UNIT-2

Medium Access Control:

Medium Access control (MAC) is a sublayer of Data link layer of the OSI reference model. MAC acts as an interface between Logical link Control (LLC) sublayer and network physical layer. The MAC layer emulates a full duplex logical communication channel in a multi point network. This channel may provide unicast, multicast or broadcast communication service.

Functions performed in MAC layer:

* Frame delimiting and recognition.
* Addressing of destination stations
* Conveyance of source - station addressing information
* Transparent data transfer of LLC PDUs, or of equivalent information in the Ethernet sublayer.
* Control of access to the physical transmission medium.

Motivation for specialized MAC:

Most commonly used MAC schemes for wired networks is carrier sense multiple access with collision detection (CSMA/CD). In this scheme, a sender senses the medium to see if it is free. If the medium is busy, the sender waits until it is free. If the medium is free, the sender starts transmitting data and continues to listen into the medium. If the sender detects a collision while sending, it stops at once a sends a jamming signal. But this scheme dosent work well with wireless networks.

Some of the problems frequently faced are,

1. signal strength decreases propotional to the square of the distance.

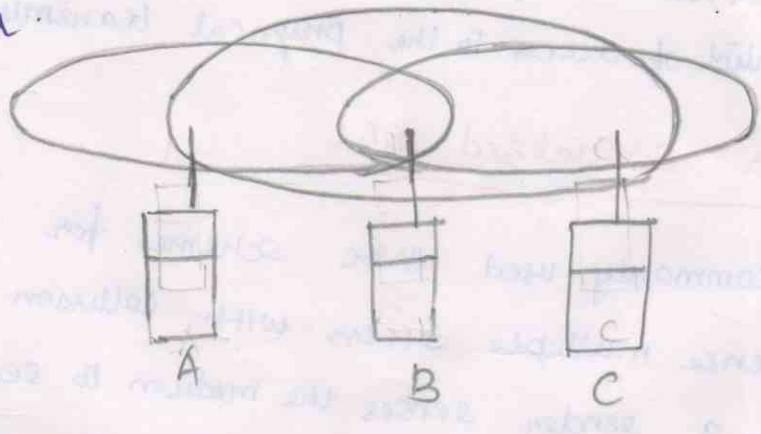
*) The sender would apply CS and CD, but the collisions happen with the reciever.

*) It might be a case that sender cannot "hear" the collision, ie, CD does not work.

*) Furthermore, CS might not work, if for eg, a terminal is hidden.

Hidden and Exposed Terminals:

Consider three mobile phones. A, B, C. The transmission range of A reaches B, but not C as it is not in the detection range. Similarly, the transmission range of C reaches B, but not A. Finally the transmission range of B reaches A and C, ie, A cannot detect C and viceversa.



Hidden terminals

* A sends to B, C cannot hear A
* C wants to send to B, C senses a "free" medium (CS fails) and starts retransmitting.
* Collision at B occurs, A cannot detect this collision (CD fails) and continoues with its transmission to B.
* A is "hidden" from C and viceversa.

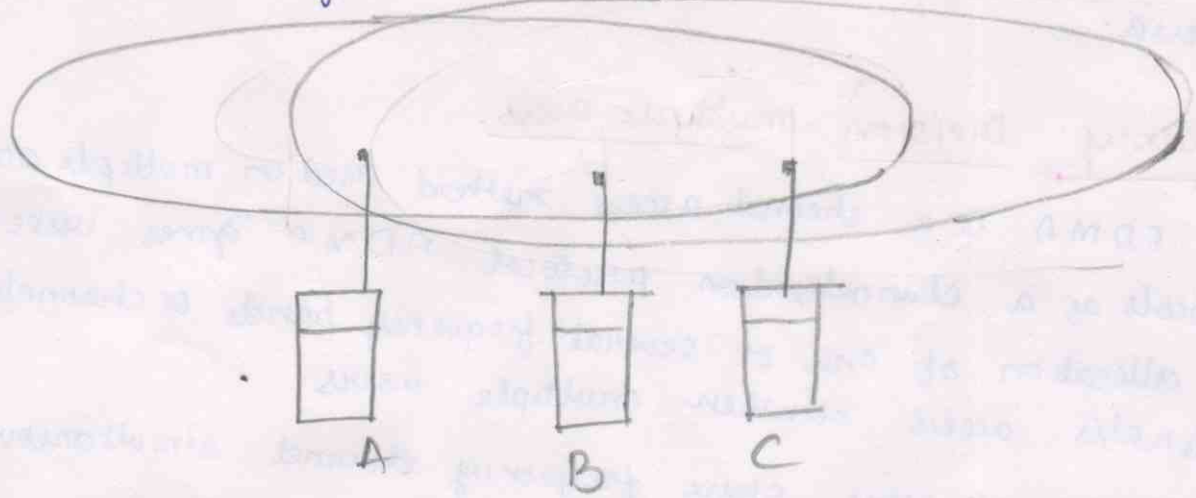
Exposed terminals

* B sends to A, C wants to send to another terminal (not A or B) outside the range.
* C senses the carrier and detects that the carrier is busy.
* C postpones its transmission until it detects the medium as being idle again.
* but A is outside range of C, waiting is not necessary.
* C is "exposed" to B.

Hidden terminals cause collisions, where as exposed terminals cause unnecessary delay.

Near and Far terminals:

Conside two mobile stations A & B. A and B are both sending with the same transmission power.



* signal strength decreases proportional to the square of the distance.
* so, B's signal drowns out A's signal making C unable to reciere A's transmission.
* If C is an arbiter for sending rights, B drown out A's signal on physical layer making C unable to hear out A.

Space division multiple access :

Space division multiple access (SDMA) is a channel access method based on creating parallel spatial pipes next to higher capacity pipes through spatial multiplexing. This improves the performance in radio multiple access communication systems.

In cellular networks, the base station has no information on the positions of mobile units within the cell and radiates the signal in all directions within the cell in order to provide radio coverage which is waste of power.

In GSM cellular n/w, the base station is aware of distance but not the direction, of a mobile phone by use of a (TA) Timing Advance. The base transceiver station (BTS) can determine how distant the mobile station is by interpreting the reported TA which helps in less use of power and thereby ensuring better battery life.

The 5th generation mobile networks will be focused in utilizing the position of the MS in relation to BTS in order to focus all MS Radio frequency power to the BTS direction and vice versa.

Frequency Division multiple access:

FDMA is a channel access method used in multiple access protocols as a channelization protocol. FDMA gives users an individual allocation of one or several frequency bands or channels. It coordinates access between multiple users.

- In FDMA all users share frequency channel simultaneously but each user transmits at single frequency
- FDMA can be used with both analog and digital signal
- It requires high performing filters in the radio hardware.
- A predetermined frequency band is available for entire period of communication, so stream data can easily be used.

- FDMA also supports demand assignment in addition to fixed assignment. Demand assignment allows all users apparently continous access of the radio spectrum by assigning carrier frequencies on a temporary basis.

