Ethernet

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The origins of Ethernet

Aloha

Origin. Send, then wait for ACK. If no ACK, resend after random time

Slotted Aloha

News: Send only in time slots

CSMA

CSMA = Carrier Sense Multiple Access

New: first sense for carrier, only send if no carrier detected

CSMA/CD

CD = Collision Detection

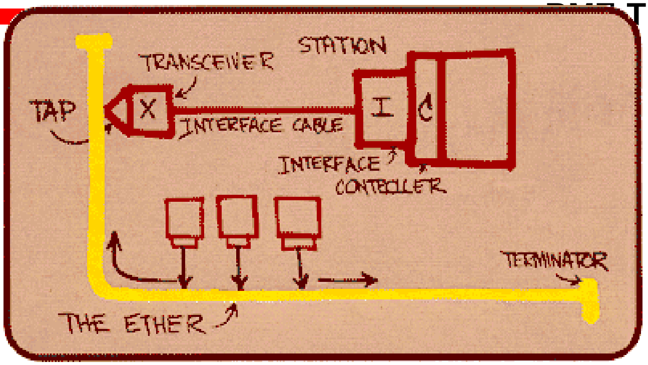
New: Stop sending when collision detected

Start of Ethernet

- 1972 Dr Robert Metcalfe

1976 first mention of Ethernet name

- The original DIX Ethernet V2 standard
  - 1982 (DEC-Intel-Xerox)
- Az IEEE 802.3
  - 10Base-5 - 1983
  - 10Base-2 - 1988
  - 10Base-T - 1990



The first Ethernet picture

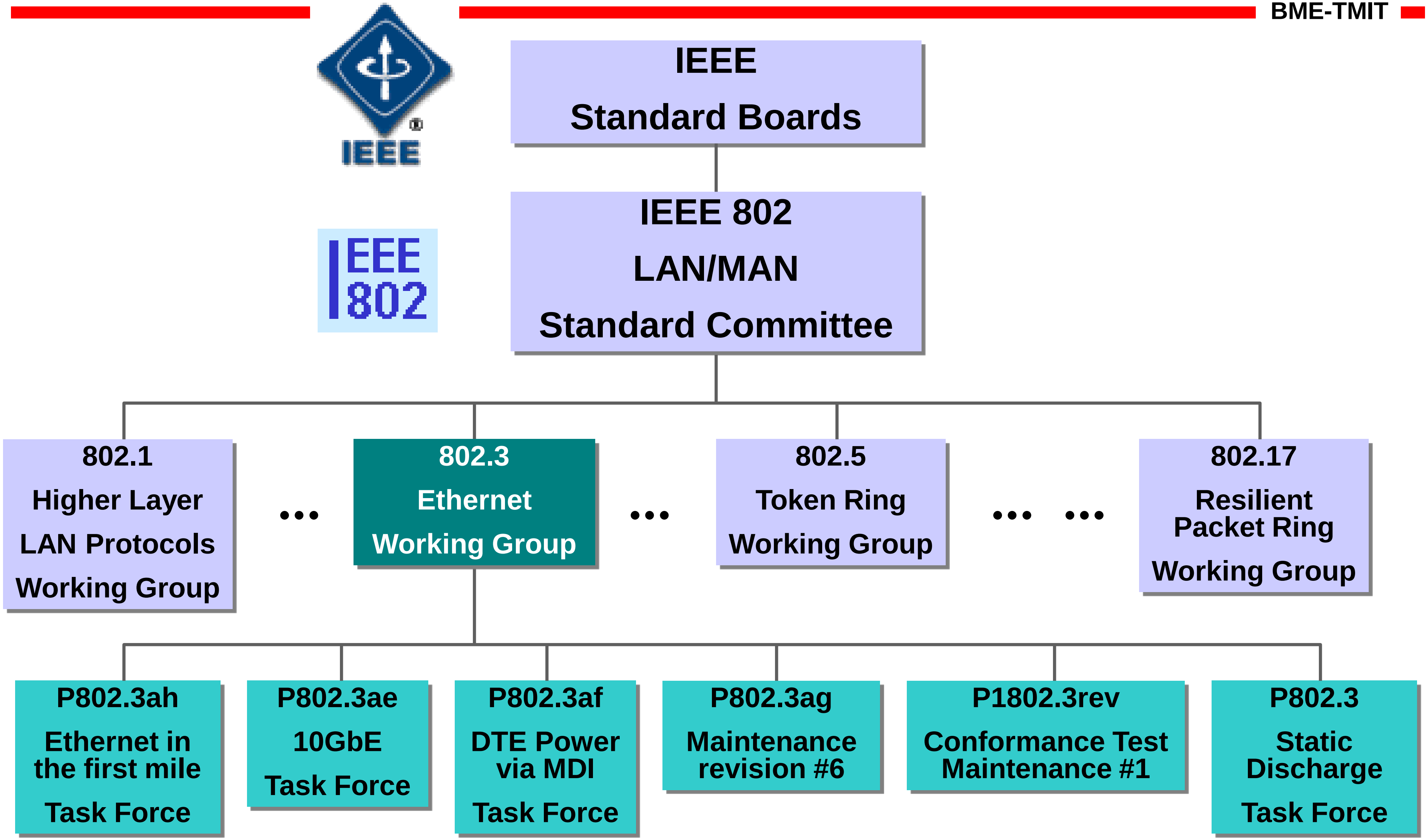
- Ethernet evolution – after 10M
  - 100BASE-TX (Fast Ethernet)
    - IEEE 802.3u: 1995
  - 1000BASE-X (Gigabit Ethernet)
    - IEEE 802.3z: July 1998
  - 1000BASE-T (Gigabit on Copper)
    - IEEE 802.3ab June 1999
  - 10 Gigabit Ethernet (IEEE 802.3ae)
    - IEEE 802.3ae 2002
  - 40GBE, 100GBE available now

Ethernet and OSI model

	OSI MODEL	TCP / IP		Exchange Unit
7	**Application Layer** Communication Type: E-mail, FTP, client/server…	**FTP, HTTP, SMTP, DNS, Telnet**	**Application Protocol**	**APDU**
6	**Presentation Layer** Encryption, data conversion: ASCII to EBCDIC, BCD to binary…		**Presentation Protocol**	**PPDU**
5	**Session Layer** Starts, stops sessions. Maintains orders.		**Session Protocol**	**SPDU**
4	**Transport Layer** Ensures delivery of entire file or message.	**TCP, UDP**	**Transport Protocol**	**Segments**
3	**Network Layer** Routes data to different LANs, WANs based on Network address.	**IP** **(ICMP, ARP, RARP)**		**Packet**
2	**Data Link (MAC) Layer** Transmit packets from node to node based on station address.	**Ethernet IEEE 802.3**		**Frame**
1	**Physical Layer** Electrical signals and cabling.			**Bits**

