Mobile Computing – Medium Access Control

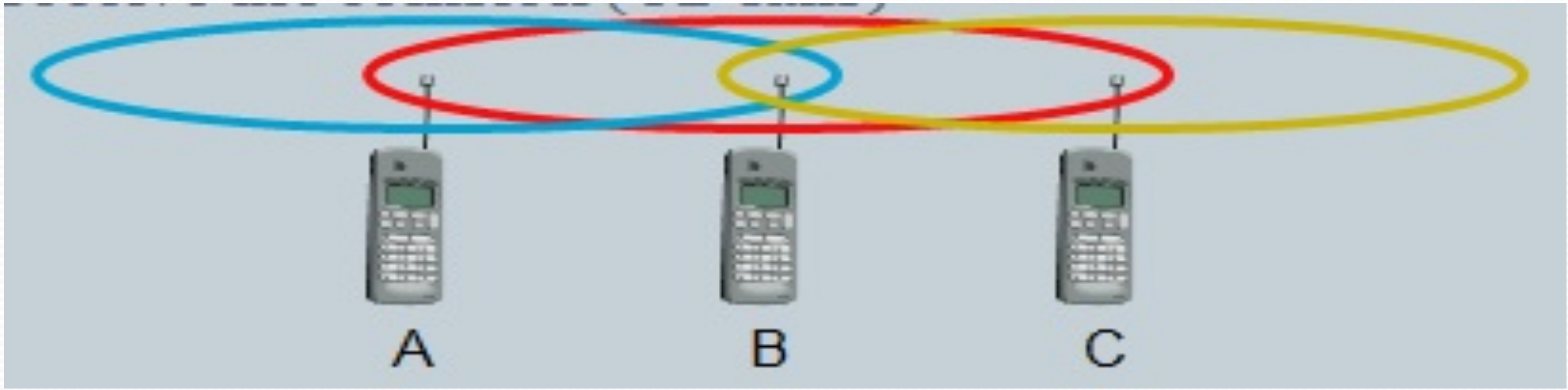
- **MAC**: It comprises all mechanisms that regulate user access to a medium using SDM, TDM, FDM or CDM
  - MAC belongs to layer 2, i.e DLL
    - DLL is subdivided into logical link control (LLC) & MAC
  - DLL: Is used to establish a reliable point to point or point to multi-point connection between different devices
- **MAC** – Wired Mode
  - Makes use of CSMA/CD – Carrier Sense Multiple Access with Collision Detection
    - Sender senses the medium to see if it is free.
      - If it is free, sender transmits the data, otherwise it waits
      - If sender detects a collision while sending, it stops and sends a jamming signal

MAC Scenario – Wireless Mode

- In wireless mode sender does not have mechanism of knowing the failure/collision
- CSMA/CD is interested in knowing the collision at the receiver
  - The strength of the signal reduces from sender to the receiver (based on distance)
    - Obstacles attenuate the signal
  - It tries to detect collision at the receiver
    - Collision may happen at the receiver due to second sender
  - **Collision Detection**: sender detects no collision and assumes that the data has been transmitted without errors.

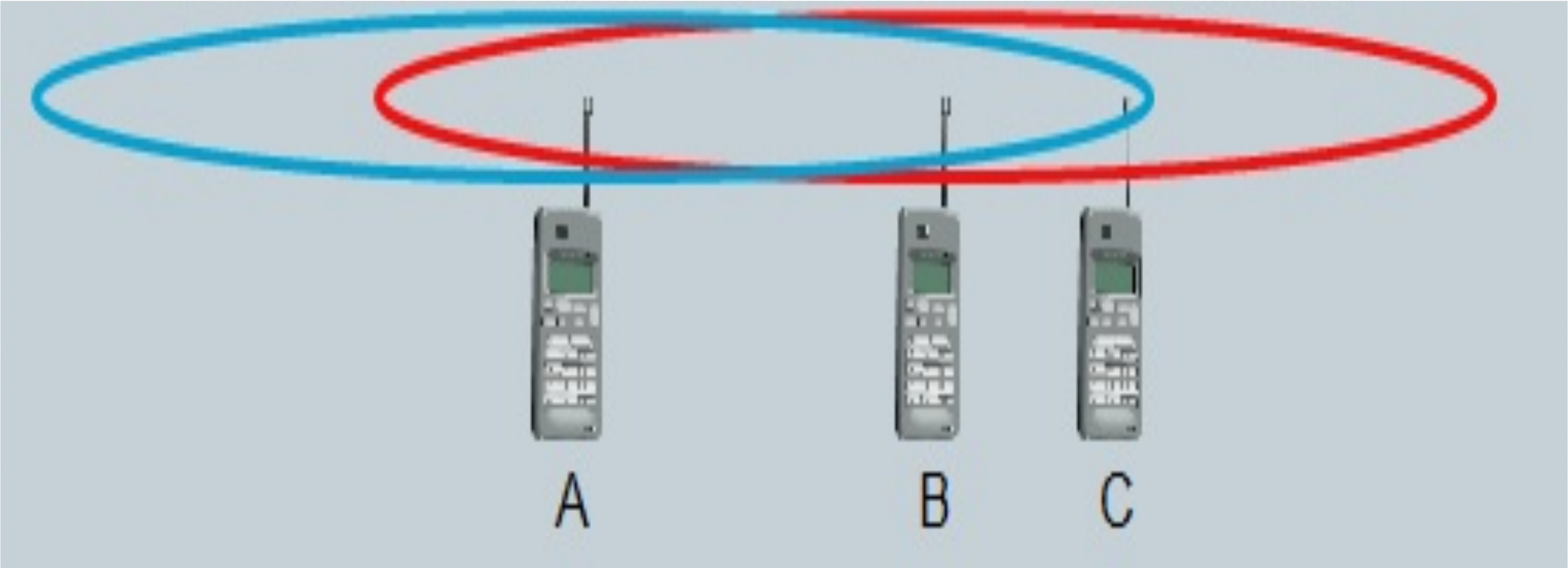
Hidden & Exposed Terminals

- Hidden terminals
  - A sends to B, C cannot receive A
  - C wants to send to B, C senses a "free" medium (CS fails)
  - Collision at B, A cannot receive the collision (CD fails)
  - A is "hidden" for C
- Exposed terminals
  - B sends to A, C wants to send to another terminal (not A or B)
  - C has to wait, CS signals a medium in use
  - But A is outside the radio range of C, therefore waiting is not necessary
  - C is "exposed" to B



