EC 553
Communication Networks

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Syllabus

- Tentatively

Week 1	Overview
Week 2	Packet Switching
Week 3	IP addressing and subnetting
Week 4	IP addressing and subnetting
Week 5	Introduction to Routing concept, Routing algorithms
Week 6	Routing protocols
Week 7	Multiple Access I
Week 8	Multiple access II
Week 9	LAN networks
Week 10	Token ring networks
Week 11	VOIP
Week 12	WLAN
Week 13	TCP
Week 14	Congestion control
Week 15	QOS

Chapter 16

Connecting LANs, and Backbone Networks

16.1 Connecting Devices

Repeaters

Hubs

Bridges

Two-Layer Switches

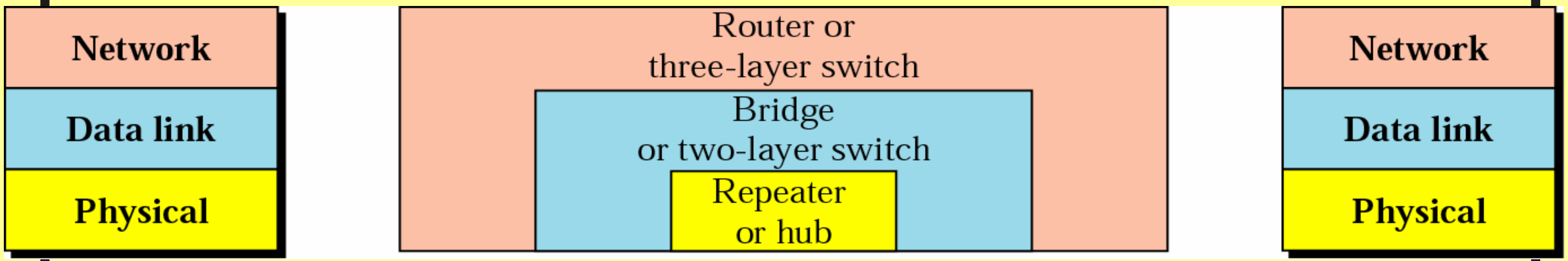
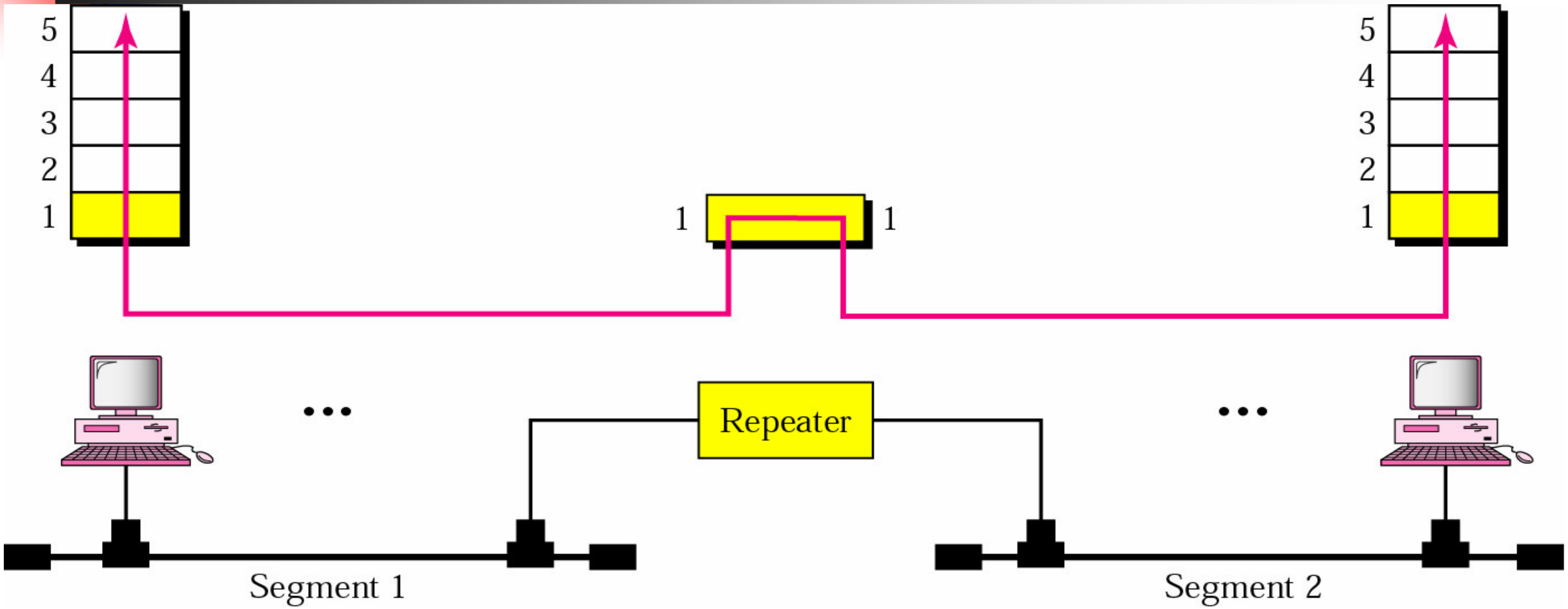


Figure 16.2 Repeater



A repeater connects segments of a LAN. Repeaters are regenerative tools

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

Figure 16.4 Hubs

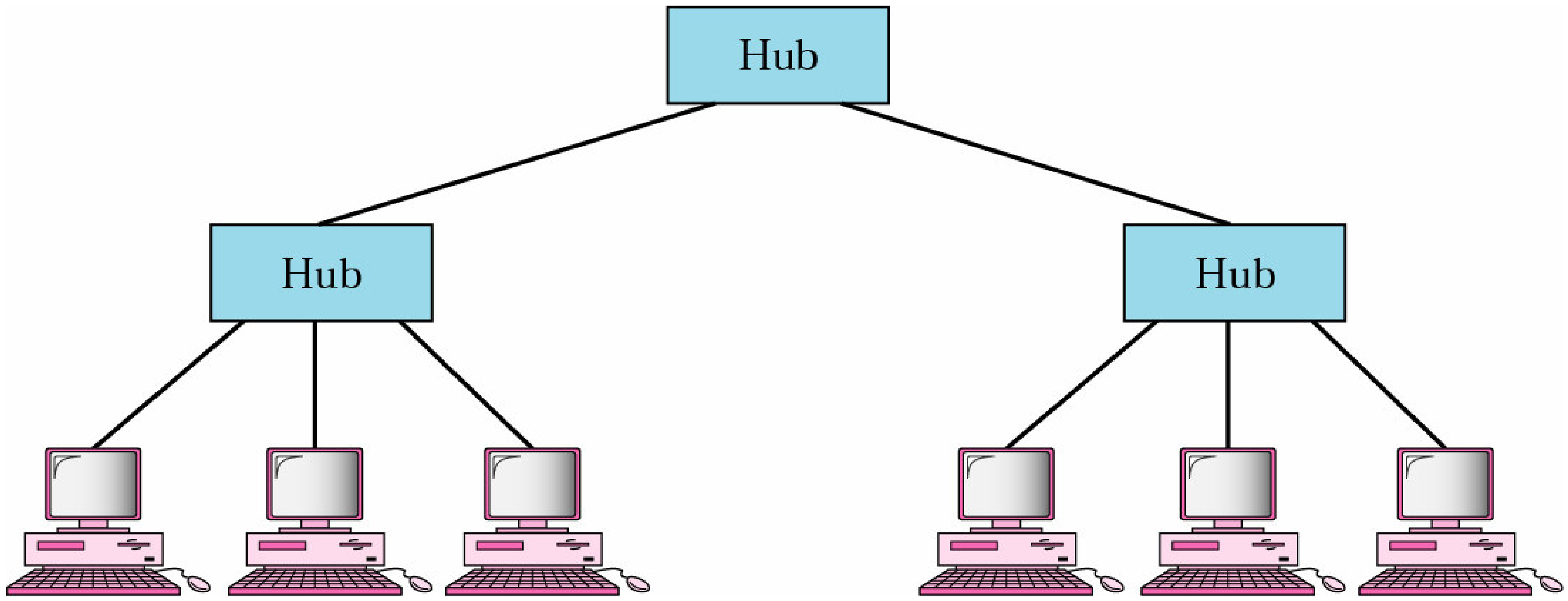
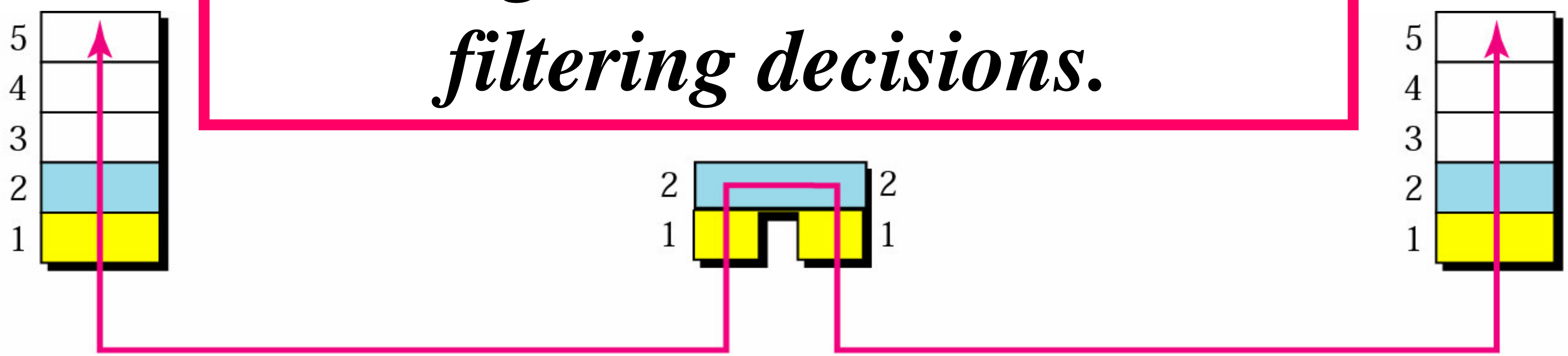


