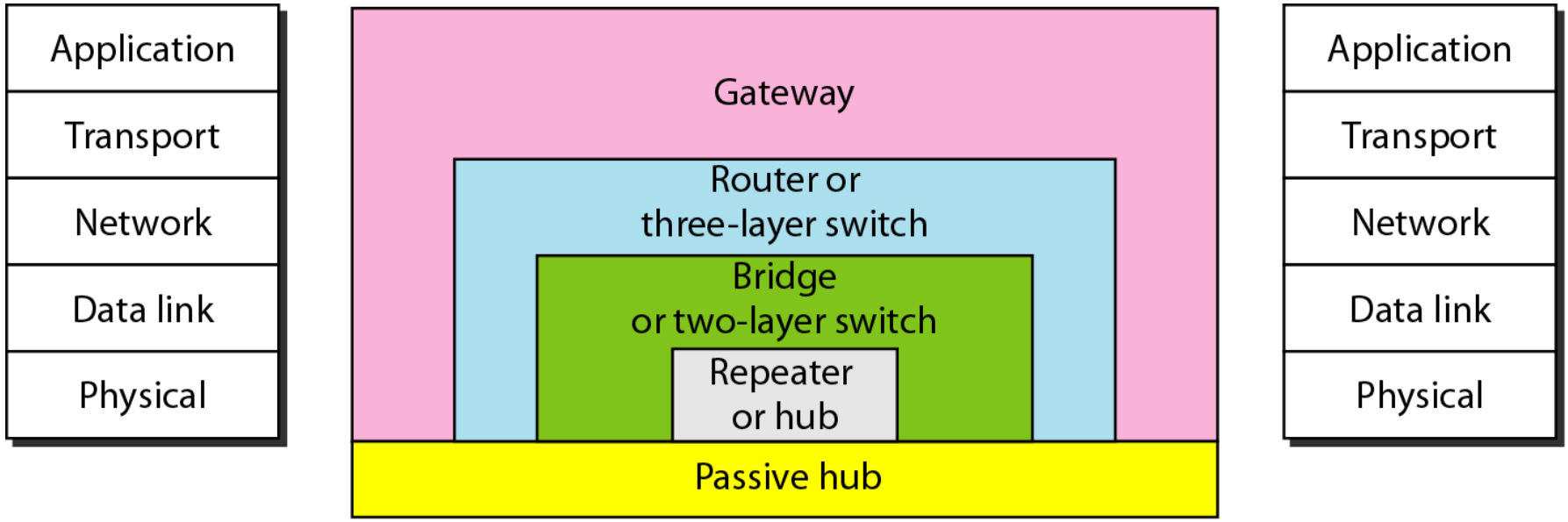
Connecting LANs, Backbone Networks, and Virtual LANs

Connecting Devices

- ***In computer network, we divide connecting devices into five different categories based on the layer in which they operate in a network.***
- ***These are :***
    - **Hubs (active or passive)**
    - **Bridges**
    - **Two-Layer or Three layer Switches**
    - **Routers**
    - **Gateways**

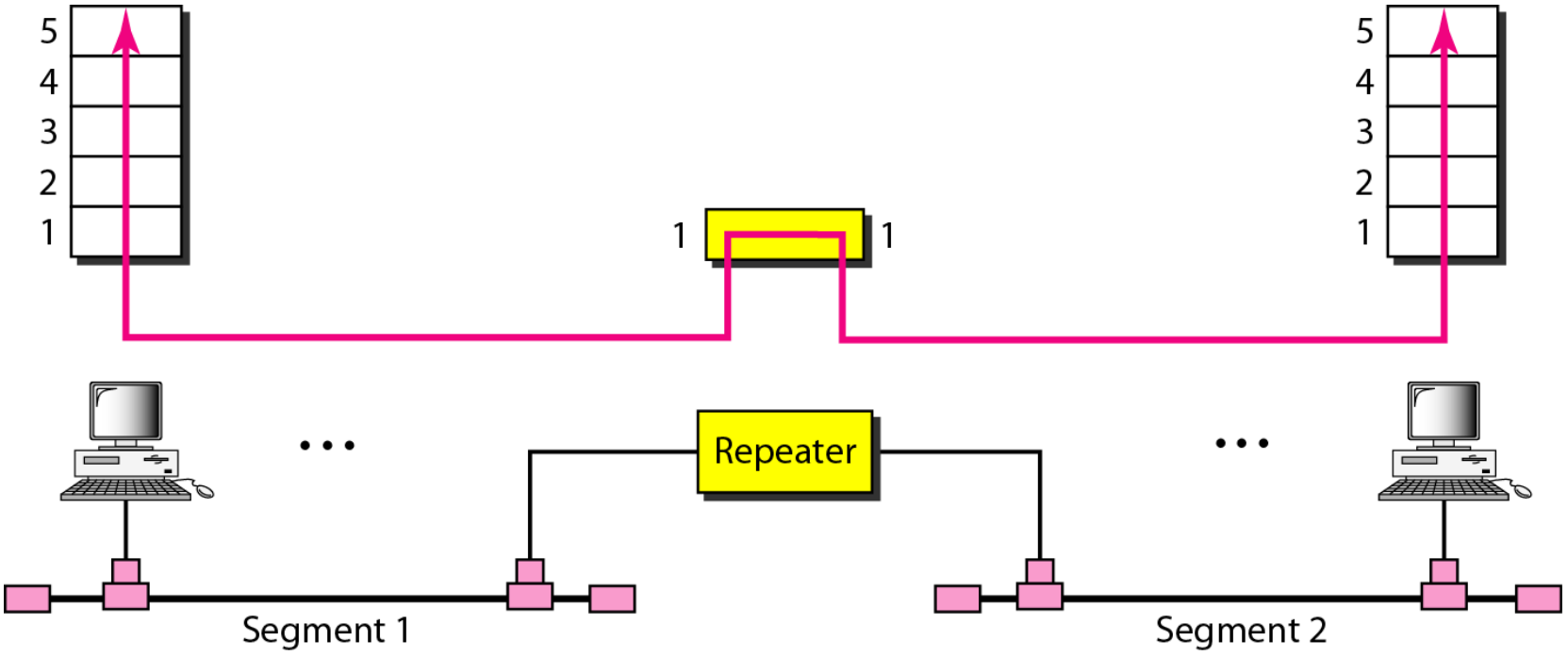
Five categories of connecting devices



Hubs

- This device operates only in the physical layer.
- Signals carry information can travel a fixed distance before attenuation endangers the integrity of the data
- **Repeater:** Receives a signal and, before it becomes too weak or corrupted, ***regenerates and retimes*** the original bit patterns.
  - The repeater the send the refreshed signal
- Nowadays, Ethernet LANs use star topology
  - *Connecting device through which all the devices are connected is called hub.*
  - *This* ***hub*** is a repeater and a multiport device

A repeater connecting two segments of a LAN



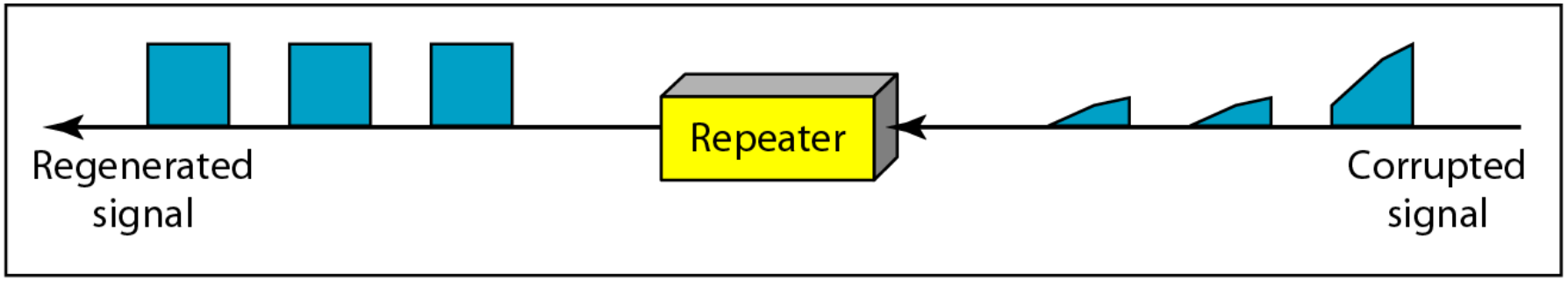
Note

A repeater forwards every frame; it has no filtering capability.

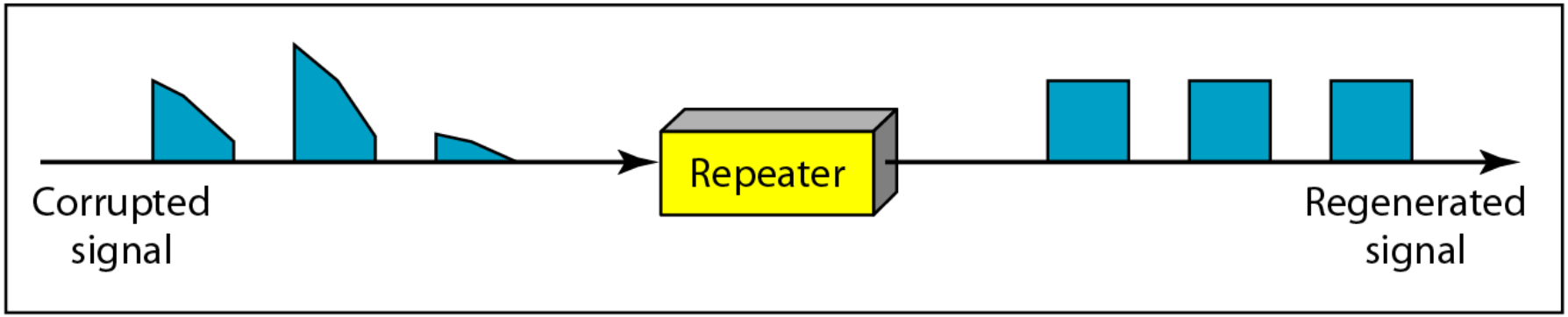
Note

A repeater is a regenerator, not an amplifier.

Function of a repeater

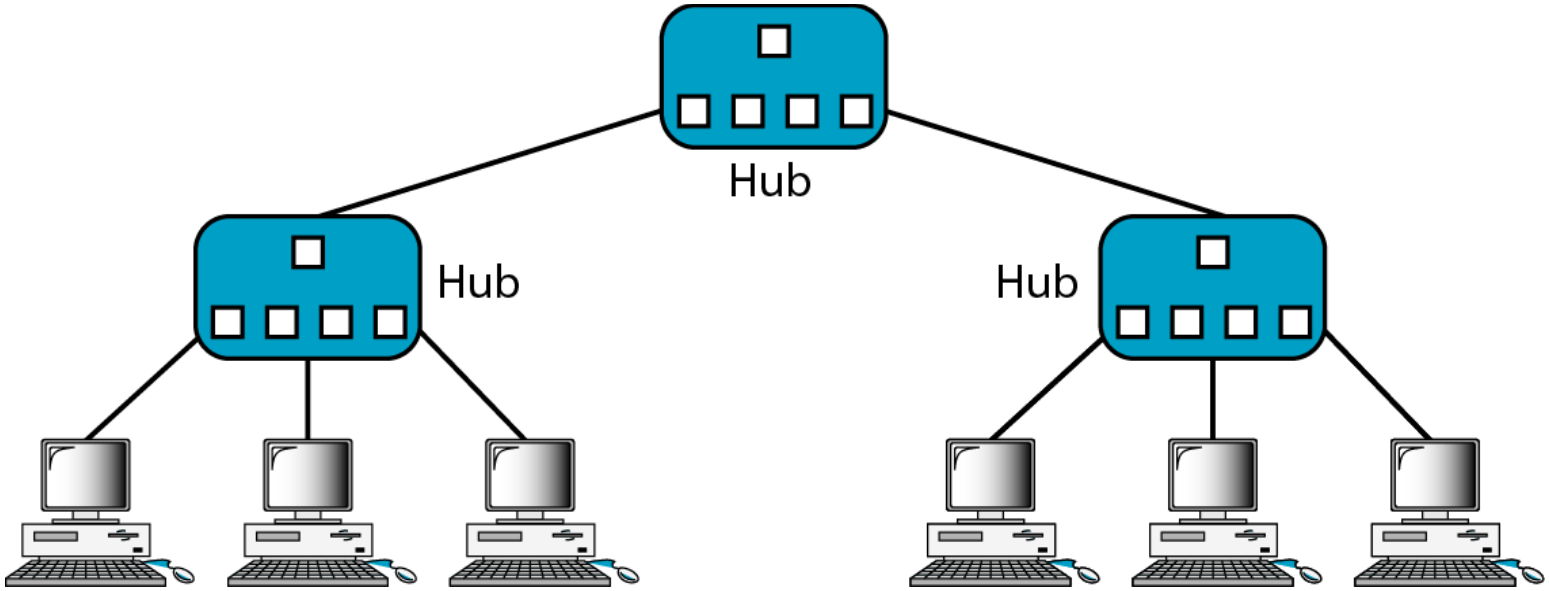


a. Right-to-left transmission.