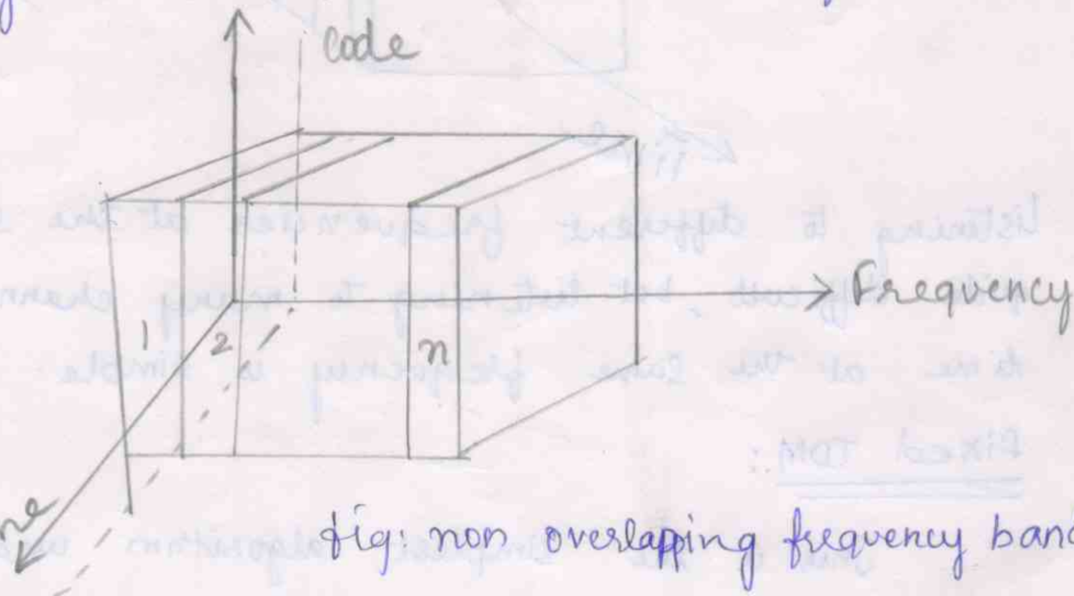
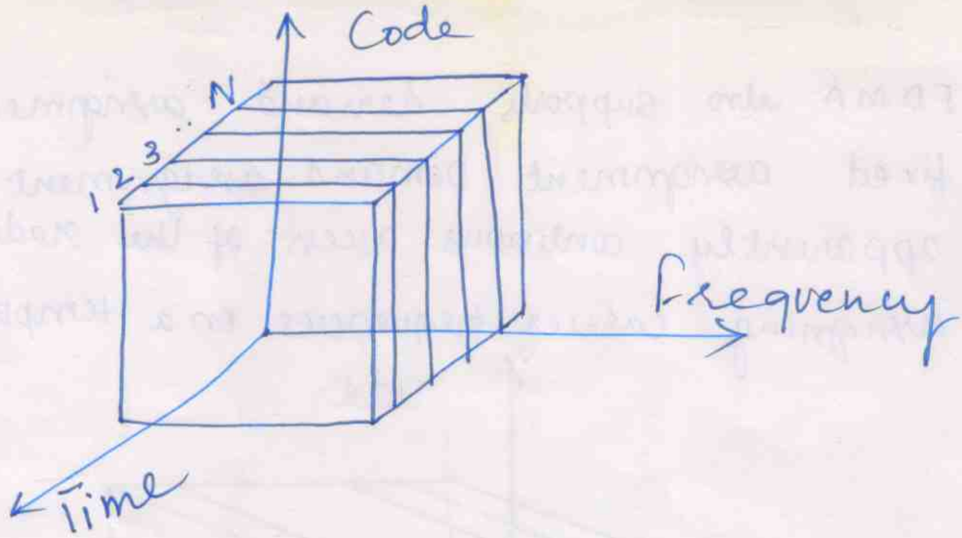


fig: non overlapping frequency bands

Disadvantage: while radio stations broadcast 24 hours a day, mobile communication typically takes place for only a few minutes at a time. Assigning a seperate frequency for each possible communication scenario would be major waste of frequency resources. Additionally, the fixed assignment of a frequency to a sender makes the scheme very inflexible and limits the number of senders.

Time Division Multiple Access:

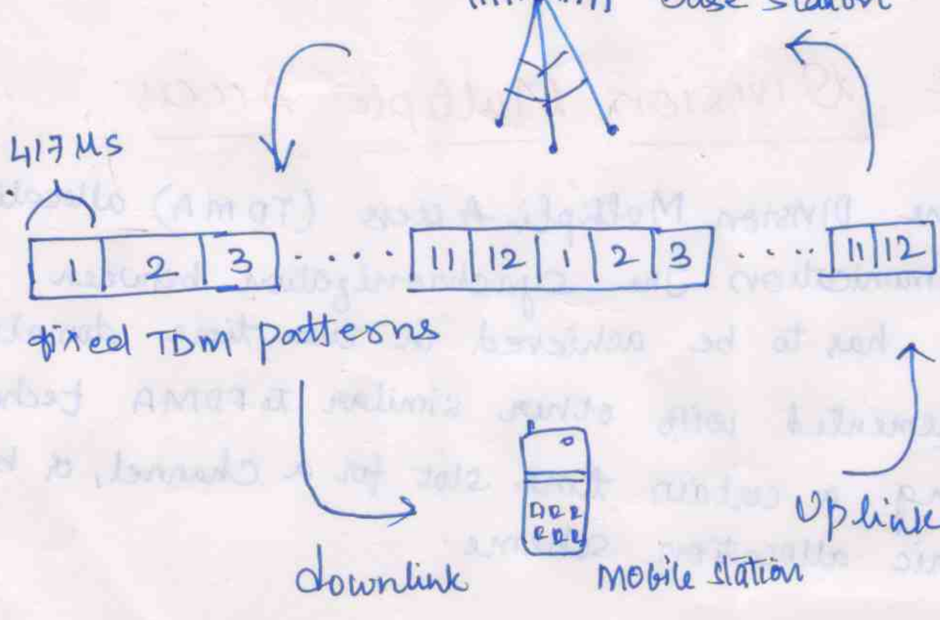
A Time Division Multiple Access (TDMA) allocates time slots for communications. The synchronization between sender and receiver has to be achieved in the time domain. TDMA can be implemented with other similar to FDMA techniques, i.e) allocating a certain time slot for a channel, or by using a dynamic allocation scheme.



listing to different frequencies at the same time is quite difficult, but listening to many channels seperated in time at the same frequency is simple.

Fixed TDM:

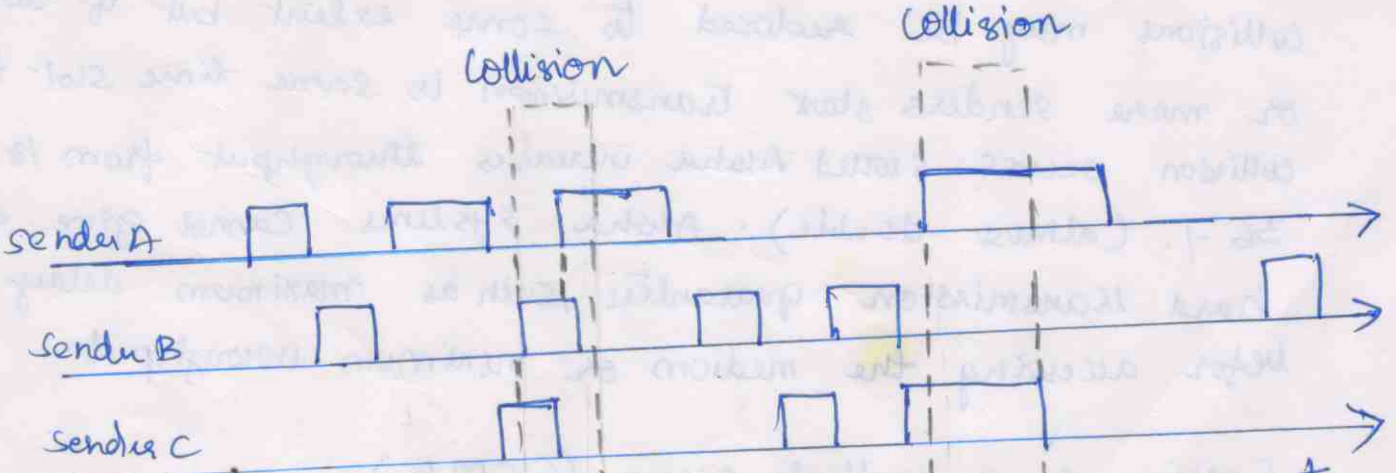
This is the simplest algorithm used for TDM. Here the time slots for channels are allocated in fixed pattern This results in a fixed bandwidth and is typical solution for wireless phone systems. MAC is simple as the only crucial factor is accessing the reserved time slot at the right moment. If this synchronization is assured, each mobile station knows its turn and no interference will happen. The fixed pattern can be assigned by the base station, where competition between different mobile stations that want to access the medium is solved.



