Computer Networks Principles
LAN - Ethernet

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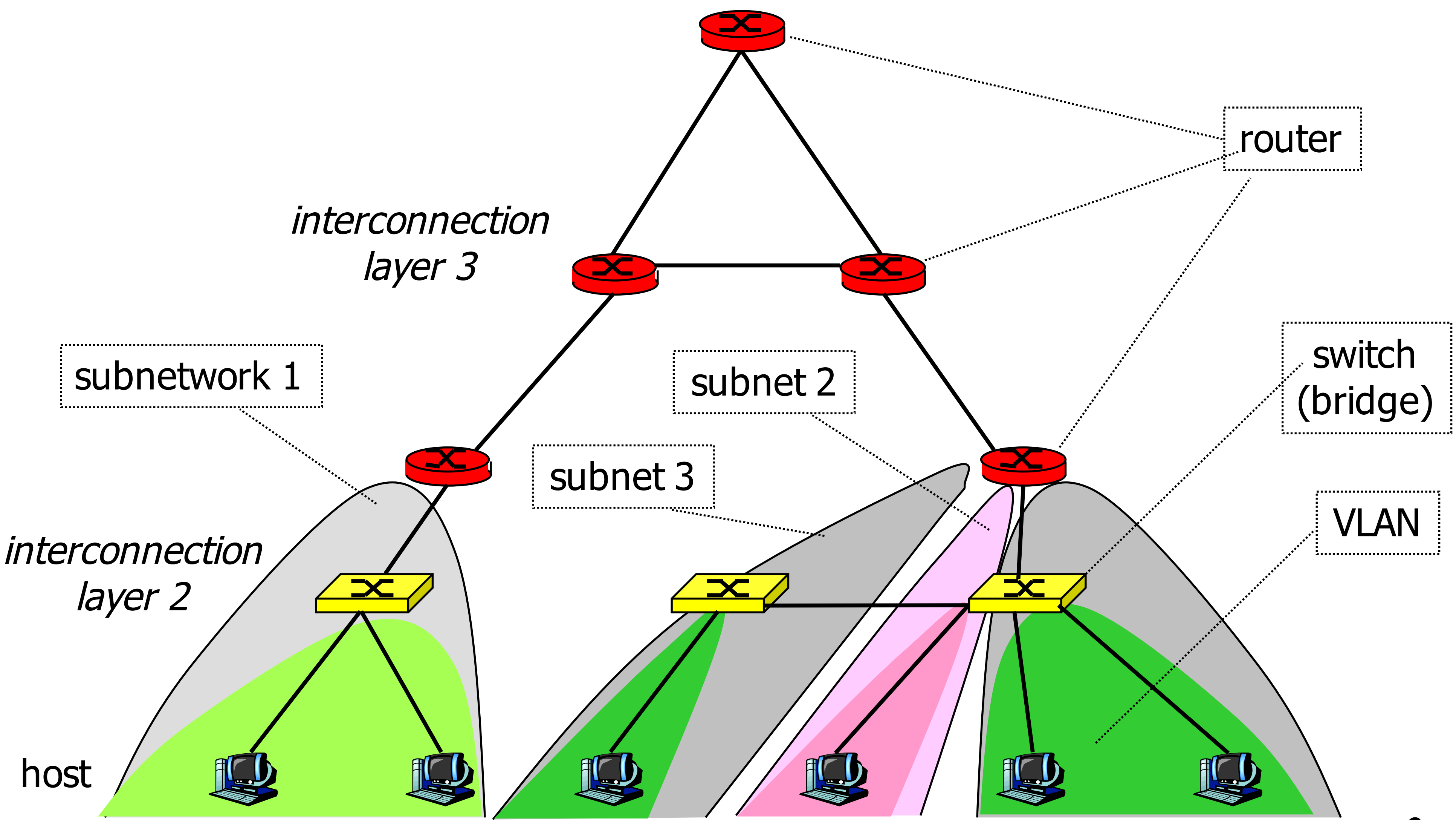
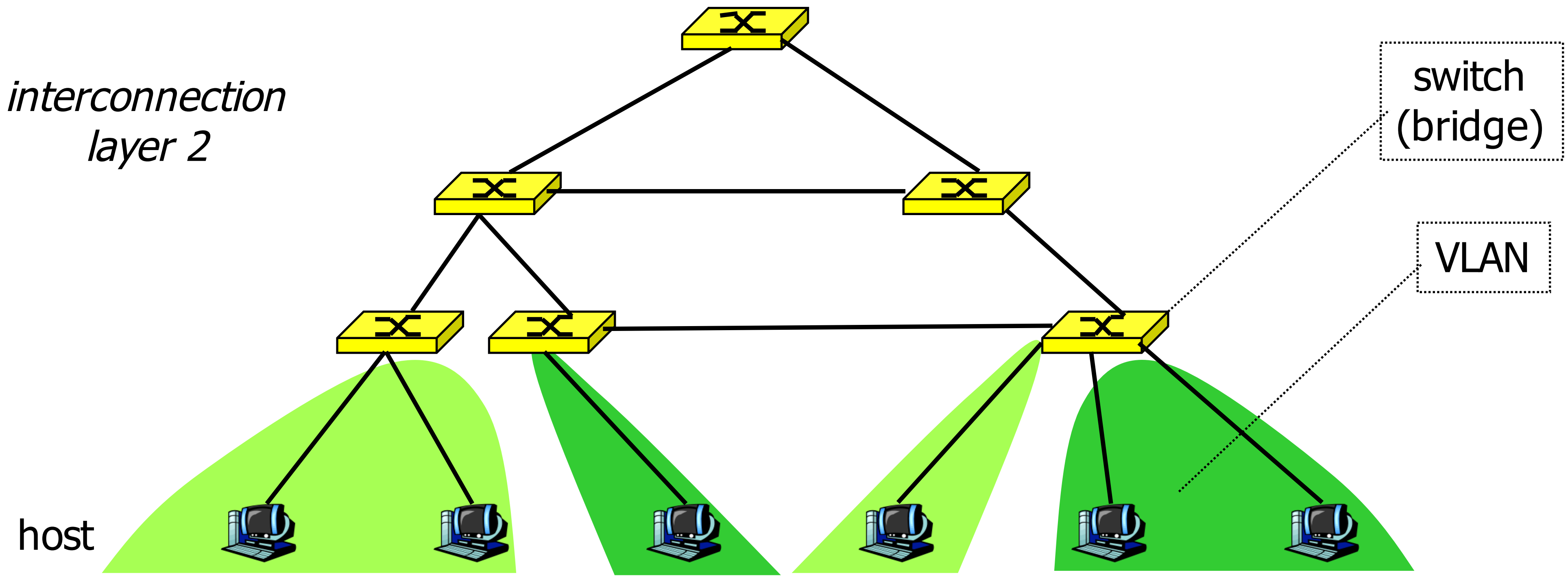
Interconnection structure - layer 3



