# Basics (cont.)

- Characteristics of data communication technologies
- OSI-Model
- Topologies
- Packet switching / Circuit switching
- Medium Access Control (MAC) mechanisms
- Coding
- Quality of Service (QoS)

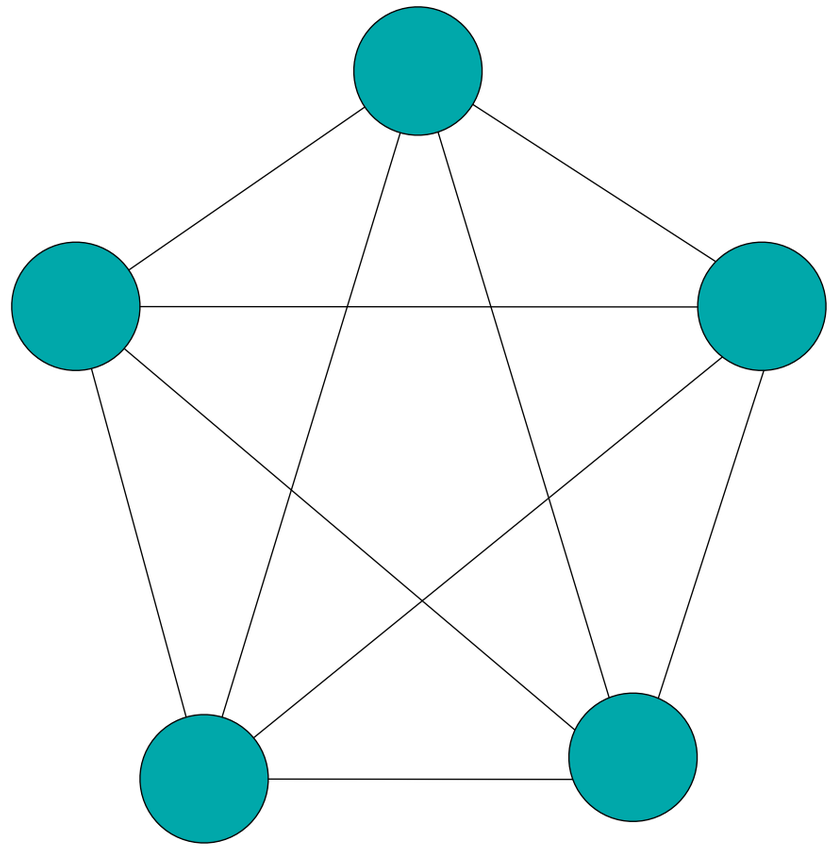
# Network Topology Considerations

- Status
  - locations of the network devices (systems, segmentation devices, etc.)
  - traffic matrix
  - cost matrix
- Variables
  - topology
  - connecting capacity
  - stream size
- Target
  - minimum costs (at a given performance)

⇒ Topological considerations are the basis for the wiring strategy

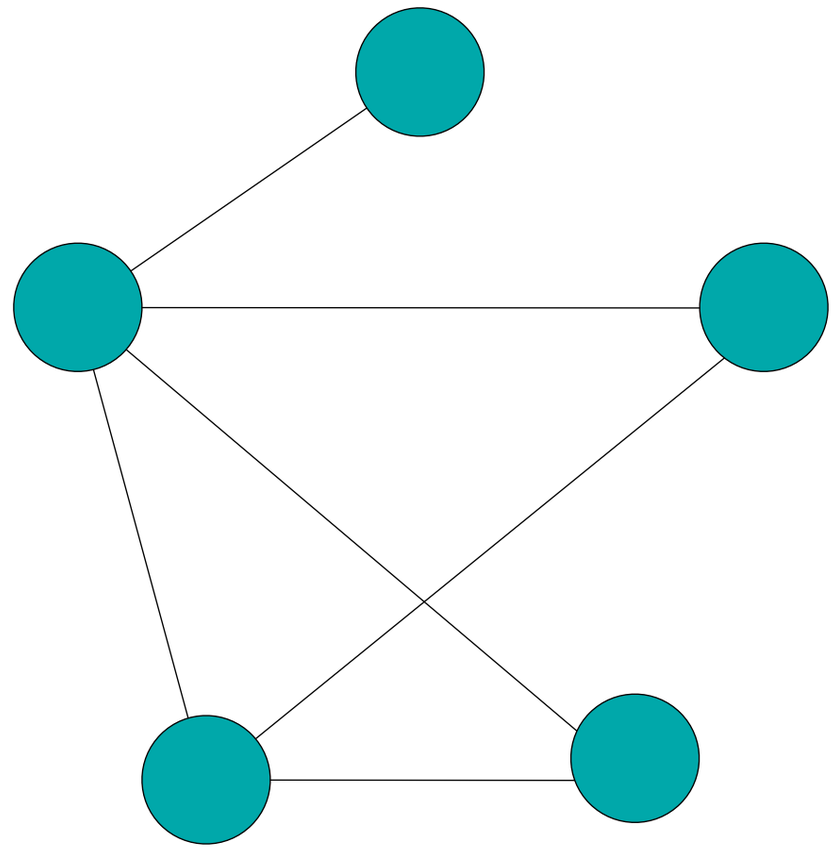
# Fully Meshed Network

- Advantages
  - Topology with the highest reliability
  - Direct connectivity between all nodes
- Disadvantages
  - expensive
  - difficult to expand
  - complex wiring



