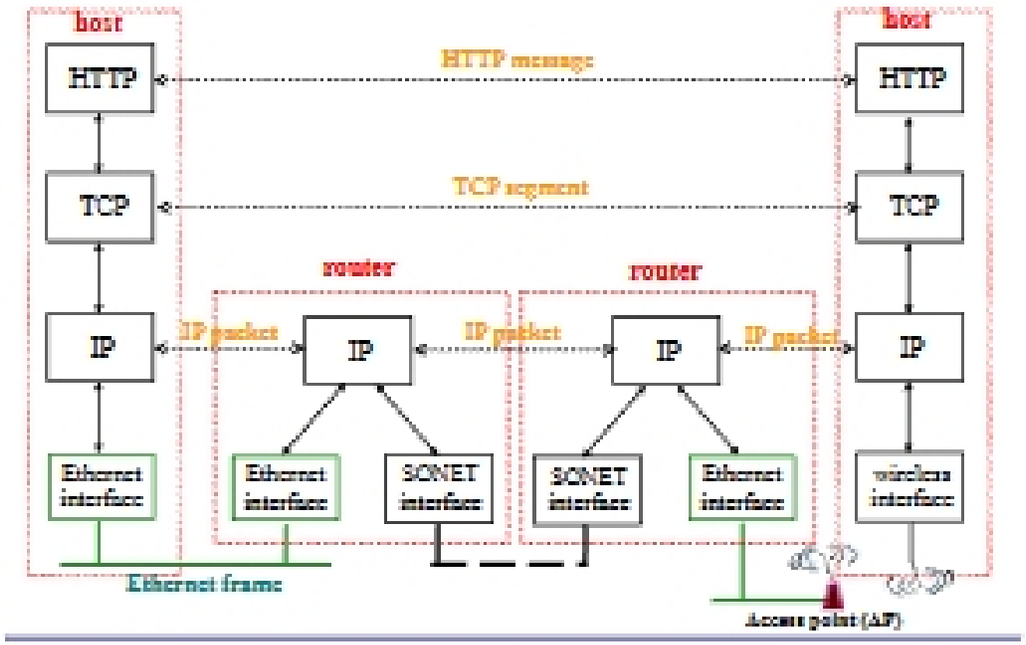
About the Final Exam

- Saturday June 4 3:00-6:00PM
- Open book, open notes; no computers
- Material to be covered
  - Chapter 2: focusing on 2.2 & 2.5
  - Chapter 3: focusing on TCP (3.5 & 3.7)
  - Chapter 4: 4.4 ~ 4.7
  - Chapter 5: 5.3 ~ 5.6
  - Chapter 6: 6.3 and 6.5
- The objective: testing the overall understanding of the material

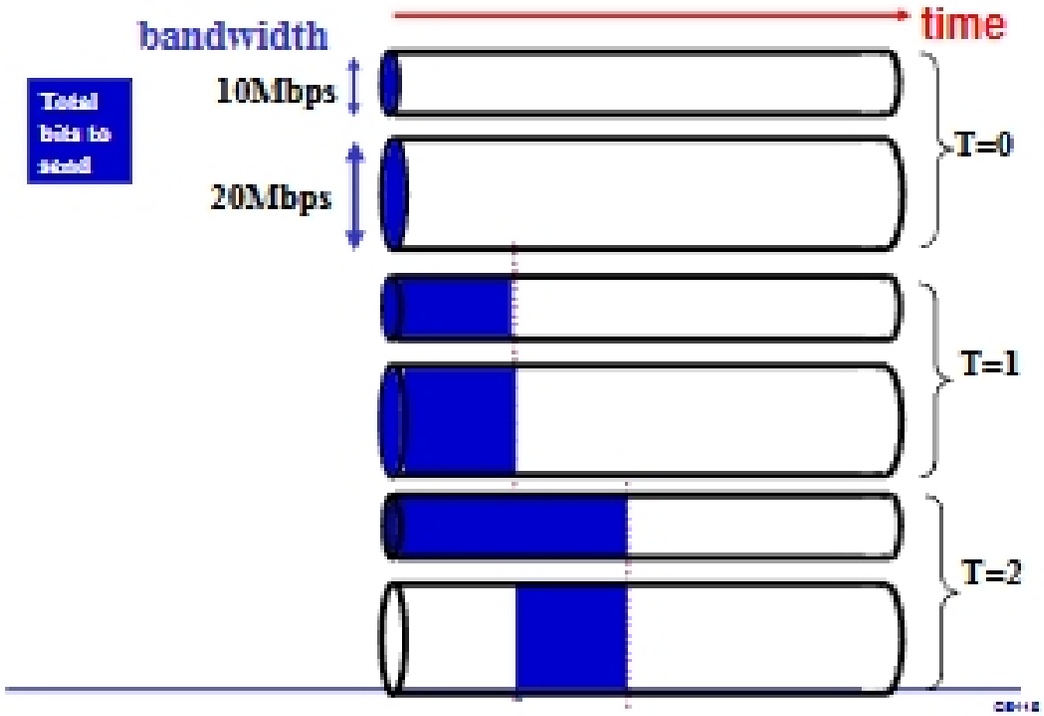
The big picture



A Bottom-up Roadmap

- Physical layer: know how to calculate the delay of sending packets from one node to another
  - Transmission rate (bandwidth)
  - Transmission delay
  - Propagation delay
- Link layer: move data between two directly connected nodes
  - Error checking schemes: parity, checksum, CRC
  - Framing, byte stuffing
  - Multi-access protocols: Aloha, Ethernet (CSMA/CD), 802.11 (CSMA/CA)
  - MAC address, Address Resolution Protocol
  - Switch/bridge self-learning scheme

