TI III: Operating & Communication Systems

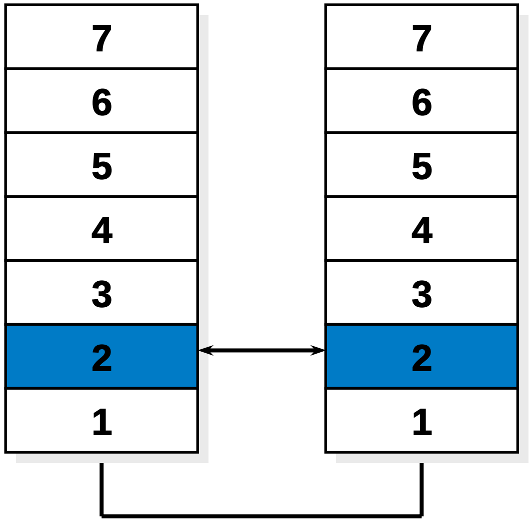
Host-to-Network III

Topologies

Medium Access

Local Area Networks

Ethernet, WLAN



Content (2)

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   - Internet
   - Layers, Protocols
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   - Media, Signals
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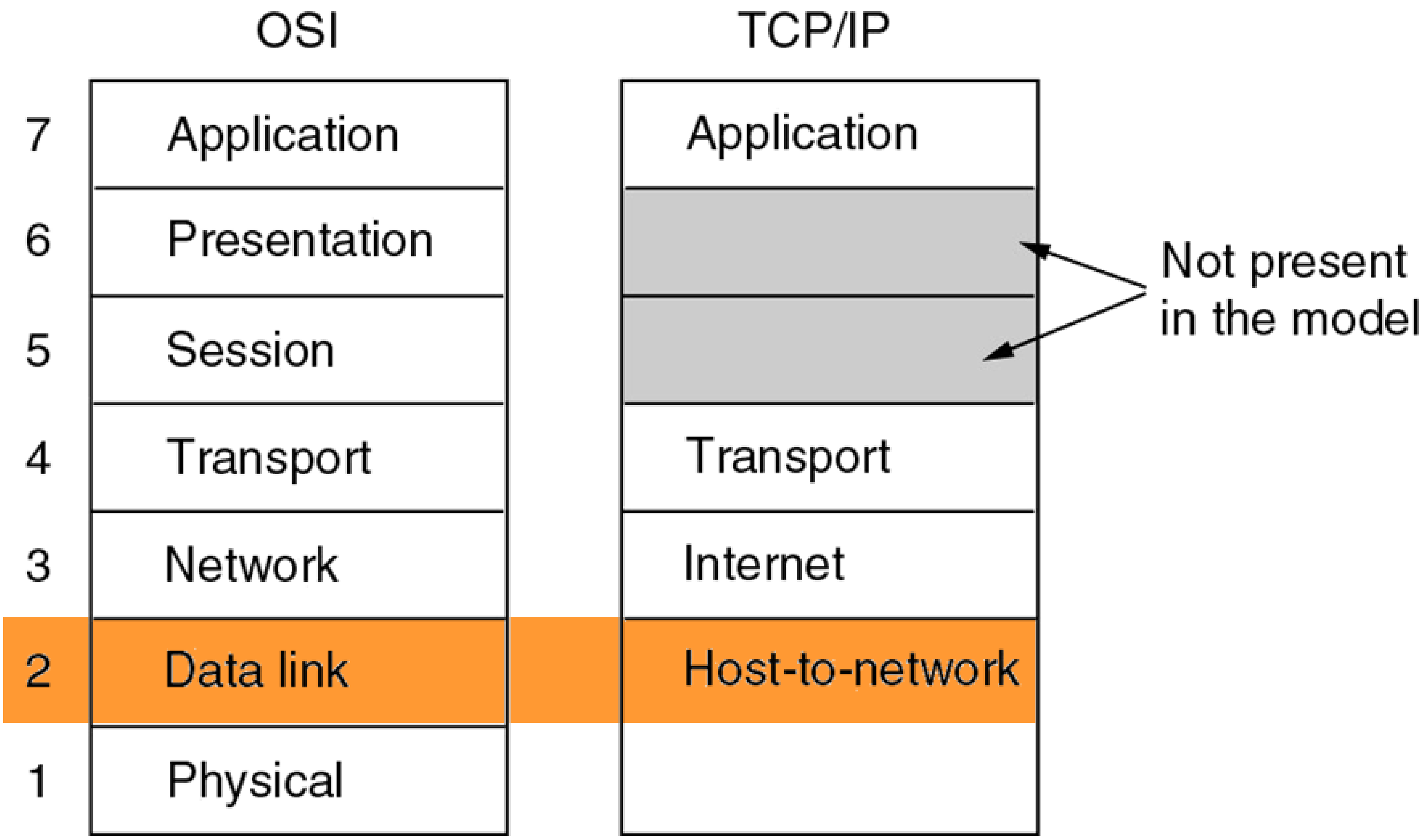
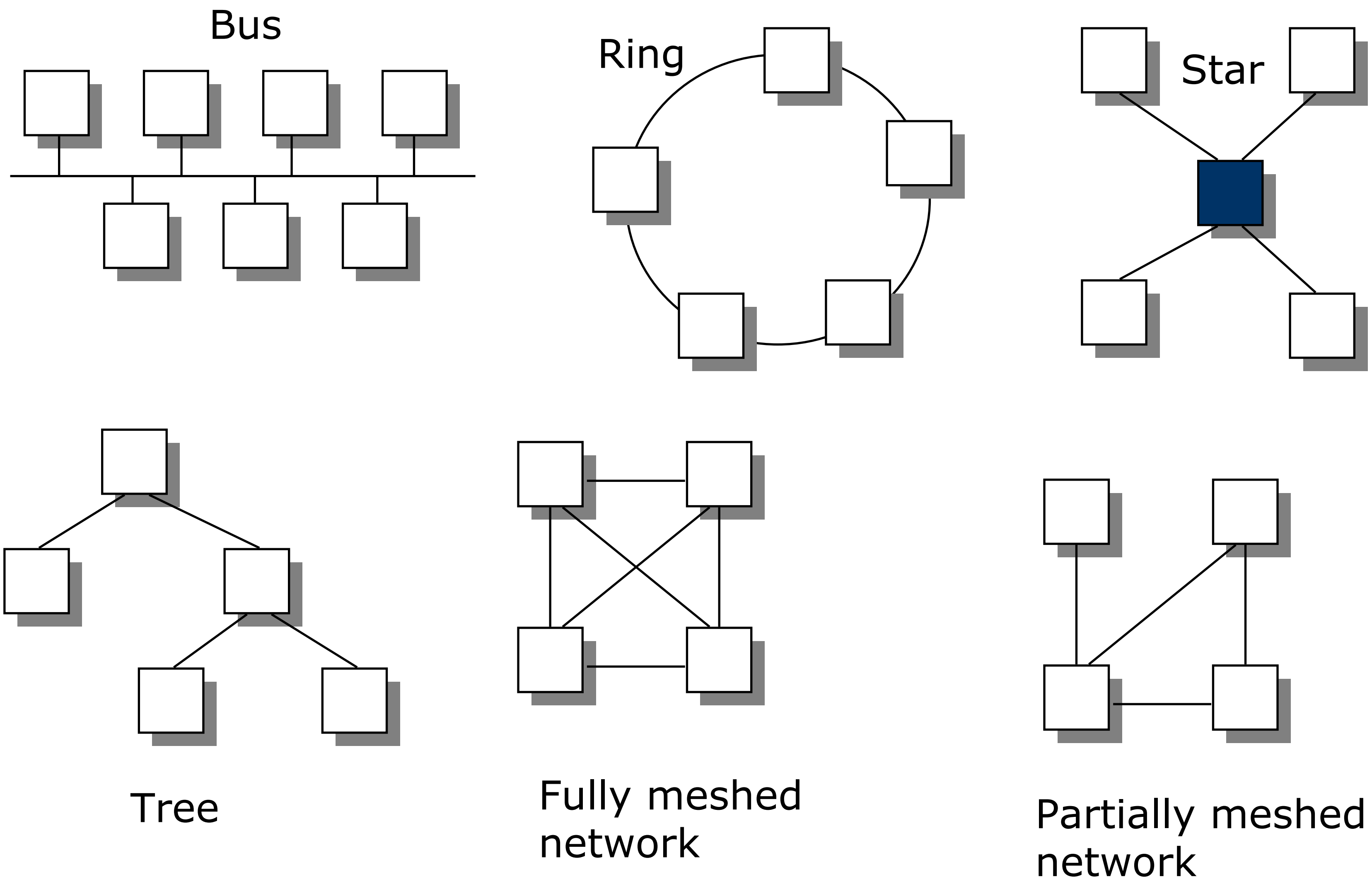
Data Link Layer

