Unit I

Chapter 1

Introduction

Syllabus

Introduction to Mobile Computing : Applications of Mobile Computing, A short history of wireless communication, **Medium Access Control :** Motivation for a specialized MAC : Hidden and Exposed terminals. Near and Far terminals.

SDMA, FDMA, TDMA : Fixed TDM, Classical Aloha, Slotted Aloha, Carrier sense multiple access, Demand assigned multiple access, PRMA packet reservation multiple access, Reservation TDMA, Multiple access with collision avoidance, Polling, Inhibit sense multiple access.

CDMA : Spread Aloha multiple access.

Chapter Contents

1.1 Introduction to Mobile Computing :

Definition :

- Mobile Computing is defined as a technical field that covers the design, development and evaluation of mobile applications with the help of appropriate solutions that meet user requirements.
- This includes learning the technology that is used to perform a various tasks on the portable devices.
- Examples of portable devices are smart phones, tablets, laptops, wearable devices, vehicles etc.
- Mobile computing has applications in the following areas :
  1. Business and consumer markets,
  2. Industrial and entertainment industries,
  3. Many specialized vertical markets.
- Even though the desktop computers have better hardware configuration capabilities and computational performance, the majority of end users prefer mobile devices.
- The main advantage of mobile computing is user's convenience, because users get access to information and computational resources anytime and anywhere.

Why is mobile computing used ?

- Mobile computing is used in both in business and by consumers in day to day life.
- It allows users to be away from a power source for periods of time.
- This allows the traveling workers to stay connected to their work while on the move.
- Consumers use mobile computing in different ways as follows :
  1. Internet access
  2. Mobile communications
  3. Web browsing
  4. Mobile applications
  5. Entertainment streaming media

1.1.1 Various Parts of Mobile Computing :

- Mobile computing system consists of infrastructure, hardware and software technology.
- Different parts of mobile computing are as follows :
  1. Mobile infrastructure
  2. Mobile hardware
  3. Mobile software

1. Mobile infrastructure :

- Infrastructure is defined as the technical pieces that allow devices to communicate. Mobile infrastructure consists of the wireless networks, wireless protocols and data formats.

2. Mobile hardware :

- The mobile hardware includes the physical mobile device and supporting hardware that users interact with.
- Mobile hardware may include cell phones, laptops, tablets, wearable computers, chargers and other accessories.

3. Mobile software :

- Mobile software is defined as the applications that run on mobile devices, including mobile operating systems (OS) and user-facing applications, such as mobile browsers and e-commerce applications.

1.1.2 Advantages of Mobile Computing :

- The advantages of mobile computing are as given below :

1. Portability :

- Mobile devices are smaller and more portable which makes them easy to carry and use.
- They work away from a power source and without a physical network connection.

2. Affordability :

- Over time, mobile devices have become less expensive compared to the desktop PC. They are easier to obtain too.
- Therefore, people have increasingly started opting for smart phones and tablets as their primary means of online connectivity.

- Therefore, mobile computing has become affordable.

3. **Wireless communications :**

- Mobile computing uses wireless communication to communicate among its users.
- This allows the mobile users to engage in phone, video and various text and instant messaging applications.

4. **Data collection :**

- Mobile computing enables companies to collect large consumer data than was possible with traditional computing.

1.1.3 Limitations of Mobile Computing :

- Some of the major limitations of mobile computing are as follows :

1. **Less power :**

- In recent days the battery life has increased substantially. Still power consumption continues to be an issue, and we need to charge mobile devices regularly.

2. **Poor connectivity :**

- Due to wireless communication, there are areas where signal strength is poor or nonexistent.

3. **Data security :**

- In mobile computing the data security is poor due to wireless communication.
- This is a grave problem because business users, especially, may have sensitive data on their devices while traveling or working remotely.
- Companies must implement security measures and policies to secure corporate data.

4. **Dependence :**

- The consumers may become overly reliant on the mobile devices, which can lead to compulsive or unhealthy behaviors such as smartphone addiction.

5. **Distraction :**

- Mobile devices can be distracting and potentially dangerous in a hazardous work environment that requires the employee's attention, such as a construction site.
- They also pose dangers if used inappropriately while driving.

1.2 Constraints on Mobile Computing :

- Mobile computing is characterized by following four major constraints :
  1. Mobile device constraints
  2. Network constraints
  3. Mobility constraints and
  4. Power constraints

1. **Mobile device constraints :**

- The small sized mobile devices have limited resources such as processor speed, storage space, display size and screen resolution.
- Therefore, mobile application designers have a great challenge on how to overcome these constraints in order to satisfy requirements of fast user interactive mobile computing environment.
- It is also necessary to address the power limitations of mobile devices in terms of what an application should do with a very limited power to use.

2. **Network constraints :**

- It is well known that wireless networks are less reliable as compared to their wired counterparts.
- Wireless networks have a limited bandwidth, high latency (delay) and frequent disconnection due to different reasons like power limitations, available spectrum and mobility.
- The most critical problem of these is the bandwidth. With increase in bandwidth, power consumption also increases which shorten the battery life of mobile devices.
- Even though the wireless connections deliver a stable high bandwidth, energy restrictions of mobile devices will limit the effectiveness of data throughput.
- Therefore, it is necessary to design data access technique for users to overcome these limitations.

3. **Mobility constraints :**

A. **Mobile elements are resource-poor :**

- Mobile elements will always be resource poor as compared to static elements.
- They have lower processor speed, smaller memory size and lower disc capacity.

B. **Mobility is inherently hazardous :**

- Portable mobile devices can be easily stolen, they have security concerns, and are more vulnerable to loss or damage.

C. **Mobile connectivity is highly variable :**

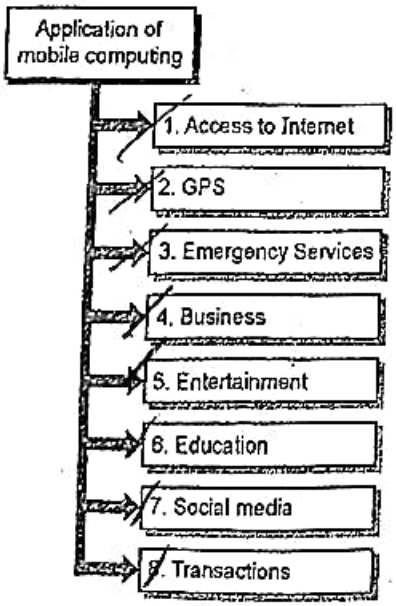
- Mobile connections are highly variable in terms of reliability.
- In some buildings the wireless connectivity may be reliable and high-bandwidth while in others there may be only low-bandwidth connectivity.
- The outdoor mobile client may have to rely on a low-bandwidth wireless network with gaps in coverage.

4. **Power constraint :**

- As mobile elements depend on finite energy source, it is necessary to be sensitive to power consumption.

1.3 Applications of Mobile Computing :

- The following is a list of some of the most important application areas of mobile computing :



(G-3045) **Fig. 1.3.1 : Applications of mobile computing**

1. **Access to the web or the Internet :**

- Sales professionals who need to travel frequently require instant access to the company's database to keep them updated about the company's current state.
- This needs an internet connection while travelling.
- With wireless access, the laptop gets converted to a mobile office and efficient synchronization mechanism ensures data consistency.

2. **GPS (Global Positioning System) :**

- Mobile computing is also used in the GPS system for navigation of vehicles, for finding a location etc.
- The GPS program provides critical capabilities to military, civil and commercial users around the world.
- In addition, GPS is the backbone for modernizing the global air traffic system, weather, and location services.

3. **Emergency services :**

- The ability to send and receive information on the move is very important where the emergency services are involved.
- Mobile computing can be used to dispatch information quickly, regarding the address, type and other details of an incident, to one or several appropriate mobile units which are in the vicinity of the incident.
- We can use emergency services for calling an ambulance, fire stations or police.

4. **Business :**

- Managers can use mobile computers in, say, critical presentations to major customers. They can access the latest market share information using mobile computing.
- They can also communicate with the office about possible new offers and call meetings for discussing responds to the new proposals.

5. **Services related to entertainment :**

- Mobile computing can provide updated information about anything at an appropriate location.

- For example, a travel guide might provide information about the history of a building through GPS, local base station contact or triangulation.
- It may also provide information about evening concert that is to be held in the building.
- We can also use mobile computing for booking tickets for movies, plays, concerts etc.
- It is also possible to watch live cricket or football and other matches or Olympic games etc on a mobile smart phone.
- Mobile computing can also be used for watching movies, listening music and gaming applications.

6. **Educational programs :**

- Mobile computing can be used for educational programs such as live interactive virtual classroom teaching, correspondence courses, workshops, webinars etc.

7. **Social media live interactions :**

- Some mobile applications allows user to keep in touch with their friends and relatives by sending messages, images, audio and video clips.

8. **Transactions :**

- Some mobile applications allow the facility of transaction such as recharge mobile, pay bills etc.

