EECS 489
Computer Networks

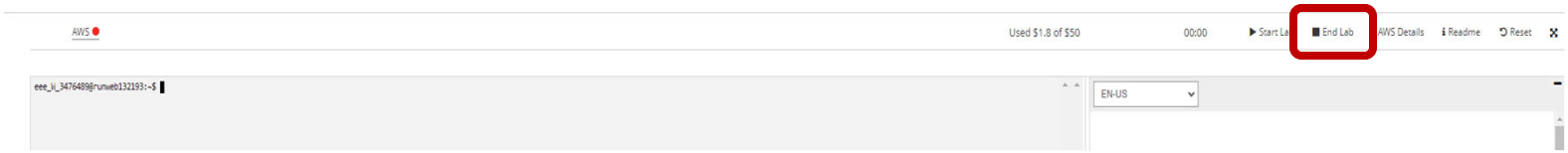
OSI Layers

Agenda

- Network Layers
- Performance Metrics

Announcements

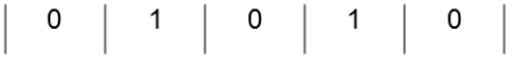
- Please complete the getting started with AWS exercise
- Important Note:
  - Please “End Lab” each time after you are done working on AWS



Simplest network

- How do we connect two computers/devices/hosts?
  - We just use a wire to connect them

- How do we transmit data from A to B?
  - Data is always going to be a sequence of 0s and 1s



  - The voltage on the wire can be high or low

  - Frequency Shift

  - Phase Shift

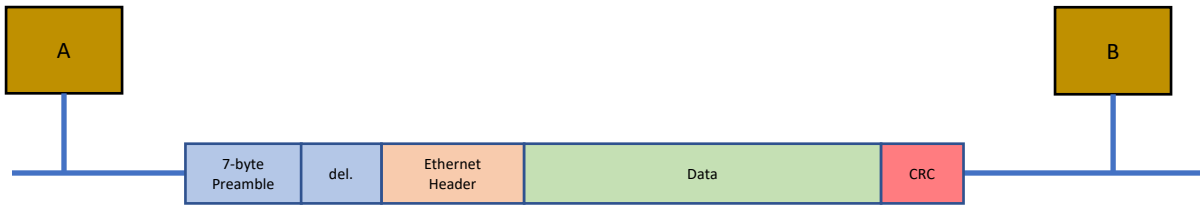
  - And Others

Medium of Transmission

- Twisted pair cable
- Coaxial Cable
- Optical Fibre
- Radio Transmissions

Data Frames

- Frames are way of breaking a stream of bits into data
- A Frame defines which bits have which function
- At a minimum – frames mark where data starts and where data ends



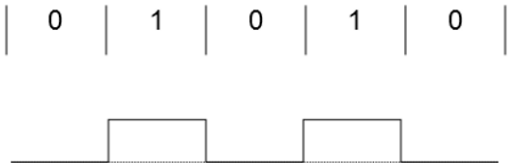
Error Checking

- A Frame can have bit errors – some bits flip from 0 to 1 or from 1 to 0
  - Electrical Interference
  - Thermal Noise

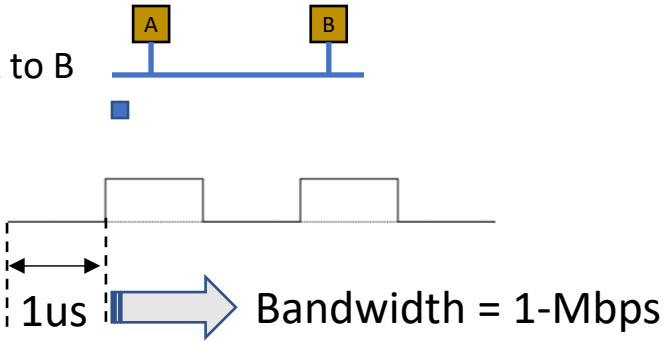
- CRC block is used to detect errors
- CRC = Cyclic Redundancy Check

