addressed with at most care. These influences the user interface less powerful CPU with less memory capacity.

The wireless application environment finds solutions for meeting the requirements in transmission of wireless data.

The important elements of WAE model are :

1. WAE - User agents
2. Content generators
3. Applications of wireless telephony

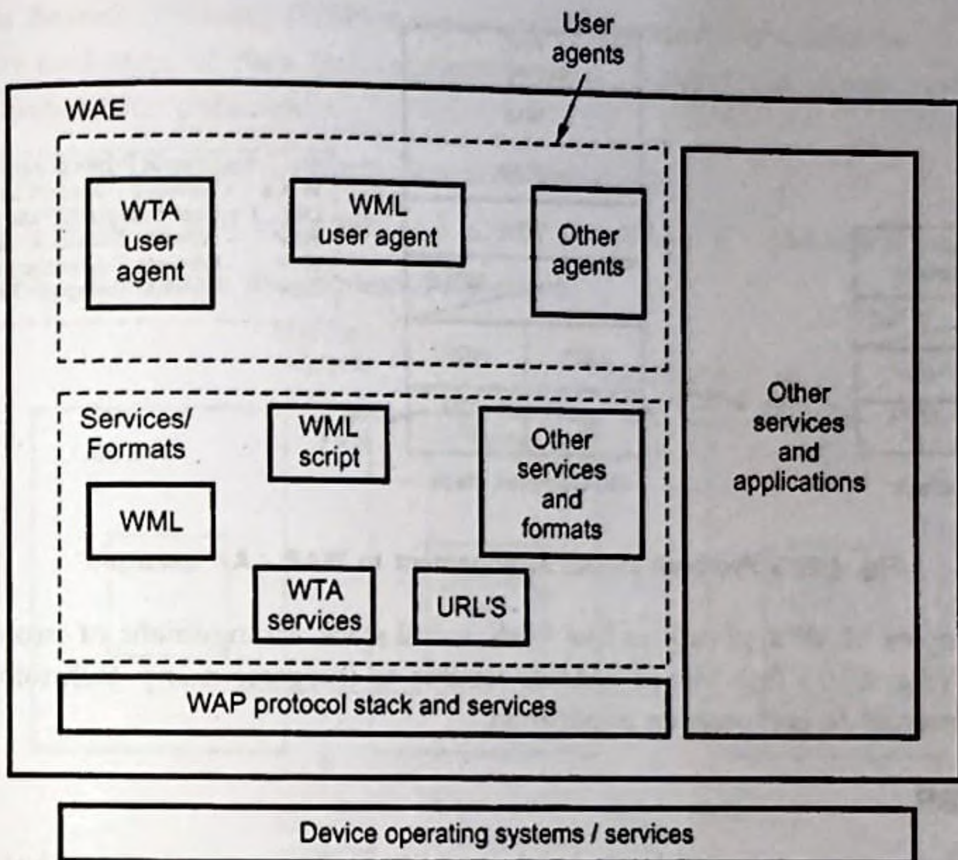


Fig. 4.10.2 Wireless applications environment-client components

WAE - User agents

It is a software that provides functionality like display content to end user and executes in user's wireless component (device).

Content generators

These are services/applications on server (origin server) that produces standard content formats in response to the requests from user agents side.

Content encoding

It allows WAE user agent to navigate the web content.

4.10.3 Stacks Arrangement with WAP

The wireless application protocol tries to make use of many technologies from Internet. It includes WDP, WTLS, WSP, WAE etc. A simple protocol stack may not require new protocols. For this purpose based on the simple stack many complex stacks can be developed by simply appending security with a most reliable transaction service. This reliable service is compatible with applications regarding distributed computing like CORBA.

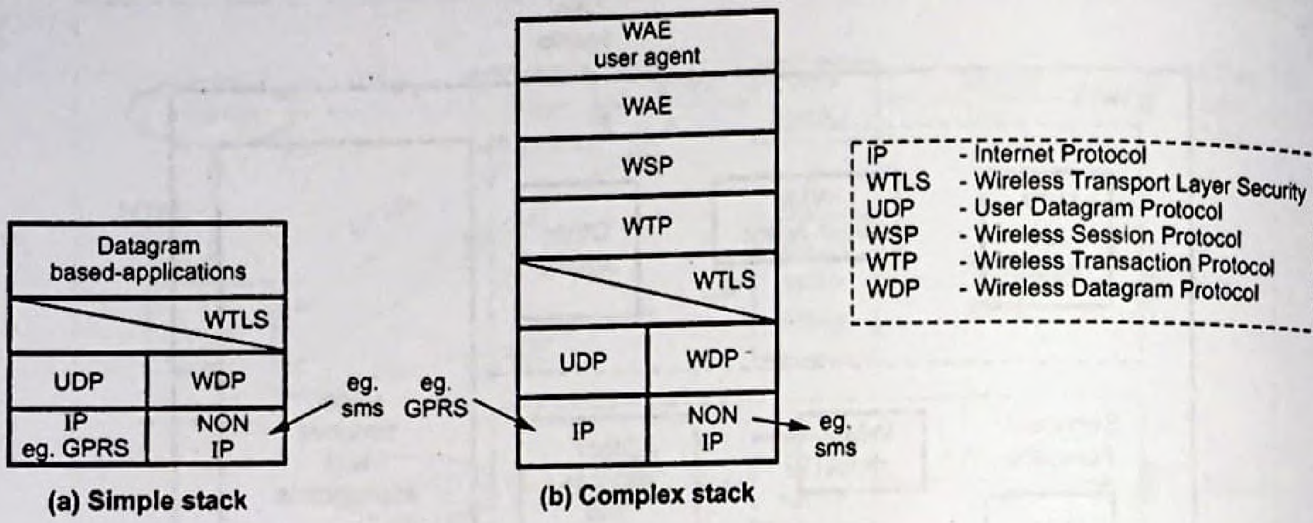


Fig. 4.10.3 Protocol stacks arrangement in WAP - An example

For a complex WAP applications like WML a full stack arrangement of protocols may be required (Fig. 4.10.3 (b)). Hence WAP is flexible to integrate many technologies from that of the Internet to complete an application.

4.10.4 WSP

The Wireless session protocol has several capabilities. They are tabulated below -

Sr. No.	Name	Type	Class	Description
1.	Size of client SDU	Positive integer	n	The size of largest transaction service data sent to client during the session(s).
2.	Aliases	List of addresses	i	It indicates which alternative addresses used by peer to access the session service.
3.	Header code pages	Set of code page names	n	A set of extension header code pages are supported by client and server.
4.	Maximum outstanding request method	Positive integer	n	Many method invocations can be active at same time during session (s).
5.	Protocol options	Facilities and features	n	It may include confirmed push, session resume and acknowledge headers
6.	Size of server SDU	Positive integer	n	The size of largest transaction SDU which may be transmitted to server during session (s).

Table 4.10.1 Wireless Session Protocol (WSP) capabilities

- n : Negotiable
- i : Informational

In WAP the "S-Disconnect" primitive is mainly used for session termination, and the request primitive for termination includes many parameters like;

1. Redirect security
2. Reason code
3. Error headers and the error set
4. Redirect address

Wireless Session Protocol (WSP) supports session suspend and resume. A transaction includes an exchange of data (information) between a client and server nodes and the request includes four parameters.

1. Request URI (Request Uniform Resource Identifier).
2. Request headers and body set.
3. Client transaction ID (Identification).
4. Method (To identify the requested operation).

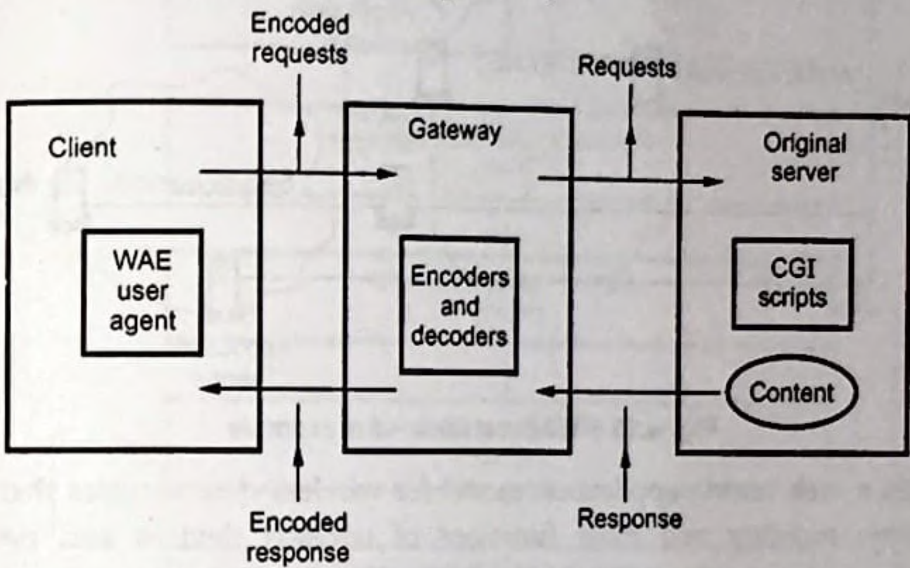


Fig. 4.10.4 Programming model of WAP

4.10.4.1 Features in WSP/B

WSP/B is a protocol that supports browsing. It has HTTP/1.1 functionality and binary encoded. Push and pull type of data transfer takes place. Also it allows asynchronous requests in the system. In WSP there are connection-mode and connectionless-mode available. A connection-mode WSP/B client has to support initiation of WTP class 0 and also class 2 type of transactions. The wireless session protocol/B enhances the browsing operations in the WAP applications.

Architectural Goals

The goals of WAP Forum architecture is listed below.

a) Enable the personalisation and customisation of the device, the content delivered to it, and the presentation of the content.

b) Provide secure access to local handset functionality.

c) It facilitates network-operator and third party service provisioning.

d) Defines a layered, scalable and extensible architecture.

e) Provide support for secure and private application and communication in a manner that is consistent and interoperable.

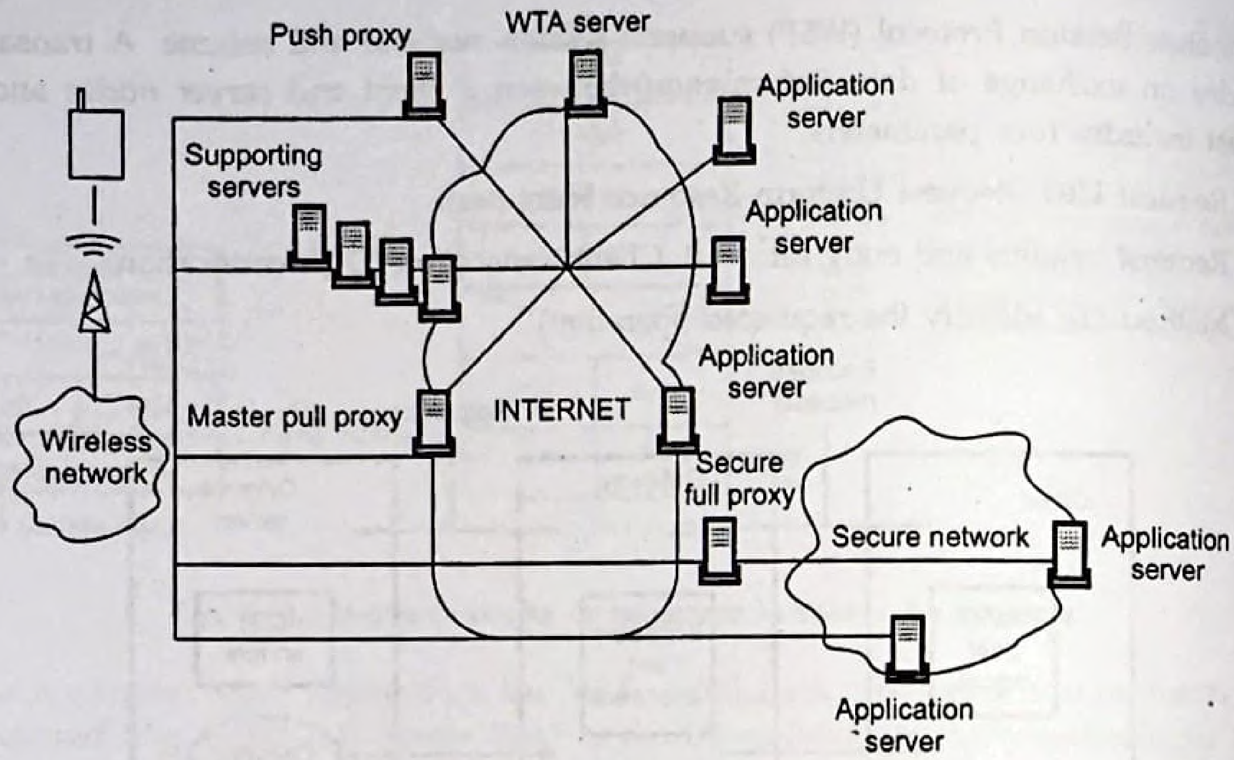


Fig. 4.10.5 WAP-network - An example

f) Provides a web centric application model for wireless data services that utilises the telephony, mobility and other functions of wireless devices and networks and enables maximum flexibility and ability for vendors to enhance the user experience.

The WAP clients communicate with application servers through a number of different proxies or directly. WAP clients supports the proxy selection mechanism that can allow them to utilise approximate proxy for a given service or to connect to that service directly. The proxies can be utilized to augment a request. They translate between WAP protocols and worldwide web (www) protocols (TCP, HTTP) so as to allow the WAP client to submit request to the origin server.

