CPSC 317 INTERNET COMPUTING

Module 1: Design of the Internet

LEARNING GOALS

- Isolation and privacy
- Data Loss
- **Performance**
- Naming and location
- Layering and abstractions

SPECIFIC LEARNING GOALS

- Explain the difference between bandwidth and latency
- Perform computations with respect to bandwidth, throughput, and delay
- Enumerate and classify forms of delay
- Identify the sources of delay in a given network
- Analyze a given network structure and identify bottlenecks
- Identify sources of packet loss and explain the effect of packet loss on performance

NETWORK STRUCTURE

- Brainstorming: what makes up the Internet?
  - Enumerate everything you can think of that makes up a computer network

NETWORK STRUCTURE

- Hosts
  - "Things" the users interact with: desktop computers, laptops, cell phones, etc.
  - End systems or edge components
- Connecting media
  - Wires, cables, radio waves
- Interconnecting hardware
  - Routers, switches, hubs, firewalls
- Network interface components
  - Convert digital data to/from transmission signals

NETWORK METRICS: LATENCY

- Latency: delay from when something is sent until it is received
  - "Something" depends on context, but must be consistent
- Examples:
  - Packet latency: from start of sending packet until completely received
  - Bit/byte latency: from start of sending bit/byte until completely received

NETWORK METRICS: RTT

- Round Trip Time (RTT): latency for sending a packet and receiving a response
  - Latency for message + latency for response + processing time
- Easier to compute (single location for clock)
- Reported by ping, traceroute, etc.

NETWORK METRICS: JITTER

- Observe that not all ping times are the same
- Jitter: variation in latency and/or RTT
- What causes jitter?

NETWORK METRICS: THROUGHPUT

- Throughput: amount of data moved from one location to another in a given time
- Usually expressed in bytes per second (B/s, MB/s, etc.) or bits per second (bps, Mbps, etc.)

NETWORK METRICS: BANDWIDTH

- Bandwidth: maximum rate at which data can be sent over a link
  - Throughput is the rate that is actually achieved
- Throughput cannot exceed bandwidth

NETWORK METRICS: GOODPUT

- Goodput: rate at which *useful* data arrives
  - Does not include headers and encoding costs
- May depend on context and application-layer protocol

CLICKER QUESTION

An ISP advertises 150 Mbps download speed. What speed is that?

A. Latency
B. RTT
C. Bandwidth
D. Throughput
E. Goodput

CLICKER QUESTION

If I download a 100 MB file in 10 seconds, that's 10MB/s. What speed is that?

A. Latency
B. RTT
C. Bandwidth
D. Throughput
E. Goodput

CLICKER QUESTION

If lightning happens 1km from me, it takes about 3 seconds for me to hear the thunder. What time is that?

A. Latency
B. RTT
C. Bandwidth
D. Throughput
E. Goodput

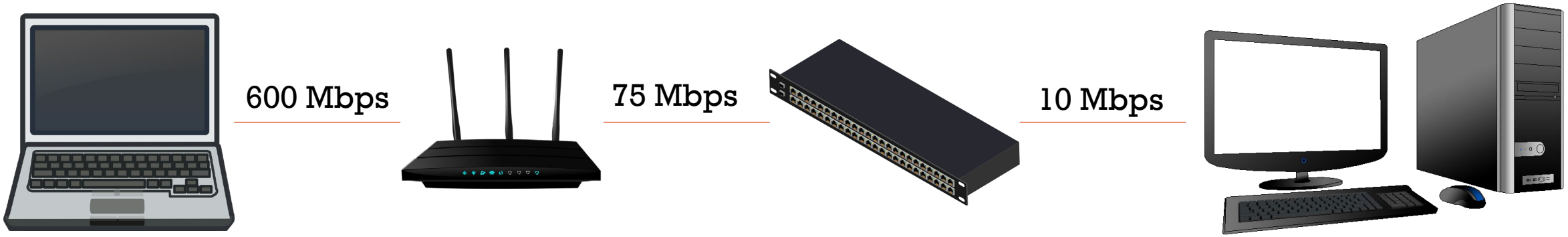
CLICKER QUESTION

When a student watching the lecture online asks a question on MS Teams, it takes 2 minutes for them to hear the response. What does this time represent?

A. Latency
B. RTT
C. Bandwidth
D. Throughput
E. Goodput

BOTTLENECKS

- What is the maximum throughput possible (bandwidth) between two nodes connected by a network?
  - Can traffic at maximum bandwidth in all links?



TYPES OF DELAY

- ***Processing delay***: examine packet to decide where to direct it
- ***Queueing delay***: waiting time to get access to the link
- ***Transmission delay***: time to actually write the packet onto the medium
- ***Propagation delay***: time spent to move each bit from source to destination on the transmission medium
- ***End-to-end delay***: sum of all sources of delay

TRAFFIC INTENSITY

- How much data can a router handle?
  - At what rate can the router process data?
  - At what rate can the router forward data out?
- Queueing: when a router receives data faster than it can dispose of

TRAFFIC INTENSITY CALCULATION

- Traffic intensity is determined by
  - Number of packets arriving (L)
  - Average packet size (a)
  - Transmission rate: rate at which bits are disposed of (R)
- Traffic intensity is, thus: La/R
- Example:
  - Suppose a router is connected to a 1Mbps link. The router receives an average of 100 packets per second, each averaging 500 bytes. What is the traffic intensity?

