Ethernet

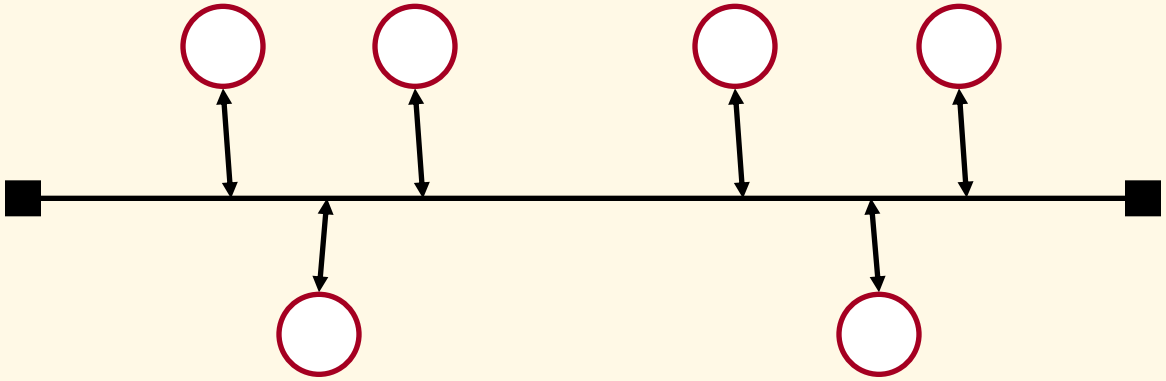
Advanced Computer Networks

C13

Ethernet Outline

- Ethernet
  - Binary Exponential Backoff
- Ethernet versus IEEE 802.3
- Ethernet Evolution
  - 10BASE5, 10BASE2, 1BASE5, 10BASE-T
- Switched Ethernet
- Switching Hub

Ethernet [DEC, Intel, Xerox]



- 1-persistent, CSMA-CD with Binary Exponential Backoff.
- Manchester encoding.

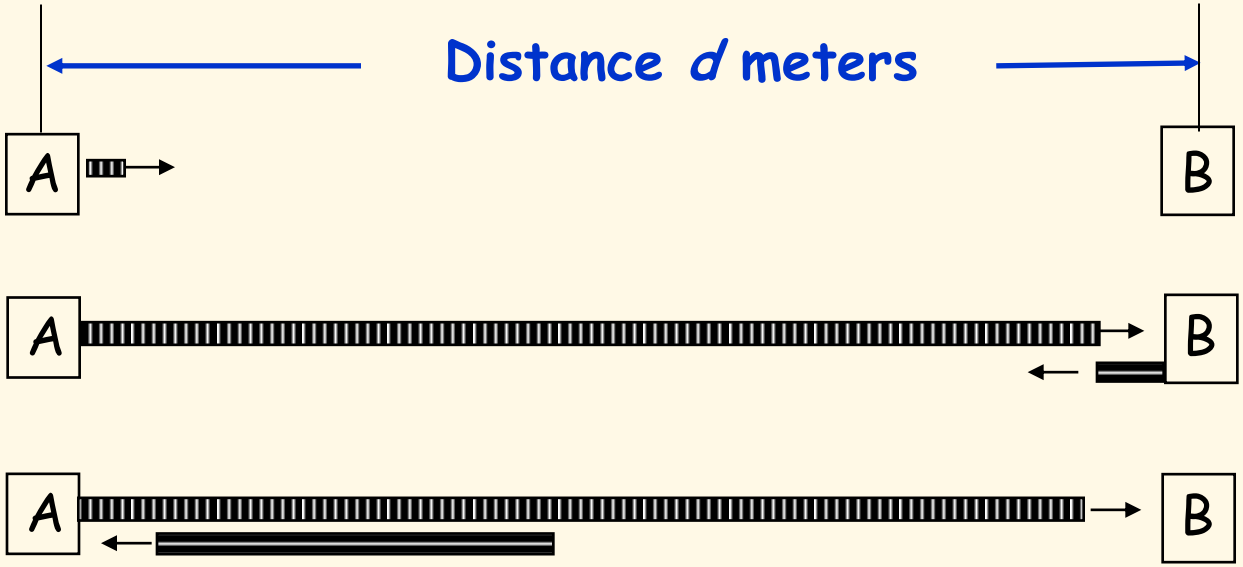
Ethernet [operational in 1974]

Initially 3 Mbps baseband coaxial cable (thick Ethernet).

Operational Description

- *Ethernet stations sense the channel* (CS).
- *When the channel is free, the station transmits a frame* (1-persistent).
- *The stations monitor the 'ether' during the transmission* (MA).
- *If a collision is detected by any station* (CD), *the transmission is terminated immediately and a jam signal is sent.*
- *Upon collision, transmitting stations backoff using a local counter and then retransmit* (BEB).

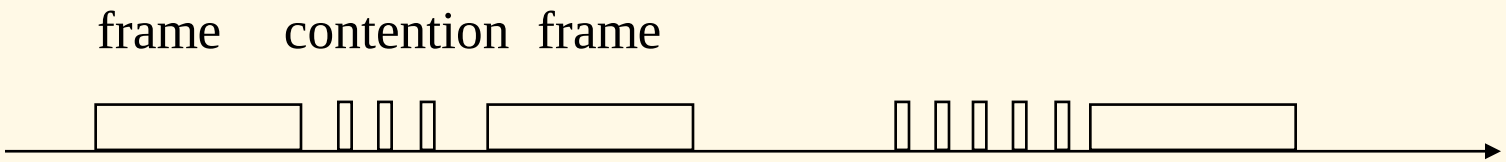
Worst Case Collision Scenario



$t_{prop} = d / v$ seconds

Leon-Garcia & Widjaja: *Communication Networks*

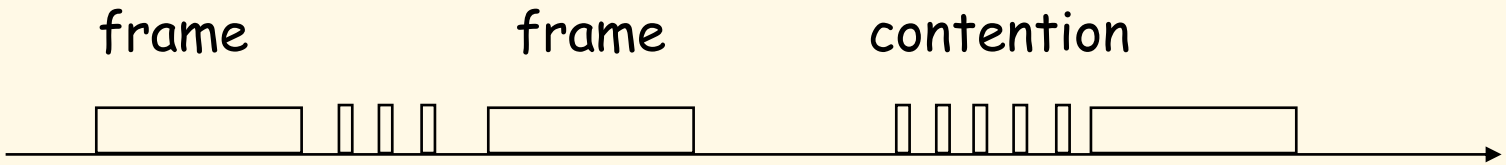
Ethernet



- A frame *seizes the channel after* 2 t_{prop}
- On 1 km Ethernet, t_{prop} is approximately 5 microseconds.
- Contention interval = 2 t_{prop}
- *Interframe gap = 9.6 microseconds*
- Modeled as *slotted scheme* with

  slot = 2 t_{prop}

Model (slotted Bernoulli Trial)

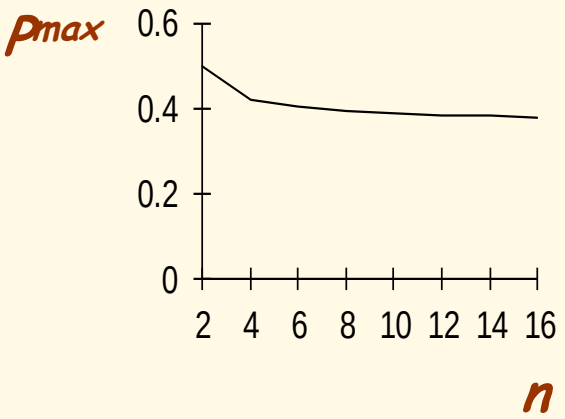


Probability of 1 successful transmission:

