

2.4 SPACE DIVISION MULTIPLE ACCESS (SDMA)

Definition of SDMA

Space Division Multiple Access (SDMA) is used for allocating a separated space to users in wireless networks. It involves assigning an optimal Base Station (BS) to a mobile phone user.

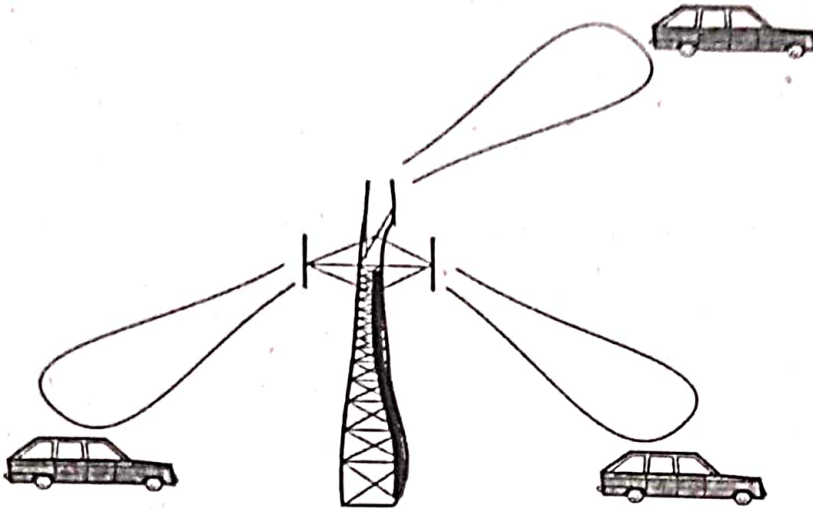


Fig 2.17 SDMA scheme

- ✦ The mobile phone may receive several base stations with different quality. A MAC algorithm has to decide which base station is best, and based on the technology it should identify which frequencies (FDM), time slots (TDM) or code (CDM) are still available.
- ✦ SDMA never used in isolation, it will always in combinations with any one of FDM, TDM or CDM.
- ✦ SDMA serves different users by using *spot beam antennas* (beam forming antenna arrays). These different areas covered by the antenna beam may be served by the *same frequency* or *different frequencies*.
- ✦ Single users are separated in space by *individual beams*. This can improve the overall capacity of a cell tremendously.

2.5 FREQUENCY DIVISION MULTIPLE ACCESS (FDMA)

2.5.1 Introduction

- ✦ One of the *simplest* analog multiple access method is called Frequency Division Multiple Access (FDMA) and it is commonly used for the *voice* and *data* transmission of the analog signal in the first generation (1G) wireless communication.
- ✦ The first US analog cellular system, the *Advanced Mobile Phone System (AMPS)* is based on FDMA / FDD.
- ✦ FDMA dealt with allocating *frequencies* to transmission channels according to the *Frequency Division Multiplexing (FDM)*. This allocation can be either fixed, or dynamic (demand driven).

Definition of FDMA

FDMA assigns individual channels to individual users. Here, the total system bandwidth is divided into a number of non – overlapping frequency subbands. Each user is allocated a unique frequency subband (or) channel for the duration of the connection, whether the connection is in an active (or) idle state. These channels are assigned on demand to users based on their request service.