The proxies may be located in many places including wireless carriers or independent service providers in order to facilitate feature enhancements coupled to the wireless networks or to optimise communication between device and application server. The supporting servers provide support functions required by devices, proxies and the application servers. These functions includes user agent profiles, provisioning etc.

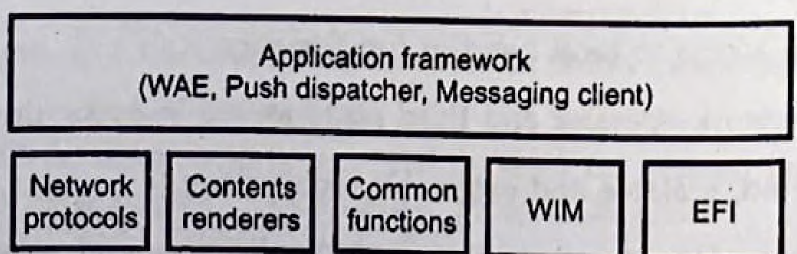


Fig. 4.10.6 WAP-client architecture

4.10.5 Web Client Architecture

The application framework provides the device execution environment for WAP applications. WAP applications are comprised of markup, script, style sheets and multimedia content all of which are rendered on the device. The WAP Application

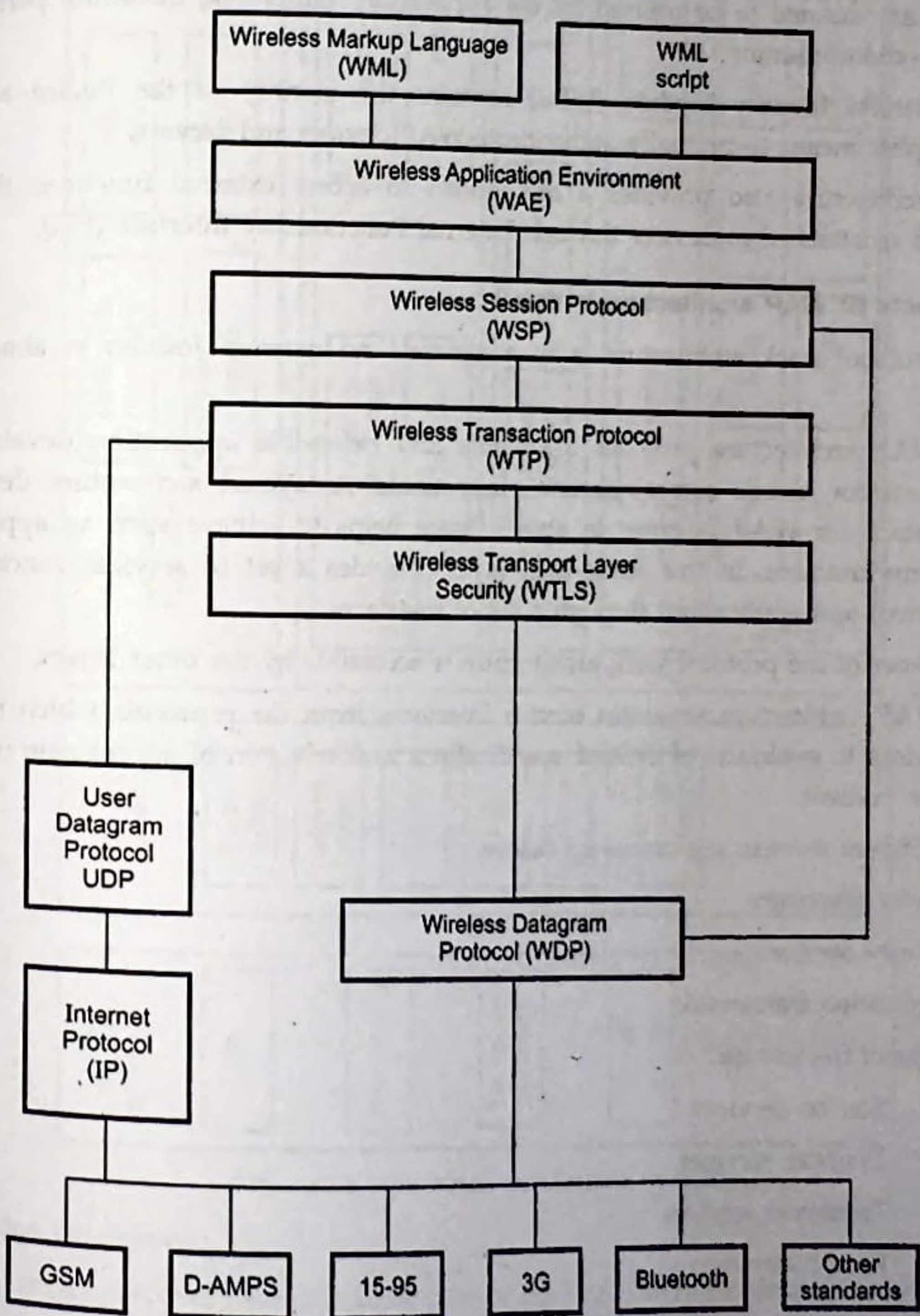


Fig. 4.10.7 Protocol stack of WAP

Environment (WAE) processing model defines the structure in which these various forms of executable and non-executable content interact.

The network protocols on the WAP client are shared between client and server. They are described in further detail given below. Content renderers interpret specific forms of content and present them to the end user for perusal or interaction. Some common functions are defined to be utilised by the application framework, including persistence and data synchronisation.

The Wirelss Identity Module (WIM) contains the identity of the device and the cryptographic means to mutually authenticate WAP devices and servers.

The architecture also provides a mechanism to access external functions that are embedded or attached to devices through External Functionality Interface (EFI).

Components of WAP architecture in detail :

The protocol stack architecture is in a general and detailed fashion in above two diagrams.

The WAP architecture provides a scalable and extensible application development environment for mobile communication components. A layered architecture design of protocol stack for WAP as given in above figure helps to achieve such an application oriented environment. In this stack each layer provides a set of services/functions to other services and applications through a set of interfaces.

Each layer of the protocol stack architecture is accessible by the other layers.

The WAP architecture separates service interfaces from the protocols which provide those services to evolution of desired specifications and selection of appropriate protocol for a given content.

The different services are discussed below.

1. Service discovery
2. Security services
3. Application framework
4. Protocol framework
   a) Session services
   b) Transfer services
   c) Transport services
   d) Bearer services

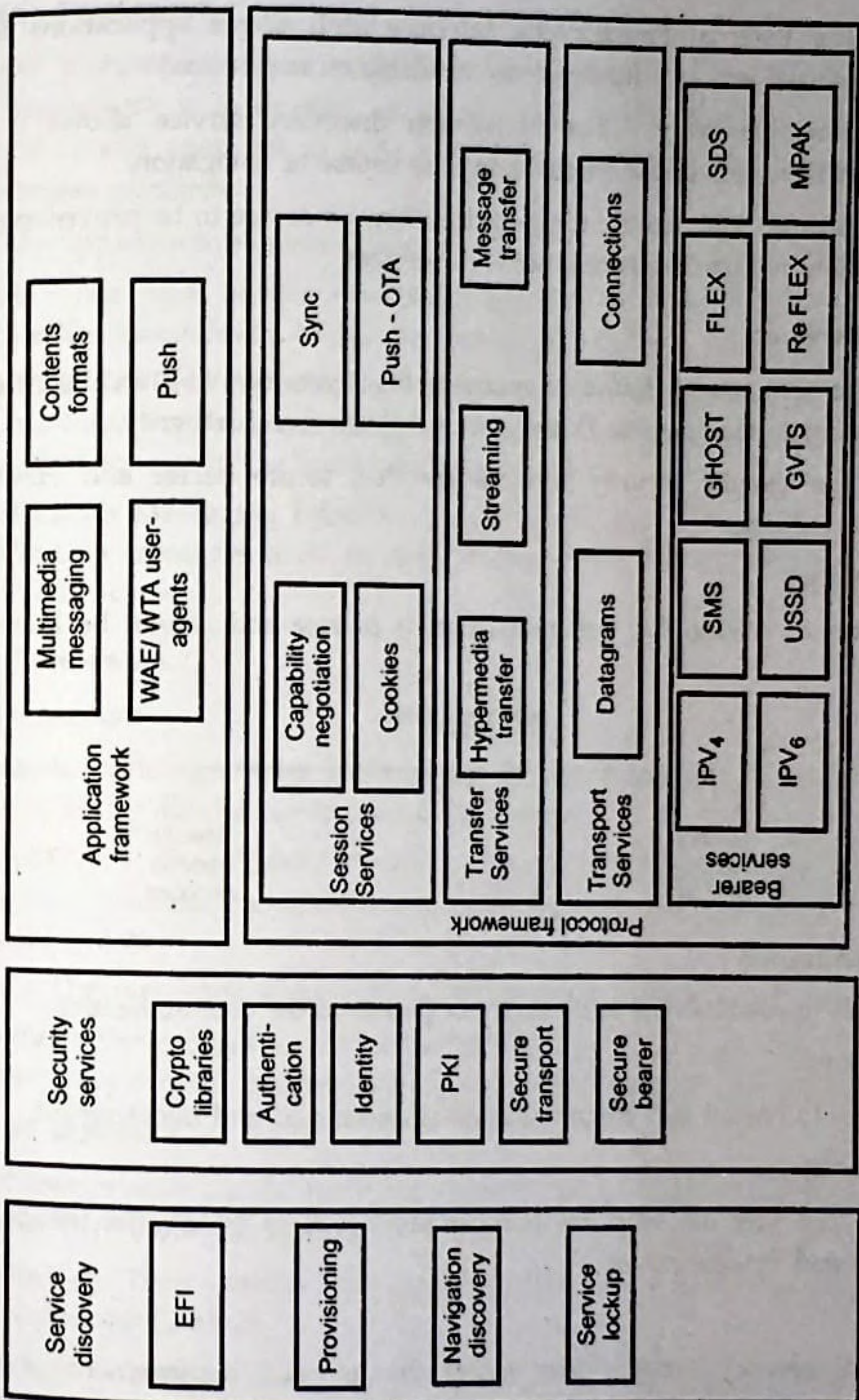


Fig. 4.10.8 WAP stack architecture in detail

1) Service Discovery :

The service discovery forms a basic part of the WAP architecture and its services can be found at several layers. Some of the examples of the service discovery are EFI, Navigation discovery and provisioning.

a) **EFI** : The External Functionality Interface (EFI) allows applications to discover what external services/functions are available on the device.

b) **Navigation discovery** : The Navigation discovery service allows a device to discover new network services during the course of navigation.

c) **Provisioning** : The provisioning service allows a device to be provisioned with the parameters required to access network services.

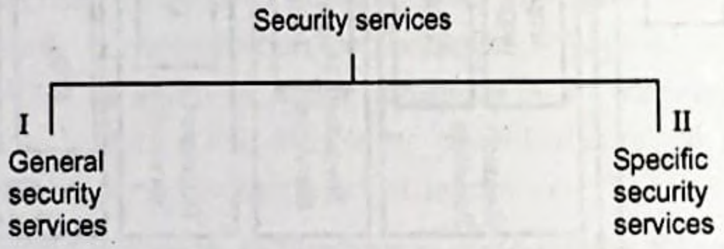
2) Security Services :

Security services can be found in many of the layers of WAP architecture. Some of the general security facilities are Privacy, Authentication and Integrity.

Some of the specific security services are PKI, secure bearer and identity. These services are listed below.

[I] (i) Privacy :

It facilitates to ensure that communication is private and cannot be known by any third person.



(ii) Authentication :

It facilitates to establish the authenticity of parties to the communication.

(iii) Integrity :

If facilitates to ensure that communication is unchanged and uncorrupted.

[II] (i) Identity :

The WIM provides the functions that can store process information needed for user identification and authentication.

(ii) PKI :

The set of security services that enable the use and management of public-key cryptography.

(iii) Secure bearer :

Some bearer networks provide bearer level security.

3) Application Framework :

It provides a general purpose application environment. The main objective of the application framework is to develop an interoperable environment that will allow the service providers and operators to build applications and services that can reach wide variety of wireless platforms.

Some of the applciation framework are,

i) **Push** : The push service provides a general mechanism for the network to initiate the transmission of data to applications resident on the WAP devices.

ii) **WAE / WTA User Agent** : WAE is a micro browser environment allowing for the markup, scripting, telephony services etc. and programming interfaces, all optimised for use in the hand-held mobile units.

iii) **Multimedia Messaging (MMS)** : It provides for the transfer and processing of multimedia messages such as electronic mail and instant messages to that of the WAP devices.

4) Protocol Framework :

a) Session services :

These session services provides for the establishment of shared state between network elements. Some of the session services are given below.

i) **Push-OTA** : The Push-OTA (Over The Air) session service provides for network - initiated transactions to be delivered to wireless devices that are able to receive data.

ii) **Sync** : The sync service provides for the synchronization of replicated data.

iii) **Cookies** : The cookies service allows applications to establish state on the client or the proxy which survives multiple hypermedia transfer transactions.

b) Transfer services :

These services provide for the structured transfer of information between the network elements. Some of the transfer services are given below.

i) **Streaming** : They provide a means for transferring isochronous data like audio and video information.

ii) **Message transfer** : They provide the means for transfer asynchronous multimedia messages such as electronic mail or any instant messages. The MMS Encapsulation is a protocol used to transfer messages between WAP devices and MMS services.

iii) **Hypermedia transfer** : The hypermedia transfer service provides for the transfer of self-describing hypermedia resources.

c) Transport services :

These services offer a set of consistent services to other upper layer protocols and links/maps those services to the bearer services available.

