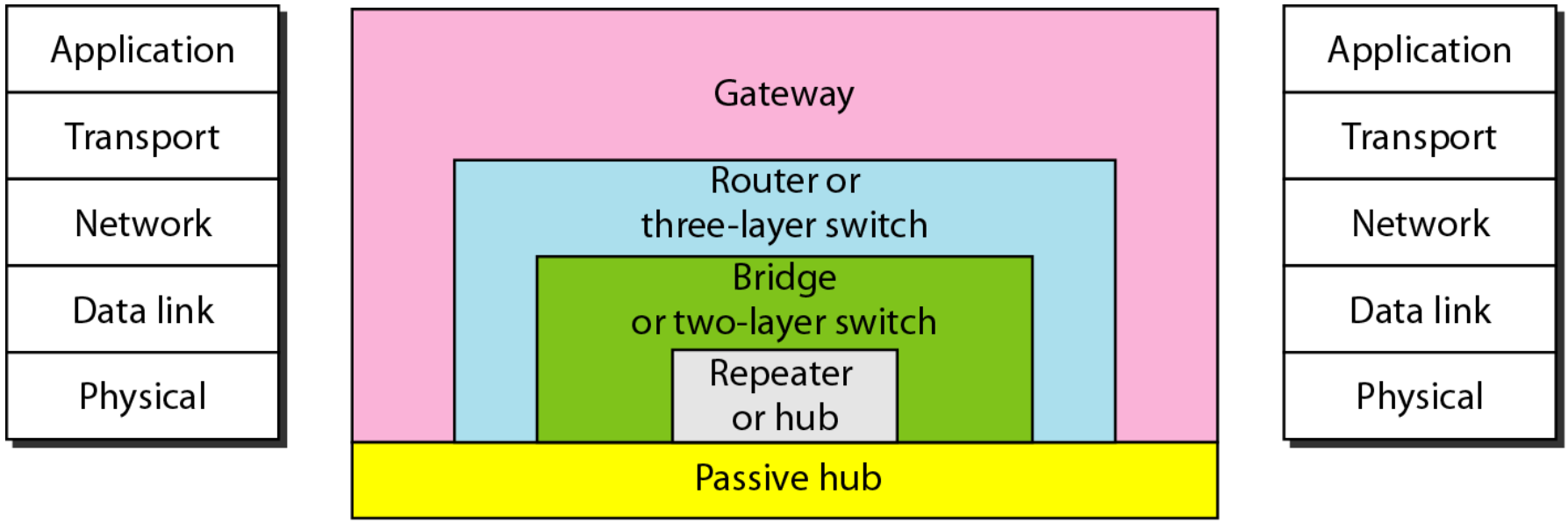
15.1 Connecting Devices

- Five connecting devices
  - Repeaters
  - Hubs
  - Bridges
  - Switches
  - Routers
  - Gateway

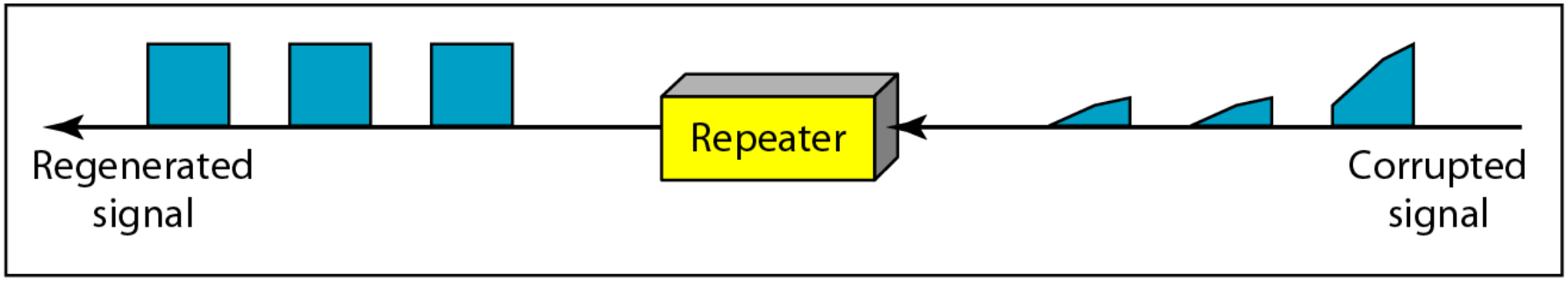
Figure 15.1 *Five categories of connecting devices*



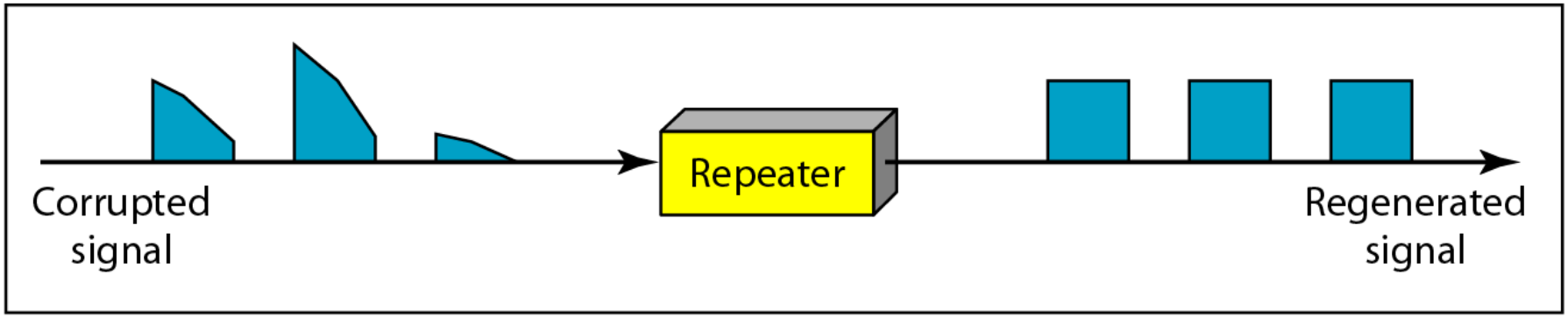
Repeaters

- A **physical layer** device the acts on **bits** not on **frames** or packets
- Can have two or more interfaces
- When a bit (0,1) arrives, the repeater receives it and **regenerates** it, the transmits it onto all other interfaces
- Used in LAN to **connect cable segments** and **extend** the **maximum cable length** ➔ extending the **geographical LAN range**
  - Ethernet 10base5 – Max. segment length 500m – 4 repeaters (5 segments) are used to extend the cable to **2500m**)
  - Ethernet 10Base2- Max. segment length 185m - 4 repeaters (5 segments) are used to extend the cable to **925m**
- Repeaters do not implement any **access method**
  - If any two nodes on any two connected segments transmit at the same time **collision** will happen

Figure 15.3 *Function of a repeater*

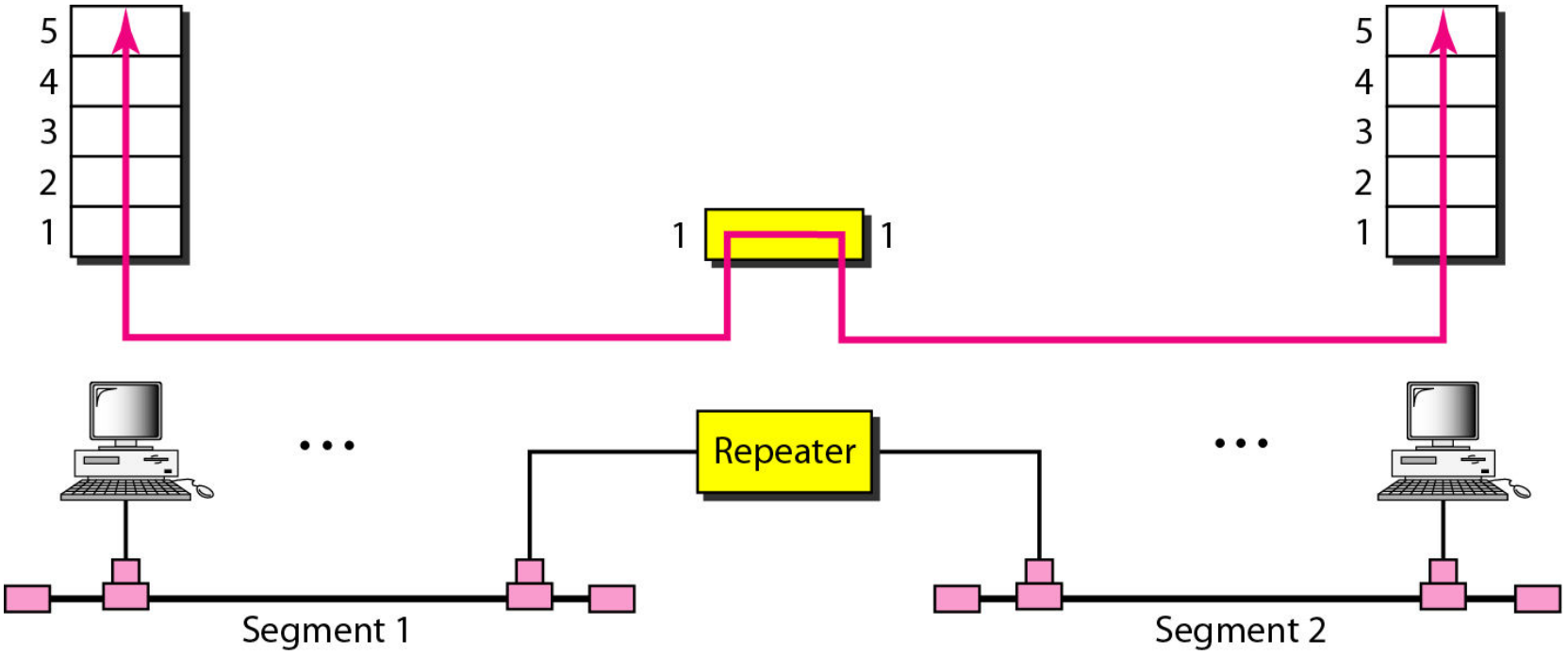


a. Right-to-left transmission.



b. Left-to-right transmission.

