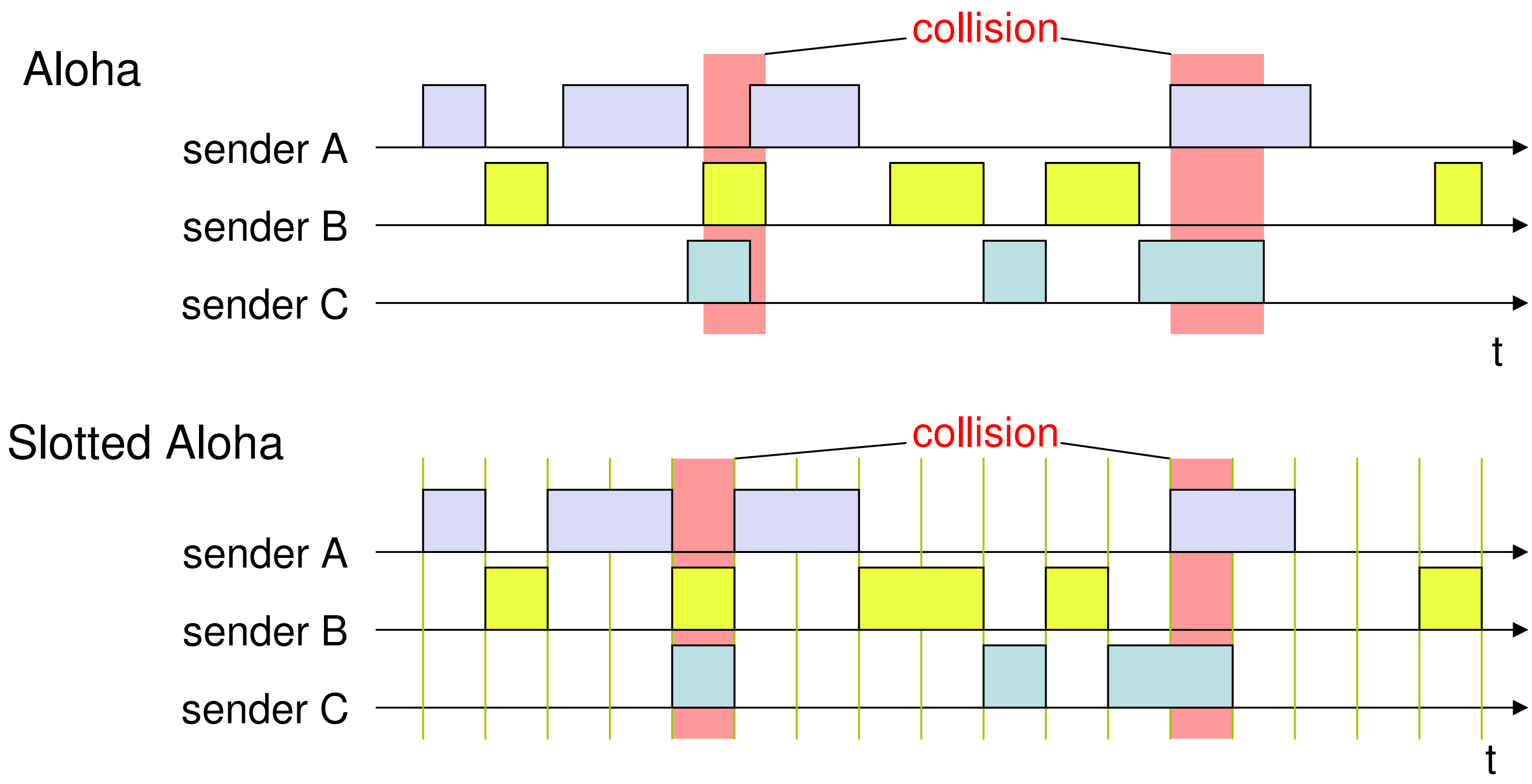
CSMA

2/13/06

Aloha and slotted aloha

- Slotted aloha: transmissions are synchronized and only start at the beginning of a time slot.



