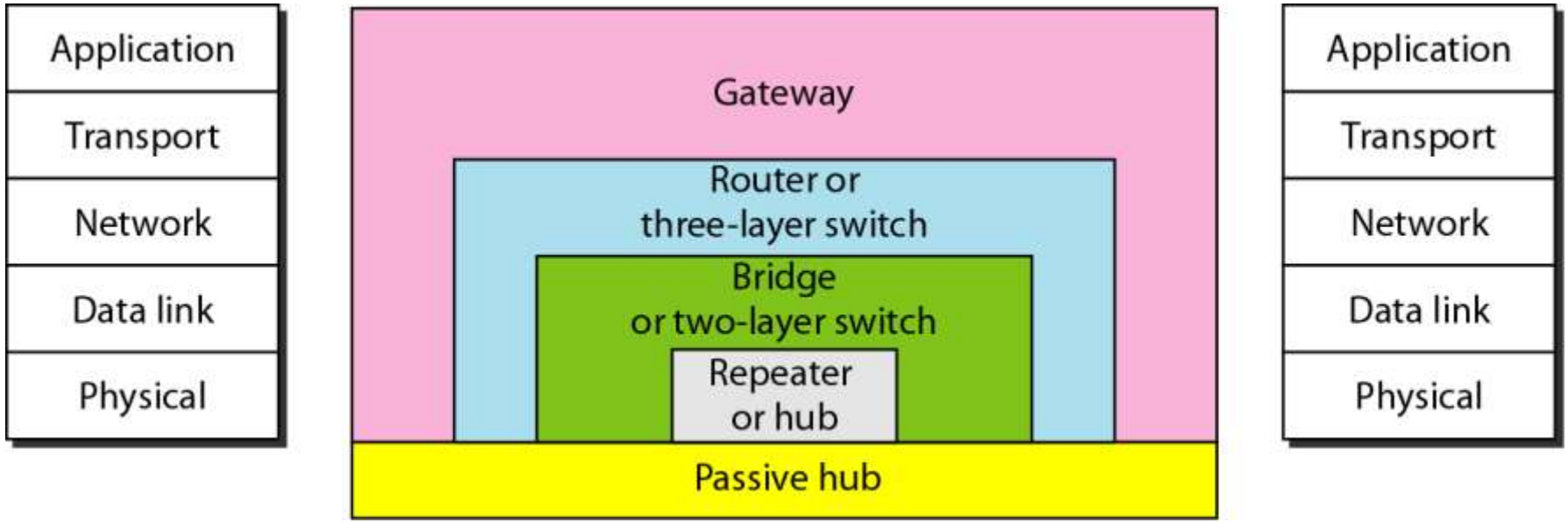
UNIT 5: Connectivity Devices

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

Figure 5.1 *Five categories of connecting devices*



Repeaters

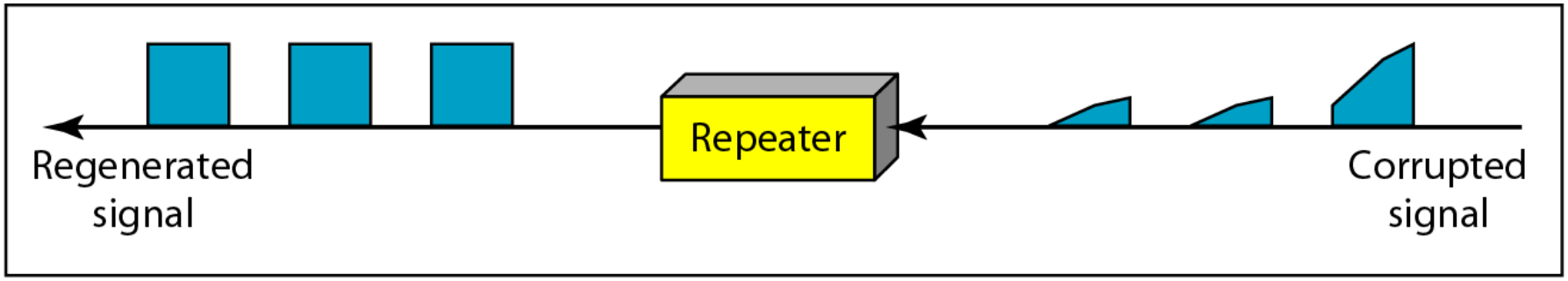
- A **physical layer** device that acts on **bits** not on **frames** or packets
- Can have two or more interfaces
- When a bit (0,1) arrives, the repeater receives it and **regenerates** it, the transmits it onto all other interfaces
- Used in LAN to **connect cable segments** and **extend** the **maximum 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

Repeaters

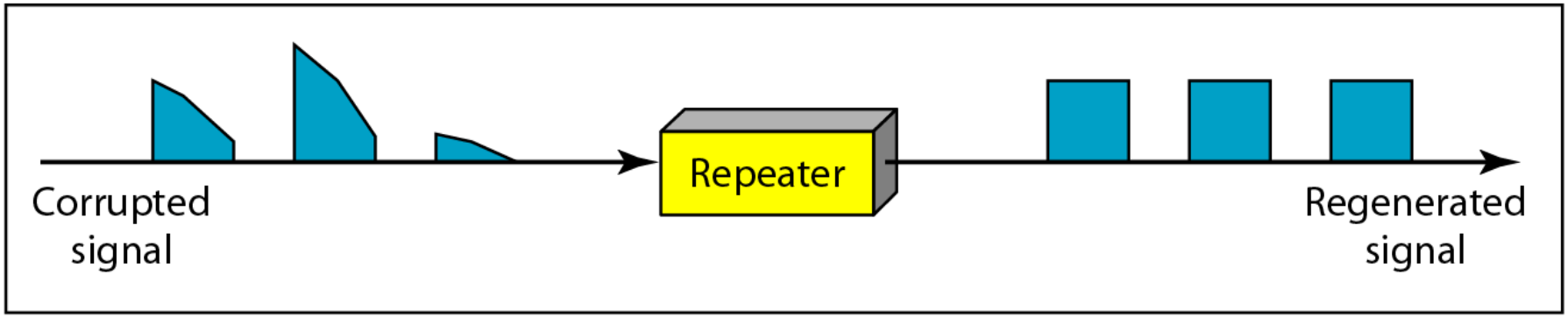
Important features of a repeater are as follows:

- A repeater connects different segments of a LAN
- A repeater forwards every frame it receives
- A repeater is a regenerator, not an amplifier
- It can be used to create a single extended LAN

Figure 5.2 *Function of a repeater*

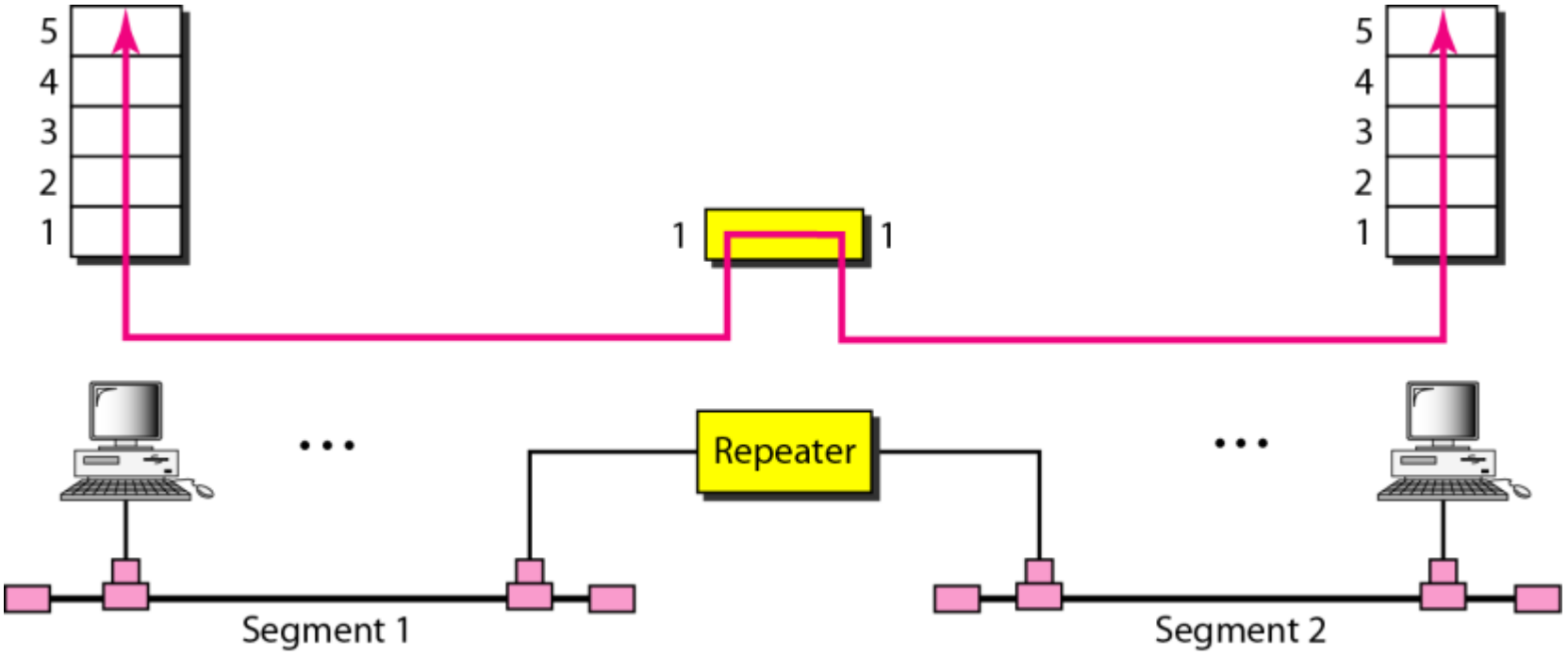


a. Right-to-left transmission.



b. Left-to-right transmission.

