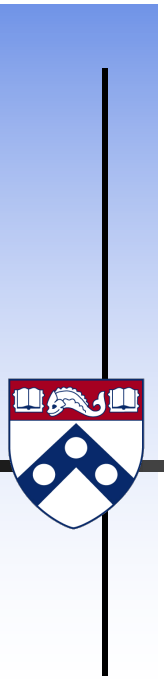


CIS 5530: Networked Systems

Components of a Network

January 25, 2023

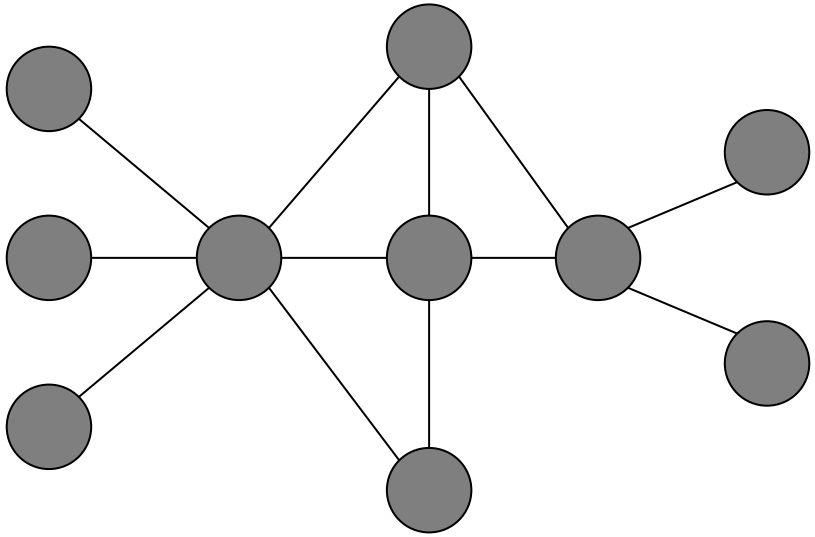
Agenda

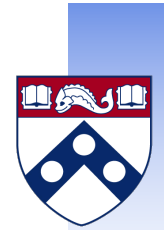
- Layering and the end-to-end principle 
- Performance metrics 
- Components of a Network 

