(7) Mobile and Wireless Devices

Some examples of mobile and wireless devices which graded by increasing the performance such as CPU, memory, display, input devices etc are,

- Sensor,
- Embedded controllers,
- Pager,
- Mobile phones,
- Personal Digital Assistant(PDA),
- Pocket computer, and
- Notebook / Laptop.

1.3 GENERATIONS OF MOBILE COMMUNICATION TECHNOLOGIES

1.3.1 Introduction

- Last five decades, mobile communication technology has advanced at a very pace. The gradual technology improvements over the last four decades can be roughly divided into four generations.
- Each generations basically provides higher data rate and additional capabilities, which is shown in Fig 1.4.

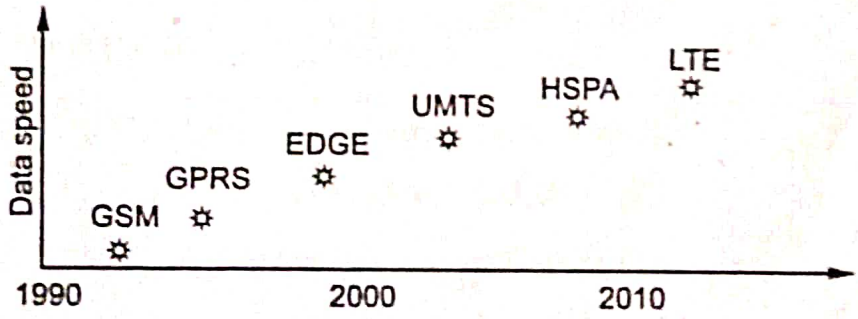


Fig 1.4 Mobile technology advancements in years

- The important characteristics of the various generations of cellular mobile systems is summarized in Table 1.1 and you can see that, each mobile Cellular generation system has a significant technology advancements which results in

improving the quality of the services and also to increase the number of services and at the same time the cost to the customer to drop considerably.

Table 1.1 Comparisons of Cellular Wireless Communication Systems.

Generation	Period of commercial use	Important features	Standards	Data speed
1G	70's to 90's	Analog transmissions, primarily usage restricted to voice communication.	NMT, AMPS, TACS	No direct Support
2G	90's to 2000	Data transmissions, improved performance by letting multiple users share a single channel.	GSM	9.6 kbps
2.5G	2001-2005	Enhanced multimedia and streaming video, web browsing.	GPRS	28 kbps or higher
3G	2005-2015	Enhanced multimedia and streaming video capabilities.	UTMS, HSPDA, EDGE, W-CDMA	384 kbps or higher
4G	2010-till date	Support interactive multimedia, voice, video, wireless internet and other broadband services.	LTE, WiMAX	100 Mbps or higher

1.3.2 First Generation (1G)

- The first generation (1G) cellular system was designed in the late 1960s but was commercially deployed in the early 1980s.

- The first commercial 1G system in the United States (US) was known as ***Advanced Mobile Phone System(AMPS)*** which became operational in the year 1982 but ***only supported voice calls***. This was completely ***analog system.***
- Fig 1.5 shows an analog system. In this, analog signals are transmitted by modulating them using a high frequency carrier signal.
- The information signal is not converted into a digital form through the process of ***quantization***. So it is difficult to support ***Short Message Service (SMS)*** and other data services.

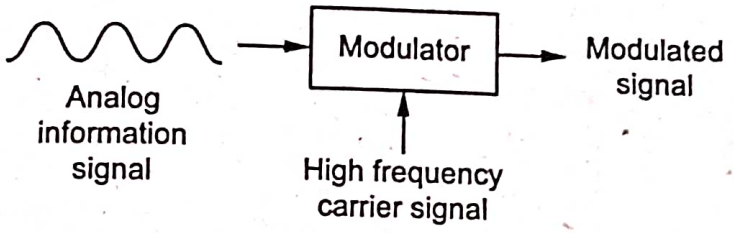


Fig 1.5 Analog system

(1) Subbands (or) Channels

- *In a 1G system, the available frequency spectrum (total system bandwidth) was splitted into a number of subbands (or) channels based on number of users and each subbands were used by a different users(callers).*