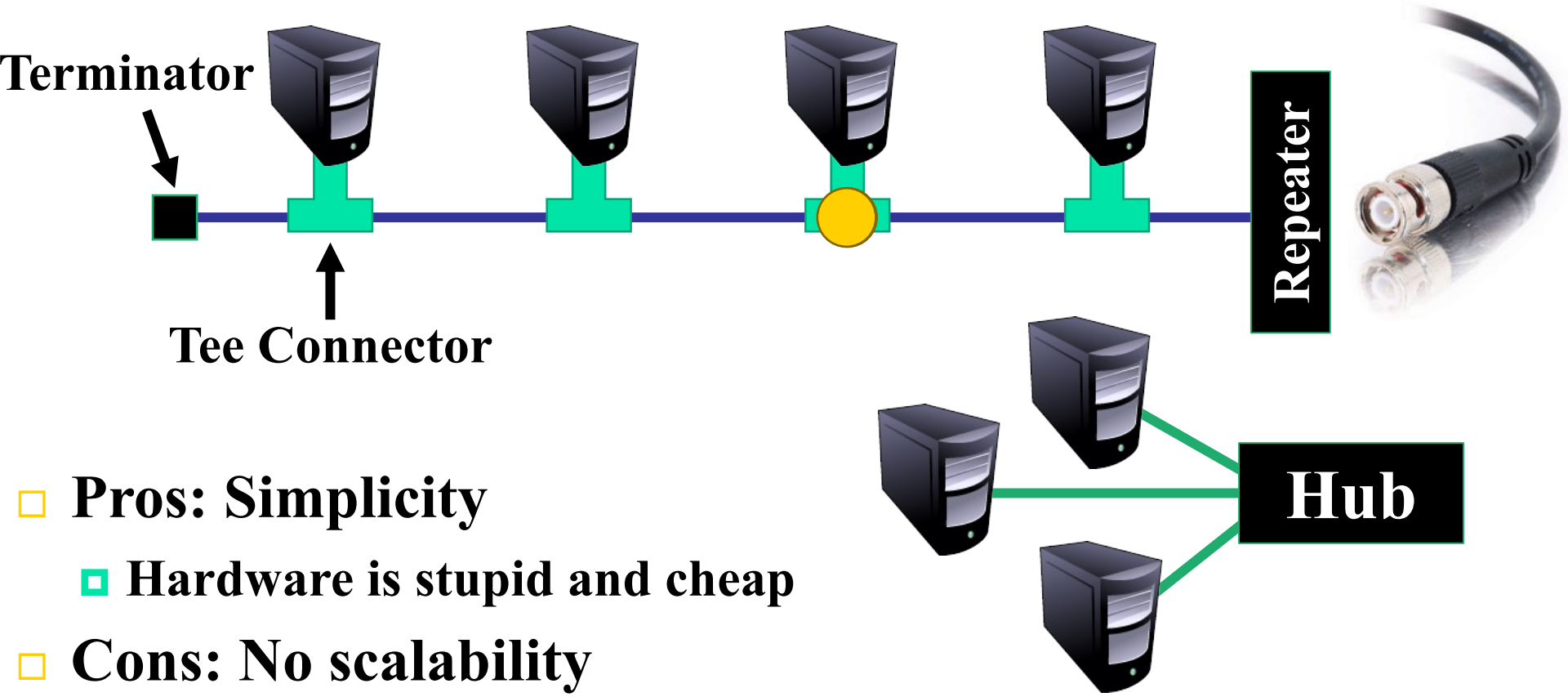
b. Left-to-right transmission.

A hierarchy of hubs



Recap

- Originally, Ethernet was a broadcast technology



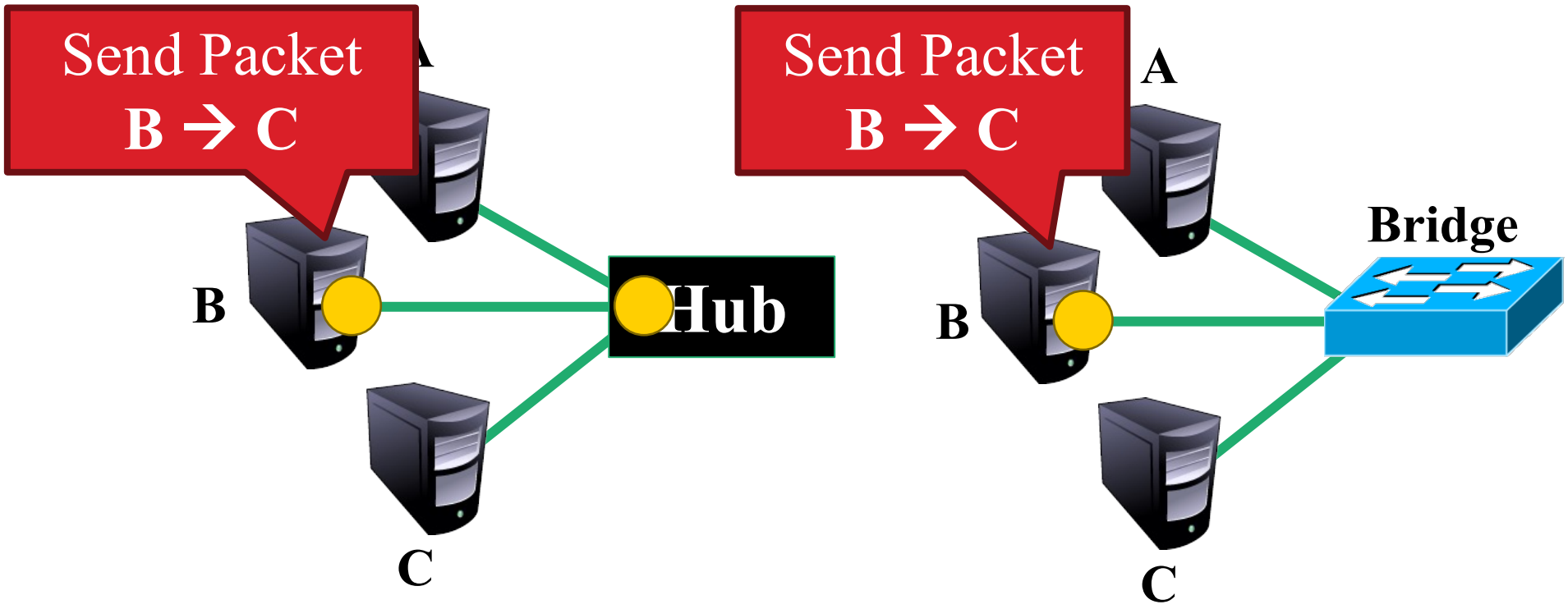
- **Pros: Simplicity**
  - **Hardware is stupid and cheap**
- **Cons: No scalability**
  - **More hosts = more collisions = pandemonium**

Bridge

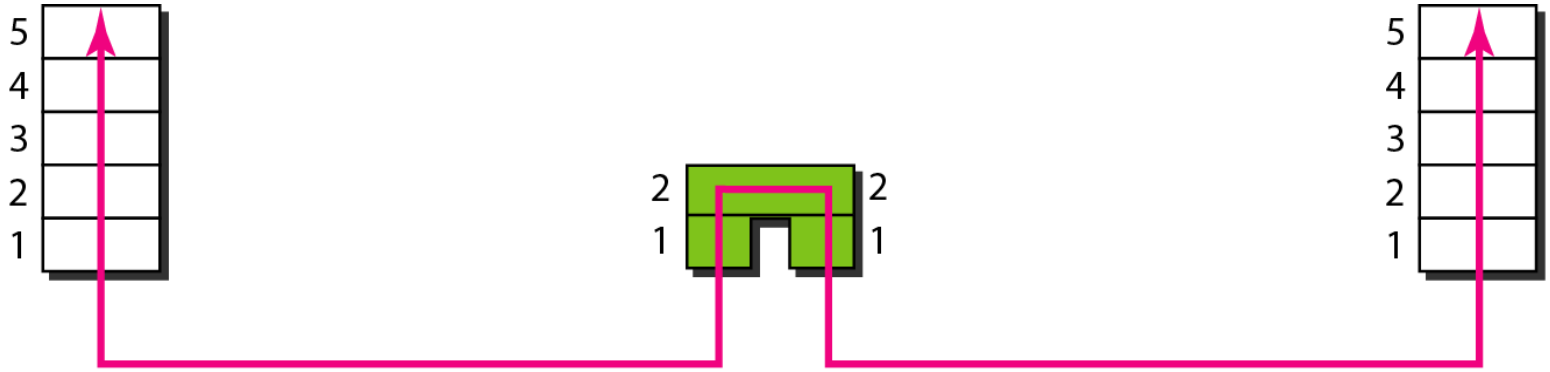
- A bridge operates at data link layer.
- A bridge is a repeater, with *add on functionality of filtering content* by reading the *MAC addresses of source and destination.*
- It is also used for *interconnecting two LANs* working on the same protocol.
- It has a single input and single output port, thus making it a 2 port device.

The Case for Bridging

- Need a device that can ***bridge*** different LANs
  - Only forward packets to intended recipients
  - No broadcast!

