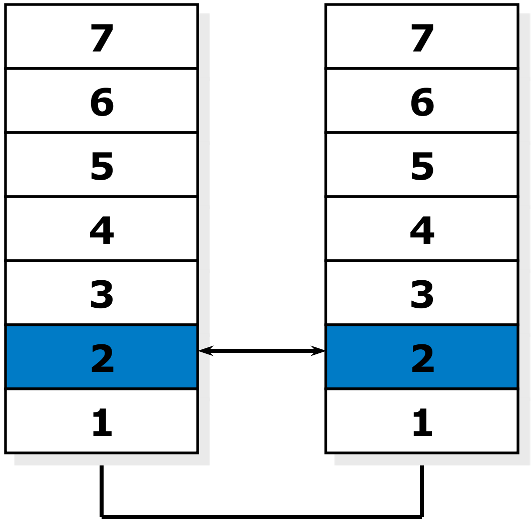
Operating Systems & Computer Networks

Host-to-Network III

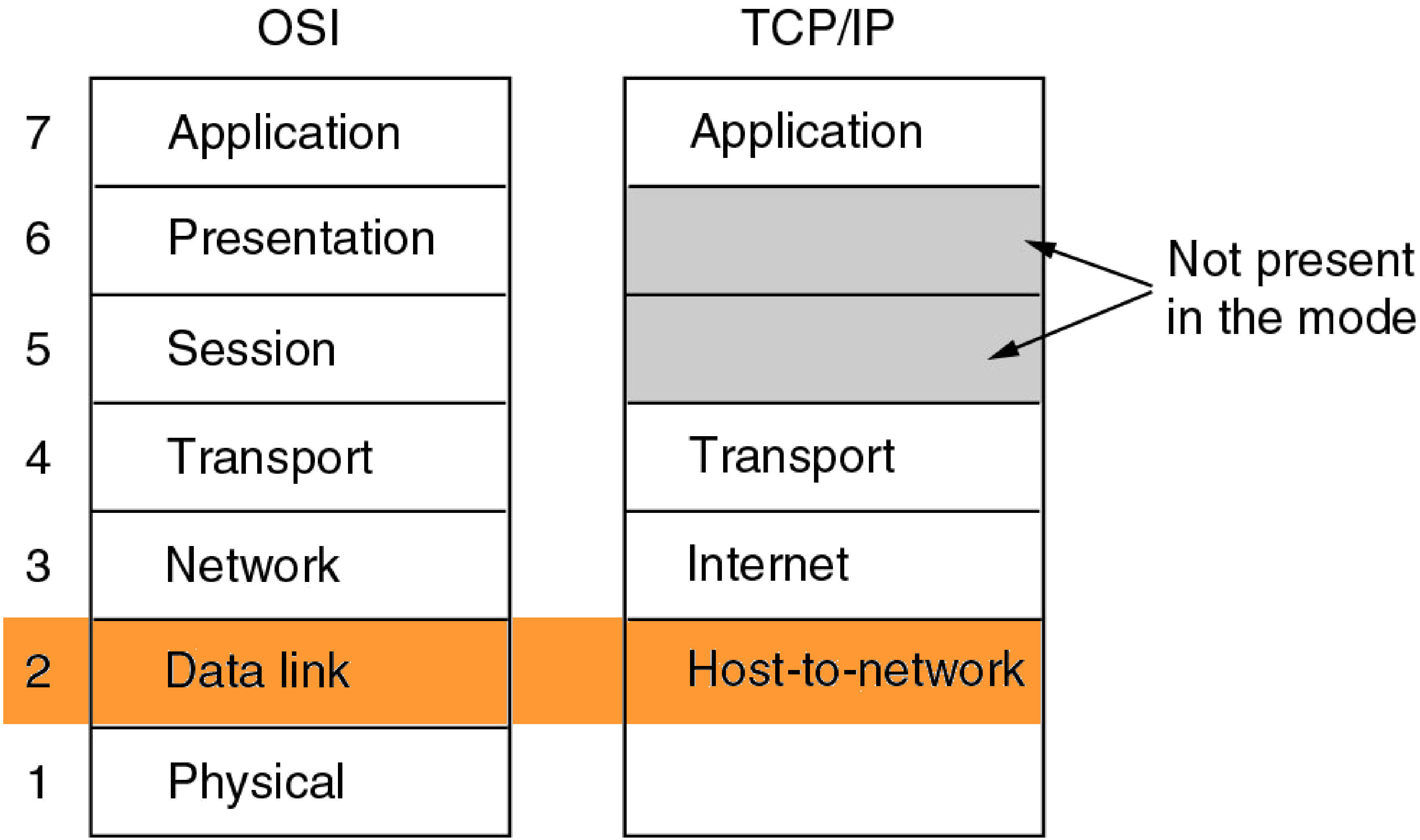
- Topologies
- Media Access
- Local Area Networks
- Ethernet, WLAN



Content (2)

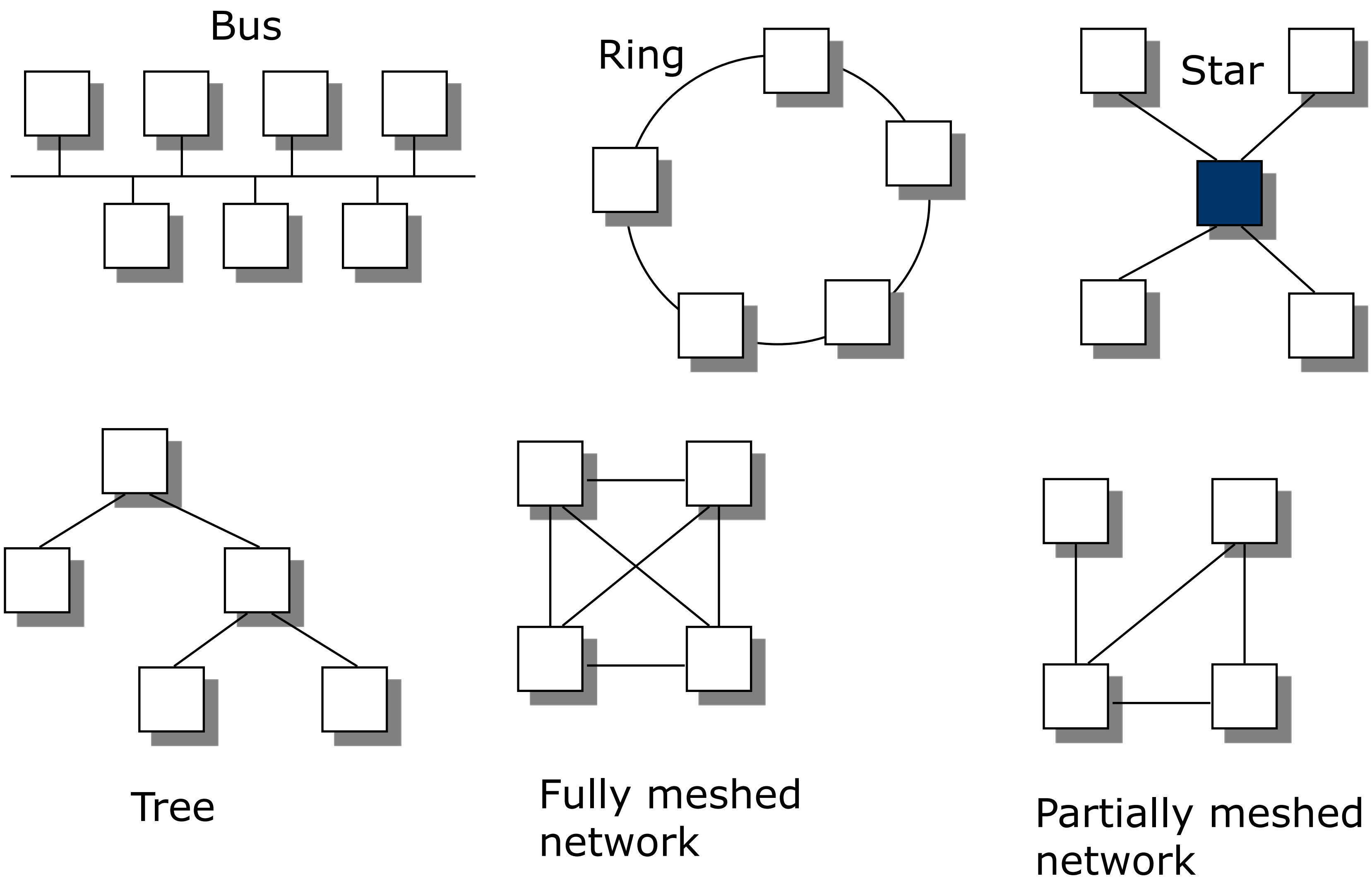
8. Networked Computer & Internet
9. Host-to-Network I
10. Host-to-Network II
11. **Host-to-Network III**
12. Internetworking
13. Transport Layer