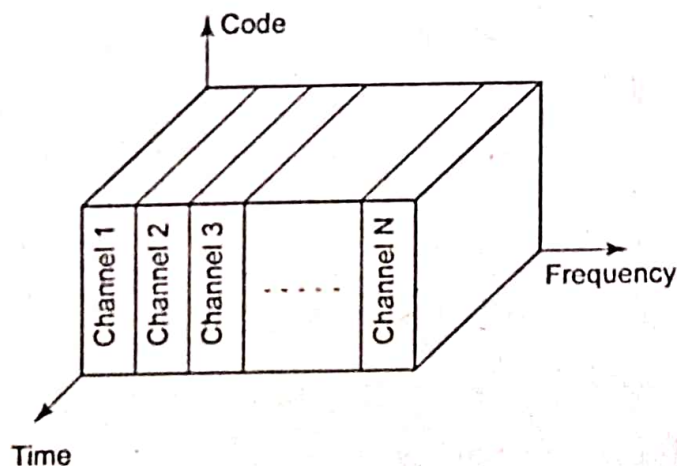


Fig 2.18 FDMA scheme

- * During the entire period of the call, no other user can share the same channel. In FDD systems, the users are assigned a channel as a pair of frequencies that is,
 - (i) One frequency is used for the forward channel, and
 - (ii) Other frequency is used for the reverse channel.

2.5.2 Techniques of FDMA

The following two techniques are used in FDMA as,

- (i) **Pure FDMA:** Channels assigned to the same frequency at all times.
- (ii) **FDMA- TDMA:** (FDMA combined with TDMA)
Assigning different frequencies according to a certain pattern.

Frequency hopping:

Circumvent narrow band interference at certain frequencies known as *frequency hopping*. Sender and receiver must agree on a hopping pattern, otherwise the receiver could not tune to the right frequency.

2.5.3 Duplexing

- * *Duplexing is nothing but a two – way communication in which both the terminals (or) users can transmit simultaneously.*
- * By considering any duplex channel which is actually made of two simplex channels that is, normally a forward and a reverse channels. Duplexing is generally required in *wireless telephone systems*.
- * Duplexing may be done using *frequency* (or) *time domain* techniques.

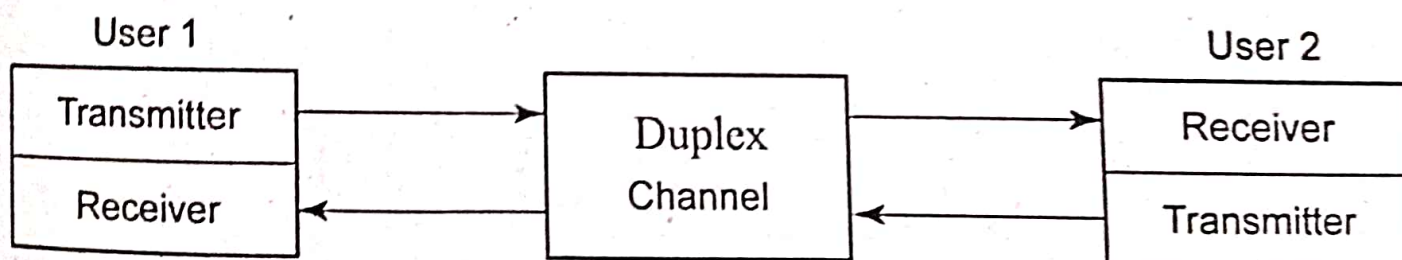


Fig 2.19 A two way communication channel (duplex)

- ♣ All uplinks uses the band between *890.2 to 915 MHz* and all downlinks uses between *935.2 to 960 MHz*. Generally, up and down link have a fixed relation.
- ♣ If uplink frequency is $f_u = 890\text{MHz} + 0.2(n)\text{MHz}$ for a certain channel '*n*' and downlink frequency is $f_d = f_u + 45\text{MHz}$. i.e., $f_d = 935\text{ MHz} + 0.2 (n) \text{ MHz}$.
- ♣ The base staion can selects the channel in such a way that, each channel (uplink and downlink) has a bandwidth of 200 kHz and thus 124 channels per direction will be available.

☑ Advantages of FDMA

- (i) FDMA is more simple than TDMA.
- (ii) The bandwidths of channels are narrow.

☒ Disadvantages of FDMA

- (i) Cell site cost is higher.
- (ii) Adjacent Channel Interference (ACI) is high.

