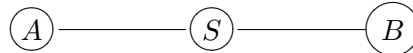


What to turn in: Submit hardcopy answers to the questions below. Please include your name, e-mail address, and the number of hours you spent working on the assignment.

1. (20 points)

Consider a point-to-point link 2km in length. At what bandwidth would propagation delay (at a speed of 2×10^8 m/sec) equal transmit delay for 100-byte packets? What about 512-byte packets?

2. (20 points)



Hosts A and B are each connected to a switch S via 10-Mbps links as shown above. The propagation delay on each link is $20\mu s$. S is a store-and-forward device that can send and receive bits simultaneously; it begins retransmitting a received packet $35\mu s$ after it has finished receiving it (if it can). Calculate the total time in milliseconds required to transmit 12,000 bits from host A to host B

- As a single packet.
- As three 4,000 bit packets sent one right after the other.

3. (20 points)

The utility program `ping` can be used to estimate the RTT to various Internet hosts. It is available on both Unix systems (`/bin/ping`) and Windows (`c:/WINNT/system32/ping`).

The Unix program `traceroute` (or the Windows equivalent `tracert`) can be used to find the sequence of routers through which a message is routed.

Using `ping` and `traceroute`, estimate the RTT and number of hops to the following hosts. How well does RTT correlate with number of network hops? How well does the number of hops correlate with geographical distance? Test at least three additional hosts to support your claims. Note that your results may vary depending on the time of day and location of the host you use to run the experiment. (Why?)

- `eniac.cis.upenn.edu`
- `www.upenn.edu`
- `www.merck.com` (in New Jersey)
- `www.cam.ac.uk` (in England)
- `www.kyoto-u.ac.jp` (in Japan)

4. (20 points)

Suppose we want to transmit the message 11001001 and protect it from errors using the CRC polynomial $z^3 + 1$.

- Use polynomial long division to determine the message that should be transmitted. Show your work.

- b. Suppose the first bit of the message is inverted due to noise on the transmission link. What is the result of the receiver's CRC calculation? Show your work.

5. (20 points)

Let A and B be two stations attempting to transmit on an Ethernet. Each has a steady queue of frames ready to send. A's frames are numbered A_1, A_2 , and so on; B's frames are numbered similarly. Let $T = 51.2\mu s$ be the exponential backoff base unit.

Suppose A and B simultaneously attempt to send frame 1, collide, and happen to choose backoff times of $0 \times T$ and $1 \times T$, respectively, meaning A wins the race and transmits A_1 while B waits. At the end of this transmission, B will attempt to retransmit B_1 while A will attempt to transmit A_2 . These attempts will collide, but now A backs off for either $0 \times T$ or $1 \times T$, while B backs off for time equal to one of $0 \times T, \dots, 3 \times T$.

- a. Give the probability that A wins this second backoff race immediately.
- b. Suppose A wins the second backoff race. A transmits A_3 , and when it is finished, A and B collide again as A tries to transmit A_4 and B tries once more to transmit B_1 . Give the probability that A wins this third backoff race immediately.
- c. Give a reasonable lower bound for the probability that A wins the remaining backoff races.
- d. What happens to frame B_1 ? (This is known as the Ethernet *capture effect*.)