MODULE 1
Medium Access Control

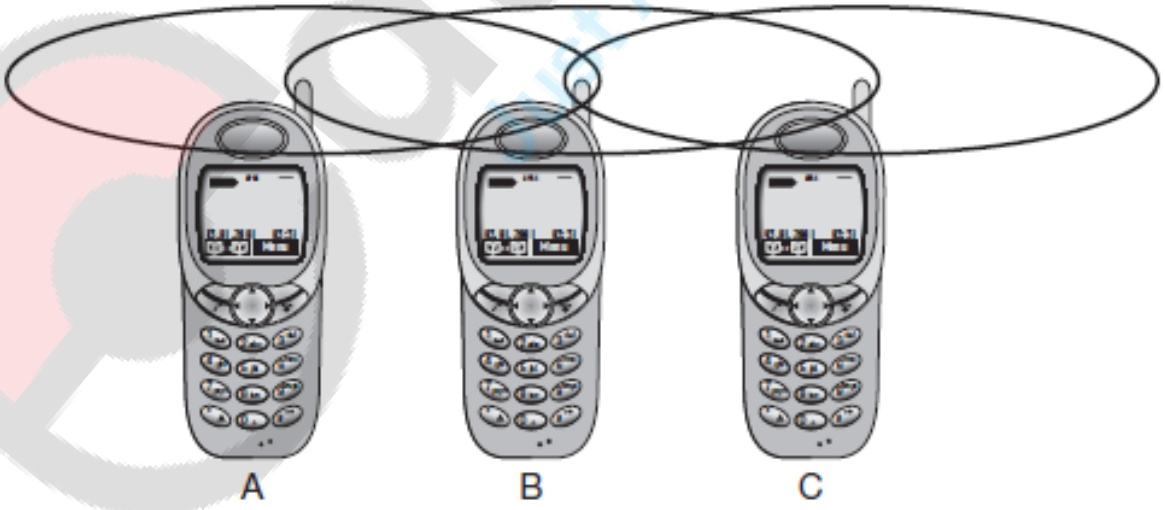
Medium access control

- mechanisms that regulate user access to a medium using SDM, TDM, FDM, or CDM.
- MAC belongs to layer 2, the **data link control layer (DLC)**. Layer 2 is subdivided into the **logical link control (LLC)**, layer 2b, and the MAC, layer 2a.
- The task 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.
- standard MAC schemes known from wired networks often fail in wireless network.
  - Hidden and exposed terminals.
  - Near and far terminals.

Hidden and exposed terminals

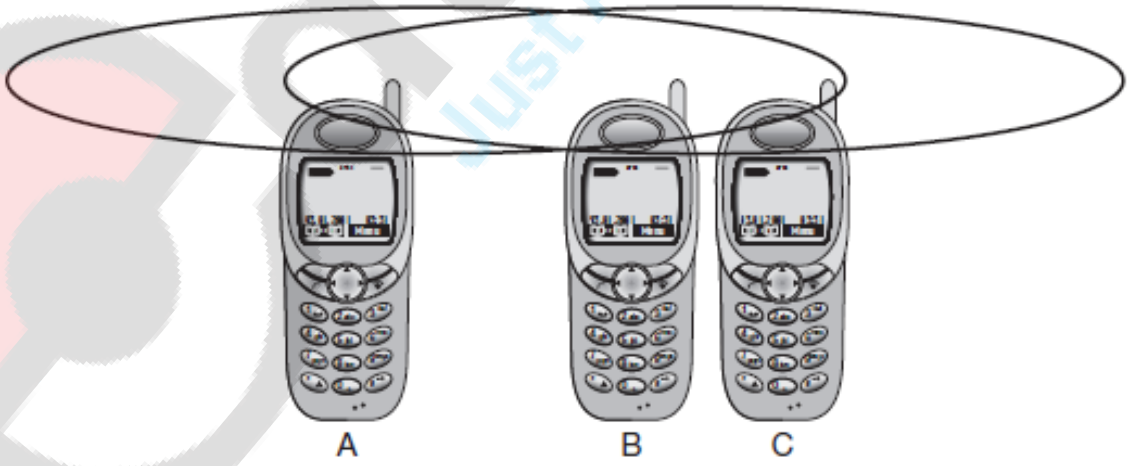
•A starts sending to B, C does not receive this transmission. C also wants to send something to B and senses the medium. The medium appears to be free, the carrier sense fails. C also starts sending causing a collision at B. But A cannot detect this collision at B and continues with its transmission.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

