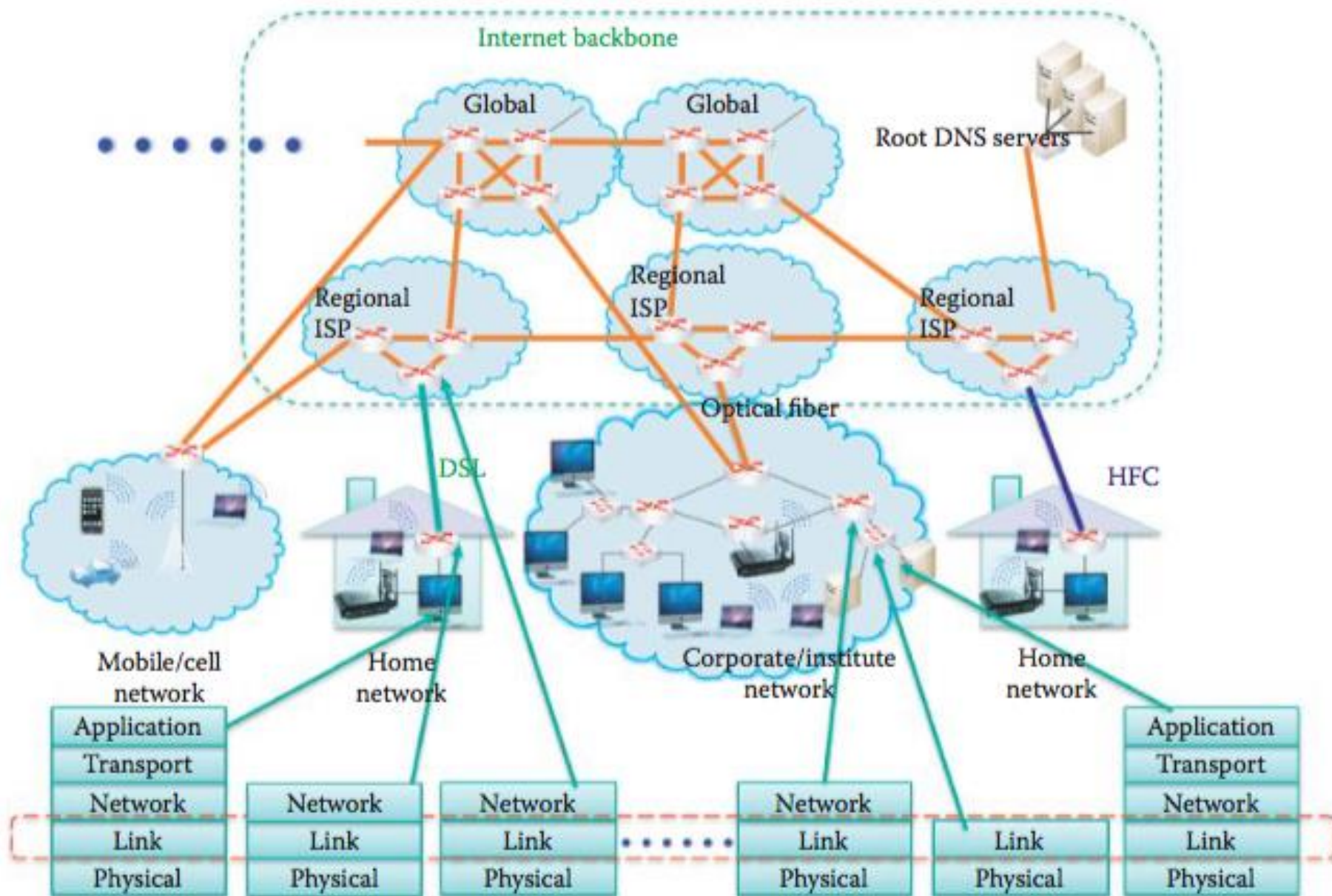Nguyễn Đăng Quang

CHAPTER 2:
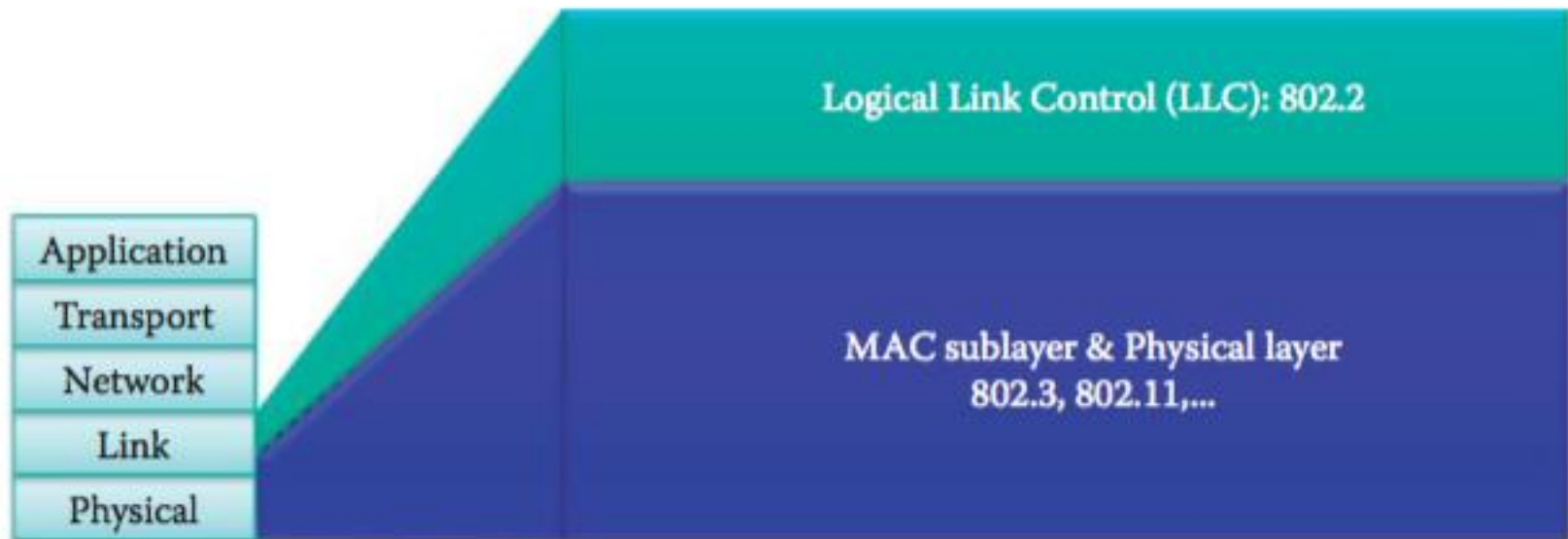# THE LINK LAYER & ETHERNET

Contents

- Link layer functions and Terminologies
- Ethernet
- CSMA/CD
- Ethernet network devices
- Internetworking devices

Link Layer Functions

- Relies upon the physical layer to deliver a frame to a neighbor connected by physical link.