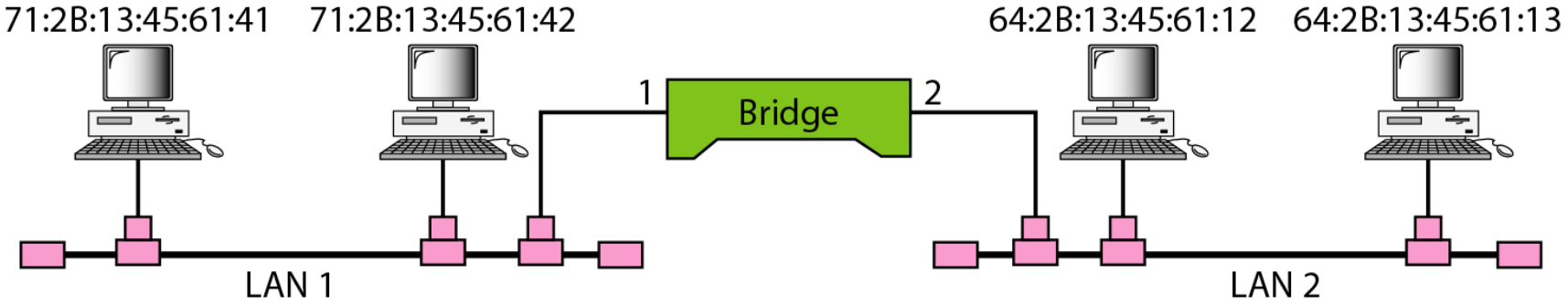


A bridge connecting two LANs

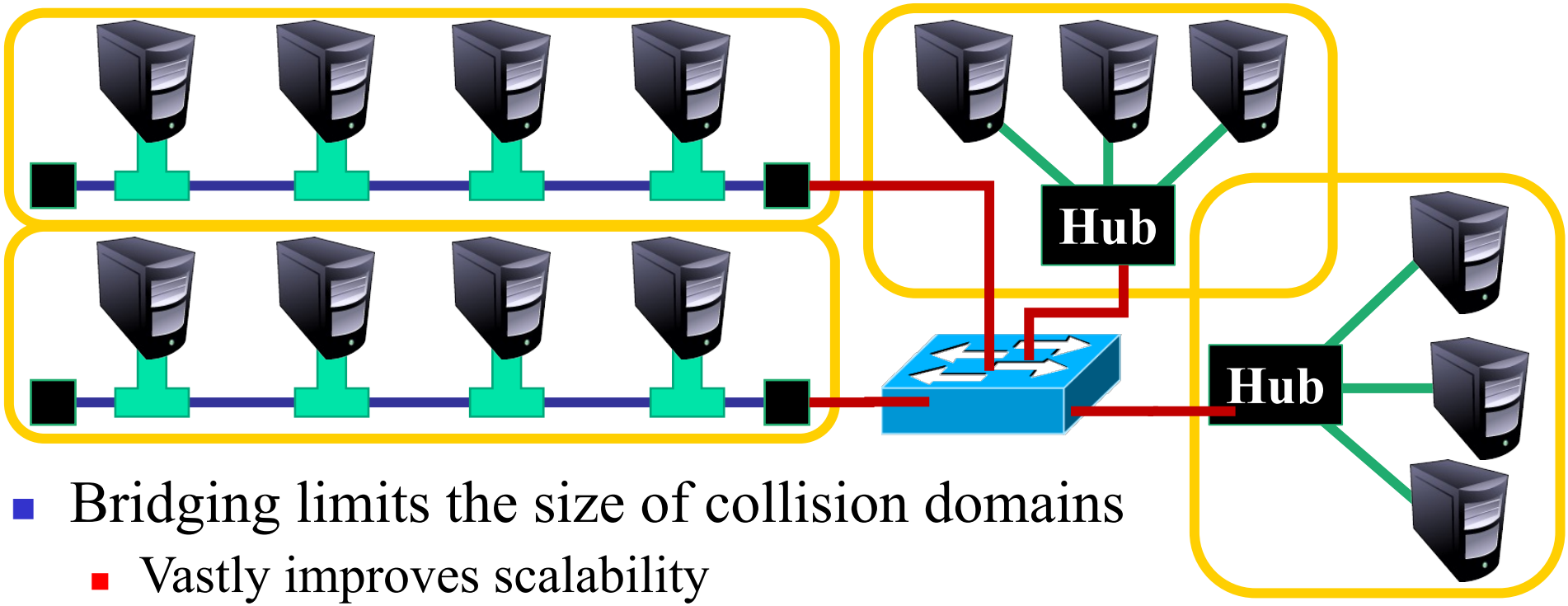


Address	Port
71:2B:13:45:61:41	1
71:2B:13:45:61:42	1
64:2B:13:45:61:12	2
64:2B:13:45:61:13	2

Bridge Table

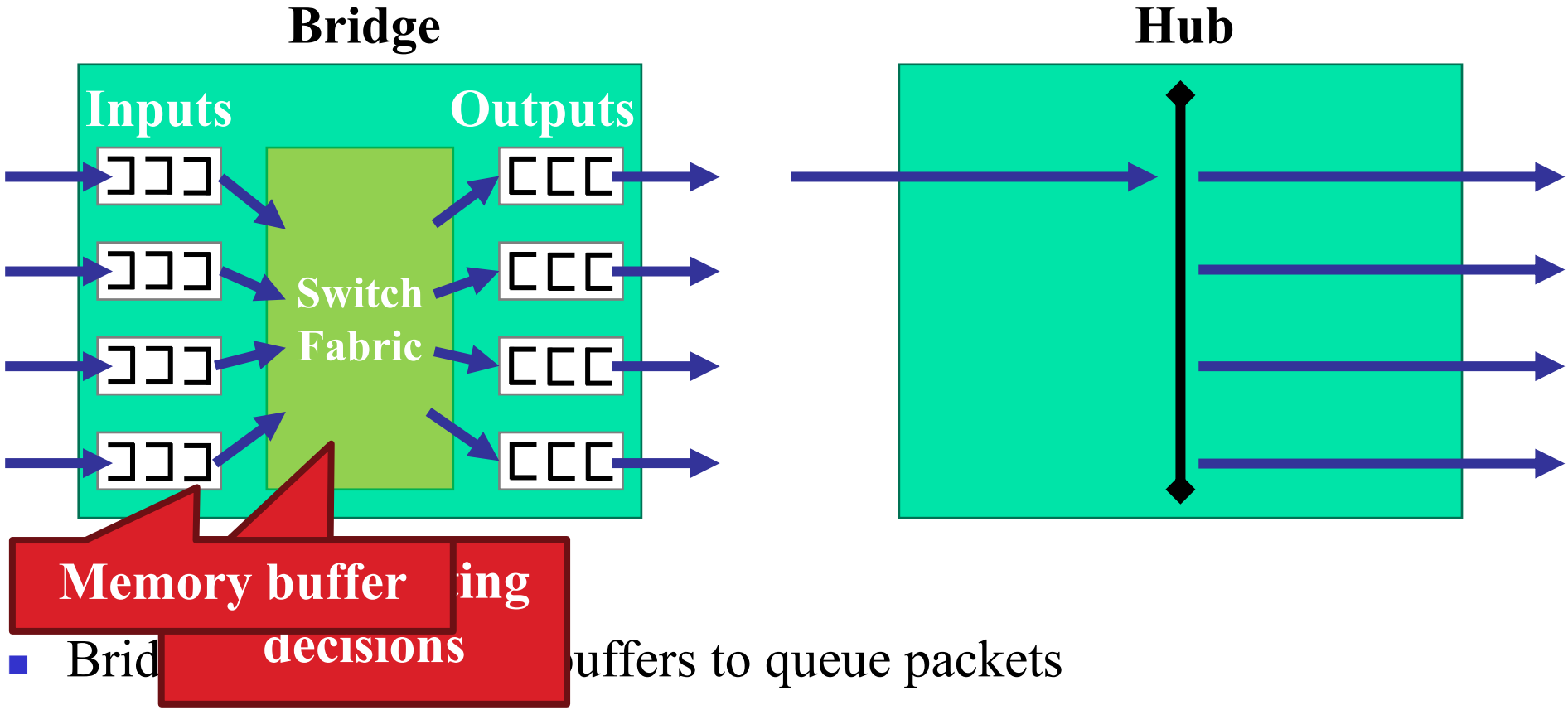


Bridging the LANs



- Bridging limits the size of collision domains
  - Vastly improves scalability
  - Question: could the whole Internet be one bridging domain?
- Tradeoff: bridges are more complex than hubs
  - Physical layer device vs. data link layer device
  - Need memory buffers, packet processing hardware, routing tables

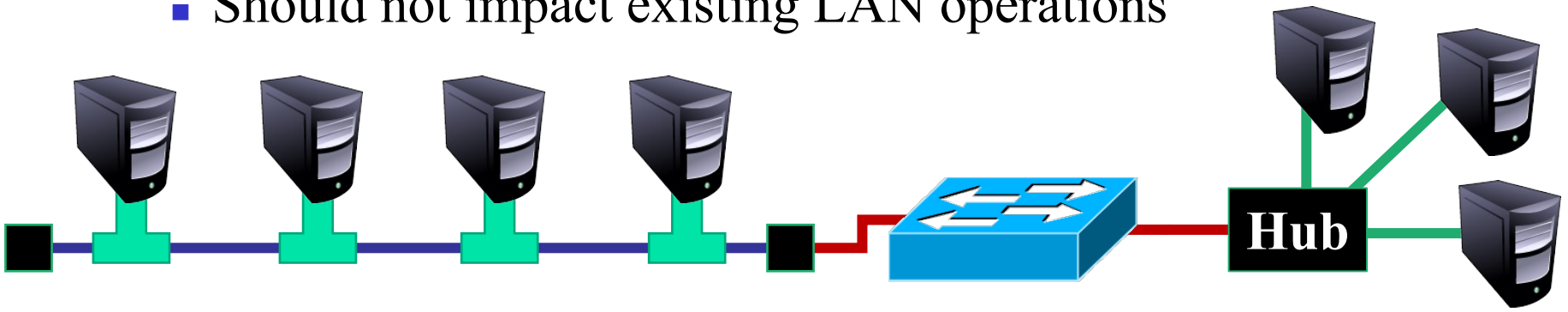
Bridge Internals



- Brid uffers to queue packets
- Bridge is intelligent, only forwards packets to the correct output
- Bridges are high performance, full N x line rate is possible

Bridges

- Original form of Ethernet switch
- Connect multiple IEEE 802 LANs at layer 2
- Three basic functions:
  1. **Forwarding of frames**
  2. **Learning of (MAC) Addresses**
  3. **Spanning Tree Algorithm (to handle loops)**
- Goals:
  - No hardware of software changes on hosts/hubs
  - Should not impact existing LAN operations

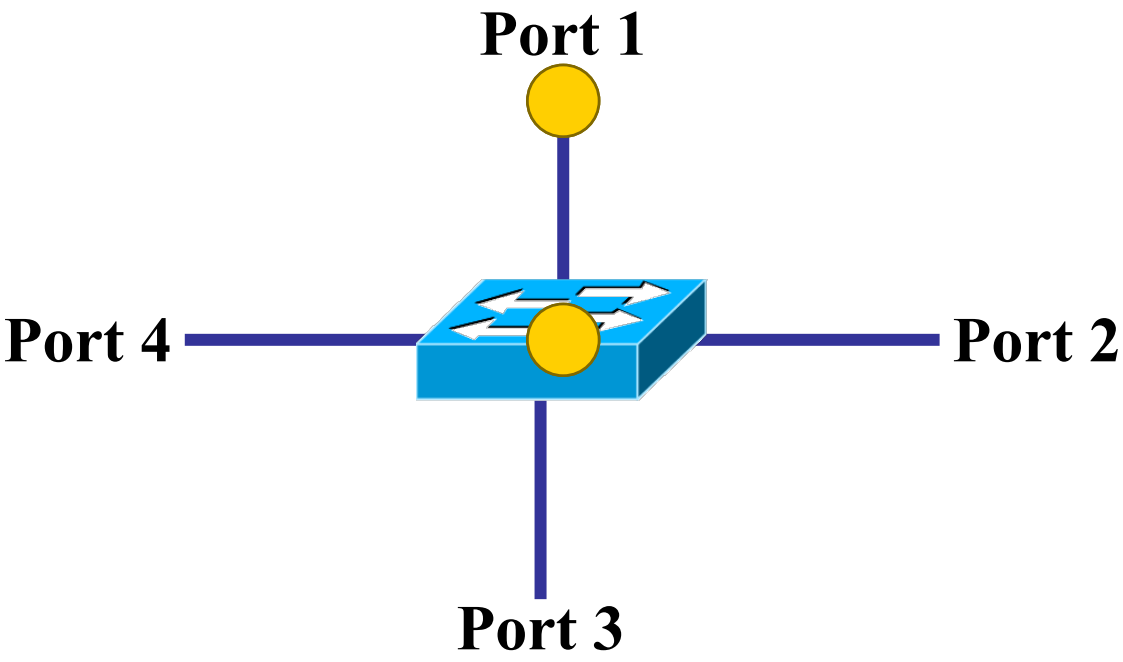


Frame Forwarding Tables

- Each bridge maintains a ***forwarding table***

MAC Address	Port	Age
00:00:00:00:00:AA	1	1 minute
00:00:00:00:00:BB	2	7 minutes
00:00:00:00:00:CC	3	2 seconds
00:00:00:00:00:DD	1	3 minutes

