UNIT – II

MAC Introduction:

→ MAC is mainly adapted to wireless domain.
→ It uses all techniques such as SDM, TDM, FDM (or) CDM.
→ Generally, MAC belongs to layer 2 of the ISO /OSI model, i.e. data link control layer, which is subdivided into Logical Link Control (LLC) and medium Access Control (MAC).

Need for MAC:

→ The basic need for MAC in wireless is to establish a mechanism in wired such as CSMA / CD in wireless.
→ CSMA / CD (Carrier Sense Multiple Access with Collision Detection) is used to sense the medium, to see it is free or not, hence it avoids collision.
→ The above said mechanism won't works in wireless.
→ It leads to two problems are,
(i) Hidden and exposed station problem, and
(ii) Near and far station problem.

Hidden and exposed station problem:

→ Let three mobiles A, B, C
(i) Transmission range of A reaches B, not C and .
(ii) Transmission range of C reaches B, not A.
(iii) Transmission range of B reaches both A and C.

It is shown as

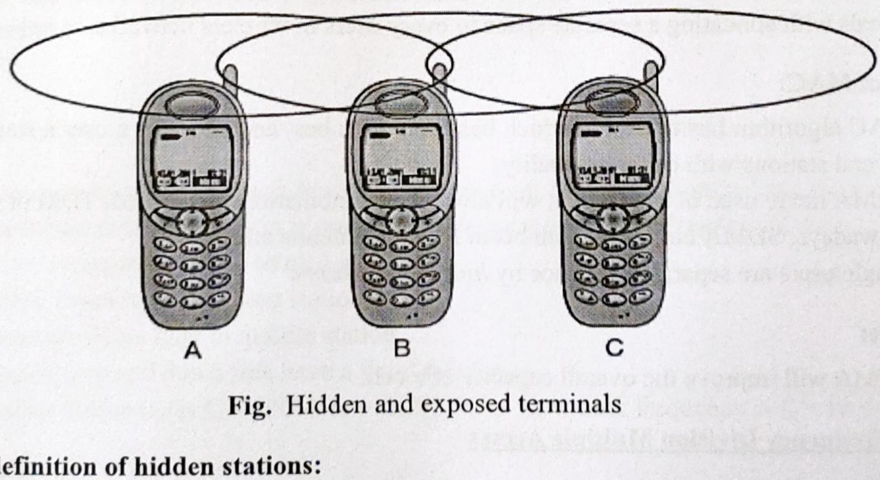


Fig. Hidden and exposed terminals

Problem definition of hidden stations:

→ A starts sending to B, and C now wants to transmit data to B, thereby senses the medium, it seems to be free and starts transmission.
→ Since, B already commits with A, C's transmission leads to ***collision.***

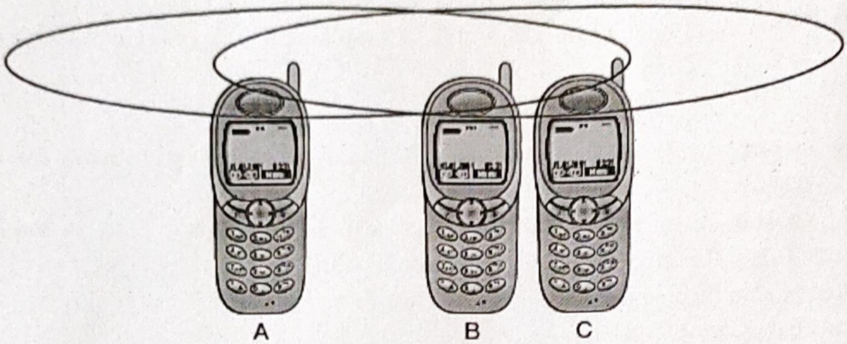
Problem definition of exposed stations:

→ This won't cause collision,. but results 'in delay.

→ If B communicates with A, now, C wants to transmit to some other station D, before transmission starts, C will sense the medium, it finds it to be busy and wait for the channel to be idle, it is an unnecessary delay, because only B communicates with A not to D.