- The hosts (stations) and routers in the communication path are called *nodes*.

- The channels (wired, wireless or optical) connecting adjacent nodes along the path are called *links*.

- Data is encapsulated in a layer-2 packet called a *frame.*

MAC & LLC Sublayers

Logical Link Control (LLC): 802.2

Application
Transport
Network
Link
Physical

MAC sublayer & Physical layer
802.3, 802.11,...

Multiple Access Protocols

- There are two types of links:

  - *Point-to-point (PPP)* and,

  - *Broadcast*
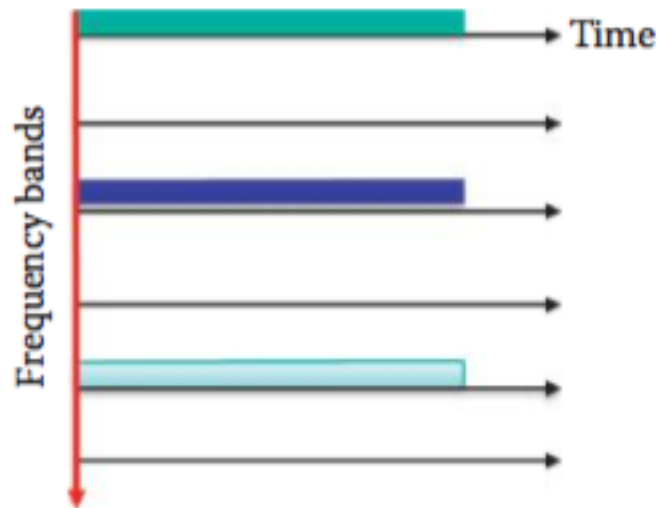
MAC Protocols

1. Channel Partitioning,

2. Random Access,

3. Token Ring.

Channel Partitioning

- TDMA

- FDMA

Shard Ethernet & WLAN Random Access

- In these environment, each station transmits at the full link rate (baseband), there is no a priori coordination among stations → collisions are a regular occurrence.

- Random access MAC protocols:

  - CSMA,

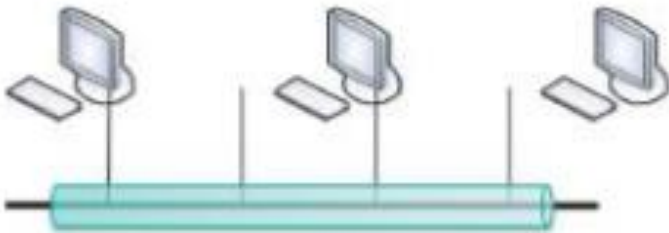 - CSMA/CD (Ethernet 802.3)

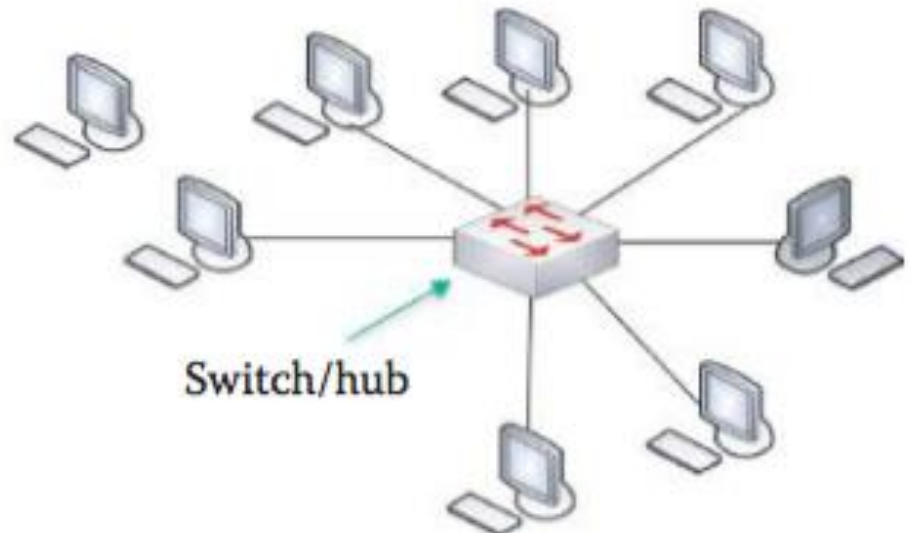 - CSMA/CA (Ethernet 802.11)

ETHERNET

Timeline

- 1973 – Documented the invention of Ethernet, building on the ALOHAnet protocol (2.94Mbps),

- 1978 – [Xerox](#) developed X-Wire, a 10 Mbps Ethernet running on a coaxial cable,

- 1979 – Intel, DEC, Xerox jointly develop an Ethernet specification based on X-Wire. This group was called DIX.

- 1983 – 802.3 Specification approved by IEEE

- 1984 – ISO adopted IEEE 802.3

- 1985 – Twisted-pair Ethernet Hub

- 1987 – 3COM developed intelligent switching hubs

- 1992 – Fast Ethernet (100Mbps)
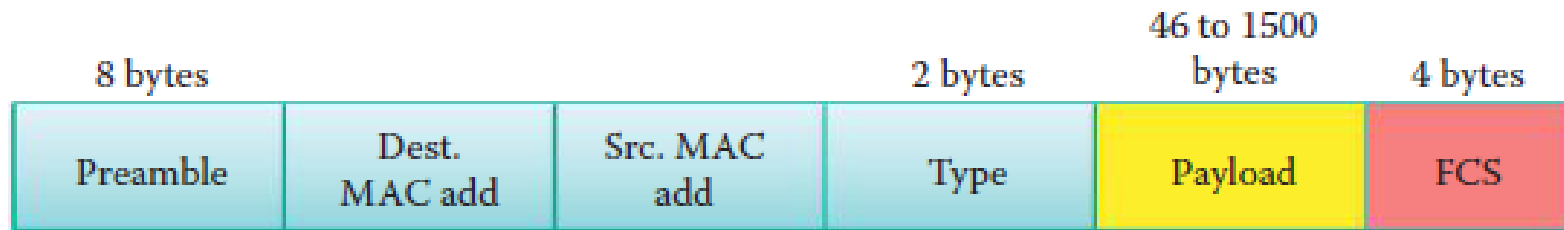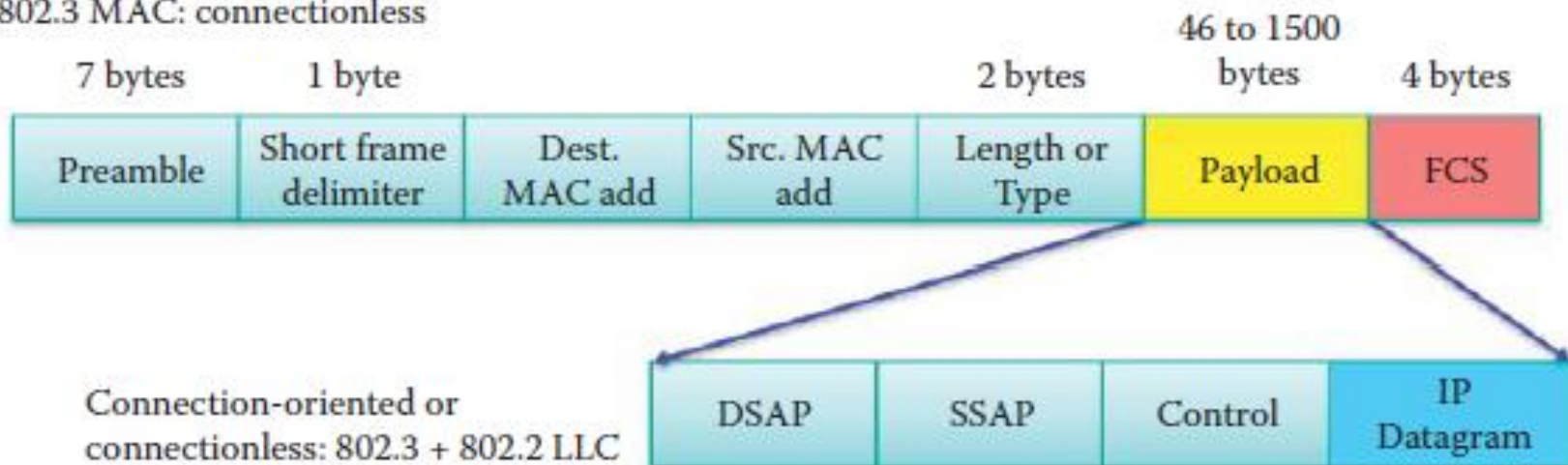
Topologies

