Mobile Communications
Chapter 3 : Media Access

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- SDMA, FDMA, TDMA
- Aloha
- Reservation schemes
- Collision avoidance, MACA
- Polling
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- Comparison

Motivation

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 when medium is free, listen to medium if collision occurs (IEEE 802.3)

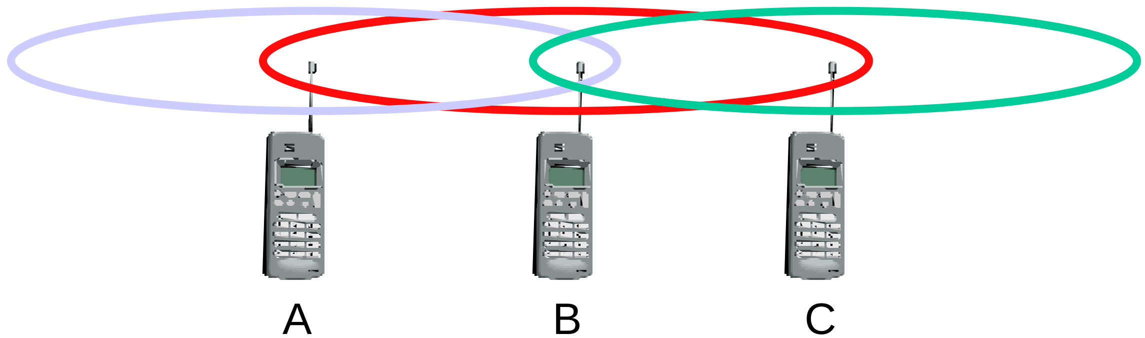
Problems in wireless networks

- signal strength decreases with distance
- sender applies CS and CD, but collisions happen at receiver
- sender may not “hear” collision, i.e., CD does not work
- Hidden terminal: CS might not work

Motivation - hidden and exposed terminals

Hidden terminals

- A sends to B, C cannot hear A
- C wants to send to B, C senses a “free” medium (CS fails)
- Collision at B, A cannot receive the collision (CD fails)
- C is “hidden” from A



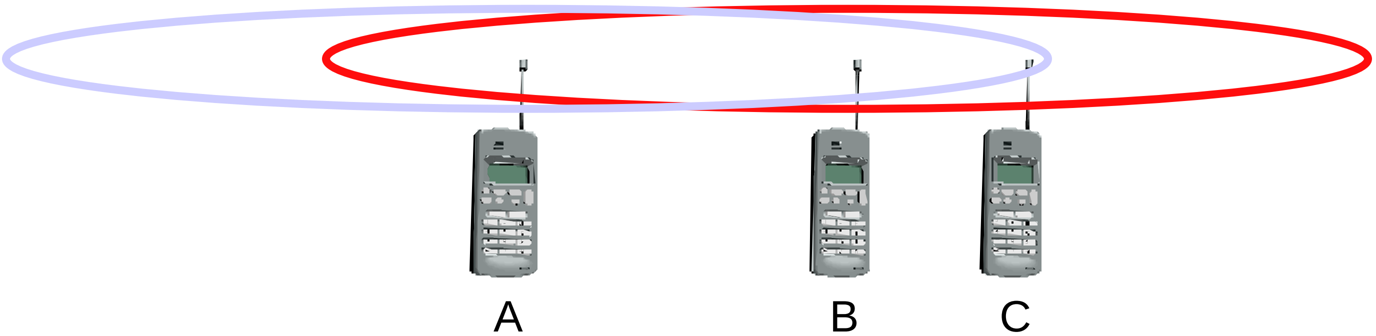
Exposed terminals

- 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 radio range of C, waiting is **not** necessary
- C is “exposed” to B

Motivation - near and far terminals

Terminals A and B send, C receives

- signal strength decreases proportional to the square of the distance
- B's signal drowns out A's signal
- C cannot receive A



If C was an arbiter, B would drown out A

Also severe problem for CDMA-networks - precise power control needed!