  - Physical-layer links
  - Framing
  - L1/L2 nodes
  - VLANs

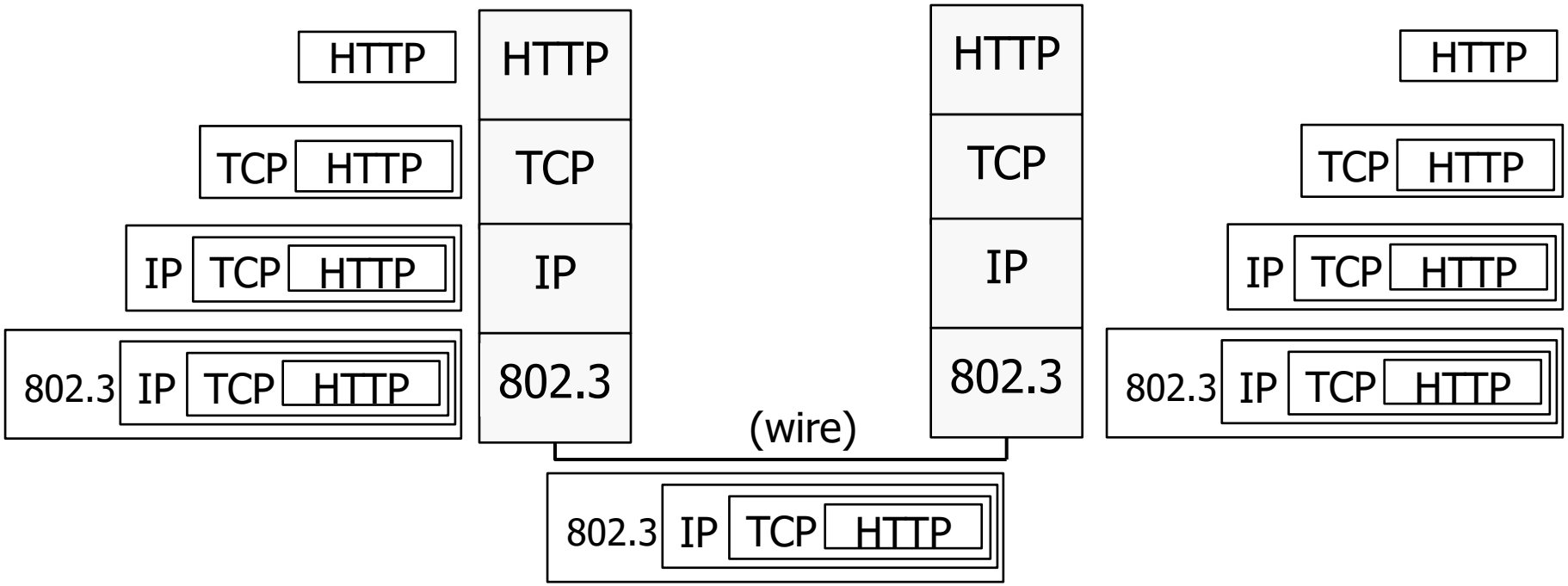
Networked Systems

- Study of systems of links that interconnect computers in order to move data

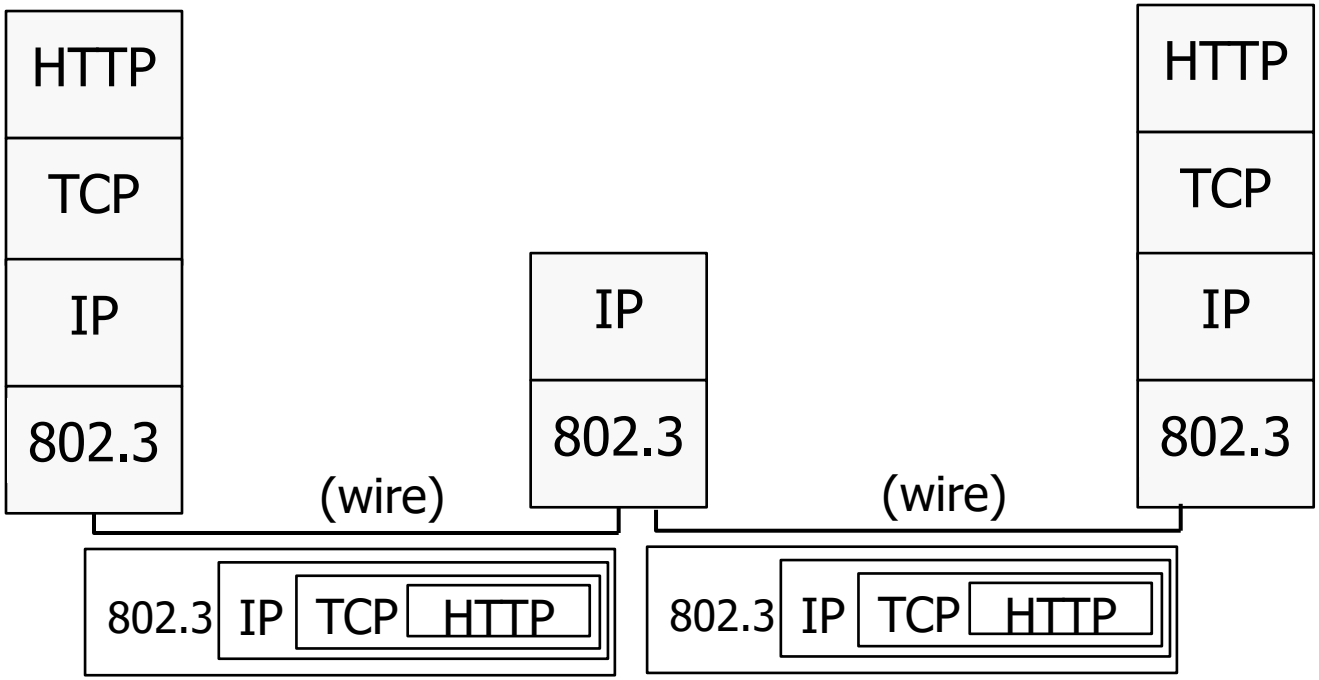




Encapsulation



Encapsulation (multihop)

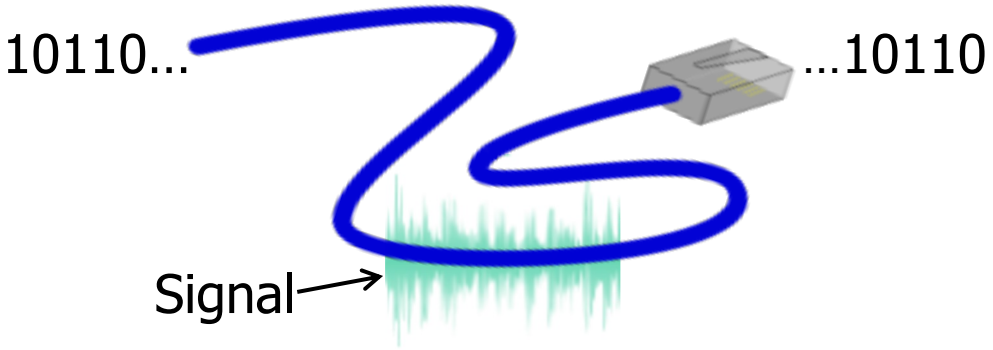


Layer 1: Physical layer

- Connects: Transmitters and receivers

- Lower interface: Analog signals
- Upper interface: Stream of digital bits

- Name of network: Physical links
- Name of message: Bits



Layer 2: Data link layer

- Connects: physical interfaces
  - Usually all the same physical layer protocol
- Lower interface: Stream of bits
- Upper interface: Messages with payloads
- Name of network: Local Area Network (LAN)
- Name of message: Frame