Frame Forwarding in Action



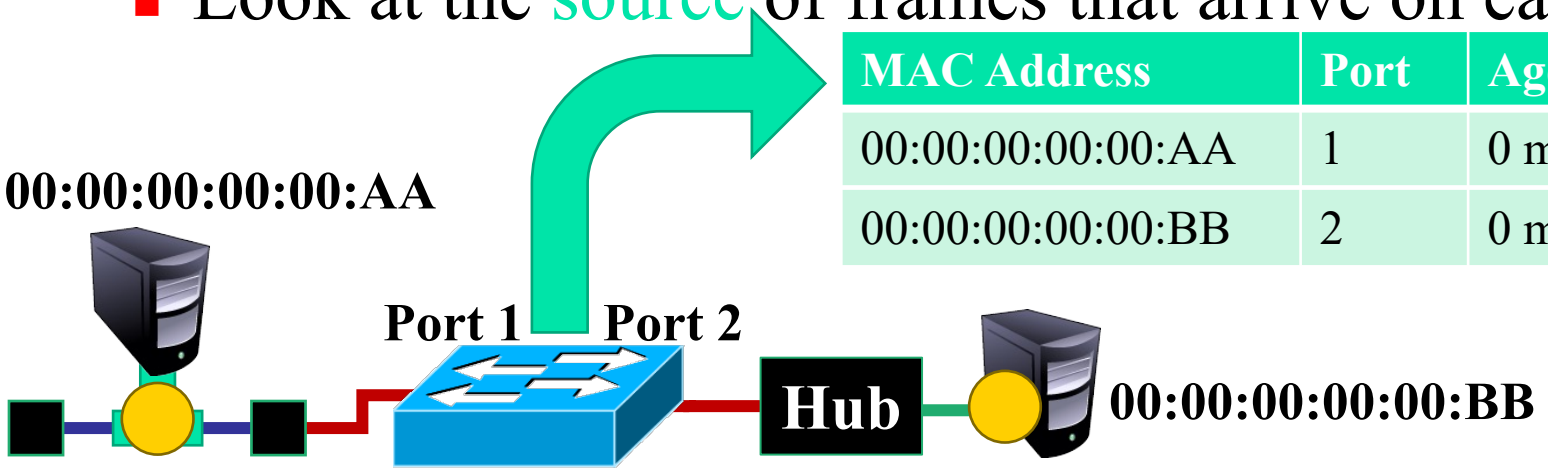
- Assume a frame arrives on port 1
- If the destination MAC address is in the forwarding table, send the frame on the correct output port
- If the destination MAC isn't in the forwarding table, broadcast the frame on all ports except 1

Learning Addresses

- Manual configuration is possible, but…
  - Time consuming
  - Error Prone
  - Not adaptable (hosts may get adde
- Instead, learn addresses using a s
  - Look at the source of frames that arrive on each rt