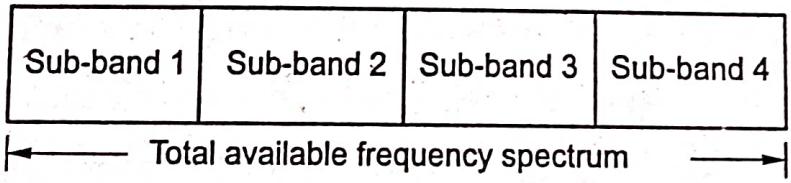


Fig 1.6 Frequency band split into five sub-bands in 1G

Forward Band Channel:

- *Frequency Division Duplexing (FDD) provides two distinct bands (forward & reverse band) of frequencies for every user at the same time.*
- The ***forward band (channel)*** allows ***traffic*** from the ***base station*** to the ***mobile***, which is also referred to as ***downlink (or) broadcasting.***

- These systems typically allocated a ***25 MHz frequency band*** (869-89 MHz) for the signals to be sent from the Base Station (BS) to the Mobil unit (incoming signal).

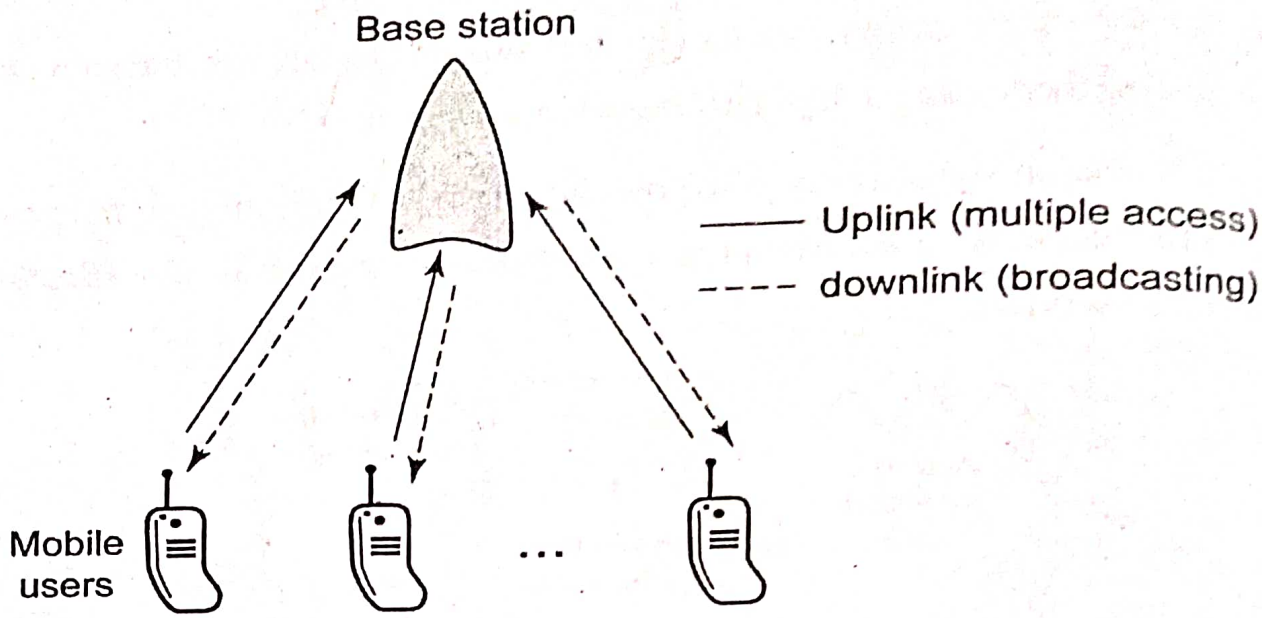
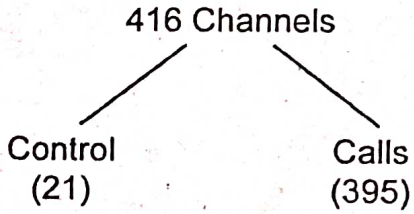


Fig 1.7 The uplink and downlink transmissions

Reverse Band Channel:

- The ***reverse band (channel)*** allows ***traffic*** from the ***mobile*** to the ***base station***, which is also referred to as ***uplink (or) multiple access.***
- These system allocates the other 25 MHz (824-849 MHz) band for the signal transmitted from the mobile to base station (outgoing call).
- A channels are spaced ***30kHz*** from adjacent channels, which allows a total of 416 channels per operator.



Need of Guard Bands

The adjacent channels in this system are likely to be an interference with each other. Therefore, to avoid such interference it is necessary to include the guard bands between the adjacent channels.

