CS2031
Telecommunications II

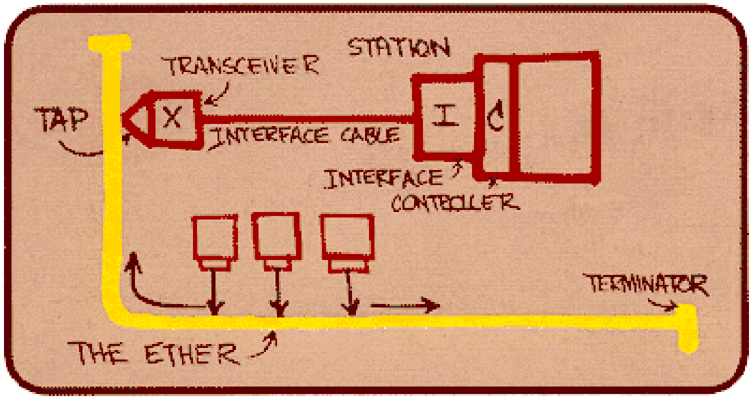
Ethernet

Ethernet

- Developed by Metcalfe 1972/3
- Standards in 1978, 1995, 1998

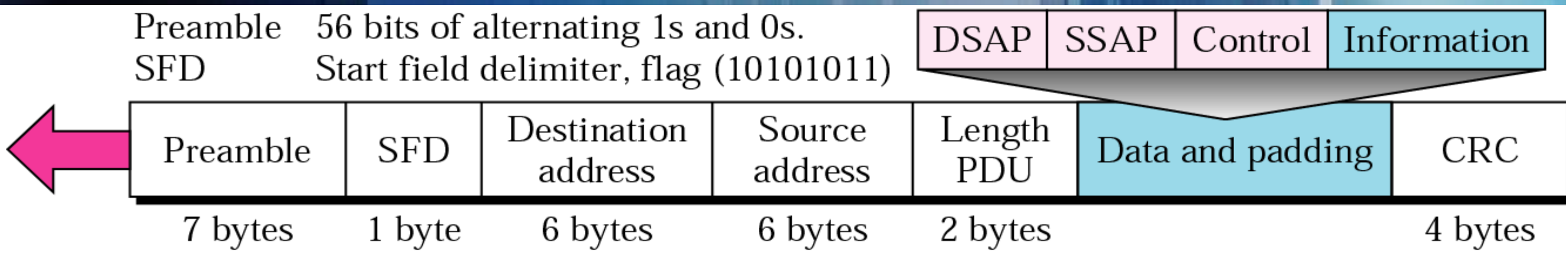
- Types of Ethernet
  - Original Ethernet
  - Switched Ethernet
  - Fast Ethernet
  - Gigabit Ethernet

- Manchester Encoding
- Medium Access Control
  - CSMA/CD



Metcalfe's Ethernet sketch

802.3 MAC Format



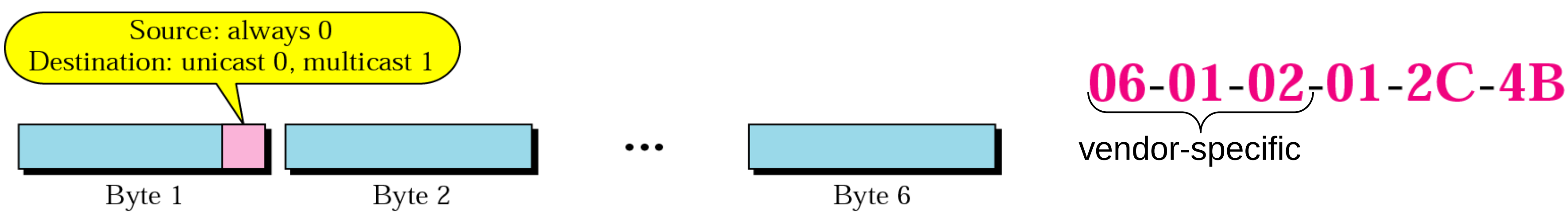
- 64-bit frame preamble (10101010) used to synchronize reception
  - 7 bit preamble (10101010) + 1 start flag (10101011)

- Maximum frame length: 1536 bytes
  - ⇨ max 1500 bytes payload
- Minimum frame length: 64 bytes
  - ⇨ min 46 bytes payload

* Figure is courtesy of B. Forouzan

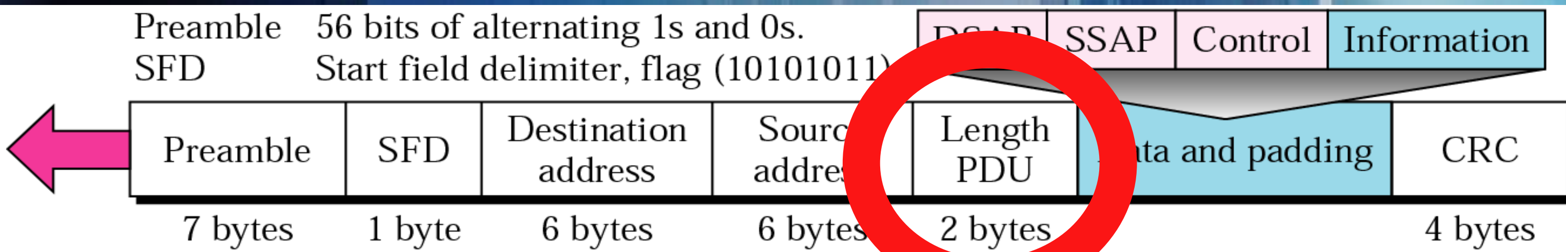
Ethernet Addresses

- Types of Addresses:
  - Unicast – delivered to one station
    - 00-10-4B   3Com 3C905-TX PCI
    - 00-A0-C9   Intel (PRO100B and PRO100+)
  - Multicast – delivered to a set of stations
    - 01-80-C2-00-00-00   Spanning tree (for bridges)
    - 03-00-00-00-00-01   NETBIOS
  - Broadcast – delivered to all stations
    - FF-FF-FF-FF-FF-FF



* Figure is courtesy of B. Forouzan

802.3 MAC Format



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- Maximum frame length: 1536 bytes
  ⇨ max 1500 bytes payload
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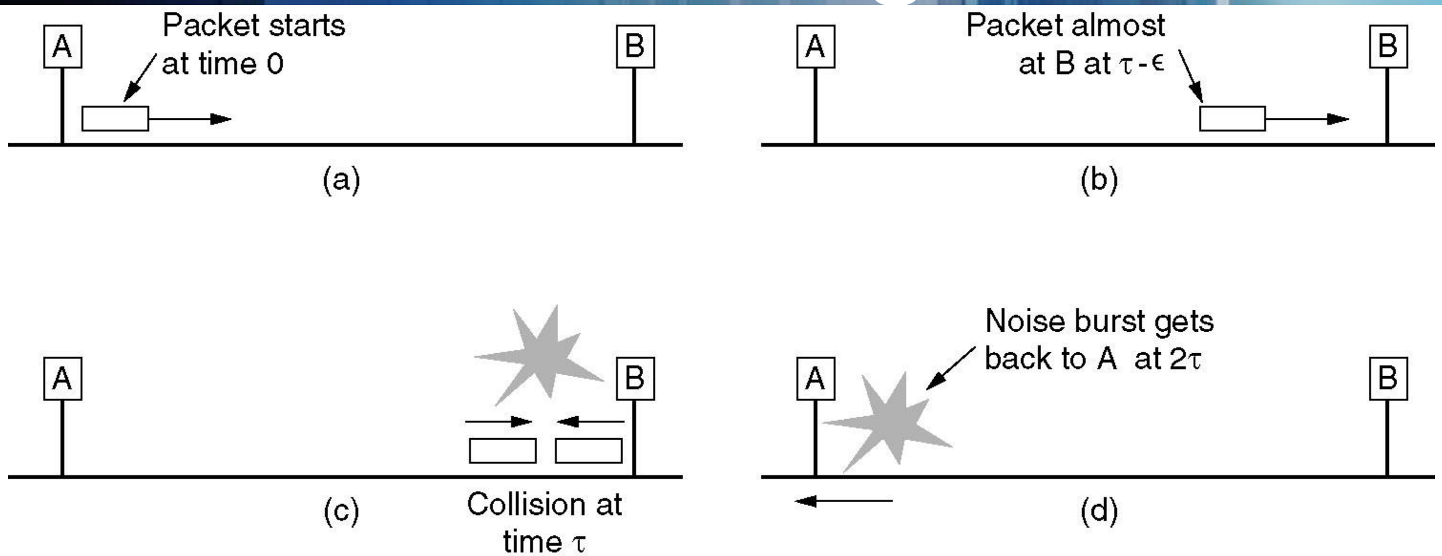
  ⇨ min 46 bytes payload

Length: Up to 0x600
Type: eg. 0x800 IP
0x806 ARP

* Figure is courtesy of B. Forouzan

Frame Length

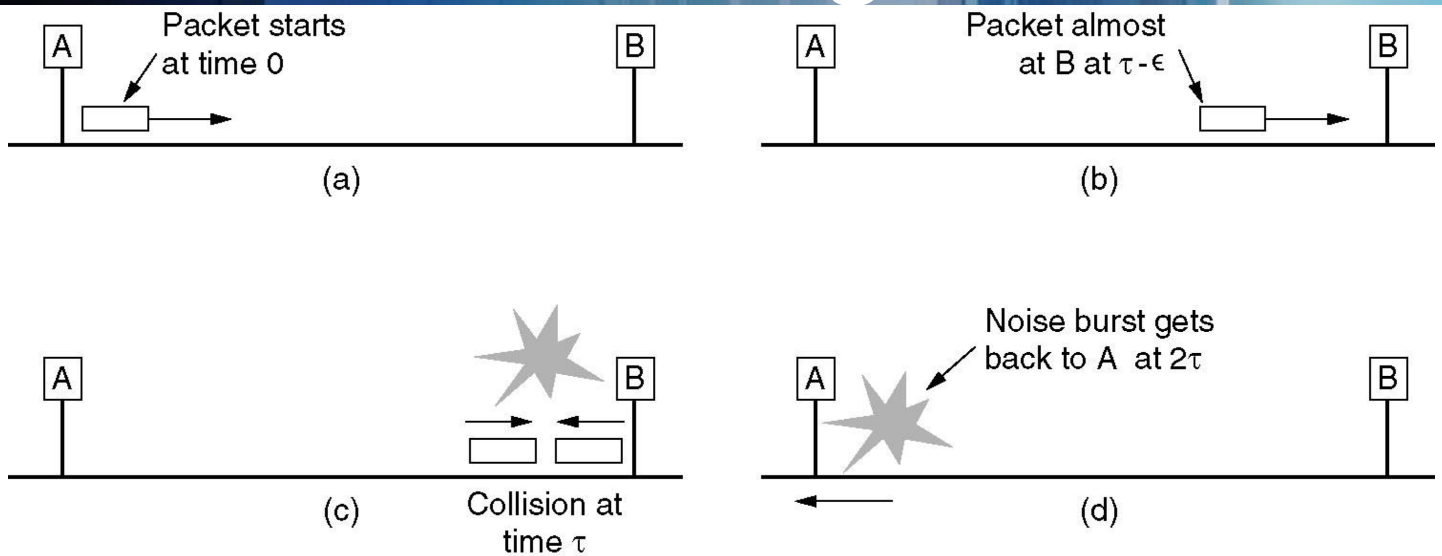


- Sender starts at t= 0
- Packet takes τ time to get to B
- Shortly before B starts transmitting
  - But discovers collision with A's signal
- 48-bit Jamming signal takes τ time to get to B

⇒ It takes at 2τ to detect a collision

* Figure is courtesy of A. Tanenbaum

Frame Length II

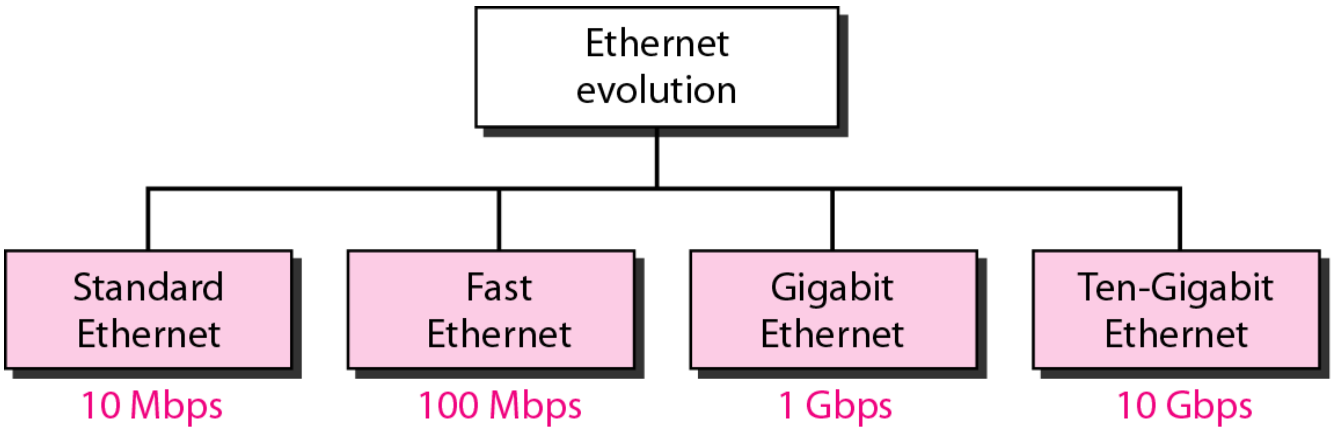


- It takes at 2τ to detect a collision
- Roundtrip time = 100чsec
- 10 Mbit/s ⇒ 500 bits

  ~512 bits or 64 bytes

* Figure is courtesy of A. Tanenbaum

Evolution of Ethernet

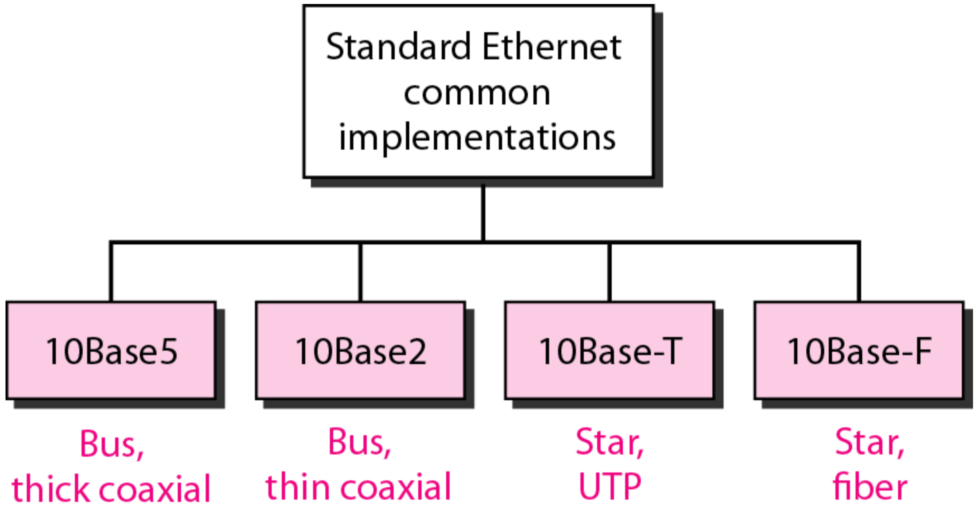


- 1972/73 defined for coaxial cable
- Fast Ethernet used mainly unshielded twisted pair (UTP)

- Gigabit Ethernet common in desktops and laptops
- 10GB Ethernet used mainly for backbone

* Figure is courtesy of B. Forouzan

Types of Ethernet



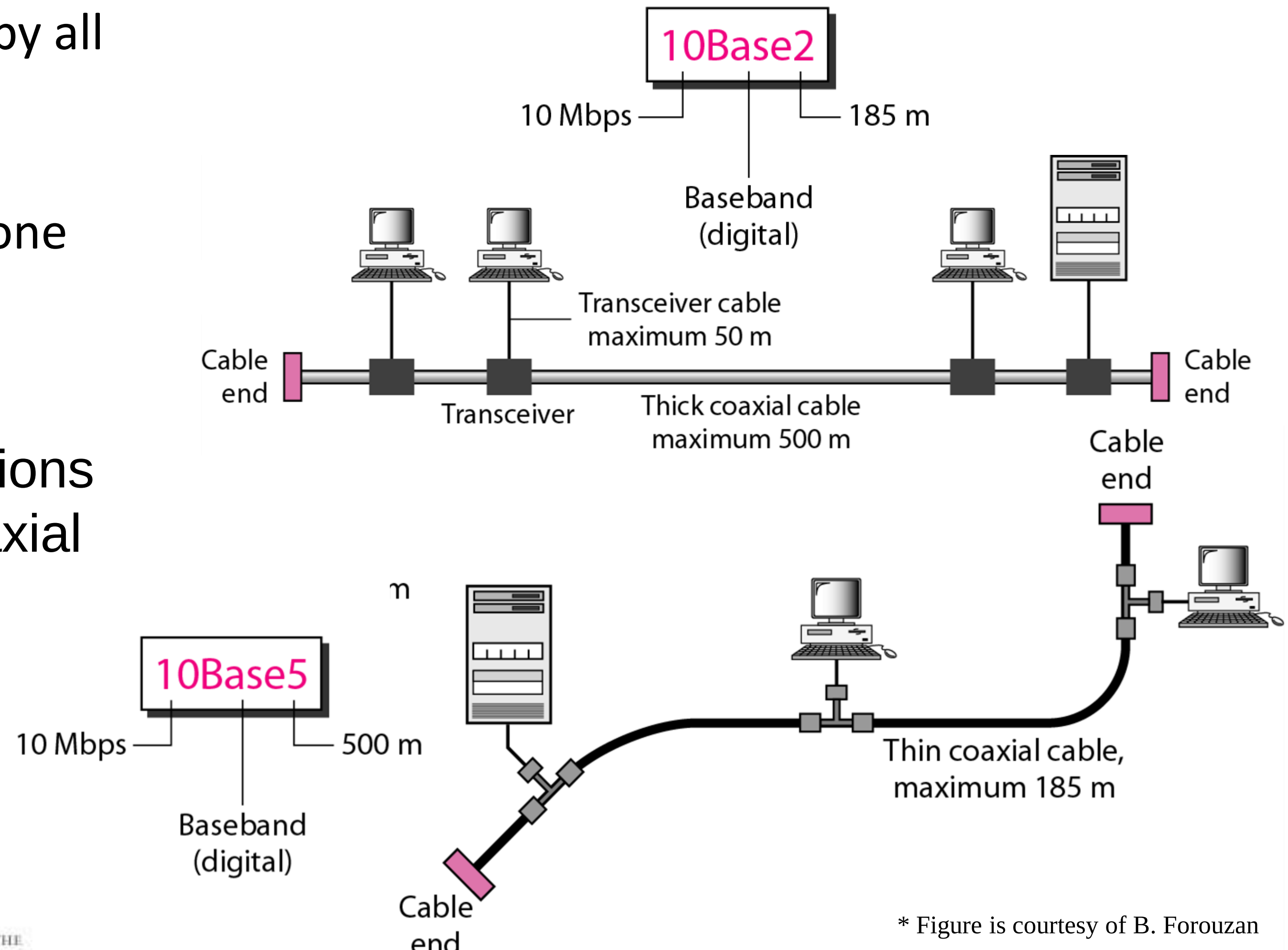
Name	Cable	Max. seg.	Nodes/seg.	Advantages
10Base5	Thick coax	500 m	100	Original cable; now obsolete
10Base2	Thin coax	185 m	30	No hub needed
10Base-T	Twisted pair	100 m	1024	Cheapest system
10Base-F	Fiber optics	2000 m	1024	Best between buildings