2.6 TIME DIVISION MULTIPLE ACCESS(TDMA)

2.6.1 Introduction

☒ Definition of TDMA

*TDMA systems divides the radio spectrum into time slots, that is, the channel time is partitioned into frames. A TDMA frame is further partitioned into *N* time slots. At each slot only one user is allowed either to transmit or receive. Users have to transmit in their assigned slots only from frame to frame.*

- ♣ No frequency tuning is possible, i.e. the receiver can stay at the *same* frequency the *whole time*. Like FDMA, allocation here can be

(i) Fixed:

Allocating a certain time slot for a channel. It doesn't require any identification.

(ii) Dynamic allocation:

This scheme requires an identification for each transmission, MAC address is generally used for such identification.

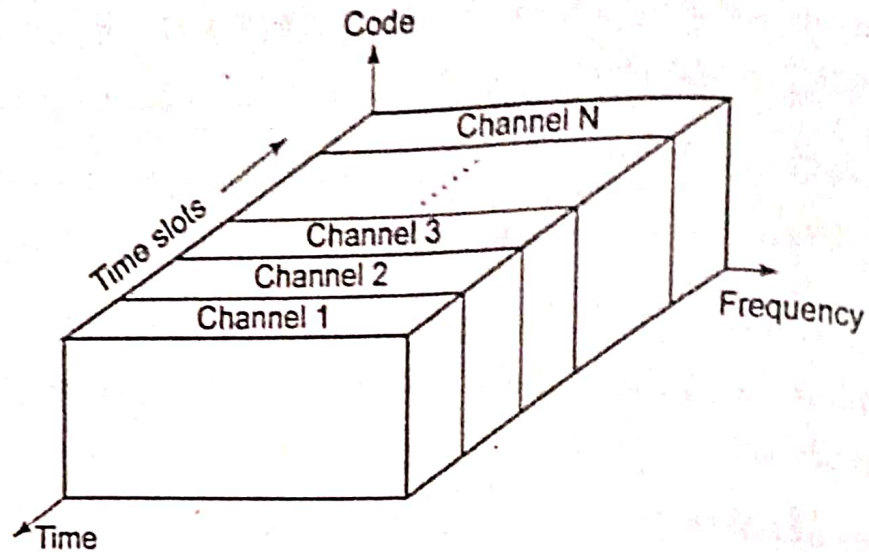


Fig 2.22 TDMA scheme

2.6.2 Fixed TDM

- ✦ The simplest algorithm for using TDM is allocating time slots for channels in a fixed pattern. Here, fixed bandwidth is mainly used in wireless phone systems.
- ✦ MAC is quite simple and the only crucial factor is accessing the reserved slot at the right moment.
- ✦ TDMA schemes with fixed access patterns are used for many digital mobile phone systems like IS-54, IS-136, GSM, DECT, PHS and PACS.