Performance

- Lets assume some wired connection with high/low voltage representing 1/0

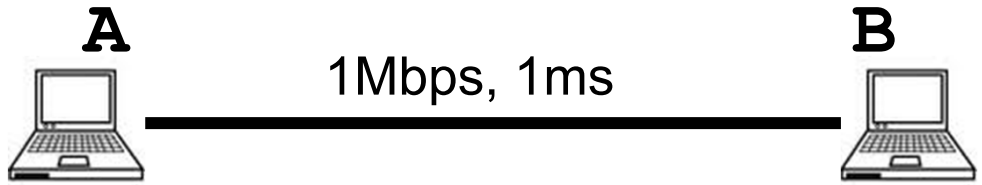


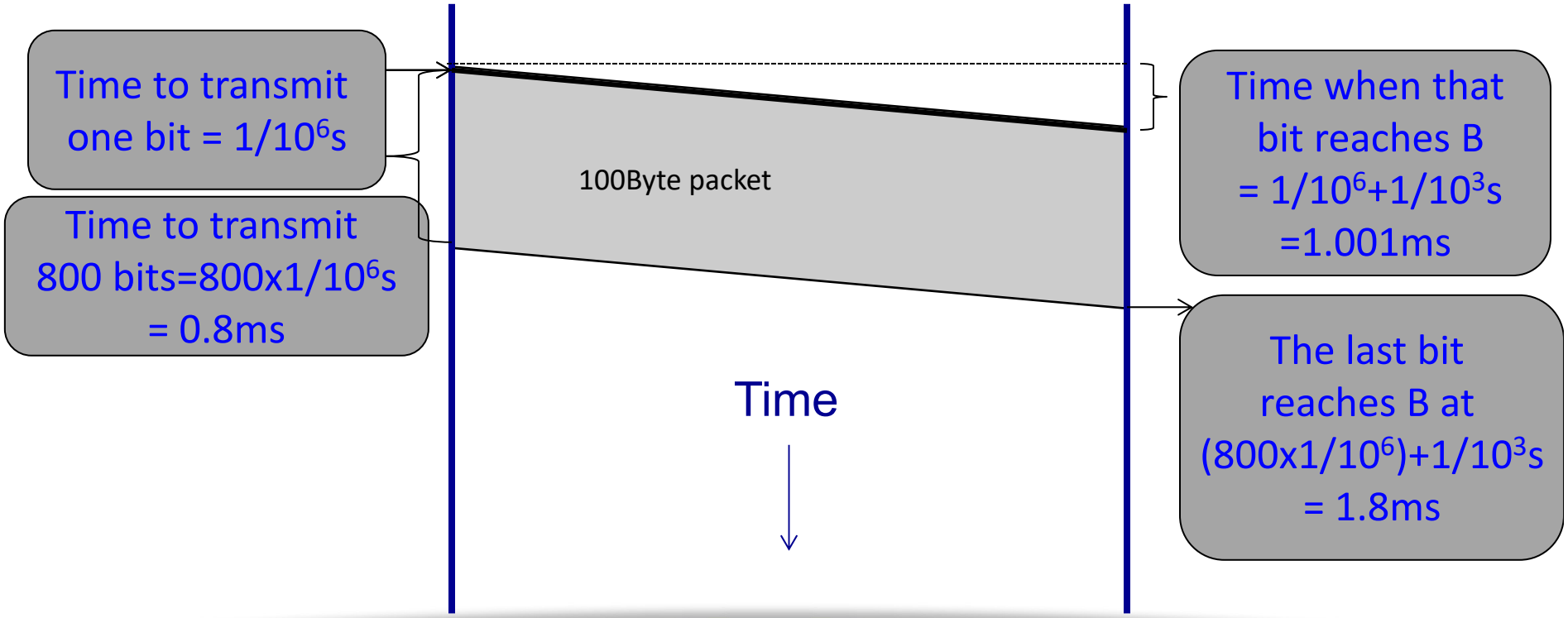
- Delay
  - Propagation Delay - Time for one bit to move from A to B
    - Link Length / Link Speed
    - 30km / 3×10^8 m/sec = 0.0001 sec
  - Transmission Delay
    - Size of data / Bandwidth (bits/(bits/sec))



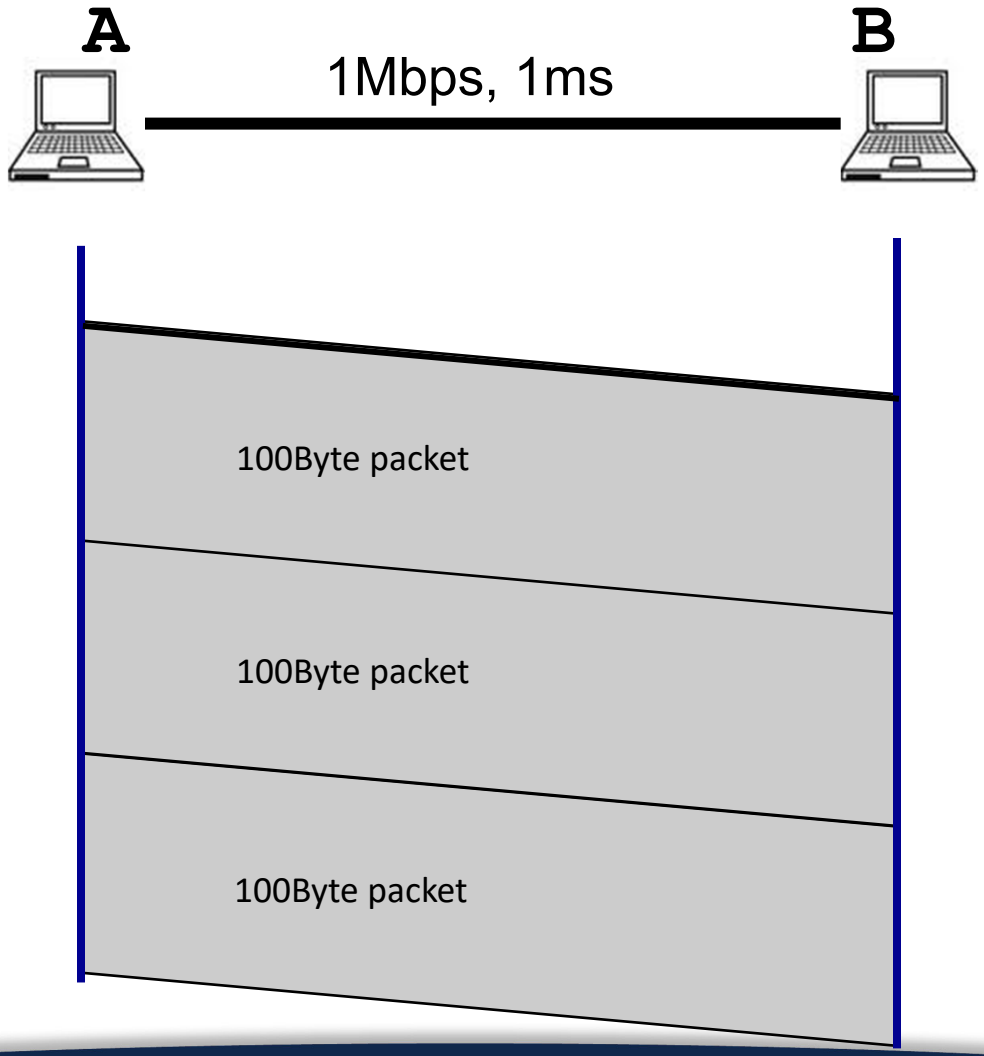
- Delay = Propagation + Transmission (for now)