Near & Far Terminals

- Terminals A & B sends, C receives
  - Signal strength reduces proportional to the square of the distance
  - Signal of B may drown out A's signal
  - C cannot receive A's signal



Access Methods SDMA/FDMA/TDMA

- SDMA (Space Division Multiple Access)
  - segment space into sectors, use directed antennas
  - cell structure
- FDMA (Frequency Division Multiple Access)
  - assign a certain frequency to a transmission channel between a sender and a receiver
  - permanent (e.g., radio broadcast), slow hopping (e.g., GSM), fast hopping (FHSS, Frequency Hopping Spread Spectrum)
- TDMA (Time Division Multiple Access)
  - assign the fixed sending frequency to a transmission channel between a sender and a receiver for a certain amount of time

Space Division Multiple Access (SDMA)

- SDMA is used to allocate a separate space to users in wireless networks.
  - Application involves assigning an optimal base station to a mobile phone user.
  - Mobile phone may receive several base stations with different quality.
    - MAC algorithm decides which base station is best, depending on which frequencies (FDM), time slots (TDM), or code (CDM) are available.
  - The basis for SDMA is formed by cells and sectorized antennas

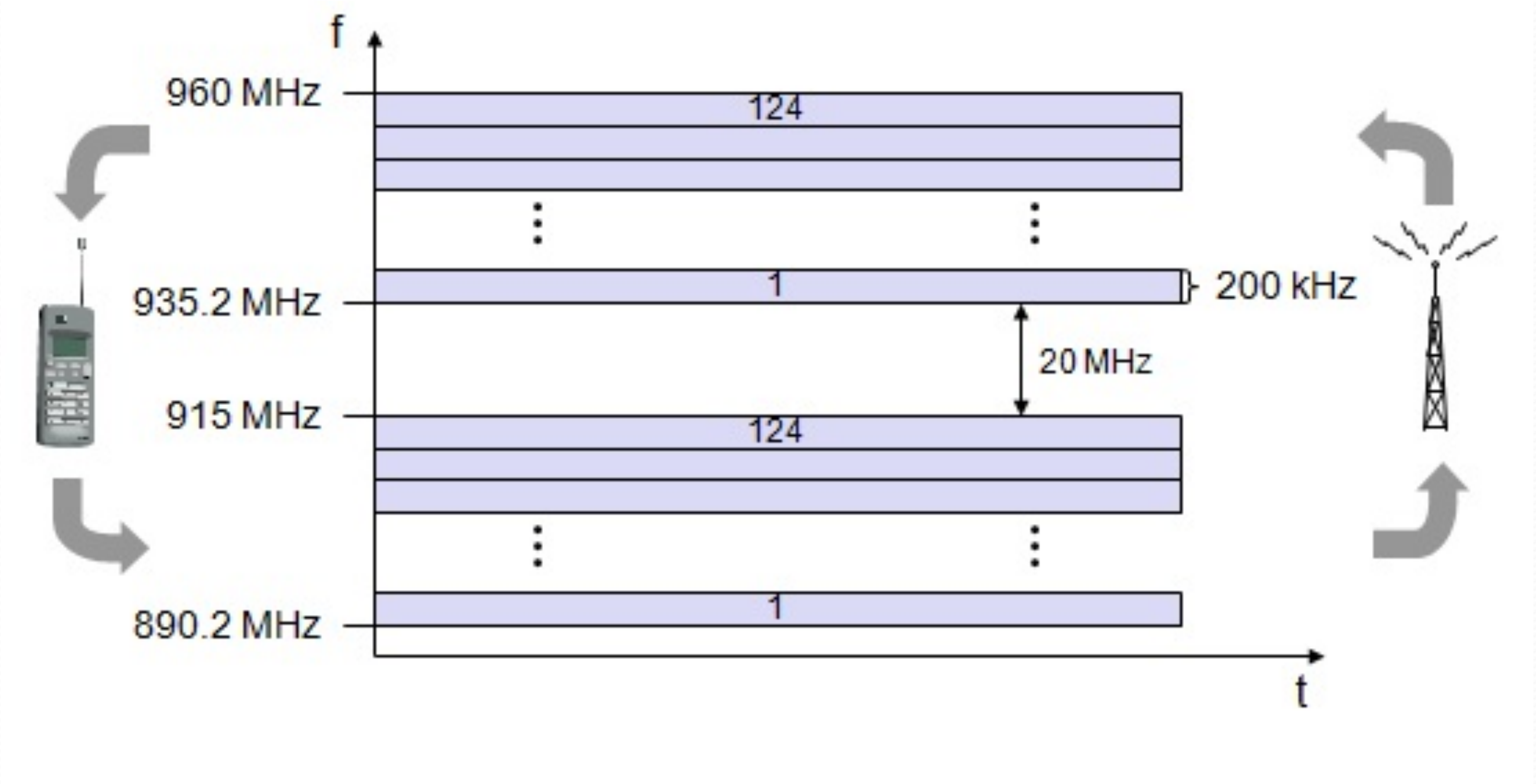
Frequency Division Multiple Access (FDMA)

- FDMA allocates frequencies to transmission channels using FDM.
  - Allocation can be either fixed or dynamic (demand driven)
- FDMA patterns
  - Pure FDMA: channels assigned the same frequency at all times
  - FDMA –TDMA- channel frequency is changed according to pattern
    - To reduce narrowband interference at certain frequencies
      - Sender and receiver have to agree on a hopping pattern

(FDMA) – Frequency Division Duplex (FDD)

- FDD: simultaneous access to the medium by base station and mobile station in cellular networks
  - E.g by using **duplex channel**
    - Channel that allows for simultaneous transmission in both directions.
    - Mobile station to base station and vice versa are separated using different frequencies
    - **Frequencies:**
      - **Uplink:** used from mobile station to base station or from ground control to satellite
      - **Downlink:** used from base station to mobile station or from satellite to ground control.