•B sends something to A and C wants to transmit data to some other mobile phone outside the interference ranges of A and B. C senses the carrier and detects that the carrier is busy (B's signal). C postpones its transmission until it detects the medium as being idle again. But as A is outside the interference range of C, waiting is not necessary. Causing a 'collision' at B does not matter because the collision is too weak to propagate to A. In this case, **C is exposed to B.**



Near and far terminals

- A and B are both sending with the same transmission power.
- As the signal strength decreases proportionally to the square of the distance, B's signal drowns out A's signal. As a result, C cannot receive A's transmission.
- C as being an arbiter for sending rights (e.g., C acts as a base station coordinating media access). In this case, terminal B would already drown out terminal A on the physical layer.
- C in return would have no chance of applying a fair scheme as it would only hear B.



Space Division Multiple Access (SDMA)

- Used for allocating a separated space to users in wireless networks.
- e.g. assigning an optimal base station to a mobile phone user.
- SDMA is never used in isolation but always in combination with one or more other Schemes
- The SDMA algorithm is formed by cells and sectorized antennas which constitute the infrastructure implementing space division multiplexing
- Also antenna arrays can be used improving overall capacity.

Frequency division multiple access (FDMA)

- Allocating frequencies to transmission channels according to the frequency division multiplexing (FDM) scheme.
- Allocation can either be fixed (as for radio stations or the general planning and regulation of frequencies) or dynamic (i.e., demand driven).
- Channels can be assigned to the same frequency at all times, i.e., pure FDMA,
- change frequencies according to a certain pattern, i.e., FDMA combined with TDMA- the common practice for many wireless systems to circumvent narrowband interference at certain frequencies, known as frequency Hopping.
- Frequency division duplex (FDD) -
  - often used for simultaneous access to the medium by base station and mobile station in cellular networks.
  - The two directions, mobile station to base station and vice versa are separated using different frequencies forming a duplex channel.

Time division multiple access (TDMA)

- more flexible scheme, which comprises all technologies that allocate certain time slots for communication, i.e., controlling TDM.
- tuning in to a certain frequency is not necessary, i.e., the receiver can stay at the same frequency the whole time.
- Using only one frequency, and thus very simple receivers and transmitters, many different algorithms exist to control medium access.
- listening to different frequencies at the same time is quite difficult, but listening to many channels separated in time at the same frequency is Simple.
- synchronization between sender and receiver has to be achieved in the time domain.
- Allocation is either fixed or dynamic.
- schemes can be combined with FDMA to achieve even greater flexibility and transmission capacity.

1. Fixed TDM

- allocating time slots for channels in a fixed pattern.
- results in a fixed bandwidth.
- only crucial factor is accessing the reserved time slot at the right moment.
- fixed pattern can be assigned by the base station.
- Fixed access pattern, fixed bandwidth and fixed delay.
- Up to 12 different mobile stations can use the same frequency without interference using foolowing scheme. Each connection is allotted its own up- and downlink pair.
- fixed access patterns, are perfectly apt for connections with a constant data rate.
- Drawback: very inefficient for bursty data or asymmetric connections.

