Discussion 3, Ethernet

CS 168, Fall 2024 @ UC Berkeley

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Logistics

- Project 1a due (last week) on the 10th
- Project 1b due on the 20th
- Homework 1 releasing on the 23rd

- Midterm on October 15th (faaaar away)

- (from Arjun) Wheeler 204 is now the discussion room for me!

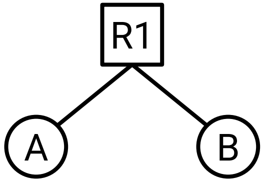
Connecting Local Hosts

Ethernet

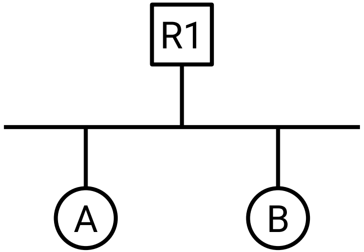
- **Connecting Local Hosts**
- Multiple Access Protocols
- Sending Packets
- Layer 2 Networks

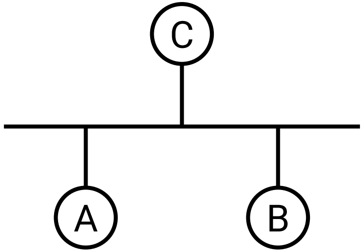
Connecting Local Hosts

So far, we've assumed that every link connects exactly two machines:



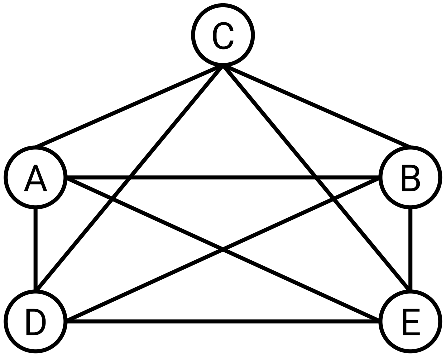
In reality, a single wire can connect multiple computers:

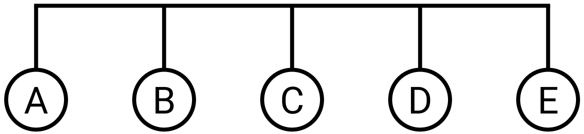




Connecting Local Hosts

How could we connect hosts in a local network?





Mesh: Link between every pair of machines.

- For every new host, we have to add new links to every other host.
- Need a lot of (physical) ports per host.

Bus: A single wire for all machines.

- Introduces a **shared media**.

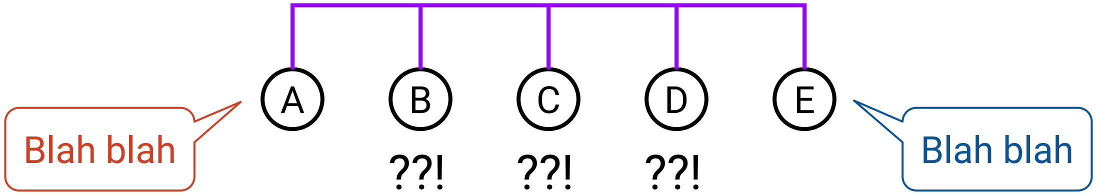
Shared Media

Shared media: Many machines using the same wire.

- If multiple machines transmit at the same time, signals will *interfere* or *collide*.
- Analogy: People talking simultaneously on a group call.

Note: Shared media is not necessarily a wire.

- Could be light signals on a shared optical fiber.
- Or radio waves on a shared wireless link.



Multiple Access Protocols

Ethernet

- Connecting Local Hosts
- **Multiple Access Protocols**
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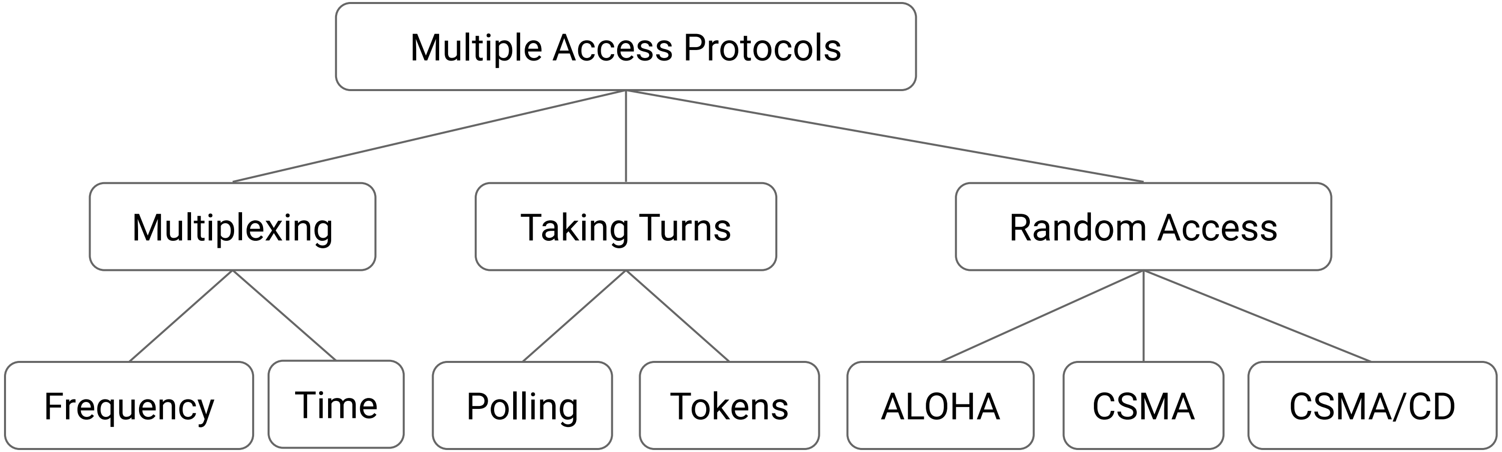
Multiple Access Protocols