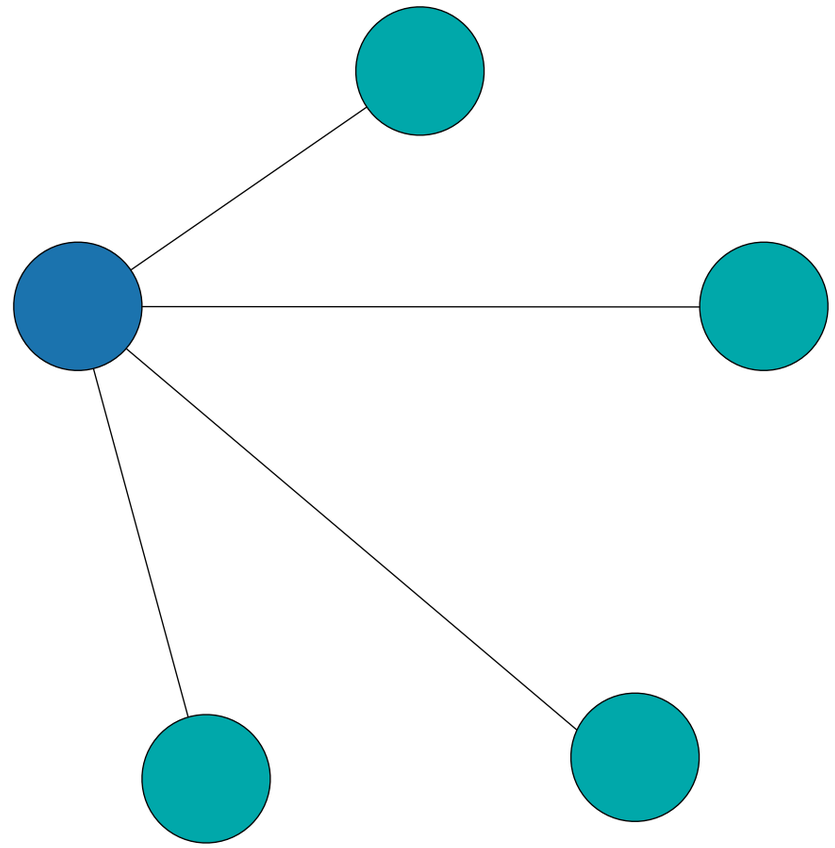
# Partly Meshed Network

- Advantages
  - relatively high reliability
  - alternative routes available in case of failure of the dedicated node
- Disadvantages
  - still not suitable for large networks
  - complex wiring



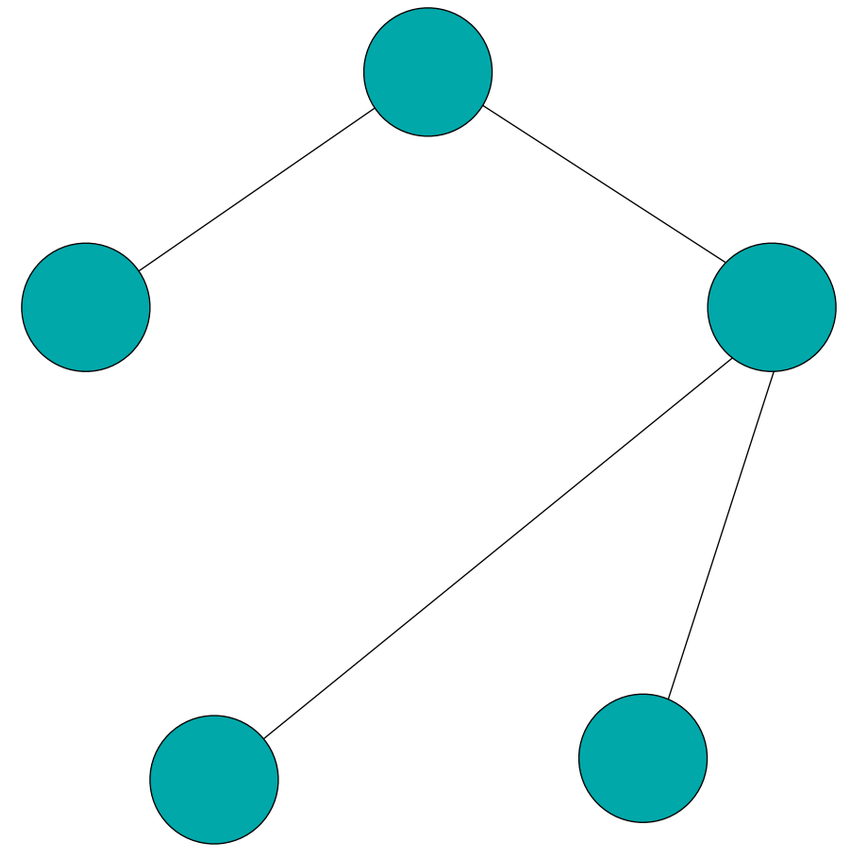
# Star Topology

- Advantages
  - simple expansion
  - straightforward network management
- Disadvantages
  - single point of failure (in case of failure of the central node: collapse of the network)