$$P_{success} = np(1-p)^{n-1}$$

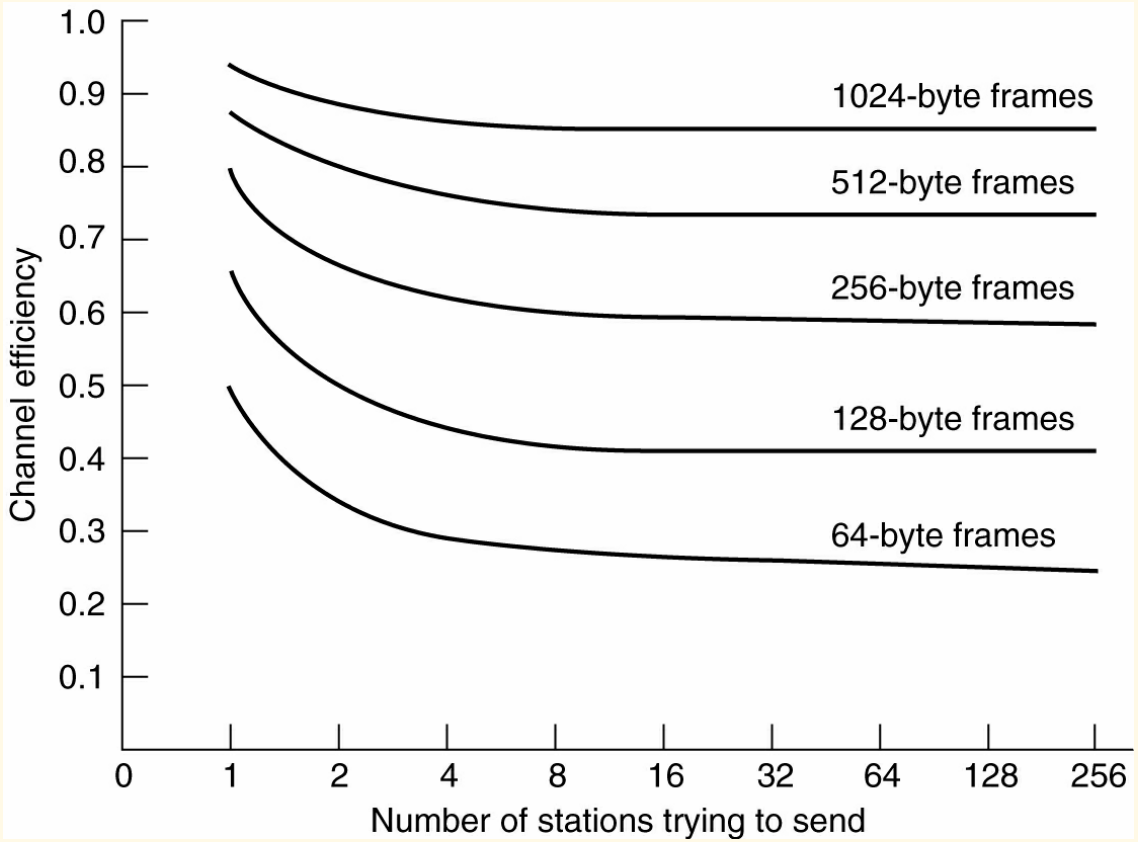
$P_{success}$ is maximized at $p = 1/n$:

$$P_{success}^{\max} = n(1-\frac{1}{n})^{n-1} \rightarrow \frac{1}{e}$$



Tanenbaum

Ethernet Performance



Efficiency of Ethernet at 10 Mbps with 512-bit slot times.

Tanenbaum

Binary Exponental Backoff (BEB)

- Upon a collision, the sending stations increment a local counter K. The backoff interval is randomly selected using a uniform distribution over the $L = 2^K$ slots.
- K is initially set to 0.
- Thus upon collision, the value of L is doubled locally for each sending station.

Binary Exponental Backoff (BEB)

Slotted ALOHA has been shown to be unstable when

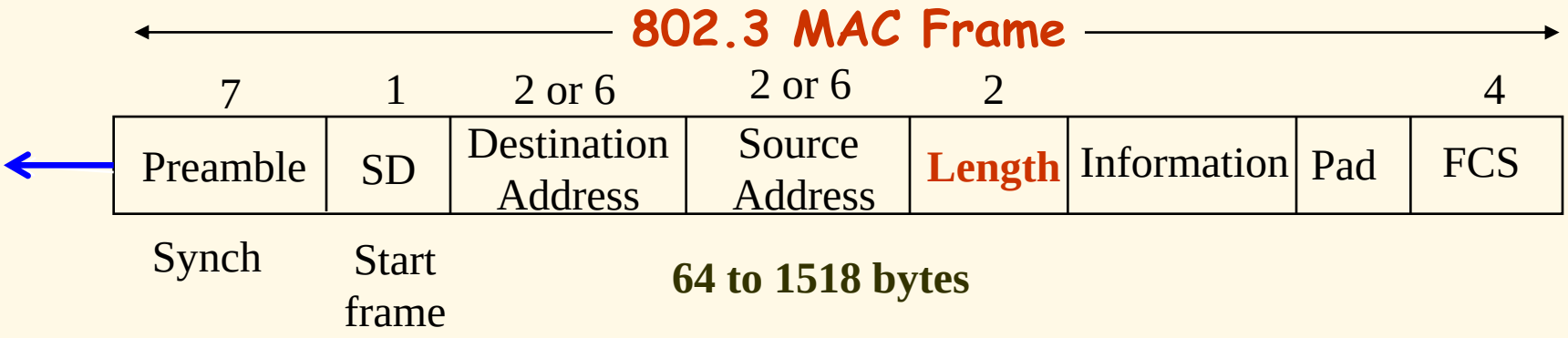
$$p > 1/n$$

Since Ethernet permits up to 1024 stations, backoff continues until $K = 10$, $L = 2^{10}$, and $p = 1/2^{10}$

Normally K is incremented up to 10, but BEB is set for 16 retries. After 16 retries, MAC gives up trying to send the frame.

{The IP packet is now considered lost}.

IEEE 802.3 Frame Format



0	Single address
1	Group address

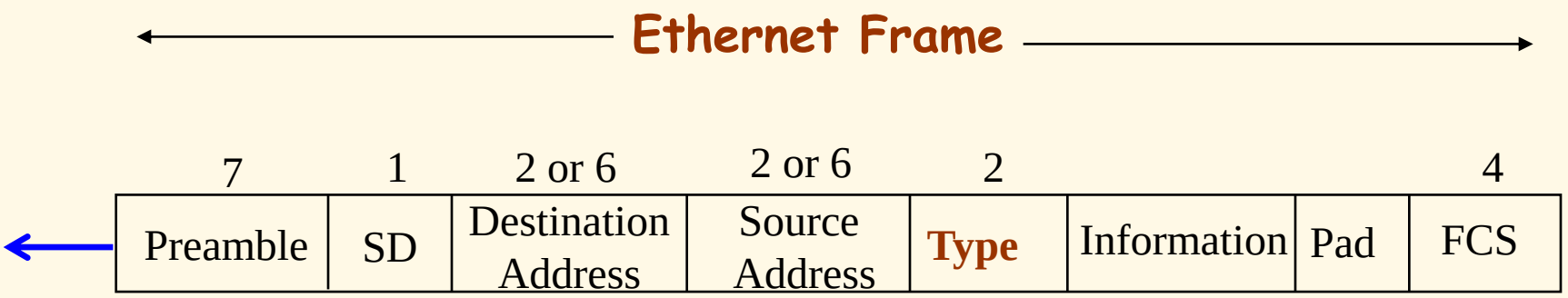
- Destination address is either single address or group address (broadcast = 111...111)

0	Local address
1	Global address

- Addresses are defined on local or universal basis
- 2^{46} possible global addresses

