CS2105 Introduction to Computer Networks

Lecture 10

Local Area Network

29 October 2018

PREVIOUS LECTURE

Link Layer

- Link layer transmits data over a single link
- Possible services by link layer protocols:
  - Framing (*basic*)
    - IP datagrams are encapsulated in link layer frames for transmission
  - Error Checking (*optional*)
    - Parity check (single, 2D); CRC
    - May also optionally perform Error Correction
  - Multiple Access Control (*optional*)
    - Determine in which manner multiple nodes share a broadcast channel
    - *Be Nice!*

PREVIOUS LECTURE

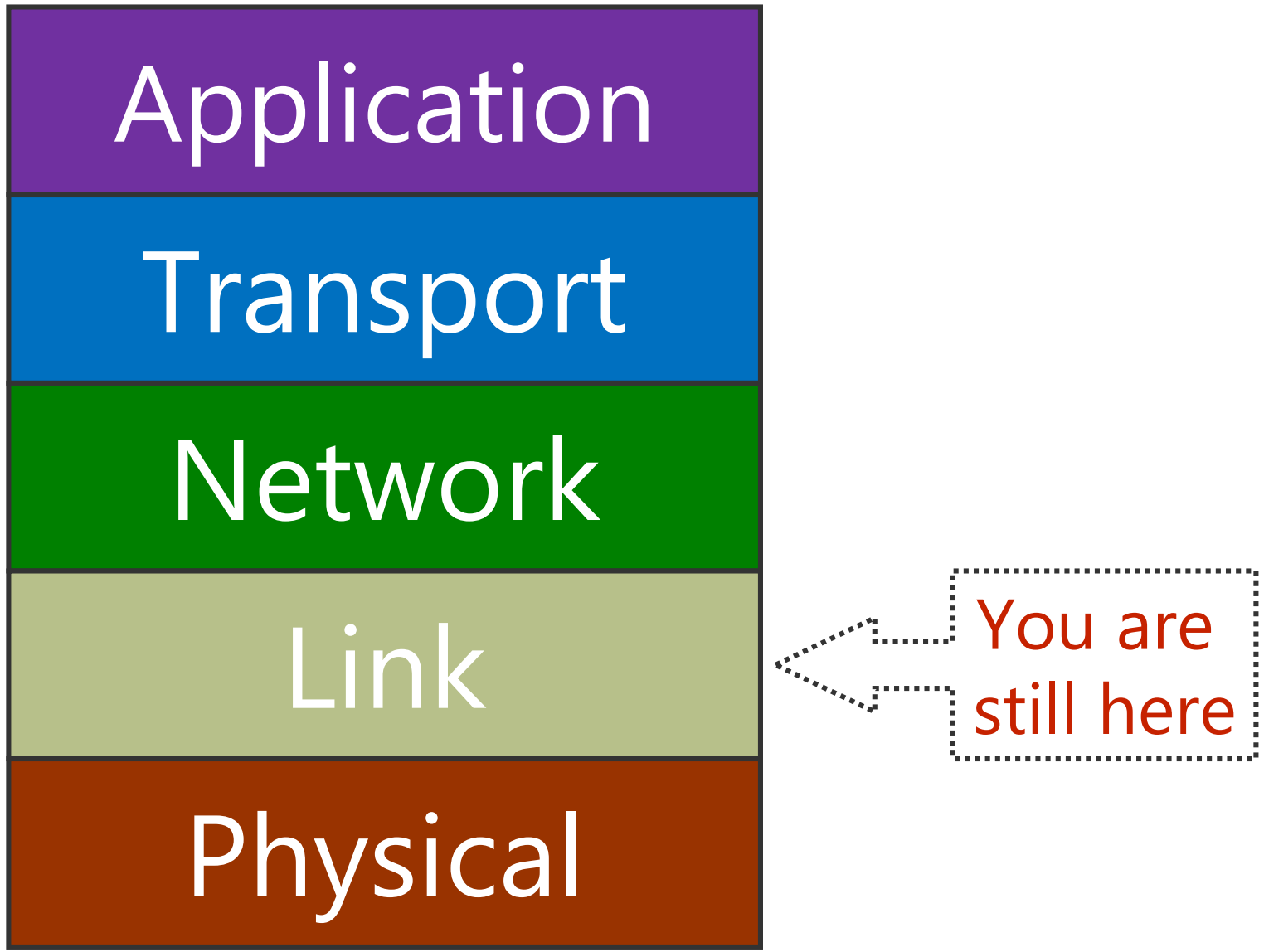
Multiple Access Protocols

- Channel partitioning protocols:
  - Divide channel into slots by time, frequency, or code
  - Channel is shared fairly and efficiently if most nodes have data to send
- Random access protocols:
  - Efficient at low load: single node can fully utilize channel
  - High collision rate at high load: wasted channel time
- Taking turns protocols:
  - Polling from master node or token passing
  - Efficient at both low and high load
  - Single point of failure

Learning Outcomes

After this class, you are expected to understand:

- the role MAC address.
- the role a switch in interconnecting subnets in a LAN.
- how switching table is built and how it is used to forward link-layer frames.
- how ARP allows a host to discover the MAC address of other nodes in the same subnet.
- the link properties of a wireless link.
- how CSMA/CA works and how it addresses the hidden node problem


Application
Transport
Network
Link
Physical
You are
still here

Chapter 5

5.1 Introduction to the Link Layer

5.2 Error detecting and correction

5.3 Multiple access protocols

- 5.3.1 Channel Partitioning Protocols
- 5.3.2 Random Access Protocols
- 5.3.3 Taking-Turns Protocols

Discussed Last week

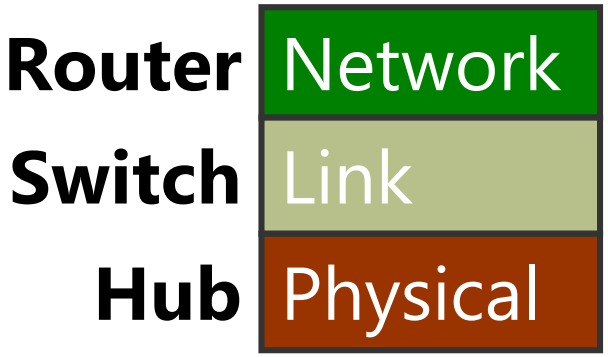
5.4 Switched Local Area Networks

- 5.4.1 Link layer addressing and ARP
- 5.4.2 Ethernet
- 5.4.3 Link layer switches

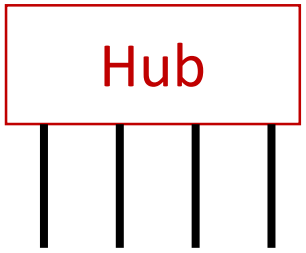
Kurose Textbook, Chapter 5
(Some slides are taken from the book)

Local Area Network

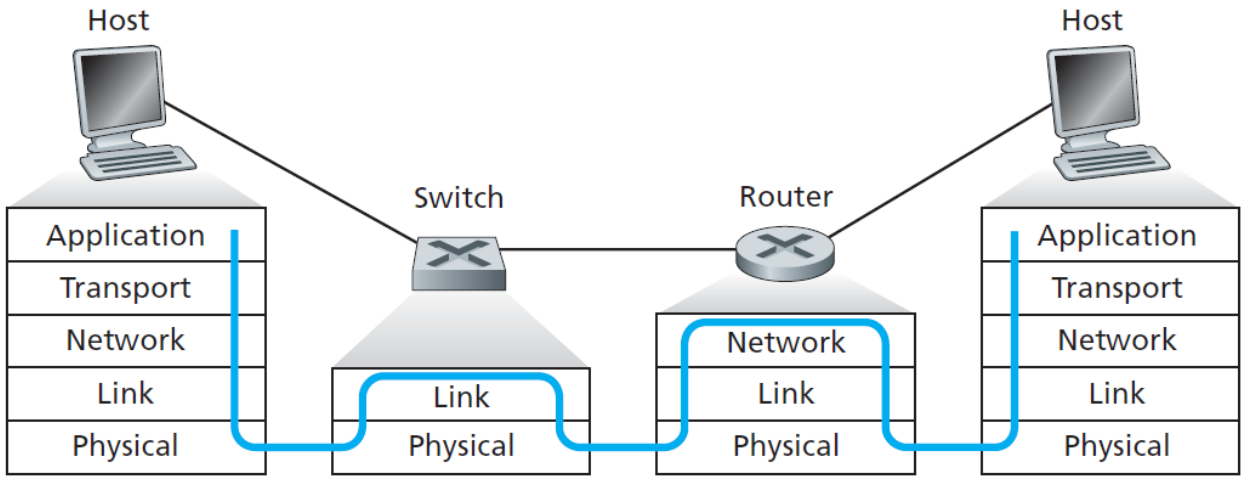
- How to inter-connect a large number of hosts in a subnet?