Layer 3: Network layer

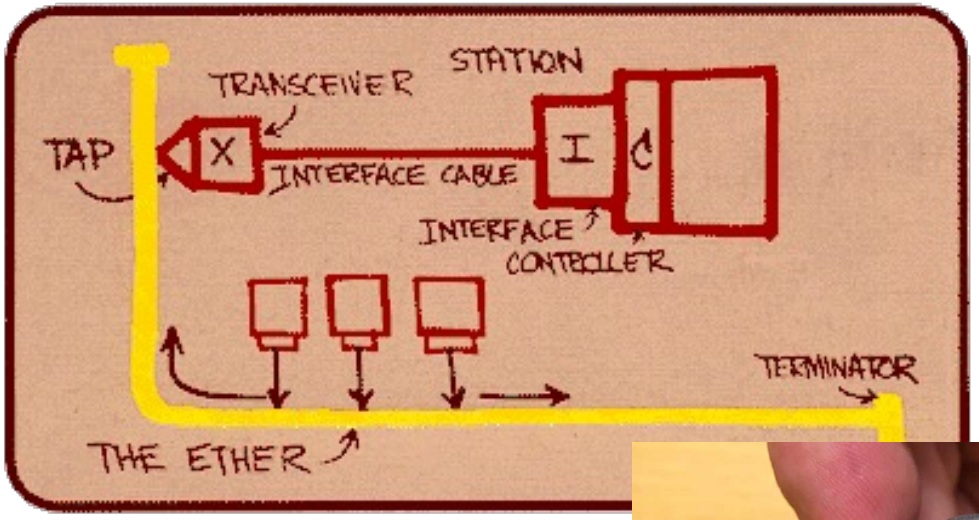
- Connects: LANs
  - Possibly different technologies (e.g., WiFi and Ethernet)
- Lower interface: A packet of data
- Upper interface: A segment of data
  - Same thing, just has an extra header
- Name of network: Internet
- Name of message: Packet