Near and far terminals problem:

It is shown as,



→ If A and B are both sending with same ***transmission power***. *The* closest terminal drowns out farther terminal signals.

→ *B's signal* drowns out A's signal, hence, C cannot receives *A's transmission.*

→ Near / far effect is a severe problem of wireless networks using CDM.

<u>SDMA (Space Division Multiple Access)</u>

Def: It deals with allocating a separate space to every users in wireless networks.

Function of MAC:

→ MAC algorithm has to decide which base station is best and allocates a user a station from a several stations with different quality.

→ SDMA never used in isolation, it will always in combinations with FDM, TDM or CDM.

→ Nowadays, SDMA comes up with beam forming antenna arrays.

→ Single users are separated in space by ***individual beams.***

Advantage:

→ SDMA will improve the overall capacity of a cell.

<u>FDMA - Frequency Division Multiple Access</u>

Def: It deals with *allocating frequencies* to transmission channels according to the *Frequency Division Multiplexing (FDM).*

Allocation can be either, Fixed, or Dynamic (demand driven).

Techniques of FDMA:

(i) **Pure FDMA**: Channels assigned to the *same frequency* at all times.

(ii) **FDMA / TDMA:** Assigning *different frequencies* according to a certain pattern.

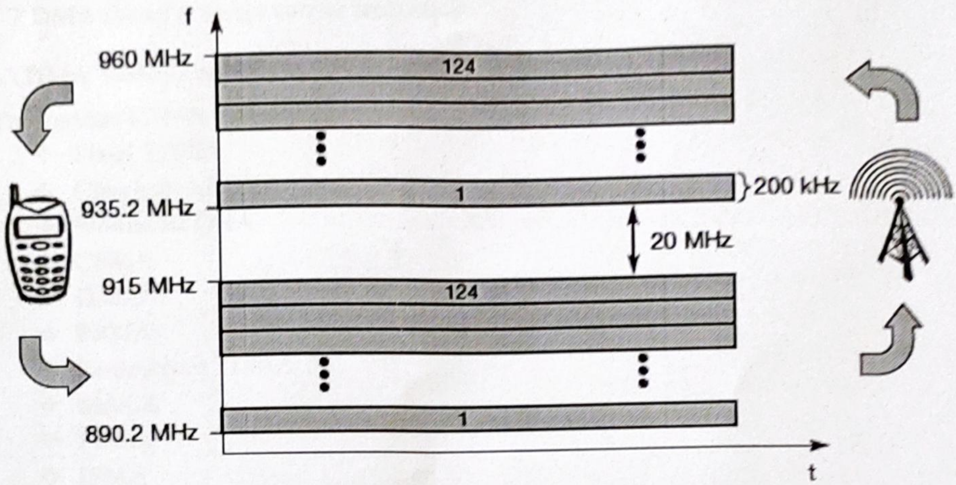
Frequency Hopping:

→ Narrow band interference at certain frequencies known as frequency hopping.
→ Sender and receiver must agree on a hopping pattern.

Description

→ FDM is generally used for simultaneous access to the medium by base *station* and *mobile station* in cellular networks.

It is shown as,



→ The two partners establish ***duplex channel**, i.e., the simultaneous* transmission in both directions.

FDD:

→ If separate frequency is used for transmission from mobile station to base station and from base station to mobile station is said to be ***Frequency Division Duplex (FDD).***
→ These two frequencies are termed as
Uplink: From mobile to base station, and
Downlink: From base to mobile station.
→ Generally, up and down link have a fixed relation.
→ If uplink frequency is f_u = 890MHz + O.2(n)MHz downlink frequency is f_d = fu + 45MHz.

Advantages:

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

Disadvantages:

(i) Cell site cost is higher.

(ii) Adjacent Channel Interference (ACI) is high.

TDMA - Time Division Multiple Access

→ It deals with allocating certain *time slots* for communication i.e using *TDM.*

→ No frequency tuning is possible, i.e. the receiver can stay at the *same* frequency the *whole time.*

→ Like FDMA, allocation here can also be

→ **Fixed**: It doesn't require any identification.