FDMA) – Frequency Division Duplex (FDD) - Example



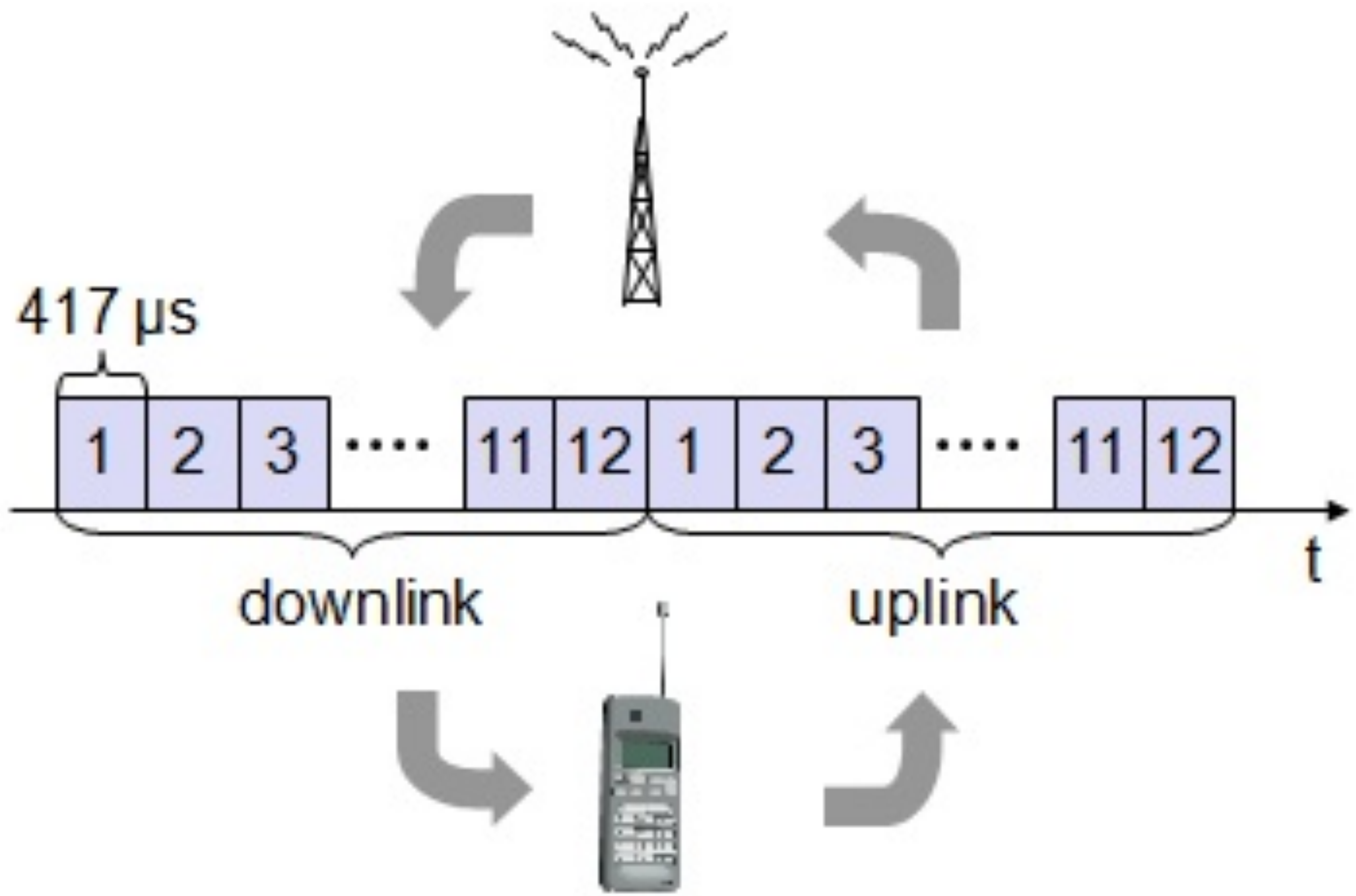
Time Division Multiple Access (TDMA)

- Uses TDM – receiver can stay at the same frequency at one particular time
  - E.g the ethernet technology
- TDMA patterns
  - Fixed TDMA: By allocating certain time slot for a channel
  - Dynamic TDMA: It requires identification for each transmission by using MAC address.
    - Identification enables a receiver in a broadcast medium to recognize if it is really is the **intended receiver of a message**.

Time Division Multiple Access (TDMA) – Fixed TDM

- It allocates fixed bandwidth
- Each mobile station knows its turn and no interference will happen
- **Advantages:**
  - It fits well for connections with a fixed bandwidth
  - It guarantees a fixed delay
- Time Division Duplex (TDD):
  - Assigns different slots for uplink and downlink using same frequency
    - Base station uses one of the slot
    - Mobile station uses one of the slot
    - **Advantages:** suitable for connections with constant data rate
      - e.g for voice data
    - **Disadvantages:** Inefficient for bursty data
      - e.g browsed data, video files, link, buttons etc

