EP1100

Data Communication and Computer Networks

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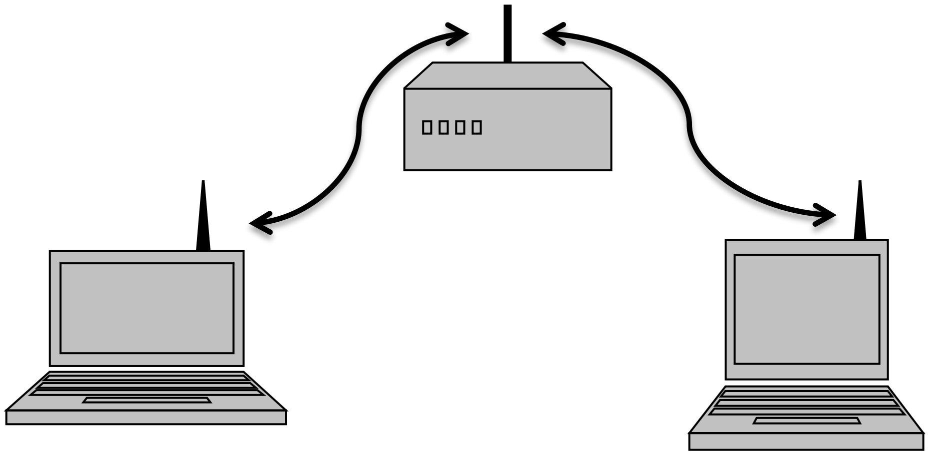
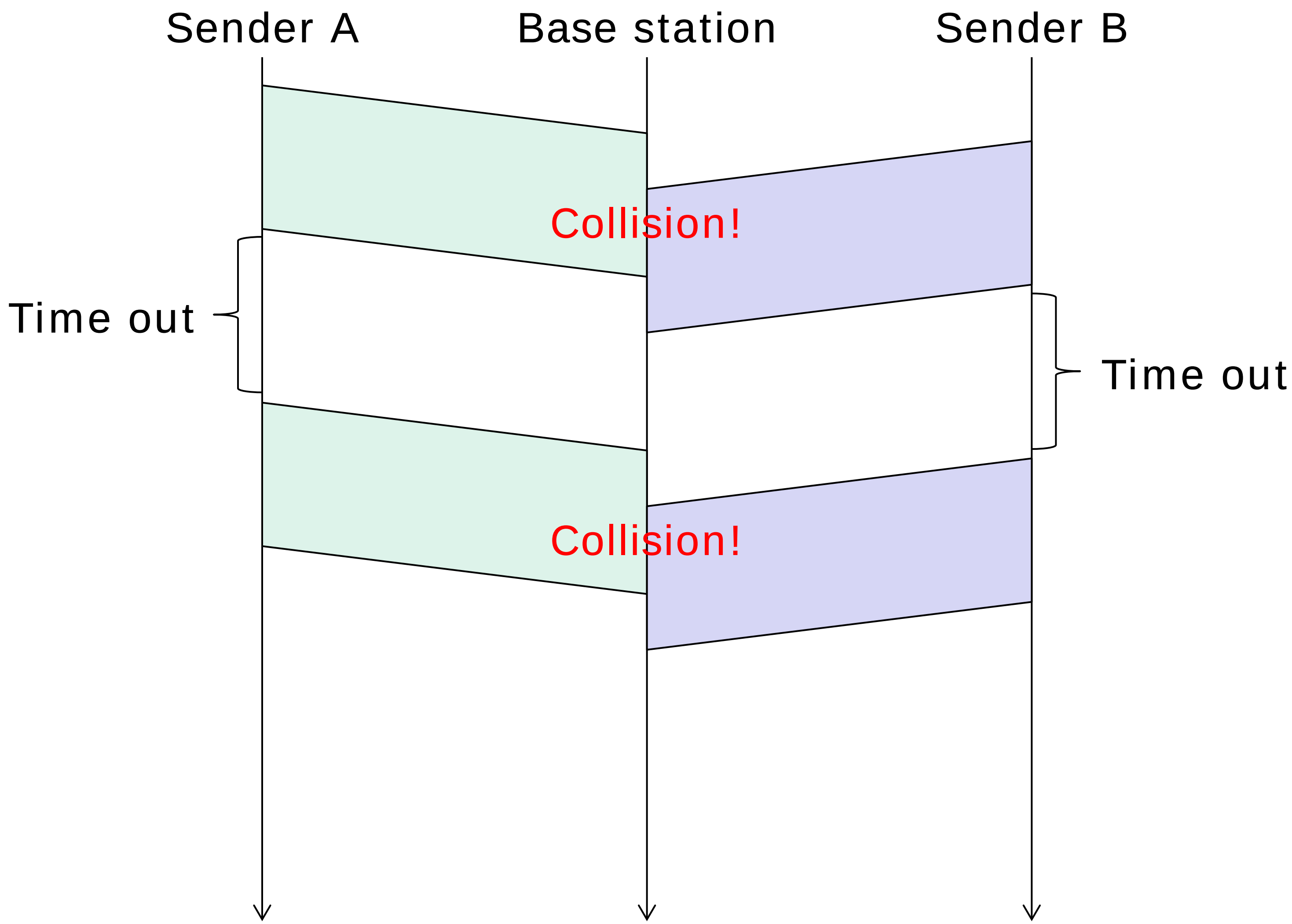
Multiple access