Some of the transport services are given below.

i) **Datagrams :** The datagram service provides data transport in which self-contained, independent entities of data carries required information to be routed from source to destination node independent of earlier exchanges between the nodes.

ii) **Connections :** The connection service provides data transport service in which communication will take place in three phases namely connection establishment, two-way reliable data transfer and connection release.

d) Bearer networks :

The bearer services includes short message packet data and circuit-switched data. The bearers offer differing level of quality of service with respect to error rate, delays and throughput. The transport service layer provides interface between bearer services and remaining WAP protocol stack.

Thus the different network services of WAP protocol stack enables efficient wireless communication.

Network Architecture

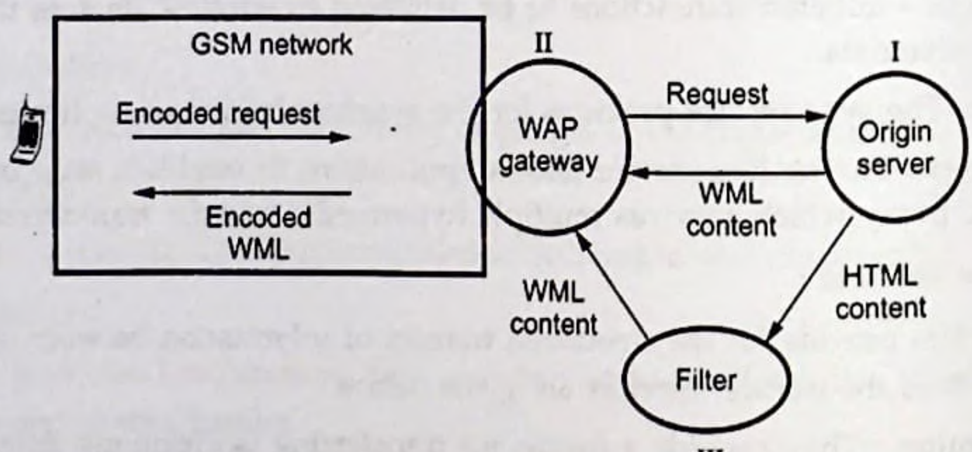


Fig. 4.10.9 Wireless Application Protocol (WAP)-Network configuration

The Wireless Application Protocol (WAP) network architecture is shown above. The server at origin (say) at position I is connected with handheld mobile unit. i.e. the mobile unit communicates with the server through the mobile network. The server is a standard HTTP or a web server. The contents received by the WAP handset are encoded in a binary format that is in Wireless Markup Language (WML).

This facilitates proper delivery in band limited mobile network. The function of WAP gateway located between Internet and mobile network (II) receives the request (WAP request) from mobile handset and decodes it from binary format into text form and then forwards it to the origin server. This server provides only HTML (Hypertext Markup Language) contents and hence the HTTP responses of origin server is first sent to HTML filter (III). It translates HTML text into a WML format. The Wireless Application Protocol (WAP) verifies the contents, and encodes into WML byte code format which is finally sent to WAP handset.

The WAP mainly provides end to end security as communication is directly possible with WAP protocols. The WML mentioned above is an XML language (wireless XML) which describes the WAP content of WAP handsets.

The WML documents are aggregated into set of cards where each of them represents a unit of interaction between user agent and user. These cards are also grouped into "deck" which is a basic WML unit. The WAP defines a user interface standard model for mobile handheld devices.

The WAE discussed previously mainly defines WAP application layer that provides proper environment for mobile users on wireless platforms. WAE supports User Agent Profile (UAP), which enhances its capability to the application servers and other network entities and hence contents based on the mobile handsets capabilities can also be generated accurately.

4.10.6 Advantages of WAP

This WAP 2.0 protocol focusses on the schemes combining wireless applications with the Internet. The WAP 2.0 provides support for the protocols like IP, TCP and HTTP. It is also flexible with air interface technologies and then corresponding bearers. For example GPRS and 3G cellular standards are interoperable with it. Then delivery of data to mobile phones, personal digital assistants (PDA) is also possible.

These devices also have the better hardware factors like battery life, ROM, limited RAM etc. The WAP provides many features and it is attractive since it is user friendly by providing several user interface (UI) designs.

WAP 2.0 reduces processing power and efficiently uses network resources to increase performance.

4.10.7 WAP Programming Model

This model is aligned with that of the web programming model. The WAP extends the web architecture by adding the telephony support with the WTA that enables a push model and the server available there can send the content to the client.

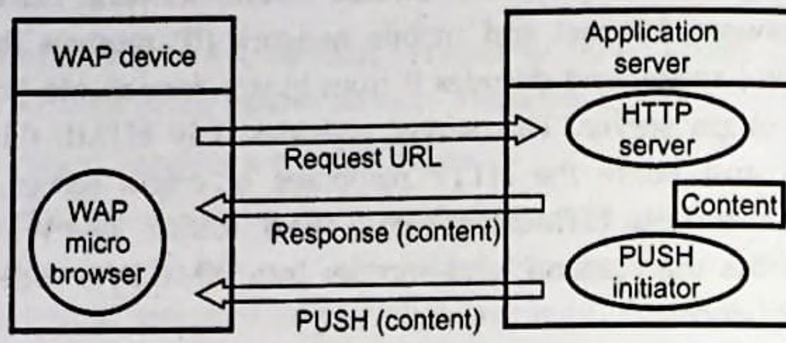


Fig. 4.10.10 WAP - "Programming model"

The WAP 2.0 version does not require a WAP proxy because the communication link between the origin server and the client can be conducted using the HTTP/1.1 But a WAP proxy is important for providing 'PUSH' functionality.

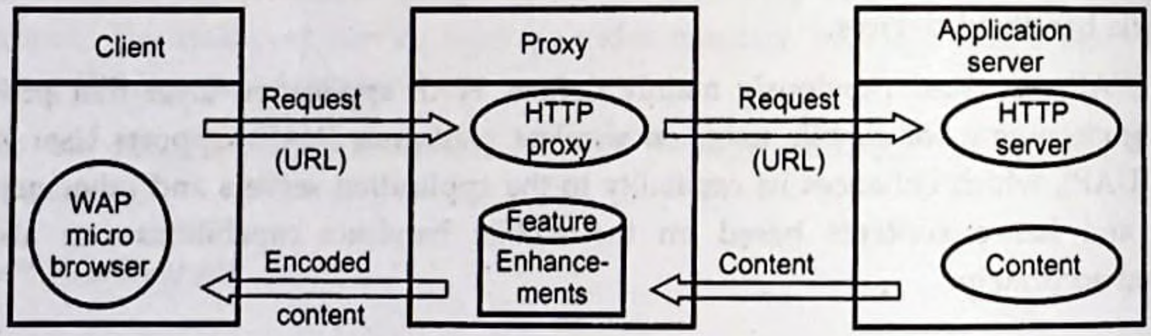


Fig. 4.10.11 WAP - 'Optional proxy model'

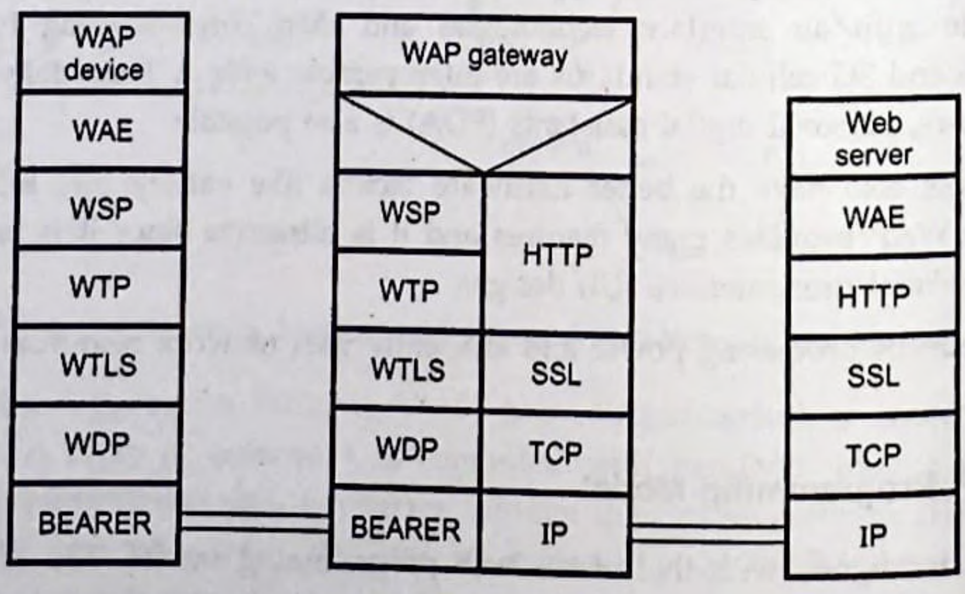


Fig. 4.10.12 WAP - 1.x 'Gateway'

When an IP connectivity is available to that of the mobile device it is then supported by WAP 2.0.

The protocol layers are Wireless Session Protocol (WSP), Wireless Transaction Protocol (WTP), Wireless Transport Layer Security (WTLS) and Wireless Datagram Protocol (WDP). In this the WSP provides upper level application layer of WAP with relevant interfaces for connection mode service and connectionless service.

The WTP is a light weight transaction oriented protocol suitable for implementation in 'thin' clients/mobile stations which operates effectively over the wireless datagram networks. WTP has several advantages which includes,

- High reliability over other datagram services.
- Improved efficiency over the connection oriented services.
- Supports 'service oriented transactions' like browsing.

The Wireless Transport Layer Security (WTLS) is designed to provide privacy, authentication and data integrity between different communicating applications. It also provides upper level layer of WAP with secure transport service interface for managing secured conditions. The WDP is a general datagram service providing consistant service to upper layer protocol for transparent communication with underlying bearer services.

It provides common interface to upper layers to function independently. The protocol layers for the networks supporting Internet protocol are

i) Wireless profiled HTTP

ii) Transport layer security

iii) Wireless profiled TCP.

WAP 2.0 also supports several enhanced services, like WAP push, User agent profile (UA prof), Wireless Telephony Application (WTA), External Functionality Interface (EFI), Persistent Storage Interface. Data synchronization, Multimedia Messaging Service (MMS), Provisioning and Pictogram Services.

4.10.8 WAP 2.0

Wireless Application Protocol (WAP 2.0) - Advantages

This WAP 2.0 protocol focusses on the schemes combining wireless applications with the Internet. The WAP 2.0 provides support for the protocols like IP, TCP and HTTP. It is also flexible with air interface technologies and then corresponding bearers. For example GPRS and 3G cellular standards are interoperable with it. Then delivery of data to mobile phones, Personal Digital Assistants (PDA) is also possible.

These devices also have the better hardware factors like battery life, ROM, limited RAM etc. The WAP provides many features and it is attractive since it is user friendly by providing several User Interface (UI) designs.

WAP 2.0 reduces processing power and efficiently uses network resources to increase performance.

The Wireless Application Protocol (WAP) forum released its first specification termed as WAP 1.0 in the year 1998. Then WAP forum viewed interoperability with many additional features. The WAP 2.0 is next generation standard which was released later and intended to a set of work under wireless with Internet operations. It has backward compatability with the previous WAP technologies.

The main architectural components of WAP 2.0 is listed below.

1. Protocol stack support
2. WAP application environment
3. Addition services and capabilities
4. Networks and network bearers
5. TCP/IP as transport protocol
6. Processors
7. Mobile friendly technology

All these seven components are discussed in detail with an example in this chapter.

1. Protocol stack support

In WAP 1.0 version the WAP stack was introduced and WAP 2.0 appends high support and services on the stack based on Internet stack that includes support for TCP, HTTP etc. The version WAP 2.0 provides connectivity model on a broader range of networks and other wireless bearers.

2. WAP application environment

It is generally viewed as the WAP browser and the WAP 2.0 application environment has evolved to develop standards for the Internet markup language.

3. Additional services and capabilites

The WAP specifications have had items that were neither part of 'WAP Browser' nor the 'WAP Stack' but helped to enrich the environment defined in the WAP specification list. It is worth noting that with WAP 2.0 there is a considerable increase in the number of features present to operators, developers and end users. The WAP protocols are largely based on Internet technologies.

WAP was developed to use the Internet technologies for wireless networks and other devices.

4. Network and network bearers

Networks in the world over are switching on to high speed bearer such as General Packet Radio Service (GPRS) and High Speed Circuit Switched Data (HSCSD). For the introduction of third generation (3G) mobiles with higher bandwidth such as W-CDMA. This enables new type of content such as streaming media, video etc. over the higher capable network bearers.

5. TCP/IP as transport protocol

Today several wirelss network technologies provide IP packet support as primary data transport protocol. A mobile profile of TCP wireless links are used in the Performance Implications of Link Characteristics (PILC) working group thus enabling interoperability over the internet with common TCP.

6. Processors

Hardware manufacturers today are keen on introducing smaller devices which are more efficient, consuming less power and much faster in their performance. Due to VLSI technology more sophistication is achieved. Therefore new wireless devices provide enhanced services and have a variety of capabilities.

7. Mobile friendly technologies :

Today catering to the needs of the mobile user has become very important. The WAP forum has therefore worked with standards like Internet Engineering Task Force (IETF) to address the issues generated by the wireless usage of the web. This has resulted in more user friendly mobile technologies.

For example, the basic profile for Extensible Hypertext Markup Language (XHTML) is incorporated with the core elements of the XHTML language in order to provide a bigger framework for enhancement and expansion.

