

Data Link Layer II

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Semester 2, 2020



Ethernet

- LAN, Ethernet Fundamentals
- History and Evolution
- Ethernet, Fast Ethernet, Gigabit Ethernet and Cabling
- IEEE802.1 Ethernet DLL
 - LLC Services
 - MAC data frame
 - MAC protocol
 - Deployment
- Adaptive Learning

What is LAN?

- **Private ownership**

- ✓ freedom from regulatory constraints of WANs

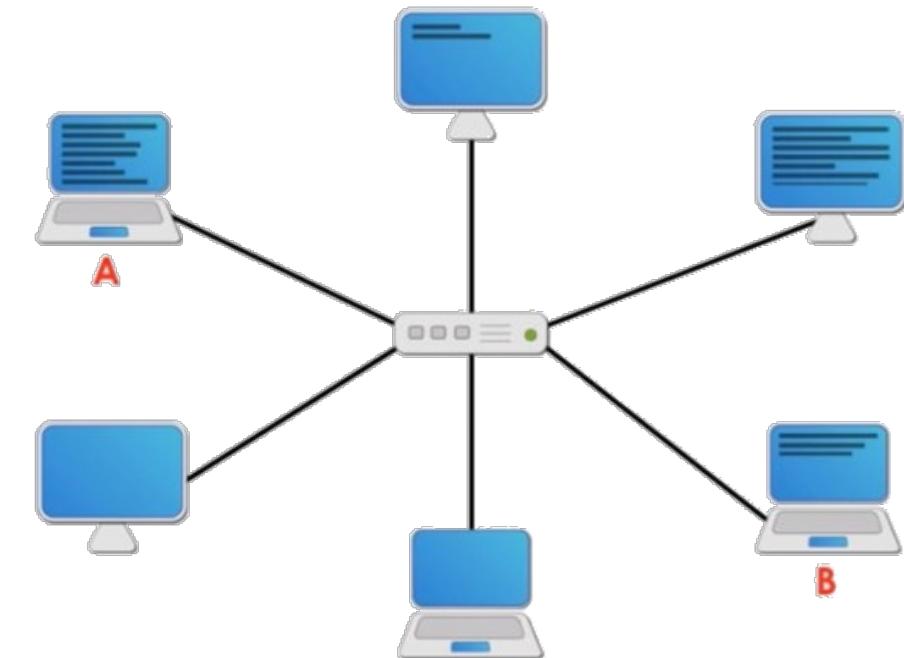
- **Short distance** (~1km)

- ✓ low cost
 - ✓ very high-speed, relatively error-free communication
 - ✓ complex error control unnecessary

- **LAN** characterizes:

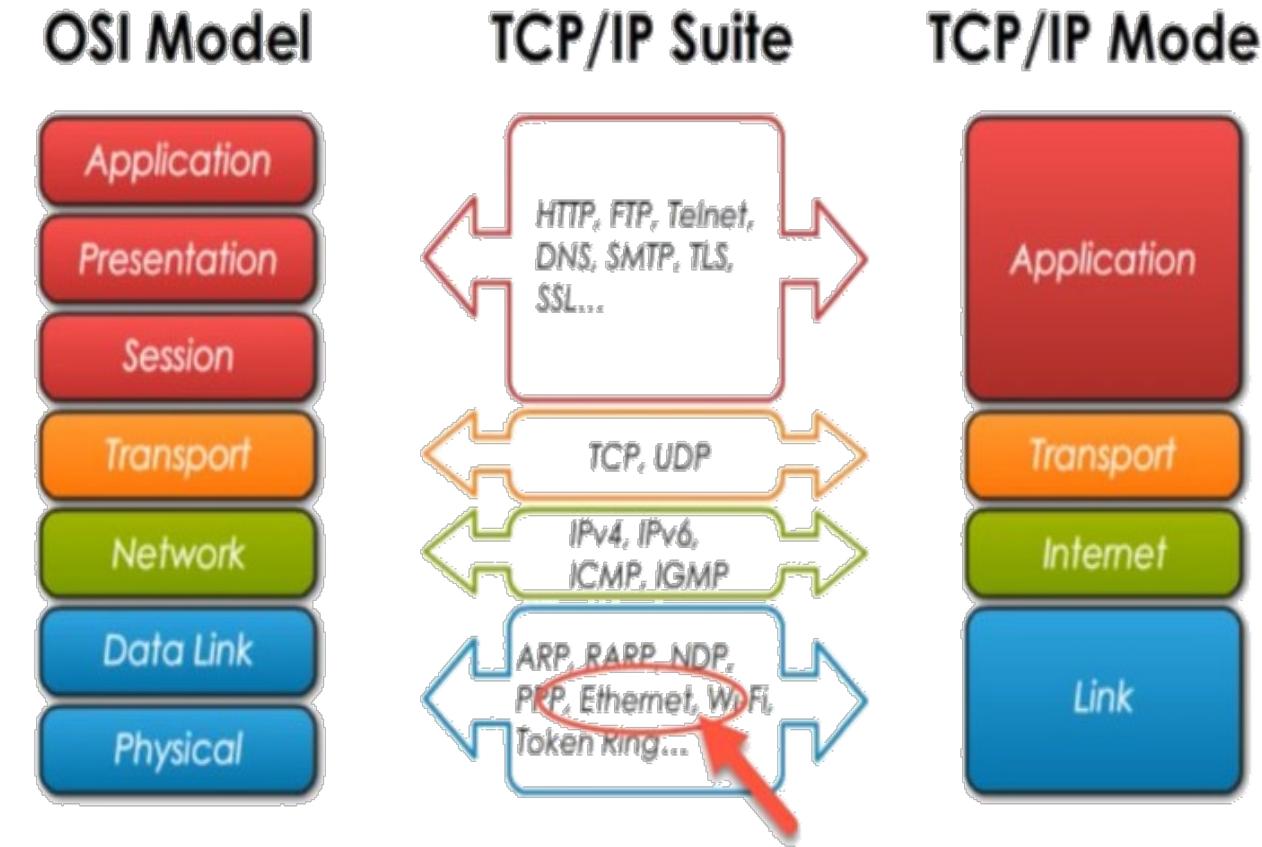
- ✓ Topology (Star, Bus, Mesh, etc.)
 - ✓ Protocols (CSMA/CD, CSMA/CA, etc.)
 - ✓ Media (twisted pair, coaxial, fiber optic)

Ethernet network - Local Area Network (LAN)



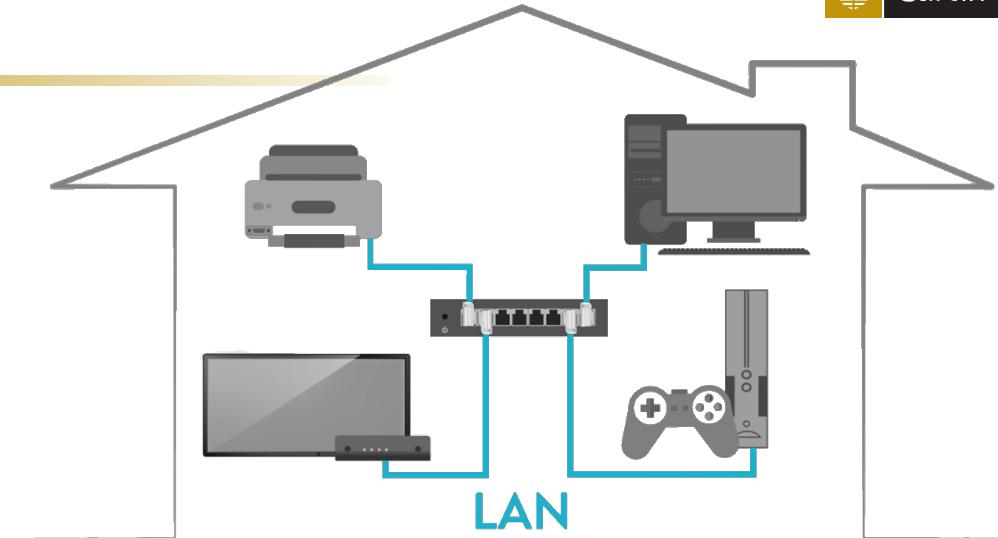
Ethernet

- **is a LAN Technology** (*most popular*)
- Other LAN technologies
 - ✓ Token Ring
 - ✓ FDDI (Fiber Distributed Data Interface)
 - ✓ ARCNET
- Operates at both **physical** and **data link layer**



Ethernet

- Is a **baseband** system

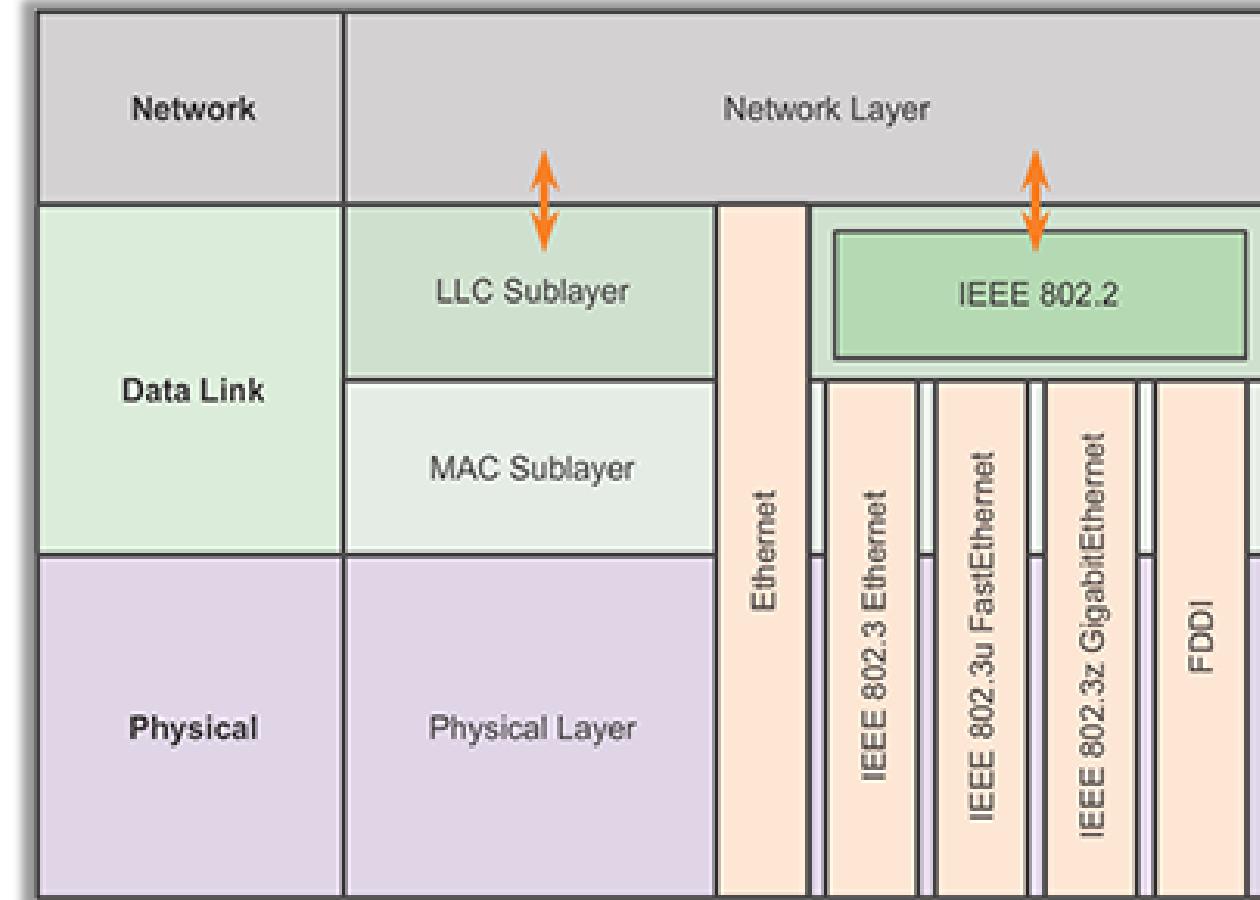


- Ethernet implementations of the network may differ
- But,
 - **Basic Topology**
 - **Frame Type**
 - **Network Access Method**

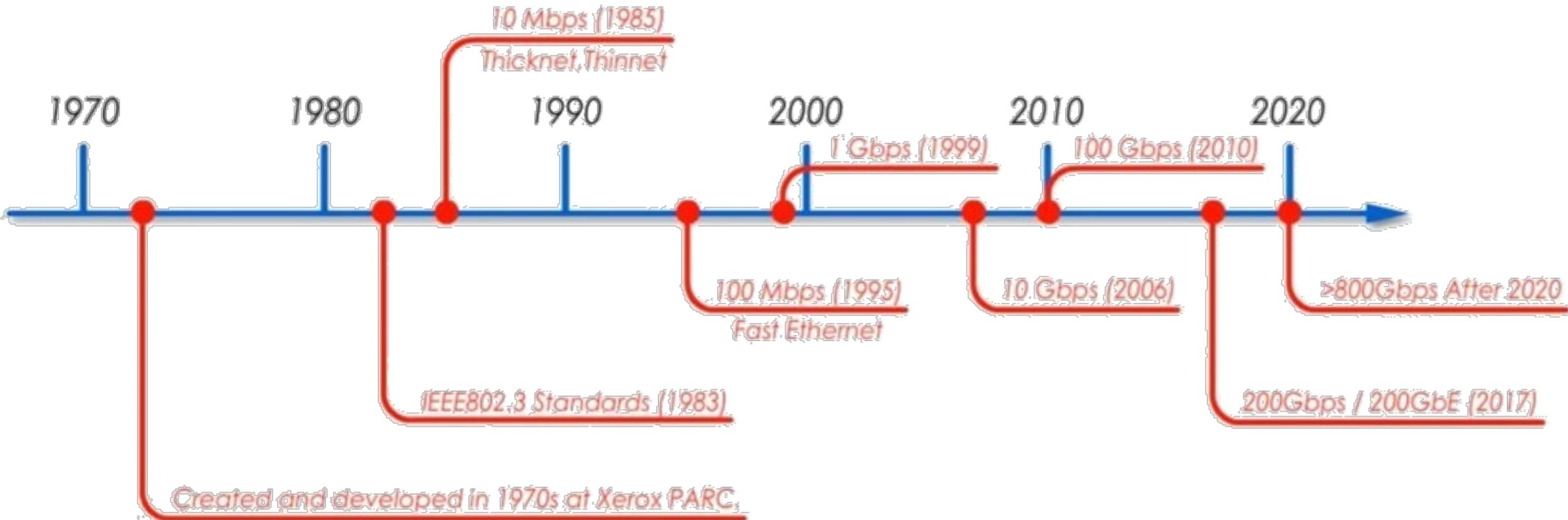
} **Same**

Project 802 of the IEEE

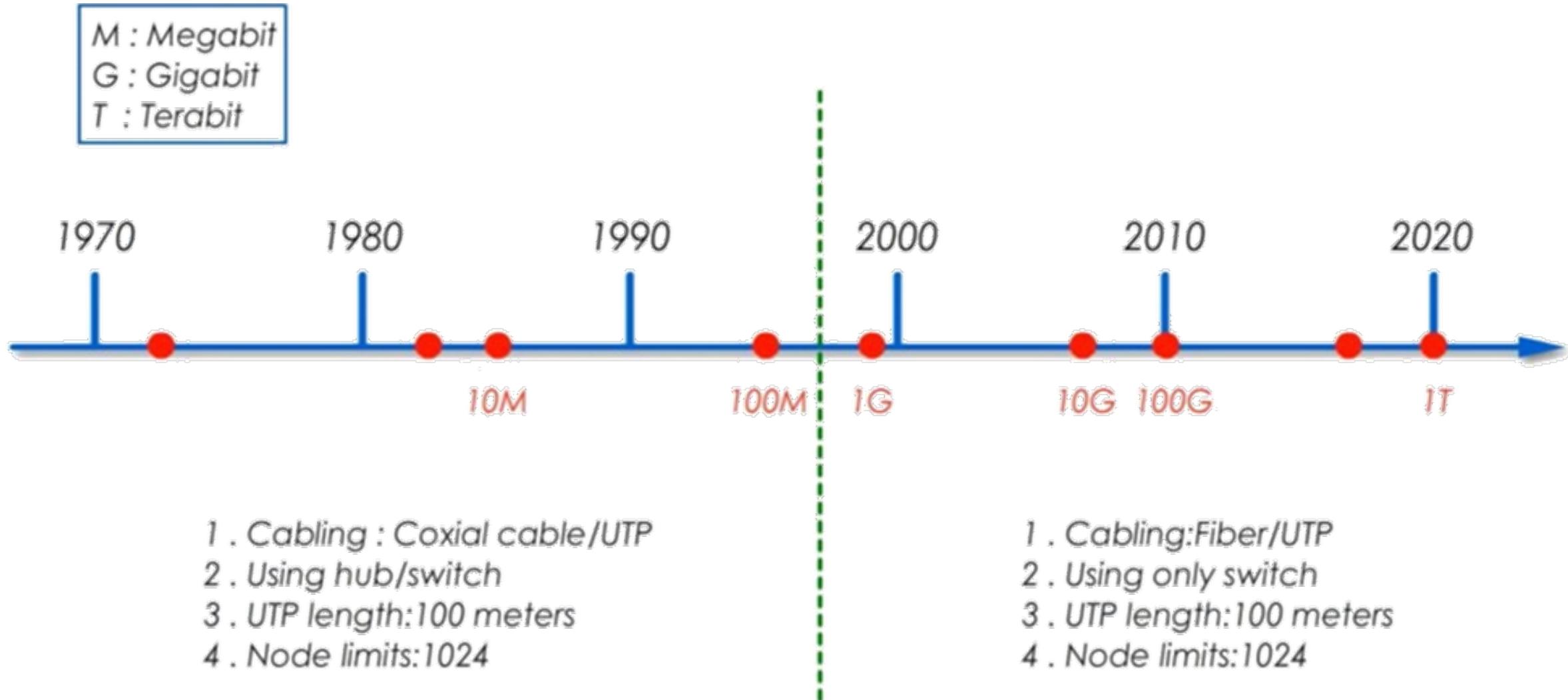
- The Computer Society of the **IEEE** began a special project in 1985 that was known as **Project 802**
- Its purpose was to set **standards** that would enable **intercommunication between equipment** from a variety of manufacturers
- **Project 802** is a way of specifying functions of the **physical layer and the data link layer** of major LAN protocols



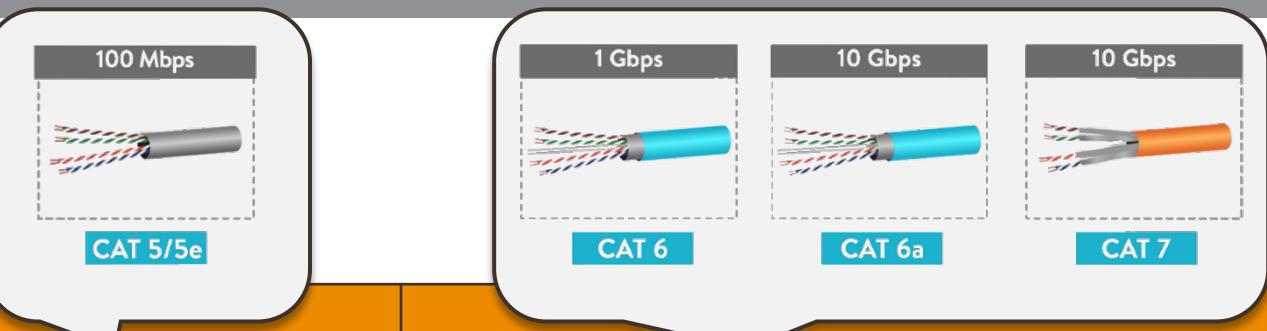
Ethernet Timeline



Ethernet Evolution – Physical Layer



Ethernet Cabling



Basis for Comparison	Ethernet	Fast Ethernet	Gigabit Ethernet
Speed	10 Mpbs	100 Mbs	1000 Mbps
Alternative Name (Baseband ver.)	10Base-T	100Base-T	1000Base-T 1000Base-LX (Fiber, long haul) 1000Base-SX (Fiber, short haul)
IEEE Standard	IEEE 802.3	IEEE 802.3u	IEEE 802.3ab IEEE 802.3z (Fiber standards)
Medium	Copper	Copper	Copper, Fiber
Maximum Network Segment Size	100 meters	100 meters	100 meters – copper 550 meters – SX 5 kilometers - LX



Data Link Layer: Services

LLC:

- Provide services to network layer protocols
- **Flow Control**
- **Error Control**

MAC:

- **Framing:** bits to frame (vice versa)
- Physical addressing (**MAC addressing**)
- Multiple access methods for channel-access control (**CSMA/CD, CSMA/CA**)
- LAN switching (packet switching), including MAC filtering, **Spanning Tree Protocol (STP)**
- Data packet queuing or scheduling
- Store-and-forward switching or cut-through switching
- Quality of Service (QoS) control
- **Virtual LANs (VLAN)**

From
Last Week!