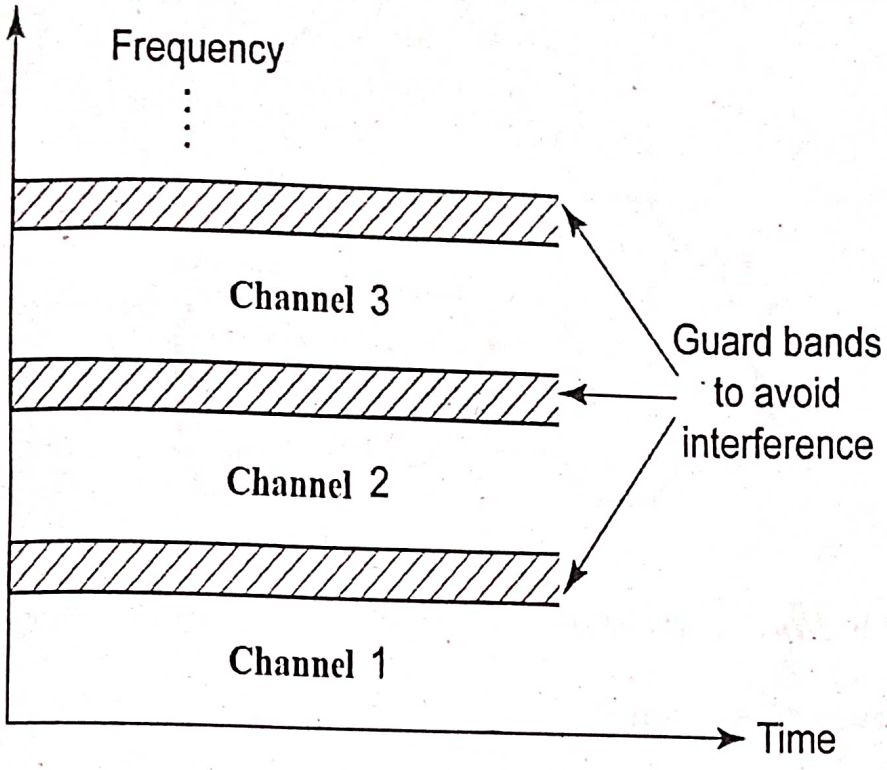


Fig 1.8 Guard bands in 1G system

1G Standards:

Different 1G standards were used in different countries:

(i) *Advanced Mobile Phone System(AMPS) in USA.*

(ii) *Nordic Mobile Telephone(NMT) in various European countries.*

(iii) *Total Access Communications System(TACS) in the UK.*

(2) Multiple Access

- *Multiple access schemes are used to allow many mobile users to communicate with each other simultaneously by using a single (or) a same propagation channel (or) a finite amount of radio spectrum.*
- 1G system used Frequency Division Multiplexing Access (FDMA), which permits to reuse the same frequencies in the non-adjacent cells.

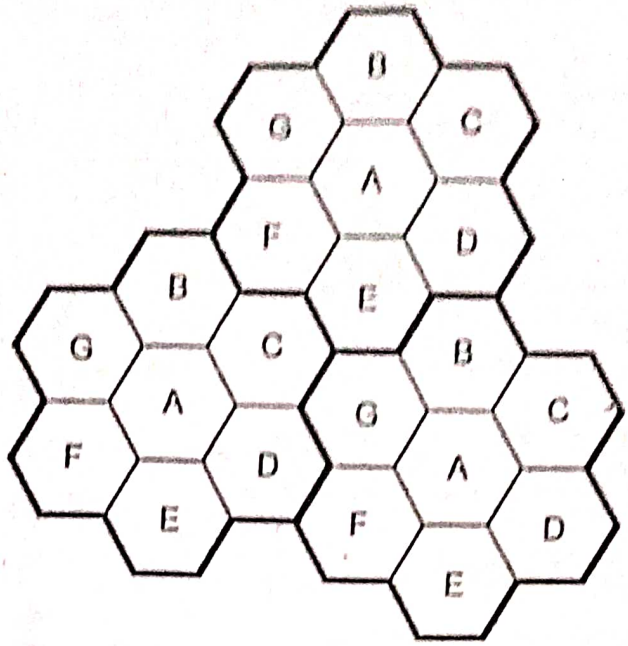


Fig 1.9 Illustration of the cellular frequency reuse concept.

Disadvantages of 1G System

The disadvantages of 1G system are,

(i) The number of callers that could be accommodated being low.