The Components of WAP 2.0

The main components of WAP 2.0 are like "Application support", "Protocol support" and others.

The Wireless Application Environment (WAE) provides interaction between web/WAP applications and the wireless devices containing WAP microbrowser.

The markup language XHTML Mobile Profile (XHTMLMP) is supported by the version WAP 2.0. Then it is possible to have services for wireless devices with languages compatible to them. The WAE also provides WBMP images, V Calender, V Card etc. WAP 2.0 supports an application centric approach by defining the XHTML-MP and few other technologies including several elements.

4.10.9 Wireless Markup Language (WML)

The WML is nothing but a document manipulation language. It is tag-based. To specify user interaction and presentation on mobile phones and wireless devices. The devices find it difficult to manage with few design complexities like user-input facilities, displays, network connections, restricted memory resources, computational resources etc. WML is capable of implementing two types of metaphor.

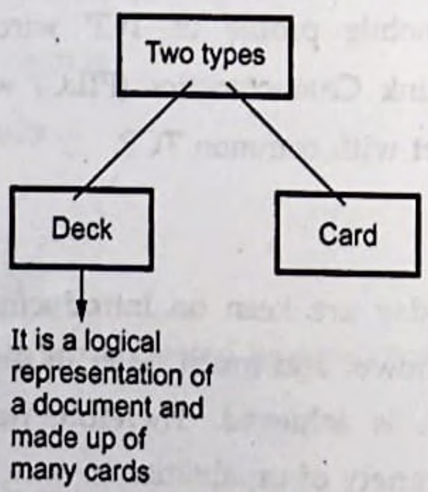


Fig. 4.10.13

Each one of the WML card in the desk can perform a particular task for specific user interaction. For accessing a document user navigates to a card and first reviews its contents. After making a choice it even moves to next card. These WML decks are storable in a static files. It can be generated using a Java servlets running on a server (Origin point server).

The WML has features like;

- Support for user inputs.
- Support for text and images.
- Task invocation controls.
- MMI independence.
- Context and state management.
- Narrow-band optimization.
- International support.

WML is intended with rendering text. Here usage of tables and resources are restricted.

All the tags are case sensitive. In a deck the cards are linked with each other.

A card element contains,

- Text
- Input-fields
- Images and
- Links etc.

Whenever WML page is accessed from a mobile phone and navigation between the cards is possible.

Example :

```
< wml >
        < Card id = "no1" title = "Card1"
        ........................ Hello !......
        </ Card >
        < Card id = "no 2" ........
        ............. Welcome to the WML !.....
        </ Card >
</ wml >
```

The WML document is nothing but a XML document.

A module of WML is given above and if is executed the result will be as below :

. . . Card 1..... Hello !		. . . Card 2 . . . Welcome to the WML !

In WML it is easier to write and display information with many cards in a deck.

Review Questions

Part A

1. *What is TCP ?*
2. *Define any two types of TCP.*
3. *What is DHCP ?*
4. *What are the advantages of TCP/IP ?*
5. *List any two improvements of TCP/IP.*
6. *Define WAP.*
7. *Define WAE.*
8. *What are the elements of WAE ?*
9. *Write short note on 'Wireless Telephony Application'.*
10. *Explain WAP and WAE in detail.*
11. *Explain 'Wireless Session Protocol' in detail.*
12. *Explain the protocol stack of WAP.*
13. *Write short note on WAP 2.0 version.*
14. *Explain the programming model of WAP.*
15. *What are the advantages of WAP 2.0 version ?*
16. *Explain WML and WML scripts in detail.*

Part B

1. *What is TCP ? Explain the architecture of TCP/IP with a schematic diagram.*
2. *Write short notes on*
   i) Mobile IP
   ii) Snooping TCP
   iii) Overview of TCP/IP.

University Questions with Answers

Part A

Q.1 *What is multicasting ?* **(Refer section 4.5)** **AU : Dec.-16, Marks 2**

Q.2 *Compare and contrast MANET Vs VANET.* **(Refer section 4.7)** **AU : Dec.-16, Marks 2**

Q.3 *Show the structure of a TCP segment.* **(Refer Fig. 4.3.2)** **AU : May-19, Marks 2**

Part B

Q.4 *With a neat diagram explain the architecture of TCP/IP.* **(Refer sections 4.6, 4.5.2)** **AU : June-16, Marks 8**

Q.5 *Explain the various improvements in TCP performance with diagram.* **(Refer section 4.7)** **AU : June-16, Marks 8**

Q.6 *Give the comparision of various TCP advantages and disadvantages in wireless networking.* **(Refer section 4.5.6)** **AU : Dec.-16, Marks 16**

Q.7 *Discuss and compare the various mechanisms used to improve the TCP performance in mobile networks.* **(Refer section 4.7)** **AU : Dec.-17, Marks 8**

Q.8 *Explain Indirect TCP(I-TCP) with the help of a suitable schematic diagram.* **(Refer section 4.5.2)** **AU : May-18, Marks 8**

Q.9 *Discribe how mobile TCP improves TCP efficiency for mobile networks ? How does mobile TCP maintain end to end schematics ?* **(Refer section 4.7)** **AU : May-18, Marks 8**

Q.10 *Define I-TCP and explain indirect TCP (I-TCP) with the help of a suitable schematic diagram.* **(Refer section 4.5.2)** **AU : Dec.-18, Marks 13**

Q.11 *What is the reaction of standard TCP in case of packet loss ? In what situation does this reaction make sense and why is it quite often problematic in the case of wireless networks and mobility ?* **(Refer section 4.8)** **AU : Dec.-18, Marks 15**

Q.12 *Outline the popular TCP congestion control algorithms.* **(Refer section 4.5)** **AU : May-19, Marks 13**

Notes

Unit V

Mobile Platforms and Applications

Syllabus

Mobile Device Operating Systems - Special Constrains & Requirements - Commercial Mobile Operating Systems - Software Development Kit: iOS, Android, BlackBerry, Windows Phone - M-Commerce - Structure - Pros & Cons - Mobile Payment System - Security Issues.

Contents

5.1 Mobile Device Operating Systems

AU : Dec.18

The main responsibility of mobile devices is to monitor effective utilization of the resources by attending to several tasks. The resources may include, processor, files, memory and other devices, like speaker, keyboard, camera etc.

Basically mobile devices have to process many applications that may run several tasks. Each task in it may have many threads.

They might be voice communication, e-mail, text messaging, recording and so on. The operating system of the mobile device acts as an interface to the user of the mobile device and also interacts with other devices.

5.2 Special Constraints and Requirements of Mobile Operating System

AU : May-17,18, Dec.-16,17,18

A mobile device has several constraints. One of them is handling a limited energy in the battery. The complex tasks has to be completed fast and goes to sleep mode. But this is not the case with traditional computer. Hence the mobile device is turned on often, and a mobile operating system (OS) undergoes booting process many times.

In addition to this the size of Kernal is very small. In design of mobile device operating system meets many constraints to work efficiently.

The specific constraints of mobile OS are listed here.

Processing power

The mobile OS has limited processing power. Few processors are energy efficient, cost effective and also powerful. The chip size and off-chip memory size is limited.

Since the mobile OS has to overcome the problems like restricted power, storage etc. it can process only lesser number of functions.

Battery power

The mobile device has to be light weight to make ease of portability. Mobile device has smaller battery. The mobile OS is expected to consume only less power.

The processor and the display screen are often put to sleep mode for managing with little power.

Memory

A mobile device has lesser volatile and permanent storage. As the memory is less, the OS has to be smaller. But the OS should be capable of processing several tasks to serve the market demand. The Kernel size has to be planned carefully.

Limited screen size and keyboard

The screen size of mobile device should be small for better portability. This leads to limited size of displaying screen.

The mobile device can have a smaller size keypad or a display screen (acting as keypad) in touch screen mode with the help of stylus. But still comparing to desktop systems the documentation jobs including typing are difficult in the hand held mobile devices.

Bandwidth

The wireless medium is susceptable to noise, multipath fades and would result in higher Bit Error Rates (BER). In mobile environment the bandwidth also fluctuates which may cause noise in the device performance. This results in hand-offs in the communication. For uninterrupted communication factors like prefetching, data caching, and integration are useful.

5.3 Service Requirements

Particular communication protocol

A mobile device has to communicate with the nearest base station, peripheral devices and other devices. The communication protocols used are based on 1G and 2G technology. To communicate with other computers TCP / IP and WLAN protocols are also used.

Compliance with open standards

If open standards are accepted then it will facilitate more applications from user's end. The mobile OS has to consider smaller screen size, limited memory, limited battery power, less weight in its designing aspects.

Library support

The mobile OS should offer Library support for various applications in order to make it convenient for the developers. The basic library support includes facilitating e-mail, SMS, bluetooth, MMS and GSM / GPRS related functionalities. Thus the mobile OS needs the above service requirements.

An interface should consider access control data and also the voice communication with that of the base station making use of various protocols.

Also an operating system recognizes input information from the keyboard, analyze it and send the output information to the display.

It also interfaces with other devices like computer, printer etc. Some of the popular device operating systems include,

1. Symbian
2. Android
3. Windows mobile
4. Palm OS
5. Blackberry
6. iOS etc.

5.4 Device Management

The challenges included in device management is discussed below. The challenges involved in device management are ;

- Device location tracking.
- User-device relationship.
- Updating software of the existing devices.
- Installation of new software and adaptability.
- Providing secured access to the device information.
- Control of device versions and softwares.

Software distribution

It deals with problem of obtaining new software or updating existing software to the devices. A better device management system must consider following issues into consideration.

- Hardware version management.
- Hardware capabilities.
- Software version management.
- Device connectivity.
- Library Management.
- Insecured connections.
- Unstable connections.
- Updating operating system.

Approaches

For pervasive devices all the above solutions cannot be attended. To achieve device management the devices has to be separated from each other by using unique identifiers. There are few techniques available to counter software download problem. It includes ;

- Hardware capabilities.

- Library management.
- Hardware and software versions management.
- Insecured connections.
- Updation of operating systems.
- Devices connectivity

In system design of device management both the server side and pervasive computing devices has to be considered. The data management in server layer can be solved with IT or database management systems like Hewlett-Packard open view Tivoli (IBM) etc.

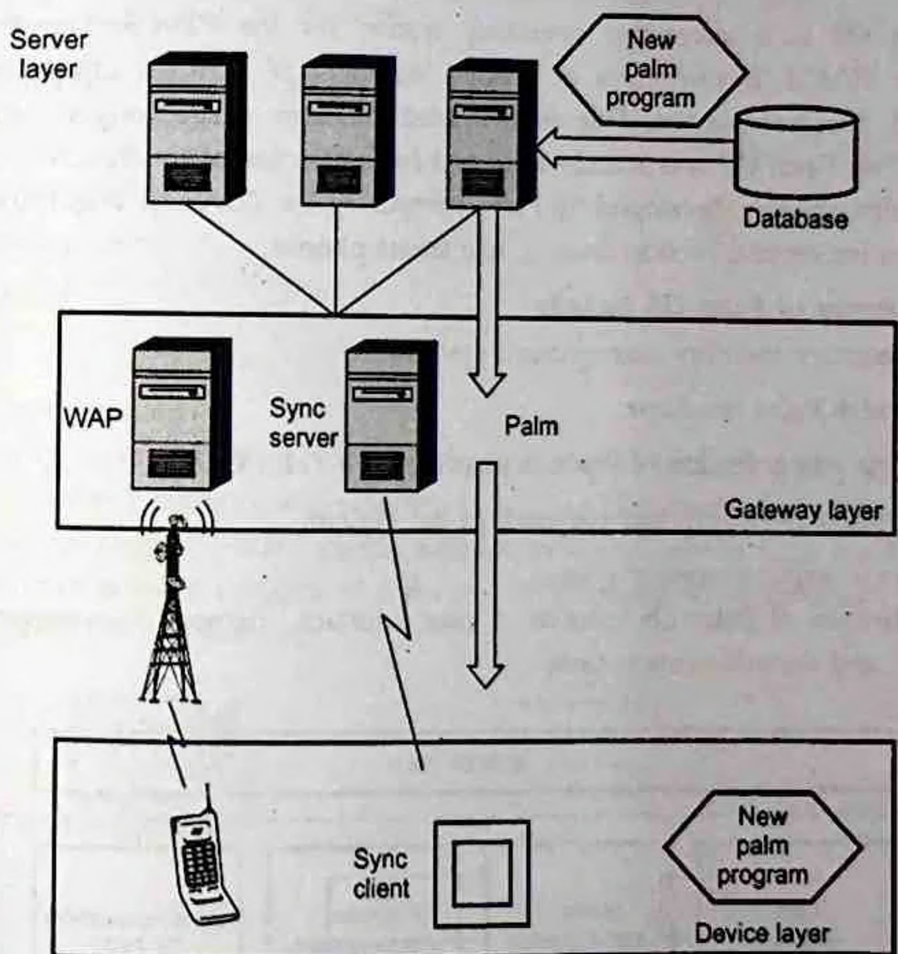


Fig. 5.4.1 Device-management System

In the above device management system the gateway layer consists of the device gateway for every single device with proper synchronization. The software updation problems can be solved with proper synchronization.

5.5 Commercial Mobile Operating Systems

AU : June-16, Dec.-16,18, May-17,18,19

Designing an operating system for mobile device is a difficult task. The mobile OS should have a set of expected core capabilities for supporting the mobile devices. The mobile OS also be capable to allow a vendor to develop an application software with the device.