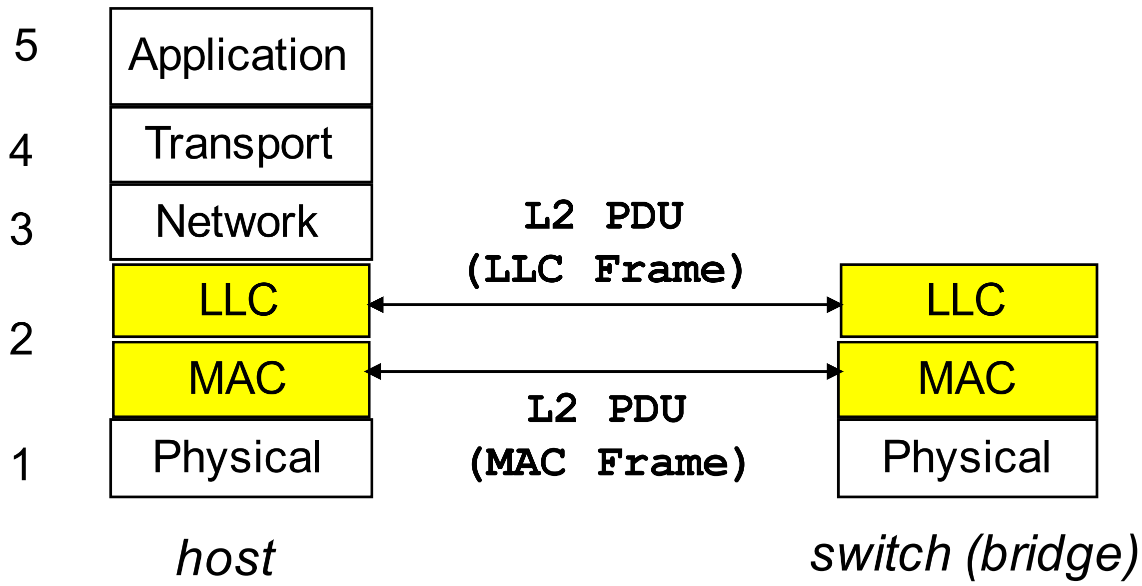
Interconnection structure - layer 2



Interconnection at layer 2

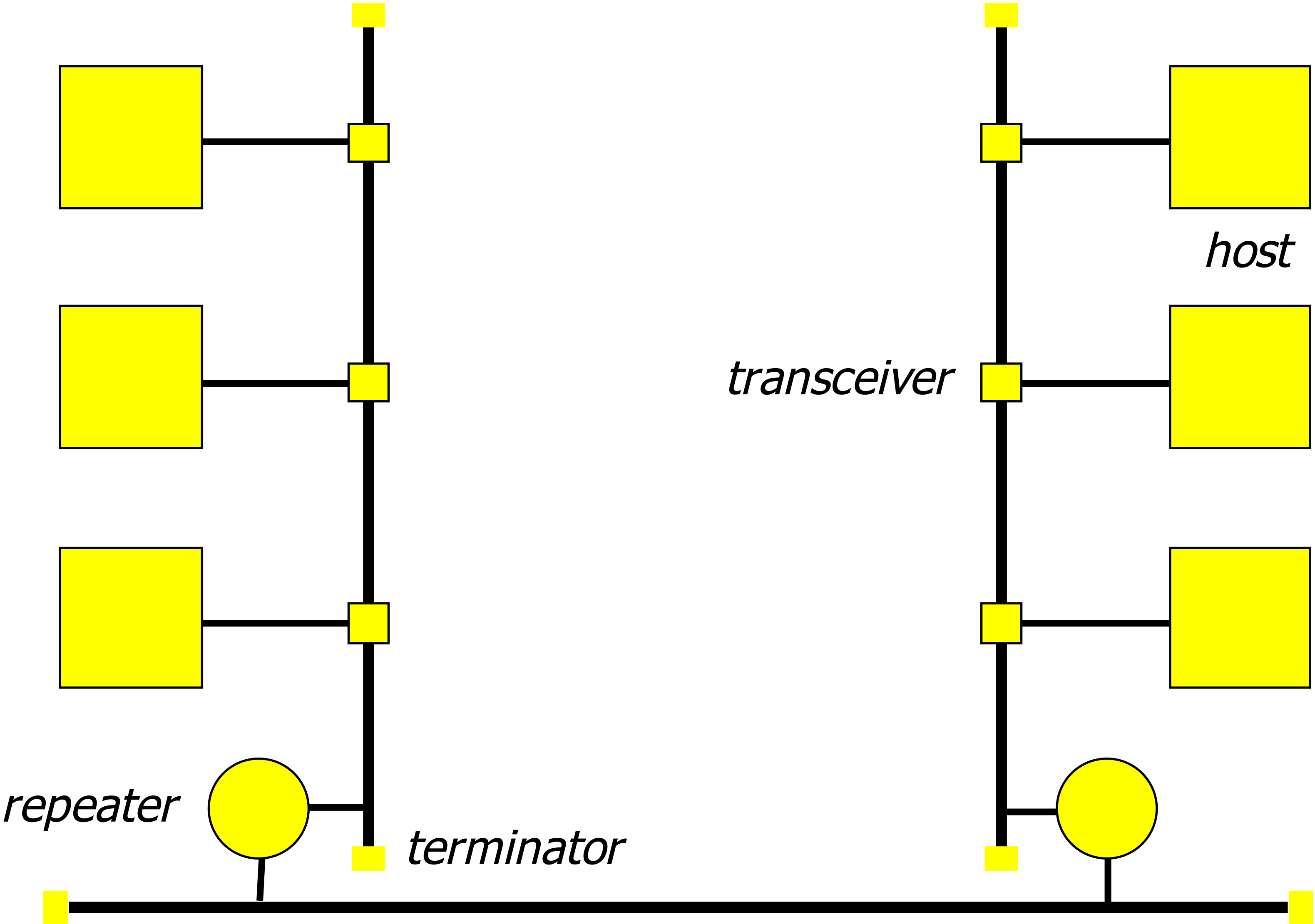
- Switches (bridges)
  - interconnect hosts
  - logically separate groups of hosts (VLANs)
  - managed by one entity
- Type of the network
  - broadcast
- Forwarding based on MAC address
  - flat address space
  - forwarding tables: one entry per host
  - works if no loops
    - careful management
    - Spanning Tree protocol
  - not scalable

Protocol architecture



- Switches are layer 2 intermediate systems
- Transparent forwarding
- Management protocols (Spanning Tree, VLAN)

IEEE 802.3 - Ethernet



Random Access protocols

- When node has packet to send
  - transmit at full channel data rate R.
  - no *a priori* coordination among nodes
- two or more transmitting nodes -> "collision",
- random access protocol specifies:
  - how to detect collisions
  - how to recover from collisions (e.g., via delayed retransmissions)
- Examples of random access protocols:
  - ALOHA, slotted ALOHA
  - CSMA, **CSMA/CD** (Ethernet), **CSMA/CA** (802.11)

CSMA/CD (Collision Detection)

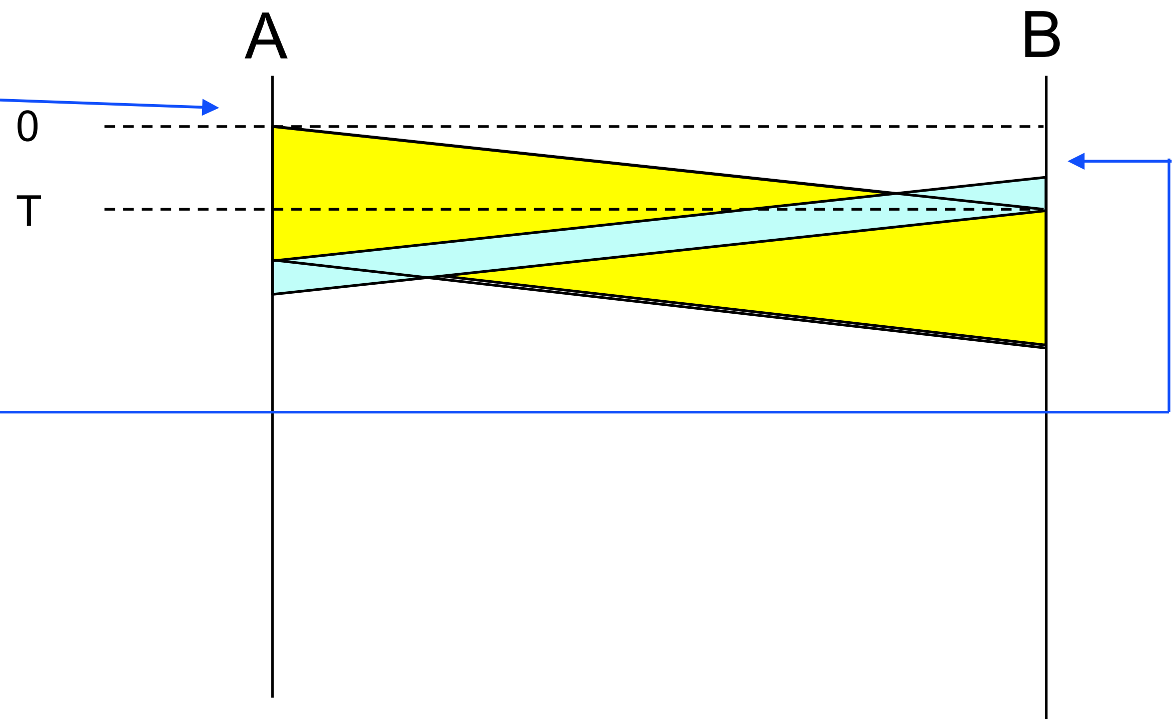
- CSMA/CD *(Carrier Sense Multiple Access/ Collision Detection)*
  - carrier sensing, deferral if ongoing transmission
  - collisions *detected* within short time
  - colliding transmissions aborted, reducing channel wastage
  - persistent transmission
- collision detection:
  - easy in wired LANs: measure signal strengths, compare transmitted, received signals
  - difficult in wireless LANs: receiver shut off while transmitting