Access methods SDMA/FDMA/TDMA

SDMA (Space Division Multiple Access)

- segment space into sectors, use directed antennas
- cell structure

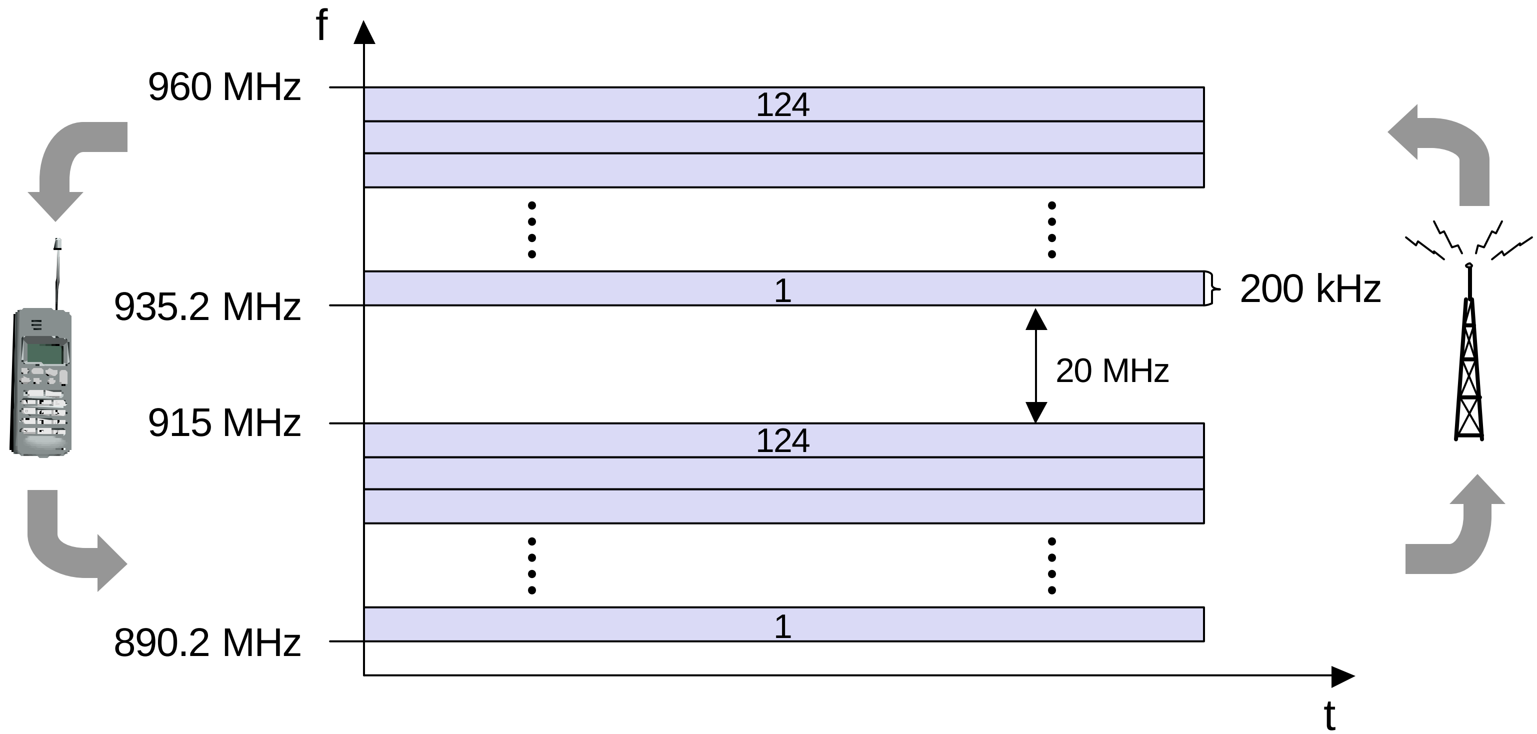
FDMA (Frequency Division Multiple Access)

- assign a frequency to a transmission channel
- permanent (e.g., radio broadcast), slow hopping (e.g., GSM), fast hopping (FHSS, Frequency Hopping Spread Spectrum)