(ii) Due to analog transmission, the voice quality was poor.

(iii) No security was provided at all, any one could hear a call by tuning the channel.

(iv) High risk of call drops can occur during handoffs.

(v) Inefficient usage of the bandwidth spectrum.

(vii) This system could not capable of providing several useful services such as caller identity and SMS.

1.3.3 Second Generation (2G)

- The disadvantages of 1G systems were overcomed by the second generation (2G) cellular system, which encoded the voice and other information digitally before transmitting them.

- Digital transmission (or) 2G has many advantages over analog transmission (1G):
  - (i) *Noise immunity.*
  - (ii) *Better bandwidth utilizations.*
  - (iii) *Offered significant advancements in an evolution of the mobile cellular technologies.*
  - (iv) *Reductions in the cost of phone calls.*
  - (v) *Wider range of services includes both security and SMS.*
- Due to the above advantages of 2G, more improvements in the quality of services can be achieved than 1G. The second generation systems uses two different signal modulation techniques (or) multiple access techniques:

(i) Code Division Multiple Access (CDMA): IS 95

It can multiplex up to 64 calls per channel in the 800 MHz band.

(ii) Time Division Multiple Access (TDMA): GSM, IS 136.

Global System for Mobile Communication (GSM) can multiplex up to 8 calls per channel in the 900 and 1800 MHz bands.

- The first commercial deployment of GSM was done in 1992 which supported higher voice quality and provided data services such as SMS and e-mail.
- In 1993, another 2G system CDMA -1 (CDMA one) was standardized and commercially deployed in South Korea and Hong Kong in 1995 which was followed by the United States of America in 1996.

1.3.4 2.5 Generation

- ***General Packet Radio Service (GPRS)*** is an extension of GSM which was considered to be the 2.5 generation technology. It is based on ***packet switching*** when compared to circuit switching used in 2G.

Improvements of 2.5 G over 2G:

The significant improvements of 2.5 G over 2G are,

(i) *Reduced call cost compared to 2G.*

(ii) *Supported **MegaBy.:(MB)** of data transfer.*

(iii) *It allows users to remain connected to the Internet without incurring additional charge when the customer was not used.*

(iv) *Supports multimedia capabilities including graphics and video communications.*

- *GPRS deployments began in 2000 which is followed by **Enhanced Data GSM Environment (EDGE)** in 2003. EDGE is a faster version of the GSM wireless service designed to deliver the data at rates up to 384 kbps and can enable the delivery of multimedia and other broadband applications to mobile phone and computer users.*
- This technology provided faster data rates over 2G systems but did not offer the multi-megabit data rates which are the characteristics of the 3G. So it is called as 2.5G.

1.3.5 Third Generation (3G)

- The 3G systems are often referred to as ***International Mobile Telecommunications- 2000 (IMT -2000) systems*** as it was made a global standard by ***International Telecommunication Union (ITU)***.
- The 3G systems support much ***higher data transmission rates*** and offer ***increased bandwidth***, which makes them suitable for high – speed data applications as well as for high quality traditional voice calls.
- The 3G systems can be considered to be as ***purely data networks***, since voice signals are converted in to digital data which may be used for some other purposes.
- The 3G systems use packet – switching technology, and provide ***cheaper calls*** while giving ***better average call quality*** than the ***2G systems***.

3G Services:

The 3G network provides many innovative applications and services as follows:

(i) *Email.*

(ii) *Instant messaging and video telephony.*

(iii) *Multimedia gaming.*

(iv) *Live- video buffering.*

(v) *Location-based services.*

- NTT DoCoMo of Japan initiated an enhanced 3G network services utilizing the WCDMA protocol by incorporating ***HSDPA (High Speed Downlink Packet Access)*** that provided improved downlink data rates (99.3 Mbps).
- ***Universal Mobile Telephone System (UMTS)*** is one of the 3G mobile systems that was developed within the ITU's IMT-2000 framework.
- UMTS was developed mainly for the GSM networks, so that these could be easily upgraded to UMTS networks.
- UMTS provides coverage as the combination of a variety of cell sizes ranging from ***"in building" pico cells*** to ***global cells*** by using satellites.
- European countries have adopted to UMTS standard, while the USA uses CDMA 2000.

1.3.6 Fourth Generation (4G)

- A 4G system provides a ***faster data rate*** *(at least 10 times faster)* than that of 3G and makes broadband Internet access possible from smartphones and laptops with the USB wireless modems. ***4G standards*** are given as,

(i) Worldwide Interoperability for Microwave Access (WiMax).