Aloha schemes

- Random schemes, simple.
- Good for initial call setup.

- Channel efficiency only 18% for Aloha, 36% for Slotted Aloha (assuming Poisson distribution for packet arrival and packet length)
- No delay guarantee.

- Combine Aloha with other schemes.

Improvement I: sense the carrier before access the medium

Evolution

- Aloha: invented in the 70s.
- Slotted Aloha: only transmit at the beginning of a time slot.
- CSMA: Carrier Sense Multiple Access, Start transmission only if no transmission is ongoing
- CSMA/CD: CD = Collision Detection. Stop ongoing transmission if a collision is detected (e.g. Ethernet).

CSMA

- Non-persistent CSMA: stations sense the carrier and start sending immediately if the medium is idle; otherwise wait for a random amount of time and retry.
- P-persistent CSMA: sense the carrier and if idle, only transmit with probability p; defer to the next slot with probability 1-p.
- 1-persistent CSMA: many stations listen and transmit at the same time which causes collisions.

Random backoff

- Non-persistent CSMA: stations sense the carrier and start sending immediately if the medium is idle; otherwise wait for a random amount of time (K) and retry.

Exponential Backoff:

- 1st collision: choose K randomly from [0, T].
- 2nd collision: choose K randomly from [0, 2T].
- after next collision double K (and keep doubling on collisions until success.

Random backoff

- Probability of retransmission attempt (equivalently length of randomization interval) adapted to current load
  - simple, load-adaptive, multiple access

more collisions → heavier Load (most likely), more nodes trying to send → randomize retransmissions over longer time interval, to reduce collision probability

MAC in wireless networks

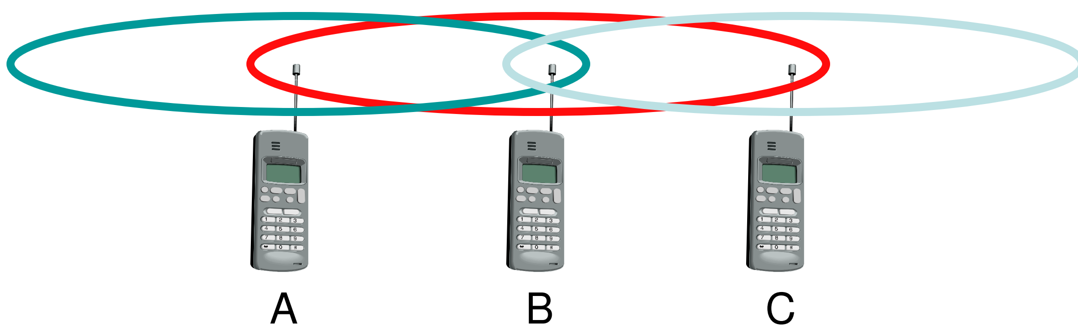
- Can we apply media access methods from fixed networks?
- Example CSMA/CD
  - **C**arrier **S**ense **M**ultiple **A**ccess with **C**ollision **D**etection
  - send as soon as the medium is free, listen into the medium if a collision occurs (original method in IEEE 802.3)

CDMA/CD in wireless networks

- Problems in wireless networks
  - signal strength decreases proportional to the square of the distance
  - the sender would apply CS and CD, but the collisions happen at the receiver
  - it might be the case that a sender cannot “hear” the collision, i.e., CD does not work
  - furthermore, CS might not work if, e.g., a terminal is “hidden”

