

Data communication I

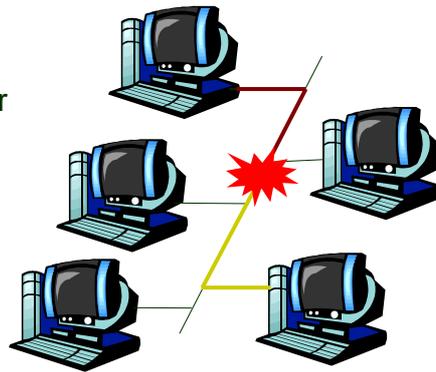
Lecture 5 – Medium Access Control (MAC)

MAC – Medium Access Control

- A MAC protocol organizes the access of several sources to the common medium
- Who decides who is to talk when and for how long?
 - Centralized MAC
 - Decentralized MAC
- What factors are included into the decision?
 - Fairness?
 - Quality-of-Service or real-time requirements of the individual participants?

Data collision

- Two or more simultaneous transmissions over the same medium (not considering FDM or CDM solutions) render all involved data useless
- Collisions are costly
 - Unreadable to the receiver
 - Retransmission



How to deal with data collisions?

- Just accept that collisions exist
 - Random access MAC protocols
 - try to reduce the probability of their occurrence
 - Quickly recover from collision
- Make sure the multiple senders do not interfere with each other
 - Channel partitioning MAC protocols
 - divide channel into smaller "pieces" (time slots, frequency, code)
 - allocate piece to node for exclusive use
 - "Taking turns" MAC protocols
 - nodes take turns, but nodes with more to send can take longer turns

Channel Partitioning MAC protocols: TDMA (Time Division Multiple Access)

- Access to channel in "rounds"
 - Each station gets fixed length slot in each round
 - Slot length = e.g. length of one data packet
- Doesn't work well when
 - The number of nodes and their requirements change over time
 - Data comes in bursts with periods of no (or little) data inbetween
- Disadvantages
 - Unused slots go idle → waste of bandwidth
 - Tight synchronization between all nodes required



Channel Partitioning MAC protocols: TDMA (Time Division Multiple Access)

- Perfectly fair, but do we always want fairness?

N = number of supported nodes

R = data rate on the common channel

Available data rate R^* per node (no matter if this node has nothing to send or a lot to send):

$$R^* = R/N$$



Random Access Protocols

- When node has packet to send
 - Transmit at full channel data rate R .
 - No *a priori* coordination among nodes
- Random Access MAC protocol specifies:
 - How to detect collisions
 - How to avoid collisions
 - How to recover from collisions
- Advantages:
 - Not much administration needed
 - Synchronization not as crucial as in TDMA
- Disadvantages:
 - Collisions can happen at any time

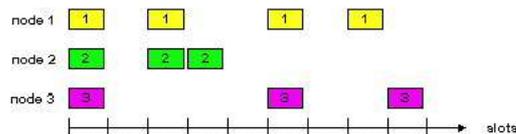
Slotted ALOHA

Assumptions:

- All frames same size
- Time divided into equal size slots (time to transmit 1 frame)
- Nodes start to transmit only in the beginning of a slot
- Nodes are synchronized
- If 2 or more nodes transmit in the same slot, all nodes detect collision

Operation:

- When a node obtains fresh frame, it automatically transmits in the next slot
 - *if no collision*: node continues transmission
 - *if collision*: node retransmits frame in each subsequent slot with probability p until success



Slotted ALOHA

Advantages

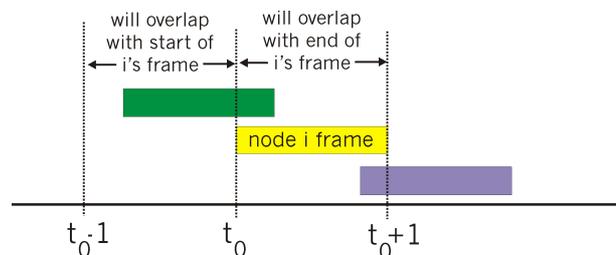
- A single active node can continuously transmit at full channel data rate R
- Highly decentralized: only slots in nodes need to be in sync
- Simple

Drawbacks

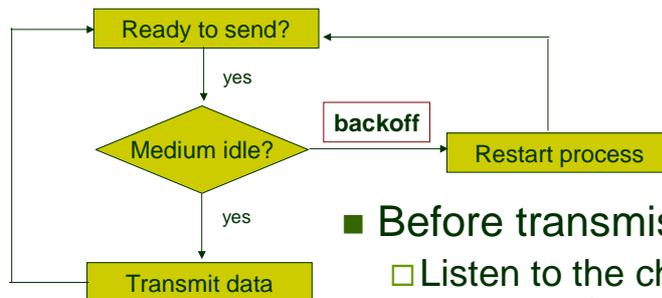
- Collisions occur, wasting time slots
- Slots might remain idle although nodes have data to send
- Clock synchronization needed