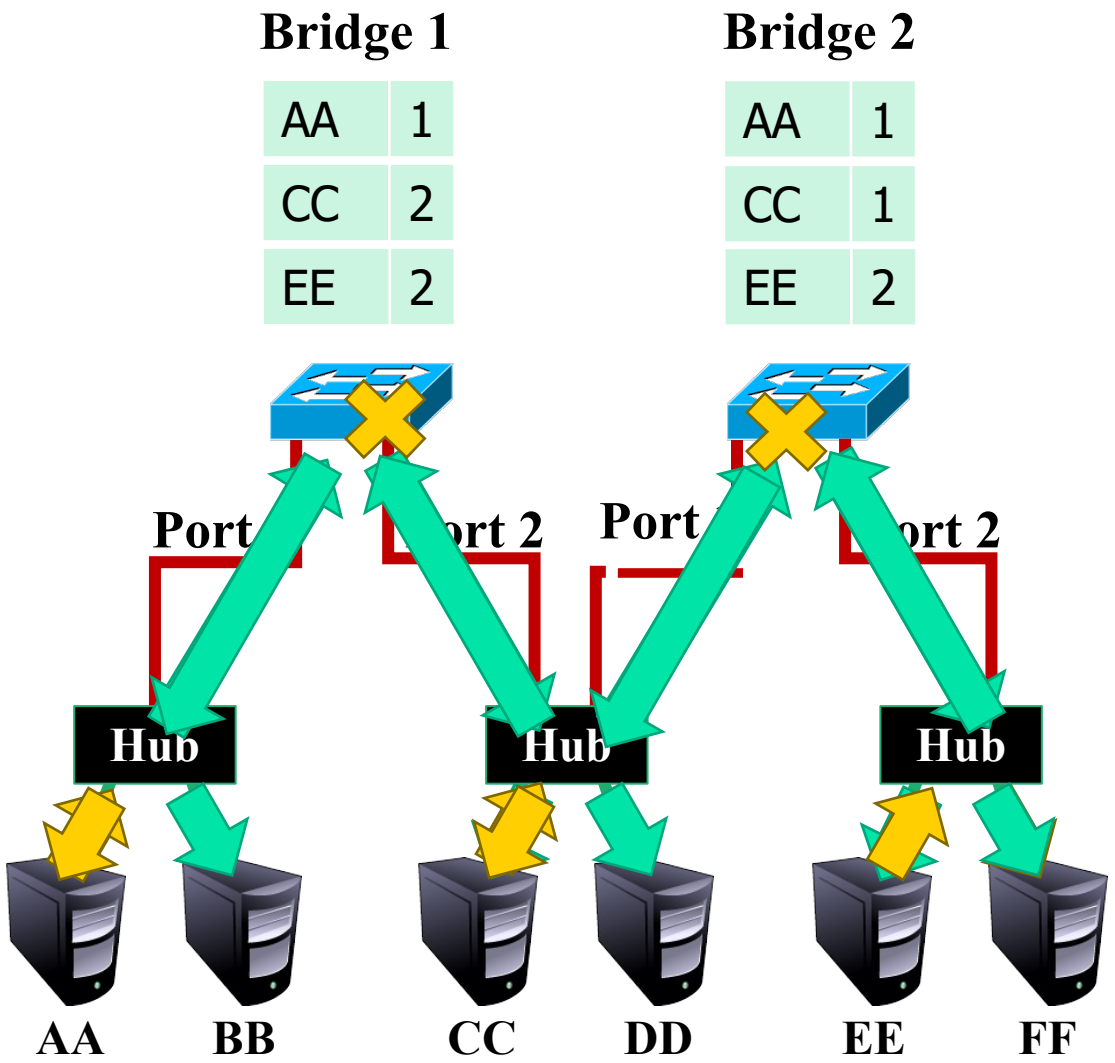
Delete old entries after a timeout

MAC Address	Port	Age
00:00:00:00:00:AA	1	0 minutes
00:00:00:00:00:BB	2	0 minutes



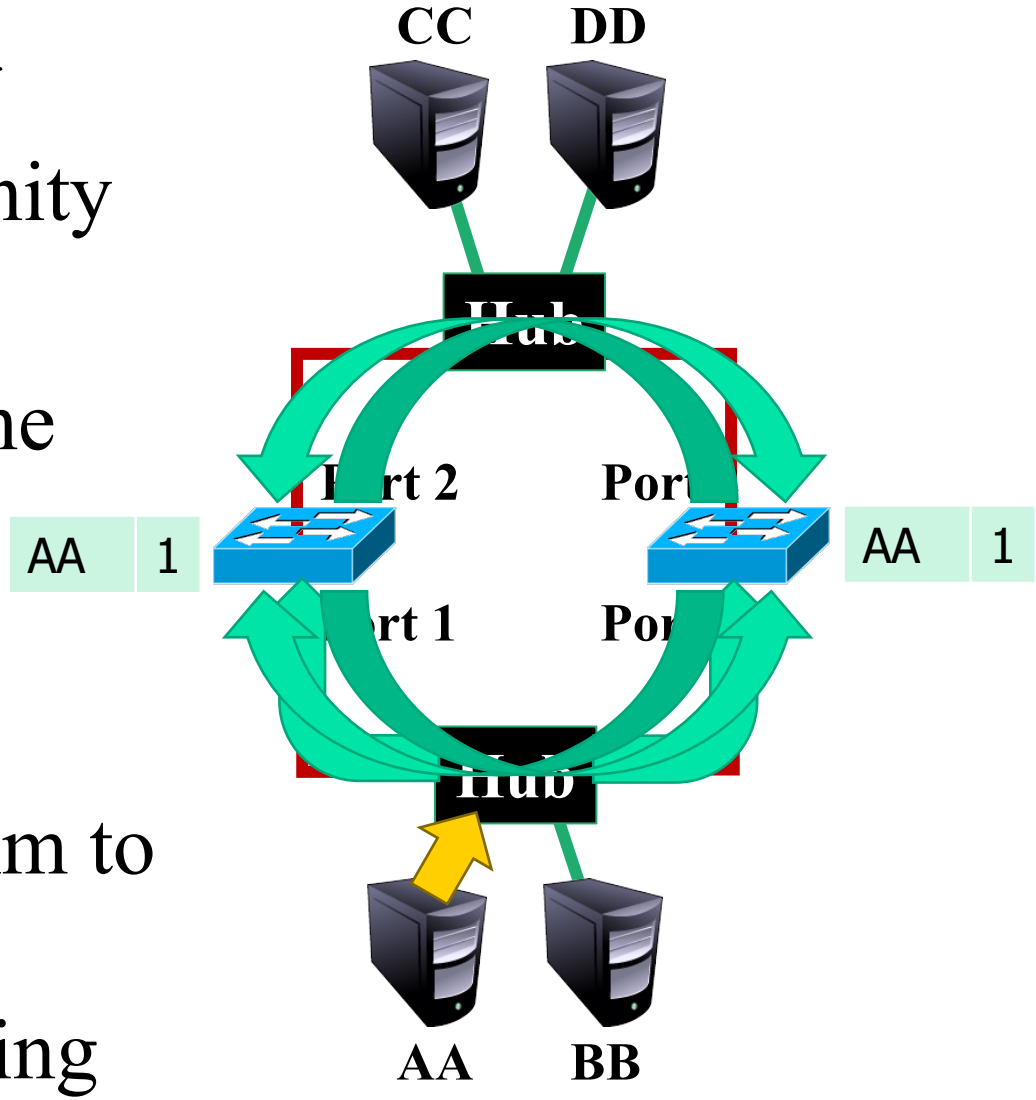
Complicated Learning Example

- <Src=AA, Dest=FF>
- <Src=CC, Dest=AA>
- <Src=EE, Dest=CC>



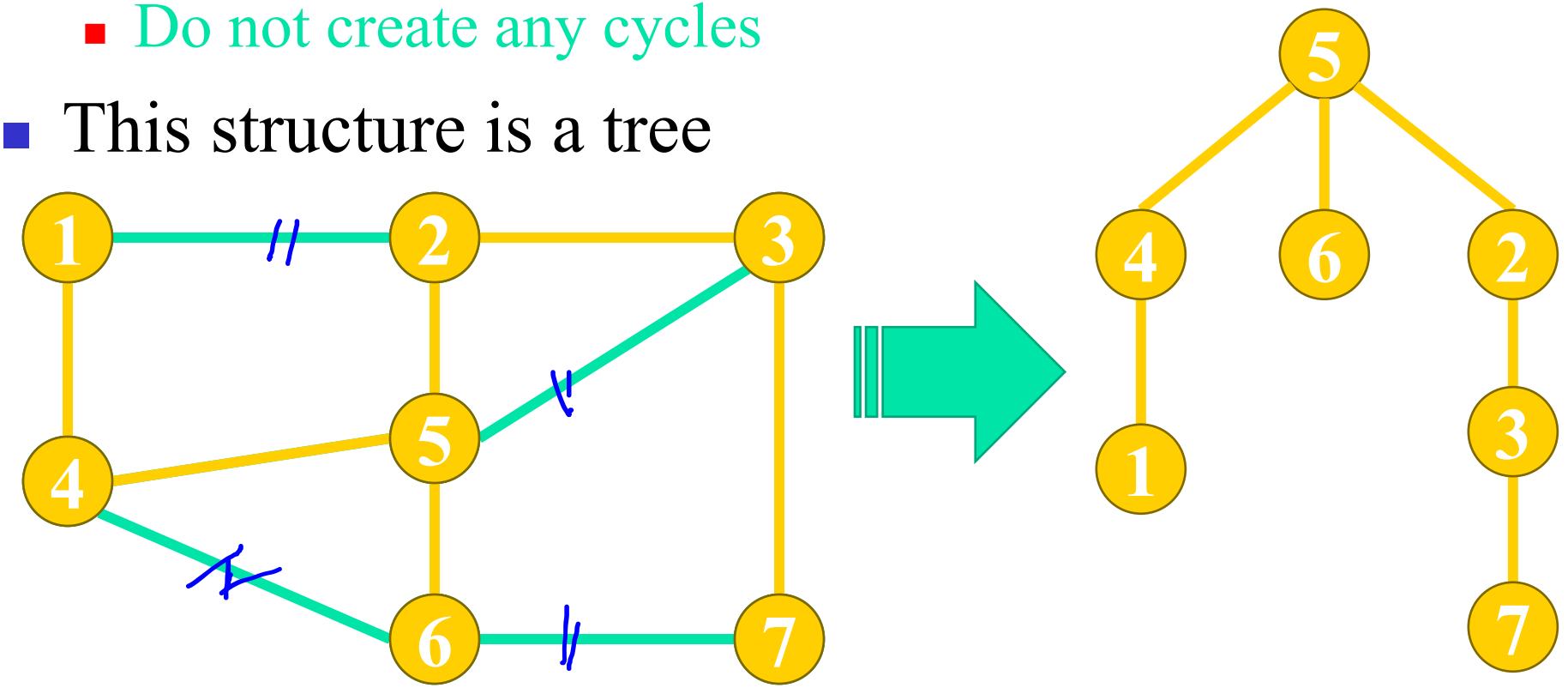
The Danger of Loops

- <Src=AA, Dest=DD>
- This continues to infinity
  - How do we stop this?
- Remove loops from the topology
  - Without physically unplugging cables
- 802.1 uses an algorithm to build and maintain a spanning tree for routing



Spanning Tree Definition

- A subset of edges in a graph that:
  - Span all nodes
  - Do not create any cycles
- This structure is a tree



Definitions

- Bridge ID (BID) = <Random Number>
- Root Bridge: bridge with the lowest BID in the tree
- Root Path Cost: cost (in hops) from a port of a transmitting bridge to the root
- Port ID: Each port on a bridge has a unique Port ID
- Root Port: The port having the least root path cost is called root port. This port forwards to the root on each bridge
- Designated Bridge:
  - Among several bridges connected to LAN, one of the bridges is the designated bridge for forwarding the data from that LAN
  - The bridge on a LAN that provides the minimal cost path to the root is considered as a designated bridge.
  - The designated bridge on each LAN is unique
  - If more than one bridges have the same root path cost, the bridge with lower identifier is chosen as the designated bridge.
- Designated port: The port of the designate bridge that connects to the LAN

Bridge Protocol Data Unit (BPDU)

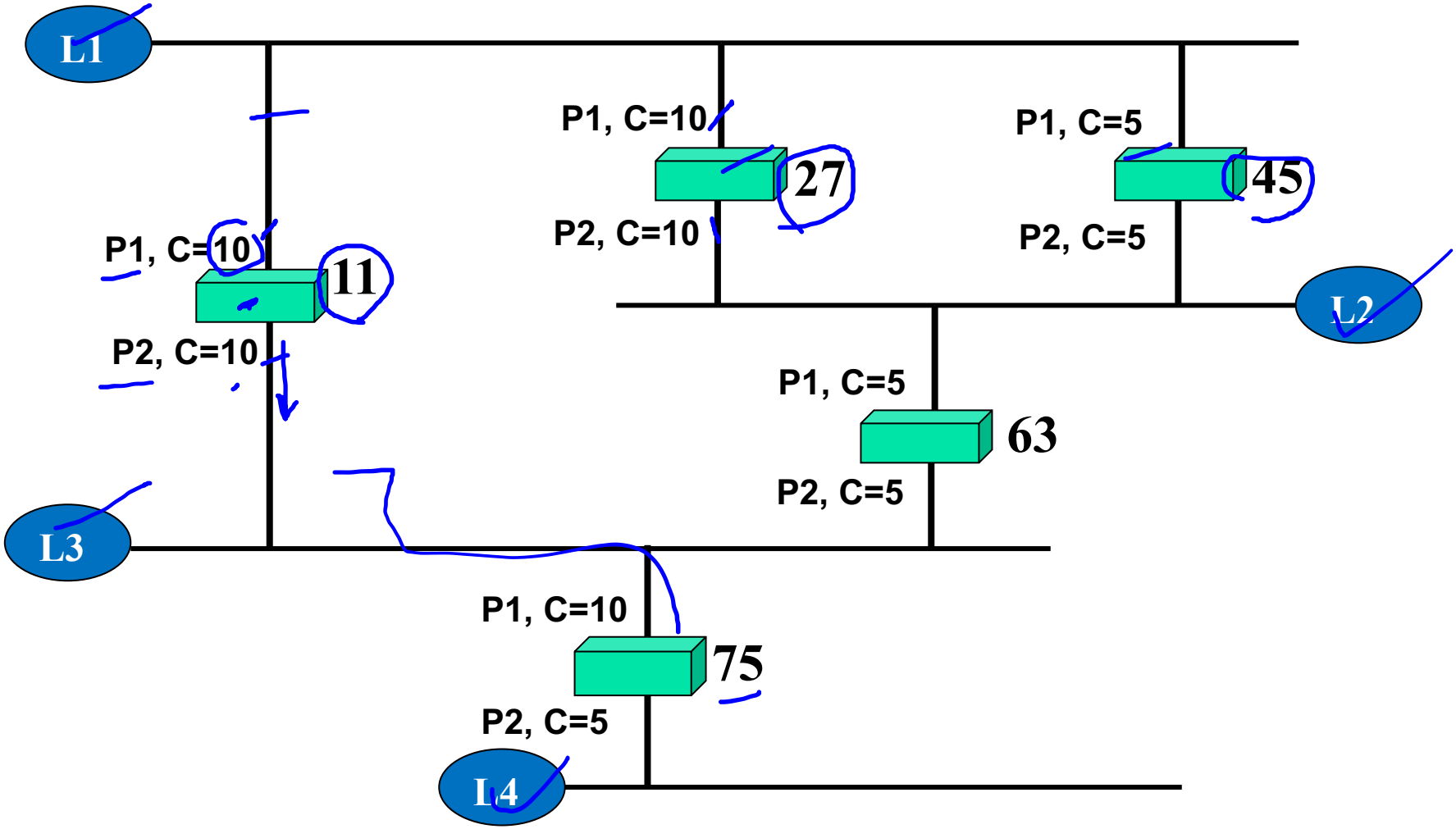
- A configuration BPDU generated by a bridge contains:
  - Bridge identifier (B-ID)
  - Root Identifier (R-ID)
  - Root Path cost(RPC)
  - Port Identifier(P-ID)
  - Other information

802.1 Spanning Tree Approach

1. Elect a bridge to be the root of the tree
2. Every bridge finds shortest path to the root
3. Union of these paths becomes the spanning tree

- Bridges exchange Configuration Bridge Protocol Data Units (BPDUs) to build the tree
  - Identification of the root bridge
  - Identification of the root ports
  - Selection of the designated bridges and ports for every LAN

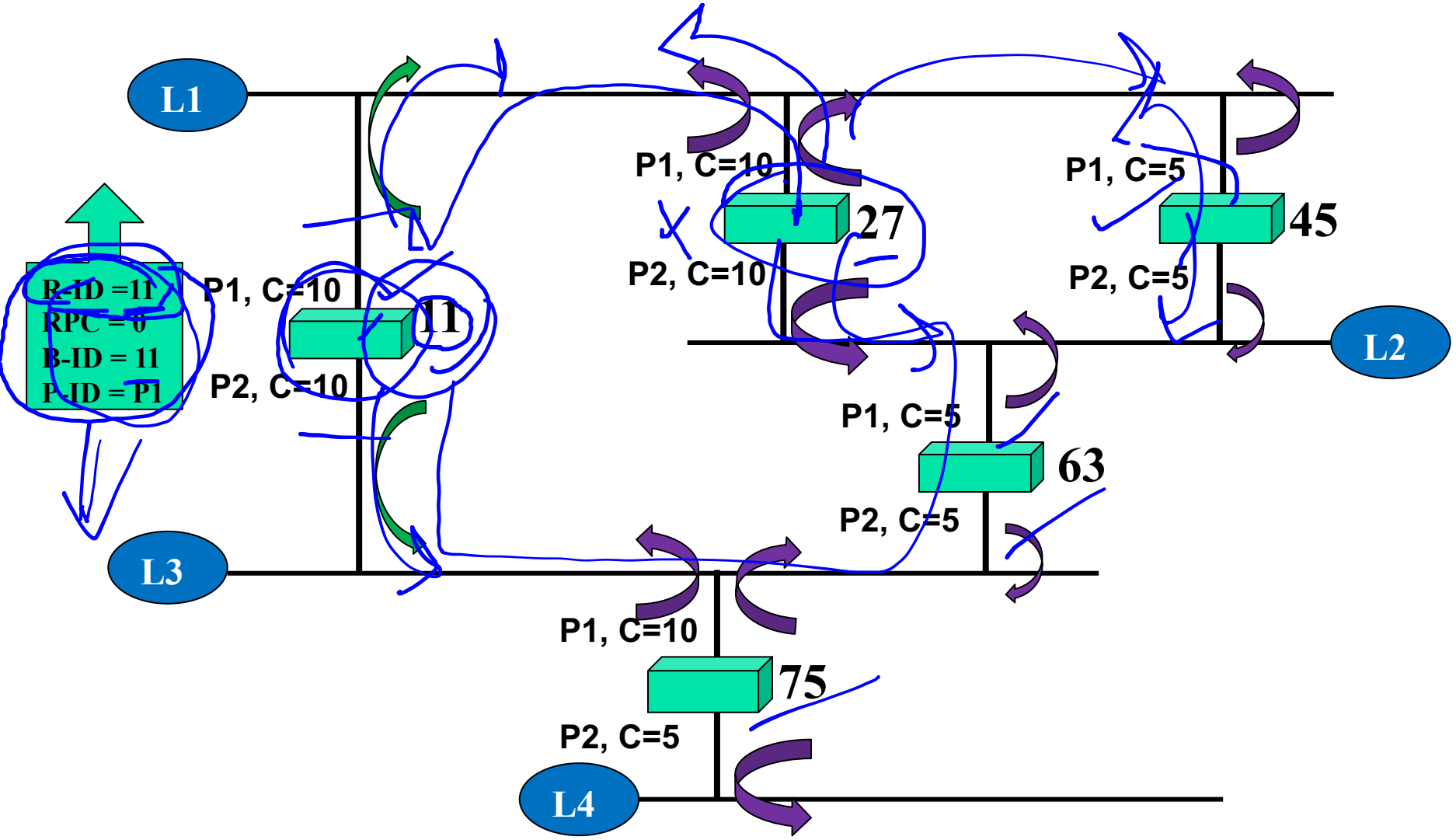
Example : Construction of the spanning tree



Selection of the root bridge

- Each bridge asserts that it is the root bridge by sending a BPDU on all its ports.
- If a bridge receives a configuration BPDU with lower root bridge identity than its own identity
  - It stops sending its BPDUs and
  - Forwards the received BPDU on its other ports with the following changes:
    - Bridge puts its own B-ID
    - Bridge puts own port identity P-ID
    - The root path cost is incremented by the cost of the port through which the BPDU is received
    - The root bridge identity is retained as it is.
- Else
  - It continues to send its own BPDUs