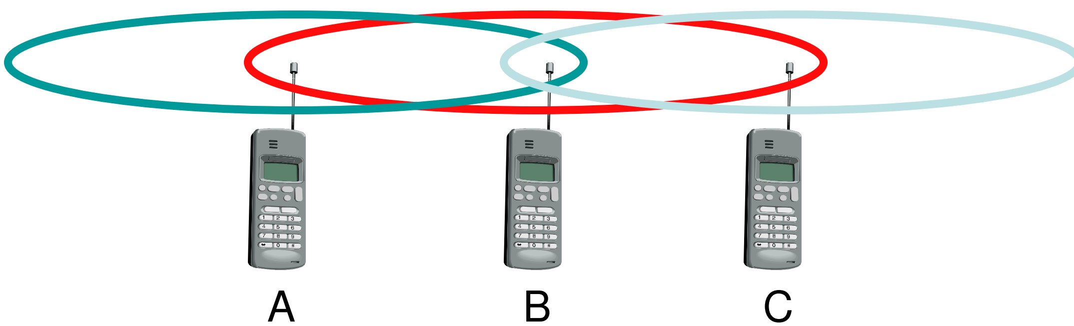
Hidden terminals

- 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

- 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

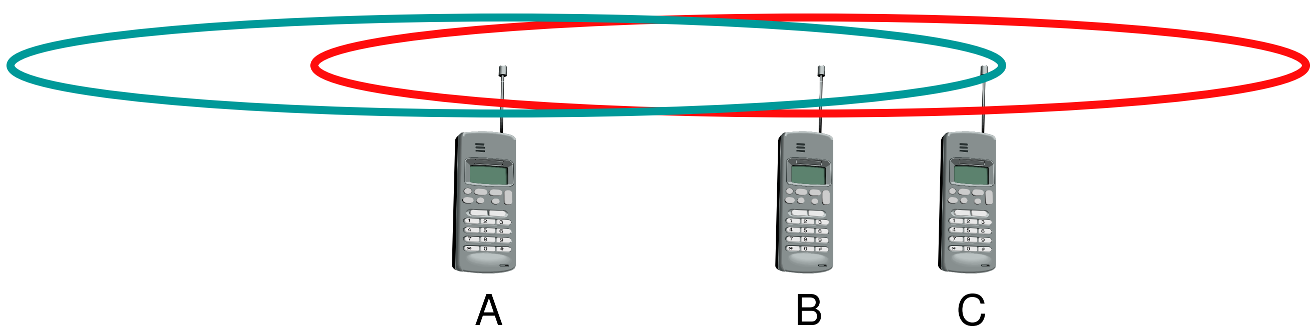


The problem with CSMA/CD

- Carrier sense and collision detection are performed at the transmitter, not the receiver.
- But only collision at the receiver matters.

Near and far terminals

- Terminals A and B send, C receives
  - signal strength decreases proportional to the square of the distance
  - the signal of terminal B therefore drowns out A's signal
  - C cannot receive A
- precise power control needed!

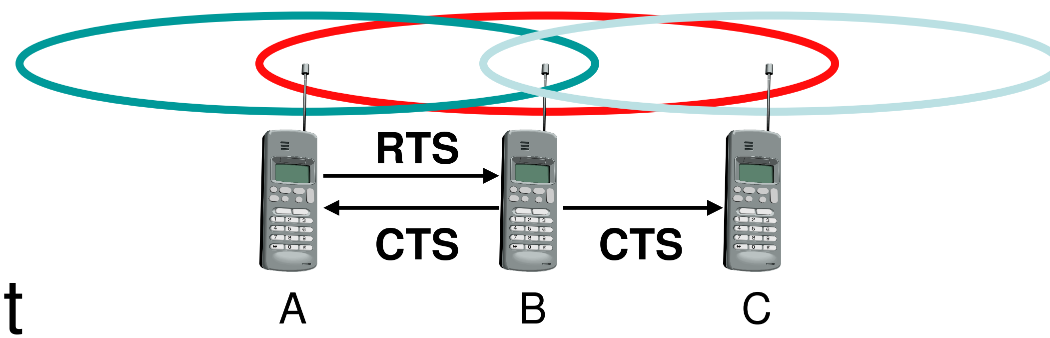


MACA - collision avoidance

- MACA (Multiple Access with Collision Avoidance) 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