→ **Dynamic allocation**: This scheme requires an identification for each transmission, MAC address is generally used for such identification.

Features of TDMA

(i) Handoff process is very simple in TDMA.

(ii) T DMA shares' a single carrier frequency.

Various TDMA Techniques:

The various TDMA techniques are,

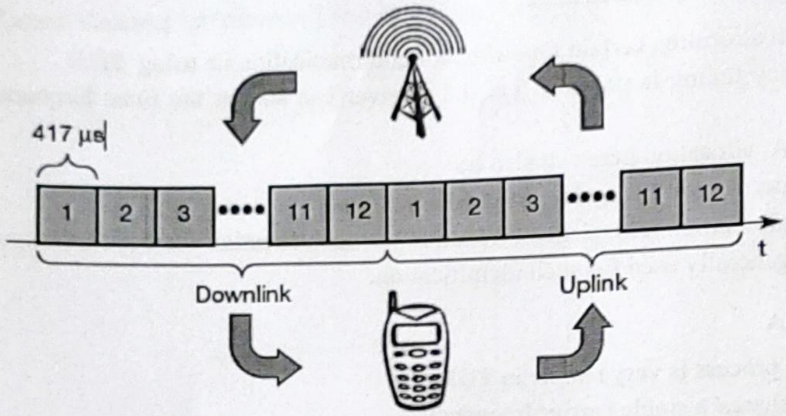
- Fixed TDMA
- Classical ALOHA
- Slotted ALOHA
- CSMA
- DAMA
- PRMA
- Reservation TDMA
- MACA
- Polling
- ISMA

Fixed TDMA

→ The simplest algorithm for using TDM is allocating time slots for channels in a fixed pattern.

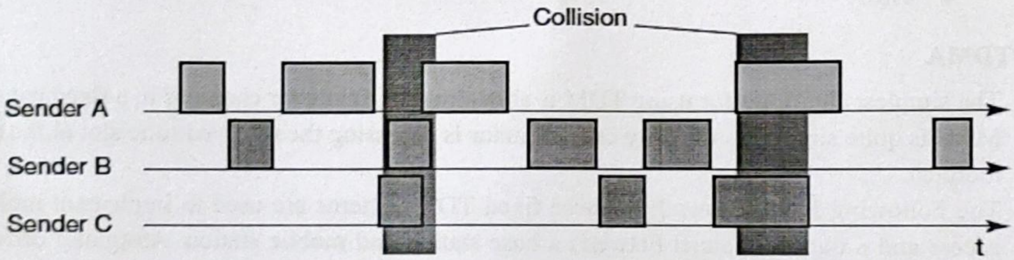
→ MAC is quite simple, as the only crucial factor is accessing the reserved time slot at the right moment.

→ The Following figure shows how these fixed TDM patterns are used to implement multiple access and a duplex channel between a base station and mobile station. Assigning different slots for uplink and downlink using the same frequency is called **time division duplex (TDD)**. As shown in the figure, the base station 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. Up to 12 different mobile stations can use the same frequency without interference using this scheme.



Classical ALOHA

→ If TDM works, without any controlling access is termed as classical ALOHA.
→ It works fine for light load and does not require any *complicated* access mechanism.
→ Each station can access the medium at any time as shown in Figure.
→ This is a random access scheme, without a central arbiter controlling access and without coordination among the stations.
→ If two or more stations access the medium at the same time, a **collision** occurs and the transmitted data is destroyed. Resolving this problem is left to higher layers (e.g., retransmission of data).



It is given as,

Fig: Classical ALOHA multiple access

Slotted ALOHA:

→ It deals with the introduction of *time slots* in classical one.
→ Here, all senders need *to* be synchronized, transmission can only start at the beginning of a *time slot.*
→ Still, access is not coordinated. Under the assumption stated above, the introduction of slots raises the throughput from 18 per cent to 36 per cent, i.e., slotting doubles the throughput.