* Figure is courtesy of B. Forouzan

10Base5 & 10Base2

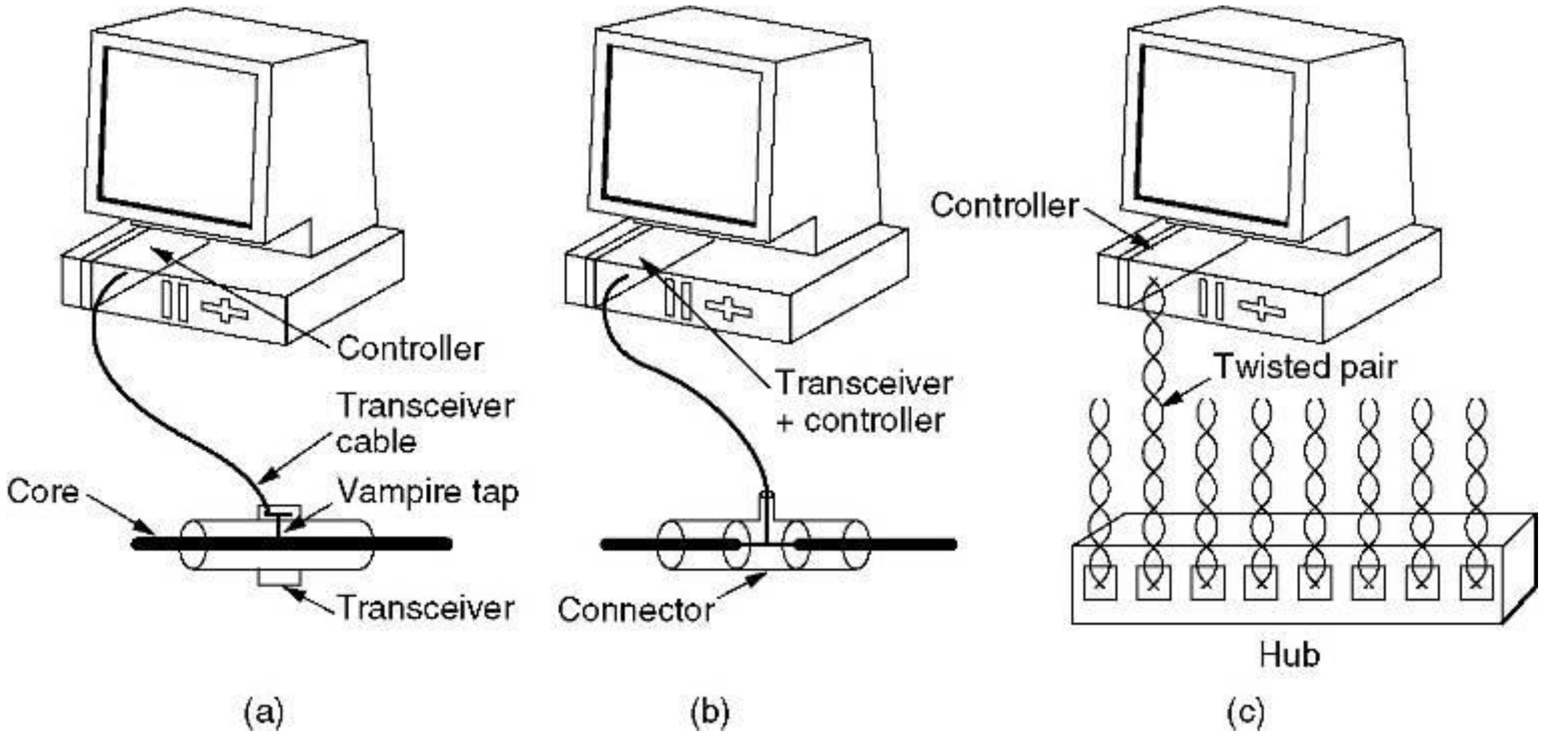
- Signal travels over cable & is picked up by all stations
- Used as backbone technology

- 10Base5: Stations linked into coaxial cable



* Figure is courtesy of B. Forouzan

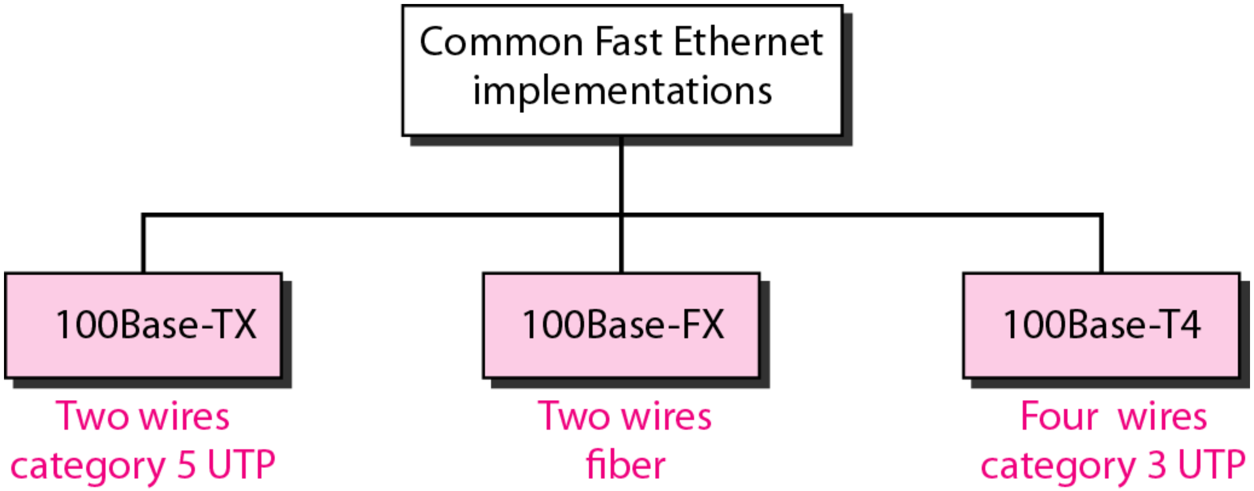
Ethernet Cabling



(a) 10Base5, (b) 10Base2, (c) 10Base-T.

* Figure is courtesy of A. Tanenbaum

100Base-X

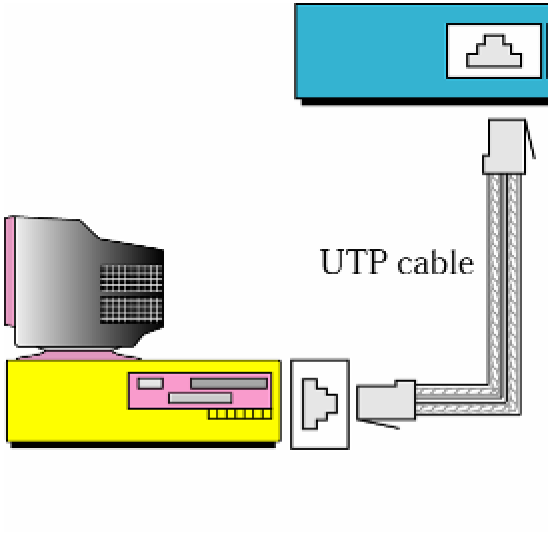


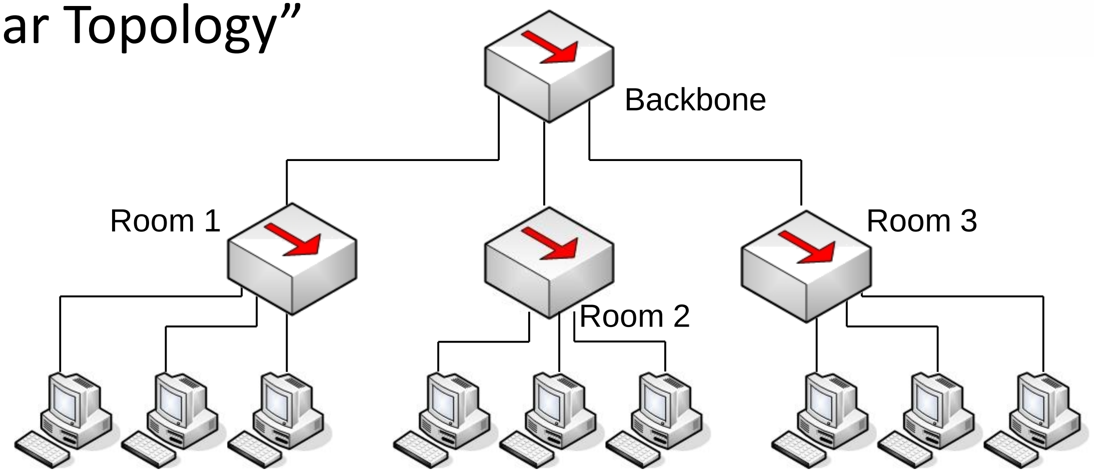
Name	Cable	Max. segment	Advantages
100Base-T4	Twisted pair	100 m	Uses category 3 UTP
100Base-TX	Twisted pair	100 m	Full duplex at 100 Mbps
100Base-FX	Fiber optics	2000 m	Full duplex at 100 Mbps; long runs

* Figure is courtesy of B. Forouzan

100Base-T

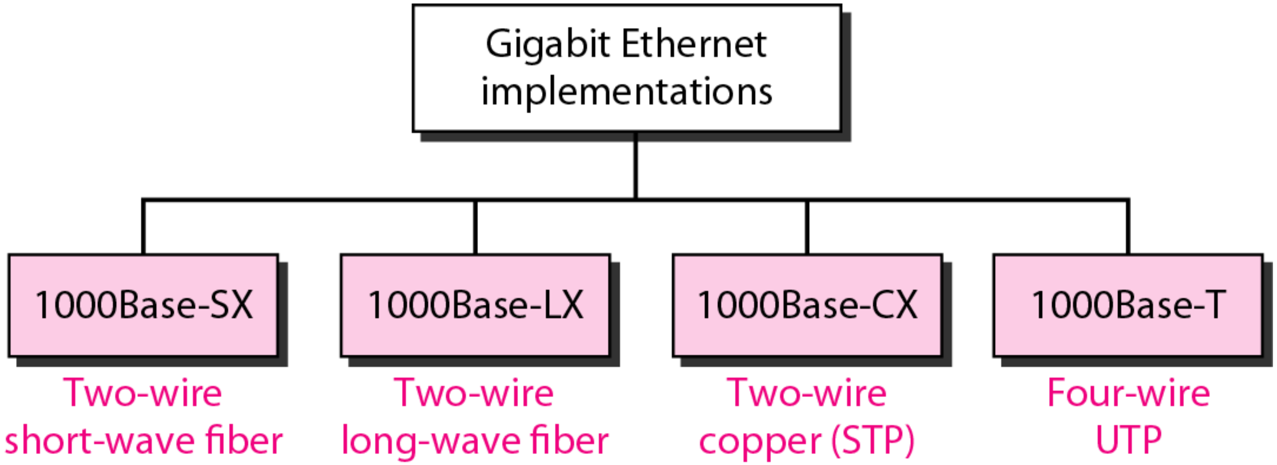
- 10/100 Mbps rate
  - latter called "Fast Ethernet"
- T stands for Twisted Pair
- Hub to which nodes are connected by twisted pair
  - "Star Topology"





* Figure is courtesy of B. Forouzan

Gigabit Ethernet



- Minimum frame length: 512 bytes

* Figure is courtesy of B. Forouzan

Ethernet Standards

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Name	Cable	Max. segment	Advantages
1000Base-SX	Fiber optics	550 m	Multimode fiber (50, 62.5 microns)
1000Base-LX	Fiber optics	5000 m	Single (10 µ) or multimode (50, 62.5 µ)
1000Base-CX	2 Pairs of STP	25 m	Shielded twisted pair
1000Base-T	4 Pairs of UTP	100 m	Standard category 5 UTP

* Figure is courtesy of A. Tanenbaum

802.3ae 10GB-Ethernet

Characteristics	*10GBase-S*	*10GBase-L*	*10GBase-E*
Media	Short-wave 850-nm multimode	Long-wave 1310-nm single mode	Extended 1550-mm single mode
Maximum length	300 m	10 km	40 km

- Backbone technology
- Based on optical fibre

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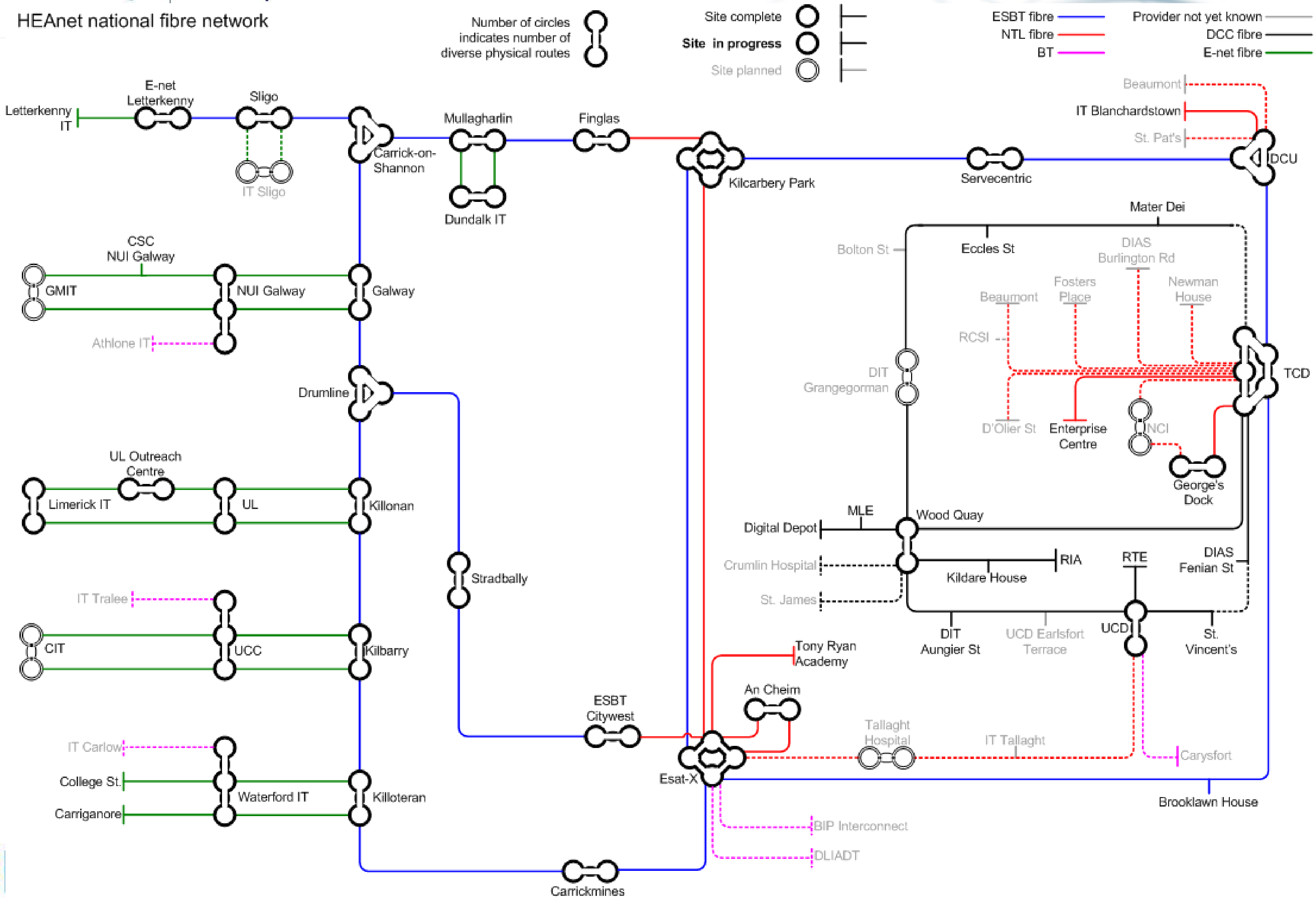
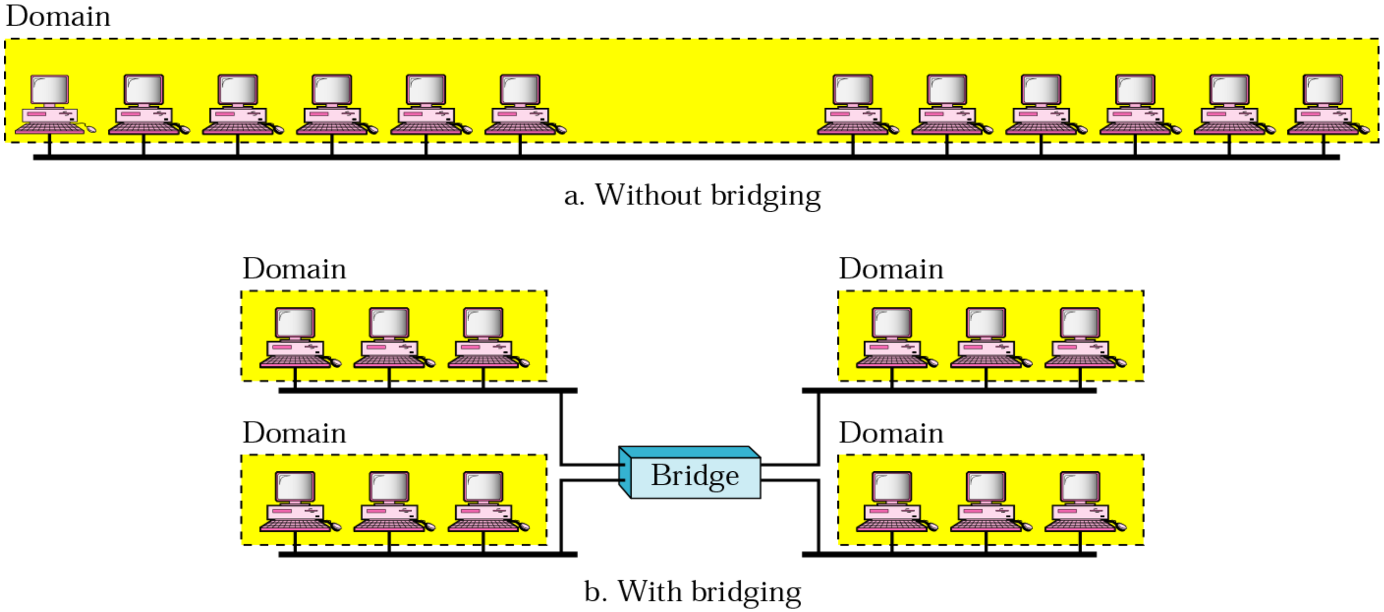
HEAnet national fibre network



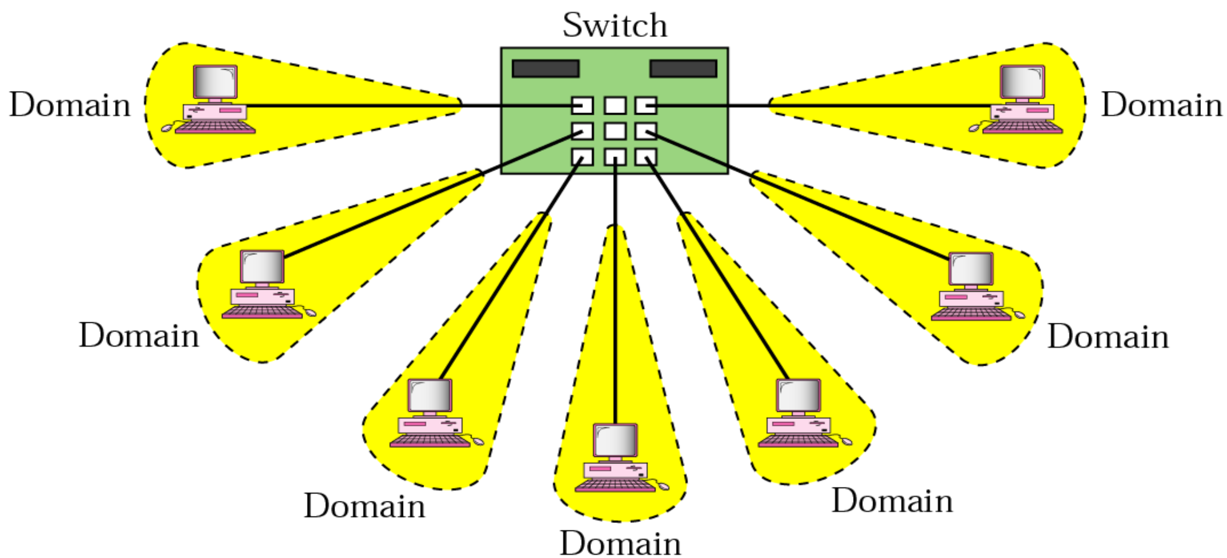
Collision Domains



- Extension of Networks:
  - Repeaters, Hubs - Physical Layer
  - Bridges, Switches - Data Link Layer
  - Routers - Network Layer
- Collision domains:
  - Collision affects all machines in one segment

* Figure is courtesy of B. Forouzan

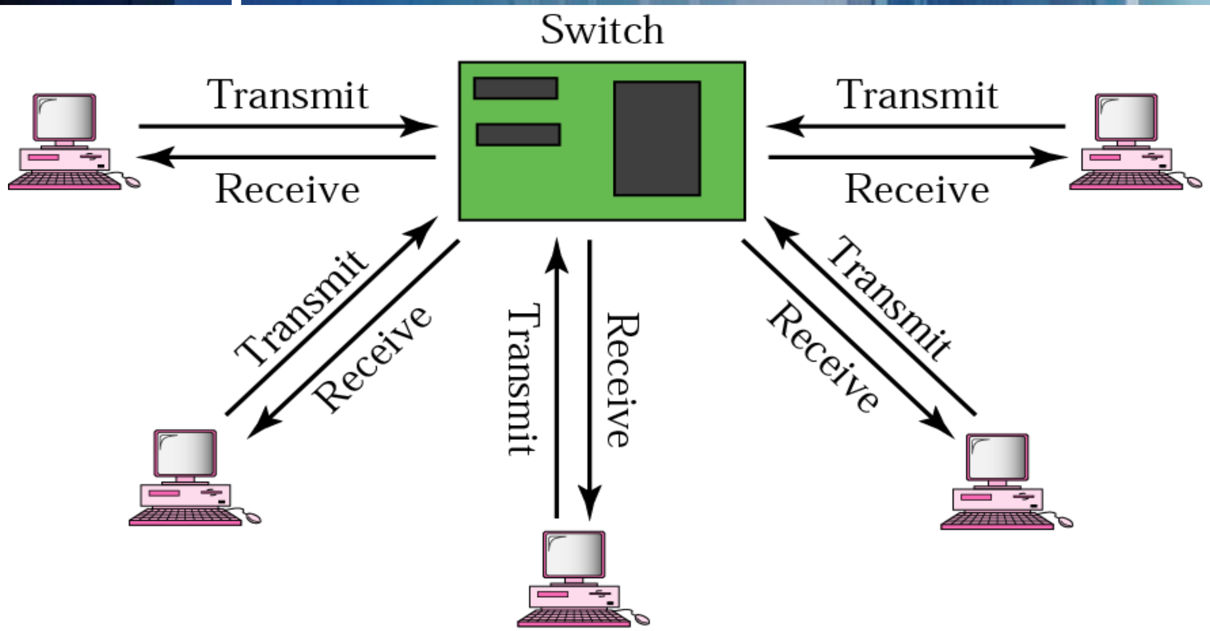
Switched Ethernet



- Switch delivers packets to individual machines
  - Without affecting communication with other machines
- Collisions only occur on individual links