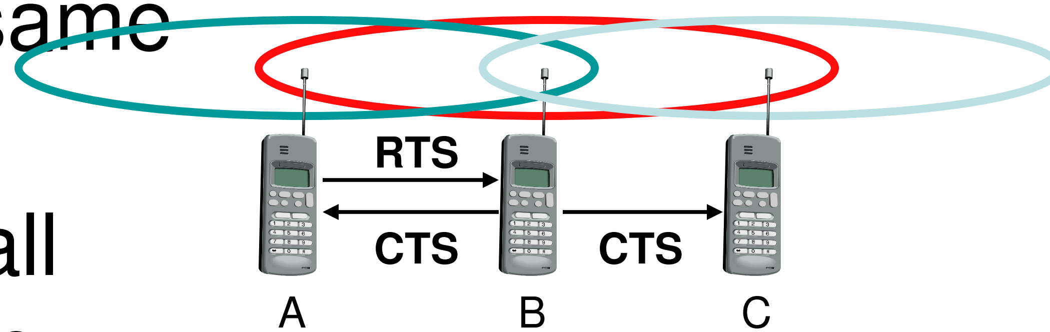
MACA: hidden terminals

- 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



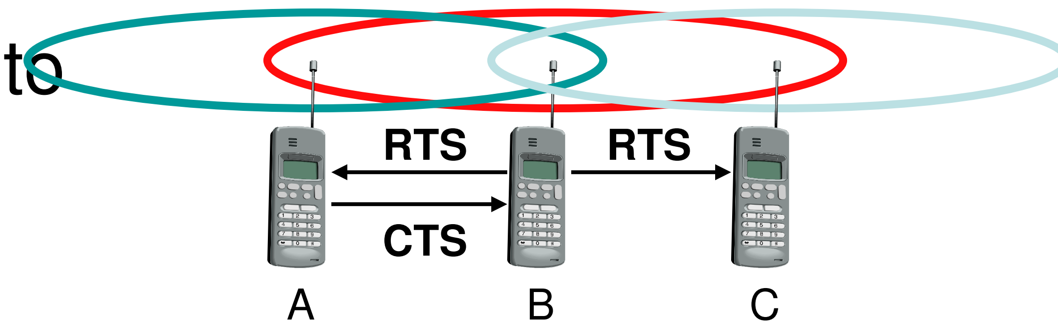
Does this fully solve the problem?

- RTS can still collide.
- Both A and C send RTS to B at the same time.
- But RTS is a small size packet so the chance of collision is much lower.