A **multiple access protocol** allocates the shared media to everyone wanting to use it.

- 3 types of approaches.
- Several protocols of each type.

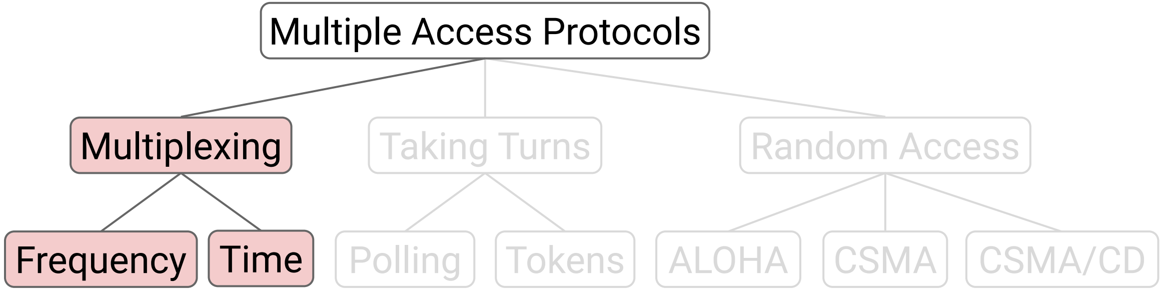


Multiple Access Protocols (1/3) – Multiplexing

Idea: Allocate a fixed slice of resources to each node.

- **Frequency-based** multiplexing: Divide medium into frequency channels.
- **Time-based** multiplexing: Give each node some fixed time slots.

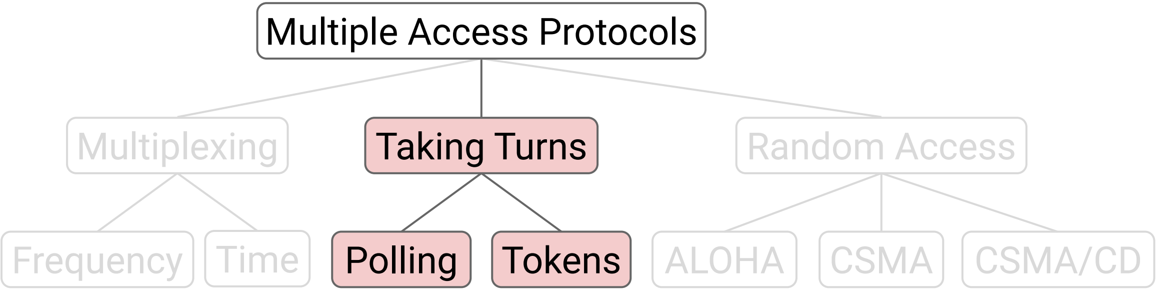
Problem: Can be wasteful.



Multiple Access Protocols (2/3) – Taking Turns

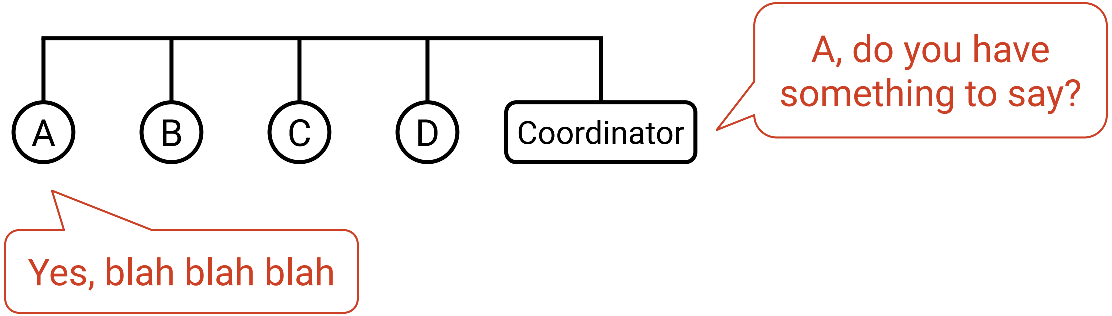
Idea: Nodes take turns speaking.

- **Polling protocols**: A coordinator decides when each node can speak.
    - Example: Bluetooth.
- **Token passing**: Pass a virtual token around. Only the node with the token can speak.