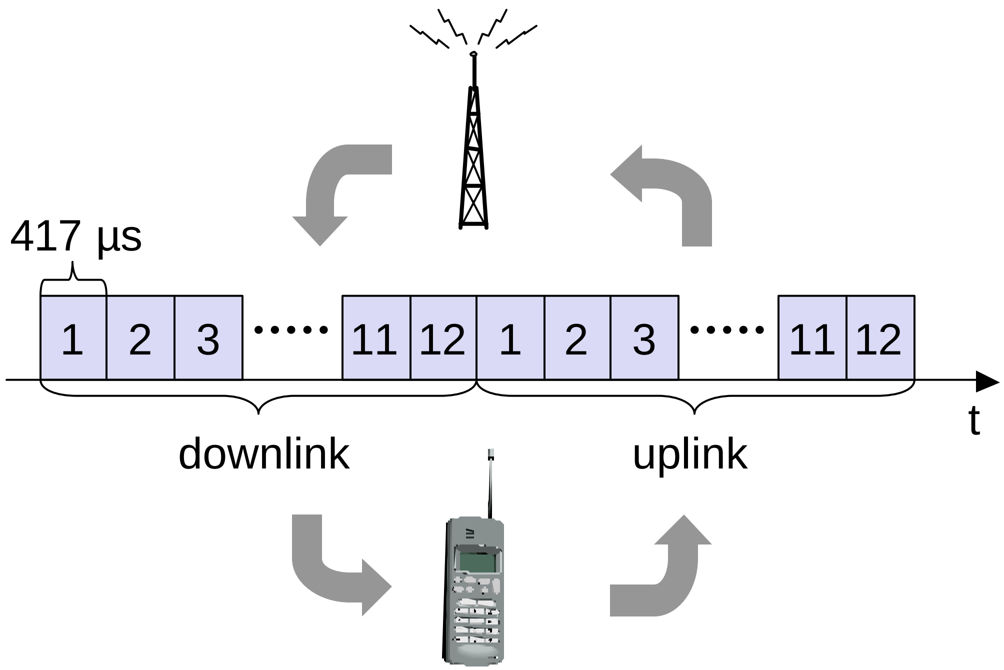
TDMA (Time Division Multiple Access)

- assign the fixed sending frequency to a transmission channel between a sender and a receiver for a certain amount of time