Leon-Garcia & Widjaja: *Communication Networks*

Ethernet Frame Format



Leon-Garcia & Widjaja: *Communication Networks*

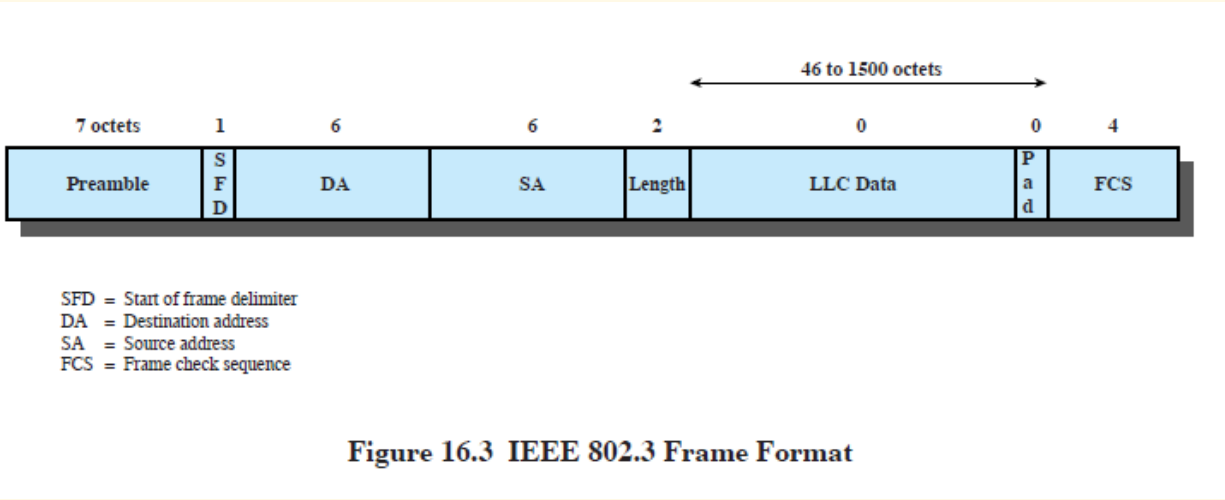
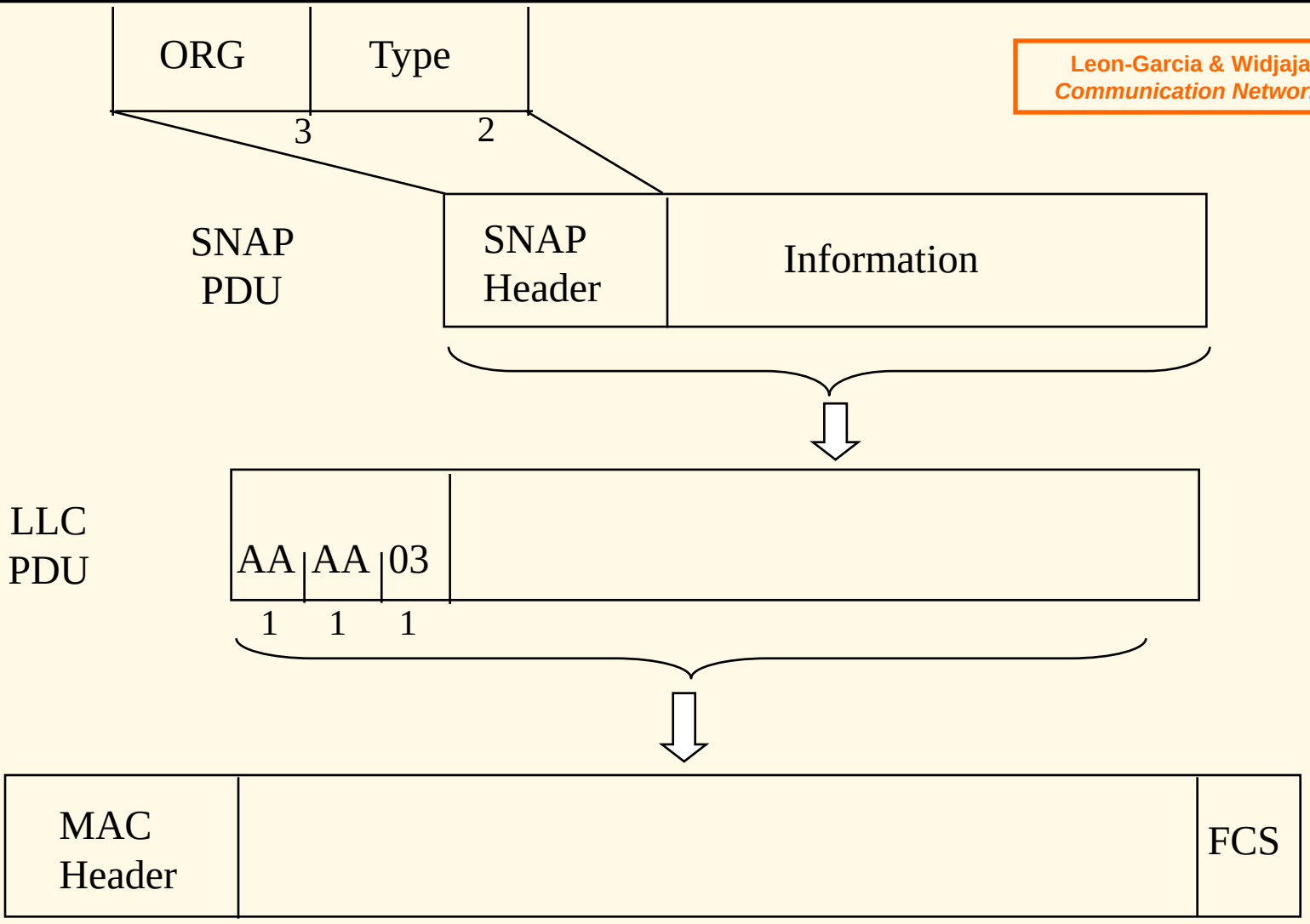


Figure 16.3 IEEE 802.3 Frame Format

DCC 6th Ed. Stallings

Ethernet Encapsulation



Leon-Garcia & Widjaja: *Communication Networks*

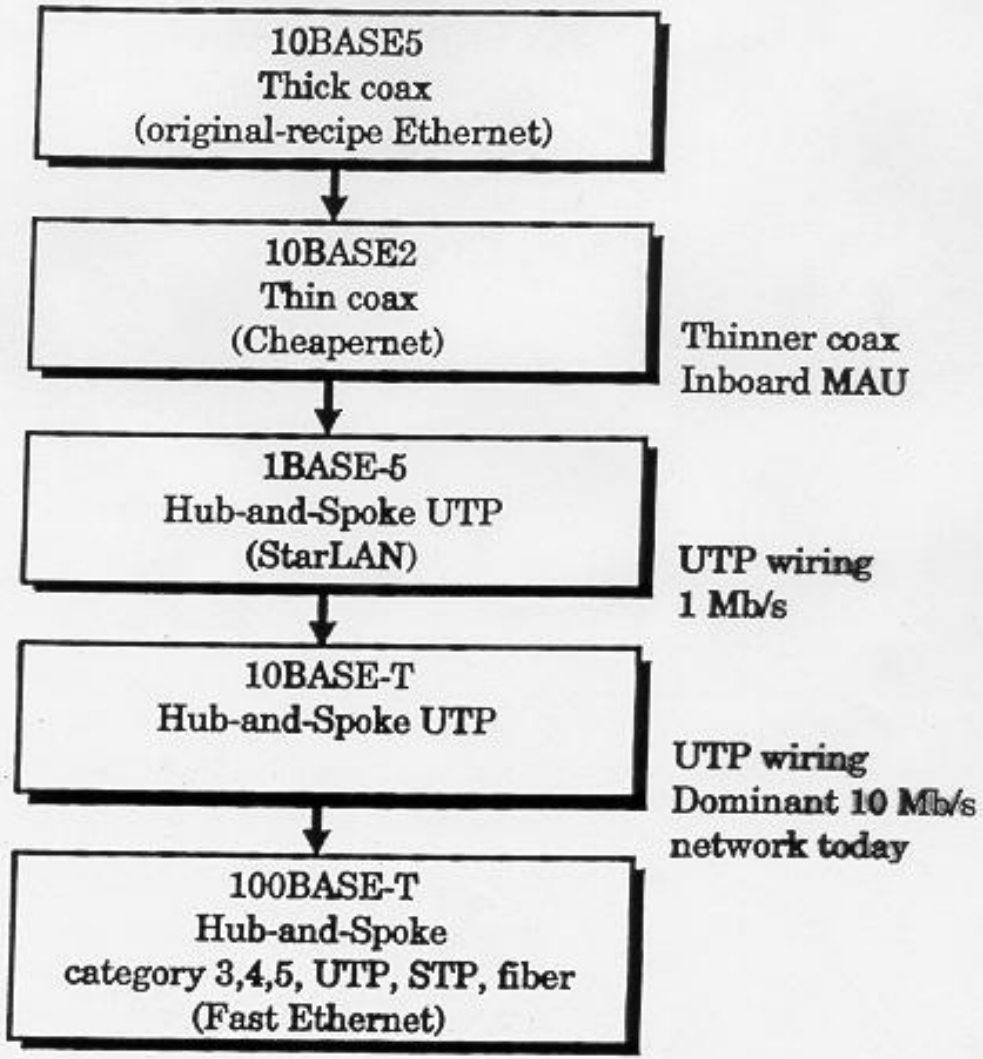


Figure 1.4 Lineage of Fast Ethernet

Ethernet Evolution

10BASE5

{1983}

- 10 Mbps
- 500 meter segment length
- Signal-regenerating repeaters
- Thick Coax
  - *Advantages:* Low attenuation, excellent noise immunity, superior mechanical strength
  - *Disadvantages:* Bulky, difficult to pull, transceiver boxes too expensive
* Wiring represented a significant part of total installed cost.