Agenda

- Components of a Network 
  - Physical-layer Links 

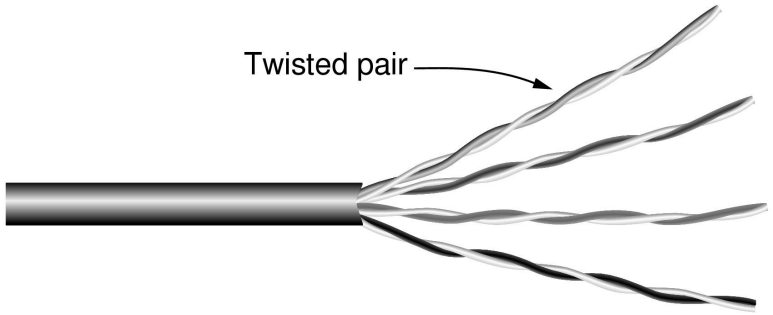
  - Framing
  - L1/L2 nodes
  - VLANs

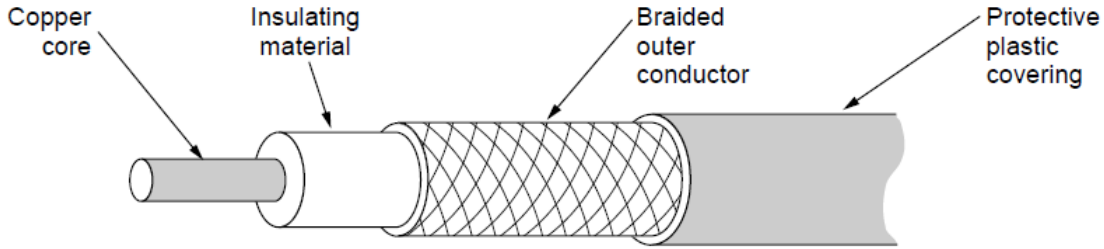
Links: Ethernet

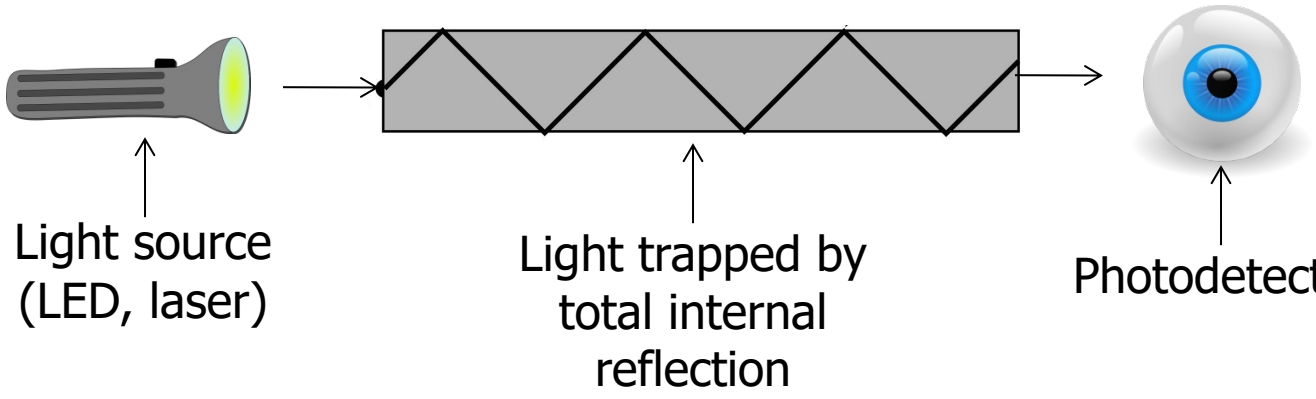


Metcalfe's Ethernet sketch

Links: Wires

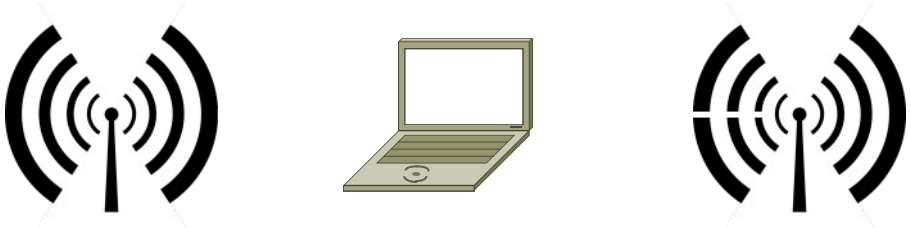

Twisted pair


Copper core
Insulating material
Braided outer conductor
Protective plastic covering


Light source (LED, laser)
Light trapped by total internal reflection
Photodetector

Links: Wireless

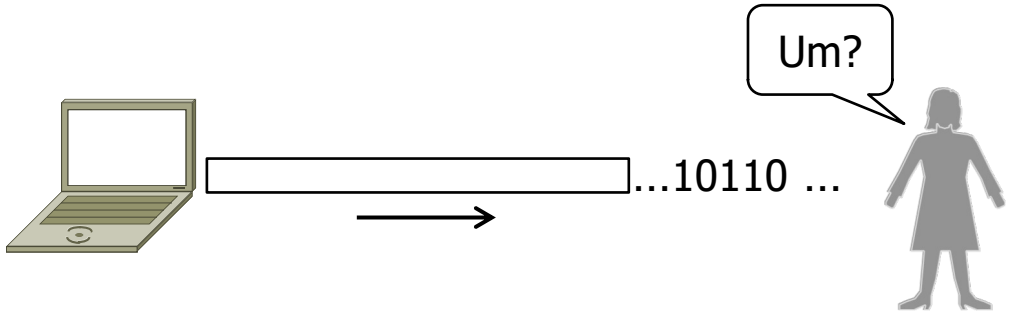
- Sender radiates signal over a region
  - In many directions, unlike a wire, to potentially many receivers
  - Nearby signals (same freq.) interfere at a receiver; need to coordinate use



How to convert bits to frames?

- Ex: A message in Ethernet:

- Physical layer puts bits on a link
- Framing problem: how does the link layer determine where each frame begins and ends?



Framing methods

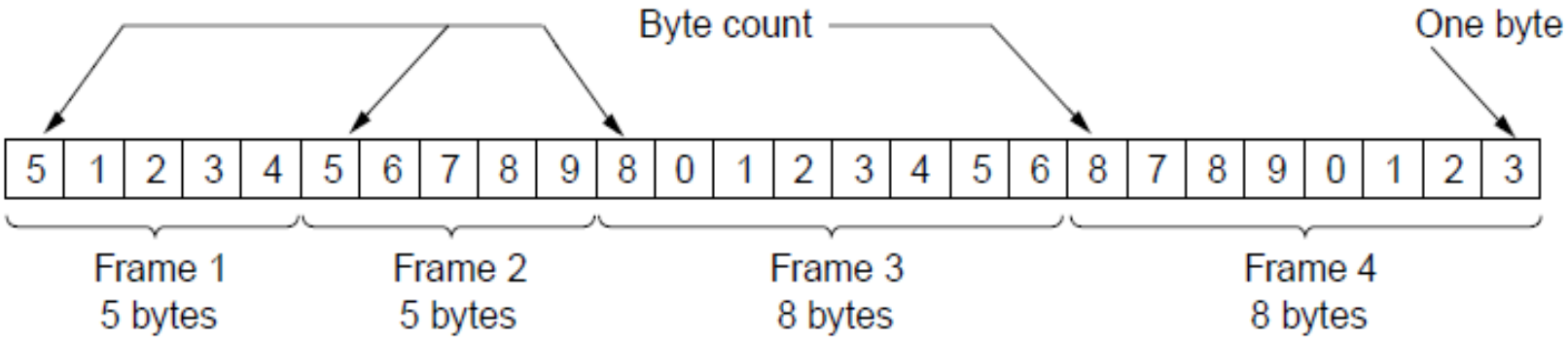
- We'll look at two:
  - Byte count (motivation)
  - Byte stuffing
- In practice, the physical layer often provides hints
  - E.g., if the signal on the wire goes flat, that's probably the end of a frame