* Figure is courtesy of B. Forouzan

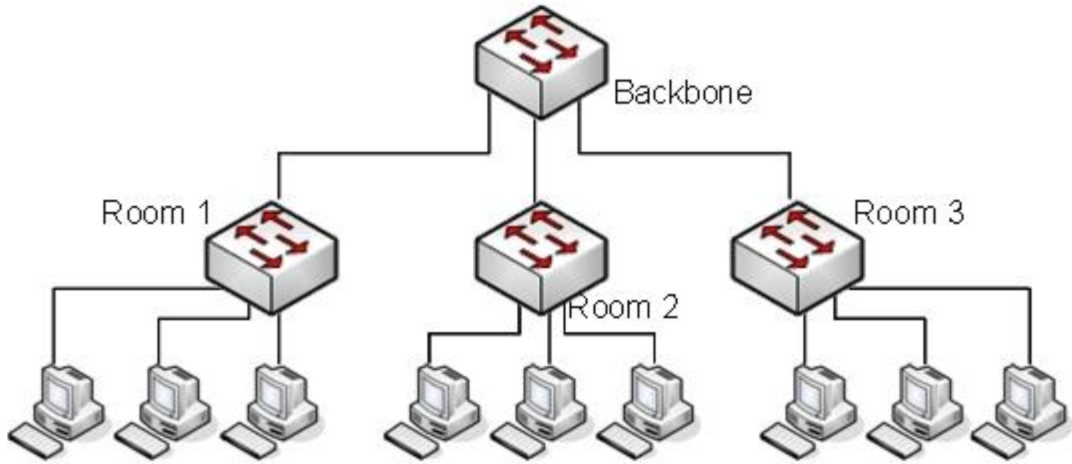
Full-duplex Switched Ethernet



- No collisions
  - One channel to send
  - One channel to transmit

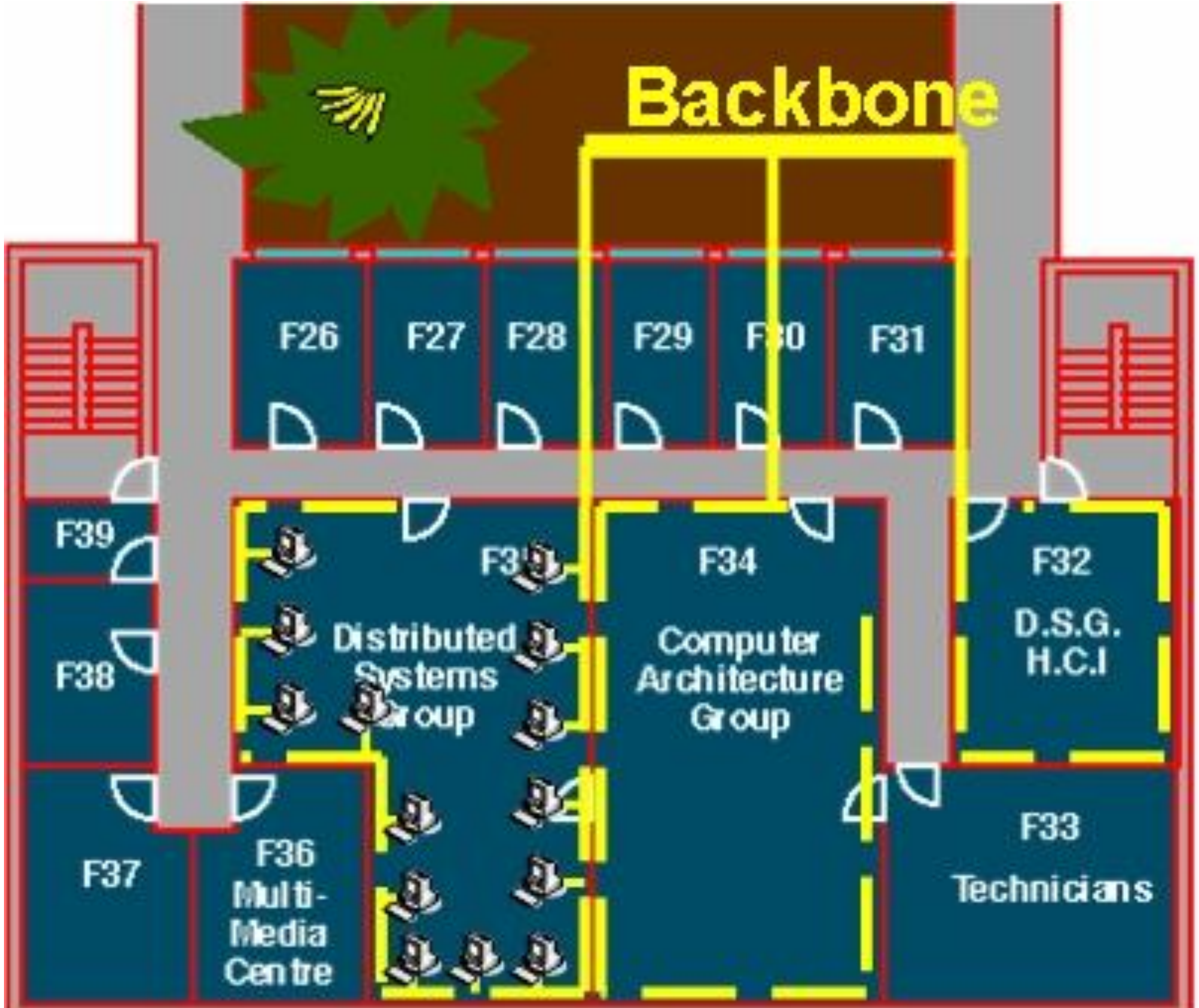
* Figure is courtesy of B. Forouzan

Switched Networks

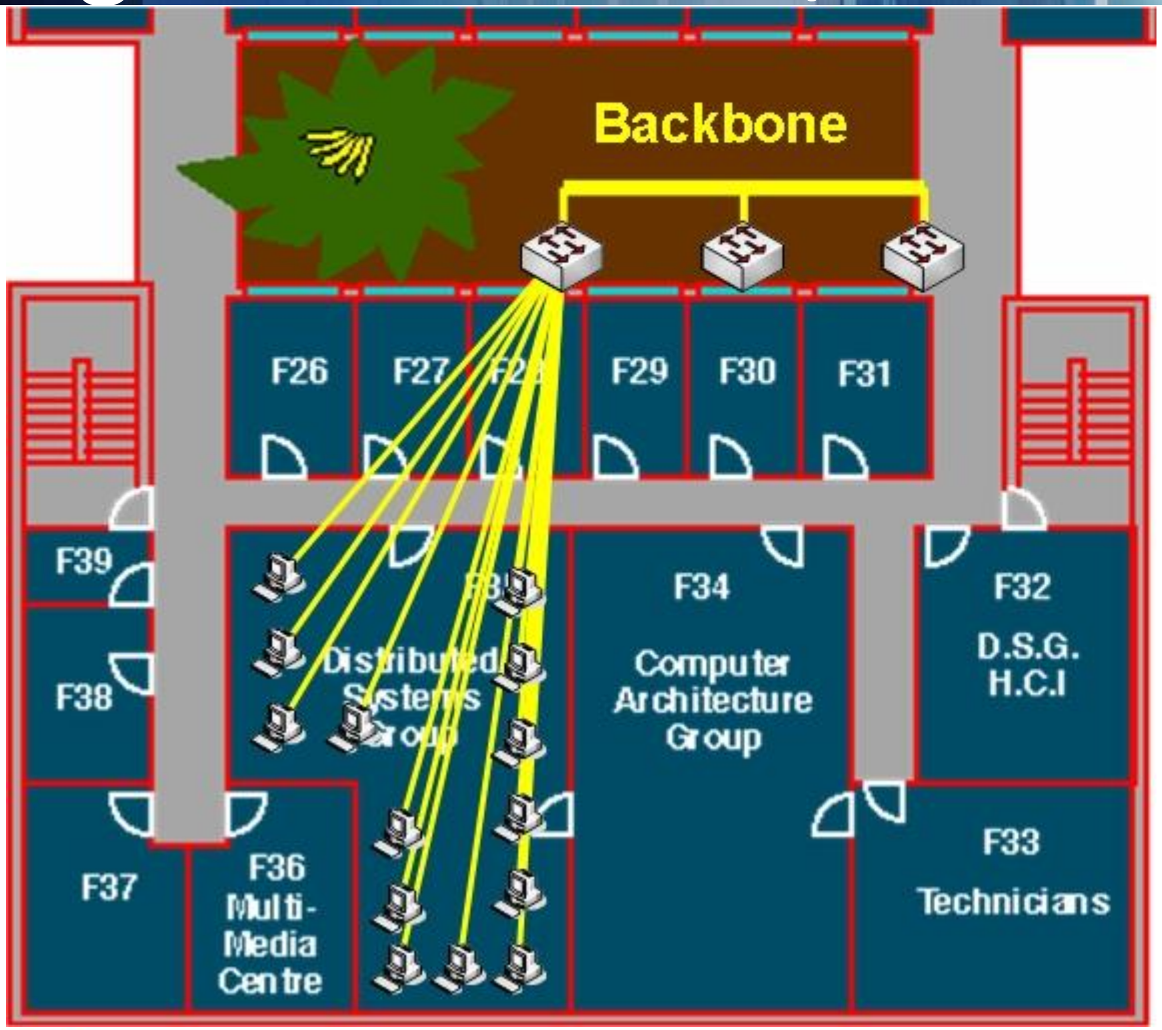


- Hierarchical Organization
- Separation into Segments
- Keep traffic in one segment - if possible