OSI = **O**pen **S**ystem **I**nterconnection

IEEE 802 Groups



IEEE

Standard Boards

IEEE 802

LAN/MAN

Standard Committee

802.1

Higher Layer

LAN Protocols

Working Group

…

802.3

Ethernet

Working Group

…

802.5

Token Ring

Working Group

… …

802.17

Resilient Packet Ring

Working Group

P802.3ah

Ethernet in the first mile

Task Force

P802.3ae

10GbE

Task Force

P802.3af

DTE Power via MDI

Task Force

P802.3ag

Maintenance revision #6

P1802.3rev

Conformance Test Maintenance #1

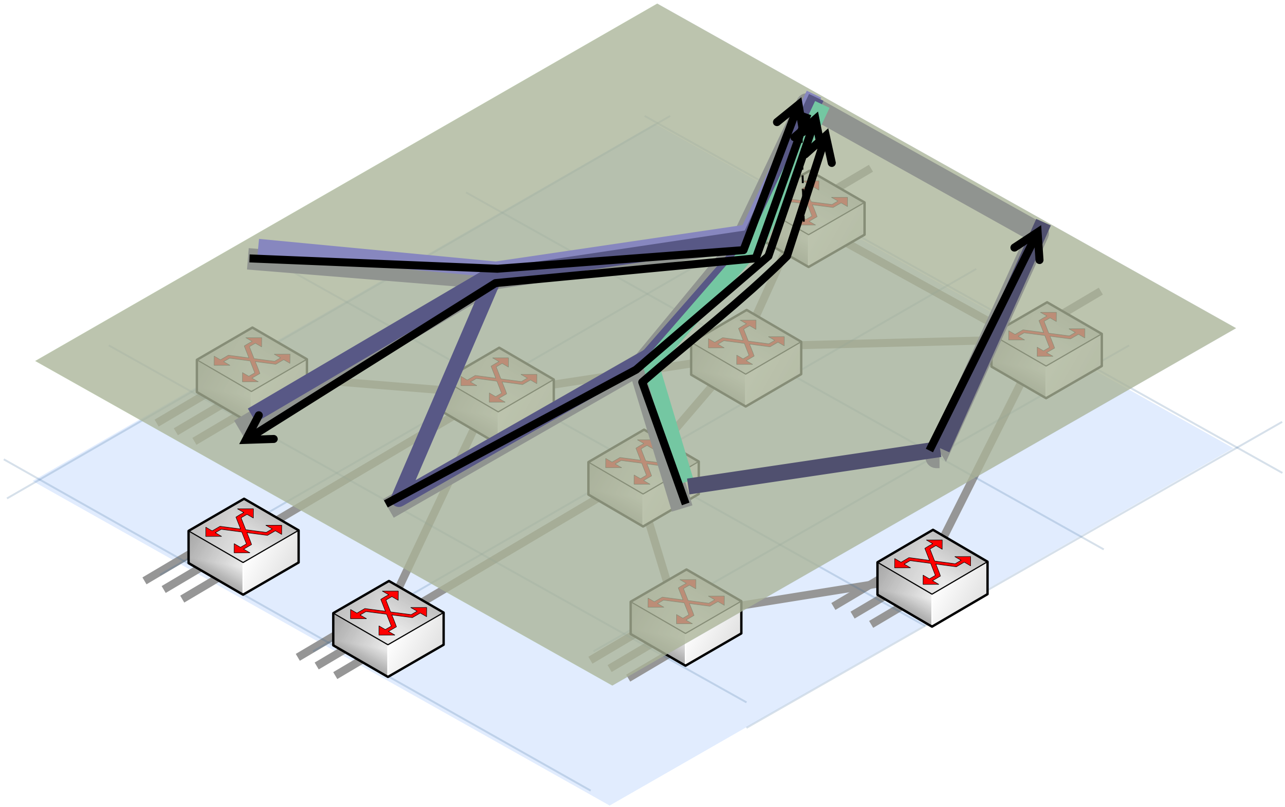
P802.3

Static Discharge

Task Force

ETHERNET OPERATION

Ethernet Forwarding



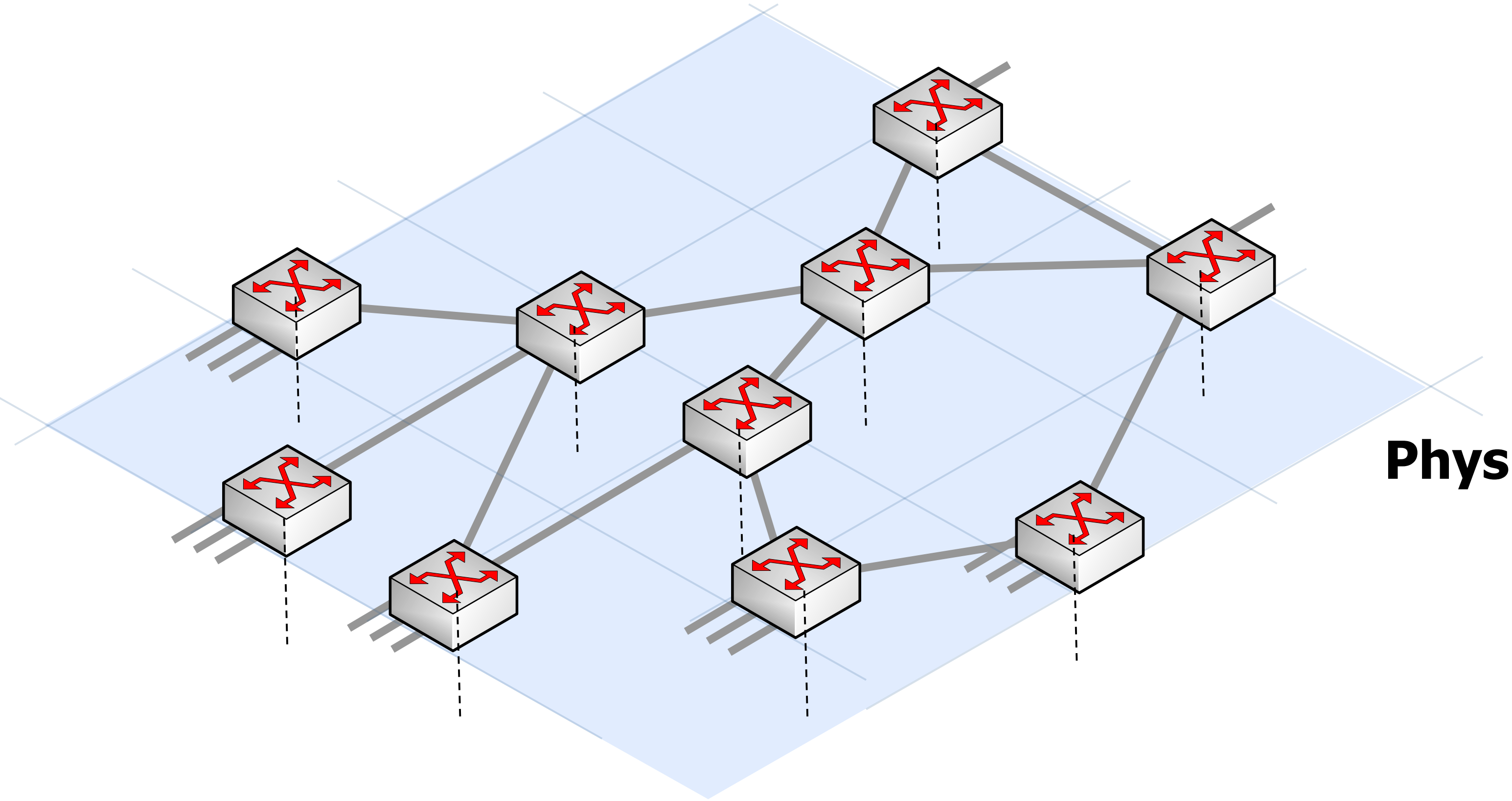
MAC Forwarding Topology

VLAN Forwarding Topology

Active (Spanning Tree) Topology

Physical Topology

Physical topology



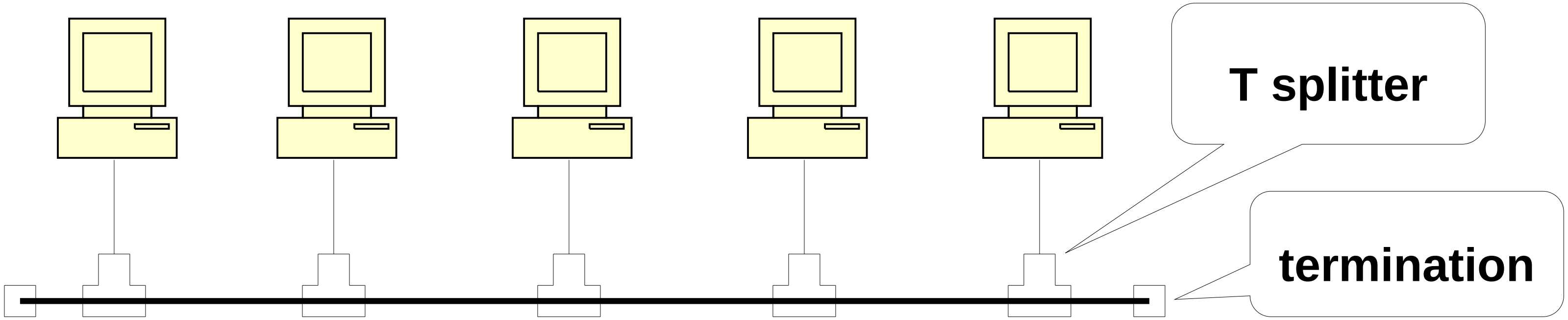
Physical topology

Physical Topology

- Ethernet Layer 2 topology
  - Determined by physical connections between switches
- It still can be an overlay topology
  - Eg. when optical overlay is used
- Properties
  - Links
  - Link speeds
  - Aggregated links (Etherchannel, 802.3ad)

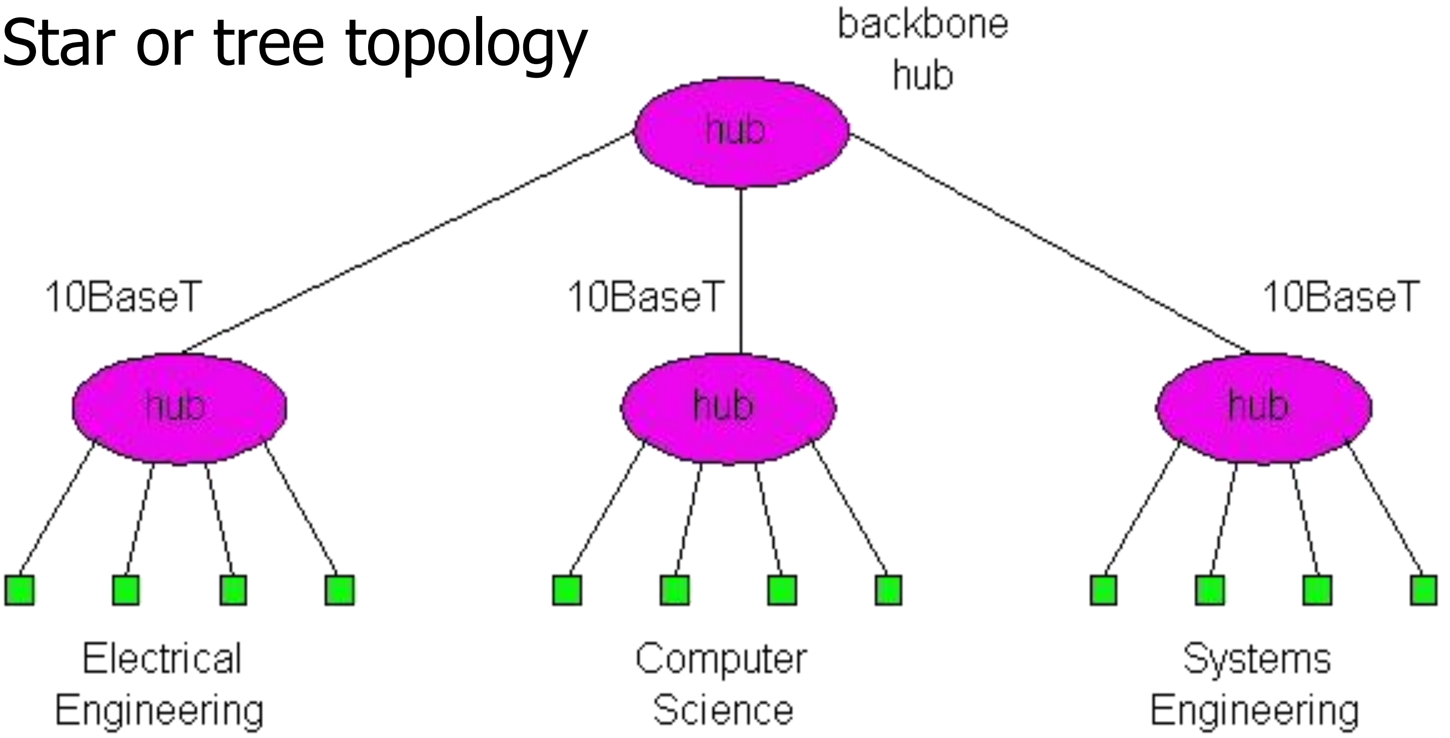
Physical connections - 1

- Coax, 10base2
  - 10: 10Mbps; 2: 200 m cable max.
  - Thin coaxial cable
- Longer distance:
  - Repeater needed



Physical connections - 2

- 10BaseT and 100BaseT up to 10GBE
  - 10, 100, 1000, 10000 MBps
  - T: Twisted Pair
  - Star or tree topology

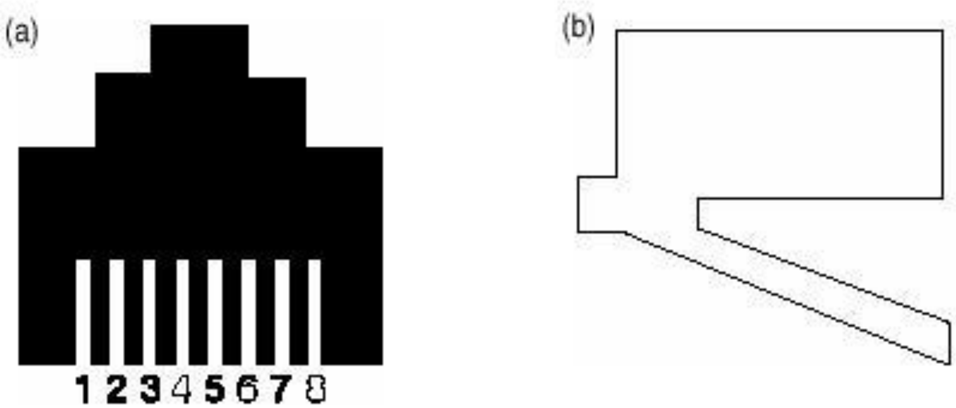


Physical connections - 3

- GE: Gigabit Ethernet
  - TX – twisted pair
  - SX/LX/FX – Optical connetion
- 10GE
  - Optical or twisted pair
- Higher speeds: 25, 40, 100Gbps
  - Usually optical, but TP also available
- 802.11: WLAN
  - It’s also Ethernet!