Router	Switches
Check IP address	Check MAC address
Store-and-forward	Store-and-forward
Compute routes to destination	Forward frame to outgoing link or broadcast



Forwards signal to ALL outgoing links



MAC Address (1/2)

- Every adapter (NIC) has a MAC address
  - Used to send & receive link layer frames
  - On receive of frame, checks destination MAC address
    - **Match self MAC address**: extracts datagram and passes up the protocol stack
    - **Does not match**: discard

MAC Address (2/2)

- 6-bytes (48-bits) burned in NIC ROM
  - Example:

Properties

IPv4 address:	172.26.184.138
IPv4 DNS servers:	192.168.140.2
Primary DNS suffix:	comp.nus.edu.sg
Manufacturer:	Intel Corporation
Description:	Intel(R) Ethernet Connection (5) I219-LM
Driver version:	12.15.22.6
Physical address (MAC):	8C-EC-4B-50-F3-59

  - Allocation administered by IEEE
    - First 3 bytes identifies the vendor
    - http://www.coffer.com/mac_find

MAC Address *vs.* IP Address

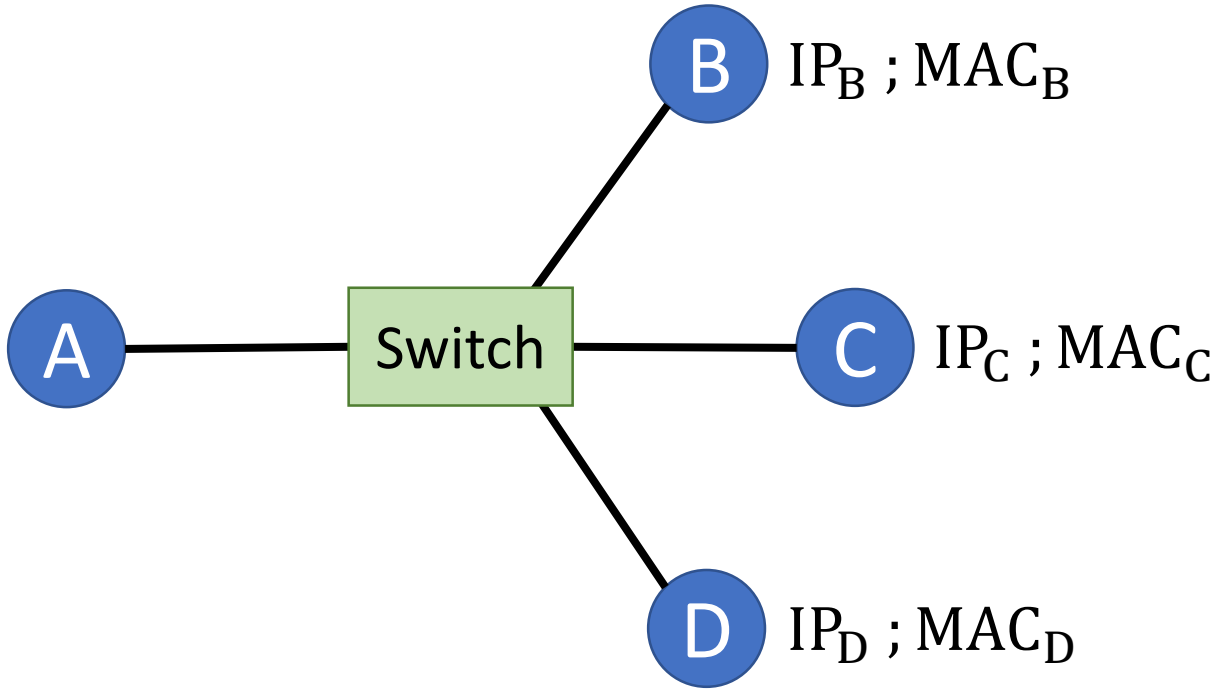
MAC Address	IP Address
Permanent	Dynamic
Hardware Assigned	Network Assigned
Node-to-node	Host-to-host
Flat	Hierarchical
Analogy: NRIC number	Analogy: Postal address

ARP: Address Resolution Protocol

- Each IP node (e.g., *host*, *router*) has an ARP table
  - Stores mapping of IP address to MAC address of other nodes in the same subnet
  - Format: `<IP address> <MAC address> <TTL>`

ARP Table of A

IP address	MAC address	TTL
IP_B	MAC_B	60
IP_C	MAC_C	60
IP_D	MAC_D	60

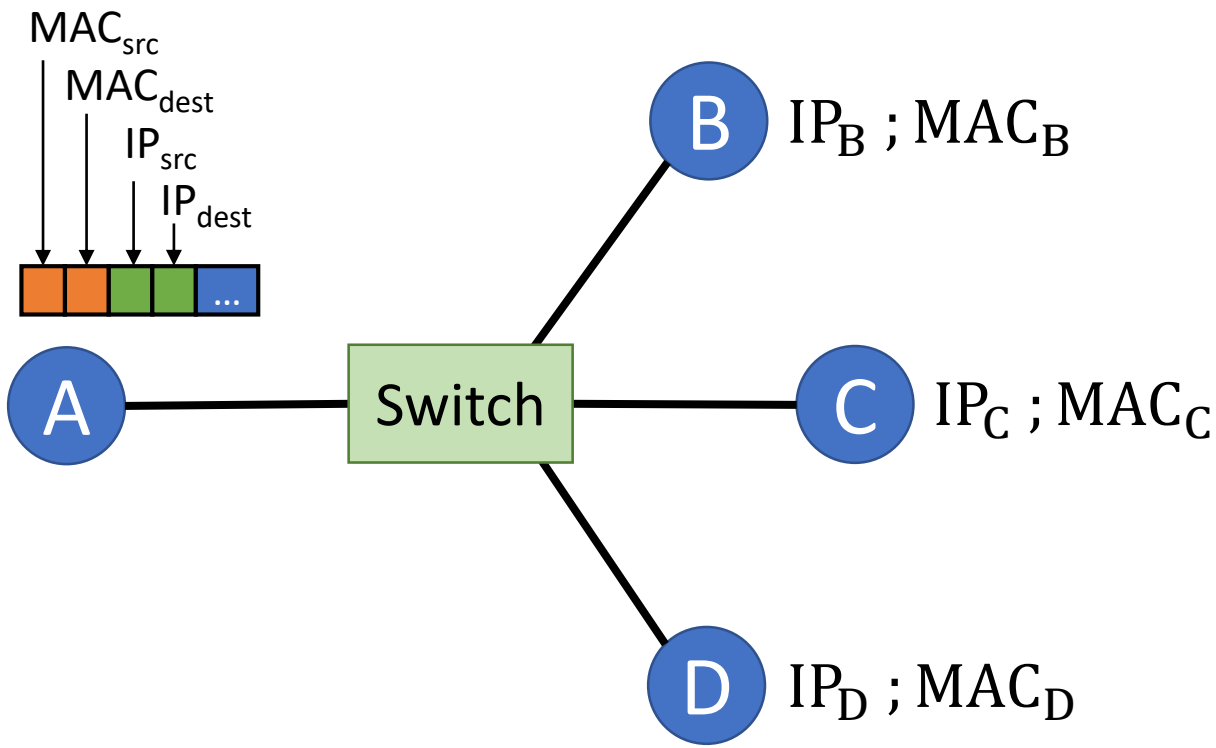


ARP: Address Resolution Protocol

- Sending frame in the same subnet (e.g., A to B)
  - Assume A knows B's MAC address from its ARP table
  - Construct frame with B's MAC address as destination address
    - Only B will process the frame
    - Others will ignore