(ii) Long Term Evolution (LTE).

4G Services:

- Some of the applications (or) services which could not be supported earlier generations of the cellular phone systems, now become possible 4G.
- The 4G can offers the following services:
  - (i) IP telephony.
  - (ii) Gaming services.
  - (iii) High-Definition (HD) mobile TV.
  - (iv) Video conferencing.
  - (v) 3 D television.

1.3.7 Fifth Generation (5G)

- Still research and development is going on in fifth generation cellular techniques. The expected characteristics of the 5G are increased data transmission capability (1 Gbps).
- Connectivity to a large number of devices due to the ***Internet of Things (IoT)*** through ***Multiple- Input and Multiple – Output (MIMO)*** technologies.

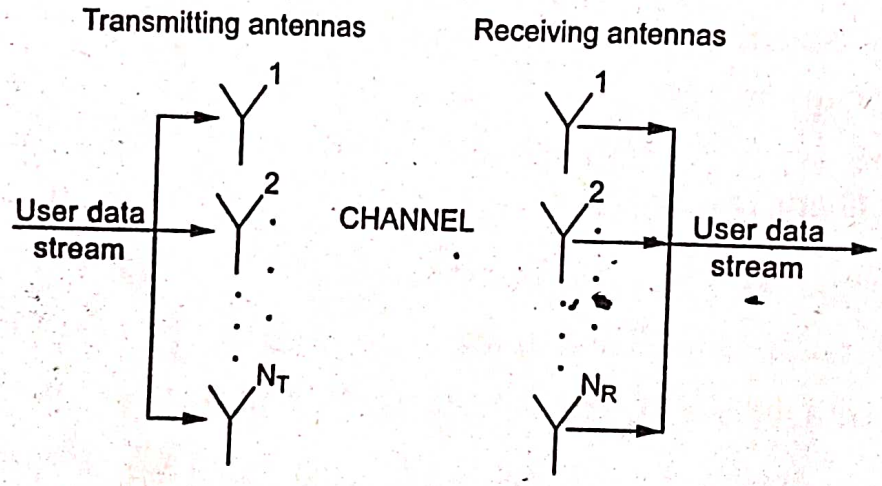


Fig 1.10 MIMO antenna configuration

- MIMO technologies uses multiple antennas for both transmission and reception, thereby effectively increases the data rate.

Generation	1G	2G / 2.5G	3G	4G	5G
Period	1985-2000	2000-2005	2005-2010	2010-2014	2016-2020
Main features	Analog voice service	Used digital radio signals. Voice encoded to digital signals. Comparatively secure.	Fast data transfer rate and greater network capacity.	Data and voice over IP. Entirely packet switched network.	Simultaneous across to different wireless technologies. Complete wireless communication leading to Wireless World Wide Web (WWWW).
Data rate	3 kbps	15-7 kbps	2.5 Mbps	180-220 Mbps to 1.5 Gbps	1 Gbps and higher
Technology	Analog voice cellular	Packet data system.	Digital broadband packet data	Digital broadband packet all, very high throughput.	IP based/seamless combination of broadband-wireless LAN.
Offered services	Only voice facility	Voice, SMS, packet data facility.	High quality audio and video	Digital information	
Switching	Circuit switching	Circuit switching with support for digital data	Packet switching	Packet switching and message switching.	

Table 1.2 Summary of characteristics of Cellular Technologies.

Transport Technology	Full form	Generation	Characteristic	Advantages and disadvantage
TDMA	Time Division Multiple Access	2G	Voice and data transmission at upto 9.6 kbps	Low processing requirement and low battery consumption. Low speed.
GSM	Global System for Mobile Communication	2G	Voice and data transmission at upto 9.6 kbps	SMS restricted to 160 characters.
GPRS	General Packet Radio Service	2.5G	Data upto 115 kbps	SMS restricted to 160 characters.
EDGE	Enhanced Data GSM	3G	Data upto 384 kbps	Easier to adopt compared to WCDMA
CDMA	Code Division Multiple Access	2G	Data upto 144 kbps but successor EVDA at 2.4 Mbps	Less popular than GSM
WCDMA	Wideband CDMA also known as Universal Telecommunicati on Systems	3G	Data upto 14 Mbps	Widely accepted

Table 1.3 Transport Technologies used Access Generations of Cellular Networks

Sl. No.	DS-SS	FH-SS
3.	DS-SS systems always use the total available band width.	FH-SS systems use, only a portion of the total bandwidth at any time.
4.	Acquisition time is long	It has a short acquisition time.
5.	Effect of distance is high.	Effect of distance is less.