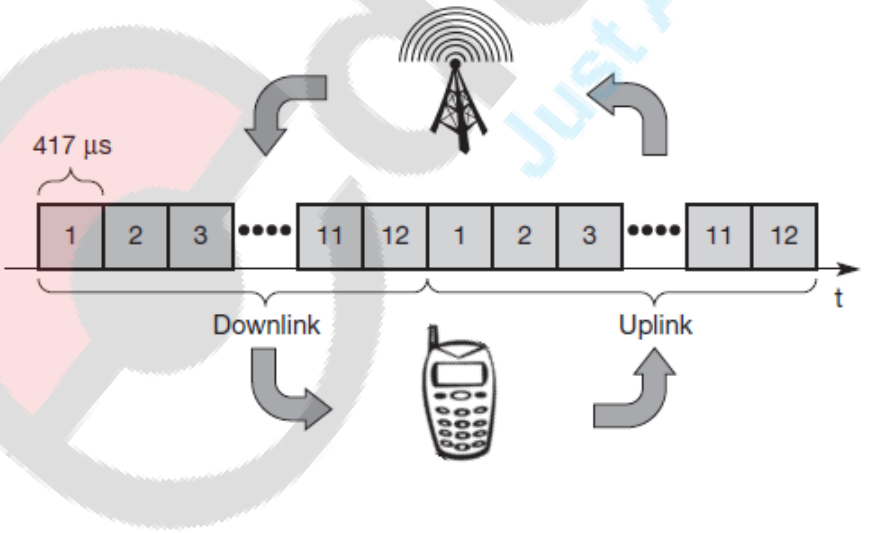
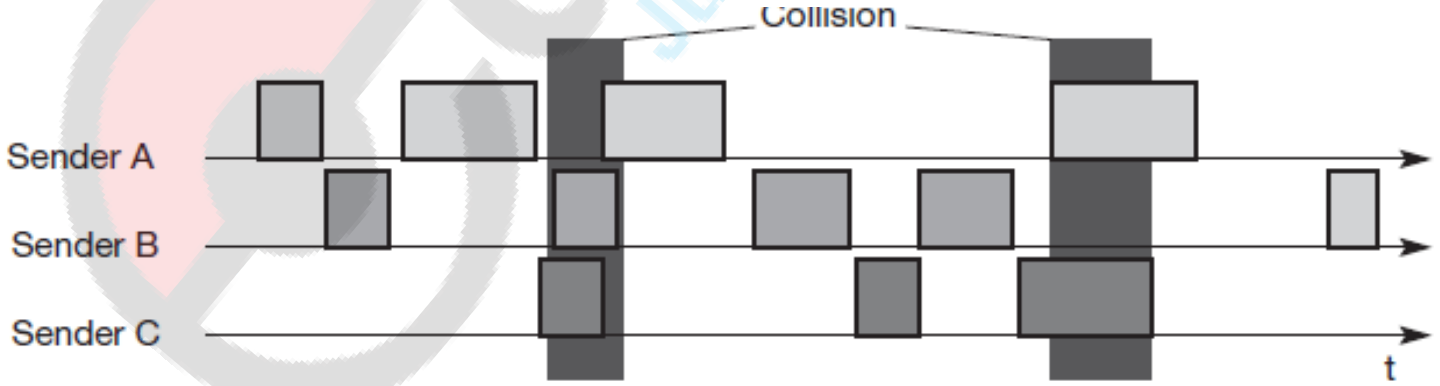


