Homework 1

Handed Out: September 16th, 2023 ***Due: September 16th, 2023***

- Homework assignments must be submitted online through Blackboard. Hard copies are not accepted. Please submit a pdf file to Blackboard. You can either type your solution or scan a legible hand-written copy. We will not correct anything we do not understand. Contact the TAs via email if you face technical difficulties in submitting the assignment.
- While we encourage discussion within and outside of the class, cheating and copying is strictly prohibited. It is also your responsibility to ensure that your partner obeys the academic integrity rules as well.
- This assignment has a total of 100 points.
- **Please write your answer in the white space to the right of the corresponding problem**.

1 Choose all that Apply - 4 x 6 points

Each question may have more than one correct answer. You will only get points if you identify all the correct answers.

1. What devices can be considered as an end system in the network?

   (a) PC

   (b) wireless laptop

   (c) web server

   (d) mobile phone

Answer: abcd

2. Consider two host A and B transmit packet through three routers S1, S2, S3. Suppose the rate of the link between A-S1 denotes R1, S1-S2 denote R2, S2-S3 denotes R3, S3-B denotes R4. R1 <R2 <R3 <R4. What should be the throughput between A and B should be

   (a) R1

   (b) R2

   (c) R3

   (d) R4

Answer: a

3. Consider a router transmitting a packet of 15KB to another router on the same university campus, at a data rate of 10 Mbps. Assuming delay is expressed as $n \cdot 10^{-k}$ (seconds), where $1 \neq n<10$, the value k for transmission delay is _ (choose from a to d). In this example, the statement that "total packet delivery time is dominated by the propagation delay time" is _(choose from e and f).

   (a) 1

   (b) 2

   (c) 3

   (d) 4

   (e) false

(f) true

Answer: be

4. What should the sum be when computing the total end-to-end delay when transmitting a packet. Assume processing delay and queueing delay is 0.

(a) Only transmission delay of all bits

(b) Only propagation delay of the first bit

(c) Propagation delay of the first bit, transmission delay of all bits and propagation delay of the last bit

(d) Propagation delay of the first bit and transmission delay of all bits

(e) Propagation delay of the last bit and transmission delay of all bits

Answer: de (the propagation delay for the first and the last bit should be the same, choose all apply)

5. Choose all the following statement(s) that is(are) correct about 'La/r', where 'a' is the packet arrival rate, 'L' is the number of bits per packet, and 'r' is the router's service rate.

(a) If average La/r>1, no packet will be dropped at queue.

(b) If average La/r<1, no packet will be dropped at queue.

(c) If average La/r decreases, average waiting time will decrease

(d) When La/r approaches to 0, the average waiting time will also approaches to 0

(e) When La/r increase and approaches 1, the average waiting time will increase linearly.

Answer: cd (b: average, still possible for packets to be dropped)

6. A network administrator tells you that at most 800 users can be accommodated by statistical multiplexing, given that each user needs 1 Mbps bandwidth and has a 20% chance of being active. This means, the total bandwidth is no less than_(choose from a and b). With TDM, 800 such users_ (choose from c and d) be accommodated.

(a) 200

(b) 160

(c) might not

(d) can surely

Answer: bc (cannot ensure 1Mbps per person when all users are active at the same time)

2 Probability and Throughput - 6 x 3 points

Suppose that 3 users are sharing a 300 Mbps connection. Each user uses the link 20% of the time. Assume their internet access activity is independent from each other and the network use is distributed uniformly.

1. What is the probability that no user is using the link simultaneously at the given time?

Answer: if assume no one user uses the link: $(1-0.2)^3 = 0.512$ if assume 0 or 1 user uses the link: 0.896

2. What is the probability that two users are using the link simultaneous at the given time?

Answer: $\binom{3}{2} \cdot 0.2^2 \cdot (1-0.2) = 0.096$

3. Suppose you want to use the link. Assume when two or more people use the bandwidth are divided fairly among them. What is the average bandwidth you will receive?

Answer: With probability $0.2^3 = 0.008$, 3 users are using the link. With probability 0.096, 2 people are using the link. With probability $\binom{3}{1} \cdot 0.2 \cdot (1-0.2)^2 = 0.384$, 1 person is using the link. With probability 0.512, no one is using the link. So the average bandwidth will be: $0.008 \cdot \frac{300}{4} + 0.096 \cdot \frac{300}{3} + 0.384 \cdot \frac{300}{2} + 0.512 \cdot 300 = 221.4 Mbps$

3 Delays - 5 x 5 points

1. Explain the difference between transmission delay and propagation delay.

2. Suppose a router processes packets at the rate R=1 packet per second. Packets are arriving into the router's queue at time ticks (in seconds) shown in the table below. Compute (A) the average packet throughput **in the first 10 seconds**(B) the average queuing delay. Please only type in the final result in the text box. (Round your answer to 2 decimal places)