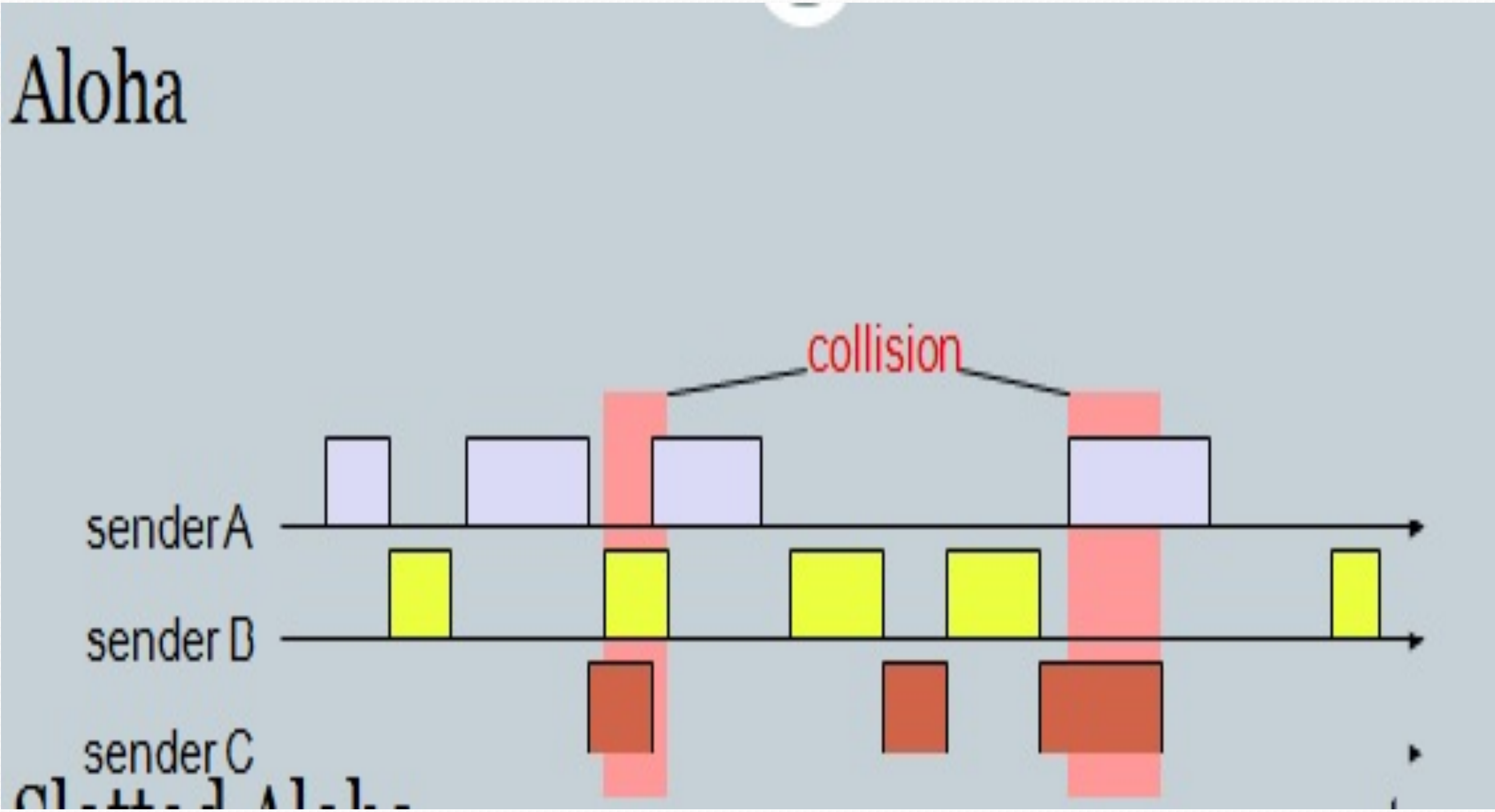
Time Division Duplex - Example



Time Division Multiple Access (TDMA) – Classical Aloha

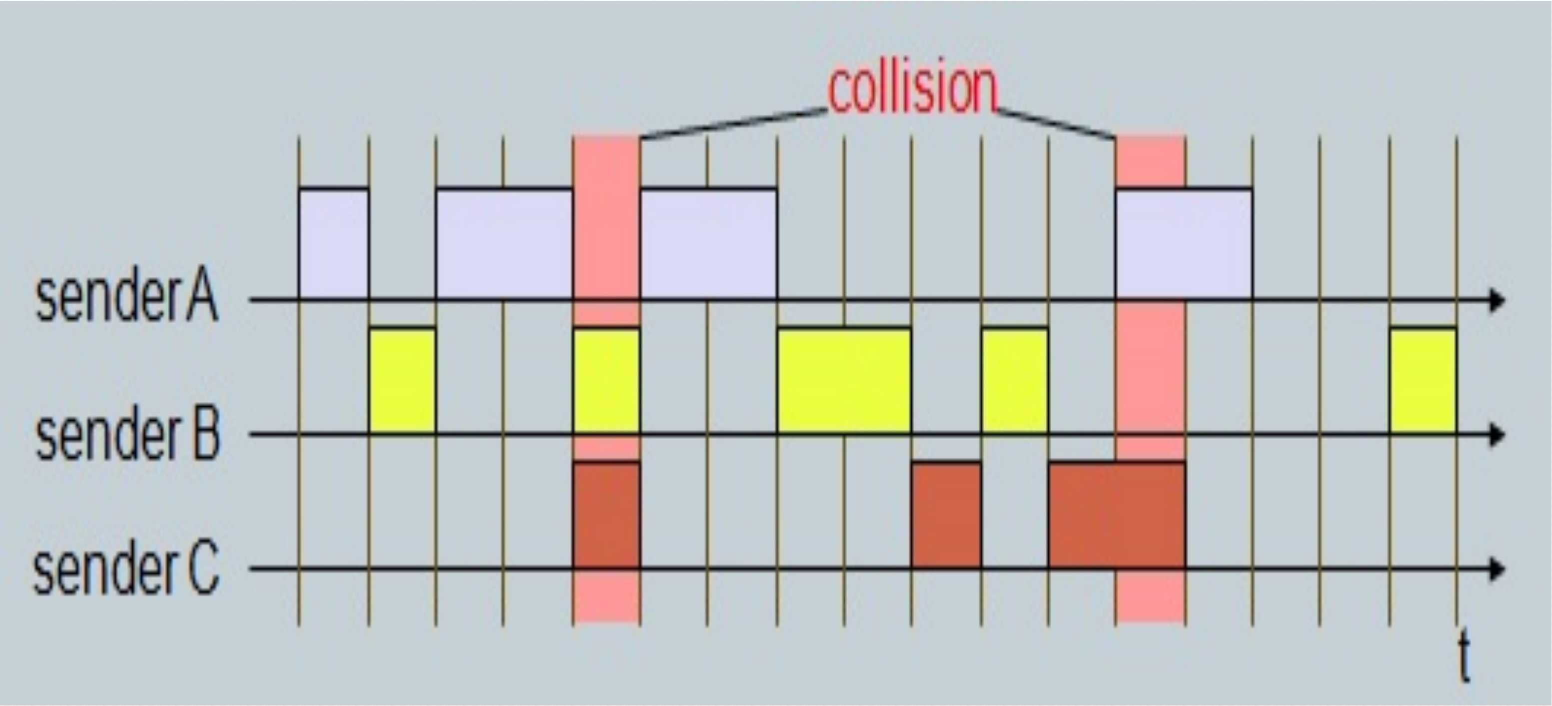
- **Classical Aloha**: It is TDMA scheme – invented at the university of Hawaii and was used in the ALOHANET (Additive Links On-Line Hawaii Area)
  - It allows TDM to be allowed without controlling access
    - It neither coordinates medium access nor does it resolve contention on the MAC layer.
    - It allows each station to access the medium at any time (**Random access scheme)** – without a central arbiter controlling access and without coordination among the stations.
    - If the collision happens between two or more stations, data is destroyed
    - Collision problem is left out to higher layers.
  - **Disadvantage:** It cannot handle higher data load