Data Link Layer



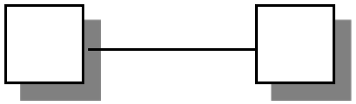
Network Topologies

Topologies by Network Structure

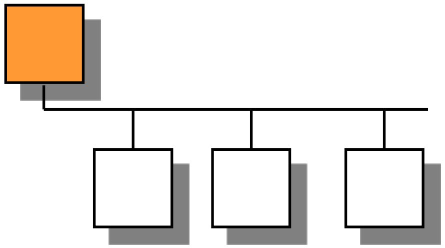


Topologies by Connectivity

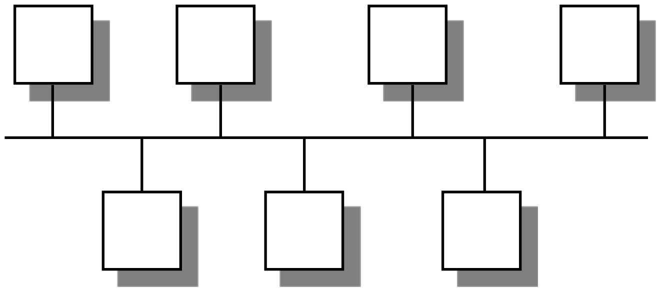
- Point-to-point connection



- Point-to-multi-point connection (asymmetrical)



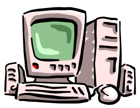
- Multi-point connection (symmetrical)



➢ Distinguish: Physical (layer 1) and logical ($\geq$ layer 2) topologies

Structured Cabling

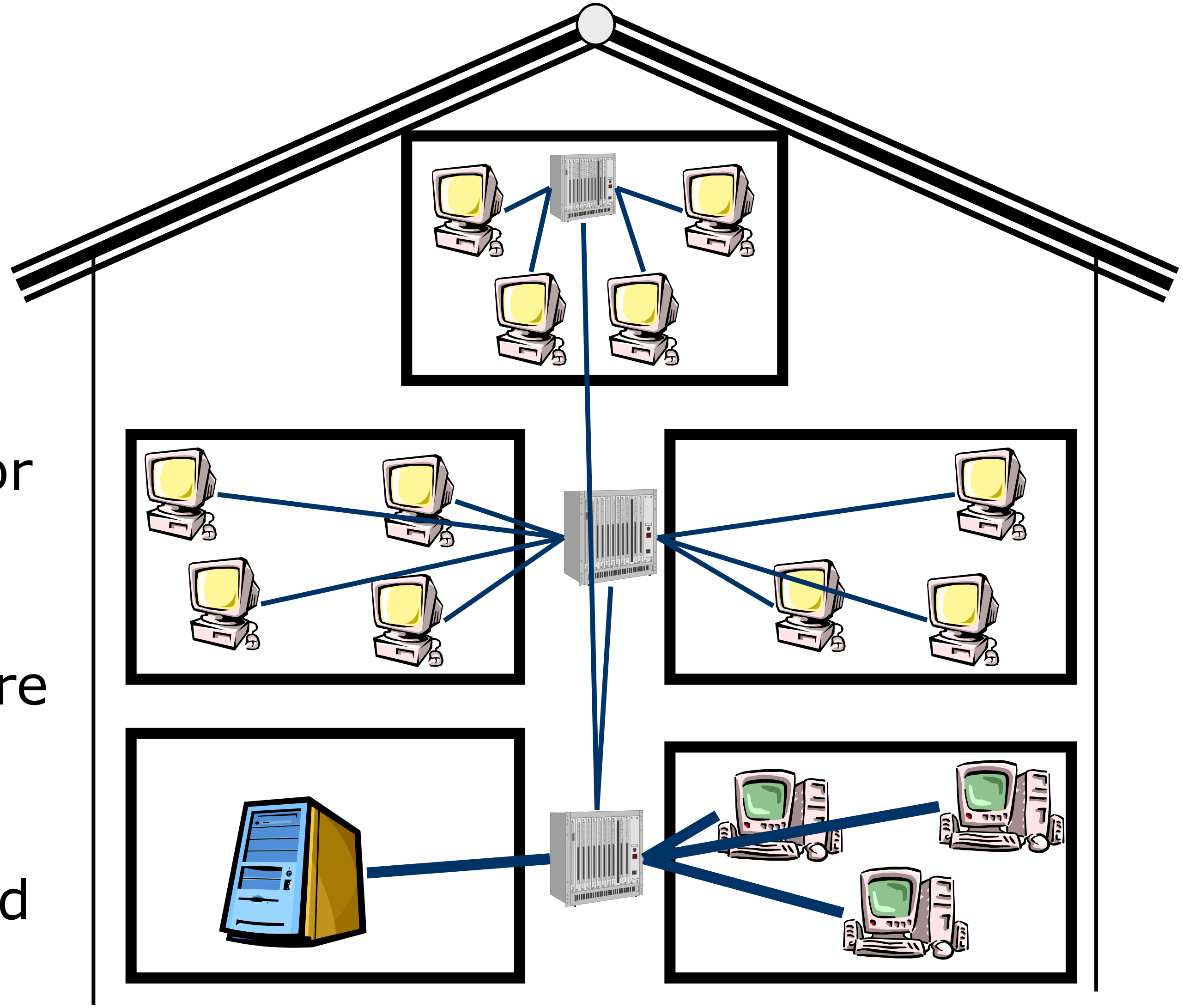
Computers



Servers

Router for Internet access

- Star on each floor
- Star to connect individual stars
  - ➢ Tree-like structure
  - ➢ Point-to-point connections avoid packet collisions