Figure 16.5 Bridge

A bridge has a table used in filtering decisions.



Address	Port
712B13456141	1
712B13456142	1
642B13456112	2
642B13456113	2

Bridge Table

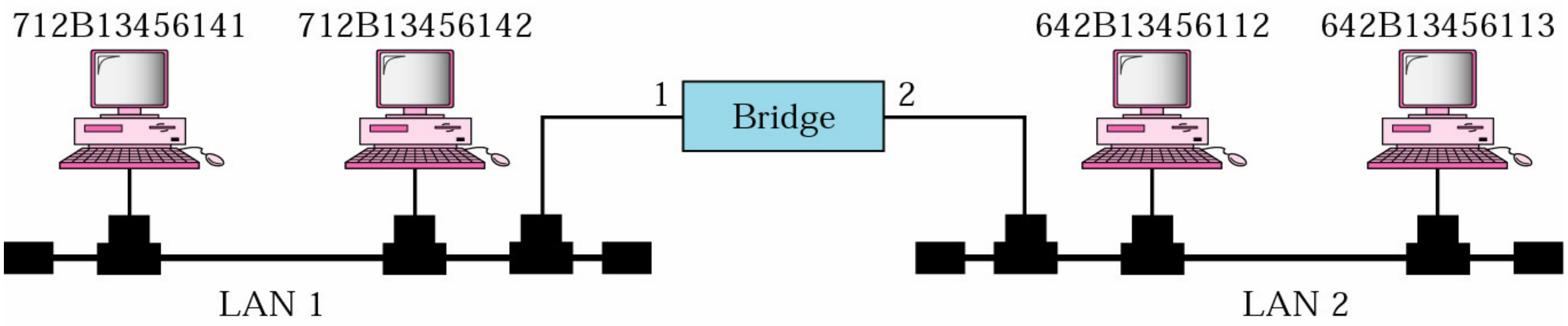
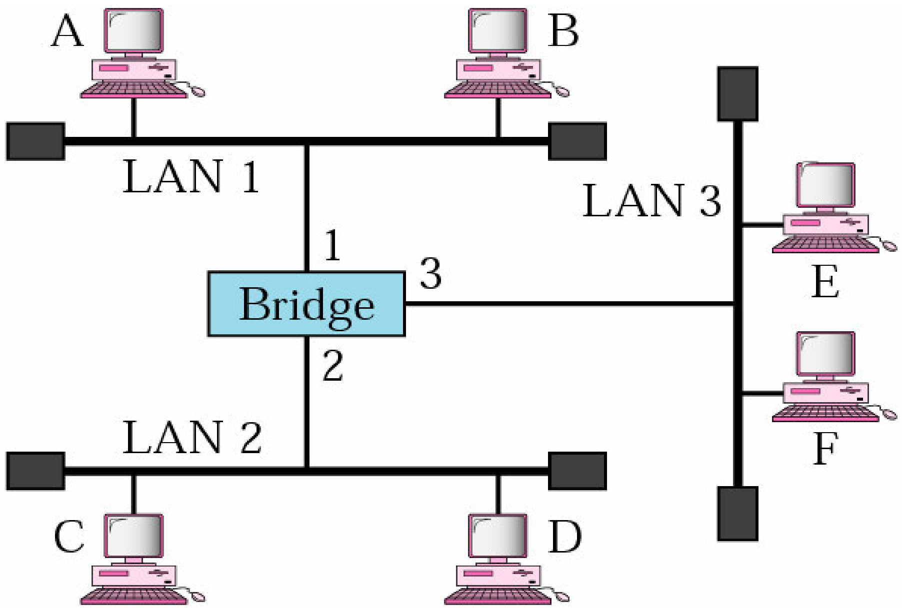


Figure 16.6 Learning bridge



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

Figure 16.7 Loop problem

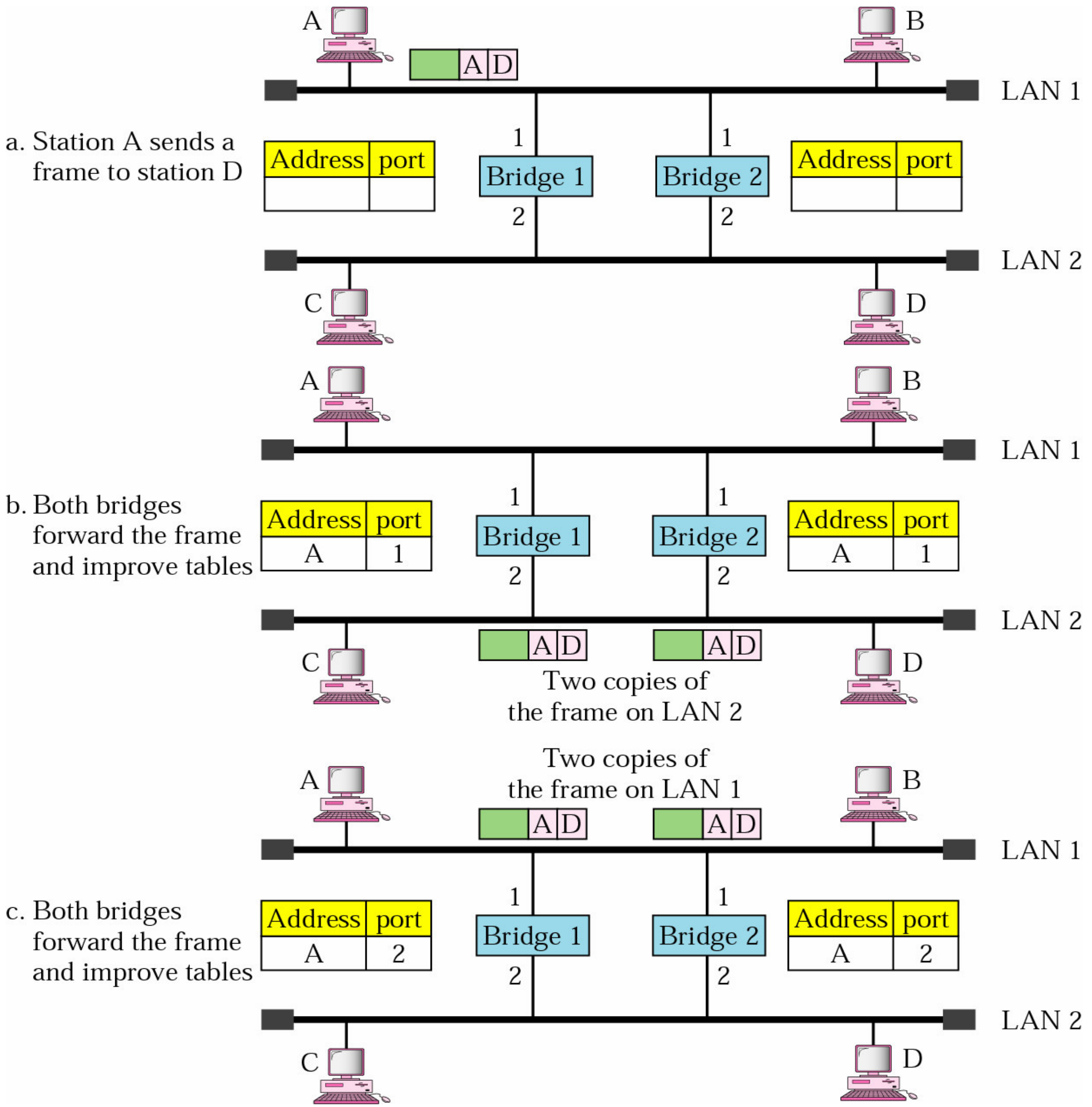


Figure 16.8 Prior to spanning tree application

- Every bridge has a unique ID
- The bridge with the smallest ID is selected as root