CSMA/CD algorithm

```
i = 1
while (i <= maxAttempts) do
        listen until channel is idle
        transmit and listen
        wait until (end of transmission) or
                    (collision detected)
        if collision detected then
                stop transmitting, send jam bits (32 bits)
      else
                wait for interframe delay (9.6 µs)
                leave
        wait random time
        increment i
end do
```

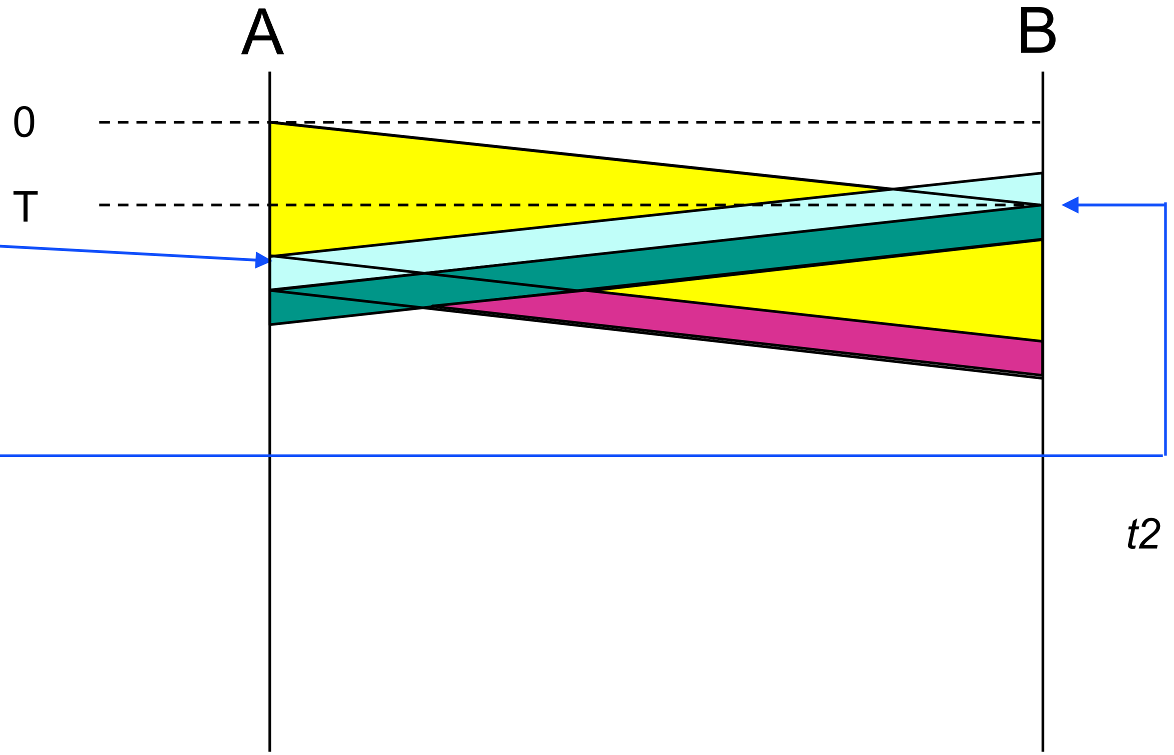
CSMA / CD Collision

- A senses idle channel, starts transmitting
- shortly before *T*, B senses idle channel, starts transmitting



CSMA / CD Jam Signal

- B senses collision, continues to transmit the jam signal (32-bit)
- A senses collision, continues to transmit the jam signal



Random retransmission interval

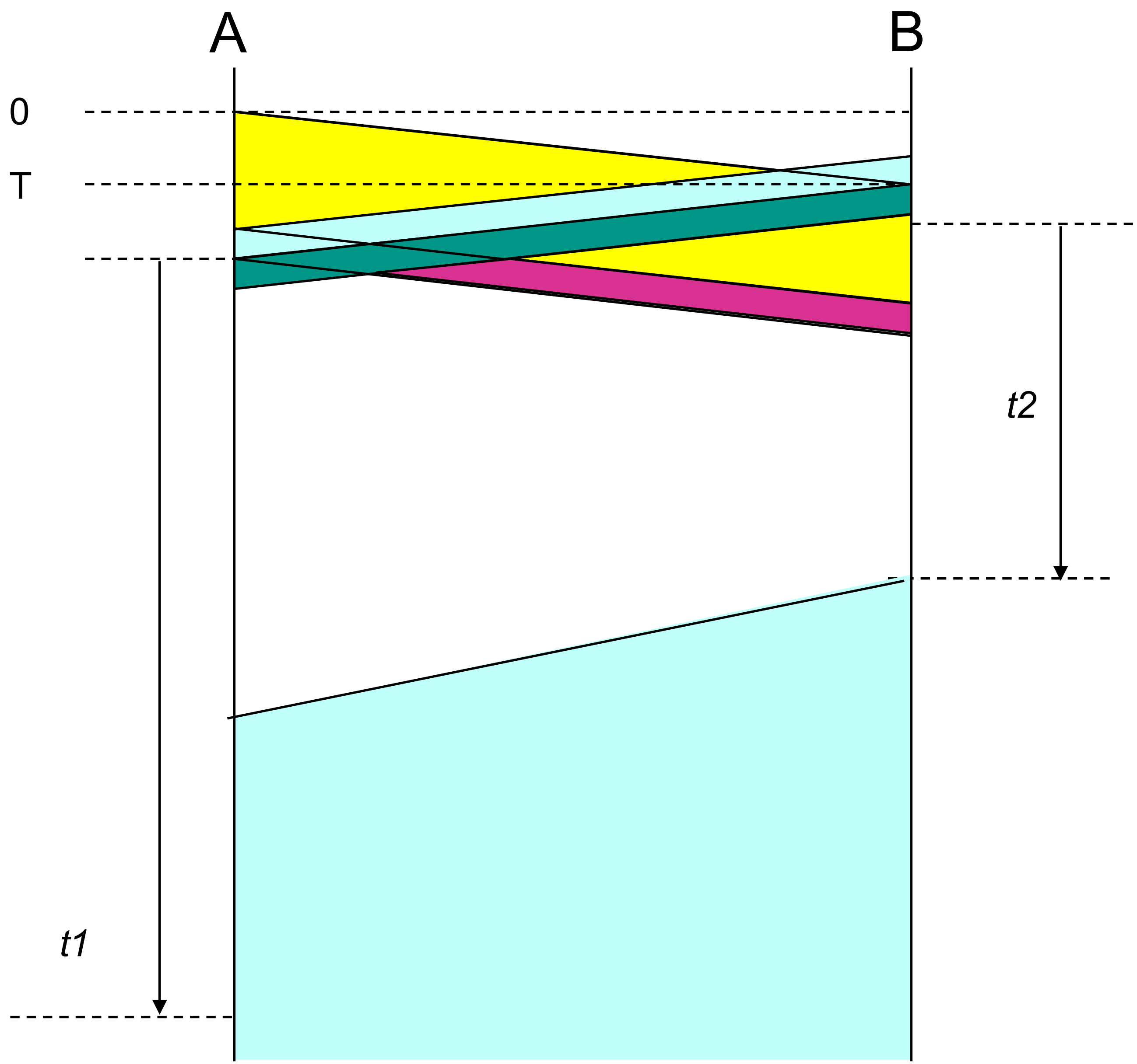
```
r = random (0, 2^k -1)
k = min (10, AttemptNb)
```

$$t_r = r \times 51.2\mu s, \quad r \in [0, 2^k - 1]$$

- **slot time** = 51.2 μs
- 1st collision, *r* = 0, 1
- 2nd collision, *r* = 0, 1, 2, 3
- 10th, *r* = 0, 1, ..., 1023
- 15th, stop