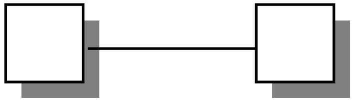


Topologies 1

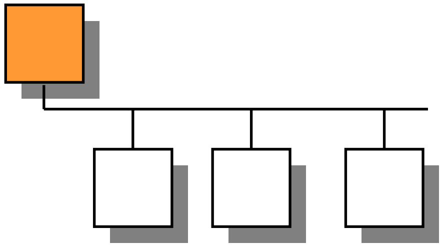


Topologies 2

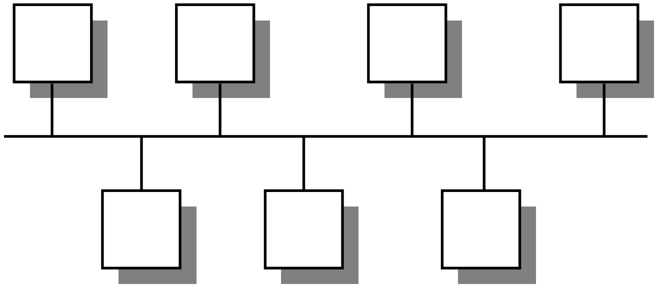
- Point-to-point connection



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

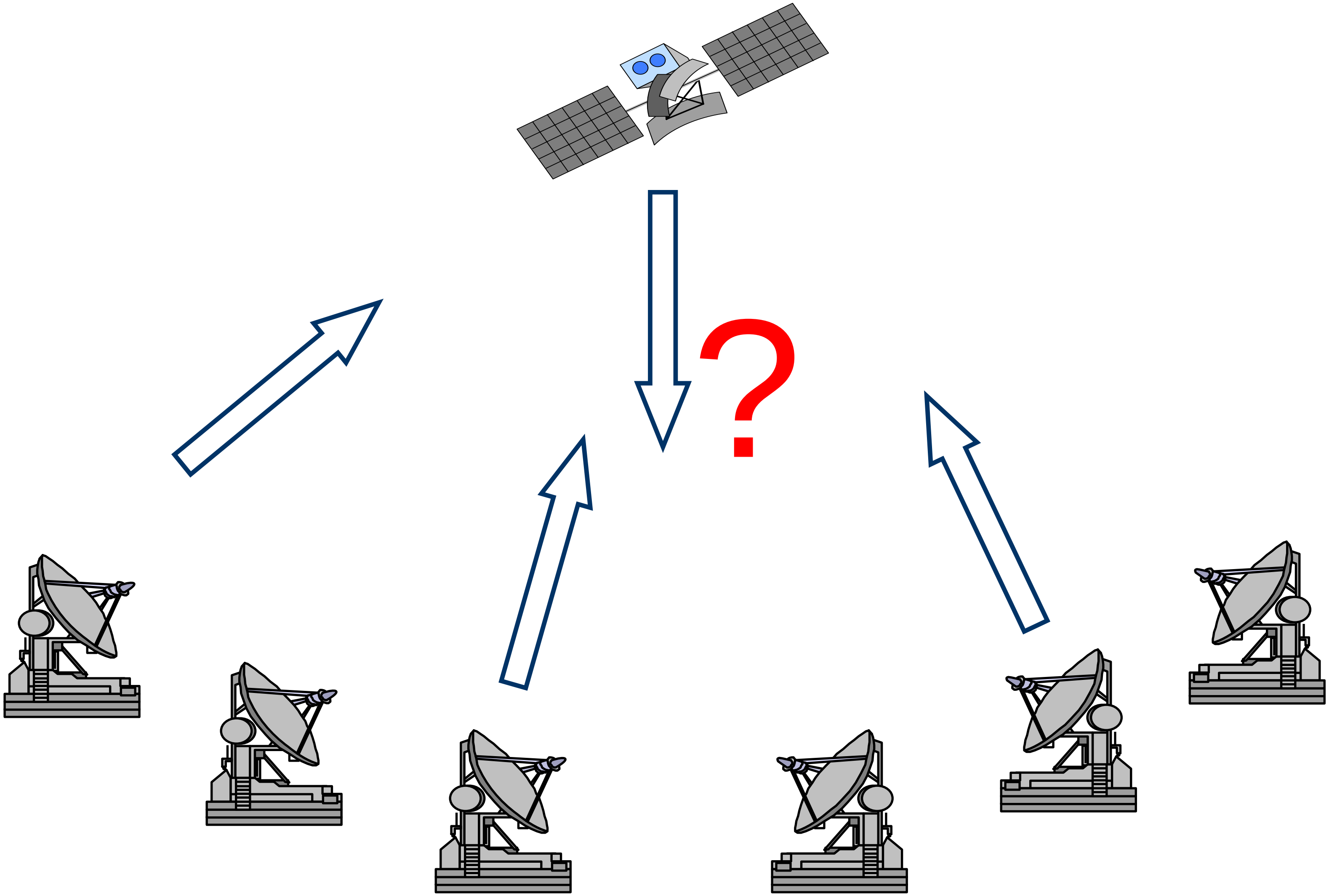


- Multi-point connection (symmetrical)

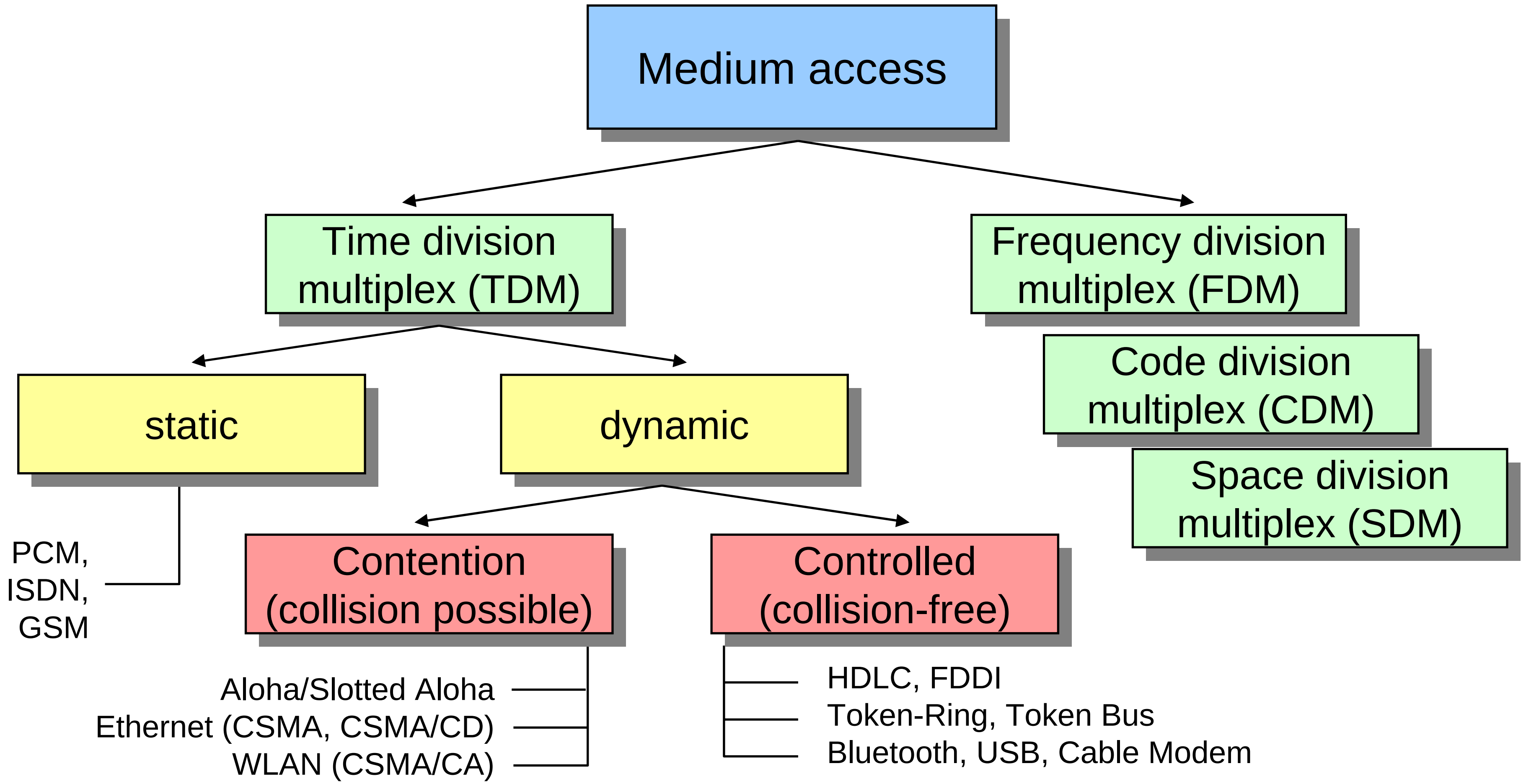


- Distinguish: physical (layer 1) and logical ($\geq$ layer 2) topology!