Some of the mobile operating devices are given below.

5.5.1 Palm OS

The Palm OS is a successful operating system for the PDA'S. The Palm OS is intended for PDA'S. It comprises of limited numbers of features attractive like low memory and processor usage. Due to restricted memory usage longer battery life is guaranteed. The Palm OS was mainly designed for better use of touch-screen based user interfaces. Palm OS was developed by Palm computing for PDA's. It was improved with more facilities for several mobile devices, like smart phones.

The main features of Palm OS include :

- It has elementary memory management system.
- Palm provides Palm emulator.
- Handwriting recognization of input is possible with Palm OS.
- It also supports recording and playback in the system.
- Palm OS is a single-operating system.

The architecture of Palm OS consists of user interface, memory management, system management, and communication unit.

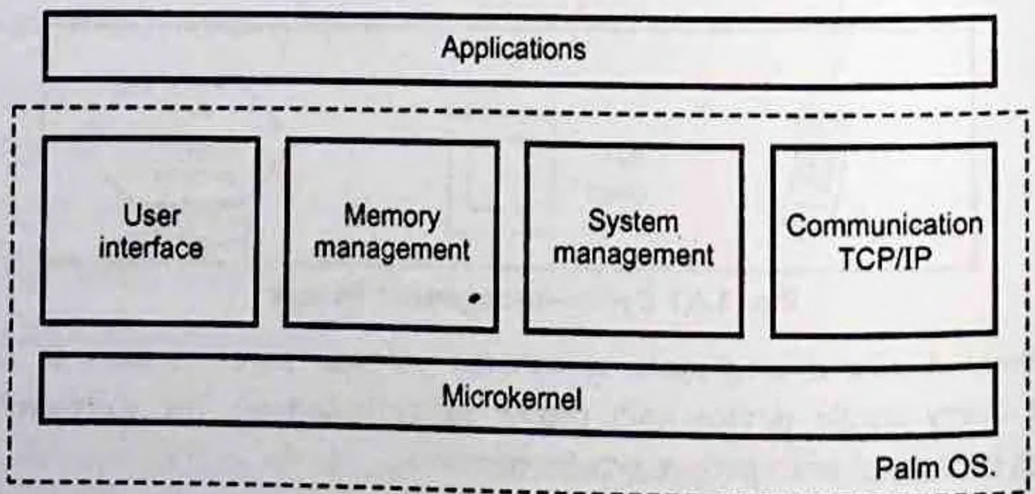


Fig. 5.5.1 Palm OS architecture

User interface	→ It is nothing but I/O; graphical input/output
Memory management	→ It consists of databases, runtime space, global variables etc.
System management	→ It looks after events, alarms, date, time, strings etc
Communication layer	→ It provides communication over serial input/output, TCP/IP etc.

The main features of Palm OS are,

- User management
- Task management
- Power management
- User interface
- OS size
- Memory management.

The memory management is divided into available memory into, dynamic heap dynamically allocated memory and storage. The Palm OS supports C and C++ softwares. At the beginning stage C++ is useful and for extensive works C is used. The Palm development environment consists of Software Dęvelopment Kit known as (SDK) which is based on GNU for windows etc.

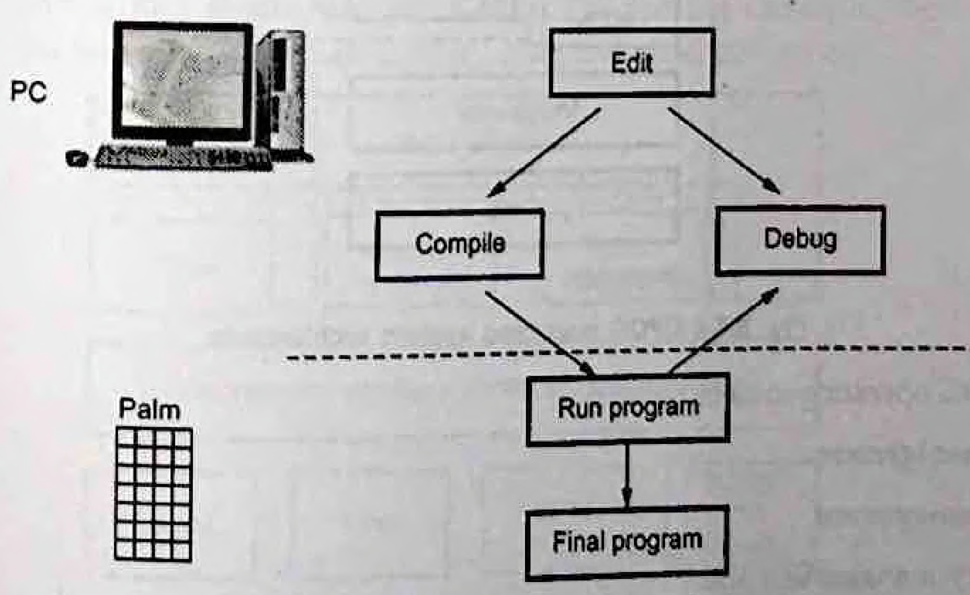


Fig. 5.5.2 Palm development cycle

The palm supplies a palm emulator that can emulate the palm hardware on the personal computer PC. This can be downloaded to real palm device. A simple palm development cycle is shown above. The program can be edited, compiled and allowed to run with palm platform. The palm applications are synchronous and event-driven. They consists of event handling and main event loop.

5.5.2 EPOC

The EPOC OS was created by the Psion and it is presently maintained by Offspring company called as 'Symbian'. It was founded by Psion, Motorola, Ericsson, Panasonic and Nokia in the year 1998. This OS was meant for phones.

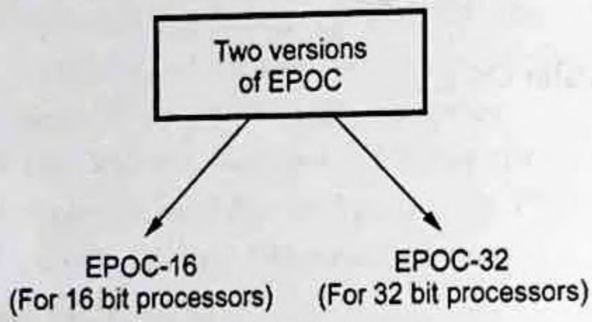


Fig. 5.5.3

The EPOC has captured Asian market. EPOC is capable of displaying 256 colors. In EPOC core operating system functionality multitasking is possible. When compared with Palm OS which can handle one task at a time. The EPOC OS can handle multiple tasks at same time.

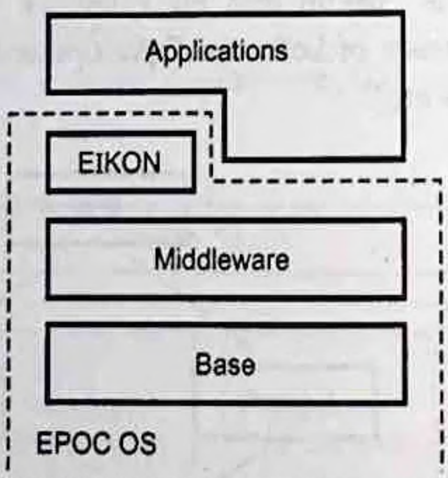


Fig. 5.5.4 EPOC operating system architecture

The EPOC operating system consists of

- User management
- Task management
- Memory management and
- User interface

The different programming languages that are supported by the EPOC OS are Java, C++, BASIC - like language etc. For system development the language choice is C++ .

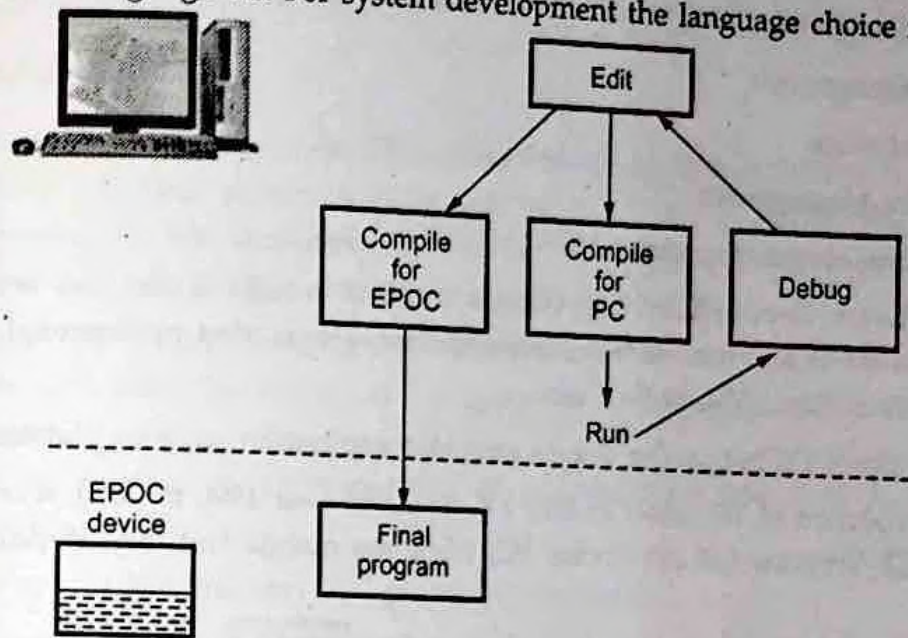


Fig. 5.5.5 EPOC development cycle

EPOC OS relies on multitasking. It supports both synchronous and asynchronous applications.

5.5.3 Windows OS

AU : Dec.- 18

It is an embedded OS developed by Microsoft. The window CE is basically a modular OS and it is configured by device manufacturer. In its architecture the kernel provides necessary memory management, task scheduling and interrupt handling. The user interface functions of the graphical output and user input are integrated by the Graphics Windows and Event Manager (GWE). The possible communication interface are infrared communication through TCP/IP, IrDA and serial drivers etc.

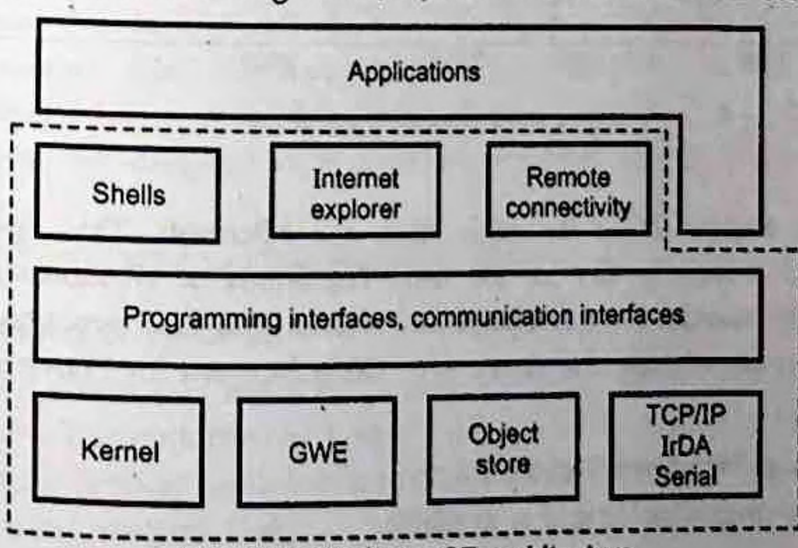


Fig. 5.5.6 Windows CE architecture

The main features offered by Windows CE are,

- User management
- Task management
- User interface
- Memory Management
- Operating system size etc.

The software development for Windows CE is mainly based on Win 32 API. It concentrates on application software development. The related professional development tools are Visual Basic, Visual C++ etc.

The Windows CE is popular due to its wider application support platform.

In the evolution of Windows mobile OS from the year 1996 to 2010, it is improved as Windows CE Versions 1.0, 2.0, Pocket PC, Windows mobile and then Windows phone 7.

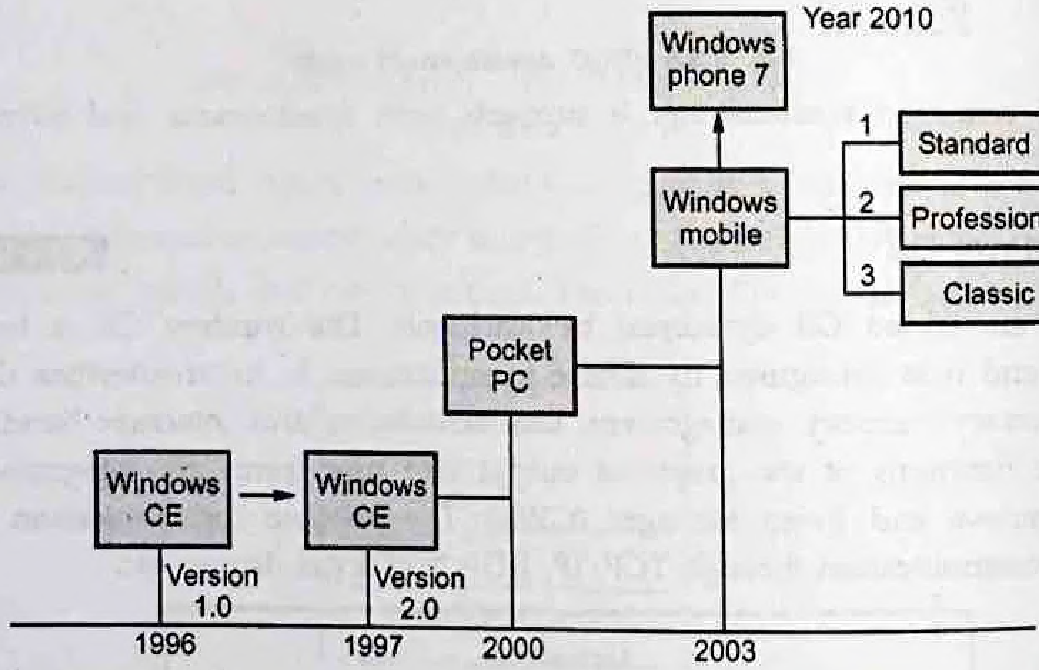


Fig. 5.5.7 Windows mobile OS

The Windows mobile OS is available from the Microsoft. This operating system supports the touch screen facility for the user. The family of Windows mobile OS has three types namely standard, professional and classic. The first two types are planned for smartphone design whereas the classic type OS is focussed for PDA's and not for the cell phone design.