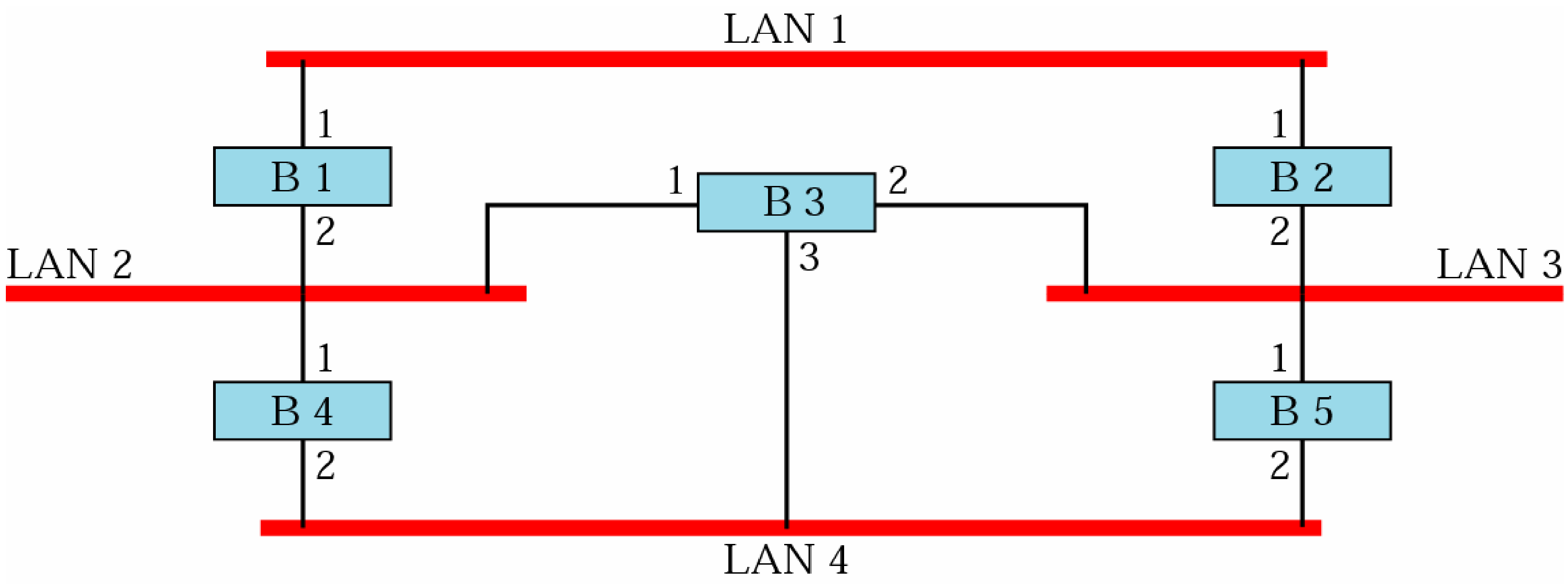
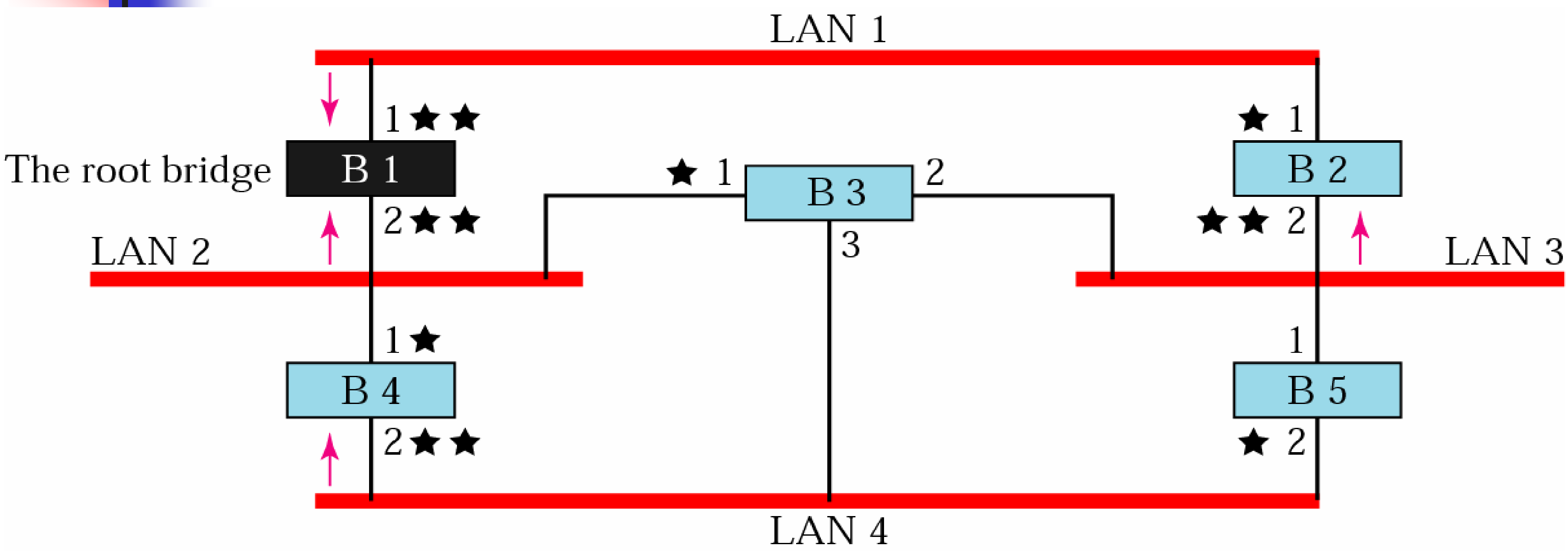
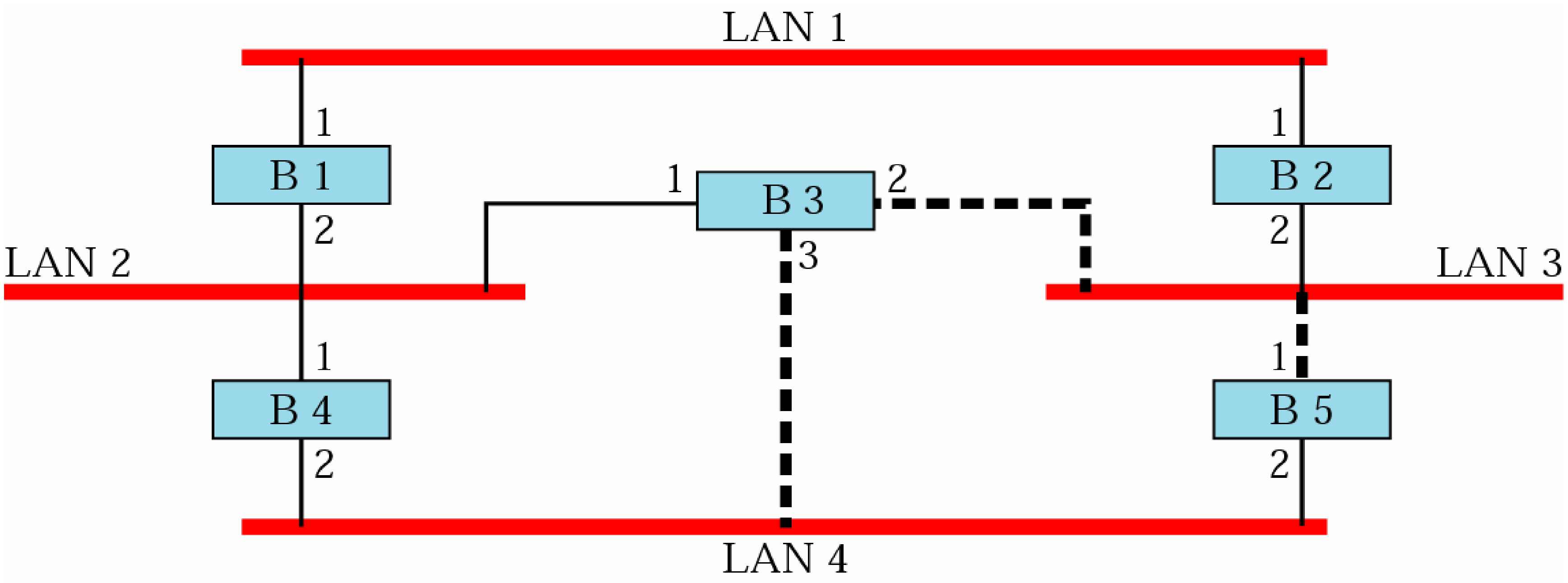