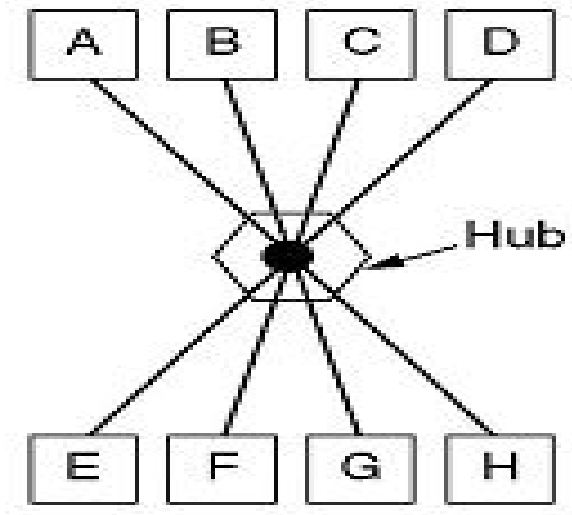
Figure 15.2 *A repeater connecting two segments of a LAN*

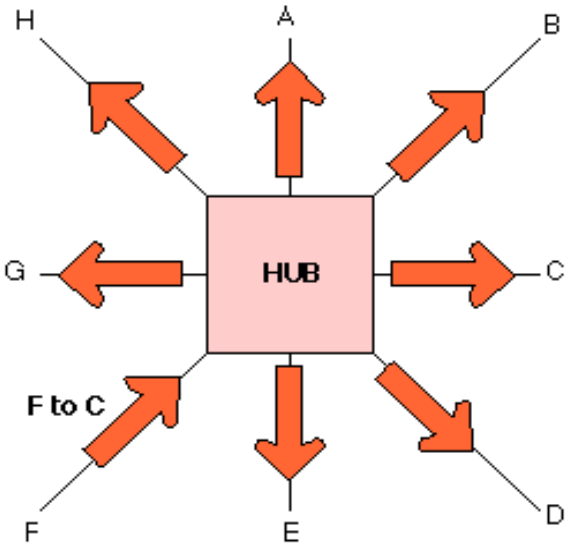


Hubs

- Acts on the **physical layer**
- Operate on bits rather than frames
- Also called **multiport repeater**
- Used to connect stations adapters in a **physical** star topology but **logically** bus
- Connection to the hub consists of **two pairs of twisted pair wire** one for **transmission** and the other for **receiving**.
- Hub receives a bit from an adapter and sends it to **all** the other adapters without implementing any access method.
- does not do **filtering** (forward a frame into a specific destination or drop it) just it copy the received frame onto **all other links**
- The entire hub forms **a single collision domain**, and **a single Broadcast domain**
  - **Collision domain**: is that part of the network (set of **NICs**) when two or more nodes transmit at the same time collision will happen.
  - **Broadcast domain:** is that part of the network (set of NIC) where each NIC can 'see' other NICs' traffic **broadcast messages.**
- Multiple Hubs can be used **to extend** the network length
- For 10BaseT and 100BaseT the maximum length of the connection between an adapter and the hub is 100 meters ➔ the maximum length between any two nodes is 200 m = maximum network length

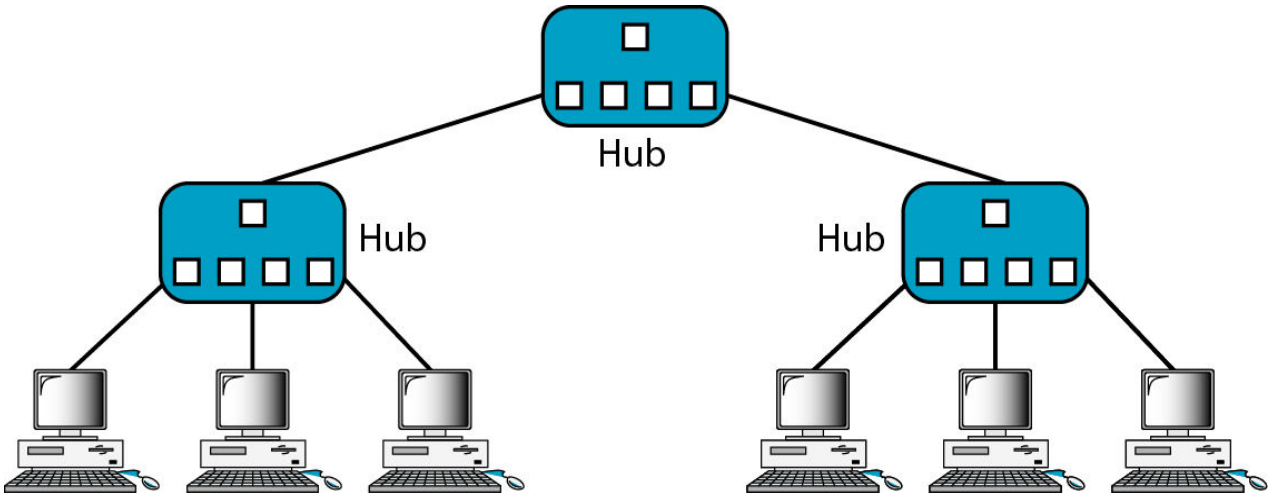
Figure 16.4 Hubs





Interconnecting with hubs

- Backbone hub interconnects LAN segments
- **Advantage**:
  - Extends max distance between nodes
- **Disadvantages**
  - Individual segment collision domains become one large collision domain ➔ (**reduce the performance**)
  - Can't interconnect different Ethernet technologies(like 10BaseT & 100BaseT) because **no buffering** at the hub



Here we have a single collision domain and a single broadcast domain

Hubs Vs. Repeaters

- Hub are different than repeaters in the following:
  - The provide **network management features** by gathering information about the network and report them to a monitoring host connected to the hub so some statistics about the network (bandwidth usages, collision rates, average frame sizes) can be generated.
  - If an adapter is not working the hub can **disconnect** it internally and the network will not be affected.

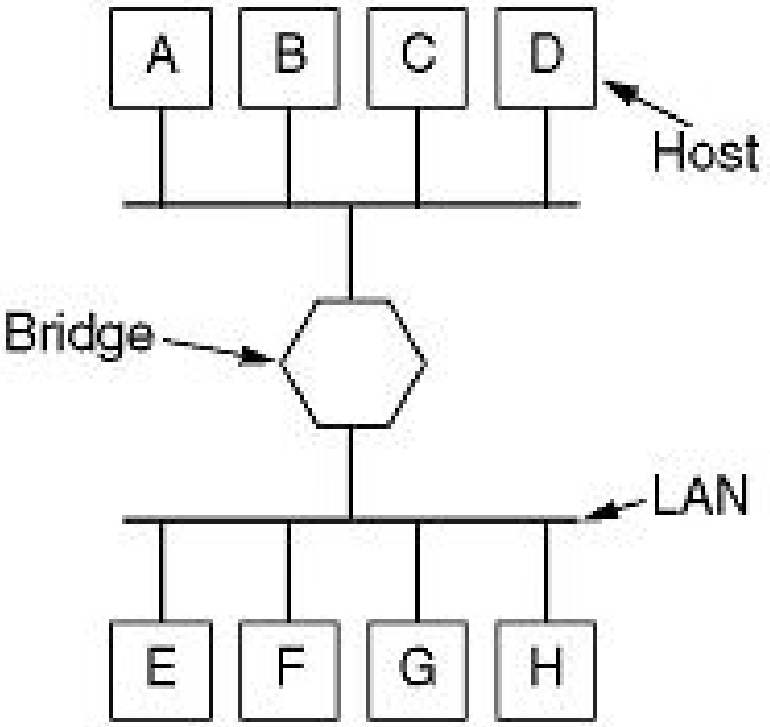
Bridges/switches

- Acts on the **data link** layer (MAC address level)
- Used to **divide** (segment) the LAN into smaller LANs segments, or to **connect** LANs that use identical physical and data link layers protocol (see figure in next slide)
- Each LAN segment is a **separate collision domain**
- Bridge does not send the received frame to all other interfaces like hubs and repeaters, but it performs **filtering** which means:
  - Whether a frame should be **forwarded** to another interface that leads to the destination or **dropped**
- This is done by a bridge table (**forwarding table**) that contains entries for the nodes on the LAN
  - The bridge table is **initially empty** and **filled automatically** by **learning from frames movements** in the network
  - An entry in the bridge table consists of : Node LAN (**MAC) Address, Bridge Interface to which the node is connected to**, **the record creation time**

Address	Interface	Time
62-FE-F7-11-89-A3	1	9:32
7C-BA-B2-B4-91-10	3	9:36
...	...	...

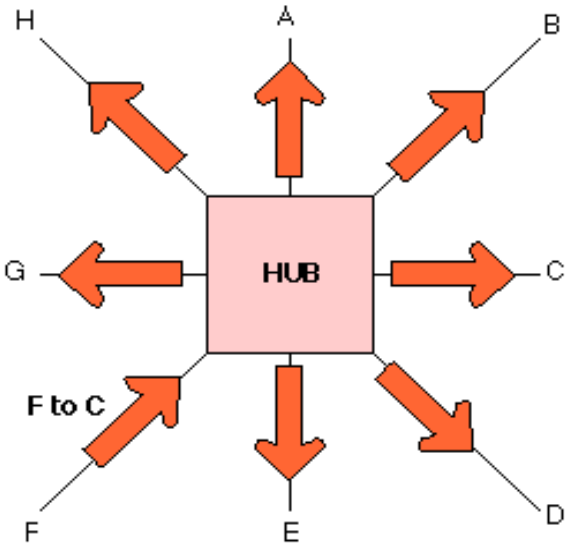
- A bridge runs **CSMA/CD before sending a frame** onto the link not like the hub or repeater
- Bridge frame handling is done in **software**

Bridges

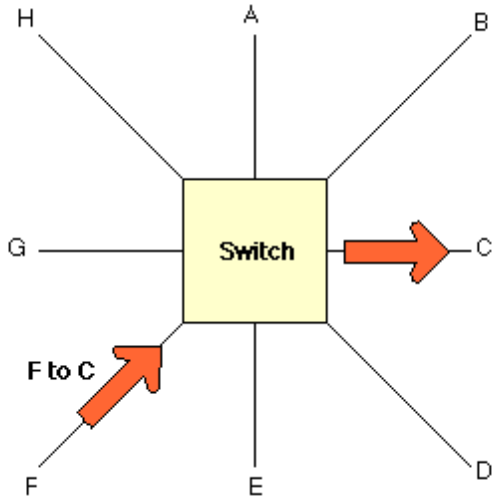


Connecting two or more LAN segments together

Bridges (Switches) Vs. Hubs

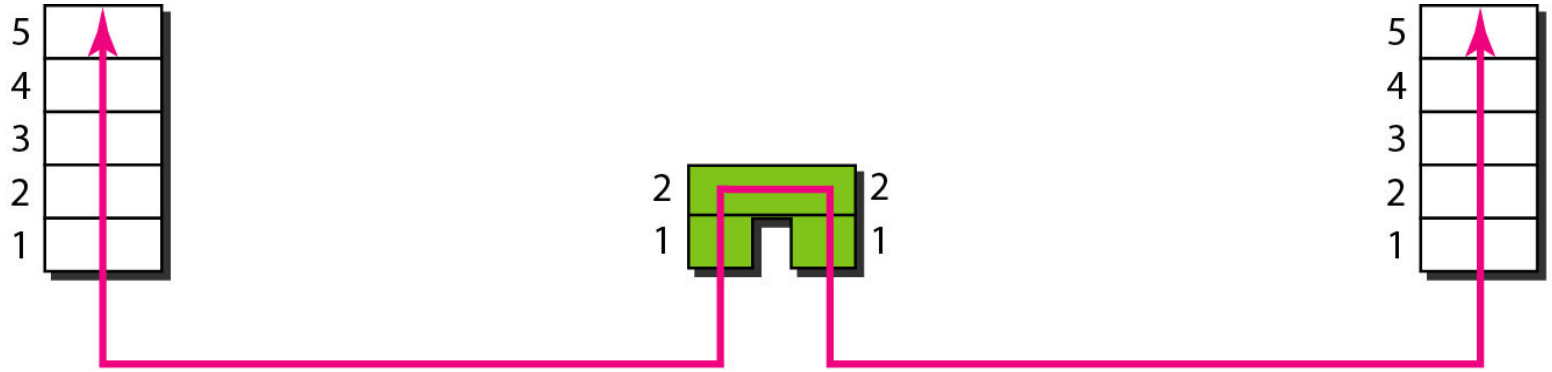


A Hub sending a packet form F to C.