Figure 3.4
Time division multiplexing for multiple access and duplex

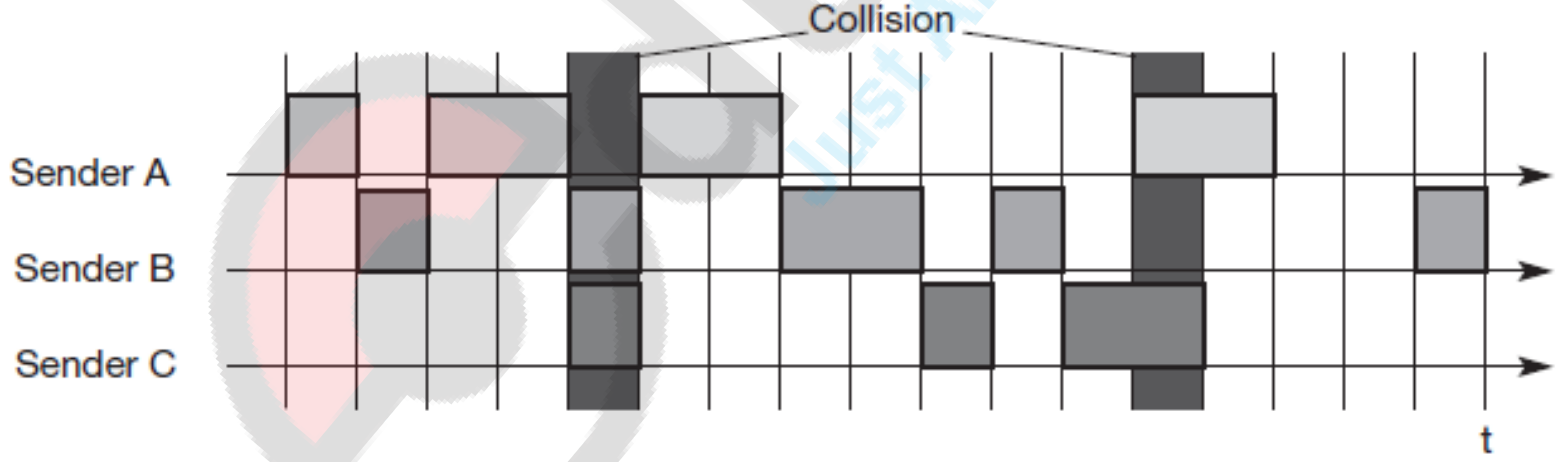
2. Classical Aloha

- TDM is applied without controlling Access.
- Aloha neither coordinates medium access nor does it resolve contention on the MAC layer. Instead, each station can access the medium at any time.
- 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).
- The simple Aloha works fine for a light load and does not require any complicated access mechanisms.



3. Slotted Aloha

- first refinement of the classical Aloha.
- The scheme provided by using different time slots i.e. slotted Aloha.
- all senders have to be synchronized, transmission can only start at the beginning of a time slot.
- Still, access is not coordinated.
- Aloha systems work perfectly well under a light load (as most schemes do), but they cannot give any hard transmission guarantees.



4. Carrier sense multiple access

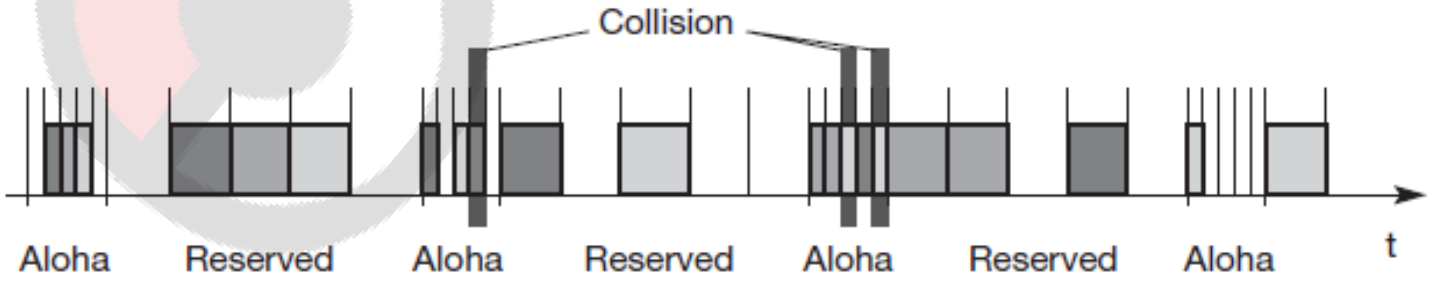
- sensing the carrier before accessing the Medium.
- Sensing the carrier and accessing the medium only if the carrier is idle decreases the probability of a collision.
- hidden terminals cannot be detected.
- so, if a hidden terminal transmits at the same time as another sender, a collision might occur at the receiver.
- This basic scheme is still used in most wireless LANs.