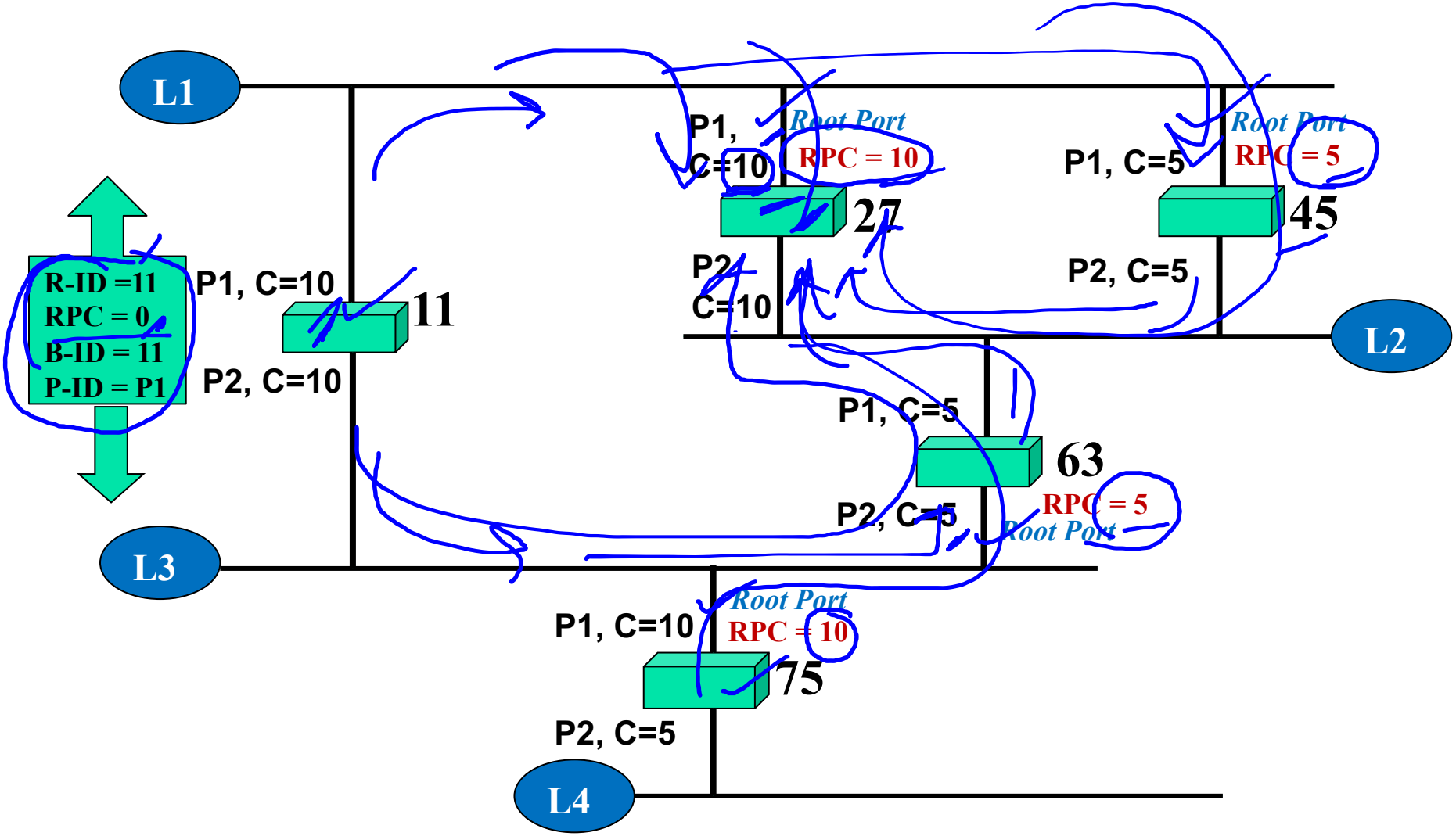
Example


L1
L2
L3
L4
B-ID =11
RPC = 0
B-ID = 11
P-ID = P1
P1, C=10
11
P2, C=10
P1, C=10
27
P2, C=10
P1, C=5
45
P2, C=5
P1, C=5
63
P2, C=5
P1, C=10
75
P2, C=5

Identification of the root ports

- Every bridge other than the root bridge determines its root port.
  - This port is with the lowest root path cost
- **Steps to find:**
  - The BPDUs generated by the root bridge are forwarded by all other bridges on their port by necessary changes (*B-ID, P-Id, RPC*)
    - The *root path cost is incremented by the cost of the port through which BPDU is received.*
  - Each bridge determines which of its port has the lowest root path cost and that port is selected as the root port.
    - If there is a tie, the port with with a lower port-ID is selected as root port.
  - The root ports are put in the forwarding mode
  - Other than root ports are put in blocked mode.

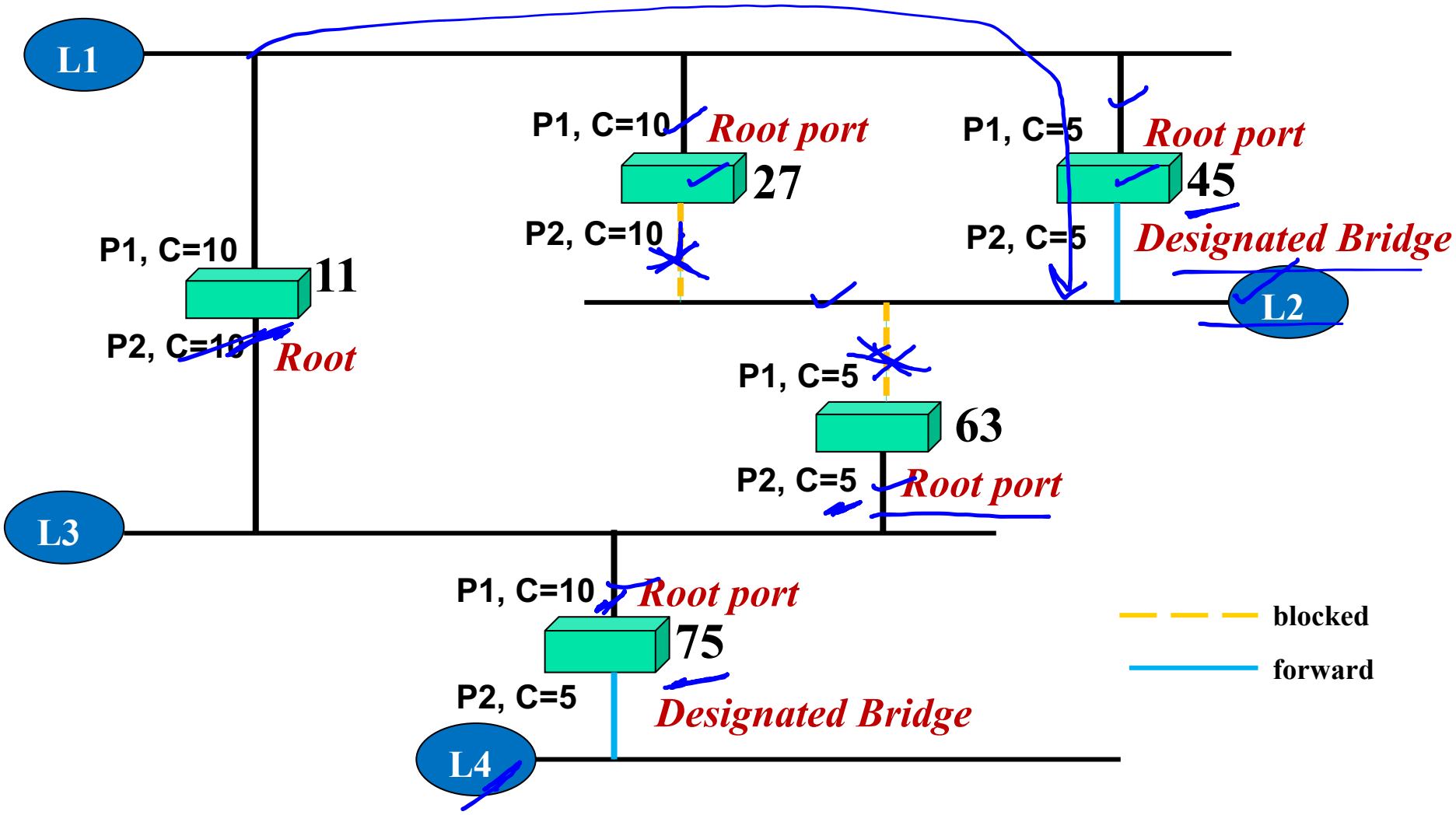
Example: Root Ports



Selection of the designated bridges and designated ports

- A bridge is designated for each LAN to carry its data frames to other LANs.
- If there are several bridges connected to a LAN,
  - the bridge that has lowest RPC is selected as a designated bridge.
  - If RPC is same then the lowest B-ID bridge is selected as a designated bridge
  - The port connected to the designated bridge is the designated port.

Example: Designated Bridge



Error situation

- Normally the root bridge send a configuration BPDU in every 1 to 10 seconds.
- If the BPDU is not received within specified time there are two possibilities.
  - The root bridge has failed
    - Whole spanning tree is rebuilt.
  - The designated bridge has failed
    - If an alternative bridge is available which can support the affected LAN, it will take over as designated bridge.
    - Here redundancy comes handy.

Bridges vs. Switches

- Bridges make it possible to increase LAN capacity
  - Reduces the amount of broadcast packets
  - No loops
- Switch is a special case of a bridge
  - Each port is connected to a ***single*** host
    - Either a client machine
    - Or another switch
  - Links are full duplex
  - Simplified hardware: no need for CSMA/CD!
  - Can have different speeds on each port

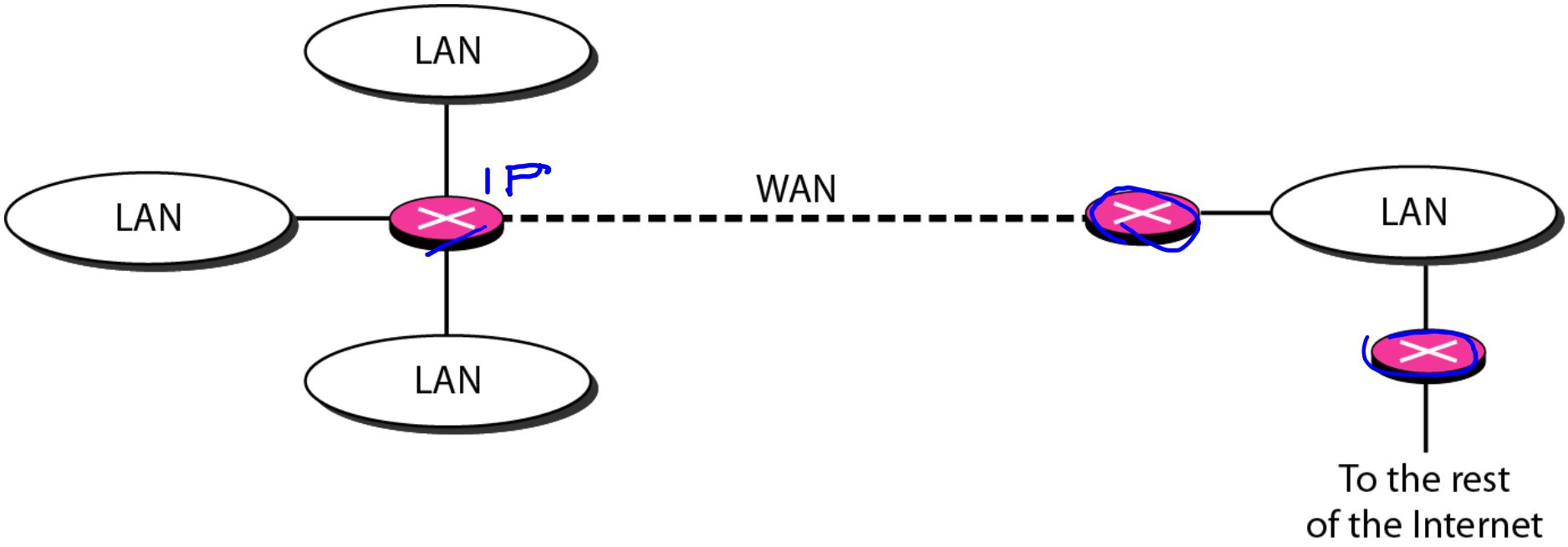
Switching the Internet

- Capabilities of switches:
  - Network-wide routing based on MAC addresses
  - Learn routes to new hosts automatically
  - Resolve loops
- Could the whole Internet be one switching domain?