In the figure, the fixed TDM patterns are used to implement multiple access and a duplex channel between a base stations and mobile station. when different slots are assigned for uplink and downlink using same frequency it is called time division duplex (TDD). Here TDM uses 12 slots for the ~~downlink~~ time division duplex The Base station uses one out of 12 slots for the downlink, whereas mobile station uses one out of 12 different slots for the uplink. Uplink and downlink are seperated in time. so, upto 12 different mobile stations can use the same frequency without interference using this scheme. Every connection is alloted its own uplink-downlink pair, but still much of the bandwidth is wasted and is inflexible for data communication. An alternate to this is connectionless, demand oriented TDMA schemes can be used.

Classical Aloha:

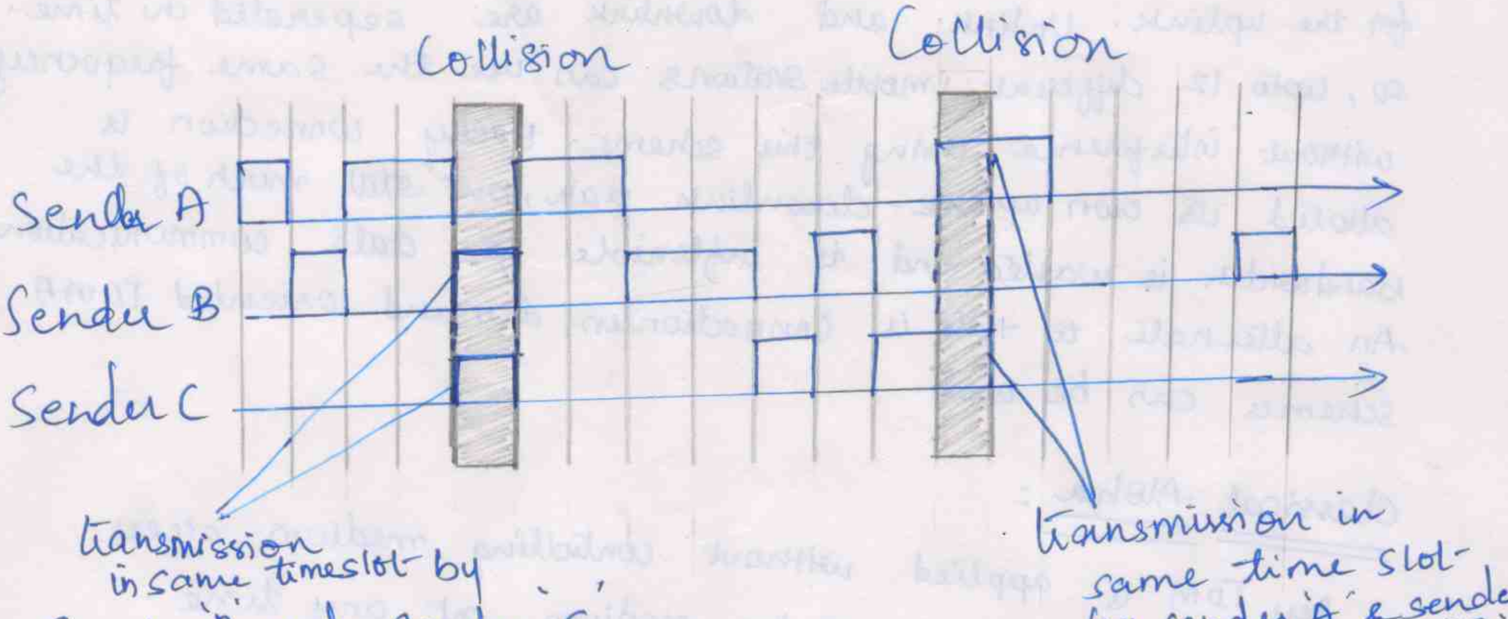
Here, TDM is applied without controlling medium access. Each station can access the medium at any time.



Classical Aloha is a random access scheme, without a central arbiter controlling access and without co-ordination among the stations. If two or more stations access the medium at the same time, a collision occurs and transmitted data is destroyed. so retransmission is required which cannot be done by classical Aloha. This simple aloha works good for light load and does not require any complicated access mechanisms.

Slotted Aloha:

In slotted Aloha the medium is divided into a number of time slots hence the name Slotted Aloha. Here all the senders have to be synchronized, transmission can start only at the begenning of of a time slot thereby, avoiding collision as in Classical Aloha.



collisions may be reduced to some extent but if two or more senders start transmission in same time slot then collision occurs. Slotted Aloha increases throughput from 18 -/. to 36 -/. (almost double). Aloha systems cannot give any hard transmission guarantees, such as maximum delay befor accessing the medium or minimum throughput.

Carrier sense multiple access (CSMA):

CSMA senses the carrier before accessing the medium. This decreases collision to a good extent. But, the hidden terminal cannot be detected. If it transmits at the same time as another sender, a collision might occur at the reciever.

The basic scheme is still used in most wireless LANs.
The different versions of CSMA are

1) 1-persistant CSMA: Here stations sense the channel and listens if its busy and transmit immediately, when the channel becomes empty. It's called 1- persistent CSMA because the host transmits with a probability of 1 whenever it finds the channel idle.
2) non-persistant CSMA: The stations sense carrier and start sending immediately if the medium is busy, the station pauses a random amount of time before sensing the medium again and repeating this pattern.
3) p-persistant CSMA: systems nodes also sense the medium, but only transmit with a probability of P, with the station differing to the next slot with probability 1-P, i.e. access is slotted in addition.

CSMA with collision avoidance (CSMA/CA) is used in Wireless LAN's 802.11. Here sensing the carrier is combined with a backoff scheme in case of a busy medium to achieve some fairness among competing stations.