Improvement of Aloha systems- Reservation mechanism

- Reservation mechanisms and combinations with some (fixed) TDM patterns.
- These schemes typically have a reservation period followed by a transmission period.
- During the reservation period, stations can reserve future slots in the transmission period.
- While, depending on the scheme, collisions may occur during the reservation Period the transmission period can then be accessed without collision.
- Alternatively, the transmission period can be split into periods with and without Collision.
- These schemes cause a higher delay under a light load, but allow higher throughput due to less collisions.

5. Demand assigned multiple access/ Reservation Aloha

- Uses a reservation scheme. a scheme typical for satellite systems.
- has two modes, Aloha and reserved.
- During a contention phase following the slotted Aloha scheme, all stations can try to reserve future slots.
- Collisions during the reservation phase do not 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 (the others are destroyed) and sends back a reservation list indicating access rights for future slots.
- All ground stations have to obey this list.
- To maintain the fixed TDM pattern of reservation and transmission, the stations have to be synchronized from time to time.
- an explici



6. PRMA: packet reservation multiple access

- An **implicit reservation** scheme- slots can be reserved implicitly.
- A certain number of slots forms 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 currently free.
- A successful transmission of data is indicated by the station's name.
- All stations wishing to transmit can now compete for this free slot in Aloha fashion.
- Comination of fixed and random TDM schemes is used with reservation.
- As soon as a station has succeeded with a reservation, all future slots are implicitly reserved for this station. This ensures transmission with a guaranteed data rate.
- The slotted aloha scheme is used for idle slots only, data transmission is not destroyed by collision.