10BASE5

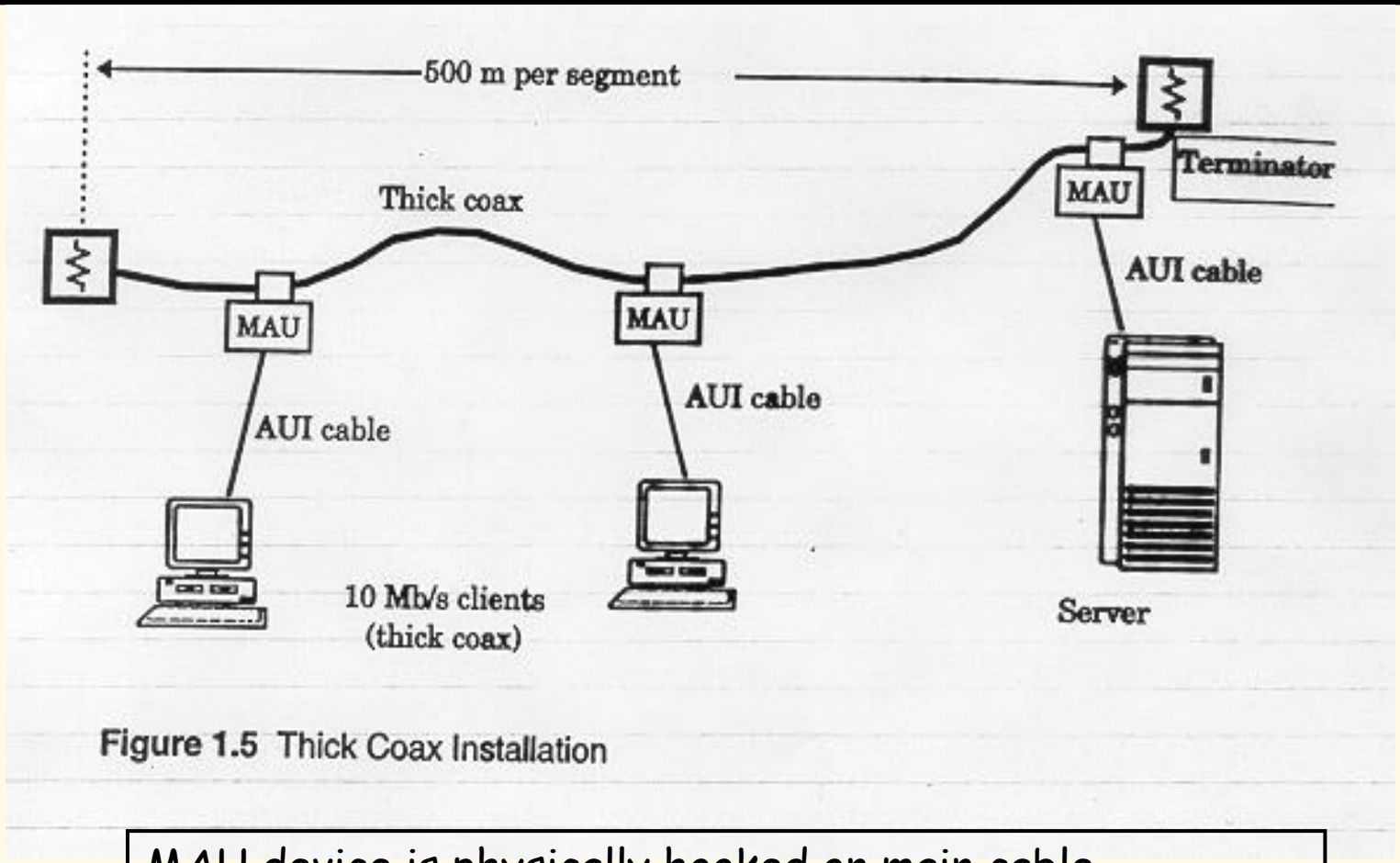


Figure 1.5 Thick Coax Installation

MAU device is physically hooked on main cable.

50 meter AUI cable from MAU to station.

Ethernet Evolution

10BASE2 'Cheapernet'

{1985}

- 10 Mbps
- 185 meter segment length
- Signal-regenerating repeaters
- Transceiver was integrated onto the adapter
- Thin Coax (coax thinner and lighter)
  - *Advantages:* Easier to install, reduced hardware cost, BNC connectors widely deployed ➔ lower installation costs.
  - *Disadvantages:* Higher attenuation and could not support as many stations due to signal reflection caused by BNC Tee Connector.

10Base2 Cheapernet

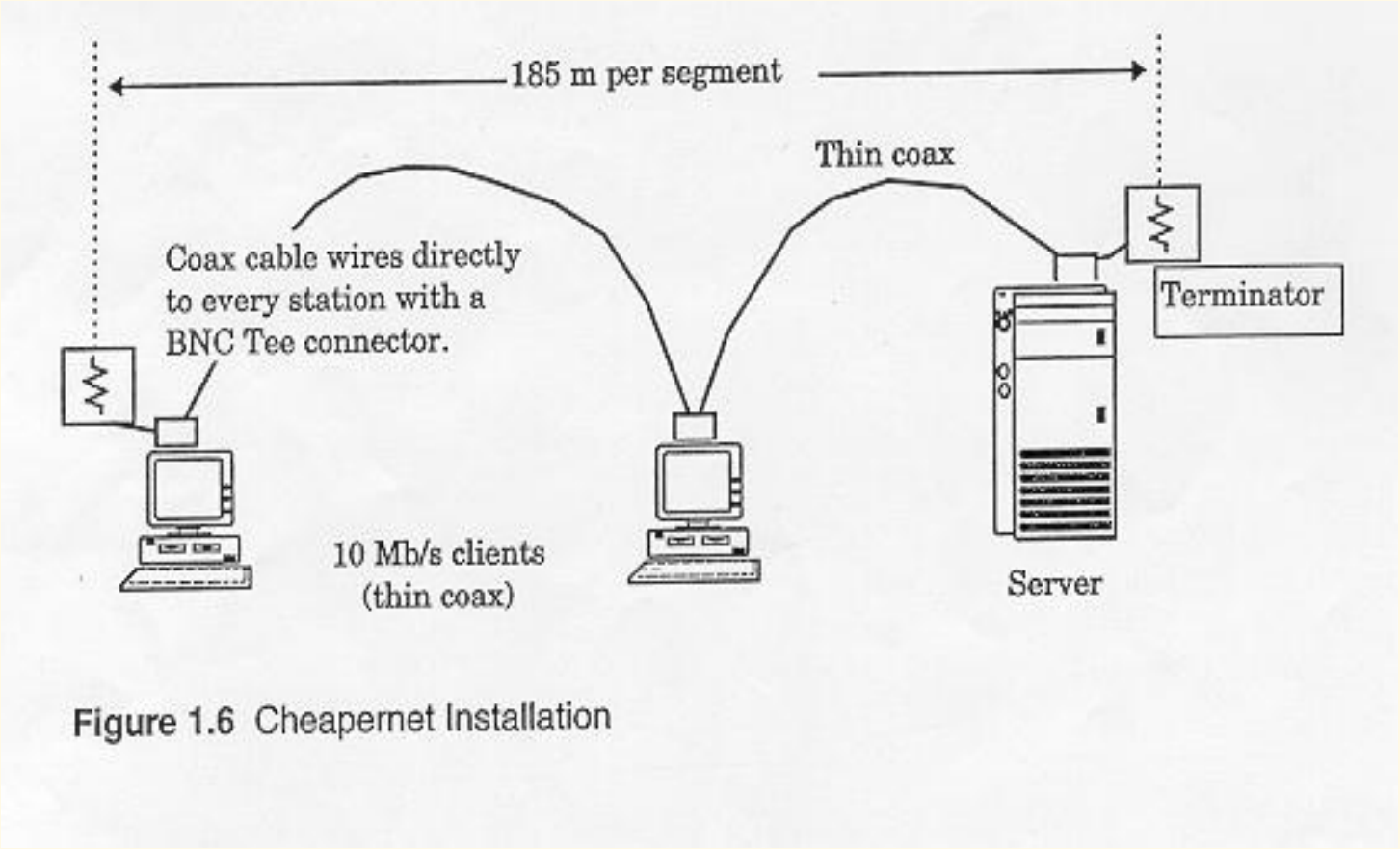
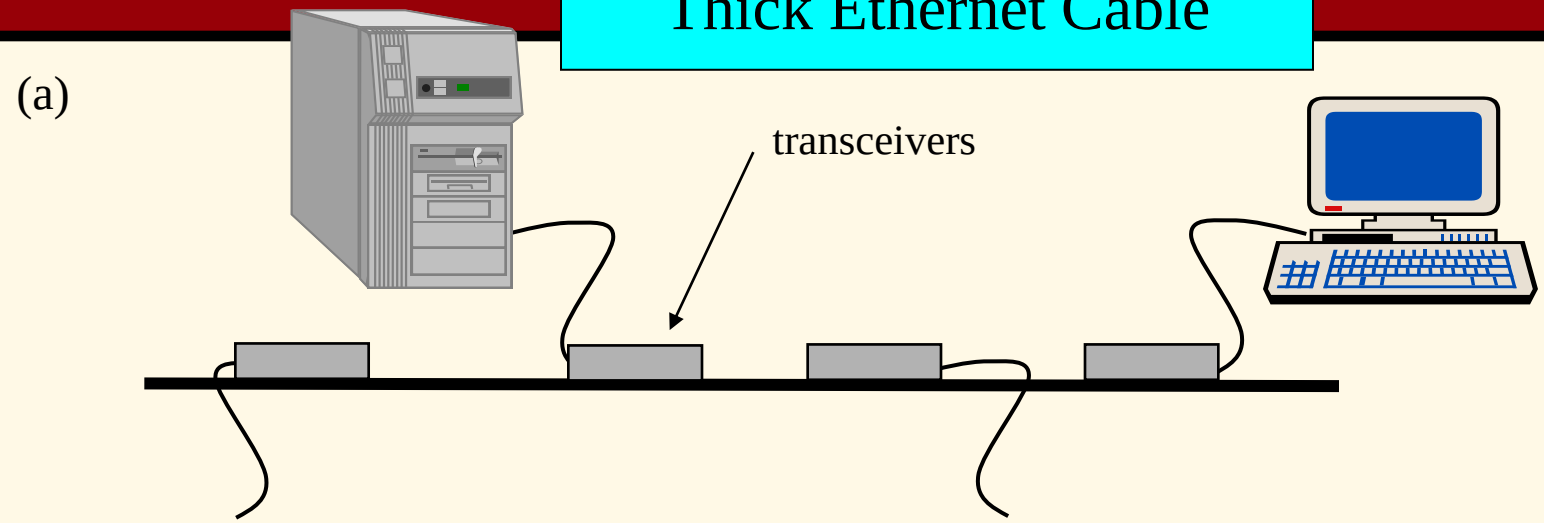
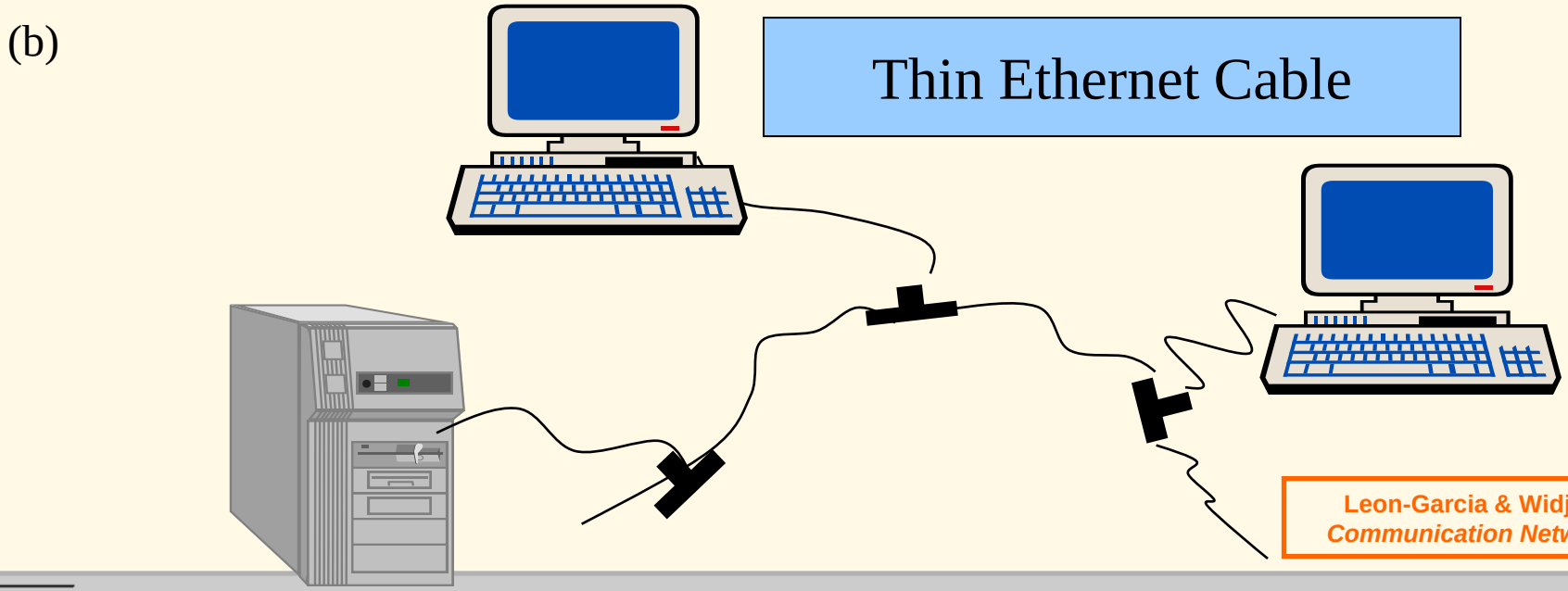