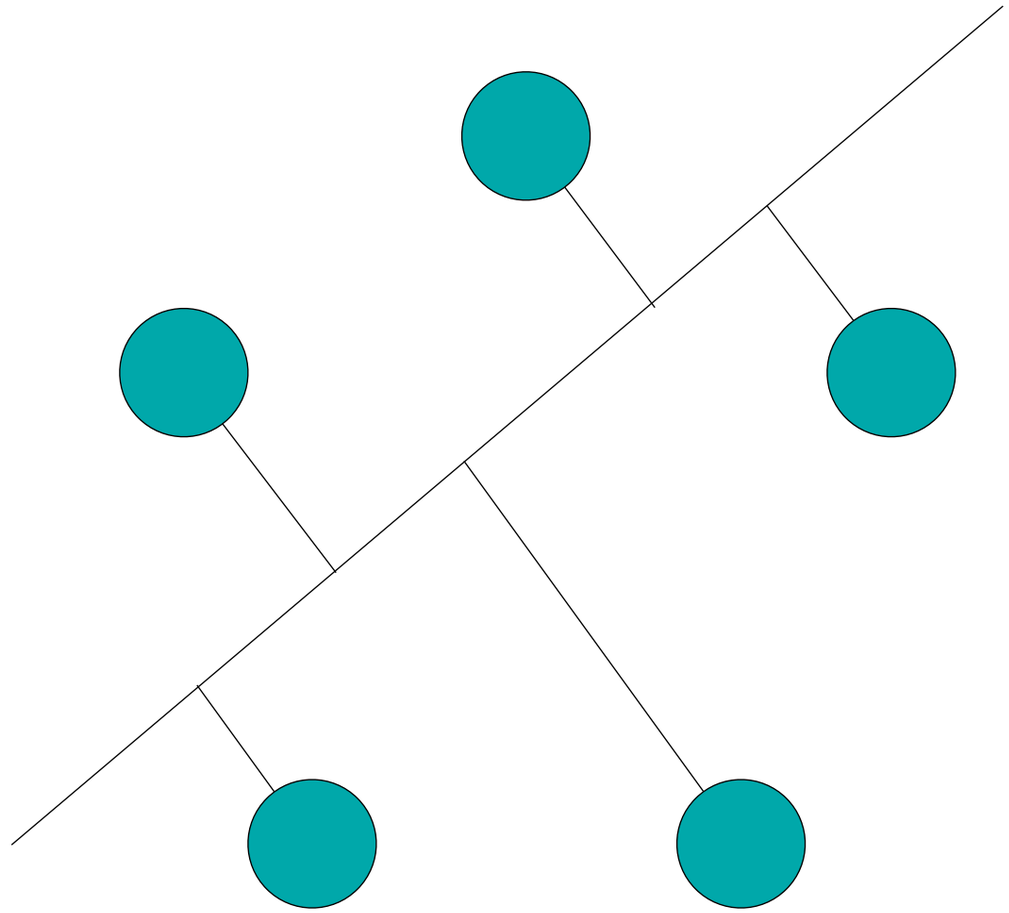
# Hierarchical Network Topology (Tree)

- Advantages
  - Easy to expand
  - In case of failure of a superior node only failure of subsystems
- Disadvantages
  - branches can be disconnected in case of failure of a superior node



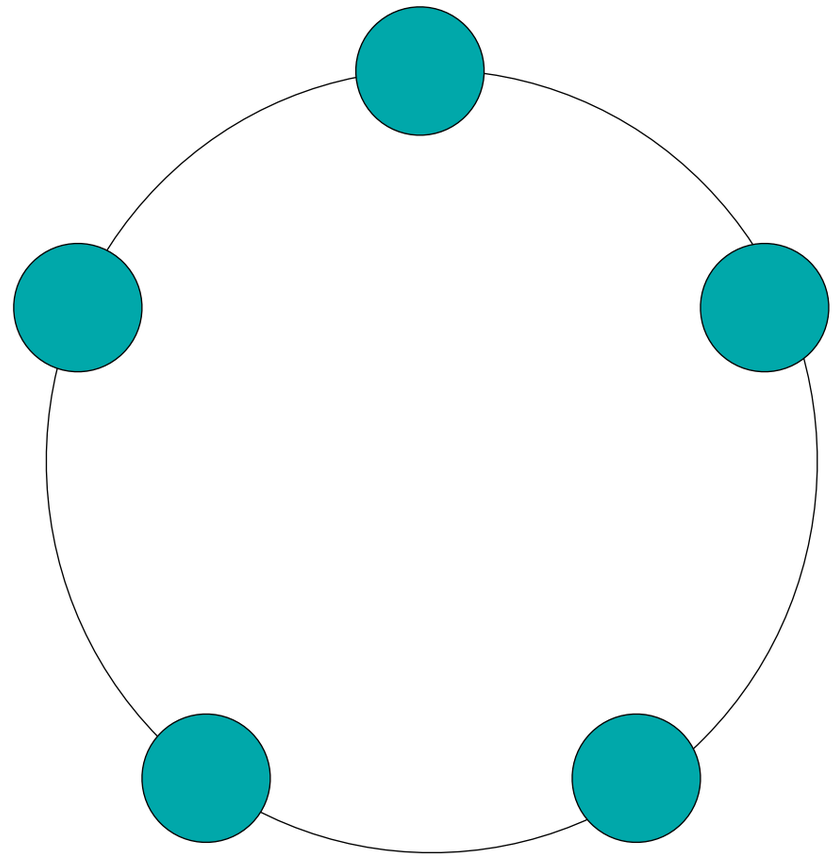
# Bus Topology

- Advantages
  - connectivity between dedicated nodes is not affected by failure of another node
- Disadvantages
  - shared bandwidth
  - (no further development)