Class exercise: Two senders on a link

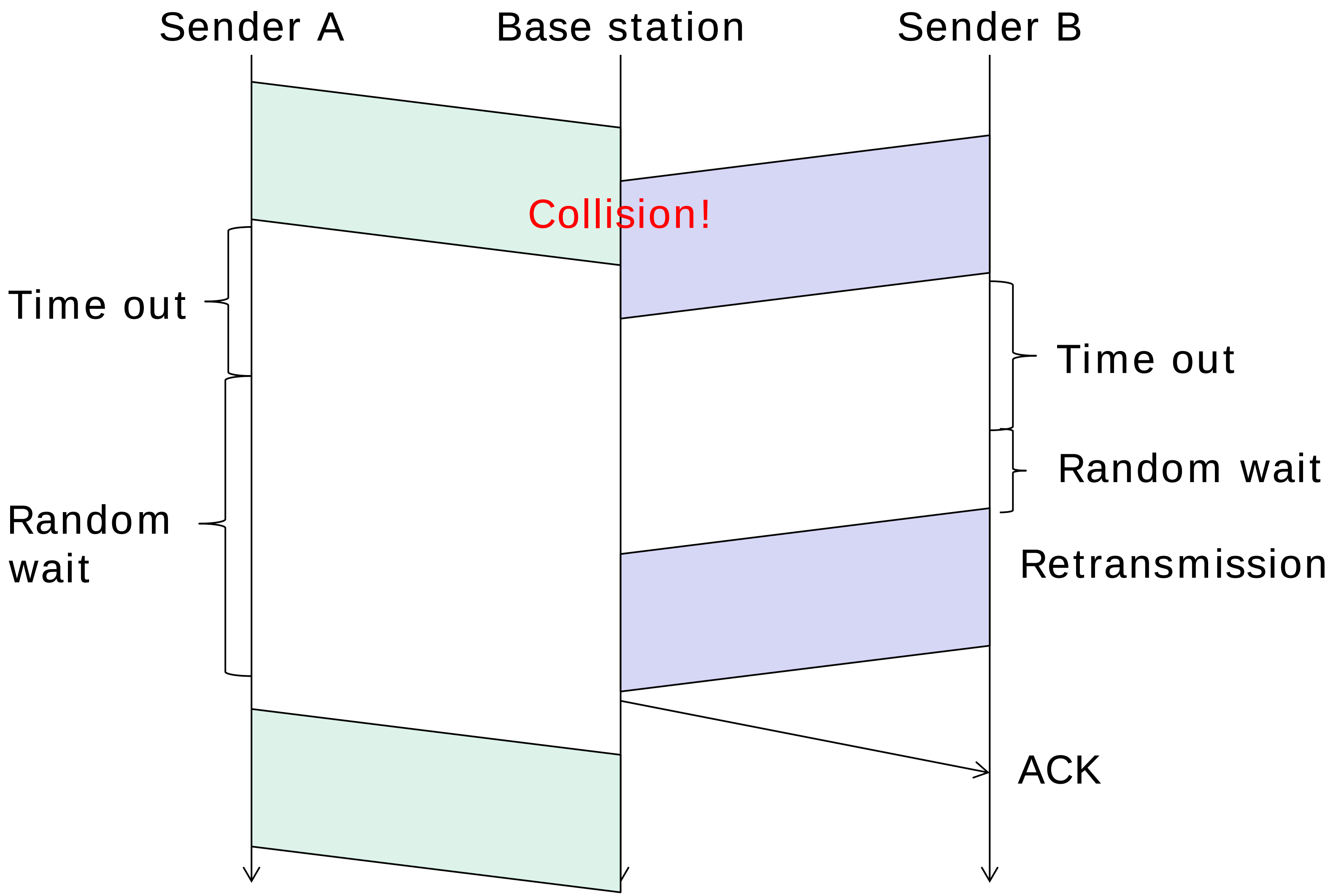
- A radio link with three nodes
  - Two senders, no coordination
  - One receiver, full-duplex communication
- How does stop-and-wait ARQ work?
  - What can happen when they transmit?
  - Does the ARQ work?