UTP – Category 5

- RJ-45



- **Pinout (10/100)**

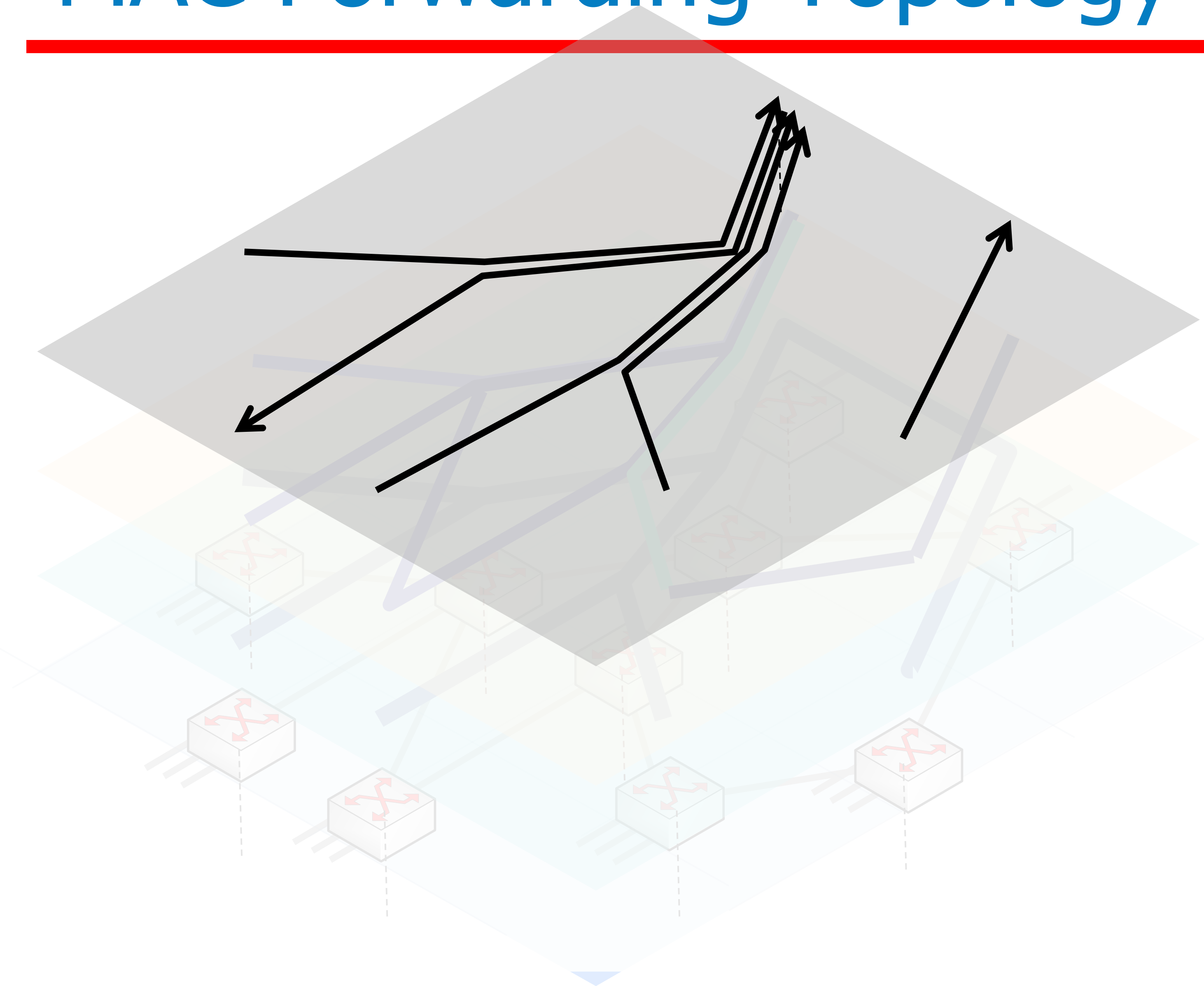
1 TD+ (Transmit Data)
2 TD- (Transmit Data)
3 RD+ (Receive Data)
4 Not used
5 Not used
6 RD- (Receive Data)
7 Not used
8 Not used

GB Ethernet uses all pairs!

Optical Ethernet

- Longer distances
  - Extends the reach up to kilometers
- Point-to-Point connection
- Usually reached with SFP modules
  - Different SFP types
    - Different distances
    - Different „colors” - WDM

MAC Forwarding Topology



MAC Forwarding topology

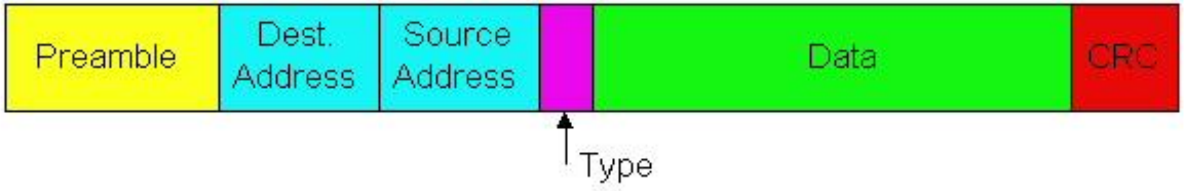
VLAN Forwarding topology

Active (Spanning Tree) topology

Physical topology

Frame format - 1

- Ethernet frame
  - I, II, 802.3 (802.2 SNAP needed for Ethernet II compatibility)
- IEEE 802.3 Data Link Control (DLC)

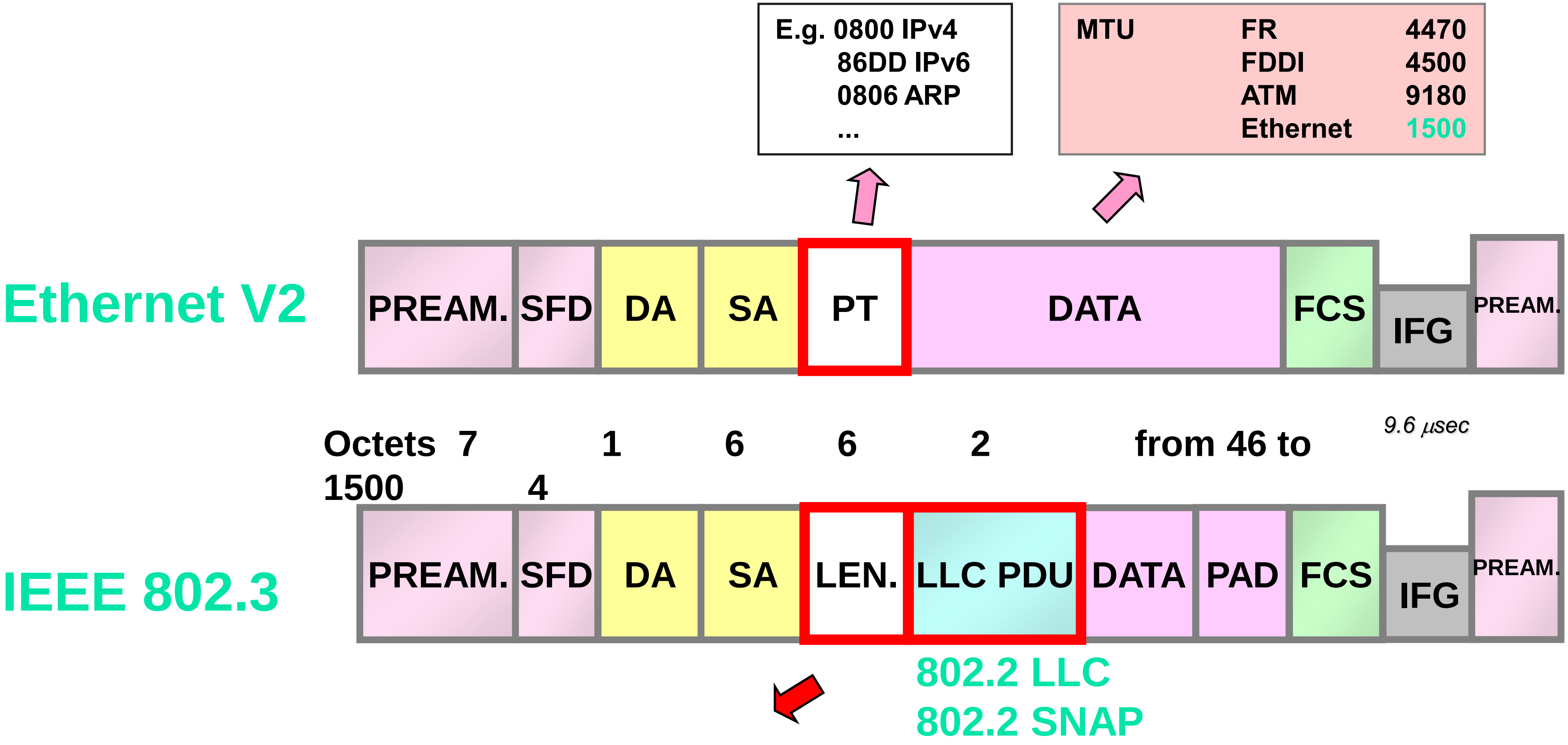


- Preamble and CRC are handled by the hardware:
  - 7 byte 10101010 followed by 10101011, needed for receiver synchronization
- IEEE 802.3 requires LLC header after the DLC

Frame format - 3

- Address: 6 byte
  - All stations receive the frame, but all drop except the one which is the destination
  - Special address: Broadcast – FF:FF:FF:FF:FF:FF
- Type field: 2 bytes
- CRC: 4 bytes, the receiver drops the frame with CRC error
- Data: maximum 1500 bytes, minimum 46 bytes
  - Maximum 9000 byte – GE Jumbo frame

Frame format - 3



E.g. 0800 IPv4
86DD IPv6
0806 ARP
...