CSMA / CD Retransmission

- A waits random time *t1*
- B waits random time *t2=slottime < t1 =2*slottime*
- B senses channel idle and transmits
- A senses channel busy and *defers* to B
- A now waits until channel is idle



Retransmission interval

- Round trip time
  - limits the interval during which collisions may occur
- Slot
  - 45 μs + 3.2 μs < 51.2 μs (512 bits)
  - channel is acquired after 51.2 μs
  - non-valid frames (results of collisions) < 512 bits
    - minimal frame size (data field ≥ 46 bytes)
  - unit of the retransmission interval

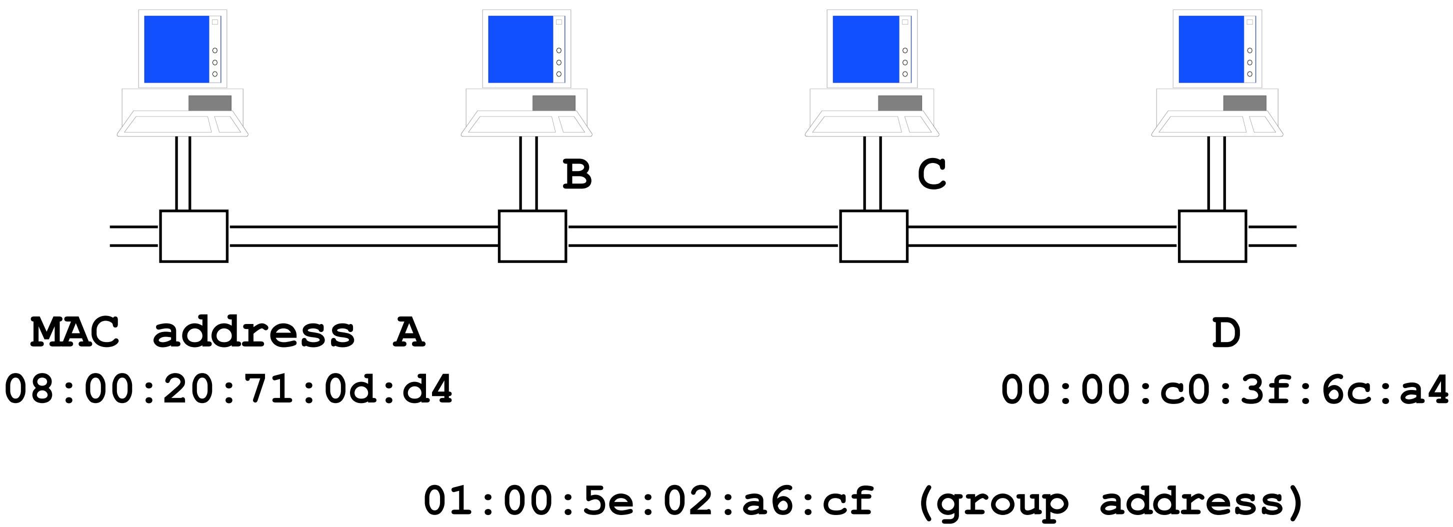
Frame format (Ethernet v.2)

preamble	dest	source	type	data	CRC
8 bytes	6 bytes	6 bytes	2 bytes	46 - 1500 bytes	4 bytes

- Preamble
  - synchronization : 10101010….0101011
- Addresses
  - unique, unicast and multicast (starts with the first bit 1)
  - broadcast: 11111…11111
- Type
  - upper layer protocol (IP, IPX, ARP, etc.)

Addressing

- MAC address: 48 bits = adapter identifier
- sender puts destination MAC address in the frame
- all stations read all frames; keep only if destination address matches
- all 1 address (**FF:FF:FF:FF:FF:FF**) = broadcast

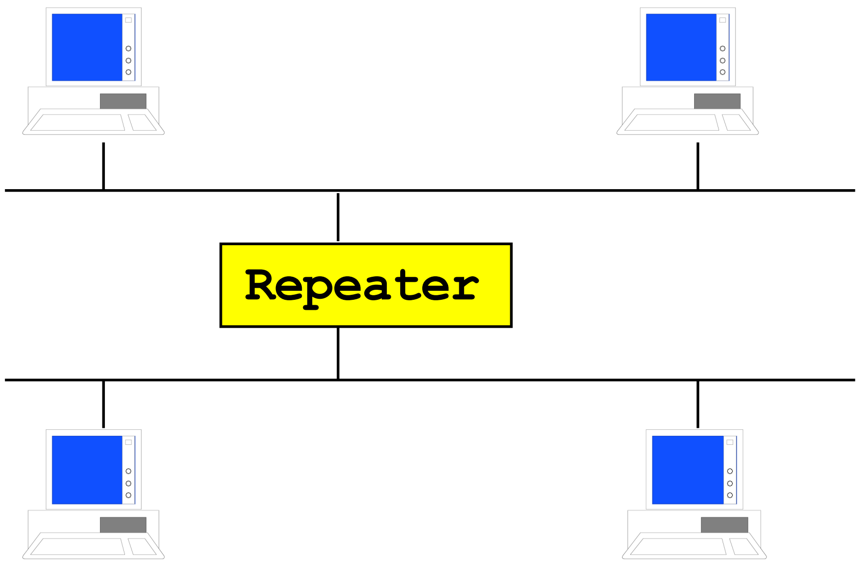


Addressing

- Data on Ethernet is transmitted least significant bit of first byte first (a bug dictated by Intel processors)
- Canonical representation thus inverts the order of bits inside a byte (the first bit of the address is the least significant bit of the first byte)
- examples of addresses:
  - **`01:00:5e:02:a6:cf (a group address)`**
  - **`08:00:20:71:0d:d4 (a SUN machine)`**
  - **`00:00:c0:3f:6c:a4 (a PC )`**
  - **`00:00:0c:02:78:36 (a CISCO router)`**
  - **`FF:FF:FF:FF:FF:FF the broadcast address`**