2.2 MAC PROTOCOLS

2.2.1 Introduction

Definition of MAC Protocol

*In a wireless network, multiple nodes can transmit on the same shared channe at the same time. The **Medium Access Control (MAC) protocol** is responsible to decides which host would be allowed to transmit.*

- Generally, MAC belongs to the second layer of the ISO/OSI model, i.e, data link layer, which is divided two different sub layers:
  - *(i) Logical Link Control (LLC) sublayer, and*
  - *(ii) Media Access Control (MAC) sublayer.*

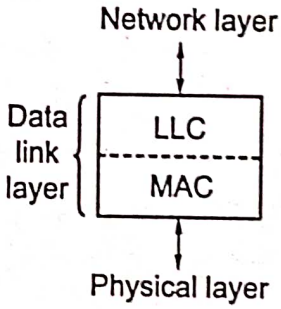


Fig 2.10 Data link layer

- *MAC* is the ***lower*** sub layer of the data link layer. It defines the ***specific access method and the framing format for each LAN*** and resolves the ***contention*** for the shared media, but upper sub layer ***LLC is common*** for all.

- The main objectives of any MAC protocol are ***maximization of the utilization of the channel*** and also concentrate on ***minimization of average latency (delay) of transmission.***

Features of MAC Protocol

A good MAC protocol needs to possess the follcwing features:

(i) *It should implement some rules that helps to enforce discipline when multiple nodes contend for a shared channel.*

(ii) *It should help in maximizing the utilization of the channel.*

(iii) *Channel allocation needs to be fair.*

(iv) *It should be capable of supporting several types of traffic having different maximum and average bit rates.*

(v) *It should be robust in the face of equipment failures and changing network conditions.*

2.2.2 Wireless MAC Protocol Issues

- The MAC protocol in a wireless medium is ***much more complex*** than MAC in wired medium. It is difficult to implement a collision detection scheme in a wireless environment, since collisions are hard to be detected by the transmitting nodes.
- In infrastructure-less networks, the following two issues can make a MAC protocol extremely inefficient:

  (i) *Hidden and exposed station problem, and*

  (ii) *Near and far station problem.*

(1) Hidden Node (Station) Problem

- *Hidden node problem occurs on a wireless network when two nodes are sending signals to a common destination but are unaware of the other exists.*
- For example, let us consider three mobiles A, B and C

(a) Transmission range of A reaches B, not C.

(b) Transmission range of C reaches B, not A.

(c) Transmission range of B reaches both A and C.

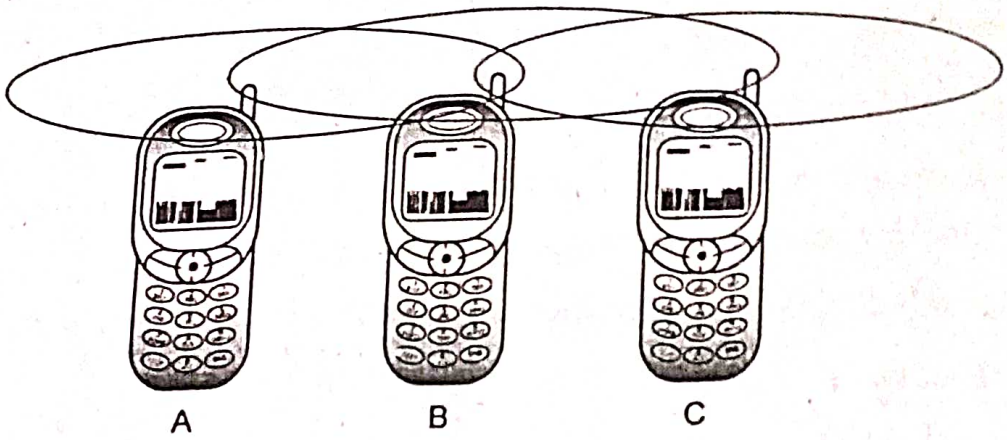


Fig 2.11 Hidden node problem

- Node '**A**' starts sending to '**B**', **C** does not receive this transmission. '**C**' nov wants to transmit data to '**B**', thereby senses the medium, it seems to be fre and starts transmission. Since, '**B**' already commits with **A**, C's transmissio leads to ***collision***.