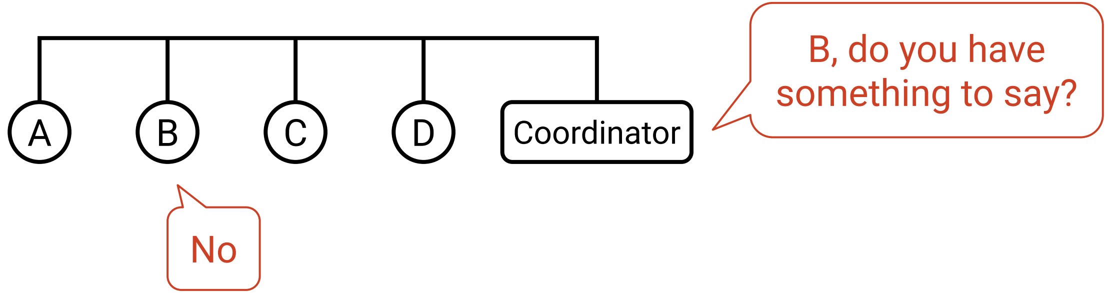


Multiple Access Protocols (2/3) – Taking Turns

Polling protocols: A coordinator decides when each node can speak.



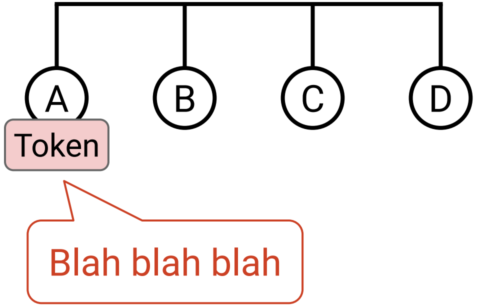
A can speak for as long as it needs.



B has nothing to say. Coordinator can immediately move on to C.

Multiple Access Protocols (2/3) – Taking Turns

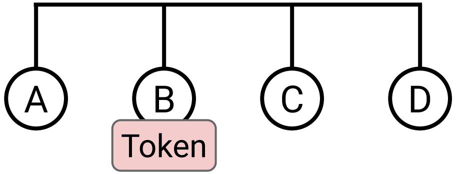
Token passing: Pass a virtual token around. Only the node with the token can speak.



A holds the token.

A can speak for as long as it needs.

When A is done, it passes the token to B.



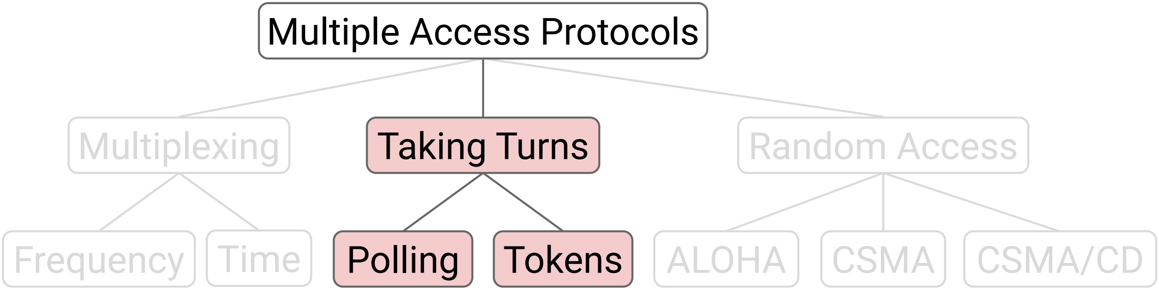
B has nothing to say.

It can immediately pass the token to C.

Multiple Access Protocols (2/3) – Taking Turns

Idea: Nodes take turns speaking.

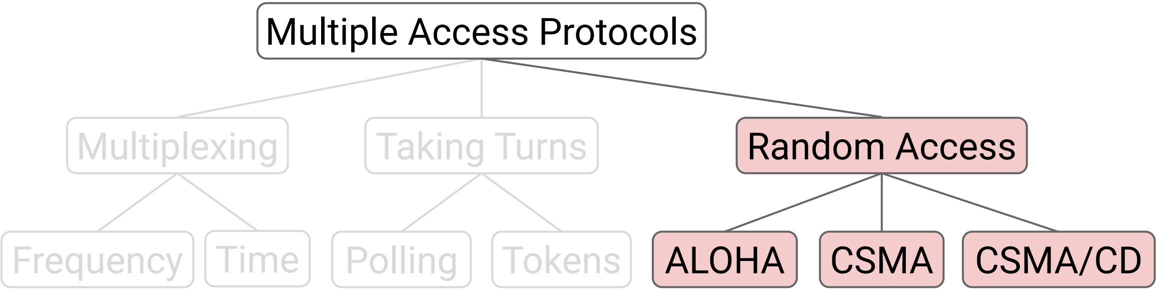
- Benefit: No more time wasted on idling.
    - If someone has nothing to say, immediately move on.
- Problem: Complexity.
    - Need to implement inter-node communication.
    - How do we elect the central coordinator?
    - What if two nodes both think they have the token?



Multiple Access Protocols (3/3) – Random Access

Idea: Nodes talk whenever they have something to say.