Figure 1.6 Cheapernet Installation

Thick Ethernet Cable





Leon-Garcia & Widjaja:
Communication Networks

Ethernet Evolution

1BASE5 StarLAN

{1987}

- 1 Mbps
- 250 meter segment length
- Signal-regenerating repeaters
- Transceiver integrated onto the adapter
- Hub-and-Spoke topology (star topology)
- Two pairs of unshielded twisted pair
  - *Advantages: Since four or more UTP are ubiquitous in buildings, it is easier to use installed wiring in the walls. Telephone wiring is hierarchical ➔ can use wiring closets.*

Ethernet Evolution

10BASE-T {1990} **Most popular

- 10 Mbps
- 100 meter segment length
- Signal-regenerating repeaters
- Transceiver integrated onto adapter
- Two pairs of UTP
- Hub-and-spoke topology {Hub in the closet}
  - *Advantages:* could be done without pulling new wires. Each hub is a repeater – recovering the incoming signal, amplifying the signal and broadcasting it on all outgoing lines.

The Hub Concept

- Separate transmit and receive pair of wires.
- The repeater in the hub retransmits the signal received from any input pair onto ALL output pairs.
- *Essentially, the hub emulates a broadcast channel with collisions detected by receiving nodes.*

10Base-T Hub Concept

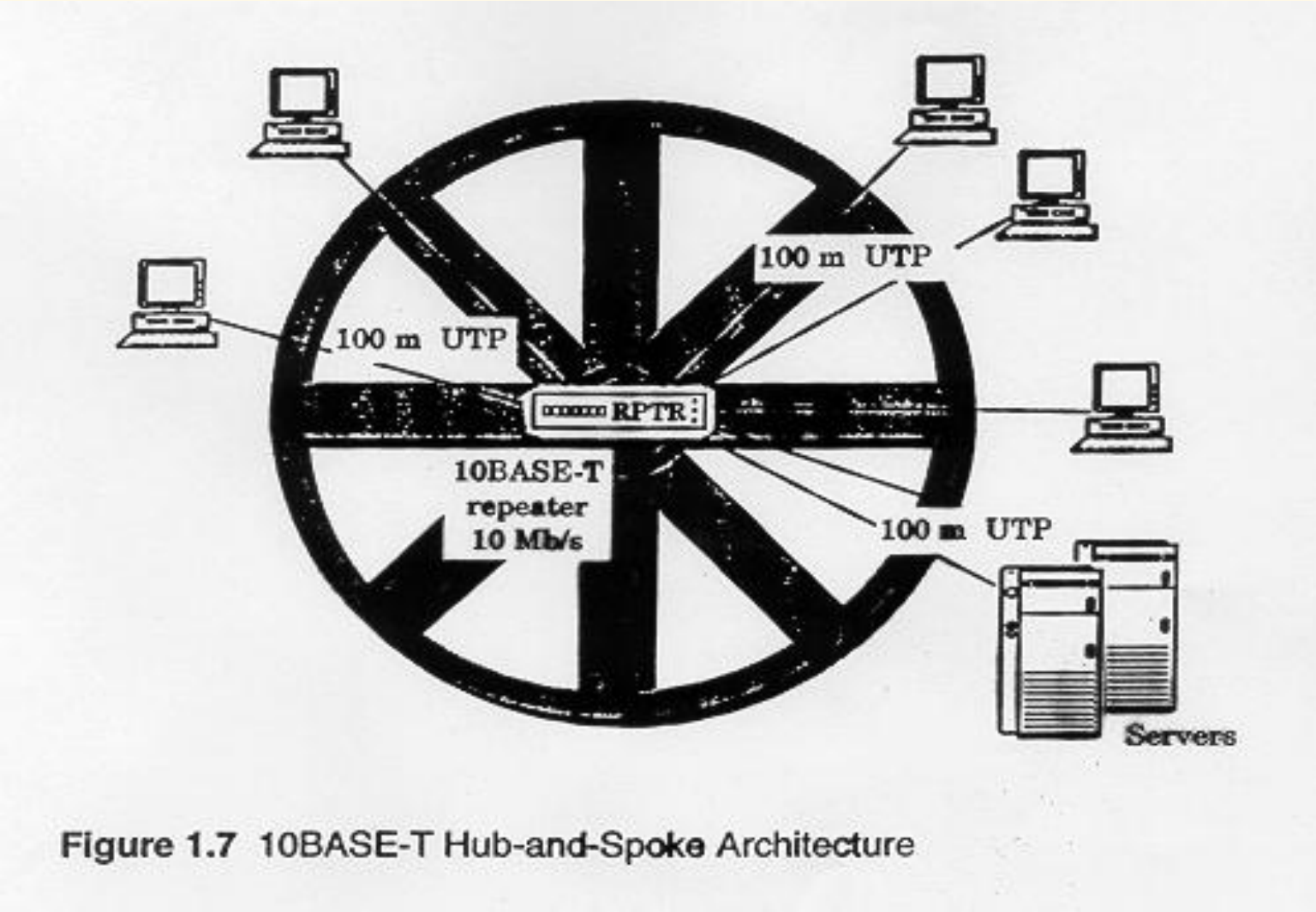
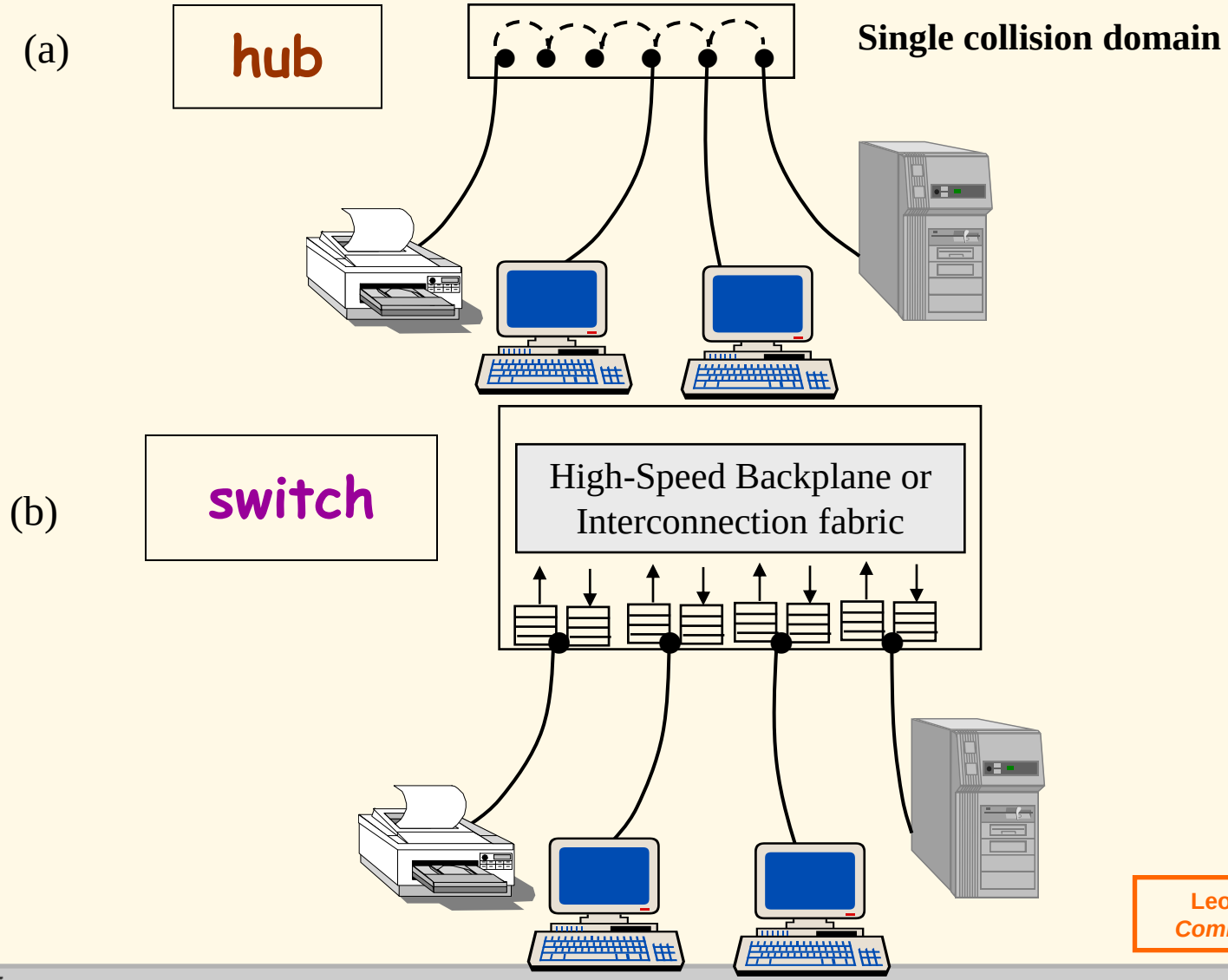