Some Features of Windows Mobile OS :

- For security cryptographic library is available.
- Virtual memory management is provided.

- The GWE can handle input and output (GWE - Graphics/Window/Event Manager).
- An improved version of Windows mobile OS may also support multitasking tasks.

5.5.4 Symbian OS

The Symbian OS was the popular OS in smart phone operating system. It was the OS used in mobile handsets that was manufactured by Ericsson, Panasonic, Nokia and Samsung. Symbian OS was developed with some of the mobile device manufacturers as mentioned above. It was suitable for installing in smart phones.

The symbian OS is a multitasking real time, 32 bit OS and it runs on the ARM-based processors design. Also the design of Symbian OS is micro-Kernal based. The other features include;

- Whenever application is not responding to a particular event CPU is switched in low-power mode.
- It is designed for low memory and power requirements.
- It also supports pre-emptive multitasking tasks.
- Symbian OS supports many networking and communication protocols.

5.6 Software Development Kit

AU : June-16, Dec.-17,18 May-18

It includes operating systems such as

i) iOS

ii) Android Operating System

iii) Blackberry Operating System

5.6.1 iOS

The iOS was the sleek mobile device. The iPhone which made a revolution in the smart phone market. Also iPhone replaced the popular iPod. The iOS was developed in 2007 by Apple and iOS was suitable OS for iPhone. This iOS is a proprietary OS owned by Apple. It was not designed to be made use by other mobile phone vendors. iOS has features like;

- Better user interaction including swipe, tap etc.

5.6.1.1 Components of iPhone OS

AU : May-18

The different abstraction layers of iphone Operating System [iOS] consists four layers as shown below. The bottom most layer is called the core OS. It form the foundation of operating system. It takes control of memory management, networking, file systems and the other operating systems Tasks.

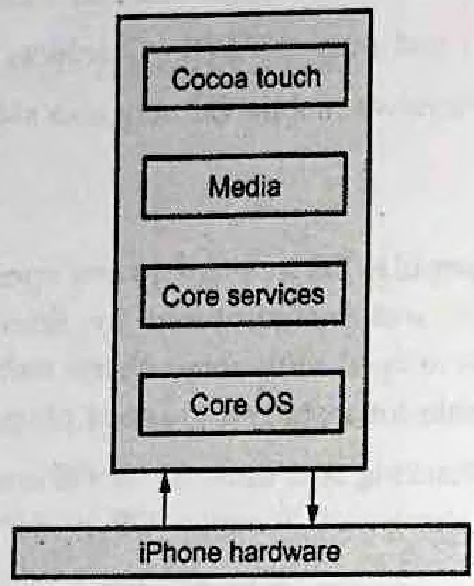


Fig. 5.6.1 iPhone OS

If can interact directly with the hardware. The core OS includes power management, security, Certificates file system, key chain etc. The core service layer provides basic access to iOS services. It has several components namely,

- Address book	Core location
- Collections	Net services
- Networking	Threading
- File accesses	URL utilities and
- SQLite	Preference

The cocoa layer is thus used by application developers.

Media layer :

The media layer of iOS provides multimedia services which can be used in iPad and iPhone applications.

- Core audio
- Audio
- Open GL

The media layer is the second layer next to Cocoa touch layer. This layer provides iPhone OS with video, audio, graphics and animation capabilities. Also with it several frameworks could be utilized when developing the iPhone applications.

Core services layer :

It forms the third layer of the stack. It forms mostly the foundation layer for the other layers to develop with Core OS Layer.

It forms the fourth or bottom most layer of stack. It is directly in contact with the hardware. This layer provides,

- Low level networking
- Access to external accessories
- Conventional operating system services including,
  - File system handling
  - Memory management and threads.

The entire iPhone hardware devices are managed by the iPhone OS several native applications are implemented with it and standard services are provided to the users. The iPhone OS is similar to the Mac OS x design but there is some difference in the architectural design where Cocoa layer of stack are not the same Mac OS x design which is used for Mac machine architecture whereas iOS is applied in the iPhone devices.

5.6.2 Android

AU : Dec.-18

In the year 2005 Google made a small beginner company known as Android, that was developing an OS for mobile hand held devices which was based on Linux. An open handset alliance was set up by Google in the year 2007.

Android operating system is a open source software for mobile handheld devices that has been developed by around 82 companies with several technical collaboration. Android provided many user friendly features.

Android permits other application developers for coding with Java.

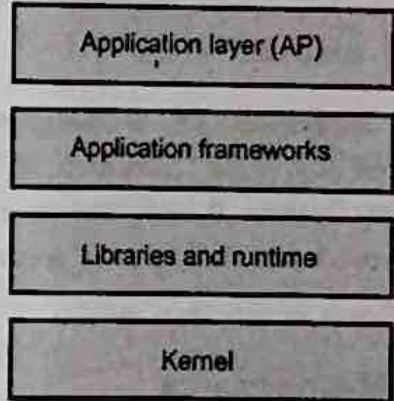


Fig. 5.6.2 : Android simple software stack

The simple Android code has four layers :

i) Application Layer (AP) :

The applications such as email, SMS, calender, web browser etc. are written using Java (J2ME). Android provides most of the basic applications.

ii) Application framework :

It is used for implementing a structure for variety of applications. This framework facilitates the user with services to develop applications.

The system manager includes content provider and manager.

iii) Library and runtime :

Android OS has libraries and runtime. Multiple languages such as C and C++ are used for its library. A Java interface is made use for calling a library function.

The runtime contains two main components. A group of libraries is used. The second runtime component is Dalvik virtual machine. A Java program is translated into machine code of device using Dalvik virtual machine.

This code is executed by the OS. It is then compiled to an ARM code, and also installed with help of Android Kit (SDK).

iv) Kernel :

The Kernel of Android OS is based on Linux Kernel. Android implements its mobile device drivers, process management, memory management and also networking functions based on Linux Kernel code.

- Android permits applications to run concurrently.
- Multitasking is possible with this OS.

Advantages of Android OS Include

i) It has open platform and suitable for many mobile phones.

ii) It needs lower footprint of 250 kB.

iii) It supports libraries and robust in nature.

iv) It has an integrated web browsing.

v) It uses Java as open programming language and it is user friendly.

5.6.3 Blackberry OS

AU : Dec.-18

The Blackberry OS is designed for the Blackberry smart phone systems which is produced by RIM (Research In Motion Limited). Blackberry OS is a proprietary operating system. It facilitates an excellent email system in the market.

- It provides high degree of security with good on-device message encryption.
- It allows instant mailing.

5.7 M-Commerce

AU : June-16, Dec.-16,18 May-17,18

Mobile Commerce (M-Commerce) is an application of mobile computing. The activities linked to selling buying, or any service are included in M-Commerce in mobile devices. Buying and selling in M-Commerce is made and care has to be taken in making payment with security. The mobile payment is in e-payment mode.

There are several applications possible with this M-Commerce. Also the two categories of it are namely :

i) Business-to-Consumer (B2C) applications.

ii) Business-to-Business (B2B) applications.

i) B2C applications :

In this type a product/service can be sold by a business firm to a consumer.

B2C applications includes,

- Advertising

- Mobile ticketing task
- Product information
- Payment services
- Loyalty services
- Catalogue shopping etc.

ii) B2B applications :

It is a form of commerce where a product/service can be sold from company firm to the dealers, and not to the consumer directly.

Some of the B2B applications includes,

- Stock tracking and control tasks,
- Inventory management etc.

5.8 Structure of M-Commerce

AU : June-16, Dec.-16, May-17,19

A simple architecture of a mobile commerce (M-Commerce) is shown below. Each layer in it has its own functionality to perform in the framework.

The layers includes mobile device, client, application and host computer linked with Internet.

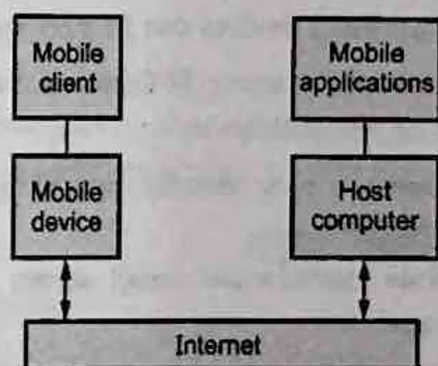


Fig. 5.8.1 A simple architecture of M-commerce framework

Some of the features required by the device for enabling M-Commerce are;

- Camera facility
- Internet
- RFID
- SMS and MMS
- Ability for scanning bar codes
- Efficient display system.

Network :

The user's requests are sent to the neighbouring wireless access point (WLAN) or to a Base Station (BS).

For M-Commerce wired networks are not essential. The server or a host computer are connected with Internet.

Mobile middleware :

The use of middleware is to map the Internet contents to mobile devices with transparency. Then it would support many operating systems and protocols. Middleware also provide secured communication with encryption and decryption techniques.

Host computers or servers :

It stores all informations required for M-commerce application. Most of the application programs consists of three main components namely;

Database servers : Used to store data.

Web servers : Help for interacting with mobile device

Support software : To implement the useful business logic of M-Commerce.

In M-Commerce all the four layers forms the structure or framework to handle several applications.

Pros and Cons :

The Mobile Commerce (M-Commerce) has several advantages and disadvantages.

i) Advantages :

- Mobile handheld devices can be personalized.
- The advantages of using M-Commerce in business organization includes, cost savings, business opportunities etc.
- M-Commerce is user friendly, providing light weight, flexibility etc.

ii) Disadvantages :

- The mobile devices has small screen which might limit user's menu choice, text typing capabilities.
- Mobile devices usually do not provide processing power or graphics of personal computers.
- Restricted bandwidth limits reach of M-Commerce everywhere in practical scenario.

5.9 Mobile Payment Systems

AU : June-16, Dec.-16,17,18 May-18,19

A number of mobile payment methods are in vogue viz

1) Micro payment

2) Credit card

3) Bank payment

Payment is usually made in by the service provider e.g. bank and the appropriate recovery made from the user.

1) Micro payment :

Payment made for purchase of Coca Cola by vending machines is a case in point. The service provider and phone company coordinate in managing the vending machine process. The mobile phone call made by the customer and the vending machine interact. This enables smaller purchases easier.

2) Credit card :

When the credit card and the mobile phone of the user are linked making an M-payment Via the Credit card to the vender is possible. Payment is easily made into the account of the seller.

3) Bank payment : Through Bank the payment can be done by linking, the bank account and mobile number. Payment on purchase is directly made into the account of the seller from the account of the buyer which are all linked by the mobile.

Security Aspects

This is a very tacklish issue which has a number of ramifications. Tracking the mobile device could itself be hectic The problems of misuse can be aggravated due to theft or loss. The identity of the user cannot be ascertained and dubious users can easily get away with fraud.

M payments are attractive, easy and customer friendly. However using the mobile to make payments is not without its risks. Simplification in the payment procedures does not automatically enable authenticated money transfers and online purchases.

5.10 Security

AU : June-16, Dec.-16

- Mobile commerce has better security and privacy.
- Subscribers of mobile devices would be difficult task for tracing due to roaming.
- Mobile devices also work in both on-line and off-line.
- But when a mobile device is lost it is a complex task to trace the device.
- Authentication mechanism still has to improve for M-Commerce devices.