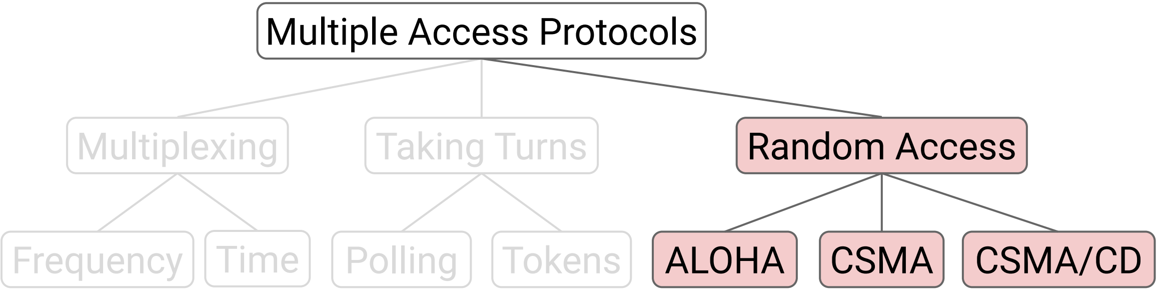
- Deal with collisions when they occur.
- Benefit: Simplicity. No coordinators or tokens.



Multiple Access Protocols (3/3) – Random Access – ALOHA (Additive Links On-line Hawaii Area)

ALOHA random access scheme: "rude" version.

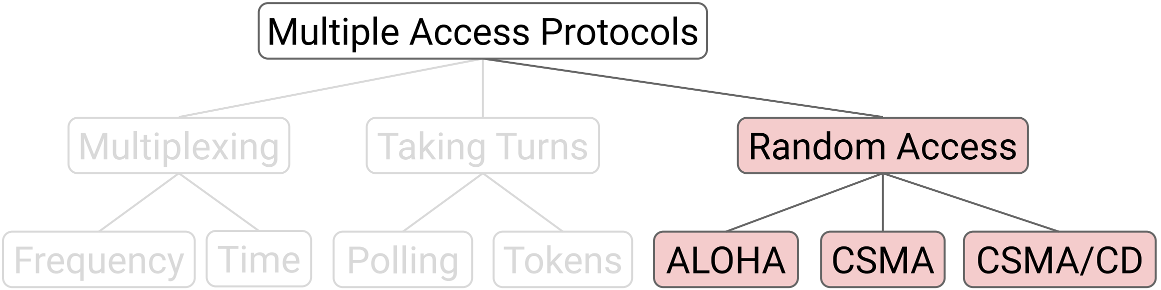
- If you have a packet, just send it.
  - Recipient replies with an ack.
- If two nodes send simultaneously, collision corrupts the packets.
  - No ack!
- If you don't get an ack: Wait some random amount of time, then resend.
  - Randomness helps avoid another collision.



Multiple Access Protocols (3/3) – Random Access – CSMA

CSMA (Carrier Sense Multiple Access): "polite" version.

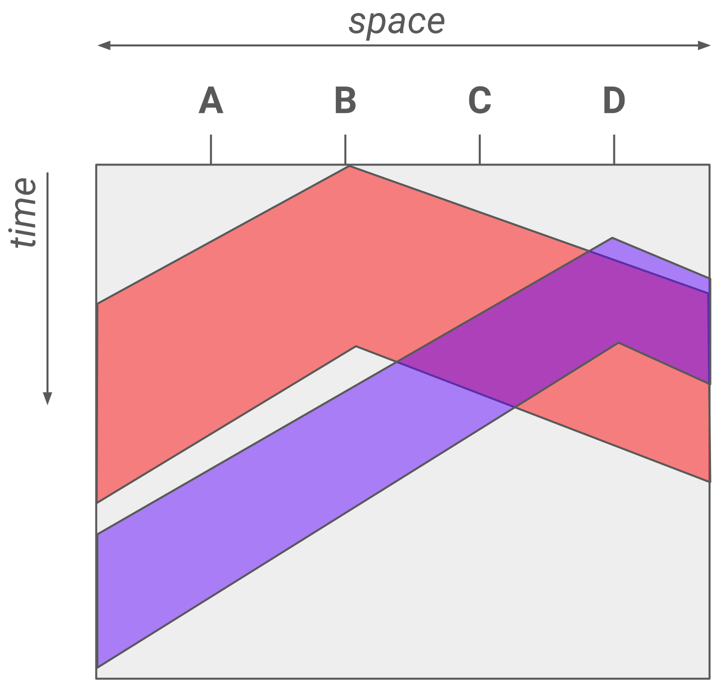
- First, listen to see if anyone is sending.
- Only start sending when it's quiet.



Multiple Access Protocols (3/3) – Random Access – CSMA and Propagation Delay

CSMA does not necessarily avoid collisions, because of **propagation delay**.

- t=0: B starts sending.
    - Signal takes time to reach A, C, D.
- t=2: D wants to send.
    - Signal hasn't reached D yet!
    - D thinks it's quiet and starts sending.
- Result: Collision!