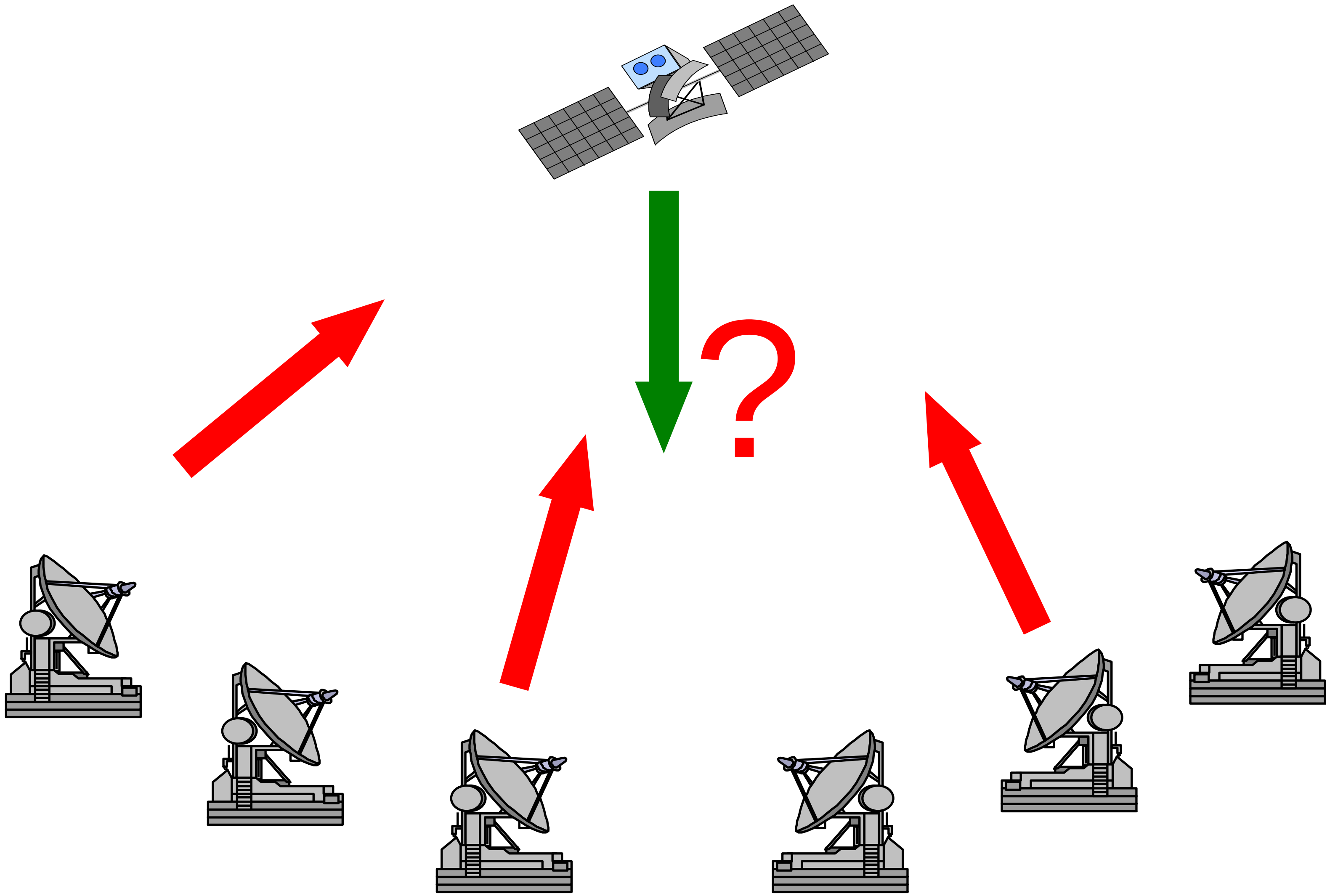


Star Topology – Lots of Cables

- Cabling not trivial:
  - Initial cost, upgradability, space for installation

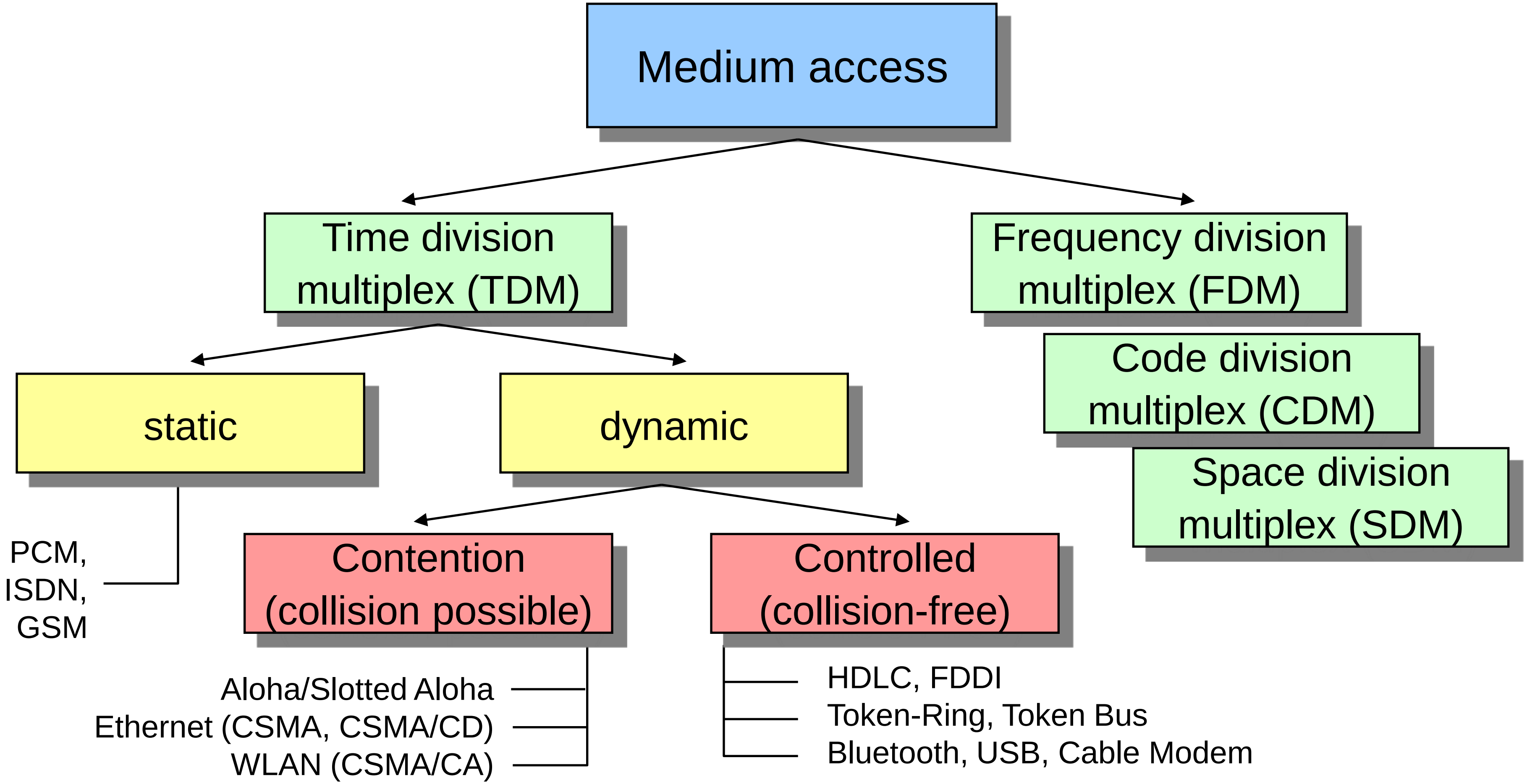
Medium Access Control

Motivation: Satellite Medium Access



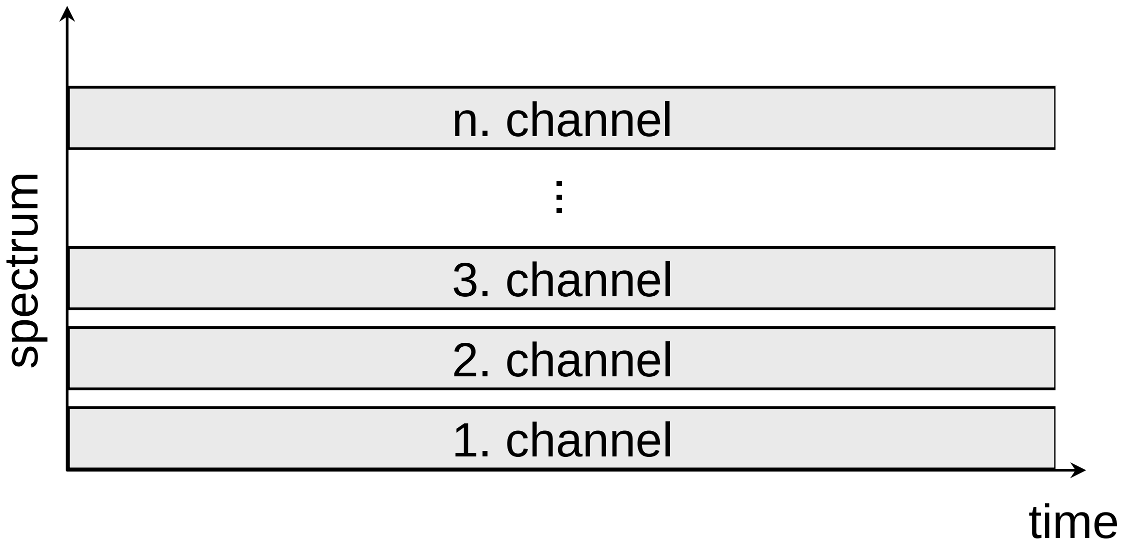
Approaches to Medium Access

- Several stations want to access the same medium – how to separate stations?