P0	P1	P2	P3	P4	P5	P6	P7	P8	P9
0	2	3	4	5	6	7	7	9	10

Average packet throughput:

Answer: 0.90

Average queueing delay:

Answer: 0.10

P0	P1	P2	P3	P4	P5	P6	P7	P8	P9
0	0	0	0	4	4	4	4	4	4

Average packet throughput:

Answer: 1.00

Average queueing delay:

Answer: 2.10

(For the following questions)Suppose two hosts, A and B connected by switch S. The link A-S is 100Mbps and has a propagation delay of 10ms. The link B-S is 80Mbps and has a propagation delay of 30ms. (1B = 8 bit, Assume 1KB = 1000B, 1MB = 1000KB)

3. Assume that no processing delay. If A sends a 1MB packet to B, what will the end-to-end delay be?

Answer: (1 * 8) Mbit/100 Mbps + 10ms + (1 * 8)Mbit /80s + 30ms = 220ms

4. Suppose A sends 20 100KB packets to B continuously. Suppose S has a 500KB buffer for packets, will the packet be dropped?

Answer: After the first packet arrive at S. The buffer will be filled at a rate of 100Mbps - 80Mbps = 20Mbps. It took 152ms for the rest 19 packets to reach S. So, the there will be 100KB + 152ms * 20Mbps = 480KB <500 KB packets in the buffer. So No packet will be dropped.

5. Assume the buffer is infinite. A sends 100KB packets continuously. How long will it take for A to send 100MB. What is the average throughput?

$t_{firstpacketarriveatS} + L/R_{SB} * 1000 + d_{propSB} = 10048ms$ Throughput = 100MB/10048ms = 79.62 Mbps
(Reasonable to consider the first question only for A to transmit all the packets to the link (i.e. 8s), but the throughput should be considered as end-to-end.)

4 Bandwidth, data rate and SNR - 5 + 3 + 5 points

Shannon's ground breaking equation says that: C = Blog_2(1 + SNR) where C is the data rate in bits/s achievable on the communication link (also called capacity), B is the bandwidth in Hz, and SNR is the ratio of received signal power to the receiver's noise power. Assume that the received signal power density $P \propto \frac{1}{R^2}$ where R is the distance between sender and receiver.

1. Suppose a laptop tends to transmit to a WIFI station located 10m away. Assume signal power density measured 2 meters from the laptop is $Q = 12milliWatt/m^2$ and the noise power density at the receiver is $N = 0.01milliWatt/m^2$. Suppose the laptop transmits at a bandwidth of 20MHz, what data rate can it achieve? (round your answer to 3 decimal places)

Answer: Signal power from laptop measured at station: $12 * 2^2/10^2 = 0.48milliWatt/m^2$
$20 * 10^6 * log_2(1 + 0.48/0.01) = 112.294Mbps$

2. List at least two methods that can increase the data rate.

Answer: Increase the bandwidth, decrease the distance

3. If the laptop intends to triple its data rate, how close should it move to the WiFi station? Assume all the other conditions are the same. (round your answer to 3 decimal places)

Answer: $1 + SNR_{new} = (1 + SNR_{old})^3$
$0.202meters$

5 Internet concepts - 10 + 10 points

1. Mark all statements that are correct based on the classical principles of the network protocol stack: (-2pt per option wrong until 0)

(a) HTTP, SMTP, FTP are application layer protocols.

(b) All Internet components that have a network layer must run the IP protocol.

(c) The Transportation layer header can be read and modified by the router.

(d) The Network layer header can be read and modified by the the router.

(e) Transport, Network, Link and Physical layers are implemented at the core routers

(f) Suppose you send an email to your friend in another country, your packets' link layer header does not contain your friend's link layer address.

(g) Reducing the size of headers improves the goodput of the network

Answer: abdfg

2. Briefly answer the following questions.

(a) List at least one advantage and disadvantage of protocol layering.

Answer: A:Protocol layering makes it easier to update system components. D: One layer may duplicate lower-layer functionality.

(b) Why will two ISPs at the same level of the hierarchy often peer with each other? How does an IXP earn money?

Answer: If the two ISPs do not peer with each other, then when they send traffic to each other they have to send the traffic through a provider ISP (intermediary), to which they have to pay for carrying the traffic. By peering with each other directly, the two ISPs can reduce their payments to their provider ISPs. An Internet Exchange Points (IXP) (typically in a standalone building with its own switches) is a meeting point where multiple ISPs can connect and/or peer together. An IXP earns its money by charging each of the the ISPs that connect to the IXP a relatively small fee, which may depend on the amount of traffic sent to or received from the IXP.