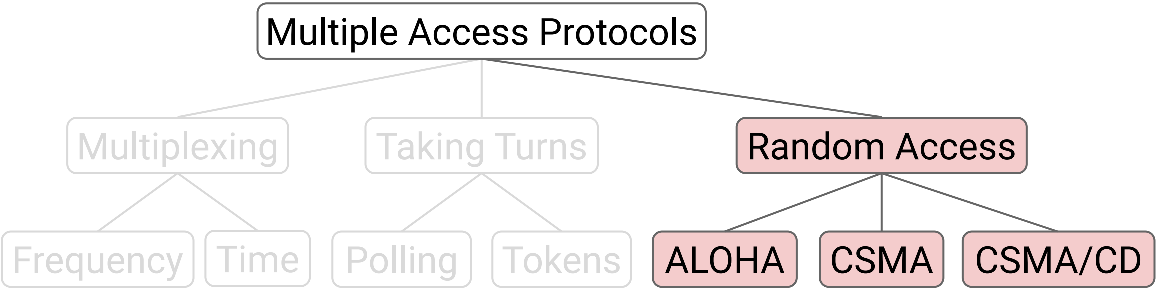
Multiple Access Protocols (3/3) – Random Access – CSMA/CD

CSMA/CD (Carrier Sense Multiple Access with Collision Detection):

- Listen before sending, but also *while* you're sending.
- If you hear someone else sending, stop! Collision detected.

CSMA/CD uses **binary exponential backoff**:

- After every collision, wait up to twice as long before resending.
  - After first collision: Wait between 0–4 seconds.
  - If resend collides again: Wait between 0–8 seconds.
- Resends fast when possible, slowing down when necessary (e.g. many senders).



Sending Ethernet Packets

Ethernet

- Connecting Local Hosts
- Multiple Access Protocols
- **Sending Packets**
- Layer 2 Networks

Ethernet as LAN Network Protocol

Local Area Networks (LANs) are generally Ethernet.

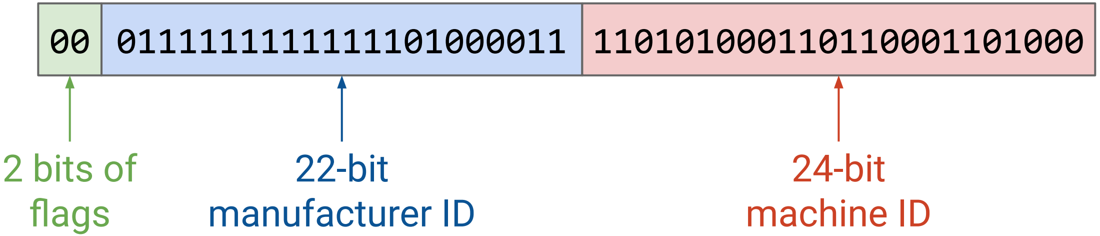
Machines in the same LAN can exchange messages directly at Layer 2!

- No need for IPs, routers, forwarding, etc.
- Analogy: If we're in the same room, we can talk without using the postal system.

Ethernet Addressing

At layer 2, each machine has a **MAC address** (*Media Access Control*).

- Can be used even if you don't have an IP address.
- 48 bits, written in hex, e.g. `f8:ff:c2:2b:36:16`.
- Stored permanently on the machine ("burned in").
  - Often can be overridden by software.
- Allocated according to organization, e.g. manufacturer of the machine.
- Globally unique. You might plug your computer in anywhere.



00 | 0111111111111101000011 | 110101000110110001101000

2 bits of flags

22-bit manufacturer ID

24-bit machine ID

Beware of endianness.

Types of LAN Communication

Ethernet supports three types of communication:

- **Unicast**: Send a packet to a single recipient.
- **Broadcast**: Send a packet to everyone on the local network.
- **Multicast**: Send a packet to everyone in a specific group.
  - Machines in the local network can join groups.

Types of LAN Communication (1/3) – Unicast

Unicast: Send a packet to a single recipient.

- Destination = the recipient's MAC address.

Recall: On a shared medium, everybody gets the signal.

- When you get a packet, check the destination to see if it's meant for you.
- If not, ignore the packet.

Types of LAN Communication (2/3) – Broadcast

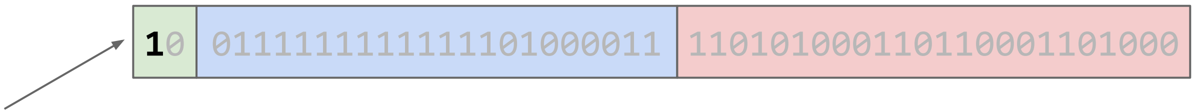
Broadcast: Send a packet to everyone on the local network.

- Packet already reaches everybody on the shared medium.
  - We just need to make sure everyone knows it's meant for them.
- Destination = the broadcast address, `FF:FF:FF:FF:FF:FF`.

Types of LAN Communication (3/3) – Multicast

Multicast: Send a packet to everyone in a specific group.

- Again, everyone gets the packet – need to ensure the group knows it's for them.
- Each group has a *group address*.
  - ○ Individual computer's address: First bit 0.
  - ○ Group address: First bit 1.
- Broadcast is just a special case of multicast, where everyone is in a group.