Medium access

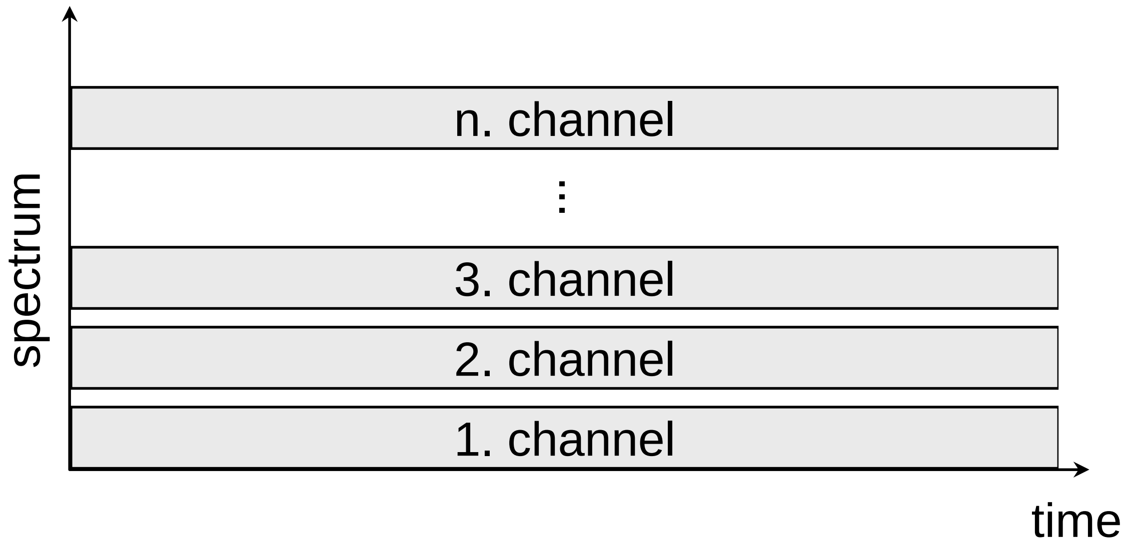


- Problem: several stations want to access a common, shared medium – how to separate stations?



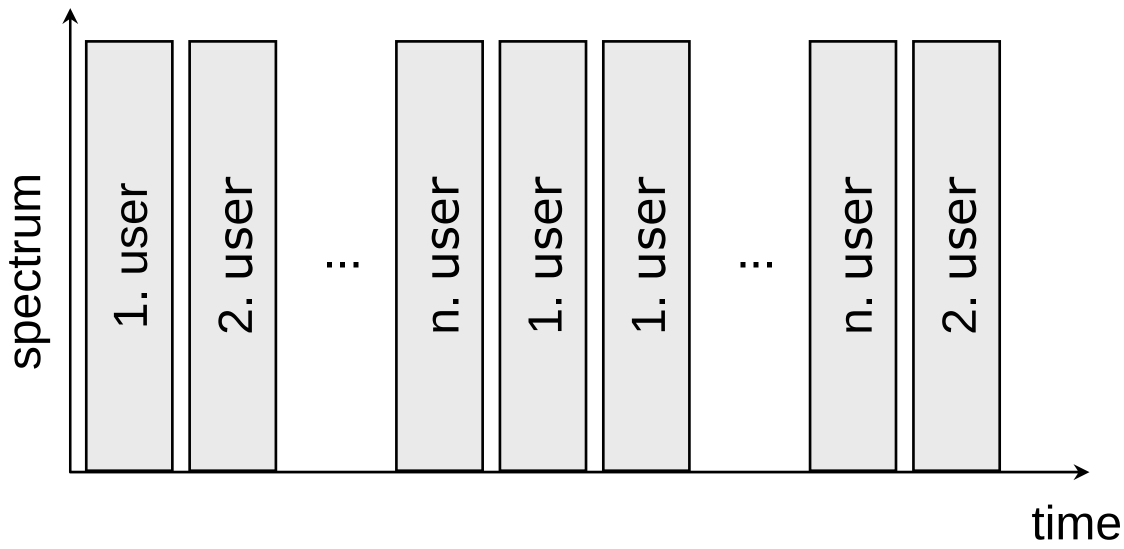
FDM + Algorithm for access: FDMA

- Frequency Division Multiple Access
  - Subdivide spectrum into sub-channels
  - Assign a sub-channel to a user
  - Examples: radio stations, cable channels

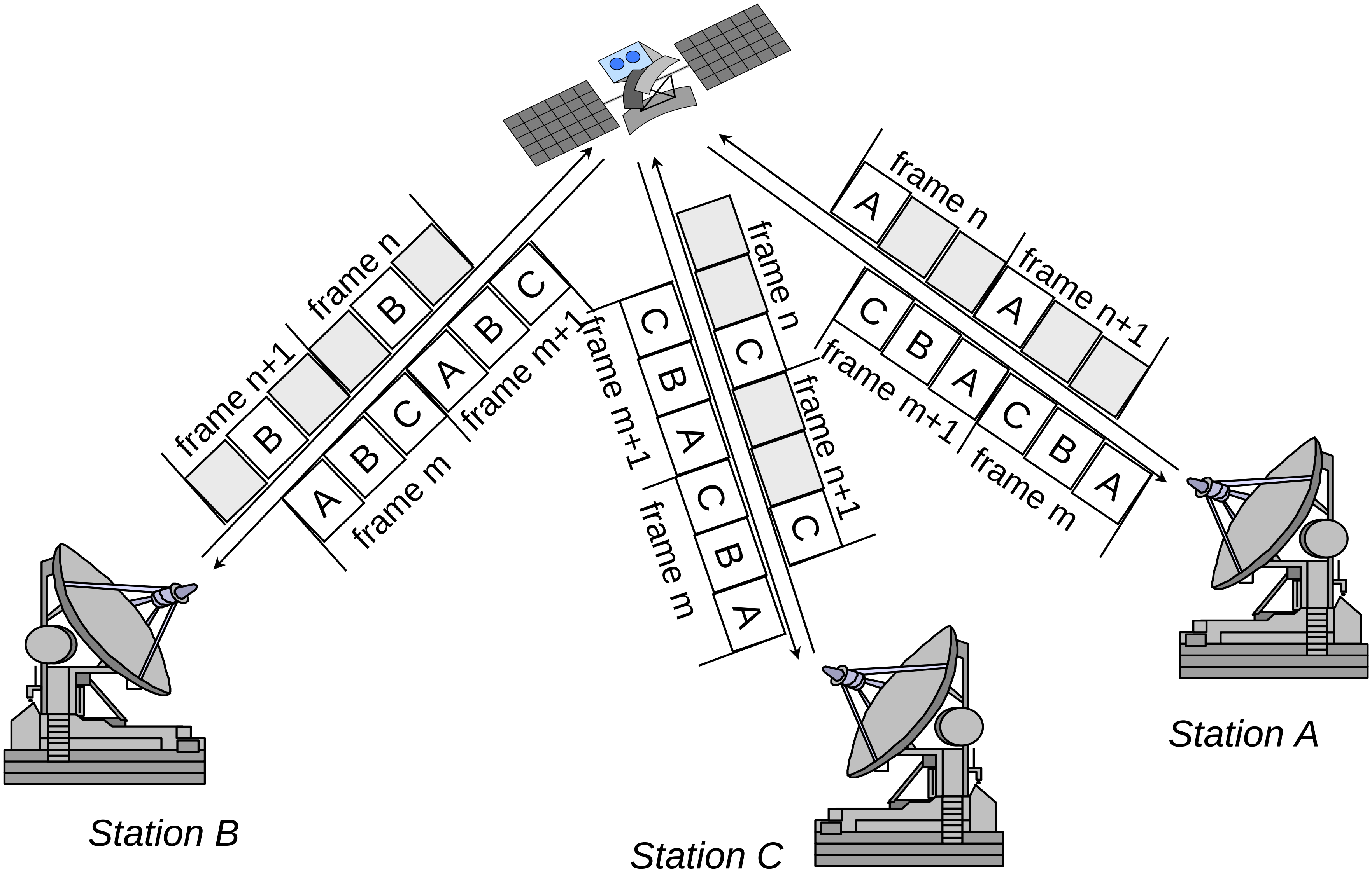


TDM + Algorithm for access: TDMA

- Time Division Multiple Access
  - Assign channel (static/dynamic) for a certain time to a 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, Bluetooth data)

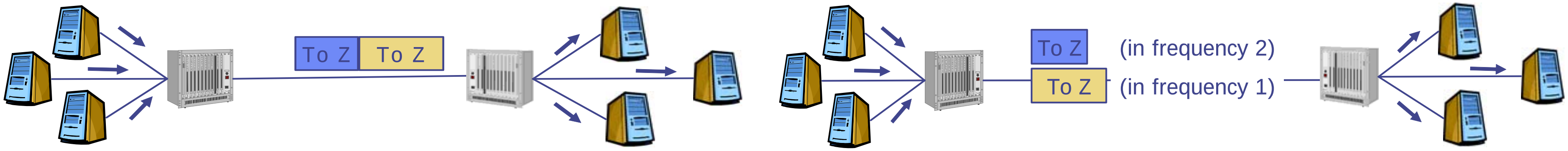


Static TDMA - Example



Static multiplexing

- Given a single resource, it can be statically multiplexed
  - Assigning fixed time slots to multiple communication pairs
  - Assigning fixed frequency bands
  - …