IEEE 802.1 Data Link Layer

Two main Sub Layers

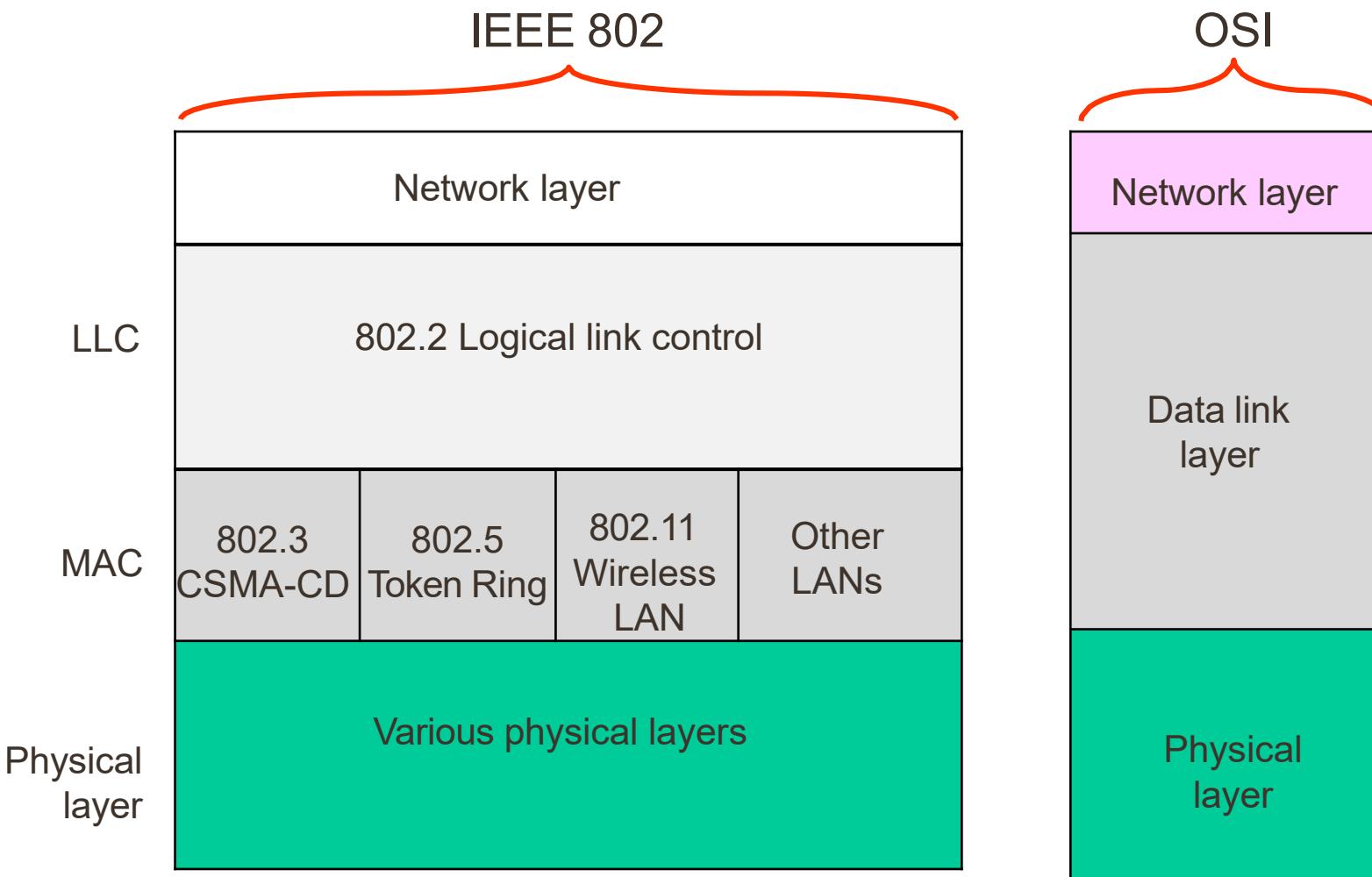
1. Logical Link Control (LLC)

- ✓ Between Network layer & MAC sublayer

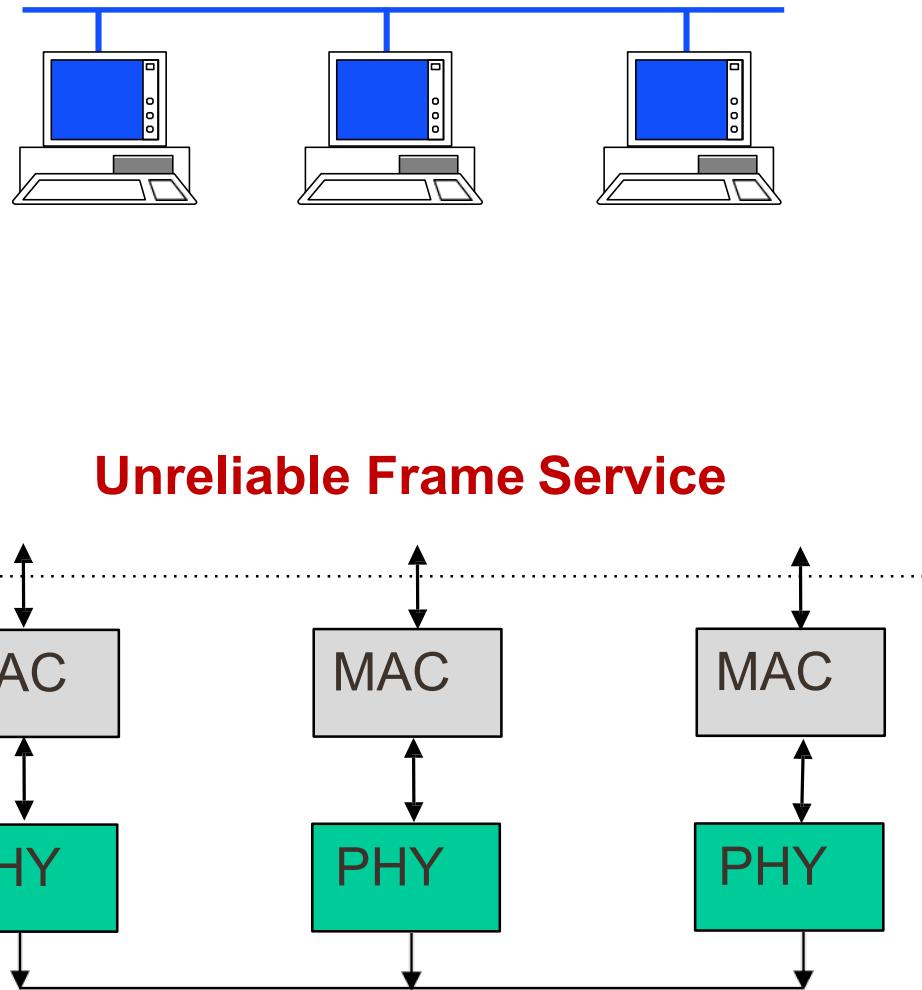
2. Medium Access Control (MAC)

- ✓ Coordinate access to medium
- ✓ Connectionless frame transfer service
- ✓ Machines identified by MAC/physical address
- ✓ Broadcast frames with MAC addresses

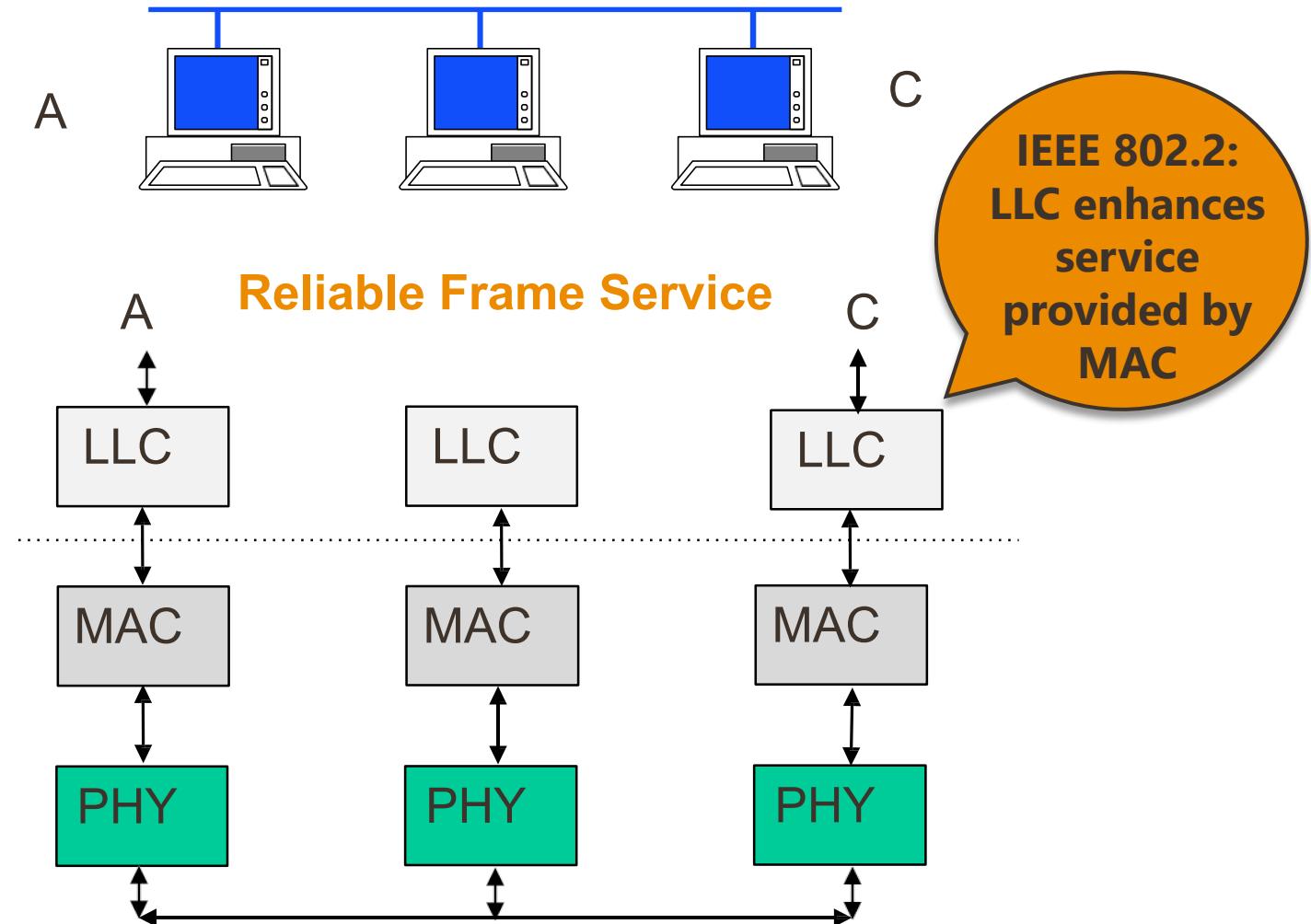
IEEE 802.1 Data Link Layer



Logical Link Control



Unreliable Frame Service



IEEE 802.2:
LLC enhances
service
provided by
MAC

Logical Link Control Services

- **Type 1: Unacknowledged connectionless** service

- ✓ Unnumbered frame mode of HDLC

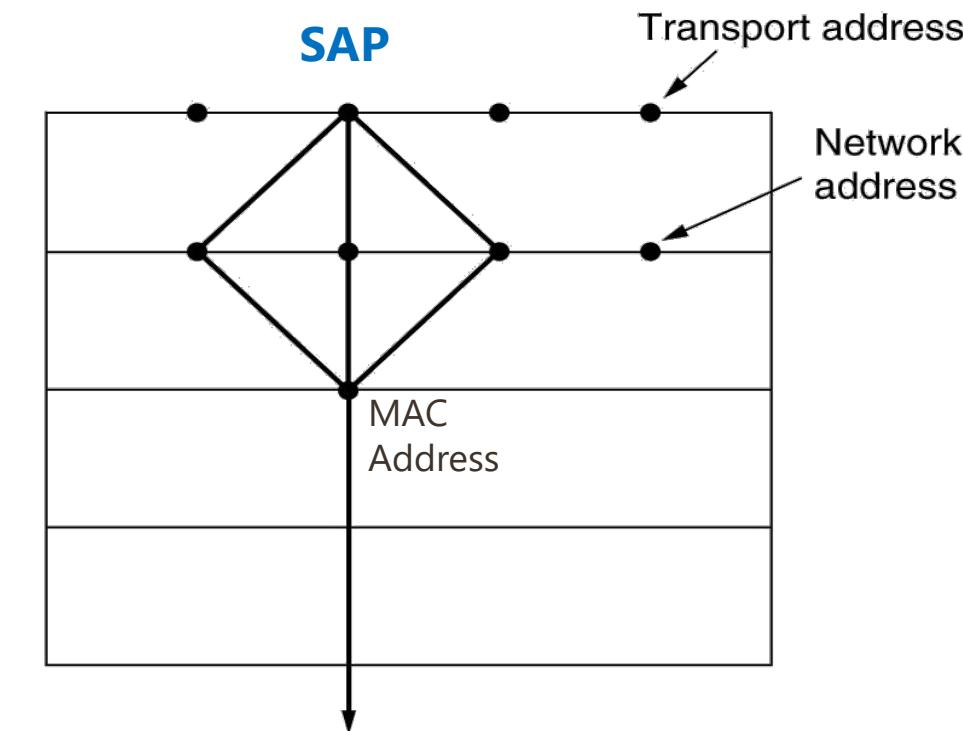
- **Type 2: Reliable connection-oriented** service

- ✓ Asynchronous balanced mode of HDLC

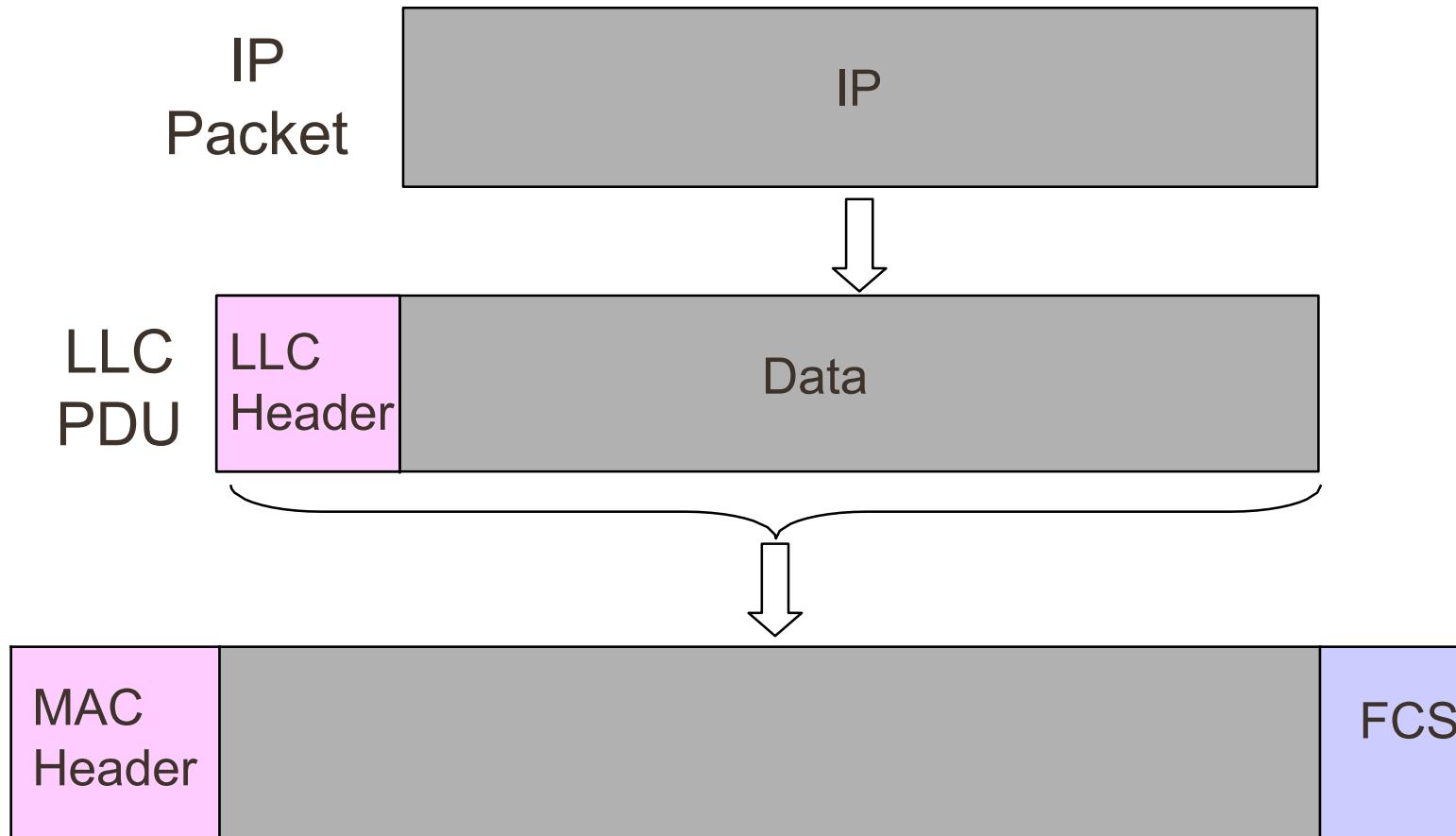
- **Type 3: Acknowledged connectionless** service

- **Additional addressing**

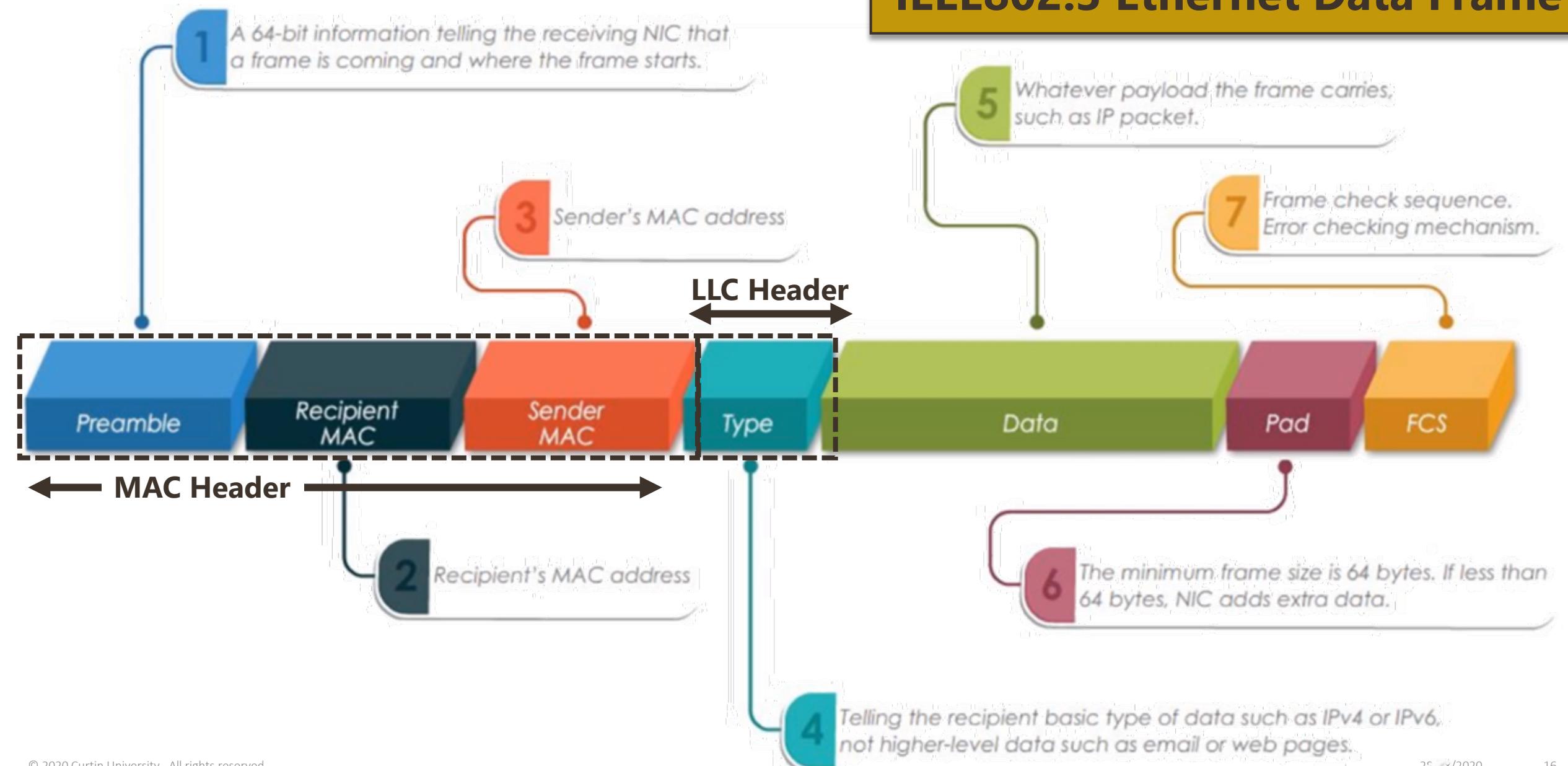
- ✓ A workstation has a single MAC physical address
 - ✓ Can handle several logical connections, distinguished by their **SAP** (service access points).