(TDMA) – Classical Aloha - Example



Time Division Multiple Access (TDMA) – Slotted Aloha

- Slotted Aloha: data is sent as per slots
  - All senders have to be synchronized, transmission can only start at the beginning of a time slot
  - Achieves throughput double that of classical Aloha



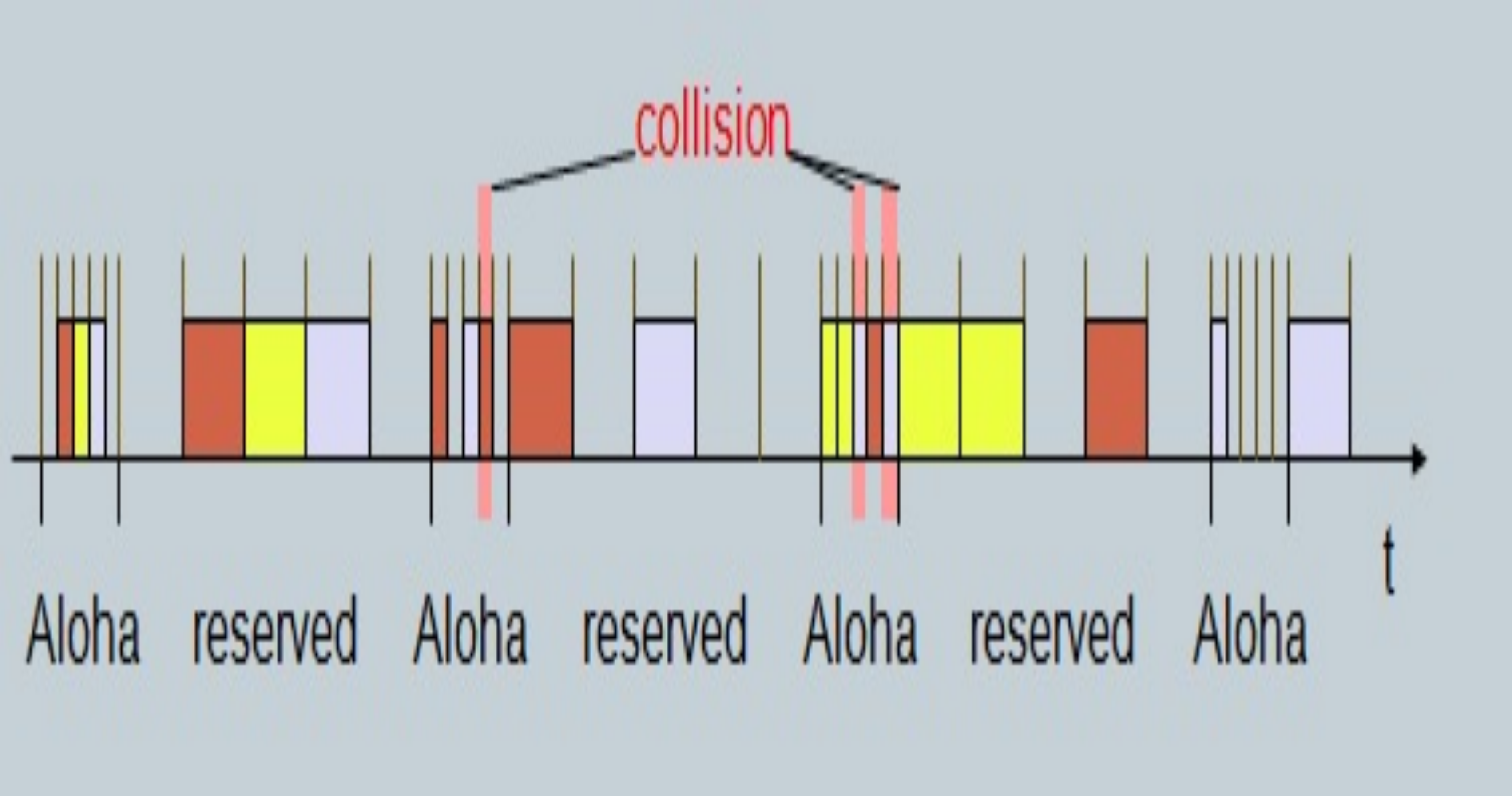
(TDMA) – Carrier Sense Multiple Access

- CSMA – Improvement over basic ALOHA
  - Senses the carrier and accesses the medium only if the carrier is idle
    - Decreases the probability of a collision.
- **Schemes of CSMA:**
  - Non-persistent CSMA:
    - stations sense the carrier and start sending immediately if the medium is idle.
    - If the medium is busy, station waits and tries again and the pattern repeats
  - P-persistent CSMA:
    - Access is slotted, stations sense the medium with probability of p.
    - Next slot with 1-p probability
  - 1-persistent CSMA:
    - All stations try to access the medium together
    - Causes many collisions
- **CSMA – CA:**
  - Solution for CSMA:
    - To reduce collisions by Collision Avoidance

(TDMA) – Demand Assigned Multiple Access (DAMA)