Simple approach: byte count

- First try:
  - Let's start each frame with a length field!
  - It's simple, and hopefully good enough …

Simple approach: byte count

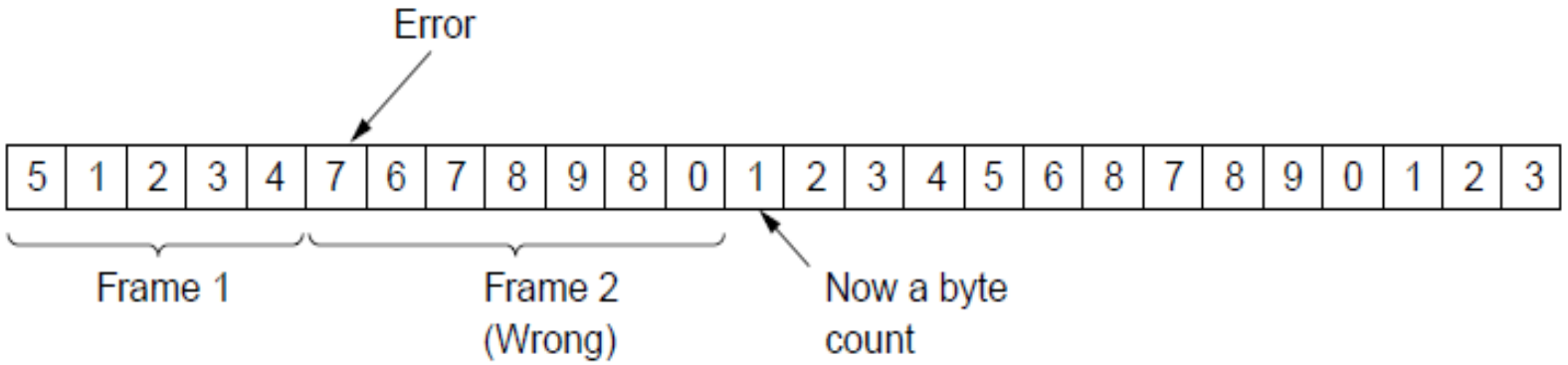
- First try:
  - Let's start each frame with a length field!



Are we done?

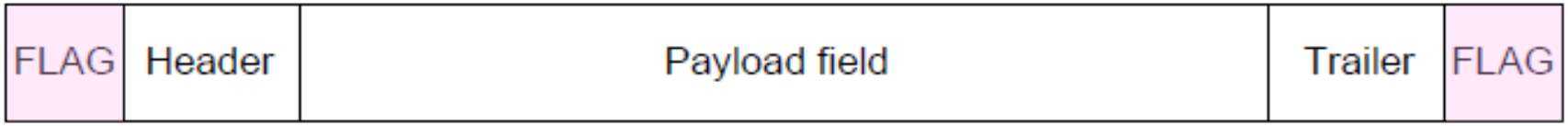
What if count is corrupted?

- We will frame the wrong bytes: framing error
  - Once framing on a link is desynchronized, it can stay that way
  - Need a method to resynchronize



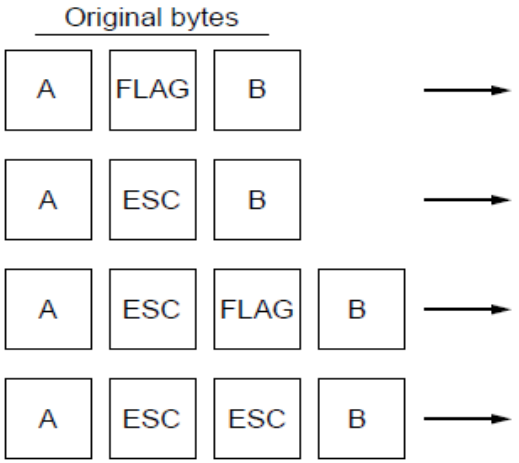
Byte stuffing

- Better idea:
  - Special FLAG byte that marks start/end of frame
  - When FLAG appears in the payload, "stuff" an escape character into the payload before the FLAG
  - Complication: must escape the escape code too!