Encapsulation of MAC Frame



IEEE802.3 Ethernet Data Frame

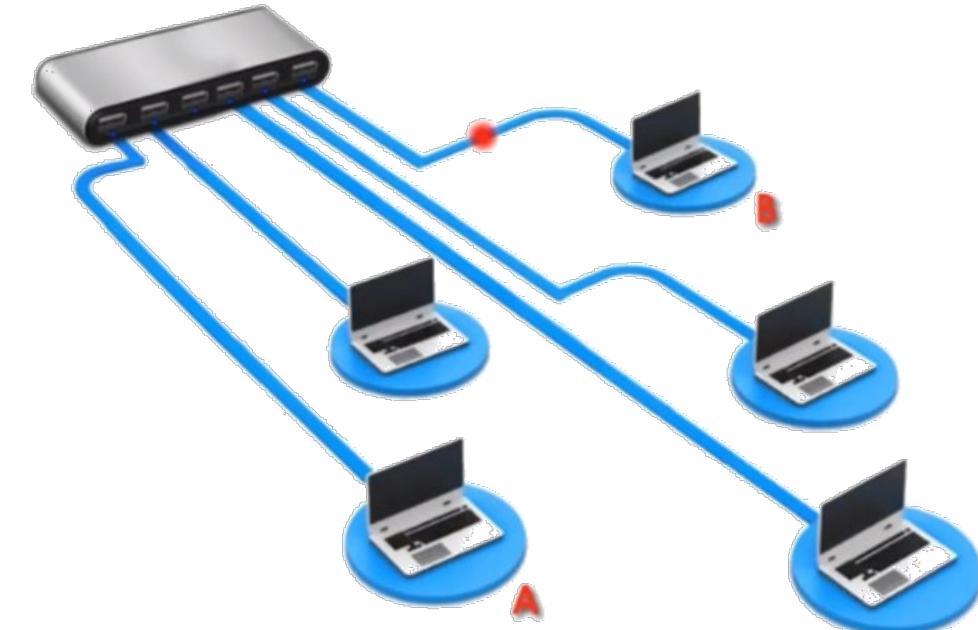


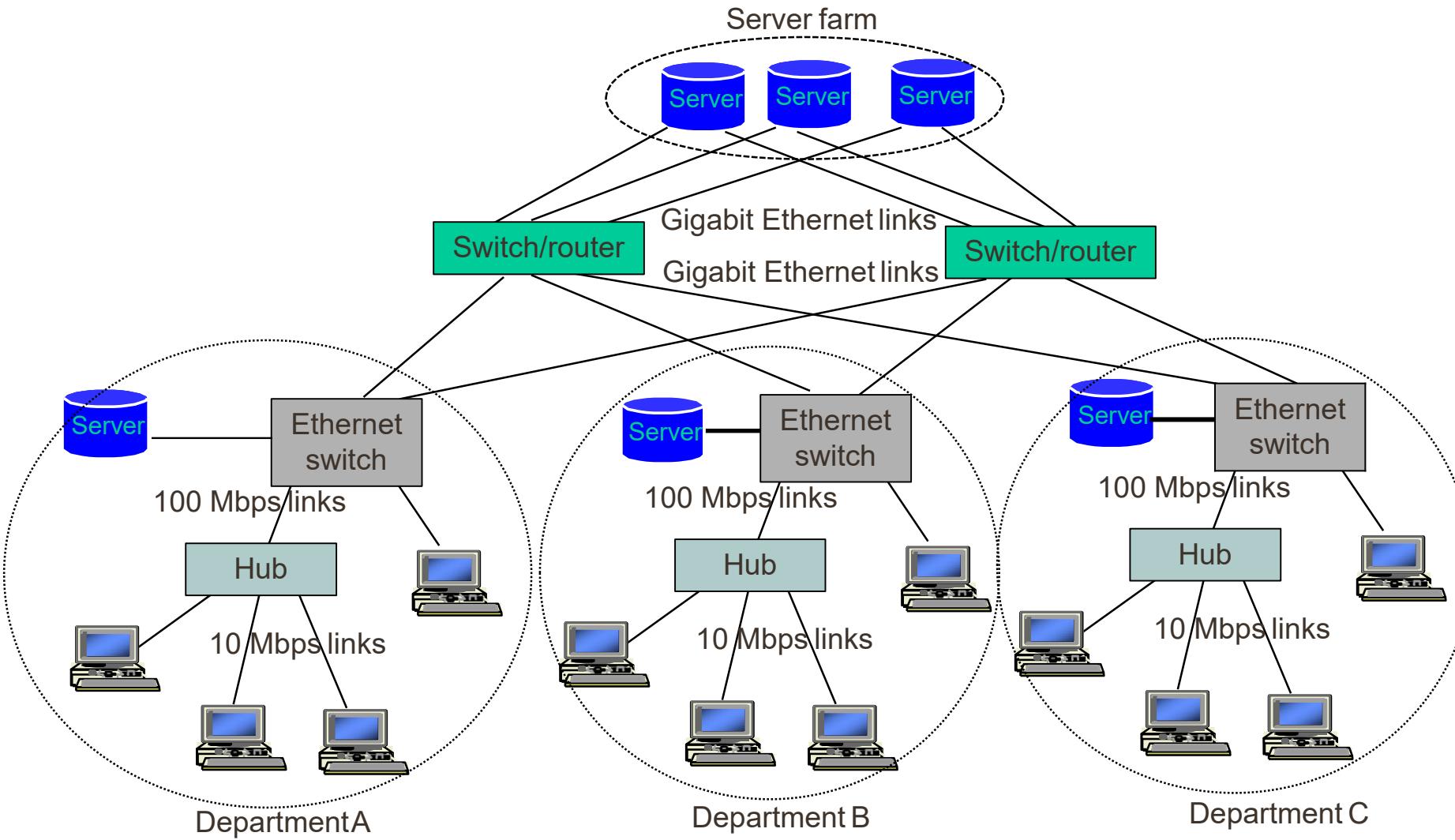
IEEE 802.3 Ethernet

▪ MAC Protocol: CSMA/CD

- ✓ Uses **binary exponential backoff delay**

- After a collision has occurred each node waits either 0 or 1 time slots before retransmitting
- If a further collision occurs each node waits 0,1,2 or 3 time slots
- In general, after **n collisions**, a random number **between 0 and $2^n - 1$** time slots is chosen, and the node waits that number of time slots before attempting to retransmit, for **$n \leq 10$**





Typical Ethernet Deployment

Adaptive Learning

- In a static network, tables eventually store all addresses & learning stops
- In practice, stations are added & moved all the time
- Introduce timer (minutes) to age each entry & force it to be relearned periodically
- If frame arrives on port that differs from frame address & port in table, update immediately



Collision vs Broadcast Domain

- What is collision, broadcast domain?
- Hub
- Bridge
- Switch
- Router
- Wi-Fi collision/broadcast domain
- Full/half duplexity and collision domain

Collision vs. Broadcast Domain

▪ Collision Domain

- ✓ A group of nodes that can hear each other
- ✓ A part of a network where packet collisions can occur

▪ Broadcast Domain

- ✓ Contains devices that can reach each other at the data link layer by using **broadcast**

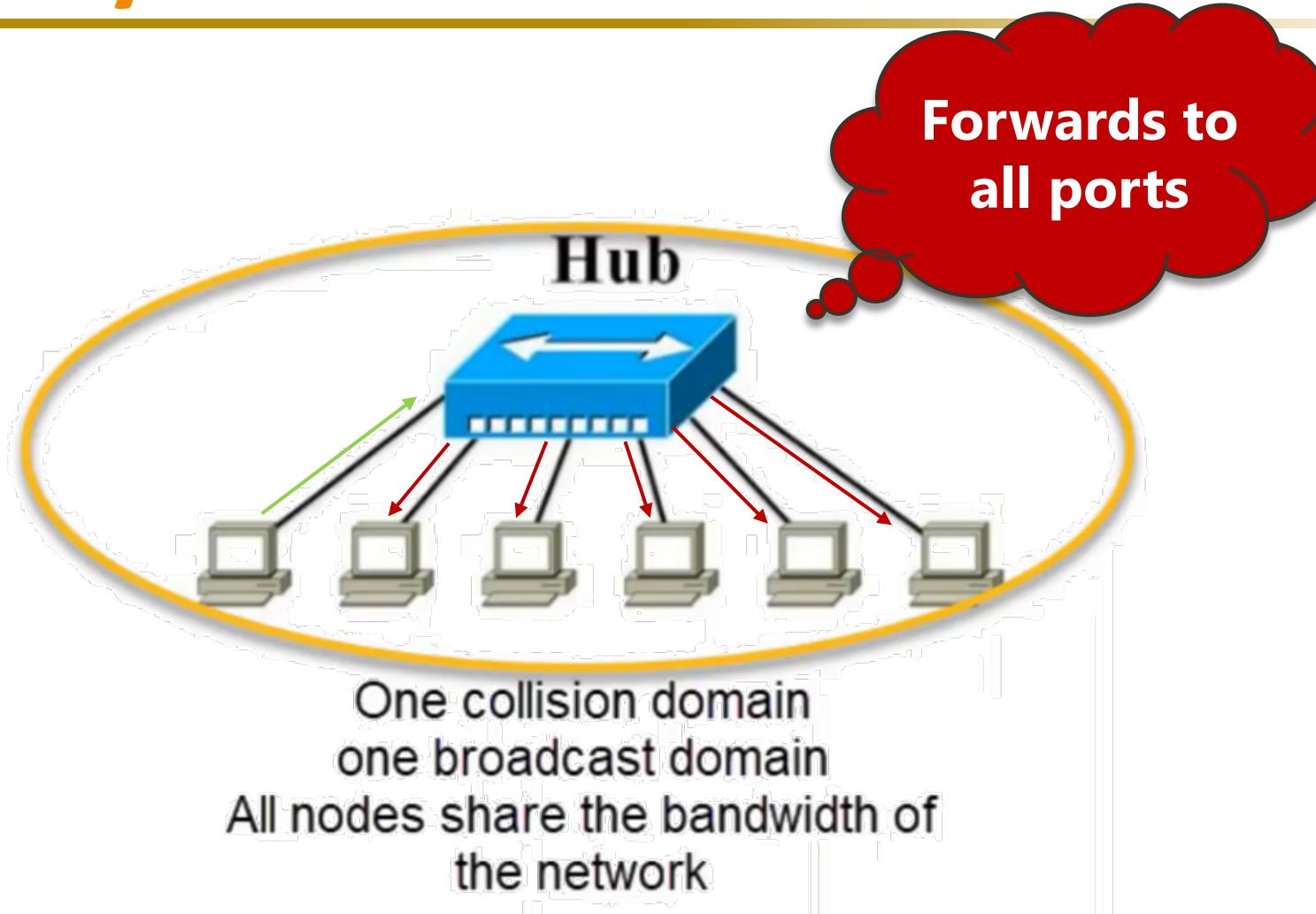


✓ A broadcast stops at the router

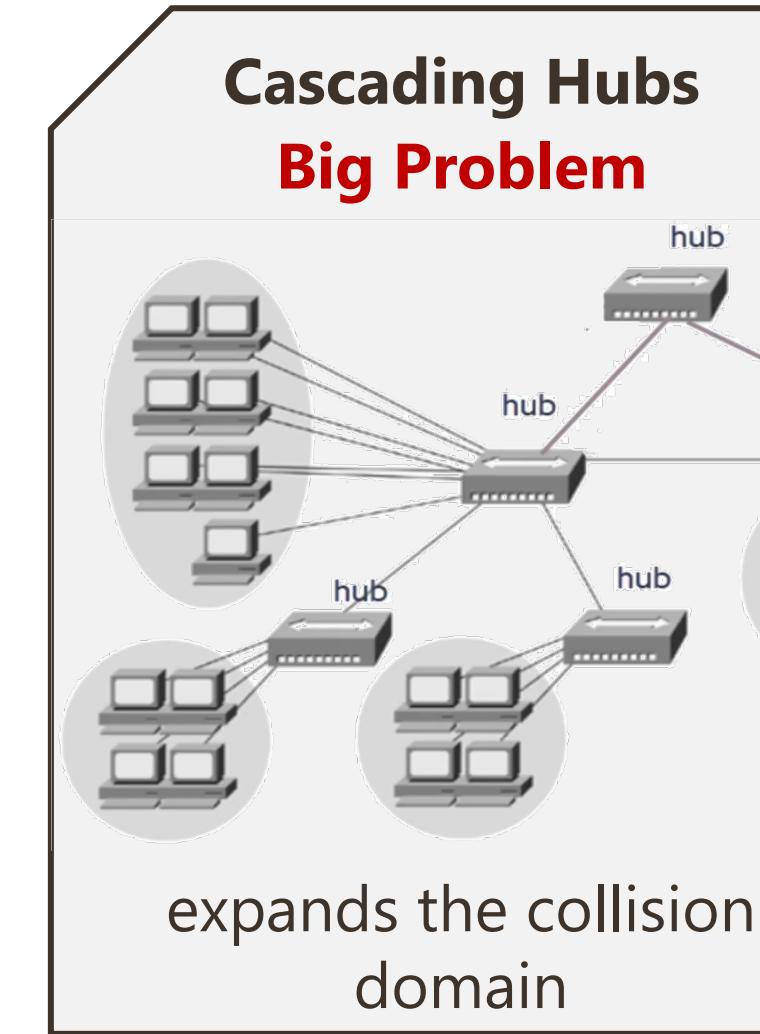
- It removes the header of the frame including the destination MAC address with another destination MAC address to send it to another broadcast domain