1.4 A Short History of Wireless Communication :

- Wired communication existed long before the existence of wireless communication.
- However, **Marconi** (1874–1937) is the name, which is most closely connected with the success of wireless communication.
- Marconi first demonstrated the wireless telegraphy in 1895 using long wave transmission with a transmission power higher than 200 kW.
- The first transatlantic transmission was successful in 1901 and in 1907, the first commercial transatlantic connections were set up.
- Reginald A. Fessenden (1866–1932) is to be credited for the first radio broadcast that took place in 1906 which transmitted voice and music for Christmas.
- In 1915, the first wireless voice transmission was set up between New York and San Francisco while the first commercial radio station started in 1920.
- A little earlier to this one of the first 'mobile' transmitters was on board in 1911.
- The first telephone in a train was available on the Berlin-Hamburg line by 1926 and in 1927, the first car radio was commercially available.
- In 1928, many field trials for television broadcasting were conducted.
- John L. Baird (1888–1946) transmitted TV across the Atlantic and demonstrated color TV.
- Up until then, amplitude modulation (AM) was being used in all wireless communication equipment.
- A big step forward in this respect came in 1933 when Edwin H. Armstrong invented frequency modulation.
- Many national and international wireless communications projects were triggered off after the Second World War.
- The first network in Germany (analog A-Netz) was set up in 1958, using a carrier frequency of 160 MHz.
- However in this network setup it was only possible to make connection from the mobile station.
- Handovers were not possible but changing of the base station, was possible.
- This system had 80 per cent coverage and 11,000 customers in 1971.
- Then in 1972 the advanced version of the earlier system (B-Netz) arrived in Germany, using the same 160 MHz frequency band.
- At the same time, the northern European countries including Denmark, Finland, Norway, and Sweden agreed upon the analog Nordic Mobile Telephone **(NMT)** system.
- This was a system with 450 MHz carrier and is still available system for mobile communication in some very remote places.
- The next version of NMT at 900 MHz followed in 1986.

- In 1982, the European countries decided to develop a pan-European mobile phone standard.
- Then in 1983 the US first generation mobile phone system called advanced mobile phone system **(AMPS)** came into existence.
- AMPS is the first generation analog mobile system working at 850 MHz, only for voice transmission.
- In 1984, the home telephones went wireless with the standard CT1 (cordless telephone).
- The digital systems were not yet available. Therefore, more analog standards such as the German C-Netz at 450 MHz with analog voice transmission arrived in the market.
- In these systems the hand-over between 'cells' was possible.
- The early 1990s saw the beginning of fully digital systems. The analog wireless network was switched off in 2000.
- ETSI adopted the standard digital European cordless telephone (DECT) for digital cordless telephony in 1991.
- In 1991 only, after many years of discussions and field trials, the second generation wireless standard GSM was standardized.
- This is known as the first version of GSM (global system for mobile communication) which works at 900 MHz and uses 124 full-duplex channels.
- However very soon it was discovered that the analog AMPS and the digital GSM are not sufficient to offer services to the high user densities in cities.
- On the other front of wireless networks, the wireless LAN standard 802.11 came out as a winner in 1997.
- The IEEE 802.11 standard works at the license-free Industrial, Science, Medical (ISM) band at 2.4 GHz and infra red frequencies and offered data speed of 2 Mbit/s in the beginning and 10 Mbps later on.
- The year 1998 marked the beginning of mobile communication using satellites with the help of the Iridium system.
- In 1998 the European countries agreed on the Universal Mobile Telecommunications System (UMTS) as the European proposal for the IMT-2000 proposed by International Telecommunication Union (ITU).
- These are the third generation mobile telephone standards.
- The IMT-2000 recommendations are important because they define a common, worldwide framework for future mobile communication at a frequency of 2 GHz (ITU, 2002).
- In 1999 several more powerful WLAN standards were introduced in the market.
- The year 2000, the systems such HSCSD, GPRS with higher data rates and packet-oriented transmission for GSM were launched.
- The digital TV via satellite existed for several years. However, in 2002 the digital terrestrial TV (DVB-T) started as regular service in Berlin.
- This system ensures a high quality TV reception while moving and requires a very small antenna.
- After third generation, came the fourth generation of the wireless networks and now we are about to receive the services of the fifth generation of wireless communication.

1.5 Medium Access Control (MAC) :

- In the following sections we introduce several medium access control (MAC) algorithms which are specifically adapted to the wireless domain.
- Medium access control consists of all the mechanisms that are necessary to regulate user access to a medium.
- MAC uses various multiplexing techniques such as SDM, TDM, FDM or CDM for the same.
- Thus MAC is similar to traffic regulations for controlling the highway vehicle traffic that uses the same highway to travel.
- The vehicles using the same street simultaneously is an example of time domain multiplexing i.e. TDM and requires rules to avoid collisions.

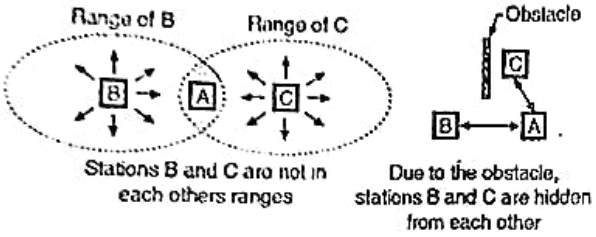
- MAC does exactly the same thing to regulate the wireless traffic using the same wireless communication channel.
- MAC belongs to layer 2, the data link control layer (DLC) of the ISO/OSI reference model.
- DLC layer is subdivided into the logical link control (LLC), layer 2b, and the MAC, layer 2a.
- The function of DLC is to establish a reliable point to point or point to multi-point connection between different devices over a wired or wireless medium.
- In the following sections we have introduced the basic MAC mechanisms.
- It is important to note that special MAC schemes are needed in the wireless domain because the standard MAC schemes from wired networks often fail to operate in wireless environment.
- We have discussed the problems such as hidden and exposed terminals or near and far terminals for the wired networks.
- However these issues present serious problems in the wireless environment.

1.6 Motivation for a Specialized MAC :

- The main question in related to MAC in the wireless communication is that can we use the MAC schemes from wired networks, such as CSMA/CD as used in the original specification of IEEE 802.3 networks (Ethernet).
- So consider the CSMA/CD which works as follows :
  1. Before sending any message, a sender senses the wired medium (coaxial cable) to check if it is free.
  2. If some other sender is already sending messages then the medium will be busy. Then the sender in step 1 waits until it is free.
  3. If the medium is free, the sender starts transmitting data and continues to check the medium.
  4. If the sender detects a collision while sending, it stops at once and sends a jamming signal.
- This algorithm works very well in the wired networks but fails in the wireless networks. The reason is as follows : CSMA/CD is interested in collisions that take place at the receiver and not at the sender.
- That means it is interested to ensure that the signal reaches the receiver without any collisions. However collisions are detected by the sender and not by the receiver.
- This is not a problem in a wired network because, the signal strength can be assumed to be the same all over the wire i.e. at the sender as well as at the receiver.
- Therefore, every sender will notice a collision occurring anywhere in the wire.
- Thus, a sender can listen into the medium at its own place and detect a collision occurring at the receiver. However, the situation is not the same in wireless networks. $S \propto \frac{1}{d^2}$
- The strength of a signal is inversely proportional to the square of the distance travelled. Hence the signal strength at the receiver is much lower than that at the sender.
- Now assume that the sender applies carrier sense and detect an idle medium and starts sending but a collision occurs at the receiver due to a second sender.
- In section 1.6.1, we have explained the hidden terminal problem. The same can happen to the collision detection.
- Thus, the sender does not detect any collision and assumes that the data has been transmitted without errors.
- However, in reality, a collision might have destroyed the data at the receiver.
- This shows that, collision detection is very difficult in wireless environment as the transmission power at the transmitter is much higher than that at the receiver. Therefore CDMA / CD fails in a wireless scenario.
- In the following sections we will discuss some more scenarios where MAC schemes from fixed networks fail.

1.6.1 Hidden Terminal Problem :

- The hidden station problem occurs when a station may not be aware that some other station is transmitting because of either range problem or some obstacle.
- In this situation collision may occur but may not be detected.
- The hidden station problem is illustrated in Fig. 1.6.1. Refer Fig. 1.6.1(a) which shows three wireless stations A, B and C.



(a) (b)

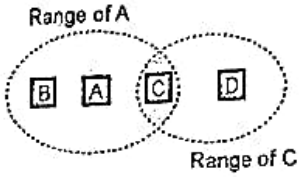
(G-2093) **Fig. 1.6.1 : Hidden station problem**

- The transmission ranges of stations-B and C have been shown by the two ovals on left and right respectively which shows that station-C is not in the range of B and B is not in the range of C.
- However station-A is in the range of both B and C. So A can hear signals transmitted by B and C.
- Refer Fig. 1.6.1(a) where station-B is transmitting to station A.
- Now if station-C checks the medium to see if anyone is transmitting, it will not hear station B because it is out of range.
- So station-C will come to a wrong conclusion that no one is transmitting and so it can start transmitting to station A.
- If station-C starts transmitting, it will create a collision at station-A and will wipe out the frames from station-B.
- This problem in which a station is not able to detect an already transmitting other station which is too far away is called as the **hidden station problem.**
- In this example it is said that stations-B and C are hidden from each other with respect to station-A.
- Now consider Fig. 1.6.1(b) which shows the hidden station problem occurring due to an obstacle.