FDD/FDMA - general scheme, example GSM



TDD/TDMA - general scheme, example DECT

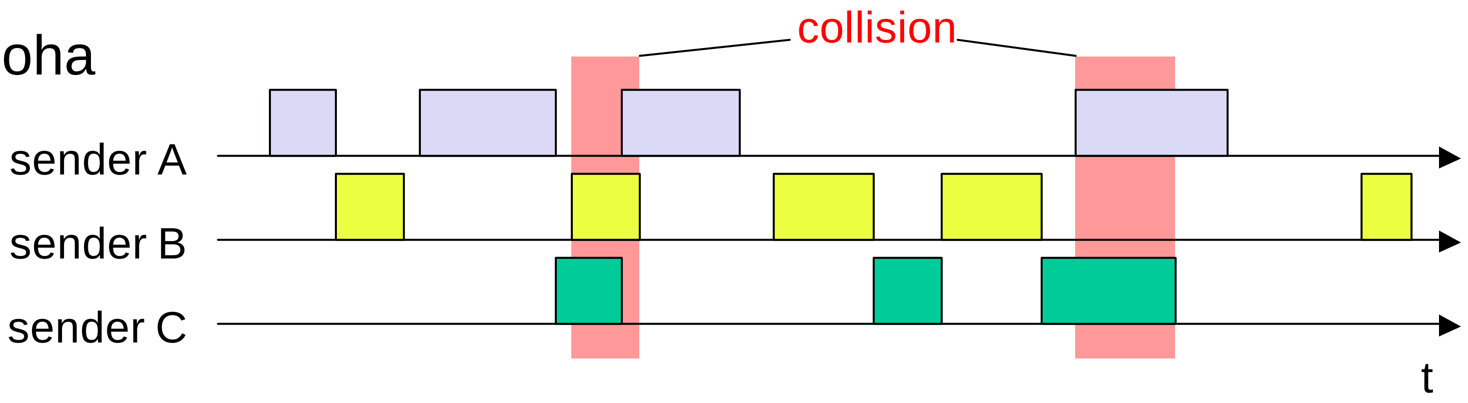


Aloha/slotted aloha

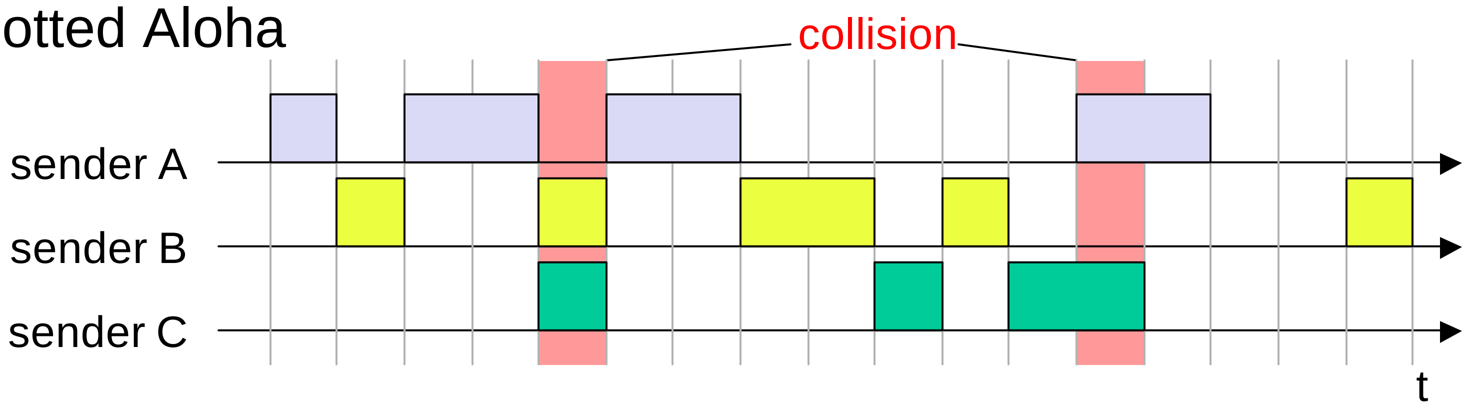
Mechanism

- random, distributed (no central arbiter), time-multiplex
- Slotted Aloha uses time-slots, sending must start at slot boundaries

Aloha



Slotted Aloha



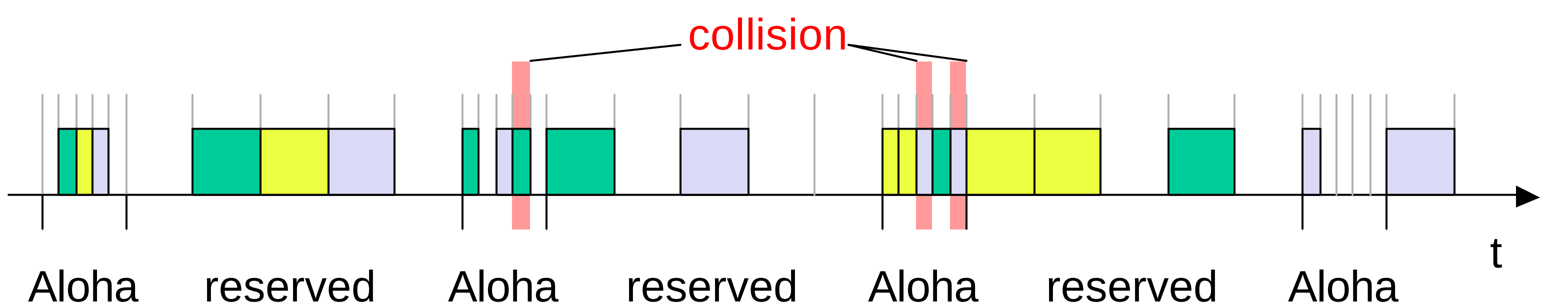
DAMA - Demand Assigned Multiple Access

- 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
- 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):