Byte stuffing examples

- Rules:
  - Replace each FLAG in data with ESC FLAG
  - Replace each ESC in data with ESC ESC



Byte stuffing examples

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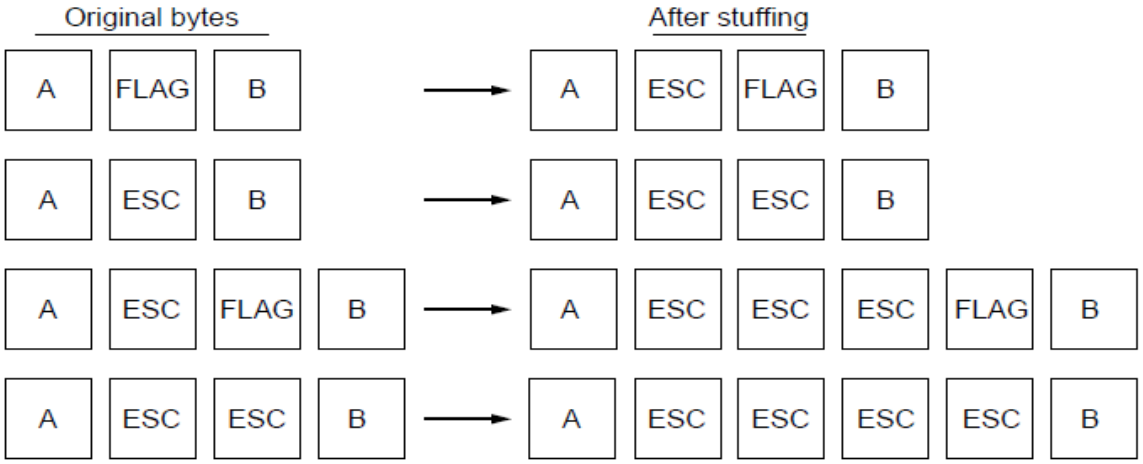


- Now any unescaped FLAG Is the start/end of a frame

Bit Stuffing

- Can stuff at the bit level too
  - Call a flag six consecutive 1s
  - On transmit, after five 1s in the data, insert a 0
  - On receive, a 0 after five 1s is deleted

Bit Stuffing Example

Data bits 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 0

Transmitted bits with stuffing

Bit Stuffing Example

Data bits 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 0

Transmitted bits with stuffing 0 1 1 0 1 1 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 0 1 0 0 1 0

Stuffed bits

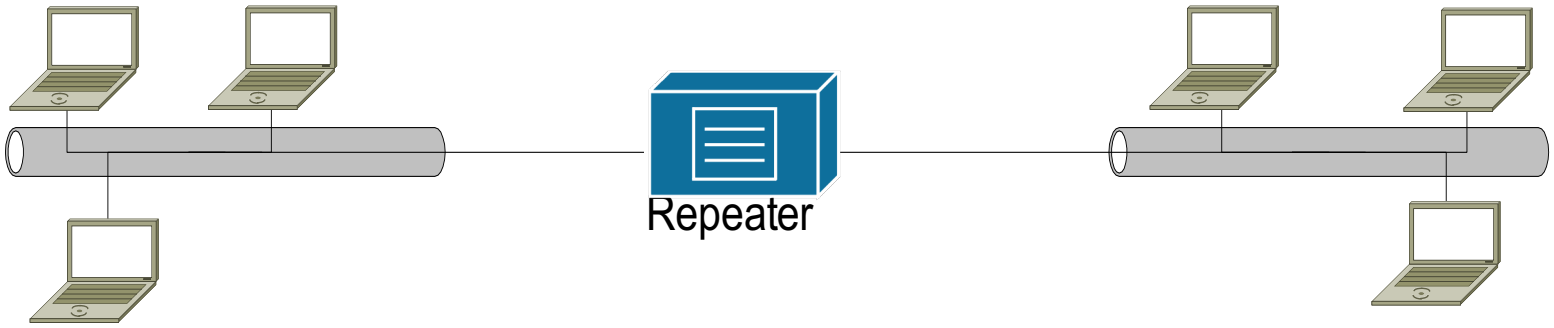
How does this compare with byte stuffing?

Agenda

- Components of a Network ✓
  - Physical-layer Links ✓
  - Framing ✓
  - L1/L2 nodes NEXT
  - VLANs