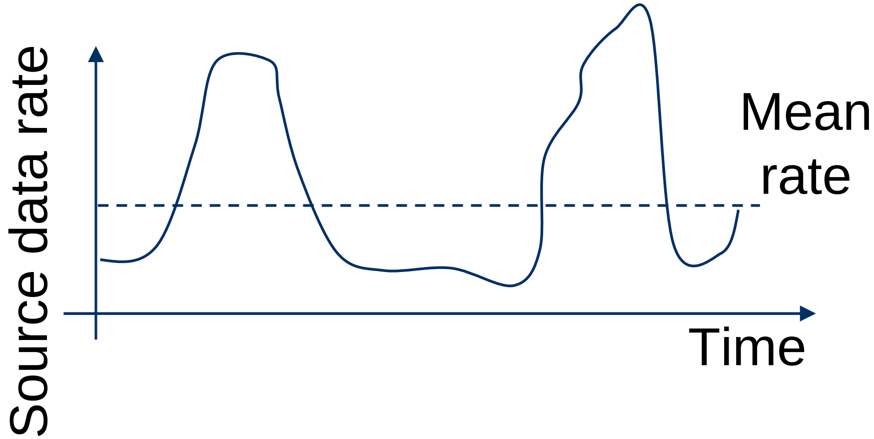


- Assigning fixed resources to different sources is fine if
  - Data rate of source and multiplexed link are matched
  - Sources can always saturate the link

- Examples: classical telephone, ISDN, GSM

Bursty traffic

- What happens if sources have ***bursty*** traffic?
  - Definition: Large difference between peak and average rate
  - In computer networks: Peak : average = 1000 : 1 quite common



Dynamic channel allocation – MAC

- Static multiplexing is not appropriate for bursty traffic sources
  - Telephony is not bursty, computer networks are bursty
- Alternative: Assign channel/link/resource to that source that **currently** has data to send
  - ***Dynamic channel allocation***
  - Instead of fixed assignments of parts of a shared resource
- Terminology: Access to the transmission has to be organized by a ***medium access control protocol (MAC)***

Figures of merit

- How to judge the efficiency of a dynamic channel allocation system?
  - Intuition: transmit as many packets as quickly as possible

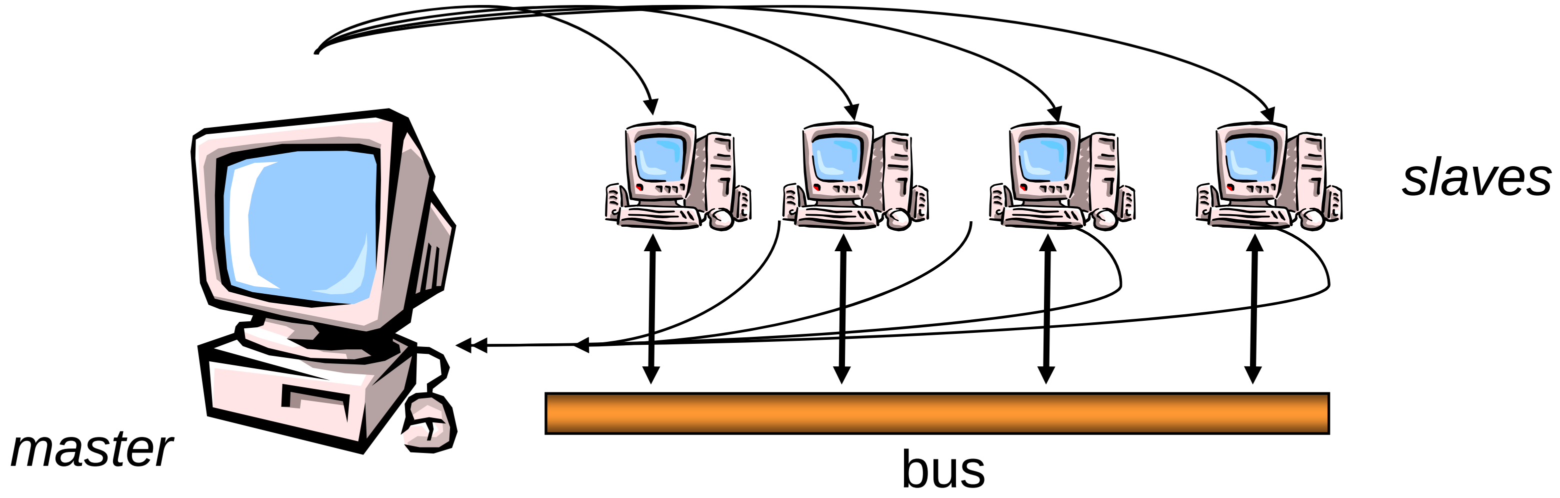
- At high load (many transmission attempts per unit time): ***Throughput*** is crucial – ensure that many packets get through

- At low load (few attempts per time): ***Delay*** is crucial – ensure that a packet does not have to wait for a long time

- ***Fairness:*** Is every station treated equally?

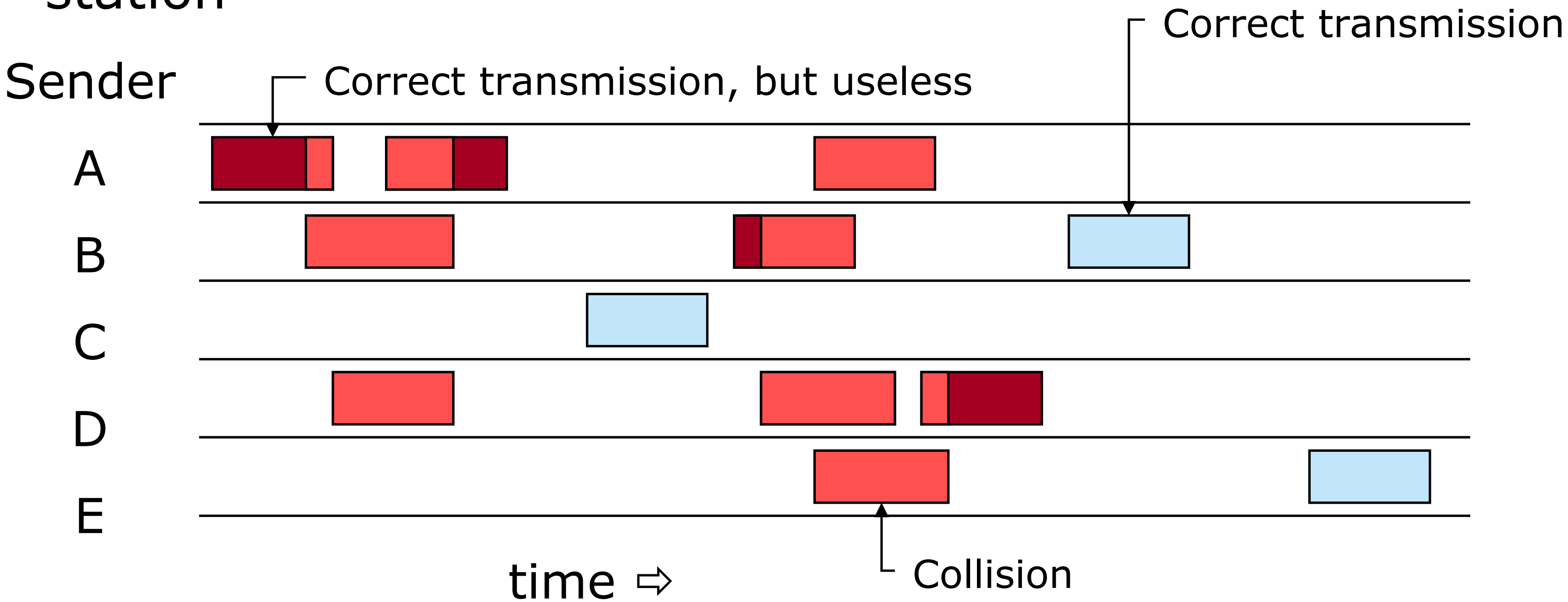
Dynamic/controlled: polling

- A single dedicated master station
- One or more slave stations
- Typically bus topology (but also tree)
- Master polls slaves according to a table or cyclically
- Slaves may answer only after being polled
- All communication via master
- Example: Bluetooth, USB, cable modems