NO

Routers connecting independent LANs and WANs

3-layer switch



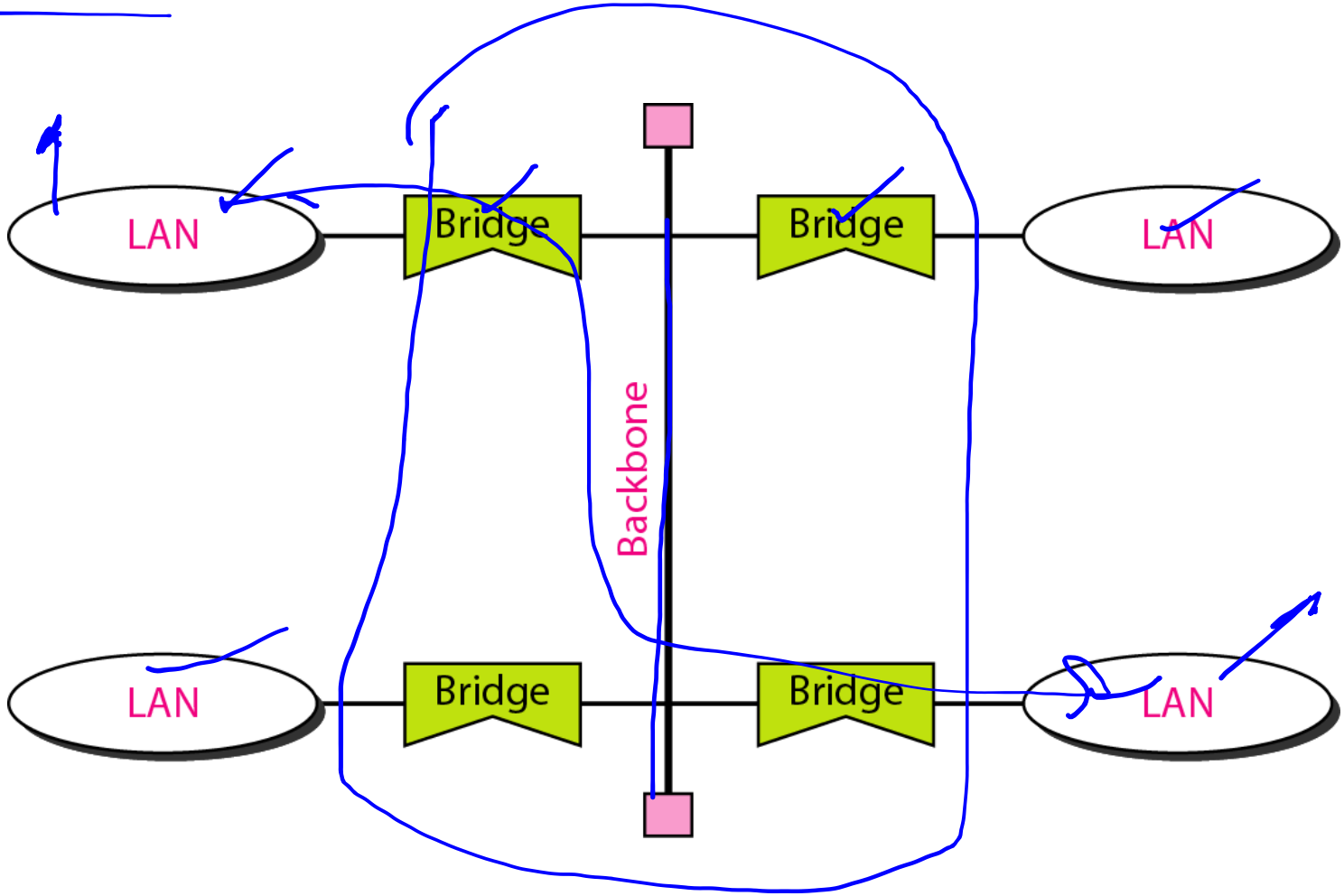
Backbone Networks

- *A backbone network allows several LANs to be connected.*
- *In a backbone network, no station is directly connected to the backbone;*
- *the stations are part of a LAN, and the backbone connects the LANs.*
- *The backbone can be of types*
  - **Bus Backbone**
  - **Star Backbone**
  - **Connecting Remote LANs**

Note

In a bus backbone, the topology of the backbone is a bus.

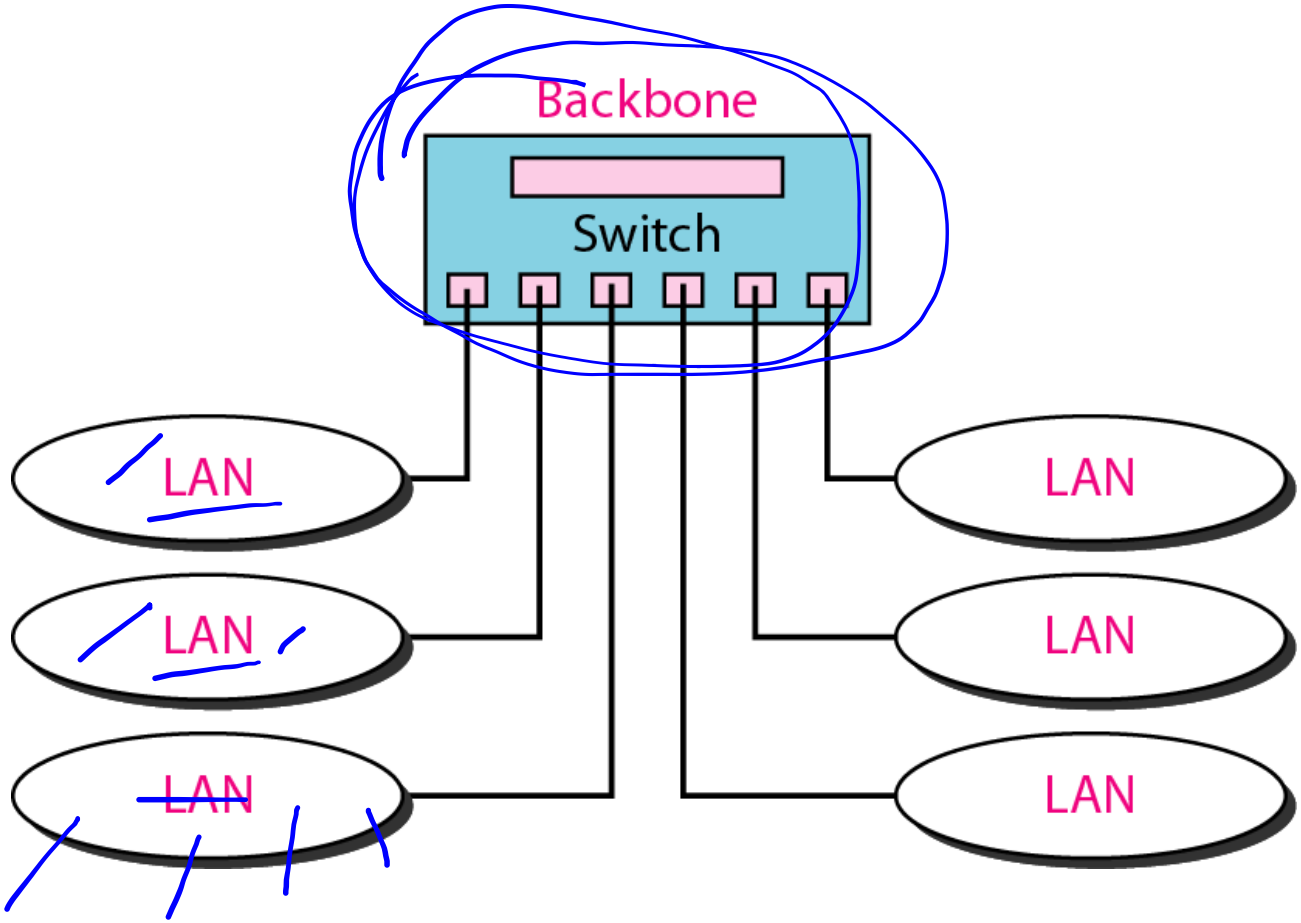
Bus backbone



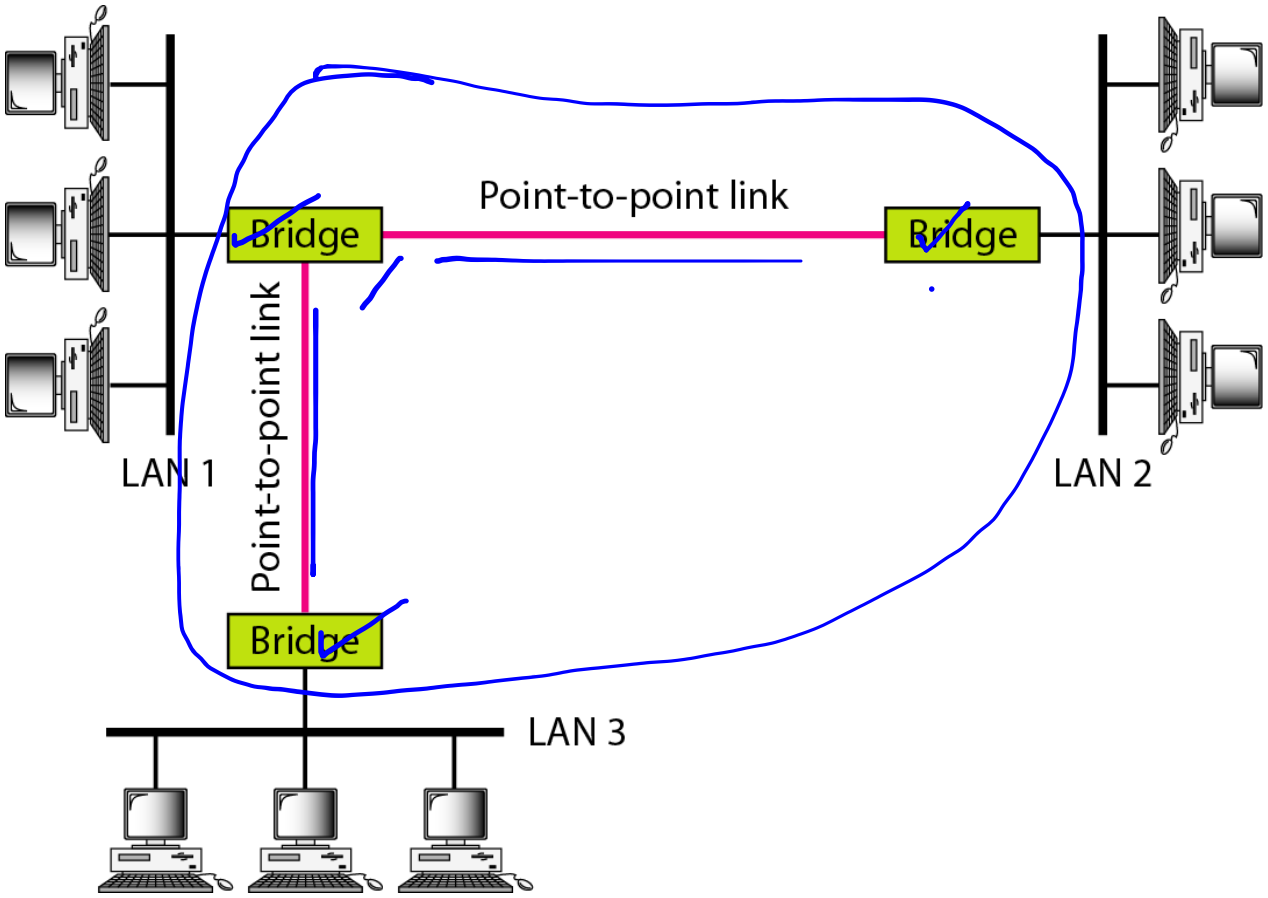
Note

- **In a star backbone, the topology of the backbone is a star**
- **The backbone is just one switch.**