Note : Due to hidden station problem, the possibility of collision increases and the capacity network will reduce.

1.6.2 Exposed Terminal Problem :

- We have discussed the problem of hidden station. The **exposed station problem** is a similar problem.
- In this problem, a station refrains from using the common medium even when no other station is using it (i.e. the channel is actually free).
- In order to understand this concept clearly refer Fig. 1.6.2 where A is the sending station and B is the destination. A is sending data to B.

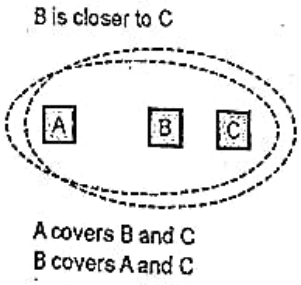


(O-918) **Fig. 1.6.2 : Exposed station problem**

- Station C wants to send its data to station D and it is possible to do so without interfering in the communication between A and B.
- As shown in Fig. 1.6.2, station C is in the range of station A. In other words C is exposed to A.
- Therefore C listens to what A is transmitting and decides to refrain itself from sending its message to D.
- This causes wastage of channel capacity.

1.6.3 Near and Far Terminals :

- Now refer Fig. 1.6.3.



(G-3135) **Fig. 1.6.3 : Near and far terminals**

- Mobile stations A and B are both transmitting with the same transmission power.
- B is closer to C as compared to A. Therefore, the strength of B at C will be higher than that of A.

- Therefore at C, B's signal drowns out A's signal and therefore, C cannot receive A's transmission.
- Now consider that C is working as an arbiter for sending rights (e.g., C acts as a base station that coordinates the media access).
- Here, terminal B has already drowned out terminal A on the physical layer.
- Hence, station C would not have any chance of applying a fair scheme as it would only hear B.
- This problem is known as the near-far effect which is a severe problem of wireless networks using CDM.
- Signals from all the stations should arrive at the receiver with more or less the same strength.
- Even if we allot different codes to the senders, the closest one would simply drown out the others.
- In order to solve this problem, and receive all senders, a precise power control is needed at a receiver.

1.7 Multiple Access Protocols :

Principle :

- A wireless system which provides simultaneous communication links to many subscribers does not have unlimited spectrum available.
- In fact only a fixed limited finite amount of radio spectrum (or number of channels) is available to provide service to multiple users simultaneously.
- Therefore, the available spectrum must be utilized optimally and efficiently without compromising on the quality of communication.
- The multiple access techniques have been developed to share the available limited spectrum among many subscribers simultaneously for achieving high subscriber capacity and desired quality of communications.
- Various multiple access techniques used in wireless communications, are : Frequency-Division Multiple Access (FDMA), Time-Division Multiple Access (TDMA), Spread- Spectrum Multiple Access (SSMA) and Space-Division Multiple Access (SDMA).
- The objective of all these multiple access strategies is to maximize the spectrum utilization.
- The choice of an access method will greatly affect the capacity and quality of service provided by a wireless network.
- The practical wireless communication systems use a combination of one or more of these multiple access strategies.

1.7.1 Multiple Access Techniques :

Definition :

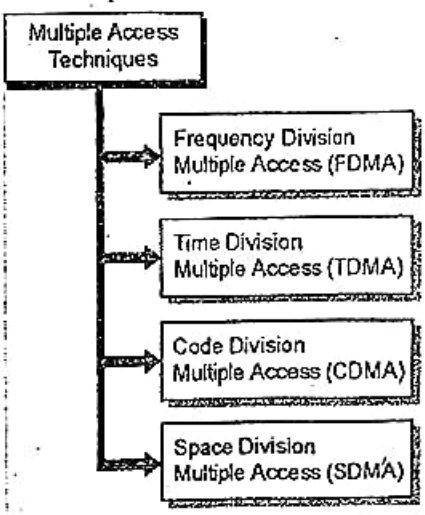
- The multiple access techniques are the techniques in which the total bandwidth of the common link is shared in the frequency domain, time domain or through codes.

Need of multiple access :

- A multiple access technique is not necessary if we have only one user.
- But if there are multiple users who need to share a wireless communication system, then we need to use a multiple access system.

Classification of multiple access techniques :

- Depending on the method of sharing there are five multiple access techniques as given below :
  1. FDMA : Frequency Division Multiple Access
  2. CDMA : Code Division Multiple Access.
  3. TDMA : Time Division Multiple Access
  4. SDMA : Space Division Multiple Access
- Fig. 1.7.1 shows the classification of multiple access techniques.



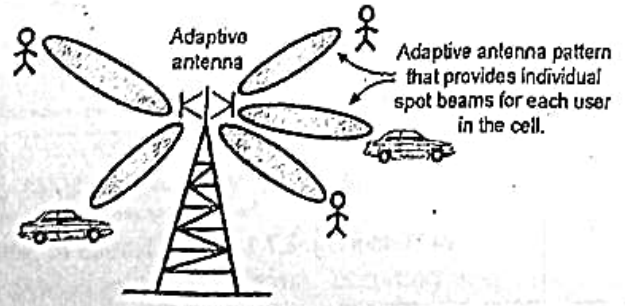
(O-1434(b)) **Fig. 1.7.1 : Classification of multiple access techniques**

1. **Frequency Division Multiple Access (FDMA) :**
   - In Frequency Division Multiple Access (FDMA), a different frequency band is assigned to individual users. All users transmit simultaneously.
2. **Time Division Multiple Access (TDMA) :**
   - In the Time Division Multiple Access (TDMA) system a separate time slot is allotted to each user and only one user is allowed to transmit or receive at any instant of time.
3. **Code Division Multiple Access (CDMA) :**
   - In Code Division Multiple Access (CDMA) systems, the narrowband message signal is multiplied by a large bandwidth carrier called spreading signal.
   - In CDMA each user is given a unique code sequence or signature sequence. This sequence allows the user to spread the information signal across the assigned frequency band.
   - In CDMA the bandwidth as well as time of the channel is shared by the user.

1.8 Space Division Multiple Access (SDMA) :

Principle :

- Space Division Multiple Access (SDMA) is a channel access method used in mobile communication systems which reuses the same set of cell phone frequencies in a given service area.
- Through the use of smart antennas with beams pointed at the direction of the mobile station, SDMA serves different users within the same region.
- Space Division Multiple Access (SDMA) is used for allocating a separated space to users in wireless networks.
- The principle of SDMA is illustrated in Fig. 1.8.1. Single users are separated in space by individual beams.



(G-1170) **Fig. 1.8.1 : Principle of SDMA**

- Two cells or two small regions can make use of the same set of frequencies if they are separated by an allowable distance (called the reuse distance).
- Space Division Multiple Access (SDMA) controls the radiated energy for each user in the space.
- It can be seen from Fig. 1.8.1 that SDMA serves different users by using the spot beam antennas.
- The users are thus separated in the space domain.
- These different areas covered by the antenna beams may use the same frequency or different frequencies.
- In traditional mobile cellular network systems, the base station has no information on the position of the mobile units within the cell and radiates the signal in all directions within the cell in order to provide radio coverage.
- This method results in wasting power on transmissions when there are no mobile units to reach.
- SDMA can save such wastage of power. Since the beams are focused, the radio energy frequency can have increased base station range.
- This attribute of SDMA allows base stations to have larger radio coverage with less radiated energy.
- This narrow beam width also allows greater gain and clarity.
- It also causes interference for adjacent cells that are using the same frequency, so called co-channel cells.
- Likewise, in the traditional mobile systems, at the receiver, the antenna receives signals coming from all directions including noise and interference signals.
- However, SDMA uses smart antenna technology and due to differing spatial locations of mobile units within the cell, it offer attractive performance enhancements.
- If the beam widths approach very small size, than the SDMA is called as optimal SDMA.
- As users are separated in space by individual beams, SDMA improves the overall capacity of a cell.

MAC in SDMA :

- Each mobile phone receives several base stations with different quality (signal strength).
- We can use a MAC algorithm to decide which base station is best, taking into account which frequencies (FDM), time slots (TDM) or code (CDM) are still available depending on the technology.
- Generally, SDMA is never used in isolation. It is always used in combination with one or more other schemes such as FDM, TDM etc.

1.8.1 Features of SDMA :

1. SDMA improves the transmission quality due to the use of focussed narrow transmission beams.
2. SDMA reduces the health and safety concerns.
3. It enhances the spatial efficiency.
4. Decreases the battery consumption of mobile stations.
5. With SDMA, all the mobile users within the system would be able to communicate at the same time using the same channel.
6. An important application of SDMA is sectored antennas.
7. SDMA finds its application in the mobile communication.
8. In the satellite communication.

1.8.2 Applications of SDMA :

1. A typical application involves assigning an optimal base station to a mobile phone user.
2. A new application of SDMA comes up together with beam-forming antenna arrays.