Coaxial Cable

Star Topology

Switch/hub

CSMA/CD

- Carrier Sense Multiple Access with Collision Detection

	Action
Step 1	The Network Interface Card (NIC) receives a datagram from the network layer and creates a frame
Step 2	If the NIC senses, via CSMA, that the channel is not being used, it begins sending a frame. If the channel is busy, it waits for an idle channel and then transmits
Step 3	If the NIC transmits the entire frame without detecting a collision, the transmission is successful; if the NIC detects a collision, via CD, while transmitting, the transmission is aborted and a jam signal, 48 bits in length, is sent to ensure that all other transmitters are aware of the collision.
Step 4	After aborting, the NIC enters what is known as *Exponential Backoff,* which is in essence an algorithm to produce a random waiting period, and then returns to step 2

Ethernet (DIXv2) & 802.2

8 bytes			2 bytes	46 to 1500 bytes	4 bytes
Preamble	Dest. MAC add	Src. MAC add	Type	Payload	FCS

802.3 MAC: connectionless

7 bytes	1 byte			2 bytes	46 to 1500 bytes	4 bytes
Preamble	Short frame delimiter	Dest. MAC add	Src. MAC add	Length or Type	Payload	FCS

Connection-oriented or connectionless: 802.3 + 802.2 LLC

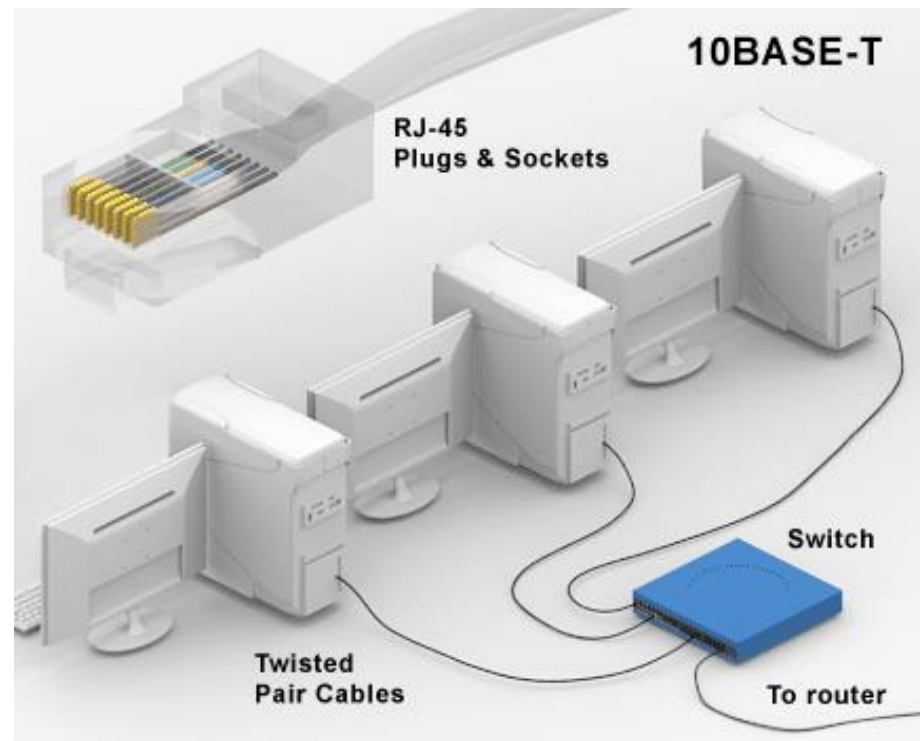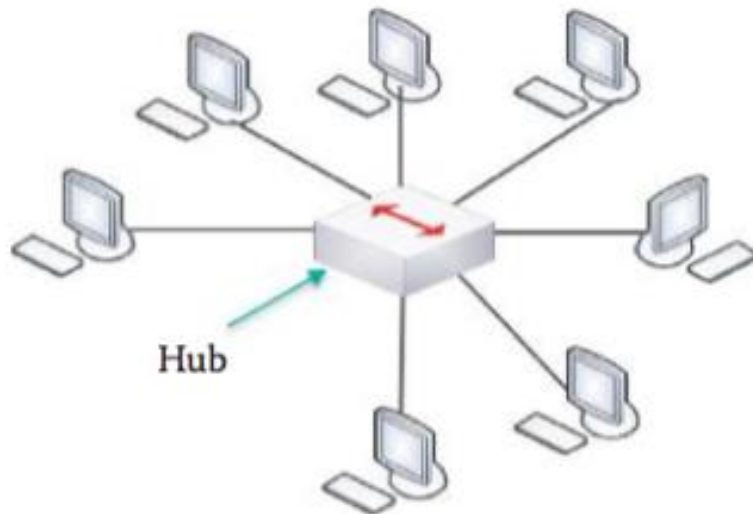| DSAP	SSAP	Control	IP Datagram

Ethernet Network & Devices

- 10BASE-5
- 10BASE-2
- 10BASE-T
- Fast Ethernet
- Gigabit Ethernet (GbE)

Ethernet Hubs

Ethernet Cables & Connectors

Name	Rate (Mbps)	Max. Length	Cable
10BASE5	10	500 m (coax)	Coax
10BASE2	10	185 m (coax)	Coax
1BASE-T	1	250 m	UTP Cat 3
10BASE-T	10	100 m	UTP Cat 3
10BASE-FL	10	2000 m (MMF)	MMF
100BASE-TX (2p)	100	100 m (cat 5)	UTP Cat 5
100BASE-T4 (4p)	100	100 m (cat 3)	UTP Cat 3
100BASE-FX	100	MMF 2 km, SMF 10km	MMF/SMF
1000BASET (4p)	1,000	100 m (Cat 5e)	UTP Cat 5e
10GBASET (4p)	10,000	100 m	UTP Cat 6 or better

Note: SMF stands for single mode fiber and MMF for multi-mode fiber.