Bandwidth, transmission delay, propagation delay



Above link layer

- Network layer
  - IP header, IP address structure (subnet, CIDR)
  - Routing: distance vector, link state; BGP; broadcast, multicast, IGMP
- Transport layer
  - UDP, TCP: header format
  - TCP
    - connection set-up & tear-down
    - congestion control
    - retransmission timer setting
  - Mechanisms for reliable data delivery; relations among sequence number, window size, RTT
- Application layer protocols

Packet switching

- Why packet switching?
- Packet: data chopped into chunks
- Forwarded in a "store-and-forward" way
  - Statistical multiplexing → queueing delay, potential losses
- Delays in the network
  - Transmission delay: packet-size/bandwidth
  - Propagation delay: link-length/prop. Delay
  - Store-and-forward delay
  - Queueing delay

Data link layer

- You need to know the concepts of (1)framing; (2)byte stuffing; (3)bit error detection
- Link layer address: MAC addresses (Medium Access Control)
  - not IP address!
  - flat address space
  - Need ARP to map IP to MAC address
- Channel access protocols for multiaccess channels (e.g. Ethernet, wireless LAN)

Random multi-access protocol

- Multi-access: *single* communication channel *shared* by multiple nodes, only one node can send *successfully* at a time
- Aloha/Slotted Aloha

  Q: for a network with 3 nodes, what is the probability that a given node sends a data frame successfully without collision?
- Ethernet
  - 1-persistent CSMA/CD

    Q: Why need collision detection?
  - Collision resolution: Q: how the exponential backup works
- 802.11 wireless LAN
  - CSMA/CA

    Q: why doing collision avoidance instead of collision detection?
  - RTS-CTS

Aloha example

- P(success by a *given* node)= $p \cdot (1-p)^{(N-1)}$
- N=3, if $P = 0.2$, $p \cdot (1-p)^{(N-1)} = 0.2(0.8)^2 \approx 0.08$
- P(success by *any* node)= $N\, p \cdot (1-p)^{(N-1)}$
- As N → 1arge, P_{max}(success by any node)=1/2e
- Maximum throughput? 1Mbps * 0.18 = 180Kbps

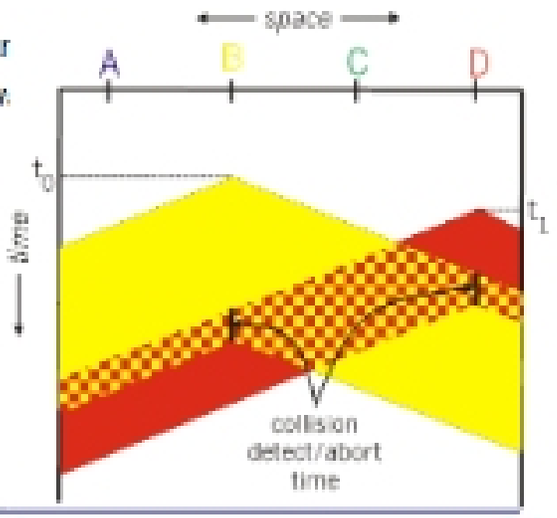
Ethernet: CSMA/CD

- Carrier Sense Multiple Access with Collision detection

  Listen before transmit
  - If channel *sensed* idle: trar
  - If channel sensed busy, w

  But collisions still possible

- To cut the loss *early*: Collision Detection: compare transmitted with received signals
  - Abort collided transmissions



Ethernet: colision detection and recovery

A: sense channel, wait if necessary until it is idle
transmit and monitor the channel;
If detect another transmission
then {
abort and send jam signal;
update # collisions (n++);
delay for K x 512bits transmission time
goto A
}
else {done with the frame; set #collisions to zero (n = 0)}

Jam Signal: make sure all other transmitters aware of the collision

Exponential Backoff algorithm:

- first collision (n=1): choose K from {0, 1} (i.e. {0, 2^n – 1})
- after second collision (n =2): choose K from {0, 1, 2, 3}…
- after 10 collisions (n=10), choose K from {0,1,2,3,4,…,1023}

Why Ethernet has a lower bound on frame size?

- Ethernet transceiver can send & listen at same time
  - If the received data stream differs from the one transmitted → collision
- to detect a collision: the sender must still be transmitting when garbled signal propagates back