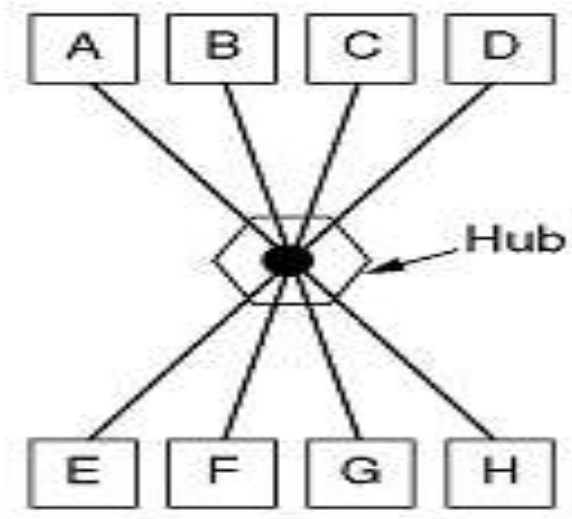
Figure 5.3 *A repeater connecting two segments of a LAN*

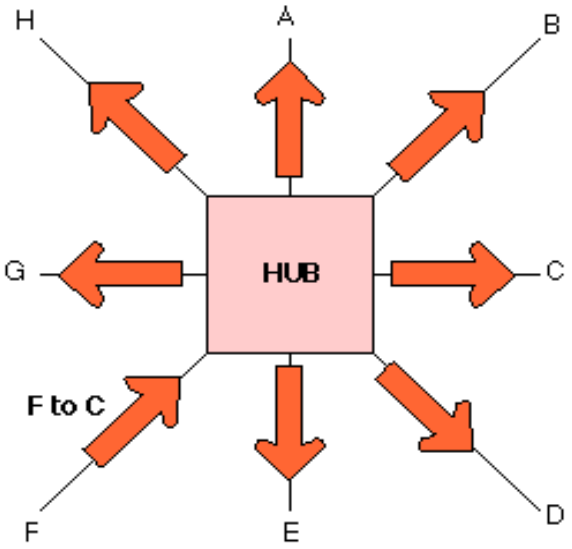


Hubs

- 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

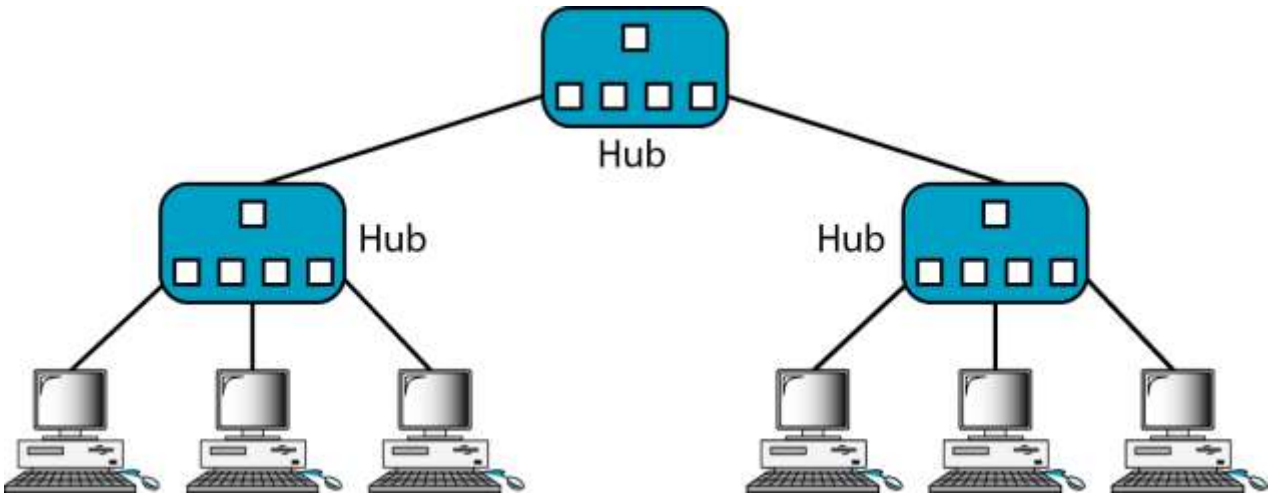
Figure 5.4 Hubs





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

- 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

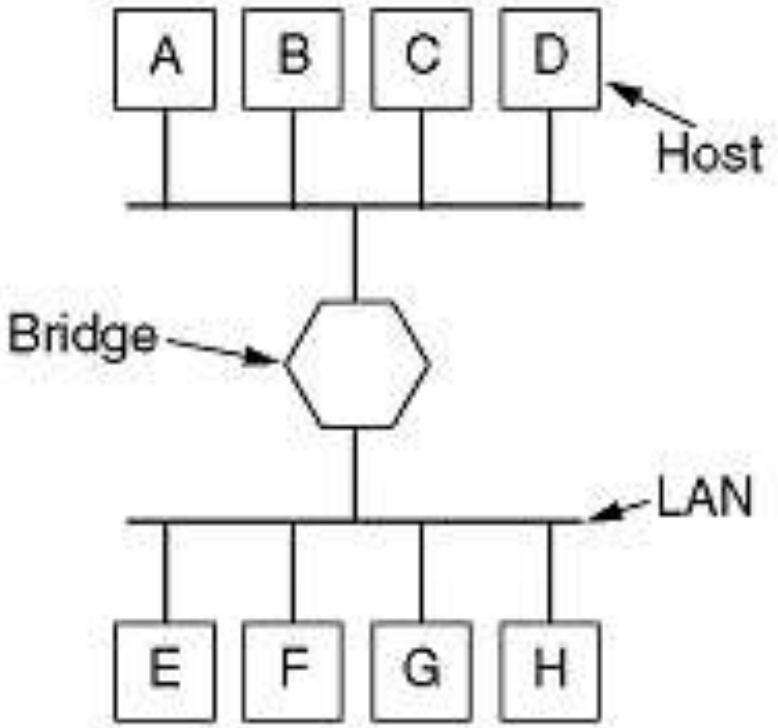
Key features of a bridge are mentioned below:

- A bridge operates both in physical and data-link layer
- A bridge uses a table for filtering/routing
- A bridge does not change the physical (MAC) addresses in a frame
- A bridge must contain addressing and routing capability
- Types of bridges:

  i) Transparent Bridges: produced as an extension of IEEE 802.1 and applicable to all IEEE 802 LANs

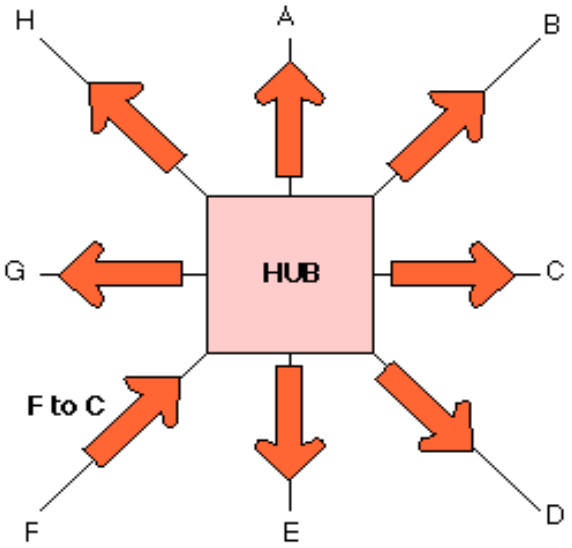
  ii) Source routing bridges: developed for the IEEE 802.5 token rings, is based on source routing approach. It applies to many types of LAN including token ring, token bus and CSMA/CD bus