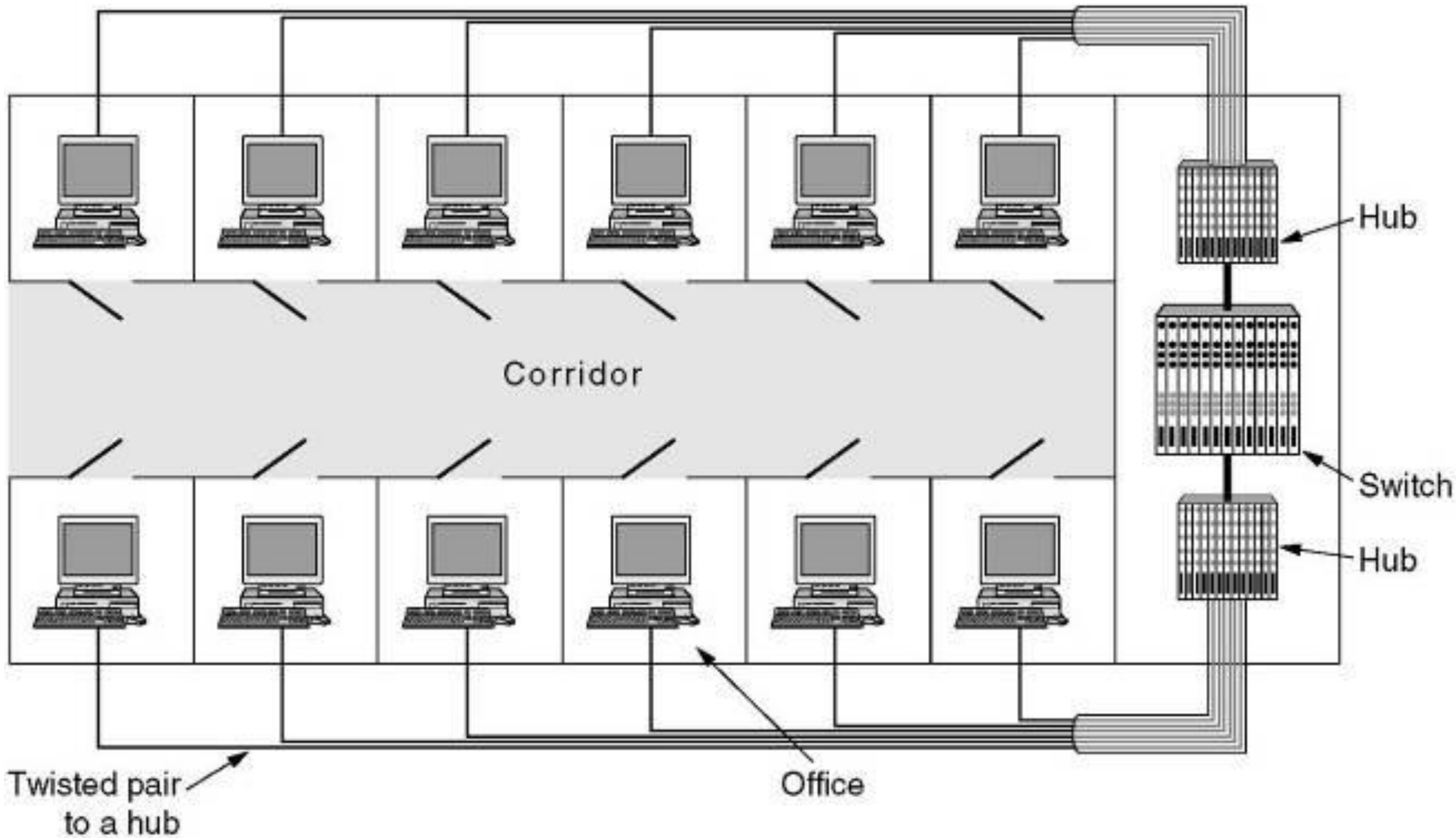
College Network – 10Base2



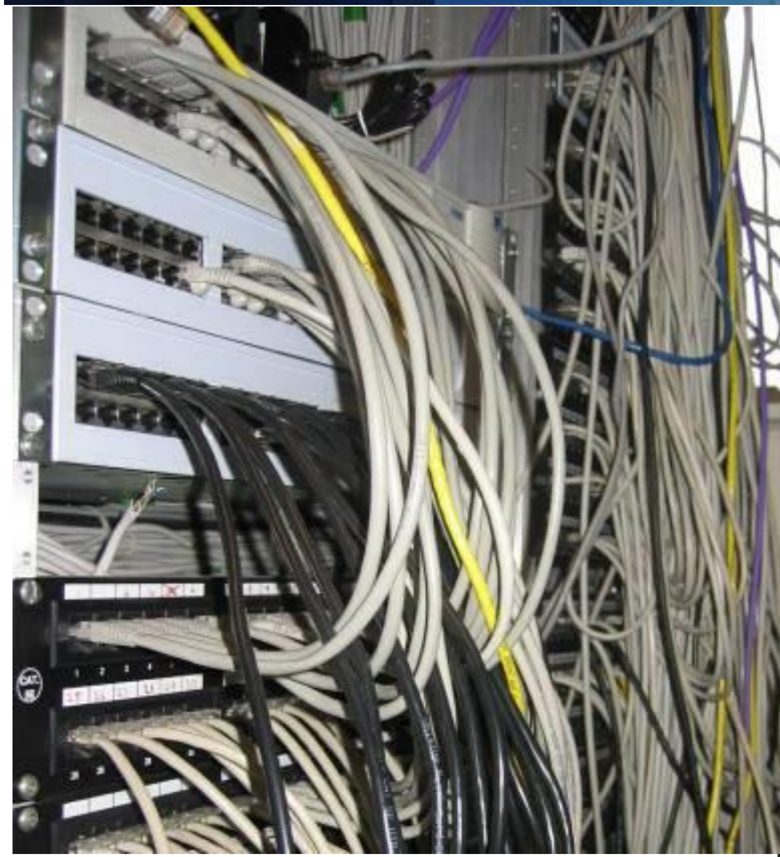
College Network–10/100BaseT

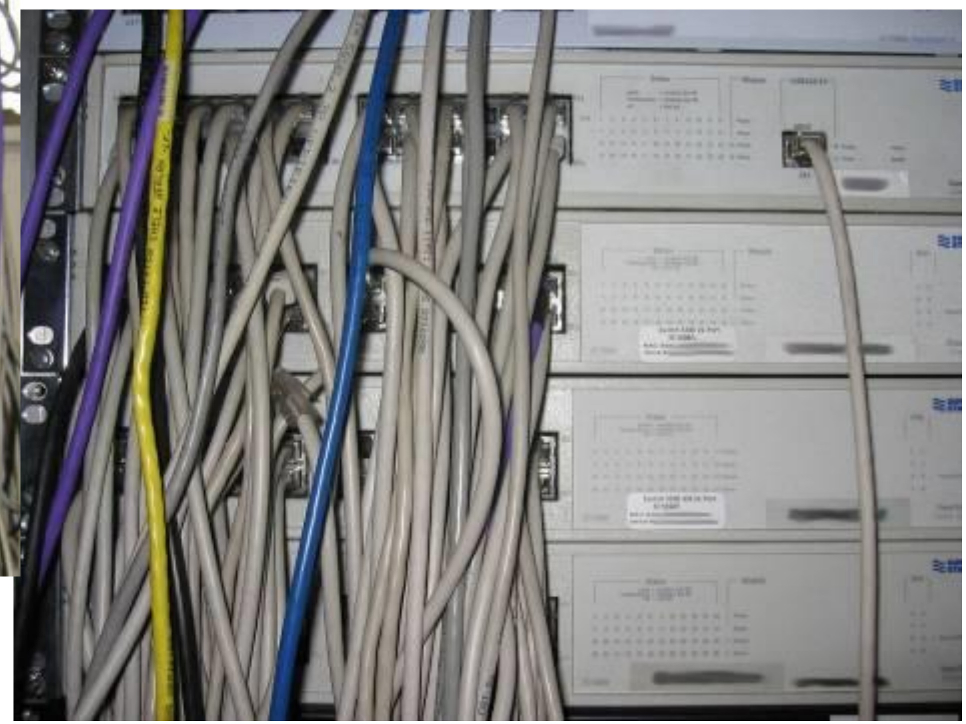


Switched Network

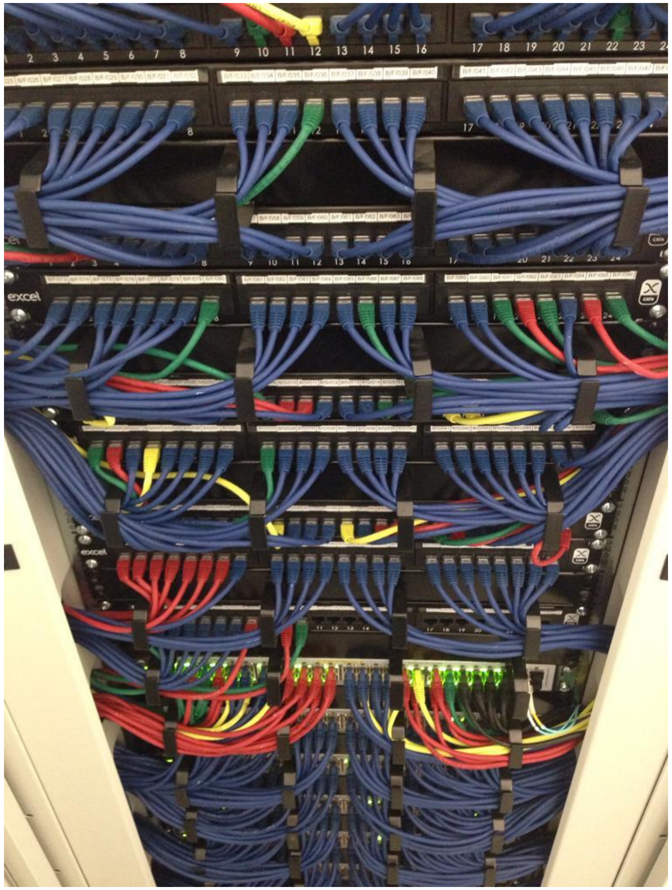


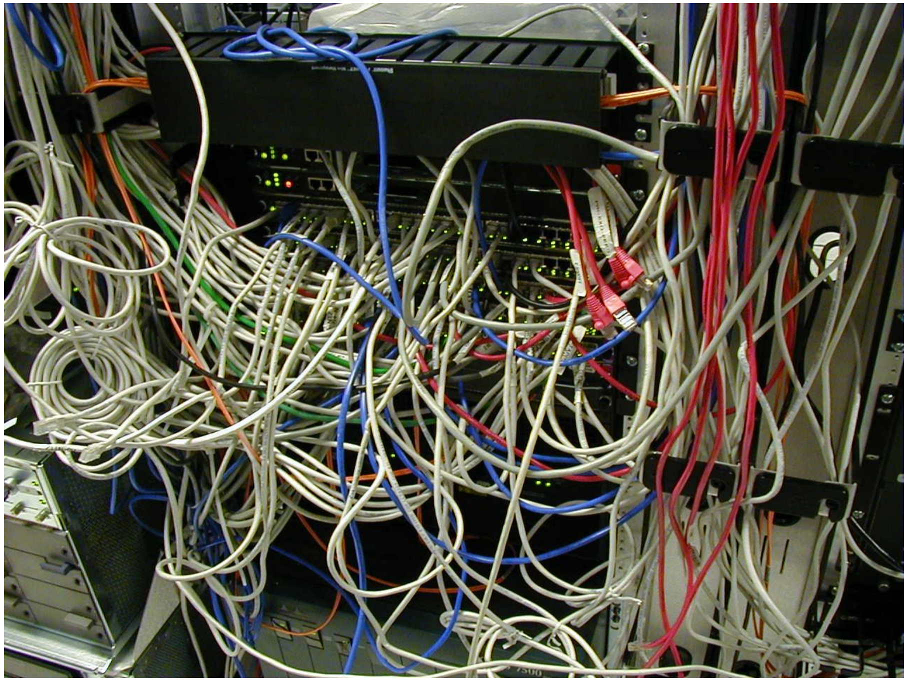
Switches in Comms Rooms



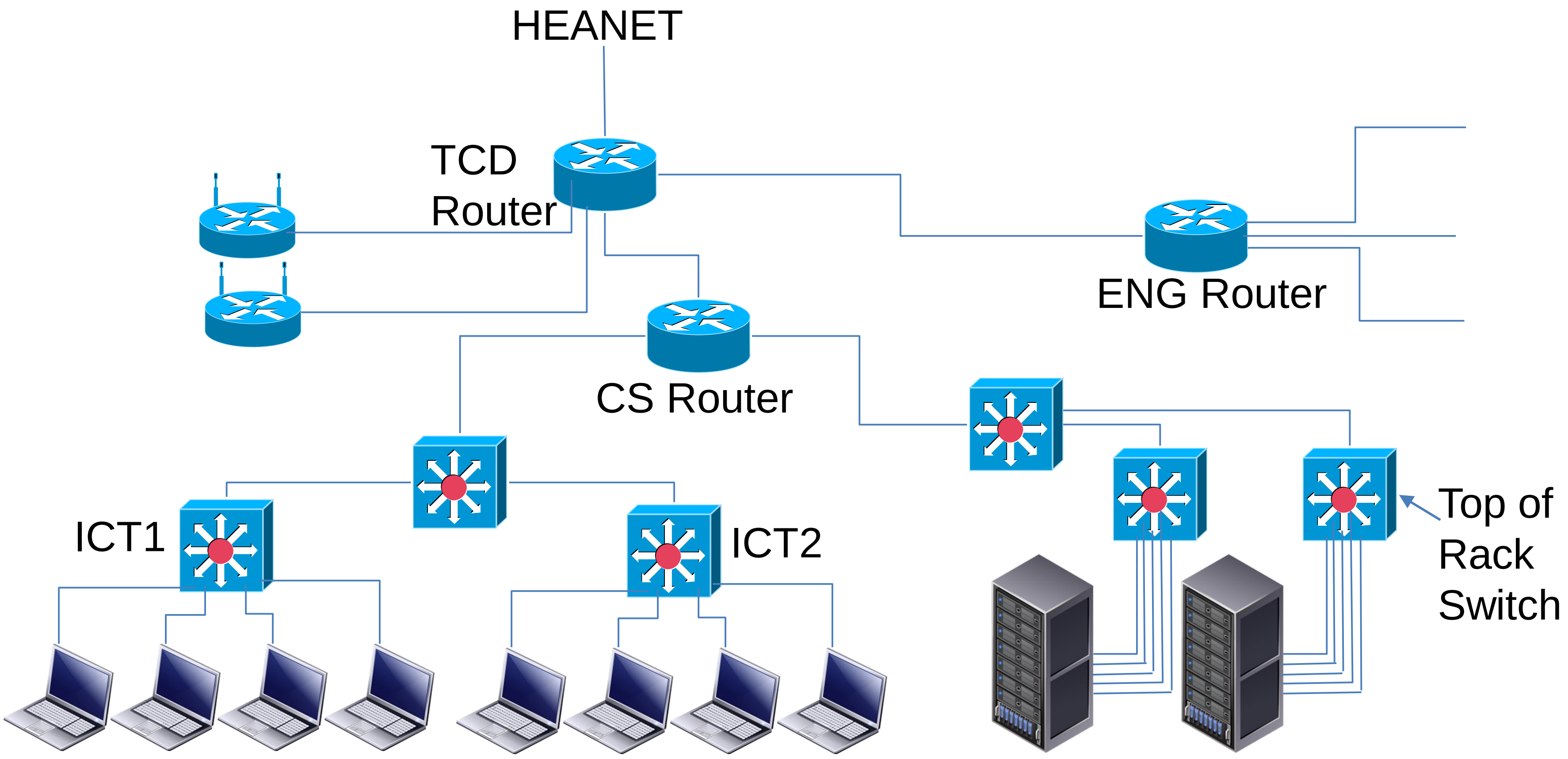


Wiring Example ☺



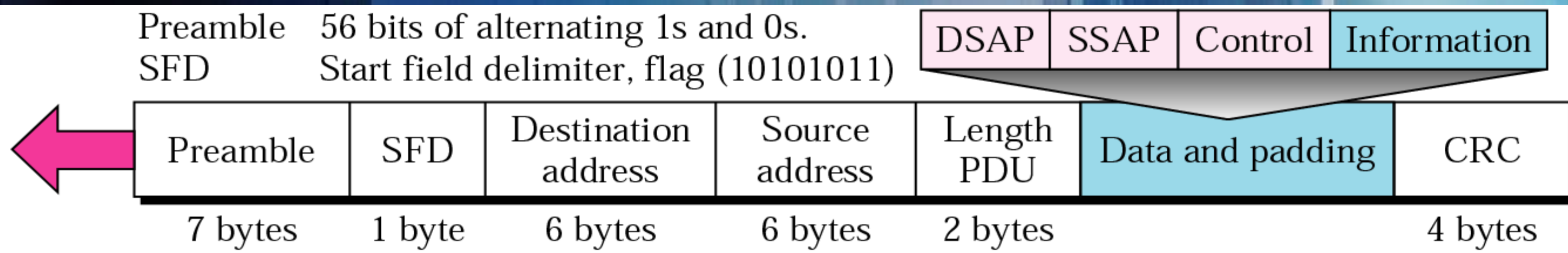


College Example



Potential topology of College; may or may not reflect the reality of our setup

802.3 & 802.2 MAC Format



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* Figure is courtesy of B. Forouzan

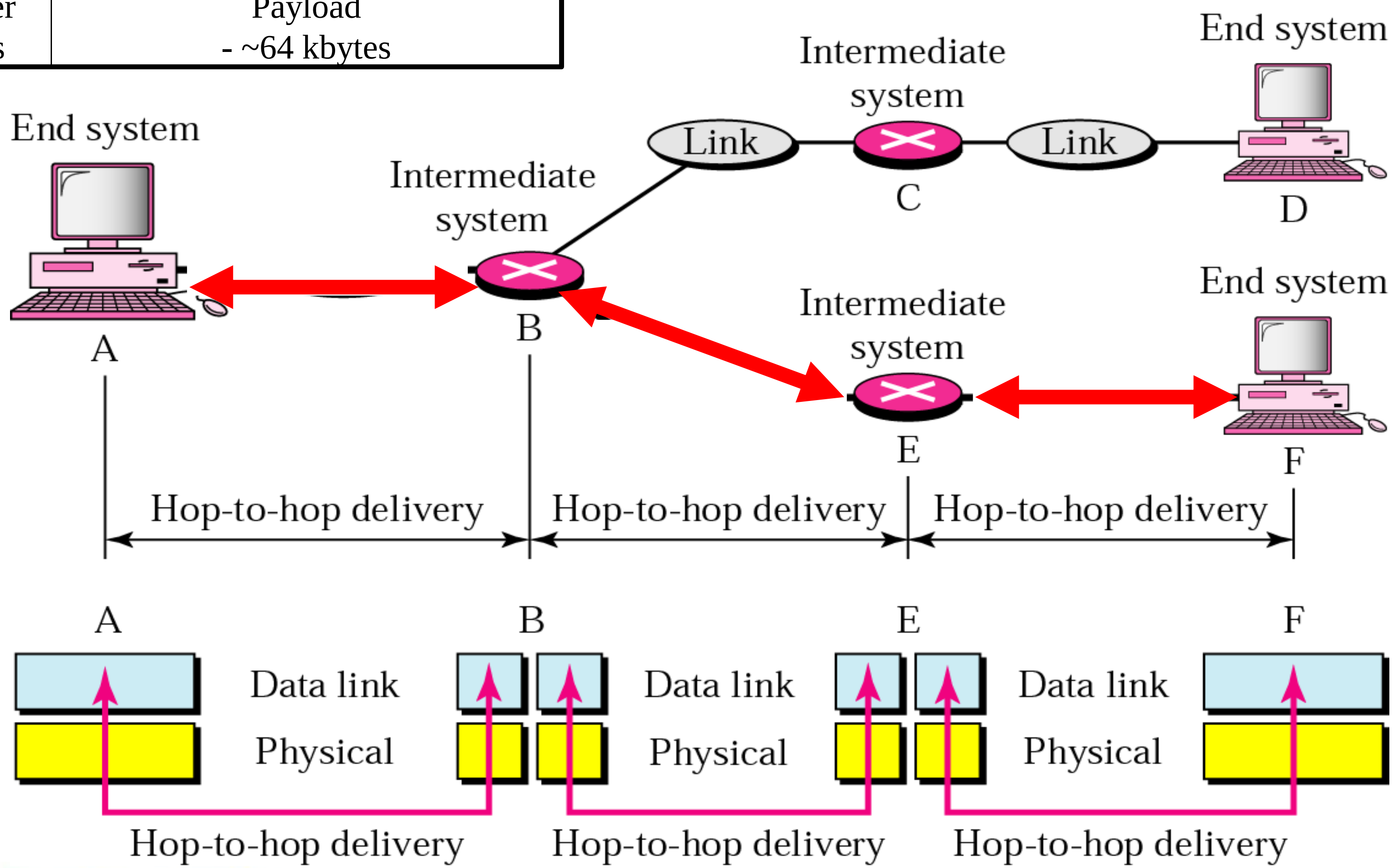
Summary: Ethernet

- Ethernet frame
  - Preamble to signal start of frame
  - MTU & minimum frame size
  - Addressing
- CSMA/CD
- Collision Domains
- Switched Networks

Link Layer

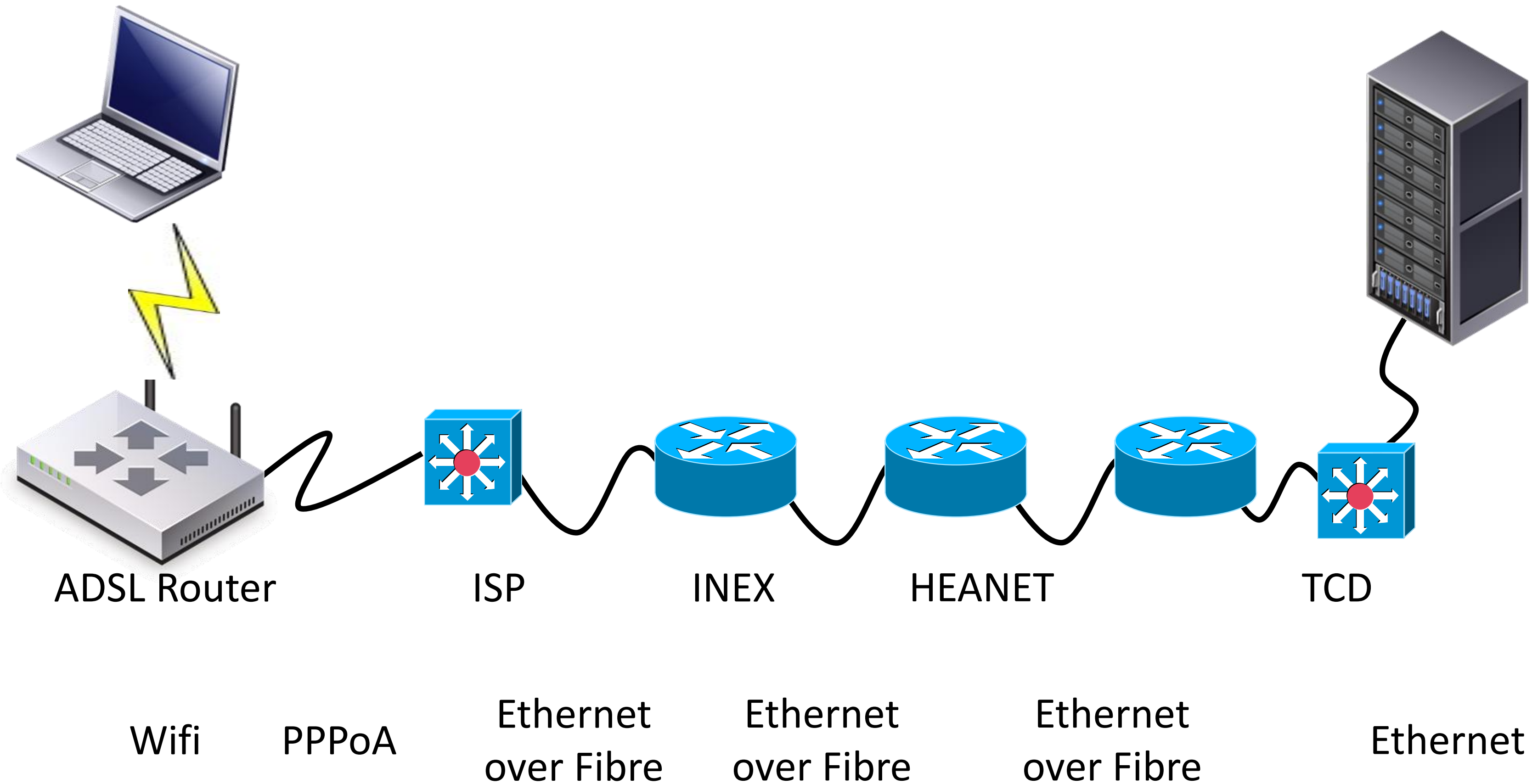
IP Packet

IP Header 20 bytes	Payload - ~64 kbytes

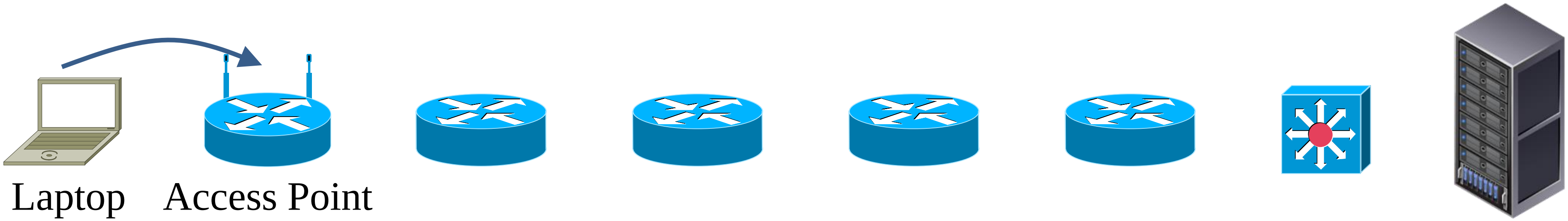


* Figure is courtesy of B. Forouzan

HTML Use Case



Wifi in Home Network



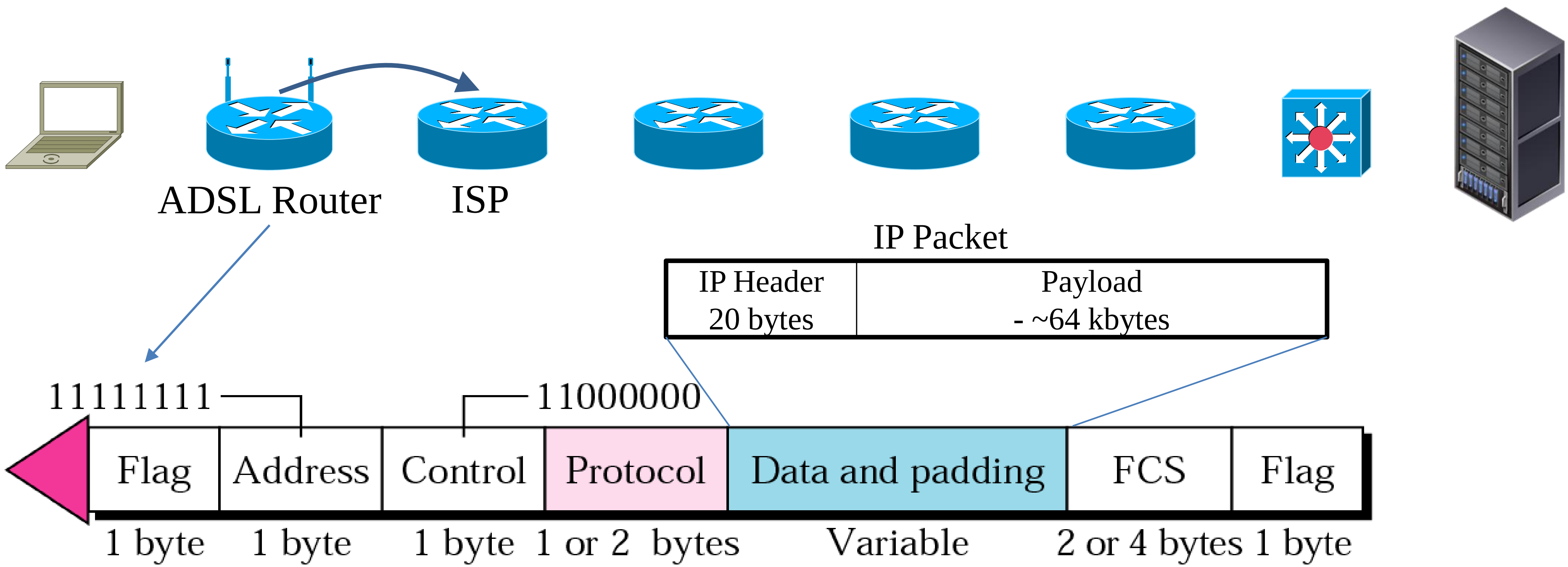
2 bytes	2 bytes	6 bytes	6 bytes	6 bytes	2 bytes	6 bytes	0 to 2312 bytes	4 bytes
FC	D	Address 1	Address 2	Address 3	SC	Address 4	**Frame body**	FCS

802.11 Frame

IP Packet

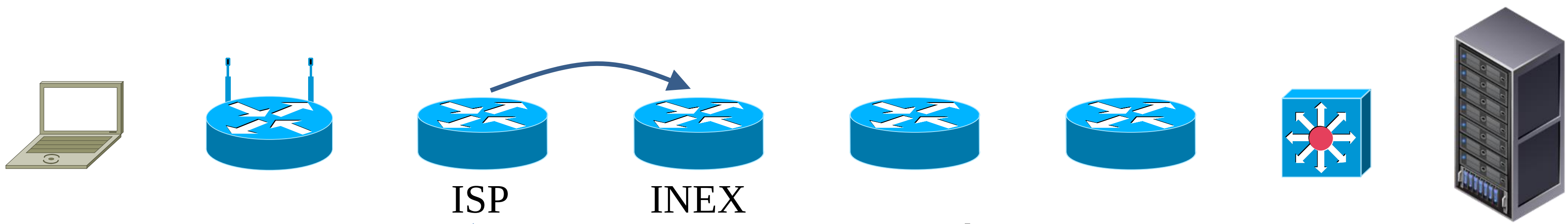
IP Header 20 bytes	Payload - ~64 kbytes

PPP to ISP



PPP Frame

Ethernet over Fibre



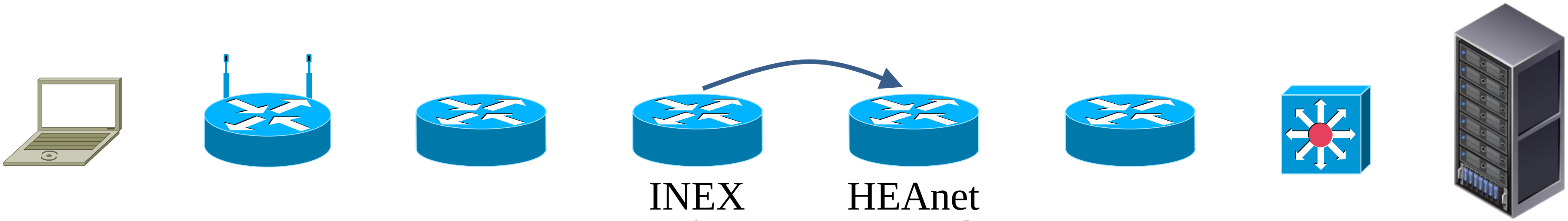
IP Packet

IP Header	Payload
20 bytes	- ~64 kbytes

Preamble	SFD	Destination address	Source address	Length PDU	Data and padding	CRC
7 bytes	1 byte	6 bytes	6 bytes	2 bytes		4 bytes