MTU		
	FR	4470
	FDDI	4500
	ATM	9180
	Ethernet	1500

Octets 7 1 6 6 2 from 46 to
1500 4

802.2 LLC
802.2 SNAP

Difference between Ethernet V2 and 802.3

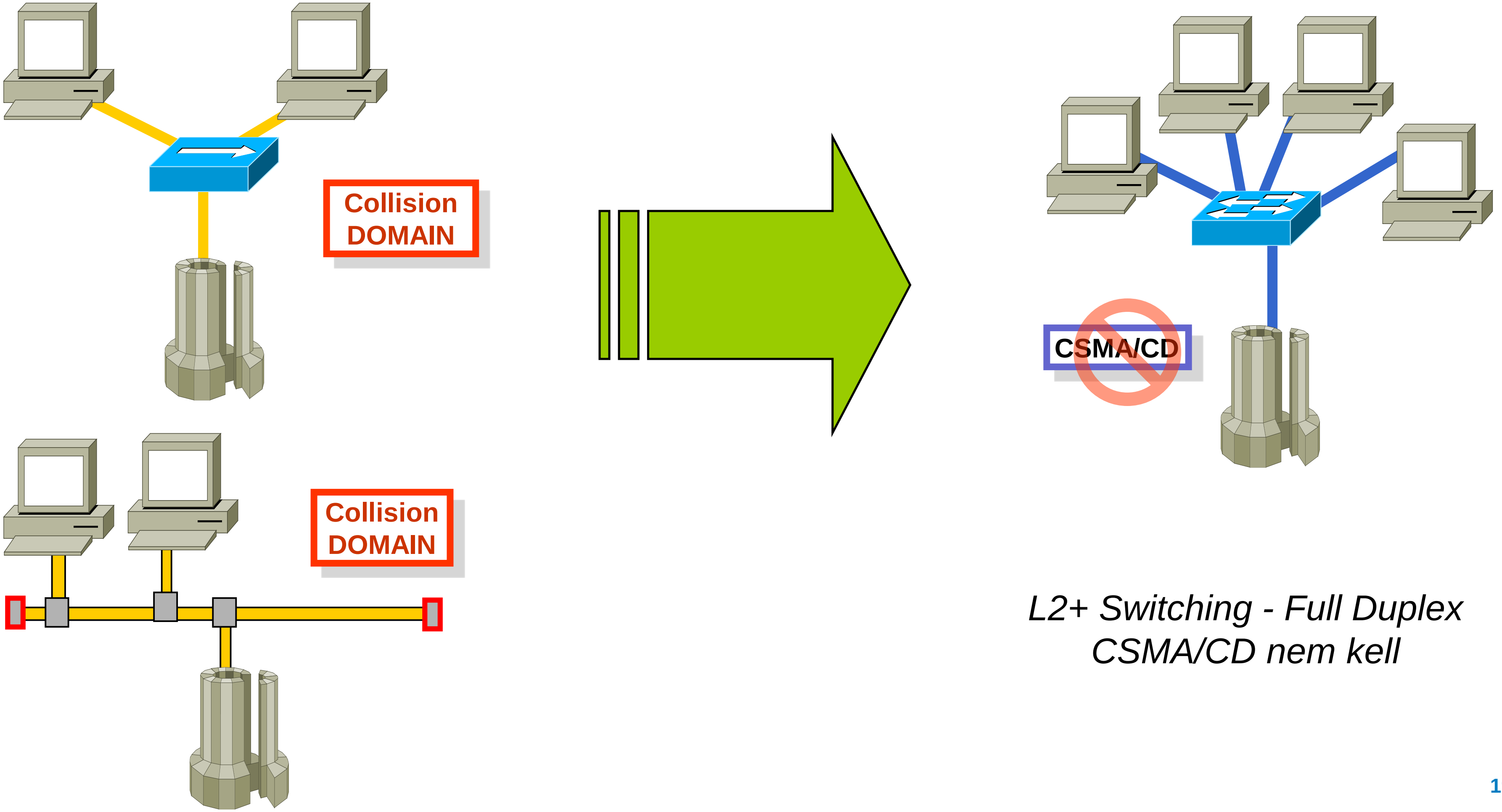
Maximum Frame Size is max.1518 (decimal), or 0x05EE Hex

EthernetV2 Ethertype is always greater than 0x05EF

http://www.iana.org/assignments/ethernet-numbers

No more collisions!

FDX & Microsegmentation
No collision



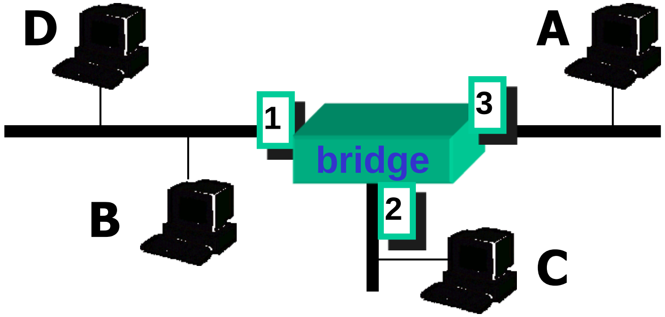
L2+ Switching - Full Duplex
CSMA/CD nem kell

Bridging - operation

- Target: transparent operation
  - Automatic plug-n-play operation
  - Automatic config
  - Cooperation with existing LAN technologies
- 3 main functionalities:
  1. forwarding
  2. MAC learning
  3. Loop avoidance: Spanning Tree

Ethernet Bridge Operation

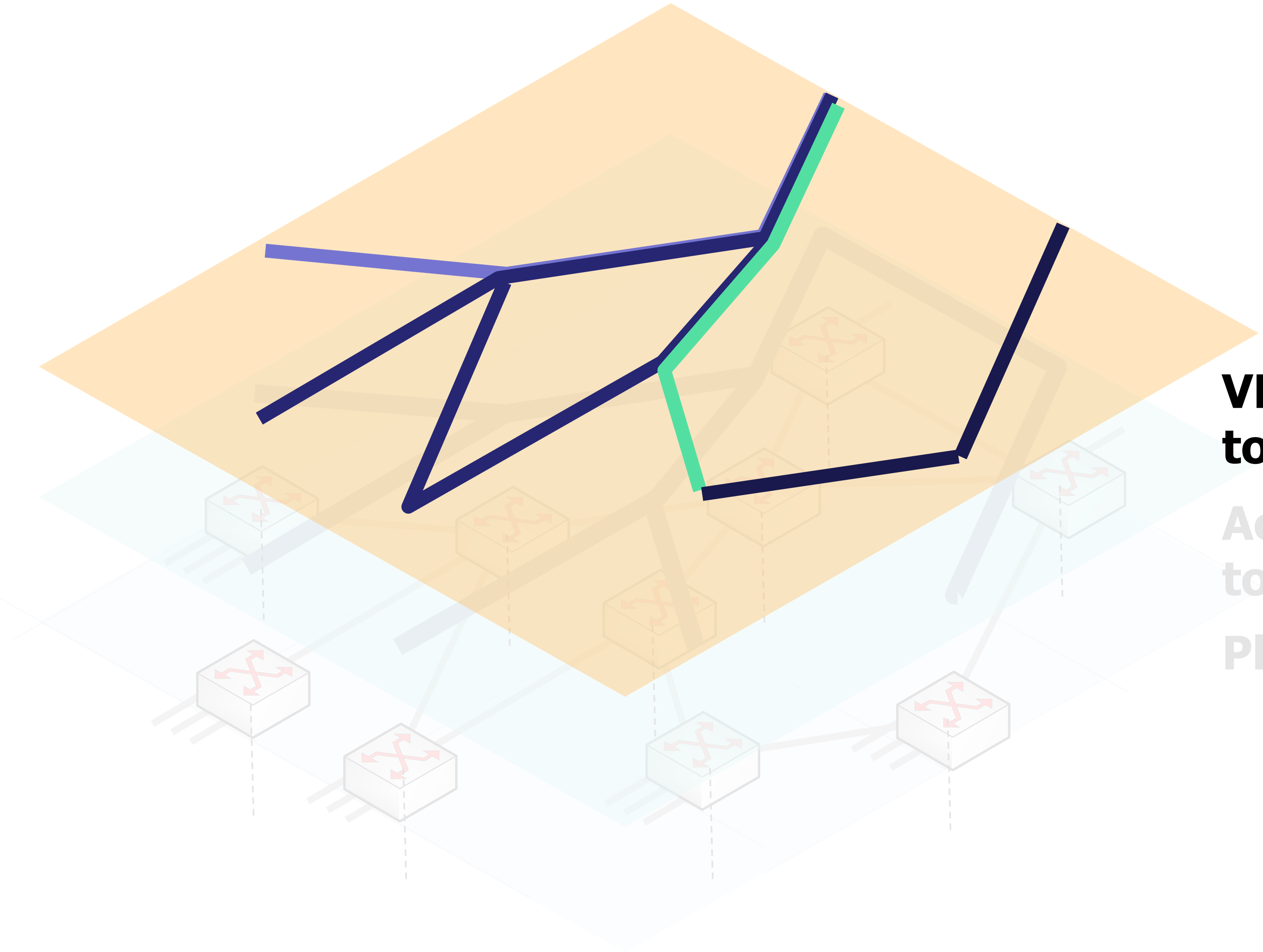
- Frame forwarding based on destination MAC address
  - MAC addresses supposed to be unique
- If destination not known: flooding
  - and learn the source MAC
- If destination MAC is already learned, forward only to that port



- Example:
  - A->D: broadcast
  - D->A: port 3
    - learn D's MAC
    - C->D: port 1