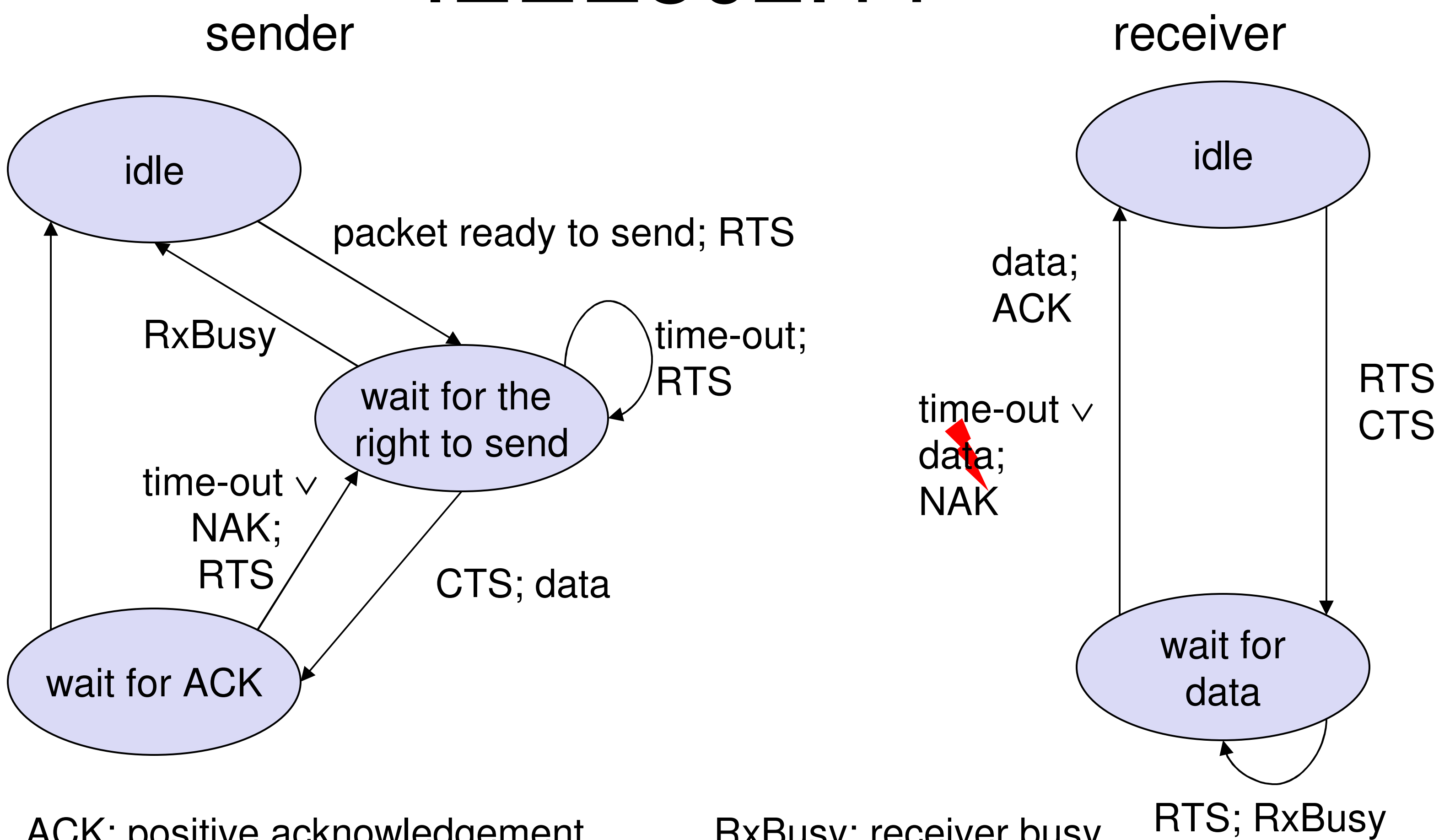


MACA: exposed terminals

- 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



MACA variant: DFWMAC in IEEE802.11



ACK: positive acknowledgement
NAK: negative acknowledgement

RxBusy: receiver busy

Improvement II: make reservations

Demand Assigned Multiple Access

- Channel efficiency only 18% for Aloha, 36% for Slotted Aloha (assuming Poisson distribution for packet arrival and packet length)
- Reservation can increase efficiency to 80%
  - a sender *reserves* a future time-slot
  - sending within this reserved time-slot is possible without collision
  - reservation also causes higher delays
  - typical scheme for satellite links