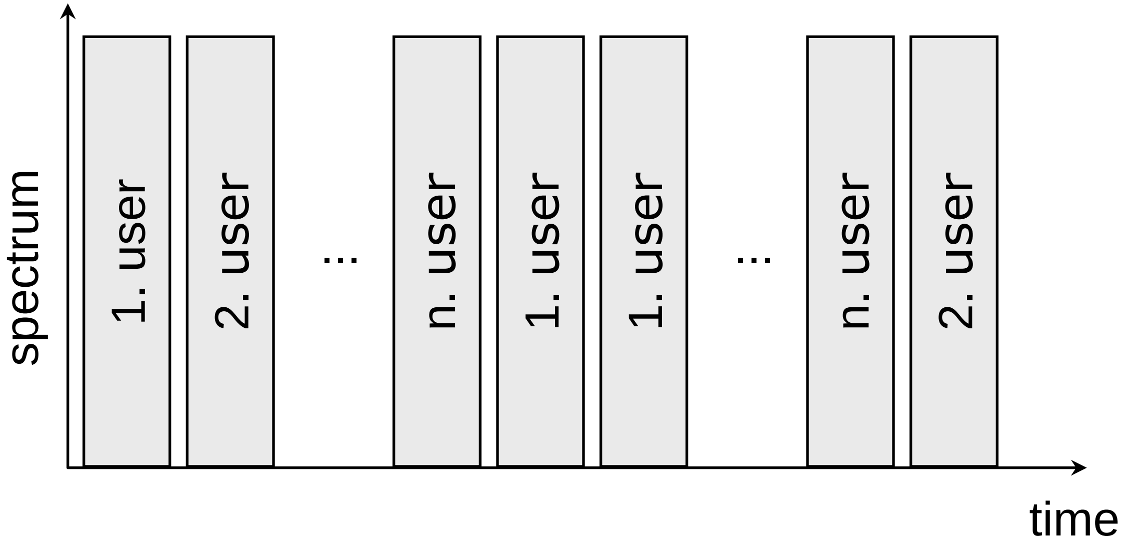
FDM + Algorithm for Access: FDMA

- Frequency Division Multiple Access (FDMA):
  - Subdivide spectrum into sub-channels
    - Use different broadband frequencies for modulation
  - Assign sub-channel to user
    - Static vs. dynamic assignment
  - ➢ Examples: Radio stations, cable channels, WLAN APs