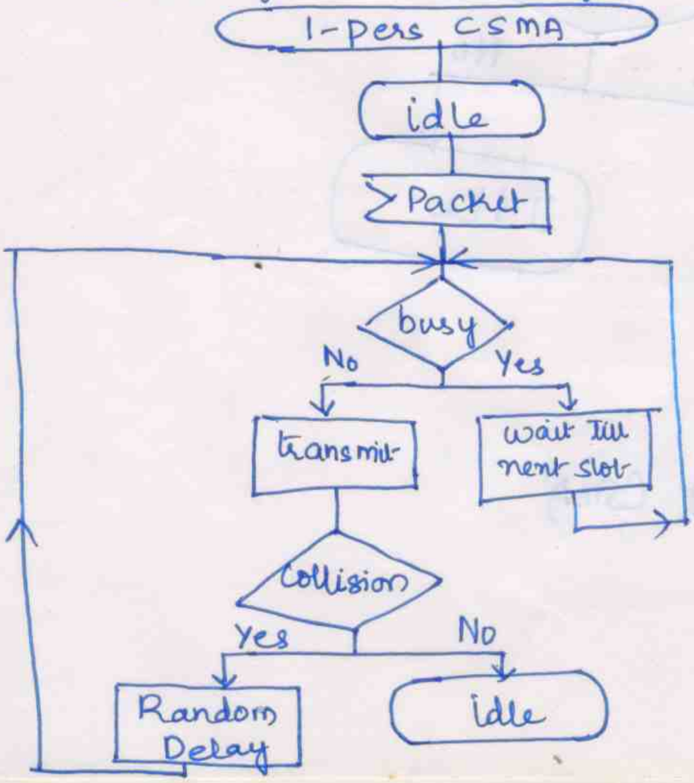


fig: 1-persistant CSMA

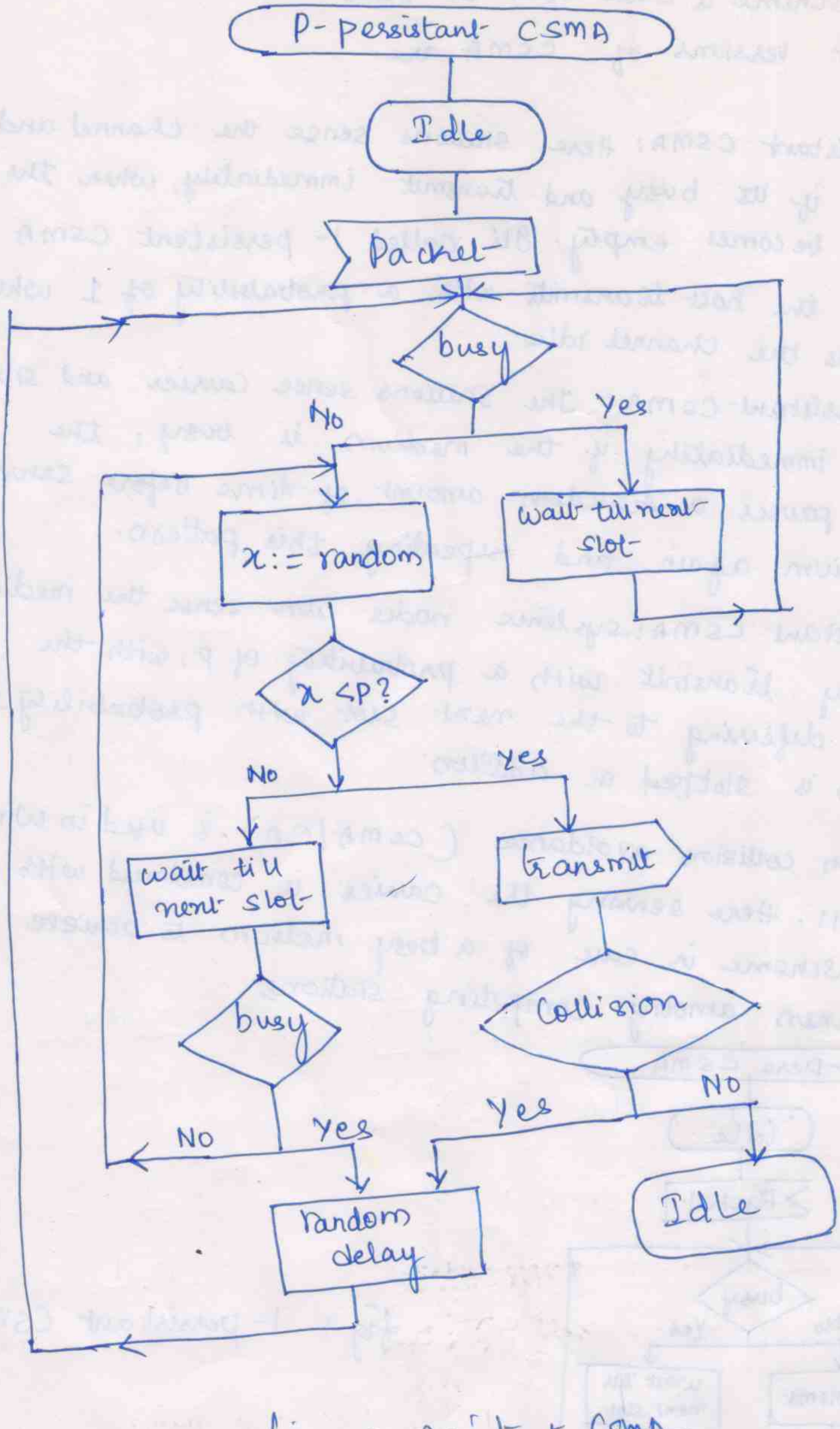


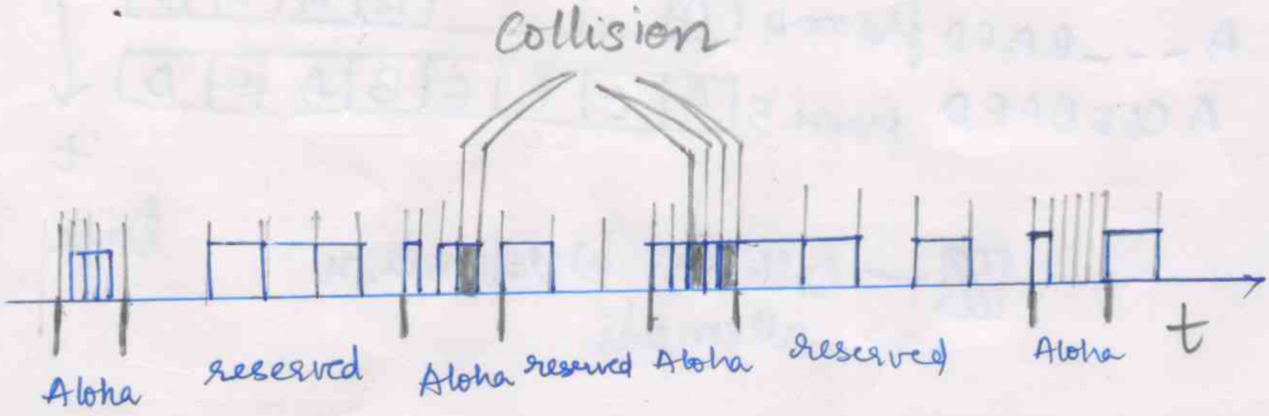
fig: p-persistant CSMA.

Demand Assigned multiple access:

The Channel effeciency using classical Aloha is 18% and by using slotted Aloha it is increased to almost double i.e 36%. It can be further increased to 80% by implementing reservation mechanisms and combinations with some fixed TDM patterns. They have a reservation period followed by a transmission period.

In reservation period, the stations can reserve future slots in transmission period. Still some collisions may occur in reservation period, but the transmission period can then be accessed without collision.