# Ring Topology

- Advantages
  - all stations have equal priority for the medium access
- Disadvantages
  - shared bandwidth
  - (no further development)



# Different Paradigms for Communication Networks

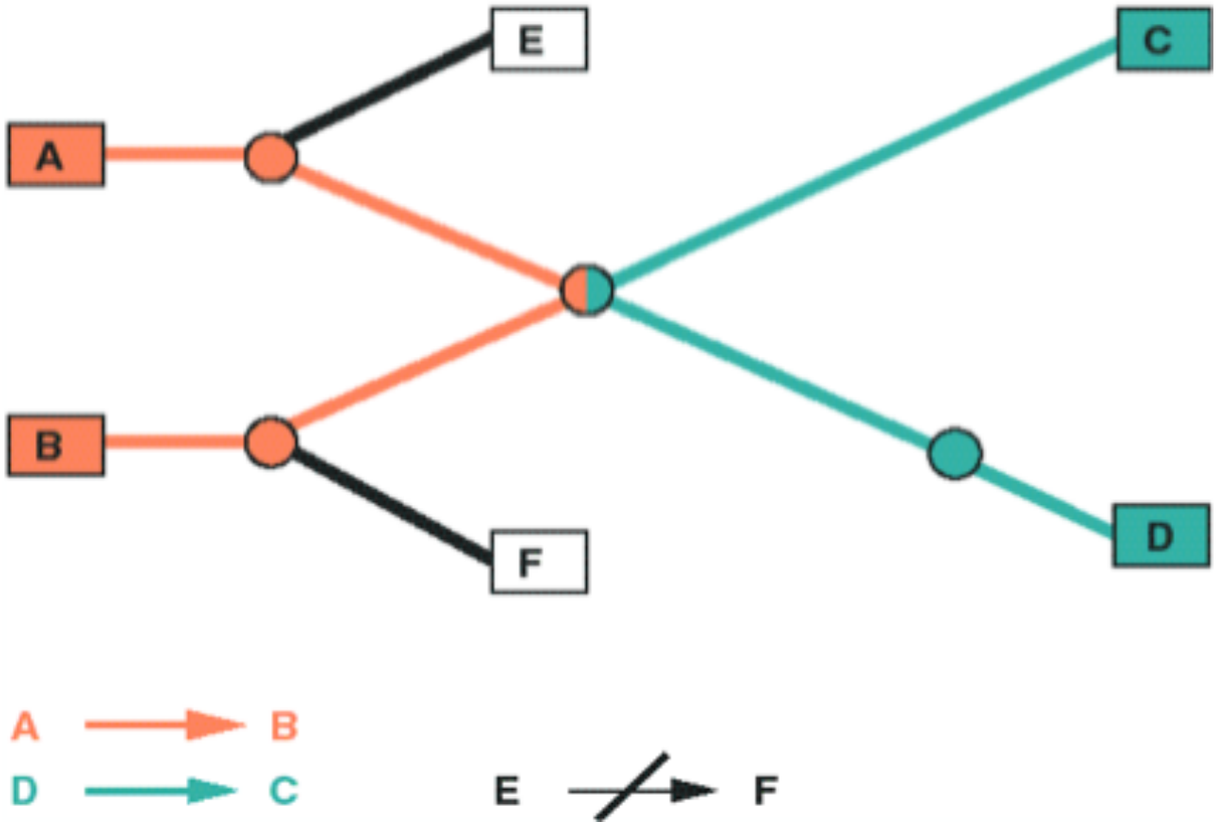
- circuit-switched
- packet-switched

# Circuit-Switching

- Dedicated line (virtual or physical)
- Exclusive use of the line resources for the communication partners.
- Line has to be established (signaling)
- Highest level of QoS

