

CSE 461 25au Section 2 – Physical Layer

Latency, Bandwidth & Theoretical Limits

Terms	Description
Latency	Total time for a message to arrive on a network. = Propagation + Transmit + Queue
Round Trip Time (RTT)	Latency for travel from source to destination to source
Propagation	How long it takes for information to travel a distance from source to destination (varies by medium). = Distance / "Speed of Light"
Transmit	How long it takes for information to be put onto the wire before travelling. = Size / Bandwidth
Queue Time	How long data must wait until it's their turn to be transmitted
Bandwidth (Data Rate)	The number of bits that can be transmitted over a period of time
Throughput	The measured performance of a system
Nyquist Limit	Maximum bit rate $R = 2B$ bits/sec (binary) or $R = 2B \log_2 V$ bits/sec (multi-level)
Shannon Capacity	Maximum lossless information carrying rate of a channel $C = B \log_2(1 + \frac{S}{N})$ bits/sec

Exercises

- 1) Suppose we have a network link with a **bandwidth of 10 Mbps**. We want to send a **100 KB file** to a friend somewhere else in the network. The RTT from us to our friend is **20 ms**. How long does it take for the entire file to be delivered?

- 2) Consider a point to point link **50 km in length**. Suppose the **propagation speed is $2 * 10^8$ m/s**. At what bandwidth in Mbps would the propagation delay equal the transmit delay for **100 B packets**? What about for 512 byte packets?

- 3) Suppose you (S) are sending a packet of size $M = 150 \text{ KB}$ to a host (D). There are $N = 8$ routers connected between S and D. Given that the bandwidth of each router = 4Mbps and the propagation delay between routers = 50ms, **what is the total time required for the packet to arrive at D?**
- 4) Suppose a **128-kbps** point-to-point link is set up between Earth and a SpaceX colony on Mars. The distance from Earth to Mars (at their closest) is approximately **55 Gm**, and data travels over the link at the speed of light (**$3 * 10^8 \text{ m/s}$**)
- a) Calculate the minimum RTT for the link.
 - b) Calculate the delay x bandwidth product for the link.
 - c) Say your aunt Betty takes a selfie on Olympus Mons, and sends a 5 MB picture to you on Earth. How quickly after the picture is taken can you receive the image from Betty?
- 5) Read the following statements, and state whether they are TRUE or FALSE
- a) The protocol stack of the Internet has an hourglass shape with a “narrow waist”. At the waist is the transport layer.
 - b) Packets traverse from the “topmost” layers to the “bottom-most” layers at the transmitter.
 - c) Alice has a noise-free channel and can transmit a single-tone to Bob. Since she can send only a single tone, i.e. Bandwidth = 0, her Shannon capacity is also zero
 - d) The Internet mandates that if Apple Inc. makes the physical and datalink layer, Apple must implement the corresponding network layer as well.
 - e) If we inspect at a packet inside a wire, the PHY header will be the outermost header.
- 6) Find the Shannon channel capacity for a Wi-Fi channel with $W_c = 80 \text{ MHz}$ and $\text{SNR} = 40 \text{ dB}$.