Figure 16.9 Applying spanning tree



- Mark one port of each bridge as the root port except the root bridge.
- A root port is the port with the least cost path from the bridge to the root bridge.
- Choose a designated bridge for every LAN.
- Designated bridge is the one with the least-cost w.r.t the root bridge.
- Mark the corresponding port as the designated port and block all other ports.

Figure 16.10 Forwarding ports and blocking ports



16.2 Backbone Networks

Bus Backbone

Star Backbone

Connecting Remote LANs

Figure 16.11 **Bus backbone**

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

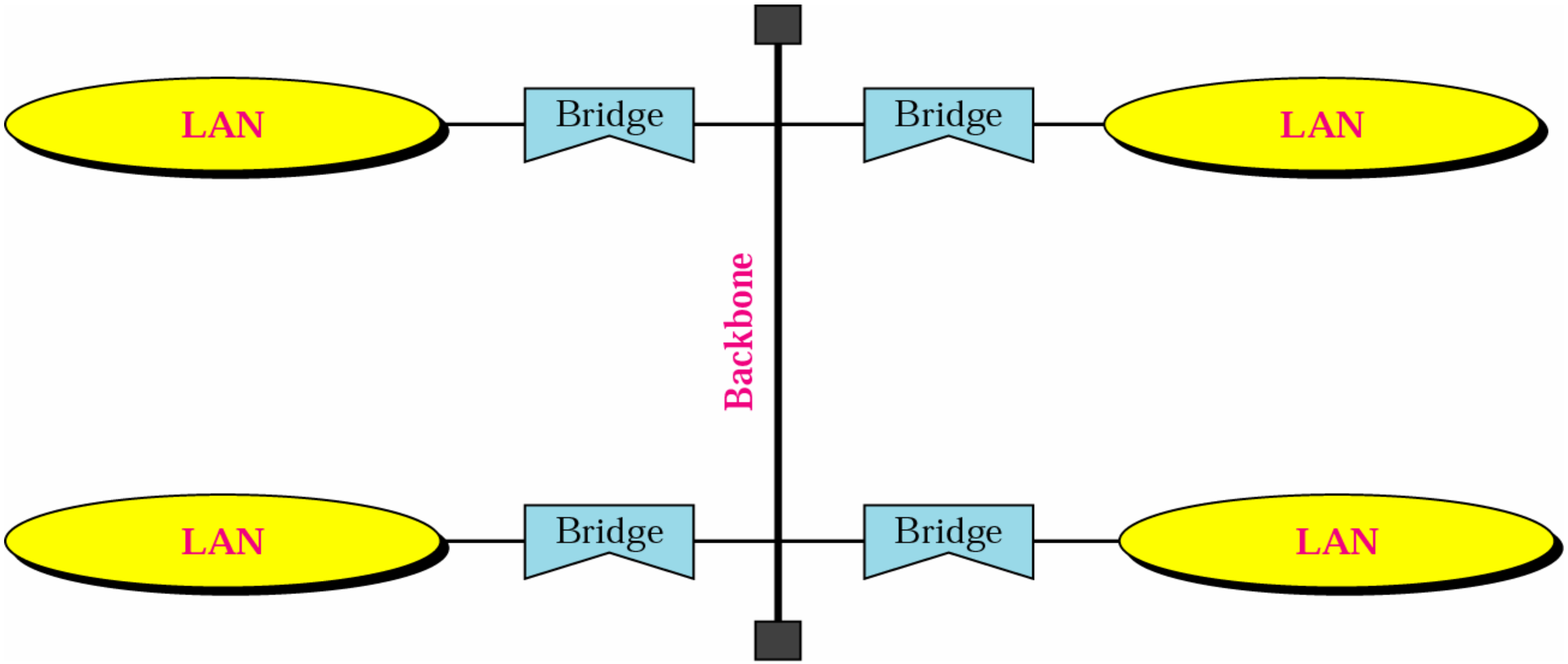


Figure 16.12 Star backbone

In a star backbone, the topology of the backbone is a star; the backbone is just one switch.

