1 Introduction to Internet

1.1 W&P, P1.1

2 Points. How many hosts can one have on the Internet if each one needs a distinct IP address?

1.2 Adapted from W&P, P1.3

8 Points. Imagine that all routers have 17 ports. There are 2^{16} hosts to be connected. Assume you can organize the hosts and routers any way you like. Your goal is to (i) design the network structure so as to minimize the number of routers required, and (ii) based on the network design in (i), assign the addresses to minimize the size (number of entries) of the routing table required in each router.

(a) **4 Points.** Describe your network structure and explain why your design gives the minimum number of routers.

(b) **4 Points.** Describe your scheme for assigning addresses and routing. Explain why your design gives the minimum routing table size in each router.

There exist theoretical lower bounds on the number of routers and the size of the routing table. Point out these lower bounds explicitly in your solution, and use them to verify your design.

1.3 W&P, P1.4

3 Points. Assume that a host A in Berkeley sends packets with a bit rate of 100Mbps to a host B in Boston. Assume also that it takes 130ms for the first acknowledgment to come back after A sends the first packet. Say that A sends one packet of 1Kbyte and then waits for an acknowledgment before sending the next packet, and so on. What is the long-term average bit rate of the connection? Assume now that A sends N packets before it waits for the first acknowledgment. Express the long-term average bit rate of the connection as a function of N. [Note: 1 Mbps = 10^6 bits per second; 1 ms = 1 millisecond = 10^{-3} second.]

1.4 B&G, 2.9: Horizontal and vertical parity checks

4 Points. A horizontal and vertical parity check of size K by L takes $(K-1)$ binary sequences each of length $(L-1)$ bits and outputs K binary sequences each of length L bits such that if these sequences are arranged into an K by L matrix, then each row and each column will have an even number of 1's. The parity check works as follows. To send $(K-1)$ data sequences each of length $(L-1)$ bits, the sender sends the K by L matrix. The receiver checks the parity of each row and each column. If there is any row or column that has odd parity, an error is detected.

(a) **2 Points.** Give an example of a pattern of six errors that cannot be detected by horizontal and vertical parity checks.

(b) **2 Points.** Find the number of different patterns of four errors that will not be detected by horizontal and vertical parity checks.

1.5 Adapted from B&G, P3.1

2 Points. Customers arrive at a fast food restaurant at a rate of five per minute and wait to receive their order for an average of 10 minutes. Customers eat in the restaurant with probability 1/2 and take out their order without eating with probability 1/2. A meal requires an average of 20 minutes. What is the average number of customers in the restaurant?

1.6 Capacity constrained network design

3 Points. Two nodes A and B need to be connected via a communication link. On average, it is estimated that 1000 packets will arrive at A destined for B each second, each packet having an average size of 1 Kbyte. There are two design choices: (i) you build a single link with rate 10Mbps between A and B, (ii) you build two parallel 5Mbps links, and send a packet arriving at A randomly via either link. Assume each link is equipped with an infinite sized buffer. Assuming the M/M/1 formula for the delay on a link, compute the average packet delay in each case. Which design choice is better? Can you explain why? You may ignore packet propagation times.

1.7 W&P: P2.6

3 Points. Consider a router in the backbone of the Internet. Assume that the router has 24 ports, each attached to a 1Gbps link. Say that each link is used at 15% of its capacity by connections that have an average throughput of 200kbps. How many connections go through the router at any given time? Say that the connections last an average of 1 minute. How many new connections are set up that go through the router in any given second, on average?

1.8 W&P, P2.7

4 Points. We would like to transfer 20 KB (1 Byte=8 bits) file across a network from node A to node F. Packets have a length of 1 KB (neglecting header). The path from node A to node F passes through 5 links, and 4 intermediate nodes. Each of the links is a 10 km optical fiber with a rate of 10 Mbps (assume speed of light in optical fiber is 2.0×10^8 m/s). The 4 intermediate nodes are store-and-forward devices, and each intermediate node must perform a 50 μs routing table look up after receiving a packet before it can begin sending it on the outgoing link. How long does it take to send the entire file across the network?

1.9 W&P, P2.9

3 Points. Consider the case of GSM cell phones. GSM operates at 270.88 Kbps and uses a spectrum spanning 200 KHz. What is the theoretical SNR (in dB) that these phones need for operation? In reality, the phones use a SNR of 10 dB. Use Shannons theorem to calculate the theoretical capacity of the channel, under this signal-to-noise ratio. How does the utilized capacity compare with the theoretical capacity?

1.10 IP addresses

2 Points. Consider an IPv4 subnet with private IP address space 166.111.8.0/24. If each IP interface in the subnet needs a distinct IP address, then how many IP interfaces can there be in the subnet? [Hint: to obtain the right answer, please look up what is a broadcast address online.]