Multi-access timing

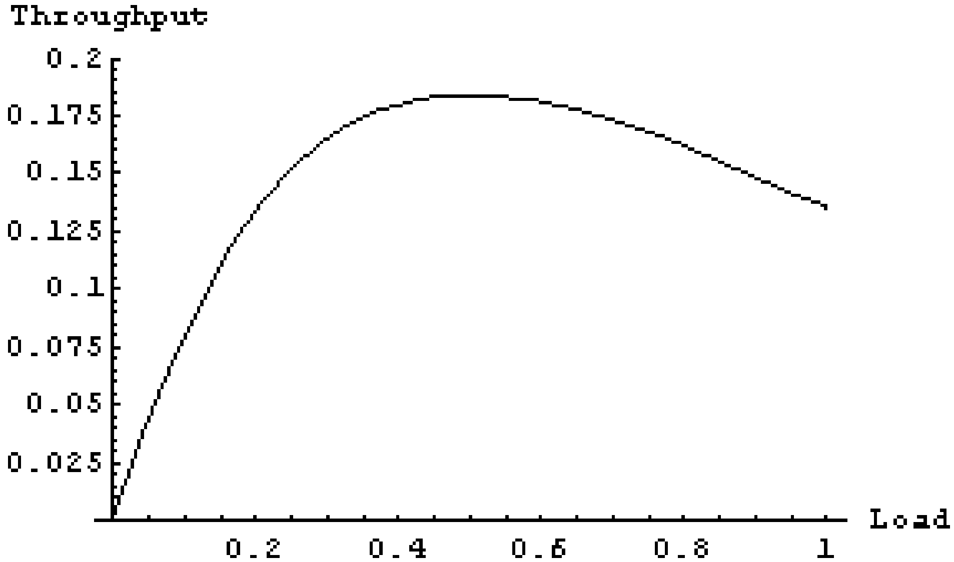


Multi-access timing



Multi-access with collisions

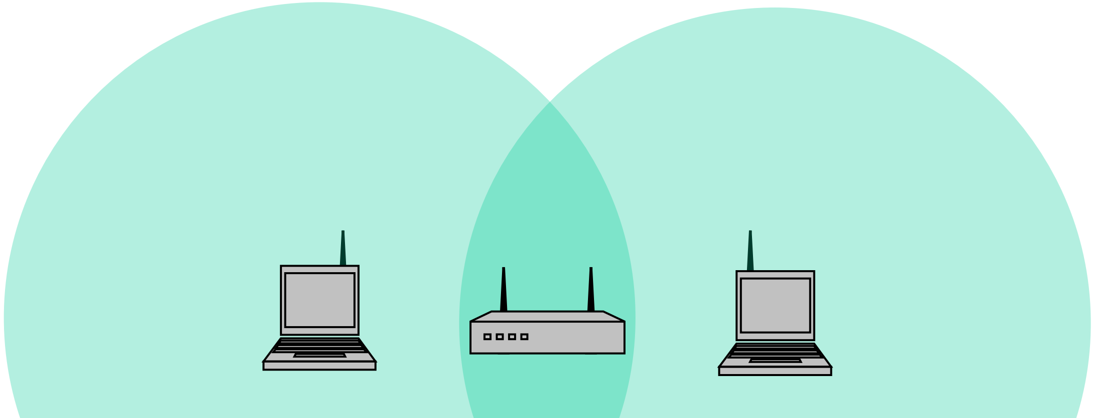
- Stop-and-wait ARQ with random wait
  - Successful if no overlap
    - Efficient since Ttr>> Tpr
  - Retransmission after timeout + random, not efficient!
  - The more data to send the higher the probability of collision
- Called the Aloha protocol
  - Maximum utilization 18% and unstable



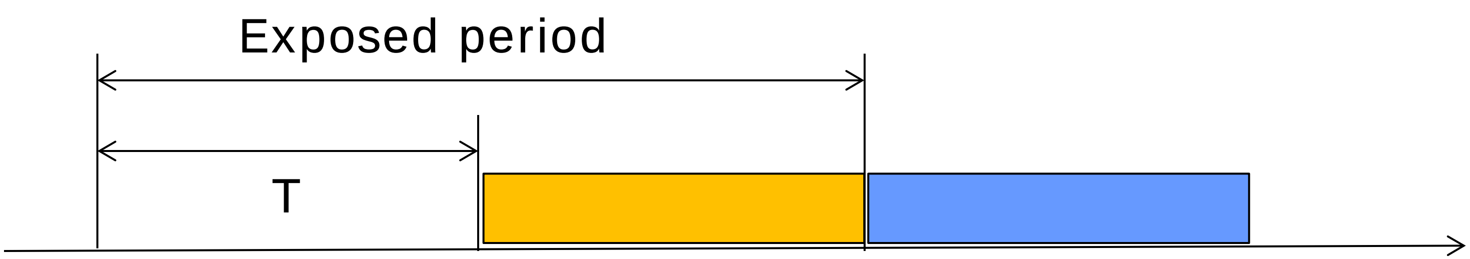
Multi-access with collisions

- Remember, link was full duplex
  - How can the protocol be more efficient?
- Listen before transmitting
  - Don't send if someone else is sending!
  - Avoid overlaps with frames that can be detected

Hidden nodes



- Nodes might not detect each others signals
  - Collision of transmissions at basestation despite listening
  - Exposed period if frames are T seconds is 2T
- How can we improve the protocol?