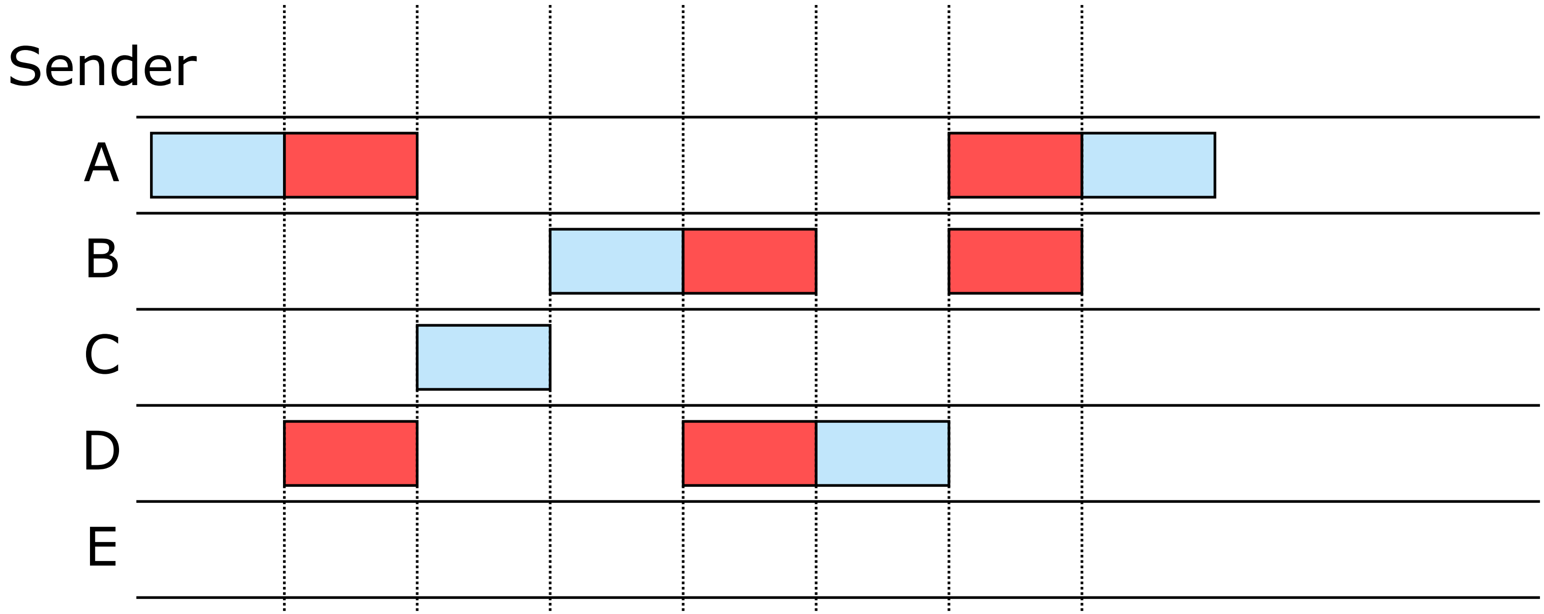
Dynamic/contention: Aloha

- Stations start sending whenever they want to
- Collisions destroy frames
- Receiver may send an acknowledgement after correct reception
- The best one can do without any carrier sensing or central station



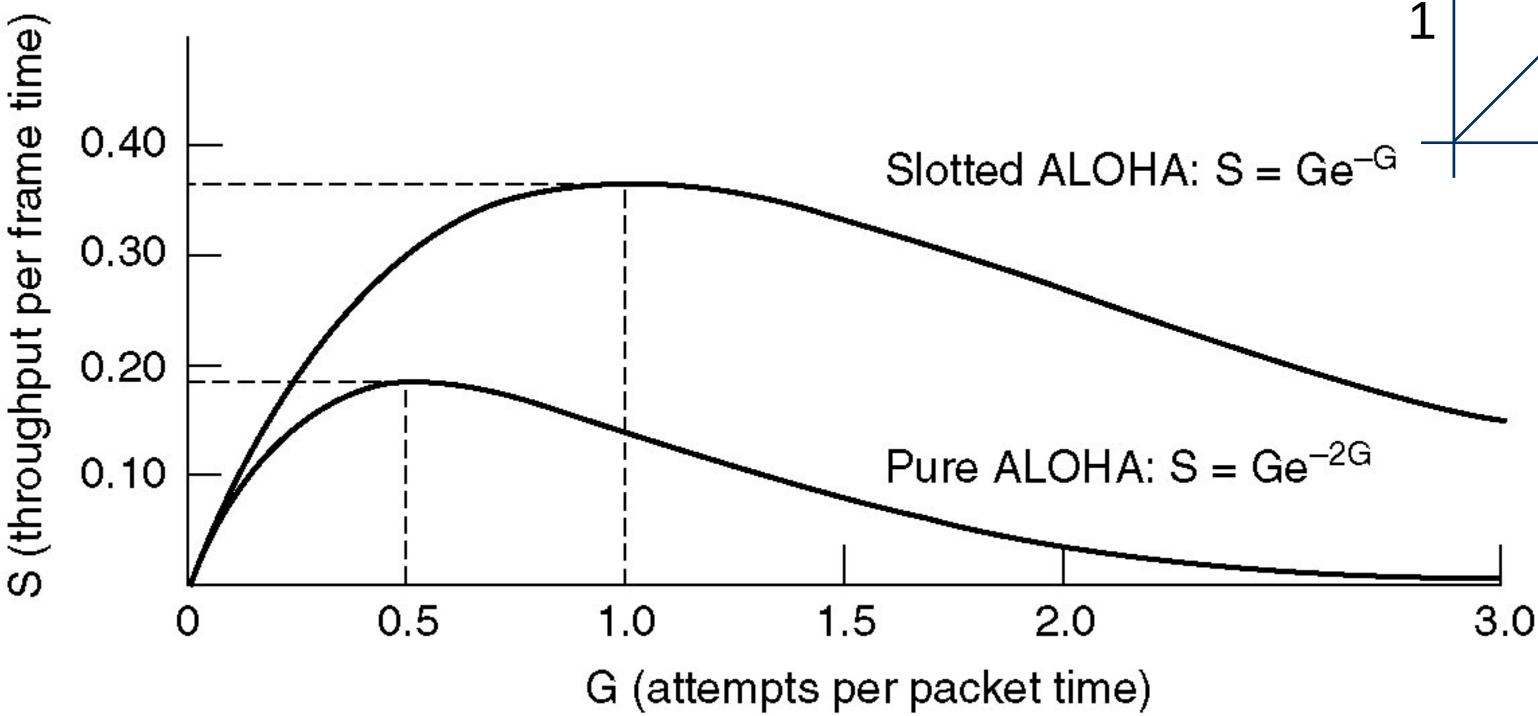
Dynamic/contention: Slotted ALOHA

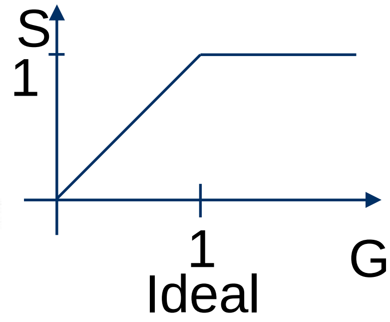
- Send packets of fixed length within fixed time-slots
- Requires a common time-base for synchronization
- Transmission starts at begin of slot only, thus only complete collisions may occur
- The best one can do without carrier sensing (but sync required)
- Example: initial medium access of GSM



Performance dependence on offered load

- For (slotted) ALOHA, closed form analysis of throughput S as function of G is simple





➔ Anything but a high-performance protocol

- In particular: throughput collapses as load increases!

Carrier sensing

- (Slotted) ALOHA is simple, but not satisfactory
- Be a bit more polite: ***Listen before talk***
  - Sense the carrier to check whether it is idle before transmitting
  - ***Carrier Sense Multiple Access (CSMA)***
  - Abstain from transmitting if carrier not idle (some other sender is currently transmitting)

- Crucial question: How to behave in detail when carrier is busy?
  - In particular: WHEN to retry a transmission

1-persistent CSMA

- When carrier is busy, wait until it is idle
- Then, immediately transmit
  - "Persistent" waiting

- Obvious problem: if more than one station wants to transmit, they are *guaranteed* to collide!
  - Just too impatient…

- But certainly better than pure ALOHA or slotted ALOHA

Non-persistent CSMA

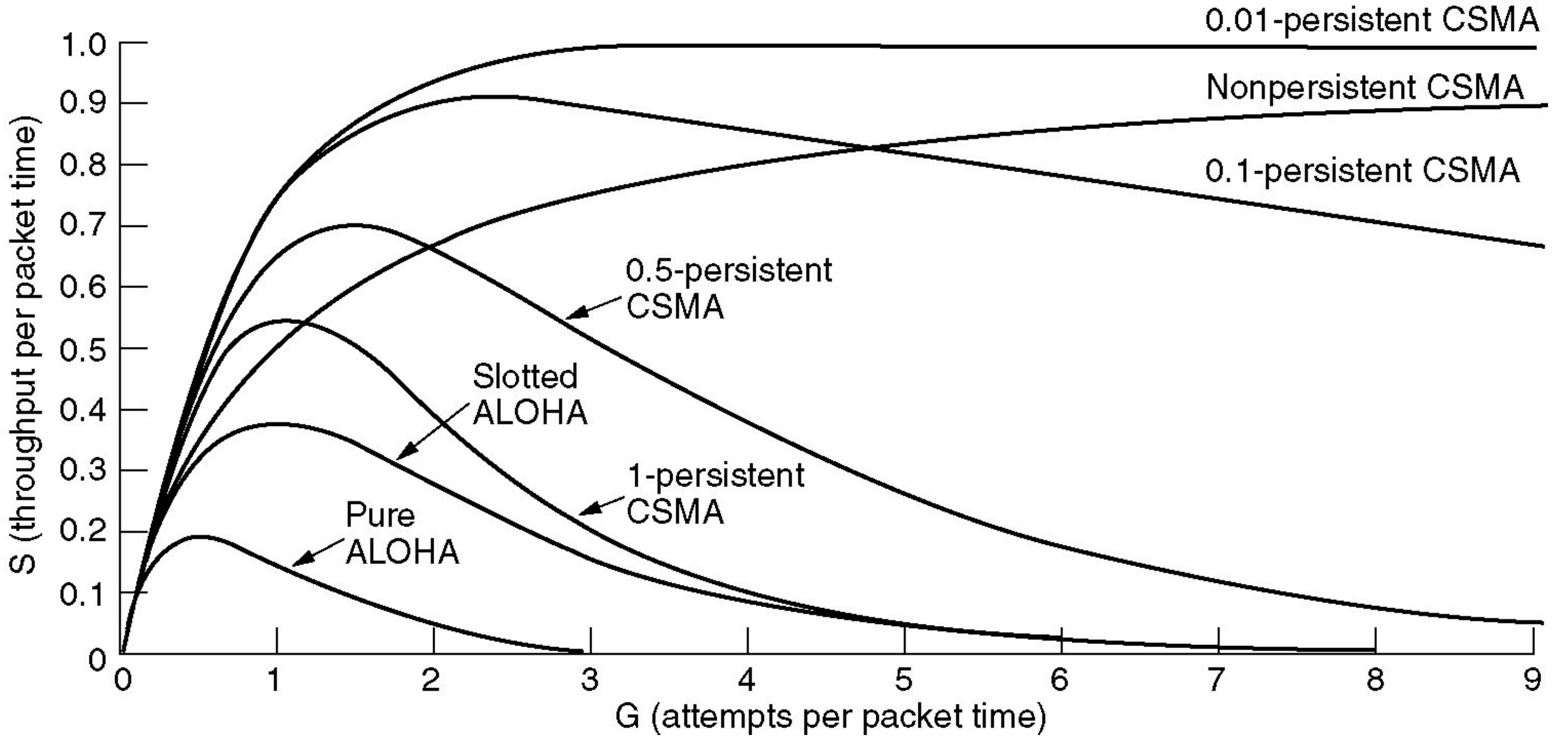
- When channel is idle, transmit
- When channel is busy, wait a random time before checking again whether the channel is idle
  - Do not continuously monitor to greedily grab it once it is idle
  - Conscious attempt to be less greedy