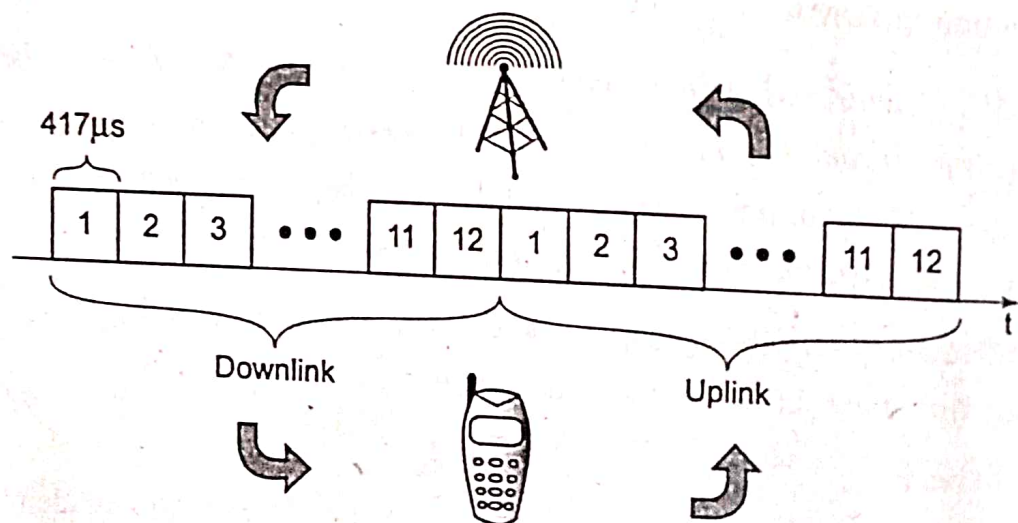


Fig 2.23 TDM for multiple access and duplex

- ✦ Fig 2.23 shows fixed TDM pattern used for multiple access and a duplex channel between a base station and mobile station.

Time Division Duplexing (TDD)

- *TDD uses time instead of frequency to provide both the uplink and downlink and where the multiple users share a single radio channel by taking turns in the time domain.*
- *Individual users are allowed to access the channel in assigned time slots, and each duplex channel has both a forward time slot and a reverse time slot in order to facilitate a bidirectional communication. TDD provides two simplex time slots on the same frequency.*
- ♣ Fig 2.23 shows the base station which uses one out of 12 slots for the *downlink*, whereas the mobile station uses one out of 12 different slots for the *uplink*.
- ♣ Uplink and downlink are separated in time. That is, up to 12 different mobile stations can use the same frequency without any interference using this scheme.
- ♣ Each slot has a duration of $417 \mu s$ and the fixed pattern is repeated every 10 ms. This repetition guarantees access to the medium every for 10 ms independent of any other connections. In this fixed TDM scheme for DECT it provides constant data rate of 32 (or) 64 kbit/s duplex.

Drawbacks of Fixed TDM

The drawbacks of fixed TDM are,

- (i) *It is very inefficient for bursty data (or) asymmetric connections.*
- (ii) *Wastes a lot of bandwidth.*
- (iii) *This scheme is too static, too inflexible for data communication.*

2.6.3 Aloha Scheme (or) Pure Aloha (or) Classical Aloha

Definition of Classical Aloha

If TDM works better without any controlling access is termed as classical Aloha. It works fine for light load (i.e., when a small number of senders send data infrequently) and does not require any complicated access mechanism.

- ♣ It is a simple communication scheme (simple protocol) that was invented at University of Hawaii and was used in the ALOHANET for wireless connection of several stations.
- ♣ In this scheme, that Pure ALOHA does not check whether the channel is busy before transmitting. If the frame successfully reaches the destination (receives acknowledgment), the next frame is sent. When the frame is not received at the destination, it will be sent again.
- ♣ The collisions will be unacceptably high when the number of data packets for transmission is also high.
- ♣ This is a random access scheme, without a central arbiter controlling access to the medium without coordination among the stations. Each station can access the medium any time as shown in Figure 2.24.