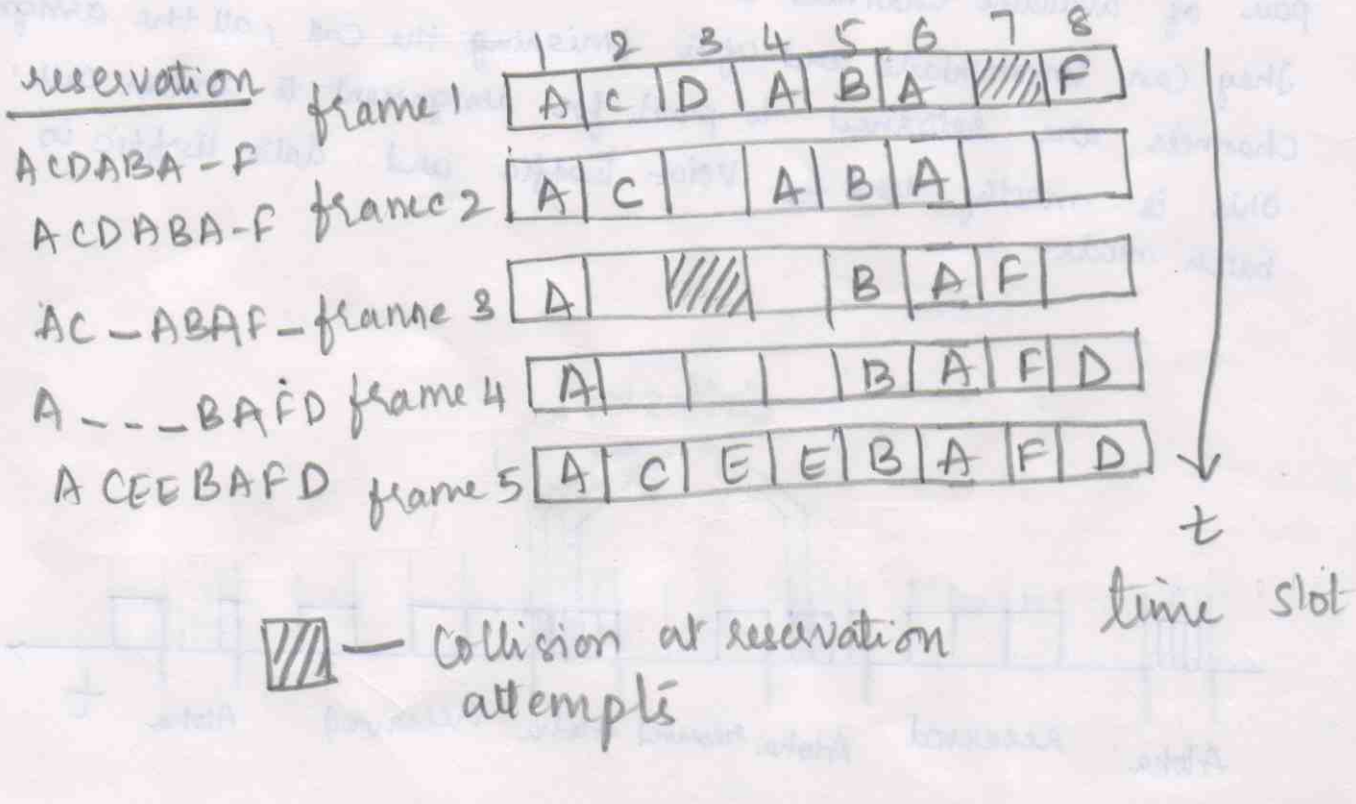
One of the basic scheme is demand assigned multiple access (DAMA) also called reservation aloha, a scheme typical for satellite systems. It increases the amount of users in a pool of satellite channels that are free for use by any station in the network. As all the users may not need to access to same channel, they can establish a call and DAMA will assign a pair of available channels based on requests issued from a user. They can communicate and after finishing the call, all the assigned channels are returned to pool for assignment to another call. This is mostly used for voice traffic and data traffic in batch mode.



During a contention phase following the Slotted Aloha, all stations can try to reserve future slots. Collisions during the reservation phase do do destroy data transmission, but only the short requests for data transmission. If it is successful, a time slot in future is reserved. Similarly all successful requests are collected and a reservation list indicating access rights for future slots is sent back, followed by all stations which is possible by their synchronization. DAMA is an explicit reservation scheme. Each transmission slot has to be reserved explicitly.

Packet reservation multiple access (PRMA):

It is a kind of implicit reservation scheme where, slots can be reserved implicitly. A certain number of slots form a frame. The frame is repeated in time i.e, a fixed TDM pattern is applied. A base station which could be a satellite, now broadcasts the status of each slot to all mobile stations. All stations receiving this vector will then know which slot is occupied and which slot is free currently.



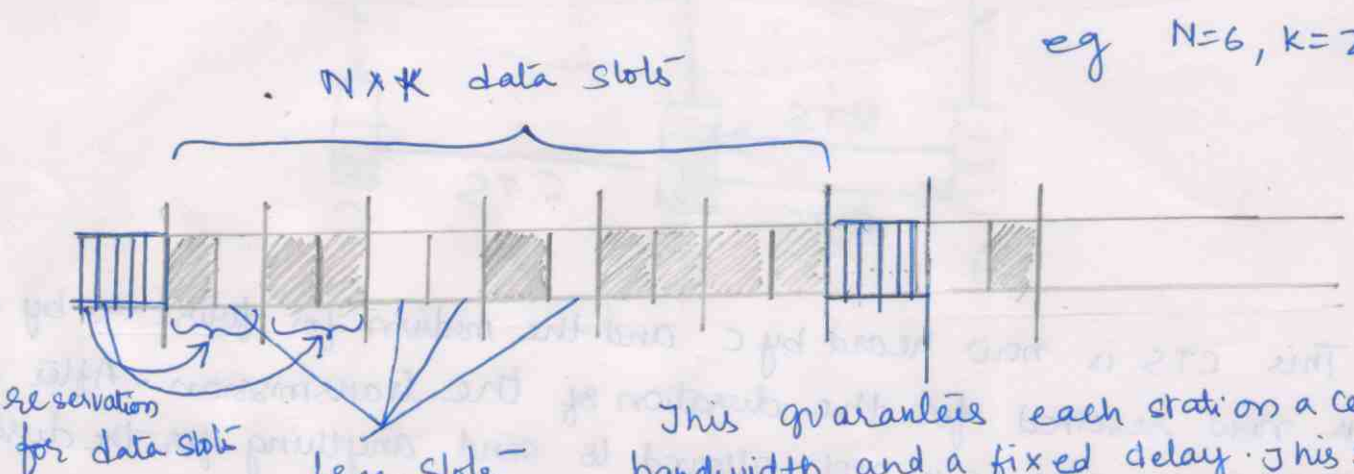
The base station broadcasts the reservation status 'ACDABA-F' to all stations from A to F. In the figure, slots one to ~~seven~~ six are occupied, but seven is free and again eight is occupied. All stations wishing to transmit can now compete for this free slot in Aloha fashion for the free slot only. where there is a chance of collision. The base station returns the reservation status 'ACDABA-F' indicating still slot seven is free and no change in other slots. Again, the stations compete for this slot. Meanwhile station D has stopped sending in slot three and station F in slot eight. This is noticed by the base station after second frame. Before the third frame starts, the base station indicates slots three and eight are now idle. Station F has succeeded in reserving slot seven as also indicated by base station.