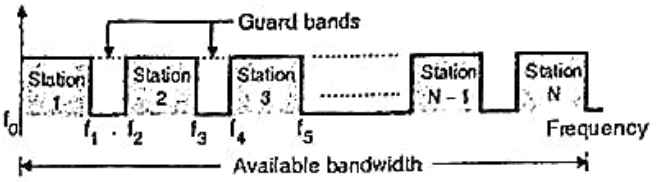
1.9 Frequency Division Multiple Access (FDMA) :

Principle :

- In the frequency division multiple access (FDMA), the available channel (medium) bandwidth is shared by all the mobile stations.
- That means each station will have its own specific frequency slot reserved in the entire channel bandwidth.
- So each station uses its allocated frequency band to send its data.
- Each band is thus reserved for a specific station. e.g. the frequency band f_0 to f_1 is for station-1, then f_2 to f_3 is for station-2 and so on.

Concept :

- The concept of FDMA is illustrated is Fig. 1.9.1.



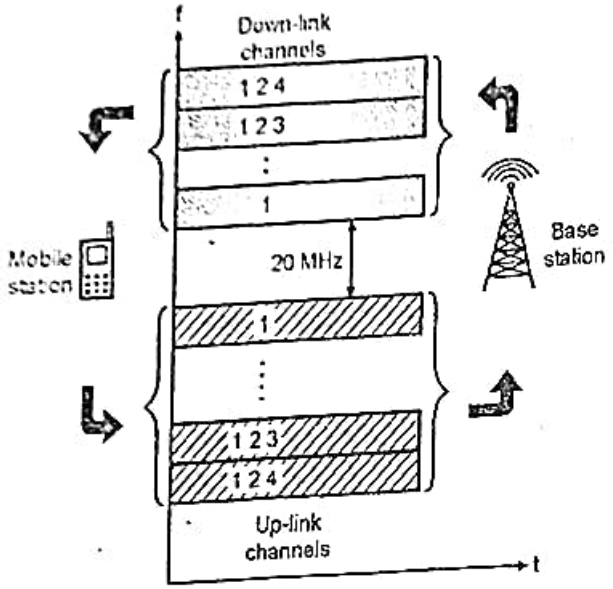
(L-739) **Fig. 1.9.1 : Concept of FDMA**

- **Guard bands** are provided in between the adjacent frequency slots. e.g. $(f_1 - f_2)$ is a guard band between the bands allotted to stations 1 and 2. Guard bands avoid the adjacent channel interference.
- FDMA is used in cellular phones and satellite networks.
- An FDMA/FDD system (FDD is frequency division duplex) used in mobile phones; each user is assigned a pair of frequencies, one for the forward channel and other for the reverse channel.

1.9.1 FDM and FDD :

- In mobile communication, the base station as well as mobile stations want to access the medium simultaneously.
- We can use FDM to allow such simultaneous access to the medium by base station and mobile station in cellular networks.
- Here the pair of base station and mobile station will establish a duplex channel, i.e., a channel that allows for simultaneous transmission in both directions.
- The transmission from mobile station to base station is called as **up-link** transmission, whereas, the transmission from base station to mobile station is called as **down-link** transmission.

- The up-link and down-link frequencies are different from each other. This scheme is then called frequency division duplex **(FDD)**.
- Again, both stations must know the frequencies in advance; they cannot just listen into the medium.
- Refer Fig. 1.9.2 to understand FDM and FDD, which shows the situation in a GSM mobile phone network for 900 MHz.



(G-3136) **Fig. 1.9.2 : FDM for multiple access and duplex**

- The basic frequency allocation scheme for GSM is fixed and regulated by national authorities.
- The frequency band allotted to the uplinks is between 890.2 and 915 MHz, whereas, all downlinks use the frequency band from 935.2 to 960 MHz.
- According to the principle of FDMA, the base station in Fig. 1.9.2, allocates a certain frequency for up- and downlink and establishes a duplex channel with a mobile phone.
- In GSM, there are 124 channels available in each direction that are multiplexed using FDM.
- Thus we can use FDM for multiple access and duplex according to a predetermined scheme.
- Similar FDM schemes for FDD are implemented in some other mobile communication systems like the AMPS, IS-54, IS-95, IS-136 etc.

1.9.2 Features of FDMA :

- The features of FDMA are as follows :

1. The overall channel bandwidth is being shared by the multiple users. Therefore a number of users can transmit their information simultaneously.
2. If a FDMA channel is not in use, it will be idle and cannot used by any other user. Therefore FDMA does not utilize the available spectrum efficiently.
3. If a frequency band (channel) is assigned to a user in FDMA, then the mobile unit and the base station start transmitting simultaneously.
4. The adjacent frequency bands in the FDMA spectrum are likely to interfere with each other. Therefore it is necessary to include the guard bands between the adjacent frequency bands.
5. FDMA needs near to ideal RF filtering to reduce the adjacent channel interference.
6. The mobile unit based on FDMA needs to use a duplexers in order to isolate signals from the transmitter and receiver operating simultaneously.
7. No code words and synchronization is not required.
8. Power efficiency is reduced.
9. FDMA is an old and proven system and is used for the analog signals.
10. The complexity of FDMA systems is less.
11. FDMA is a continuous transmission method. So few bits are required for overhead purposes (like synchronization and framing bits).

1.9.3 Nonlinear Effects in FDMA :

- In a FDMA system, the same antenna is being shared by many channels at the base station.
- The power amplifiers or the power combiners are nonlinear because they are being operated at or near saturation to obtain maximum power efficiency.

- These nonlinearities result in signal spreading in the frequency domain and generate the so called inter modulation (IM) frequencies.
- Inter modulation is the process of the generation of undesirable harmonics.
- These harmonics will be outside the mobile radio band as well as inside it.
- These frequencies are undesired RF radiation which can interfere with other channels in the FDMA systems.
- Thus spreading of the spectrum results due to nonlinearity of power amplifiers.
- This results in adjacent-channel interference.
- Harmonics generated outside the mobile radio band would cause interference to the adjacent mobile services, while those present inside the band cause interference to other users in the mobile system.

Guard bands :

- In order to avoid the effects of nonlinearity, **guard bands** are introduced in between the adjacent channels.
- However introduction of guard bands reduces the spectrum efficiency of FDMA system because guard bands do not carry any information.

1.9.4 Merits of FDMA :

1. All the stations can operate continuously all 24 hours without having to wait for their turn to come.
2. The power required for transmission depends on the number of channels being transmitted.
3. The signal to noise ratio is improved due to the use of FM.
4. No synchronization is necessary.
5. FDMA is a less complex system.

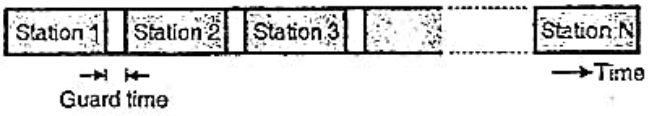
1.9.5 Demerits of FDMA :

1. Each channel can use only a part of the total bandwidth.
2. In spite of guard bands being provided, there is some adjacent channel interference present.
3. Due to the nonlinearity of the system the inter modulation products are generated.
4. It can process only one phone circuit at a time.
5. The cell site cost of FDMA systems is high.
6. The bandwidth of FDMA channels is narrow.

1.10 Time Division Multiple Access (TDMA) :

Principle :

- TDMA stands for Time Division Multiple Access. In TDMA, the entire bandwidth can be used by every user (mobile station) but not simultaneously.
- A mobile station can use the entire bandwidth only for the allocated time slot.
- Thus each channel is allocated a time slot only during which it can send its data.
- Thus the time is shared, but the frequency band is not shared. In fact all the stations can use the same frequency.
- Fig. 1.10.1 illustrates the concept of TDMA.



(L-740) **Fig. 1.10.1 : Concept of TDMA**

- **Guard times** are introduced between the adjacent time slots in order to prevent any cross talk. No data transmission takes place during the guard times.
- Thus TDMA systems transmit data in a buffer-and-burst method, and the transmission for any station is discontinuous.
- This means that, TDMA is more useful for digital data we need to use some digital modulation with it.
- TDMA finds its application in cellular phones and satellite networks.
- As all users use the same frequency, the transmitters and receivers are very simple and many different algorithms exist to control medium access.

- However, for proper operation of TDMA system, synchronization between sender and receiver has to be achieved in the time domain.

1.10.1 TDMA and MAC :

- It is difficult to listen to different frequencies at the same time but listening to many channels separated in time at the same frequency is simple.
- Almost all MAC schemes for wired networks work according to this principle, e.g., Ethernet, Token Ring, ATM etc.

Synchronization :

- It is necessary to synchronize the sender and receiver in the time domain which can be done by using a fixed pattern similar to FDMA techniques.
- For synchronization, either a certain fixed time slot is allocated for a channel, or a dynamic allocation scheme is used.
- In the dynamic allocation schemes an identification for each transmission is required similar to that for typical wired MAC schemes (e.g., sender address).
- It is possible to use MAC addresses as identification. This will enable a receiver to understand if it really is the intended receiver of a message.
- The fixed allocation schemes do not need any identification, but they are not as flexible as the dynamic schemes.
- In the following sections we will discuss several examples for fixed and dynamic schemes used for wireless transmission.
- It is possible to combine these schemes with FDMA to achieve even greater flexibility and transmission capacity.