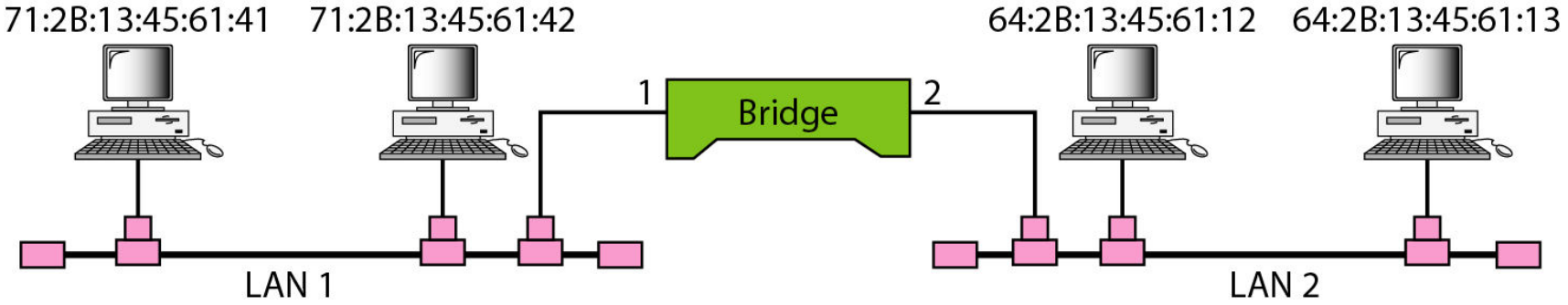
A Switch sending a packet from F to C

Figure 15.5 *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

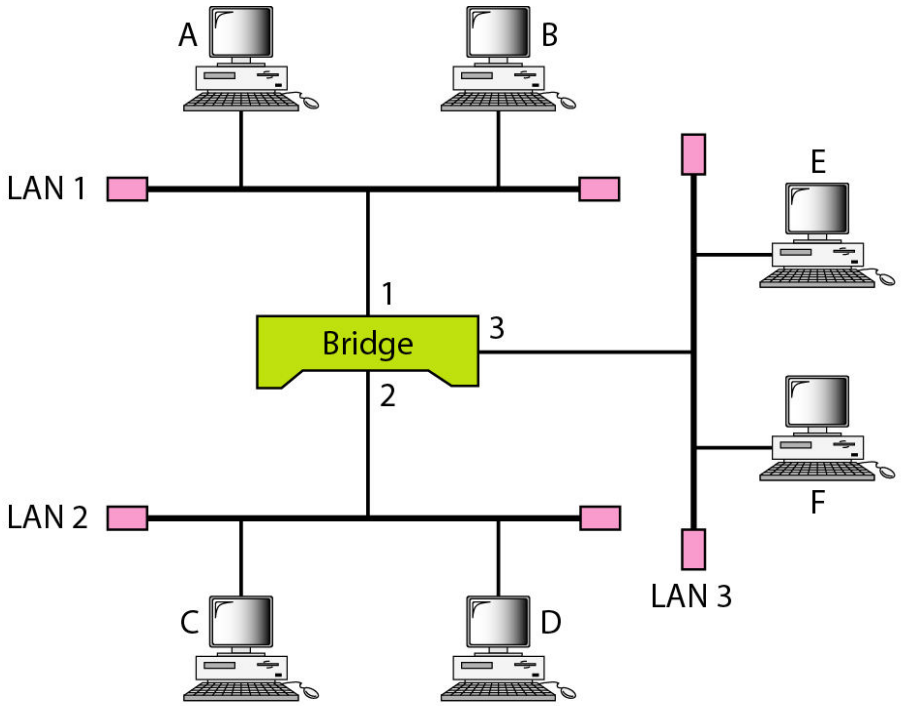
Bridge Table



Switch learning process

- When the switch receives a frame, it compares the **source address** of the frame with each entry in the forwarding table
  - If **No match is found**, the bridge will **add** to the table the frame **source address** and the **Interface** on which the frame **was received.**
  - If a **match is found**, the bridge **updates** the **Interface number** on which the frame was received if **it is different** from the one in the table also it **updates** the **record time**
- Then, the switch compares the **destination address** of the frame with each entry in the **forwarding table (MAC table)**
  - If a match is found then
    - The bridge compares the **interface number** on which the frame was received and the interface number in the table, if they are **different** the bridge **forwards** the frame through the interface number stored in the table. Otherwise, if they are the **same** the switches **discards** (**drops**) the frame.
  - If no match is found, the switch **floods the frame** on **all interfaces** except the one on which the frame was received.

Figure 15.6 *A learning switch and the process of learning*



Address	Port

a. Original

Address	Port
A	1

b. After A sends a frame to D

Address	Port
A	1
E	3

c. After E sends a frame to A

Address	Port
A	1
E	3
B	1

d. After B sends a frame to C

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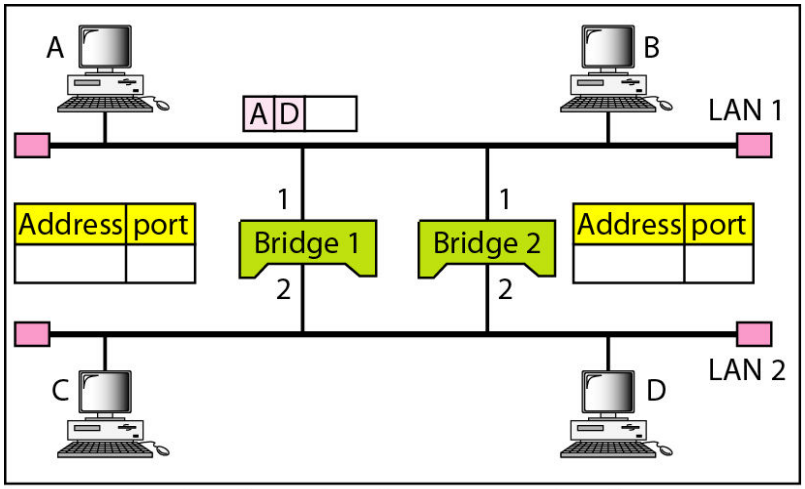
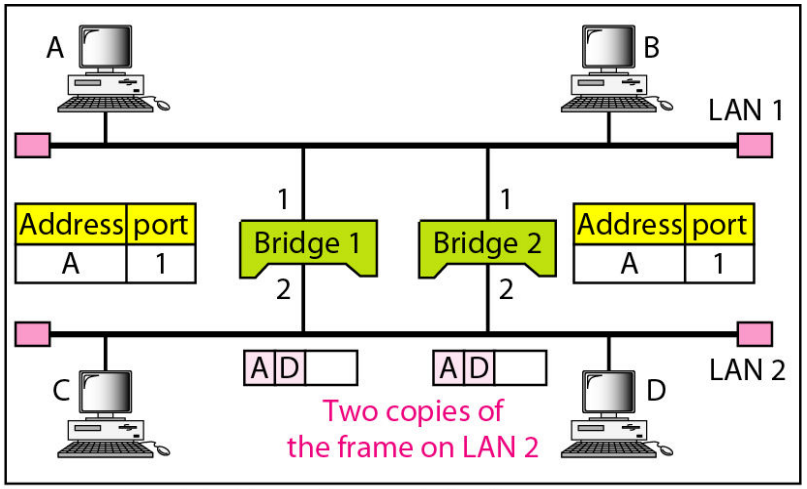
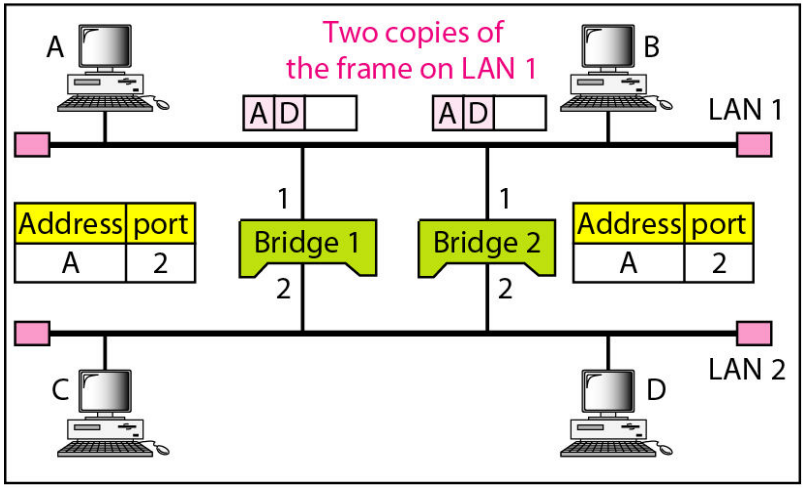
Figure 15.7 *Loop problem in a learning bridge*