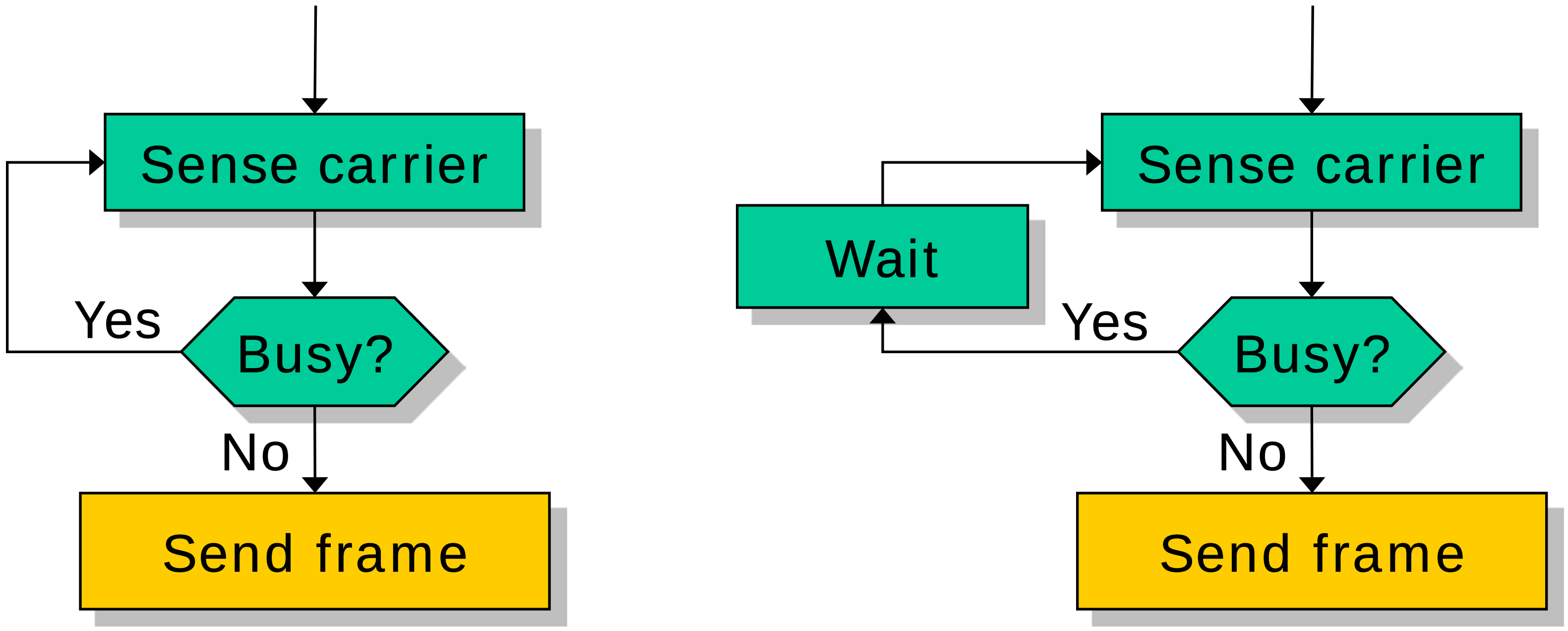
Carrier sense multiple access (CSMA)

- Carrier sense
  - Listen (sense) before sending
  - Only send if the medium is idle (silent)
  - Reduces the possibility of collisions
- Assumes that nodes are *not* hidden
  - Works well for broadcast on a wire (bus topology)
  - Small-scale radio communication or relay

Carrier sense multiple access (CSMA)

- Does not eliminate collisions
  - Propagation delay
    - Takes time before all other stations can sense a transmission
    - Small time window that collisions may occur
      - — Reduces probability of collision
- Busy medium synchronizes subsequent transmission
  - Two or more wait for medium to be idle
  - When idle, all transmit and collide with certainty
  - Need to resolve contention!

Persistence strategy



- Persistent
  - Send as soon as channel is idle
- Leads to collision if two or more stations are busy

- Non-persistent
  - Wait a random period of time before sensing again
- May avoid collision
  - Samples the channel at random times

CSMA with collision detection

- Sender listens while sending
  - Requires full duplex interface
  - Not suitable for radio links
    - Own signal stronger than received
- Detect if other stations send too
  - Physical layer detection
    - Received signal stronger due to superposition
- Stop transmitting when collision is detected
  - Reduces time cost due to collision
    - A few bytes instead of full frame
  - Back-off and repeat strategy
    - Exponential backoff: double the window for random wait