Packet delay - Sending a 100-byte packet

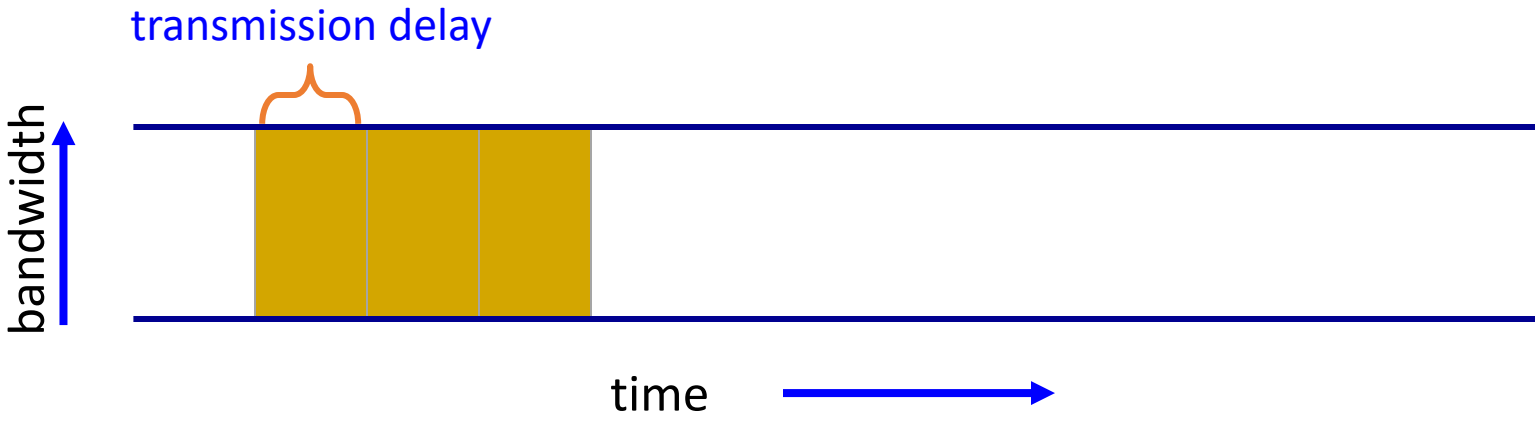




Sending a large file using 100-byte packets



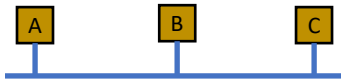
Pipe view of a link



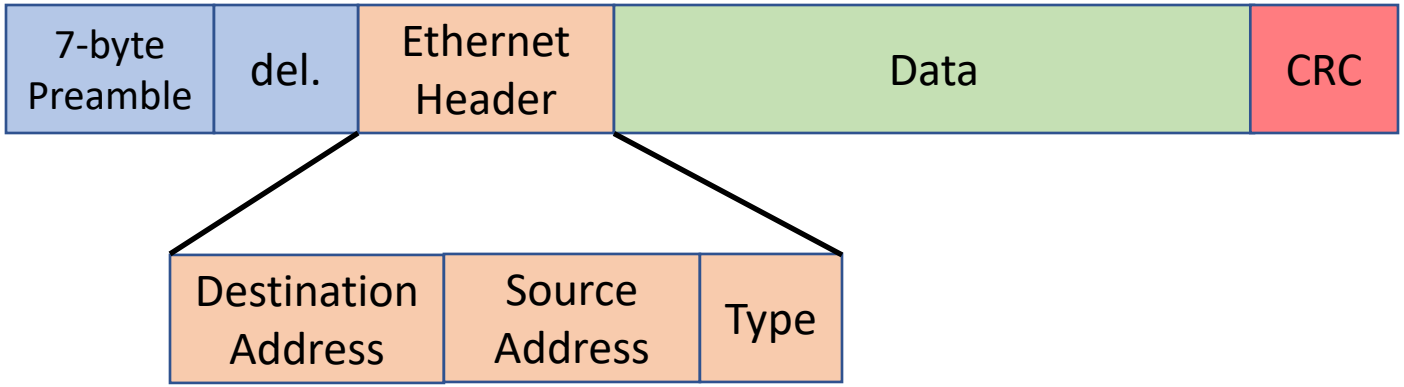
Transmission delay decreases as bandwidth increases

Simple Network with multiple hosts

- What are the challenges?
  - Addressing
  - Collisions



- Addressing
  - Assign an address to each hardware device (actually the network interface)
  - So when A transmits to B, the frame will have address for A and address for B
    - Why address of A?



Collisions

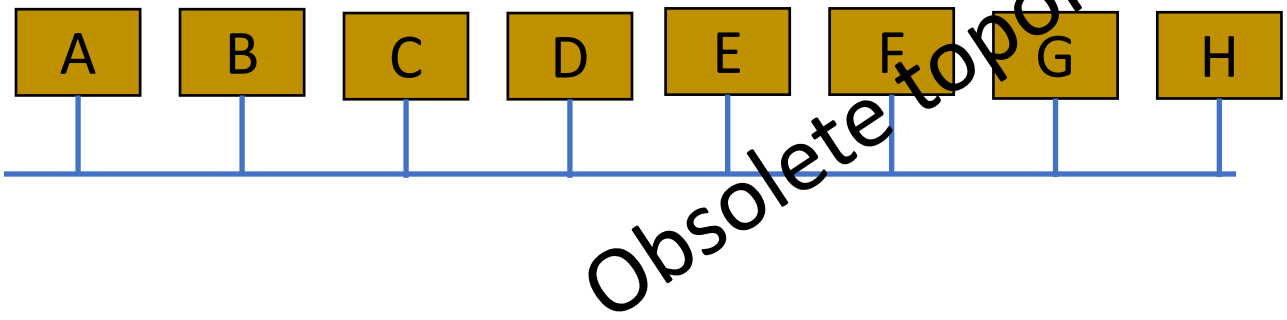
- Carrier Sense, Multiple Access with Collision Detect (CSMA/CD)
  - CSMA
    - Sense the carrier, if activity detected – wait
    - Transmit if no activity
  - CD
    - Listen on the channel while transmitting, if you hear your own message – no collision

What do we have so far

- We can send bits between two computers using some physical medium
- We can send bits using a Frame between two computers on a physical medium with multiple computers