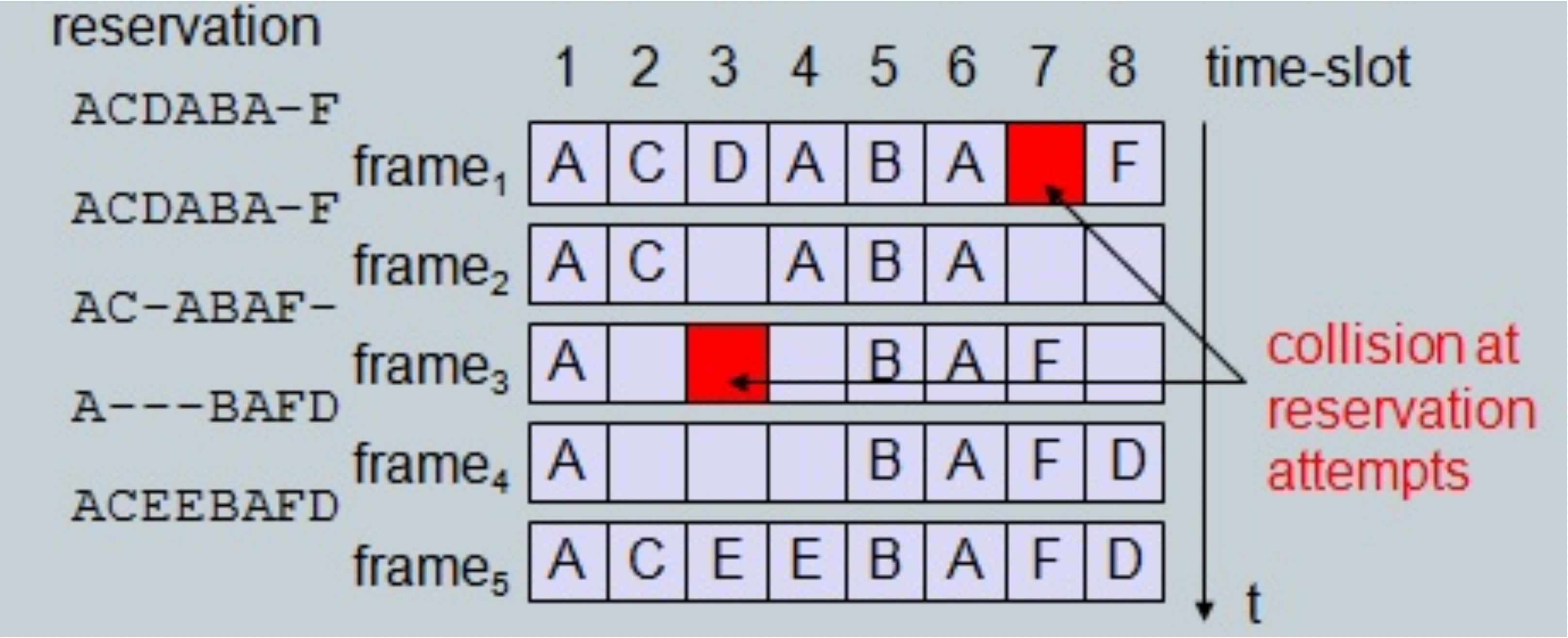
- It works on reservation mechanism:
  - Station reserves a future time slot
  - Sending within this reserved time-slot is possible without collision.
  - They cause higher delays since waiting time is involved
  - Allows higher throughput due to less collisions
- **Reservation Aloha:**
  - Example of **explicit** reservation
  - During the contention phase following the slotted aloha scheme, all stations try to reserve the slots.
    - E.g stations on earth trying to reserve access time for satellite transmission.
  - Time slot in the future is reserved and satellite collects successful requests
    - Sends back reservation list to ground stations & all stations obey this list

Demand Assigned Multiple Access (DAMA) – Explicit Example



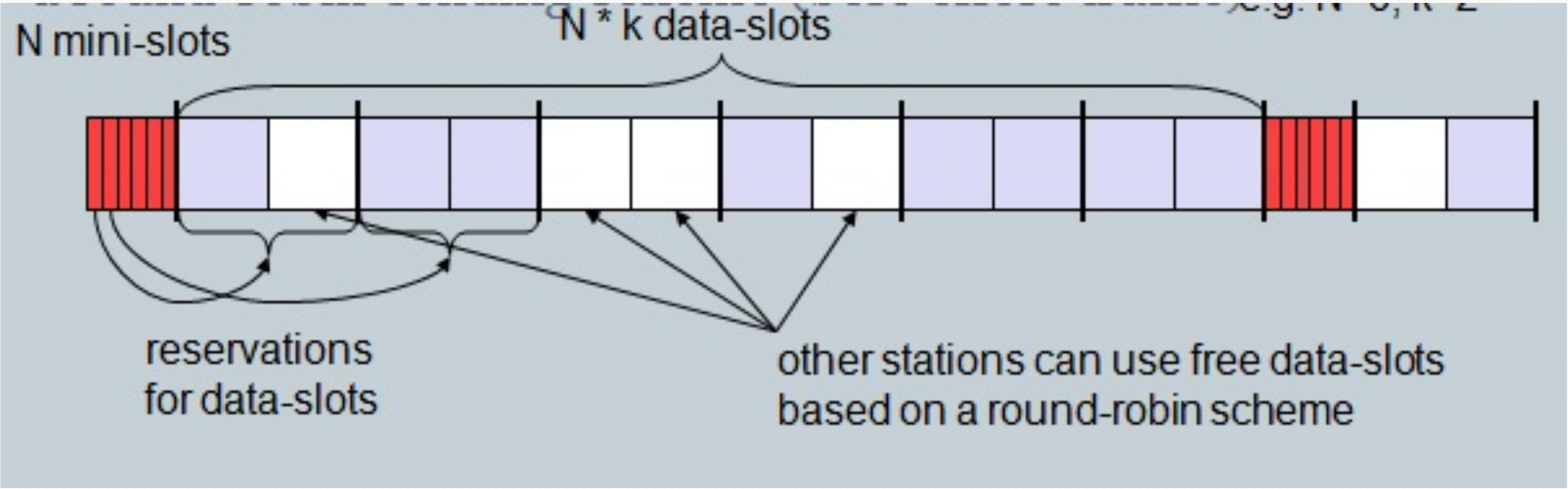
(TDMA) – Packet Reservation Multiple Access (PRMA)

- Slots are reserved implicitly
- Slots forms a frame, frame is repeated in time
- Base station (e.g satellite) broadcasts the status of each slot



(TDMA) – Reservation TDMA

- Every frame consists of N mini-slots and k data slots
- Every station has its own mini-slot and can reserve up to k data-slots using (x=N * k)
- Other stations can send data in unused data-slots according to round robin sending scheme, e.g N=6, k=2