Cat-7 cables & RJ-45 connector

Jacket

Tinned copper braid

Foil shield

Foam skin

Untwisted length

1   8
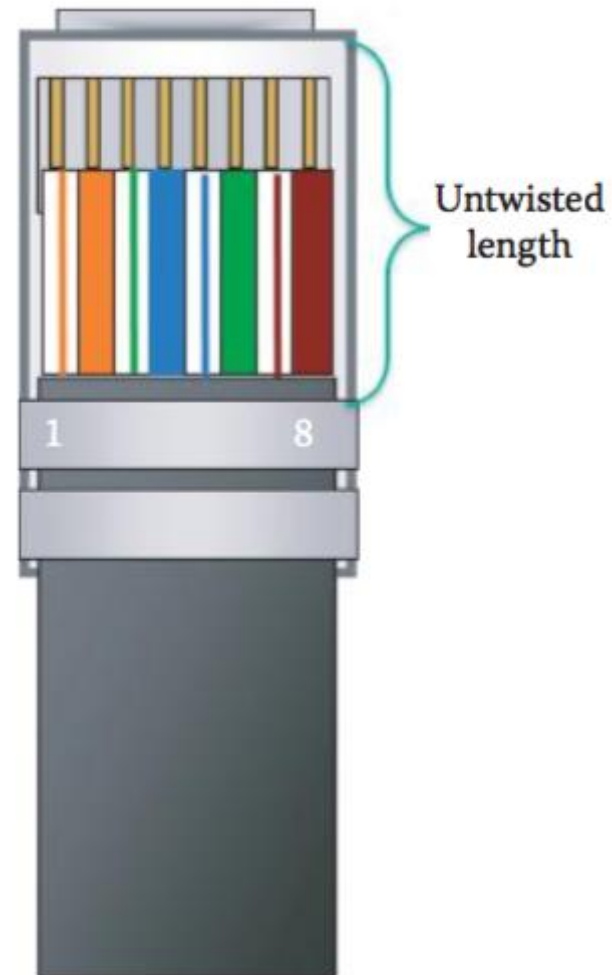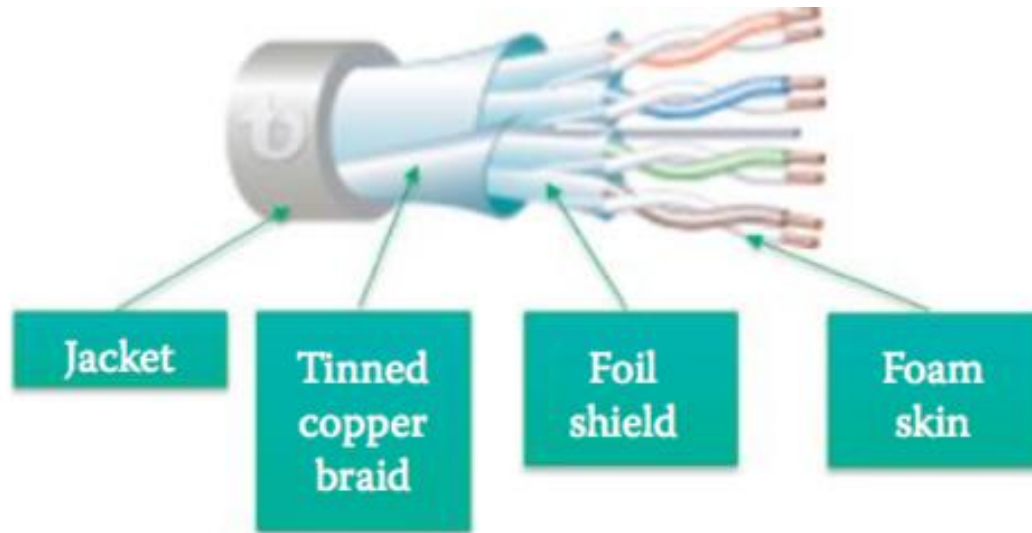
T568B

Pin	T568B Pair	Wire	T568B Color	Pins on plug face (jack is reversed)
1	2	tip	white/orange stripe	
2	2	ring	orange solid	
3	3	tip	white/green stripe	
4	1	ring	blue solid	
5	1	tip	white/blue stripe	
6	3	ring	green solid	
7	4	tip	white/brown stripe	
8	4	ring	brown solid	

Pin Position
8
7
6
5
4
3
2
1

T568A vs. T568B

8P8C Wiring (TIA/EIA-568-A T568A)

Pin	Pair	Wire	Color
1	3	1	white/green
2	3	2	green
3	2	1	white/orange
4	1	2	blue
5	1	1	white/blue
6	2	2	orange
7	4	1	white/brown
8	4	2	brown

8P8C Wiring (TIA/EIA-568-B T568B)

Pin	Pair	Wire	Color
1	2	1	white/orange
2	2	2	orange
3	3	1	white/green
4	1	2	blue
5	1	1	white/blue
6	3	2	green
7	4	1	white/brown
8	4	2	brown

EIA/TIA T568B Straight Through Diagram

1	(orange)	————————————	(orange) 1
2	(white/orange)	————————————	(white/orange) 2
3	(white/green)	————————————	(white/green) 3
4	(blue/white)	————————————	(blue/white) 4
5	(blue)	————————————	(blue) 5
6	(green)	————————————	(green) 6
7	(brown)	————————————	(brown) 7
8	(white/brown)	————————————	(white/brown) 8