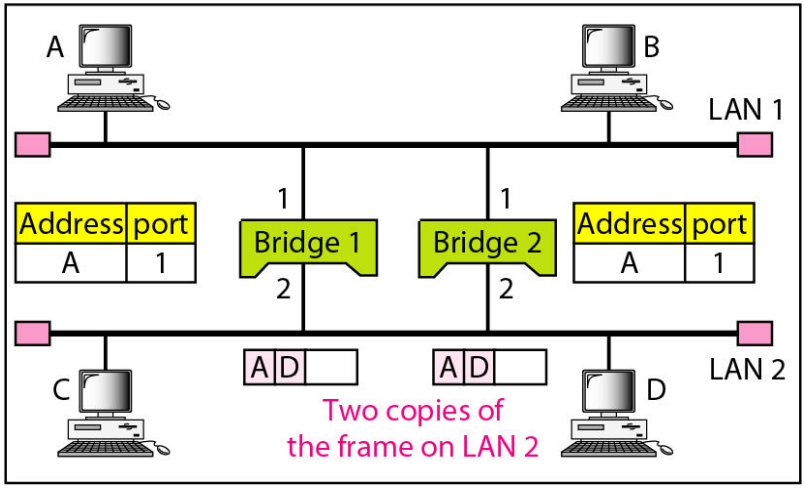
a. Station A sends a frame to station D



b. Both bridges forward the frame



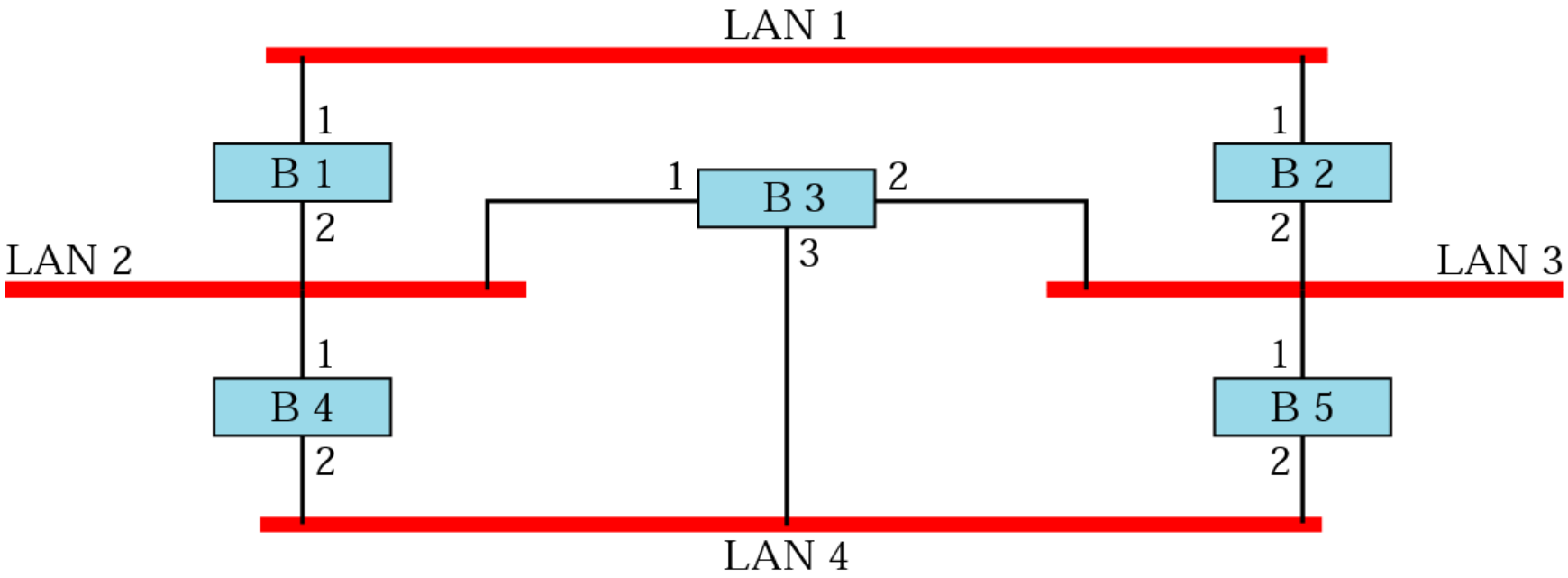
c. Both bridges forward the frame



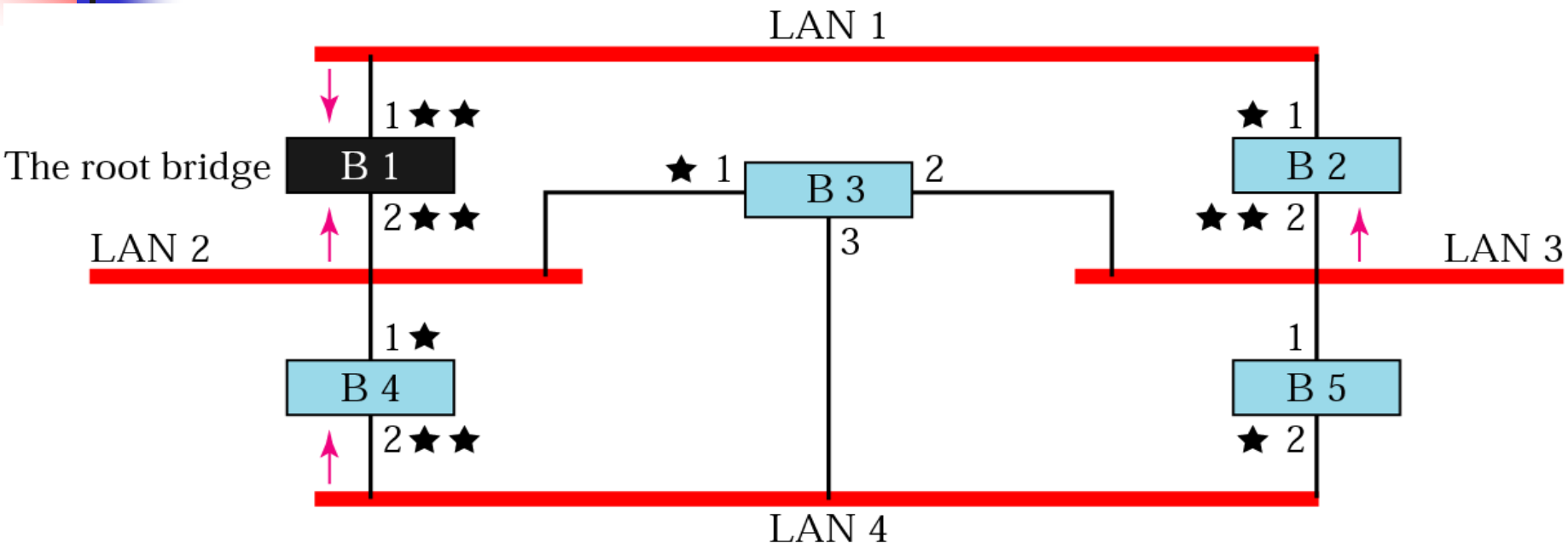
d. Both bridges forward the frame

Prior to spanning tree application

What happens if you have a loop of bridges/switches in your LAN?

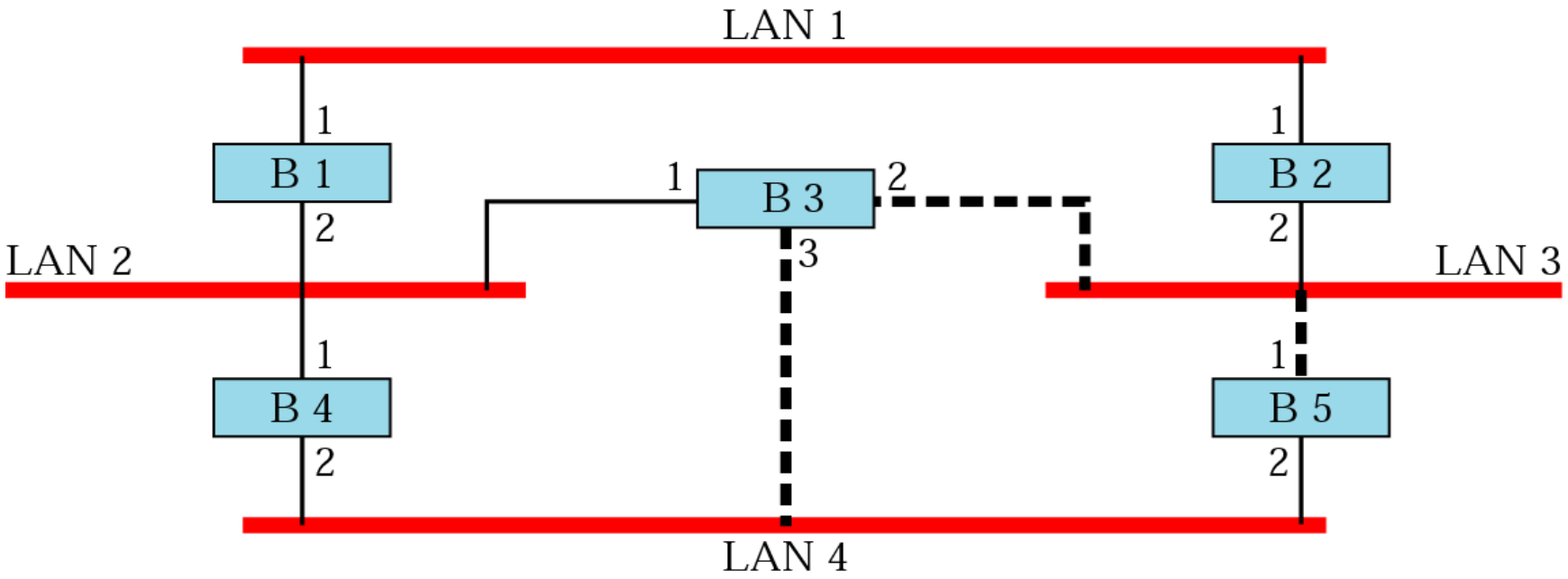


Applying spanning tree



Step 1: Every bridge has an ID. Select the bridge with smallest ID. This is the *root bridge*.
Step 2: Mark one port of each bridge (except root bridge) as the *root port*. Root port is the port with least-cost path from the bridge to the root bridge (marked with 1 star).
Step 3: For each LAN, choose a *designated bridge*. A designated bridge has the least-cost path between the LAN and root bridge (the arrows). Mark the corresponding port that connects the LAN to its designated bridge the *designated port* (two stars).

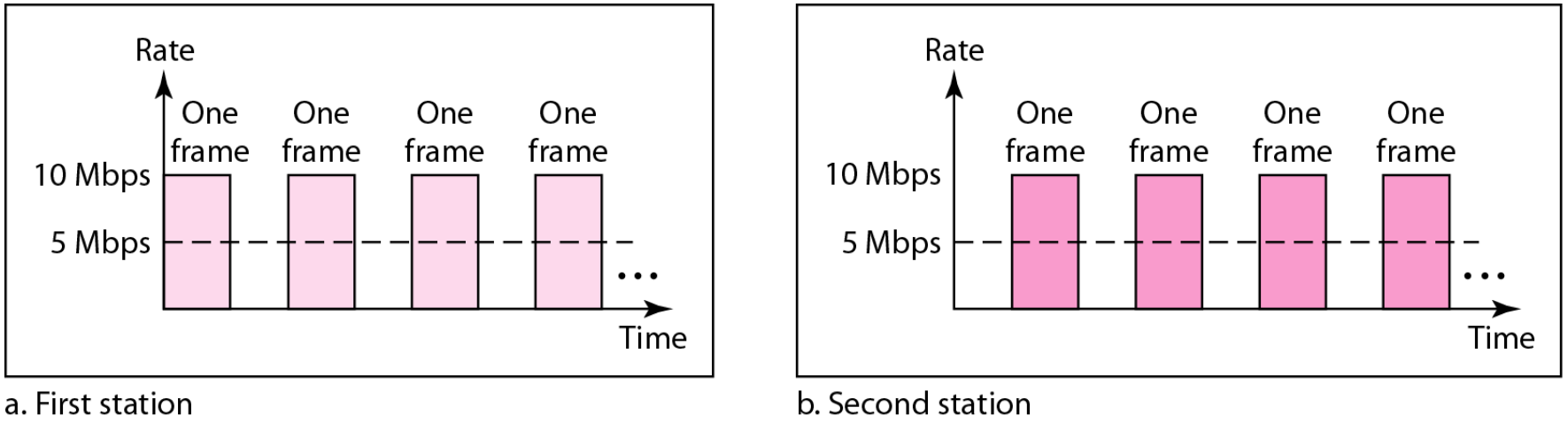
Step 4: Mark the root port and designated port as *forwarding ports*, the others as *blocking ports* (every port with 1 or 2 stars keep, ports with no stars drop). Note - there is only 1 path between any two bridges.