TDMA Features :

- The features of TDMA are as follows :
  1. TDMA is used for the transmission of data and digital voice signals.
  2. It is necessary to include "guard times" between the adjacent channels for reducing the cross talk.
  3. Synchronization is necessary in TDMA.
  4. Power efficiency of TDMA is better than that of the FDMA.
  5. TDMA is a method of time division multiplexing the digitally modulated carriers between various earth stations in a satellite network through a common satellite transponder.
  6. Each earth station transmits a **short burst** of digitally modulated carrier during the time slot assigned to it in the TDMA frame.
  7. Since TDMA uses different time slots for transmission and reception, the duplexers are not required to be used.
  8. The number of time slots in a TDMA system is determined by parameters like bandwidth, modulation method etc.
  9. As TDMA transmits data in bursts and not continuously, the battery consumption is reduced considerably.
  10. In TDMA, the handoff process is simple.

Advantages of TDMA :

1. At any instant of time, the carrier from only one station is present at the transponder. This reduces the intermodulation distortion.
2. TDMA is suitable for transmission of digital information.
3. It is possible to store the digital information, change the rate etc. in TDMA.

Advantages of TDMA over FDMA :

- The advantages of TDMA over FDMA are as follows :
  1. In TDMA since only one station is present at any given time, the intermodulation products will not get generated.
  2. The entire channel bandwidth can be allotted to a single channel at given instant of time. This is particularly advantageous for the digital channels which demand larger bandwidths.
  3. The frequency selective fading does not affect the TDMA to the extent it affect the FDMA.

4. TDMA is well suited for the digital signals therefore it can be easily used for data transmission.
5. As only one channel is being transmitted at a time it is not necessary to separate out various channels at the receiver.

Disadvantages of TDMA :

1. Precise synchronization is required.
2. Bit and frame timing must be achieved and maintained.

1.10.2 Fixed TDM :

- Fixed TDM is the simplest of all the TDM algorithms where, time slots for channels are allocated in a fixed pattern.
- This is a typical solution for wireless phone systems which results in a fixed bandwidth.
- MAC is quite simple, because, the only crucial factor is to access the reserved time slot at the correct instant of time.
- No interference will occur if this synchronization is assured because each mobile station knows its turn (time slot).
- The base station assigns the fixed pattern because the base station solves the competition between different mobile stations that want to access the medium.

Advantages of fixed TDM :

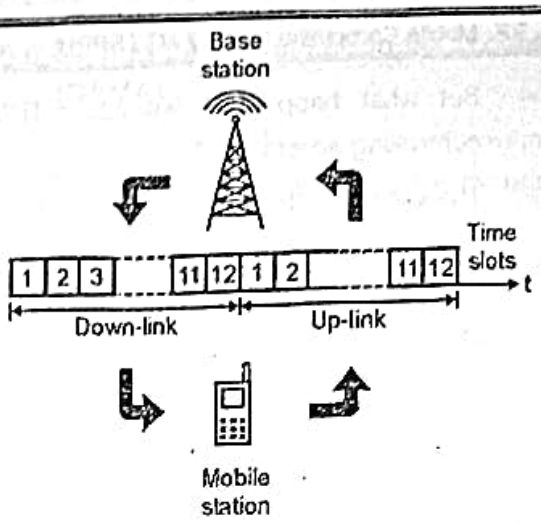
- Following are the advantages of fixed TDM :
  1. Fixed access patterns is very well suited for the connections with a fixed bandwidth.
  2. The other advantage of these patterns is that they guarantee a fixed delay.

Applications of fixed TDMA :

- The fixed access pattern TDMA schemes are used for many digital mobile phone systems like IS-54, IS-136, GSM, DECT, PHS, and PACS.

TDMA and TDD :

- Fig. 1.10.2 shows the use of fixed TDM patterns to implement multiple access and a duplex channel between a base station and mobile station.



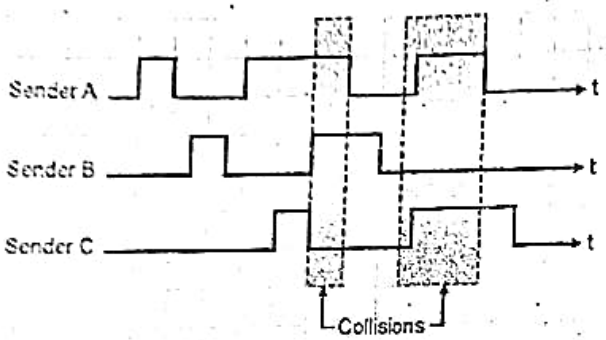
(G-3137) **Fig. 1.10.2 : TDM for multiple access and duplex**

- The transmission from mobile station to base station is called as **up-link** transmission, whereas, the transmission from base station to mobile station is called as **down-link** transmission.
- Here, the up-link and down-link frequencies are same but the transmission takes place in different time slots.
- This scheme is then called time division duplex **(TDD).**
- As shown in Fig. 1.10.2, there are 12 down-link time slots and 12 up-link time slots.
- The base station uses one of the 12 slots allocated for the downlink, whereas the mobile station uses one of 12 slots allocated for the uplink.
- Thus this scheme allows the use of up to 12 different mobile stations at the same frequency without any interference.
- The problem with this general scheme is that it wastes a lot of bandwidth.
- It is also too static and too inflexible for data communication.
- In this case, connectionless, demand-oriented TDMA schemes can be used, as the following sections show.

1.10.3 Classical Aloha :

- As mentioned earlier, TDMA consists of all the mechanisms to control medium access according to TDM.

- But what happens if we apply TDM without controlling access ?
- The classic Aloha scheme does exactly this. This scheme was used in the ALOHANET to connect various stations in a wireless manner.
- Classical Aloha does not coordinate medium access and it does not resolve contention on the MAC layer.
- In this scheme, as shown in Fig. 1.10.3, each station can access the medium at any time.

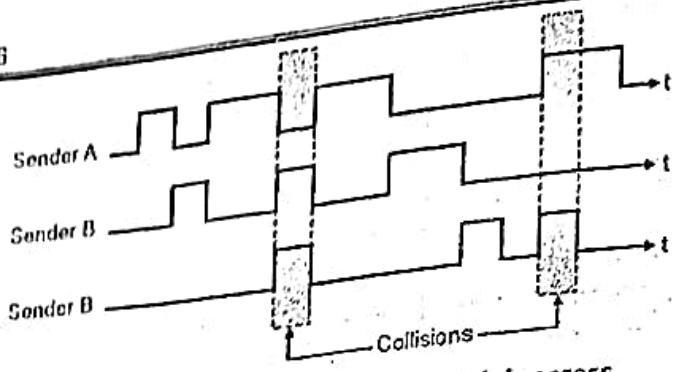


(G-3138) **Fig. 1.10.3 : Classical Aloha multiple access**

- Classical Aloha is a random access scheme. It does not have a central arbiter to control access and there is no coordination among the stations.
- If two or more stations transmit simultaneously on the common medium, a collision occurs and the transmitted data is destroyed.
- This problem can be solved by retransmitting the destroyed data, but it is left to higher layers.
- The classical Aloha is also called as simple Aloha. It works well for a light load and does not require any complicated access mechanisms.
- The maximum throughput achieved by this scheme is at 18 percent load.

1.10.4 Slotted Aloha :

- The slotted Aloha scheme provides the first refinement of the classical Aloha scheme by introducing the time slots.
- In slotted Aloha, it is essential that all senders be synchronized and as shown in Fig. 1.10.4, transmission can only start at the beginning of a time slot.



(G-3139) **Fig. 1.10.4 : Slotted Aloha multiple access**

- Still, access is not coordinated.
- Due to the introduction of slots the throughput of slotted Aloha increases to 36 percent from 18 percent, i.e., slotting doubles the throughput.
- Both the basic Aloha principles are used in many systems that implement distributed access to a medium.
- Classical and slotted Aloha systems work well under a light load, but they cannot give any of the following hard transmission guarantees :
  1. Maximum delay before accessing the medium
  2. Minimum throughput
- Therefore it is necessary to have additional mechanisms, such as combination of fixed schemes and Aloha schemes.
- However, the mobile communication systems like UMTS rely on slotted Aloha for medium access in certain situations.

1.10.5 Carrier Sense Multiple Access (CSMA) :

- CSMA scheme improves the basic Aloha scheme by introducing the sensing of carrier before accessing the medium.
- In CSMA scheme the sender first senses the carrier (to check if medium is idle) and accesses the medium only if the carrier is idle.
- This decreases the probability of a collision.
- However, as discussed in hidden terminal problem, if a hidden terminal transmits at the same time as another sender, an undetected collision might occur at the receiver.
- The basic CSMA scheme is still used in most wireless LANs.