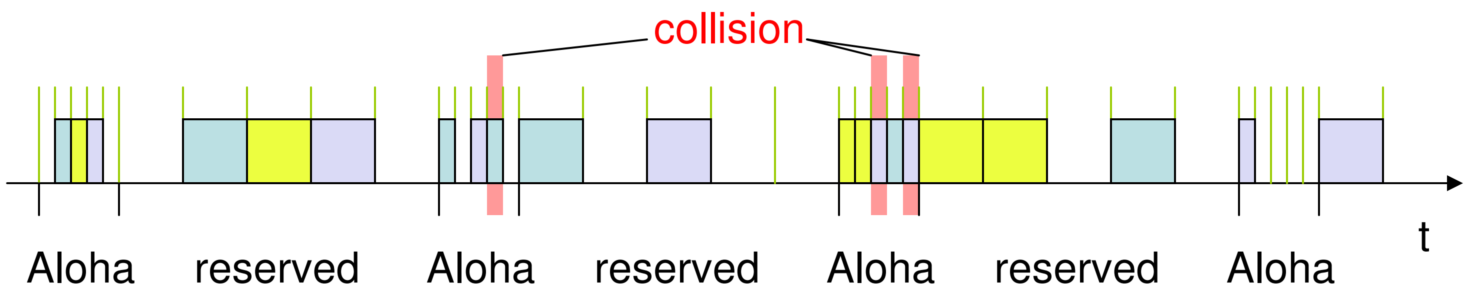
Demand Assigned Multiple Access

- Examples for reservation algorithms:
  - Explicit Reservation according to Roberts (Reservation-ALOHA)
  - Implicit Reservation (PRMA)
  - Reservation-TDMA

Access method DAMA: Explicit Reservation

- Explicit Reservation (Reservation Aloha):
  - two modes:
    - *ALOHA mode* for reservation: competition for small reservation slots, collisions possible
    - *reserved mode* for data transmission within successful reserved slots (no collisions possible)
  - it is important for all stations to keep the reservation list consistent at any point in time and, therefore, all stations have to synchronize from time to time

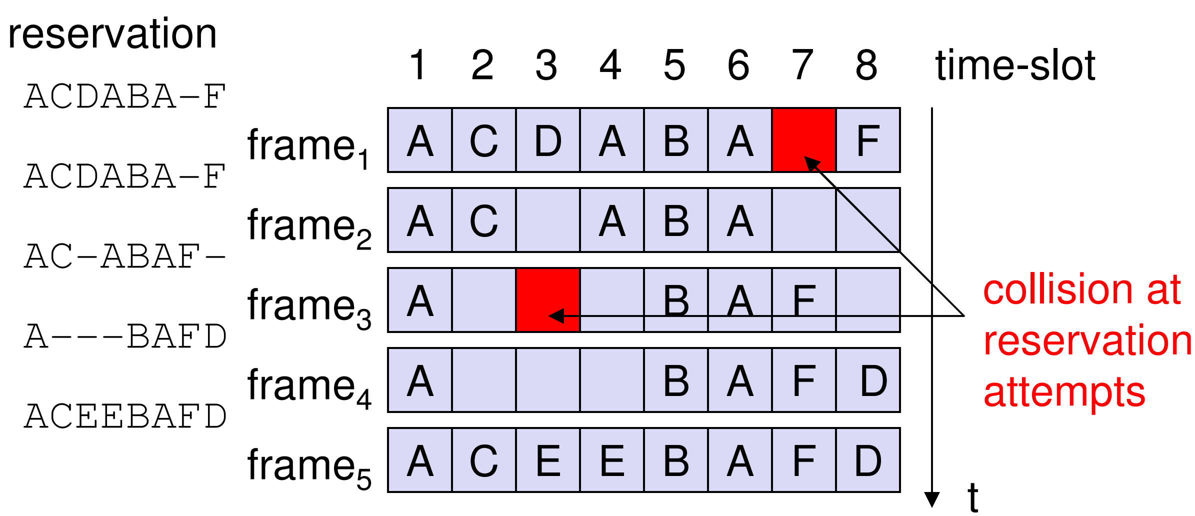
Access method DAMA: Explicit Reservation



PRMA: packet reservation MA

- Implicit reservation (PRMA - Packet Reservation MA):
  - a certain number of slots form a frame, frames are repeated
  - stations compete for empty slots according to the slotted aloha principle
  - once a station reserves a slot successfully, this slot is automatically assigned to this station in all following frames as long as the station has data to send
  - competition for this slots starts again as soon as the slot was empty in the last frame