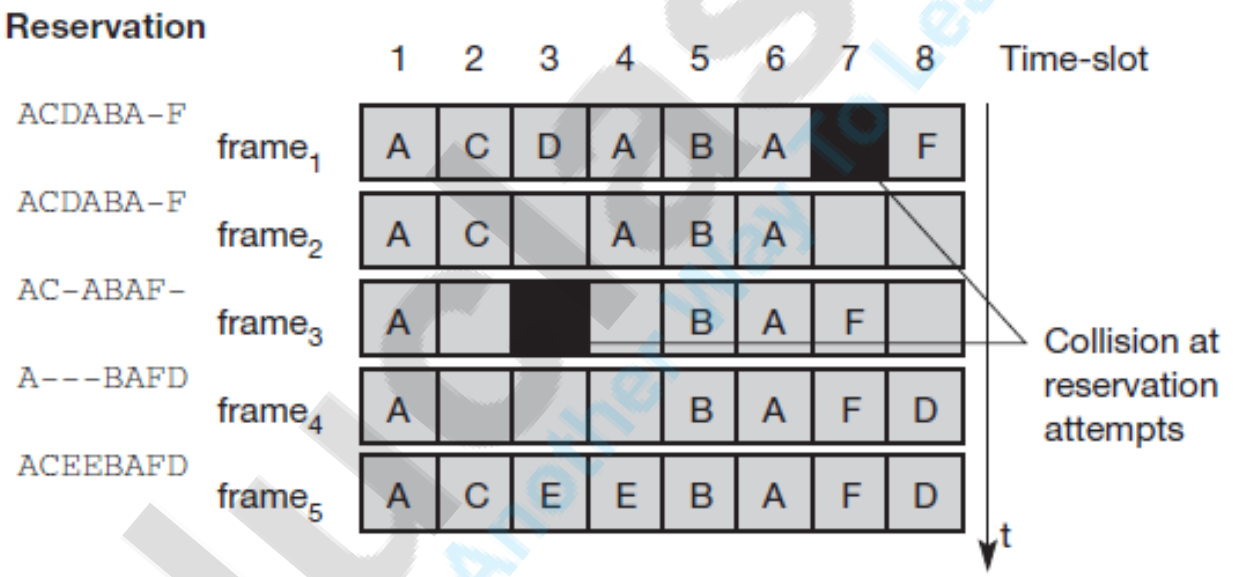
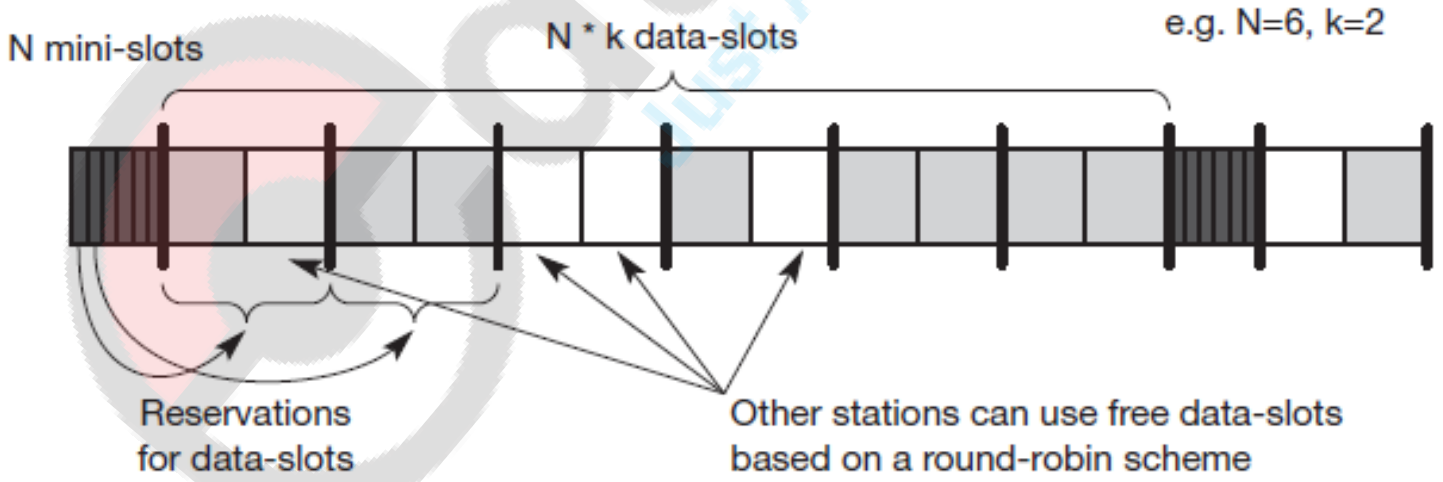


Figure 3.8
Demand assignment multiple access with implicit reservation

7. Reservation TDMA

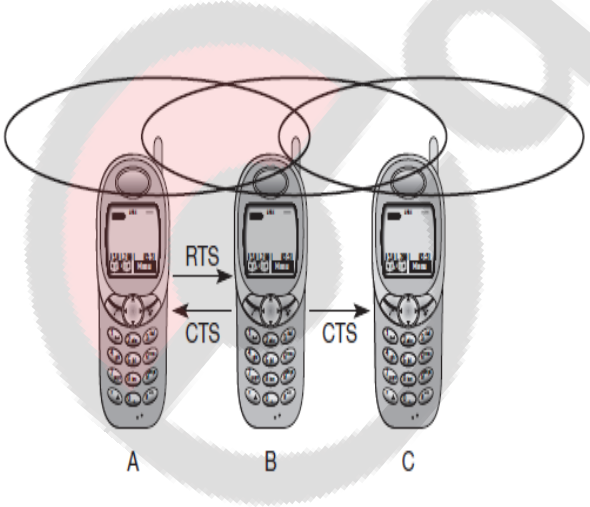
- In a fixed TDM scheme N mini-slots followed by N·k data-slots form a frame that is repeated.
- Each station is allotted its own mini-slot and can use it to reserve up to k data-slots.
- This guarantees each station a certain bandwidth and a fixed delay.
- Other stations can now send data in unused data-slots as shown.
- Using these free slots can be based on a simple round-robin scheme or can be uncoordinated using an Aloha scheme.