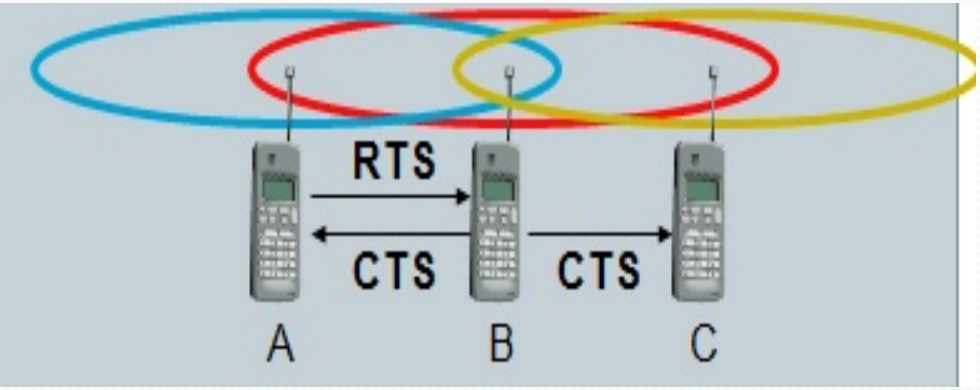


(TDMA) – Multiple Access with Collision Avoidance (MACA)

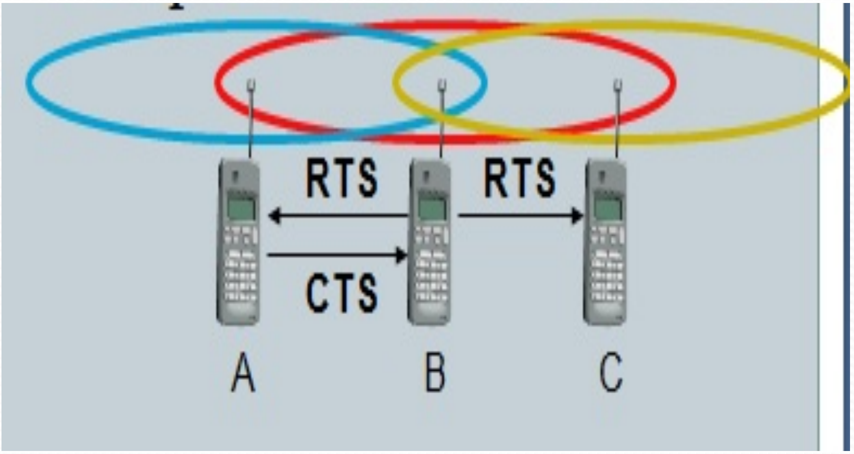
- MACA uses short signaling packets for collision avoidance
  - RTS (request to send): a sender request the right to send from a receiver with a short RTS packet before it sends a data packet.
  - CTS (clear to send): the receiver grants the right to send as soon as it is ready to receive.
- Signaling packets contain
  - Sender address
  - Receiver address
  - Packet size

MACA examples

- MACA avoids the problem of hidden terminals
  - A and C want to send to B
  - A sends RTS first
  - C waits after receiving CTS from B



- MACA avoids the problem of exposed terminals
  - B wants to send to A, C to another terminal
  - now C does not have to wait for it cannot receive CTS from A