Some switch features

- Implements CSMA/CD
- switches Isolates collision domains (each LAN segment is a separate collision domain), THIS WILL REDUCE THE POSSIBILITY OF COLLISIONS AND result in **higher total max throughput (see next slide)**
- switch forwards a frame with **broadcast address** to **all** devices attached to the whole network (**single broadcast domain**)
- Can be used to combine Ethernet segments using different Ethernet technologies (10Base2 and 100BaseT and 10BaseT) because it has buffering capabilities
- Increases reliability (how?), performance (how?), and security (how?)
- Increases geographical coverage
  - No limit on the size of the LANs connected through switches
- **Transparent**: installing or removing a switch does not require the stations networking software to be reconfigured.
- ("**plug-and-play**"): *no configuration necessary* at installation of switch /switch or when a host is removed from one of the LAN segments
- **Disadvantage**: switch does not allow multiple paths between LAN segments or between any two devices.

Figure 13.14 *Sharing bandwidth*



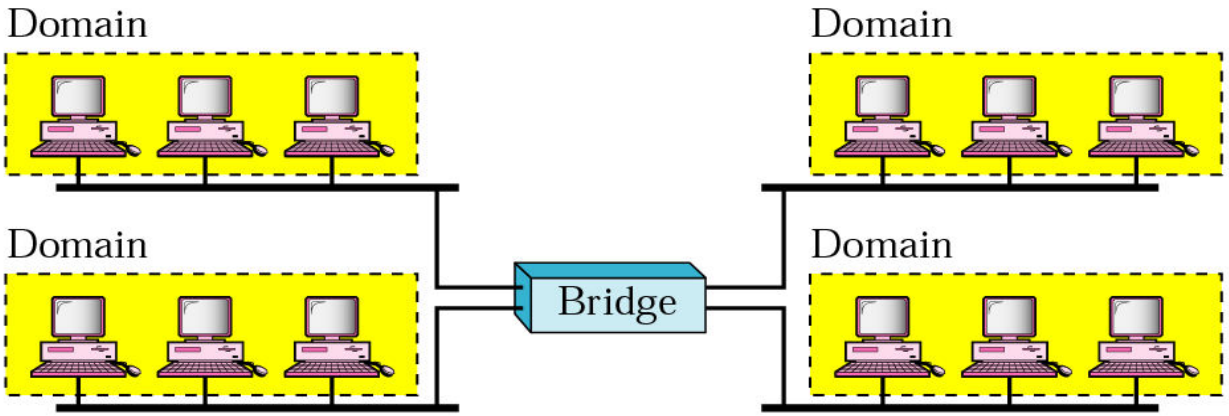
a. First station

b. Second station

Collision domains in a nonbridged and bridged network

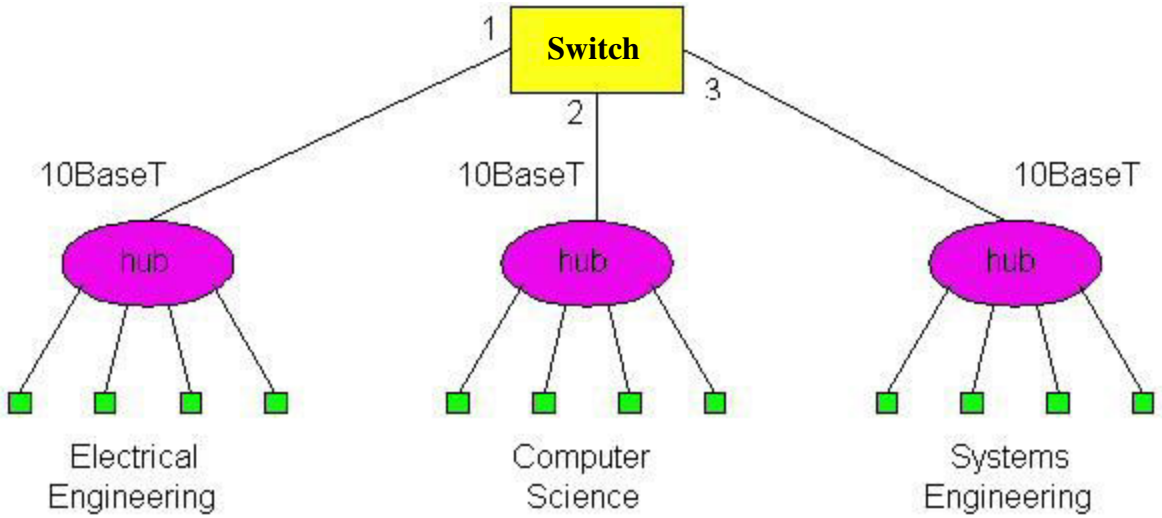
In heavy load, each station has an average effective theoretical bandwidth = 10/12

a. Without bridging



b. With bridging

Each station has an average effective bandwidth equal =10/3

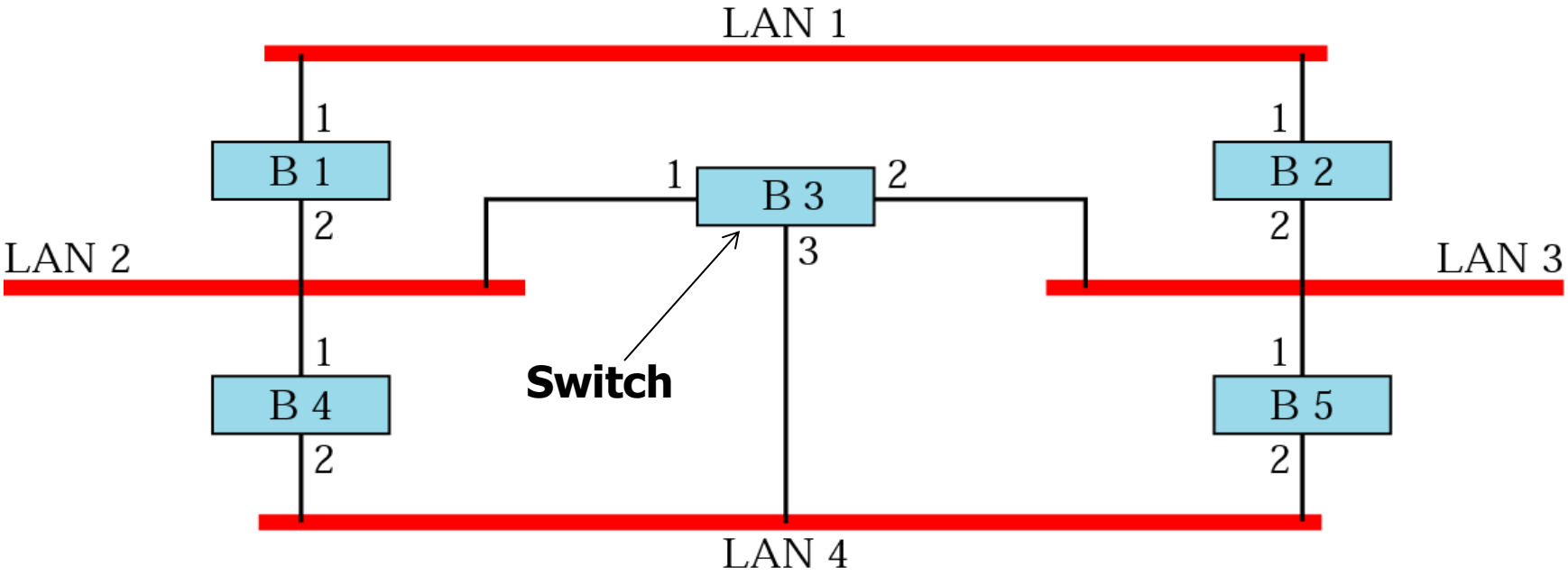


Example:

Three LANs connected through a bridge

Note: here we have *three collision* domains and *a single broadcast* domain

Figure 16.8 Prior to spanning tree application



- **When using switches, the network should not contain any loop (there should be exactly one path from any LAN to any other LAN**
- **Loops can cause number of frames in the LAN to increase *indefinitely***