Bridges

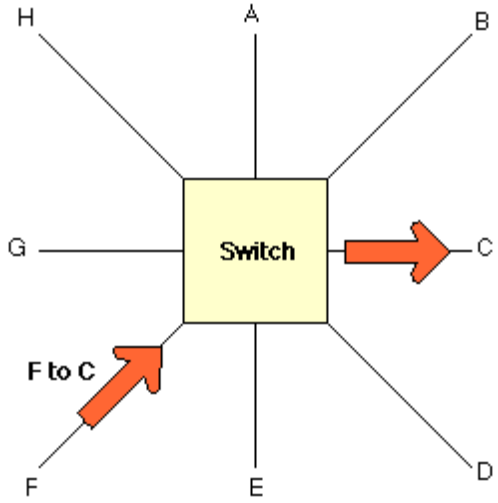


Connecting two or more LAN segments together

Bridges (Switches) Vs. Hubs

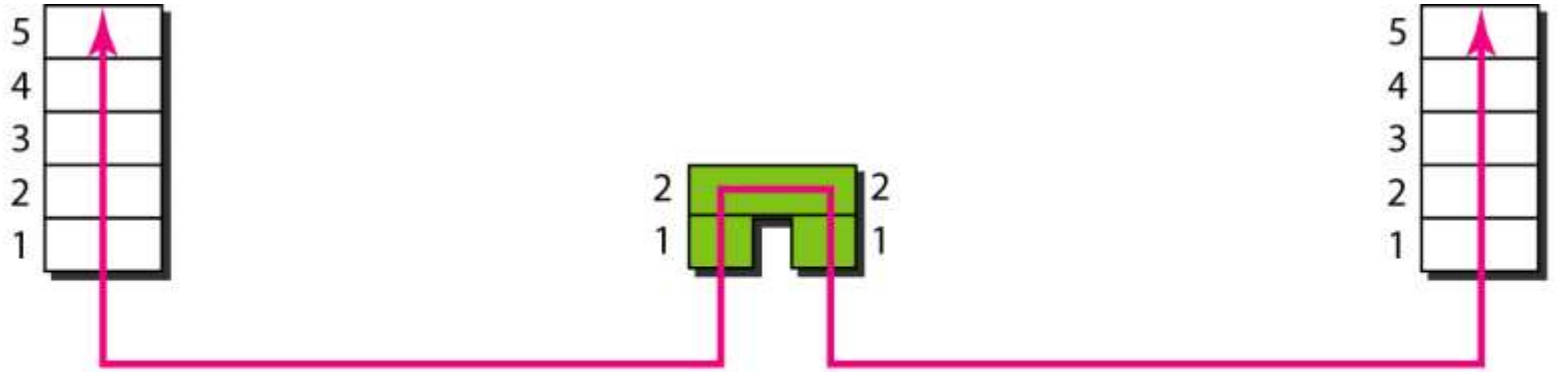


A Hub sending a packet form F to C.



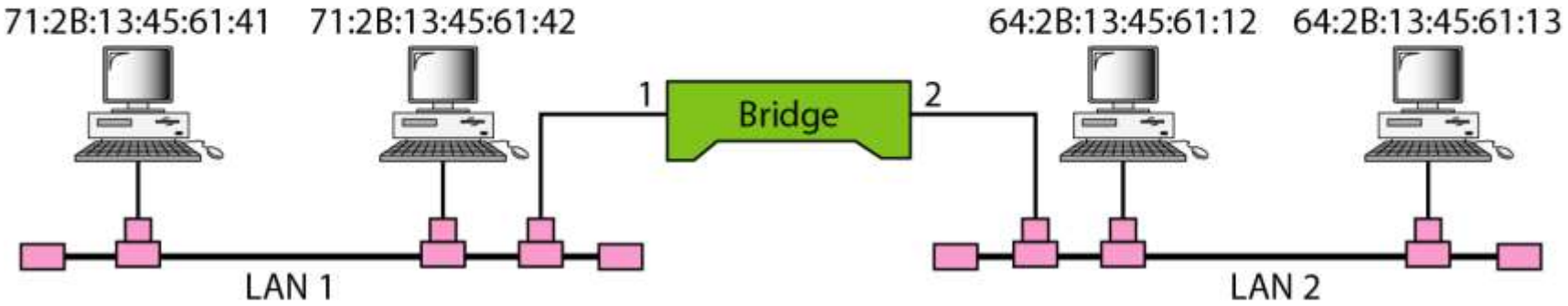
A Switch sending a packet from F to C

Figure 5.5 *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

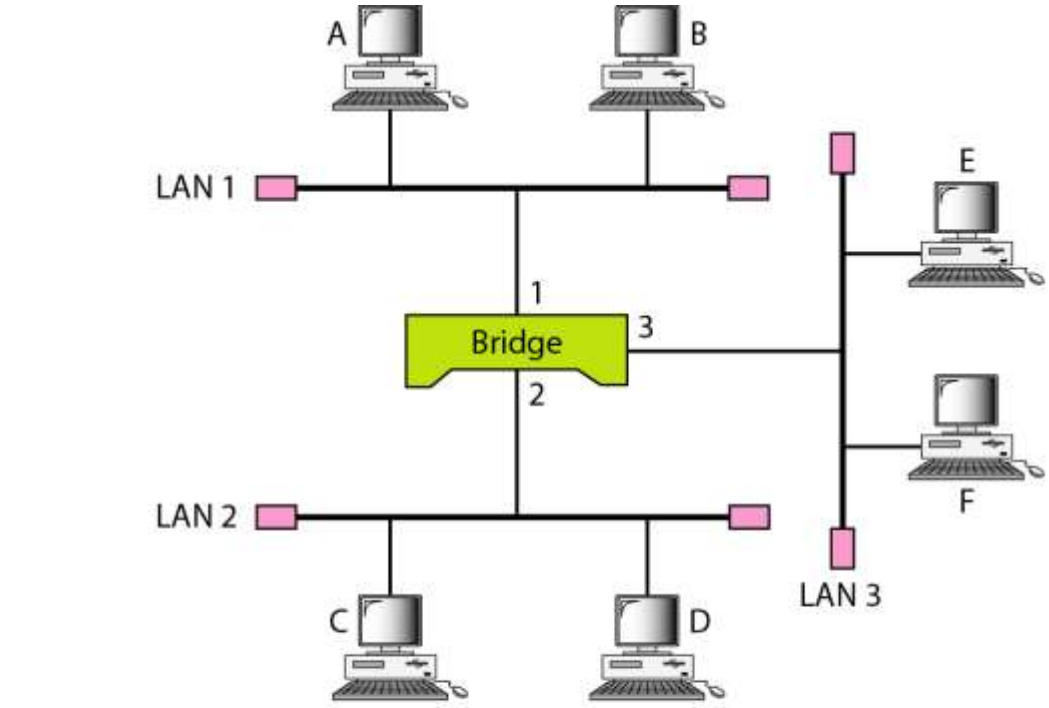
Bridge Table



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 5.6 *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

