Data communication I

Lecture 5 –

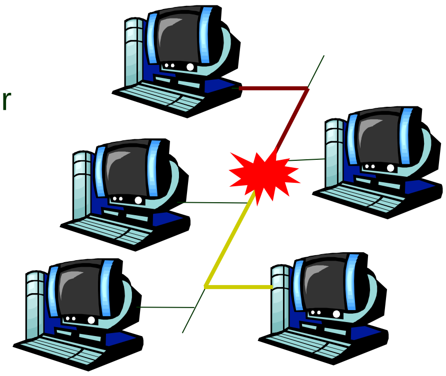
Medium Access Control (MAC)

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

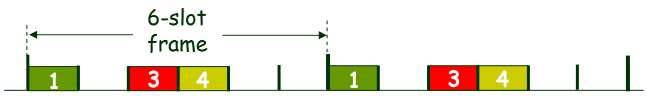


How to deal with data collisions?

- Just accept that collisions exist
  - Random access MAC protocols
    - try to reduce the probability of their occurence
    - 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

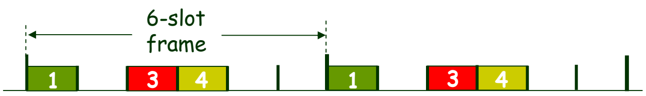


Channel Partitioning MAC protocols: TDMA (Time Division Multiple Access)

- 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

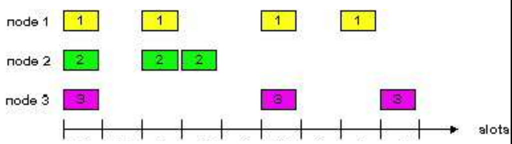
Slotted ALOHA

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

<u>Advantages</u>

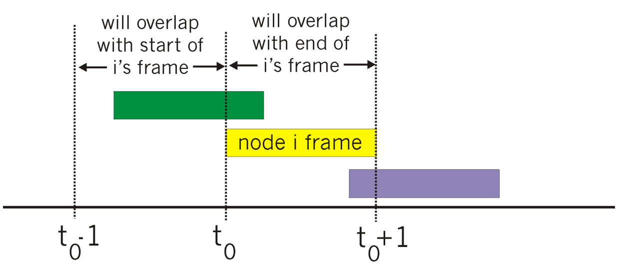
- A single active node can continuously transmit at full channel data rate R
- Highly decentralized: only slots in nodes need to be in sync
- Simple

<u>Drawbacks</u>

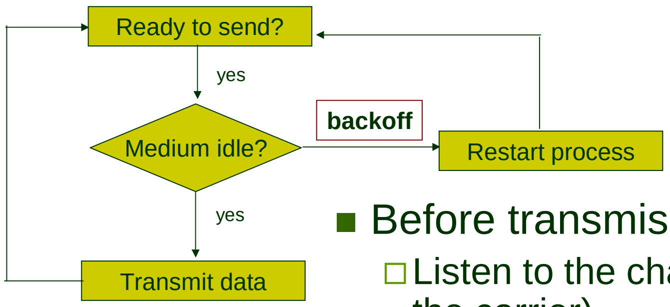
- Collisions occur, wasting time slots
- Slots might remain idle although nodes have data to send
- Clock synchronization needed

Pure (unslotted) ALOHA

- As soon as a frame is ready, it is immediately transmitted
- Drawbacks
  - collision probability increases compared to slottet 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