MAC addr.	Port
A	3
B	1
C	2

VLAN topology



VLAN Forwarding topology

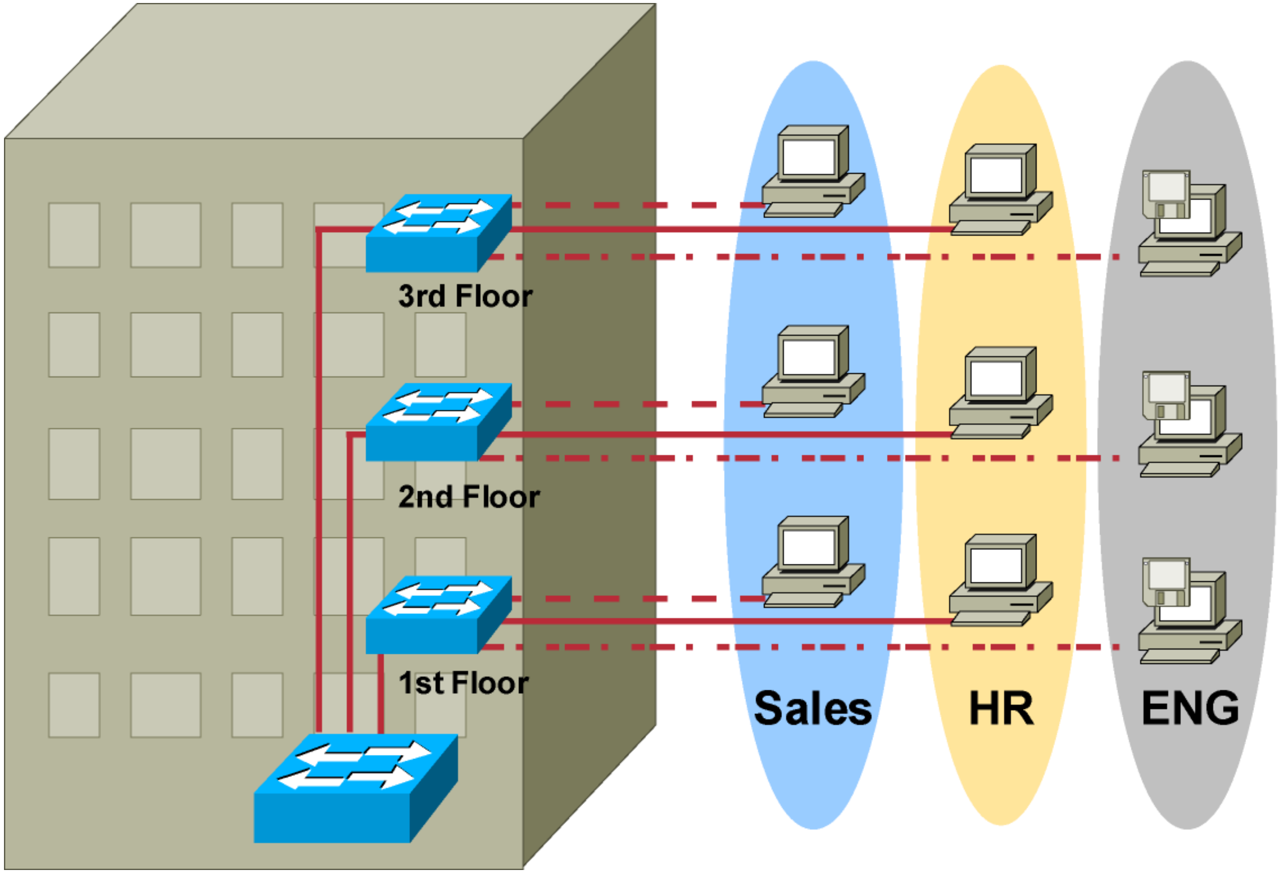
Active (Spanning T topology

Physical topology

VLAN

- LAN (Local Area Network): domain
  - Within the LAN everybody receives a broadcast
  - Limited by L3 devices (usually gateways/routers)
  - The limits are determined by cabling
  - To communicate out, router/GW is needed
  - To find an other device, adress resolution is needed (ARP)
- VLAN (Virtual LAN): administratively created broadcast domain
  - The admins determine who is in
  - Limits are virtual, not physical
  - Different VLANs do not see each other’s traffic

VLANs

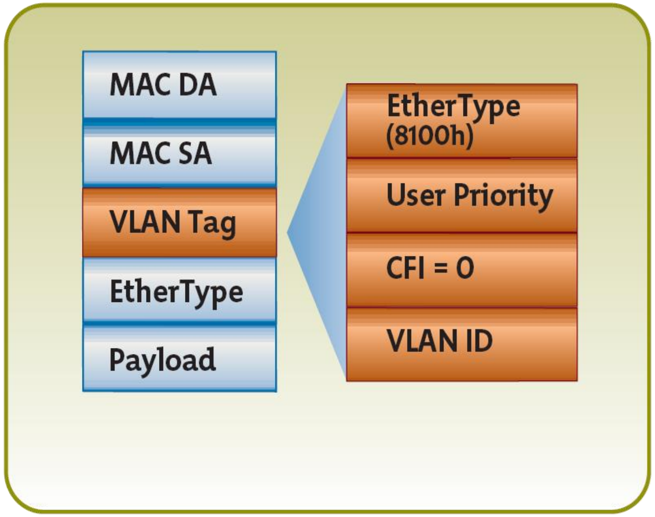


- Layer 2 connectivity
- Logical setup
- Single broadcast domain
- Management
- Security

1 VLAN = 1 Broadcast Domain = 1 Logical Subnet

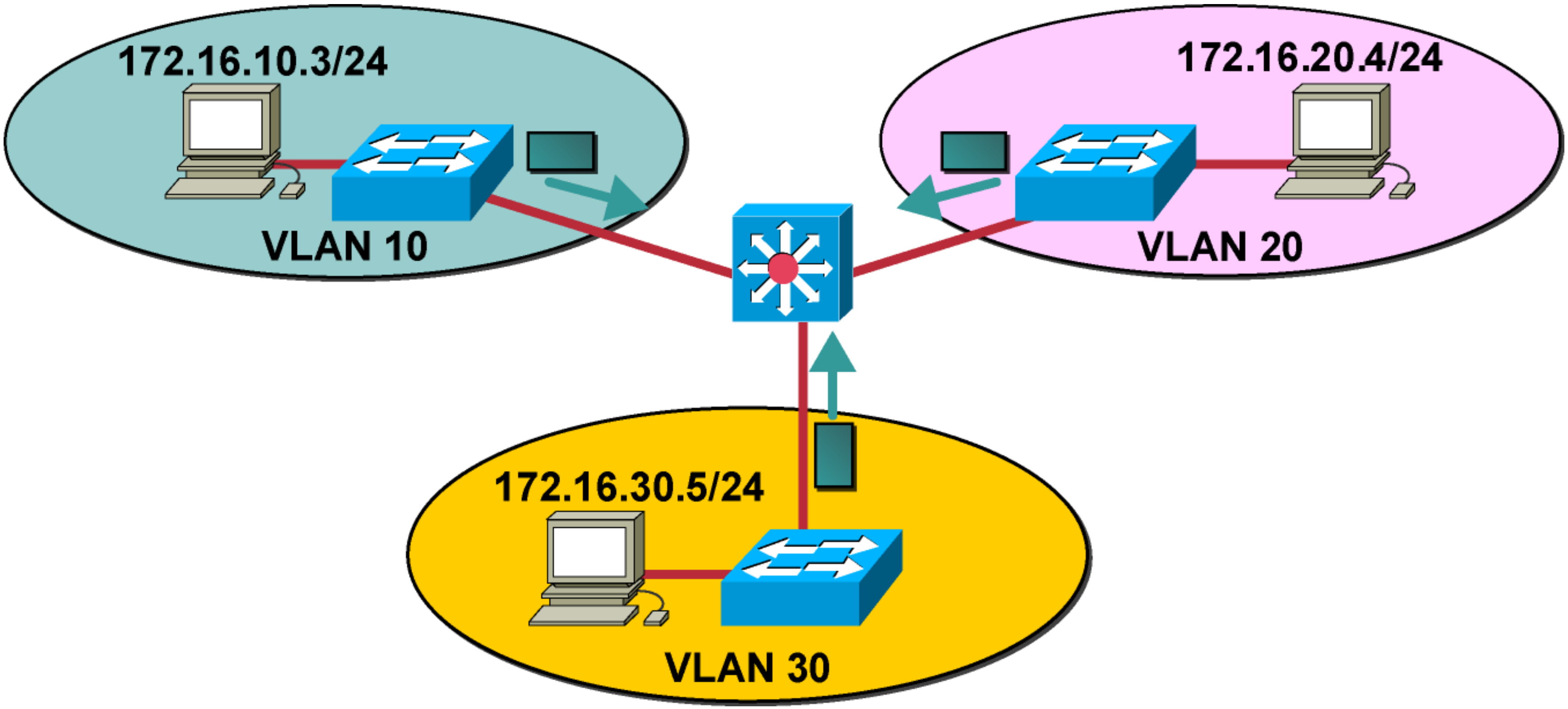
VLANs

- Virtual LANs introduced by IEEE 802.1Q
  - VLAN tag, 4096 VLANs possible
- Traffic separation by filtering
  - Filtering at ingress port
  - Filtering at egress ports
  - Does not interact with path selection!
    - It follows the Spanning Tree



- Q-in-Q, Provider Bridges (IEEE 802.1ad)
  - 4096 VLANs not enough in a provider network
  - Stacked VLANs
- Mac-in-Mac, Provider Backbone Bridges (IEEE802.1ah)
  - Solves MAC address scalability by MAC encapsulation

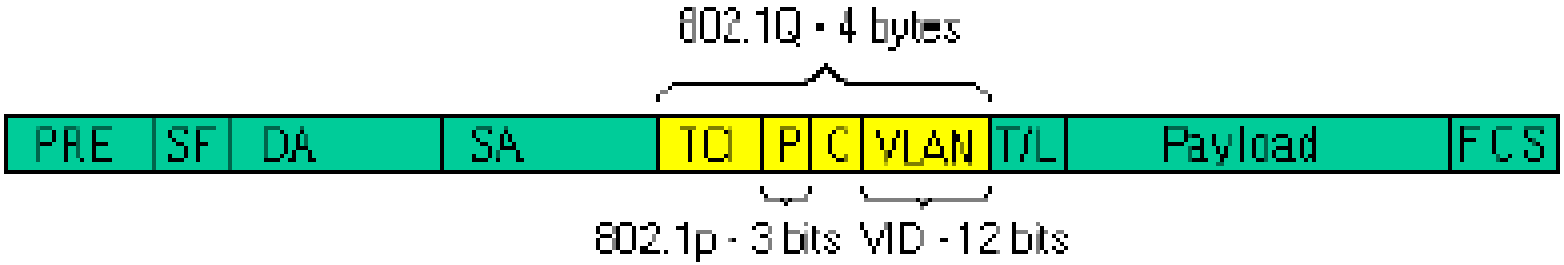
Traffic between VLANs



- No level 2 connection
- Only through an IP level router/gateway

Tagged Frame

- TCI (Tag Control Info): 8100 shows 802.1p/Q VLAN
- P: priority(0..7)
- C (Canonical Indicator): used for Token Ring
- VLAN: VID (0..4095)



VLAN operation - Filters

- Ingress filtering
  - Filtering if packets are tagged
  - Tagging if required
- Switching
  - As usual, based on learning bridge operation
  - Flooding if needed
- Egress filtering
  - Filter outgoing
  - Remove tag if needed

VLAN tagging

- Port-based VLANs: physical inteface based
- MAC-based VLANs: preconfigured MAC table
- Protocol-based VLANs: VLANs for each protocol: UDP, TCP, or even higher
- IP subnet based(not used)