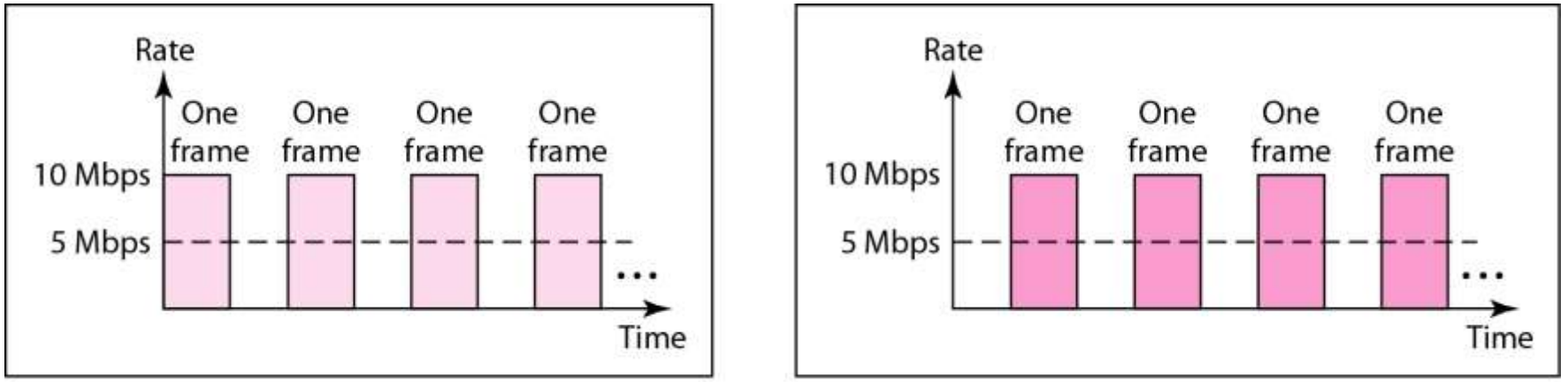
Address	Port
A	1
E	3
B	1

d. After B sends a frame to C

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 5.7 *Sharing bandwidth*

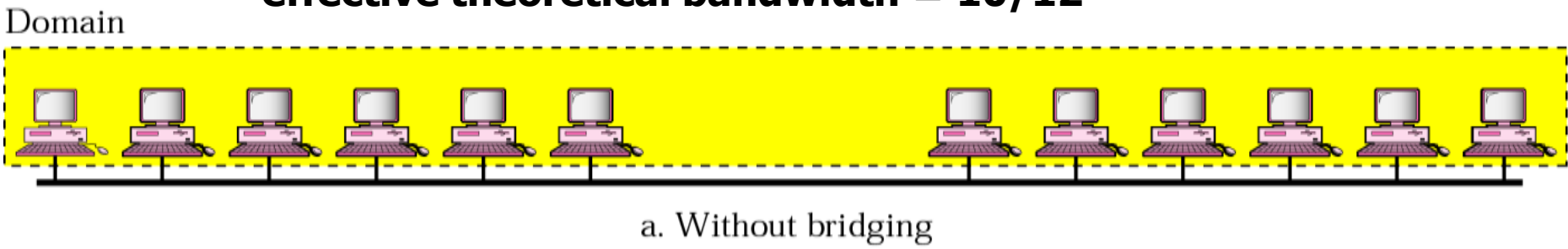


a. First station

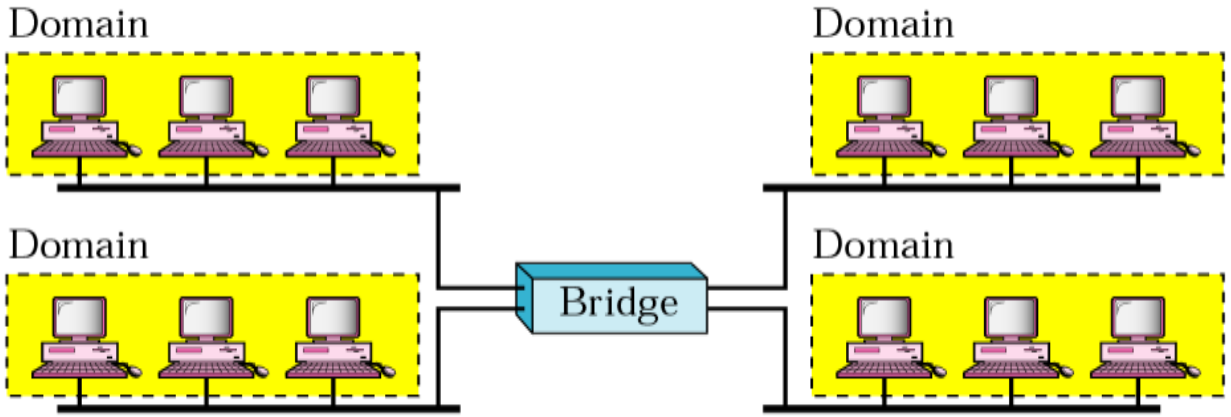
b. Second station

Collision domains in a nonbridged and bridged network

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

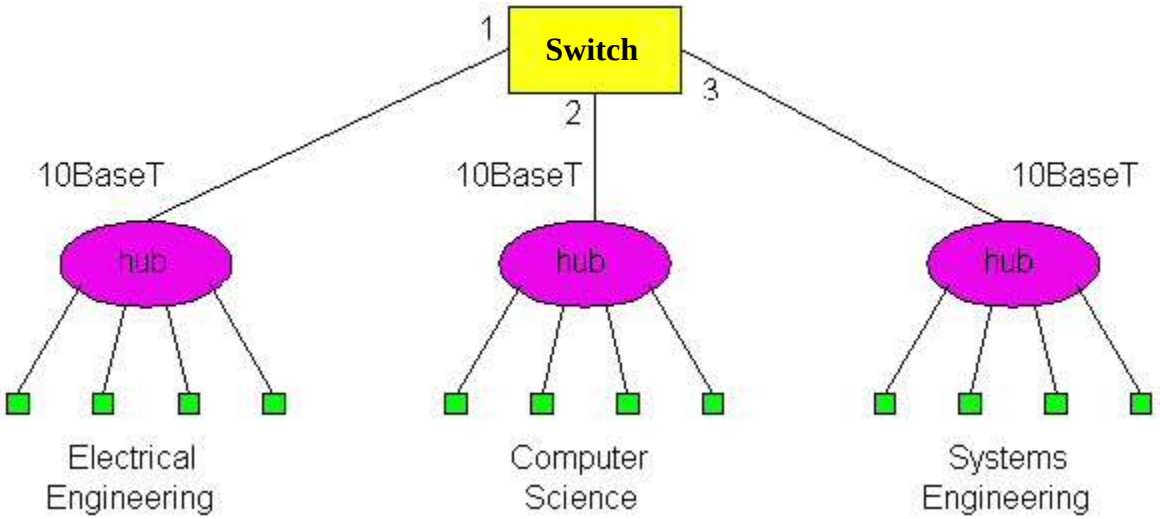


a. Without bridging



b. With bridging

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

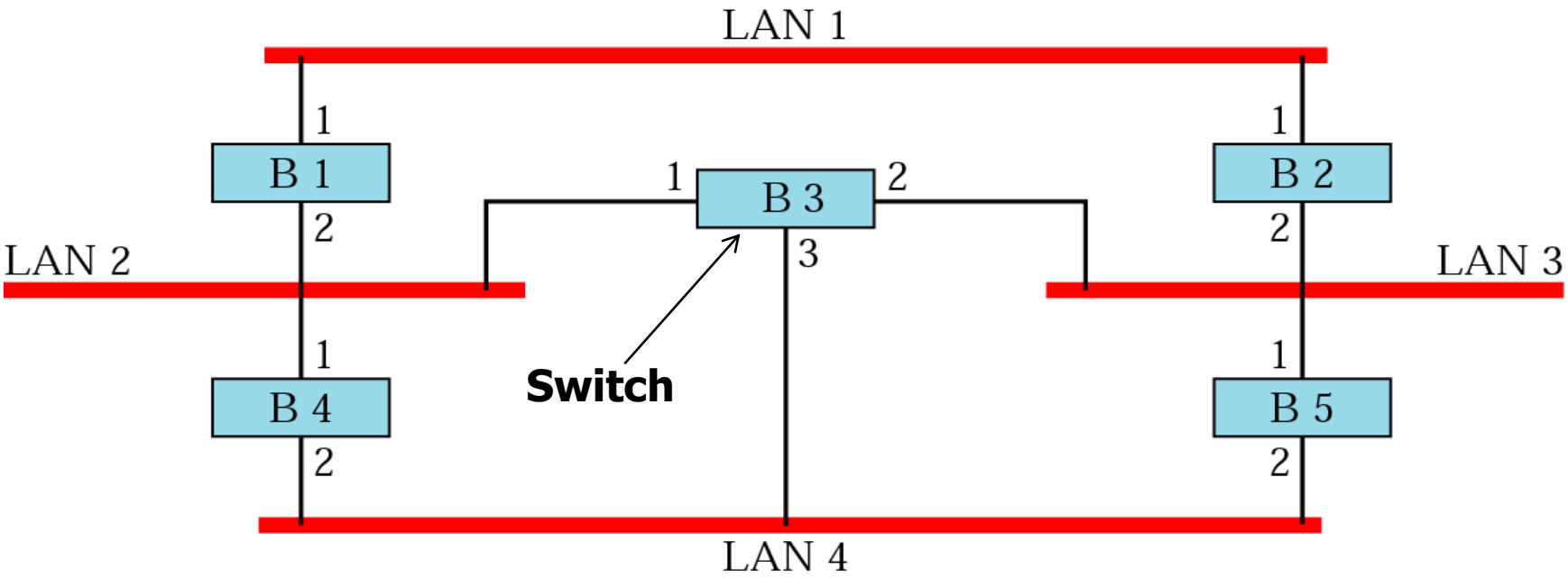


Example:

Three LANs connected through a bridge

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

Figure 5.8 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

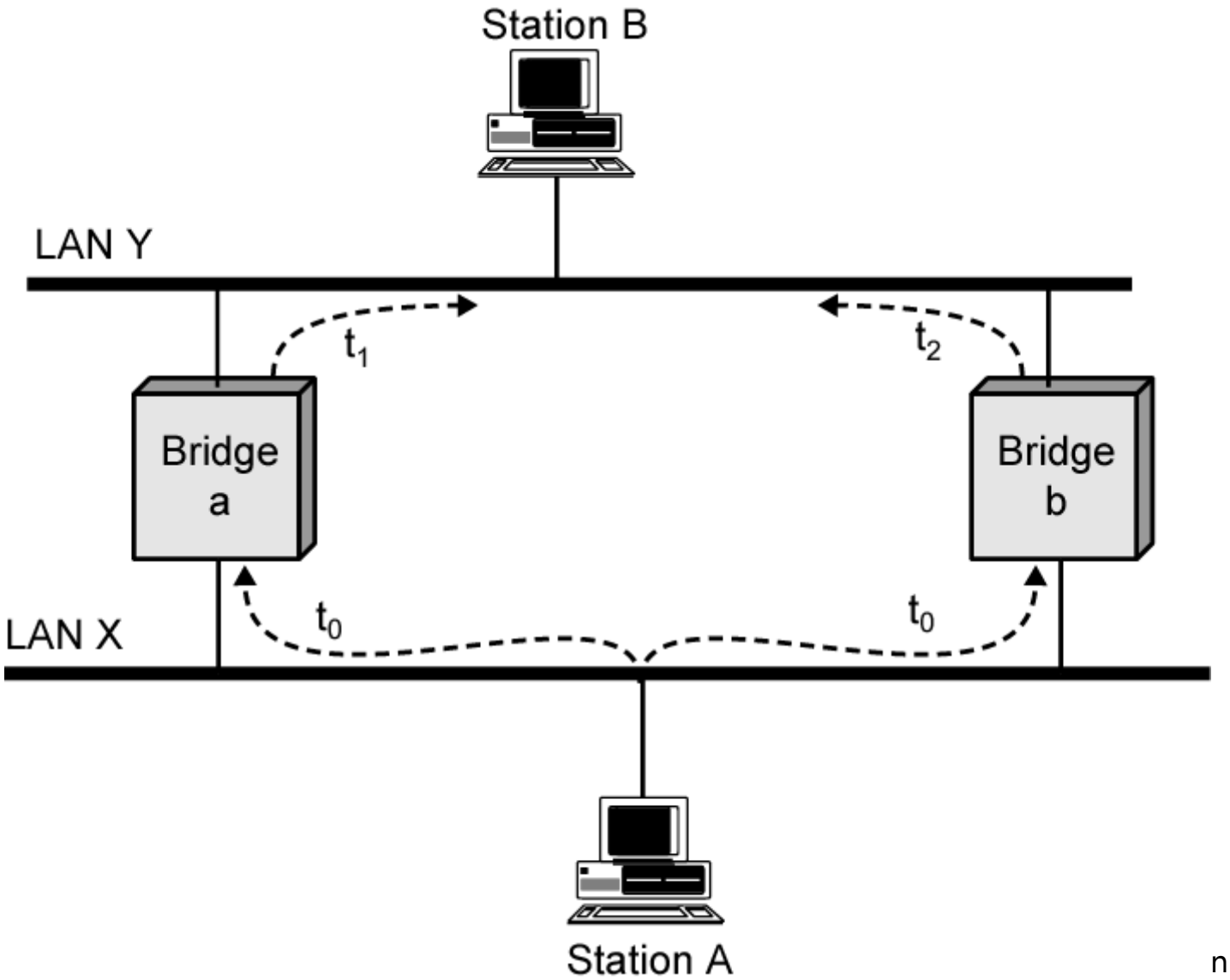
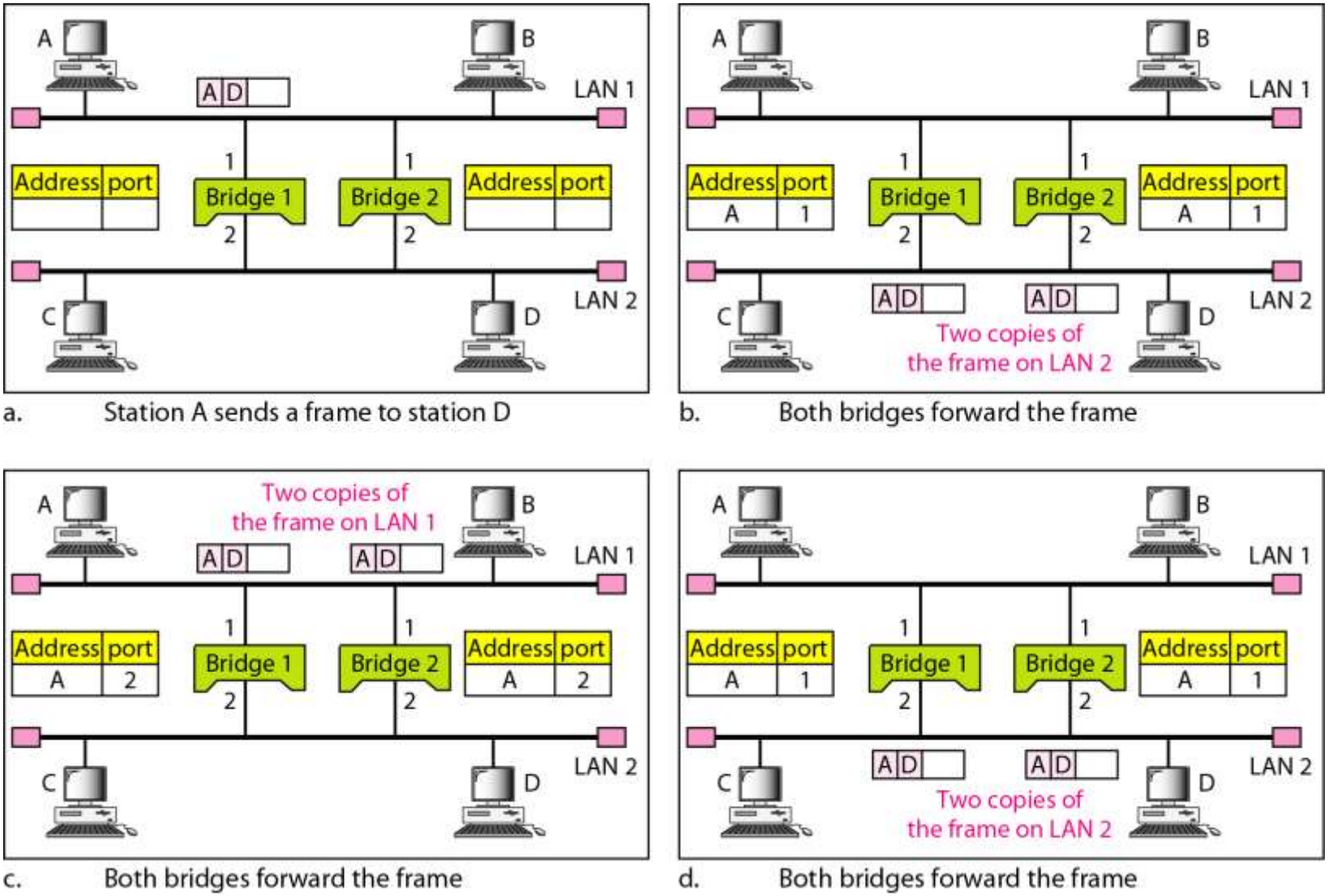