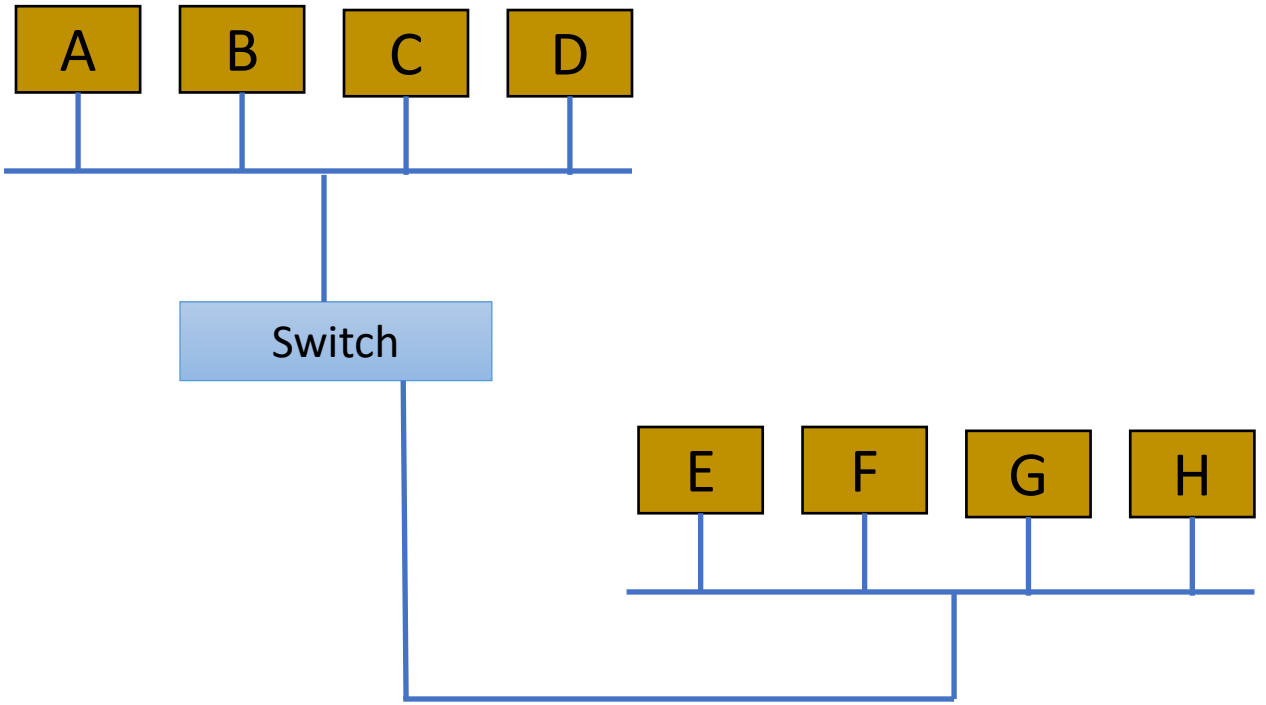
Scaling the network

- What happens when our network grows:



- Single collision domain
- Harder to Manage and difficult to scale
- Physical limitation on number of hosts in some cases

Switches

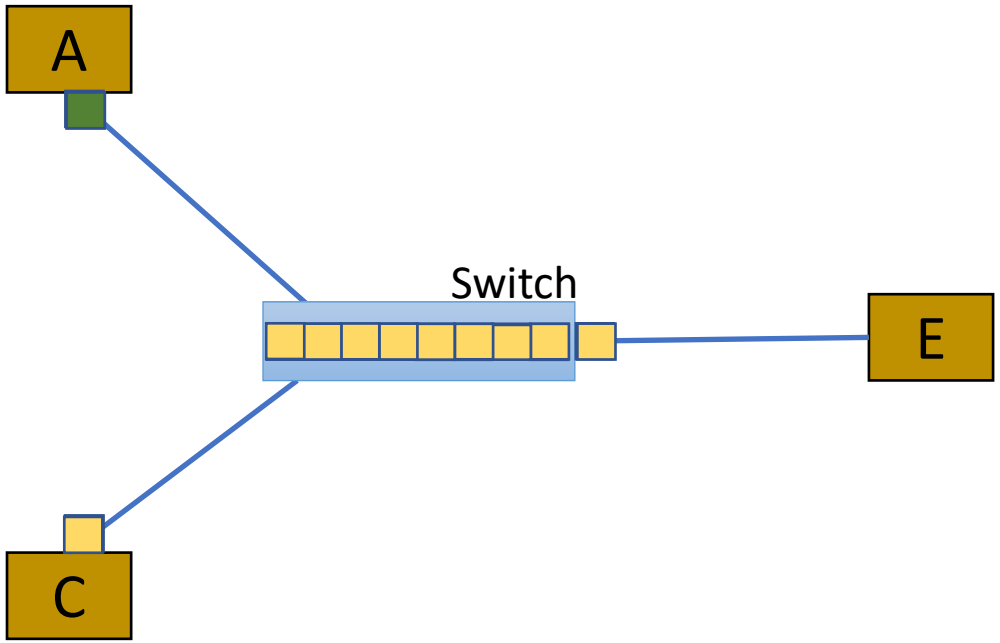


Switches

- What do switches do:
  - Forward packets from one port to the other ports
  - Breakup collision domains
  - Allow for scalability

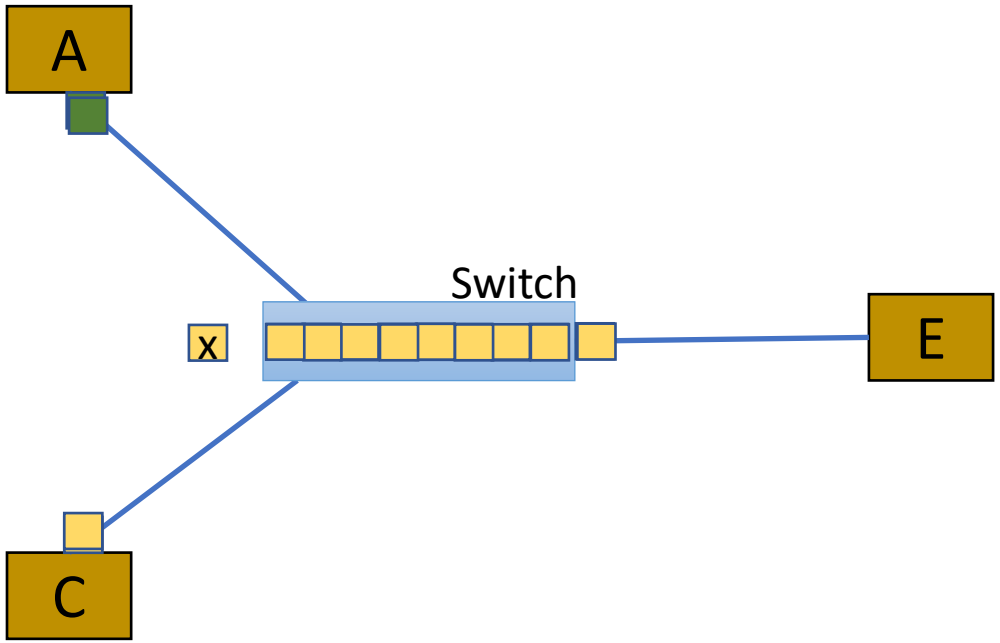
Communications

- Hosts A and C have data to Transmit to Host E



Communications – Issues?