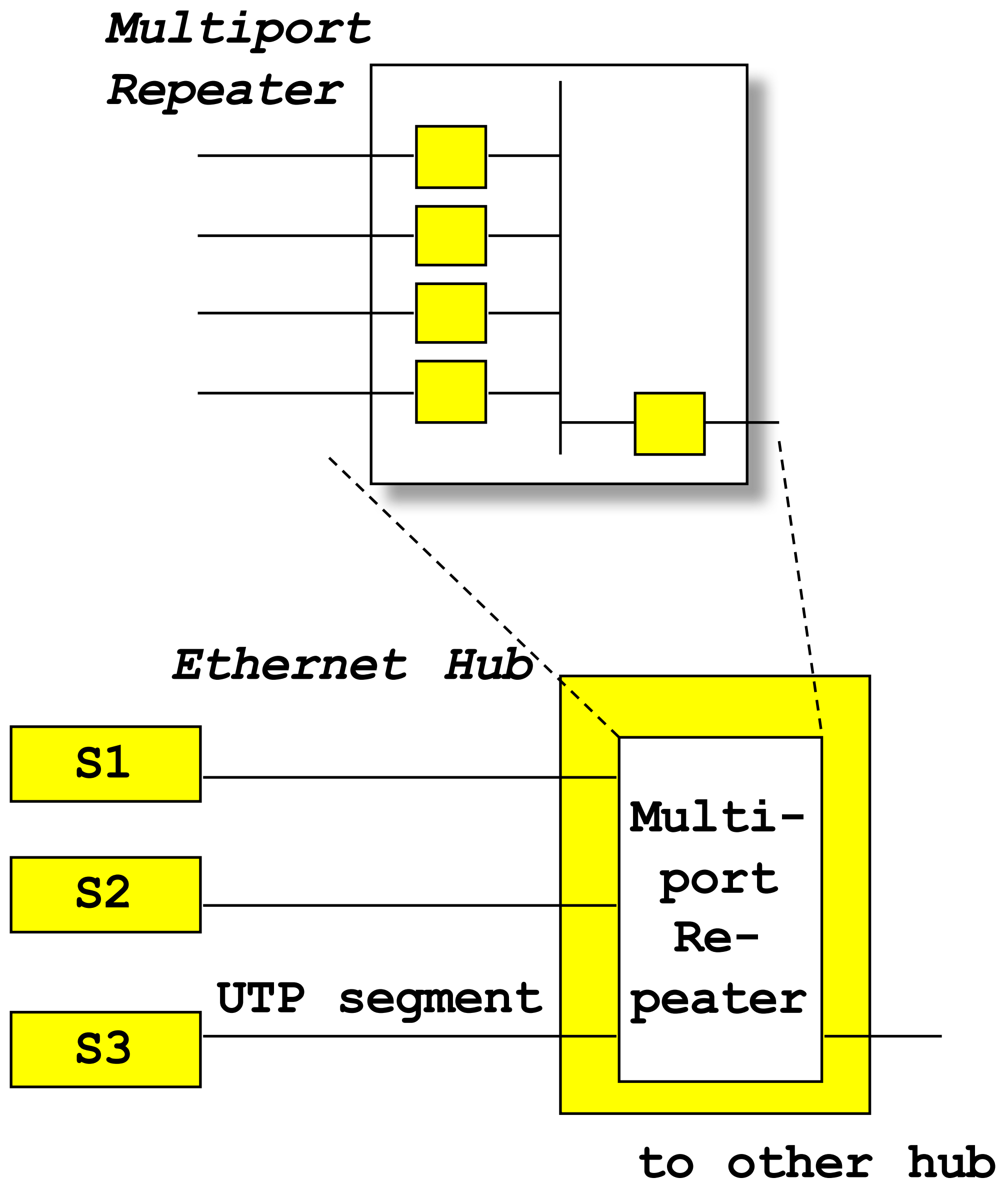
Repeaters

- Function of a simple, 2 port repeater:
  - repeat bits received on one port to other port
  - if collision sensed on one port, repeat random bits on other port
- One network with repeaters = ***one collision domain***
- Repeaters perform only physical layer functions (bit repeaters)

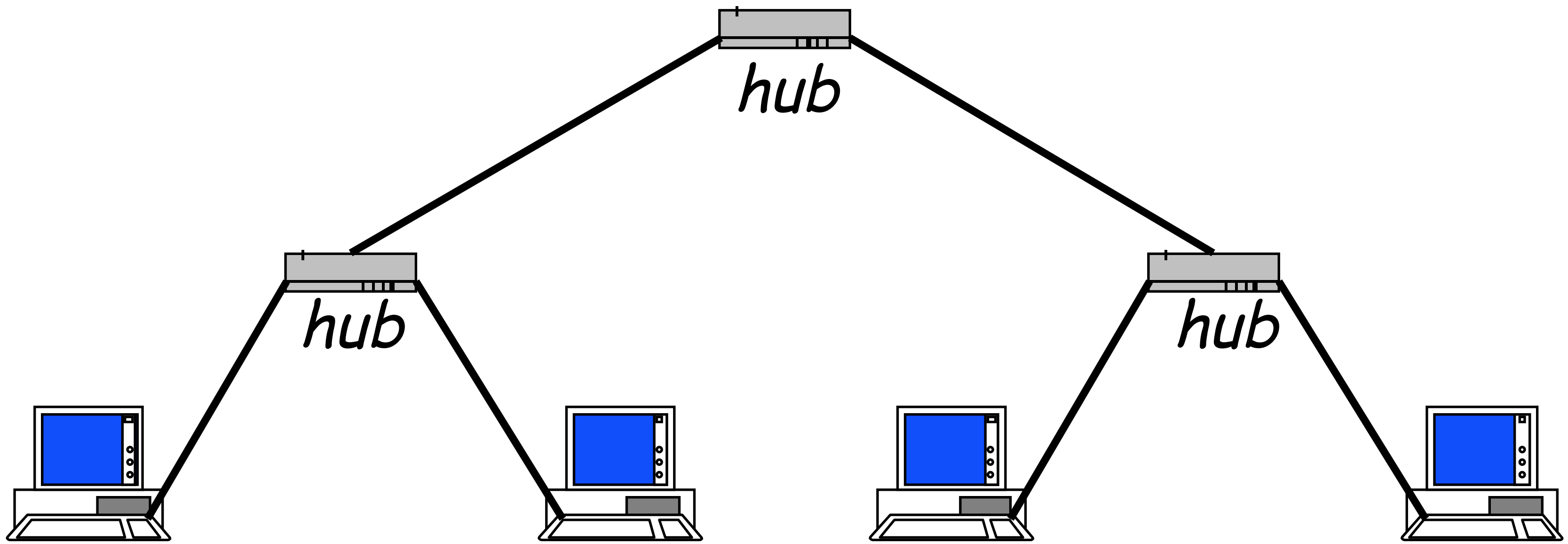


From Repeaters to Hubs

- Multiport repeater (*n* ports), logically equivalent to:
  - *n* simple repeater
  - connected to one internal Ethernet segment
- Multi-port repeaters make it possible to use point-to-point segments (Ethernet in the box)
  - ease of management
  - fault isolation