Star backbone



Connecting remote LANs with bridges



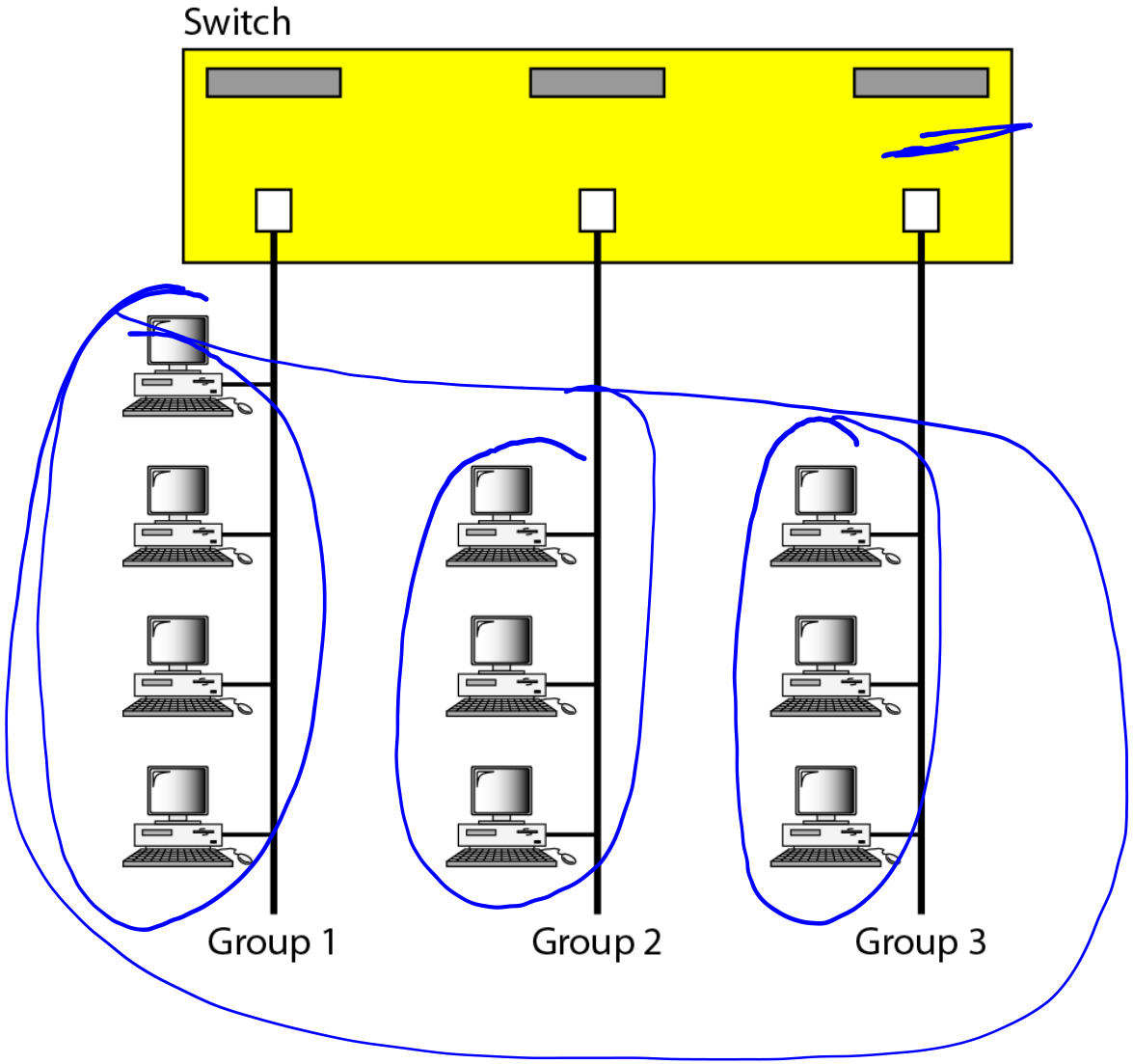
Note

A point-to-point link acts as a LAN in a remote backbone connected by remote bridges.

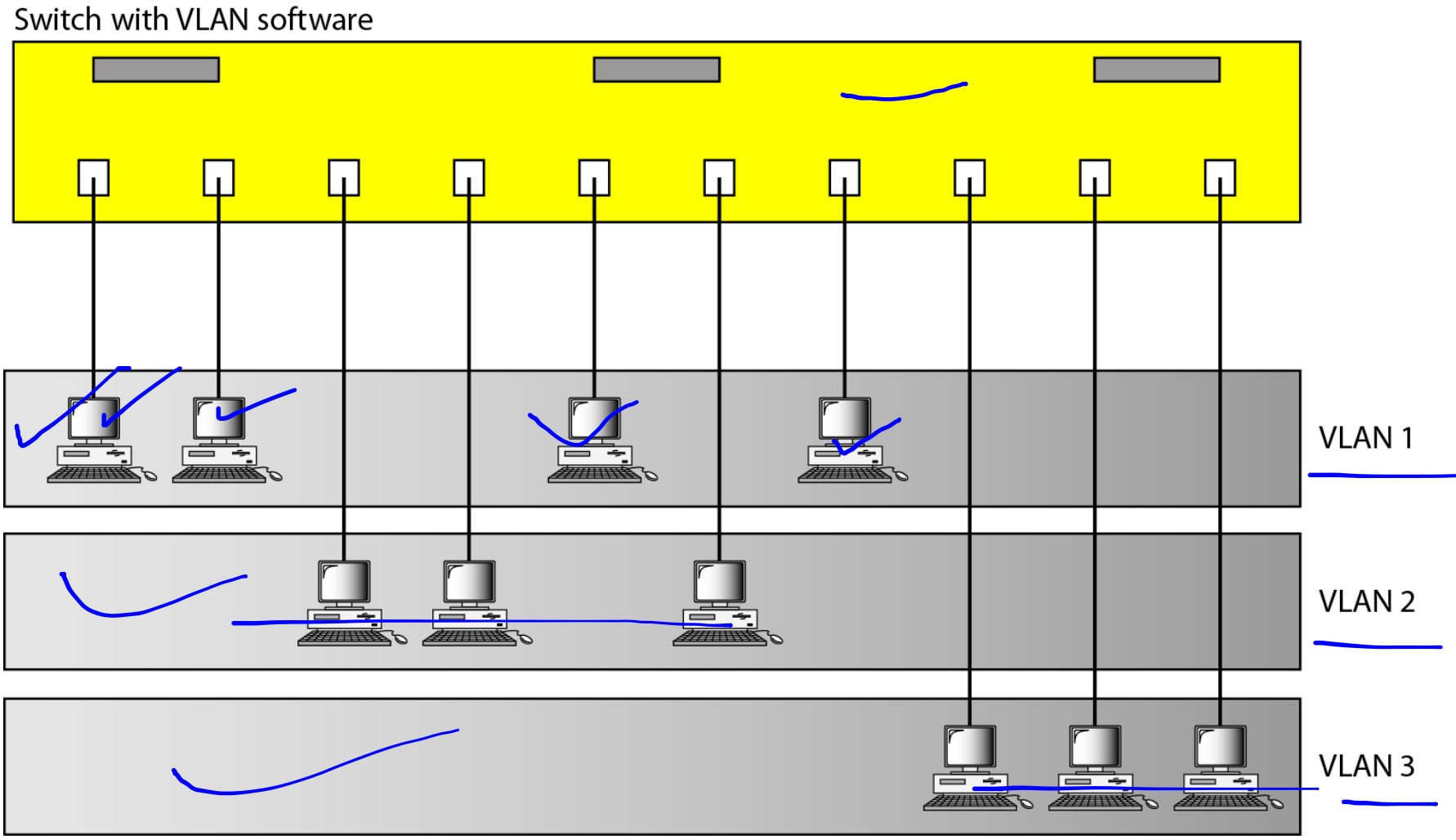
Virtual LANs

We can roughly define a virtual local area network (VLAN) as a local area network configured by software, not by physical wiring.

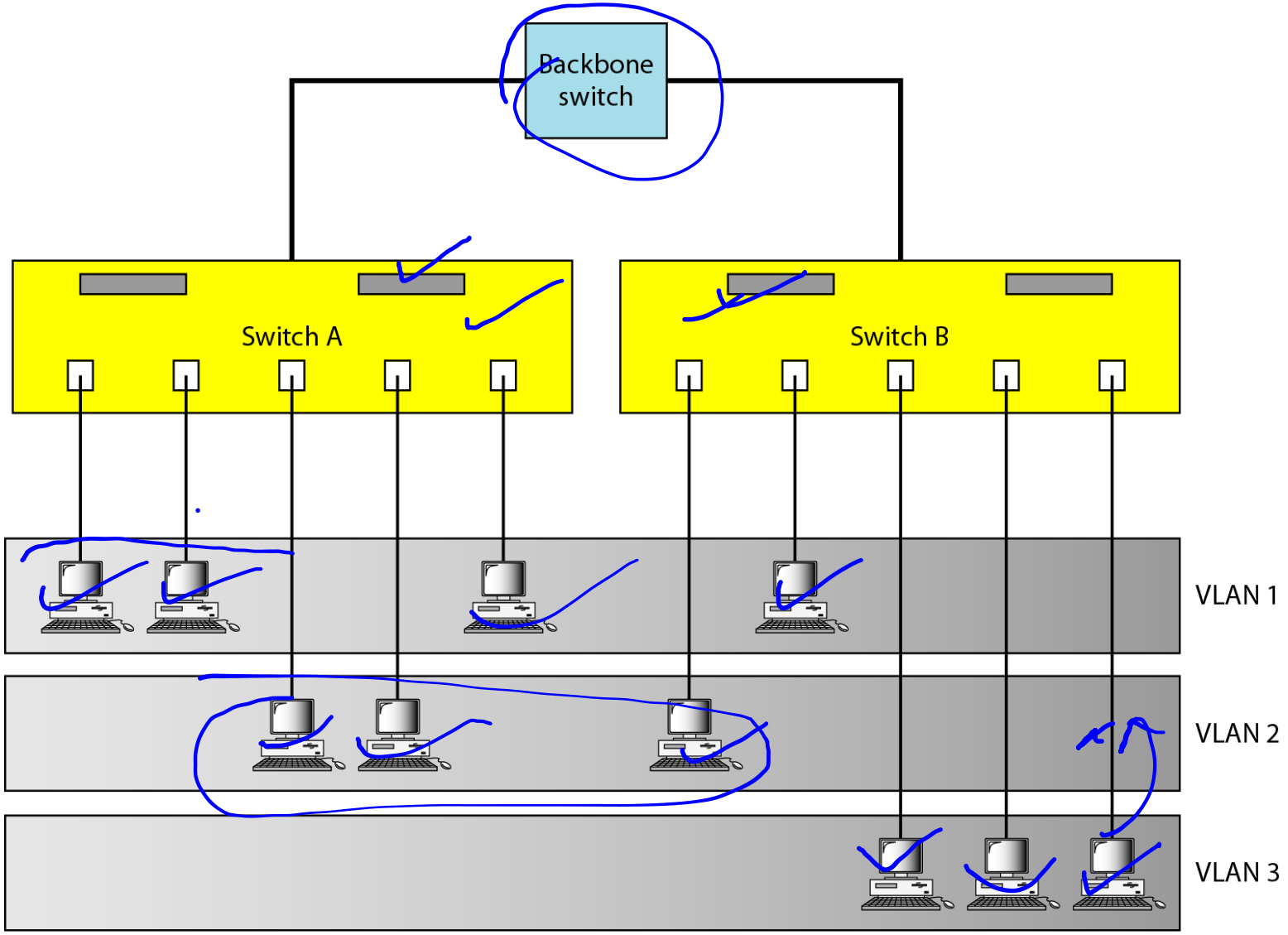
A switch connecting three LANs



A switch using VLAN software



Two switches in a backbone using VLAN software



Note

VLANs create broadcast domains.