Layer 01: Hub



Only operate in **Half Duplex mode**

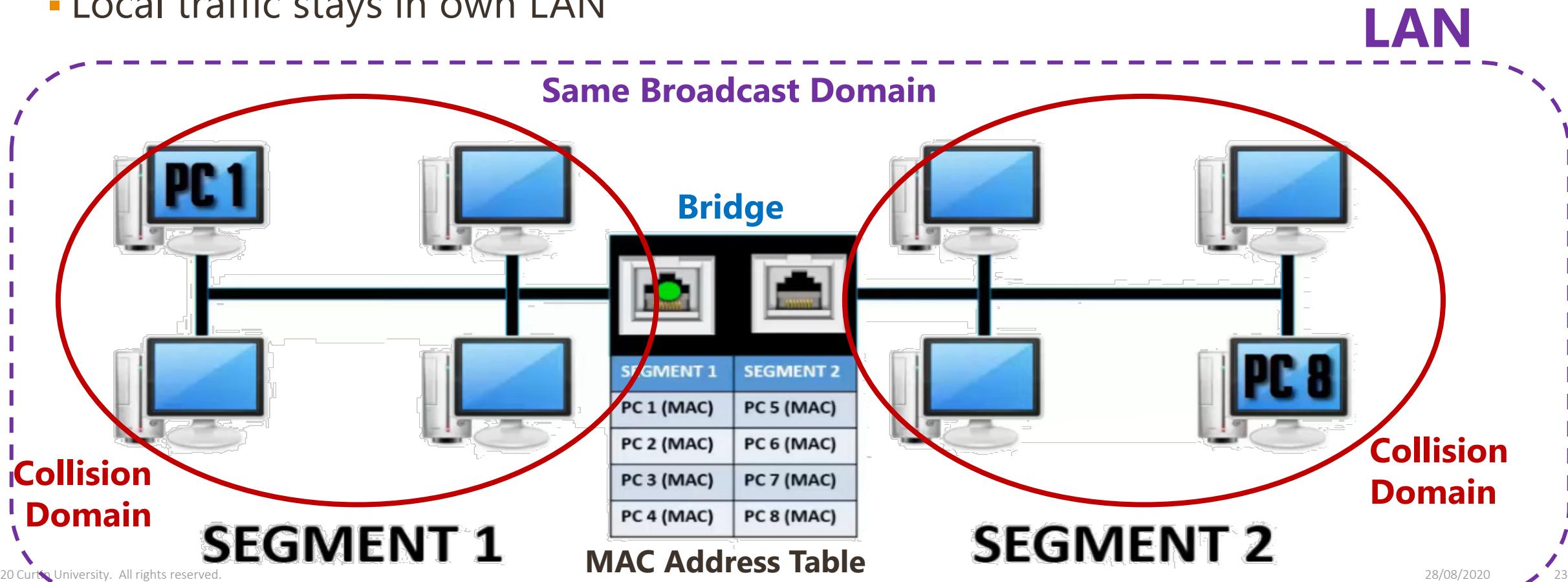


Layer 02: Bridge

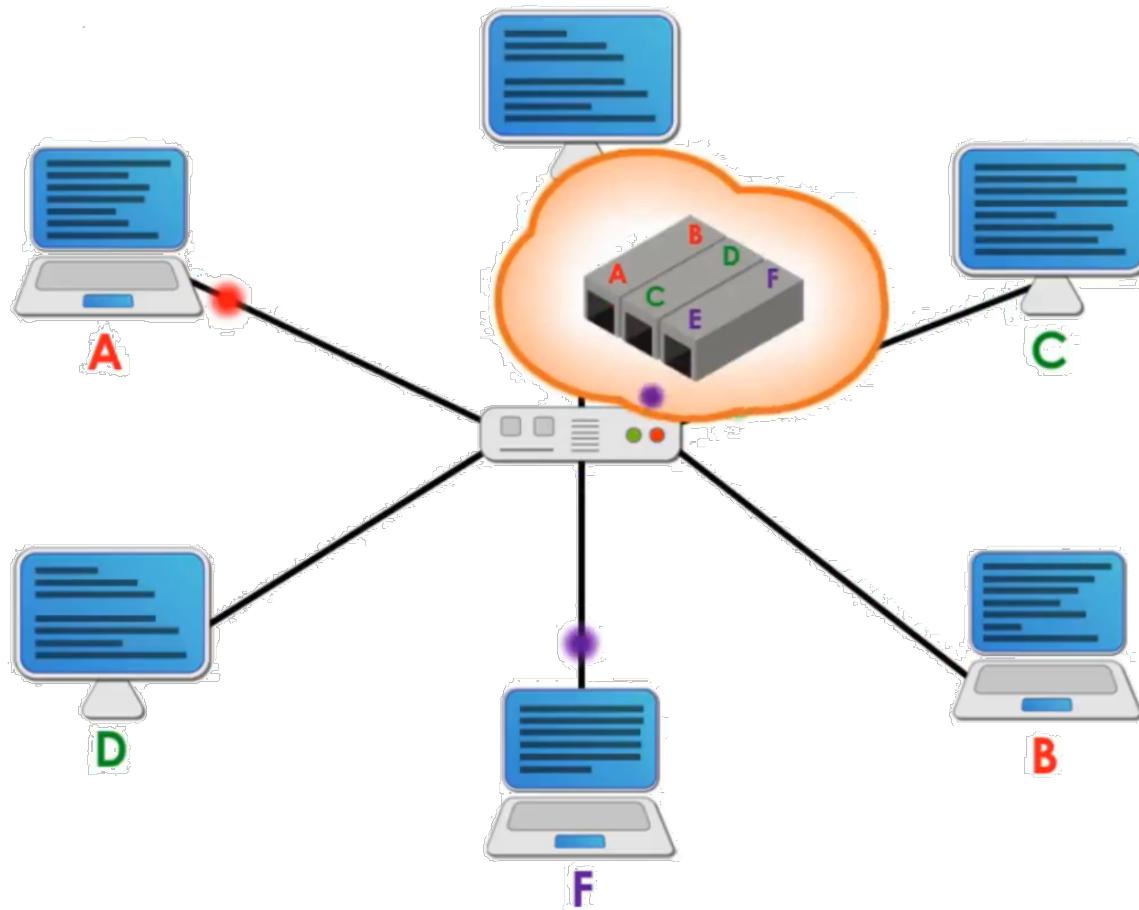
- Fewer Ports
- Replaced by Switch

- Segments a LAN

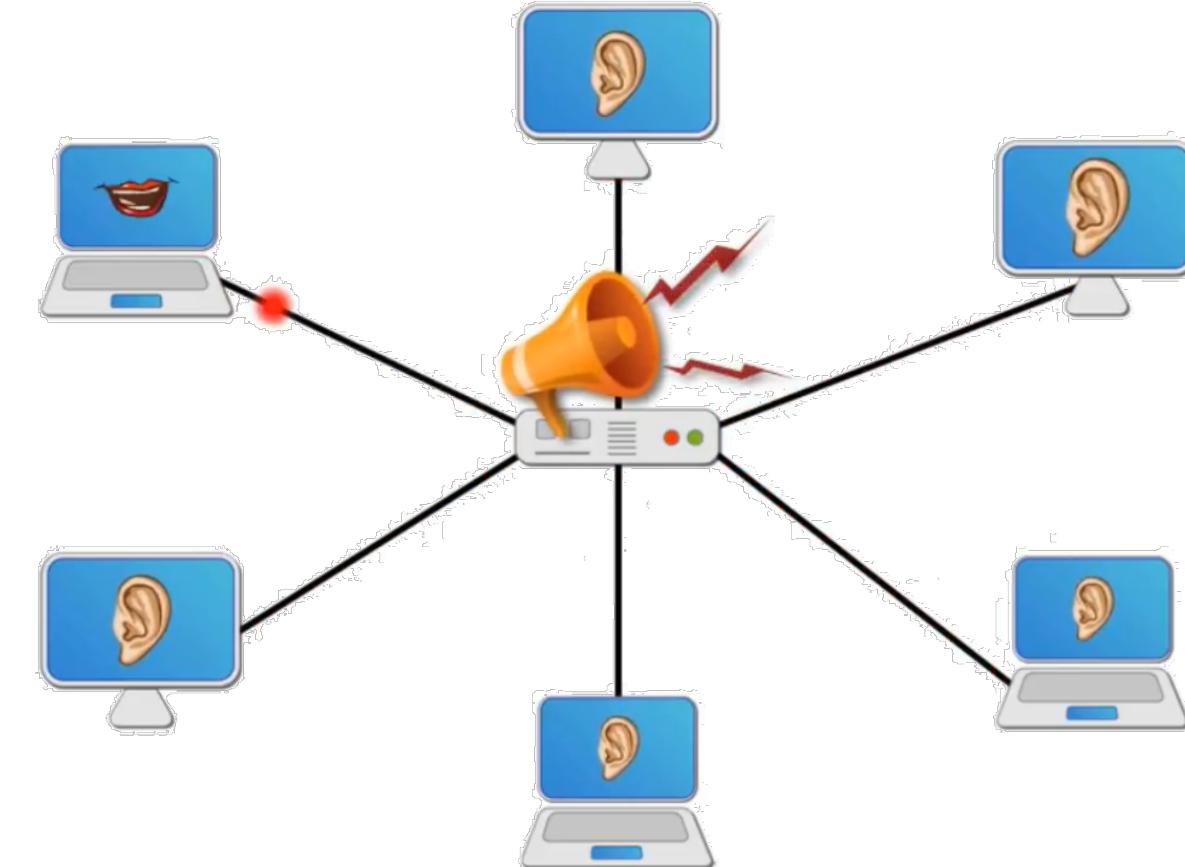
- MAC address filtering
- Local traffic stays in own LAN



Layer 02: Switch



Each port is a collision domain

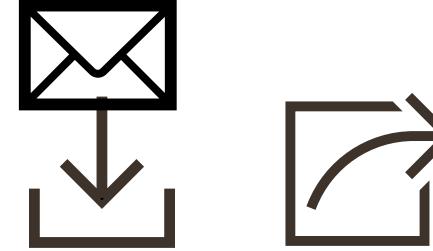


One broadcast domain

Can operate in **Full Duplex** Mode

Layer 02: Switch – cont.

- **Switch buffers** network **frames**. (**store-and-forward**)
- **Forward later** when the egress link is idle



This decoupling of receive and transmit operations enables a network that works with flows that are largely independent from each other and only compete for link bandwidth.

- **On a collision:**

- ✓ Any collision will not propagate across the switch
- ✓ Switch will retransmit the buffered frame later-on

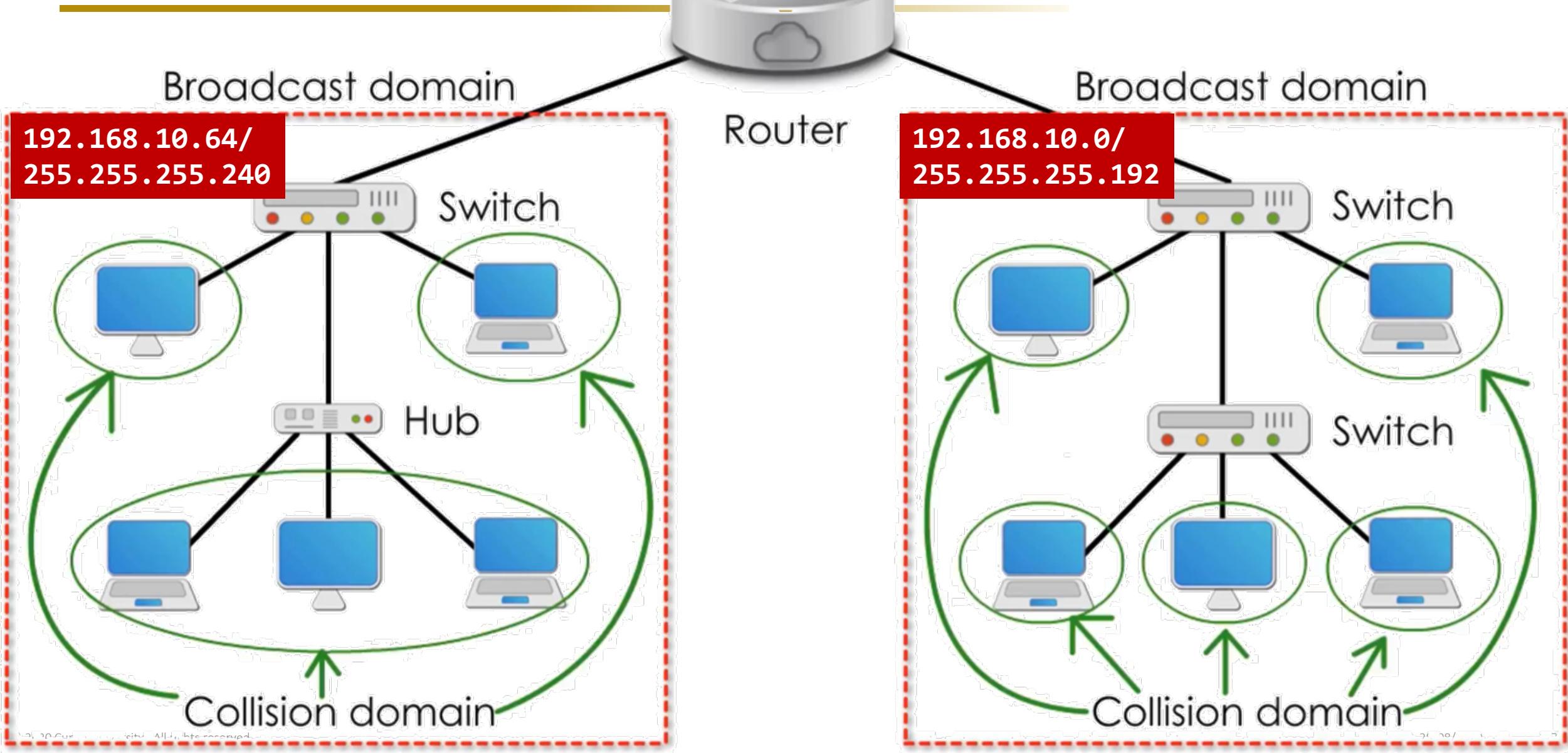
Switch segregates collision domains (on half-duplex links) or removes them completely on full-duplex links

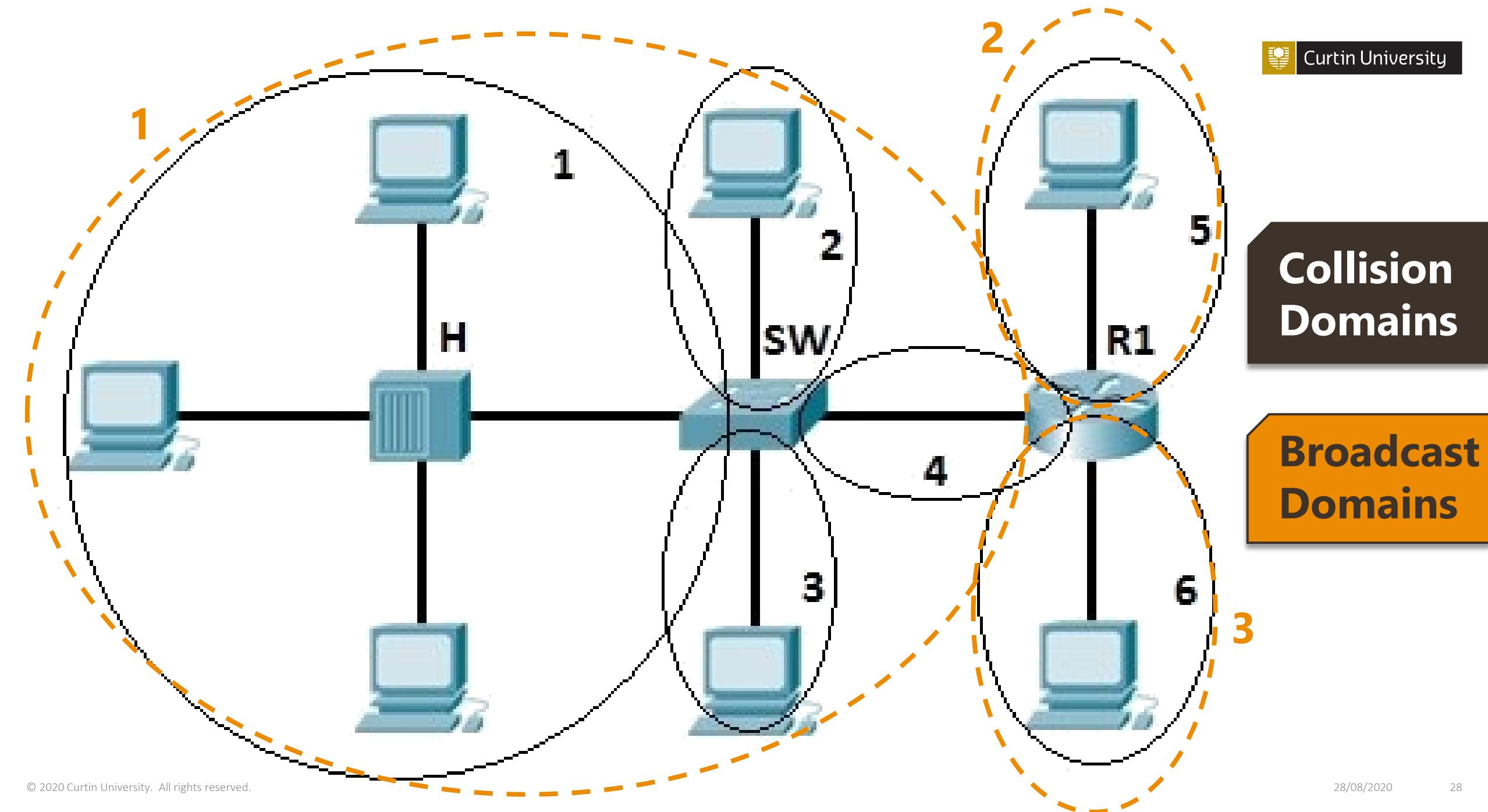
Layer 02: Switch – cont.

In contrast:

- **Hubs** repeat incoming bits as they are received (**No Buffering**)
- **On a collision:**
 - ✓ A collision on an egress interface will disrupt reception on the ingress interface
 - ✓ The hub needs to propagate an upstream collision back to the source
 - ✓ All nodes connected to a hub (or potentially chained hubs) form a single, common collision domain
- **Only one** node at a time **can transmit**

Layer 03: Router





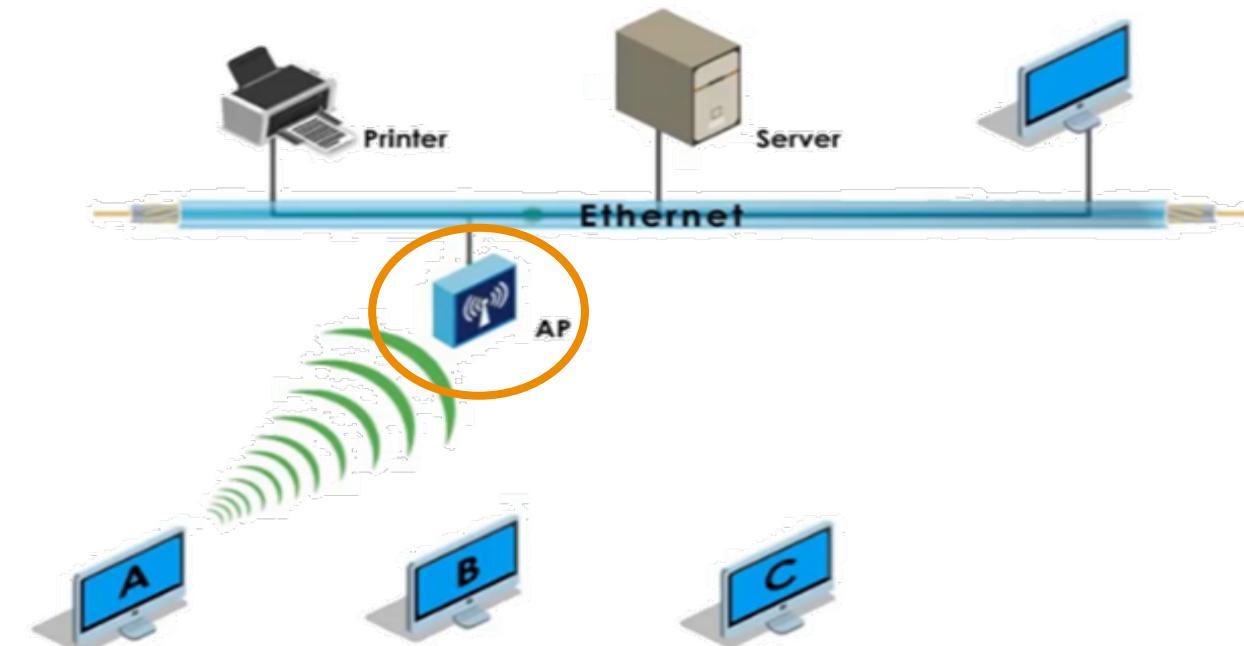
**Collision
Domains**

**Broadcast
Domains**

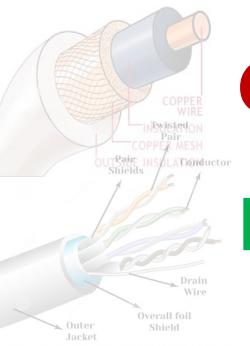
Collision/Broadcast Domains: Wi-Fi

- In Wi-Fi, all devices share the same medium
 - Hence collisions can occur during transmission
 - Wi-Fi uses **CSMA/CA – Collision Avoidance (not CSMA/CD)** due to the **difficulty of detecting collisions**

- Wireless Access Point acts as a bridge between wired and wireless network
 - Collision / Broadcast domains are similar to bridge's we saw earlier



Full/Half Duplex and Collision Domains

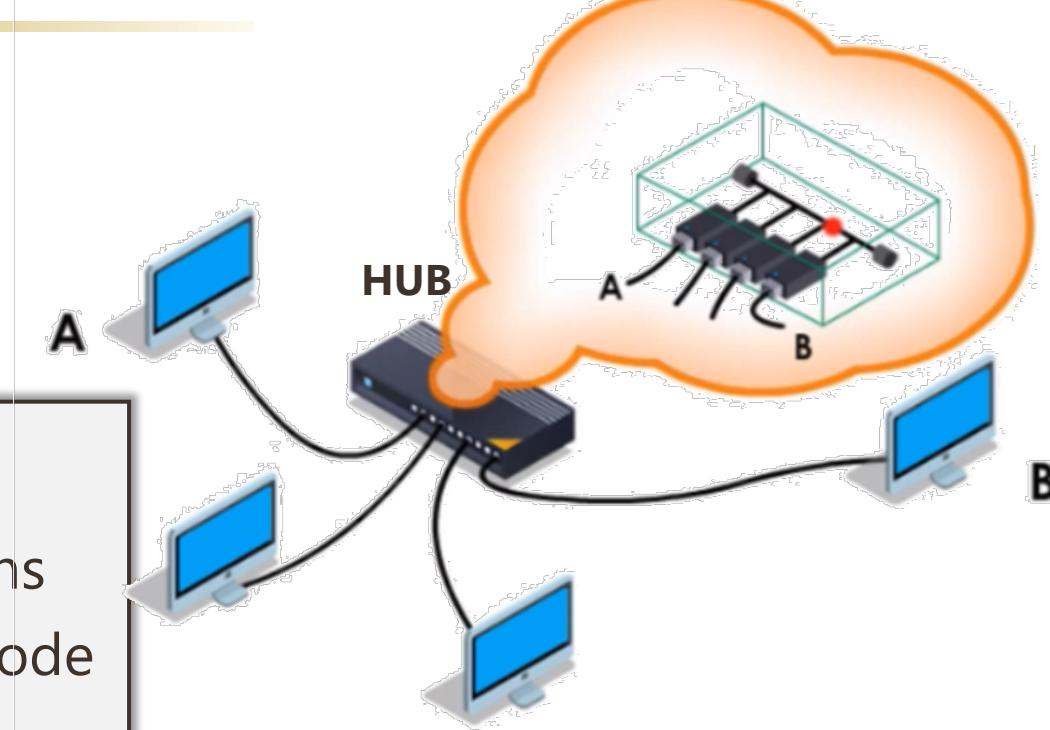
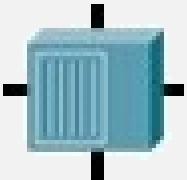


Coaxial cable: Half duplex

Fiber/UTP cable: Full duplex

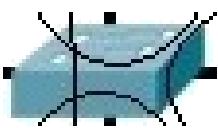
▪ Fiber/UTP cable on a hub:

- ✓ Multiple devices share send and receive paths
- ✓ Hence **hubs do not support full-duplex** mode
- ✓ Must use half-duplex with CSMA/CD



▪ Fiber/UTP cable on a switch:

- ✓ Full-duplex Ethernet doesn't use CSMA/CD
- ✓ Separate send and receive paths between two devices (i.e. switch and host)





Wi-Fi Technology

- Fundamentals
- Wi-Fi Modes
- Wi-Fi Terms (BSS, BSSID, SSID, ESS)
- Wi-Fi Scanning Methods
- IEEE 802.11 Standards
- MIMO, CSMA/CA, OFDM
- 2.4 Ghz, 5Ghz Bands
- Wi-Fi Frames
- Wi-Fi Threats

Wi-Fi (Wireless Fidelity)

- the **IEEE 802.11 standard** defines the protocols that enable communications with current Wi-Fi-enabled wireless devices

- **What is a wireless access point?**

- Allows wireless devices to connect to the wireless network.