- There are several versions of CSMA as follows :
  1. Non-Persistent CSMA
  2. 1-Persistent CSMA and
  3. P-Persistent CSMA

Non-Persistent CSMA :

- In the non-persistent CSMA scheme, if a station wants to transmit a frame and it finds that the channel is busy (some other station is transmitting) then it will wait for fixed interval of time.
- After this time, it again checks the status of the channel and if the channel is free it will transmit.

1-Persistent CSMA :

- In this scheme the station which wants to transmit, continuously monitors the channel until it is idle and then transmits immediately.
- The disadvantage of this strategy is that if two stations are waiting then they will transmit simultaneously and collision will take place. This will then require retransmission.

P-Persistent CSMA :

- The possibility of such collisions and retransmissions is reduced in the p-persistent CSMA.
- In this scheme all the waiting stations are not allowed to transmit simultaneously as soon as the channel becomes idle.
- A station is assumed to be transmitting with a probability "p". For example if p = 1/6 and if 6 stations are waiting then on an average only one station will transmit and others will wait.
- We can introduce some fairness for stations waiting for a longer time, by using the **back-off** algorithms, which are sensitive to waiting time.
- The wireless LANs following the standard IEEE 802.11 use CSMA with collision avoidance **(CSMA/CA)** access scheme.
- In this scheme, sensing the medium is combined with a back-off scheme in case of a busy medium.

1.10.6 Demand Assigned Multiple Access (DAMA) :

- It is possible to achieve some improvement in Aloha access systems performance by using the **reservation mechanisms** or by using combinations with some (fixed) TDM patterns.
- In these schemes we typically have a reservation period followed by a transmission period.
- The stations can use the reservation period, to reserve future slots in the transmission period.
- Depending on the scheme, there is a possibility of collisions occurring during the reservation period, but, the transmission period can then be accessed without collision.
- Alternatively, it is possible to split the transmission period into periods with and without collision.

Advantage :

- The advantage of DAMA is higher throughput due to less collisions.

Disadvantage :

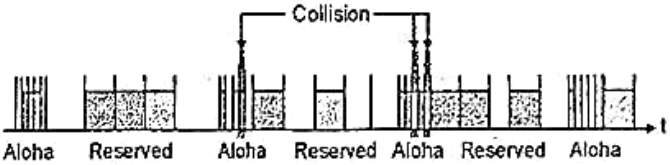
- The disadvantage of DAMA is that these schemes cause a higher delay under a light load (first the reservation has to take place.

Application :

- The Demand Assigned Multiple Access (DAMA) is also called as reservation Aloha, and it is used in satellite systems.

Modes in DAMA :

- DAMA has two modes as shown in Fig. 1.10.5 : Contention mode and reservation mode.



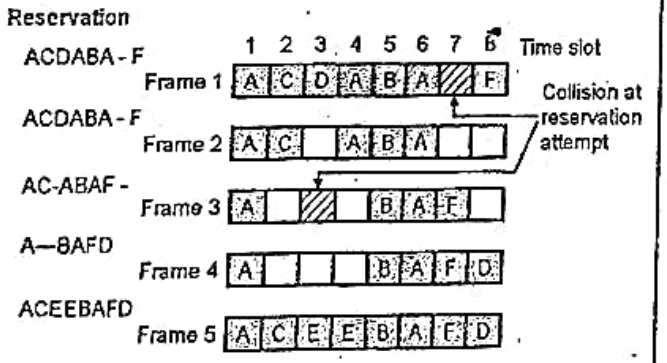
(G-3155) **Fig. 1.10.5 : DAMA with explicit reservation**

- All the earth stations in a satellite system can try to reserve future slots during a contention phase following the slotted Aloha scheme.
- That means different earth stations will try to reserve access time for satellite transmission.
- Collisions can take place during the reservation phase as well but, they do not destroy data transmission.

- At most these collisions can destroy the short requests for data transmission.
- If reservation process is successful, then a time slot in the future is reserved, and during which no other station is allowed to transmit.
- Then, the satellite will collect all successful requests (that are not destroyed) and will send back a reservation list to all the earth stations.
- All ground stations have to obey this list.
- The fixed TDM pattern of reservation and transmission can be maintained by synchronizing the stations from time to time.
- DAMA is an explicit reservation scheme where it is necessary to reserve each transmission slot explicitly.

1.10.7 Packet Reservation Multiple Access (PRMA) :

- Packet Reservation Multiple Access (PRMA) is an example for an implicit reservation scheme.
- Here, the time slots can be reserved implicitly according to the following scheme.
- Refer Fig. 1.10.6 to understand PRMA concept. Here, each frame is made of 8 time slots.

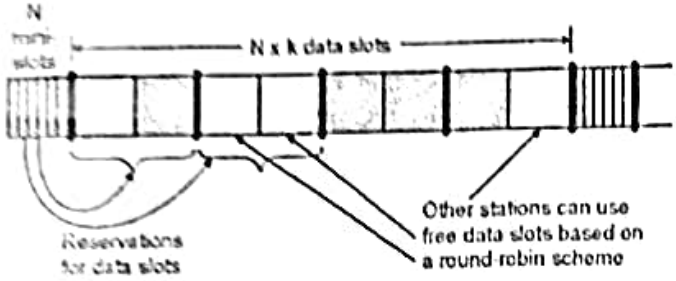


(G-3140) **Fig. 1.10.6 : DAMA with implicit reservation**

- The frame is repeated in time to form frames one to five in Fig. 1.10.6, i.e., a fixed TDM pattern is applied.
- A base station in case of a mobile system or a satellite in a satellite system now broadcasts the status of each slot as shown on the left side of the figure to all mobile stations or earth stations.
- All the stations that receive this vector then know which slot is occupied and which one is currently free.
- In Fig. 1.10.6, a successful transmission of data is indicated by the station's name (A to F).
- Now consider the first frame in Fig. 1.10.6 where, the base station broadcasts the reservation status **'ACDABA-F'** to all stations, from A to F.
- This reservation status indicates that the first six slots and the eighth slot are occupied, but slot seven is free in the following transmission.
- All mobile stations that wish to transmit can now compete for this free seventh slot in Aloha fashion.
- Therefore, more than one station wants to access this slot and as shown in Fig. 1.10.6, a collision occurs.
- The base station returns the reservation status 'ACDABA-F' to all the mobile / earth stations which indicates that the reservation of slot seven failed.
- Therefore, this slot is still indicated as free and that nothing has changed for the other slots.
- Again, stations can compete for this slot.
- Now refer to the second frame in which slot seven is free and in addition, stations D and F have stopped sending in slots three eight respectively.
- The base station notices this after the second frame.
- Therefore, before the third frame starts, the base station indicates in the reservation status 'AC-ABAF- ' that slots three and eight are now idle.
- This also shows that the seventh slot in frame two has been successfully reserved by station F.
- PRMA scheme constitutes one more combination of fixed and random TDM schemes with reservation.
- Also observe from Fig. 1.10.6 that, as soon as a station succeeds with a reservation, all future slots are implicitly reserved for this station. (e.g. station F in slot seven).
- Here, the slotted aloha scheme is used only for the idle slots and destruction of data transmission does not take place due to collision.

1.10.8 Reservation TDMA :

- Refer Fig. 1.10.7 which demonstrates the reservation TDMA scheme which is based on even more fixed pattern that still allows some random access.

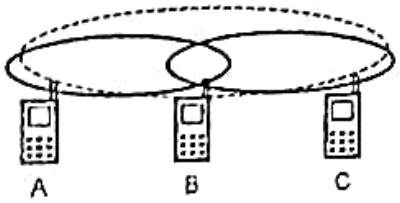


(G-3141) **Fig. 1.10.7 : Reservation TDMA access scheme**

- In a fixed TDM scheme one frame consists of N mini-slots followed by N×k data-slots. This frame is then repeated.
- A mini-slot is allotted to each station which can be used to reserve up to k data-slots.
- Due to this each station is guaranteed with a certain bandwidth and a fixed delay.
- The other stations can use the unused data-slots to send their data.
- These channels can use the free slots based on a simple round-robin scheme or can be uncoordinated using an Aloha scheme.

1.10.9 Multiple Access with Collision Avoidance (MACA) :

- Earlier in this chapter we have discussed the hidden terminal problem. How do the previous access schemes solve this ?
- For all schemes with central base stations assigning TDM patterns, the problem of hidden terminals is unknown.
- This is because, if the terminal is hidden for the base station, there is no communication between them anyway.
- However as mentioned earlier, more or less fixed access patterns are not as flexible as Aloha schemes.
- What will happen when there is no base station at all ? This is the case in ad-hoc networks which do not have a base stations.
- The hidden terminal problem can be solved by a simple scheme called Multiple Access with Collision Avoidance **(MACA).**
- MACA does not need a base station, and it is a random access Aloha scheme with dynamic reservation.
- Fig. 1.10.8 shows the same scenario as Fig. 1.6.3 with the hidden terminal problem and how MACA can avoid it.