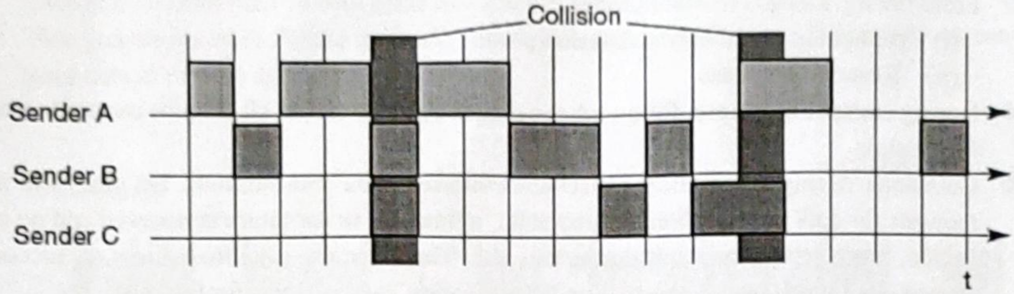


Fig: Slotted ALOHA multiple access

CSMA (Carrier Sense Multiple Access):

→ It is that *sensing* the carrier and accessing. the medium only if the carrier is *idle decreases* the *probability of a collision.*

→ Several. versions of CSMA are,

- **Non Persistent CSMA:** Stations sense the carrier and start sending immediately if the *medium is idle.*
- **P- Persistent CSMA: also** senses the medium but only transmit with a probability of P.
- **1 – Persistent CSMA:** All stations wishing to transmit access the medium at the same time, as soon as it becomes idle.

Access Schemes:

- **CSMA / CA:** Carrier sense multiple access is one of the access schemes used in wireless LANs following the standard IEEE 802.11.
  Here sensing the carrier is combined with a back-oil' scheme in case of a busy medium to achieve some fairness among competing stations.
- **EY-NMPA**: Elimination yield-Non preemptive Multiple access used in the HIPERLAN I specification. Here several phases of sensing the medium and accessing the medium for contention resolution are *interleaved* before one "winner" can finally access the medium for data transmission,

Demand Assigned MUltiple Access (DAMA):

Def: It is a type of reservation mechanism, hence called reservation Aloha.

It is shown as,

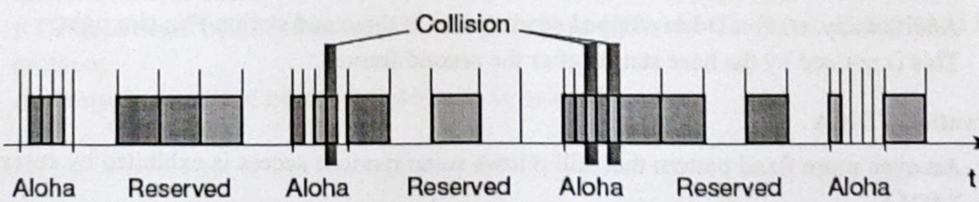


Fig: Demand assignment Multiple access with explicit reservation

- From the fig. DAMA has two modes,
  - (i) contention phase or transmission phase
  - (ii) Reservation phase
- During **contention phase**, following the slotted Aloha scheme, all stations can try to reserve future slots.
- Collisions during reservation phase don't destroy data transmission, but only the short requests for data transmission. If successful, a time slot in the future is reserved and no other station, is allowed to transmit during this slot. Therefore, the satellite collects all successful requests and sends back a reservation list indicating, *access rights* for future slots.
- It is an *explicit reservation,* where the transmission slot has to be reserved explicitly.