- **What is a mobile hotspot?**

Phone-as-a-modem

- a common feature on smartphones with both **tethered** and **untethered** connections
 - Used to share wireless network connection with other devices

- **What is portable Wi-Fi hotspot?**

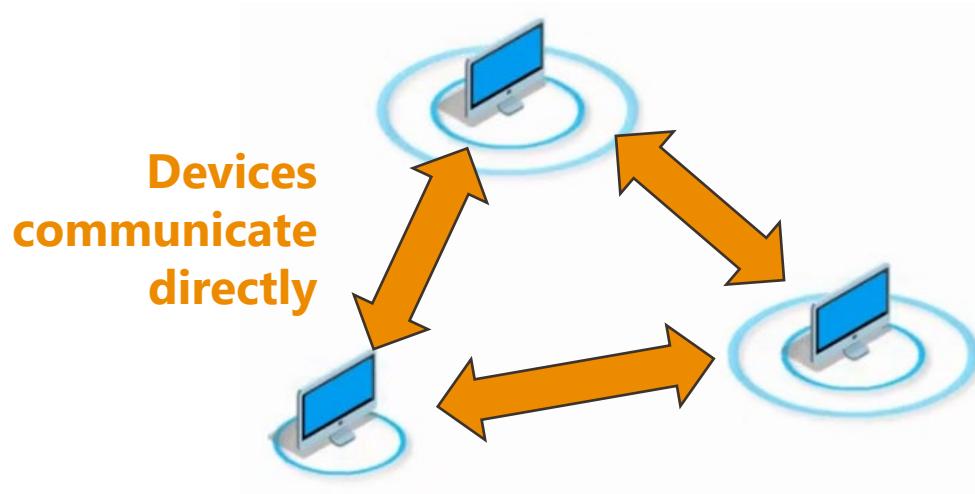
- a small device that uses cellular towers that broadcast high-speed 3G or 4G broadband signals



Wi-Fi Modes

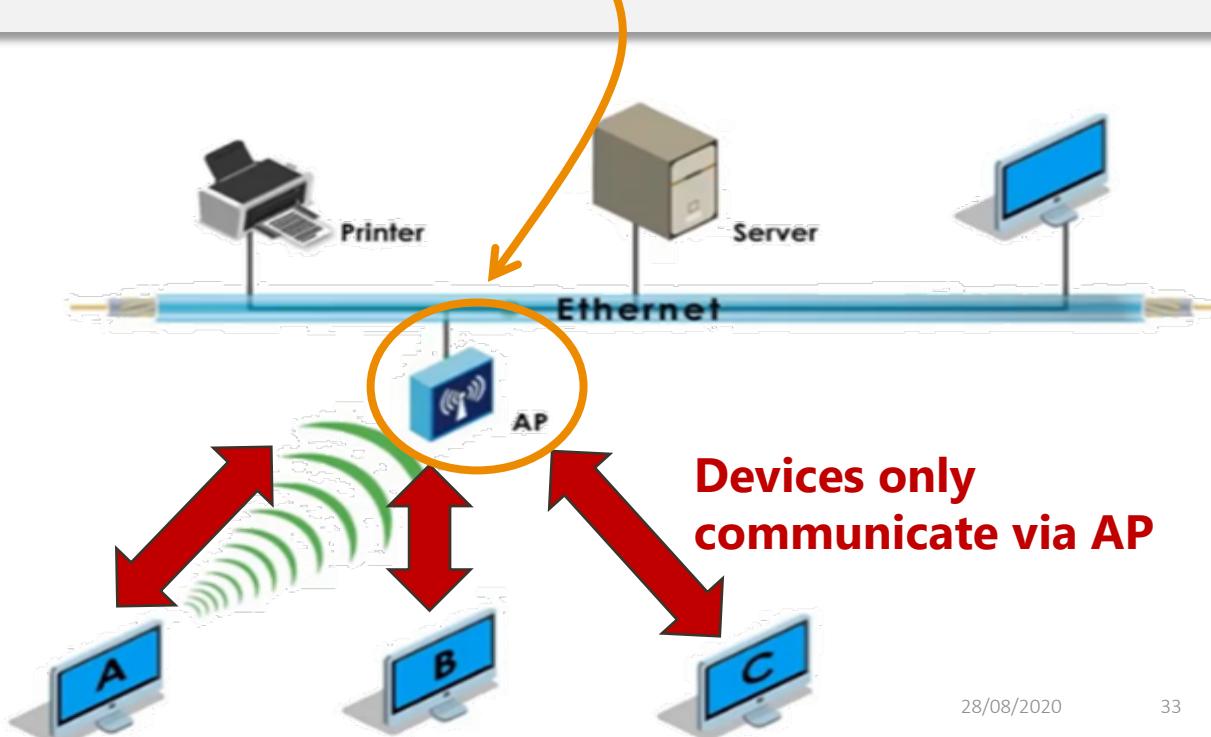
▪ Ad-hoc

- Decentralized (p2p mode)
- Easy/quick to create (no complex setup)
- More users join,
- Performance deteriorate, less secure

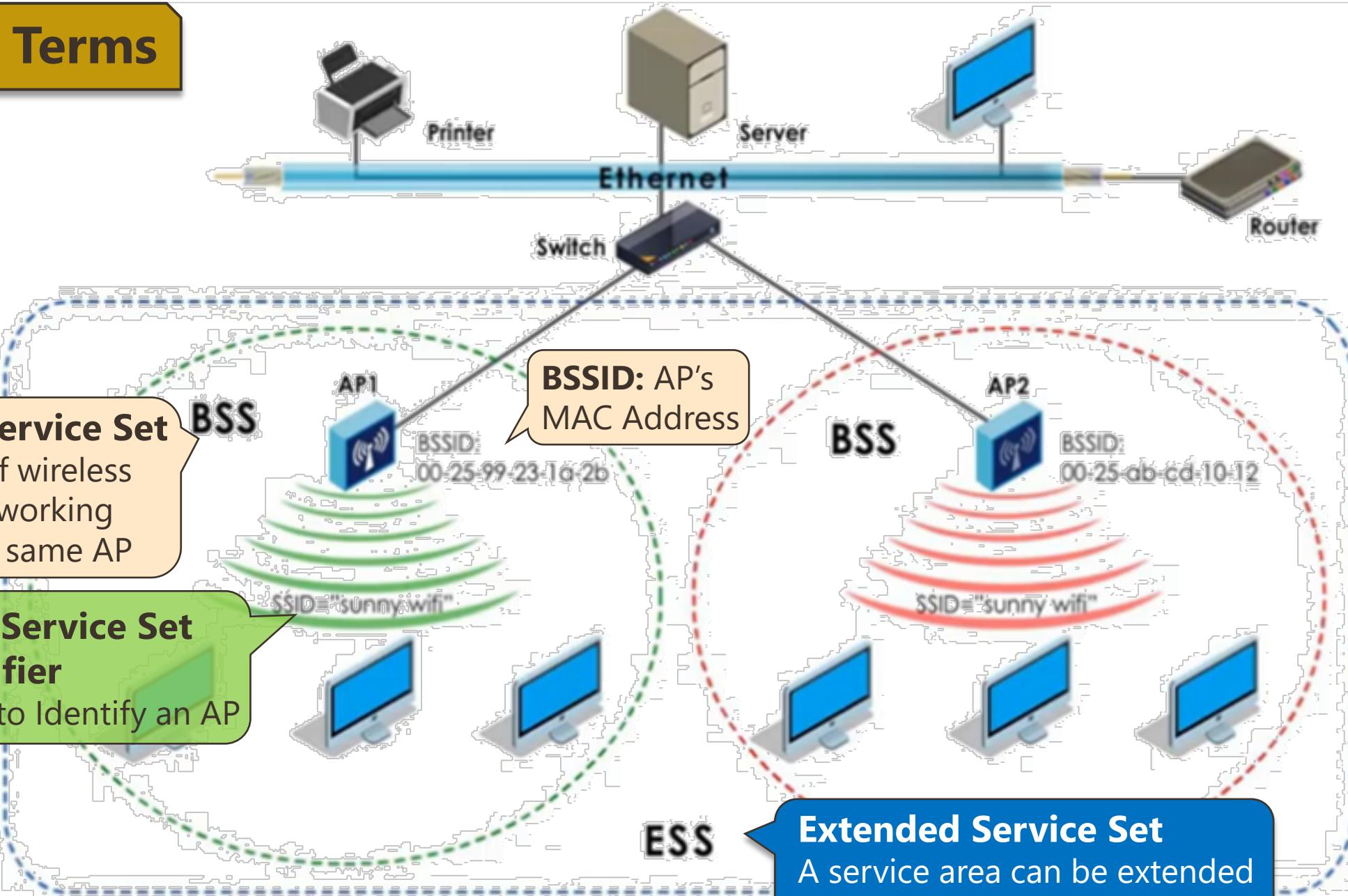


▪ Infrastructure Mode

- Centralized
- Communicate with Access Point (AP)
- AP acts as a bridge between **wireless traffic and wired network**



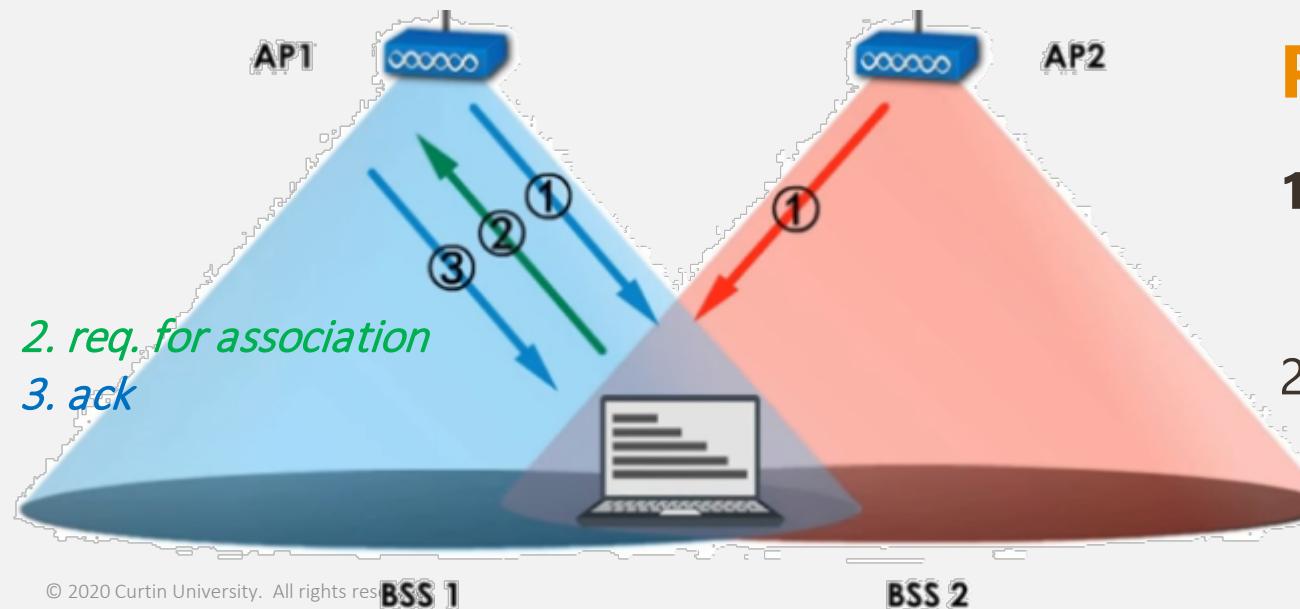
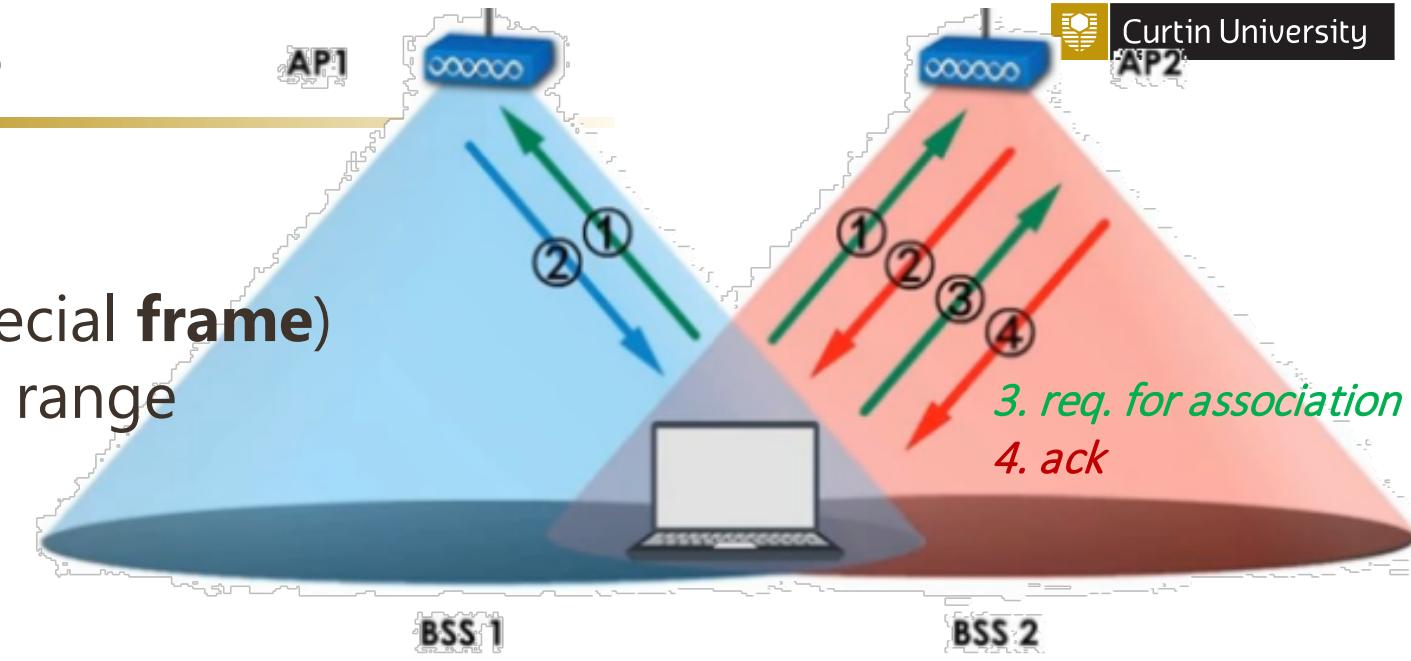
Wi-Fi Terms



Scanning Methods

Active Scanning

1. **Device broadcasts a probe (special frame)** to each channel in its frequency range
2. Waits for an AP to respond



Passive Scanning

1. **Device listens** on all available channels within a frequency range
2. AP broadcasts a **beacon frame** continually

Contains AP information. i.e. SSID

Home Router: 5-in-1 magic box

- Integrated Functions

1. Router
2. Switch
3. DHCP Server (*for automatic IP assignment*)
4. DNS Server (*for domain name resolution*)
5. Access Point



In a **business setting**,
Router, Switch, DHCP server,
DNS server **are separated**

IEEE 802.11 Standards



All use **half-duplex** | **CSMA/CA** | **2.4GHz** and/or **5GHz** bands

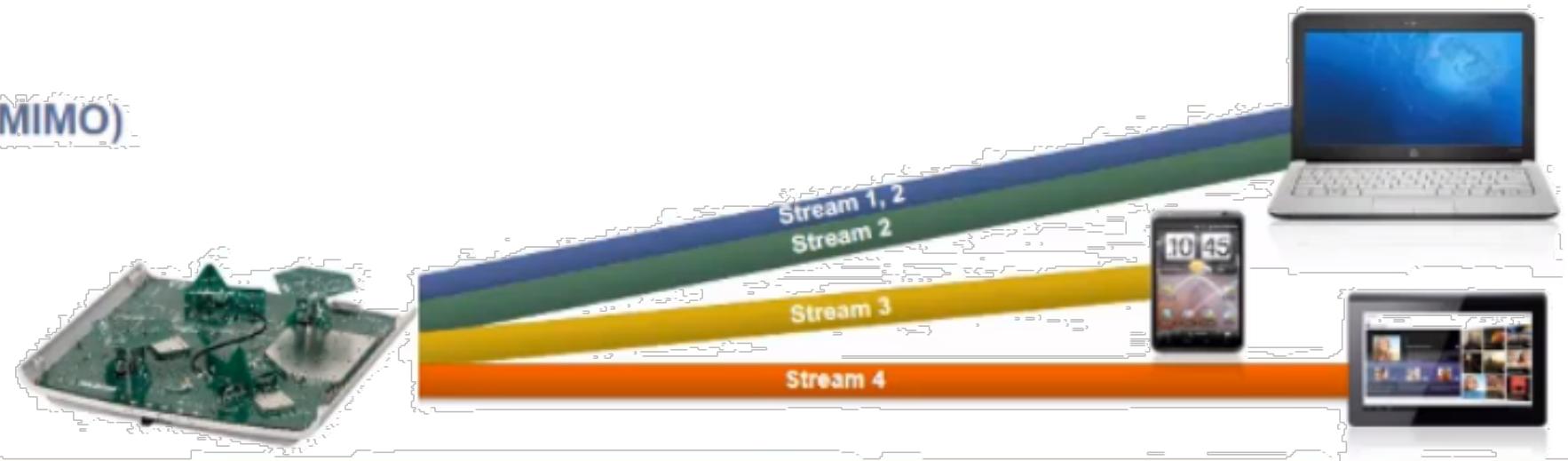
Standard	Year	Frequency Band	Speed	Modulation	Characteristics
802.11	1997	2.4GHz	1-2Mbps	DSSS,FHSS	Base version
802.11b	1999	2.4GHz	11Mbps	DSSS	Oldest, least expensive
802.11a	1999	5GHz	54Mbps	OFDM	Rarely used
802.11g	2003	2.4GHz	54Mbps	OFDM	Compatible with 802.11b networks
802.11n	2009	2.4GHz / 5GHz	65-600Mbps	OFDM	<ul style="list-style-type: none"> Backward compatible with 802.11a, b, g standards MIMO (multiple input-multiple output) Channel bonding: doubles the bandwidth Frame aggregation: reduces overhead
802.11ac WiFi 5	2014	5GHz	Up to 7Gbps	MIMO-OFDM	<ul style="list-style-type: none"> Gigabit Wi-Fi MU-MIMO (Multi User MIMO) Wave 1 (2014) vs. Wave 2 (2016)
802.11ax	2017	Wi-Fi 6 (802.11ax has 802.11ac features and more, 4x faster)			

Multi Input Multi Output (**MIMO**)

Single user MIMO (SU-MIMO)

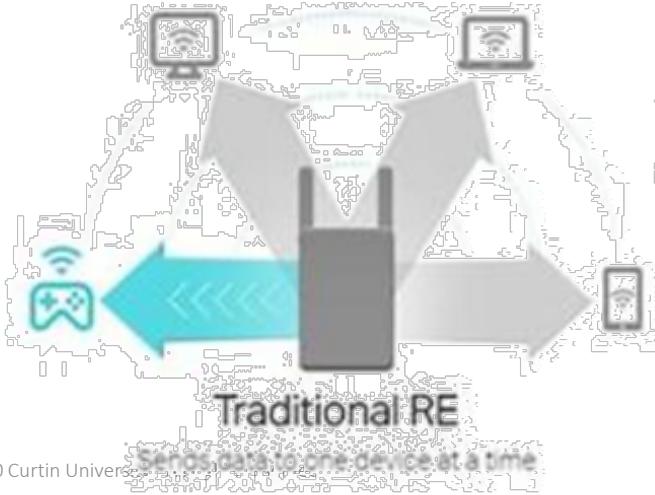


Multi-user MIMO (MU-MIMO)



More Connections and Faster for Everyone

MU-MIMO technology allows the RE650 to serve up to four devices at once, reducing wait time and greatly increasing WiFi throughput for every device. With MU-MIMO, the RE650 runs up to 4x faster than traditional AC range extenders.