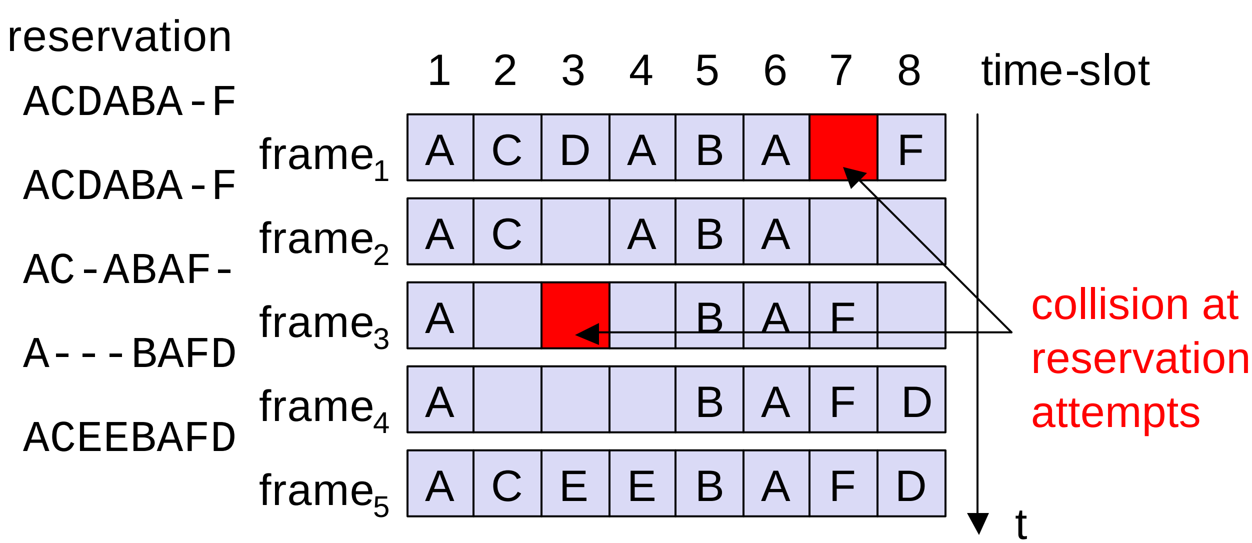
- two modes:
  - *ALOHA mode* for reservation:
    competition for small reservation slots, collisions possible
  - *reserved mode* for data transmission in reserved slots (no collisions possible)
- important for all stations to keep the reservation list consistent.
- Thus all stations have to synchronize periodically



Access method DAMA: PRMA

Implicit reservation (PRMA - Packet Reservation MA):

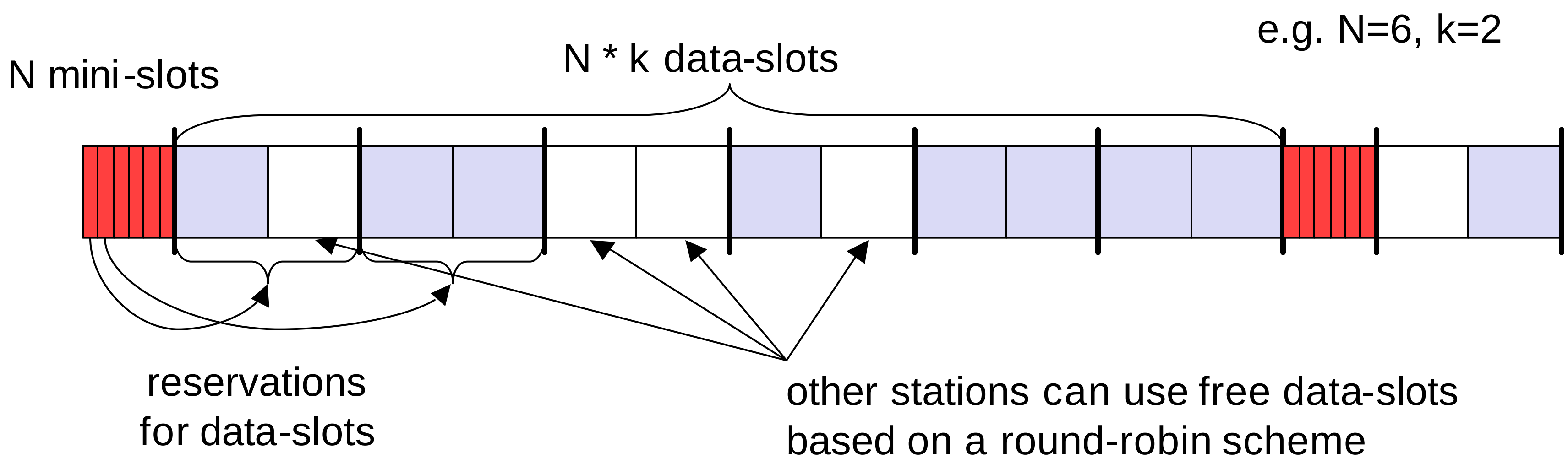
- a certain number of slots form a frame, frames are repeated
- stations compete for empty slots using slotted aloha
- once station reserves a slot successfully, slot is assigned to this station in all following frames as long as the station has data to send
- competition for a slot starts again once slot was empty in last frame