Example: public telephone system

# Circuit-Switching (illustration)

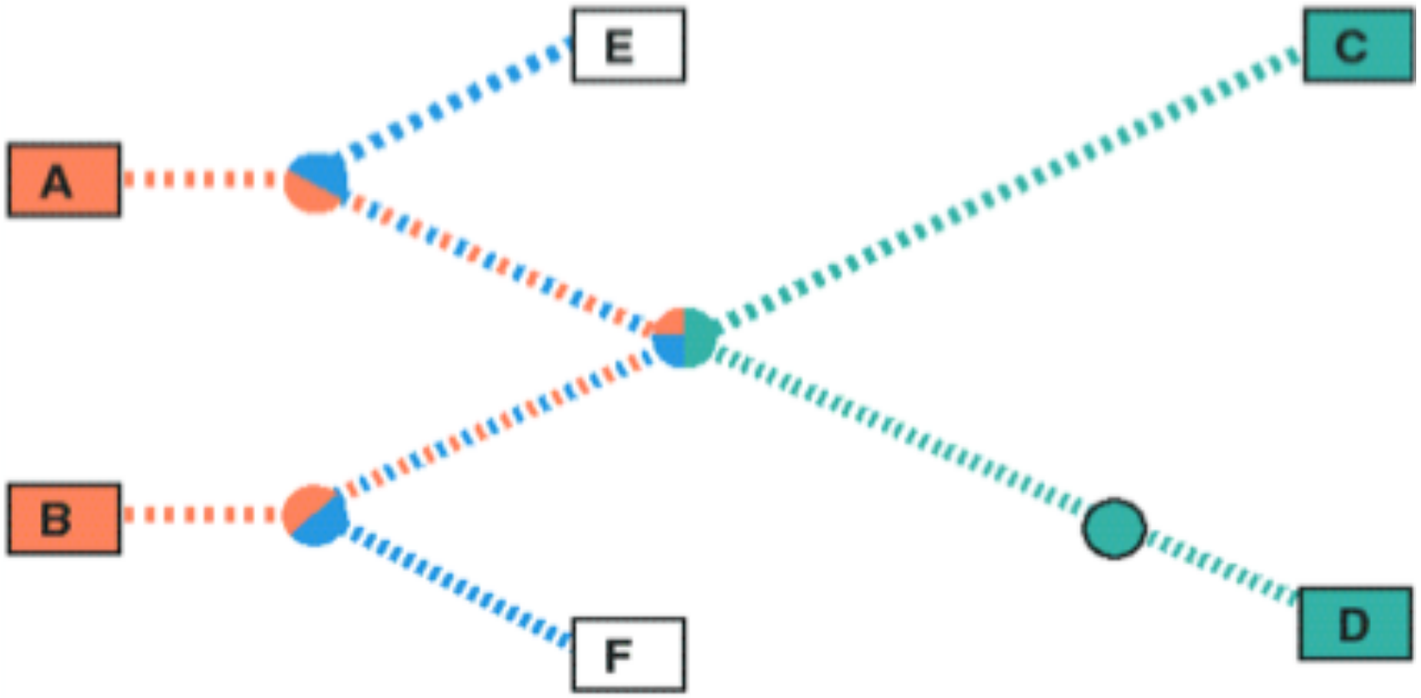


# Packet-Switching

- Segmentation of payload in packets of constant or variable size
- Autonomous transport of the packets through the network
- The packets must contain a destination address (and as a rule also the source address)
- Special case: cell switching, partial address (e.g. ATM)

Example: Shared bandwidth network

# Packet-Switched (illustration)




A → B

D → C

E → F

# Modes of Communication Services

- connection-oriented or connectionless
- sequencing
- error control
- flow control
- full-duplex or half duplex
- byte stream or message oriented

# Connection-Oriented

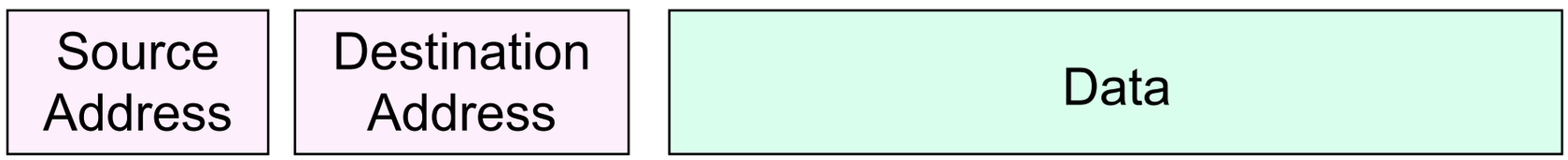
- Establishment of virtual circuits
- There are three steps involved: (signaling)
  - connection establishment
  - data transfer
  - connection termination
- From the application program‘s perspective a dedicated circuit is established between the target systems, although the data transport mechanism is based on a packet-switching network.

Example: TCP

# Connectionless

- Datagram service
- Messages called datagrams are transmitted from the source to the target system.
  Each datagram is transmitted independently and must contain all information that is necessary to reach the destination.

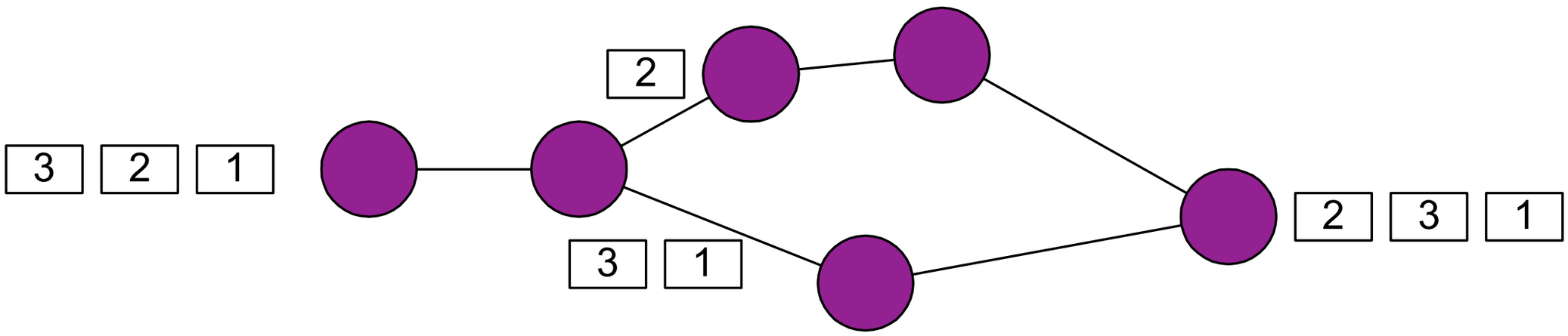
Example: UDP



# Sequencing

- In a packet-switching network, it is possible for two consecutive packets to take different routes from the source to the destination system, which could change the original sequence of the packets