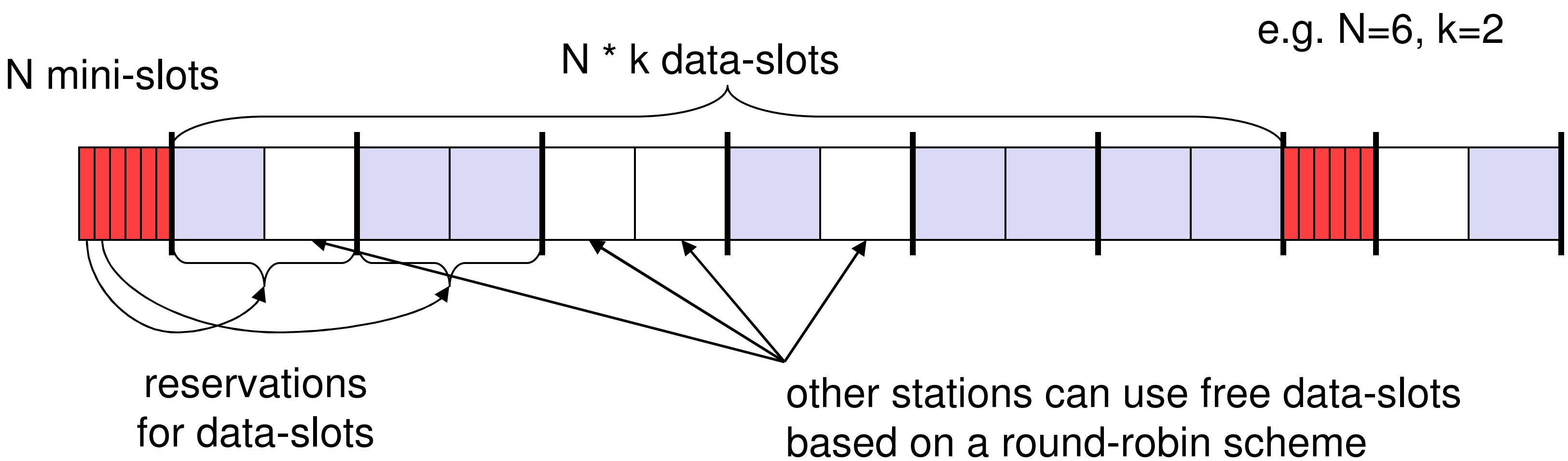
PRMA: packet reservation MA



Access method DAMA: Reservation-TDMA

- Reservation Time Division Multiple Access
  - every frame consists of N mini-slots and x data-slots
  - every station has its own mini-slot and can reserve up to k data-slots using this mini-slot (i.e. $x = N * k$).
  - other stations can send data in unused data-slots according to a round-robin sending scheme (best-effort traffic) or Aloha.

Access method DAMA: Reservation-TDMA



Access method DAMA: Reservation-TDMA

- Guarantee for worst-case delay.
- Allows a combination of two service models:
  - Fixed delay;
  - Best-effort traffic.

Improvement III: use the basestation for coordination

Polling mechanisms

- If one terminal can be heard by all others, this “central” terminal (a.k.a. base station) can poll all other terminals according to a certain scheme
  - now all schemes known from fixed networks can be used (typical mainframe - terminal scenario)

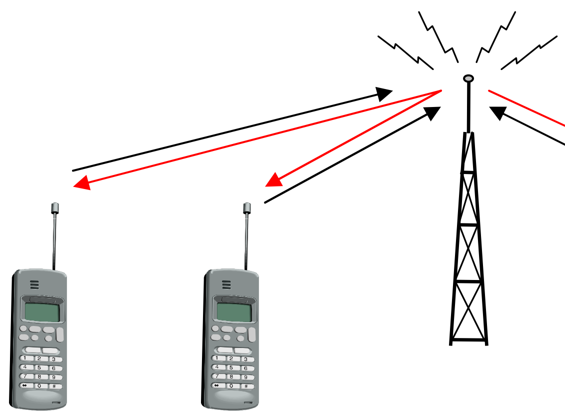
Polling mechanisms

- 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

ISMA (Inhibit Sense Multiple Access)

- 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)

ISMA (Inhibit Sense Multiple Access)



Summary

- Basic Aloha has a low throughput.
- Extension of basic Aloha Schemes
  – Carrier sense/avoidance
  – Reservation
  – Explore the power of basestation