ARP Table of A

IP address	MAC address	TTL
IP_B	MAC_B	60
IP_C	MAC_C	60
IP_D	MAC_D	60

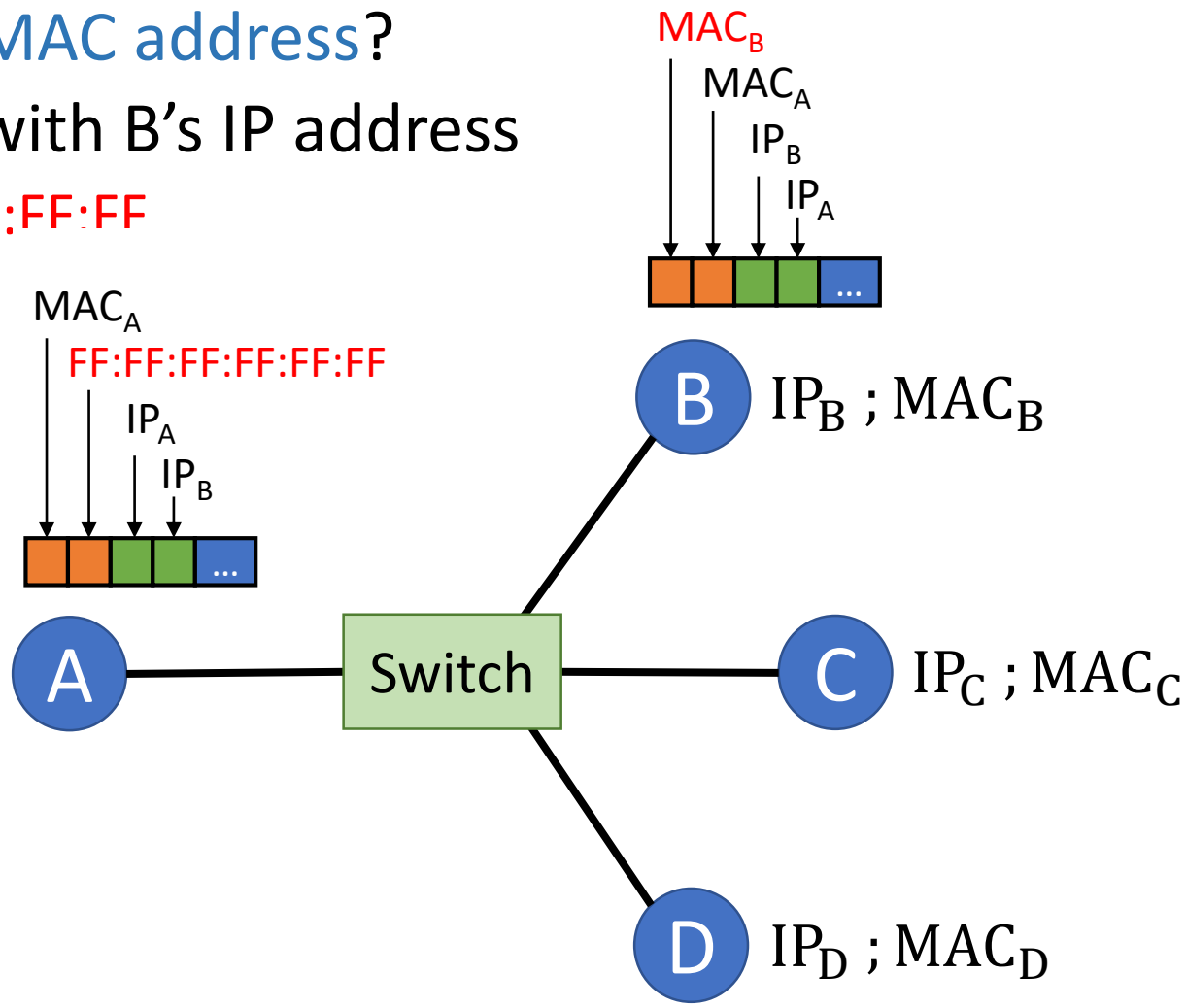


ARP: Address Resolution Protocol

- Sending frame in the same subnet (e.g., A to B)
  - What if A does not know B's MAC address?
  - Broadcast ARP query packet with B's IP address
    - Broadcast Address: FF:FF:FF:FF:FF:FF
  - B replies with MAC address
  - A caches it in ARP table

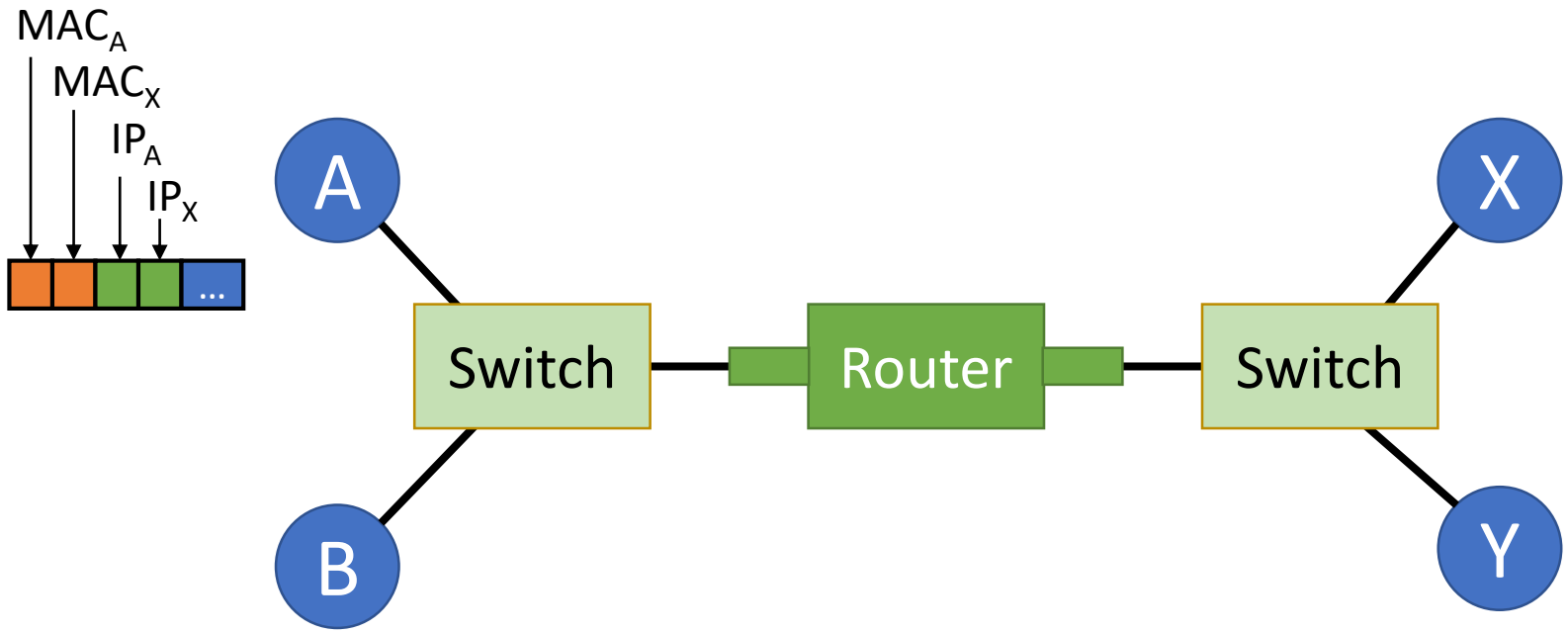
ARP Table of A

IP address	MAC address	TTL
IP_C	MAC_C	60
IP_D	MAC_D	60



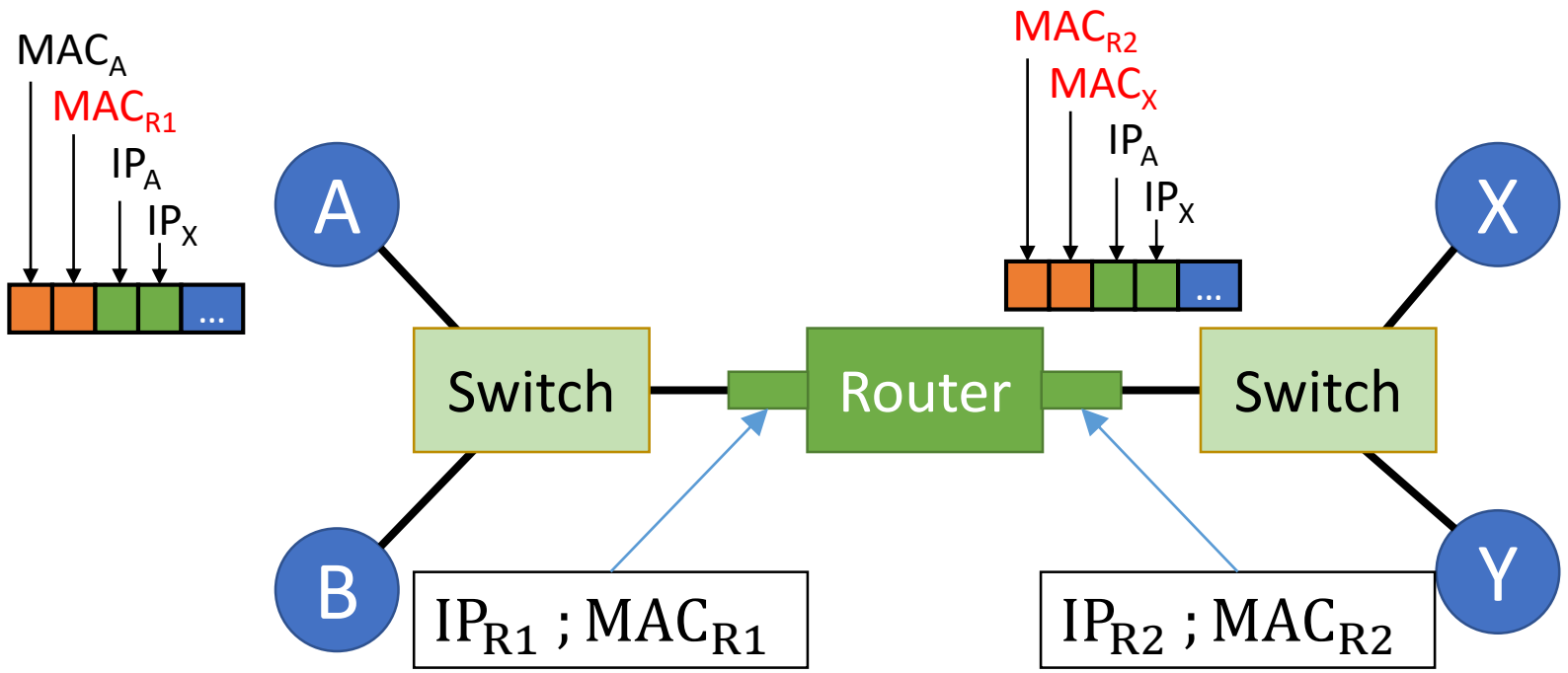
ARP: Address Resolution Protocol

- Sending frame to different subnet (e.g., A to X)
  - Attempt 1:
    - Problem?
    - Nobody has $\mathrm{MAC_X}$ in the subnet!