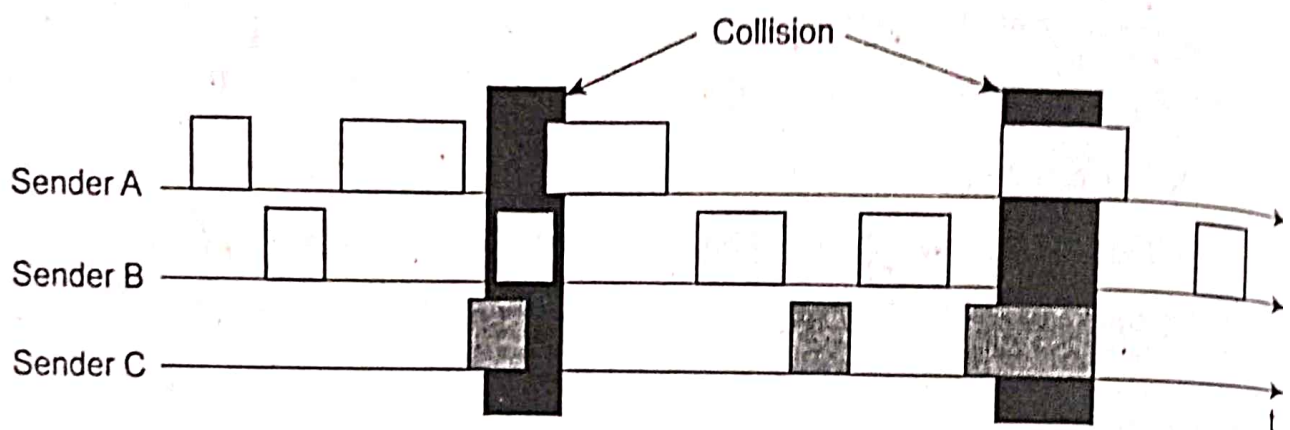


Fig 2.24 ALOHA multiple access scheme

- ♣ If two or more stations access the medium at the same time, a collision occurs and the transmitted data gets destroyed.

2.6.4 Slotted Aloha

- ♣ An improvement over the pure ALOHA scheme is the slotted ALOHA. Here the chances of collisions are attempted to be reduced.

Definition of Slotted Aloha

Slotted Aloha dealt with the introduction of time slots in classical Aloha. The time is divided into equal-sized slots where each packet can be sent. Thus the size of the packet is restricted.

Here, all senders need to be synchronized, so the transmission can only start at the beginning of a time slot.

- ✦ The slotted ALOHA system employs beacon signals that are sent at the precise intervals that mark the beginning of a slot, at which point the nodes having data to send can start to transmit.

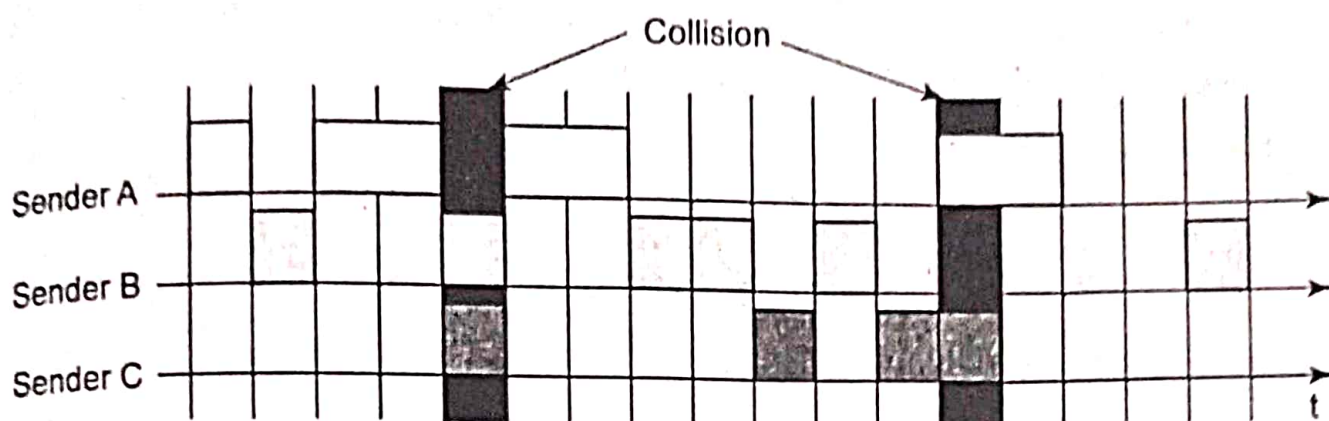


Fig 2.25 Slotted ALOHA multiple access

2.6.5 Carrier Sense Multiple Access(CSMA) Scheme

- ✦ Slotted ALOHA protocol does *not work very well* when the number of stations contending to send data is high. In such cases, the CSMA scheme works better.