EIA/TIA T568B Crossover Diagram

1	(orange)		(white/green) 1
2	(white/orange)		(green) 2
3	(white/green)		(orange) 3
4	(blue/white)		(brown) 4
5	(blue)		(white/brown) 5
6	(green)		(orange/white) 6
7	(brown)		(blue/white) 7
8	(white/brown)		(blue) 8
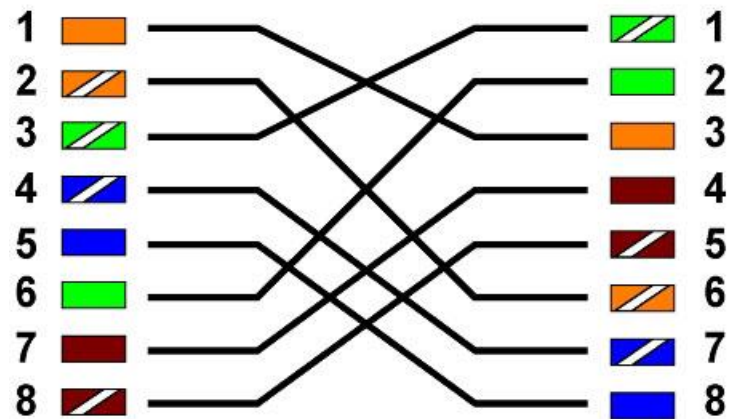
Straight-through vs. Cross-over

PC	⟷	Switch/Hub
Switch/Hub	⟷	Router

Pin	Label		Pin	Label
1	RD+	⟵	1	TD+
2	RD−	⟵	2	TD−
3	TD+	⟶	3	RD+
4	NC		4	NC
5	NC		5	NC
6	TD−	⟶	6	RD−
7	NC		7	NC
8	NC		8	NC

PC	⟷	PC
Switch/Hub	⟷	Switch/Hub
Router	⟷	Router

Pin	Label		Pin	Label
1	TD+		1	TD+
2	TD−		2	TD−
3	RD+		3	RD+
4	NC		4	NC
5	NC		5	NC
6	RD−		6	RD−
7	NC		7	NC
8	NC		8	NC

Gigabit Ethernet

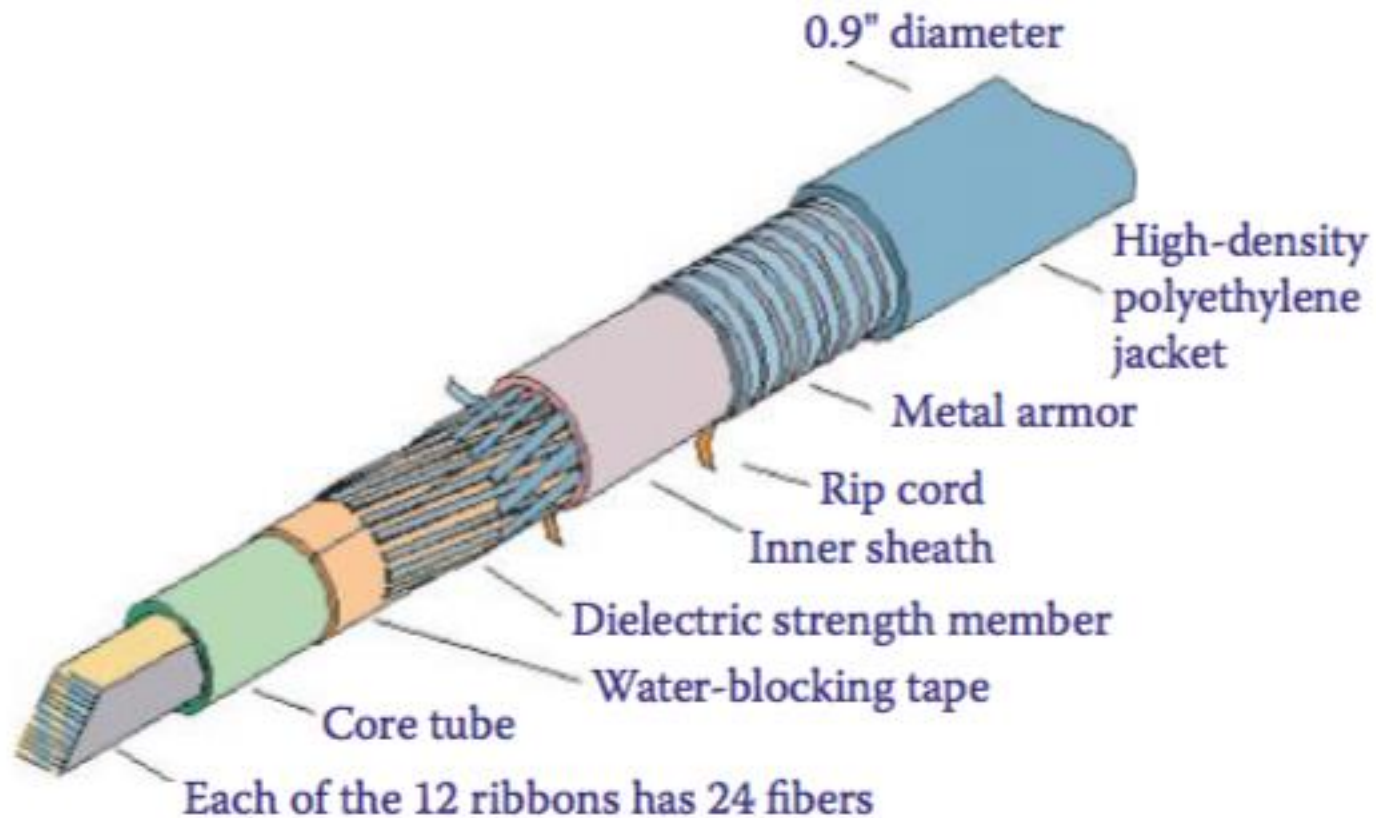| Name	Rate (Gbps)	Max. Length	Cable
1000BASET	1	100 m	Cat 5e
1000BASESX	1	Up to 550 m or laser-optimized multimode fiber (OM3) optic link spans up to 1 km	MMF: a single lane in each direction
1000BASELX	1	Up to 550 m over MMF or 10 km over SMF	MMF/SMF: a single lane in each direction
1000BASELH	1	Up to 100 km over SMF	MMF/SMF: a single lane in each direction
10GBASE-T	10	Up to 100 m	Cat 5e or better; 4 pairs
10GBASE-LX4	10	Up to 300 m over MMF or 10 km over SMF	MMF/SMF: a single lane in each direction
10GBASE-LR	10	Up to 10 km over SMF	SMF: a single lane (fiber) in each direction
10GBASE-ER	10	Up to 40 km over SMF	SMF: a single lane in each direction
10GBASE-CX4	10	15 m	Twin axial copper
10GBASE-SR	10	Up to 300 m over MMF	MMF: a single lane in each direction
10GBASE-ZR	10	Up to 80 km over SMF	SMF: a single lane in each direction
40GBASE-KR4	40	Up to 1 m over a backplane	Backplane copper
40GBASE-CR4	40	Up to 7 m over copper cable	Twin axial copper cable
40GBASE-SR4	40	Up to 100 m over OM3 MMF or 125 m over OM4 MMF	MMF: four lanes in each direction
40GBASE-LR4	40	Up to 10 km over SMF	SMF with 4-wavelength WDM, a single lane in each direction
100GBASE-CR10	100	Up to 7 m over copper cable	Twin axial copper cable
100GBASE-SR10	100	Up to 100 m over OM3 MMF or 125 m over OM4 MMF	MMF: ten lanes in each direction
100GBASE-LR4	100	Up to up to 10 km over SMF	SMF with 4-wavelength WDM, a single lane in each direction
100GBASE-ER4	100	Up to Up to 40 km over SMF	SMF with 4-wavelength WDM, a single lane in each direction