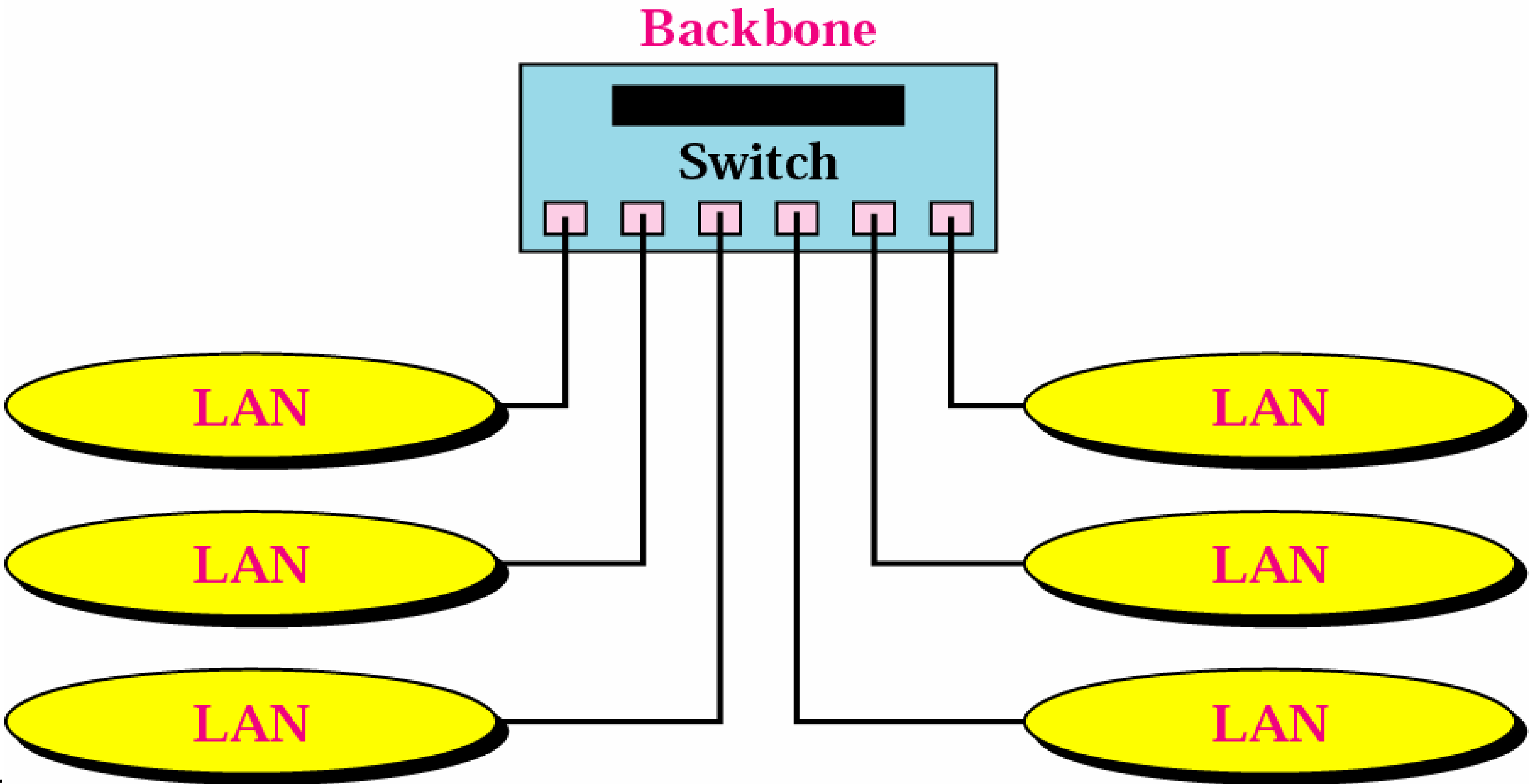
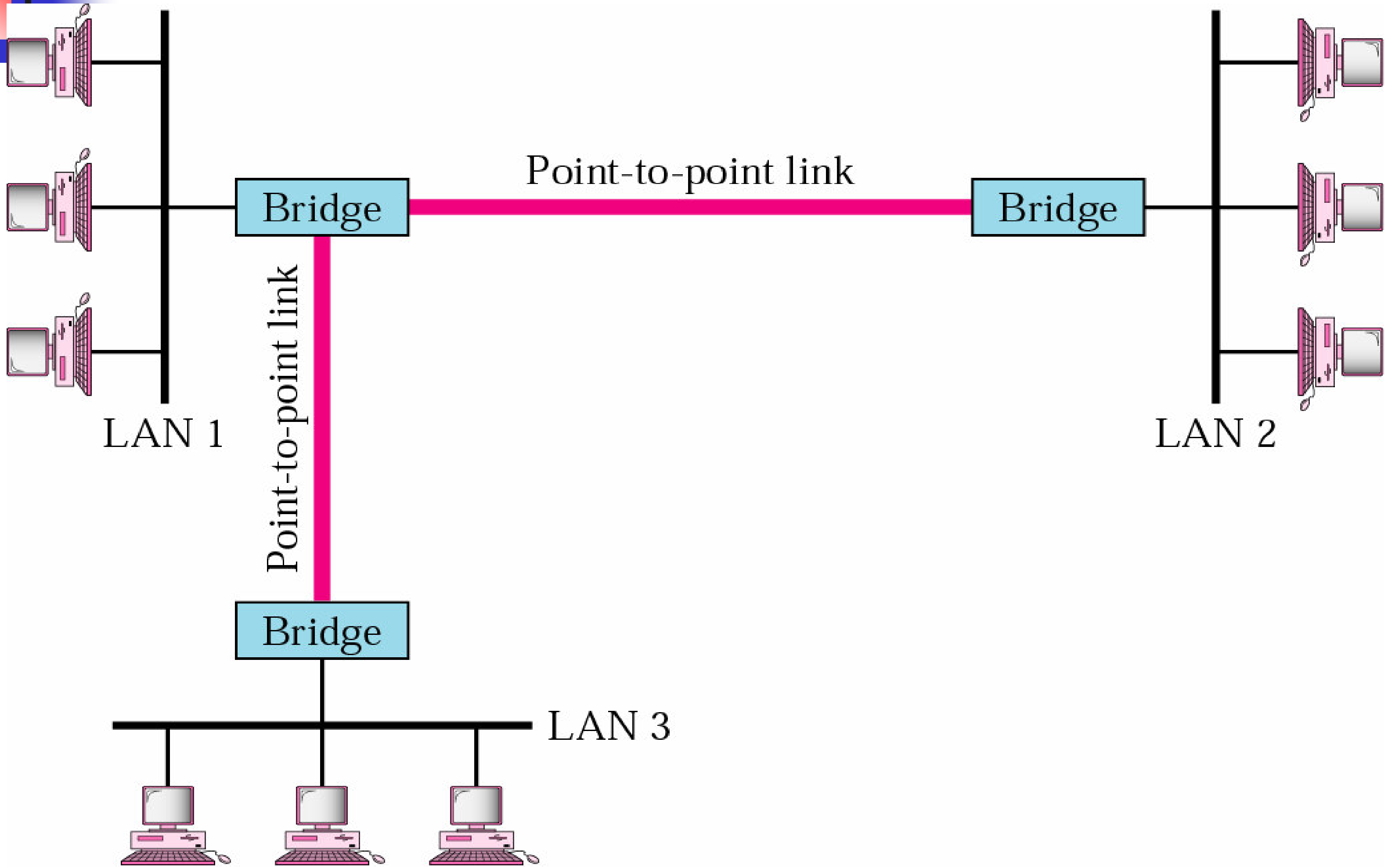


Figure 16.13 **Connecting remote LANs**

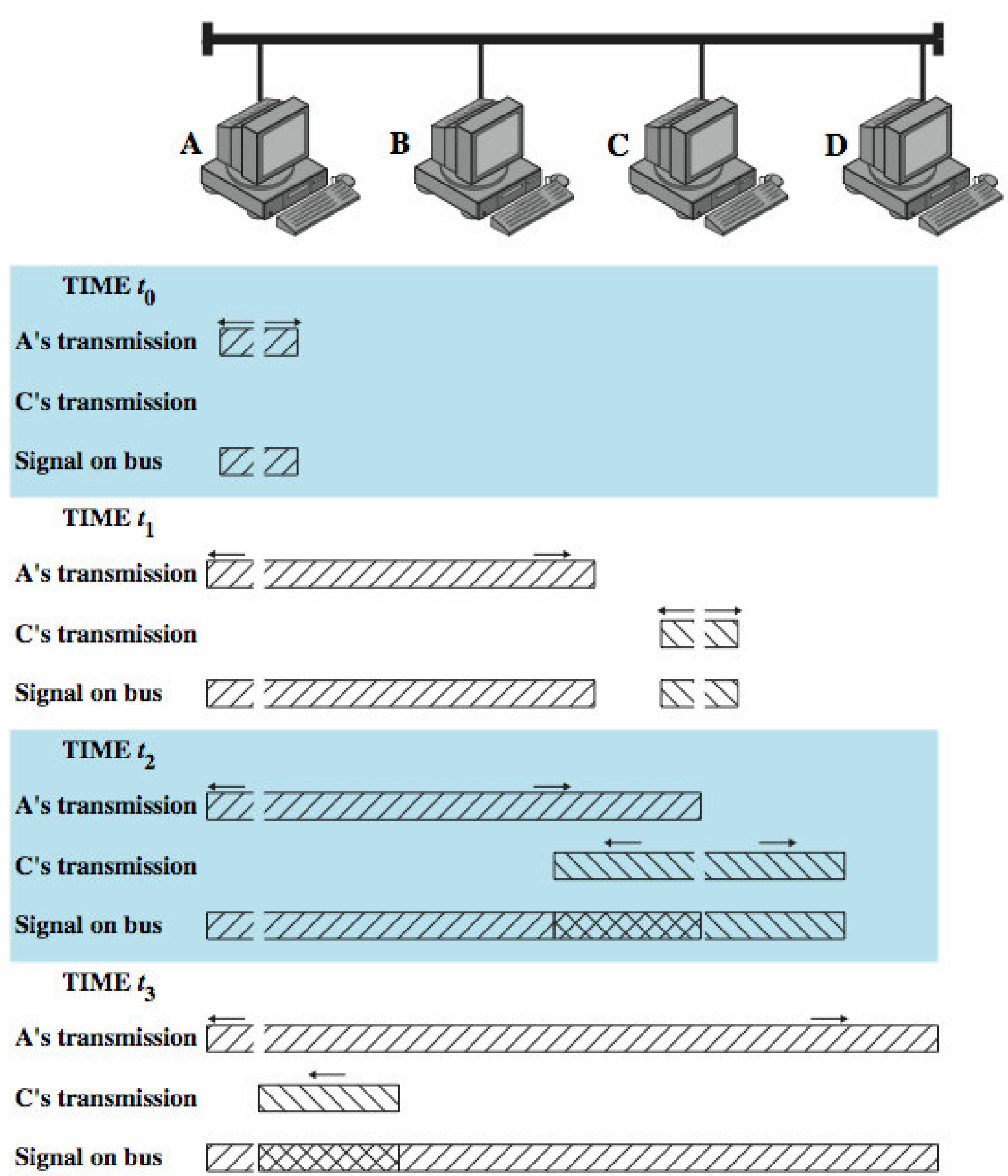


A point-to-point link acts as a LAN in a remote backbone connected by remote bridges.