10 0111111111111101000011 110101000110110001101000

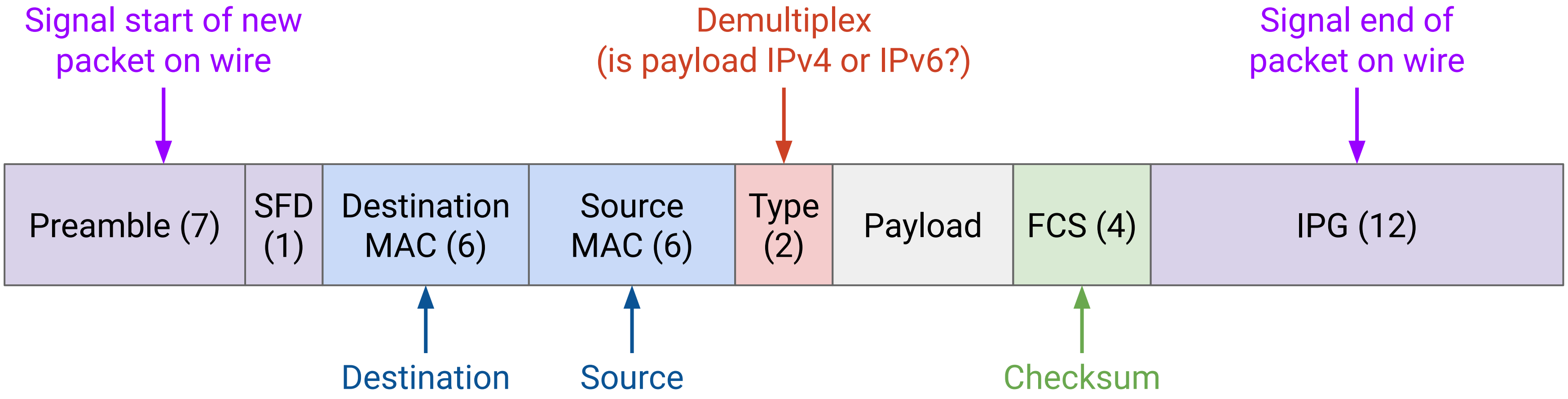
If this bit is 1, it's
a group address.

Beware of endianness.

Ethernet Packet Structure

A data packet in Ethernet is often called a *frame*.

- Many fields (destination, source, type, checksum) similar to IP header.
- Need additional fields to separate packets on the wire.



Layer 2 Networks

Ethernet

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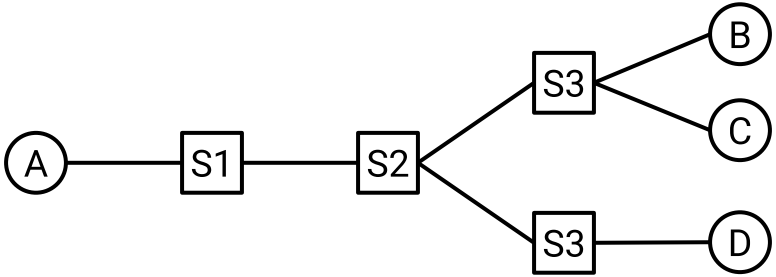
- **Layer 2 Networks**

Layer 2 Networks

We could use more than one wire in a local network.

Switches need to forward packets toward their destination.

- If a switch receives a broadcast packet: Send it to every neighbor.
- Multicast is more complicated. Need to know who's in the group.



Layer 2 Networks

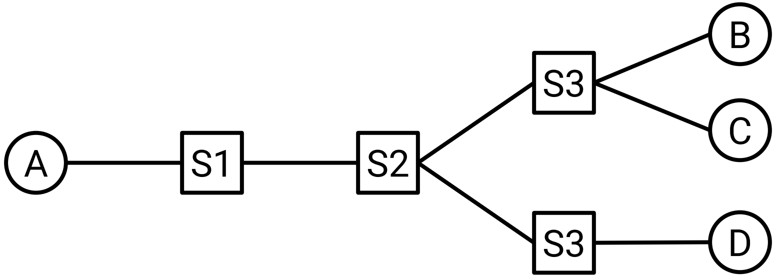
Routing protocols from Layer 3 can also be used at Layer 2.

- Destinations are MAC addresses, instead of IP addresses.

Problem: MAC addresses can't be aggregated.

- Allocated by manufacturer, not geographically.
- This is why Layer 2 can't scale to the Internet.