VLAN trunk

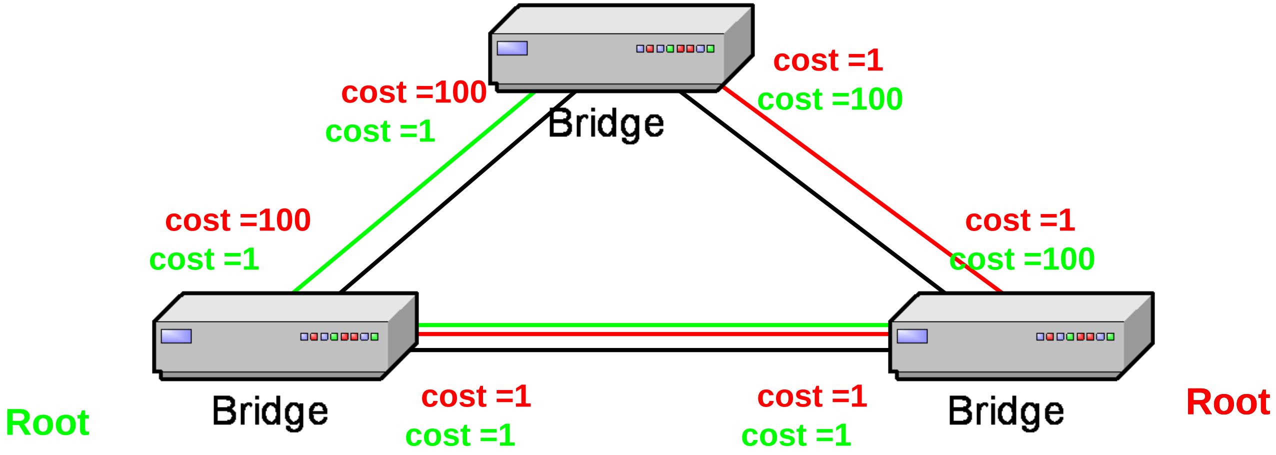
- On the uplink
  - „trunk port”
  - Tagged packets only
  - Filtering
- The trunk may also be „untagged”
  - Remove tag after filtering at egress

With VLANs and MSTP we can do

- Protection
  - Multiple disjoint trees
  - VLAN 1 assigned to primary tree, VLAN 2 to backup tree
  - On failure, traffic is switched to VLAN 2, using the backup tree
  - (requires IP level switching/failover logic)
- Traffic Engineering
  - Load balancing
  - paths can be “engineered”
  - traffic mapping to different engineered paths
- Of course, for a simple tree physical topology it is useless

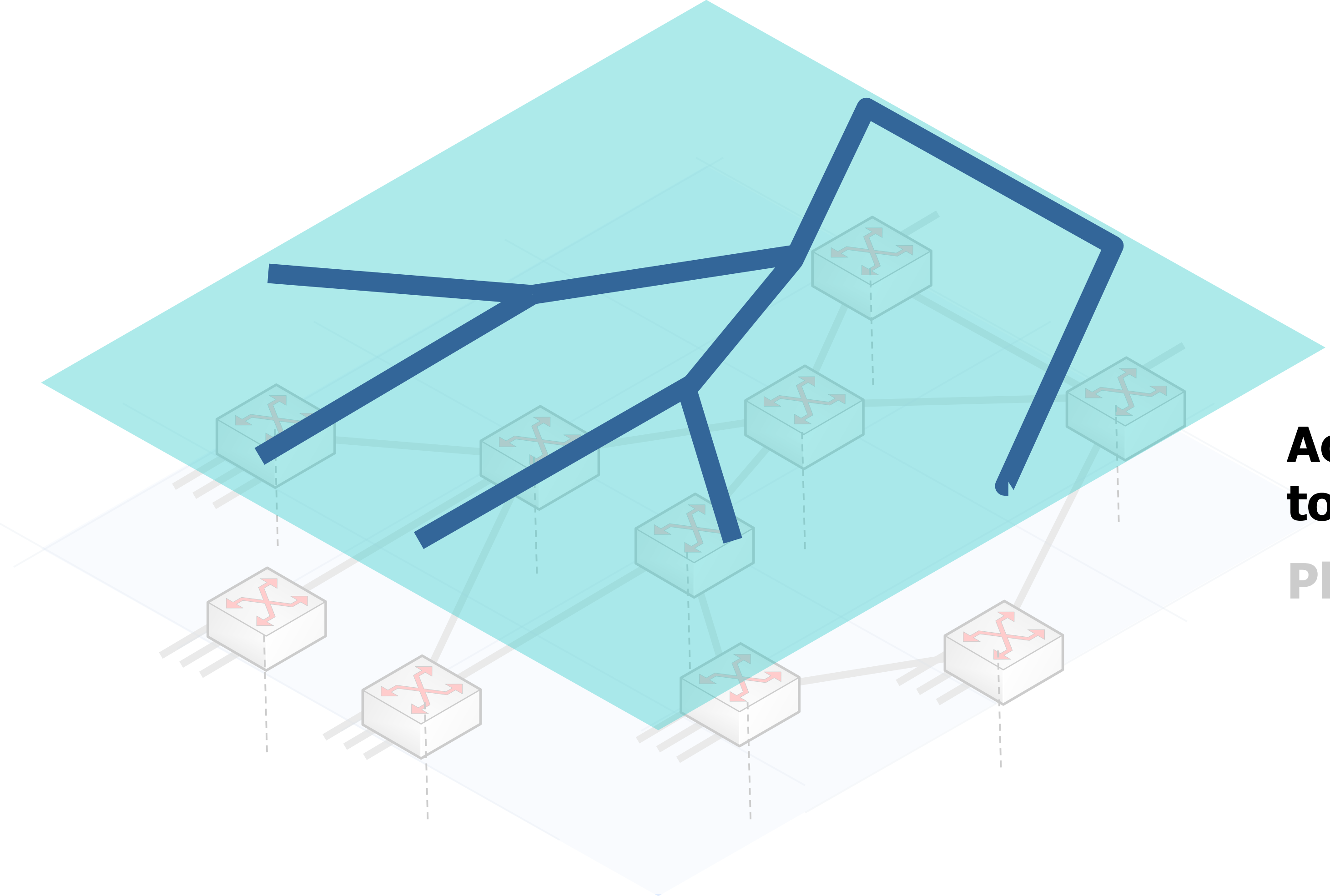
MSTP optimization

- MSTP requires configuration
- Trees are set up by setting different port costs



- Port cost assignment:
  - 1 for forwarding, (#of bridges+1) for blocking

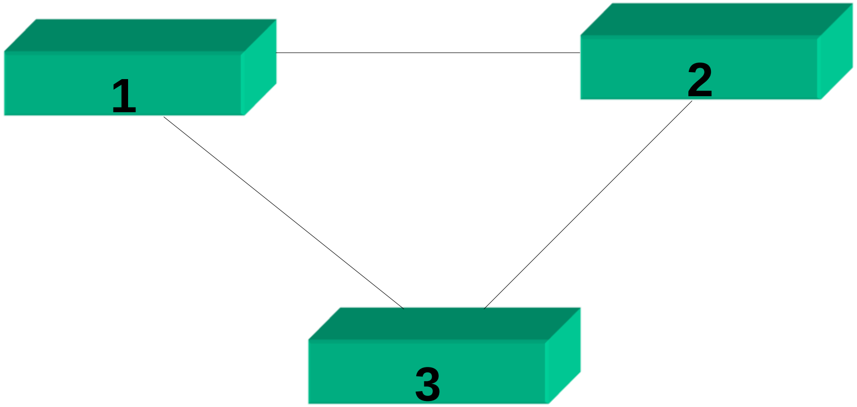
Active Topology



Active (Spanning T
topology

Physical topology

Redundancy - loop



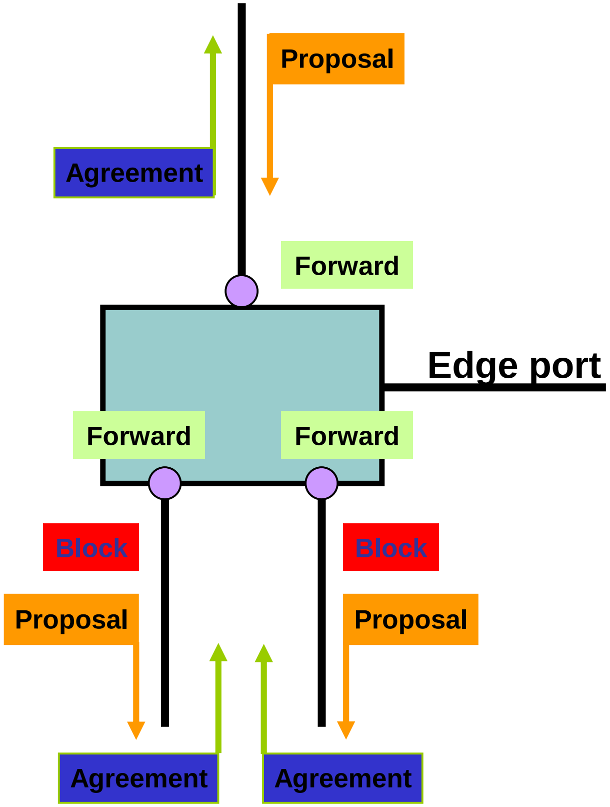
1. Broadcast packet arrives at 1. It is forwarded to 2 and 3
2. 2 sends to 3
3. 3 sends to 2
4. 2 and 3 both send it back to 1
   - Loop!

