R16: Consider sending a packet from a source host to a destination host over a fixed route. List the delay components in the end-to-end delay. Which of these delays are constant and which are variable?

* Constant: Propagation, transmission
* Variable: Queuing, Processing

R18: How long does it take a packet of length 1,000 bytes to propagate over a link of distance 2,500 km, propagation speed 2.5 \*10^8 m/s, and a transmission rate of 2 Mbps?

* 10ms

More generally, how long does it take a packet of length L to propagate over a link of distance d, propagation speed s, and transmission rate R bps?

* d/s

Does this delay depend on packet length?

* No

Does this delay depending on transmission rate?

* No

P7: In this problem, we consider sending real-time voice from Host A to Host B over a packet-switched network (VoIP), Host A converts analog voice to a digital 63 kbps bit stream on the fly. Host A then groups the bits into 56-byte packets. There is one link between Hosts A and B; its transmission rate is 2 Mbps and its propagation delay is 10 msec. As soon as Host A gathers a packet, it sends it to Host B. As soon as Host B receives an entire packet, it converts the packet's bits to an analog signal. How much time elapses from the time a bit is created (from the original analog signal at Host A) until the bit is decoded (as part of the analog signal at Host B)

* 7ms + .224ms + 10ms = 17.224 ms

P20: Consider the throughput example corresponding to Figure 1.20(b). Now suppose that there are M client-server pairs rather than 10. Denote Rs, Rc, and R for the rates of the server links, client links, and network link. Assume all other links have abundant capacity and that there is no other traffic in the network besides the traffic generated by the M client-server pairs. Derive a general expression for throughput in terms of Rs, Rc, R, and M.

* min{Rs, Rc, R/M}