Pure (unslotted) ALOHA

- As soon as a frame is ready, it is immediately transmitted
- Drawbacks
 - collision probability increases compared to slotted ALOHA where everyone only sends at the beginning of a slot (frame sent at t_0 collides with other frames sent in $[t_0-1, t_0+1]$)
- Advantages
 - No synchronization at all needed



CSMA – Carrier Sense Multiple Access

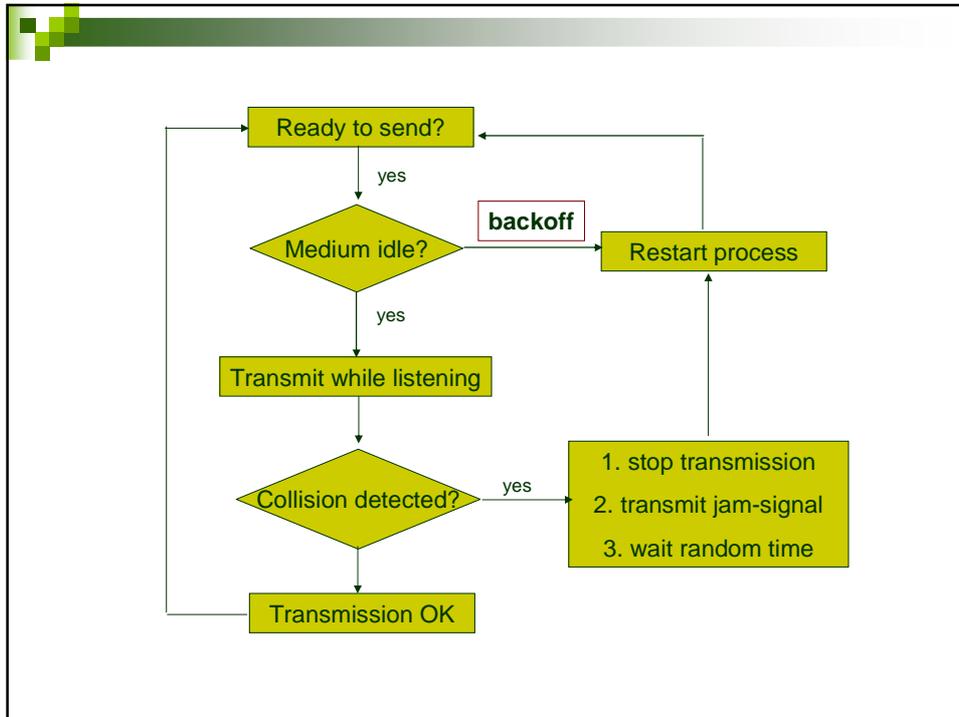


■ Before transmission

- Listen to the channel (sense the carrier)
 - If the channel is busy → don't send
 - Wait a (random) backoff time
 - Listen again
 - If channel is free → send

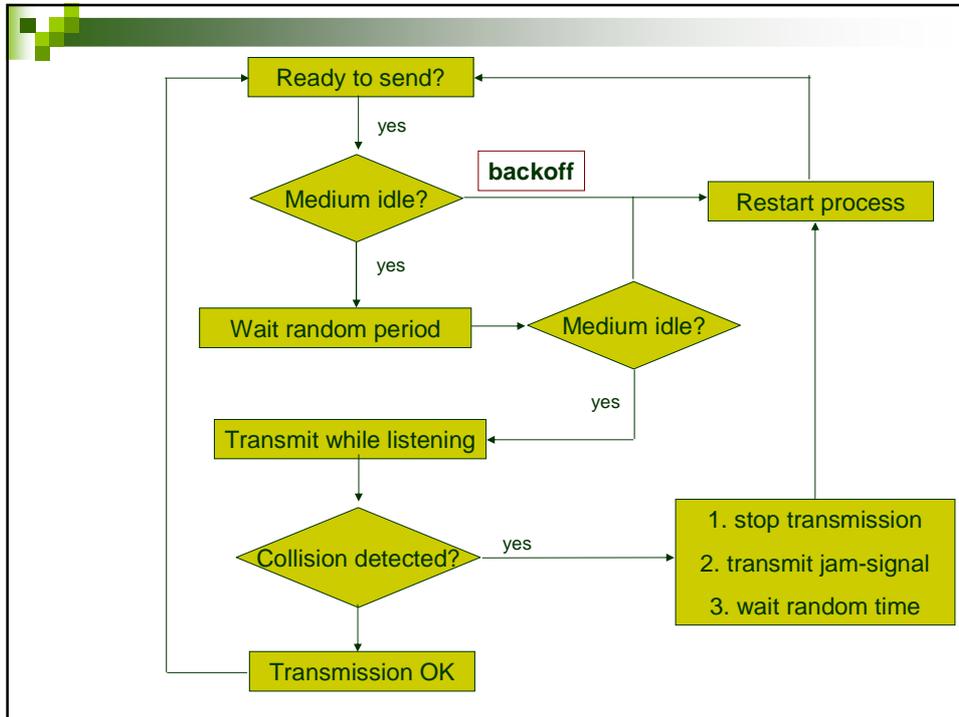
CSMA/CD (Collision Detect)