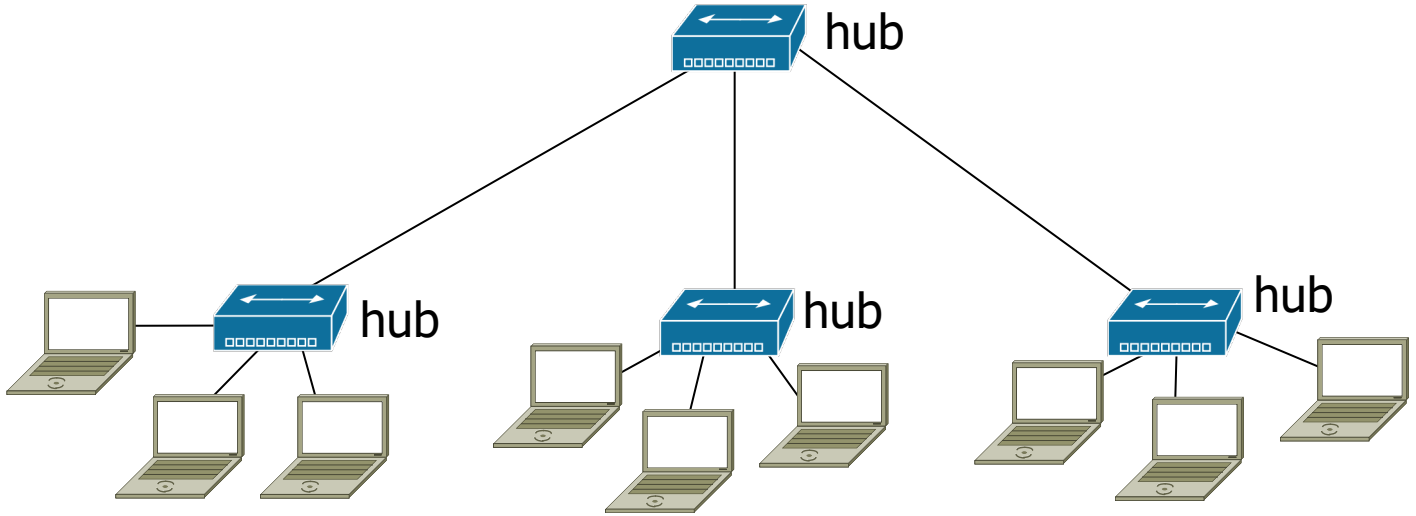
Physical Layer: Repeaters

- Distance limitations
  - Signals become weaker as they travel
  - Imposes a limit on the length of each segment of a LAN
- Repeaters join two segments together
  - Often analog electronic device
  - Continuously monitors electrical signals
  - Transmits an amplified copy



Physical Layer: Hubs

- Fancy name for multi-port repeater
- Joins multiple segments
  - Does not necessarily amplify the signal
  - Broadcasts traffic that arrives on every other port
- Very similar to repeaters
  - Also operates at the physical layer

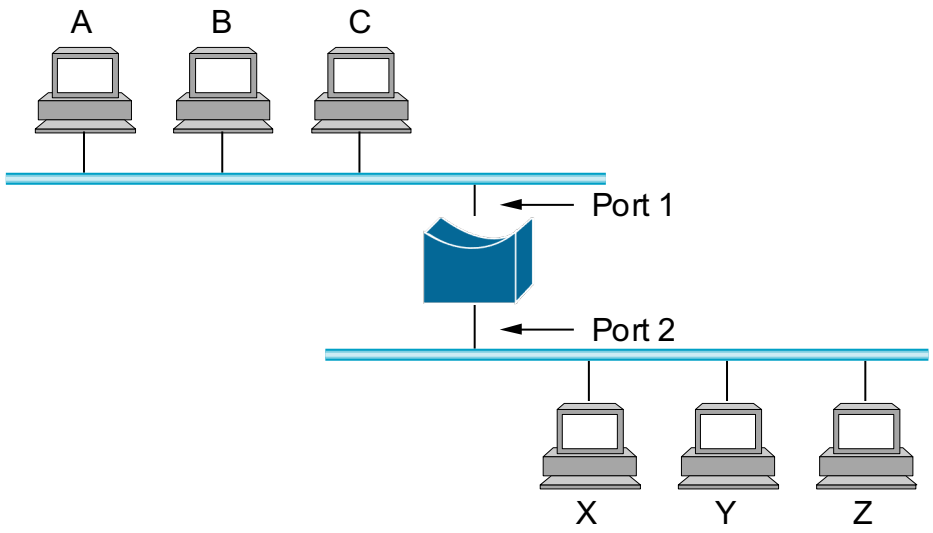


Limitations of Repeaters and Hubs

- One large shared LAN
  - Each bit is sent everywhere
  - So, aggregate throughput is limited
- Cannot support multiple technologies
  - Does not buffer or interpret frames
  - Can't interconnect between different rates/formats
- Limitations on maximum nodes and distances
  - Shared medium imposes length limits
  - E.g., cannot go beyond 2500 meters on Ethernet

Solution: Link Layer Bridges

- Connects two or more segments at the link layer
- Based around a forwarding table
  - Extracts destination address from the frame
  - Looks up the destination in a table
  - Forwards the frame to the appropriate segment