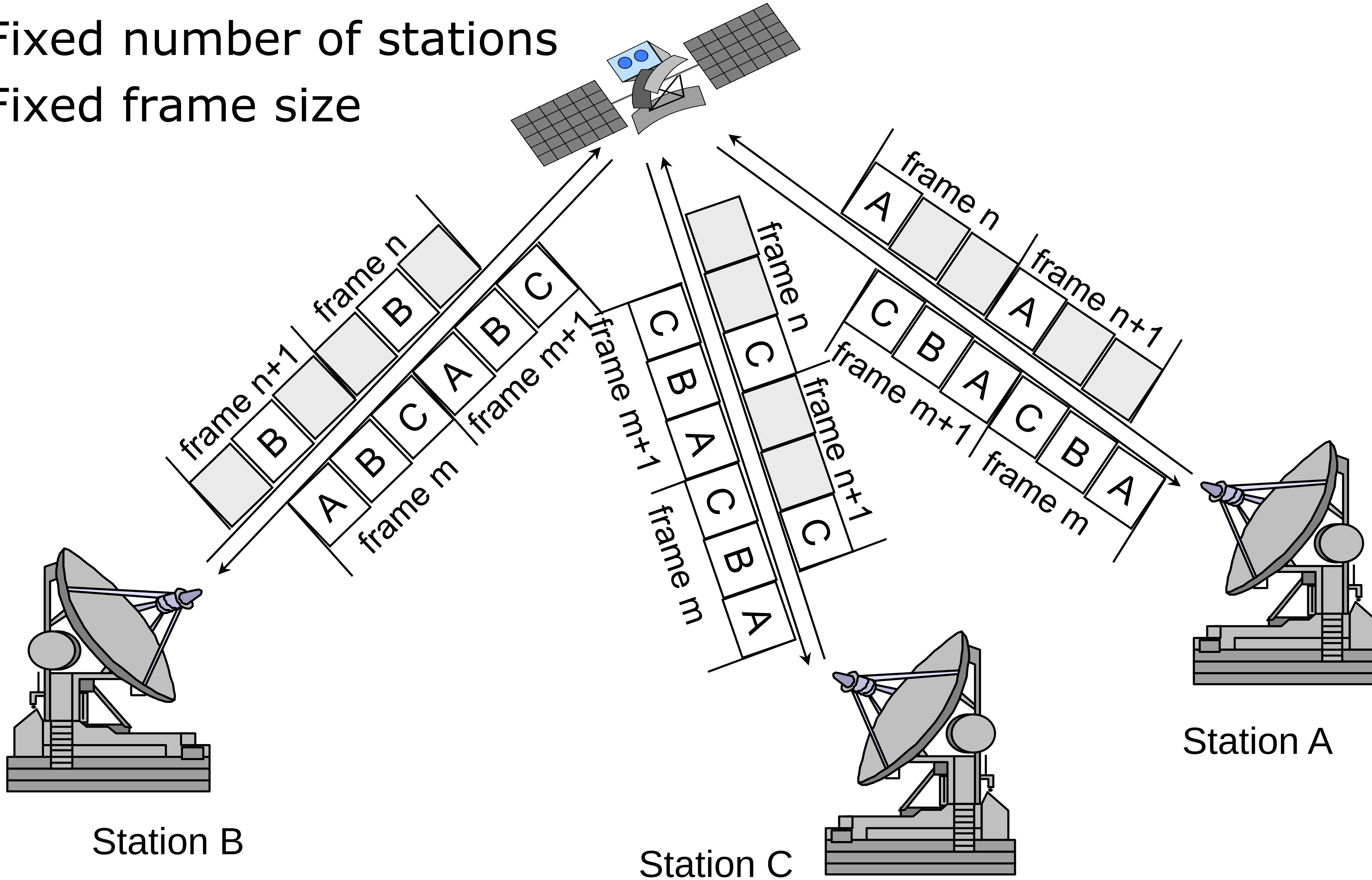
TDM + Algorithm for Access: TDMA

- Time Division Multiple Access (TDMA):
  - Assign channel (static/dynamic) for certain time to user
    - Each user can use the full channel for the assigned time
  - Static: Cyclic assignment (e.g. GSM, ISDN, Bluetooth voice)
  - Dynamic: On-demand assignment (e.g. Ethernet, WLAN hosts, Bluetooth data)



Example: Static TDMA

- Fixed number of stations
- Fixed frame size



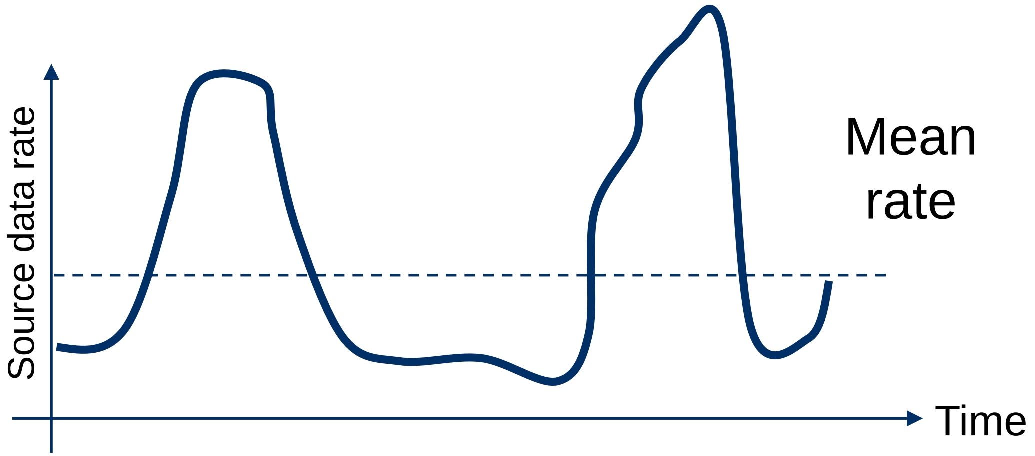
Static Multiplexing – General Idea

- A single resource can be statically multiplexed by
  - assigning fixed time slots to multiple communication pairs
  - assigning fixed frequency bands
  - …

- Assigning fixed resources to different sources is fine if
  - data rate of source and multiplexed link are matched
  - sources can always saturate the medium
- ➢ Otherwise medium is either not sufficient or not used optimally
- Examples: Classical telephone, ISDN, GSM
  - ➢ Data rate is given by application, e.g. ISDN (64kbit/s)

Bursty Traffic

- Problem: What happens if sources have *bursty* traffic?
  - Definition: Large difference between peak and average data rate
  - Example: Web traffic



- In general-purpose computer networks commonly

$$\text{Peak} : \text{Average} = 1000 : 1$$

- Static multiplexing fails to allocate medium efficiently

Dynamic Channel Allocation / MAC

- Alternative: Assign channel to that source that *currently* has data to send
  - ➢ *Dynamic* channel allocation
  - Assumes some degree of independence of usage patterns over participating hosts

- Terminology: Access to transmission medium has to be organized by **Medium Access Control (MAC) protocol**

- Pro: Better utilization of medium based on local (per host) demand
- Contra: Dynamic allocation incurs some management overhead, i.e., requires in-band signaling

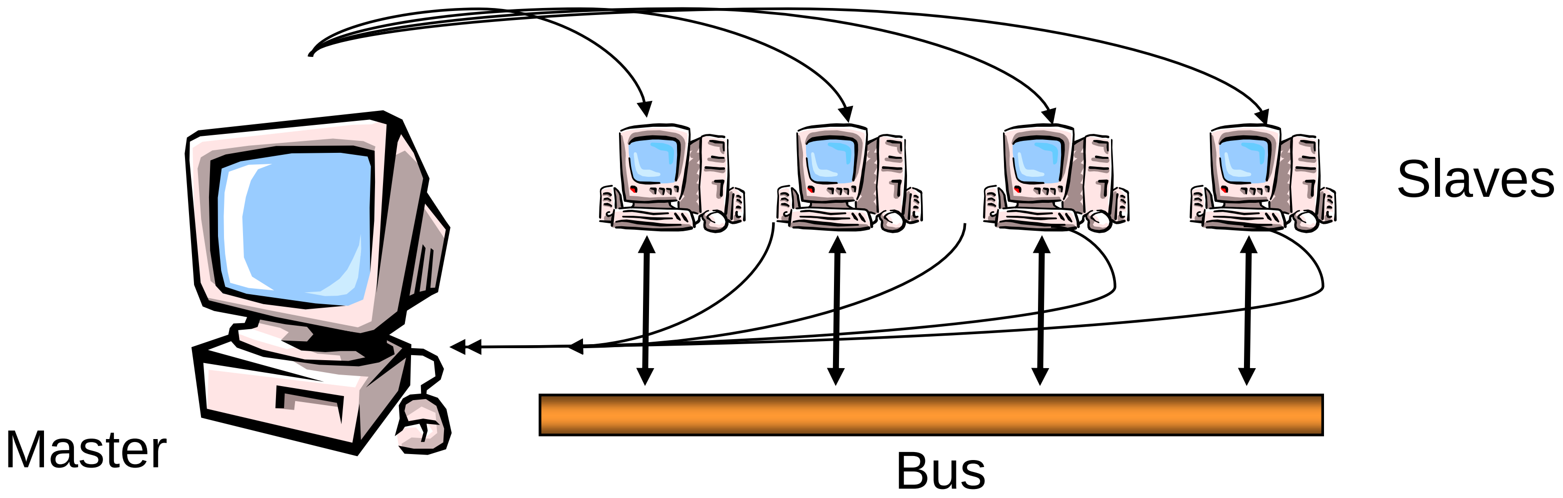
Figures of Merit

- How to judge the efficiency of a MAC protocol?
  - Intuition: Transmit as many packets as quickly as possible

1. At high load (many transmission attempts per unit time): *Throughput* is crucial – ensure that many packets are transmitted
2. At low load (few transmission attempts per unit time): *Delay* is crucial – ensure that a packet does not have to wait for a long time
3. Fairness: Is every station treated equally?