- Host A and C have data to Transmit to Host E



Queueing delay

- How long does a packet have to sit in a buffer before it is processed?

- Depends on traffic pattern
  - Arrival rate at the queue
  - Nature of arriving traffic (bursty or not?)
  - Transmission rate of outgoing link

Queueing delay

- How long does a packet have to sit in a buffer before it is processed?

- Characterized with statistical measures
  - Average queuing delay
  - Variance of queuing delay
  - Probability delay exceeds a threshold value

Basic queueing theory terminology

- Arrival process: how packets arrive
  - Average rate A
- W: average time packets wait in the queue
  - W for “waiting time”
- L: average number of packets waiting in the queue
  - L for “length of queue”

Little's Law (1961)

- L = A x W
- Compute L: count packets in queue every second
- Why do you care?
  - Easy to compute L, harder to compute W
- Arrival process: how packets arrive
  - Average rate A
- W: average time packets wait in the queue
  - W for "waiting time"
- L: average number of packets waiting in the queue
  - L for "length of queue"

4. Processing Delay

- How long does the switch take to process a packet?
  - Negligible

End-to-end delay

transmission

propagation

queueing

processing

transmission

propagation

queueing

processing

transmission

propagation

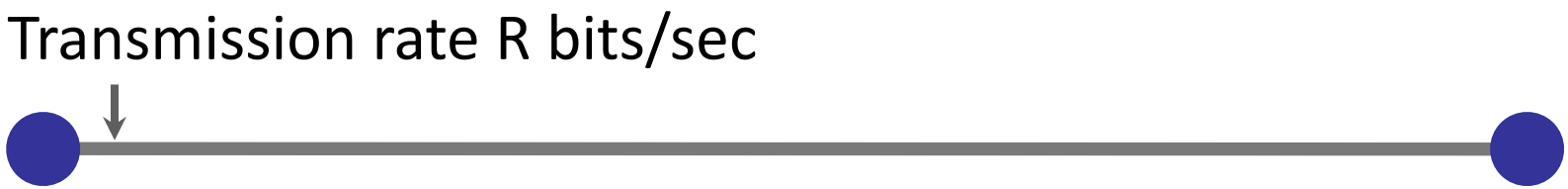
Loss

- What fraction of the packets sent to a destination are dropped?

Throughput

- At what rate is the destination receiving data from the source

Throughput – Single Link



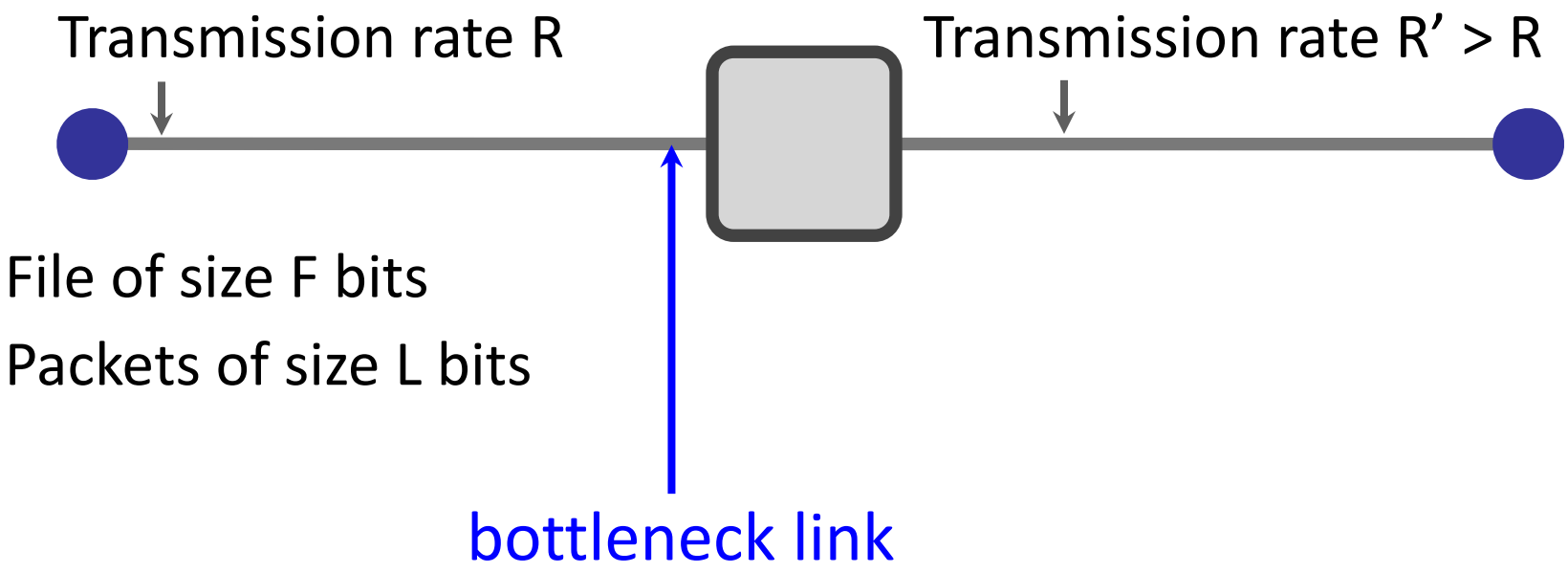
File of size F bits

Packets of size L bits

Transfer time (T) = F/R + propagation delay

Average throughput = F/T ≈ R

End-to-end throughput



Average throughput = $\min\{R, R'\} = R$

What do we have so far

- We can send bits between two computers using some physical medium
- We can send bits using a Frame between two computers on a physical medium with multiple computers
- We can connect multiple computes using some physical medium
- We can connect multiple networks through switches/bridges to break collision domains