Example: TCP provides this service, UDP does not



# Error Control

- Guarantees that error-free data is received
- Technique:  e.g. checksum and positive acknowledgement

Example:  TCP provides this service, UDP does not

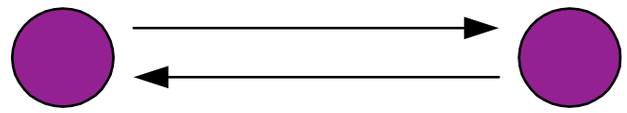
# Flow Control

- assures that the sender does not overwhelm the receiver by sending data at a higher rate than the receiver can process the data
- In case flow control is not provided, the receiver could lose data because of lack of resources.

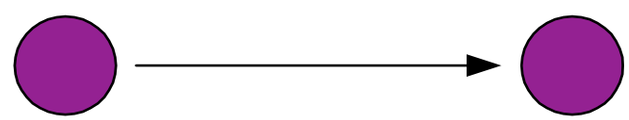
Example: TCP provides this service, UDP does not

# Full-Duplex or Half-Duplex

- A full-duplex service allows data to be transferred in both directions at the same time between dedicated devices



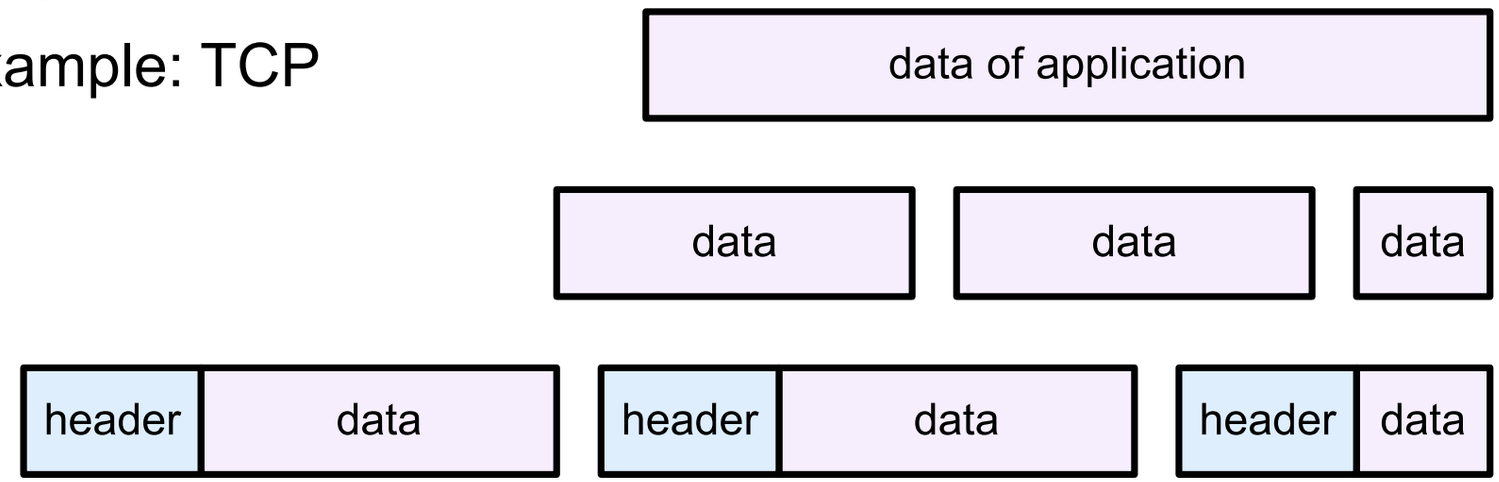
- A half-duplex service allows only unidirectional communication at the same time



# Byte Stream or Messages

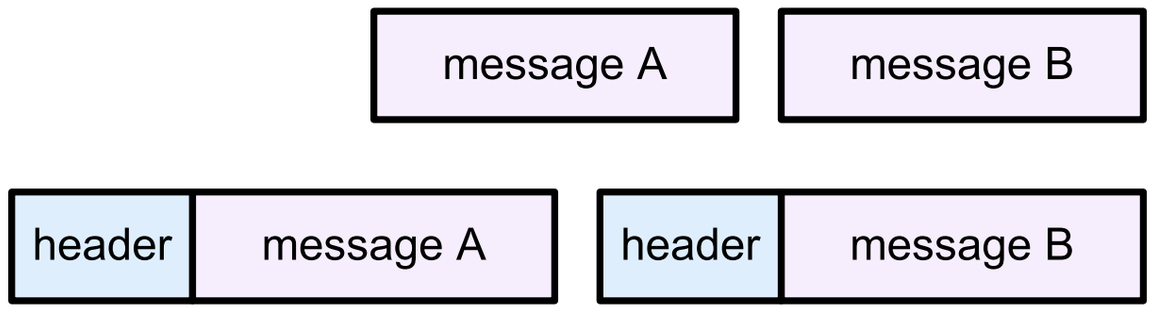
- Byte stream

Example: TCP




- Messages

Example: UDP



# Basics (cont.)

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- OSI-Model
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# Medium Access Control (MAC)