Figure 5.9 *Loop problem in a learning switch*



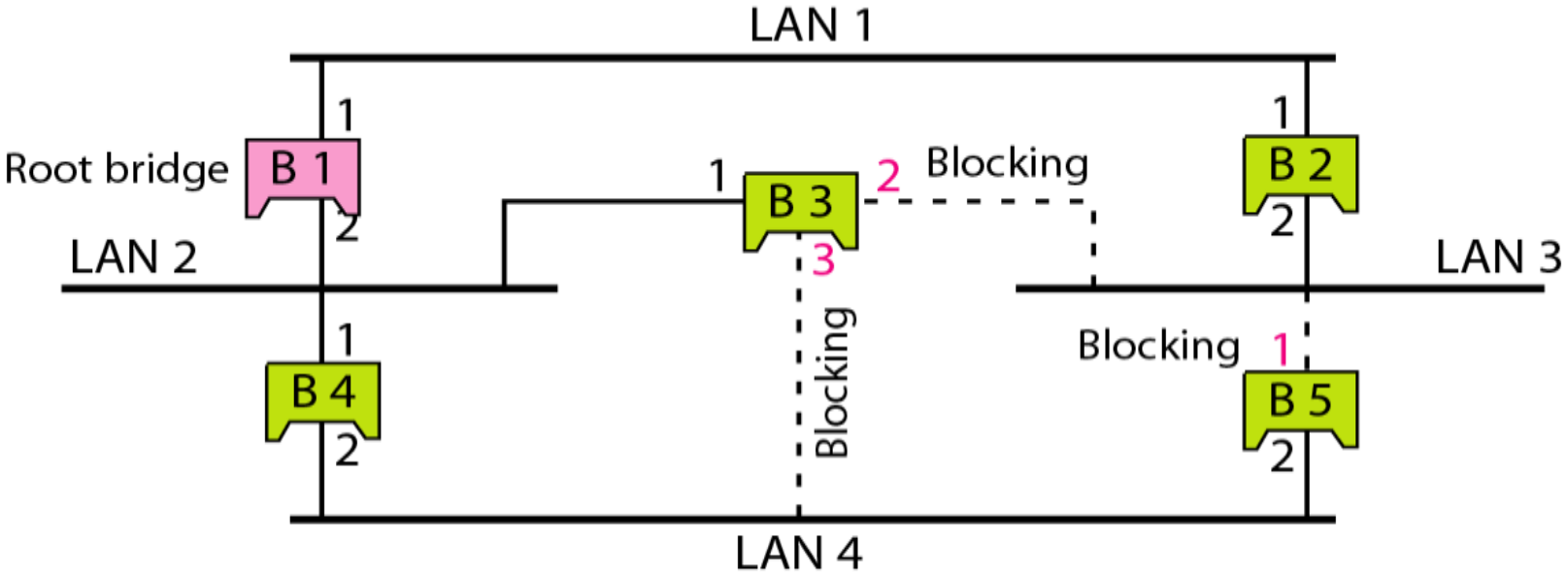
a. Station A sends a frame to station D

b. Both bridges forward the frame

c. Both bridges forward the frame

d. Both bridges forward the frame

Figure 5.10 *Forwarding and blocking ports after using spanning tree algorithm*



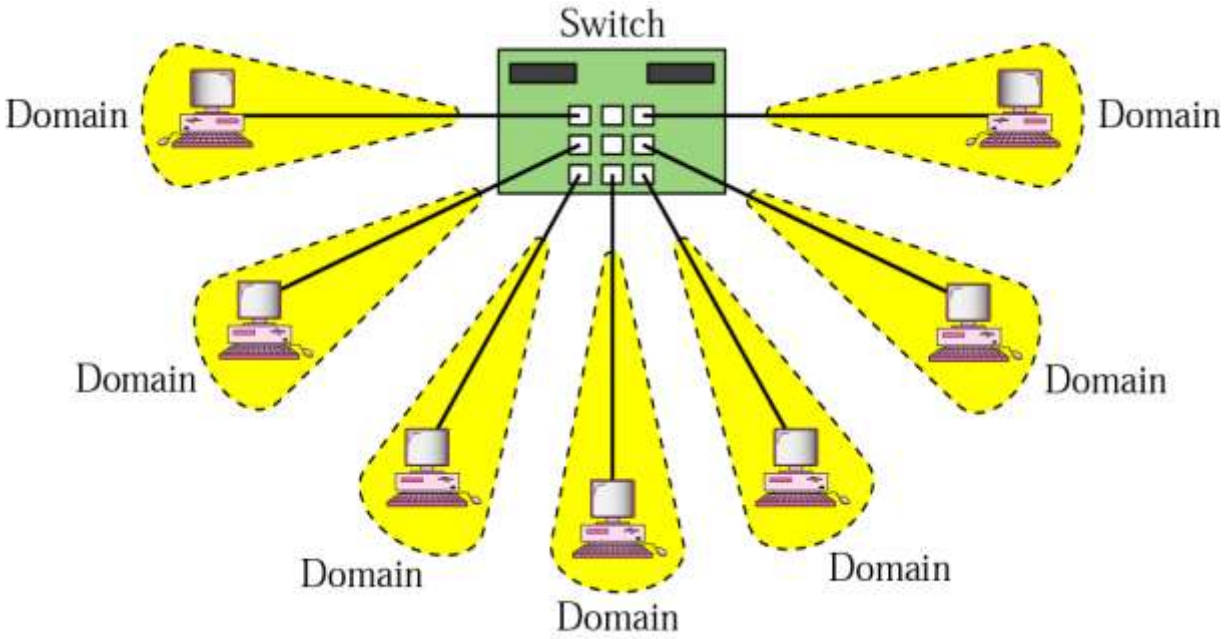
Ports 2 and 3 of bridge B3 are blocking ports (no frame is sent out of these ports). Port 1 of bridge B5 is also a blocking port (no frame is sent out of this port).

- 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

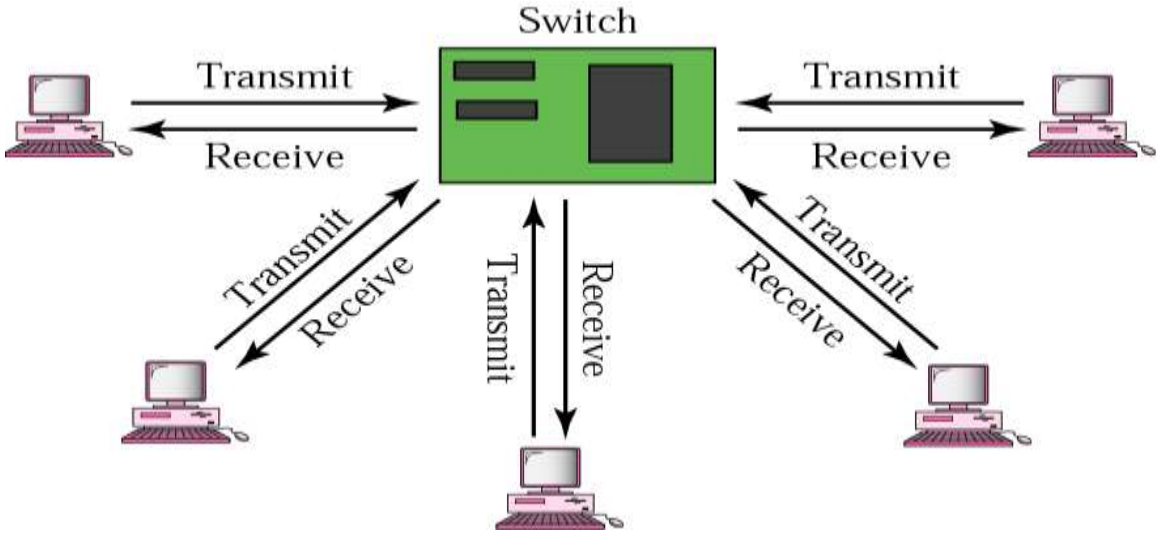
Switches

- 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



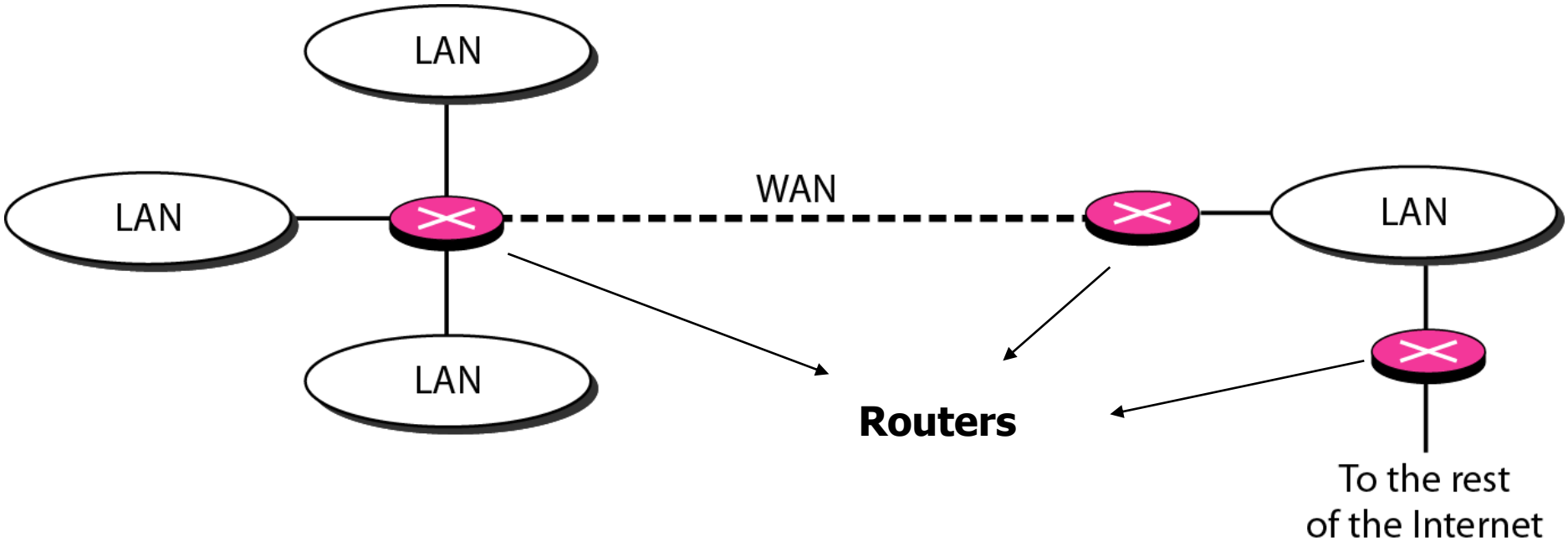
Full-Duplex operation



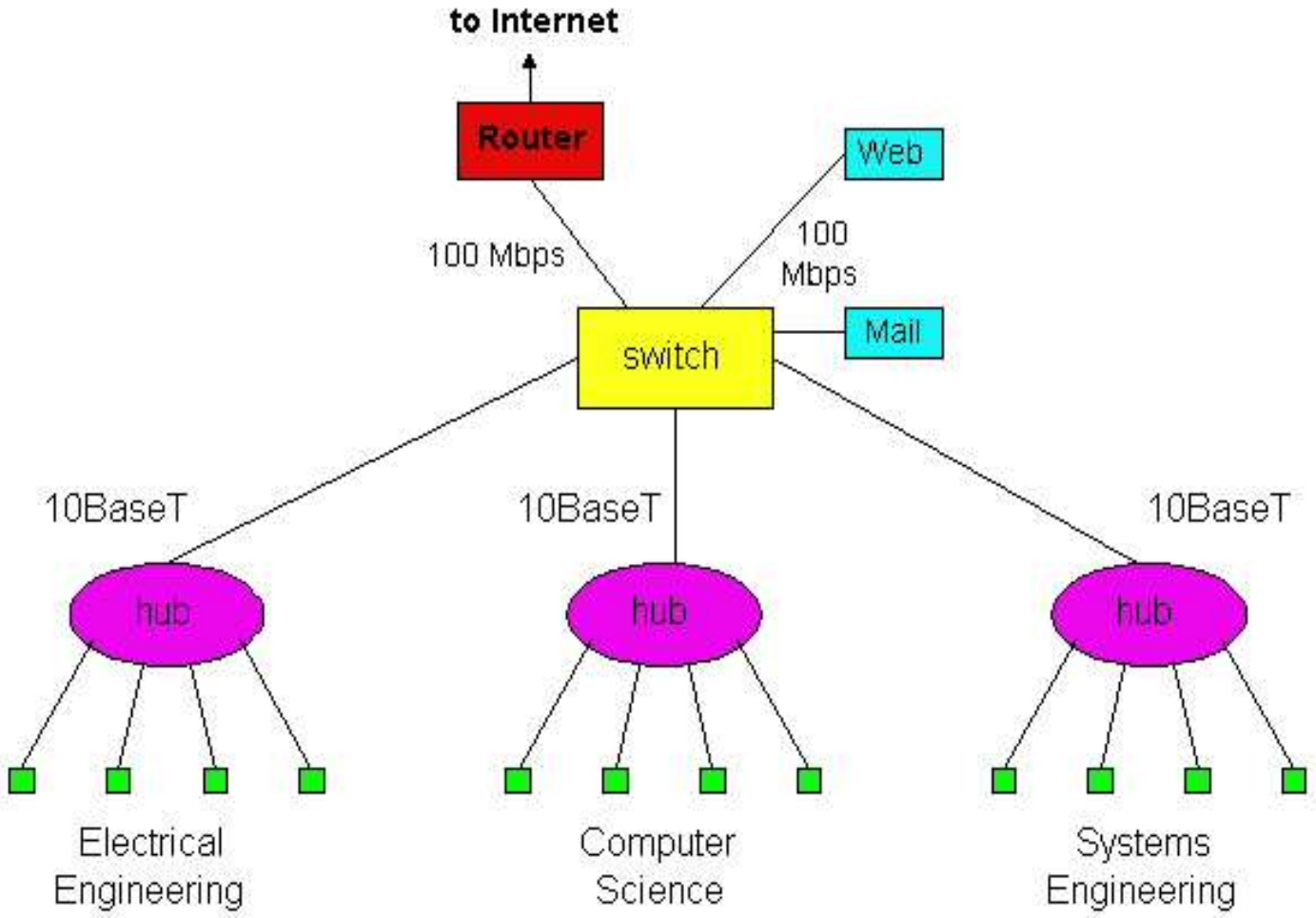
Routers

- 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 5.11 *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

Gateways

- A gateway works above the network layer, such as application layer. As a consequence, it is known as a Layer-7 relay.
- The application level gateways can look into the content application layer packets such as email before forwarding it to the other side. This property has made it suitable for use in Firewalls.