Dynamic/Controlled MAC: Polling

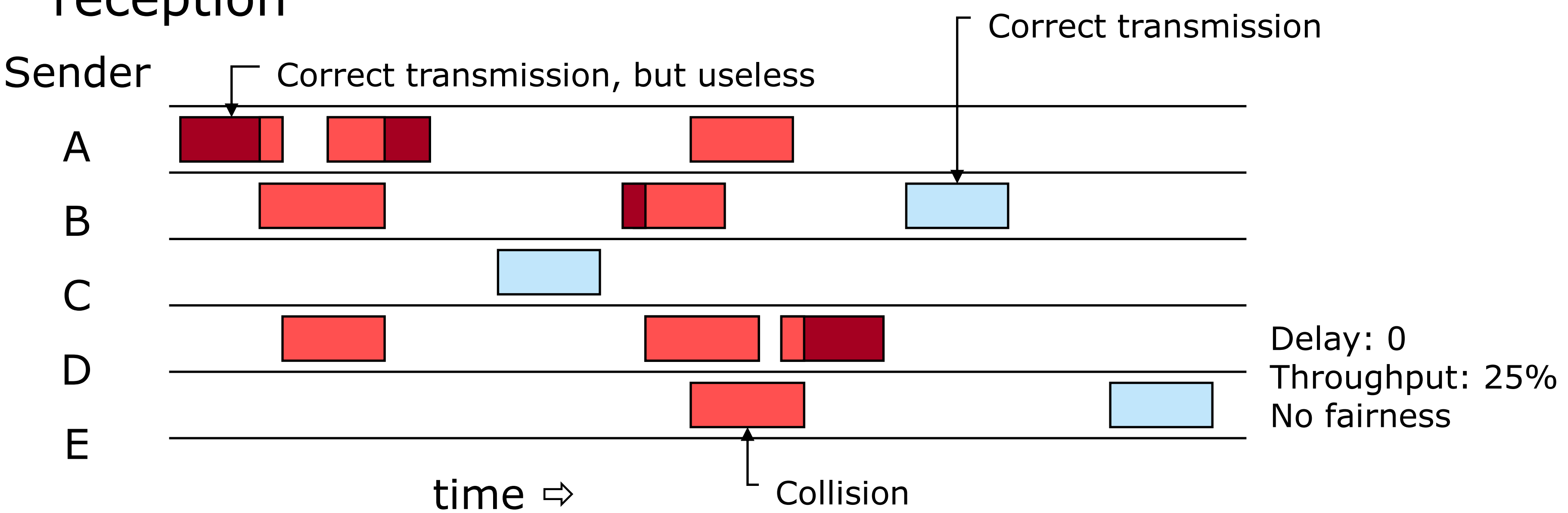
- Single master station
- One or more slave stations
- Typically bus topology (but also tree)
- Master polls slaves according to table or cyclically
- Slaves may answer only after being polled



➢ Examples: Bluetooth, USB, cable modems

Dynamic/Contention MAC: ALOHA

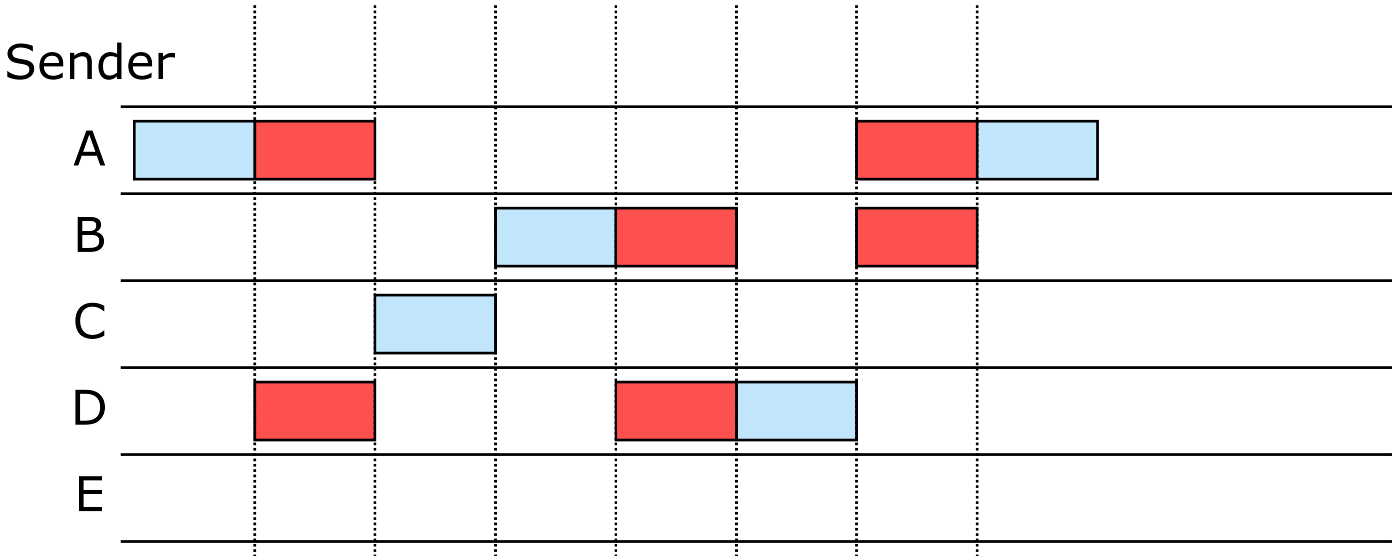
- No central control, no coordination between stations
- Stations start sending whenever they want to
  - Collisions destroy frames
- Receiver may send acknowledgement after correct reception