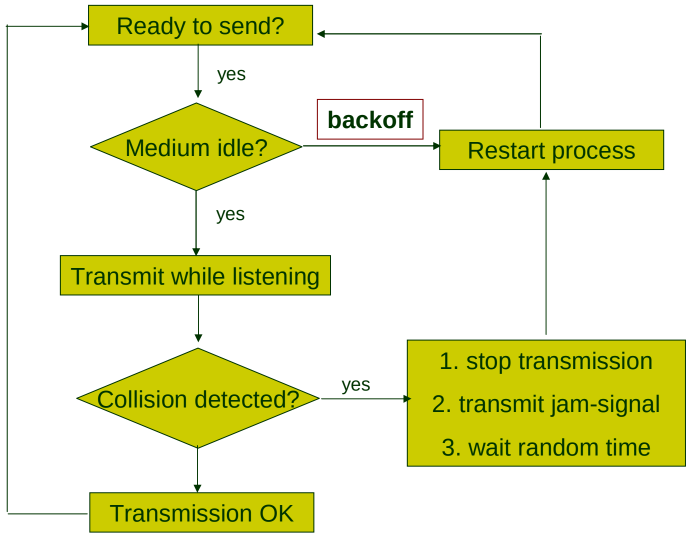
CSMA – Carrier Sense Multiple Access



- 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

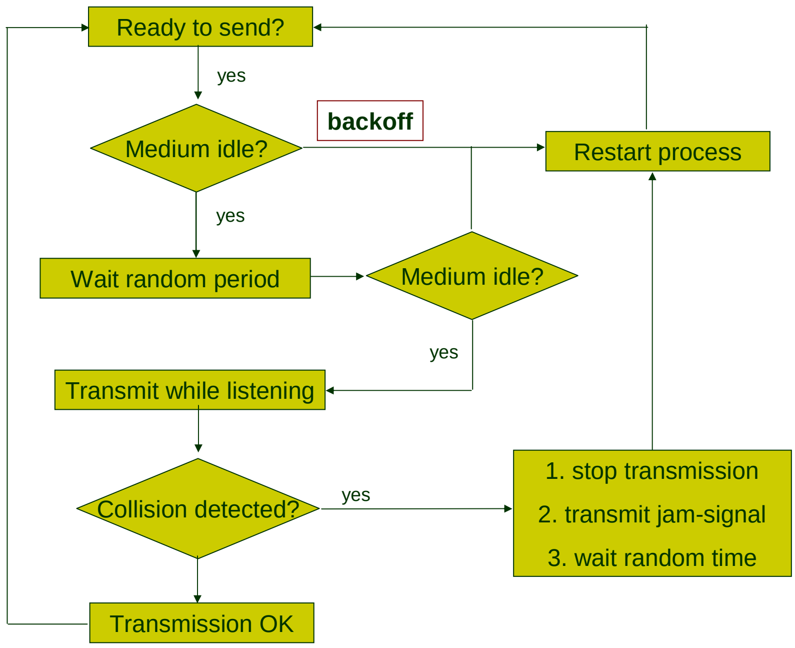
CSMA/CD (Collision Detect)

- 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 emmediately when channel is free, but waits a random intervall
    - 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

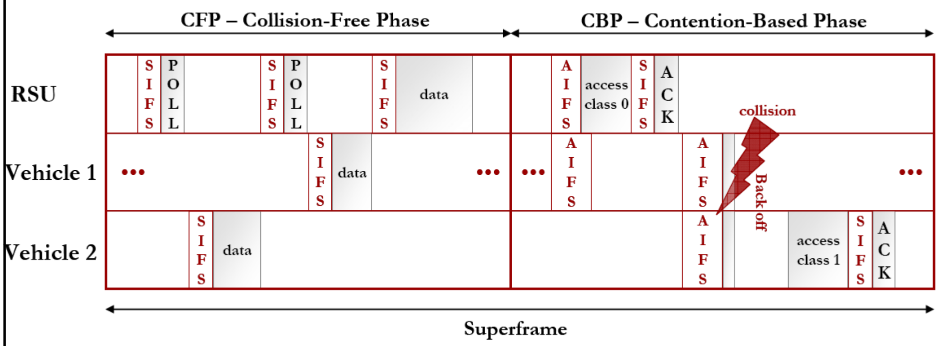
Collision-free vs contention-based

- 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 collison-free MAC
- Centralized MAC vs decentralized MAC