Media Access

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

Motivation

Can we apply media access methods from fixed networks?

Example CSMA/CD

- 

  Carrier Sense Multiple Access with Collision Detection

  send as soon as the medium is free, listen into the medium if a collision occurs (original method in IEEE 802.3)

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”
Motivation - hidden and 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

Motivation - 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

If C for example was an arbiter for sending rights, terminal B would drown out terminal A already on the physical layer
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 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

The multiplexing schemes presented in chapter 2 are now used to control medium access!

FDD/FDMA - general scheme, example GSM

![Diagram of frequency division multiple access (FDMA) scheme for GSM](image-url)
TDD/TDMA - general scheme, example DECT

Aloha/slotted aloha

Mechanism
- random, distributed (no central arbiter), time-multiplex
- Slotted Aloha additionally uses time-slots, sending must always 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 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: PRMA

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

<table>
<thead>
<tr>
<th>reservation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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</thead>
<tbody>
<tr>
<td>ACDABA-F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACDABA-F</td>
<td>A</td>
<td>C</td>
<td>D</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td></td>
<td>F</td>
</tr>
<tr>
<td>AC-ABAF-</td>
<td>A</td>
<td>C</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>A---BAFD</td>
<td>A</td>
<td></td>
<td>B</td>
<td>A</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACEEBAFD</td>
<td>A</td>
<td>C</td>
<td>E</td>
<td>B</td>
<td>A</td>
<td>F</td>
<td>D</td>
<td></td>
</tr>
</tbody>
</table>

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)

- e.g. N=6, k=2
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

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
MACA variant: DFWMAC in IEEE802.11

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)

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

Comparison SDMA/TDMA/FDMA/CDMA

<table>
<thead>
<tr>
<th>Approach</th>
<th>SDMA</th>
<th>TDMA</th>
<th>FDMA</th>
<th>CDMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idea</td>
<td>segment space into cells/sectors</td>
<td>segment sending time into disjoint time-slots, demand driven or fixed patterns</td>
<td>segment the frequency band into disjoint sub-bands</td>
<td>spread the spectrum using orthogonal codes</td>
</tr>
<tr>
<td>Terminals</td>
<td>only one terminal can be active in one cell/one sector</td>
<td>all terminals are active for short periods of time on the same frequency</td>
<td>every terminal has its own frequency, uninterrupted</td>
<td>all terminals can be active at the same place at the same moment, uninterrupted</td>
</tr>
<tr>
<td>Signal separation</td>
<td>cell structure, directed antennas</td>
<td>synchronization in the time domain</td>
<td>filtering in the frequency domain</td>
<td>code plus special receivers</td>
</tr>
<tr>
<td>Advantages</td>
<td>very simple, increases capacity per km²</td>
<td>established, fully digital, flexible</td>
<td>simple, established, robust</td>
<td>flexible, less frequency planning needed, soft handover</td>
</tr>
<tr>
<td>Dis-advantages</td>
<td>inflexible, antennas typically fixed</td>
<td>guard space needed (multipath propagation), synchronization difficult</td>
<td>inflexible, frequencies are a scarce resource</td>
<td>complex receivers, needs more complicated power control for senders</td>
</tr>
<tr>
<td>Comment</td>
<td>only in combination with TDMA, FDMA or CDMA useful</td>
<td>standard in fixed networks, together with FDMA/SDMA used in many mobile networks</td>
<td>typically combined with TDMA (frequency hopping patterns) and SDMA (frequency reuse)</td>
<td>still faces some problems, higher complexity, lowered expectations; will be integrated with TDMA/FDMA</td>
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