➢ Best option without any carrier sensing or central station

Dynamic/Contention MAC: Slotted ALOHA

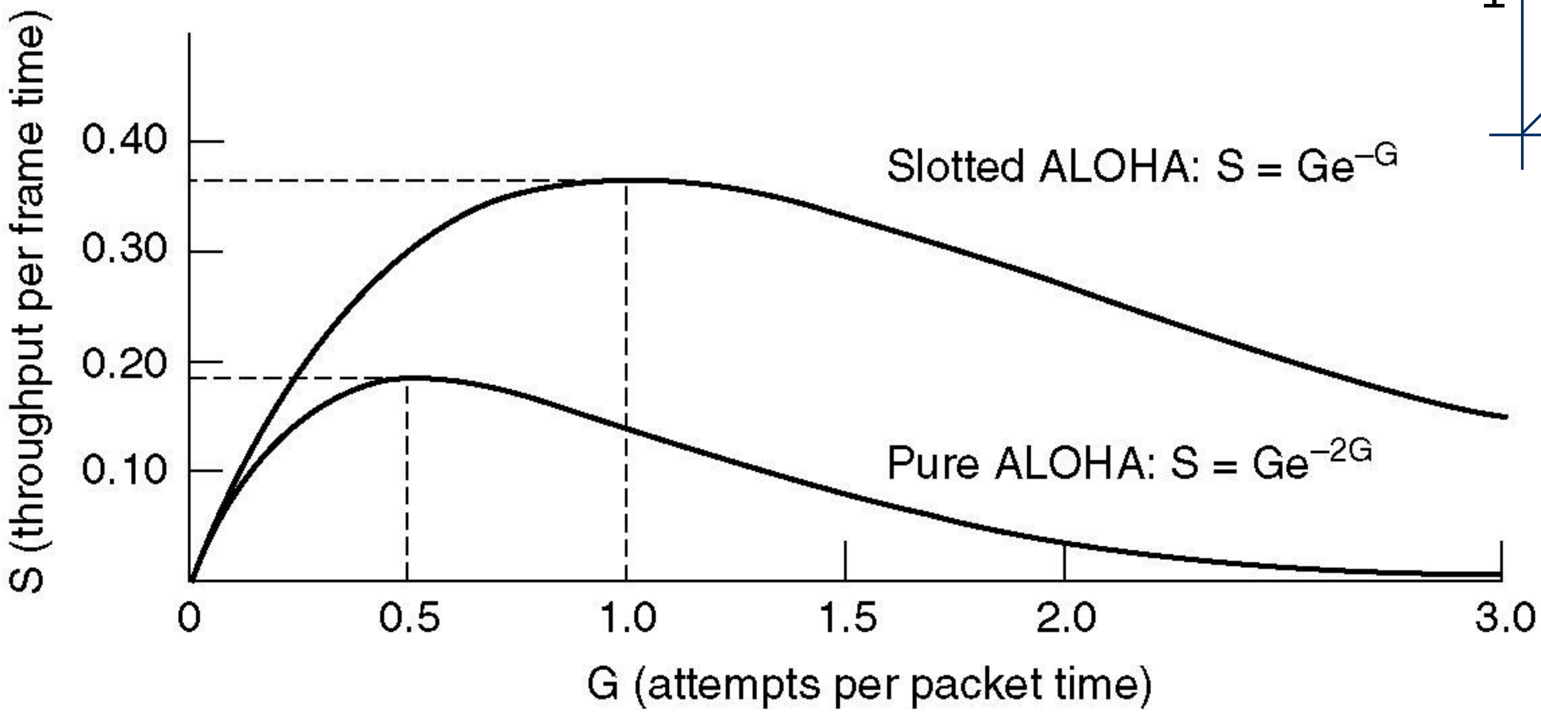
- Send packets of fixed length within fixed time-slots
  - Requires common time-base for synchronization
- Transmission starts at begin of slot only, thus only complete collisions may occur

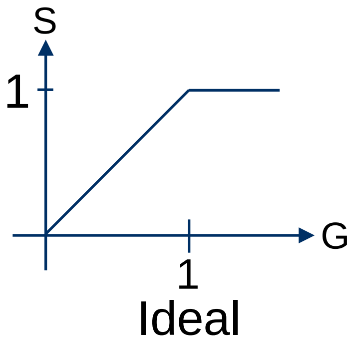


Delay: < slot time
Throughput: 45%
No fairness

- Best option without carrier sensing (but sync required)
- Example: Initial medium access of GSM control channel

- Closed form analysis (queuing theory) of throughput S as function of offered load G for (slotted) ALOHA:





➢ Anything but a high-performance protocol
  - Throughput collapses as offered load increases

Performance – Intuition

- Aloha

- Slotted Aloha

Carrier Sensing

- (Slotted) ALOHA is simple, but not satisfactory
  - Does not scale over offered load

➢ New Approach: Be a bit more polite – **Listen before talk**
  - Sense carrier to check whether medium is idle before transmitting
  - Do not transmit if medium is busy (some other sender is currently transmitting)
  - ➢ **Carrier Sense Multiple Access (CSMA)**

➢ But: How to behave in detail when carrier is busy?
  - How long to wait before retrying a transmission?

CSMA Strategies

1-persistent CSMA:

- Medium is busy: keep listening until it becomes idle
- Medium is idle: transmit the frame immediately
- ➢ Problem: if more than one station wants to transmit, they are guaranteed to collide

p-persistent CSMA:

- Medium is busy: keep listening until it becomes idle
- Medium is idle: “flip a coin”
  - With probability p, transmit the frame
  - With probability 1-p, wait until next time slot and then sense the medium again (if next slot idle, flip a coin again)