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)



MACA - collision avoidance

MACA (Multiple Access with Collision Avoidance) uses short signaling packets for collision avoidance

- RTS (request to send): a sender uses RTS packet to request right to send 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

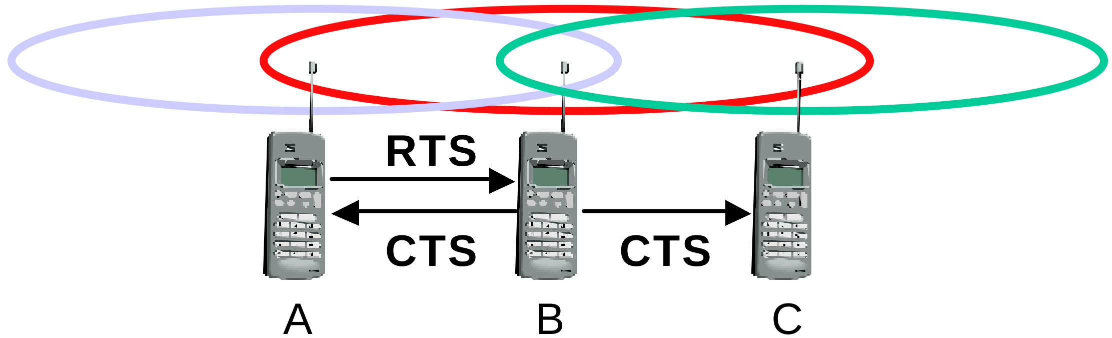
- sender address
- receiver address
- packet size

Variants of this method can be found in IEEE802.11 as DFWMAC (Distributed Foundation Wireless MAC)

MACA examples

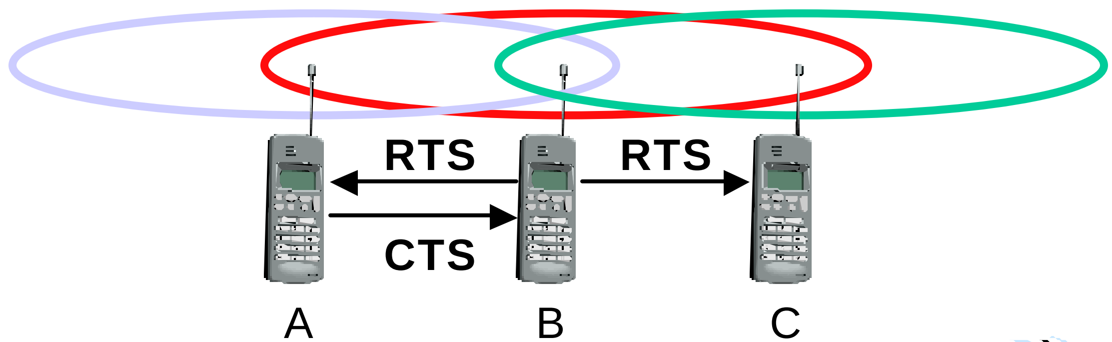
MACA avoids the problem of *hidden terminals*