✦ Definition of CSMA

In CSMA technique, a node senses the medium before it starts to transmit and accessing the medium only if the carrier is idle. If its senses that the medium is busy. i.e., some transmission is already underway, then it defers its transmission. Thus, it decreases the probability of a collision.

If the medium is busy, the station pauses for a random amount of time before sensing the medium again and repeating this pattern.

- ✦ Several versions of CSMA are,

(i) Non-persistent CSMA:

It is nothing but general CSMA

(II) p – persistent CSMA:

Node sense the medium, but only transmit with a probability of p . The station deferring to the next slot with a probability $1-p$.

(III) 1 – persistent CSMA:

All stations wishing to transmit access the medium at the *same time*, soon as it *becomes idle*. This will cause many collisions if many stations wish to send and block each other.

☑ Advantages of CSMA

- (i) It reduced the chances of collision.
- (ii) Fairly simple to implement.

☒ Disadvantage of CSMA

It can't eliminate the collision permanently.

- ♣ To create some fairness for stations waiting for a longer time, back-off algorithms can be introduced. Two popular extensions of the basic CSMA technique are,

- (i) CSMA/CD – Carrier Sense Multiple Access/ Collision Detection.
- (ii) CSMA/CA – Carrier Sense Multiple Access/ Collision Avoidance.

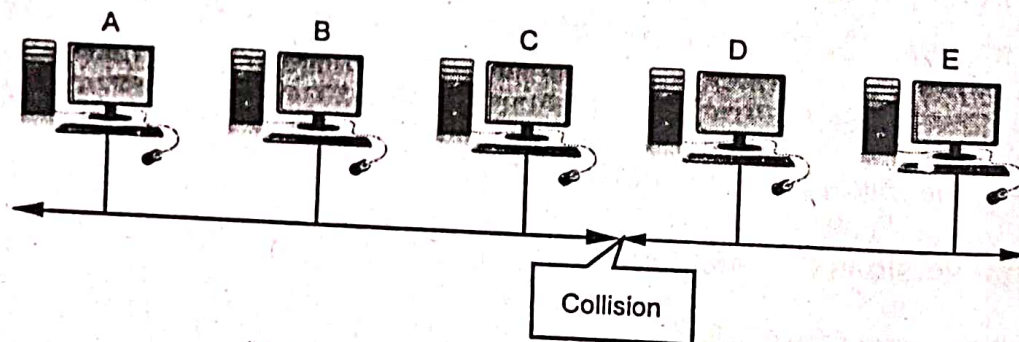
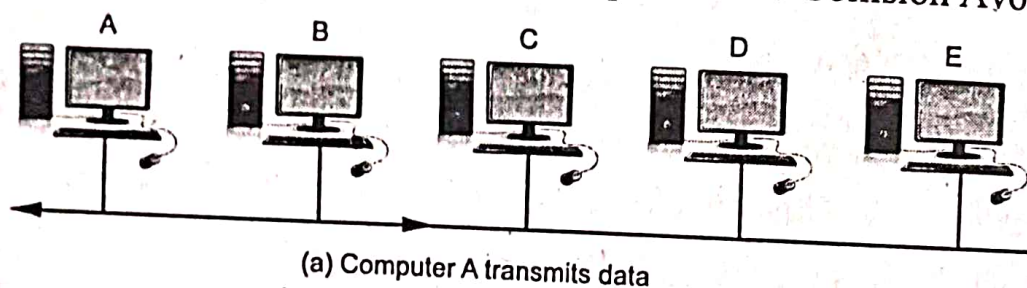


Fig 2.26 Collision in CSMA/CD

- ♣ In a wireless network the CSMA/CD technique does not work very well when it compare to CSMA/CA technique.
- ♣ To avoid this collision problem, Ethernet uses Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access mechanism.