Queries

Q1. Why a repeater is called level-1 relay?

Ans: A repeater operates in the physical layer. Data received on one of its ports is relayed on the remaining port bit-by-bit without looking into the contents. That is why repeater is called a level-1 relay.

Q2. What is bridge? How it operates in the internetworking scenario?

Ans: A bridge operates in the Data link layer. It looks into various fields of a frame to take various actions. For example, it looks at the destination address field so that it can forward the frame to a port where destination stations is connected. It also looks at the FCS field to check error in the received frame, it any. A bridge helps to create a network having different collision domains.

Queries

Q3. Why spanning tree topology is necessary for routing using a bridge?

Ans: If there exit more than one path between two LANs through different bridges, there is a possibility of continuous looping of a frame between the LANs. To avoid the loop problem, spanning tree topology is used. It is essentially an overlay of tree topology on the physical graph topology, providing only one path between any two LANs.

Q4. What is discovery frame?

Ans: In the source routing protocol, a host can discover a route by sending a *discovery frame, which spreads through the entire network using all possible paths to the destination. Each frame gradually gathers addresses as it goes. The destination responds to each frame and the source host chooses an appropriate route from these responses.*

Queries

Q5. What limitation of transparent bridge protocol is overcome by the source routing protocol?

Ans: Transparent bridge protocol uses spanning tree algorithm, where a unique path is used for communication between two stations. As a consequence, it does not make use of other paths leading to lesser utilization of network resources. This problem is overcome in source routing algorithm.

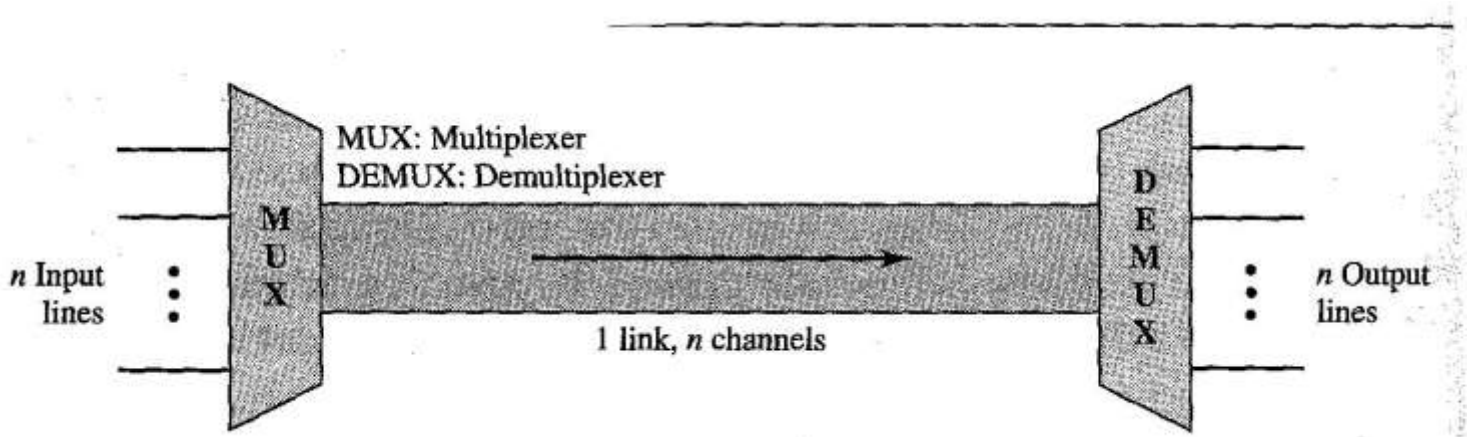
Q6. What limitations of a bridge are overcome by a router?

Ans: A router overcomes the following limitations of a bridge:

- Linking of two dissimilar networks
- Routing data selectively and efficiently
- Enforcement of security
- Vulnerability to broadcast storm

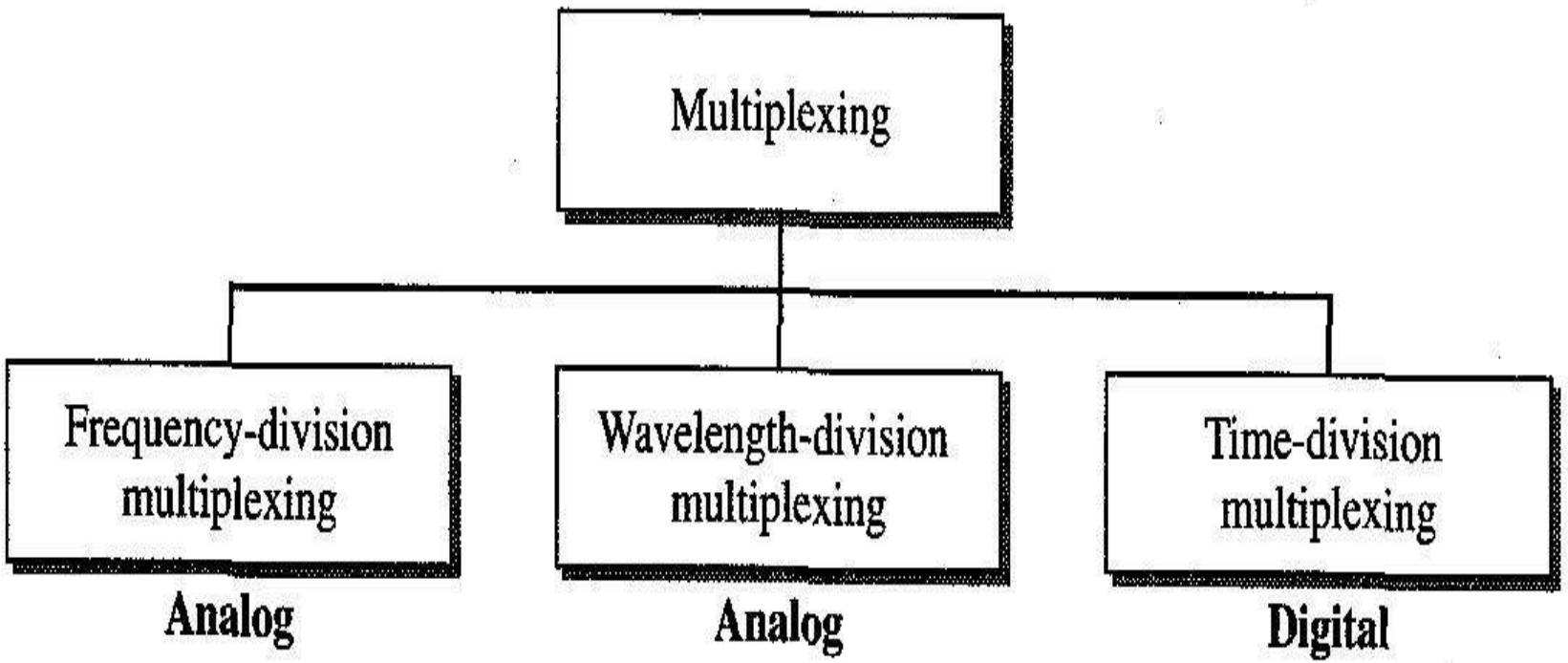
Multiplexing: allows simultaneous transmission of multiple signals across a single data link to gain efficiency

- Bandwidth is one of the most precious resources in communication
- Link refers to the physical path
- Channel refers to portion of a link that carries transmission between a given pair of lines