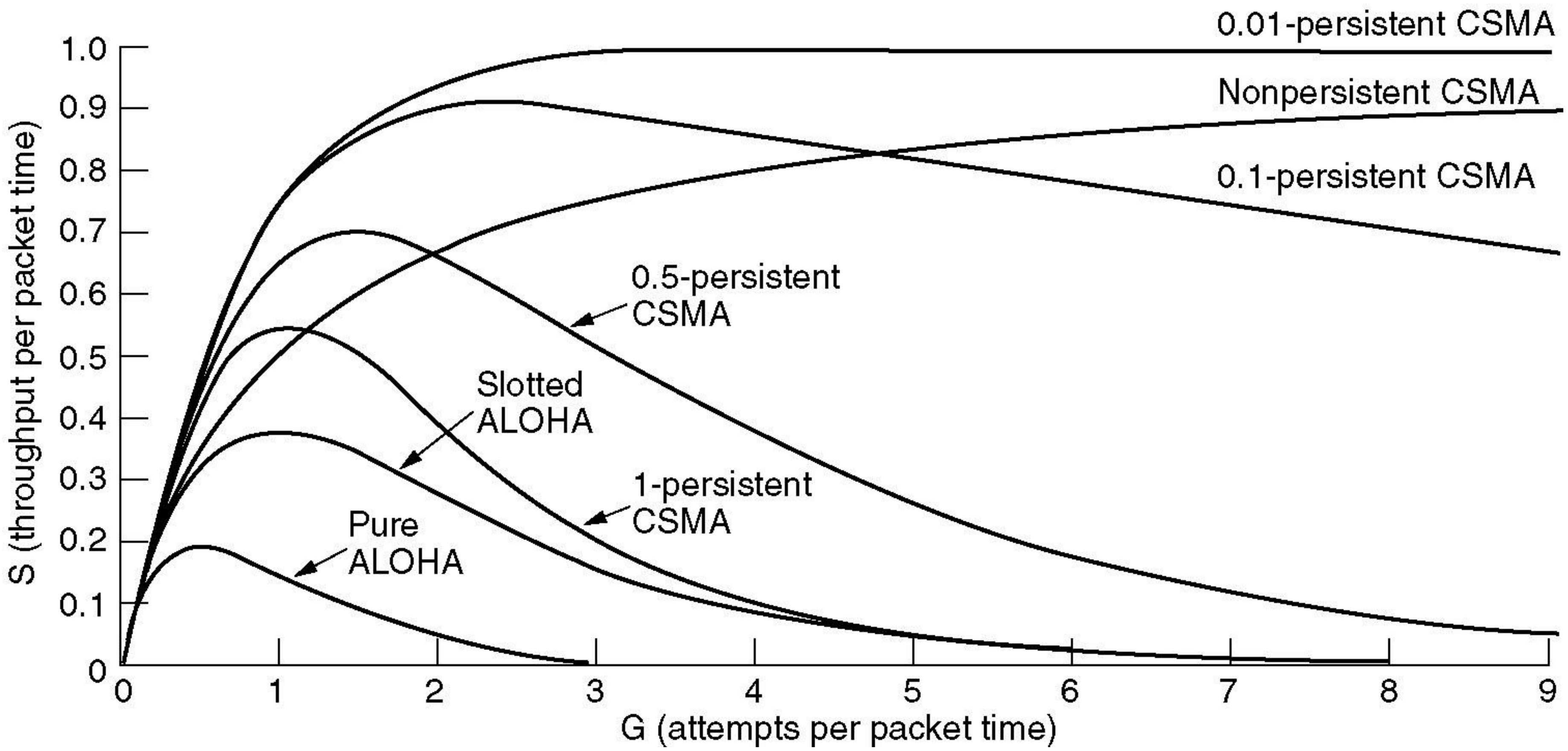
CSMA Strategies

Non-persistent CSMA:

- Medium is busy: wait a random amount of time, before sensing the medium again (don’t be greedy)
- Medium is idle: transmit the frame immediately

- ➢ Performance depends on random distribution used for waiting time
  - In general, better throughput than persistent CSMA for higher loads
  - At low loads, random waiting is not necessary and wasteful

Performance of CSMA



- Throughput characteristic increases as p decreases
- Potentially long delay before transmission starts

Local Area Networks

Local Area Network (LAN)

Possible classifications

Topology

- star
- bus
- tree
- ring
- ...

Medium

- twisted pair copper
- coaxial cable
- fiber optics
- “nothing”

Access method

- controlled/collision-free
- collision/contention
- limited contention

LANs According to IEEE 802

Active Working Groups and Study Groups		Industrial Alliance
802.1	Higher Layer LAN Protocols	
802.3	Ethernet	
802.11	Wireless LAN	WiFi
802.15	Wireless Personal Area Network (WPAN)	Bluetooth, ZigBee
802.16	Broadband Wireless Access	WiMAX
802.17	Resilient Packet Ring	
802.18	Radio Regulatory	
802.19	Coexistence	
802.20	Mobile Broadband Wireless Access (MBWA)	
802.21	Media Independent Handoff	
802.22	Wireless Regional Area Networks	

CSMA/CD

- Collision Detection:
  - During transmission, keep sensing the medium to detect collisions
  - If collision detected, stop frame transmission and send a JAM signal to guarantee that everyone detects the collision
    - Time wasted on collisions is reduced
  - Wait a random amount of time before transmitting again
    - Waiting time is determined by how many collisions have occurred before (exponential backoff algorithm)

- Example: Ethernet (with hubs)
  - When using switches, there is no need to use CSMA/CD
- Only applicable if nodes are able to detect collisions

IEEE 802.3/Ethernet Frame Format

- Common frame format

[byte]

PR	SD	DA	SA	VLAN	Type	Data	PAD	FCS
7	1	6	6	4	2	≤ 1500	≤ 46	4

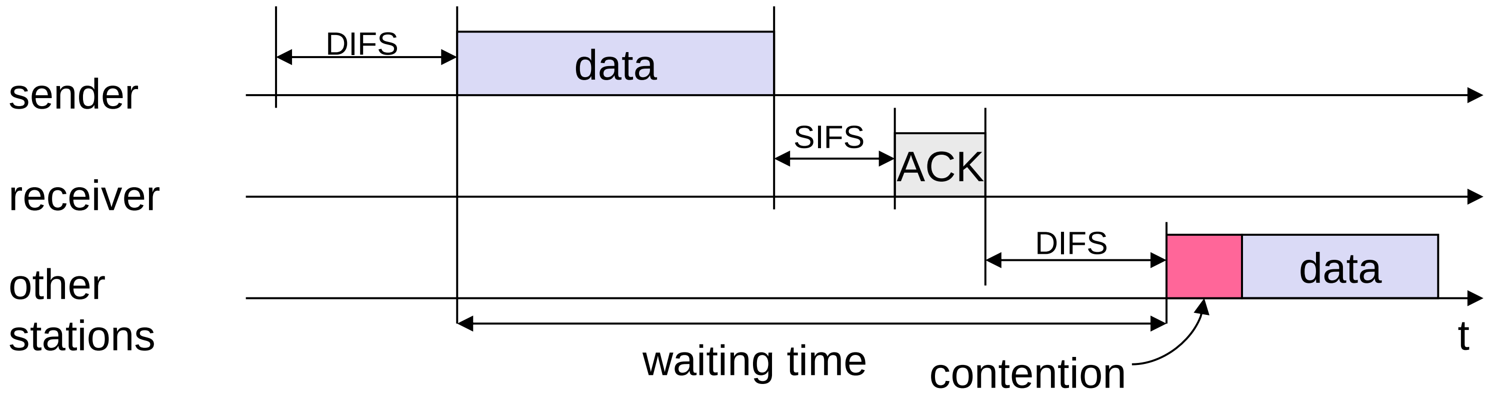
64 - 1518 (1522 VLAN)

PR:	Preamble for synchronization
SD:	Start-of-frame Delimiter
DA:	Destination MAC Address
SA:	Source MAC Address
VLAN:	VLAN tag (if present), 0x8100, 3 bit priority, 12 bit ID (cf. chapter 12)
Type:	Protocol type of payload (length if ≤ 0x0600), e.g. 0x0800 for IPv4, 0x86DD for IPv6
Data:	Payload, max. 1500 byte
PAD:	Padding, required for short frames
FCS:	Frame Check Sequence, CRC32

IEEE 802.11 (WLAN) – CSMA/CA

- In wireless networks collisions cannot be detected reliably
  - Sending and receiving (i.e. sensing collisions) at the same time is difficult
  - Hidden terminal problem
  - See lecture **Mobile Communications**

- Goal: Collision Avoidance
  - **Sender**
    - If medium is idle for a certain amount of time slots (DIFS), transmit frame
    - If no ACK received, retransmit frame
  - **Receiver**
    - Check if received frame OK (using CRC), send ACK with a short time delay (SIFS)



Conclusion

- MAC protocols are crucial for good networking performance
  - ➢ Static multiplexing just won’t do for bursty traffic
- Main categories: Static vs. dynamic, contention (with collisions) vs. controlled (collision-free), hybrid approaches (limited contention)
- Main figures of merit: Throughput, delay, fairness
  - ➢ There hardly is a “best” solution
- Important case study: Ethernet
  - ➢ Main lesson to be learned: Keep it simple!

Content (2)