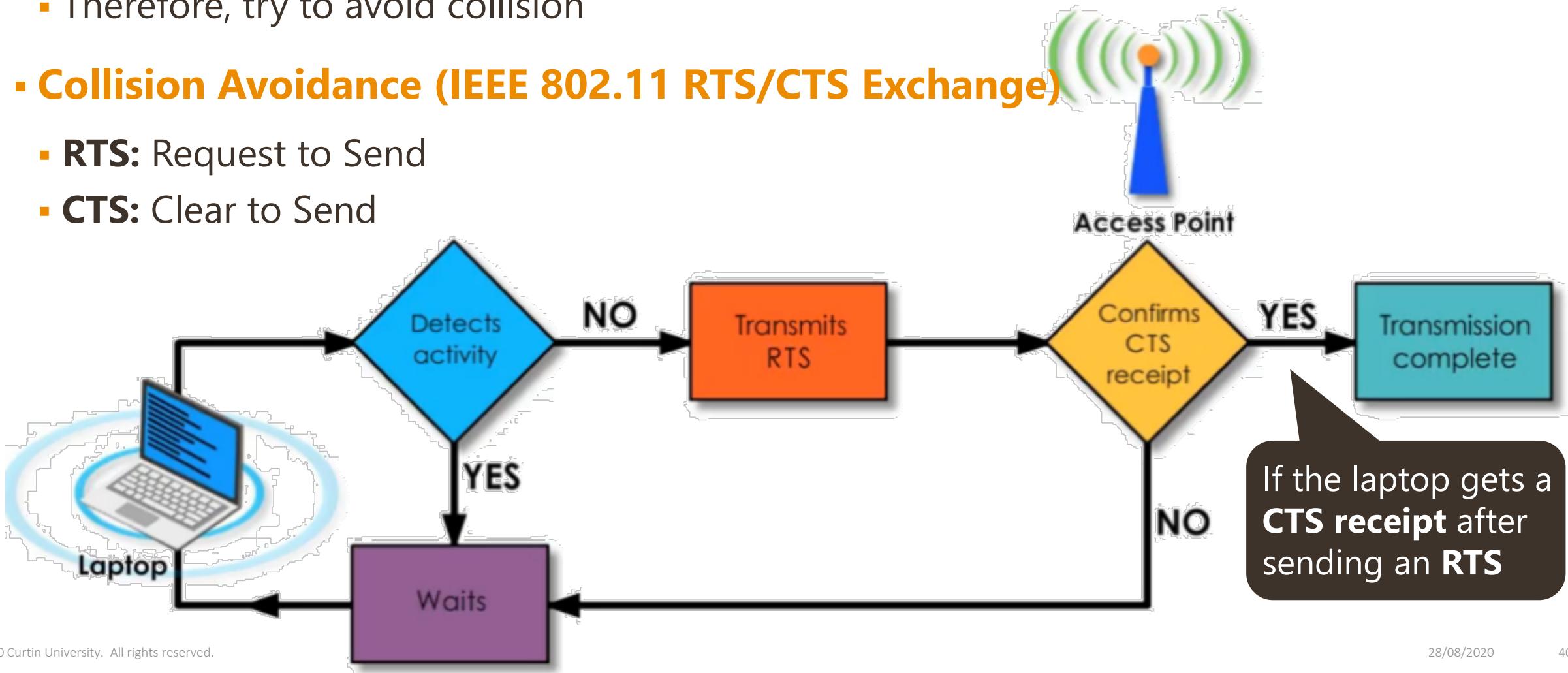


IEEE 802.11 - CSMA/CA

- Wireless nature makes harder to detect collision
 - Therefore, try to avoid collision

Collision Avoidance (IEEE 802.11 RTS/CTS Exchange)

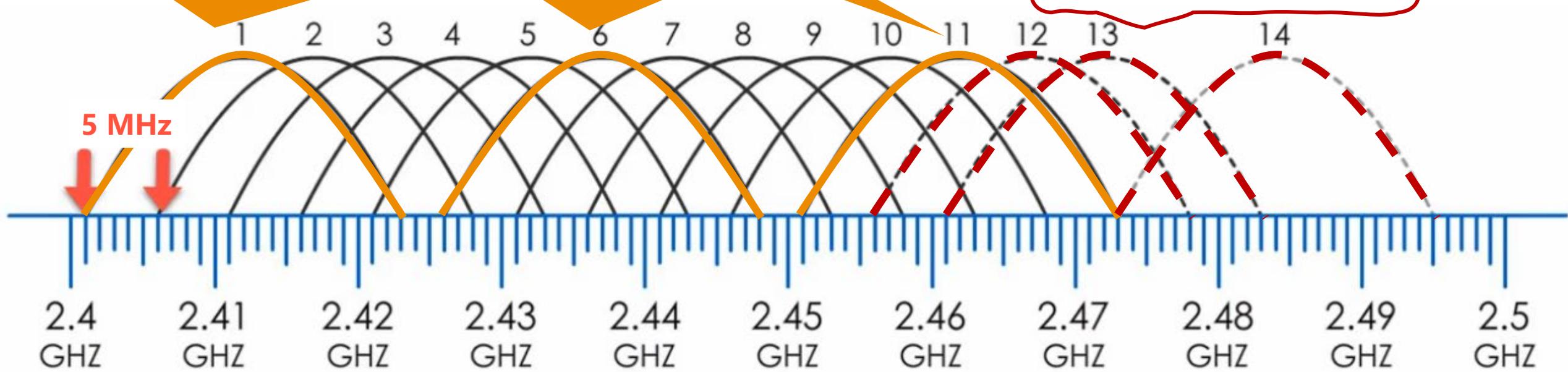
- RTS:** Request to Send
- CTS:** Clear to Send



2.4 GHz Band

Only 3 channels can be active since many overlaps

12, 13, 14 channels are restricted





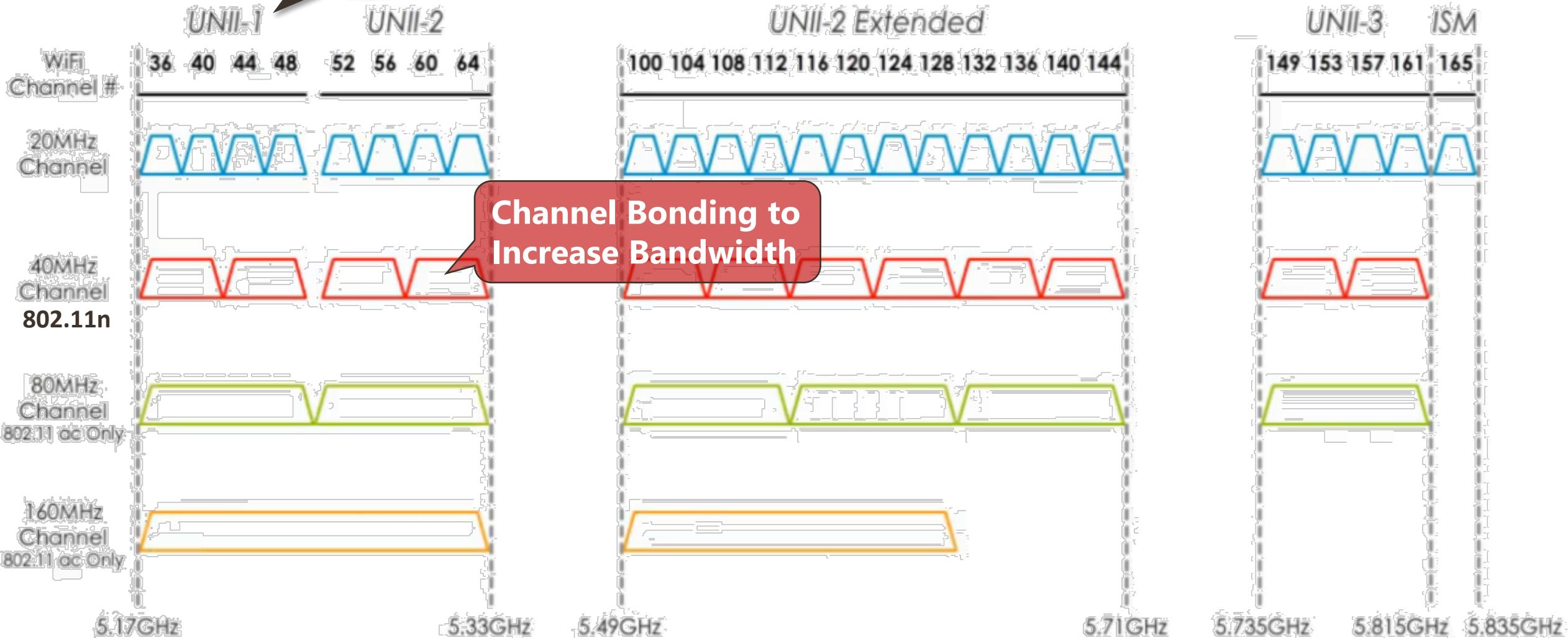
5 GHz Band

For indoor
Wi-Fi

Labels, Specifications, Regulations

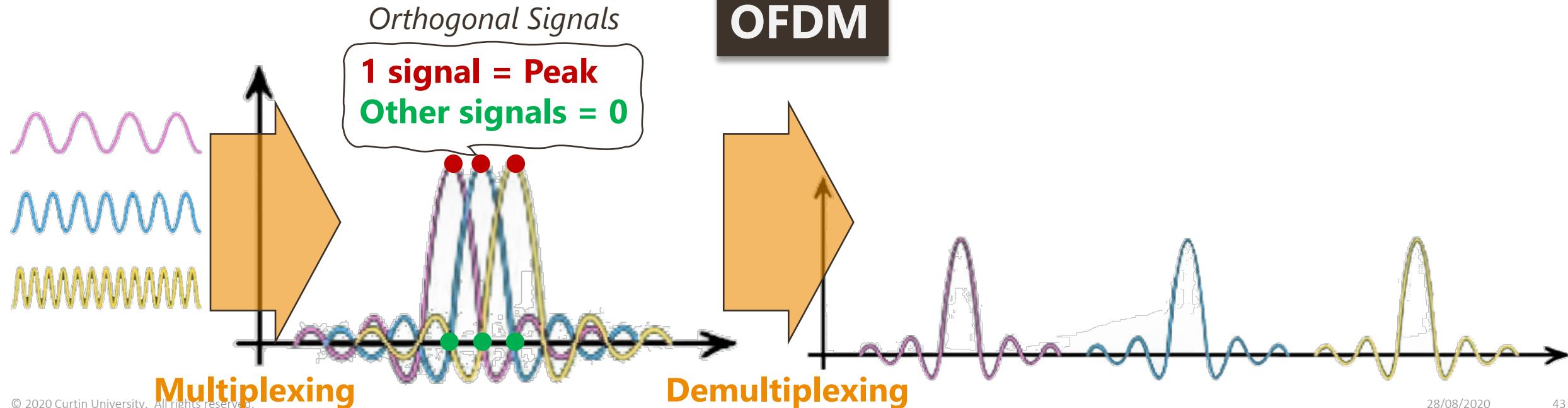
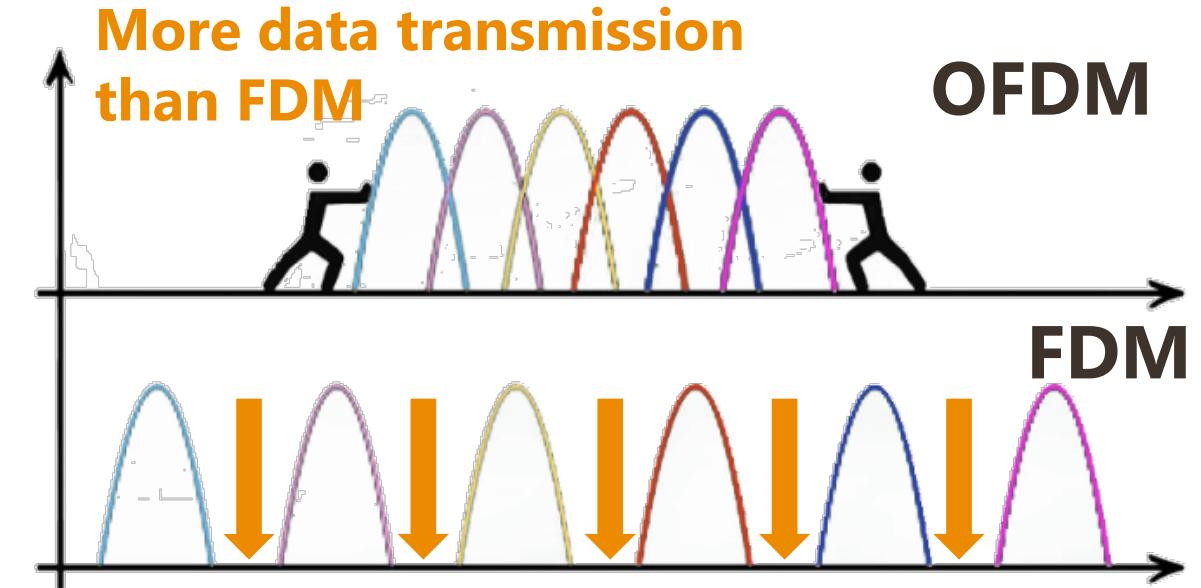
UNII: Unlicensed National Information Infrastructure

ISM: Industrial, Scientific and Medical



OFDM

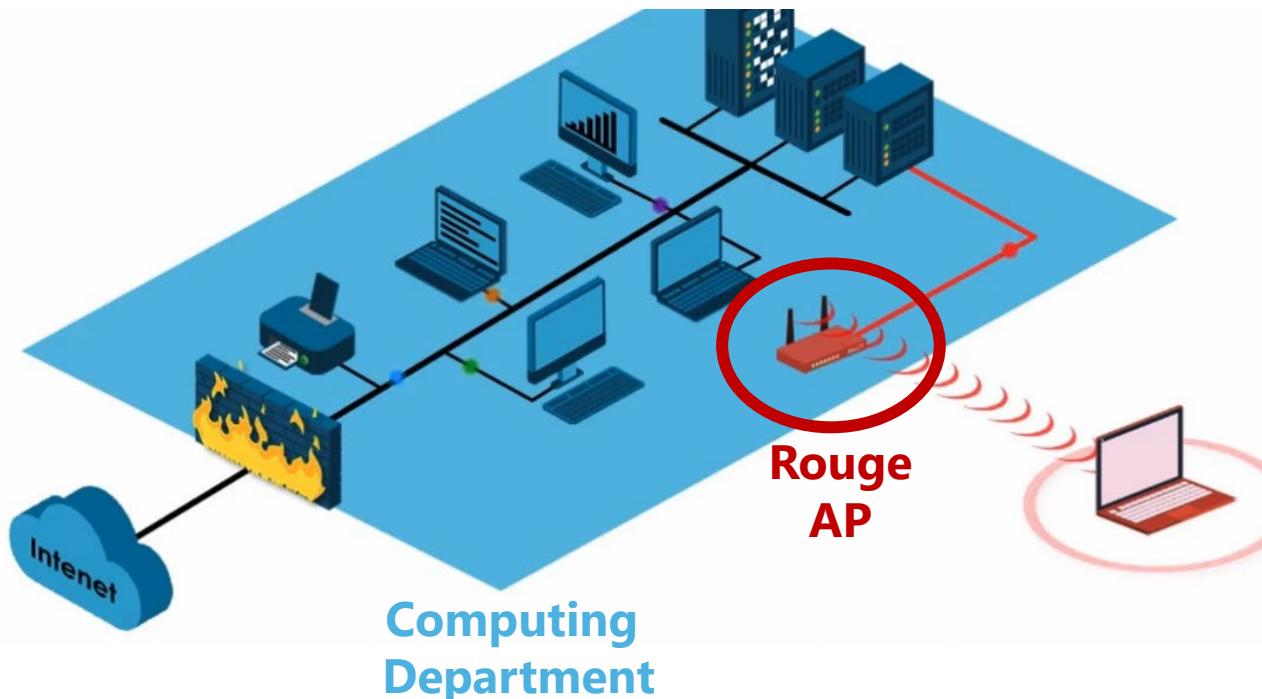
- Orthogonal Frequency Division Multiplexing
- Used by Wi-Fi 802.11ac/ax (Wi-Fi 6), 4G, 5G, WiMAX, Satellite, etc.



Wireless Threats

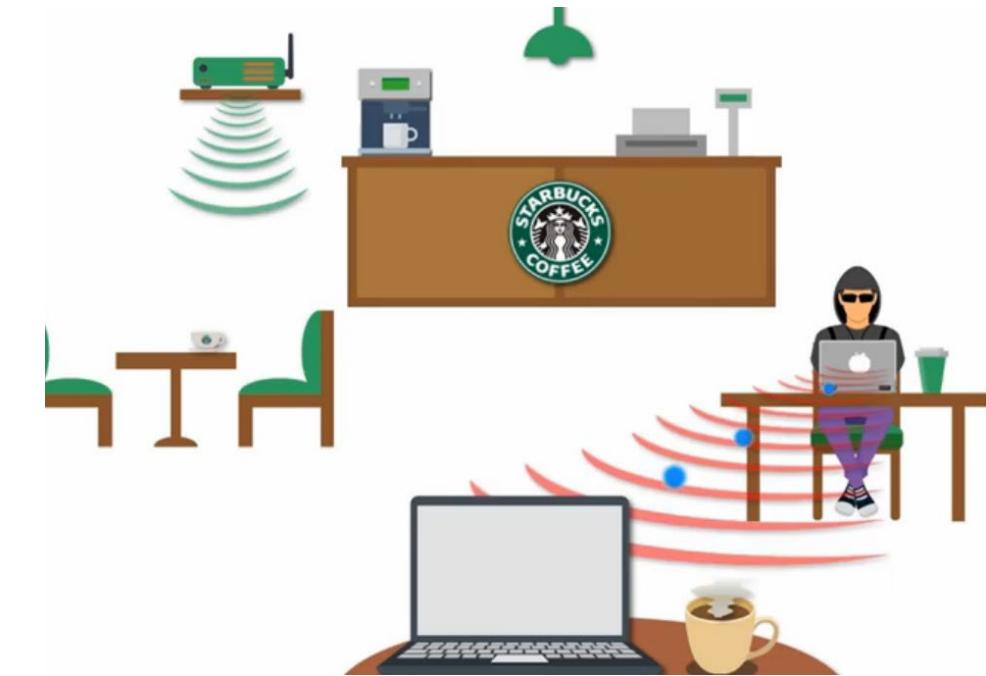
Rouge Access Point

- Threat to the **private network**
- Wireless backdoor
- By-pass firewall



Evil Twin

- Threat to the **end-user**
- Poses as a legitimate Wi-Fi access point



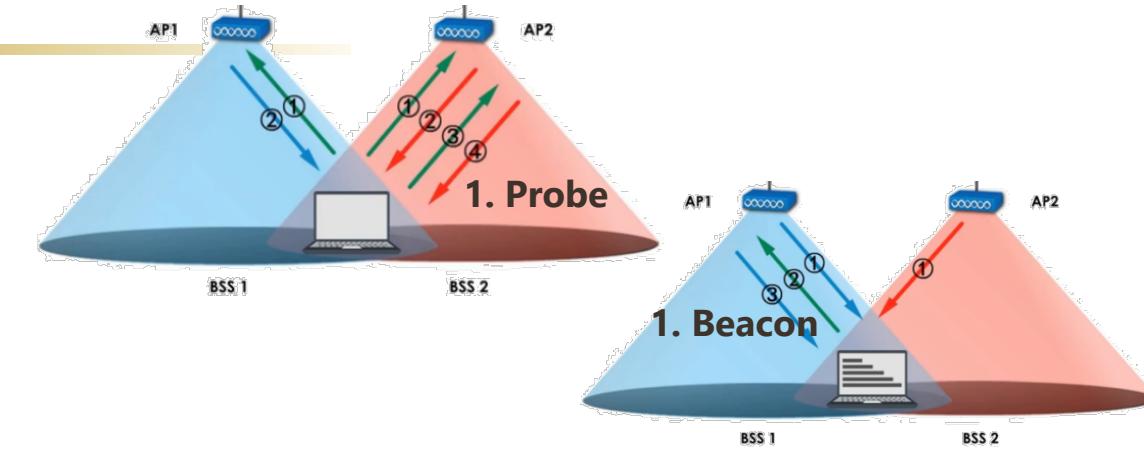
IEEE 802.3 Ethernet vs 802.11 Wi-Fi

Basis for Comparison	IEEE 802.3 Ethernet	IEEE 802.11 Wi-Fi
Layer 2 Frame:	Data Frame	<ol style="list-style-type: none">Management FrameControl FrameData Frame
Layer 2 Devices:	Switch	Access Point (AP) (bridge between Ethernet & Wi-Fi)
Data Link Layer:	CSMA/ CD	CSMA/ CA
Layer 1 Topology:	Star (most popular)	Star or Mesh
Layer 1 Medium:	UTP, Fibre Optics, Coaxial	Air