ARP: Address Resolution Protocol

- Sending frame to different subnet (e.g., A to X)
  - Attempt 2:
    - A deeper look into the router
    - Send to router! Router will forward to X!



Chapter 5

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5.2 Error detecting and correction

5.3 Multiple access protocols

- 5.3.1 Channel Partitioning Protocols
- 5.3.2 Random Access Protocols
- 5.3.3 Taking-Turns Protocols

Discussed Last week

5.4 Switched Local Area Networks

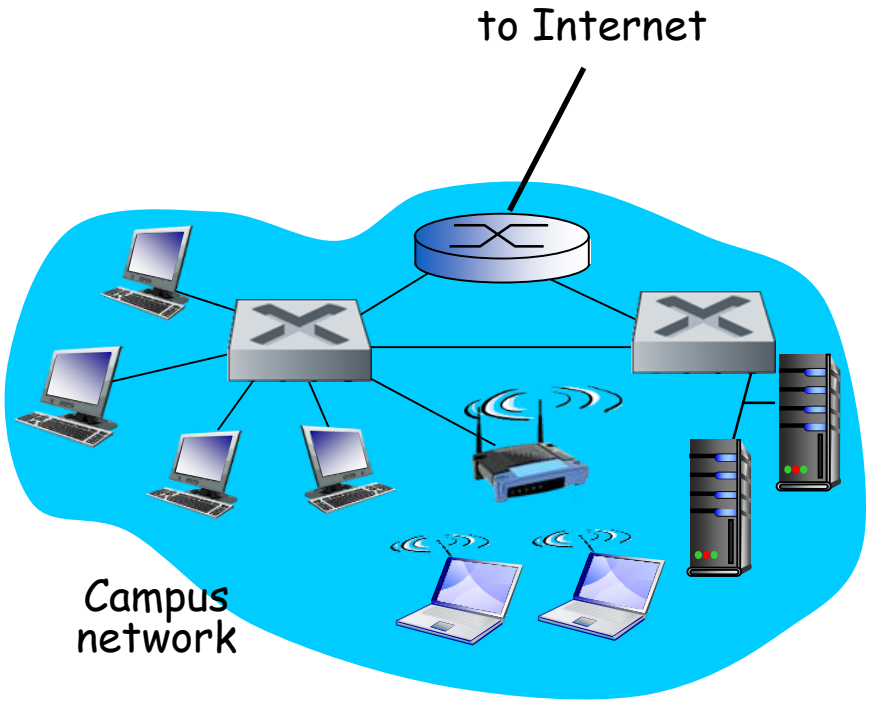
- 5.4.1 Link layer addressing and ARP
- 5.4.2 Ethernet
- 5.4.3 Link layer switches

Kurose Textbook, Chapter 5
(Some slides are taken from the book)

Local Area Network (LAN)

- LAN is a computer network that interconnects computers within a geographical area (e.g., office building or campus)

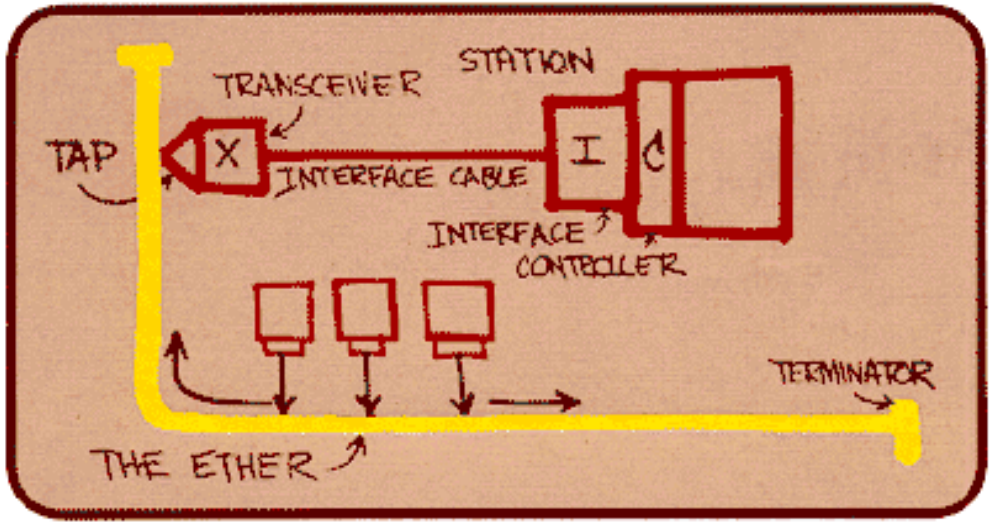
- LAN technologies:
  - IBM Token Ring: IEEE 802.5 standard
  - Ethernet: IEEE 802.3 standard
  - Wi-Fi: IEEE 802.11 standard
  - Others



Ethernet

- "Dominant" wired LAN technology:
  - Developed in mid 1970s
  - Standardized by Xerox, DEC, and Intel in 1978
  - Simpler and cheaper than token ring and ATM

Ethernet connection
(Source: Wikipedia)



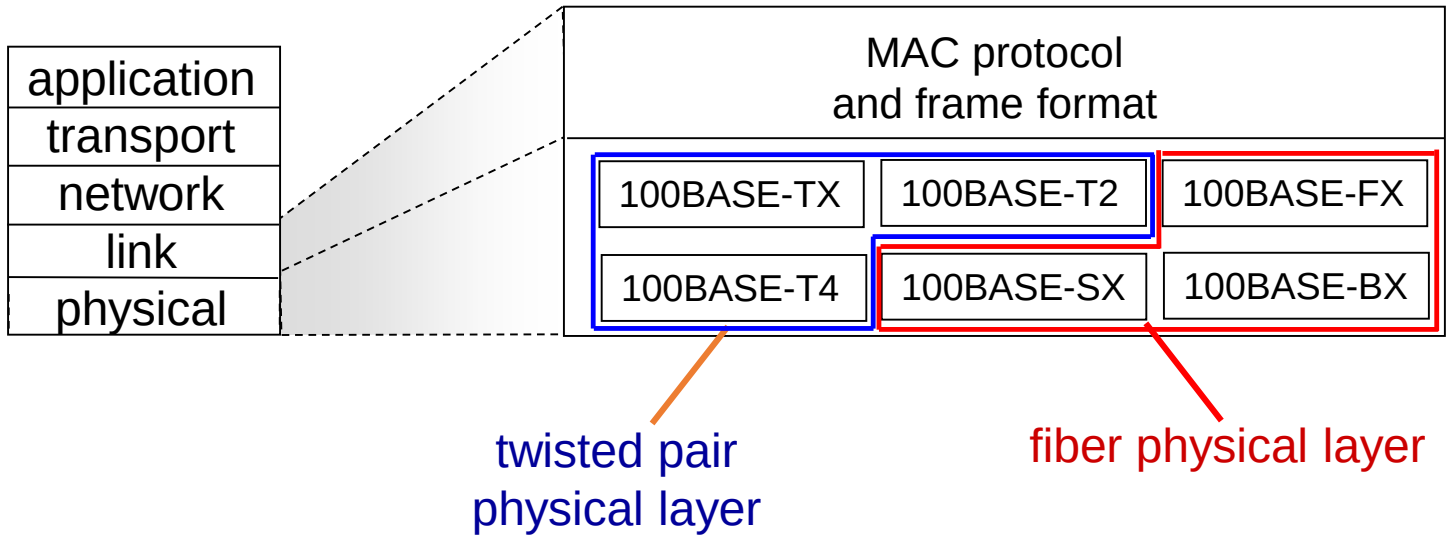
Metcalfe's Ethernet sketch

Ethernet

802.3 Ethernet Standards

- Different speeds: 2 Mbps, 10 Mbps, 100 Mbps, 1 Gbps, 10 Gbps, 100 Gbps
- Different physical layer media: Cable, Fiber optics