Packet Reservation Multiple Access (PRMA)

It is an implicit Reservation scheme.
It is shown as,

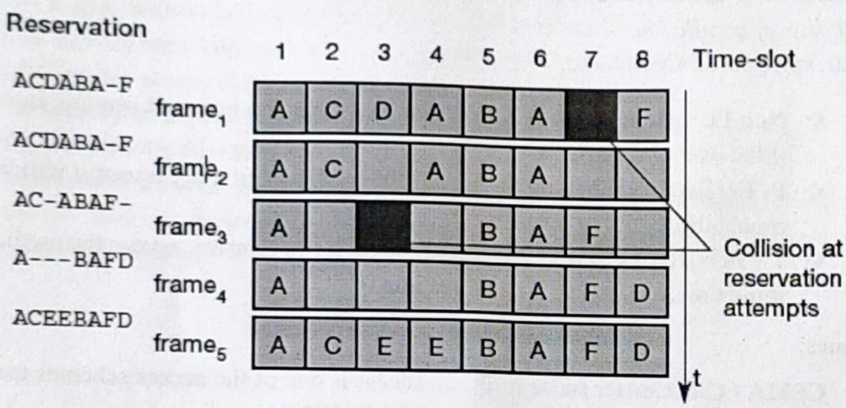


Fig: Demand assignment Multiple access with implicit reservation

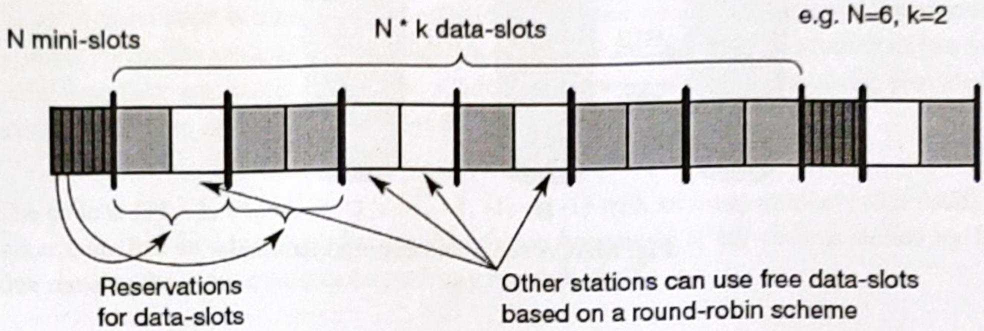
Description:

- Here, the station *broadcasts* the reservation status *'ACDABA - F* to all stations from A to F.
- This means that slots one to six and eight are occupied, but slot seven is free in the following transmission.
- All stations wishing to transmit can now compete for this free slot in aloha fashion.
- The already occupied *slots* are not touched.
- In the example fig., more than one station wants to access this slot, so a collision occurs.
- The base station returns the reservation status "ACDABA-F", indicating that the reservation of slot seven failed.
- Again, stations can compete for this slot.
- Additionally, station D has stopped sending in slot three and station F in slot right.
- This is noticed by the base station after the second frame.

Reservation TDMA

- An even more fixed pattern that still allows some random access is exhibited by **reservation TDMA.**
- In a fixed TDM scheme N mini-slots followed by N·k data-slots form a frame that is repeated.

- ❖ Each station is allotted its own mini-slot and can use it to reserve up to k data-slots.
- ❖ This guarantees each station a certain bandwidth and a fixed delay. Other stations can now send data in unused data-slots as shown.



Multiple Access with Collision Avoidance (MACA)

- ❖ It solves the hidden station problem doesn't need a base station, and is still a random access Aloha scheme but with *dynamic reservation.*