(1) CSMA/CD Operates as Follows:

- (i) Any station must use *carrier sensing* to listen, to check whether the *line* is idle or busy.
 - *If the line is idle, then the transmission can commence immediately.*
 - *If the line is busy, then the signaling process is repeated again and again until the transmission line is free for transmission.*
- (ii) During the data transmission, if it detects that another station is also transmitting then the station uses *collision detection* mechanism to check the line for the extremely high voltages that indicates a collision.

☑ Advantages of CSMA/CD

The advantages of CSMA/CD are,

- (i) *It detects collision within a short time.*
- (ii) *More efficient than a simple CSMA.*
- (iii) *It request node for transmission before sending any frame.*
- (iv) *If collision occurs then it send frame again at free time.*
- (v) *CSMA/CD is beneficial, because it avoid from a wasteful transmission.*
- (vi) *This technique is efficient for light to moderate load.*

☒ Disadvantages of CSMA/CD

The disadvantages of CSMA/CD are,

- (i) CSMA/CD protocols are probabilistic and depends on the network(cable) loading. Performance tends to collapse under heavy load.

- ✦ Here, the BS only signals a busy medium via a *busy tone* (called BUSY indicator) on the downlink. After the busy tone stops, accessing the uplink is not coordinated any further.
- ✦ The base station acknowledges successful transmissions, a mobile station detects a collision only via the missing positive acknowledgement.

2.7 CODE DIVISION MULTIPLE ACCESS (CDMA)

2.7.1 Introduction

✦ Definition of CDMA

In CDMA, multiple users can share an entire system bandwidth simultaneously at any time for transmission. It is a spread spectrum multiple access method. CDMA is an access method in which multiple users are allotted different codes or sequences of 1s or 0s to access the same channel. A special coding scheme is used that allows multiple users to be multiplexed over the same physical channel.

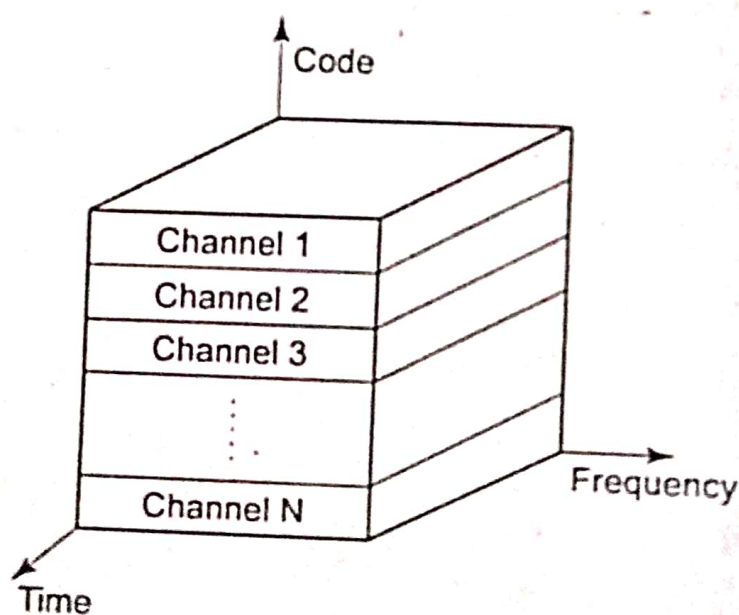


Fig 2.35 CDMA scheme

- In CDMA, the multiple access is achieved by assigning each user a different code. The code is used mainly in transforming the narrow-band user signal into a wide-band signal.
- Similarly, the coded wide-band signals from others will be sent on the common communication channel which is being shared.
- The spreading signal sequences are referred to as *Pseudorandom Noise (PN)* sequences. It is a periodic binary sequence with a noise like waveform that is usually generated by means of a feedback shift register. The same code is used in both the transmitter and the receiver for a particular user for spreading as well as for despreading.