As soon as a station has succeeded with a reservation, all future slots are implicitly reserved for this station. This ensures transmission with guaranteed data rate. The slotted aloha scheme is used for idle slots only but here data transmission is not destroyed by collision.

Reservation TDMA:

In a fixed TDM, N mini slots followed by N·K dataslots form a frame that is repeated. Each station is allotted its own minislot and can cause it to reverse upto K dataslots.

eg N=6, K=2



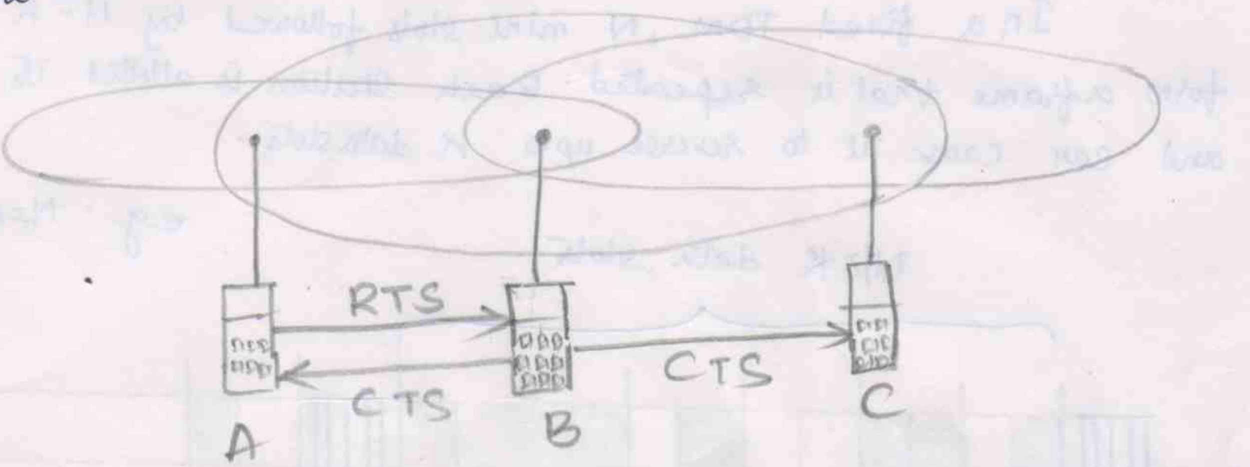
This guarantees each station a certain bandwidth and a fixed delay. This scheme allows for isochronous traffic with fixed bitrates and best effort traffic without guarantees.

Multiple access with collision avoidance :

Multiple access with collision avoidance (MACA) presents a simple scheme that solves the hidden terminal problem and is still a random access Aloha scheme but with dynamic reservation. Consider the hidden terminal problem scenario.

A starts sending to B, C dosent receive this transmission C also wants to send something to B and senses the medium. The medium appears to be free, the carrier sense fails. C also starts sending causing a collision at B. But A cannot detect this collision at B and continues with its transmission. A is hidden for C and vice versa.

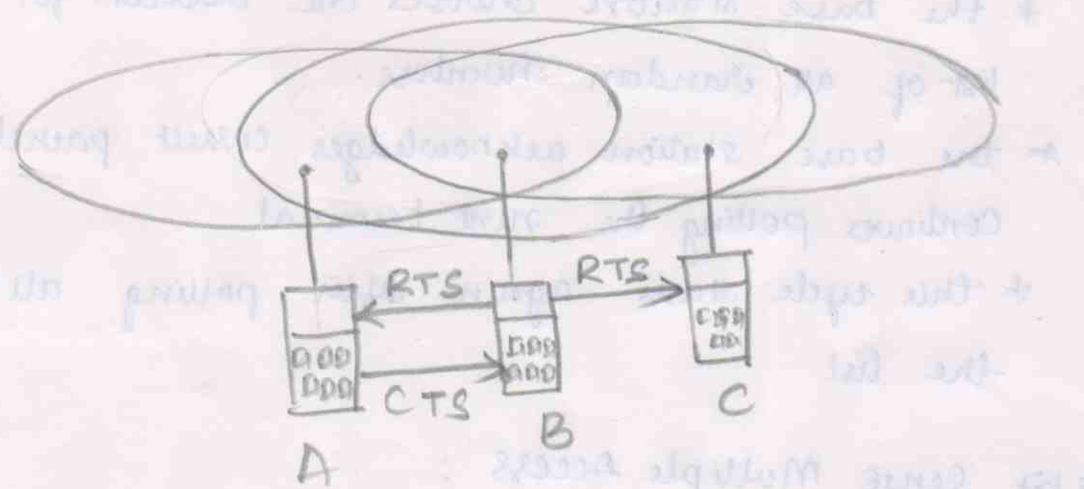
With MACA, A does not start its transmission at once, but sends a "request to send" (RTS) first. B receives the RTS that contains the name of sender and receiver, as well as the length of the future transmission. This RTS is not heard by C, but triggers an acknowledgement from B, called "Clear to Send" (CTS). The CTS again contains the names of sender (A) and receiver (B) of the user data, and the length of future transmission.



This CTS is now heard by C and the medium for future use by A is now reserved for the duration of the transmission. After receiving a CTS, C is not allowed to send anything for the duration indicated in the CTS toward B. A collision cannot occur at

B during data transmission, and the hidden terimal problem is solved. still collisions might occur when A and C transmits a RTS at the same time. B resolves this contention and acknowledges only one station in the CTS. No transmission is allowed without an appropriate CTS.

Now MACA tries to avoid the exposed terminals in the following way:



With MACA, B has to transmit an RTS first containing the name of the receiver (A) and the sender (B). C does not react to this message as it is not the receiver, but A acknowledges using a CTS which identifies B as the sender and A as the receiver of the following data transmission. C dosent receive this CTS and concludes that A is outside the detection range. C can start its transmission assuming that it will not cause a collision at A. The problems with exposed terminals is exposed terminals is solved without fixed access patterns or a base station.

Polling : Polling schemes are used when one station wants to be heard by others. Polling is a strictly centralized scheme with one master station and several slave stations. The master can poll the slaves according to many schemes like randomly, round robin, reservations etc. Contd..

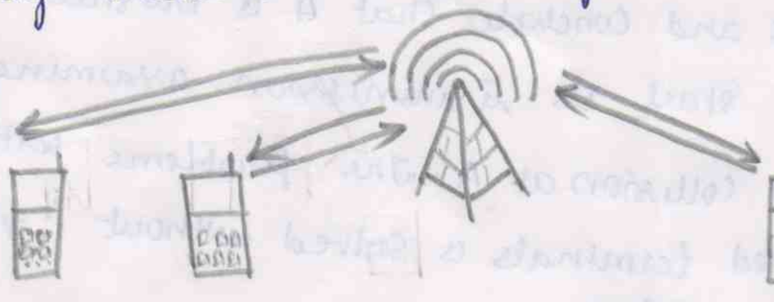
The master could also establish a list of stations wishing to transmit during a contention phase

Example : Randomly addressed polling.

* base station signals readiness to all mobile terminals
* terminals ready to send transmit random number without collision using CDMA or FDMA.
* the base station chooses one address for polling from list of all random numbers.
* the base station acknowledges correct packets and continues polling the next terminal.
* this cycle starts again after polling all terminals of the list.