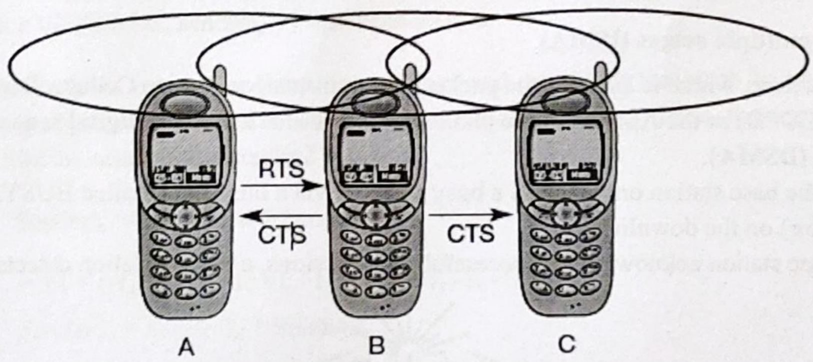


Fig: MACA can avoid Hidden terminals

- ❖ With MACA, A doesn't start its transmission at once, but sends a RTS (*request to send)* first.
- ❖ B receives the RTS that contains the name of sender and receiver, a as well as the length of the future transmission.
- ❖ RTS wont heard by C, but it hears an ack from B as *CTS (clear to Send),* hence avoid hidden problem.
- ❖ similarly, it also avoid exposed problem as in below fig.

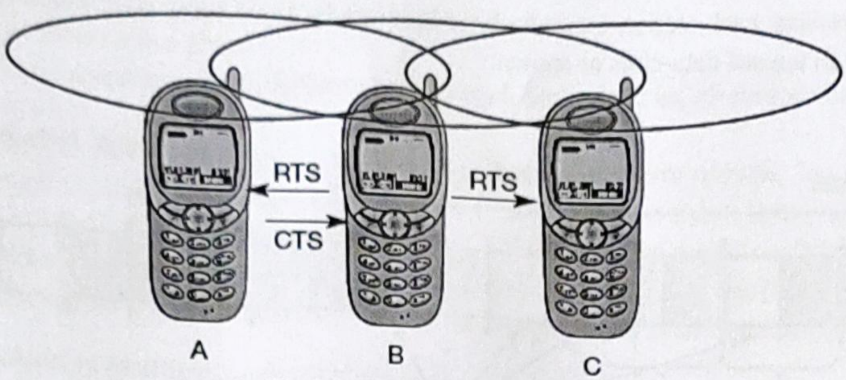


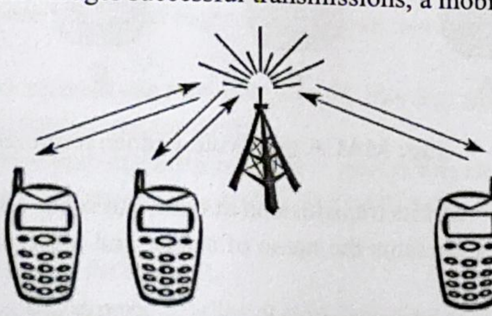
Fig: MACA can avoid exposed terminals

Polling

- Polling is a strictly centralized scheme, with one *master station and several slave stations.*
- This scheme means that one station is to be heard by all other stations.
- The master can poll the slaves according to many schemes: round robin (only efficient if traffic patterns are similar over all stations), randomly, according to reservations (the classroom example with polite students) etc.
- The master could also establish a list of stations wishing to transmit during a contention phase. After this phase, the station polls each station on the list.

Inhibit sense multiple access (ISMA)

- This scheme, which is used for the packet data transmission service Cellular Digital Packet Data (CDPD) in the AMPS mobile phone system, is also known as **digital sense multiple access (DSMA).**
- Here, the base station only signals a busy medium via a busy tone (called BUSY/IDLE indicator) on the downlink.
- The base station acknowledges successful transmissions, a mobile station detects a collision



only via the missing positive acknowledgement

Fig: Inhibit sense multiple access using busy tone

CDMA (Code Division Multiple Access):

The users in the code space can be separated by using codes with some characteristics, so that they can access the shared medium uninterruptedly. Code Division Multiple Access (CDMA) implements such a scheme. The biggest challenge in implementing CDMA is the identification of good codes. A good code is a code that is orthogonal to other codes and has good autocorrelation. Orthogonality means the same as in the 3-dimensional space i.e., if the inner product of two vectors is O(zero), then they are called orthogonal. Codes can also be closely orthogonal, provided their inner product is close to zero. For example. if the inner product is - 1.'

The code is (+1, -1, +1, +1, -1. +1, +1, +1, -1, -1, -1) with an inner product (with itself) is 11. The Barker code has an advantage, the autocorrelation becomes 1 if the code is shifted by 1 chip. The value remains the same till the code perfectly matches itself.