Single-mode and Multi-mode Fiber

SMF:

9 μm   125 μm

MMF:

62.5/50 μm   125 μm
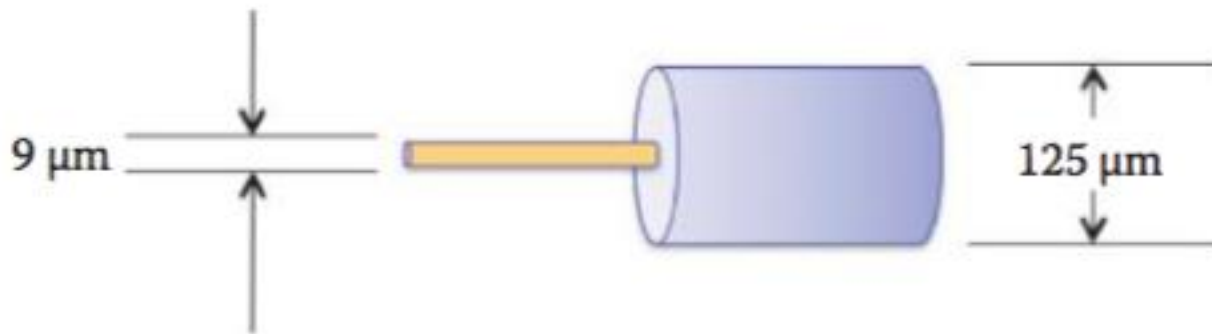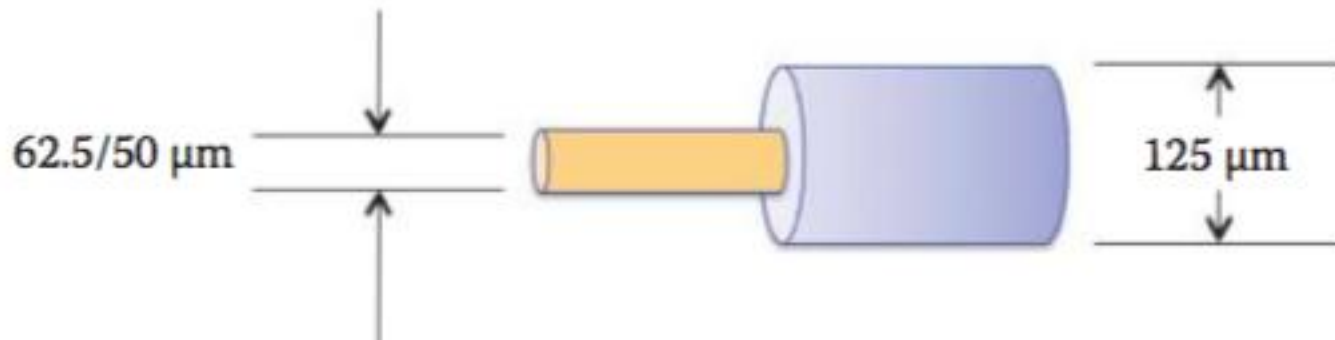
Optical Fiber structure

0.9" diameter

High-density polyethylene jacket

Metal armor

Rip cord

Inner sheath

Dielectric strength member

Water-blocking tape

Core tube

Each of the 12 ribbons has 24 fibers

Ten Gigabit Ethernet (10G)

- Commonly employed in an organization's backbones, Wide/Metropolitan Area Networks (WAN/MAN) or data centers.

- Does not support CSMA/CD, but works only in conjunction with a switch.

Name	Cable	Max. segment	Advantages
10GBase-SR	Fiber optics	Up to 300 m	Multimode fiber (0.85μ)
10GBase-LR	Fiber optics	10 km	Single-mode fiber (1.3μ)
10GBase-ER	Fiber optics	40 km	Single-mode fiber (1.5μ)
10GBase-CX4	4 Pairs of twinax	15 m	Twinaxial copper
10GBase-T	4 Pairs of UTP	100 m	Category 6a UTP