Inhibit Sense Multiple Access :

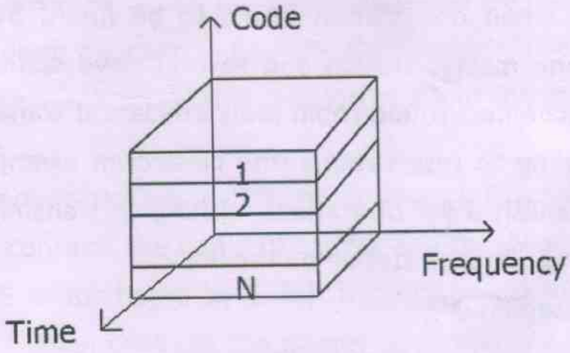
This scheme, which is used for the packet data transmission service Cellular Digital Packet Data (CDPD) in the AMPS mobile phone system, is also known as digital sense multiple access (DSMA). Here the base station only signals a busy medium via a busy tone on the downlink.



After the busy tone stops, accessing the uplink is not co-ordinated any further. The base station acknowledges successful transmissions, a mobile station detects a collision only via the missing positive acknowledgement. In case of collisions, aditional back-off and retransmission mechanisms are implemented.

CDMA

Code division multiple access systems apply codes with certain characteristics to the transmission to separate different users in code space and to enable access to a shared medium without interference.



All terminals send on the same frequency probably at the same time and can use the whole bandwidth of the transmission channel. Each sender has a unique random number, the sender XORs the signal with this random number. The receiver can "tune" into this signal if it knows the pseudo random number, tuning is done via a correlation function

Disadvantages:

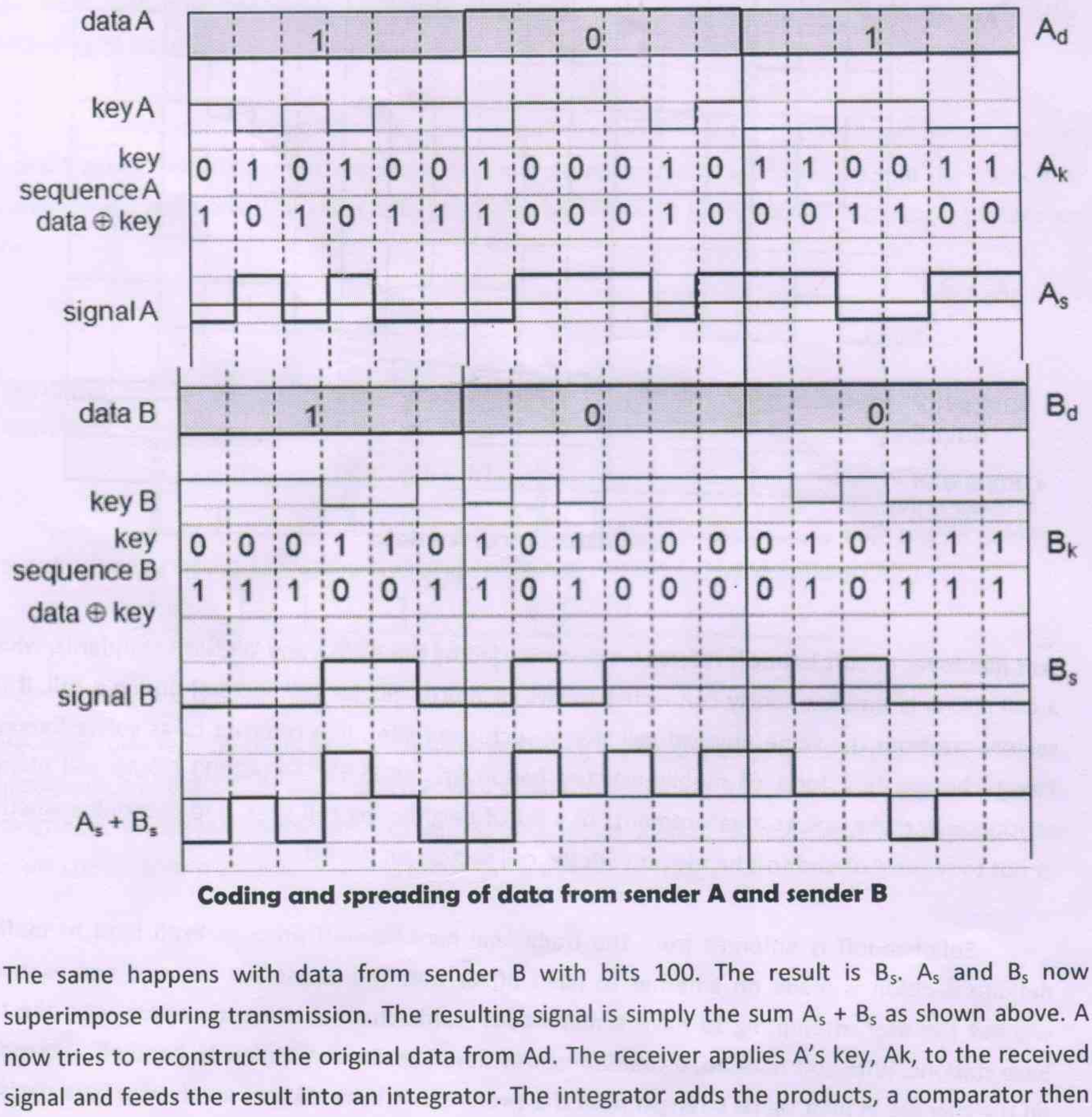
- higher complexity of a receiver (receiver cannot just listen into the medium and start receiving if there is a signal)
- all signals should have the same strength at a receiver

Advantages:

- all terminals can use the same frequency, no planning needed
- huge code space (e.g. 2^{32}) compared to frequency space
- interferences (e.g. white noise) is not coded
- forward error correction and encryption can be easily integrated