Effect of Loop of switches

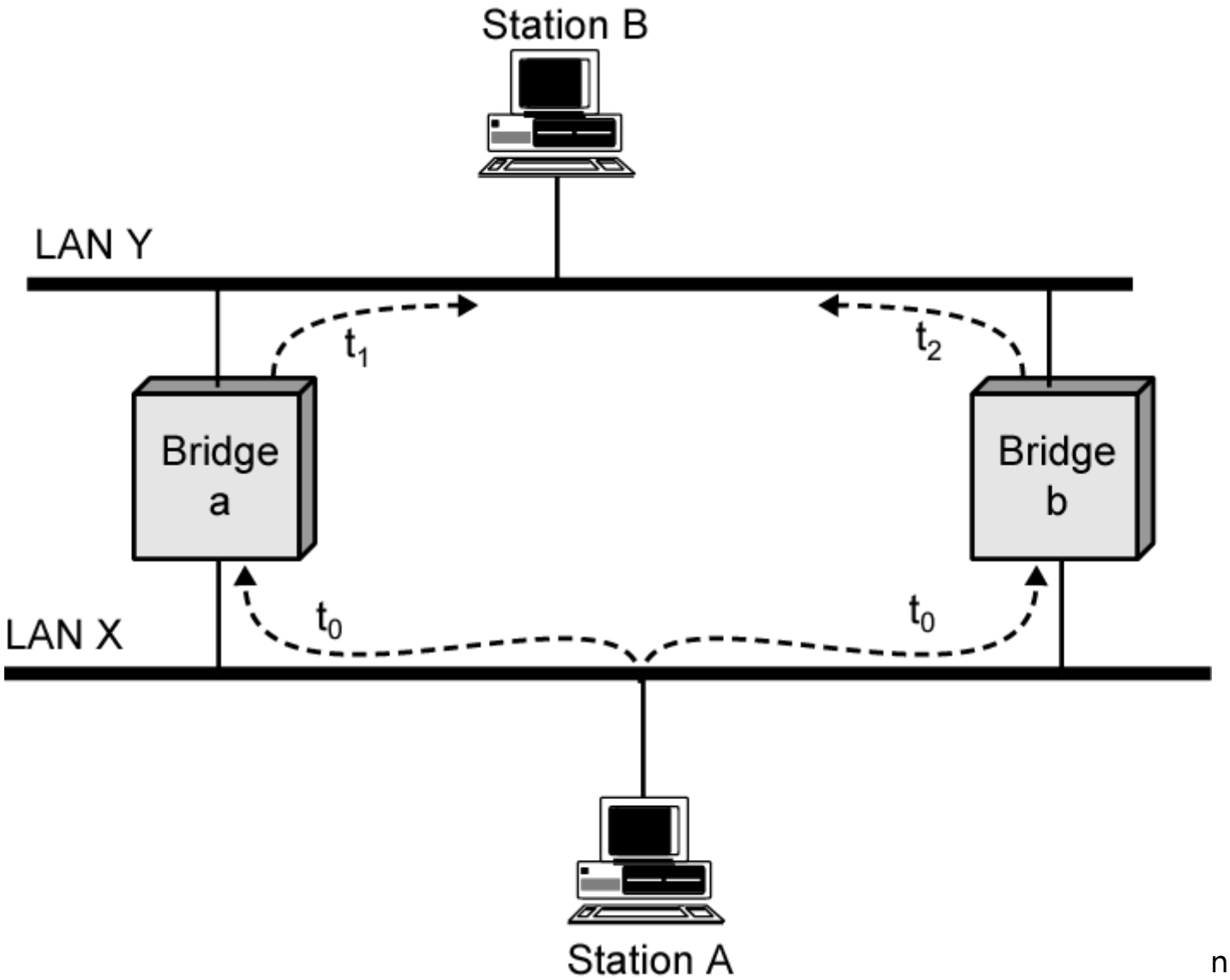
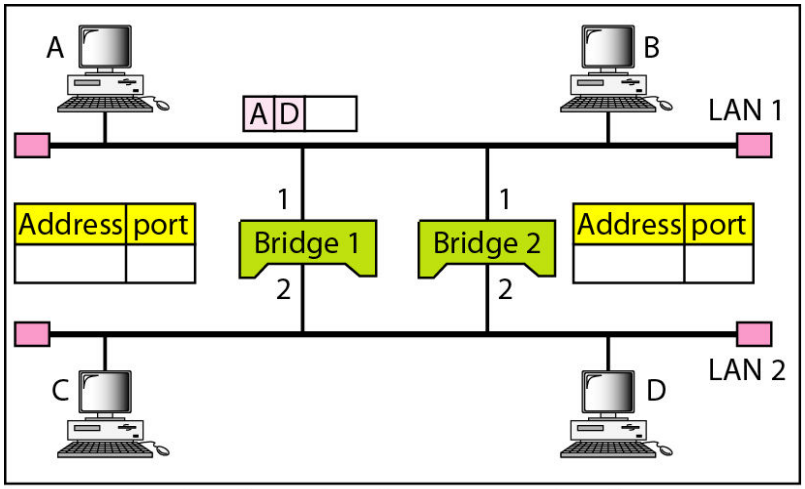
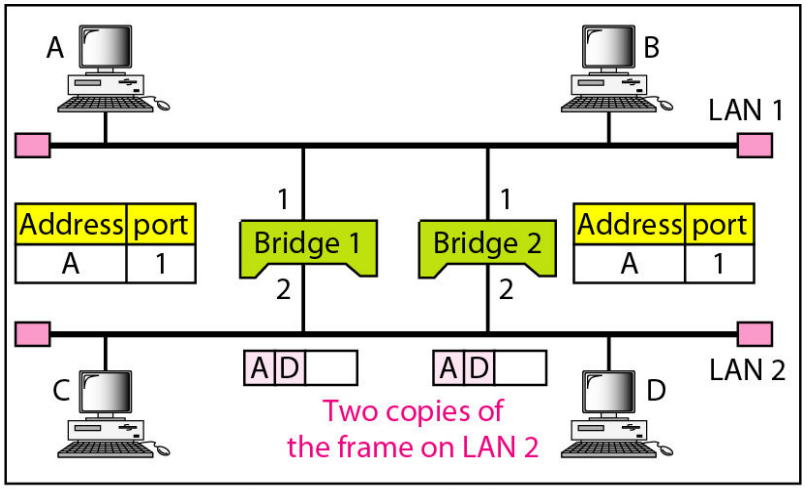


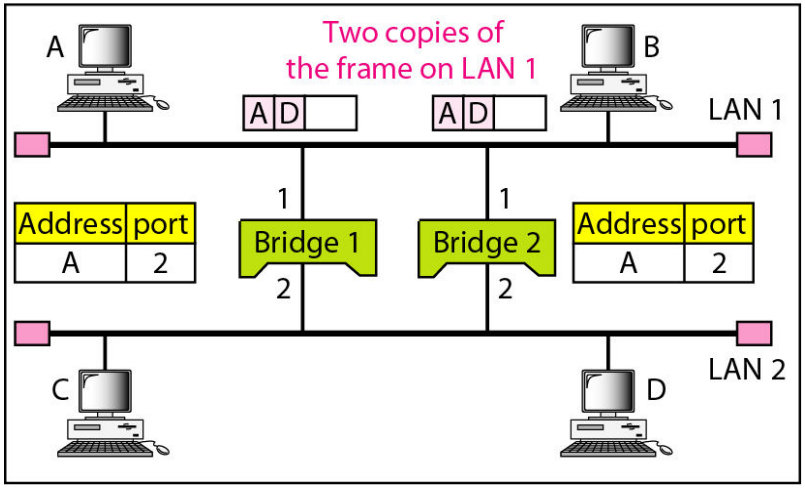
Figure 15.7 *Loop problem in a learning switch*



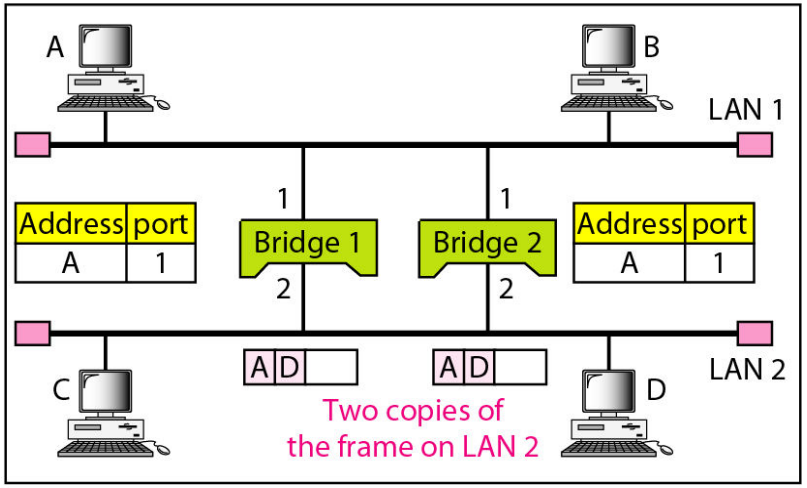
a. Station A sends a frame to station D



b. Both bridges forward the frame

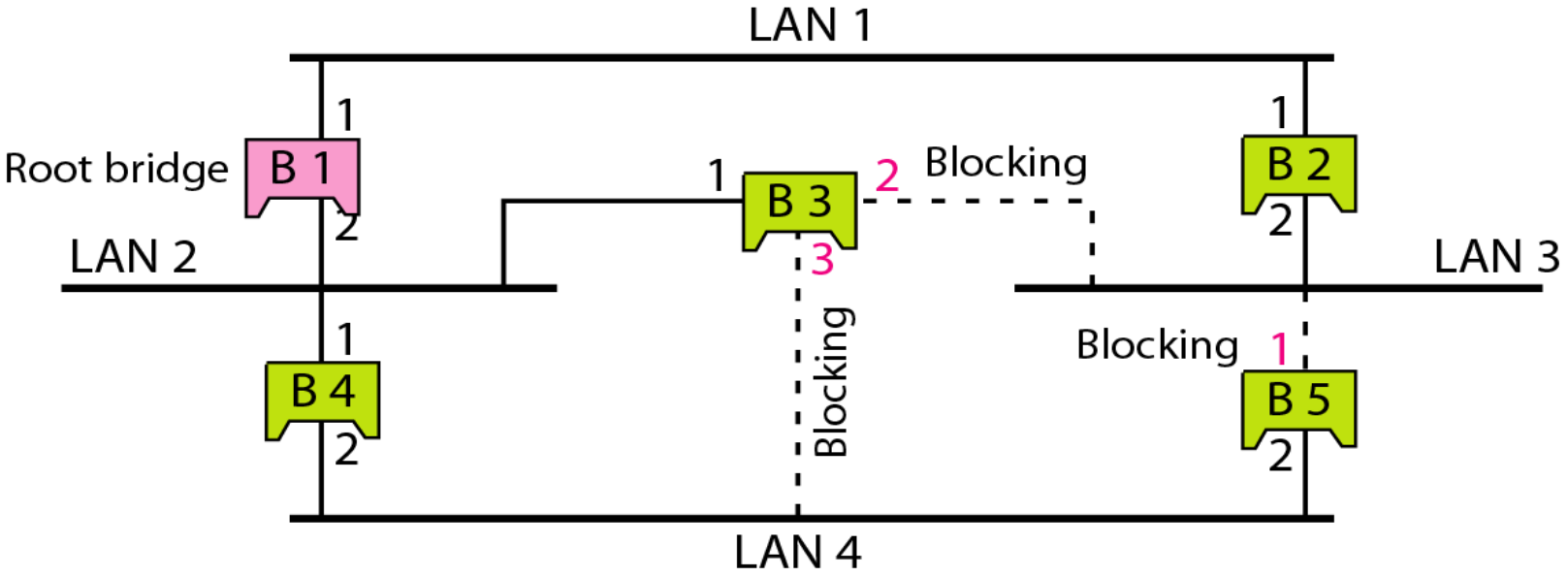


c. Both bridges forward the frame



d. Both bridges forward the frame

Figure 15.10 *Forwarding and blocking ports after using spanning tree algorithm*



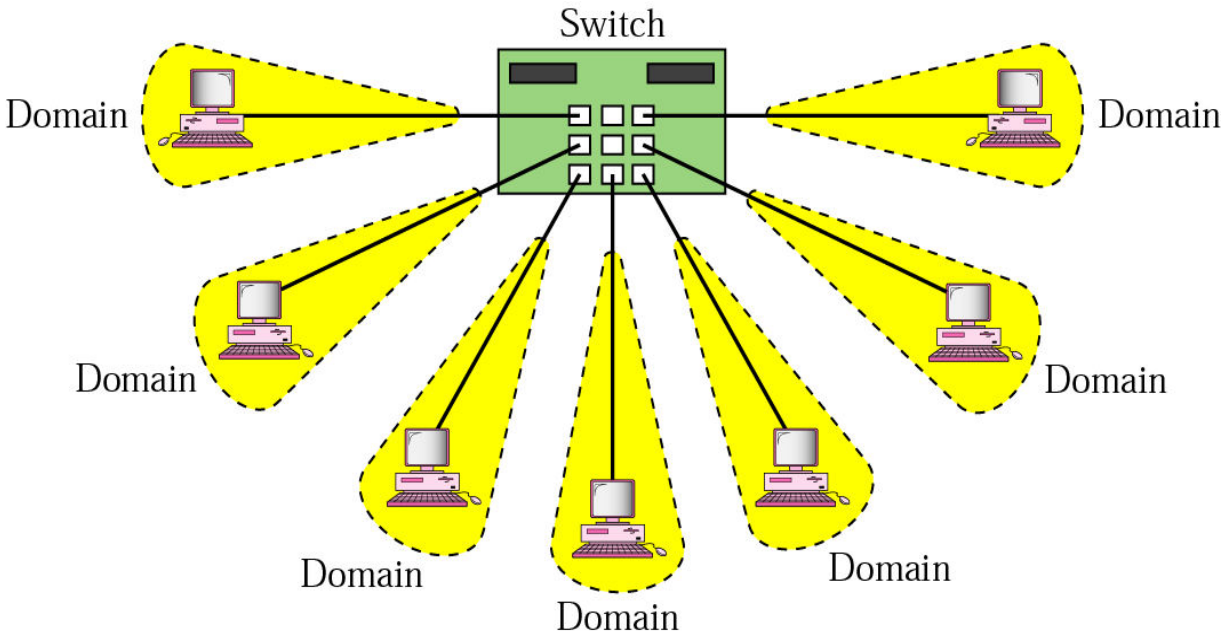
Ports 2 and 3 of bridge B3 are blocking ports (no frame is sent out of these ports).
Port 1 of bridge B5 is also a blocking port (no frame is sent out of this port).