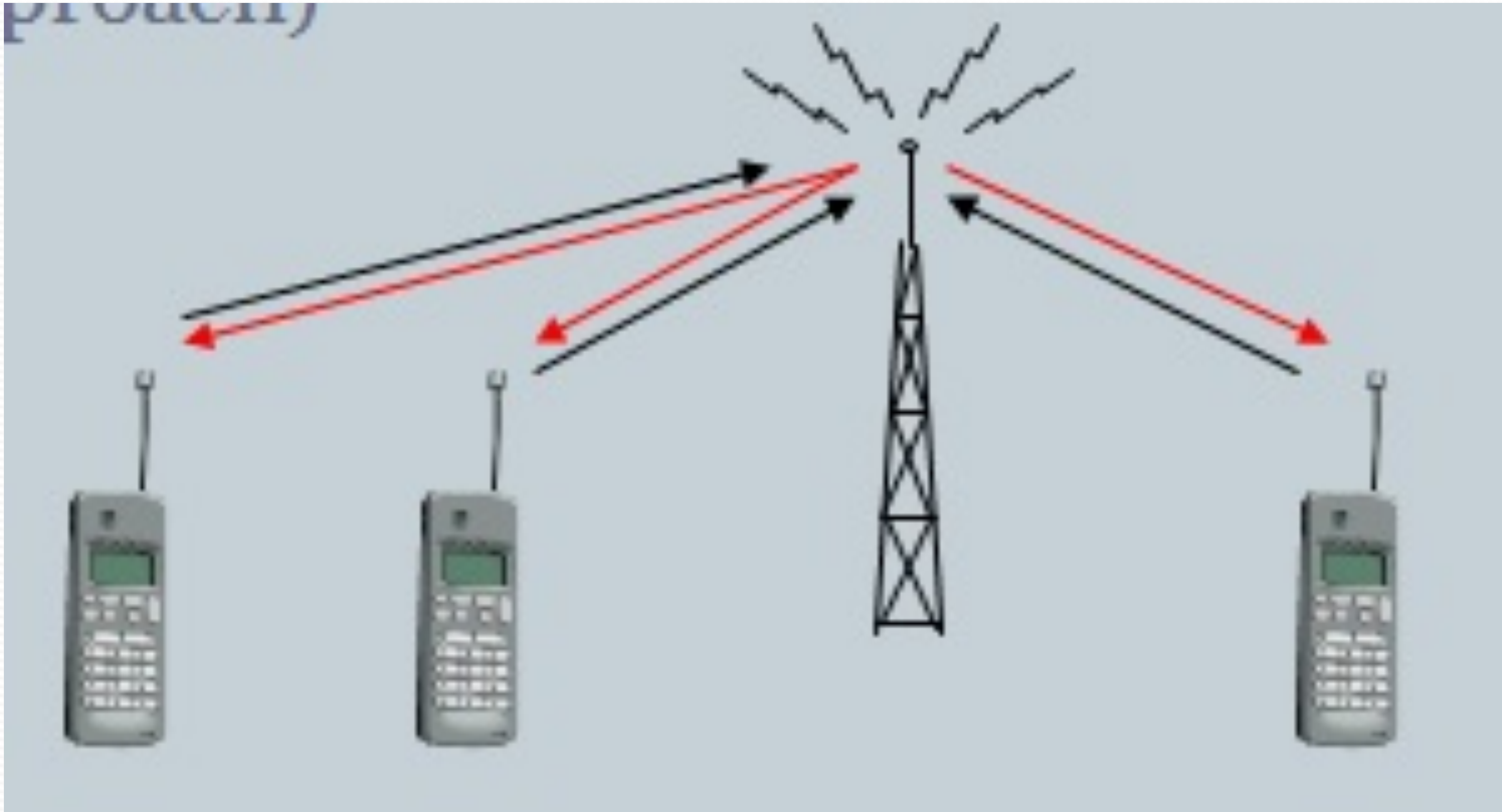
(TDMA) - Polling

- Base station can poll all other terminals according to a certain scheme
- Example: Randomly Addressed Polling
  - base station signals readiness to all mobile terminals
  - terminals ready to send can now transmit a random number without collision with the help of CDMA or FDMA (the random number can be seen as dynamic address)
  - the base station now chooses one address for polling from the list of all random numbers (collision if two terminals choose the same address)
  - the base station acknowledges correct packets and continues polling the next terminal
  - this cycle starts again after polling all terminals of the list

(TDMA)- Inhibit Sense Multiple Access (ISMA)

- Current state of the medium is signaled via a "busy tone"
  - the base station signals on the downlink (base station to terminals) if the medium is free or not
  - terminals must not send if the medium is busy
  - terminals can access the medium as soon as the busy tone stops
  - the base station signals collisions and successful transmissions via the busy tone and acknowledgements, respectively (media access is not coordinated within this approach)

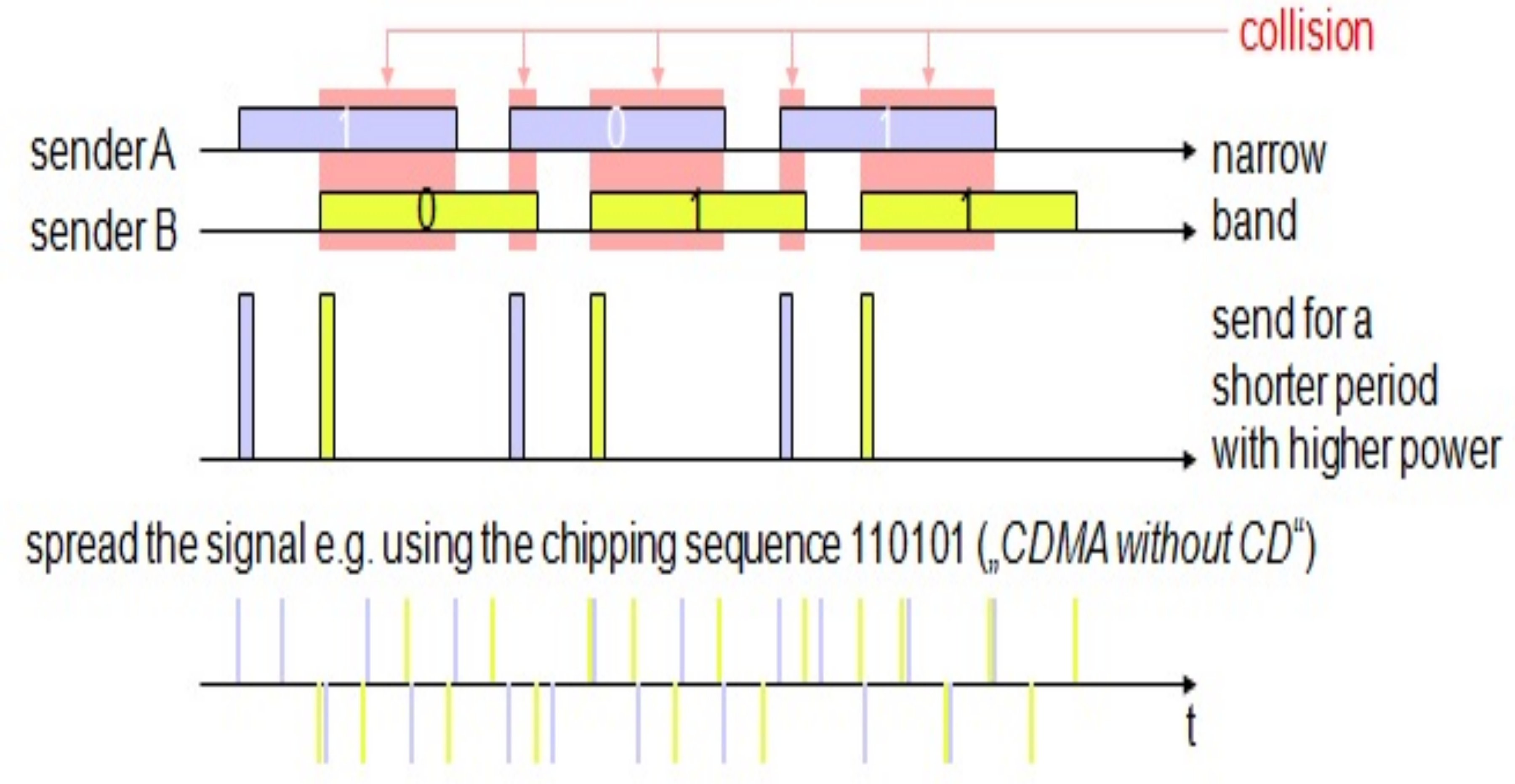
Inhibit Sense Multiple Access



Access Methods - CDMA

- Uses codes to separate different users in code space and enables access to a shared medium without interference.
- **Challenges**
  - It requires receiver to be able to decode n different codes
  - Complexity needed for CDMA is integrated in the base stations
  - Bursty traffic creates overhead in CDMA technique.
    - E.g ad-hoc networks
- **Solution**
  - Spread Aloha Multiple Access (SAMA)
    - Combine spreading of CDMA and the medium access Aloha
    - Makes use of a single code for all senders in slots

CDMA – Spread Aloha Multiple Access (SAMA)



Comparisons of SDMA/TDMA/FDMA/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, 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