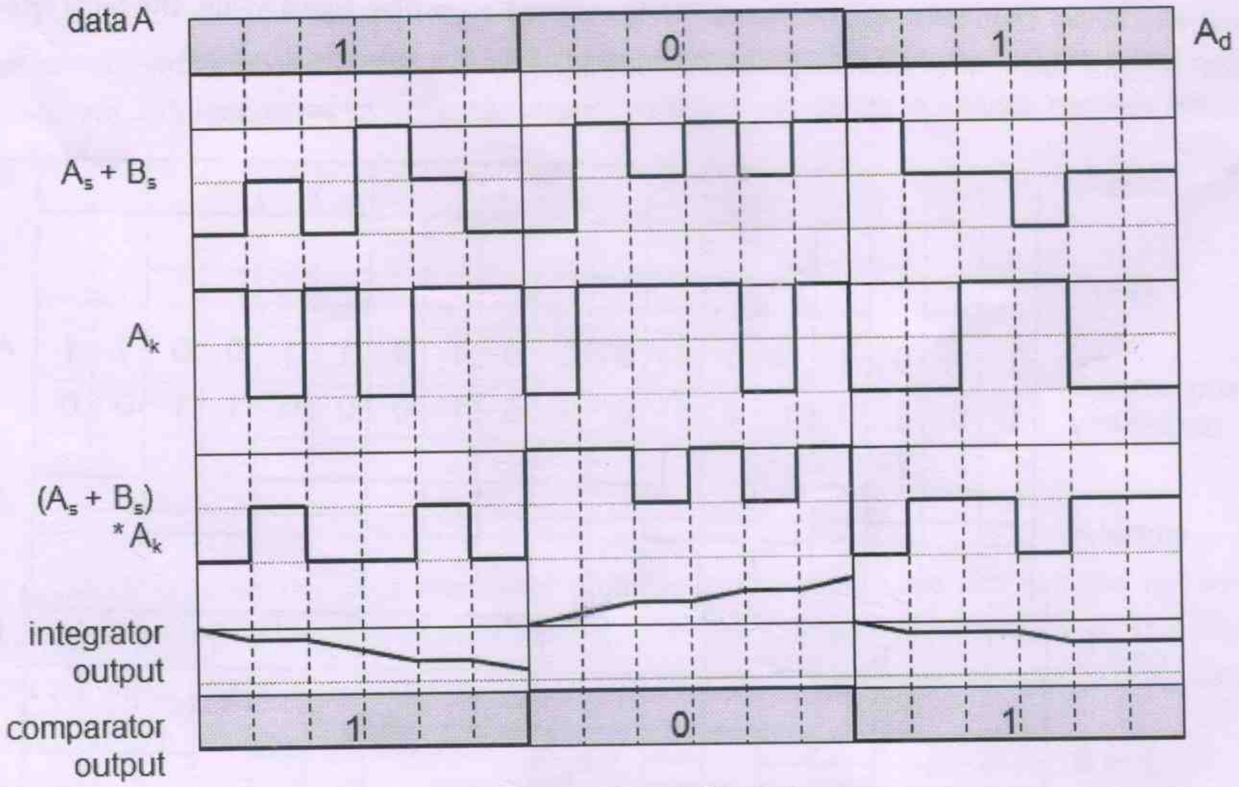
- Sender A
  - sends $A_d = 1$, key $A_k = 010011$ (assign: "0"= -1, "1"= +1)
  - sending signal $A_s = A_d * A_k = (-1, +1, -1, -1, +1, +1)$
- Sender B
  - sends $B_d = 0$, key $B_k = 110101$ (assign: "0"= -1, "1"= +1)
  - sending signal $B_s = B_d * B_k = (-1, -1, +1, -1, +1, -1)$
- Both signals superimpose in space
  - interference neglected (noise etc.)
  - $A_s + B_s = (-2, 0, 0, -2, +2, 0)$
- Receiver wants to receive signal from sender A
  - apply key A_k bitwise (inner product)
    - $A_e = (-2, 0, 0, -2, +2, 0) \bullet A_k = 2 + 0 + 0 + 2 + 2 + 0 = 6$
    - result greater than 0, therefore, original bit was "1"
  - receiving B
    - $B_e = (-2, 0, 0, -2, +2, 0) \bullet B_k = -2 + 0 + 0 - 2 - 2 + 0 = -6$, i.e. "0"

The following figure shows a sender A that wants to transmit the bits 101. The key of A is shown as signal and binary sequence A_k. The binary "0" is assigned a positive signal value, the binary "1" a negative signal value. After spreading, i.e., XORing A_d and A_k, the resulting signal is A_s.



Coding and spreading of data from sender A and sender B

The same happens with data from sender B with bits 100. The result is B_s. A_s and B_s now superimpose during transmission. The resulting signal is simply the sum $A_s + B_s$ as shown above. A now tries to reconstruct the original data from Ad. The receiver applies A's key, Ak, to the received signal and feeds the result into an integrator. The integrator adds the products, a comparator then has to decide if the result is a 0 or a 1 as shown below. As clearly seen, although the original signal form is distorted by B's signal, the result is quite clear. The same happens if a receiver wants to receive B's data.



Reconstruction of A's data

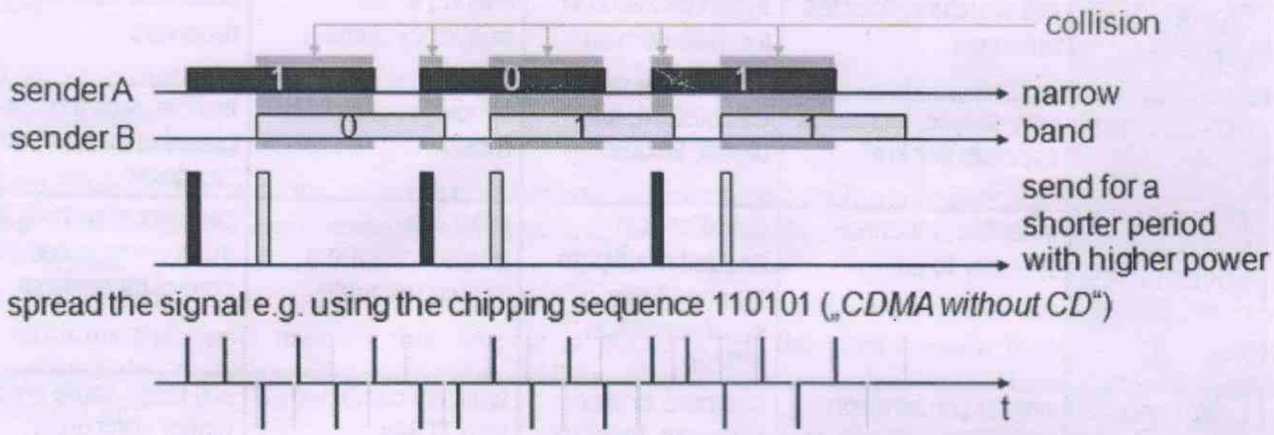
Soft handover or **soft handoff** refers to a feature used by the CDMA and WCDMA standards, where a cell phone is simultaneously connected to two or more cells (or cell sectors) during a call. If the sectors are from the same physical cell site (a sectorised site), it is referred to as **softer handoff**. This technique is a form of mobile-assisted handover, for IS-95/CDMA2000 CDMA cell phones continuously make power measurements of a list of neighboring cell sites, and determine whether or not to request or end soft handover with the cell sectors on the list.

Soft handoff is different from the traditional hard-handoff process. With hard handoff, a definite decision is made on whether to hand off or not. The handoff is initiated and executed without the user attempting to have simultaneous traffic channel communications with the two base stations. With soft handoff, a c*onditional* decision is made on whether to hand off. Depending on the changes in pilot signal strength from the two or more base stations involved, a hard decision will eventually be made to communicate with only one. This normally happens after it is evident that the signal from one base station is considerably stronger than those from the others. In the interim period, the user has simultaneous traffic channel communication with all candidate base stations. It is desirable to implement soft handoff in power-controlled CDMA systems because implementing hard handoff is potentially difficult in such systems.

Spread Aloha multiple access (SAMA)

CDMA senders and receivers are not really simple devices. Communicating with n devices requires programming of the receiver to be able to decode n different codes. Aloha was a very simple scheme, but could only provide a relatively low bandwidth due to collisions. SAMA uses spread spectrum with only one single code (chipping sequence) for spreading for all senders accessing according to aloha.

In SAMA, each sender uses the same spreading code, for ex 110101 as shown below. Sender A and B access the medium at the same time in their narrowband spectrum, so that the three bits shown causes collisions. The same data could also be sent with higher power for shorter periods as show.



The main problem in using this approach is finding good chipping sequences. The maximum throughput is about 18 per cent, which is very similar to Aloha, but the approach benefits from the advantages of spread spectrum techniques: robustness against narrowband interference and simple coexistence with other systems in the same frequency bands.

Comparison SDMA/TDMA/FDMA/CDMA

Universität Berlin

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, flexible	simple, established, robust	flexible, less frequency planning needed, soft handover
Dis-advantages	inflexible, antennas typically fixed	guard space needed (multipath 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)	still faces some problems, higher complexity, lowered expectations; will be integrated with TDMA/FDMA