Ethernet Frame

Ethernet over Fibre



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Ethernet Frame

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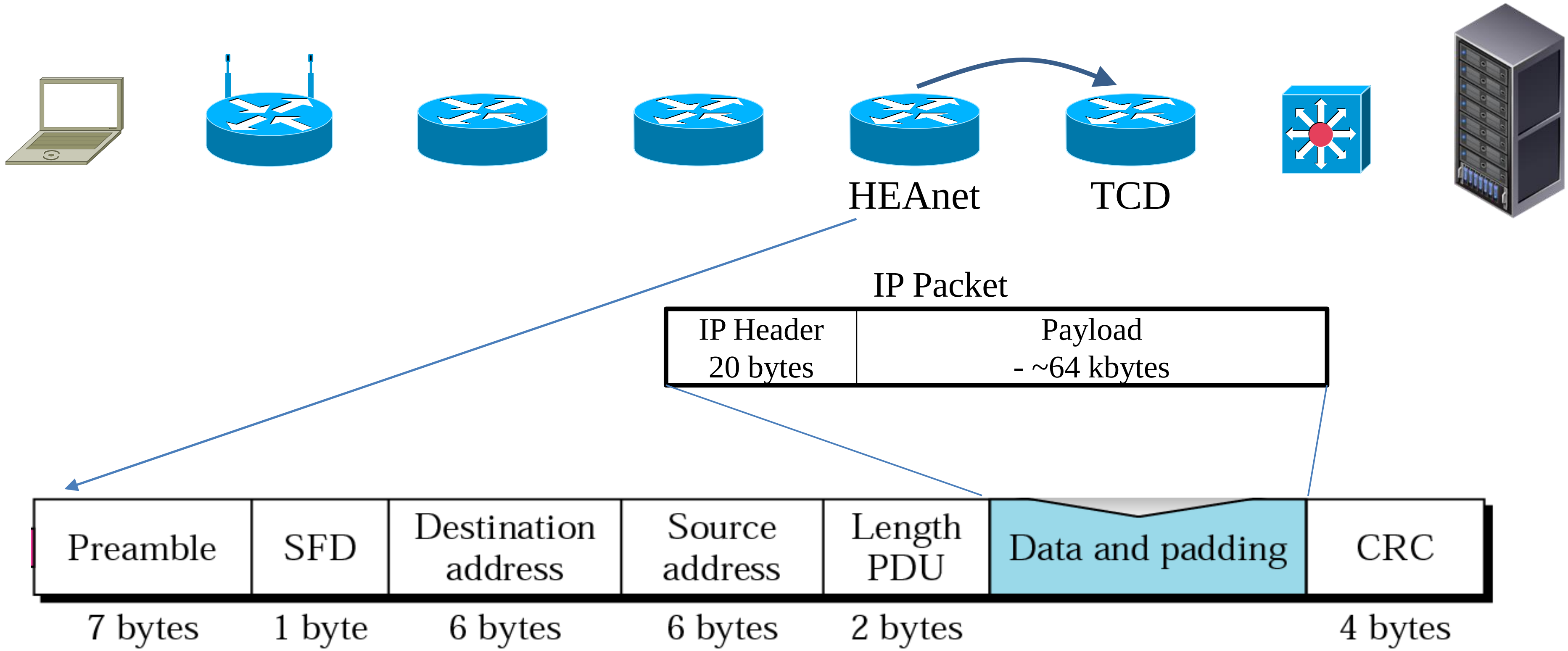
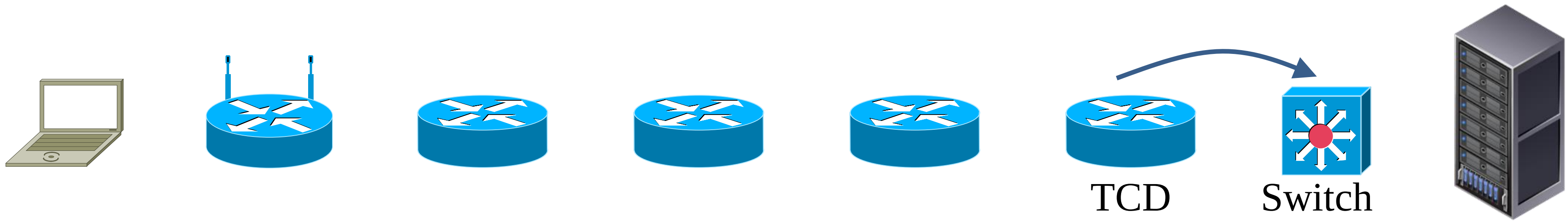


Ethernet Frame

Ethernet



IP Packet

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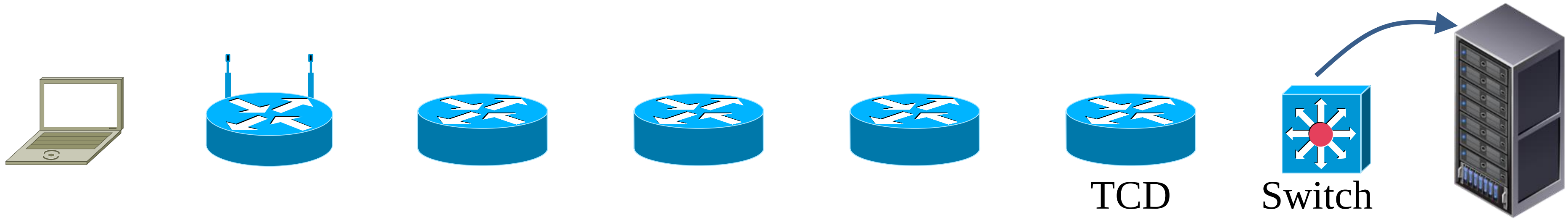
Ethernet Frame

Ethernet



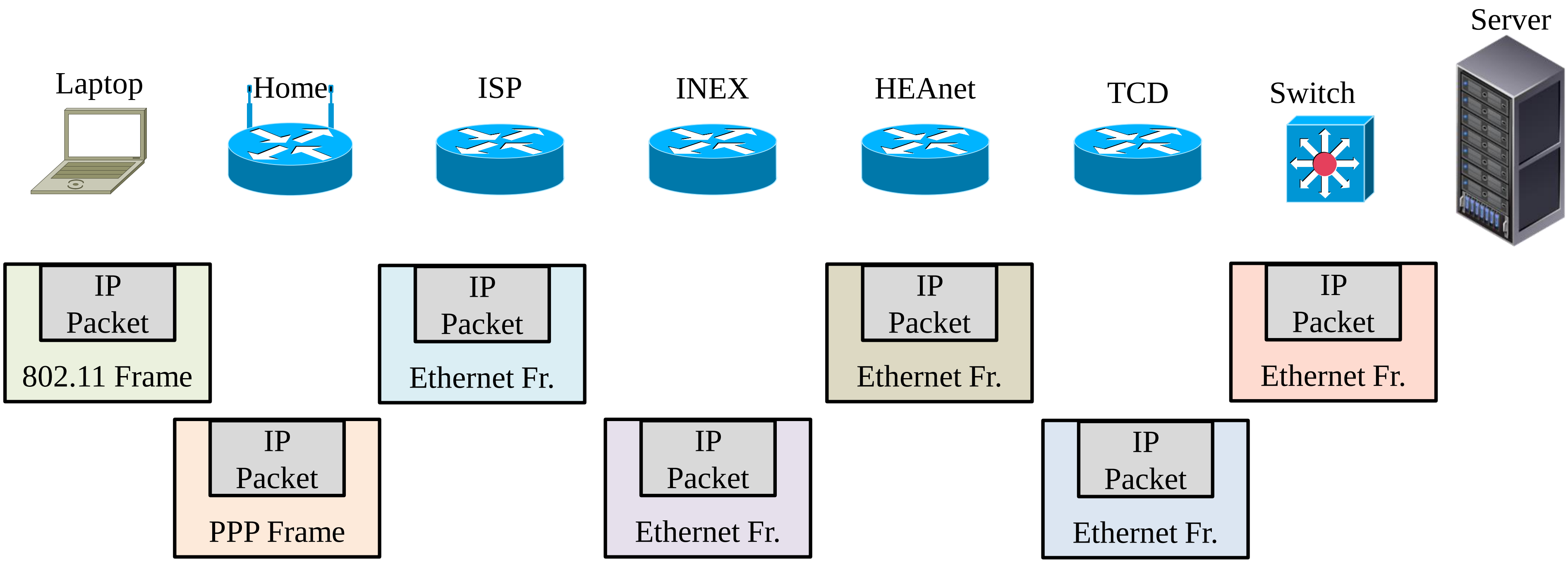
IP Packet

IP Header	Payload
20 bytes	- ~64 kbytes

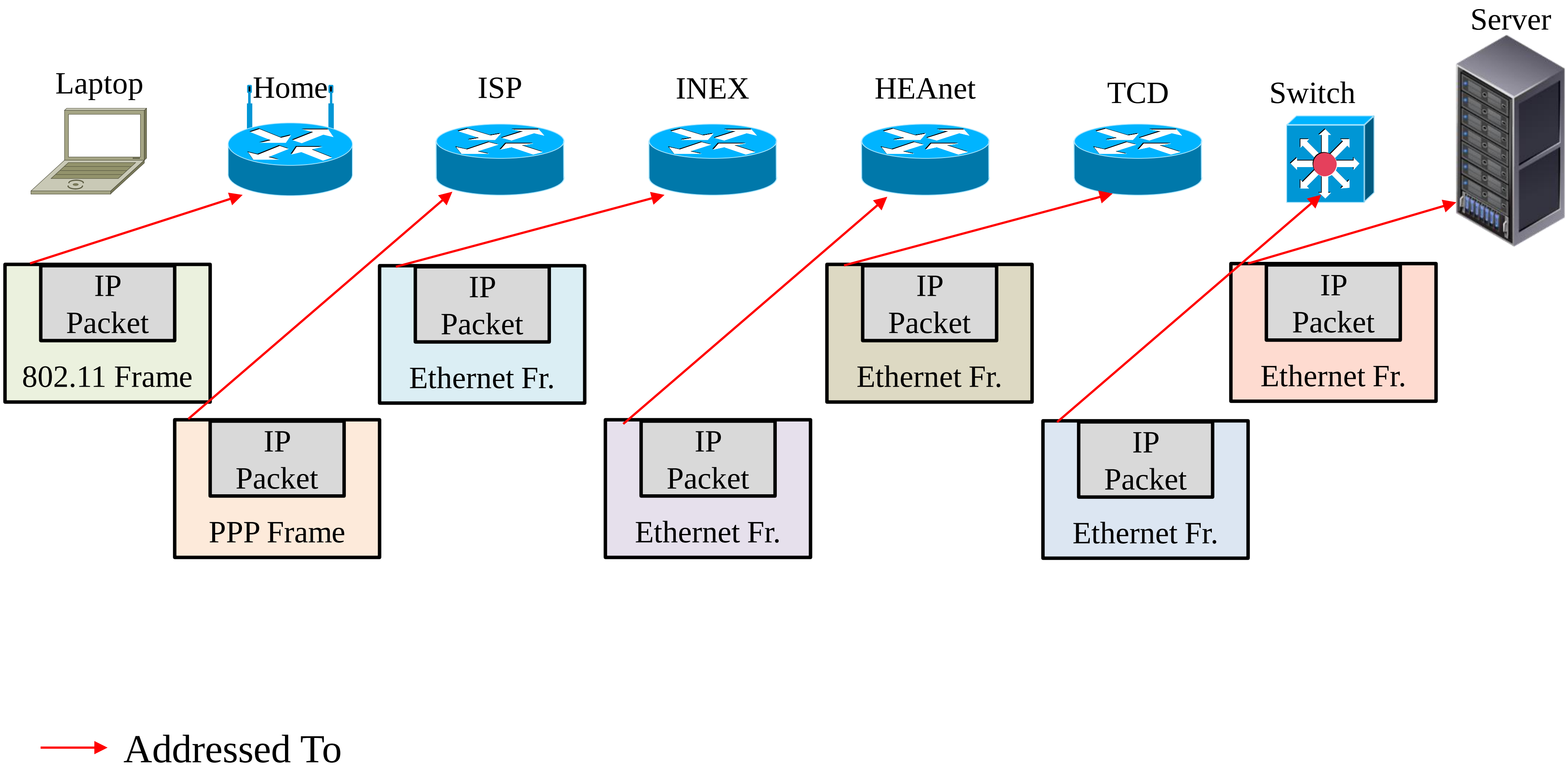
Preamble	SFD	Destination address	Source address	Length PDU	Data and padding	CRC
7 bytes	1 byte	6 bytes	6 bytes	2 bytes		4 bytes