- Performance depends a bit on the random distribution used for the waiting time
  - But in general better throughput than persistent CSMA for higher loads
  - At low loads, random waiting is not necessary and wasteful

p-persistent CSMA

- Combines ideas from persistent and non-persistent CSMA
  - Uses a slotted time model
- When channel is idle, send
- When channel is busy, continuously monitor it until it becomes idle
  - But then, do not always transmit immediately
  - But flip a coin – transmit with probability p
  - With probability 1-p, do not send and wait for the next slot
    - If channel is busy in the next slot, monitor for idleness
    - Else, flip a coin again

Performance of CSMA



Local Area Network (LAN) classification

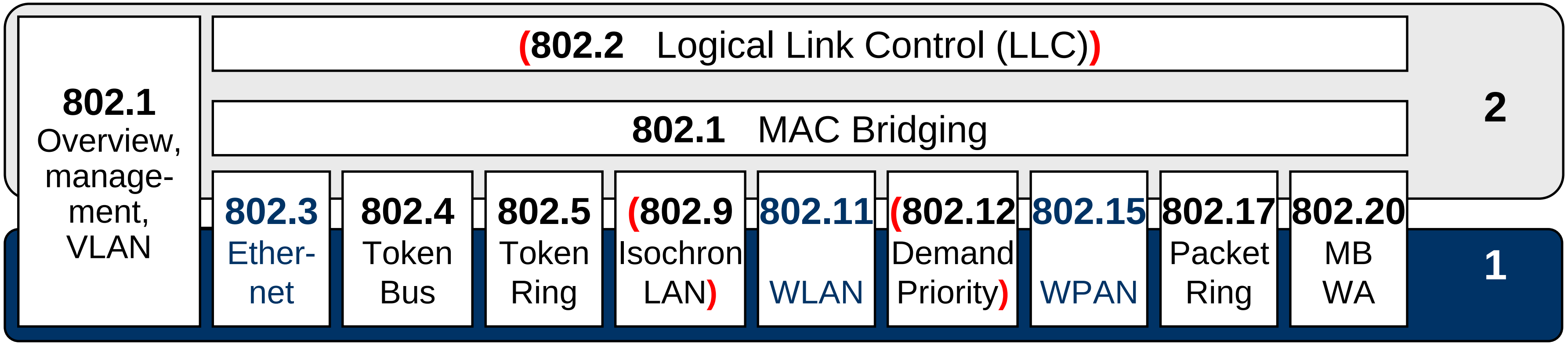
Possible classifications

Topology
- star
- bus
- tree
- ring
- …

Medium
- twisted pair copper
- coaxial cable
- fiber optics
- "nothing"

Access method
- controlled/collision-free
- collision/contention
- limited contention

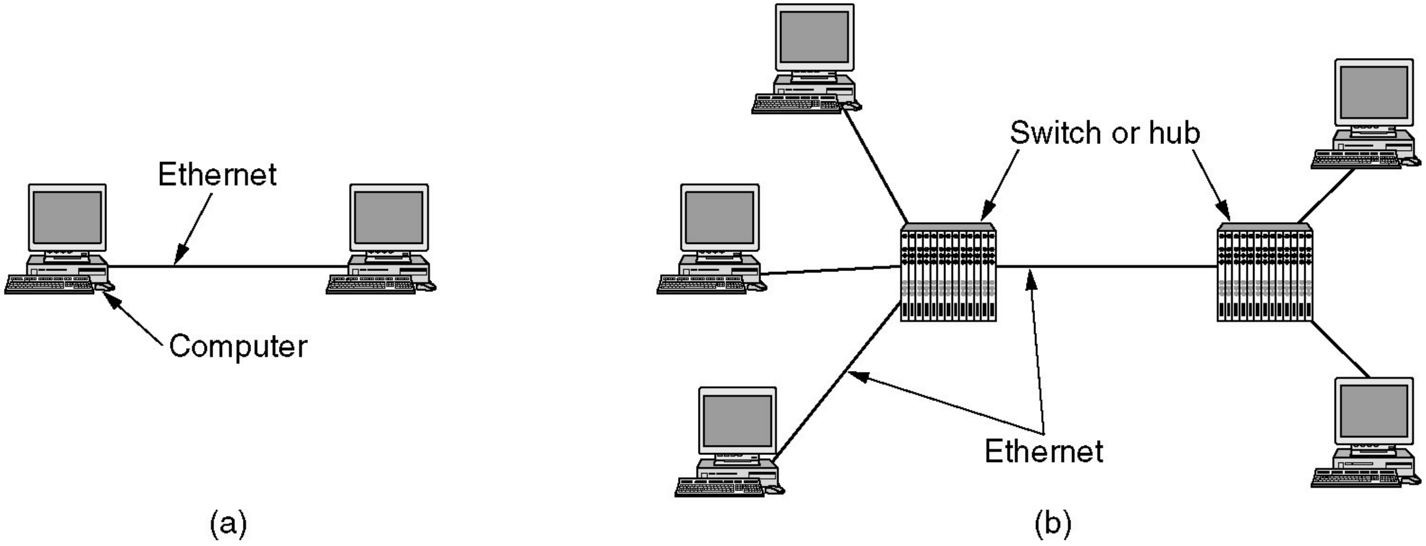
LANs according to IEEE 802



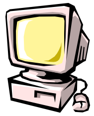
Active Working Groups and Study Groups	Industrial Alliance
• 802.1 Higher Layer LAN Protocols	
• 802.3 Ethernet	
• 802.11 Wireless LAN	WiFi
• 802.15 Wireless Personal Area Network (WPAN)	Bluetooth, ZigBee
• 802.16 Broadband Wireless Access	WiMAX
• 802.17 Resilient Packet Ring	
• 802.18 Radio Regulatory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

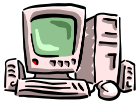
Example: Ethernet

- Most dominant wired LAN technology today
- Historical
  - Bus topology, CSMA/CD for MAC, coax cable, 10 Mbit/s
- Today
  - Star topology, switched, point-to-point connection between computer and switch (or switch/switch, switch/router …)
  - 100, 1000 or even 10000 Mbit/s, twisted pair or optical fiber