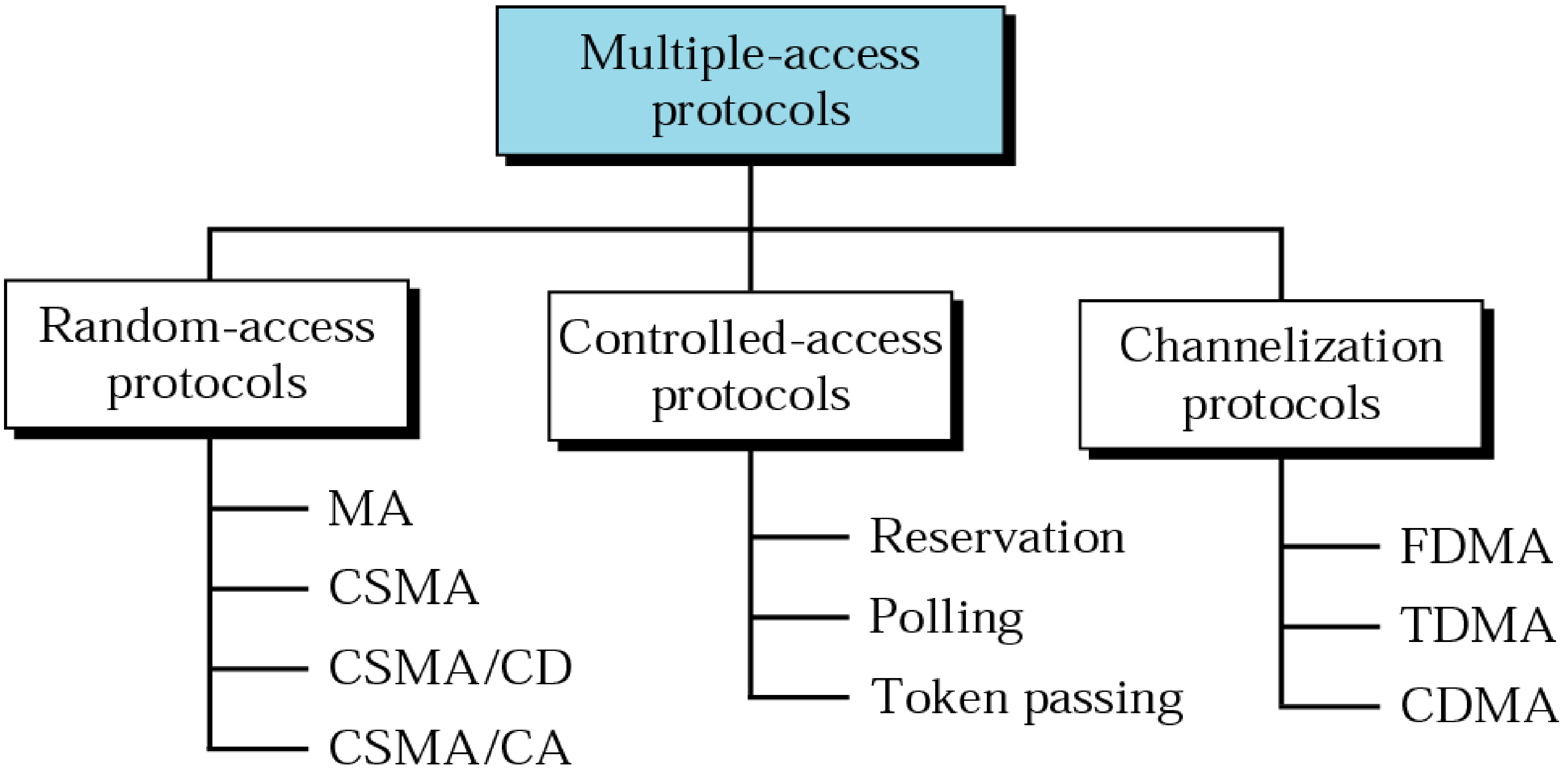
Overview

- Multiple access
  - CSMA, CSMA/CD, CSMA/CA
  - Controlled access
- LAN: characteristics, basic principles
- Protocol architecture
- WLAN systems: IEEE 802.11

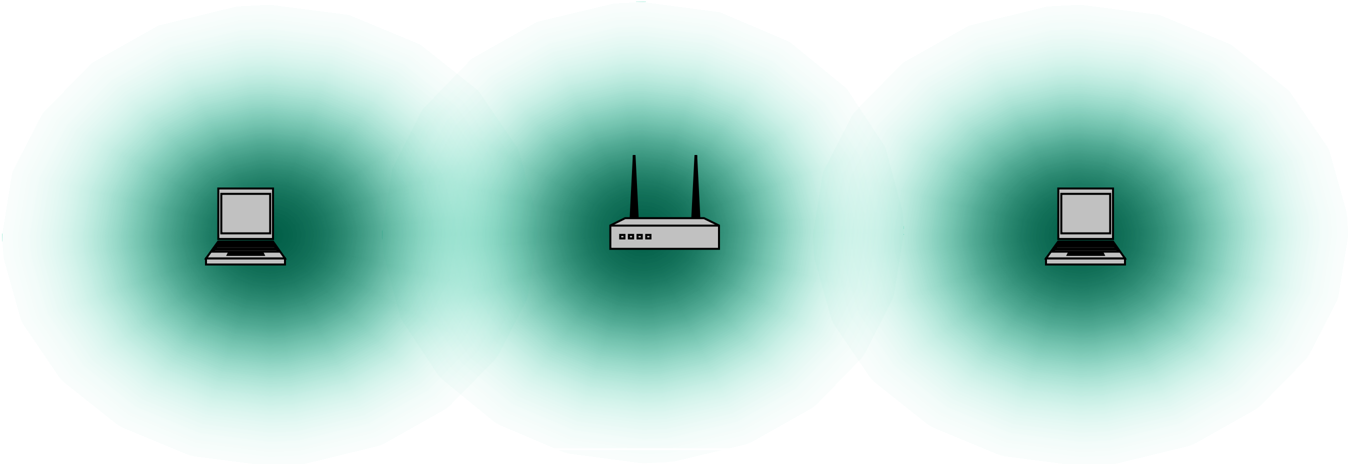
Communication on LANs

- Multiple nodes sharing one common data link
  - The nodes are at different locations on the link
  - Each node transmits frames on the link
  - Asynchronous time-division multiplexing of the link capacity
  - Primary problem to control the sending of data
    - What happens if two or more nodes send at the same time?
  - Goal: simple and cheap solution for networking a group of computers
- Characteristics
  - small area, limited number of users, all nodes can communicate directly
  - The use of shared medium and broadcast transmission
  - simple network elements, simple network management
- Property of LANs
  - propagation time << frame transmission time
    - ($T_{pr} << T_{tr} \Leftrightarrow a << 1$)
  - if a station transmits, all other nodes will soon know about it

Multiple access



Wireless networks – signal strength problem



- Carrier sense does not work for hidden nodes
- Collision detection does not work well on wireless networks
  - Attenuation is high for radio propagation
    - Signal from station's own transmitter is stronger than signals from other stations
  - Would require *full duplex* radio interfaces