Working

The below steps are followed by a system implementing CDMA.

1. An orthogonal and unique key is assigned to each sender. For example, if sender1 and sender2 wants to send data, for sender 1 a key called sender 1_k = 010011 and for sender2 a key Called sender2_k = 110101 is assigned. We may assume that a binary 1 is coded as +1 and a binary 0 as -1, in order to apply the basic multiplication and addition rules. And, both of these senders wants to transmit a bit each i.e., senderl$_d$= 1 and sender2$_d$= o.

2. Each sender uses its key as the chipping sequence and multiplies the bit to be transmitted with the chipping sequencing. Such a multiplication is called spreading. Thus, the signals that are to be transmitted by sender1 and sender2 are,

   $$Senderl_s = Sender1\ d * Sender1_k$$

   $$= +1 * (-1, +1, -1, -1, +1,+1) = (-1, +1, -1, -1, +1, +1)$$

   $$Sender2_s = Sender2_d * Sender2_k$$

   $$= - 1 * (+1, +1, -1, +1, -1, +1) = (-1, -1, +1. -1, +1, -1)$$

3. The two signals sender 1_s and sender2_s, are transmitted simultaneously, Thus, the two signals gets superimposed or overlapped. The receiver receives a combined signal *'R'* given by,

   $$R = Sender1_s + Sender2_s$$

   $$= (-1, +1, -1, -1, +1, +1) + (-1, -1, +1, -1\ +1, -1)$$

   $$= (-2, 0, 0, -2, +2, 0)$$

   This reception assumes that,

   (i) Interference from environmental noise and other senders is discarded.

   (ii) All signals at the receiver has same strength .

4. The receiver perform dispreading on the received signal. If the resultant value is negative then the receiver detects a binary '0' and if it is larger than '0' or positive then a binary 1. Dispreading

means, multiplying the received signal with the chipping sequence of the senders, one after another. Thus, for sender1$_s$ and sender2$_s$ transmitted bit, the following calculations are made .

$$R^* \text{ Sender1}_k = (-2, 0, 0, -2, +2, 0) * (-1, +1, -1, -1, +1, +1)$$
$$=2+0+0+2+2+0$$
$$=+6$$
$$R^* \text{ Sender2}_k = (-2, 0, 0, -2, +2, 0) * (+1, +1, -1, +1, -1, +1)$$
$$= -2+0+0-2-2+0$$
$$= -6$$

→ Since, a negative value is obtained by dispreading the received signal with sender2's chipping sequence, the receiver understands that a binary '0' was transmitted by sender2. Similarly, a binary' 1' by sender1.

→ However, these calculations were based on some assumptions. If these assumptions are not considered then the following difficulties may arise.

(a) If signal 1$_s$ is 3 times stronger than signal2$_s$, then the receiver would receive,

$$R' = 3 * \text{Sender1}_s + \text{Sender2}_s$$
$$= (-3, +3, -3, -3, +3, +3) + (-1, -1, +1, -1, +1, -1) = (-4, +2, -2, -4, +4, +2)$$

Then to despread the received signal for sender 1 $R' *$ Sender l$_k$, is evaluated as,

R^* Sender l$_k$ = (- 4, +2, - 2, - 4, +4, +2) * (-1, +1, -1, -1, +1, +1) =+4+2+2+4+4+2 = 18

Thus, the binary bit' 1' transmitted by sender1 is accurately received and analyzed by the receiver. But, for despreading sender2's signal, the receiver evaluated as,