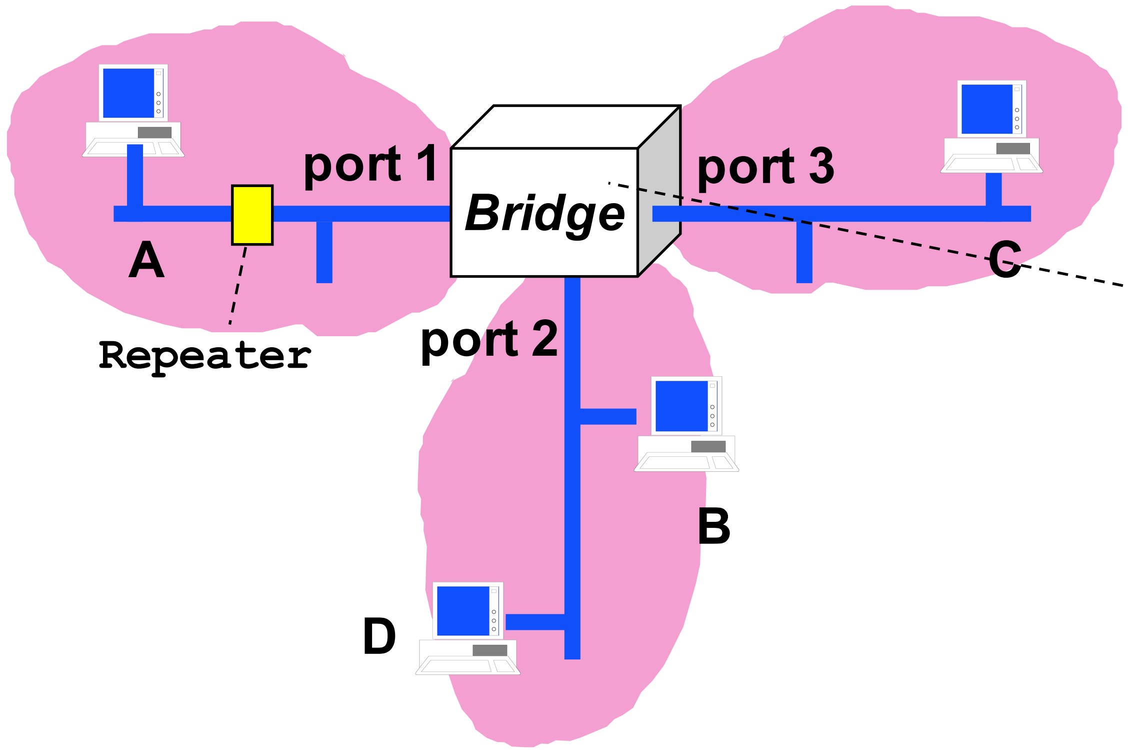


10 BASE T Hubs



- Tree topology (star)
  - hub *(répéteur multiport)*
  - max. 4 hubs

Bridges



Forwarding Table

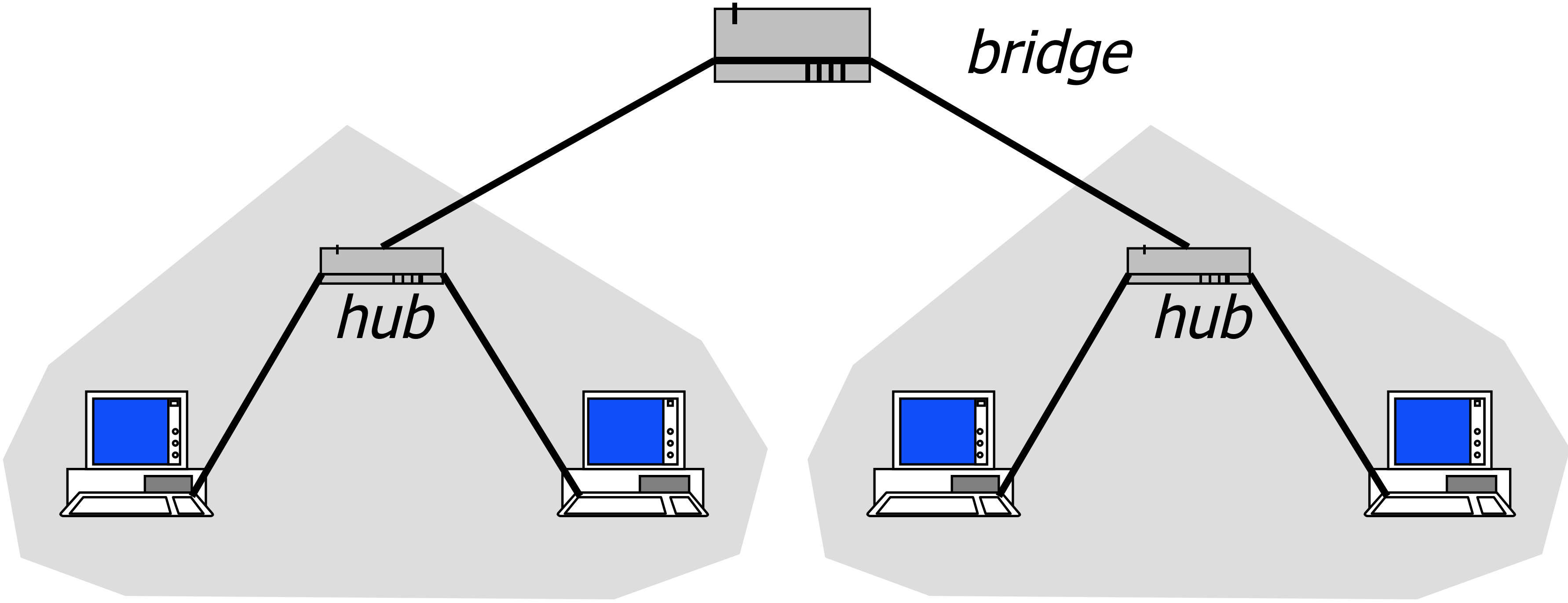
Dest MAC addr	Port Nb
A	1
B	2
C	3
D	2

- Bridges are intermediate systems, or switches, that forward MAC frames to destinations based on MAC addresses
- Transparent bridges: learn the Forwarding Table

Transparent Bridging (TB)

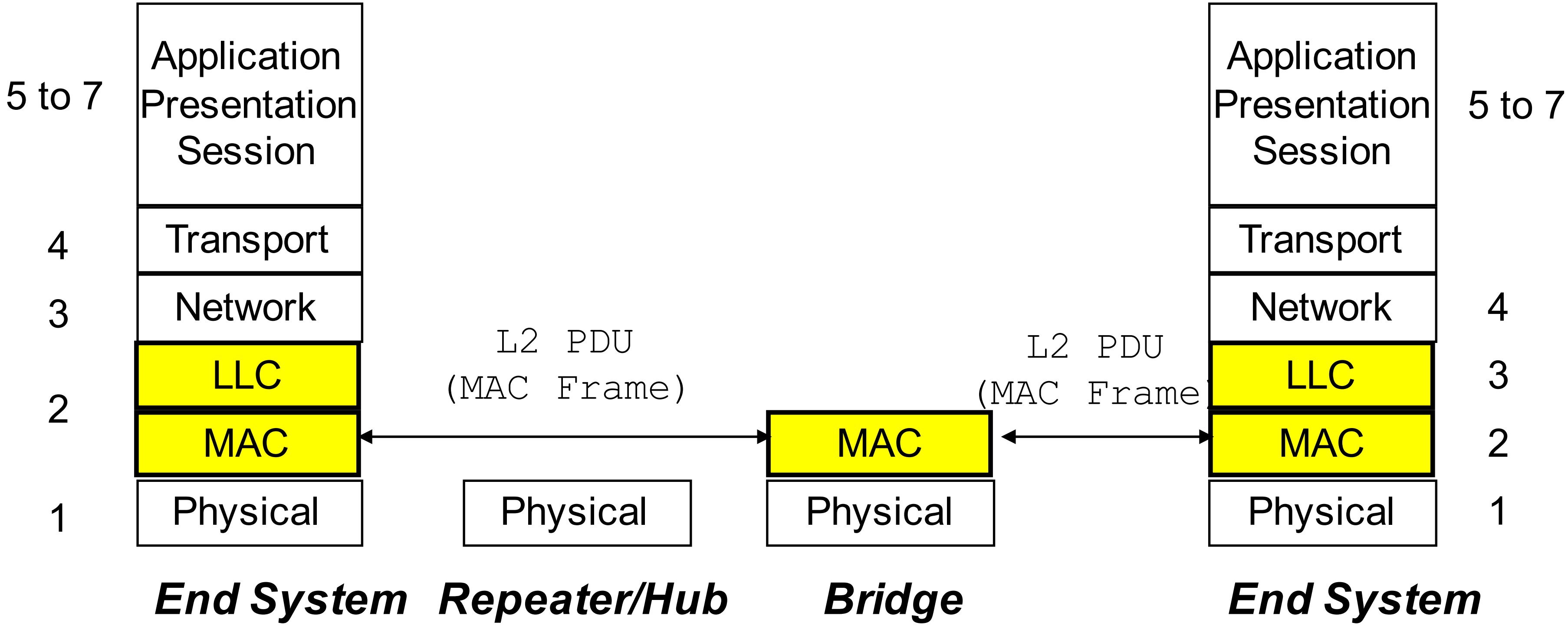
- Bridges are intermediate systems that forward MAC frames to destinations based on MAC addresses
- Interconnect systems beyond one LAN segment, keeping main characteristics of LAN
  - without additional addresses
    - MAC addresses used to identify end systems
- End systems ignore that there are transparent bridges
  - bridge is transparent
  - MAC frames not changed by bridges
  - frames not sent *to* bridge, but rather: bridge is promiscuous
    - listens to all frames and retransmits if needed

Collision domains



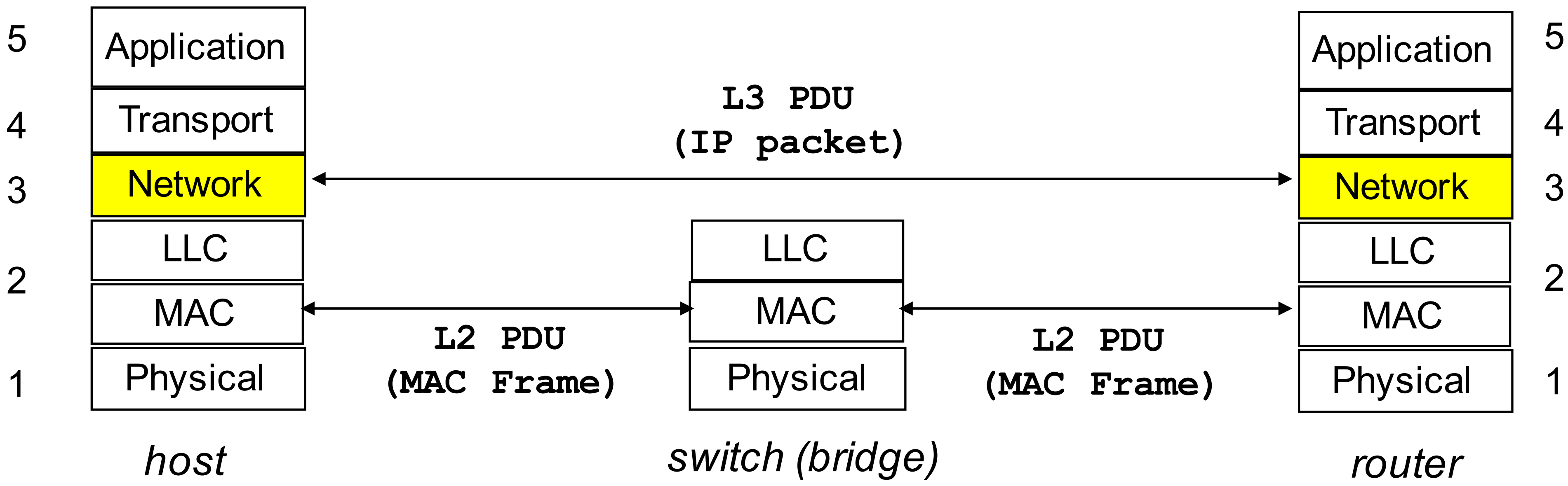
- Bridges separate collision domains
  - a bridged LAN maybe much larger than a repeated LAN
  - there may be several frames transmitted in parallel in a bridged LAN