- **For any connected graph there is a spanning tree that maintains connectivity but contains no closed loops**
- **Loops are logically disabled by the minimum spanning tree algorithm**

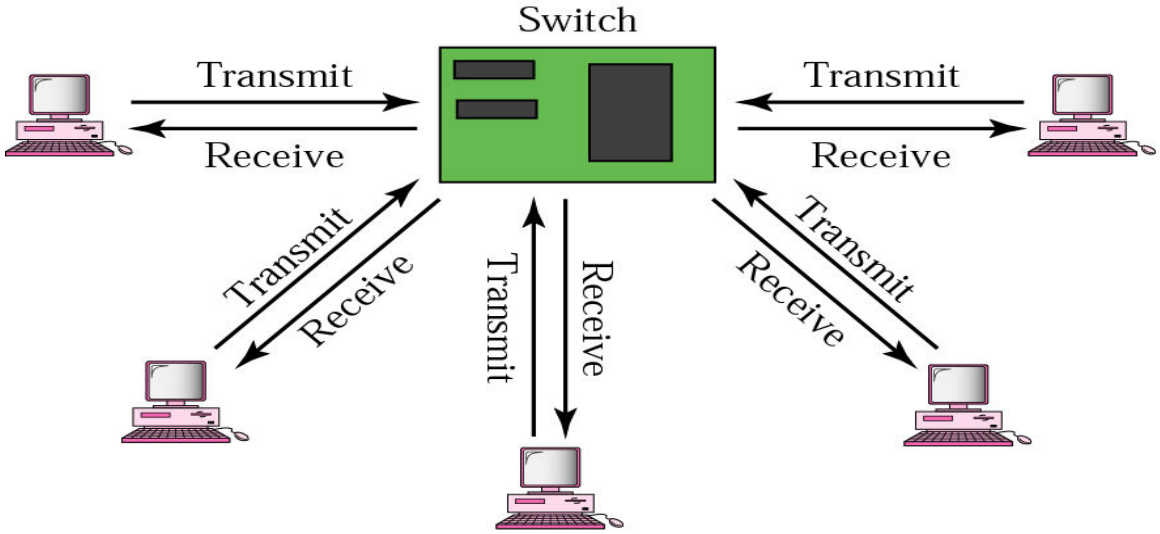
Switches

- N-Port bridge where N is equal to number of stations
- Usually used to connect individual computers not LANs like bridge
- Allows more than one device connected to the switch directly to transmit **simultaneously**
- Can operates in **Full-duplex** mode (can send and receive frames at the same time over the same interface)
- Performs MAC address recognition and frame forwarding in **hardware** (bridge in software)
- *Two types :*
  - ***Store-and-forward***: switch receives the whole a frame on the input line, buffers it briefly , performs error checking, then routes it to the appropriate output line (similar to bridge). **Buffering** will cause some **delay**.
  - **Cut-through**: based on the fact that the destination address appears at the beginning of the MAC frame, so once the address is recognized the frame is directly sent to the appropriate output line if the output buffer is empty (no need to buffer it). ➔ no buffering delay ➔ NO ERROR CHECKING