Ethernet Frame

Encapsulation



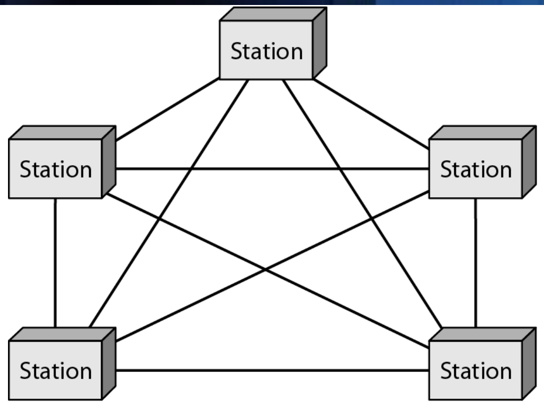
Addressing Next Hop



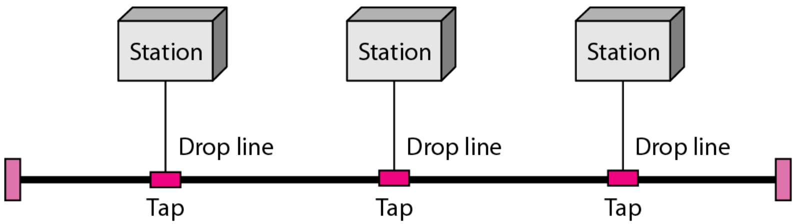
CS2031
Telecommunications II

Bridges, Switches & Routers

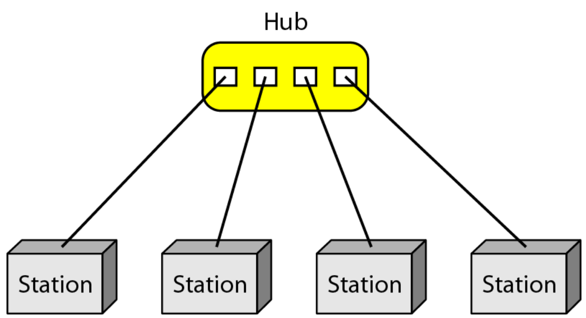
Topologies



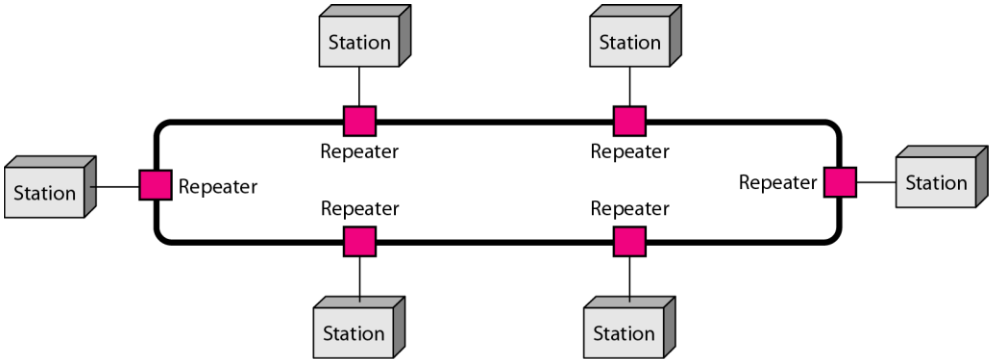
Mesh



Bus



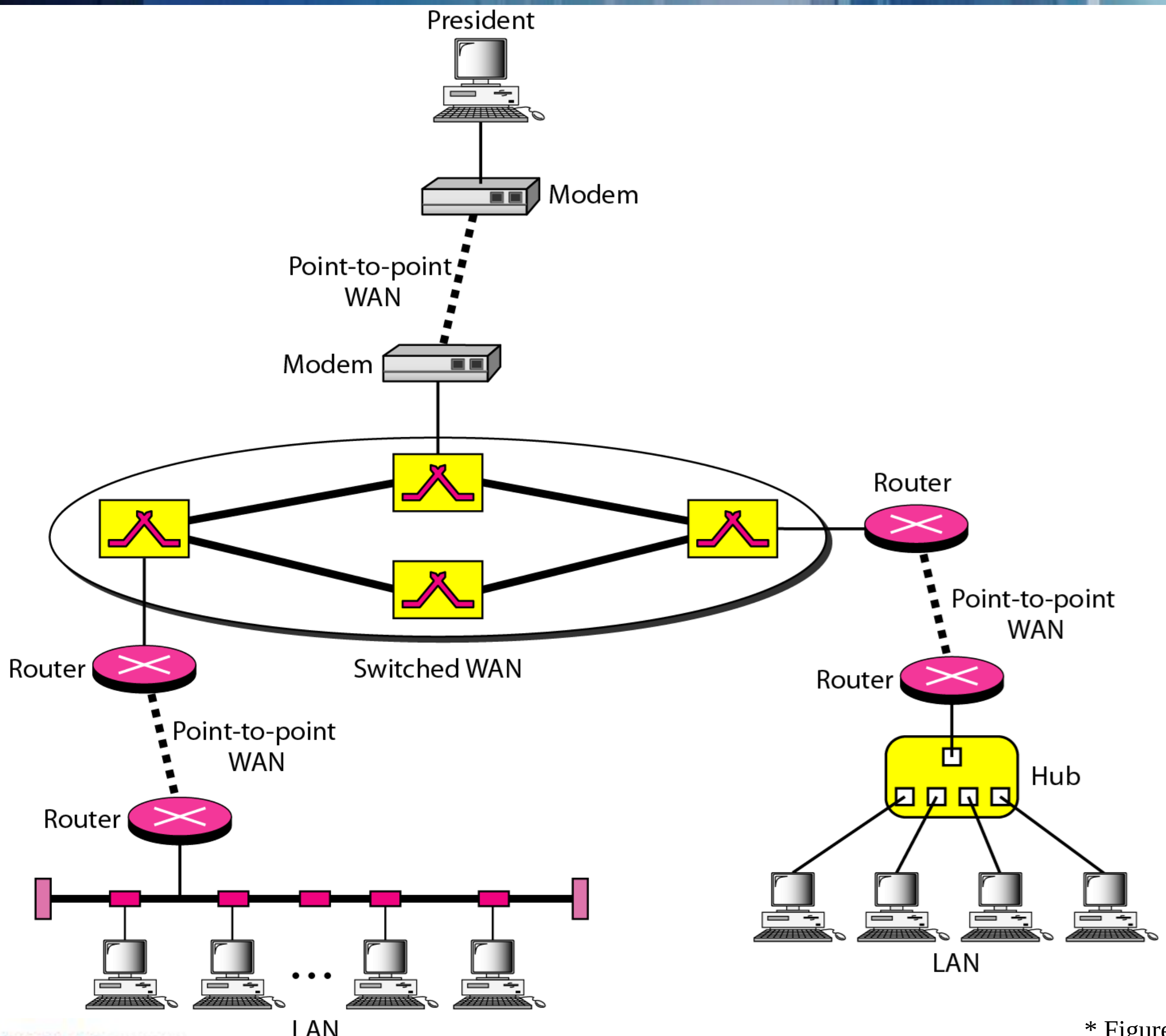
Star



Ring

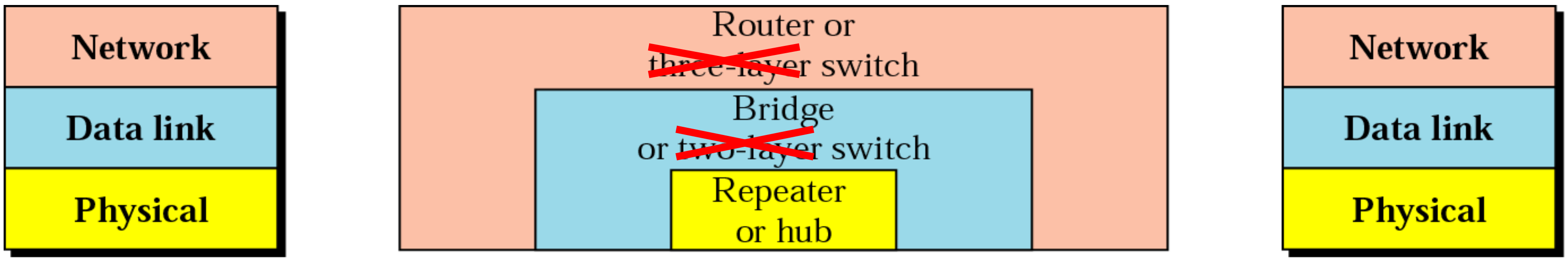
* Figure is courtesy of B. Forouzan

Combined Networks



* Figure is courtesy of B. Forouzan

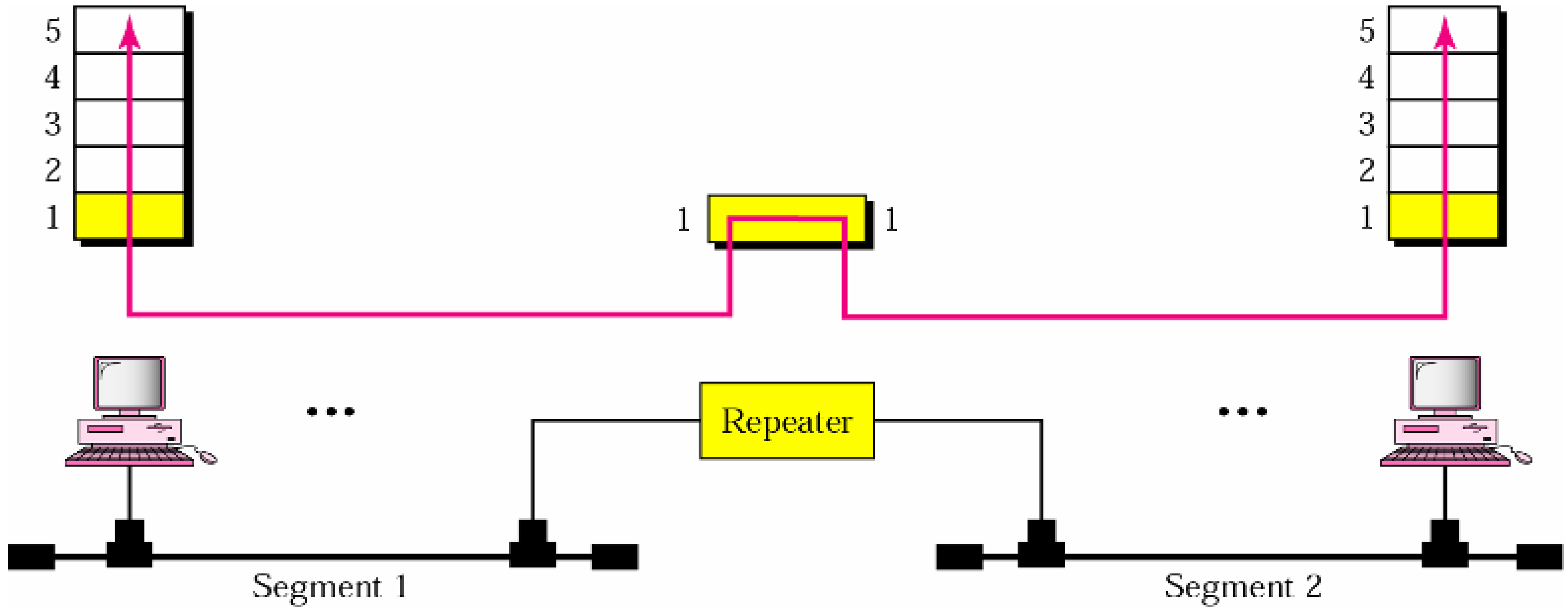
Connecting Devices



- Physical Layer: Repeater or Hub
- Data Link Layer: Bridge or Layer-2 Switch
- Network Layer: Router or Layer-3 Switch

* Figure is courtesy of B. Forouzan

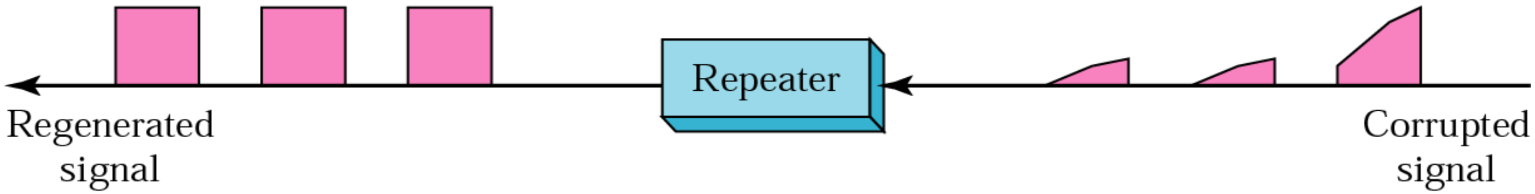
Repeater



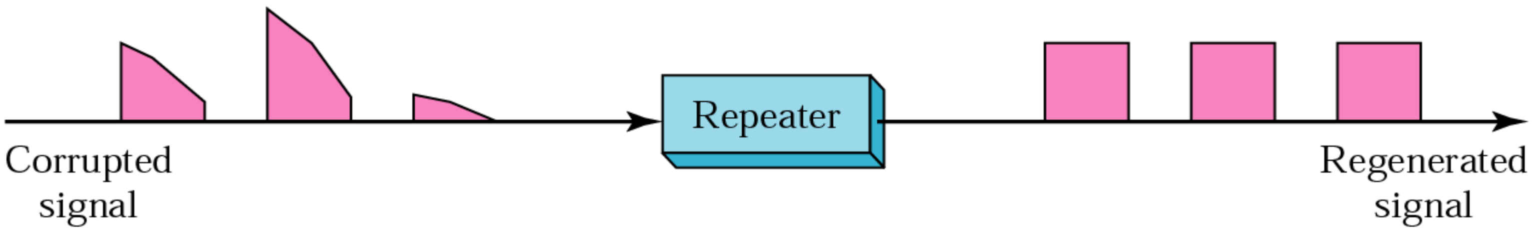
- A repeater connects segments of a LAN
- A repeater forwards every frame; it has no filtering capability

* Figure is courtesy of B. Forouzan

Function of a Repeater



a. Right-to-left transmission.



b. Left-to-right transmission.

- A repeater is a regenerator,

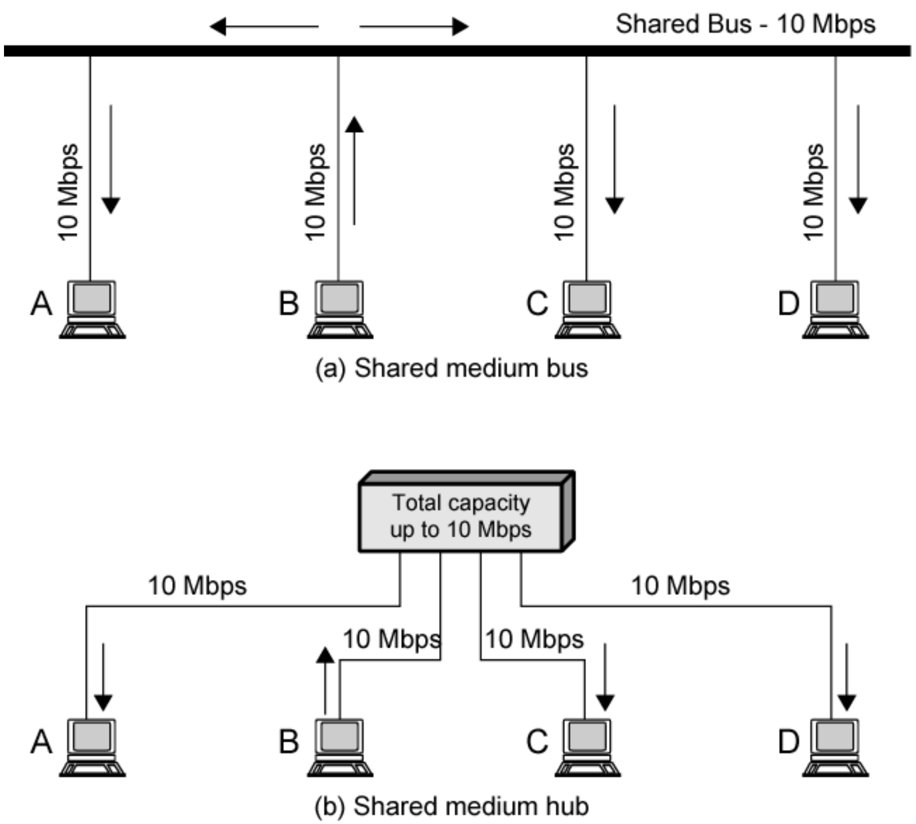
  not an amplifier!

* Figure is courtesy of B. Forouzan

Buses and Hubs

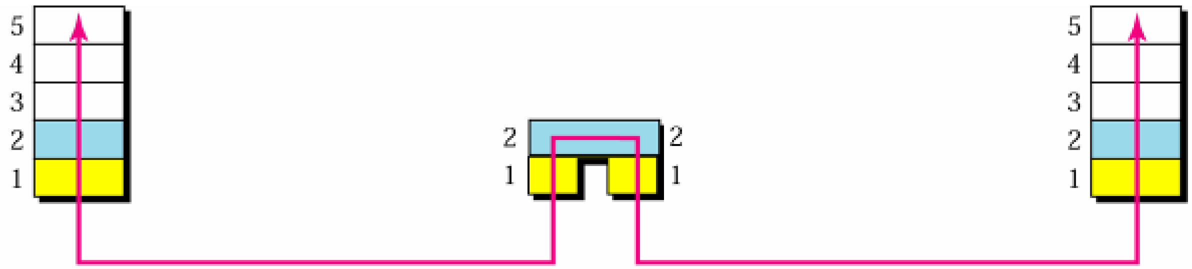
- Bus configuration
  - All stations share capacity of bus (e.g. 10Mbps)
  - Only one station transmitting at a time

- Hub uses star wiring to attach stations to hub
  - Transmission from any station received by hub and retransmitted on all outgoing lines
  - Only one station can transmit at a time
  - Total capacity of LAN is 10 Mbps



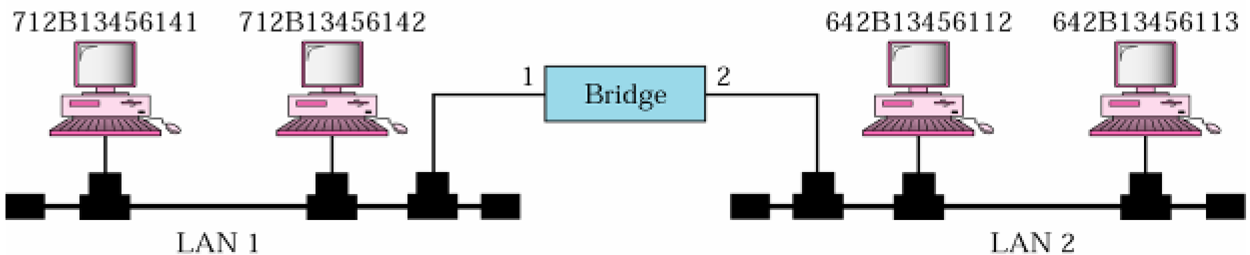
* Figure is courtesy of W. Stallings

Functions of a Bridge



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

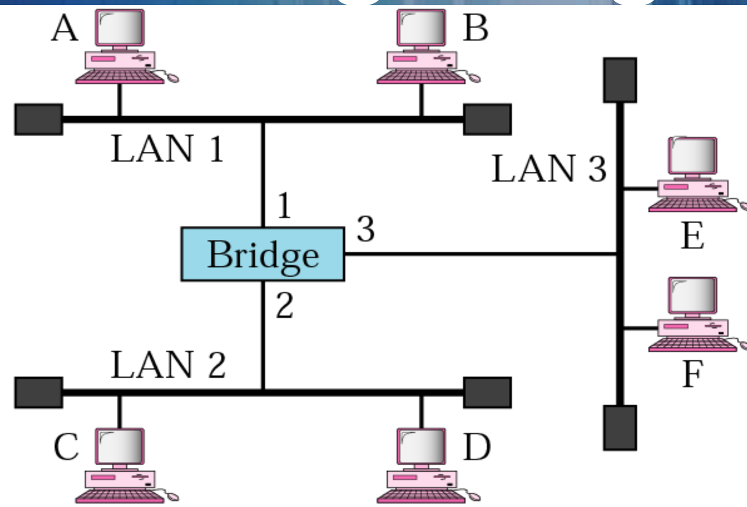
Bridge Table



- Read all frames transmitted on one LAN and accept those address to any station on the other LAN
- Using MAC protocol for second LAN, retransmit each frame
- Do the same the other way round

* Figure is courtesy of B. Forouzan

Learning Bridges



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

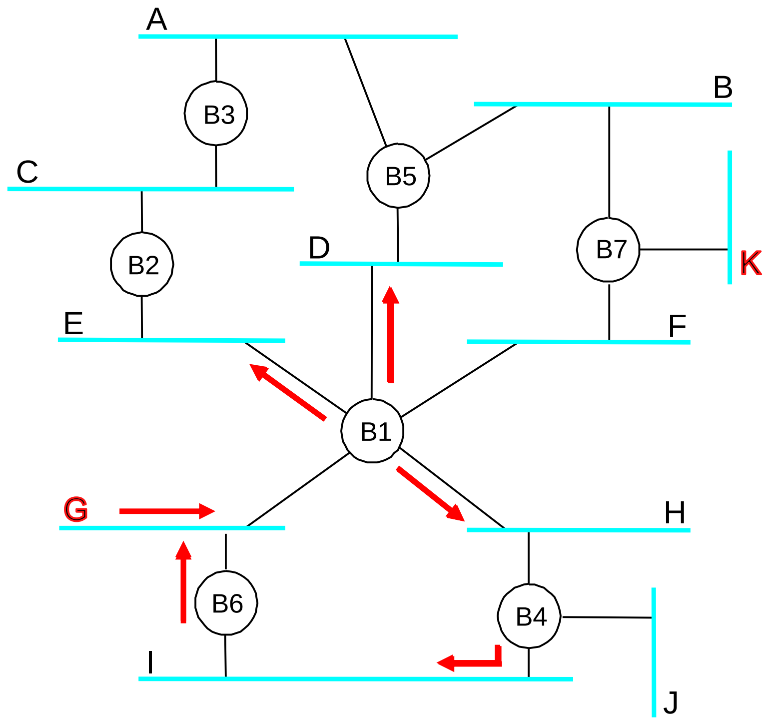
- Initially bridge forwards frames on all segments except incoming port
- Learns addresses from frames that pass through

* Figure is courtesy of B. Forouzan

Problem with Learning Bridges

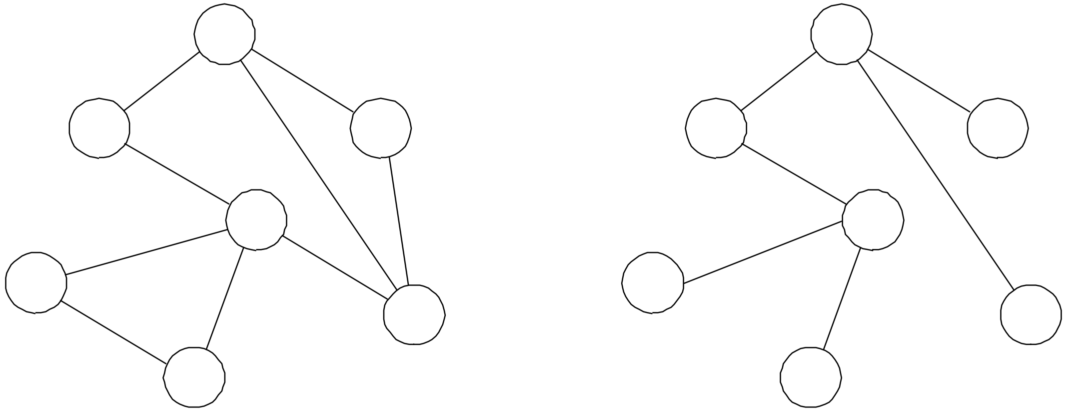
- Problem with learning bridges is <u>loops</u>

$G \rightarrow K$



Spanning Tree Algorithm

- Bridges run a distributed spanning tree algorithm
  - select which bridges actively forward
  - developed by Radia Perlman
  - now IEEE 802.1 specification
- Spanning tree includes all nodes
- Spanning tree only includes edges on the shortest path from the root to any other given node



Spanning Tree Algorithm

1. Bridge with smallest ID is selected as root bridge
2. Mark port on each bridge with least-cost to root bridge as root port
3. Select designated bridge for each LAN that has root port with least-cost to root bridge – if two bridges with same cost select bridge with lowest ID
4. Mark root ports and designated ports as forwarding ports; other ports as blocking ports

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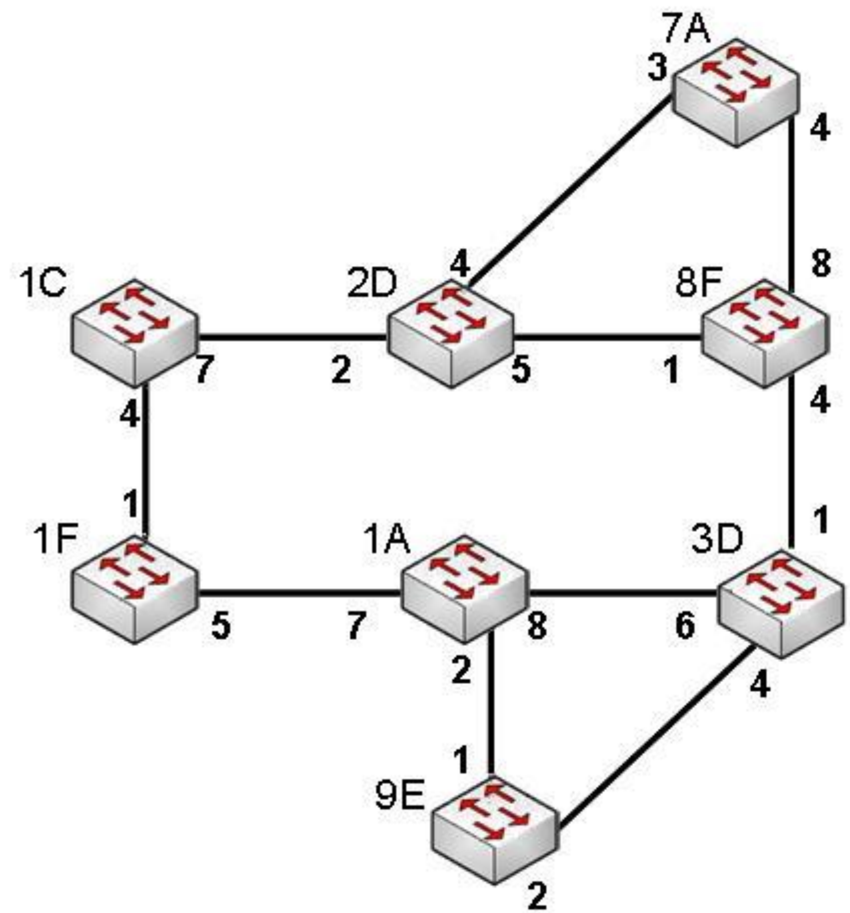

Spanning Tree Algorithm

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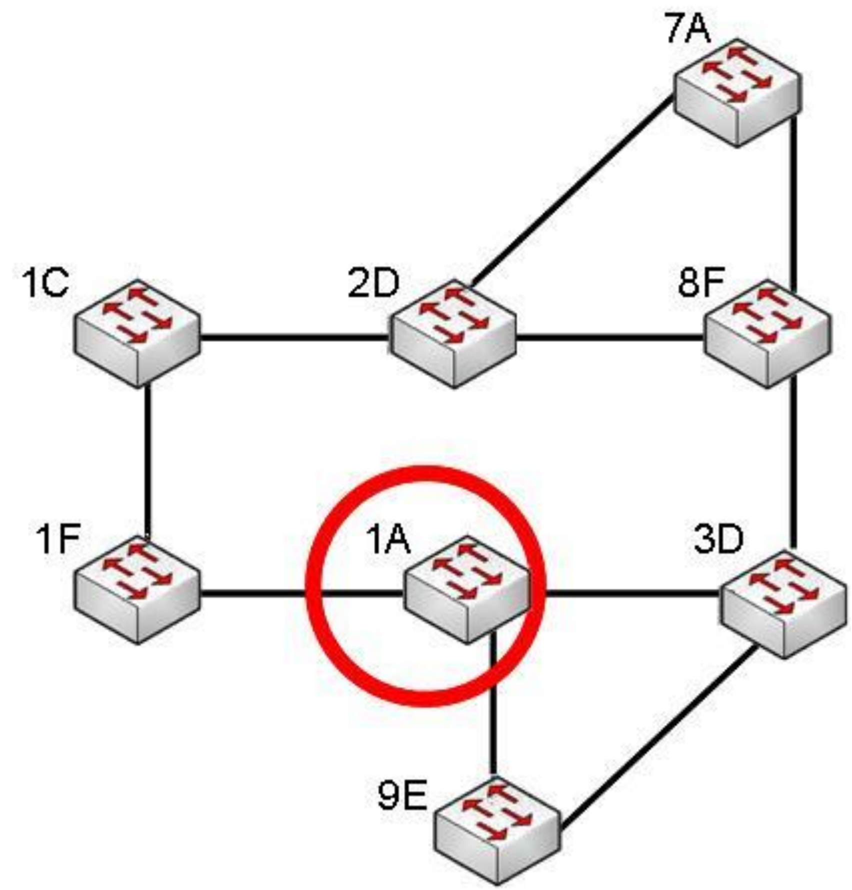