Figure 1.7 10BASE-T Hub-and-Spoke Architecture

Twisted Pair Ethernet



Leon-Garcia & Widjaja:
Communication Networks

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

DCC 9th Ed. Stallings

Switched Ethernet

*Basic idea: improve on the Hub concept

- The switch *learns destination locations* by remembering the ports of the associated source address in a table.
- The switch may not have to broadcast to all output ports. It may be able to send the frame only to the destination port.
- ➔ a big performance advantage over a hub, if more than one frame transfer can go through the switch concurrently.

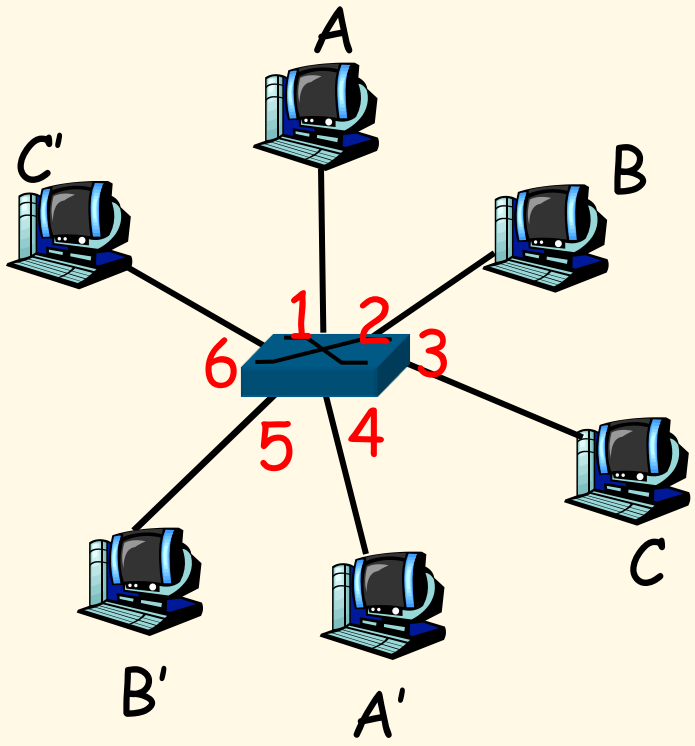
Switches

- link-layer devices: smarter than hubs, take *active* role
  - Store and forward Ethernet frames.
  - Examine incoming frame's MAC address, selectively forward frame to one-or-more outgoing links when frame is to be forwarded on segment, uses CSMA/CD to access segment.
- *transparent*
  - hosts are unaware of presence of switches.
- *plug-and-play, self-learning*
  - switches do not need to be configured.

K & R

Switches
allows *multiple* simultaneous transmissions

- Hosts have dedicated, direct connection to switch.
- Switches buffer packets.
- Ethernet protocol used on each incoming link, but no collisions due to full duplex.
  - each link is its own collision domain.
- switching: A-to-A' and B-to-B' simultaneously, without collisions.
  - not possible with dumb hub!!

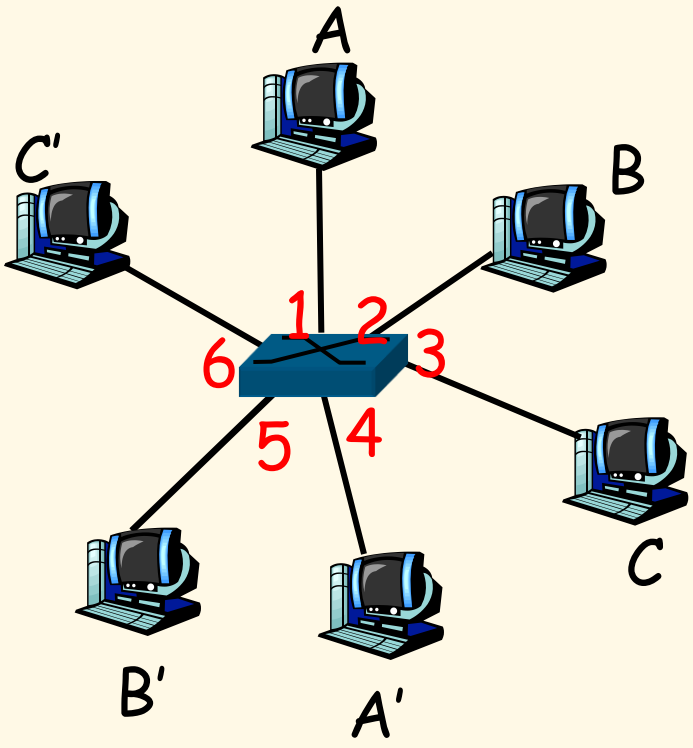


switch with six interfaces (1,2,3,4,5,6)

K & R

Switch Table

- *Q:* How does switch know that A' is reachable via interface 4, B' is reachable via interface 5?
- *A:* Switch has a switch table, each entry:
  - (MAC address of host, interface to reach host, time stamp)
- looks like a routing table!
- *Q:* How are entries created, maintained in switch table?
  - something like a routing protocol?

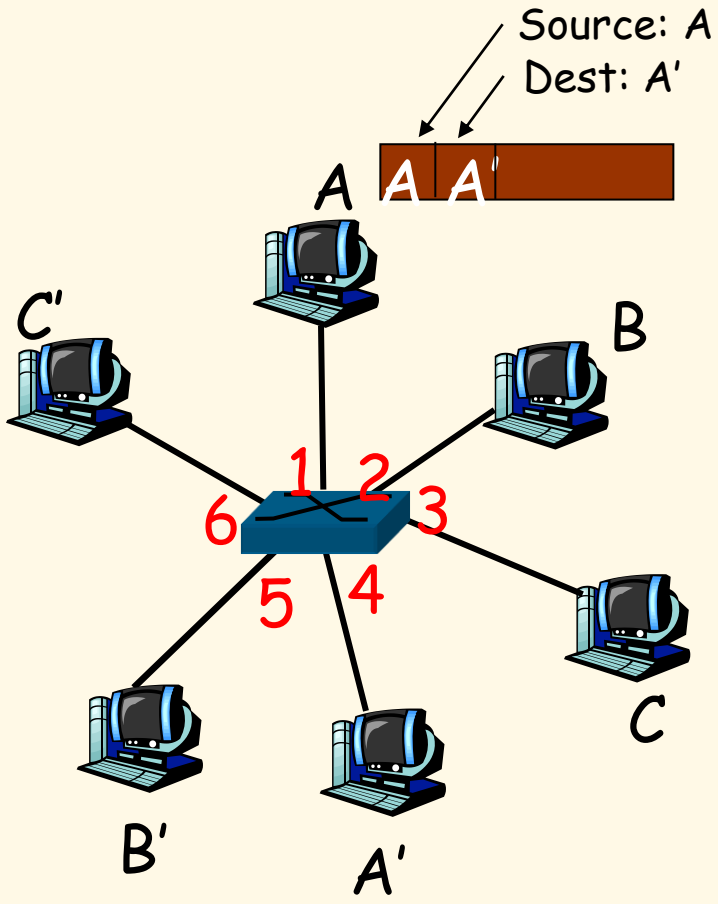


switch with six interfaces (1,2,3,4,5,6)

K & R

Switch: Self-Learning

- switch *learns* which hosts can be reached through which interfaces
  - when frame received, switch "learns" location of sender: incoming LAN segment.
  - records sender/location pair in switch table.