- 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



Polling mechanisms

If base station can poll other terminals according to a certain scheme

- schemes known from fixed networks can be used

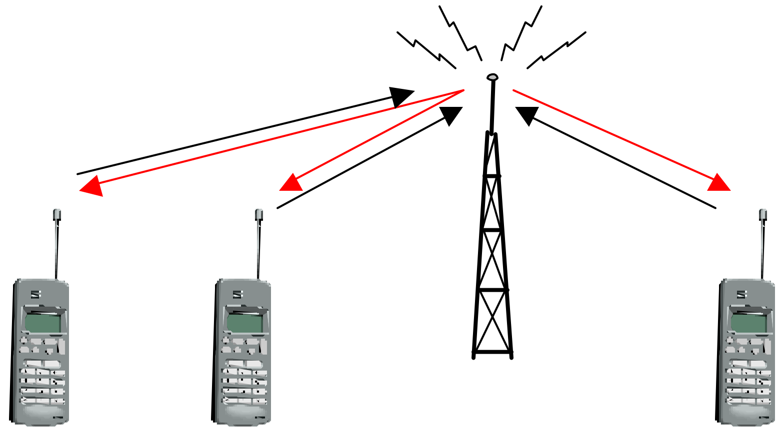
Example: Randomly Addressed Polling

- 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 (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)
- mechanism used, e.g., for CDPD (USA, integrated into AMPS)



Access method CDMA

CDMA (Code Division Multiple Access)

- all terminals send on same frequency at the same time using ALL the bandwidth of transmission channel
- each sender has a unique random number, sender XORs the signal with this random number
- the receiver can “tune” into this signal if it knows the pseudo random number

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
- interference (e.g. white noise) is not coded
- forward error correction and encryption can be easily integrated

CDMA in theory

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 $B_s = B_d * B_k = (-1, -1, +1, -1, +1, -1)$

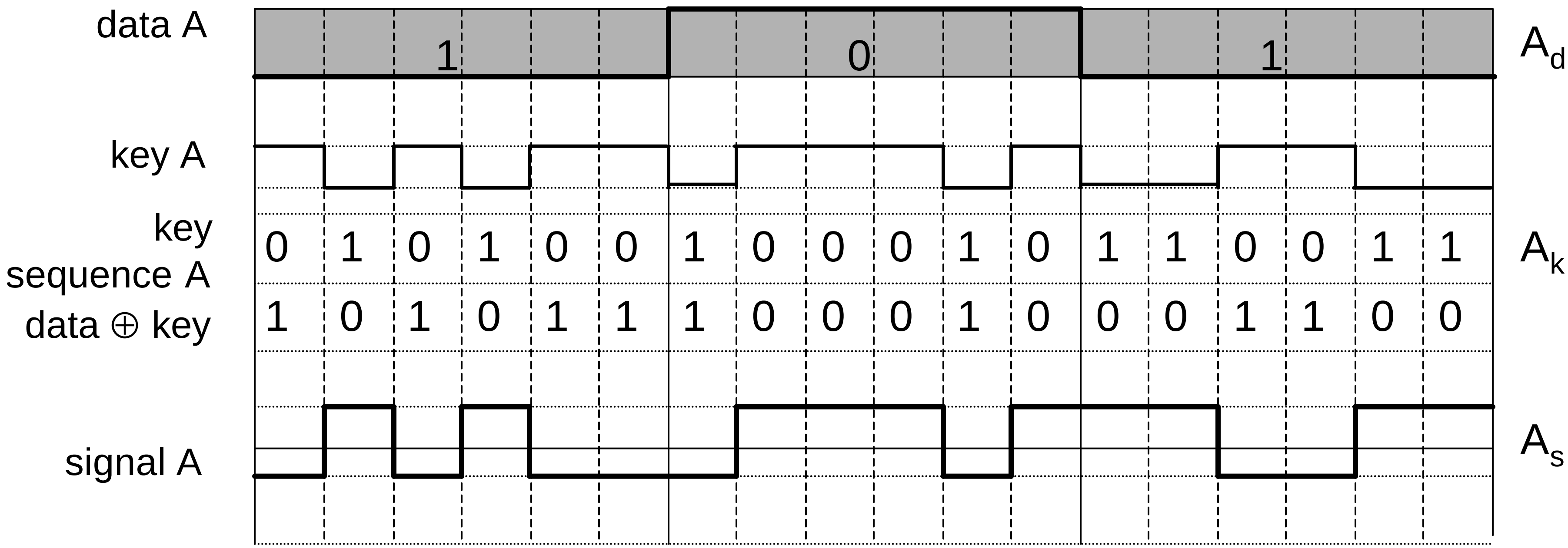
Both signals superimpose in space

- 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“

CDMA on signal level I



Real systems use much longer keys resulting in a larger distance between single code words in code space.

Comparison 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