TRAFFIC INTENSITY RATIONALE

- Traffic intensity helps us understand how busy a link is
- Queueing delay is related to the intensity
  - Queueing delay is delay caused by waiting for queue to clear
  - Packets arriving must wait for packets already there to leave
  - Packets are not spaced out evenly
  - Higher intensity means higher probability that there is one or more packets in the queue

TRAFFIC INTENSITY VS QUEUEING DELAY

- Suppose La bits/second arrive randomly for an outgoing link in a router
  - Sustained traffic, not bursts
- Suppose that the router can transmit R bits/second
- Draw a graph of queueing delay vs traffic intensity
  - What does $La = R$ mean?
  - What does $La > R$ mean?
  - What does $La < R$ mean?
  - What does $La \ll R$ mean?

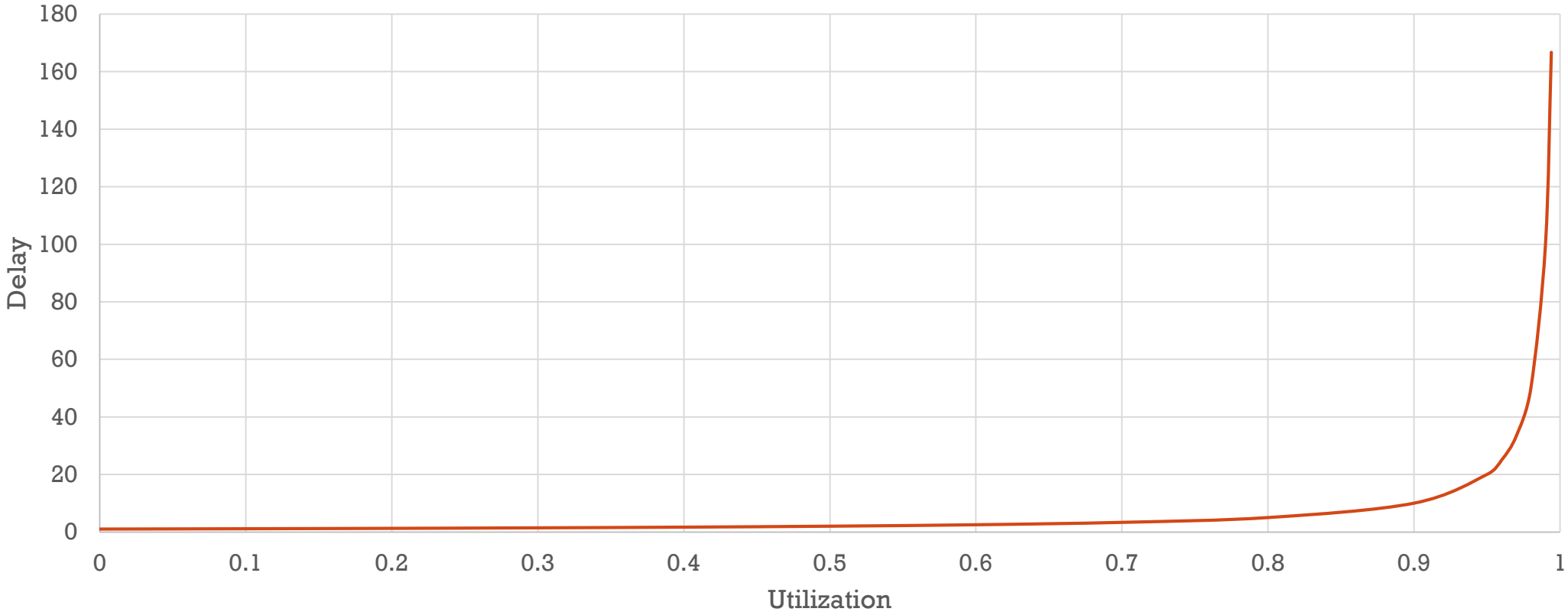
Traffic Intensity vs Queueing Delay

- Assuming packets arrive at an exponential distribution, delay is given by:

$$Delay = \frac{S}{1 - U}$$

- Where:
  - S is average service time when server is idle
  - U is server utilization (usually traffic intensity)

DELAY VS UTILIZATION



SOME OBSERVATIONS

- Routers don't have infinite buffer space
- If packets arrive faster than they can be disposed of, they may have to be dropped
- Packets may also be corrupted in transit
  - These packets must be discarded, since their content is no longer valid
  - Even routing information (e.g., destination IP) may be corrupted
- How can a transmission be considered reliable with this in mind?