S2's Table	
Destination	Next Hop
A	R1
B	R3
C	R3
D	R4

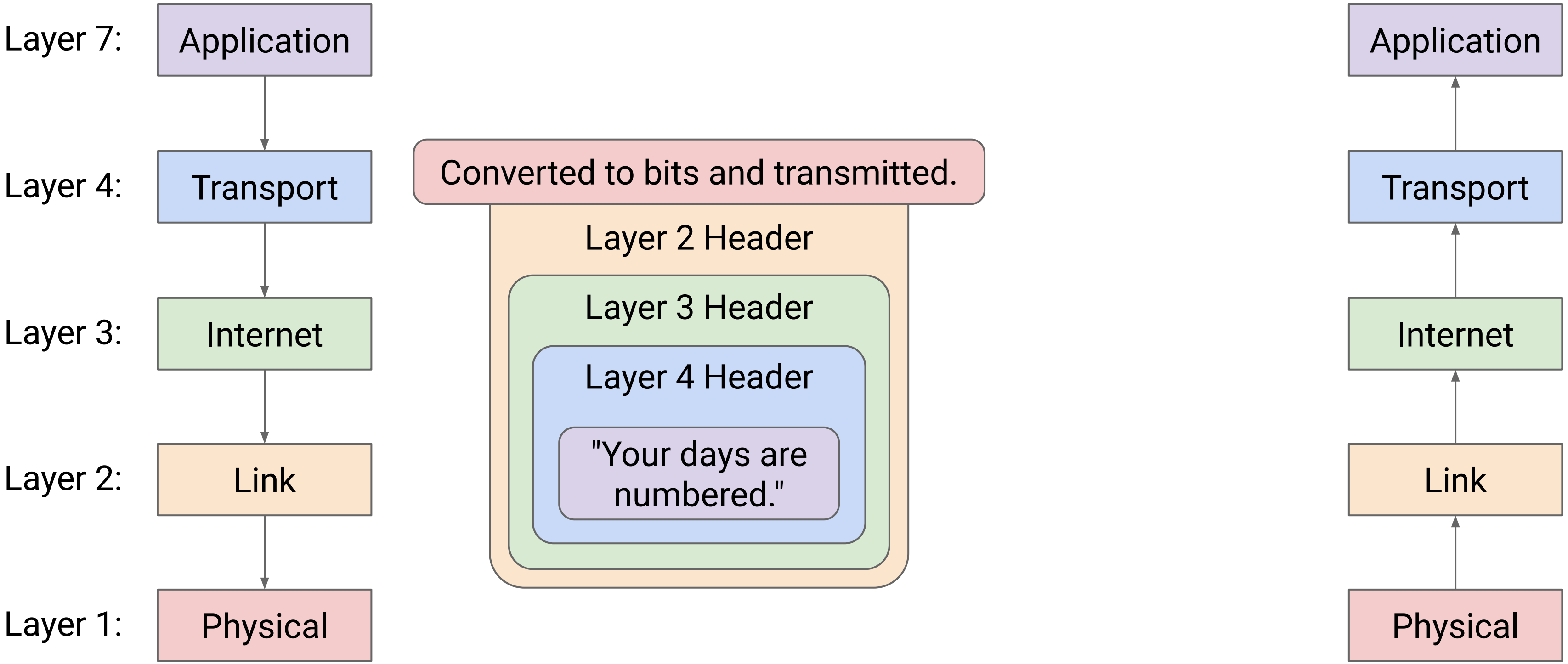


Questions?