MAC addr	interface	TTL
A	1	60

Switch table (initially empty)

K & R

Switch: Frame Filtering/Forwarding

When frame received at the switch:

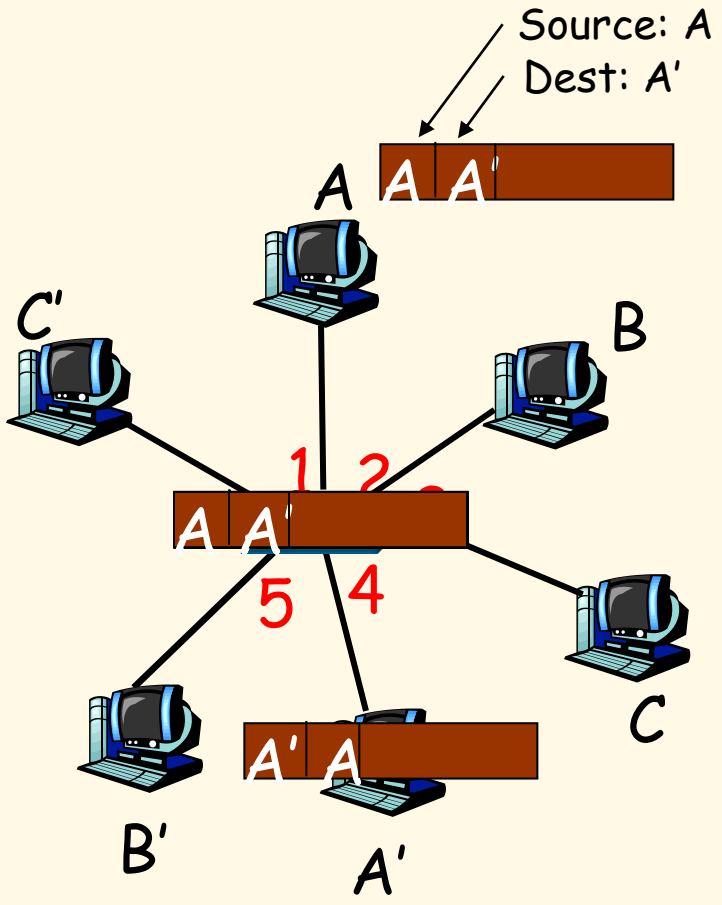
K & R

1. Record link associated with sending host.
2. Index switch table using MAC destination address.
3. if entry found for destination then
   {
   if dest on segment from which frame arrived
   then drop the frame
   else forward the frame on interface indicated
   }
   else flood

forward on all but the interface on which the frame arrived

Self-learning, Forwarding: Example

- **frame destination unknown:** flood
- destination A location known: **selective send**



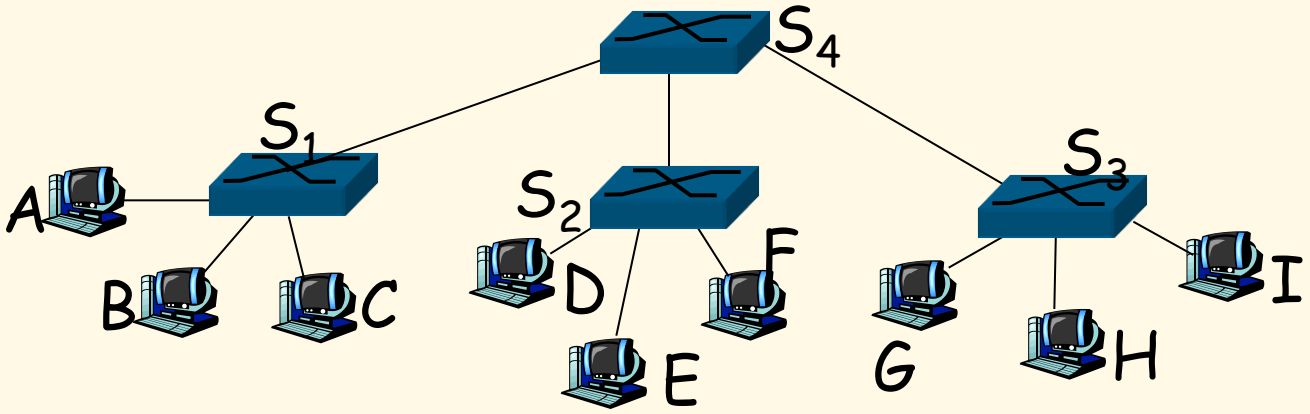
MAC addr	interface	TTL
A	1	60
A'	4	60

Switch table (initially empty)

K & R

Interconnecting Switches

- Switches can be connected together.

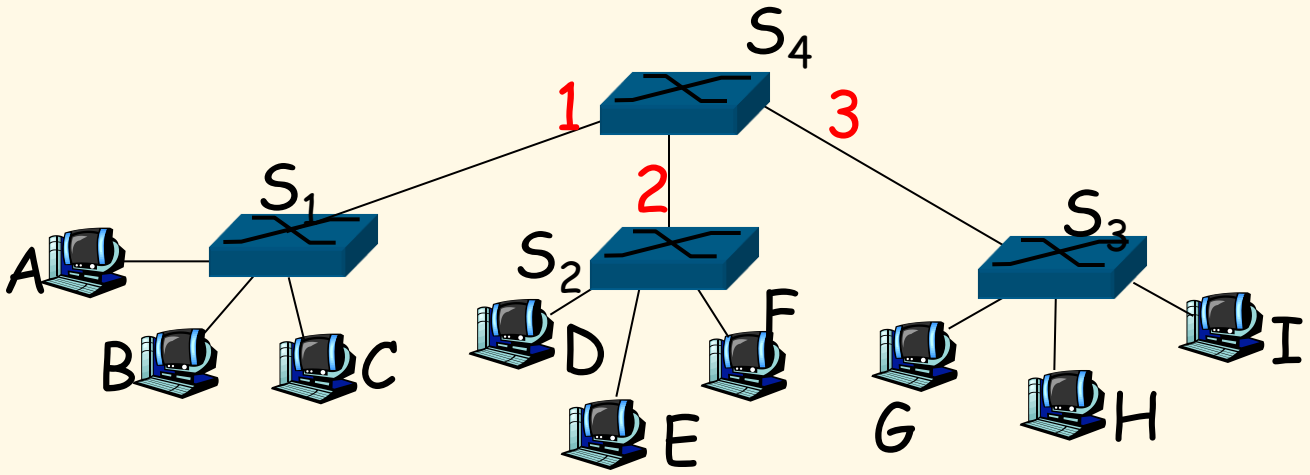


- Q: sending from A to G - how does S_1 know to forward frame destined to G via S_4 and S_3?
- A: self learning! (works exactly the same as in single-switch case!)

K & R

Self-learning Multi-Switch

Suppose C sends frame to I, I responds to C



- Q: show switch tables and packet forwarding in S_1, S_2, S_3, S_4

K & R

Switched Ethernet

- The advantage comes when the switched Ethernet backplane is able to repeat more than one frame in parallel *(a separate backplane bus line for each node).*
  - The frame is relayed onto the required output port via the port's own backplane bus line.
- Under this scheme collisions are still possible when two concurrently arriving frames are destined for the same station.
- Note – each parallel transmission can take place at 10 Mbps!!