CSMA/CA

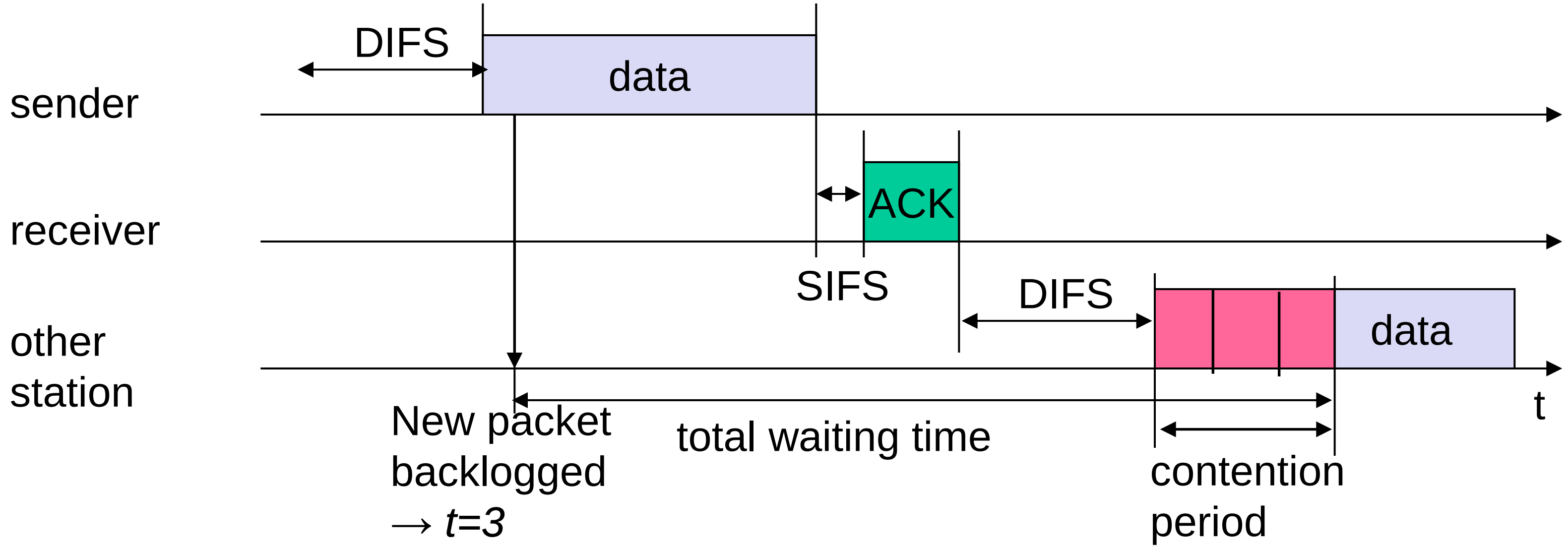
- Carrier Sense Multiple Access with Collision Avoidance
  - Carrier sense with non-persistent transmissions
    - Non-backlogged nodes can send after sensing the medium, if idle
    - Packets arriving when medium is busy create backlog
    - Backlogged nodes transmit after sensing the medium idle for a random time
      - — lowers the collision probability
    - Provides all station with same rate of transmission opportunities
      - — The access point is treated as any station
  - Optional use of control signals before transmission
    - Request to send, clear to send (RTS/CTS)
    - Reduces cost of collision (short transmission lengths)
    - Avoids hidden terminal problem (either RTS or CTS is heard by all)
- Acknowledgments confirm successful transmissions
  - stop-and-wait!

Interframe spaces (IFS)

- Distributed coordination function IFS (DIFS)
  - Longest IFS
  - Minimum access delay for frames
- Short IFS (SIFS)
  - Shortest IFS
  - Used for immediate response actions
    - Acknowledgment (ACK)
    - Clear to send (CTS)
- Other IFS excists
  - Short IFS length gives priority over longer lengths

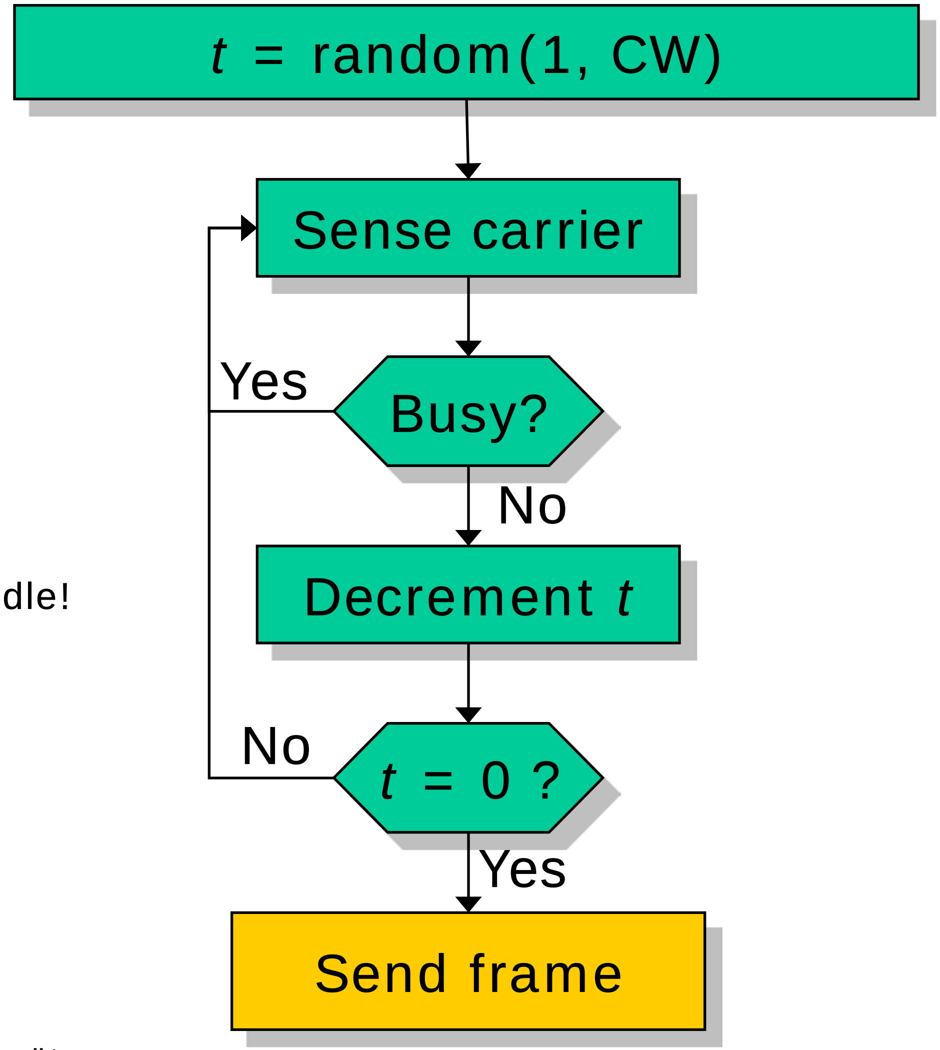
802.11 Distributed coordination function