(G-3142) **Fig. 1.10.8 : MACA can avoid hidden terminals**

- In Fig. 1.10.8, both A and C want to send their transmission to B. But A is hidden for C therefore C is unaware of A's transmission.
- Therefore A and C both transmit simultaneously, thereby causing a collision at B.

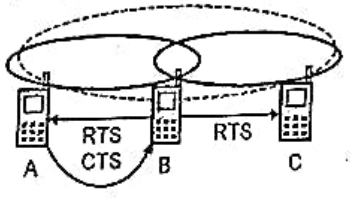
MACA solves hidden station problem :

- When we use MACA protocol, the operation is modified as follows :
- Station A does not start transmitting at once, but sends a request to send **(RTS)** signal first.
- This RTS signal contains the name of sender and receiver, as well as the length of the future transmission.
- B receives this RTS and in response transmits the clear to send **(CTS)** signal in all directions.
- The CTS contains the names of sender (A) and receiver (B) of the user data, and the length of the future transmission.
- This RTS sent by A is not heard by C, but it hears the CTS signal sent by B.
- After receiving a CTS, C understands that A is already transmitting.
- Hence C is not allowed to send anything for the duration indicated in the CTS toward B.
- Thus, MACA solves the hidden station problem and prevents any congestion occurring due to it.

- However collisions can still take place at B when the RTS signals are sent by A and C simultaneously to B.
- However, RTS is very short as compared to the data transmission. Hence, the probability of RTS collision is much lower.
- If B receives RTS from A and C at the same time, it resolves this contention and acknowledges only one station in the CTS.
- The station mentioned in CTS starts the data transmission on receiving the CTS.
- No station is allowed to transmit without an appropriate CTS.
- The MACA medium access scheme is one of the schemes that is optionally used in the standard IEEE 802.11.

MACA solves exposed station problem :

- Let us see how MACA can also help to solve the 'exposed terminal' problem.
- Consider a situation where, B wants to send data to A and C to someone else.
- But C is senses the medium before transmitting, and finds that the medium is busy due to the transmission from B and C will restrain from transmission.
- When MACA is used, the first step is, B transmits RTS containing the name of the receiver (A) and the sender (B) as shown in Fig. 1.10.9.



(G-3143) **Fig. 1.10.9 MACA can avoid exposed terminals**

- A and C both receive the RTS from B. But C does not react to this message as its name is not mentioned in The RTS.
- However, A responds to this RTS by sending its CTS which identifies B as the sender and A as the receiver of the following data transmission.
- Now, C does not receive this CTS and concludes that A is outside the detection range.
- Now, C can start its transmission assuming it will not cause a collision at A.
- MACA thus solves the problem of exposed terminals without fixed access patterns or a base station.

Disadvantages :

1. One disadvantage of MACA is the increased overheads due to transmission of RTS and CTS packets.
2. The delay added by these signals will not be negligible for short and time-critical data packets.
3. The operation of MACA is based on the assumption that the transmission and reception is symmetrical.

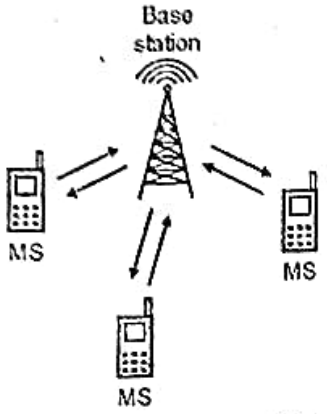
1.10.10 Polling :

- The polling schemes are used where, one station is to be heard by all others (e.g., the base station of a mobile phone network).
- Polling is a strictly centralized scheme which contains one master station and several slave stations.
- The master can poll the slaves according to the following different schemes :
  1. Round robin
  2. Randomly according to reservations
- It is possible that the master establishes a list of stations wishing to transmit during a contention phase.
- Then after the contention phase the master polls each station on the list.
- Similar schemes are used, in the Bluetooth wireless LAN and as one possible access function in IEEE 802.11 systems.

1.10.11 Inhibit Sense Multiple Access (ISMA) :

- The Inhibit Sense Multiple access (ISMA) represents another combination of different schemes. It is also known as Digital Sense Multiple Access (DSMA).

- This scheme is used for the packet data transmission service Cellular Digital Packet Data (CDPD) in the AMPS mobile phone system.
- Refer Fig. 1.10.10. In ISMA scheme, the base station only sends a busy tone to signal the mobile stations that the medium is busy. The busy tone is also called BUSY/IDLE indicator.

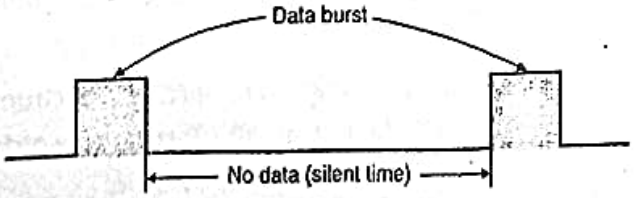


(G-3144) **Fig. 1.10.10 : Inhibit Sense Multiple Access using a busy tone**

- After the busy tone stops, the mobile stations can access the up-link without any further coordination.
- Every successful transmission is acknowledged by the base station.
- If a positive acknowledgement is missing, then the a mobile station understands that a collision has occurred.
- Additional back-off and retransmission mechanisms are implemented if a collision occurs.

1.10.12 Problems with FDMA and TDMA :

- The problem with the FDMA and TDMA system is that, the channel is basically divided into independent sub-channels.
- That means each sub-channel in the FDMA is allotted to a single user and each time slot in TDMA has been allotted to a separate single user.
- The FDMA and TDMA systems however prove to be inefficient when the data from the users is bursty in nature as shown in Fig. 1.10.11.



(E-906) **Fig. 1.10.11 : Bursty data signal with low duty cycle**

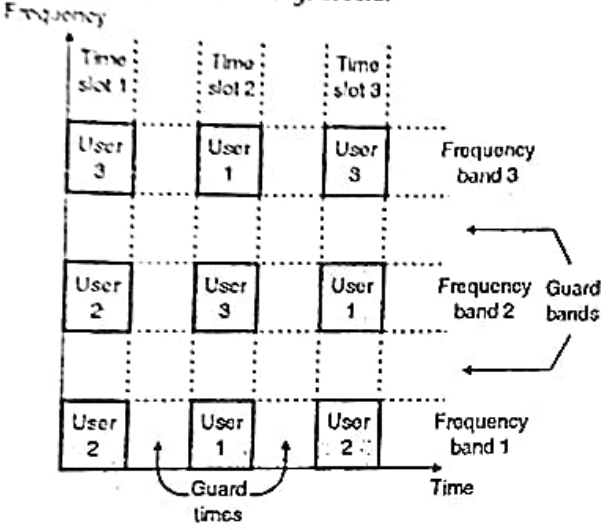
- This type of data has low value of duty cycle. i.e. the time for which data is being transmitted is much shorter than the time for which data is not being transmitted.
- Under such circumstances where the transmission from different users is bursty and low duty cycle, the FDMA and TDMA system will not be very efficient.
- A large percentage of the available time or frequency slots do not convey any information and therefore are wasted.
- Such a type of data is observed in computer communication networks and to some extent, in the mobile cellular communication systems carrying digitized voice.

1.11 Code Division Multiple Access (CDMA) :

Concept :

- An alternative to FDMA and TDMA is an another system called code division multiple access (CDMA).
- In CDMA more than one user is allowed to share a channel or sub channel with the help of direct-sequence spread spectrum (DS-SS) signals.
- In CDMA each user is given a unique code sequence or signature sequence.
- This sequence allows the user to spread the information signal across the assigned frequency band.
- At the receiver the signal is recovered by using the same code sequence.
- At the receiver, the signals received from various users are separated by checking the cross-correlation of the received signal with each possible user signature sequence.
- In CDMA the users access the channel in a random manner.
- Hence the signals transmitted by multiple users will completely overlap both in time and in frequency.

- The CDMA signals are spread in frequency. Therefore the demodulation and separation of these signals at the receiver can be achieved by using the pseudorandom code sequence.
- CDMA is sometimes also called as Spread Spectrum Multiple Access (SSMA).
- In CDMA as the bandwidth as well as time of the channel is being shared by the users, it is necessary to introduce the guard times and guard bands as shown in Fig. 1.11.1.



(E-907) **Fig. 1.11.1 : Structure of CDMA showing the guard bands and the guard times**

- CDMA does not need any synchronization, but the code sequences or signature waveforms are required to be used.
- In CDMA one channel carries all the transmission simultaneously.
- As the same channel is used by several users, there may be a problem of **near-far effect**.
- The near-far problem occurs if the power of each user within the cell is not controlled such that they appear equal at the base station.
- To minimize the near-far problem power control is essential in CDMA systems.
- The main advantage of CDMA when compared to other multiple access methods is reduced level of interference.