Ethernet (CSMA/CD)

- most widely used LAN standard
- developed by
  - Xerox - original Ethernet
  - IEEE 802.3
- Carrier Sense Multiple Access with Collision Detection (CSMA/CD)
  - random / contention access to media

CSMA/CD Operation



Binary Exponential Backoff

- for backoff stability, IEEE 802.3 and Ethernet both use binary exponential backoff
- stations repeatedly resend when collide
  - on first 10 attempts, mean random delay doubled
  - value then remains same for 6 further attempts
  - after 16 unsuccessful attempts, station gives up and reports error
- 1-persistent algorithm with binary exponential backoff efficient over wide range of loads
- but backoff algorithm has last-in, first-out effect

Collision Detection

- on baseband bus
  - collision produces higher signal voltage
  - collision detected if cable signal greater than single station signal
  - signal is attenuated over distance
  - limit to 500m (10Base5) or 200m (10Base2)
- on twisted pair (star-topology)
  - activity on more than one port is collision
  - use special collision presence signal

10Mbps Specification (Ethernet)

	10BASE5	10BASE2	10BASE-T	10BASE-FP
Transmission medium	Coaxial cable (50 ohm)	Coaxial cable (50 ohm)	Unshielded twisted pair	850-nm optical fiber pair
Signaling technique	Baseband (Manchester)	Baseband (Manchester)	Baseband (Manchester)	Manchester/on-off
Topology	Bus	Bus	Star	Star
Maximum segment length (m)	500	185	100	500
Nodes per segment	100	30	—	33
Cable diameter (mm)	10	5	0.4 to 0.6	62.5/125 μm

100Mbps Fast Ethernet

	100BASE-TX		100BASE-FX	100BASE-T4
Transmission medium	2 pair, STP	2 pair, Category 5 UTP	2 optical fibers	4 pair, Category 3, 4, or 5 UTP
Signaling technique	MLT-3	MLT-3	4B5B, NRZI	8B6T, NRZ
Data rate	100 Mbps	100 Mbps	100 Mbps	100 Mbps
Maximum segment length	100 m	100 m	100 m	100 m
Network span	200 m	200 m	400 m	200 m

$$a = \frac{\text{Propagation time}}{\text{Transmission time}}$$

$$a = \frac{\text{length of data link in bits}}{\text{length of frame in bits}}$$