- Within OSI layer 2a
- Several nodes are connected to the same physical medium
- An access protocol is required, if these nodes share the medium

  If two or more nodes send a signal on the medium at the same time (collision)
  - ➔ Interference of the signals on the medium
  - ➔ Demodulation of the signal fails at the receiver(s)
  - ➔ Send data is not received correct

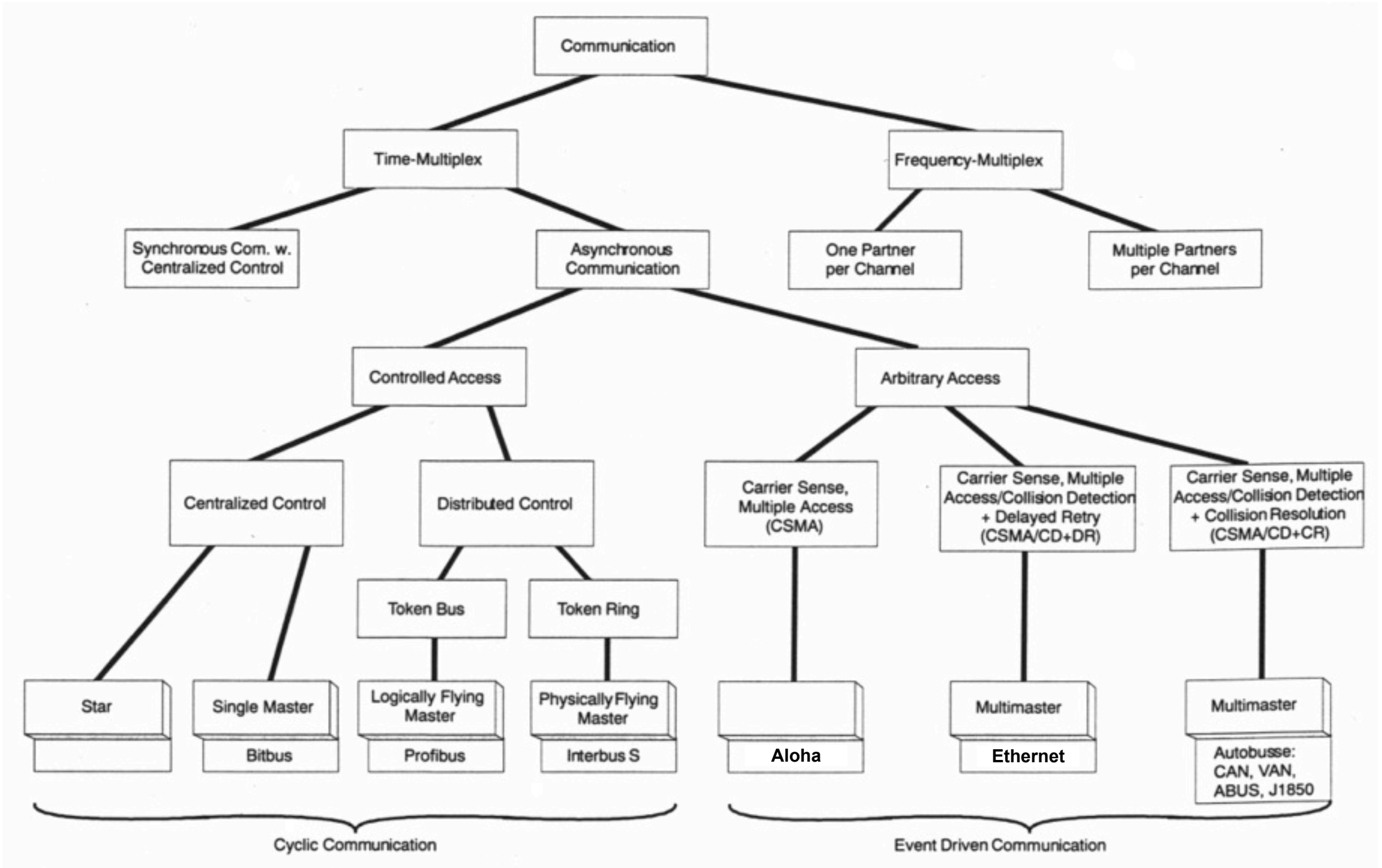
# Medium Access Control (MAC)

- Contention-based MAC protocols
  - Nodes compete for the channel access
  - Detects and/or avoids collision of data frames

- Allocation of the medium based on reservation of resources
  - Division of available resources in fair (equal) sized portions for N users (basic idea)

  - Frequency Division Multiplexing (FDM) – Division of available bandwidth
  - Time Division Multiplexing (TDM) – Allocation each N-th time slot to one specific user
  - Code Division Multiplexing (CDM)
  - Space Division Multiplexing (SDM)

# Medium Access Methods



# Aloha

- Pure Aloha
  - Any station starts transmission at any time
  - Station waits for acknowledge (ACK)
  - Retransmission if no ACK has arrived after a certain time interval
  - High collision probability
    - ➔ max. throughput is low (18,4% of available bandwidth)