- Non-backlogged station waits for a DCF interframe space (DIFS) before sending
  - Receiver acknowledges after waiting for short IFS (SIFS)
    - Allows sender to switch from sending to listening mode (half duplex!) and vice versa for receiver
    - If the packet was received correctly (CRC), ACK is sent reliably a lowest bit rate; heard by everyone
    - SIFS < DIFS ensures that the ACK has priority over new frames that wait a DIFS before access
  - Automatic retransmission of packets in case of transmission errors (ACK + time out)
- Backlogged node waits DIFS plus *t* idle slots before transmitting
- Interframe frame spaces (IEEE 802.11b)
  - DIFS 50 μs, SIFS 10 μs



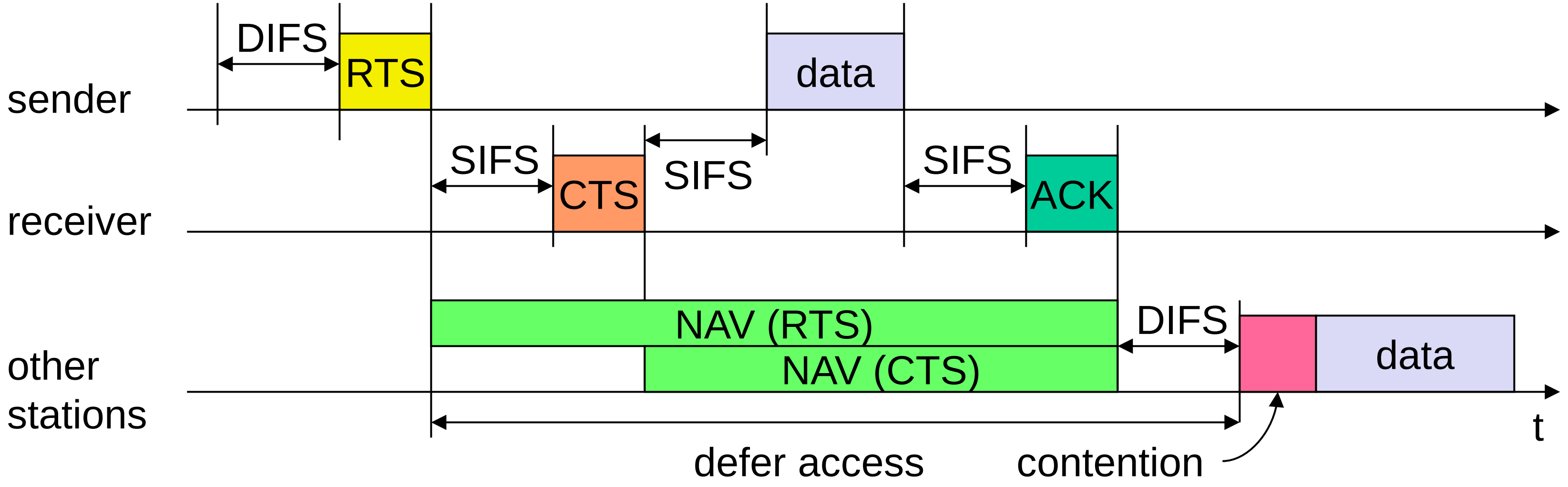
IEEE 802.11 CSMA/CA wait procedure

- Backlogged node waits before sending
  - Selects a random waiting time
    - Initializes timer with the waiting time
    - Measured in slots
      - Slot time 20 µs (802.11b)
      - Enough time to sense transmission
    - Interval from 1 to CW
  - Contention window CW
    - CWmin = 32 (default)
    - Doubled after each collision
      - CWmax = 2^mCWmin (m=5 default)
  - Decrement timer only when medium idle!
    - One slot at a time
- Reduces probability of collision
  - Only if two or more stations generate same timer value
  - Synchronized with respect to ACK of previous frame



CSMA/CA with RTS/CTS

- Station send request-to-send for reservation after waiting for DIFS
  - RTS/CTS frames contain duration field with the time that the medium is reserved for transfer
  - acknowledgment via clear-to-send after SIFS by receiver (if ready to receive)
  - Sender can now send data after a SIFS, acknowledgment via ACK
  - Other stations store a net allocation vector (NAV) to keep track of the reservation
- Works well for hidden terminals
  - A terminal hears either RTS from sender or CTS from receiver
  - Overhead could be high for short frames