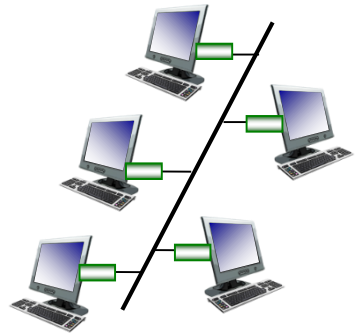
❖MAC protocol and frame format *remains unchanged*



Ethernet

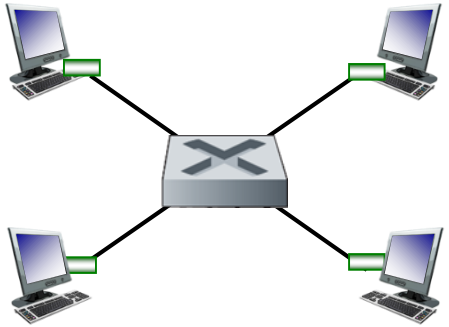
Physical Topology

- Bus topology: popular in mid 90s
  - All nodes can collide with each other



Ethernet with bus topology

- Star topology: prevails today
  - Switch in center
  - Nodes do not collide with each other

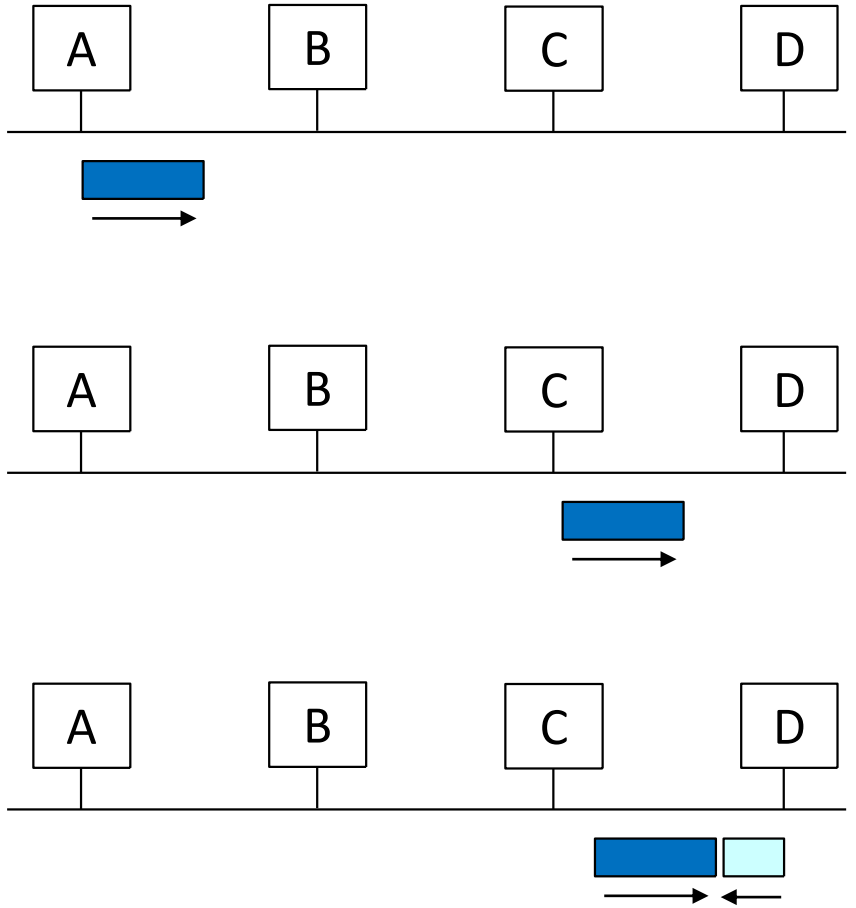


Ethernet with star topology

Ethernet

Physical Topology

- Bus topology: popular in mid 90s
  - All nodes can collide with each other
  - Example:
    - A sends a frame at time t
    - A's frame reached D at time $t + d$
    - D begins transmission at time $t + d - 1$
    - Collision!

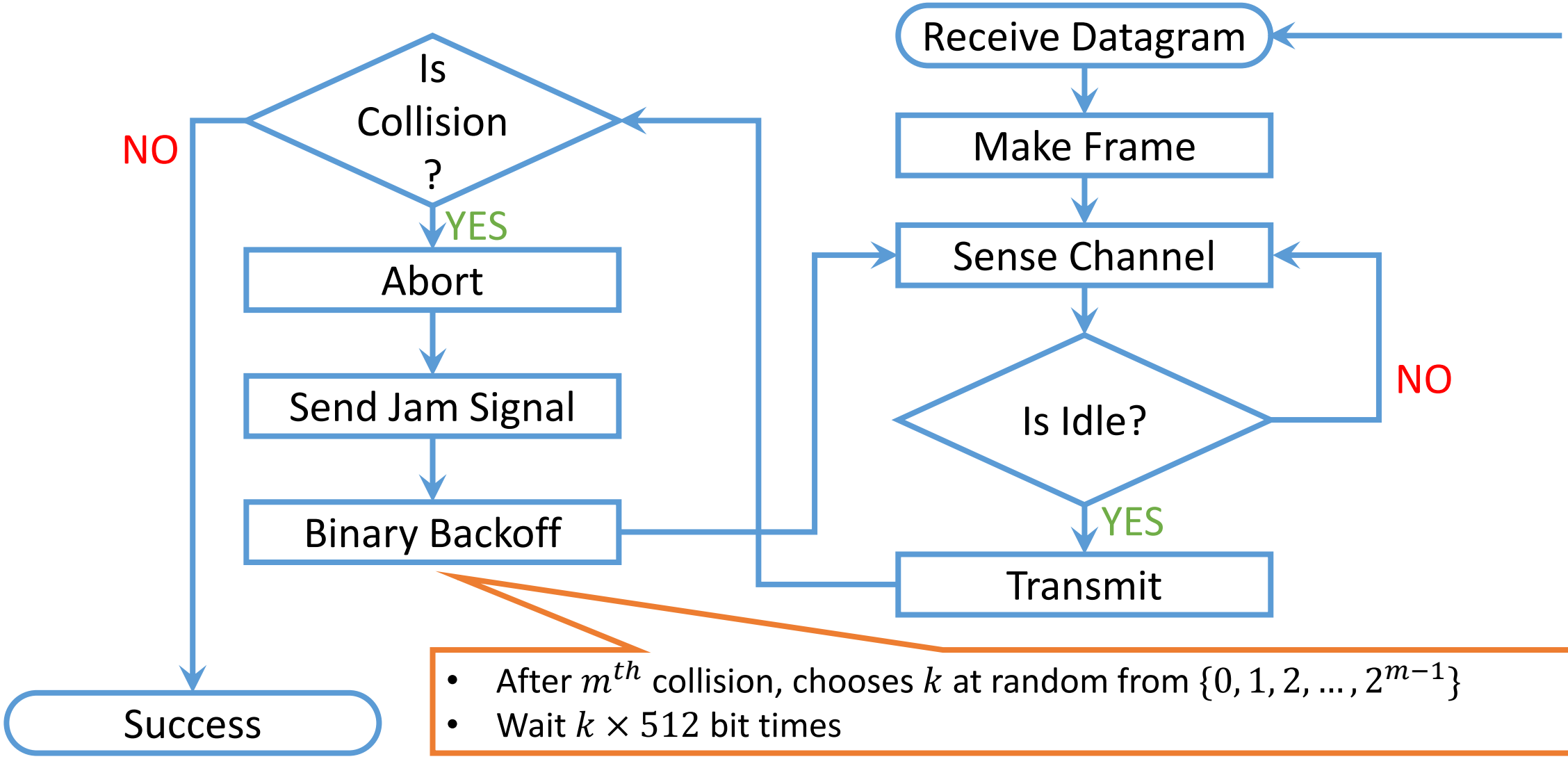


Ethernet

Data Delivery Service

- Connectionless: no handshaking between sending and receiving NICs.
- Unreliable: receiving NIC doesn't send ACK or NAK to sending NIC.
  - Data in dropped frames will be recovered only if initial sender uses higher layer RDT (e.g., TCP)
  - Otherwise, data is lost
- MAC: **CSMA/CD** with binary (exponential) backoff

Ethernet CSMA/CD Algorithm



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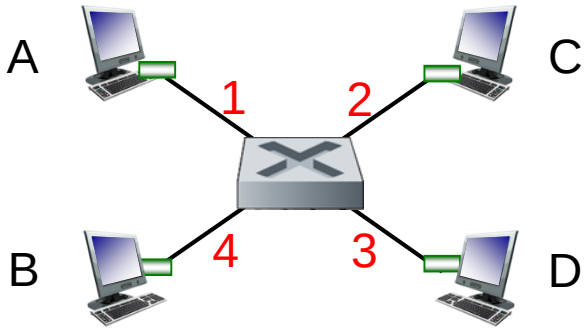
Ethernet Switch