$$U = \frac{\text{Throughput}}{\text{Data rate}}$$

$$R = \text{data rate of the channel}$$

$$\text{d} = \text{maximum distance between any two stations}$$

$$\text{V} = \text{velocity of signal propagation}$$

$$\text{L} = \text{average frame length}$$

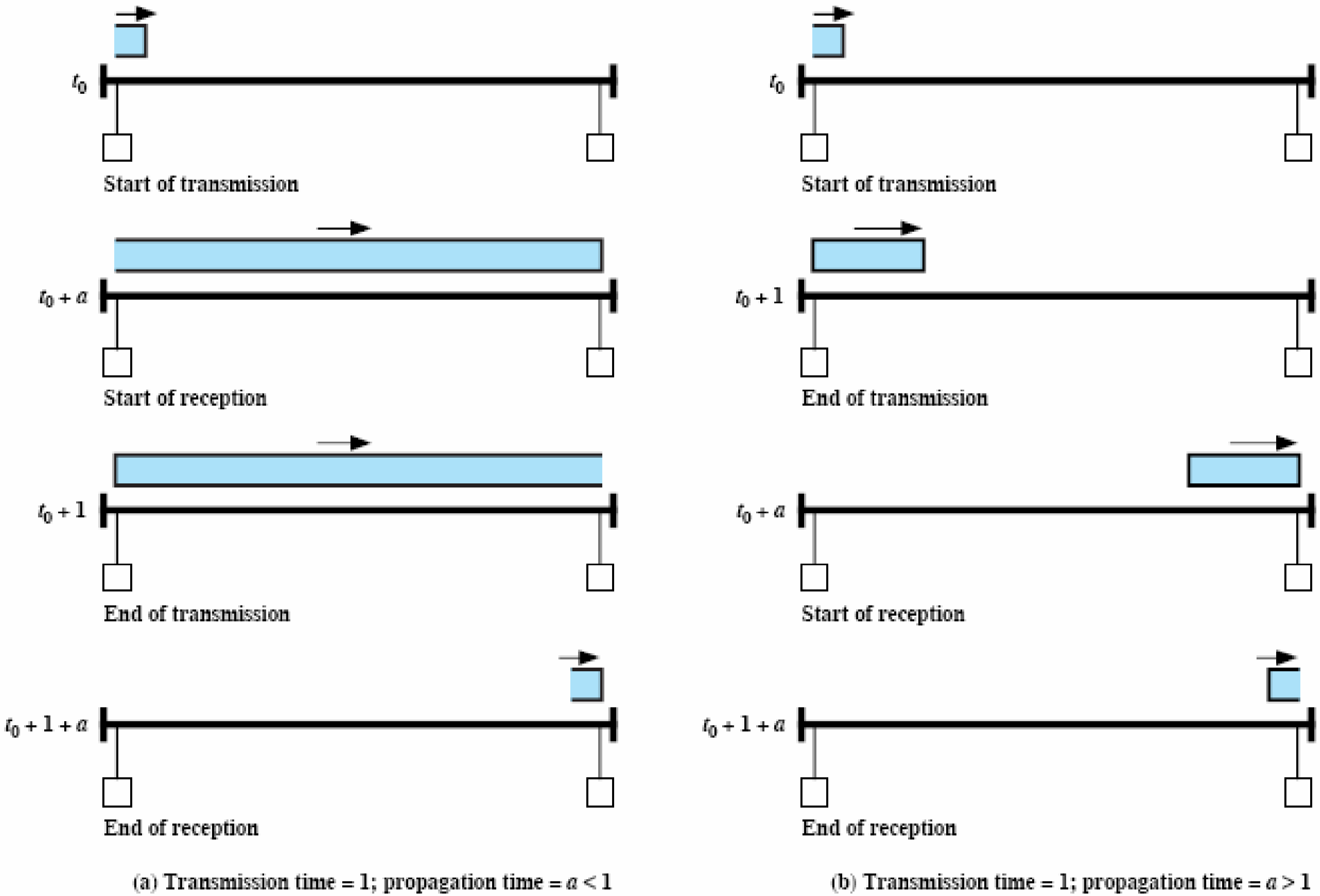


Figure 16.14 The Effect of *a* on Utilization for Baseband Bus

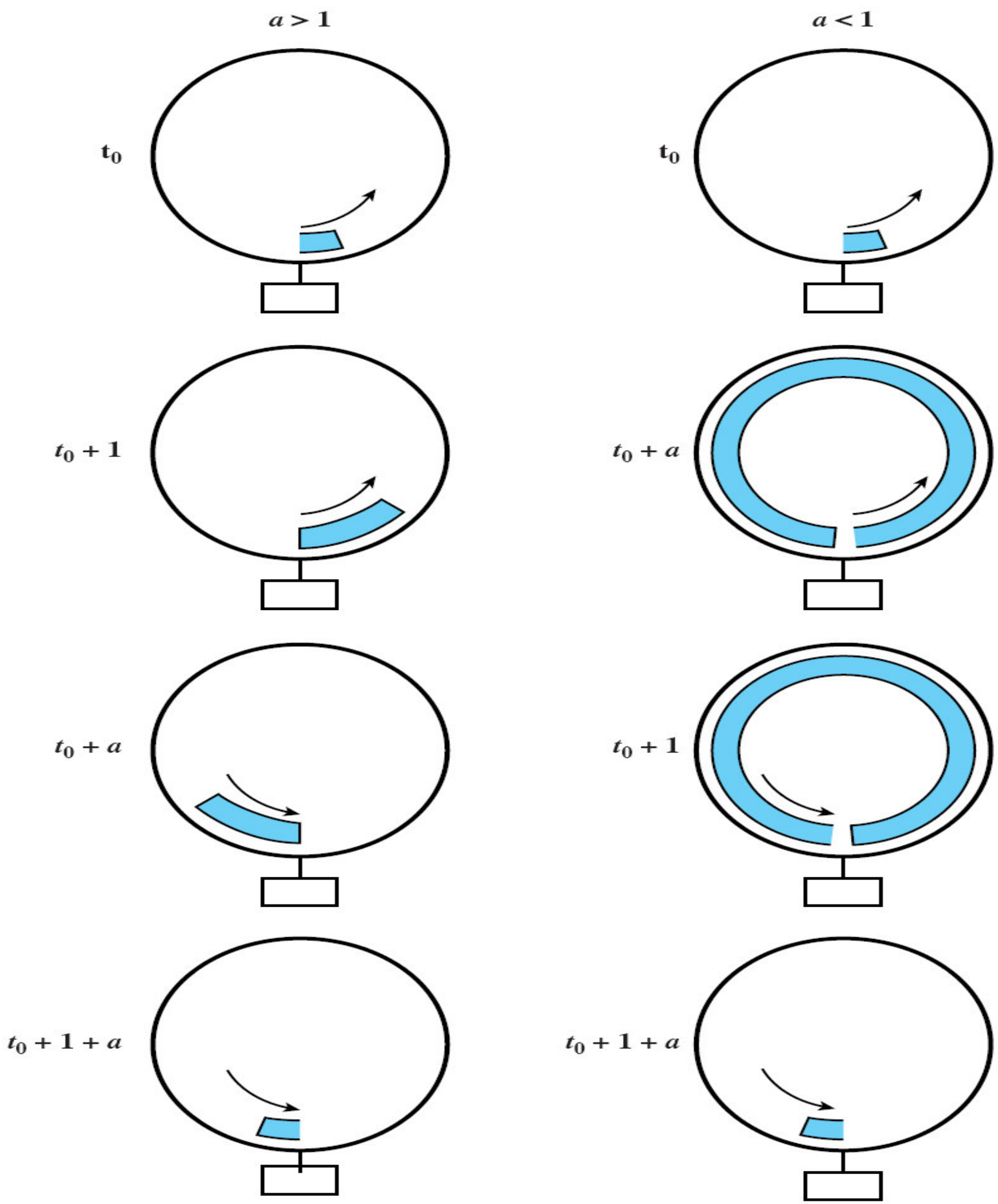


Figure 16.15 The Effect of a on Utilization for Ring

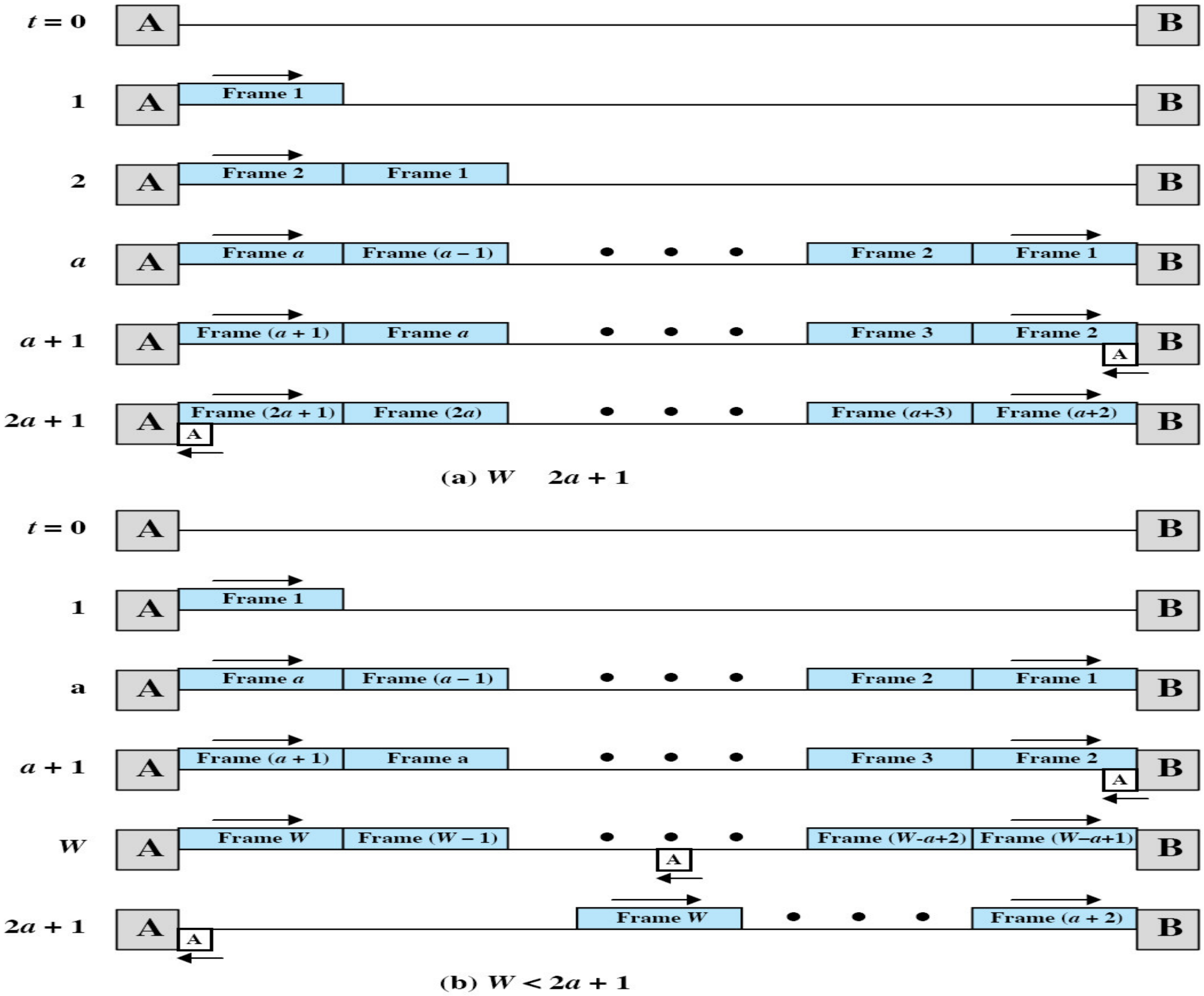
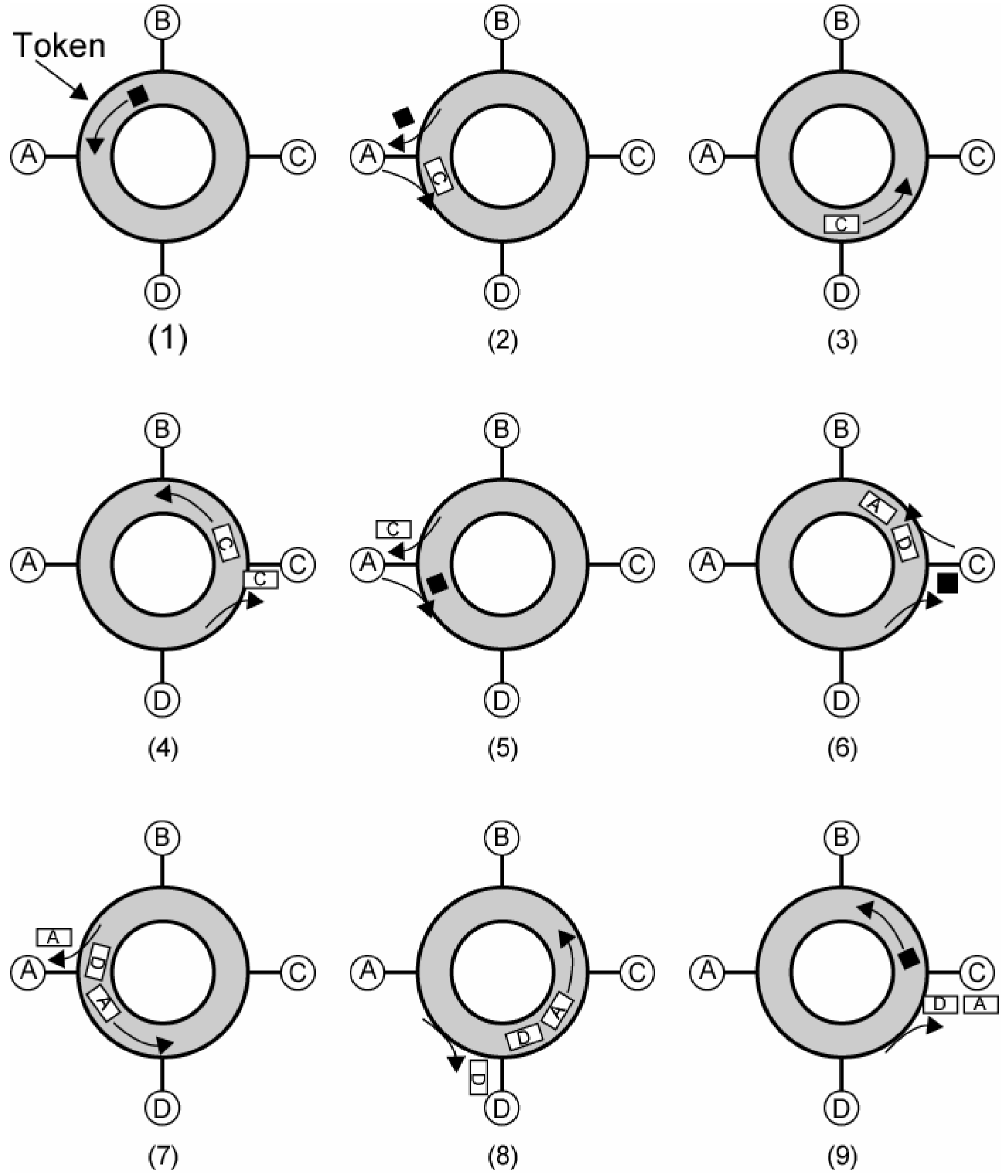