Review Questions

1. *What is the significance of device OS ?*
2. *List two constraints of mobile device OS.*
3. *Mention any two mobile operating system.*
4. *Write a note on Palm OS.*
5. *What is the function of iOS ?*
6. *Write a note on Android.*
7. *List the four layers of structure of Android.*

8. *Write a note on Blackberry.*
9. *What is M-Commerce ? Give two advantages.*
10. *Write a short note on mobile payment system.*
11. *What are the special constraints and requirements of mobile operating system question*
12. *Explain commerce mobile operating system.*
13. *What is the importance of software development kit iOS and Blackberry? Explain.*
14. *Write a note on Android, Blackberry, Windows phone in detail.*
15. *Explain M-Commerce and security system in detail.*

University Questions with Answers

Part A

Q.1 *What is M- Commerce ?* **(Refer section 5.7).** **AU : June-16, Marks 2**

Q.2 *Differentiate E-Commerce and M-Commerce.* **(Refer section 5.7).** **AU : Dec.-16, Marks 2**

Q.3 *Explain the pros and cons of M-commerce* **(Refer section 5.8).** **AU : May-17, Marks 2**

Q.4 *What are limitations of mobile computing ?* **(Refer section 5.2)).** **AU : Dec.-16, Marks 2**

Q.5 *What are the special constrains and requirements of mobile O/S* **(Refer section 5.2).** **AU : May-17, Marks 2**

Q.6 *What are the constraints in mobile OS ?* **(Refer section 5.2).** **AU : Dec.-17, Marks 2**

Q.7 *What are the advantages and disadvantages of BlackBerry OS ?* **(Refer section 5.6.3).** **AU : Dec.-17, Marks 2**

Q.8 *What is M-Commerce ? List its disadvantages.* **(Refer section 5.7)** **AU : May-18, Marks 2**

Q.9 *What are the constraints of mobile device OS ?* **(Refer section 5.2)** **AU : May-18, Marks 2**

Q.10 *What are the features of Blackberry operating system ?* **(Refer section 5.6.3)** **AU :Dec.-18, Marks 2**

Q.11 *Write any two features of windows phone.* **(Refer section 5.5.3)** **AU :Dec.-18, Marks 2**

Q.12 *List some special constraints for mobile operating systems.* **(Refer section 5.5)** **AU : May- 19, Marks 2**

Q.13 *What are the desirable properties of a mobile payment system ?* **(Refer section 5.9)** **AU : May- 19, Marks 2**

Part B

Q.14 *Explain the components of Mobile Operating Systems.* **(Refer section 5.5)** **AU : June-16, Marks 8**

Q.15 *Write a short notes on Android SDK.* **(Refer section 5.6.2)** **AU : June-16, Marks 8**

Q.16 *Explain the various applications of M-Commerce.* **(Refer sections 5.7, 5.8)** **AU : June-16 Marks 8**

Q.17 *Explain the Mobile payment schemes and Security issues.* **(Refer sections 5.9, 5.10)** **AU : June-16, Marks 8**

Q.18 *Compare and contrast the various mobile OS.* **(Refer section 5.5)** **AU : Dec.-16, Marks 10**

Q.19 *Discuss the applications of M-Commerce.* **(Refer section 5.7)** **AU : Dec.-16, Marks 6**

Q.20 *Explain mobile payment models and security issues.* **(Refer sections 5.9, 5.10)** **AU : Dec.-16, Marks 10**

Q.21 *Explain various operating systems for mobile computing.* **(Refer section 5.5)** **AU : May-17, Marks 16**

Q.22 *Write detailed notes on mobile commerse.* **(Refer section 5.9)** **AU : May-17, Marks 16**

Q.23 *Illustrate the process of mobile payment. Compare and contrast mobille payment schemes.* **(Refer section 5.9)** **AU : Dec.-17, Marks 16**

Q.24 *Explain Android platform with its features, software stack and SDK.* **(Refer section 5.6.2)** **AU : Dec.-17, Marks 16**

Q.25 *Explain in detail components of iPhone operating systems. List the special features of a mobile operating system.* **(Refer sections 5.5 and 5.6.1)** **AU : May-18, Marks 13**

Q.26 *Explain in detail mobile payment schemes and their security issues.* **(Refer section 5.9)** **AU : May-18, Marks 13**

Q.27 *What are the features of mobile operating system ? Explain in detail about android SDK.* **(Refer sections 5.1, 5.2, 5.6.2)** **AU : Dec.-18, Marks 13**

Q.28 *Describe mobile payment system. Explain the different payment systems that are available.* **(Refer section 5.9)** **AU : Dec.-18, Marks 8**

Q.29 *What is M-commerce ? Explain the advantages and disadvantages of M-commerce.* **(Refer section 5.7)** **AU : Dec.-18, Marks 5**

Q.30 *Explain android software with neat diagram.* **(Refer 5.6, 5.6.2)** **AU : Dec.-18, Marks 15**

Q.31 *Outline the features of Windows mobile, Symbian and Android operating systems.* **(Refer sections 5.5.3, 5.5.4 and 5.6.2)** **AU : May-19, Marks 13**

Q.32 *Explain the structure of mobile commerce framework.* **(Refer section 5.7)** **AU : May-19, Marks 9**

Q.33 *State the pros and cons of mobile commerce.* **(Refer section 5.8)** **AU : May-19, Marks 4**

□□□

Notes

June-2016 Mobile Computing Semester - VI (CSE / IT) - (57492) Regulation 2013	AU Solved Paper

Time : Three Hours] [Maximum Marks : 100

Answer ALL Questions

PART - A (10 × 2 = 20 Marks)

Q.1 *List the advantages of mobile computing.* **(Refer section 1.1)**

Q.2 *Explain hidden and exposed terminal problems in infrastructure - less network.* **(Refer section 1.11.2)**

Q.3 *What is DHCP ?* **(Refer Sec. 3.2)**

Q.4 *What is encapsulation in mobile IP.* **(Refer section 3.6.1.2)**

Q.5 *List the 3 important features of GSM security.* **(Refer section 2.9)**

Q.6 *What are the main elements of UMTS ?* **(Refer section 2.12.1)**

Q.7 *List the characteristics of MANETs.* **(Refer section 3.5.1)**

Q.8 *Compare MANET Vs. VANET.* **(Refer section 3.10)**

Q.9 *Give four examples of Mobile OS.* **(Refer section 5.5)**

Q.10 *What is M-Commerce ?* **(Refer section 5.7)**

PART - B (5 × 16 = 80 Marks)

Q.11 a) *i) Explain the characteristics of mobile computing.* **(Refer section 1.6)** **[8]**

ii) Explain the structure of mobile computing application. **(Refer sections 1.3, 1.3.1)** **[8]**

OR

b) *Explain the various taxonomy of MAC protocols in detail.* **(Refer sections 1.11, 1.11.1)** **[16]**

Q.12 a) *i) With a diagram explain DHCP and its protocol architecture.* **(Refer section 3.2)** **[8]**

ii) Explain IP-in-IP, Minimal IP and GRE encapsulation methods. **(Refer section 3.1.6)** **[8]**

OR

b) *i) With a neat diagram explain the architecture of TCP/IP.*
(Refer section 4.3) **[8]**

ii) Explain the various improvements in TCP performance with diagram.
(Refer section 4.7) **[8]**

Q.13 a) *i) Describe GSM architecture and its services in detail.*
(Refer section 2.6.1 and 2.6.2) **[8]**

ii) Explain GSM Authentication and security. **(Refer section 2.9)** **[8]**

OR

b) *i) Explain GPRS and its protocol arechitecture.* **(Refer section 2.11)** **[8]**

ii) Explain in detail about UMTS architecture. **(Refer sections 2.12)** **[8]**

Q.14 a) *i) Explain characteristics, applications of MANET.*
(Refer sections 3.5, 3.5.1 and 3.11) **[4+4]**

ii) Explain DSR routing protocols in detail. **(Refer section 3.7.2)** **[8]**

OR

b) *i) Draw and explain the architecture of VANET.* **(Refer section 3.9.1)** **[8]**

ii) Explain the various security and attacks on VANET.
(Refer sections 3.10 and 3.11) **[8]**

Q.15 a) *(i) Explain the components of mobile operating systems.* **(Refer section 5.5)** **[8]**

(ii) Write a short note on Android SDK. **(Refer section 5.6.2)** **[8]**

OR

b) *(i) Explain the various applications of M-Commerce.*
(Refer sections 5.7 and 5.8) **[8]**

(ii) Explain the mobile payment schemes and security issues.
(Refer sections 5.9 and 5.10) **[4+4]**

May-2017
Mobile Computing
Semester - VI (CSE / IT) - (72056) Regulation 2013

AU Solved Paper

Time : Three Hours] [Maximum Marks : 100

Answer ALL Questions

PART - A (10 × 2 = 20 Marks)

Q.1 *Differentiate mobile computing and wireless networking.* **(Refer section 1.5)**

Q.2 *List some random assignment scheme.* **(Refer section 1.11.3)**

Q.3 *What is route optimization ?* **(Refer section 3.6)**

Q.4 *List the modifications proposed in single-hop and multi-hop wireless networks.*

Ans. : In wireless sensor network for computing purposes energy efficiency is important. Nodes in the network transmit data either with single hop or with multiple hops. The transceiver in the system consumes more power. When comparing single and multihop routing option energy efficiency is high in single hop transmission where power consumption of transceiver is also accounted.

Q.5 *Name the teleservices provided by GSM.* **(Refer section 2.10.1)**

Q.6 *Write the suggestions of mobile phone with respect to human body.*

Ans. : The mobile phone radiation is hazardous to human body. Mobile communication is electromagnetic radiation (EMF) that consists of radio waves of electric and magnetic energy which travels with speed of light. The absorption of EMF in human body is not good. If a call duration exceeds 6 minutes per day it is harmful to human body. A statistics about the absorption of EMF radiation is given by specific absorption radiation distribution value.

Also there are several elements influences the measure of RF radiations such as,

i) Using speaker mode or headphone set and its usage time.

ii) Closeness with mobile phone tower.

iii) Measure of time period for which a human is on mobile phone etc.

Q.7 *List the applications of MANETs.* **(Refer section 3.5)**

Q.8 *Distinguish proactive and reactive protocols.* **(Refer section 3.7)**

Q.9 *What are the special constrains and requirements of mobile O/S.* **(Refer section 5.2)**

Q.10 *Explain the pros and cons of M-commerce.* **(Refer section 5.8)**

PART - B **(5×16 = 80 Marks)**

Q.11 a) *i) Explain the wireless MAC issues in detail.* **(Refer sections 1.11 and 1.11.1)** **[8]**

ii) Explain the various applications of mobile computing. **(Refer section 1.1 and 1.12)** **[8]**

OR

b) *i) Explain fixed assignment scheme with a neat diagram.* **(Refer section 1.11.5)** **[8]**

ii) Explain MAC protocols for Ad Hoc Networks. **(Refer section 1.11.6)** **[8]**

Q.12 a) *With a neat diagram explain how packet delivery to and from a mobile node is transferred in mobile IP.* **(Refer sections 3.1.3 and 3.1.5)** **[16]**

OR

b) *What is encapsulation ? Explain in detail the various encapsulation techniques in mobile IP.* **(Refer section 3.1.6)** **[16]**

Q.13 a) *Explain the GSM architecture in detail.* **(Refer section 2.6.1)** **[16]**

OR

b) *Explain GPRS protocol architecture.* **(Refer section 2.11)** **[16]**

Q.14 a) *Explain the design issues of MANET routing protocols in detail.* **(Refer sections 3.5.1, 3.11.1, 3.11.2 and 3.11.3)** **[16]**

OR

b) *Explain any two VANET routing protocol with an example.* **(Refer section 3.9.2)** **[16]**

Q.15 a) *Explain various operating systems for mobile computing.* **(Refer sections 5.5)** **[16]**

OR

b) *Write detailed notes on mobile commerce.* **(Refer sections 5.7 and 5.8)** **[16]**

□□□

May-2018 Mobile Computing Semester - VI (CSE / IT) - (41298) Regulation 2013	AU Solved Paper

Time : Three hours] [Maximum : Marks 100

Answer ALL Questions

PART - A (10 × 2 = 20 Marks)

Q.1 *Distinguish between mobile computing and wireless networking.* **(Refer section 1.5)**

Q.2 *List the issues of wireless MAC.* **(Refer section 1.11)**

Q.3 *What is the purpose of DHCP ?* **(Refer sections 3.2 and 3.1.4 (2))**

Q.4 *What is the purpose of agent solicitation message ?* **(Refer sections 2.1 and 2.2)**

Q.5 *What is frequency range of uplink and downlink in GSM network ?* **(Refer section 2.6.1)**

Q.6 *What are the informations are stored in SIM ?*

Ans. : SIM is chip that stores informations like

- International Mobile Subscriber Identity Number (IMSI)
- Authentication key
- Mobile number
- Contacts
- Temporary information which is related mainly to the local network.

Q.7 *Compare VANET with MANET.* **(Refer section 3.10)**

Q.8 *Differentiate cellular with adhoc networks.* **(Refer sections 3.5 and 3.5.1)**

Q.9 *What is M-Commerce ? List its disadvantages.* **(Refer section 5.7)**

Q.10 *What are the constraints of mobile device OS ?* **(Refer section 5.2)**

PART - B (5 × 16 = 80 Marks)

Q.11 a) *i) Discuss in detail the structure of a mobile computing application.* **(Refer section 1.3.1)** [6]

ii) Apply mobile computing to design taxi dispatcher and monitoring service. Explain the components in detail. [7]

Ans. : Taxi dispatching system and dispatching method :

Mobile computing is useful in the application taxi dispatching system and dispatching method. Using a mobile phone a taxi customer requests a taxi dispatch. At first the control center acquires this request. It authenticates the tele phone number by an incoming call log and then sends an e-mail with URL to the e-mail address of that taxi customer. There after the taxi customer accesses the URL and inputs the dispatch conditions which is distributed to several taxi drivers. An optimal taxi is been selected by control center based by the offer from te taxi drivers that satisfies the necessary dispatch conditions.

Once the selection is made, the taxi customer, taxi driver and the taxi company automatically notifies it.