Categories of multiplexing

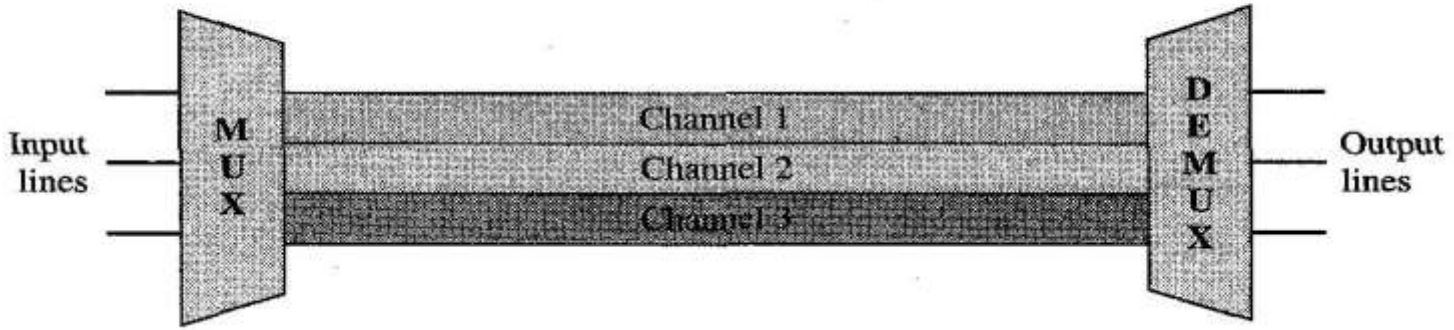
FDM & WDM are for analog signals, while TDM is for digital signals



Frequency Division Multiplexing

- Signals generated by each sending device modulate different carrier frequencies
- These modulated signals then combined into a single composite signal that can be transported by the link

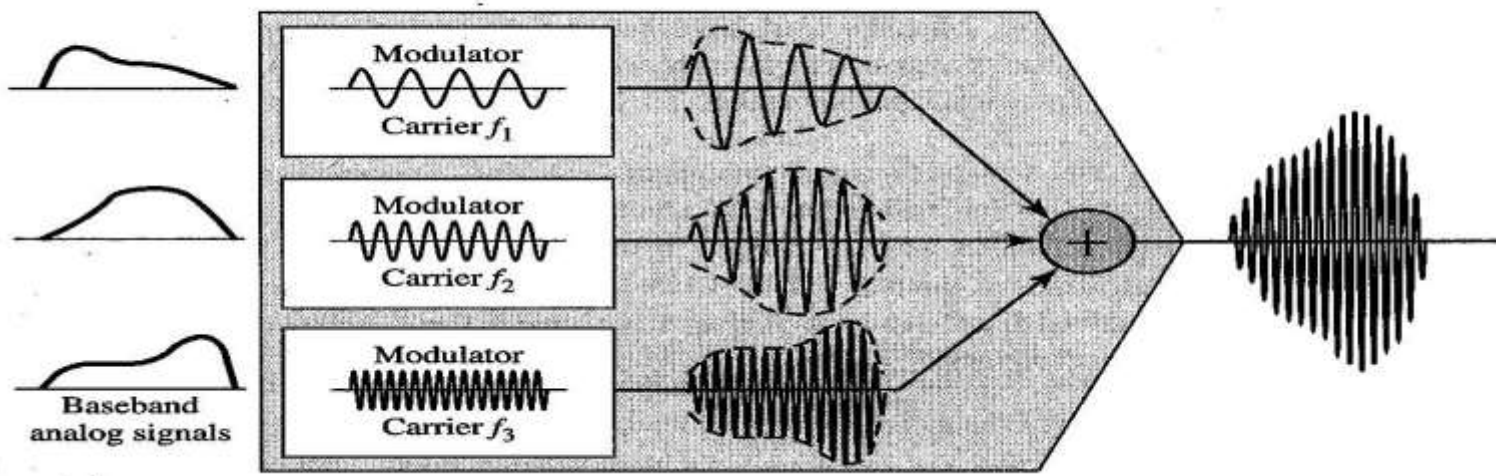
6.3 *Frequency-division multiplexing*



FDM multiplexer view

- Each source generates a signal of a similar frequency range
- These similar signals modulate different carrier frequencies (f1,f2,f3)
- Resulting modulated signals are combined into a single composite signal

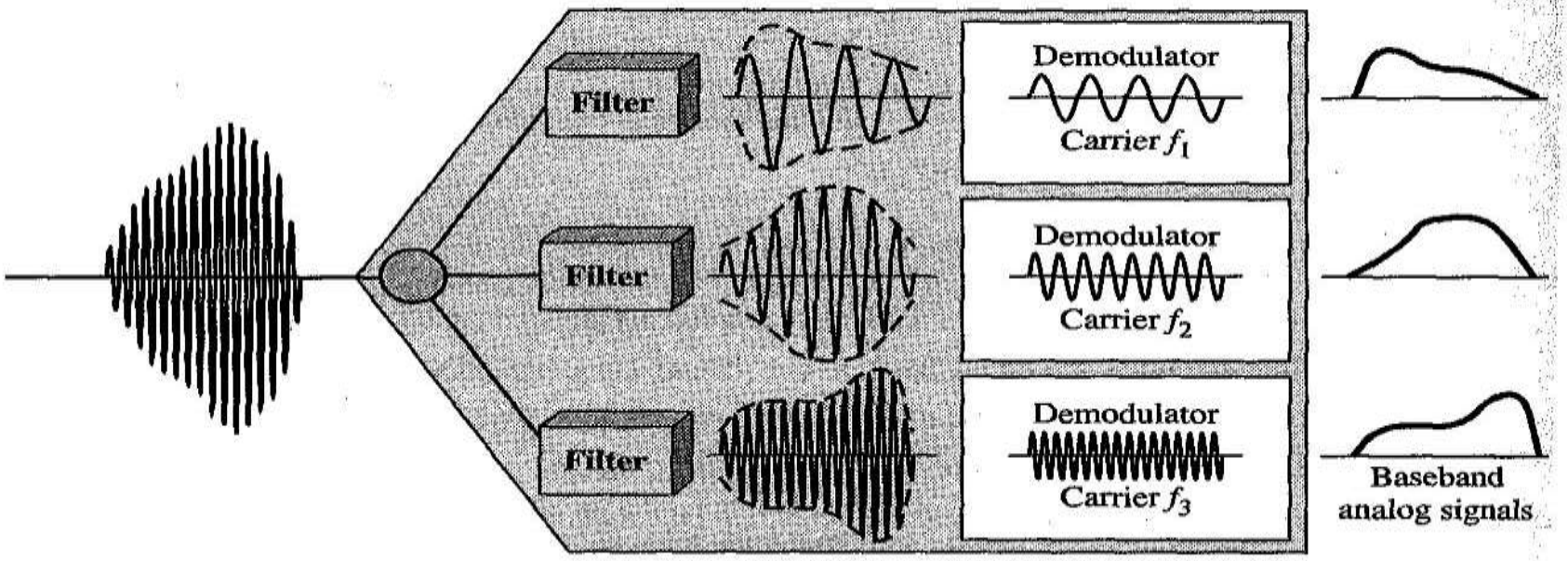
re 6.4 *FDM process*



FDM Demultiplexing

- Filters are used to decompose multiplexed signal into its component signals
- Individual signals are separated from their carriers and passed to output lines

gure 6.5 *FDM demultiplexing example*



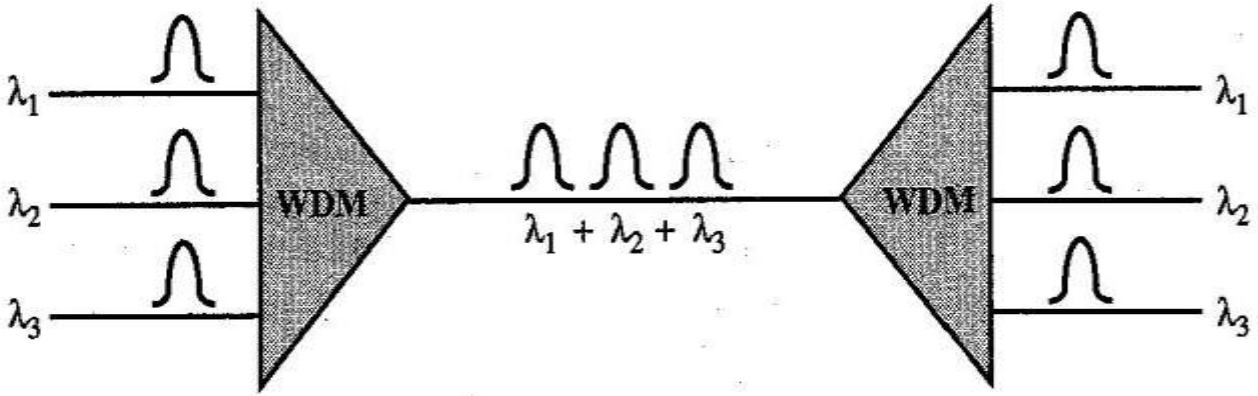
Applications of FDM

- AM Radio: Assigned band from 530 to 1700 KHz. Each AM station needs 10 KHz BW. Each station uses a different carrier frequency.
- Without multiplexing, only one AM station could broadcast to the air
- FM Radio: Wider band of 88 to 108 MHz, each having BW of 200 KHz
- TV Broadcasting: Each TV channel has BW of 6 MHz

Wavelength Division Multiplexing

- Used for high data rate capability of OFC
- It is same as FDM, except that mux & demux involve optical signals through OFC
- Application is SONET (Synchronous Optical Network), a WAN to carry n/w traffic from other WANs

Figure 6.10 *Wavelength-division multiplexing*



Time Division Multiplexing

It is a digital process in which each process occupies a portion of time in link.

All the data in a message from source 1 always go to one specific destination, be it 1,2,3,4

It is divided in 2 schemes: synchronous & statistical TDM