Figure 7.11 Timing of Sliding-Window Protocol

802.5 MAC Protocol

- Small frame (token) circulates when idle
- Station waits for token
- Changes one bit in token to make it SOF for data frame
- Append rest of data frame
- Frame makes round trip and is absorbed by transmitting station
- Station then inserts new token when transmission has finished and leading edge of returning frame arrives
- Under light loads, some inefficiency
- Under heavy loads, round robin



$$Throughput = \frac{\mathrm{L}}{\mathrm{d/V + L/R}}$$

$$U = \frac{1}{1+a}$$

$$U = \frac{T_1}{T_1 + T_2}$$

$T_1 = Average$ time to transmit a data frame

$\mathrm{T}_2 = Average$ time to pass a token

$$\mathrm{U} = \begin{cases} \dfrac{1}{1+a/N} \\ \dfrac{1}{a+a/N} \end{cases}$$

CSMA/CD Network Size Restriction

"To ensure that a packet is transmitted without a collision, a host must be able to detect a collision before it finishes transmitting a packet."

From example on previous slide we can see that for a Host to detect a collision before it finishes transmitting a packet, we require:

$$TRANSP > 2 \times PROP$$

In other words, there is a minimum length packet for CSMA/CD networks.

Performance of CSMA/CD

We're going to analyze the performance of a CSMA/ CD network.

1. Our performance metric will be Efficiency, η. This is defined to be the fraction of time spent sending useful/successful data. The more time spent causing and detecting collisions, the less efficient the protocol is. More precisely:

$$\eta = \frac{\text{Time taken to send data}}{\text{Time taken to send data + overhead}}$$

2. To make the analysis simple, we'll assume that time is slotted and all packets are the same length. In any given time slot, a host will either decide to transmit or not with probability p. (This includes packets transmitted for the first time and retransmissions).
3. First, we will try and find the value of p that maximizes the throughput (in fact, it's the goodput).
4. Then, using the optimal value of p, we'll find the efficiency.

Performance of CSMA/CD

Maximizing goodput

Find the goodput, $\alpha(p)$:

Probability that exactly one node transmits in a given slot.

$$\alpha(p) \equiv \binom{N}{1} p(1-p)^{N-1}$$

$$\frac{d\alpha}{dp} = N(1-p)^{N-1} - pN(N-1)(1-p)^{N-2}$$

$$\therefore \alpha_{\max} \approx 36\% \approx 40\% \qquad when: \qquad p = 1/N$$

Performance of CSMA/CD

Finding the overhead

Define A to be the expected number of time slots wasted before a packet is transmitted successfully:

$$A = \sum_{i=1}^{\infty} i\alpha(1-\alpha)^{i-1} = \frac{1-\alpha}{\alpha}$$

$$A = (\alpha \times 0) + (1-\alpha)(1+A)$$

$$\therefore when: \quad \alpha = \alpha_{\max}, \quad A = 1.5$$

Performance of CSMA/CD

Finding the efficiency

$$\eta_{CSMA/CD} = \frac{TRANSP}{TRANSP + E[\text{\# of wasted slots per packet}]}$$

$$= \frac{TRANSP}{TRANSP + A(2 \times PROP)}$$

$$= \frac{TRANSP}{TRANSP + (3 \times PROP)}$$

$$\eta_{CSMA/CD} = \frac{1}{1+3a}, \quad \text{where: } a \equiv \frac{PROP}{TRANSP}$$

$$CSMA-CD \qquad U = \frac{1}{1+2a(1-\alpha)/\alpha}$$

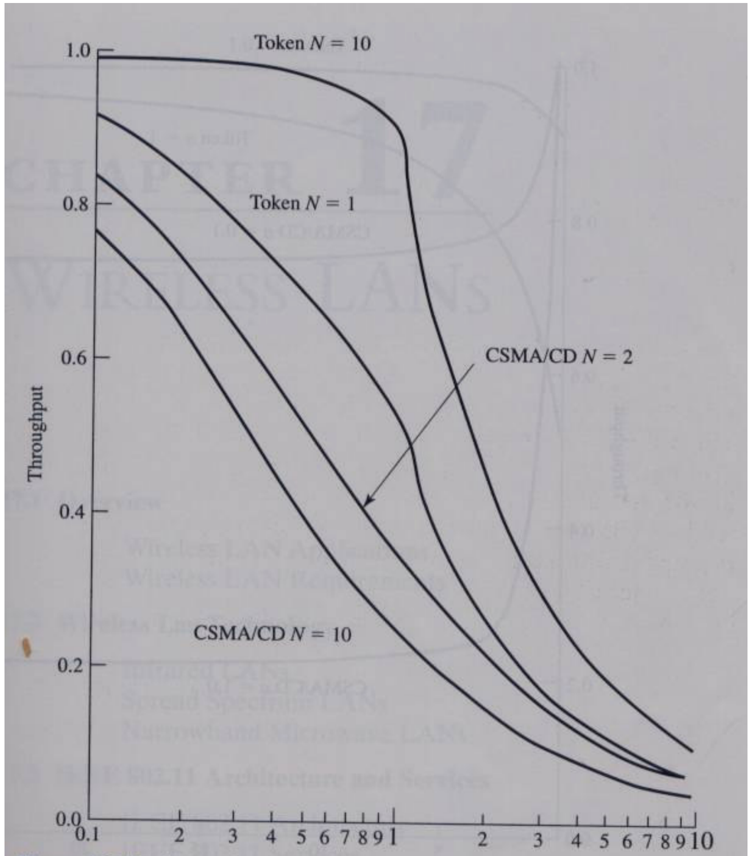


Figure 16.17 Throughput as a Function of *a* for Token Passing and CSMA/CD

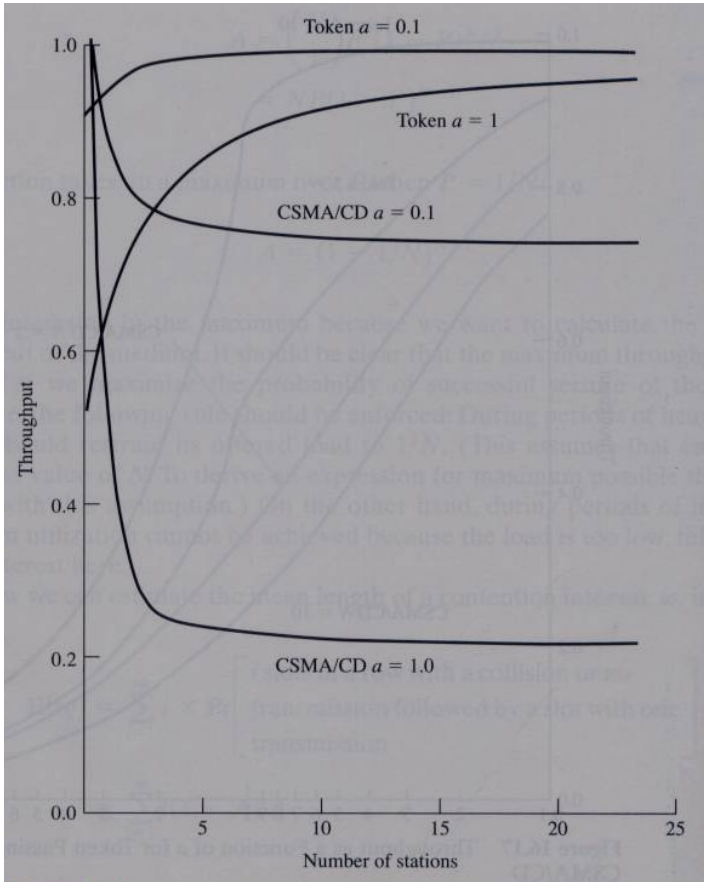


Figure 16.18 Throughput as a Function of *N* for Token Passing for CSMA/CD