Properties:

- Store and forward Ethernet frames
  - Examine incoming frame's MAC address
  - Selectively forward frame to one-or-more outgoing links
- Transparent to hosts
  - No IP address
- Star topology
  - Each host has dedicated link to switch
- Full duplex
- Buffered

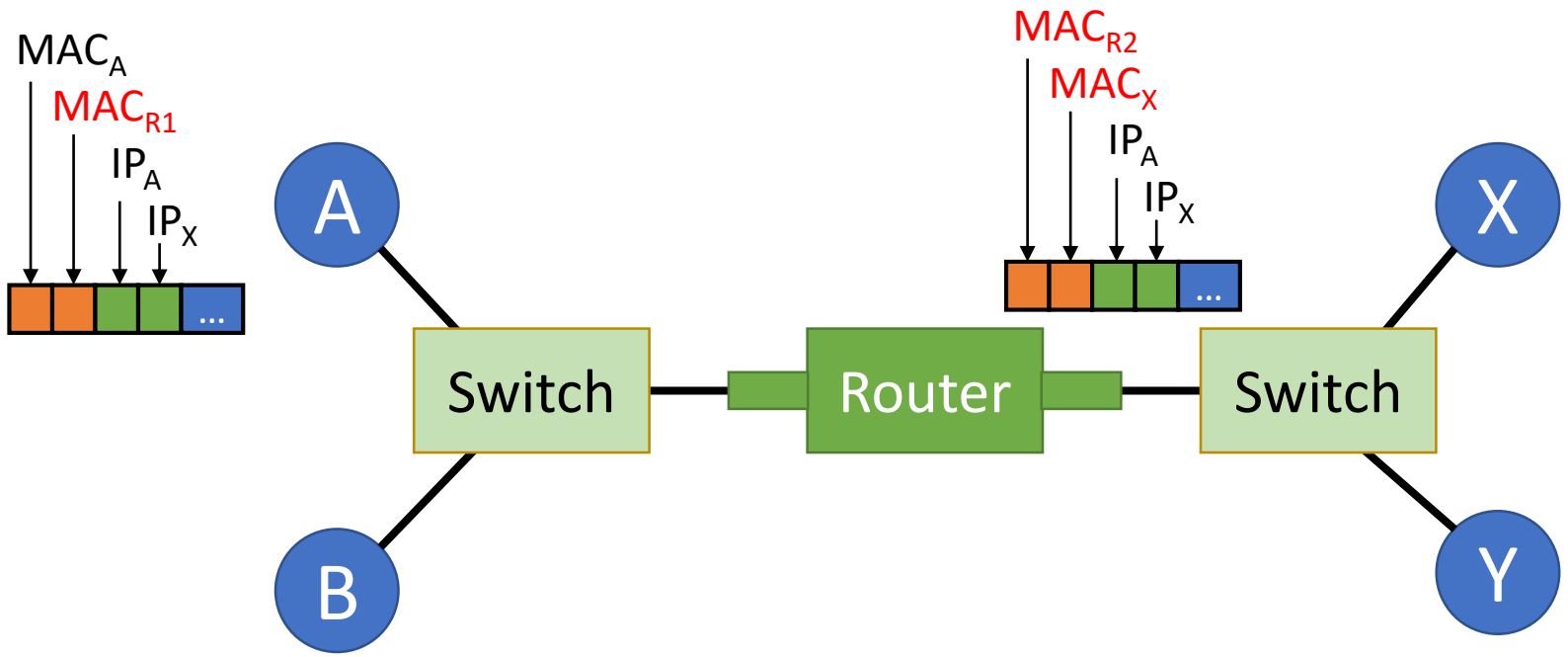
a 50-port Ethernet switch
(Source: Wikipedia)



A switch with 4 interfaces
(1, 2, 3, 4)

Switch Forwarding Table

- Recall: switch does not “broadcast” like a hub
- Question: how does a switch know which interface to forward the frame to?



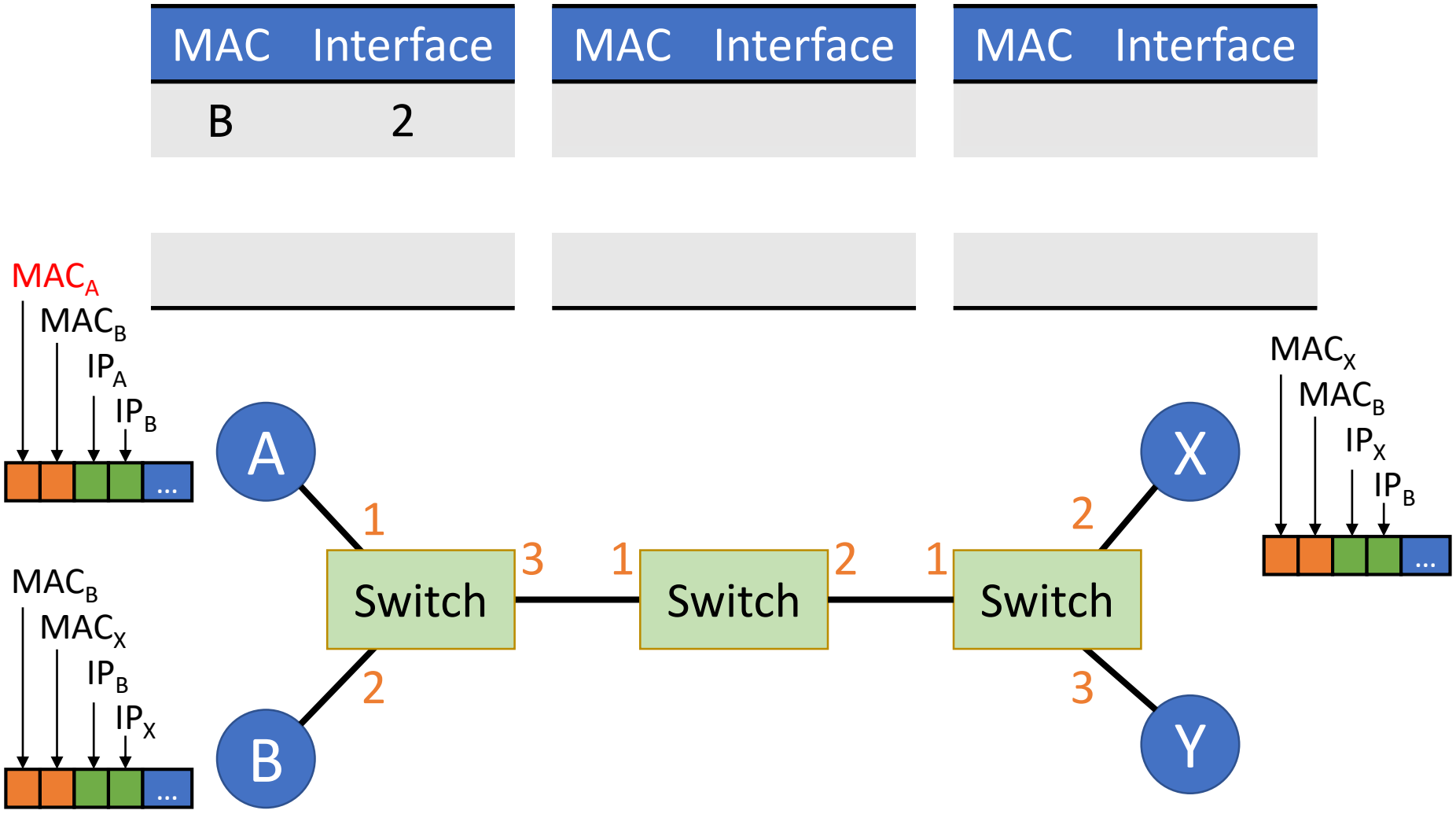
Switch Forwarding Table

- Format of entry:
  - `<MAC address> <interface> <TTL>`

- Self-learning:
  - Switch learns which hosts can be reached through which interface
    1. Broadcast
    2. Forwarding
    3. Filtering