Isolated collision domains



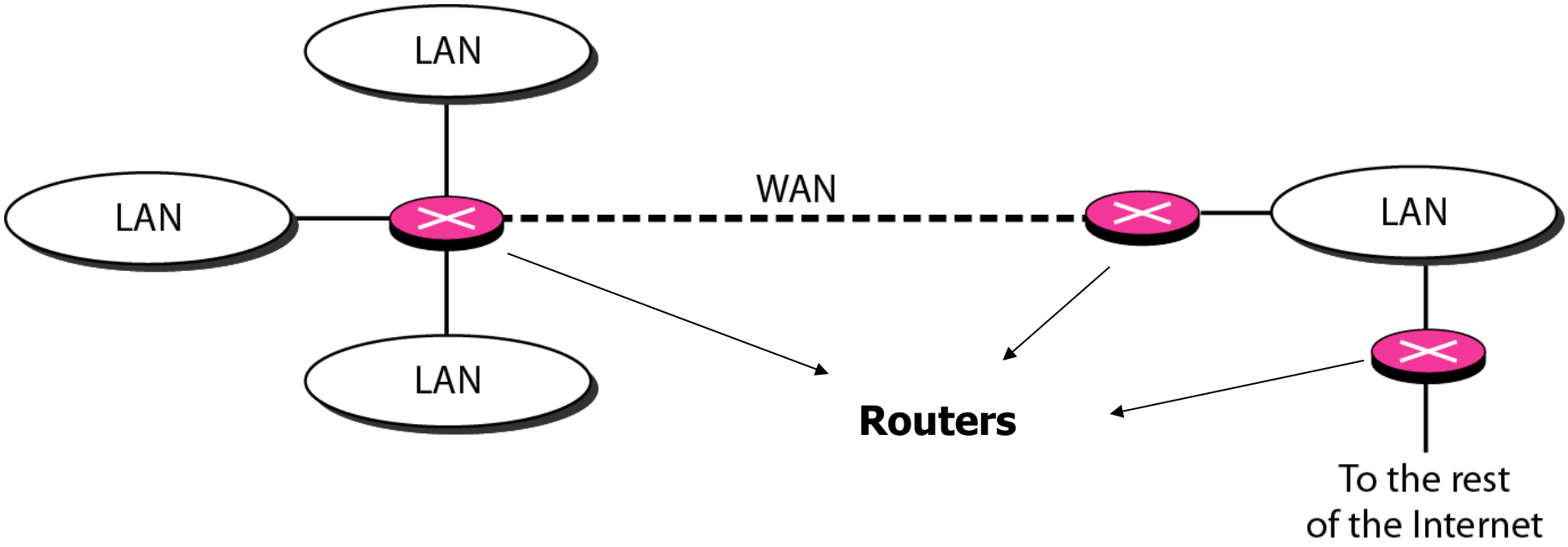
Full-Duplex operation



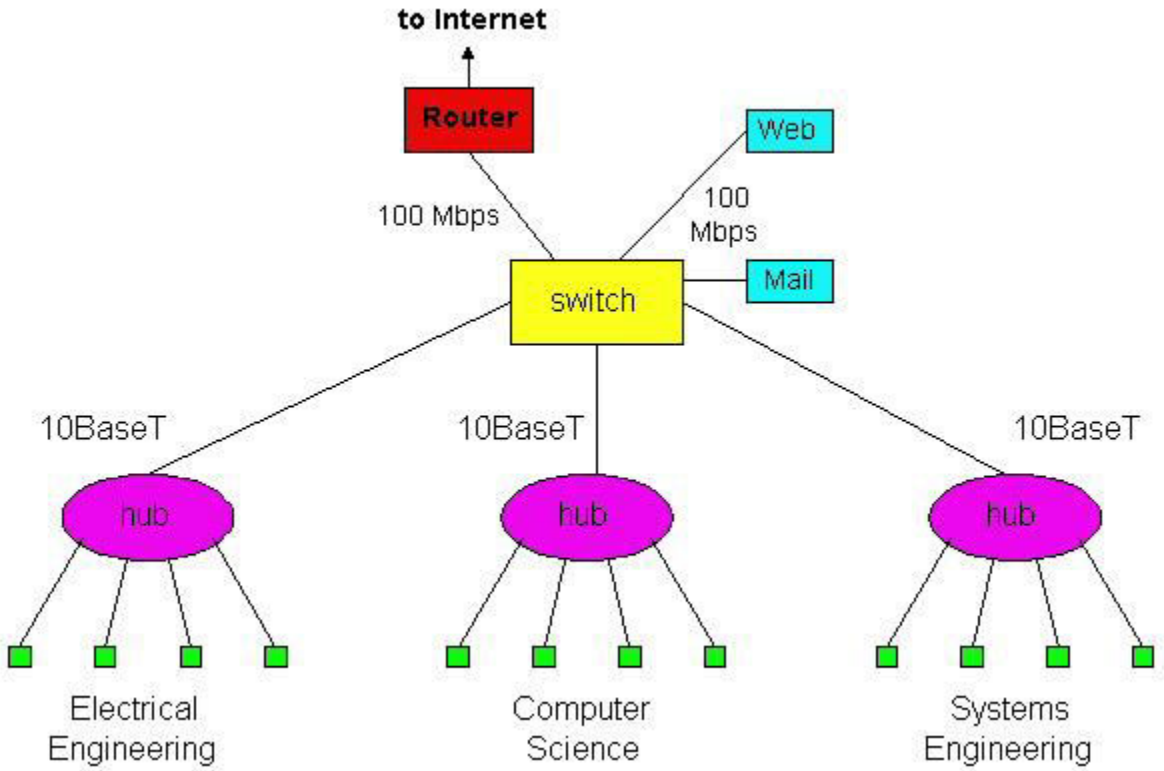
Routers

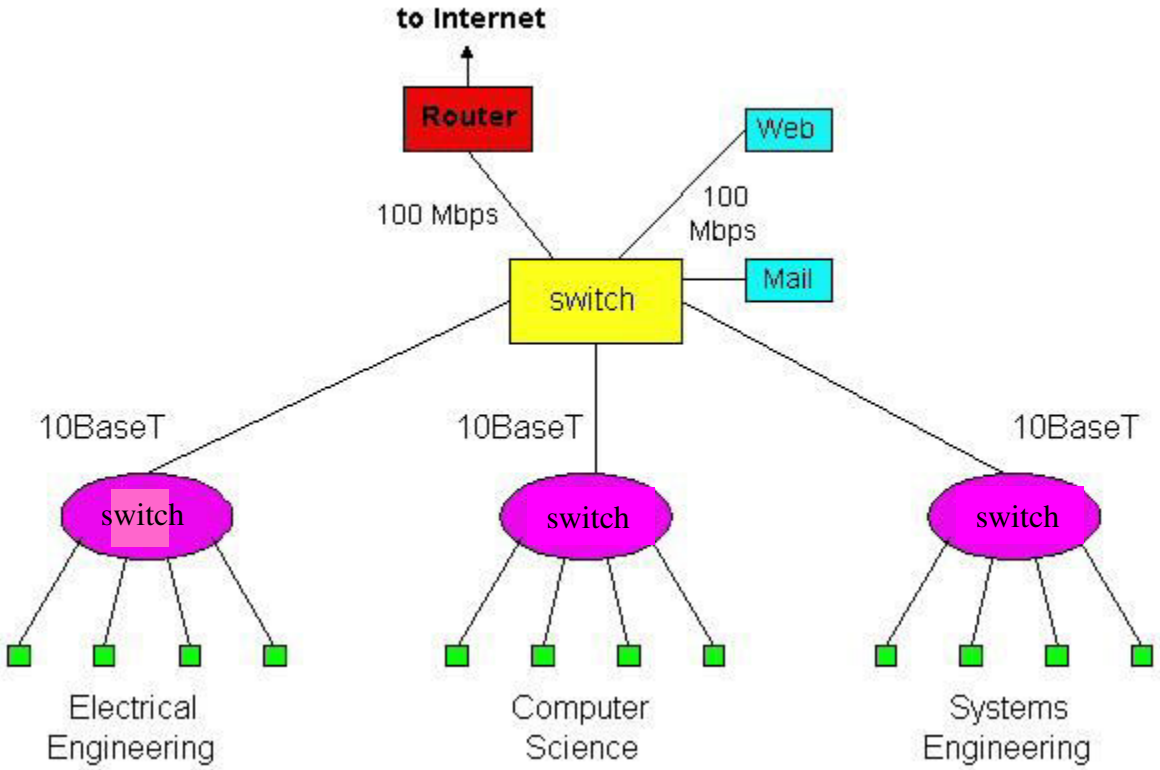
- Operates at network layer = deals with **packets** not **frames**
- Connect LANs and WANs with similar or different protocols together
- Switches and bridges **isolate collision domains** but forward broadcast messages to **all LANs** connected to them. Routers **isolate both** *collision* domains and *broadcast* domains
- Acts like normal stations on a network, but have **more than one** network address (an address to each connected network)
- Deals with global address (network layer address (IP)) not local address (MAC address)
- Routers **Communicate with each other** and exchange routing information
- Determine best route using **routing algorithm** by special software installed on them
- **Forward traffic if information on destination** is available otherwise **discard** it (not like a switch or bridge)

Figure 15.11 *Routers connecting independent LANs and WANs*



An Institutional Network Using Hubs, Ethernet Switches, and a Router

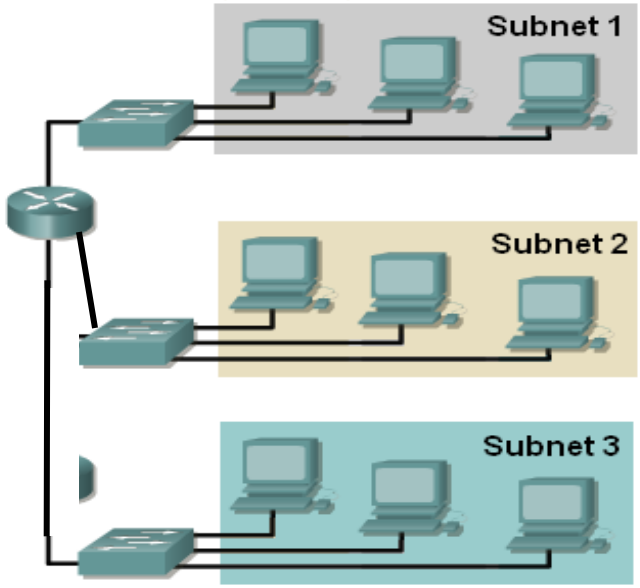




Summary comparison

	hubs	bridges	routers	switches
traffic isolation	no	yes	yes	yes
plug & play	yes	yes	no	yes
optimal routing	no	no	yes	no
cut through	yes	no	no	yes

15.3 Virtual LANs



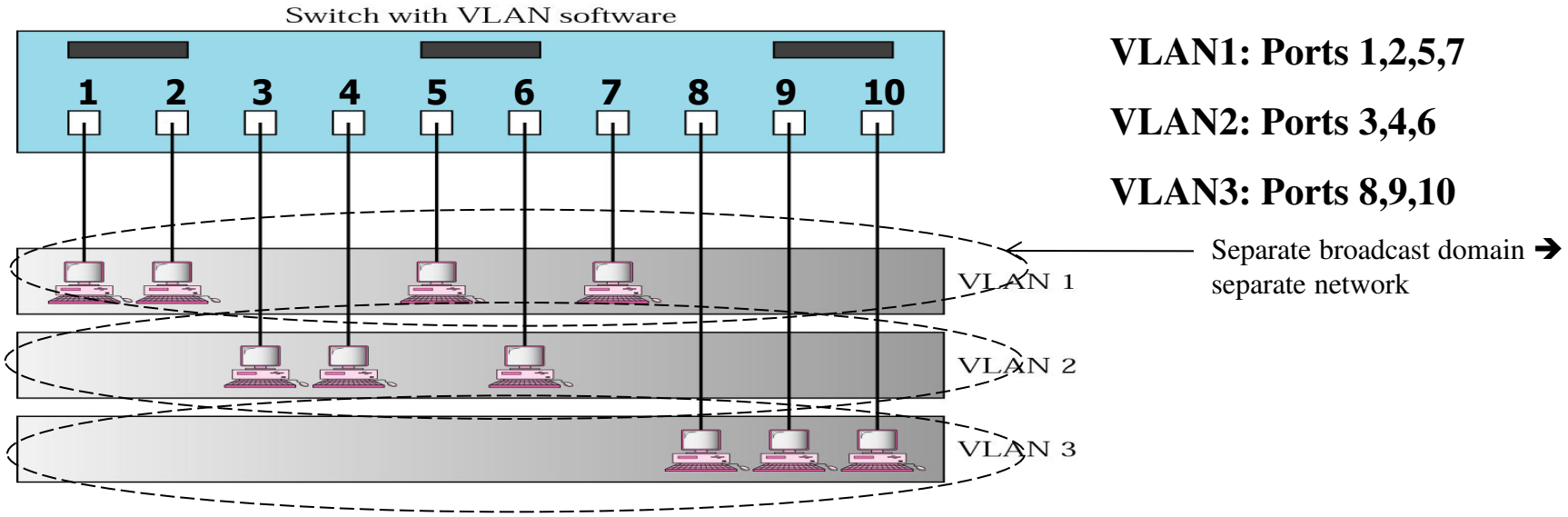
3 Collision domains
3 Broadcast domains

If we want to move computers from group1 to group3, then rewiring (physical replacement) has to be done

What is the alternative solution??

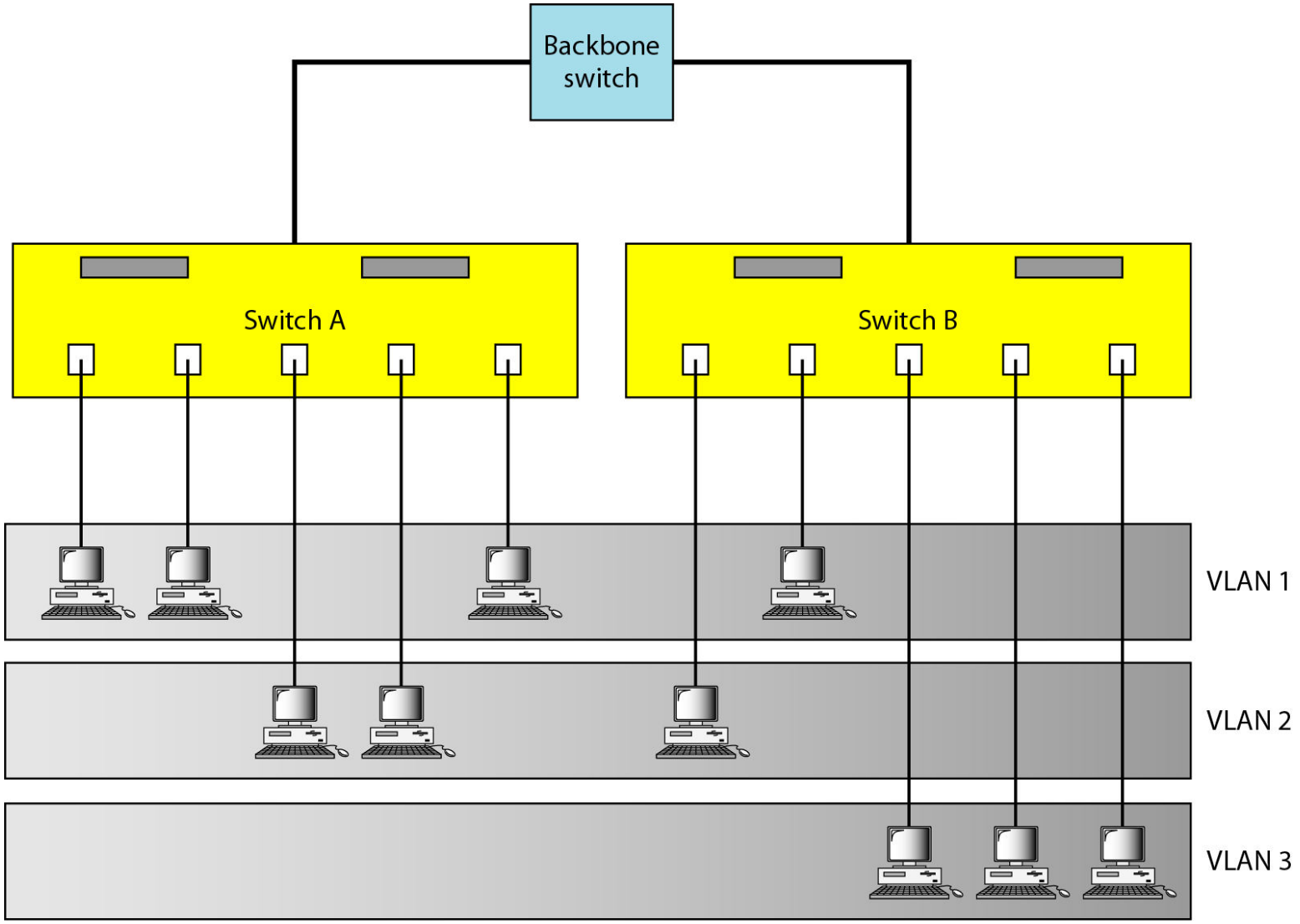
VLAN: Virtual (logical) Local Area Network : Local Area Network configured by **software** not by physical wiring

Figure 16.15 A switch using VLAN software



- Using the Virtual LAN technology will allow **grouping** computers **logically** instead of **physically**.
- VLAN divides the physical LAN into several **Logical LANs** called VLANs
- Switch maintains a look up table to know to which LAN a machine belongs to.

Figure 15.17 *Two switches in a backbone using VLAN software*



VLANs create broadcast domains.

Advantages Of VLAN

- **Reduce cost and installation time**:
  - Instead of **physically moving** a station to another segment or another switch, it can be moved by *software*.
- **Increase security**:
  - A group of users needing a high security can be put into a VLAN so that NO users outside the VLAN can communicate with them.
  - Stations belong to the same group can send **broadcast messages** that will NOT be received by users in others VLAN groups
- **Creating Virtual Workgroups**
  - Stations located at physically different locations can be added easily to the same broadcast domain so that they can send broadcast messages to one another.
    - EXAMPLE: people from different departments working on the same project