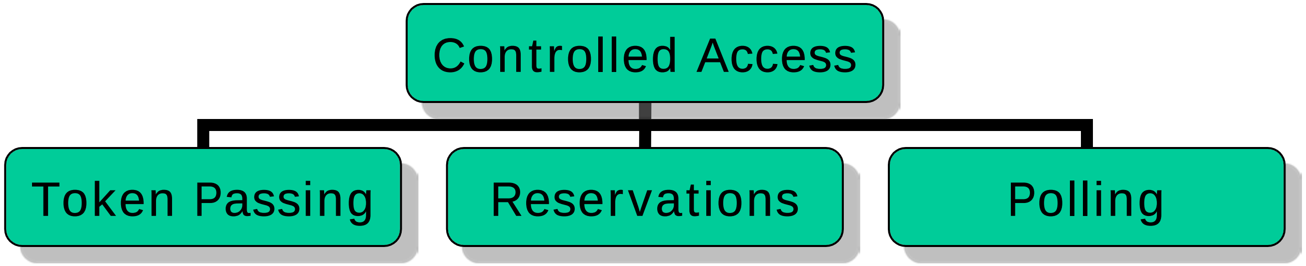
IEEE 802.11 CSMA/CA summary

- Link-layer acknowledgments
  - Stop-and-wait
- Randomized back-off timers
  - Counted down only while medium is idle
- Optional RTS/CTS reservation scheme

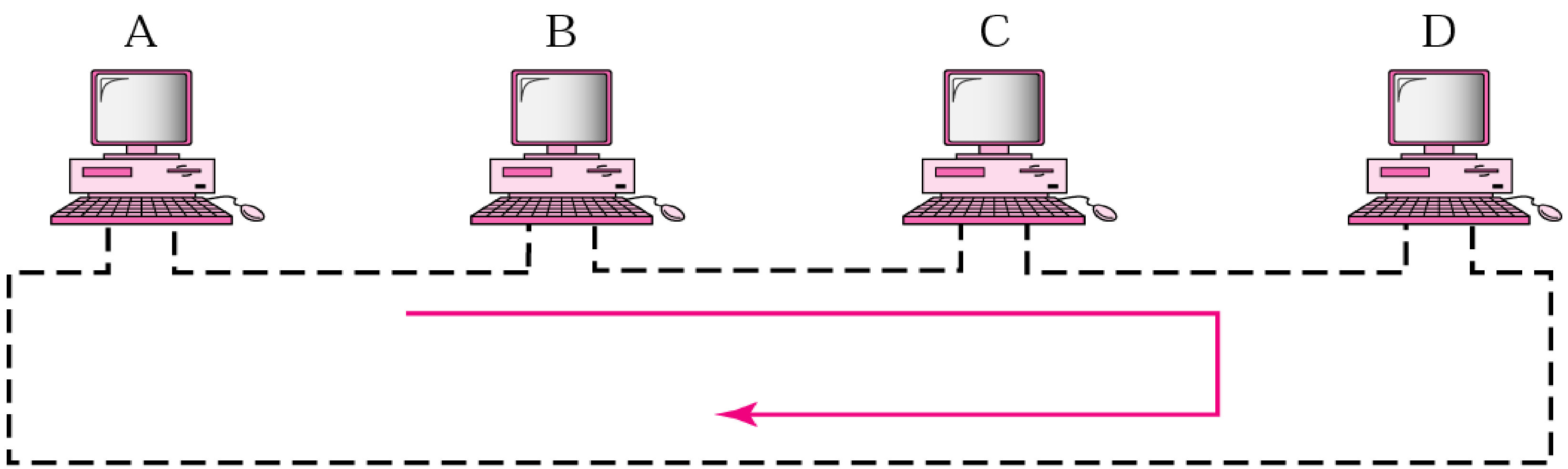
Comparisons of random medium access

- Aloha only of historical interest
- Carrier sense
  - Always used to avoid obvious collision situations
    - Unslotted transmissions more natural than slotted
      - Little loss in performance, no synchronization
    - Non-persistent best strategy
  - Generically unstable as all Aloha
    - Can be stabilized
- Collision detection
  - Reduces the cost of collisions and cost of accessing medium
    - Can be persistent and hence does not wait unnecessarily
  - Requires full duplex transceiver
  - Does not work well for wireless communication
  - Not used for wired LAN (uses point-to-point links to a hub)

Controlled access



Token passing



- Token (a control frame) circulates among the nodes
- The node that holds the token has the right to transmit
- Used in Token Ring LAN

Polling: point coordination function (PCF)

- Polling mode for IEEE 802.11 wireless LAN
  - Implemented by few if any
  - Could provide bit-rate guarantees to stations
    - Would require admission control to be strict
- APs send "beacon" frames at regular intervals
  - usually every 100 ms
- Between beacon frames, PCF defines two periods
  - Contention free period (CFP) when polling is used
    - The access point is the coordinator
    - Sends contention free-poll (CF-Poll) frames to each station
    - grants each station the right to send a frame
  - Contention period (CP) when the DCF is used

Channelization

- FDMA/WDMA
  - A station is allocated a frequency band (wavelength) on an FDM (WDM) link
- TDMA
  - Entire bandwidth is one channel
  - A station is allocated time slots on a TDM link
- CDMA (Code Division Multiple Access)
  - Entire bandwidth is one channel
    - Data from all inputs are transmitted at the same time
    - Different encoding of data bits allow (limited) superposition of signals without collision

Summary on multi-access links

- Random access may lead to collission
  - Carrier sense reduces this probability
  - Reduce cost of collision
    - collision detection
    - RTS/CTS which also addresses hidden nodes
- Use of multi-access links
  - for wireless communication
  - wired networks use switches