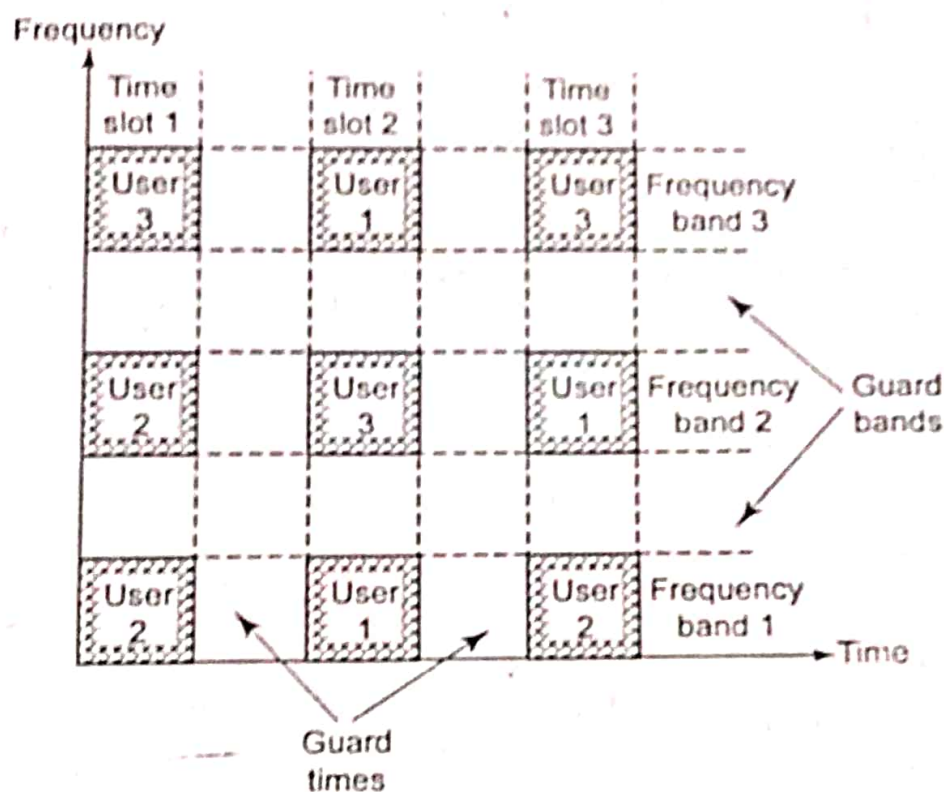


Fig 2.36 Structure of CDMA showing the guard bands and the guard times

- All users in a CDMA system uses the same carrier frequency and may transmit simultaneously. Each user has its own pseudorandom codeword which is approximately orthogonal to all other codeword and used to avoid unauthorized users for the security purpose.

2.7.3 Advantages and Disadvantages of CDMA

☑ Advantages of CDMA

(i) Frequency Reuse:

Many users of a CDMA system share the *same frequency*. This is achieved either by means of TDD (or) FDD.

(ii) Soft Capacity

During the peak traffic hours, if the users can tolerate a lower QoS to a certain degree, then the system can accommodate more users to satisfy the high service demands in that period.

(iii) Reduction in Multipath Fading

Multipath fading may be substantially reduced because the signal is spread over a large spectrum.

(iv) Higher Data Rate

The data rates of a channel are *very high* in CDMA systems.

(v) Soft Handoff

- When the mobile user is at the cell boundary, it can establish a connection with the new base station before terminating the connection with an old base station.
- Soft handoff is performed by the Mobile Switching Center (MSC), which can simultaneously monitor two (or) more base stations for a particular user.
- The MSC may choose the best version of the signal at any time without switching frequencies. This will improve the handoff performance.

(vi) Flexibility

CDMA has *more flexibility* than TDMA in supporting multimedia services.

☒ Disadvantages

The disadvantages of CDMA system are,

(i) Near – Far Problem

Some of the mobile units are close to the *base station* while others are far away from it. A strong signal received at the base from the near units can cause interference to the weak signals received from the far units.