Repeaters and Bridges in OSI Model



- Bridges are layer 2 intermediate systems
- Repeaters are in layer 1 intermediate systems
- Routers are layer 3 intermediate systems (IP routers)

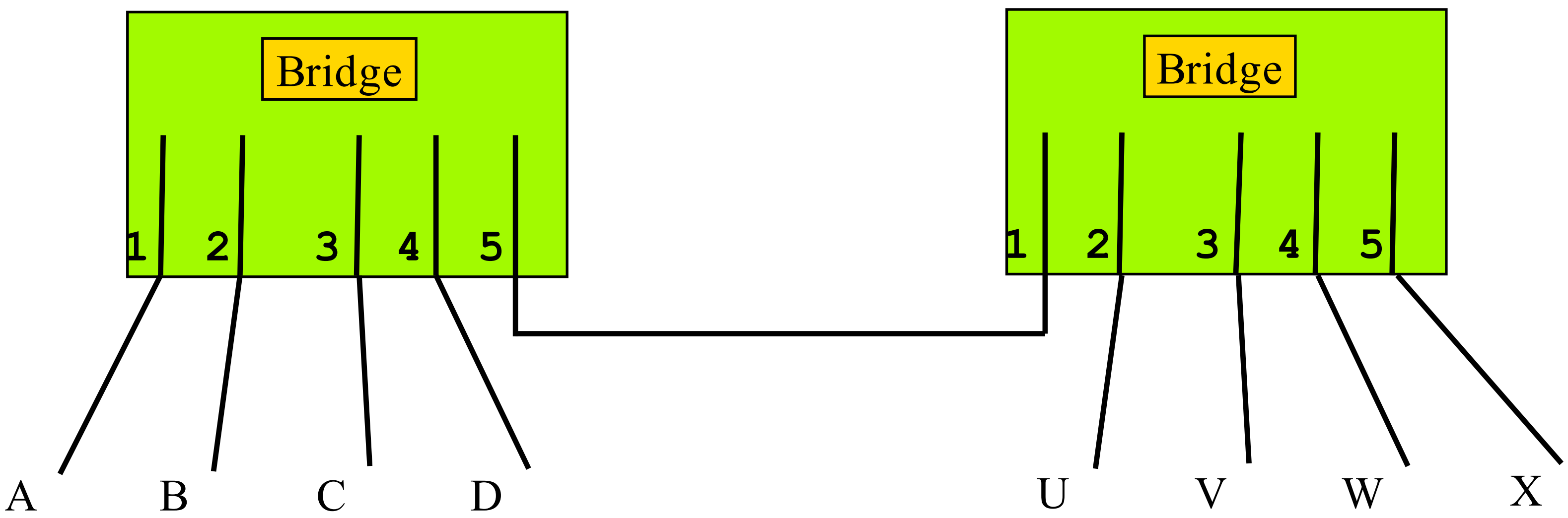
Protocol architecture



- Routers are layer 3 intermediate systems
- Explicit forwarding
  - host has to know the address of the first router
- Management protocols (control, routing, configuration)

Switched Ethernet

- Switched Ethernet = bridge in the box
- Total bandwidth is not shared
  - parallel frame transmission
- Half and full-duplex operation

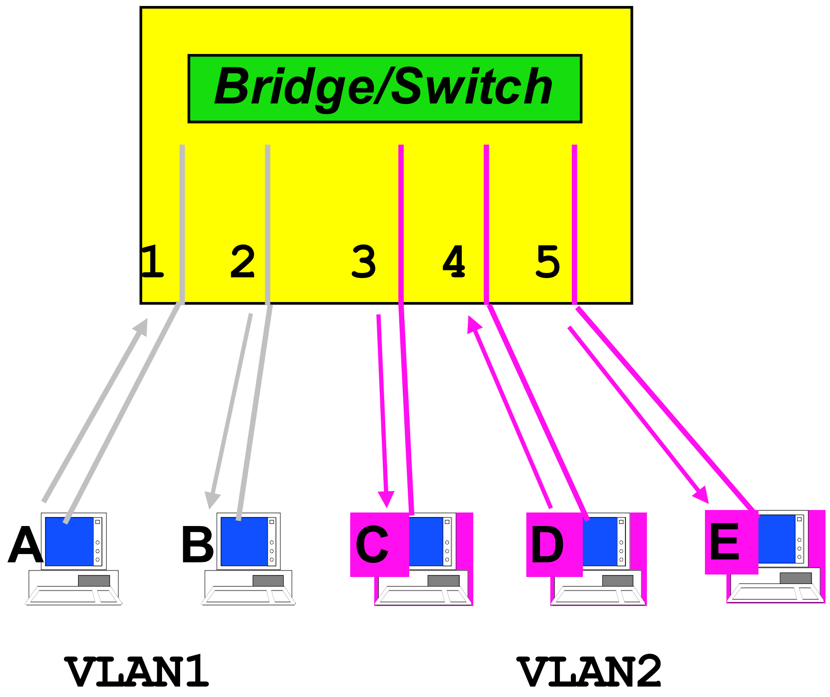


Switching

- Store and forward
  - receive full frame, check if valid, retransmit
  - 50 μs delay for a 64 bytes frame
- Cut through
  - address read, retransmit at line speed
    - 14 bytes read and decision made on output link
    - if link busy, defaults to store and forward
  - 20 μs delay for a 64 bytes frame
  - transmission of non-valid frames
    - CRC check at end of forwarding
- Flow control
  - back pressure using false collision notification
  - on full duplex links, send PAUSE to hosts