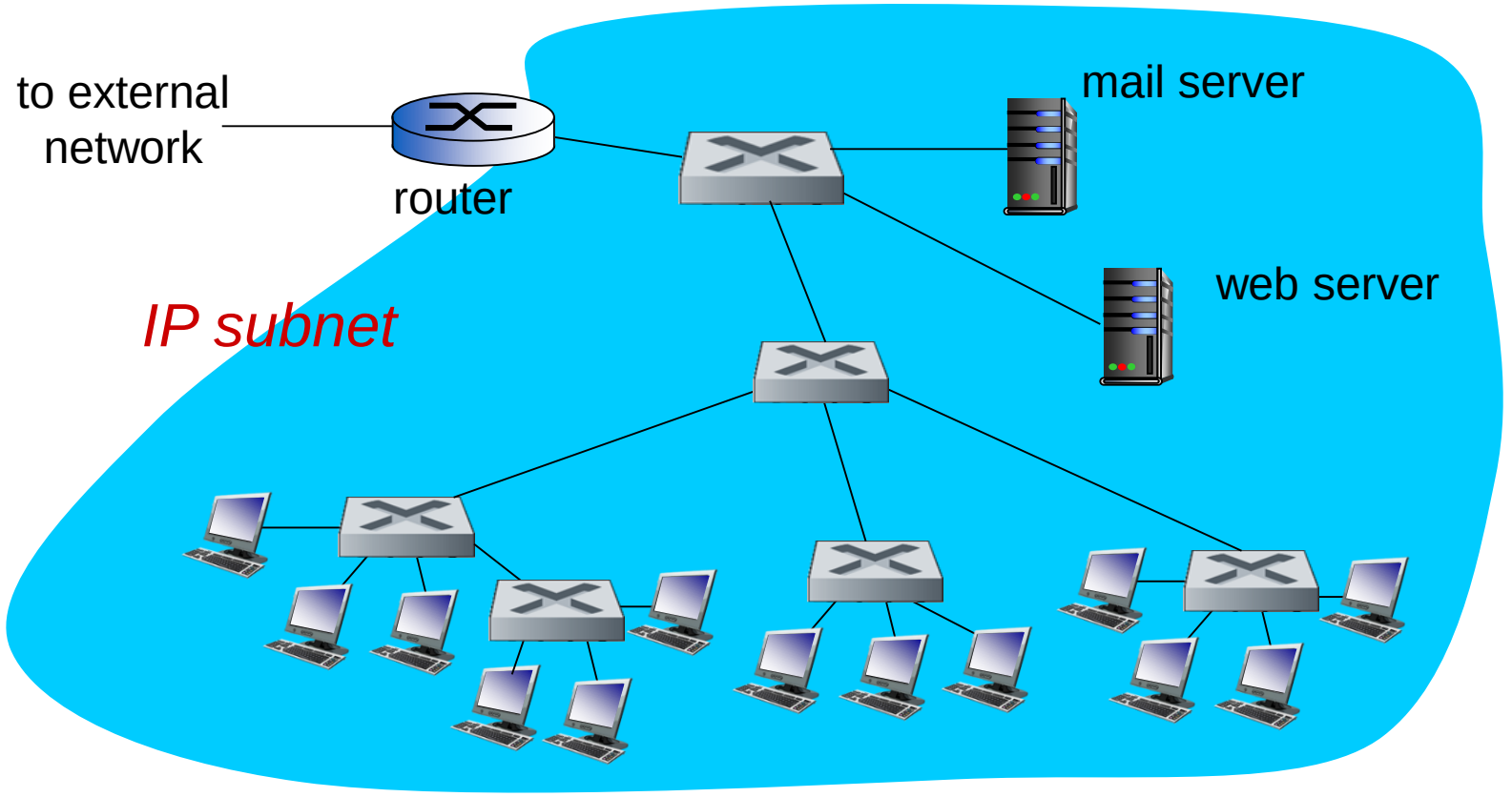
MAC Address	Interface	TTL
FA:CE:BD:0C:11:FD	1	60
66:23:C6:1D:FE:32	2	60
15:00:2A:F1:CE:A1	3	60

Switch Forwarding Table



Interconnecting Switches

- Switches can be connected in hierarchy



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More on Wireless LAN

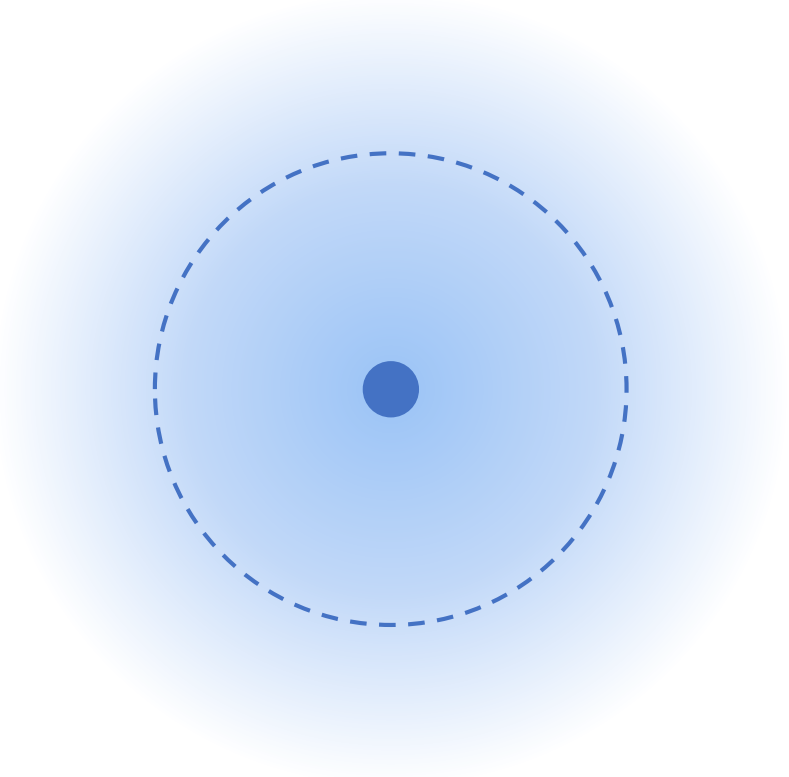
Kurose Textbook, Chapter 5
(Some slides are taken from the book)

Wireless LAN

- Terminology
  - BSS: Basic Service Set
  - AP: Access Point
  - SSID: Service Set Identifier
  - RSSI: Received Signal Strength Indicator

Wireless LAN

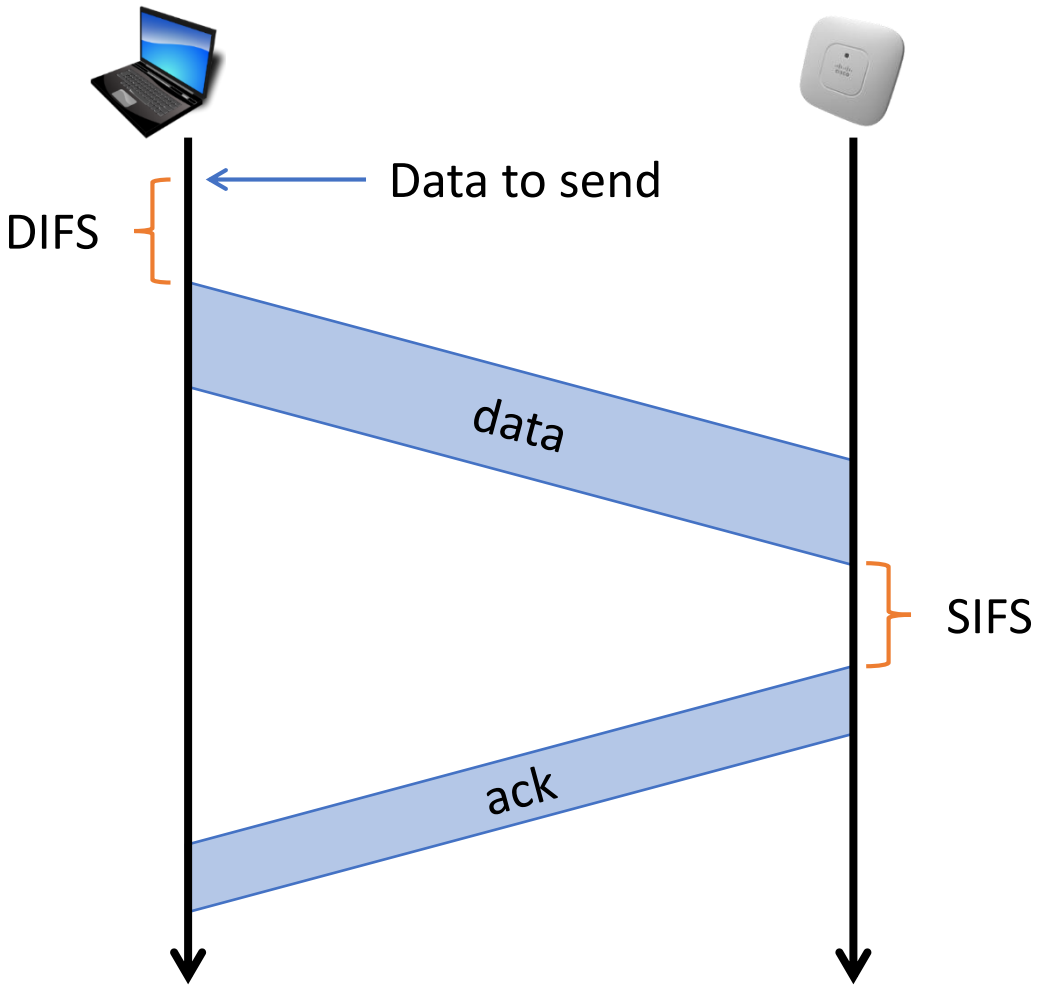
- Implications of ***wireless***
  - Limited Range
  - Broadcast
  - High Error Rate
  - Multipath Propagation