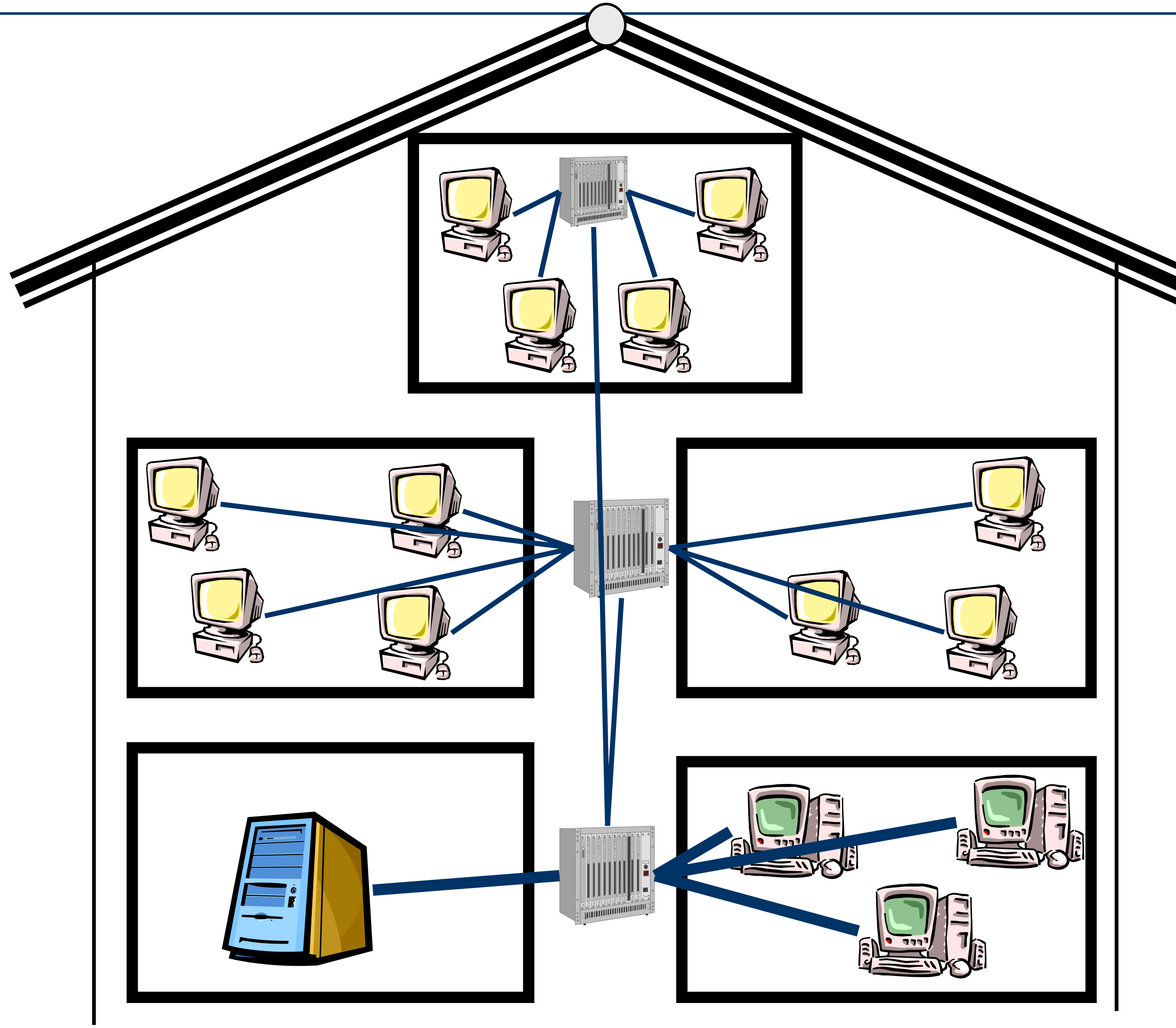


Structured cabling

 Computers

 Servers

 Router for Internet access



Star topology – lots of cables

Frame format for IEEE 802.3/Ethernet

Freie Universität Berlin

- Common frame format

[byte]

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

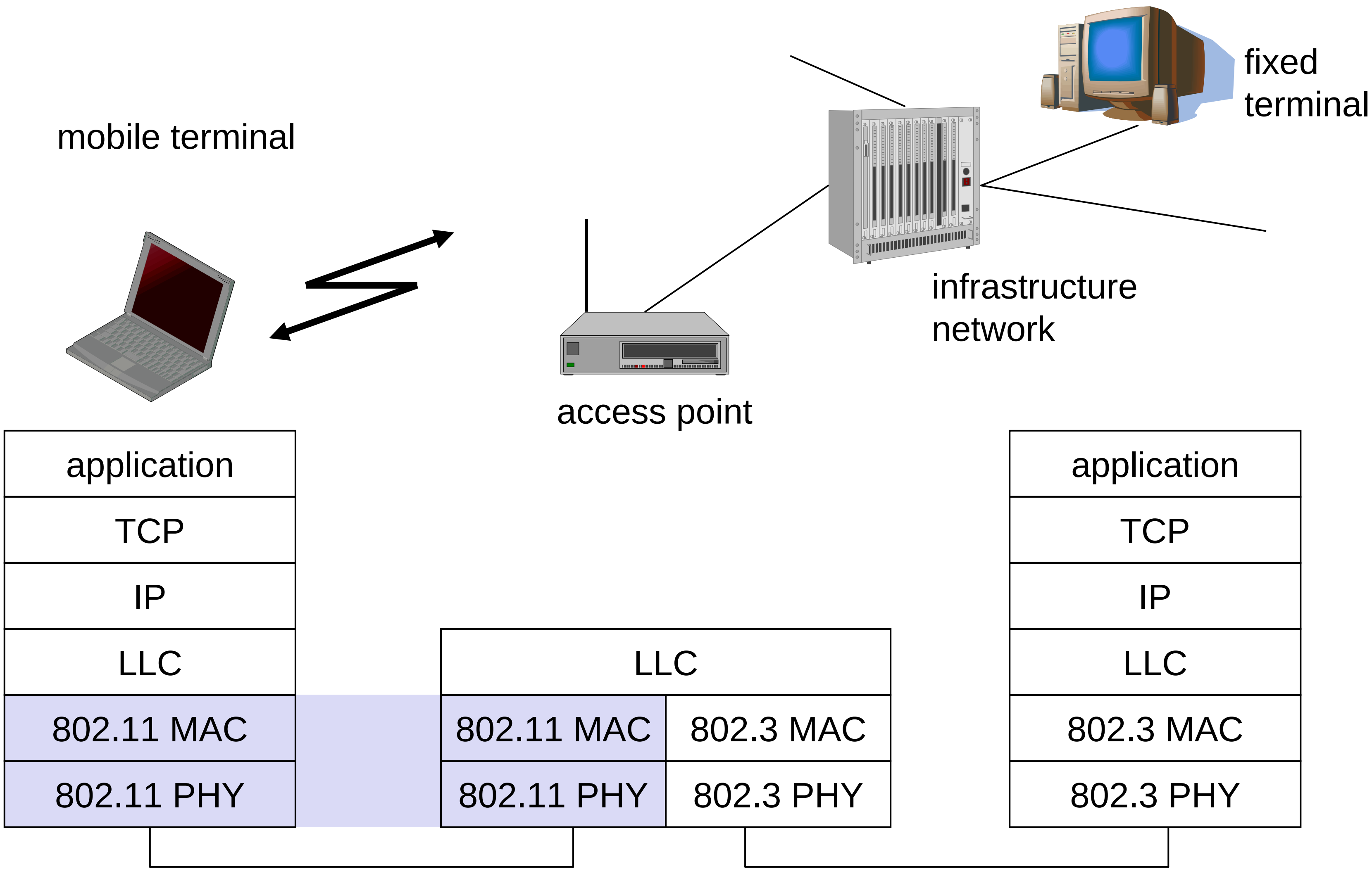
64 - 1518 (1522 VLAN) (DA through FCS)

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

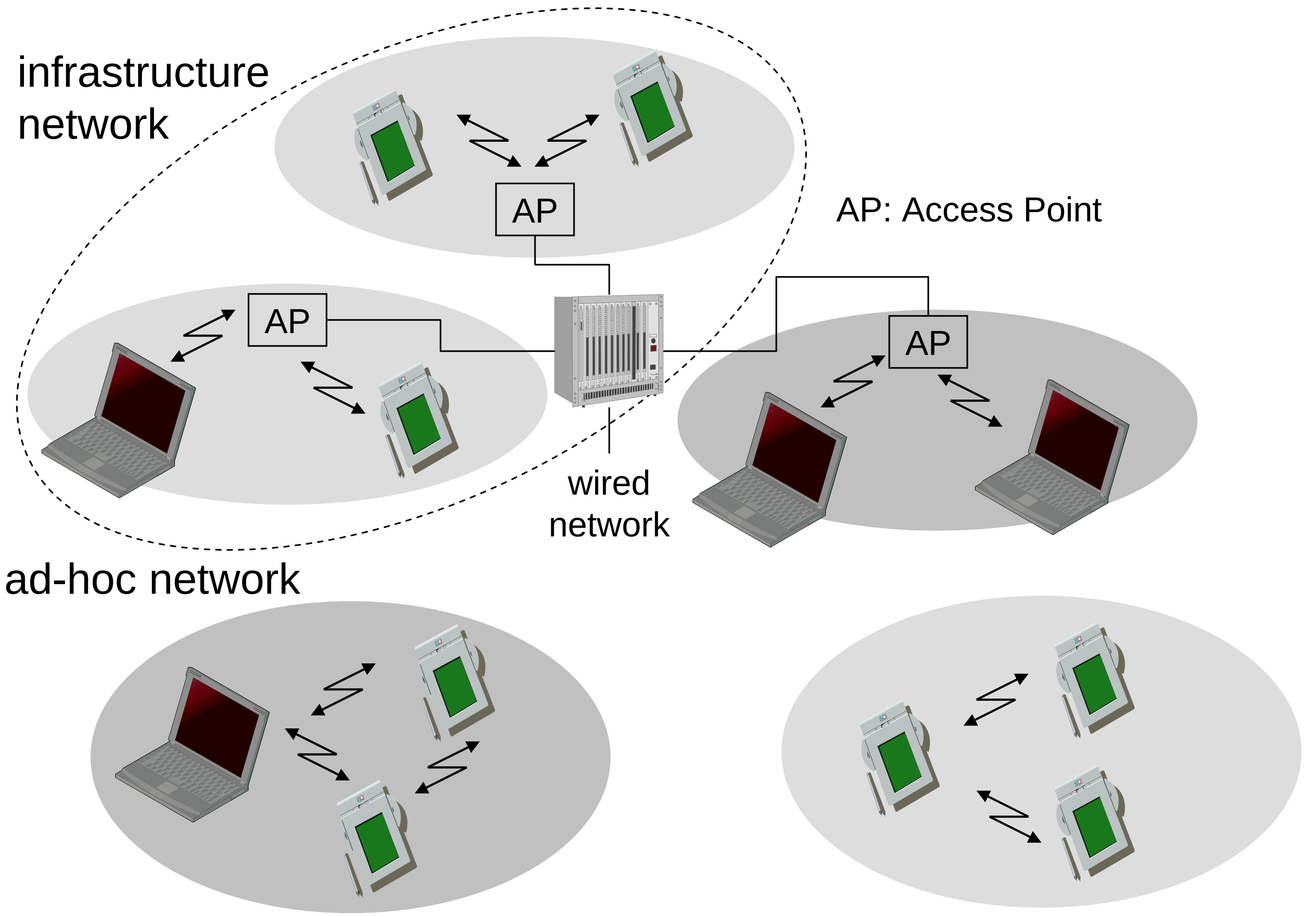
Ethernet development (examples)