Collision Domain

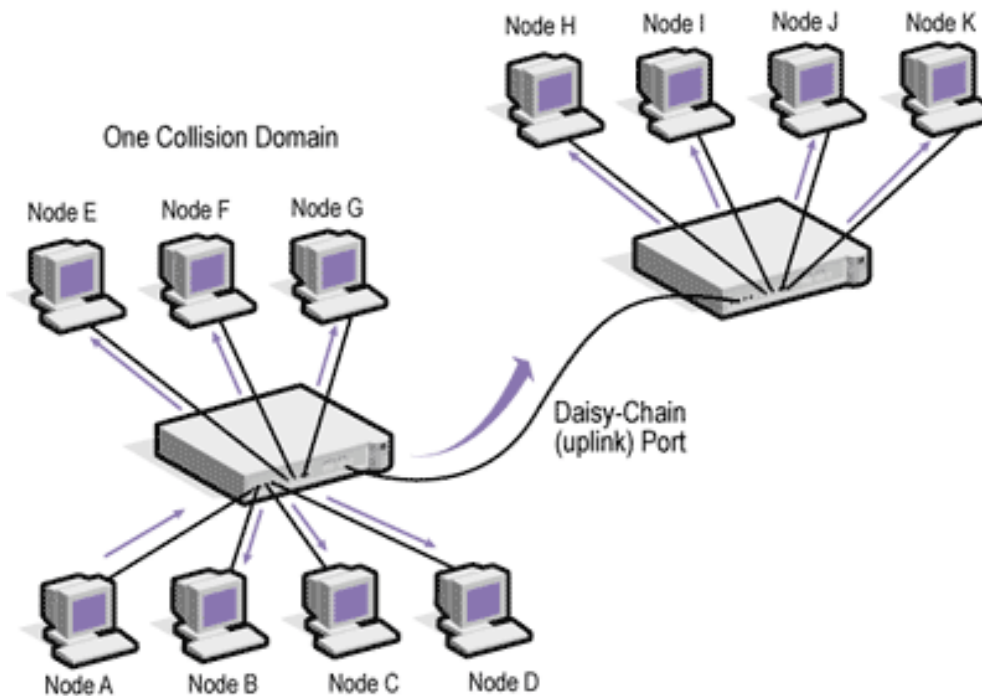A part of a network where packet collisions can occur
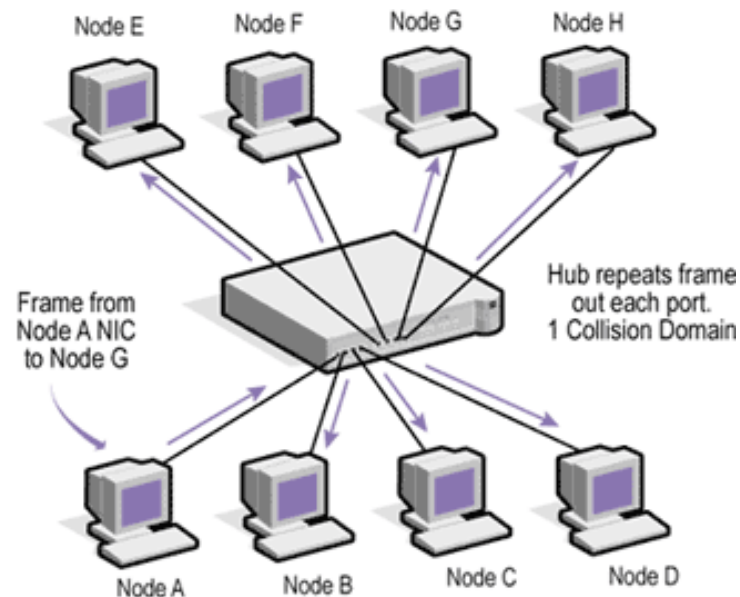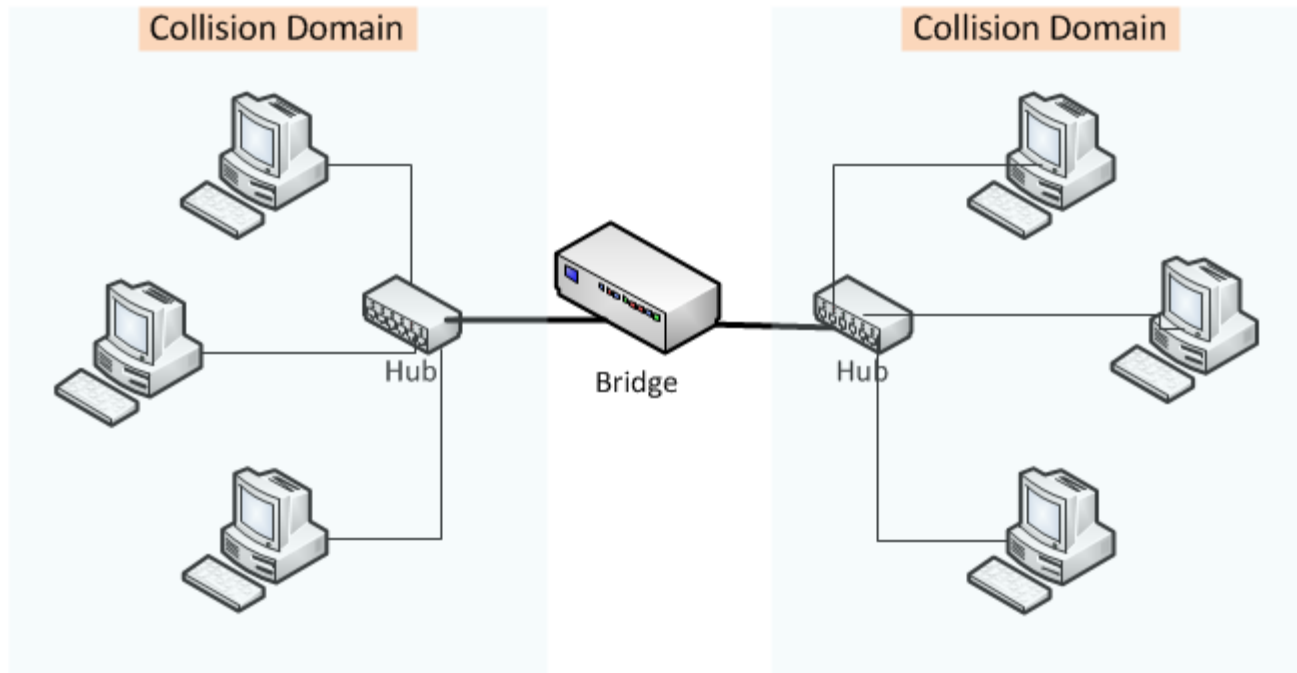
Collision Domain
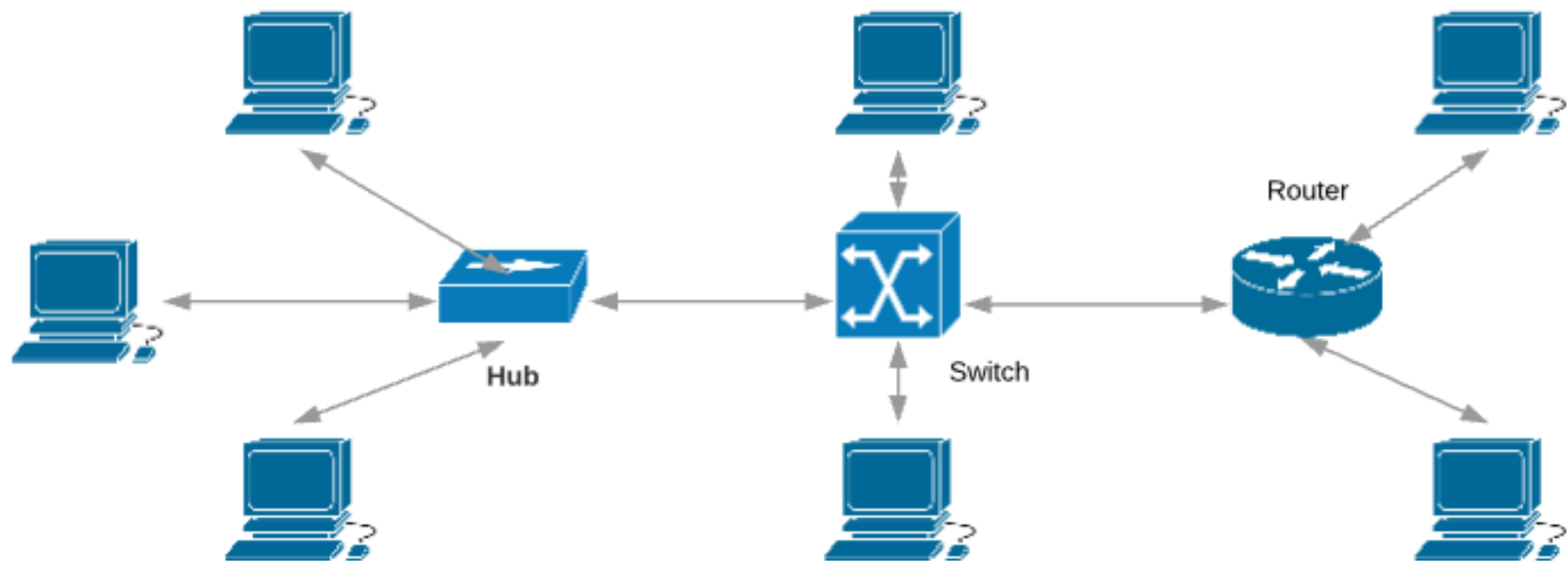
Collision Domain