Wi-Fi Frames

1. Management Frames involve in:

- ✓ Wireless association
- ✓ Re-association
- ✓ Probe
- ✓ Beacon

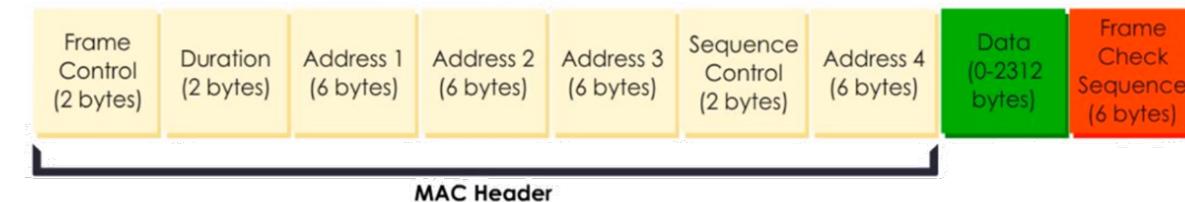


2. Control Frames involve in:

- ✓ Media Access and Data Delivery
- ✓ i.e. RTS/CTS frames in CSMA/CA

3. Data Frames involve in:

- ✓ Carry data (sender <-> receiver)



802.11 Wi-Fi Data Frame

Field transmission duration

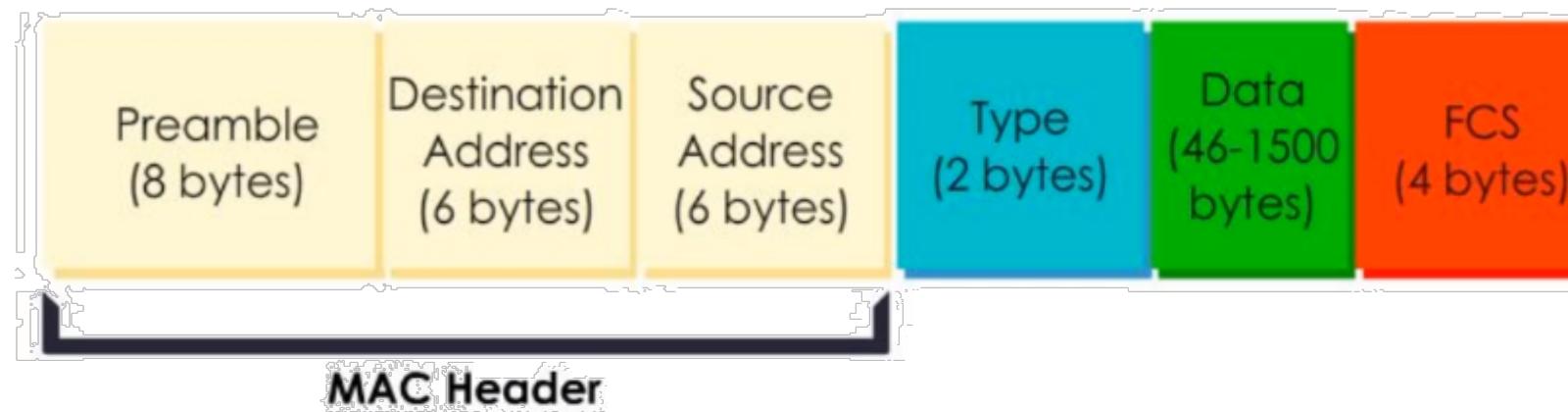
So other devices know when the channel will be available again

Transmitter /
AP MAC
(BSSID)

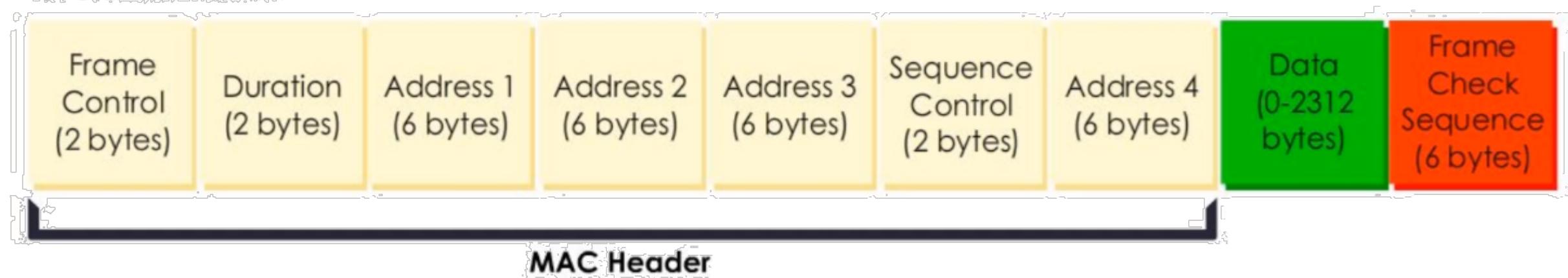
How a large packet
is fragmented



MAC Header

Ethernet Data Frame:

Ethernet vs Wi-Fi Data Frame

Wi-Fi Data Frame:

Wi-Fi (large header) traffic is not as efficient as Ethernet

Latest 802.11ac Wi-Fi uses **frame aggregation** to reduce overhead

5G vs WiFi6





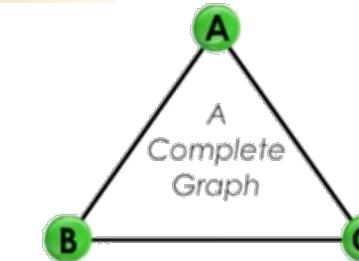
STP: Spanning Tree Protocol

- Fundamentals
- Protocol Brief

Complete Graph vs Spanning Tree

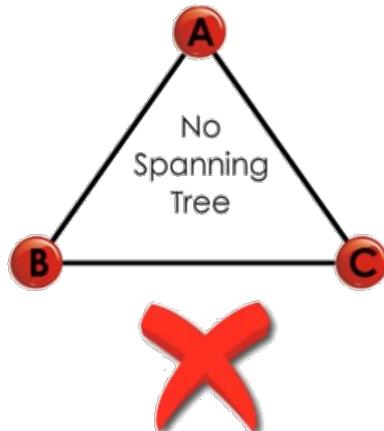
■ Complete Graph:

Each pair of vertices connected by a line
i.e. Fully Meshed Network

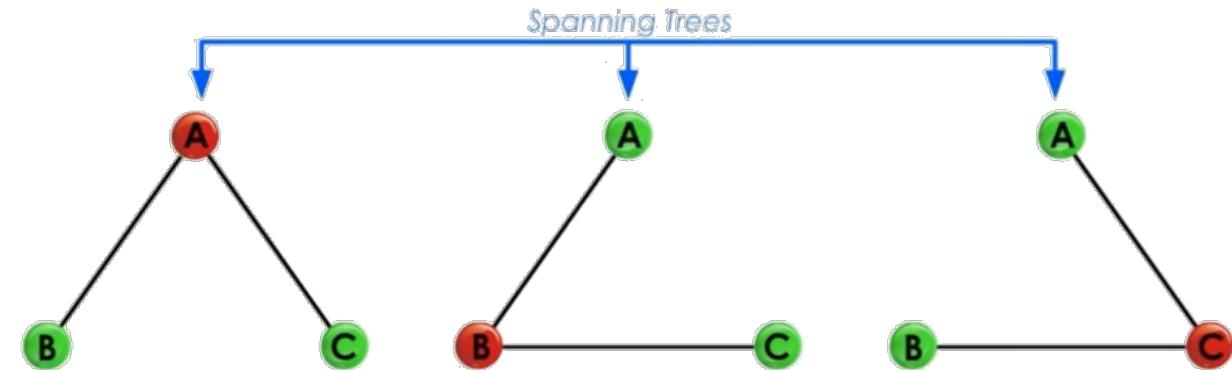


■ Spanning Tree:

Each pair of vertices connected by a line



1) A spanning tree has no loop

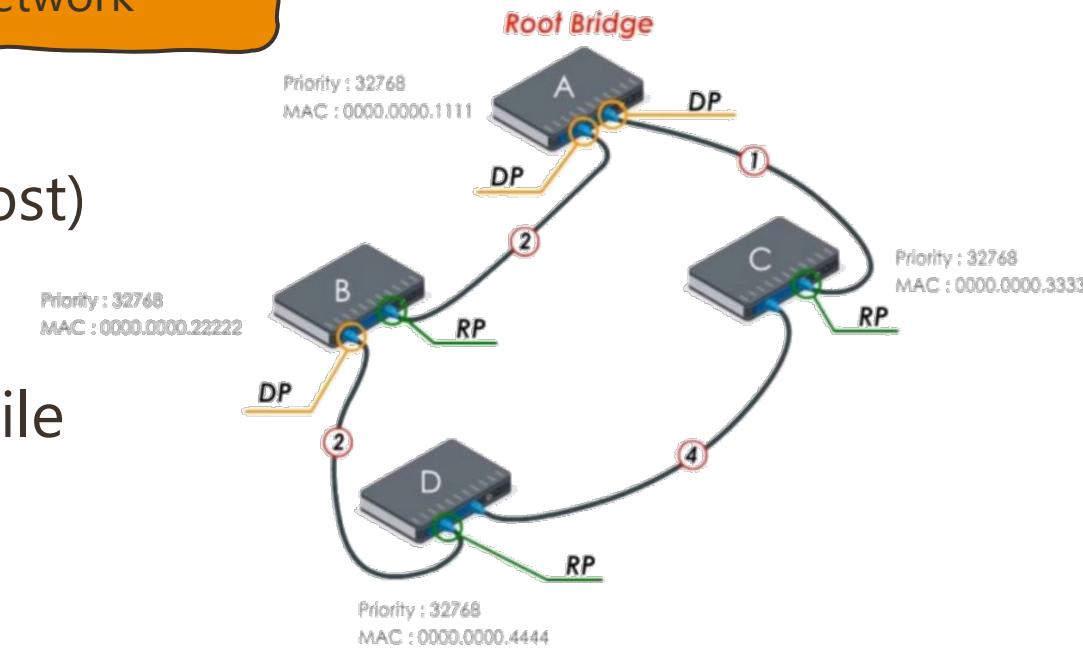


Spanning Tree Protocol (STP)

- Layer 2 protocol runs on bridges and switches
- Used to build a loop-free logical topology

▪ Steps

- 1 Select one switch as **root bridge**
 - 2 It chooses the **shortest path** (the least cost) **from a switch to root bridge**
 - 3 It **blocks** links that could cause **loops** while maintaining these links as backups (fault tolerance)
- is the central point on the network





VLAN

- Fundamentals
- VLAN Types
- IEEE802.11q Standard
 - Access Ports
 - VLAN Tag
- Default VLAN
- Native VLAN

Virtual LAN (VLAN)

- VLAN is a logical network that group devices/users regardless of their different physical locations
- **VLAN is created at the switch**

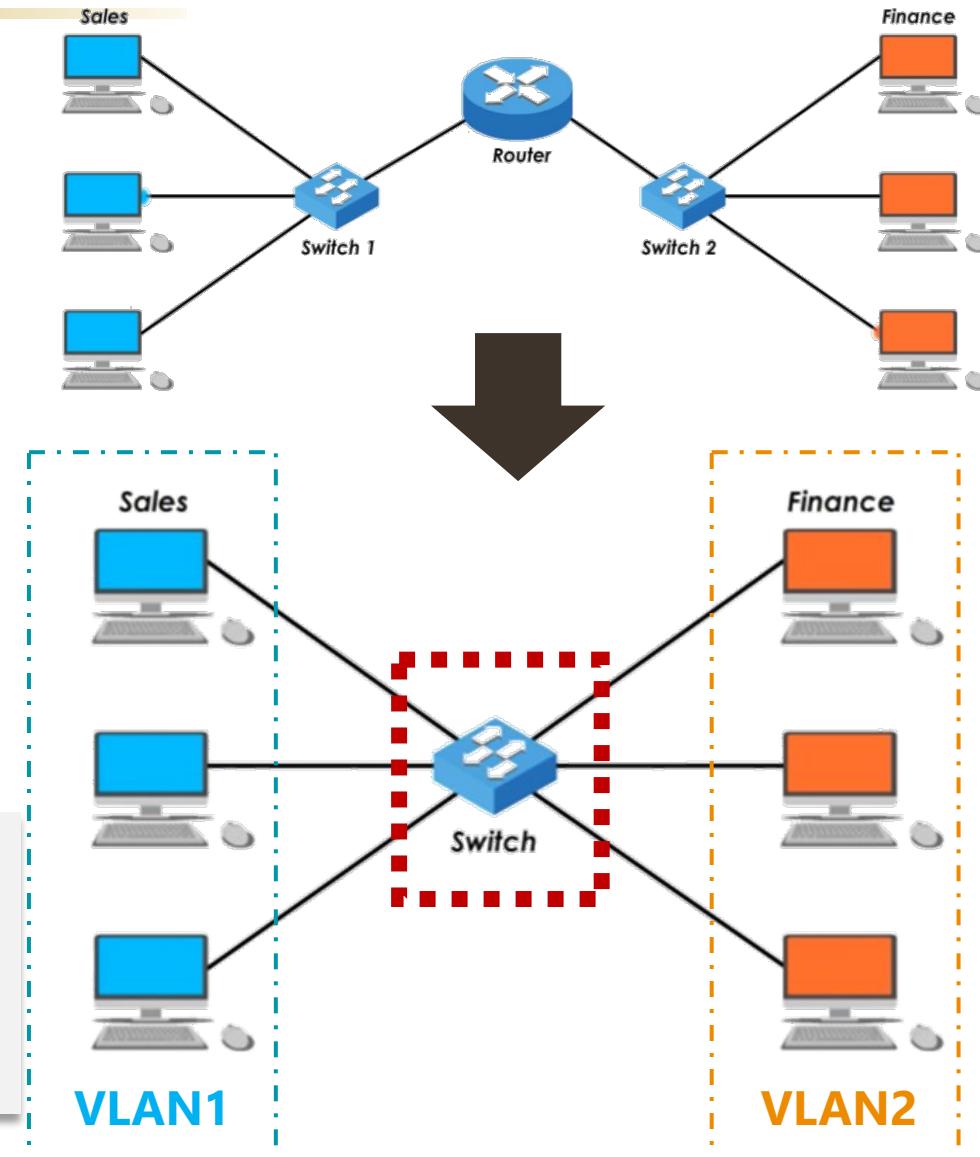
▪ Why VLAN

- Network Segmentation
- Security
- Traffic Prioritizing
- Network Management

Network Design, Deployment,
Troubleshooting without
affecting other VLANs

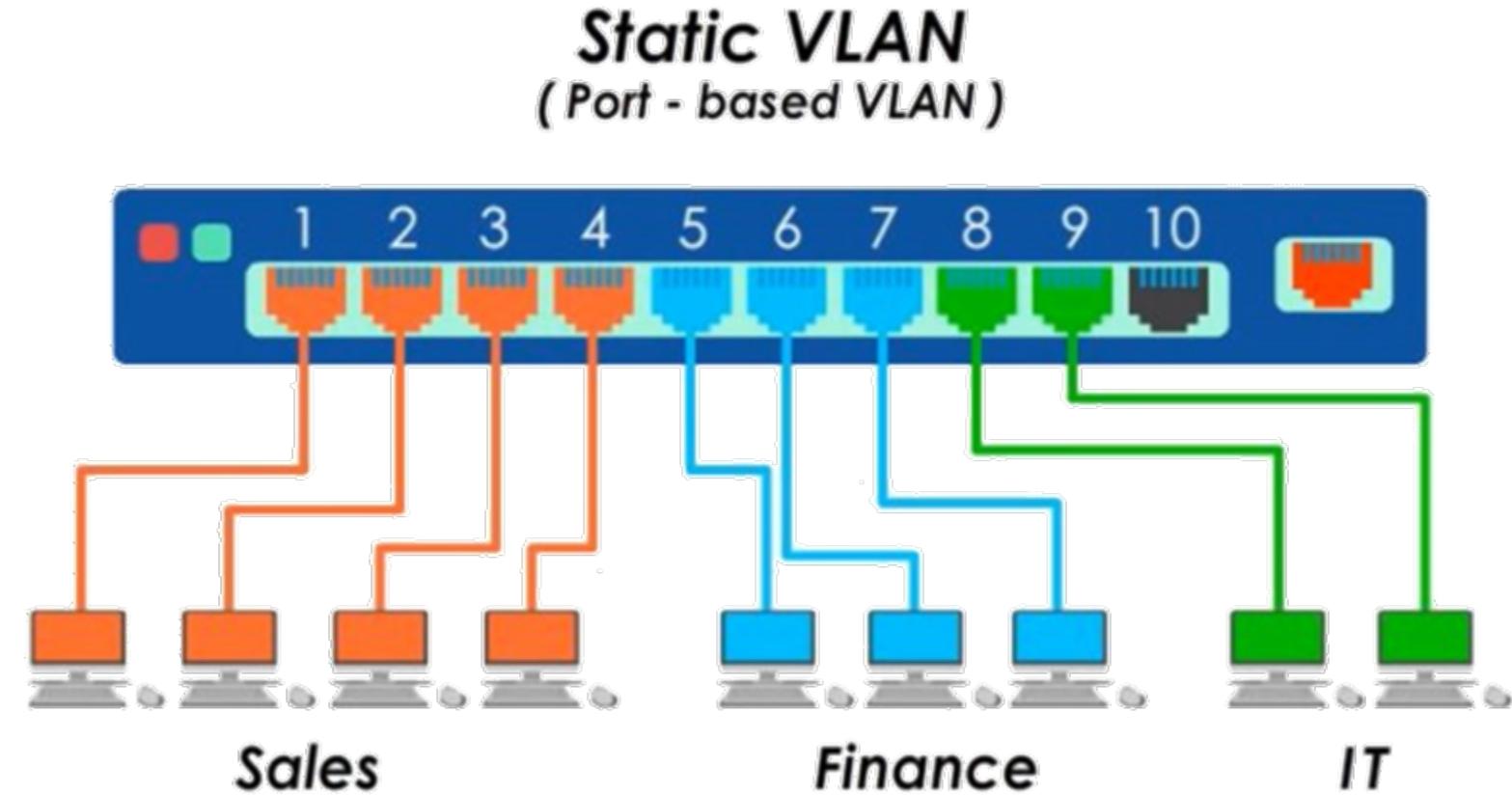
▪ VLAN Types:

1. **Static VLAN**
2. **Dynamic VLAN**



Type: Static VLAN

- Port based
- Manual Assignment
of individual ports on
a switch to a VLAN



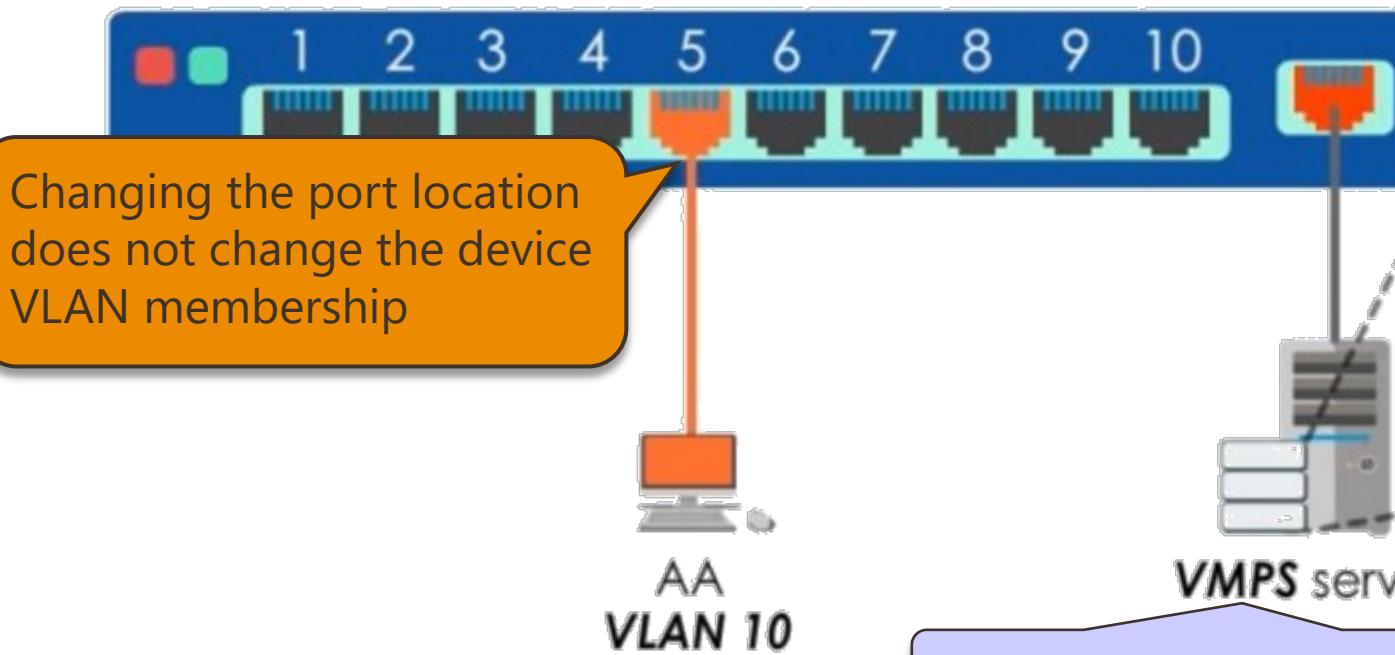
Sales VLAN cannot communicate with Finance or IT VLAN vice versa

Type: Dynamic VLAN

- MAC based or IP based
- Defined based on a device instead of a port location

+VE
Flexibility
Security

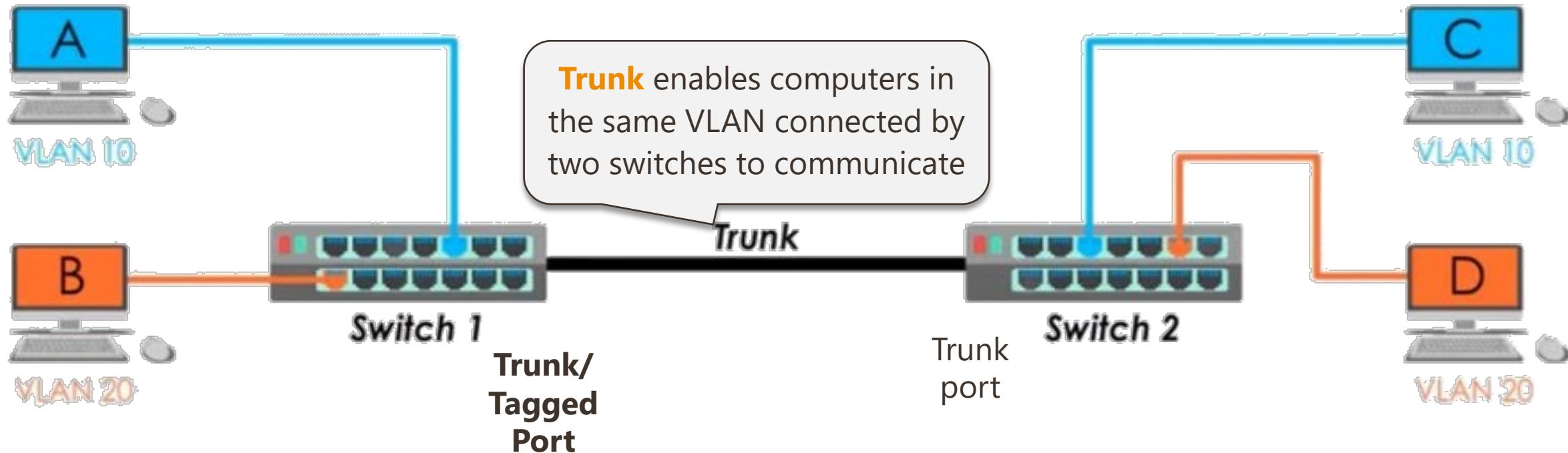
Dynamic VLAN
(MAC based)



MAC Address	VLAN
AA	VLAN 10
BB	VLAN 10
CC	VLAN 20
DD	VLAN 30
EE	VLAN 30
...	...

IEEE802.1Q Standard

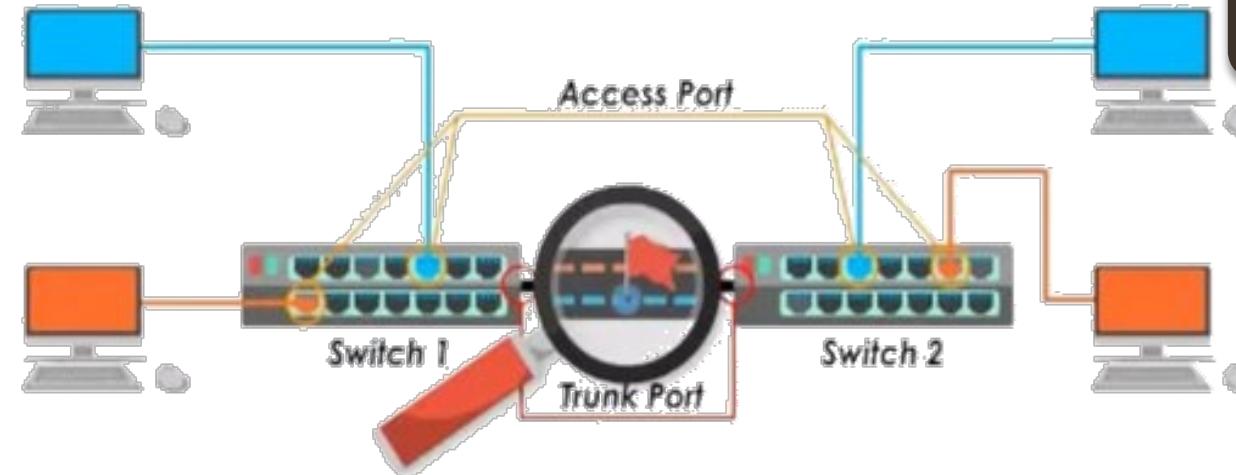
- supports VLANs on the Ethernet network
- defines a **method of tagging traffic between two switches or switch-router to tell which traffic belongs to which VLAN**



Ports

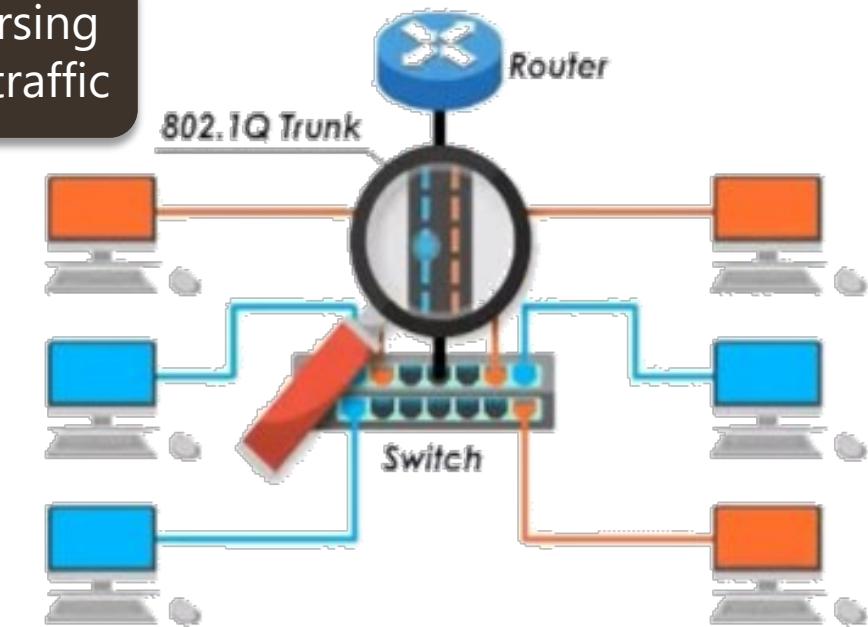
- **Trunk/Tagged Port:** Send and expect traffic with VLAN tag
- **Access Port:** Send and expect traffic with no VLAN tag

Trunking between two switches

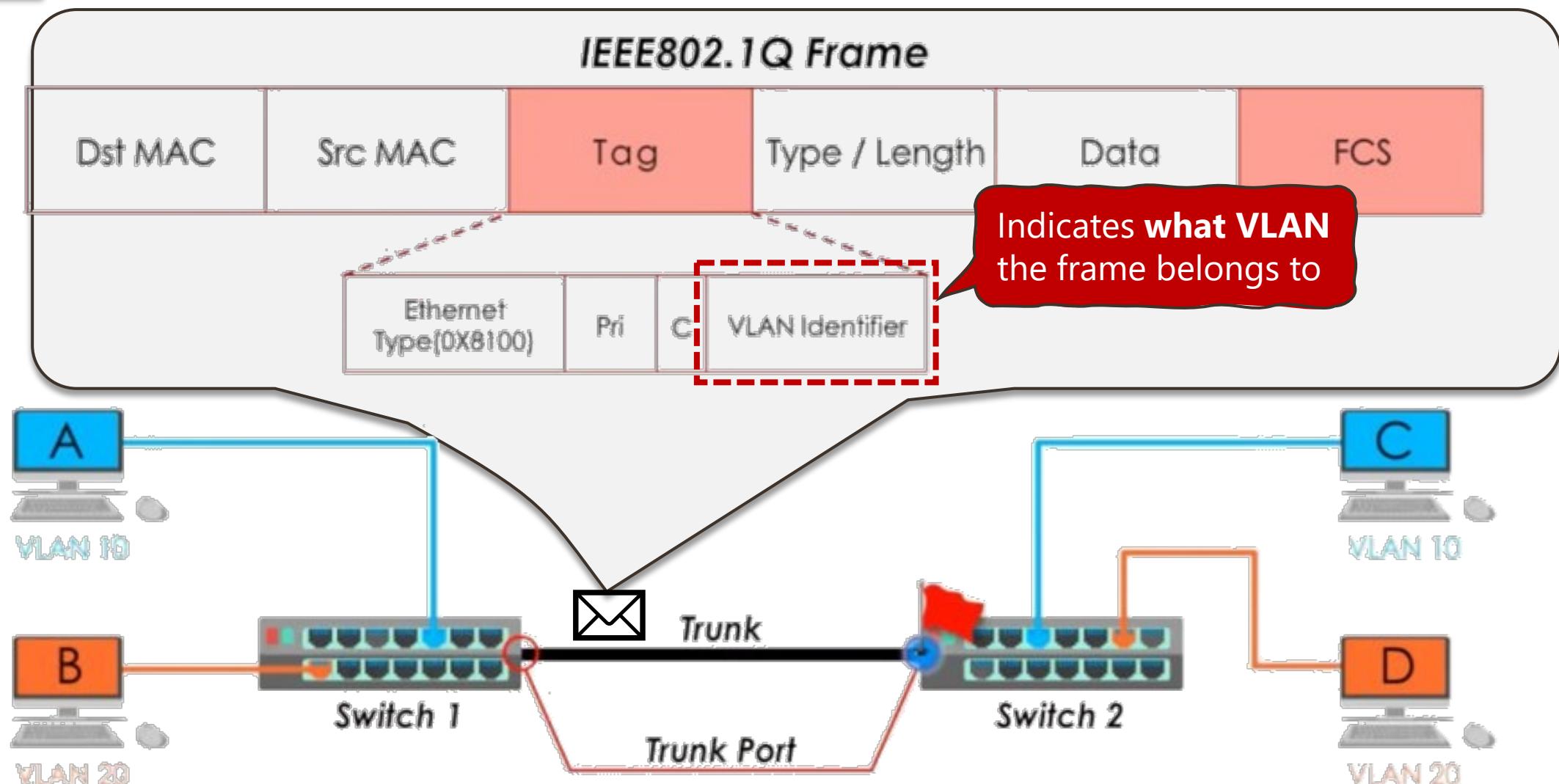


Process of traversing
different VLAN traffic

Trunking between a switch and a router



VLAN Tag



Default VLAN: VLAN 1

- **Cannot change, or delete** default VLAN
- Not intended to be used as a standard data VLAN

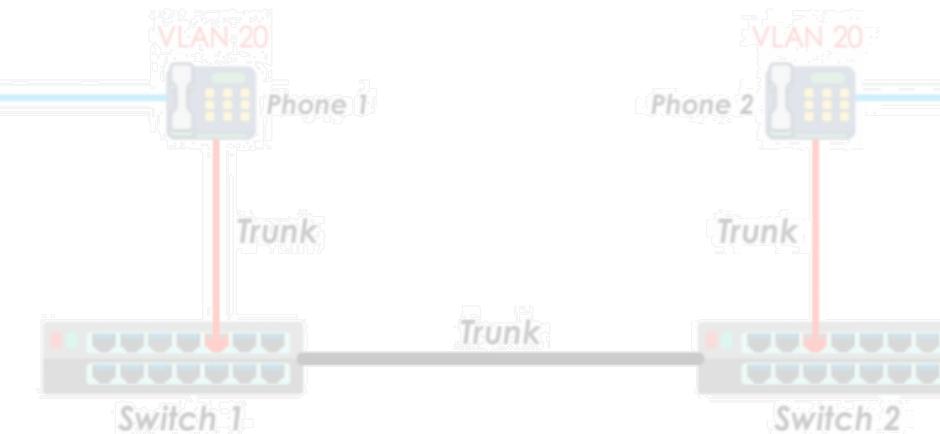
Switch1#show vlan brief				
VLAN Name	Status	Ports		
1 default	active	Fa0/1, Fa0/2, Fa0/3 Fa0/4, Fa0/5, Fa0/6 Fa0/7, Fa0/8, Fa0/9 Fa0/10, Fa0/11, Fa0/12 Fa0/13, Fa0/14, Fa0/15 Fa0/22, Fa0/23, Fa0/24 Gi0/1, Gi0/2		
10 Engineering	active			
20 Finance	active			
30 Management	active			
40 Marketing	active			
50 Sales	active			
1002 rcd1-default	act/unsup			
1003 token-ring-default	act/unsup			
1004 fddinet-default	act/unsup			
1005 trnet-default	act/unsup			

Default setting
on cisco switches
for all ports

Native VLAN

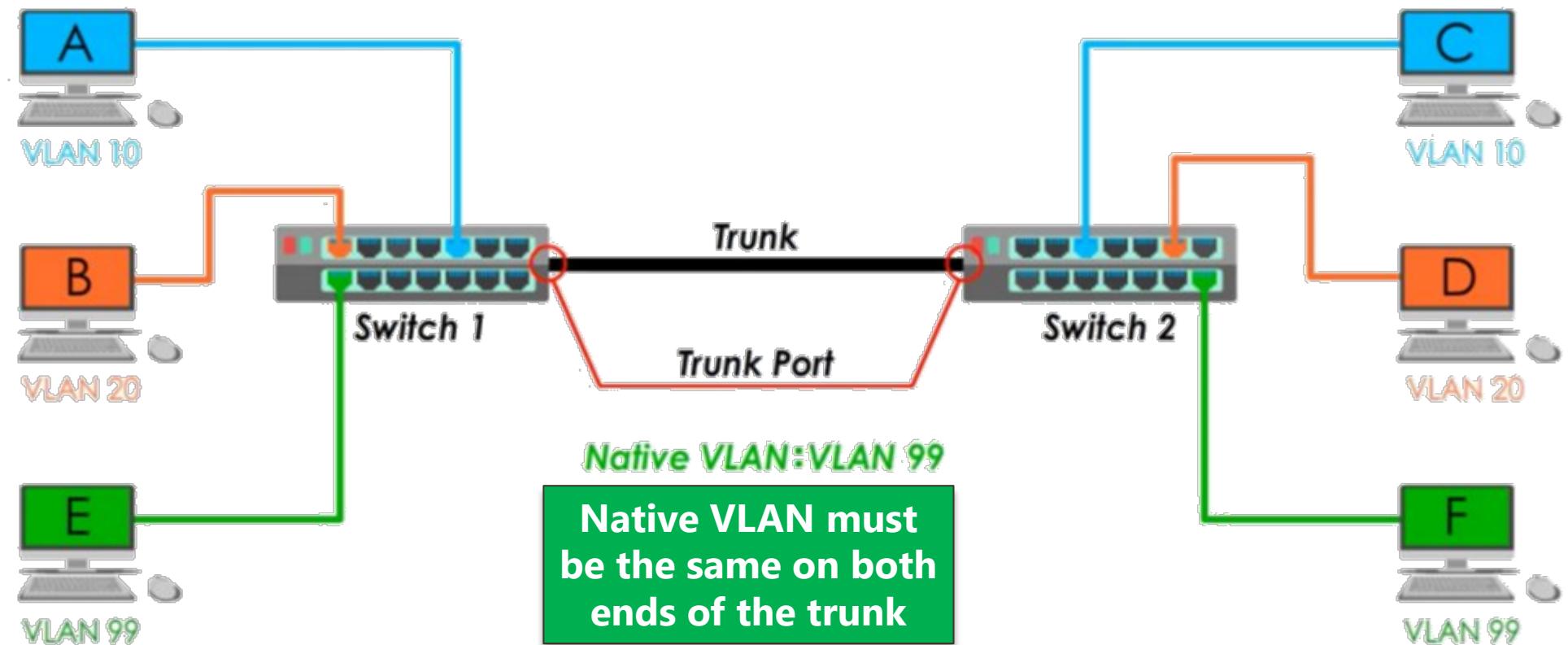
Devices that do not support VLANs

1. Provides **backward compatibility** for **old devices** that do not speak 802.1q standard
2. Used by the switch to **carry** specific **control and management protocol traffic**
 - i.e. Cisco Discovery Protocol (CDP),
 - VLAN Trunking protocol (VTP),
 - Spanning Tree Protocol (STP)
3. **Useful in VOIP** (Voice Over IP)



Native VLAN

Native VLAN is a special VLAN whose **traffic** traverses **on 802.1q trunk without the VLAN tag**



By default,

Native VLAN = Default VLAN = VLAN 1



■ Ethernet

- LAN, Ethernet Fundamentals
- History and Evolution
- Ethernet, Fast Ethernet, Gigabit Ethernet and Cabling
- IEEE802.1 Ethernet DLL
 - LLC: Services
 - MAC: Data Frame
 - MAC: Protocol
- Deployment
- Adaptive Learning

■ Collision vs Broadcast Domain

- Fundamentals
- Hub, Bridge, Switch, Router

■ Wi-Fi

- Fundamentals
- Modes (adhoc, infrastructure)
- Terms (BSS, BSSID, SSID, ESS)
- Scanning Methods (active, passive)
Applications
- IEEE802.11 Standards
(b/a/g/n/ac/ax, Wi-Fi 6)
- MIMO (SU-MIMO, MU-MIMO)
- CSMA/CA
- 2.4 Ghz, 5Ghz Bands
- OFDM
- Wireless Threats
- Ethernet vs Wi-Fi Technology
- IEEE802.11 Wi-Fi Frames
 - Management Frame
 - Control Frame
 - Data Frame
- Ethernet vs Wi-Fi Data Frame

■ Spanning-Tree Protocol

- Fundamentals
- Protocol Brief

■ VLAN

- Fundamentals
- VLAN Types
- IEEE802.11q Standard
 - Access Ports
 - VLAN Tag
- Default VLAN
- Native VLAN

THANK YOU

Make tomorrow better.