- Slotted Aloha
  - Improved Aloha protocol
  - Stations are only allowed to send at the beginning of discrete timeslots
  - Probability of collisions is reduced
    - ➔ higher max. throughput (36,8% of available bandwidth)

# CSMA (Carrier Sense Multiple Access)

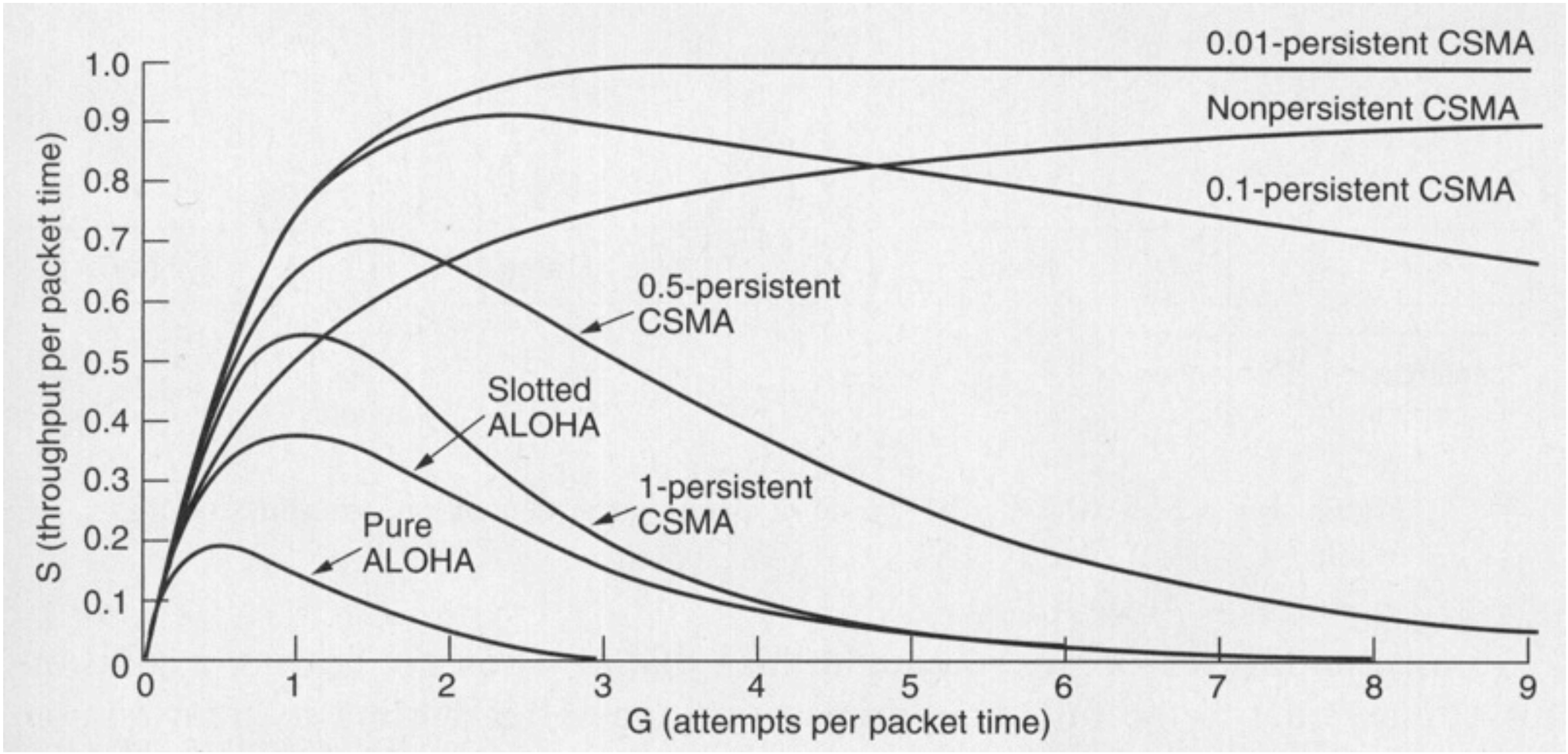
- General approach: when there is data to be sent, listen to the medium if anyone else is transmitting at the moment
- 1-persistent CSMA
  - Wait for free medium, then start transmission
  - Collisions due to propagation delay and simultaneous transmission begins
  - Performance better than using ALOHA
- p-persistent CSMA
  - Slotted approach
  - After medium becomes free, a station transmits with a probability p,
    It defers to the next slot with probability q = 1 - p
  - If the medium is still idle at the beginning of the next slot, this process is repeated

# CSMA (Carrier Sense Multiple Access)

- non-persistent CSMA
  - Sense the medium and start transmission if the medium is free
  - If medium is busy, station does not continue sensing.
  - Instead the station waits for a random number of time and repeats the process.
  - Better channel utilization but longer delays than 1-persistent CSMA

# CSMA vs. ALOHA

Comparison of channel utilization for the different approaches




Source: Computer Networks, 4th Edition, Andrew S. Tanenbaum

# CSMA with Collision Detection (CSMA/CD)

- Collision detection by monitoring the signal on the medium while sending
- Medium must have been free for the time of a Interframe Gap (IFG) before sending
- If a collision is detected while transmitting
  - Transmit a jam signal
    - → all stations will recognize the collision
  - Wait for a random time and reattempt (backoff)