- Fast Ethernet (1995): 100 Mbit/s
  - 100BASE-TX is the predominant form, runs over two pairs of wires in category 5 cable (one pair of twisted wires in each direction, thus full-duplex), maximum distance of 100 meters
- Gigabit Ethernet (1998): 1 Gbit/s
  - 1000BASE-T (802.3ab) at a minimum category 5 cable (better cables recommended), requires all four twisted pairs to be present, far less tolerant of poorly installed wiring than 100BASE-TX, maximum distance of 100 meters
- 10 gigabit Ethernet
  - 10GBASE-T (2006): 802.3an, twisted pair copper, 50-100m, category 6 or 7
  - 40 km and more with optical solutions
- 100 gigabit Ethernet: currently under study

Example: Wireless LAN (IEEE 802.11)

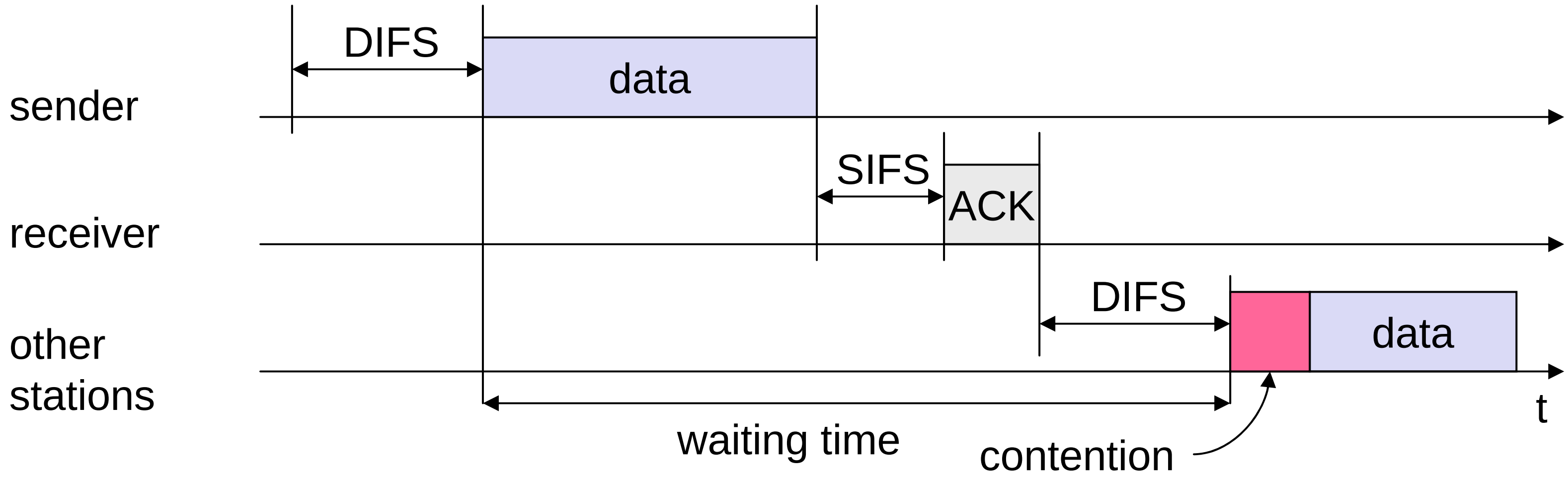


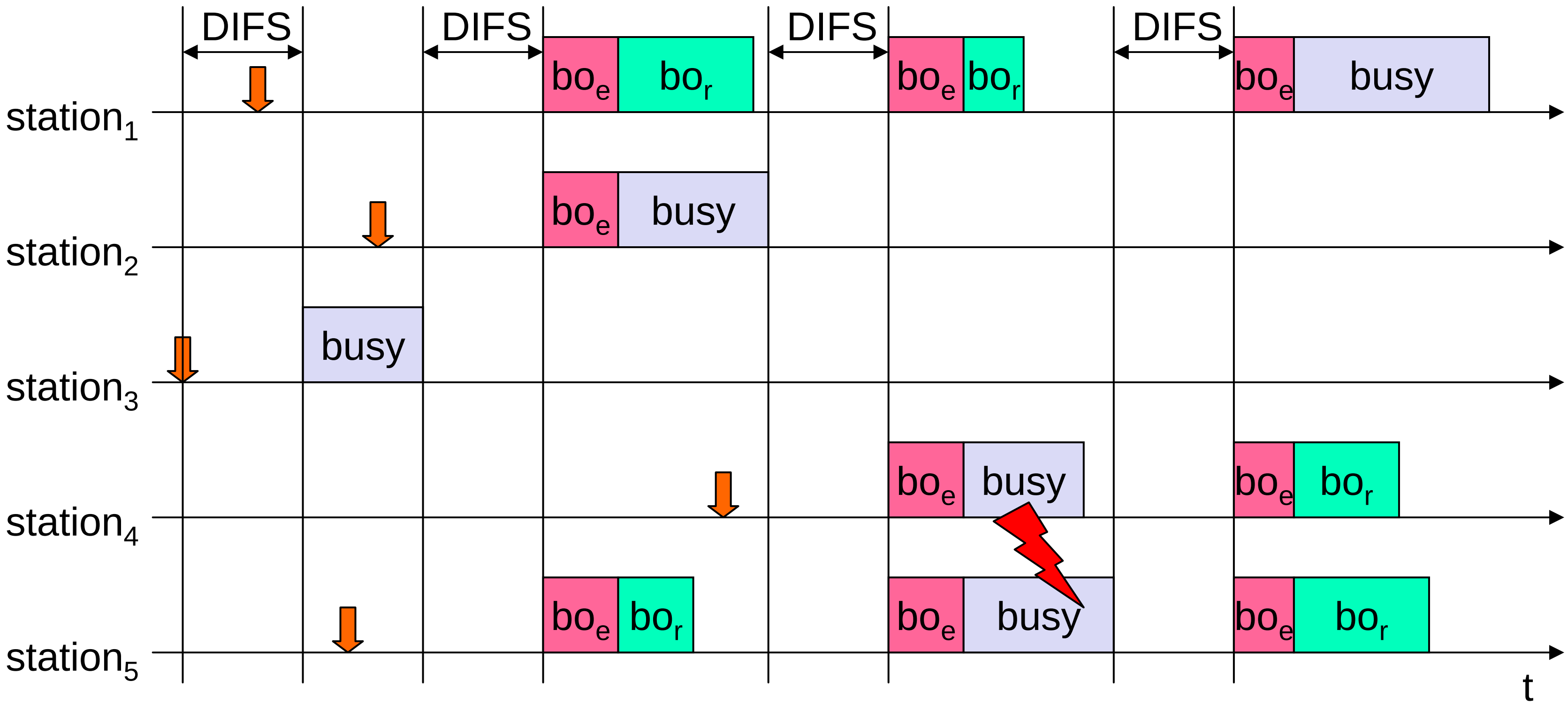
WLAN as infrastructure or ad-hoc network



802.11 – Medium Access

- Sending unicast packets
  - Station has to sense an idle medium for DIFS (Distributed Inter-Frame Spacing) before sending data
  - Receivers acknowledge at once (after waiting for SIFS [Short Inter-Frame Spacing]) if the packet was received correctly (CRC)
  - Automatic retransmission of data packets in case of transmission errors





- busy: medium not idle (frame, ack etc.)
- packet arrival at MAC
- bo_e: elapsed backoff time
- bo_r: residual backoff time

Conclusion

- MAC protocols are a crucial ingredient, pivotal for good performance
  - Static multiplexing just won't do for bursty traffic
- Main categories: Collision, collision-free, (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!