- Can collisions still occur with CSMA?
 - Yes!
 - E.g. two nodes find the medium to be free and start sending simultaneously → collision
- Collision Detect mechanism
 - Node transmits when channel is free but listen to its own data
 - Measure signal strength: above certain threshold, keep transmitting
 - Above threshold: someone else is sending at the same time (=collision)
 - Random backoff time
 - Start all over again



CSMA/CA (Collision Avoidance)

- Collision Avoidance mechanism
 - As CSMA/CD
 - Node does not transmit immediately when channel is free, but waits a random interval
 - Probability that other nodes start sending at the same time is decreased
- E.g. used in WLAN standard (802.11)



"Taking turns" MAC protocols

■ Examples

□ Polling

- A central node makes a schedule based on information about the individual nodes' requirements
- Central node polls the individuals for data with small beacons
→ centralized

□ Token passing

- Only the node that holds a token is allowed to send (as long as it needs to)
- Token is passed on to next node in a sequential manner
- Often used in ring topology
→ decentralized

A way to group MAC protocols on how they deal with collisions

- Collision-free (contention-free)
 - The traffic over the common medium is managed in a way that only one source is allowed to use the medium at a time (or per frequency etc, depending if it is TDM, FDM etc)
 - Need for an "agreement" between all participants prior to the communication
 - No collision between data packets
 - channel partitioning MAC methods, "taking turns" MAC methods
- Contention-based
 - Everyone who wants to use the medium has to compete for access
 - Some mechanism or pure randomness decide who's the winner
 - Collisions between packets possible
 - random access MAC methods

Collision-free vs contention-based

- Collision-free
 - Drawbacks
 - Need for an "agreement" between all participants prior to the communication → schedule
 - Joining or leaving sources have to be integrated into the schedule → continuous updates required
 - Each source needs to be informed about the current schedule or be informed on a per-packet (or per-message) level if it may send data or not
 - More organizational overhead involved
 - Advantages
 - No collision between data packets can occur
 - It can be calculated in advance when (the latest) a source may send its data → determinism
 - Suitable for real-time data traffic where we need guarantees that the deadlines are met

Collision-free vs contention-based

■ Contention-based

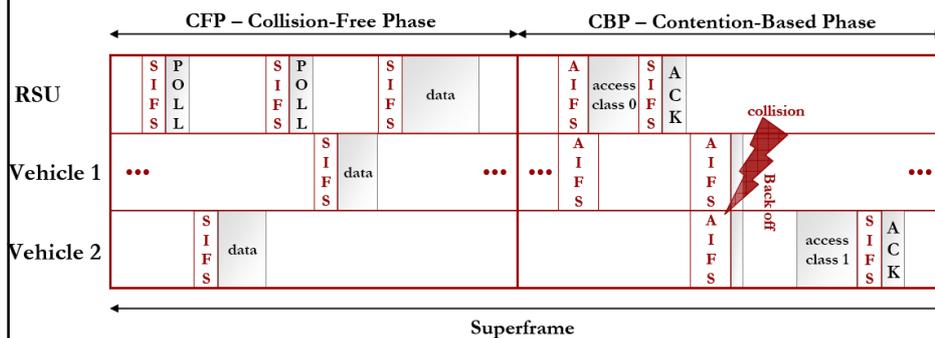
□ Drawbacks

- No determinism possible due to randomness
- It can take indefinitely for a source to be able to send

□ Advantages

- Joining and leaving sources can easily be integrated → flexible
- Can easily adapt to data traffic bursts and changes in packet length etc.
- No schedule prior to transmission needed
- decentralized

Example of a combined collision-free and contention-based MAC protocol (IEEE 802.11e)



- Here used for communication between cars and between cars and road-side access points (road side units – RSU)
- Collision-free phase
 - The RSU is the central node making the schedule and polling the vehicles for data
- Contention-based phase
 - CSMA/CA

Key terms

- Medium Access Control (MAC)
- Data collision
- Random access MAC protocol
- Channel partitioning MAC protocol
- "Taking turns" MAC protocol
- Sensing the medium
- Backoff time
- TDMA
- ALOHA
- Slotted ALOHA
- CSMA
- CSMA/CD
- CSMA/CA
- Polling
- Token passing
- Contention-based MAC vs collision-free MAC
- Centralized MAC vs decentralized MAC