Wireless LAN

Recap

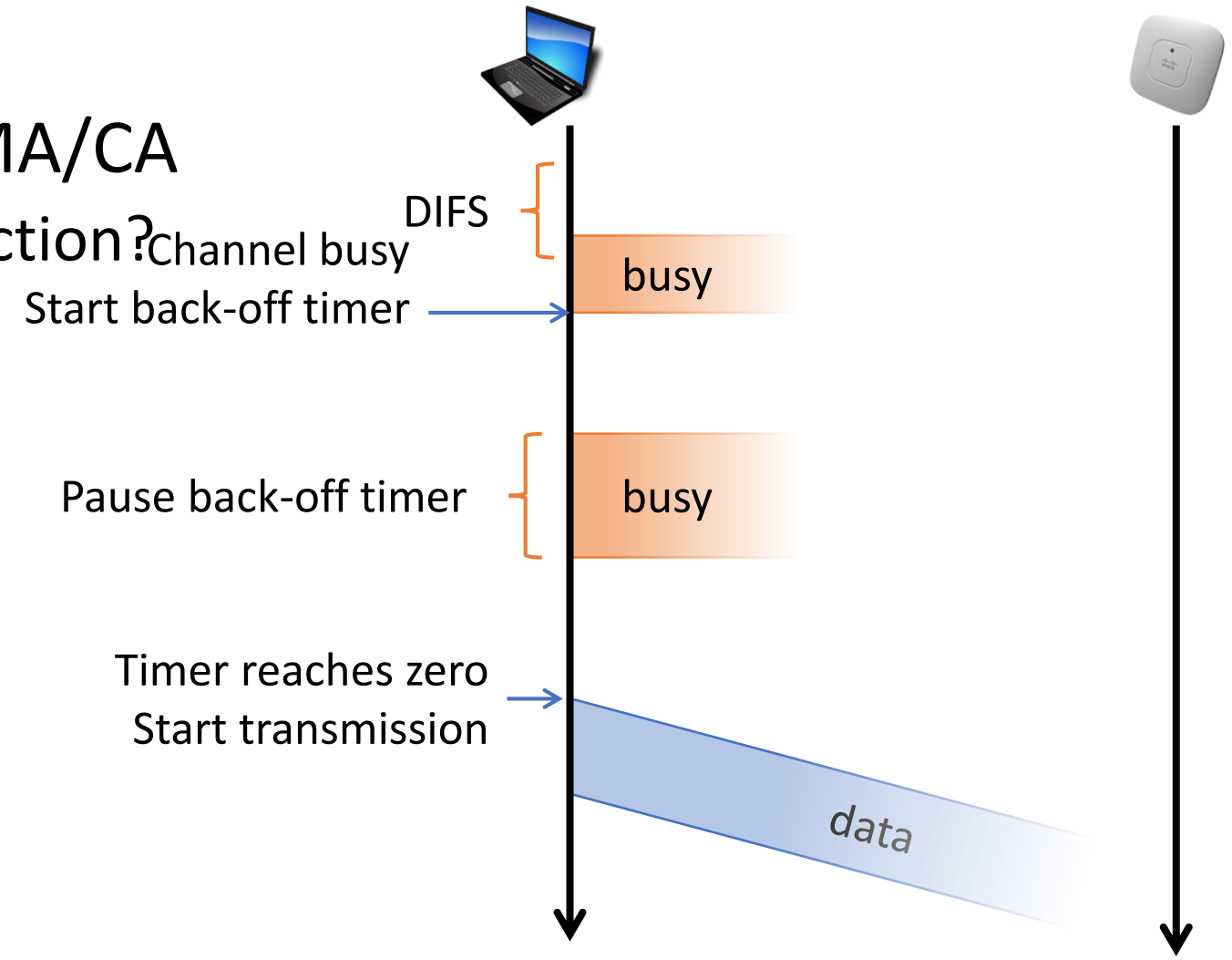
- Use link-layer ACK to detect collision



Wireless LAN

Recap

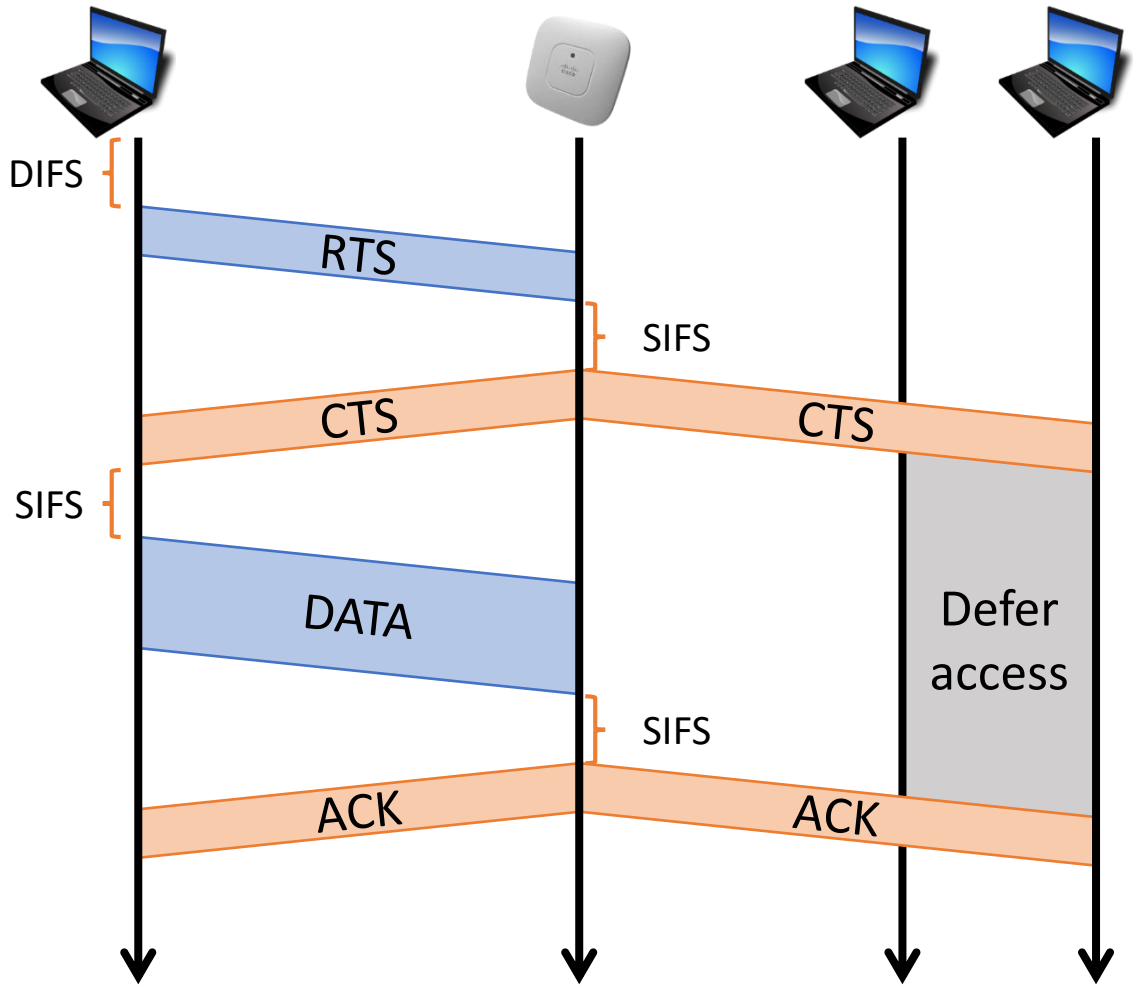
- Wireless LAN uses CSMA/CA
  - Why not collision detection?
    - $RSSI_{rcv} < RSSI_{snd}$
    - Hidden Node problem



Wireless LAN

Recap

- Wireless LAN uses RTS/CTS
  - Hidden Node problem
  - RTS before sending
  - On CTS, send
  - Wait for ACK
  - Other nodes wait until ACK



Summary

- ARP protocol to resolve IP $\leftrightarrow$ MAC mapping
- Ethernet (IEEE 802.3)
  - CSMA/CD protocol with binary (exponential) back-off
  - Self-learning Ethernet switch table
    - Broadcasting
    - Forwarding
    - Filtering
- Wireless LAN (IEEE 802.11)
  - CSMA/CA with RTS/CTS ACK/NAK
  - Hidden node problem