(2) Exposed Node Problem

- *Exposed node problem situation occurs on a wireless network when two node receive signals from a common source but each one can able to reach othe nodes that do not receive this signal.*

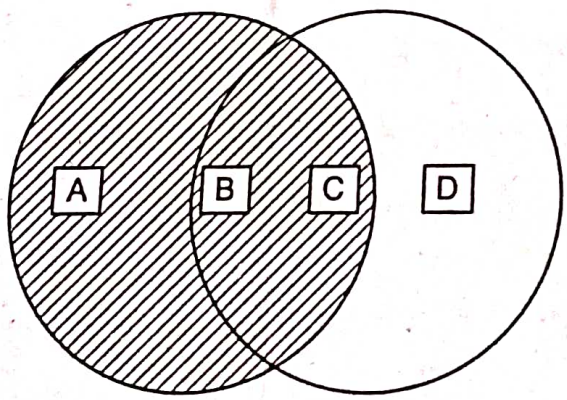


Fig 2.12 Mobiles A and D both are within range of B & C

- Suppose, B is sending to A and at the same time C wants to send to D so it listens to the channel. When it hears a transmission, it falsely concludes that it

cannot transmit to anyone and wait for the channel to be idle, it is an ***unnecessary delay***, because only B communicates with A not to D.

- This won't be a problem since C's transmission to D will not interfere with A's receiving signal from B.

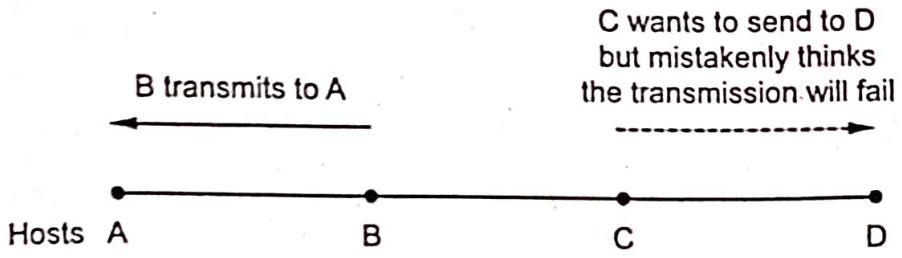


Fig 2.13 Exposed node problem

(3) Near and Far Terminals Problem

- In the Fig 2.14, consider A and B are both sending with same ***transmission power.*** As the signal strength decreases proportionally to the square of the distance. The closest terminal drowns out the farther terminal signals.

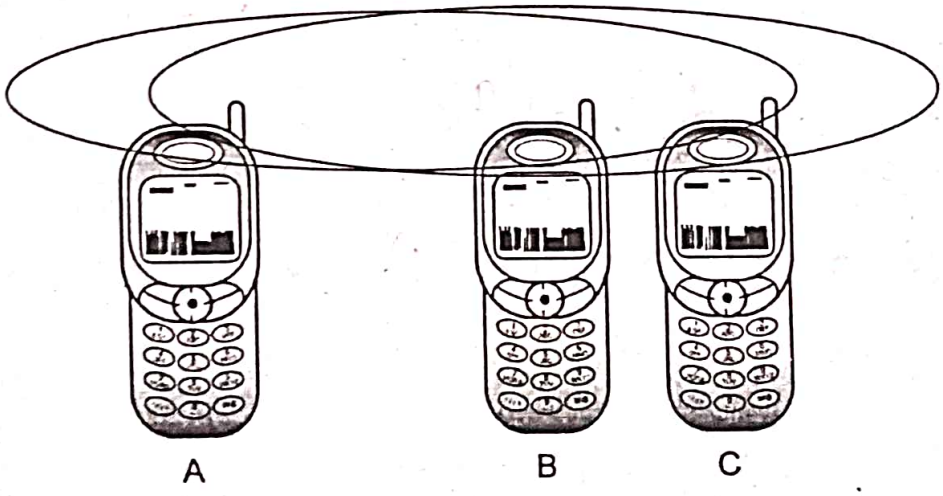


Fig 2.14 Near and far terminals problem

- When ***B's signal*** drowns out A's signal, hence, C cannot receives ***A's*** transmission. Near / far effect is a severe problem of wireless networks using CDM. Precise ***power control*** is needed to receive all senders with same strength.