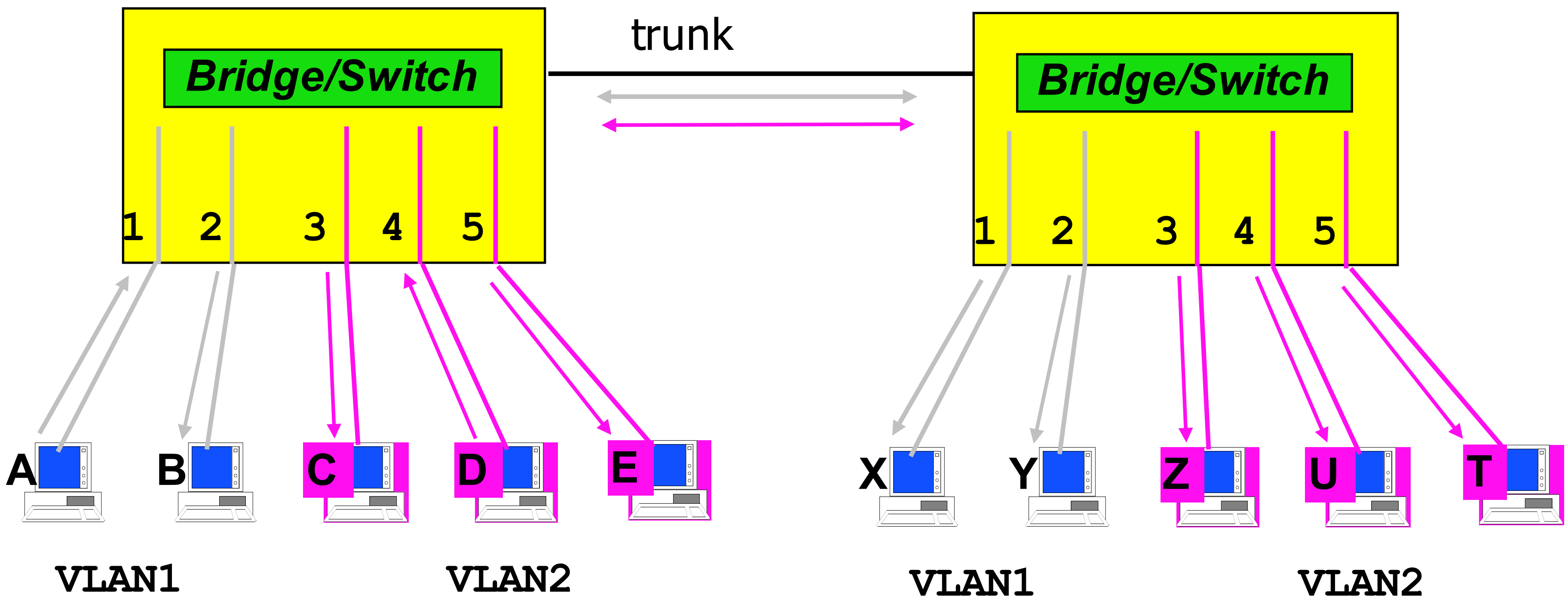
VLAN - Virtual LAN

- Keep the advantages of Layer 2 interconnection
  - auto-configuration (addresses, topology - Spanning Tree)
  - performance of switching
- Enhance with functionalities of Layer 3
  - extensibility
  - spanning large distances
  - traffic filtering
- Limit broadcast domains
- Security
  - separate subnetworks

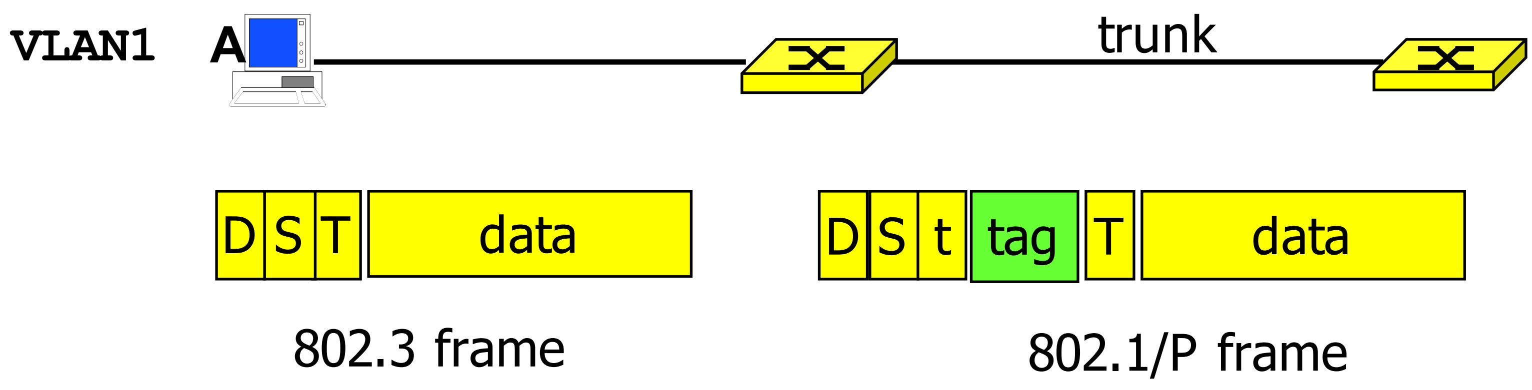


Virtual LANs

- No traffic between different VLANs
- VLANs build on bridges or switches



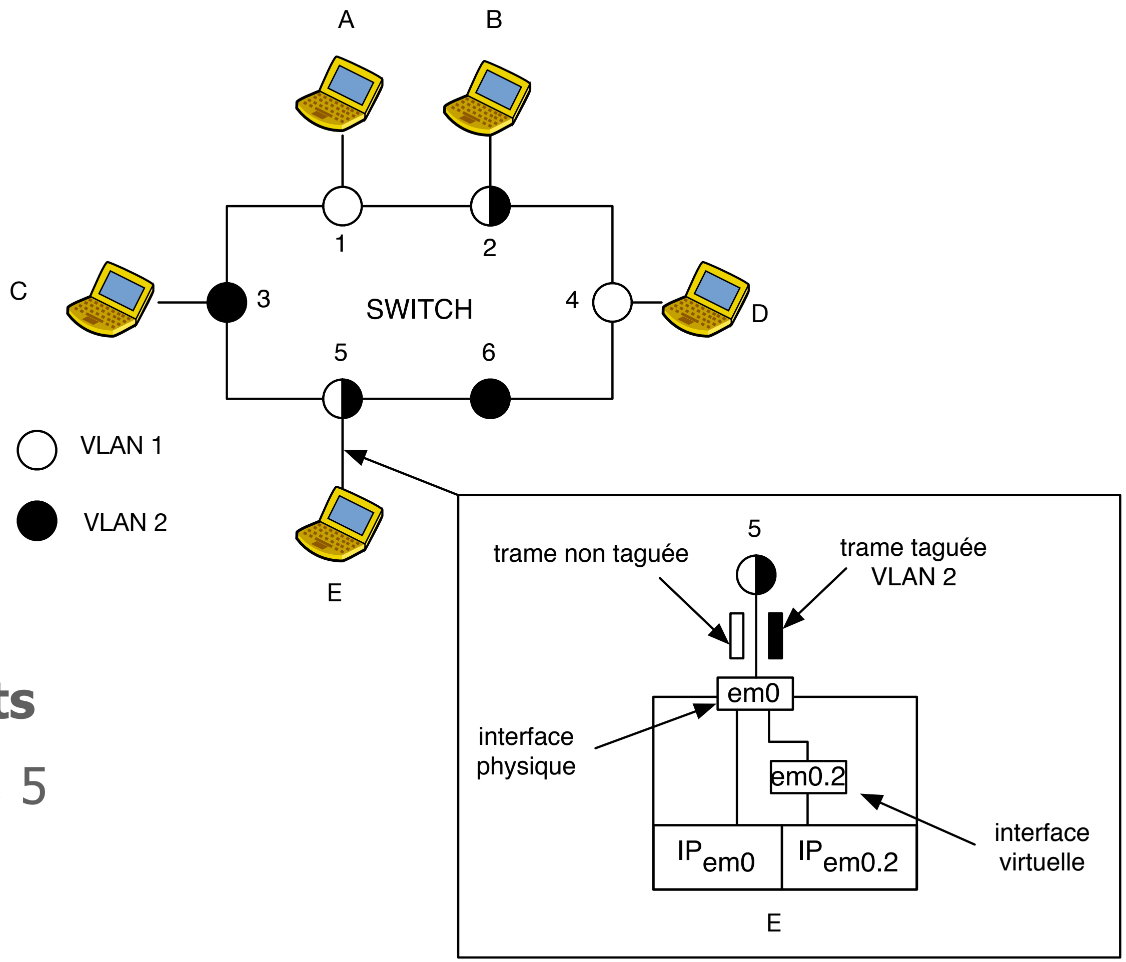
802.1Q



- Frame encapsulation
  - extension for assigning frame priority and VLAN tag
  - t - 2 bytes of TPI (Tag Protocol Identifier): 0x8100
  - tag - 2 bytes of TCI (Tag Control Information): priority (3 bits), VLAN Id (12 bits) (VID 0x001 often reserved for management)
  - max length = 1522 bytes

Tagged VLANs

- VLAN table



VLAN	tag	ports
1	untagged	1, 4, 5
1	tagged	2
2	untagged	2,3
2	tagged	5

Summary

- Original Ethernet is a shared medium: one collision domain per LAN
- Bridges are connectionless intermediate systems that interconnect LANs
- Using bridging, we can have several collision domains per LAN
- Ethernet switches use bridging
- State of the art
  - switched 100 Mb/s Ethernet to the host
  - 1 Gb Ethernet between switches
- Wireless LANs become increasingly popular
  - WiFi, Bluetooth