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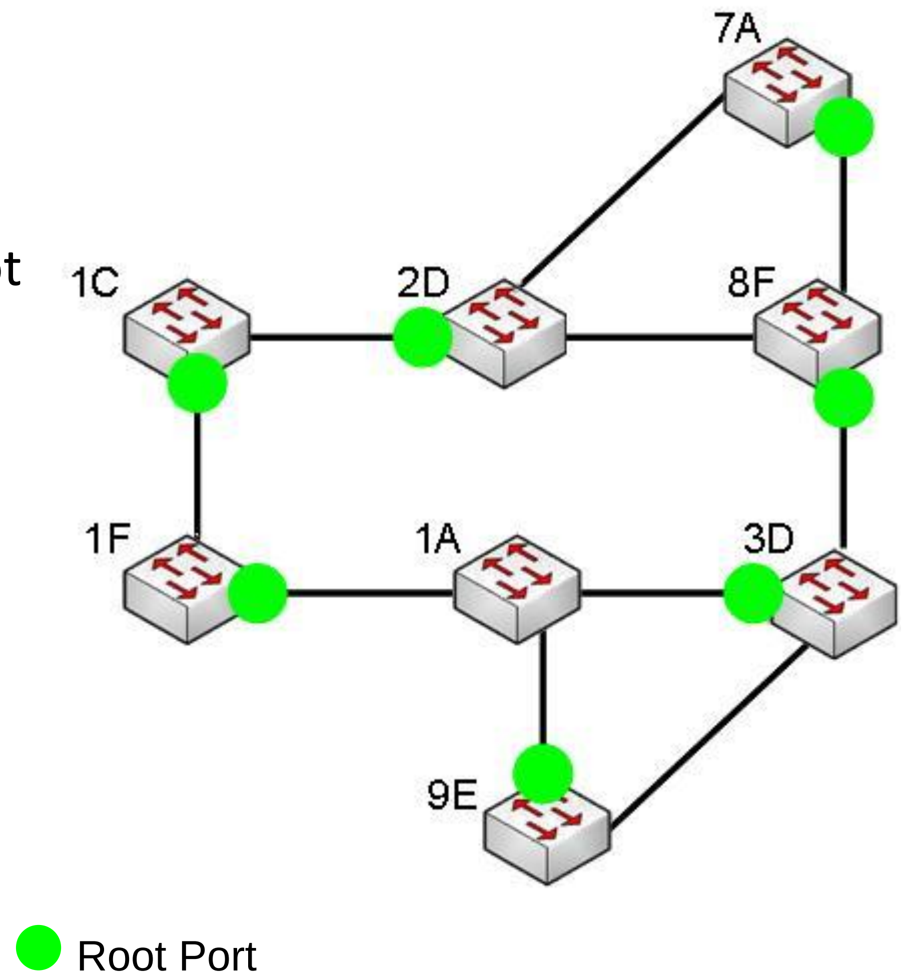

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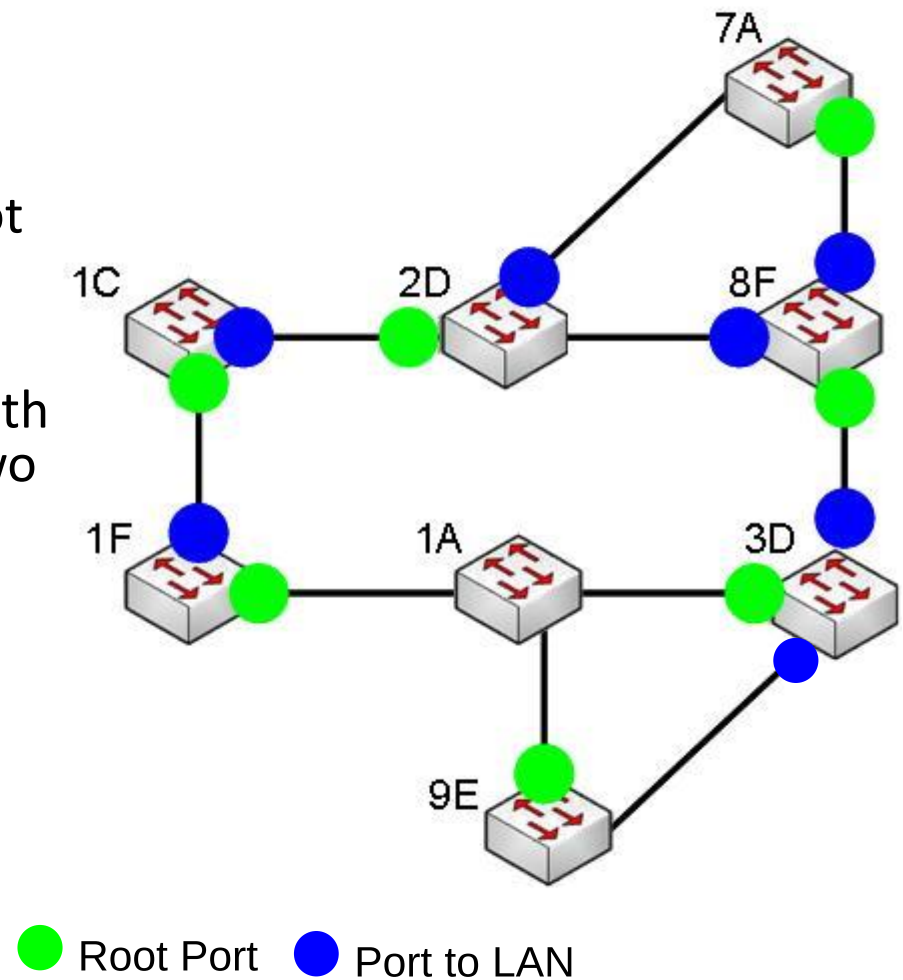

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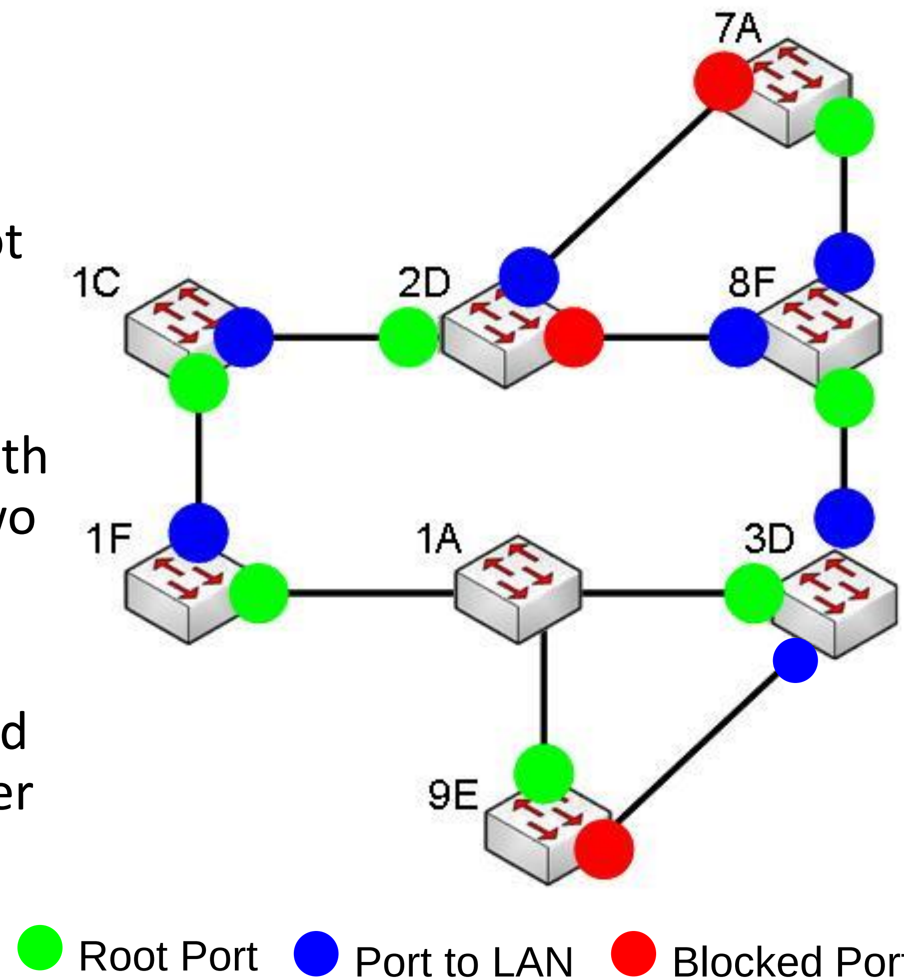

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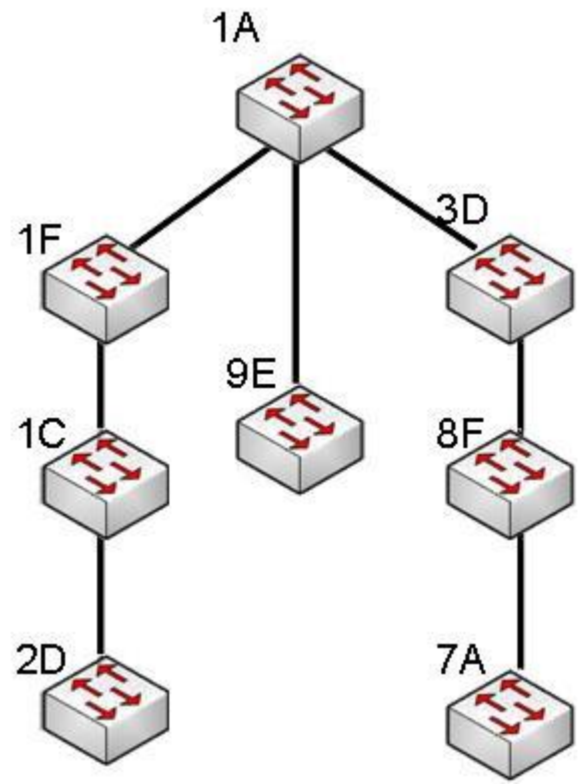
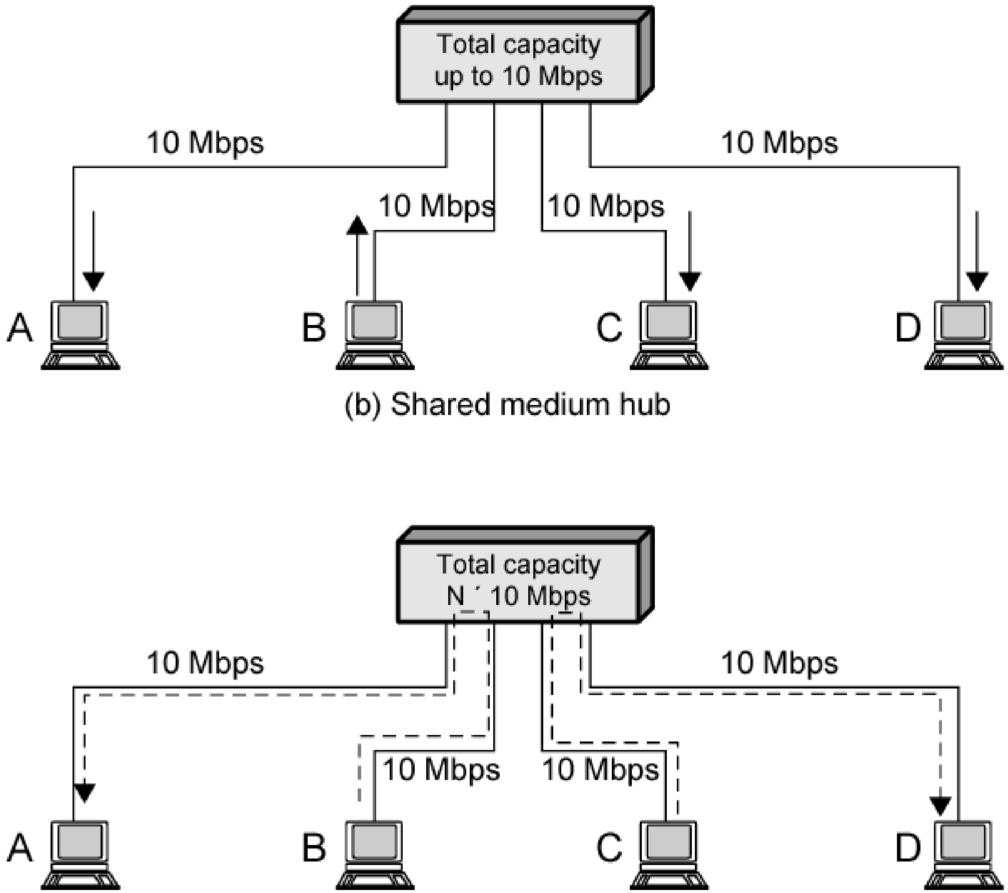


Hub and Layer-2 Switch



(b) Shared medium hub

(c) Layer 2 switch

* Figure is courtesy of W. Stallings

Types of Layer 2 Switches

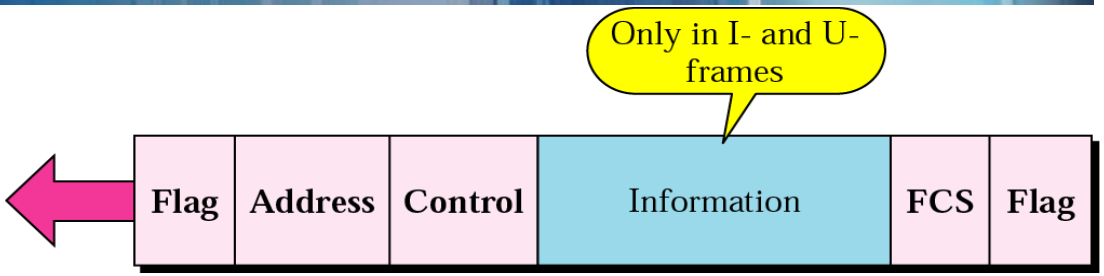
- Store-and-Forward switch
  - Accepts frame on input line
  - Buffers it briefly,
  - Then routes it to appropriate output line
  - Delay between sender and receiver
  - Boosts integrity of network
- Cut-Through switch
  - Takes advantage of destination address appearing at beginning of frame
  - Switch begins repeating frame onto output line as soon as it recognizes destination address
  - Highest possible throughput
  - Risk of propagating bad frames
    - Switch unable to check CRC prior to retransmission

Summary: Repeaters, Hubs & Switches

- Repeaters & Hubs
- Bridges
  - Learning Bridges
  - Spanning Tree Algorithm
- Layer-2 Switches
  - Store-and-Forward
  - Cut-Through


That's all folks
Telecomms II

HDLC Frame

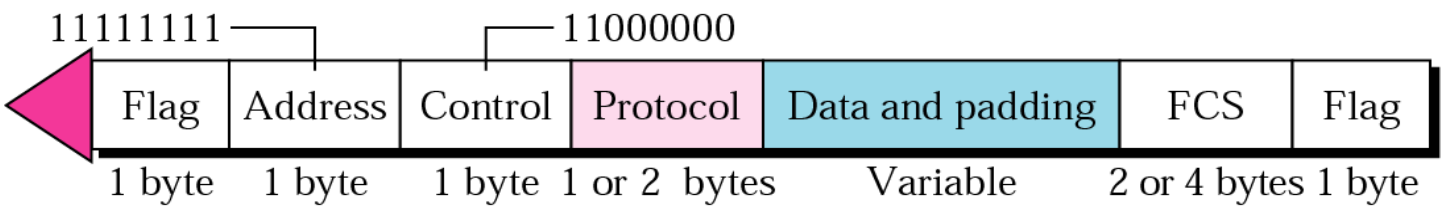


- Flag= 01111110
  - Specifies beginning and end of frame
- Address
  - Specifies secondary station
    as either sender or receiver
- Control
  - Specifies type of frame and seq.&ack. number
- Frame Check Sequence (FCS)
  - Either 16- or 32-bit CRC

* Figure is courtesy of B. Forouzan

PPP Frame

- Modified HDLC frame:

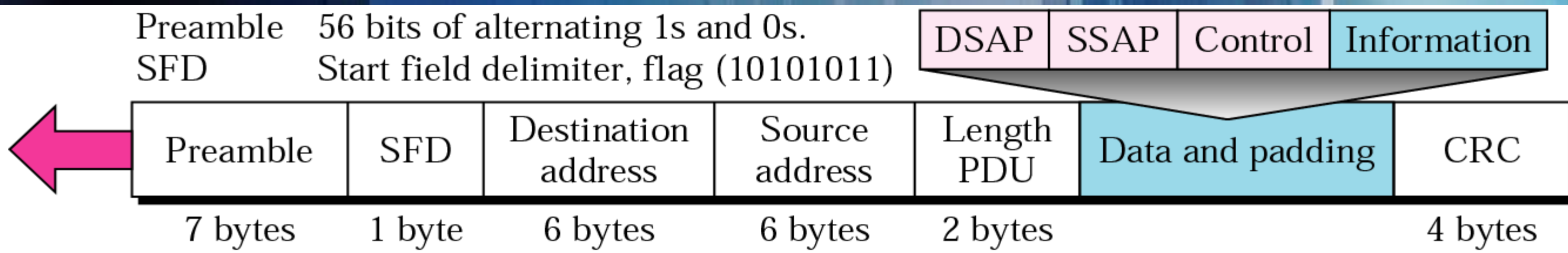


- Byte-oriented Protocol
  - Flag Byte: 01111110
  - Escape Byte: 01111101

- FCS: 16- or 32-bit CRC
  - $x^{16} + x^{12} + x^5 + 1$
    - 1 0001 0000 0010 0001 → **16 bits remainder** ← **16-degree polynomial**
  - $x^{32}+x^{26}+x^{23}+x^{22}+x^{16}+x^{12}+x^{11}+x^{10}+x^8+x^7+x^5+x^4+x^2+x+1$

* Figure is courtesy of B. Forouzan

802.3 MAC Format

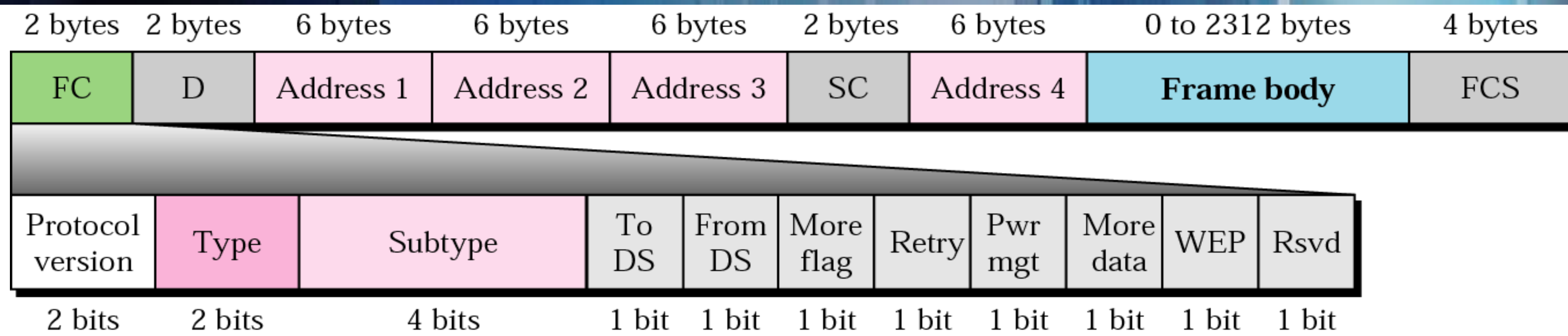


- 64-bit frame preamble (10101010) used to synchronize reception
  - 7 bit preamble (10101010) + 1 start flag (10101011)

- Maximum frame length: 1536 bytes
  - ⇨ max 1500 bytes payload
- Minimum frame length: 64 bytes
  - ⇨ min 46 bytes payload

* Figure is courtesy of B. Forouzan

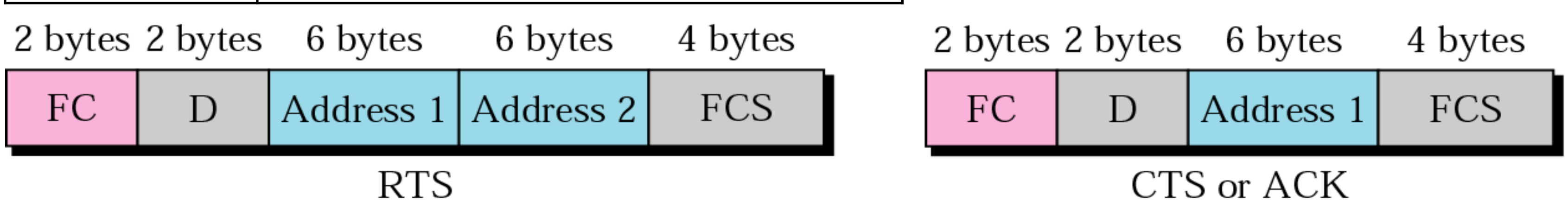
802.11 MAC Frame Format



Control Frames

Type:management (00), control (01), or data (10).