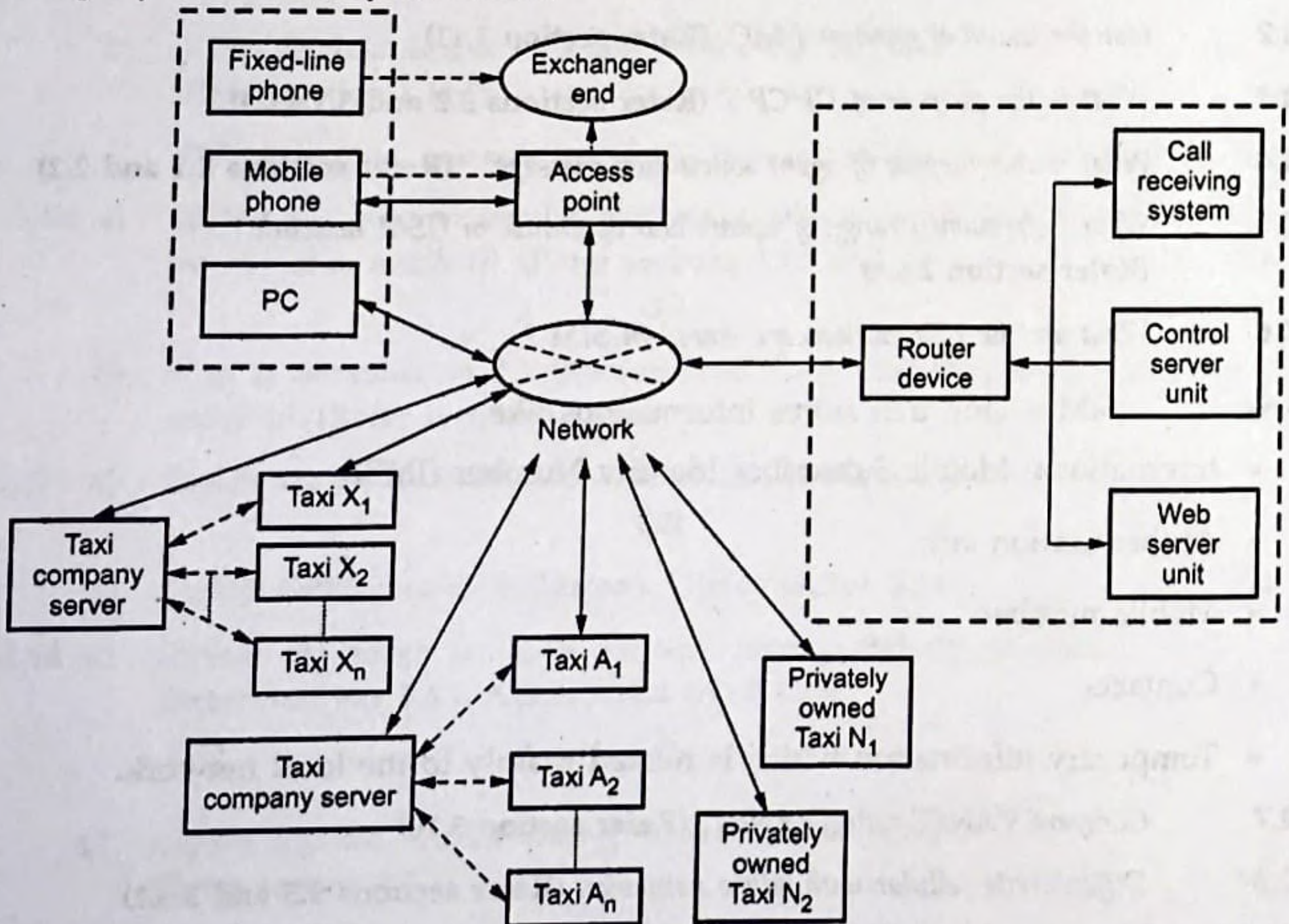


Fig. 1 Simple taxi dispatch system

Due to this arrangement it enables a taxi to be dispatched automatically without the need for a telephone conversation between the control center the taxi driver.

With desired conditions a taxi customer can automatically take a taxi in this process.

Thus mobile computing environment enables taxi dispatching system and provides this service to the user in an efficient manner.

OR

b) *i) List the characteristics of mobile systems.* **(Refer section 1.6)** **[6]**

ii) What is CSMA ? What are the categories of CSMA ? Explain their working with advantages and disadvantages. **(Refer section 1.13.2)** **[7]**

Q.12 a) *i) Explain Indirect TCP(I-TCP) with the help of a suitable schematic diagram.* **(Refer section 2.7.2)** **[8]**

ii) Explain the agent discovery process in mobile IP. **(Refer section 3.1.4)** **[5]**

OR

b) *i) Describe how mobile TCP improves TCP efficiency for mobile network ? How does mobile TCP maintain end to end schematics ?* **(Refer section 2.7.4)** **[8]**

ii) Briefly explain about the adaption of TCP window. **(Refer section 4.7.1)** **[5]**

Q.13 a) *Write in detail about the various types of handover in GSM. Also discuss the timeline diagram of the Intra MSC handover.* **(Refer section 3.1.1.5)** **[13]**

OR

b) *Explain in detail network architecture of UMTS with a neat diagram.* **(Refer section 3.3)** **[13]**

Q.14 a) *Describe the architecture of VANET with a neat diagram.* **(Refer section 3.9.1)** **[13]**

OR

b) *Explain the design issues in MANET and the applications of adhoc network.* **(Refer sections 3.6 and 3.7)** **[13]**

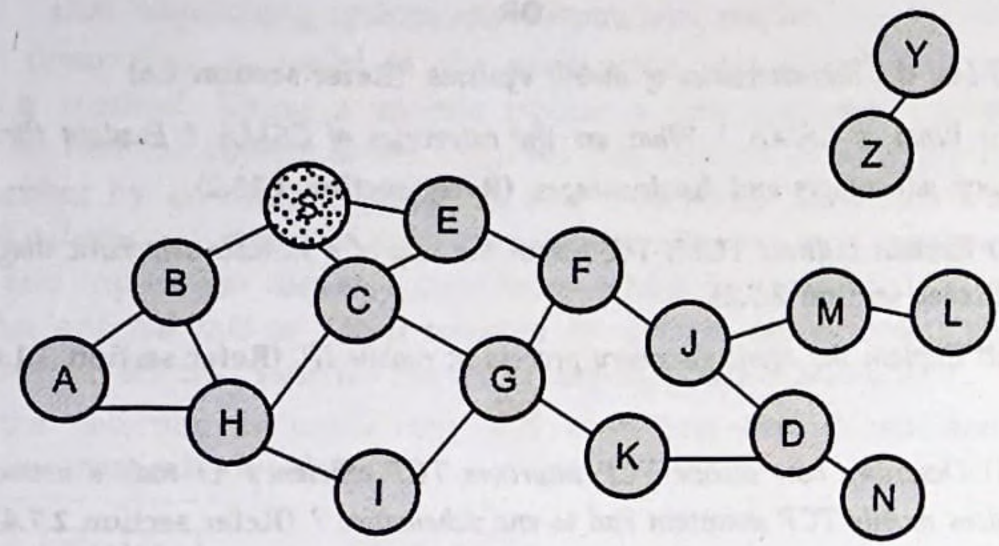
Q.15 a) *Explain in detail components of iPhone operating systems. List the special features of a mobile operating system.* **(Refer sections 5.6.1 and 5.6.1.1)** **[13]**

OR

b) *Explain in detail mobile payment schemes and their security issues.* **(Refer section 5.9)** **[13]**

PART - C (1×15 = 15 Marks)

Q.16 a) *Consider the network given below. Here 'S' is source node and 'D' is target node. Illustrate the process of route discovery, route reply, data delivery and route caching using DSR. Explain the approach.* **(Refer sections 3.7 and 3.7.2)**



OR

b) *Enumerate the processes involved in data packet delivery using mobile IP in adhoc networks.* **(Refer sections 3.1.4 and 3.1.5)**

May-2019 **Mobile Computing** **Semester - VI (CSE / IT) - (53238) Regulation 2013**	**AU** **Solved Paper**

Time : Three hours] **[Maximum : Marks 100**

Answer ALL Questions

PART A - (10 × 2 = 20 Marks)

Q.1 *What do you mean by mobile computing ?* **(Refer section 1.1)**

Q.2 *Give some examples of reservation based schemes in MAC protocols.* **(Refer section 1.11.4)**

Q.3 *Identify the desirable features of Mobile IP.* **(Refer section 3.1.5)**

Q.4 *Show the structure of a TCP segment.* **(Refer Fig. 4.3.2)**

Q.5 *Identify the services offered by GPRS.* **(Refer section 2.11)**

Q.6 *List out the advantages of UMTS networks over 2G networks.* **(Refer section 2.12)**

Q.7 *Why is routing in MANET so complex task ?* **(Refer section 3.6)**

Q.8 *Compare MANET versus VANET.* **(Refer section 3.10)**

Q.9 *List some special constraints for mobile operating systems.* **(Refer section 5.5)**

Q.10 *What are the desirable properties of a mobile payment system ?* **(Refer section 5.9)**

PART B - (5 × 13 = 65 Marks)

Q.11 a) *i) Describe the characteristics of mobile computing.* **(Refer section 1.6)** **[5]**

ii) Explain the structure of mobile computing application with an illustrative example. **(Refer section 1.3.1)** **[8]**

OR

b) *Summarize the functions of Fixed-assignment schemes in MAC protocols.* **(Refer section 1.11.5)**

Q.12 a) *With a neat diagram explain the packet delivery process between the correspondent node and the mobile node.* **(Refer sections 3.1.3 and 3.1.5)**

OR

b) *Outline the popular TCP congestion control algorithms.* **(Refer sections 4.5.1 and 4.5.1.1)**

Q.13 a) *i) Outline the services offered by GSM.* **(Refer section 2.10.1)** **[7]**

ii) Analyze the important features associated with security in GSM. **(Refer section 2.9)** **[6]**

OR

b) *Draw and explain the architecture of GPRS. List its advantages and limitations.* **(Refer section 2.11)**

Q.14 a) *Describe the characteristics and applications of Mobile Ad hoc networks.* **(Refer sections 3.3, 3.3.1 and 3.4)**

OR

b) *Summarize the two important classes of routing protocols for traditional network.* **(Refer sections 3.6.2 and 3.7)**

Q.15 a) *Outline the features of Windows mobile, Symbian and Android operating systems.* **(Refer sections 5.5.3, 5.5.4 and 5.6.2)**

OR

b) *i) Explain the structure of Mobile commerce framework.* **(Refer section 5.7)** **[9]**

ii) State the pros and cons of Mobile commerce. **(Refer section 5.8)** **[4]**

PART C - (1 × 15 = 15 Marks)

Q.16 a) *Organize the steps involved in operation of Destination-Sequenced Distance-Vector Routing protocol. Illustrate with an example.* **(Refer section 3.7 and 3.7.1)**

OR

b) *Discuss in detail about the mobile IP working principle with a neat diagram. Explain the tunneling operation with a encapsulated format message.* **[15]**
(Refer section 3.1.6)

□□□

Mobile Computing

Solved Model Question Paper

Time : Three Hours] **[Maximum Marks : 100**

PART A – (10 × 2 = 20)

Q.1 *Define mobile computing.* **(Refer section 1.1)**

Q.2 *Write a short note on fixed assignment schemes.* **(Refer section 1.11.5)**

Q.3 *What are the features of mobile IP ?* **(Refer section 3.1)**

Q.4 *Write about security issue in GSM.* **(Refer section 2.9)**

Q.5 *What is the use of VANET ?* **(Refer section 3.9)**

Q.6 *Differentiate Ad-hoc network and wired network.* **(Refer sections 3.5.1 and 3.6.2)**

Q.7 *Write a note on Mobile TCP.* **(Refer section 4.6)**

Q.8 *Write a short note about WML.* **(Refer section 4.7.9)**

Q.9 *List few constraints in mobile device operating system.* **(Refer section 5.2)**

Q.10 *Write a short note on Android and Blackberry mobile software.* **(Refer sections 5.6.2 and 5.6.3)**

PART B – (5 × 16 = 80)

Q.11 a) *Compare mobile computing and wireless networking. Mention the characteristics of mobile computing.* **(Refer sections 1.5 and 1.6)**

OR

b) *i) Explain MAC protocols.* **(Refer section 1.11)** **[10]**

ii) Draw the structure of mobile computing. **(Refer section 1.3.1)** **[6]**

Q.12 a) *i) What is the handover procedure in GSM ?* **(Refer section 2.7.1 and Fig. 2.7.2)** **[8]**

ii) Explain the GSM architecture in detail. **(Refer section 2.6.1)** **[8]**

OR

b) *What is UMTS ? Explain UMTS in detail. Mention the advancement of 3G standard compared with 2G cellular standard.* **(Refer section 2.12)** **[16]**

Q.13 a) *Explain the features of mobile IP and key mechanism in mobile IP.* **(Refer sections 3.1, 3.1.1 and 3.1.2)** **[16]**

OR

b) *i) Define hybrid protocol. Explain ZRP protocol in detail.* **(Refer section 3.7.4 and 3.7.4.1)** **[8]**

ii) Write a note on DSR routing protocol. **(Refer sections 3.8 and 3.7.2)** **[8]**

Q.14 a) *i) Explain WAP architecture in details with a neat block diagram.* **(Refer sections 4.7.5)** **[16]**

OR

b) *i) Write a note on Mobile TCP.* **(Refer section 4.6)** **[8]**

ii) What is known as WML ? Explain its significances. **(Refer section 4.7.9)** **[8]**

Q.15 a) *i) Explain the constrains in mobile operating system.* **(Refer section 5.2)** **[6]**

ii) Explain the commercial mobile operating system. **(Refer section 5.5)** **[10]**

OR

b) *Write short note on the following software development kit.*

i) Android ii) Blackberry iii) M-Commerce and iv) Mobile payment system. **(Refer sections 5.6.2, 5.6.3, 5.7 and 5.9)** **[16]**

PART C - (1 × 15 = 15 Marks)

Q.16 a) *Describe the architecture of TCP / IP. Give the improvement in TCP performance.* **(Refer sections 4.3 and 4.7)** **[15]**

OR

b) *i) Explain the mobile payment schemes and the security issues.* **(Refer section 5.9 and 5.10)** **[7]**

ii) Explain the applications of M-commerce. **(Refer sections 5.7 and 5.8)** **[8]**

□□□