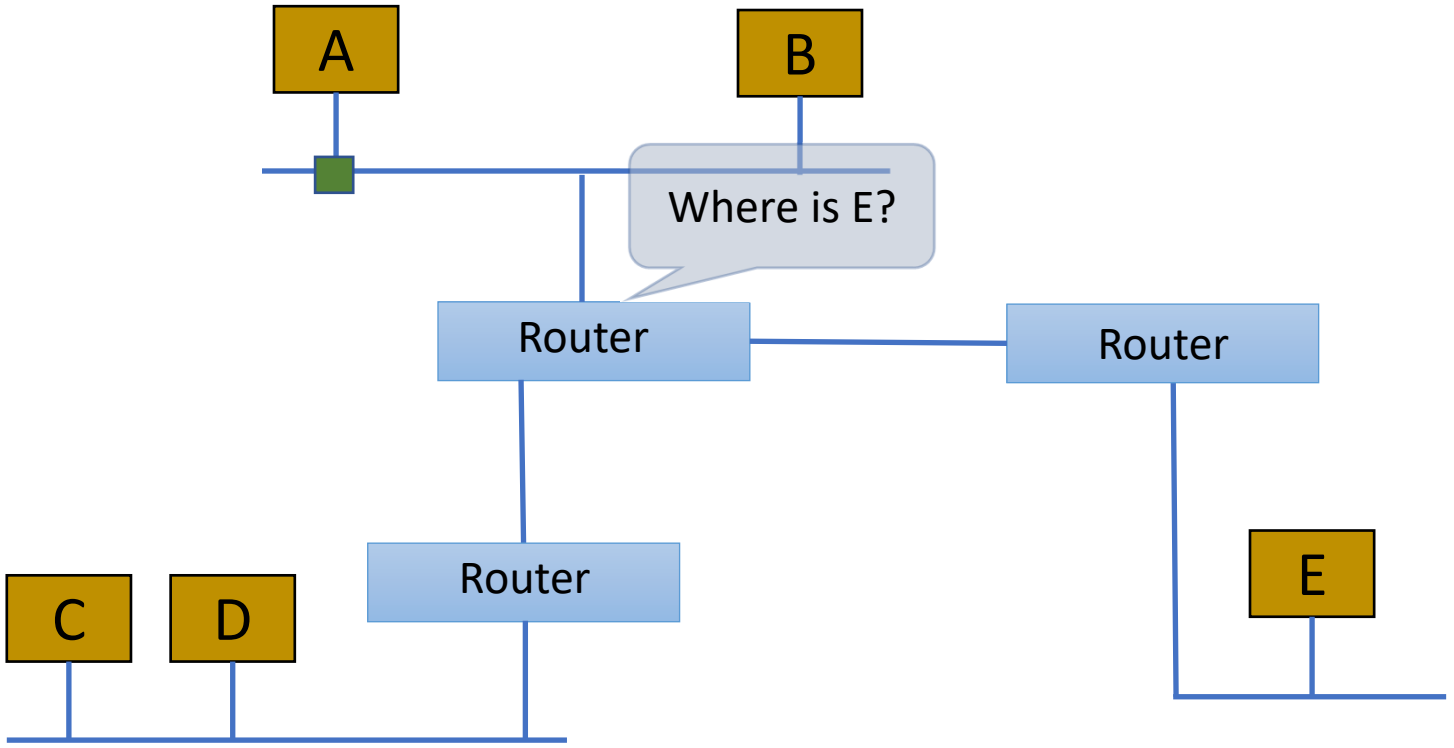
Network Layers

Defines the format of data + MAC Addresses

Transmits raw bits over physical medium

Finding hosts

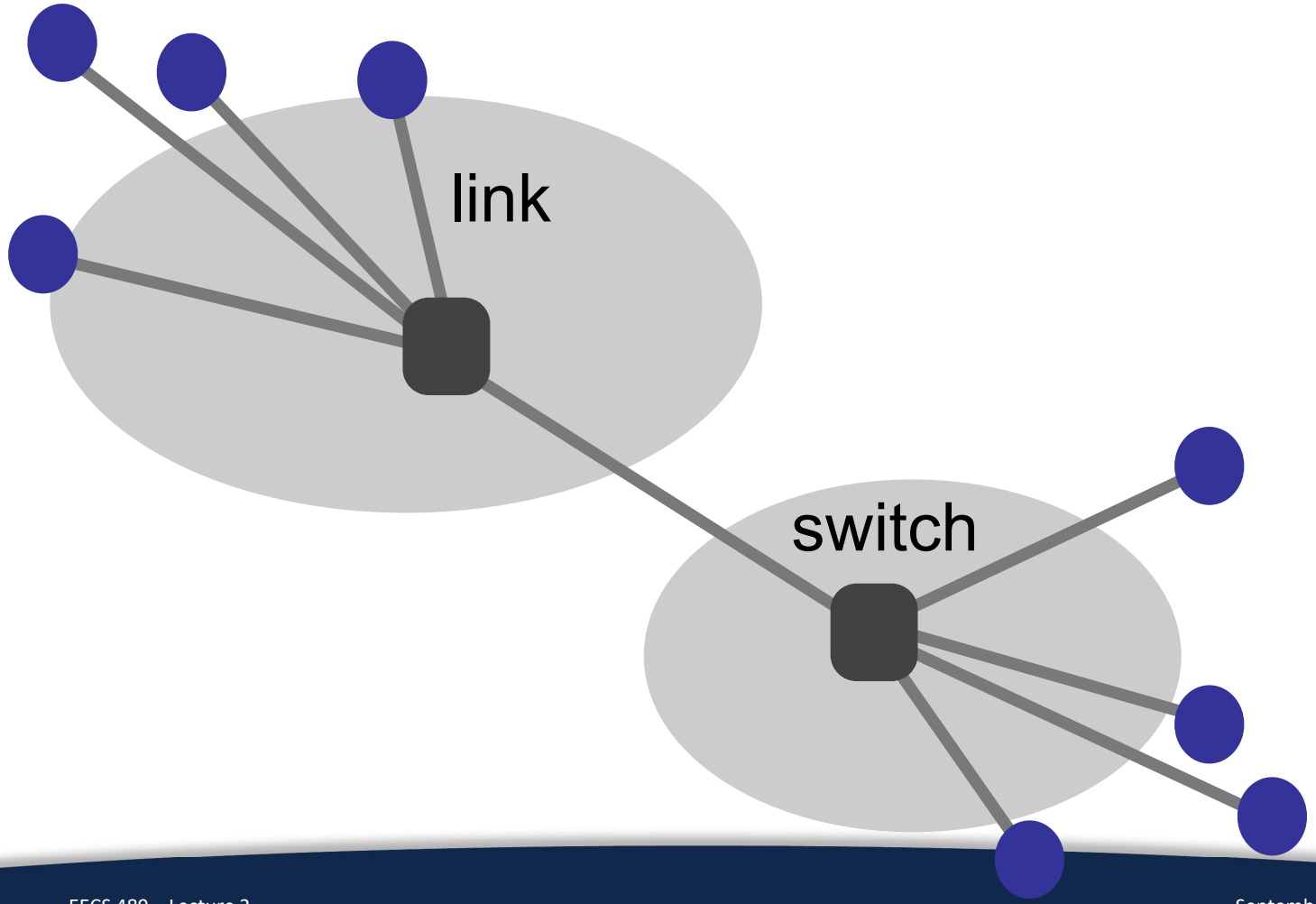
- A wants to transmit to E



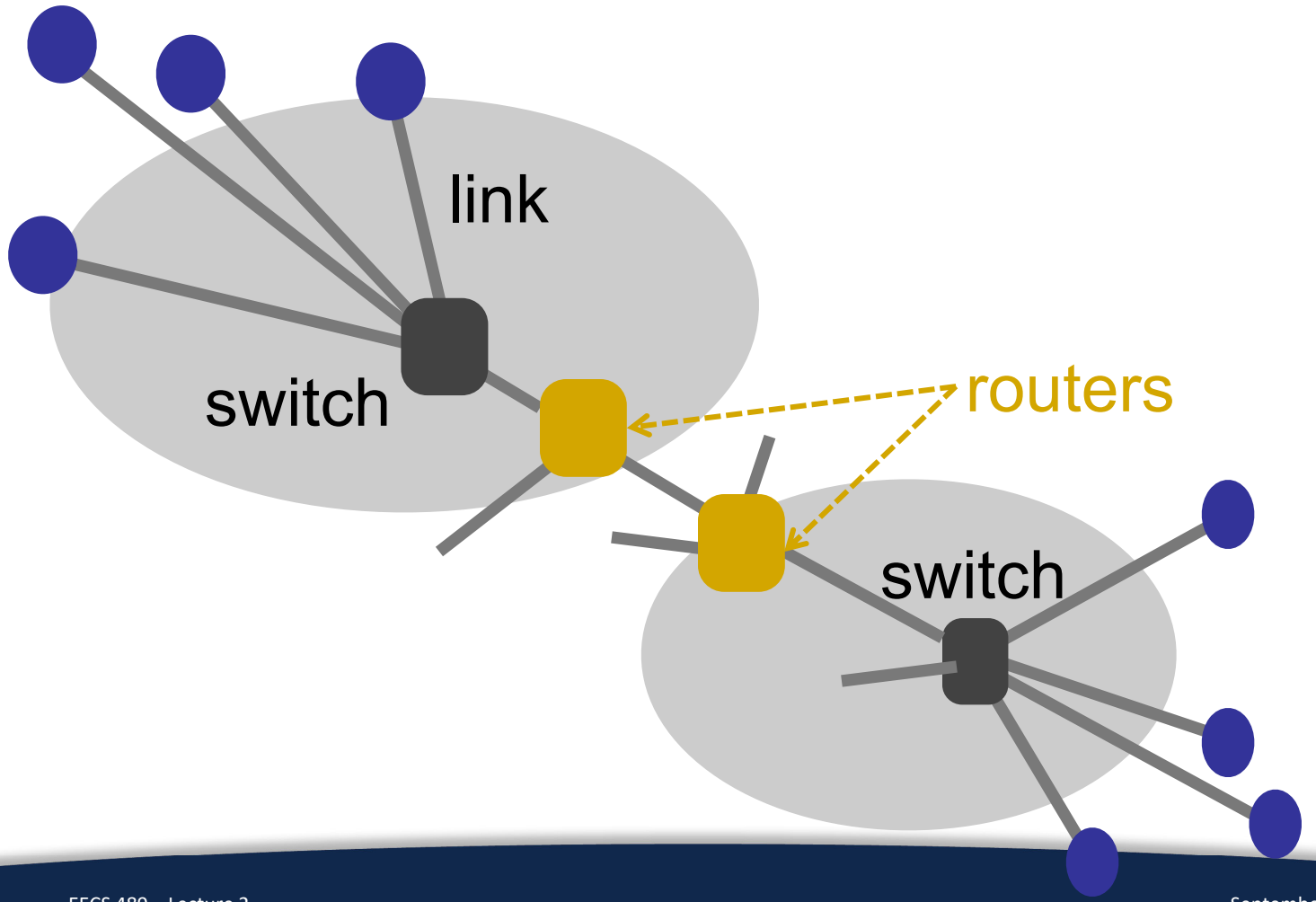
Network Layer

- Physical addresses are agnostic to geography
- How do we scale the routing system (how we find paths between packet source to packet destinations)?
- Hierarchy in network addresses will help.
- IP (Internet Protocol) addresses
  - 192.168.24.1
- IP is a best effort protocol – I will try my best to get your packet to the destination

A closer look at the network



A closer look at the network

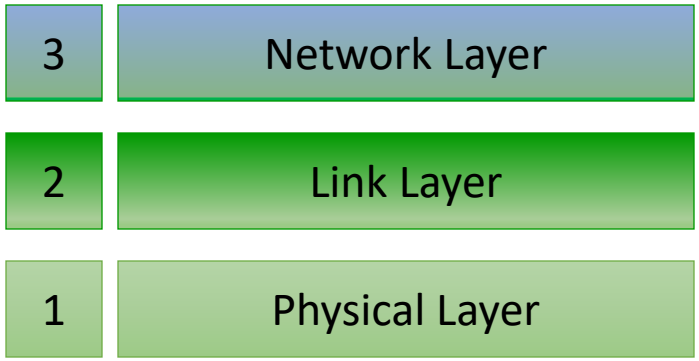


Switches vs. Routers

- Switches do what routers do but don't participate in global delivery, just local delivery
  - Switches only need to support L1, L2
  - Routers support L1-L3

- Won't focus on the router/switch distinction
  - Almost all boxes support network layer these days

Network Layers



Determines routes for data through the network

Defines the format of data + MAC Addresses

Transmits raw bits over physical medium

What gets implemented in the network?