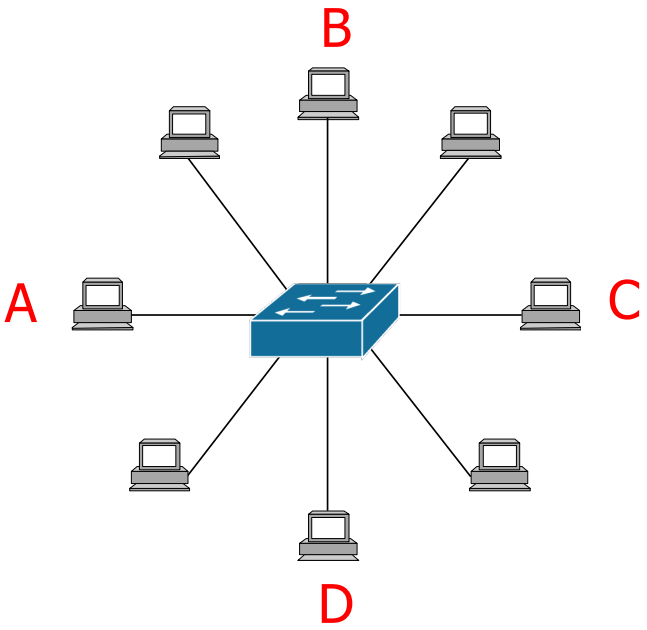


Host	Port
A	1
B	1
C	1
X	2
Y	2
Z	2

Forwarding table

Link Layer Switches

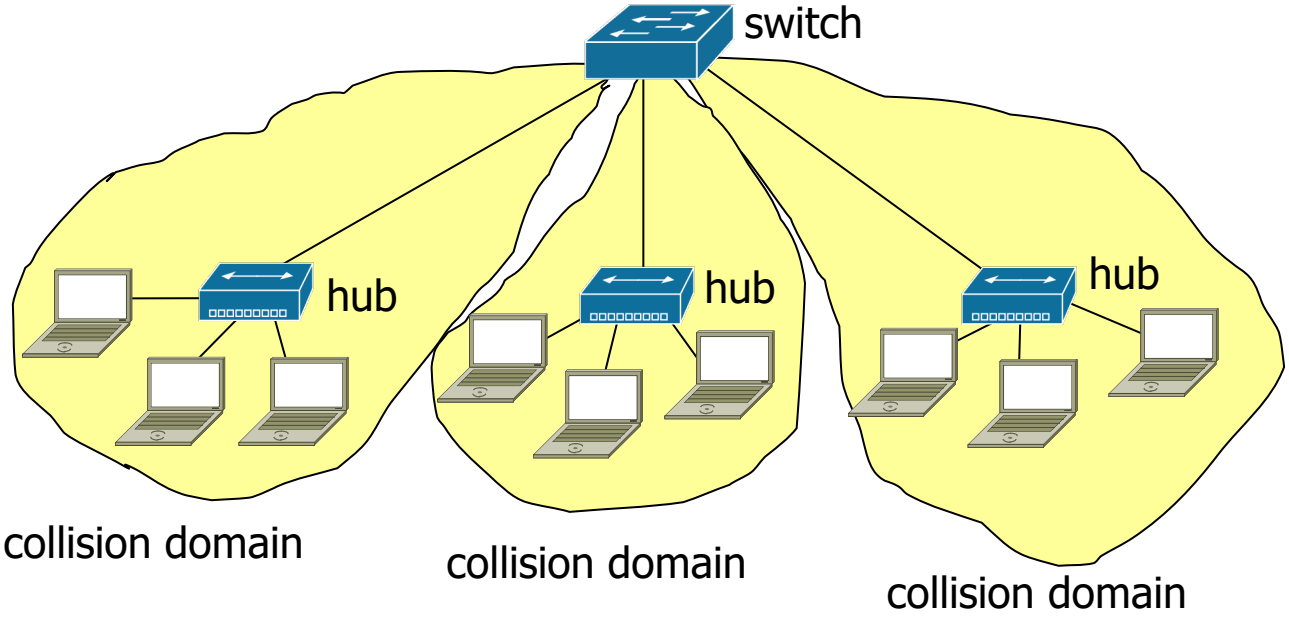
- Typically connects individual computers
  - A switch is essentially the same as a bridge
  - … though typically used to connect hosts, not segments
- Like bridges, support concurrent communication
  - Host A can talk to C, while B talks to D



Cisco Gigabit Ethernet switch

Bridges and Switches: Traffic Isolation

- Breaks network into segments
- Filters packets
  - Frame only forwarded to the necessary segments
  - Segments become separate collision domains



Advantages Over Hubs/Repeaters

- Only forwards frames as needed
  - Filters frames to avoid unnecessary load on segments
  - Sends frames only to segments that need to see them
  - Separate collision domains allow longer distances

- Joins segments using different technologies
  - E.g. Ethernet (10MBps, 100MBps) – made possible with buffering
  - Not complete heterogeneity
    - E.g. Ethernet and ATM not compatible