8. Multiple access with collision avoidance

- solves the hidden terminal problem, does not need a base station.
- a random access Aloha scheme – but with dynamic reservation.
- Problem oof hidden terminals and exposed terminals can be solved.
- Using RTS(Request to send) and CTS(Clear to send).
- collisions can occur during the sending of an RTS. Though probability is much lower.
- One problem of MACA is clearly the overheads associated with the RTS and CTS transmissions – for short and time-critical data packets.

Figure 3.10
MACA can avoid hidden terminals



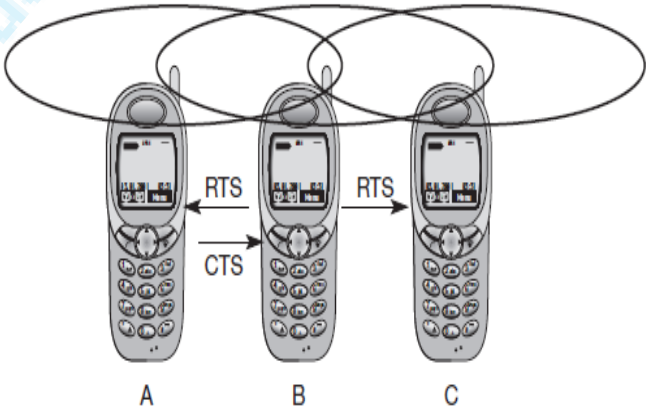


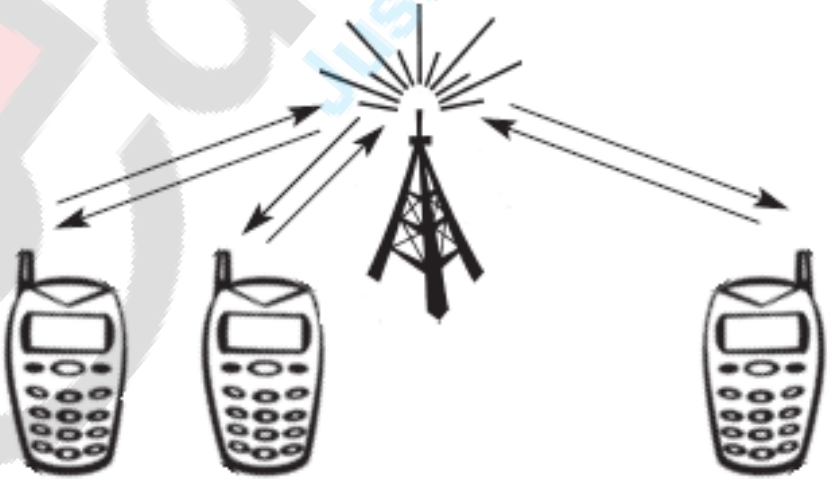
Figure 3.11
MACA can avoid exposed terminals

9. Polling

- Applied where one station is to be heard by all others.
- strictly centralized scheme with one master station and several slave stations.
- The master can poll the slaves according to many schemes: round robin, randomly, according to reservations 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.
- Similar scheme is used in Bluetooth wireless LAN.

10. Inhibit/ Digital sense multiple access

- used for the packet data transmission service, Cellular Digital Packet Data (CDPD) in the AMPS mobile phone system.
- Here, the base station only signals a busy medium via a busy tone (called BUSY/IDLE 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.
- In case of collisions, additional back-off and retransmission mechanisms are implemented.



Code division multiple access (CDMA)

- codes with certain characteristics can be applied to the transmission.
- use exactly these codes to separate different users in code space and to enable access to a shared medium without interference.
- The main problem is how to find “good” codes and how to separate the signal from noise generated by other signals and the environment.
- Orthogonality and Auto-correlation.

Comparison of SDMA, TDMA, FDMA, and CDMA mechanisms

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 km^2	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

References

Mobile Communications, Second Edition, Jochen Schiller, Pearson Education- Chapter 3

University Questions

1. Write a short note on Hidden and Exposed Terminals- Nov 16- 5M.