Switched Ethernet

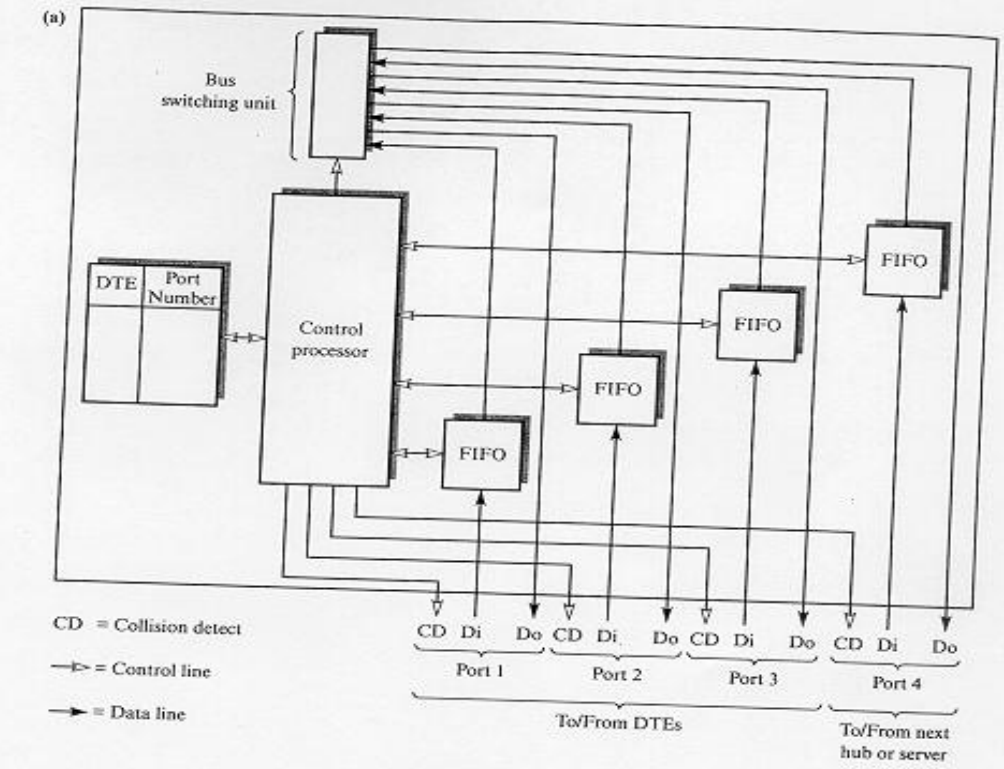
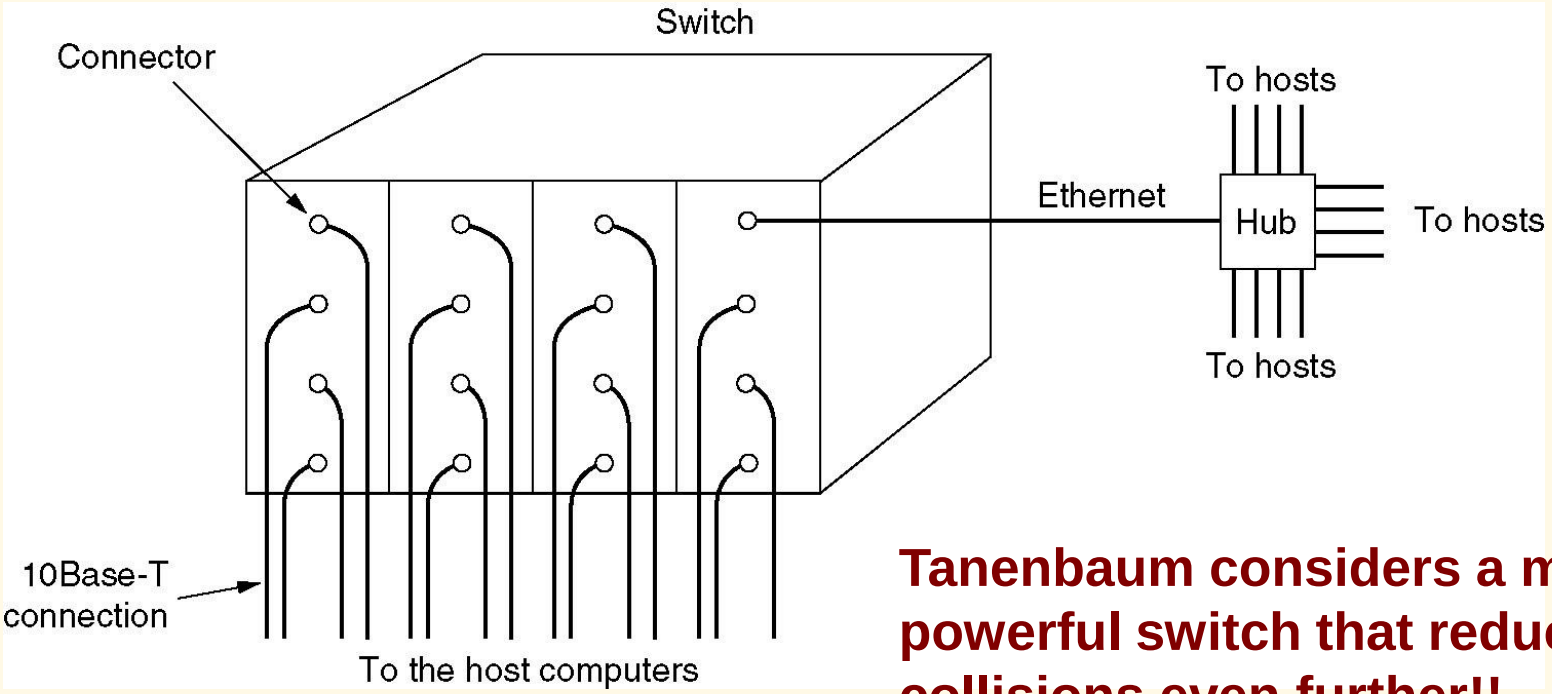


Figure 7.2
Ethernet switching:
(a) switching hub schematic;
(b) switching hub derivative.

Halsall

Switched Ethernet



Tanenbaum considers a more powerful switch that reduces collisions even further!!

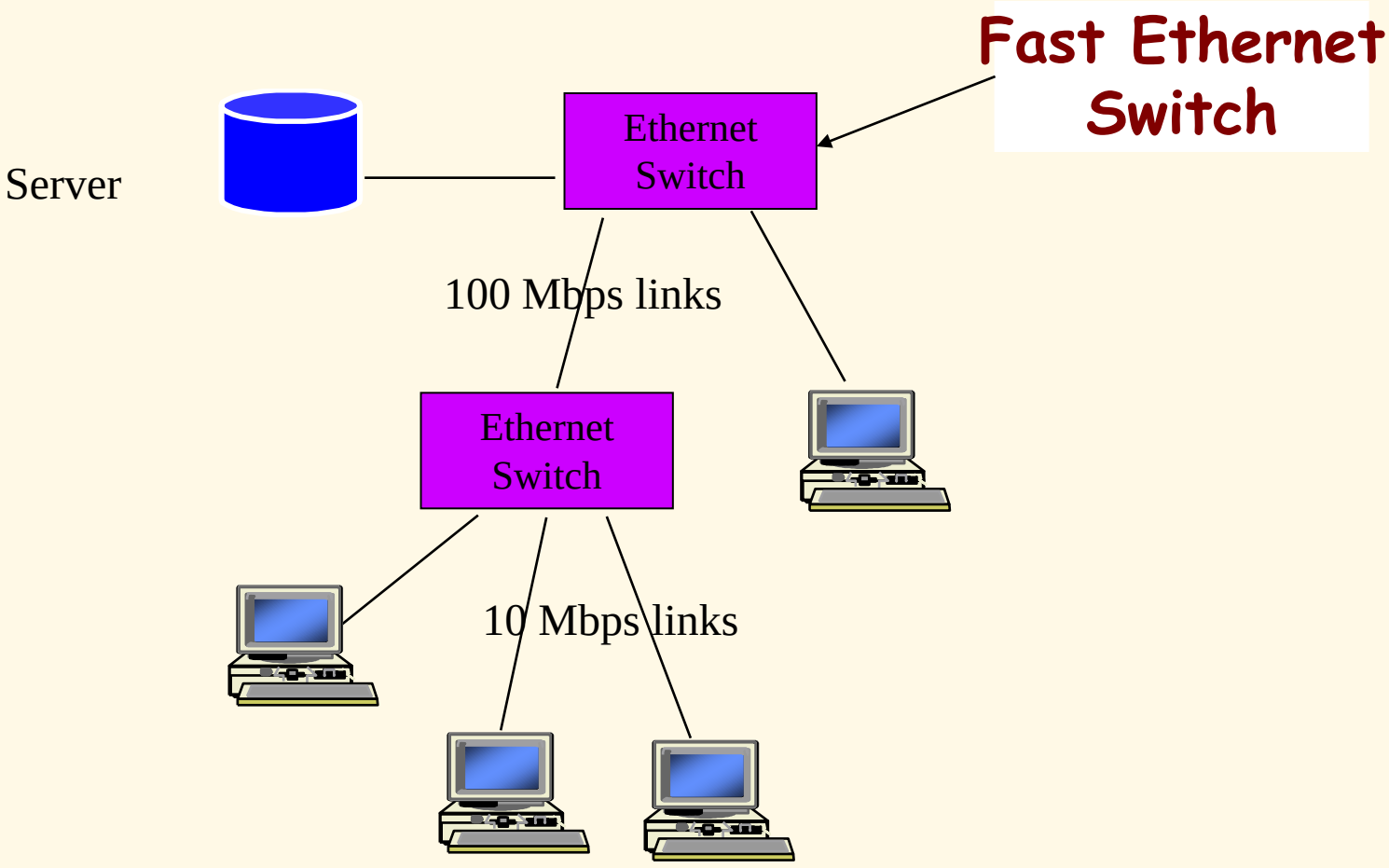
Figure 4-20. A simple example of switched Ethernet.

Tanenbaum

Switched Ethernet Hub

- Since servers are often shared by multiple nodes, one can employ a switching hub with one port which operates at a higher rate than the other ports.
  - ➔ This requires extra buffering inside the hub to handle speed mismatches.
- Can be further enhanced by higher rated port full-duplex.

Switching Hierarchy



Leon-Garcia & Widjaja: *Communication Networks*

Ethernet Summary

- Ethernet
  - Binary Exponential Backoff
- Ethernet versus IEEE 802.3
- Ethernet Evolution
  - 10BASE5, 10BASE2, 1BASE5, 10BASE-T
- Switched Ethernet
- Switching Hub