Subtype	Meaning
1011	Request to send (RTS)
1100	Clear to send (CTS)
1101	Acknowledgment (ACK)



* Figure is courtesy of B. Forouzan

802.11 Frames

- DSSS PLCP frame format

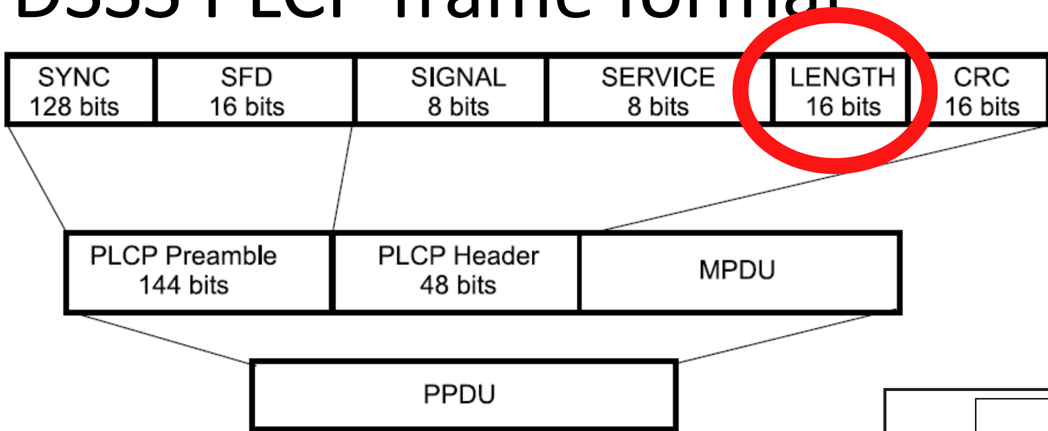


Figure 86—PLCP frame format

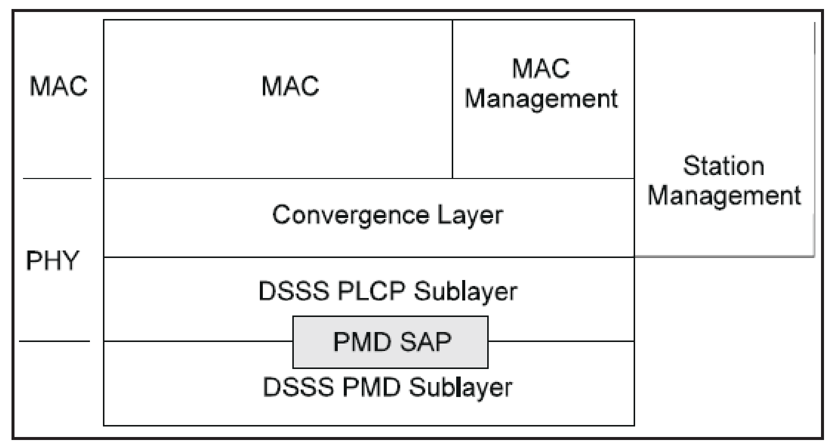
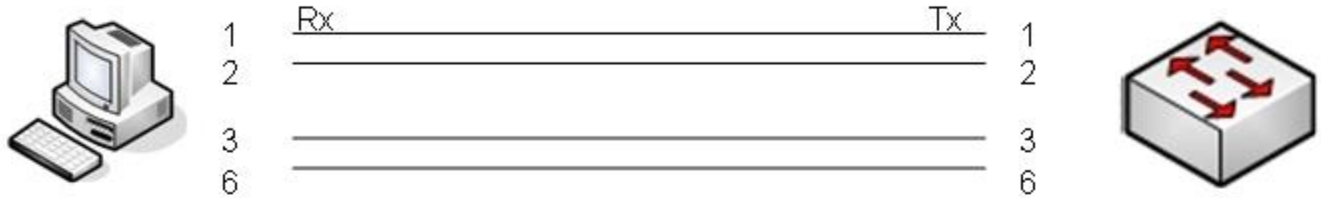
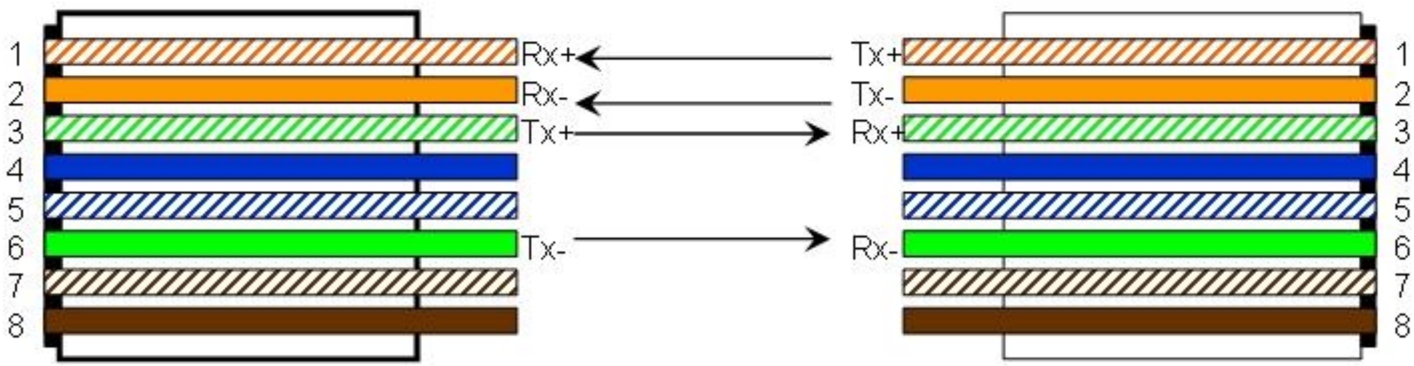


Figure 95—PMD layer reference model

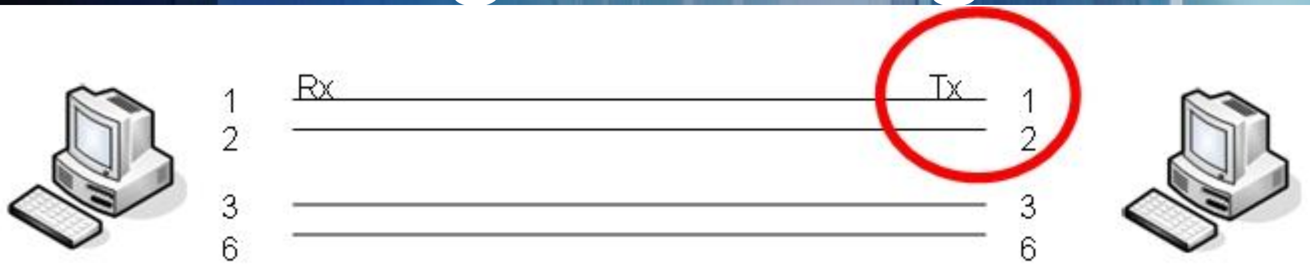
Straight Cabling & RJ45

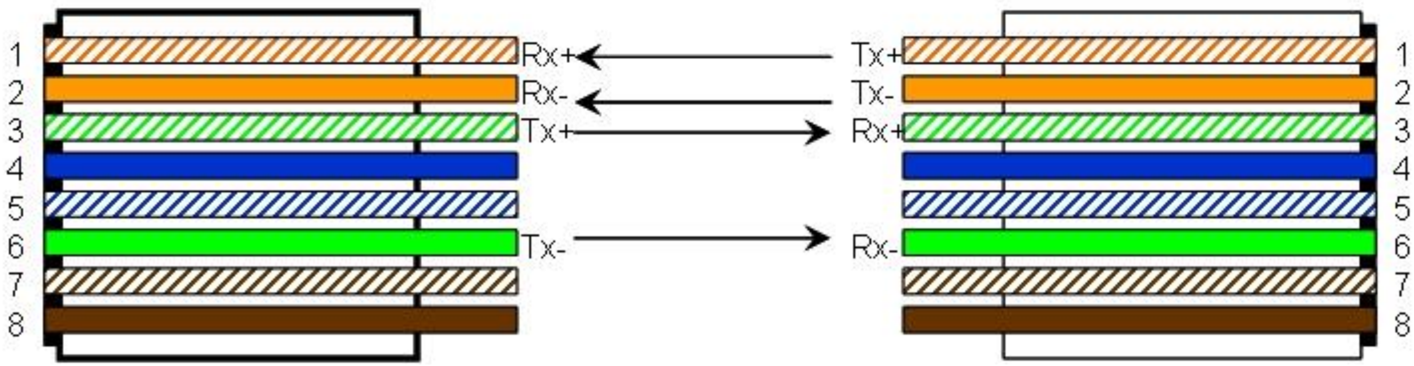




- Switch expects
  - Transmission from station on 3 & 6
  - Transmits on 1 & 2

Straight Cabling II





- Switch expects
  - Transmission from station on 3 & 6
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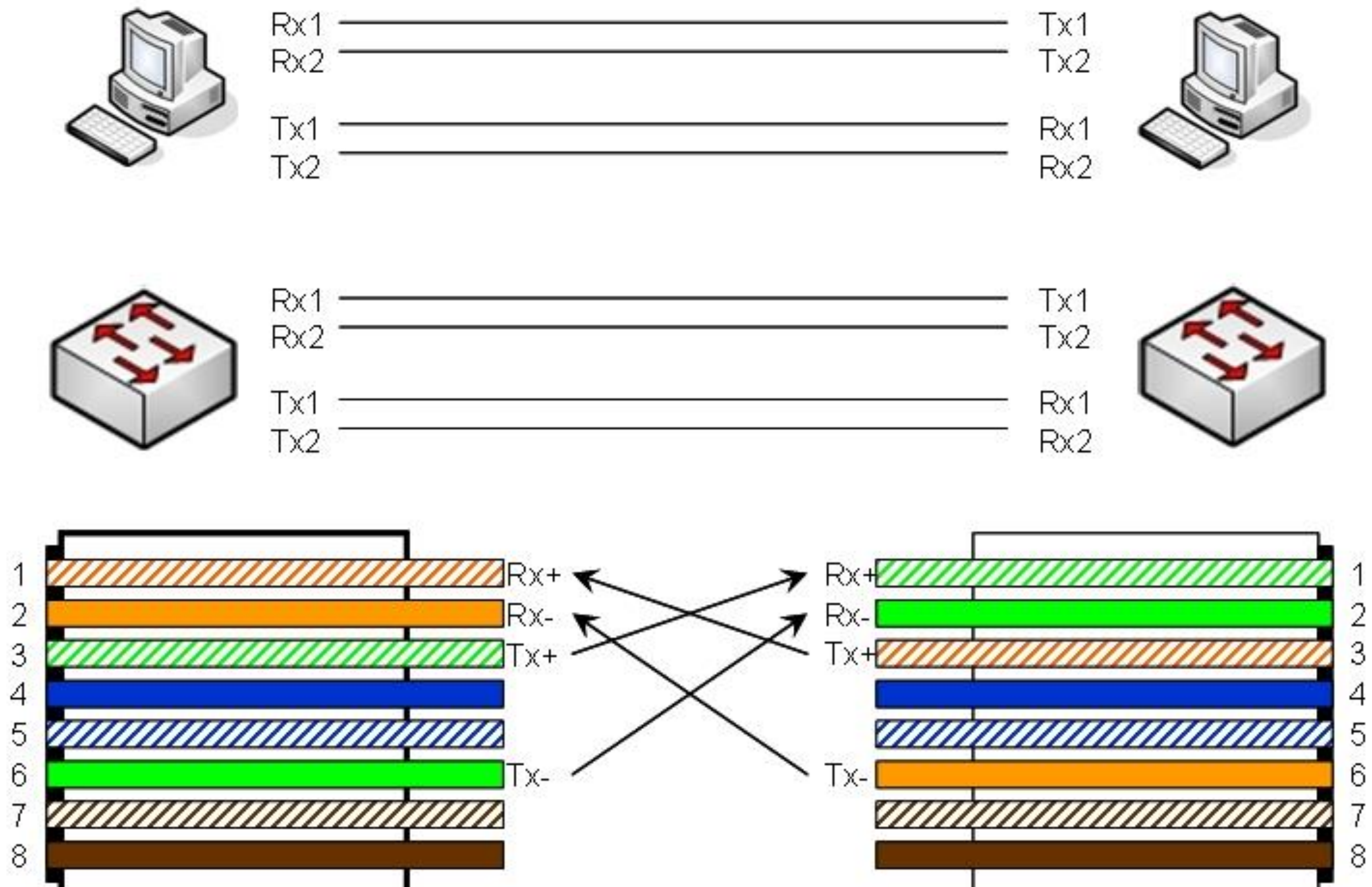
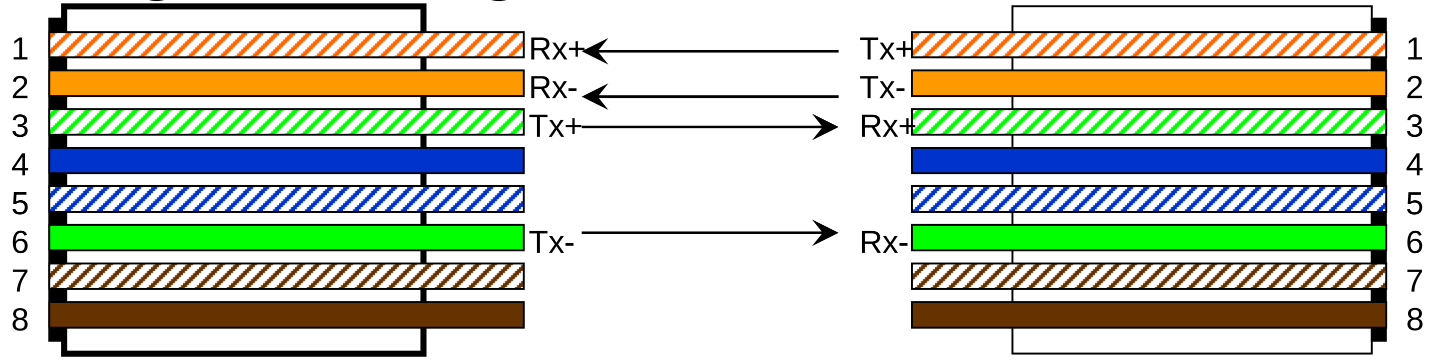
Crossover Cabling



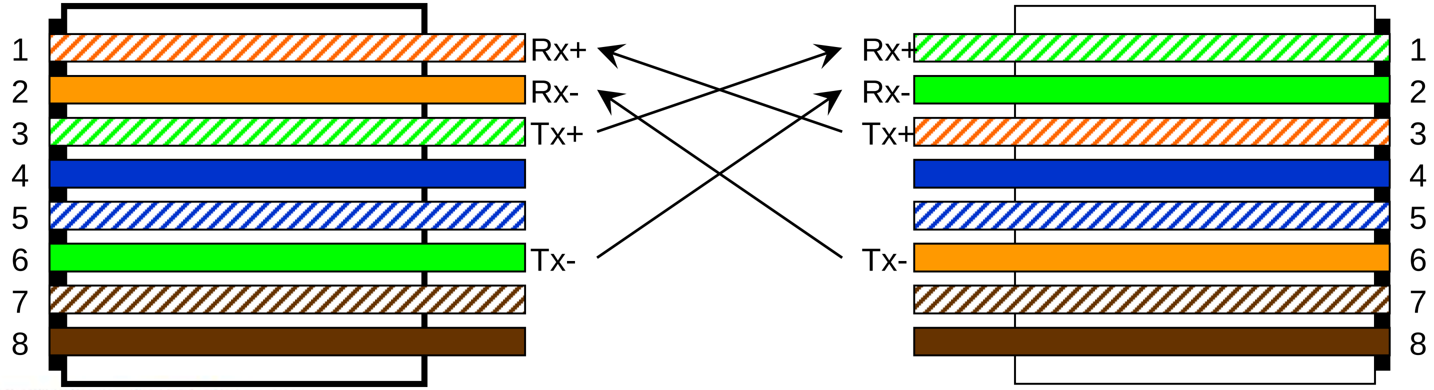
- Direct connection of desktops & infrastructure equipment

RJ45 Cabling

- Straight cabling:



- Crossover cabling:



File Input

```
String fname;
File file= null;
FileInputStream fin= null;
byte[] buffer= null;
int size;

fname= terminal.readString("Name of file: ");

file= new File(fname);
buffer= new byte[(int) file.length()];
fin= new FileInputStream(file);
size= fin.read(buffer);
```

Read filename

Open file

Reserve byte buffer

Initialize input stream

Read file content

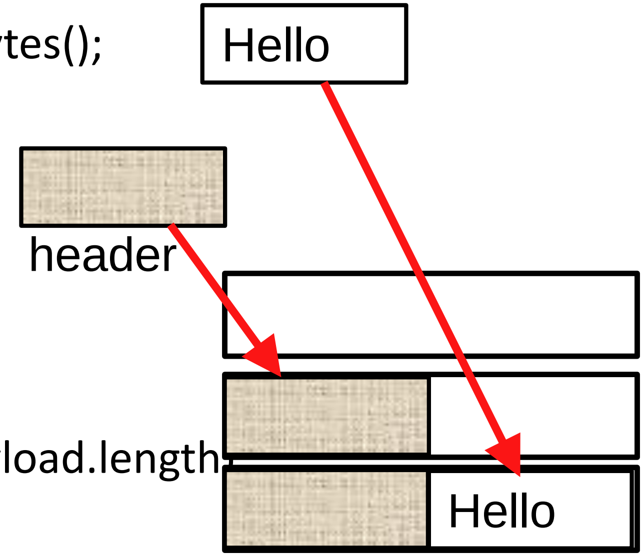
Rest of File Input

```
if (size==-1) {
        fin.close();
        throw new Exception("Problem with File Access");        }

terminal.println("File size: " + buffer.length);
fcontent= new FileInfoContent(fname, size);
terminal.println("Sending packet w/ name & length");
packet= fcontent.toDatagramPacket();
packet.setSocketAddress(dstAddress);
socket.send(packet);
terminal.println("Packet sent");
this.wait();

fin.close();
```

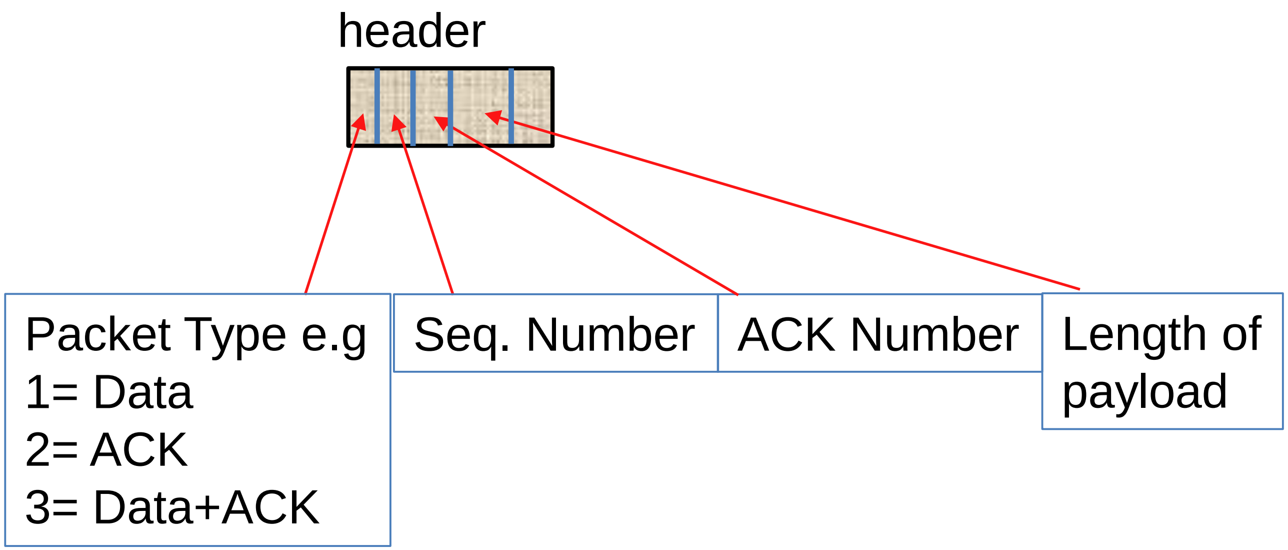
End file access

Byte[] copying

```
DatagramPacket packet= null;
byte[] payload= null;   byte[] header= null;   byte[] buffer= null;

payload= (terminal.readString("String to send: ")).getBytes();

header= new byte[PacketContent.HEADERLENGTH];

buffer= new byte[header.length + payload.length];
System.arraycopy(header, 0, buffer, 0, header.length);
System.arraycopy(payload, 0, buffer, header.length, payload.length);

packet= new DatagramPacket(buffer, buffer.length, dstAddress);
socket.send(packet);
this.wait();
```



Example Header



tcd.lossy.DatagramSocket

```
package tcd.lossy;
public class DatagramSocket extends java.net.DatagramSocket {
	...
	public void send(DatagramPacket arg0) throws IOException {
		if ((Math.random()*100) > noise) {
			super.send(arg0);
		}
		else {
			System.out.println("** Packet dropped");
		}
	}
}
```

“import tcd.lossy.DatagramSocket;” instead of “import java.net.DatagramSocket;”