STP Bridge

- Avoid loops
  - Reduces topology to a tree
- Learning bridge based
- Packets travel along the tree only
  - In the direction of the root
- 802.1d

IEEE 802.1w sequence of events

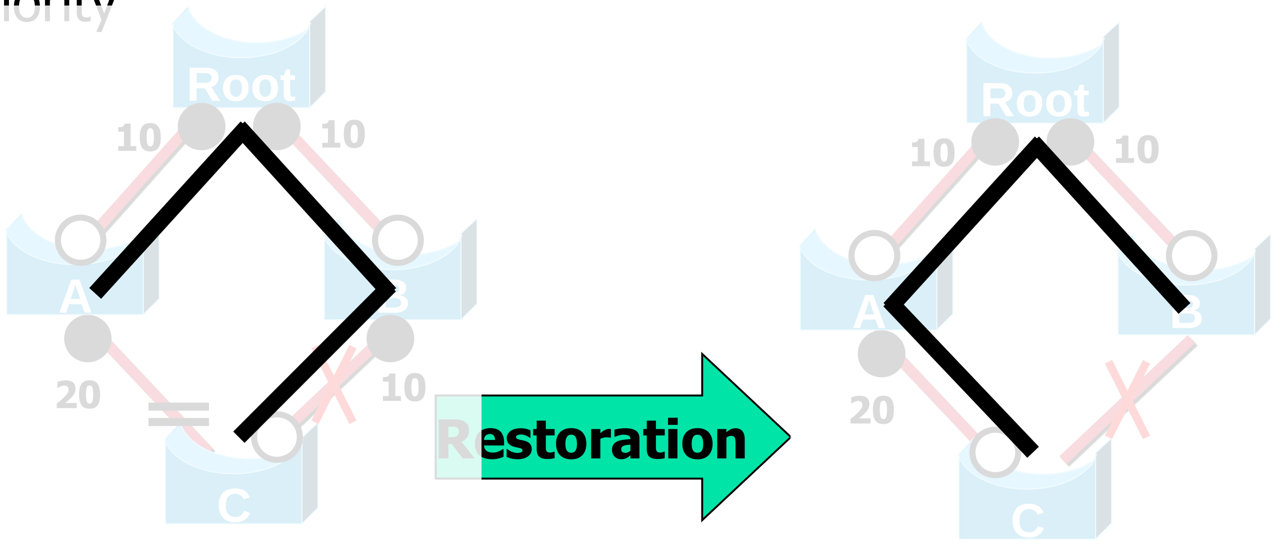
- Receive a proposal
  - Block all other non-edge ports
- Send an agreement back
  - Put the new root port to forwarding
- Send out proposals on other ports
- Receive agreement from others
  - Put ports into forwarding



RSTP operation

- Distributed operation
  - Uses BPDUs to communicate

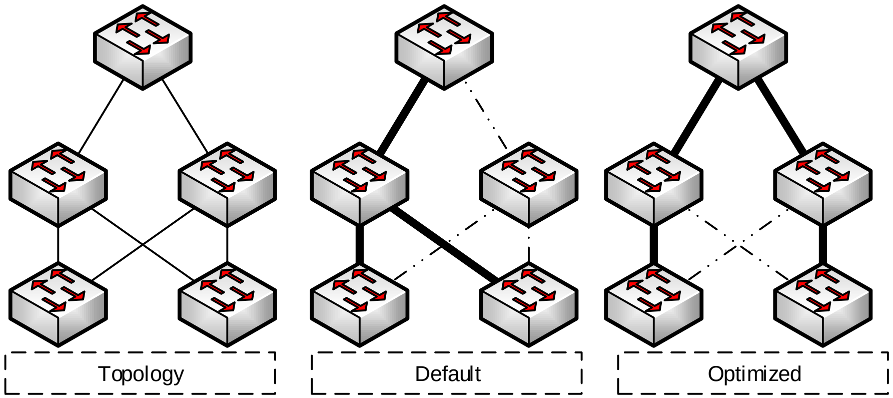
- Parameters affecting the active topology
  - Bridge ID (priority)
  - Port cost, priority

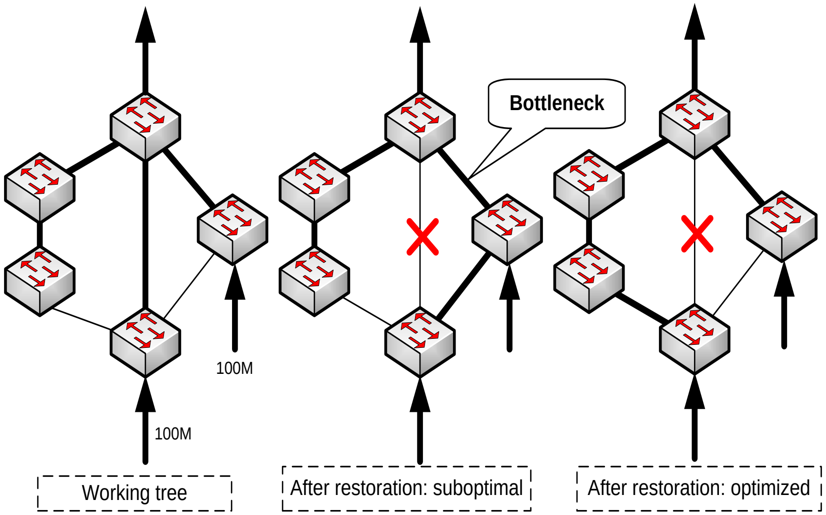


- The resulting topology is unambigously determined

RSTP optimization

- RSTP constructs the loop-free forwarding topology based on link cost and bridge ID
  - May not be optimal
- In case of failure
  - With default cost set we don’t have bandwidth guarantees
    - – The restored topology may also be suboptimal
  - With optimization we give bandwidth bounds even after restoration (if possible)





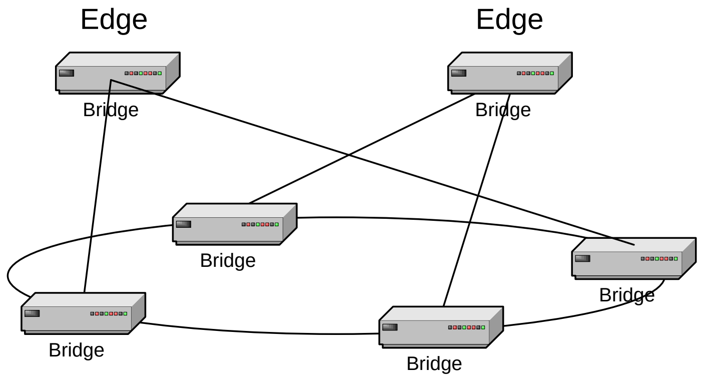
MSTP

- RSTP disadvantage: bad resource utilization
- Cisco: PVST (Per-VLAN Spanning tree)
  - Each VLAN: an RSTP
  - Many VLANs – not scalable, unnecessary
- IEEE: MSTP
  - Multiple spanning trees
  - VLANs assigned to trees

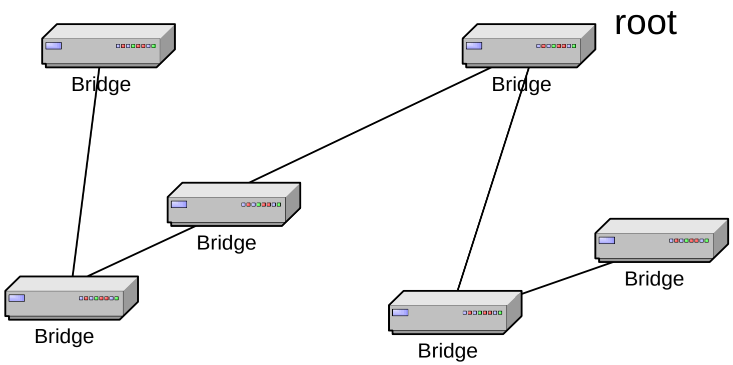
MSTP operation

- RSTP based, technology upgrade
- Max. 64 tree(MST instance)
- For each tree we can set
  - root
  - Link cost/priority
  - VLAN assignment
- 1 VLAN to 1 tree only!

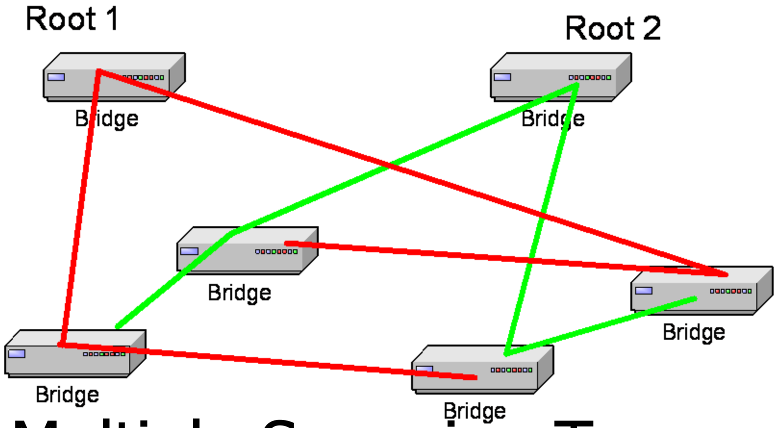
MSTP Advantages



- Network Topology: 2 exits
- Ring - redundancy
  - Higher reliability



- STP: one tree

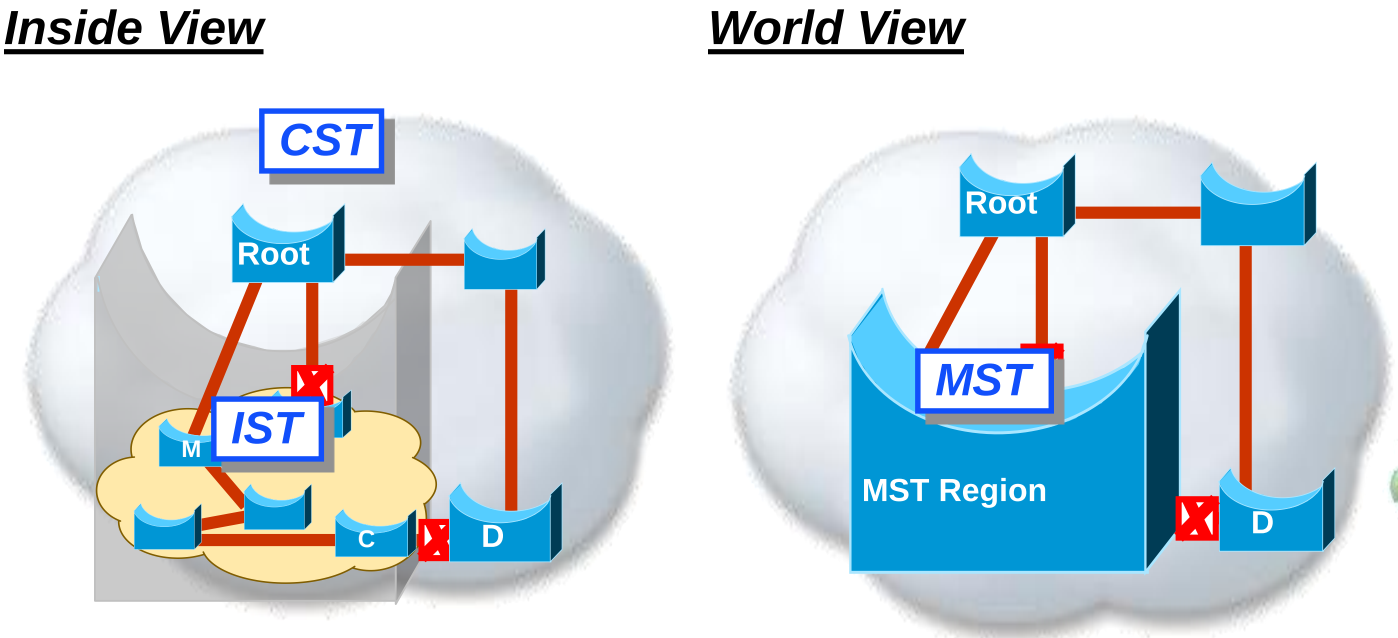


- Multiple Spanning Tree
  - 2 trees

Evolution to multiple trees & regions

- Why regions?
  - Different administrative control over different parts of the L2 network
  - Not all switches in the network might run/support MST - different kinds of STP divide network into STP regions
  - All benefits of MST are available INSIDE the region, outside it is single instance (topology) for all VLANs
- MST region is a linked group of MST switches with same MST configuration
  - Inside region: many instances
    - IST – Internal Spanning Tree (instance 0), always exists on ALL ports
    - MSTI - Multiple Spanning Tree Instance
  - Outside of region: one instance