Feedback Form:
https://tinyurl.com/cs168-disc-fa24

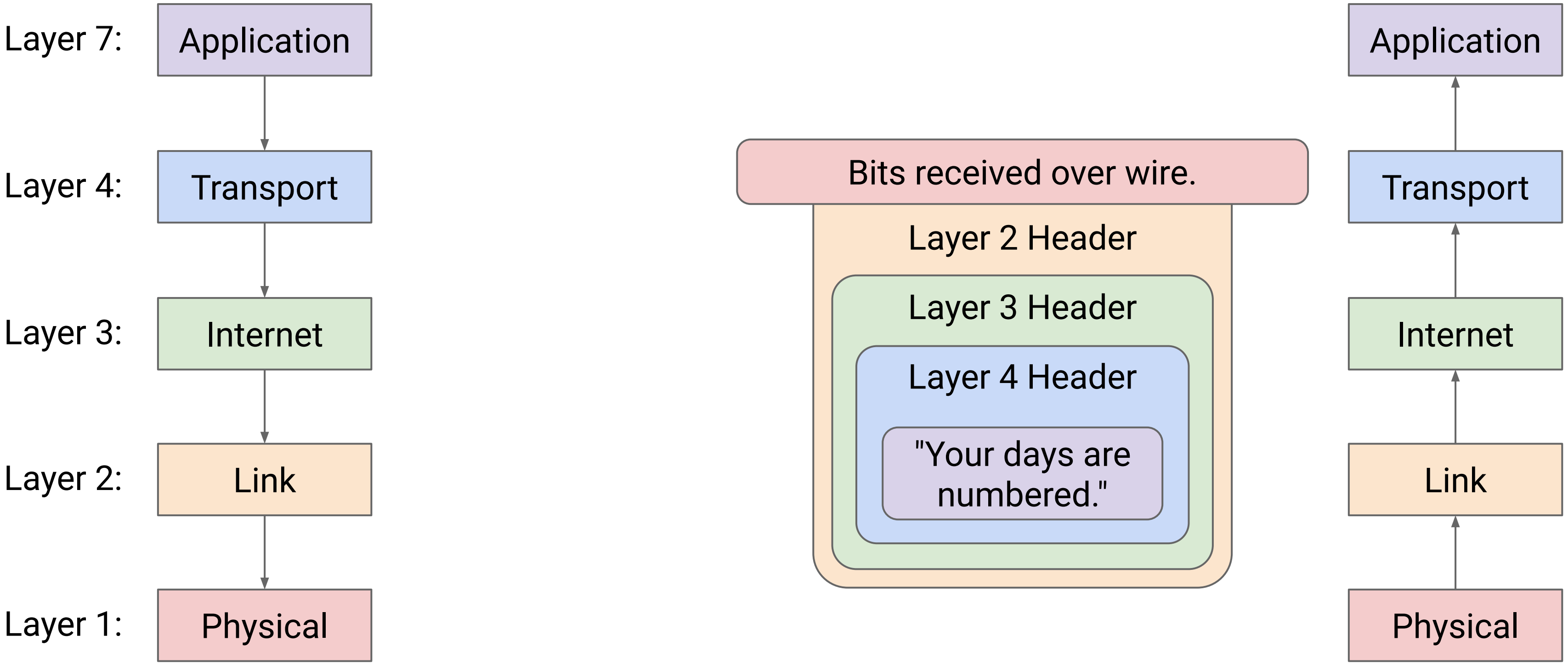
Multiple Headers

As we move to lower layers, we wrap additional headers around the packet.



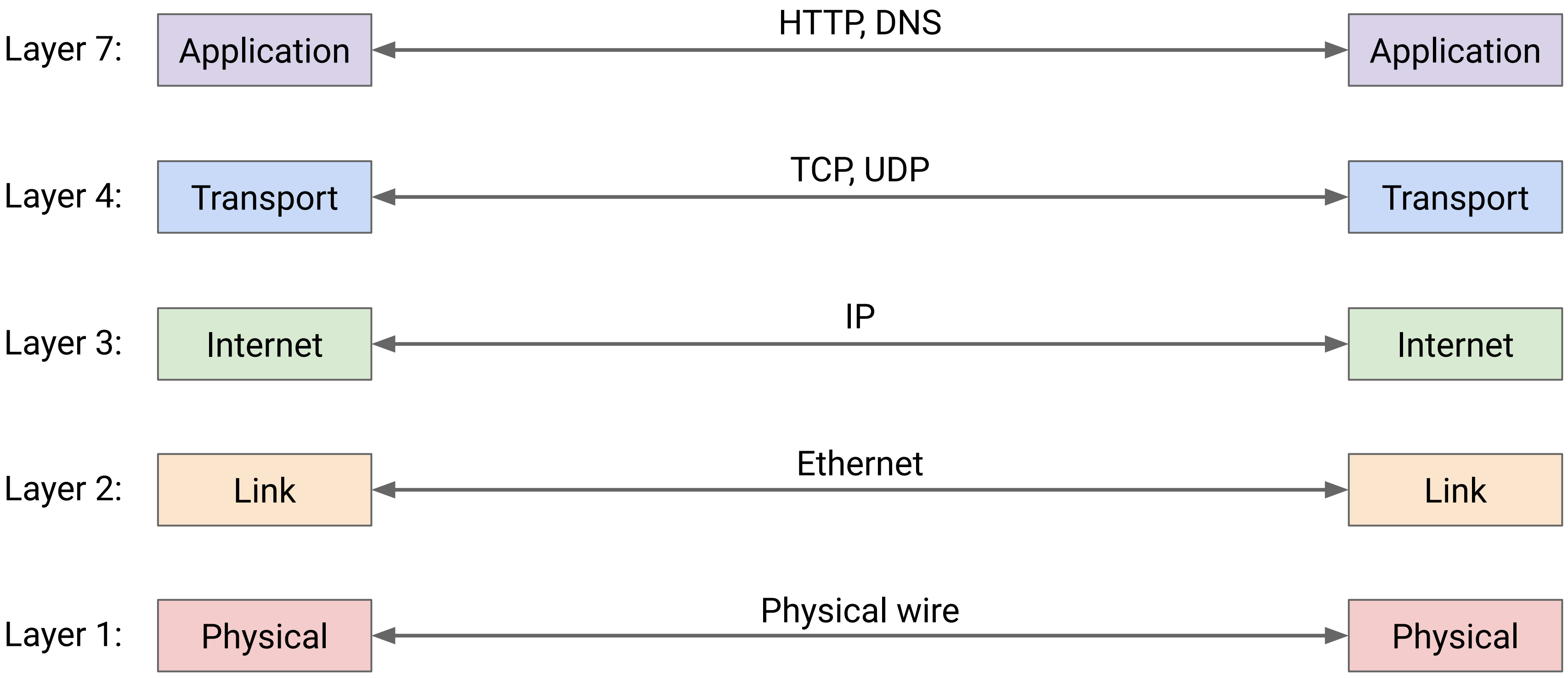
Multiple Headers

As we move to higher layers, we peel off headers, revealing the inner headers.



Multiple Headers

Peers at the same layer communicate with each other using the header at that layer.


Layer 7:
Application
HTTP, DNS
Application
Layer 4:
Transport
TCP, UDP
Transport
Layer 3:
Internet
IP
Internet
Layer 2:
Link
Ethernet
Link
Layer 1:
Physical
Physical wire
Physical