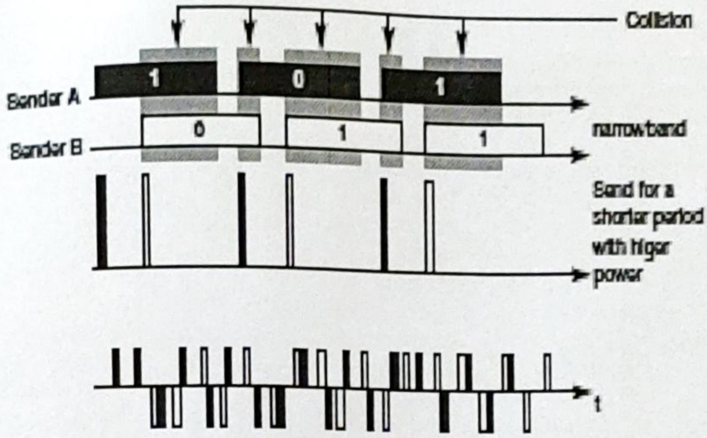
$R' *$ Sender2$_k$ = (- 4, +2, -2, -4, +4, +2) * (+1, +1, - 1, +1, -1,+1) = - 4 + 2 + 2 - 4 - 4 + 2 = -6

Thus, the absolute value mod (-6) = 6 is relatively smaller than + 18 and is close to '0', making the receiver to detect the signal as noise.

Spread Aloha Multiple Access (SAMA):

The senders and receivers in CDMA are complex devices. The complexity in the sender is because of the ability to be incorporated in the base station to handle wireless and mobile devices. On the other hand, the receiver needs to communicate with *m* devices i.e., decoding *m* received codes and transmitting *m* codes. The CDMA technique poses overheads when the communication between *m* devices is bursty and spontaneous. Thus, programming the sender and receiver becomes highly challenging in such situations.

An alternative is to use simple aloha. However, due to collisions, this scheme results in very less network bandwidth. The best solution could be SAMA (Spread Aloha Multiple Access) i.e., combine the medium access Of aloha and spreading of CDMA. The figure depicting the SAMA scheme is as follows.



If only aloha scheme is used, then the upper part of the figure is applicable. Here, a collision arises when the carrier is accessed simultaneously by the sender and receiver in their narrowband spectrum. However, if SAMA is used the collisions can be avoided, provided,

1. The same spreading code is used by each sender.
2. Spread spectrum is used.
3. High powered transmissions for shorter period are made.

The 2nd condition increases the bandwidth of the network. In the figure, the spreading code is 110101 and the spreading factor is 6. As depicted in the middle part of the figure, the chipping phases still differs even though the two signals are spread. The two signals can still be seperated if two different receivers are synchronized with sender 1 and sender2 (one receiver for sender1 and another for sender2).

Drawbacks

→ Good chipping sequences must be determined.
→ Code orthogonality and autocorrelativity are difficult to maintain.
→ The maximum network throughput is same as the one in aloha, i.e., 18%.
→ The sender and receiver are complex devices.

Advantages

→ The advantages of SAMA are mainly due to the usage of spread spectrum. This ensures robustness and in the same frequency band the device cooperates with other devices.
→ Flexible.

Comparison of S/T/F/CDMA

Approach	SDMA	TDMA	FDMA	CDMA
Idea	Segment space into cells/sectors	Segment sending time into disjoint time-slots, demand driven or fixed patterns	Segment the frequency band into disjoint sub-bands	Spread the spectrum using orthogonal codes
Terminals	Only one terminal can be active in one cell/one sector	All terminals are active for short periods of time on the same frequency	Every terminal has its own frequency, uninterrupted	All terminals can be active at the same place at the same moment, uninterrupted
Signal separation	Cell structure directed antennas	Synchronization in the time domain	Filtering in the frequency domain	Code plus special receivers
Advantages	Very simple, increases capacity per km²	Established, fully digital, very flexible	Simple, established, robust	Flexible, less planning needed, soft handover
Disadvantages	Inflexible, antennas typically fixed	Guard space needed (multi-path propagation), synchronization difficult	Inflexible, frequencies are a scarce resource	Complex receivers, needs more complicated power control for senders
Comment	Only in combination with TDMA, FDMA or CDMA useful	Standard in fixed networks, together with FDMA/SDMA used in many mobile networks	Typically combined with TDMA (frequency hopping patterns) and SDMA (frequency reuse)	Used in many 3G systems, higher complexity, lowered expectations; integrated with TDMA/FDMA