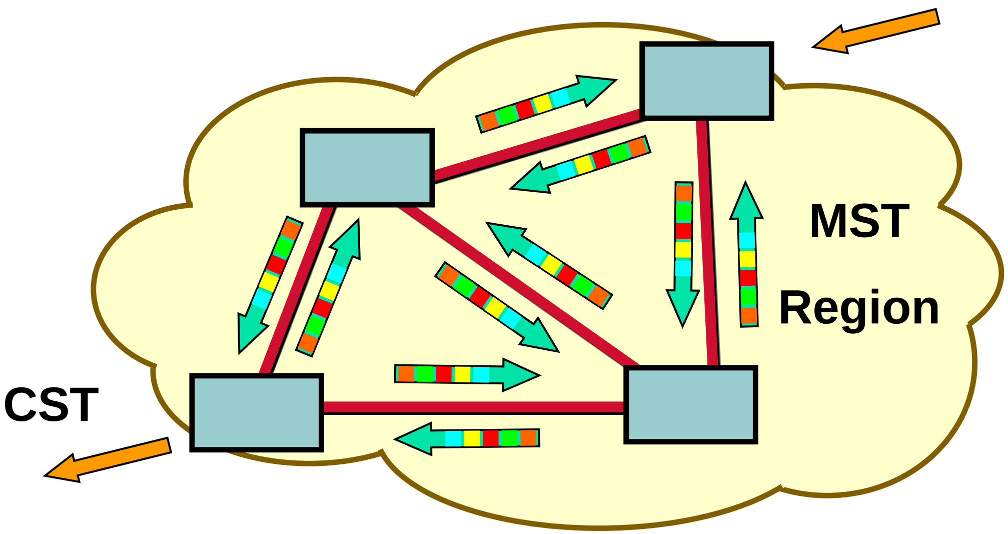
802.1s: CST, IST, MST - Lots of Trees ...



- **CST 802.1Q Common SPT** => Single Instance only
- **IST 802.1s Internal SPT** => receives and sends BPDUs to the CST represents the MST to the Outside World as CST Bridge
- **MST 802.1s Multiple SPT** => represent several VLANs mapped to a single MST Instance

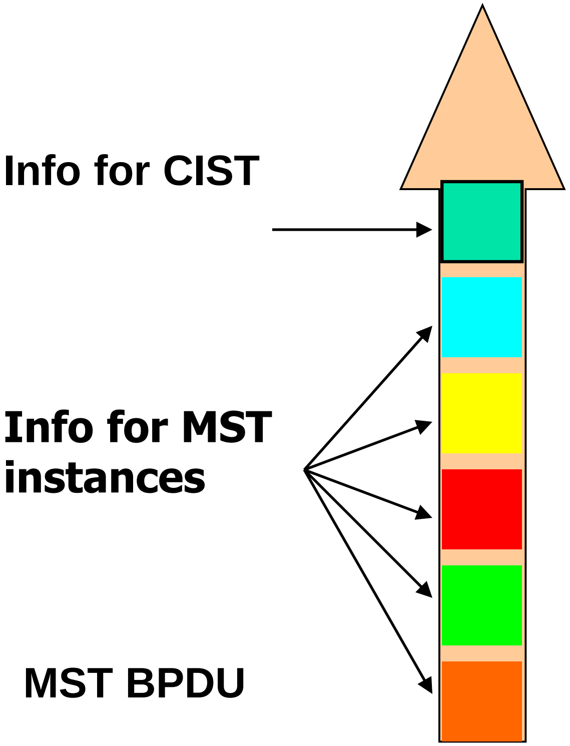
MST instances

- MSTIs are STP instances, defined only in a region
- MSTIs are not connected to the outer world
- One BPDU is sent with info for all trees
- Only one has timer related parameters (IST instance)
- The MST BPDUs are sent on all ports
- BPDUs are sent in all directons unlike in 802.1D where designated bridge sends only



MST Region

CST



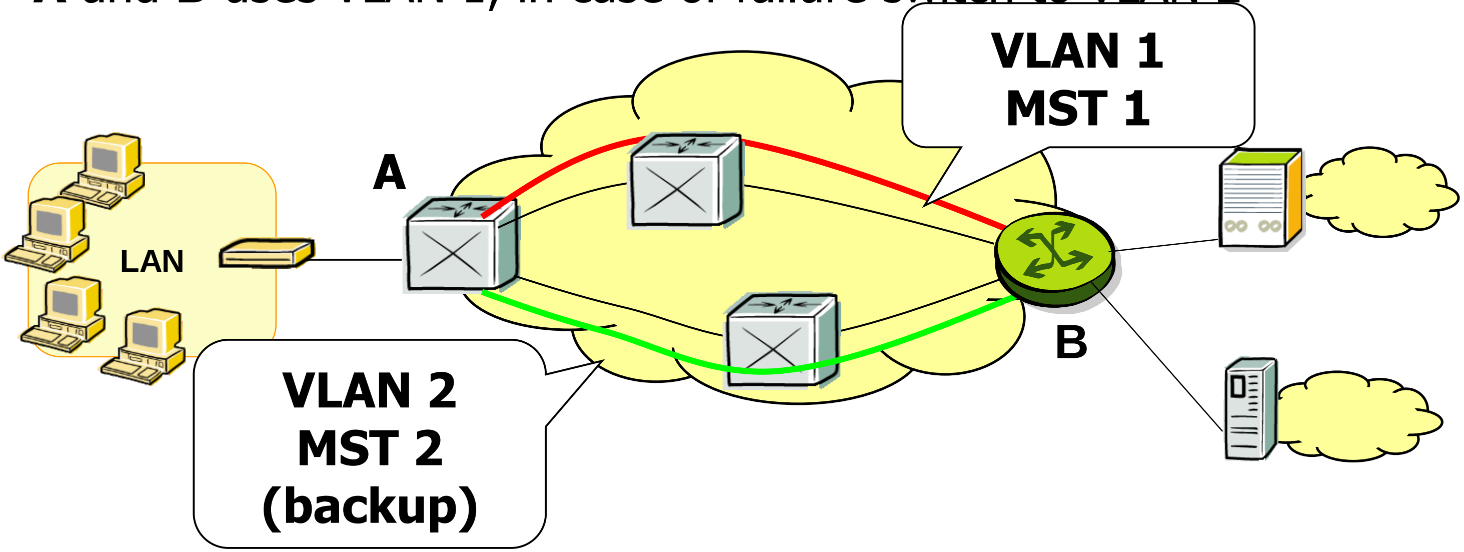
Info for CIST

Info for MST instances

MST BPDU

Protection switching

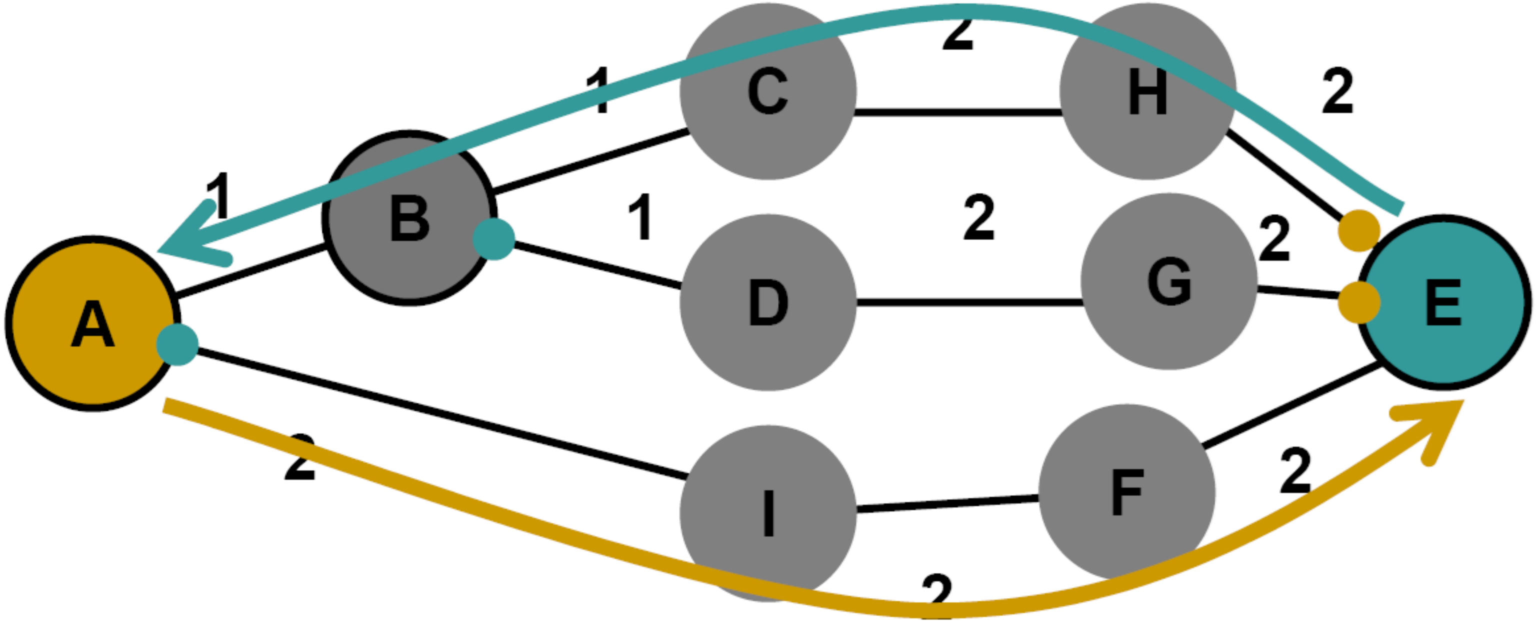
- Using MSTP
  - 2 MSTI trees, two paths: red and green
  - VLAN 1 -> MST 1, VLAN 2 -> MST 2
  - **A** and **B** uses VLAN 1, in case of failure switch to VLAN 2



- **Alternatives: 802.3ad Link Aggregation**
  - **uses redundant links for load balancing and protection**

Shortest Path Bridging

- IEEE 802.1aq
- Multiple trees rooted at each bridge
  - Each using shortest path
- Problem
  - MAC learning requires symmetrical paths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