- Bits arrive on wire → physical layer (L1)
- Packets must be delivered across links and local networks → datalink layer (L2)
- Packets must be delivered between networks for global delivery → network layer (L3)

- Switches implement only physical and datalink layers (L1, L2)
- Routers implement the network layer too (L1, L2, L3)

End to End connectivity

- If we are pedantic, hosts don't communicate with each other processes do – hosts are just carrying process data
- Processes have different requirements
  - Get my packet to the host as soon as possible
  - Make sure my packet gets to the destination
  - Make sure packets gets to the destination with some time guarantee
- If we receive a packet, we need to know which process it belongs to
  - Port numbers

Transport Layer

- End-to-End Protocols
- UDP
  - Connectionless protocol.
  - It is used for VoIP, video streaming, gaming and live broadcasts.
  - The packets don't necessarily arrive in order.
  - Allows missing packets -- the sender is unable to know whether a packet has been received.
  - Better suited for applications that need fast, efficient transmission
- TCP
  - Reliable protocol where the receiver always sends either positive or negative acknowledgement about the data packet to the sender.
  - Ensures in-order delivery of data.
  - Connection oriented - requires that connection between source and destination is established before sending data.
  - TCP provides flow control and quality of service.

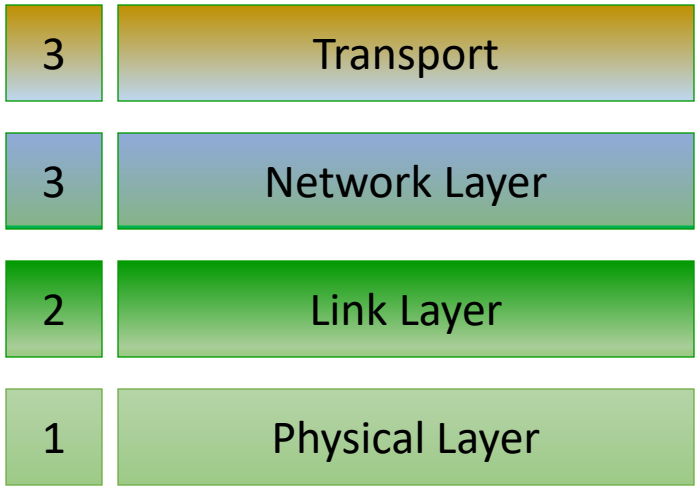
Round Trip Time (RTT)

- Time for a packet to go from a source to a destination and to come back

- Why do we care?
  - Measuring delay is hard from one end

- RTT/2 equals *average* end-to-end delay
  - Why not exact?

Network Layers



Provides End-to-End connectivity

Determines routes for data through the network

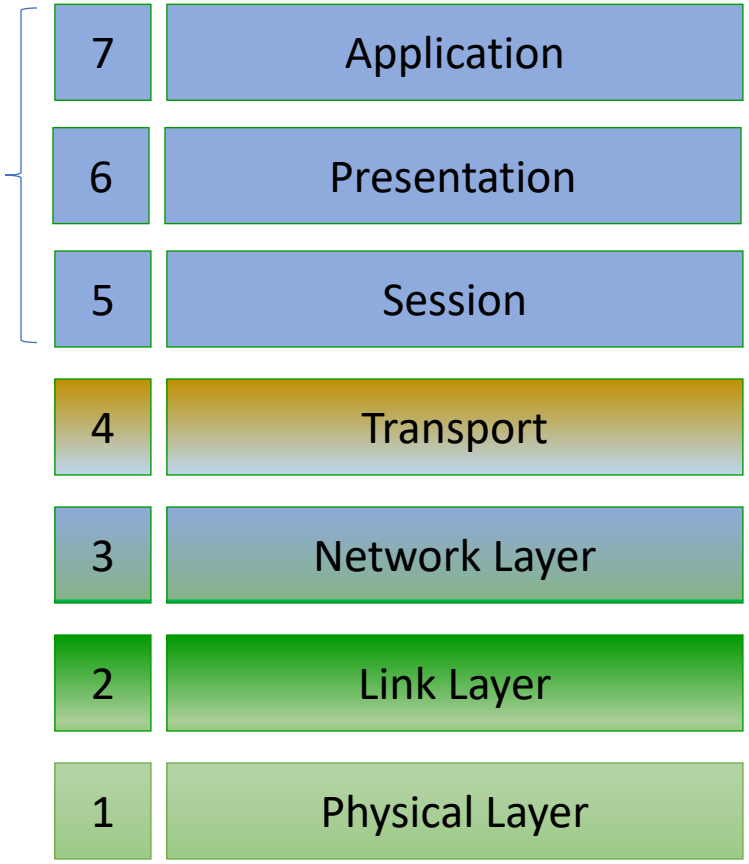
Defines the format of data + MAC Addresses

Transmits raw bits over physical medium

Top Three layers

- Application Layer
  - This is where the application protocols reside like HTTP, FTP, SMPT, DNS, etc.
- Presentation Layer
  - Encryption/Decryption
  - Compression
  - Encoding
- Session Layer
  - Communication Channels
  - Checkpointing Data Transfers

Network Layers



High level applications that users can interact with

Data Encoding, Compression, and encryption

Maintain Connections and ports

Provides End-to-End connectivity

Determines routes for data through the network

Defines the format of data + MAC Addresses

Transmits raw bits over physical medium

Quiz 1 – Due Aug 28 by 10pm

- https://forms.gle/tG6EU5cQSPTsfKi3A