Spread spectrum and CDMA :

- The spread spectrum is the modulation technique which is highly tolerant of all types of interferences.
- The spread spectrum technique is the basis for the access technique called as spread-spectrum multiple access or code-division multiple access (CDMA).
- In CDMA multiple access technique, every transmitting individual mobile subscribers occupies the complete available frequency spectrum.
- That means, the same spectrum, at the same time can be occupied by several mobile subscribers.
- In a CDMA environment, it is possible to accomplish the mixing of different types of traffic such as voice, data, and video because subscribers do not need any specific coordination.
- The CDMA system can accommodate different subscribers having different bandwidth requirements, switching methods and technical characteristics without many problems.
- The efficient CDMA systems, implement accurate power control of mobile stations for reducing interference because each subscriber signal contributes to the interference received by other subscribers.
- In CDMA since all subscribers are using the entire spectrum, it is necessary to spread their signals with a specific PN code, in order to distinguish a subscriber signal from other signals.
- All subscribers in the CDMA transmit information simultaneously with the use of the same carrier frequency.
- Therefore each subscriber in CDMA has its own code word. This code word is orthogonal to code words of other subscribers.
- In order to detect the information, the receiver must know the exact code word used by the transmitter.
- The receiver performs a time correlation operation for detecting the signal.
- An interesting feature of spread spectrum modulation CDMA is that, all other code words except the intended one appear as noise.
- To minimize this noise power at the receiver end the signal power should be high.

- In CDMA, one unique code is assigned to every subscriber and different codes are used for different subscribers.
- Each subscribers uses its code to mix with each information bit before transmitting it.
- These encoded bits, can be decoded by using the same code at the receiver.
- The receiver would interpret the received information as noise if there is any mismatch between the code allotted to it and the code used by the received signal.
- The CDMA technique uses a wider frequency band for every subscriber.
- In this system, the PN code generator generates different spread-spectrum codes and these codes are assigned to each subscriber.
- In CDMA, many subscribers share the same frequency.

1.11.1 Salient Features of CDMA Systems :

- Following are the important features of CDMA systems :
  1. CDMA technique is used in some 2G digital cellular systems like IS-95 and most of the third-generation cellular systems.
  2. In CDMA, many subscribers share the same frequency in combination with FDD or TDD.
  3. As the number of active subscribers is not limited, a CDMA system has a soft capacity. With increase in the number of active subscribers the noise floor increases in a linear way. Therefore, there is no absolute limit on the number of active subscribers.
  4. With increase in the number of active subscribers, the performance of the system gradually degrades for all active subscribers.
  5. As the signal in CDMA is spread over a large spectrum, multipath fading is considerably reduced.
  6. The inherent frequency diversity will moderate the effects of small-scale fading because the spread spectrum bandwidth is larger than the coherence bandwidth of the channel.
  7. The channel data rates in CDMA are very high. It results in the extremely short duration of the symbol or chip and typically much less than the channel delay spread.
  8. In CDMA system, Multipath delayed by more than a chip will appear as noise because PN sequences have low autocorrelation.
  9. In order to improve reception by collecting time-delayed versions of the required signals, a RAKE receiver can be used to improve the reception.
  10. As CDMA uses co-channel cells in adjacent cells, it can use macroscopic spatial diversity scheme in order to provide soft hand-off.
  11. Mobile station controller (MSC) can simultaneously monitor the signal strength of a particular subscriber from two or more base stations which allows it to perform soft hand-off if required.
  12. At any time, the MSC can select the best version of the received mobile signal without the need of switching frequencies.
  13. If spreading sequences of different subscribers are not exactly orthogonal then the self-jamming problem occurs.
  14. If the received signal power of a required subscriber at the cell-site is less than that of the undesired subscribers then the near-far problem occurs.
  15. In CDMA system, each subscriber operates independently without knowledge of other subscribers.

1.11.2 Advantages of CDMA :

- Some of the advantages of CDMA are :
  1. It does not need any synchronization.
  2. More number of users can share the same bandwidth.
  3. Sharing of bandwidth as well as time is possible.
  4. Due to codeword allotted to each user, interference (crosstalk) is reduced.

1.11.3 Disadvantages of CDMA :

1. The CDMA system is more complicated.
2. Guard band and guard time both are required to be provided

1.11.4 CDMA Applications :

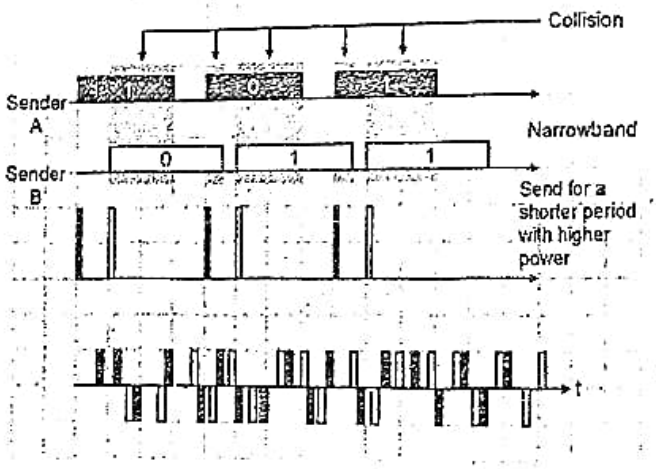
- Following are some of the important CDMA services :
  1. Voice services
  2. Data services
  3. Circuit switched data
  4. Packet switched data
  5. Message services
  6. CDMA radio
  7. Location based services
  8. CDMA radio channel

1.11.5 Spread Aloha Multiple Access (SAMA) :

- As discussed earlier, we can use different codes with certain properties for spreading data to obtain powerful multiple access scheme, namely CDMA.
- However CDMA has a disadvantage that its senders and receivers are not simple devices.
- In order to communicate with n CDMA devices we need to program the receiver to decode n different codes and send n different codes, too.
- In mobile phone systems, a lot of the complexity needed for CDMA is integrated in the base stations.
- The wireless and mobile devices communicate with the base station only and not directly with each other.
- However, the CDMA technique seems to pose too much overhead, if spontaneous, bursty traffic is to be supported between an arbitrary number of devices.
- In case of ad-hoc networks, there is no centralized base stations and mobile stations communicate directly with each other.
- Using CDMA in such a network will not be easy because, no one wants to program many different spreading codes.
- On the other hand, Aloha was a very simple scheme, but it has a problem of providing a relatively low bandwidth due to collisions.
- What will happen if the spreading of CDMA and the medium access of Aloha are combined together ?
- The result of such combination is a scheme called Spread Aloha Multiple Access (SAMA).
- SAMA is a combination of CDMA and TDMA.

Working of SAMA :

- The working of SAMA is as follows :
- Refer Fig. 1.11.2 where, each SAMA sender uses the same spreading code of 110101.



(G-3145) **Fig. 1.11.2 : Spread Aloha Multiple Access**

- The upper part of this figure shows the standard case for Aloha access.
- Here, Sender A and sender B access the medium at the same time in their narrowband spectrum, which results in collision at all three bits.
- We can send the same data using short but higher power pulses as shown in the middle.
- Now spread spectrum is used to spread these shorter signals to increase their bandwidth (spreading factor s = 6).
- The spread signal is shown at the bottom of the Fig. 1.11.2.

- It is still possible to separate the two signals if one receiver is synchronized to sender A and another one to sender B.
- The signal of an unsynchronized sender appears as noise.
- It is important that the probability of a 'collision' is quite low if the number of simultaneous transmitters stays below 0.1 – 0.2s.
- The maximum through put of this scheme is about 18 per cent, which is very similar to Aloha, but the approach has the following benefits.

Advantages of SAMA :

1. Robustness against narrowband interference
2. Simple coexistence with other systems in the same frequency bands.

1.11.6 Comparison of Multiple Access Strategies :

Table 1.11.1 : Comparison of SDMA, TDMA, FDMA and CDMA

Sr. No.	Approach	SDMA	TDMA	FDMA	CDMA
1.	Principle	Space is segmented into cells / sectors.	Time is segmented into disjoint time-slots.	Frequency band is segmented into disjoint sub-bands.	Spectrum is spread using orthogonal codes.
2.	Terminals	Only one terminal can be active per cell / sector.	All terminals are active for short periods of time and operate at the same frequency.	Every terminal operates at its own frequency without any interruption.	All terminals can be active at the same place at the same time without interruption.
3.	Signal Separation at receiver	With help of cell structure and directed antennas.	Using synchronization in the time domain.	With help of filters in the frequency domain.	Using code and special receivers.
4.	Advantages	simple, increases capacity per km^2.	Established system, fully digital, flexible.	Simple, established, robust, no synchronization needed.	Flexible, Needs less frequency planning, soft handover.
5.	Disadvantages	Inflexible, fixed antennas	Synchronization difficult, needs guard time	Inflexible, Inter modulation distortion, bandwidth is a scarce resource.	Complex receivers, needs more complicated power control for senders.

Review Questions

Q. 1 What is mobile computing ?

Q. 2 Why is mobile computing used ?

Q. 3 State and explain various parts of mobile computing system.

Q. 4 State the advantages of mobile computing.

Q. 5 State the limitations of mobile computing.

Q. 6 State and explain the constraints on mobile computing.

Q. 7 State and explain the applications of mobile computing.

Q. 8 Write a short note on : History of wireless communication.

Q. 9 What is MAC ? Why is it needed ?