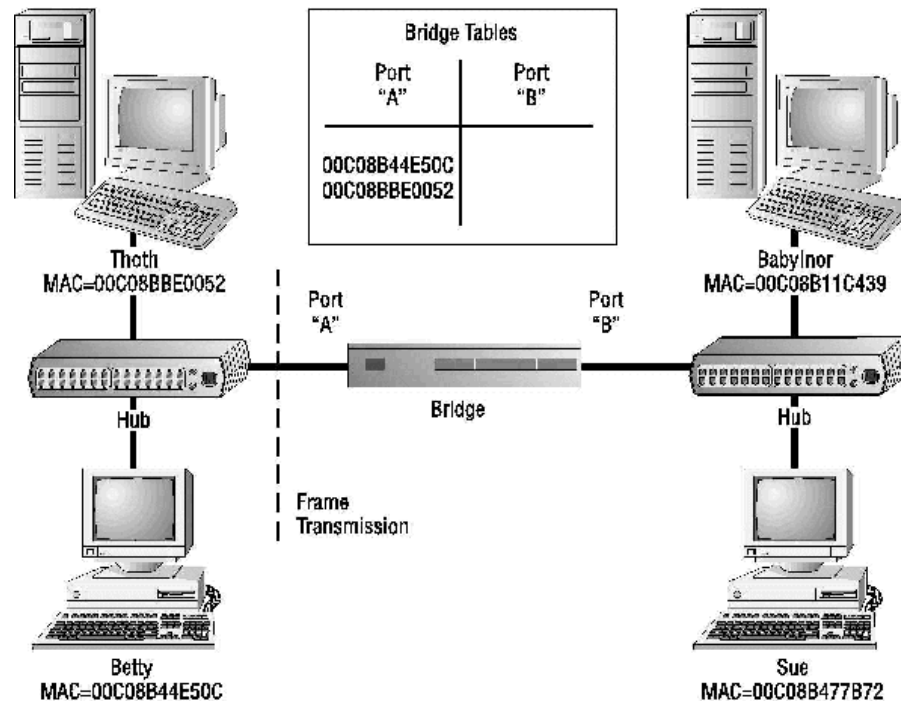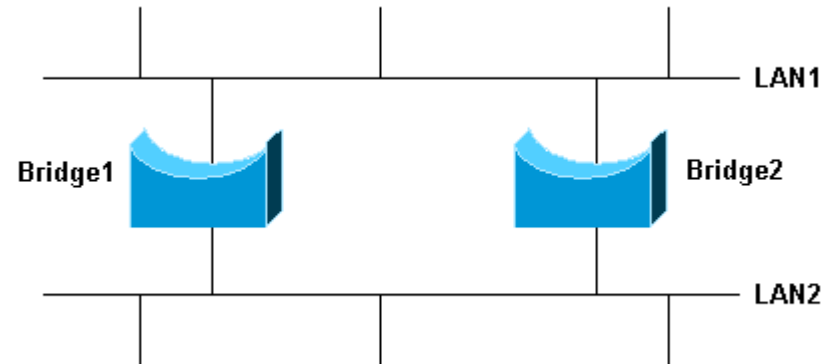- Expand network with Hub will enlarge collision domain

Internetworking Devices

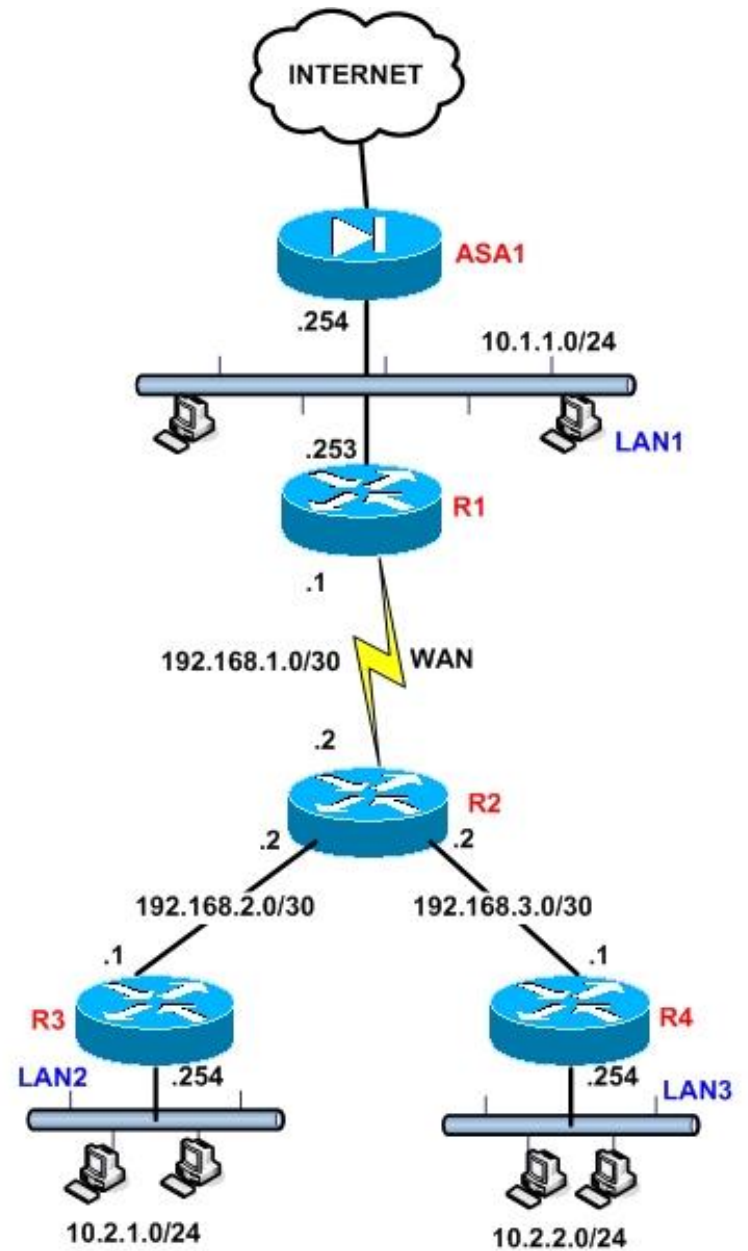• Expanding network with internetworking devices avoids widening collision domain

Bridge

- Learning
- Filtering
- Forwarding

Router

Cisco Router

datacenter routing table

Network	Interface
123.21.1.0	FE0
123.21.3.0	TR1
123.21.5.0	FE0

123.21.1.0

FE0   FE0

FE1

123.21.5.0

123.21.3.0

manfloor routing table

Network	Interface
123.21.1.0	FE0
123.21.3.0	FE0
123.21.5.0	FE1