Faculty of Arts and Science
University of Toronto
CSC 358 - Introduction to Computer Networks, Winter 2019

Solutions for Assignment 4

Question 1 (10 points)
In the following, we explore some properties of IP address and MAC addresses.

(a) Let the following be addresses of IP networks:

Network 1:	155.19.0.0/16
Network 2:	155.21.0.0/16
Network 3:	151.19.12.0/24

Let the IP-addresses of five hosts be given as follows:

Host A:	151.19.19.19
Host B:	155.21.12.19
Host C:	151.19.12.19
Host D:	151.21.12.21
Host E:	151.19.21.21

To which network do the different hosts belong? Are there any hosts that do not belong to any of the above networks?

Host A:	none of the networks
Host B:	network 2
Host C:	network 3
Host D:	none of the networks
Host E:	none of the networks

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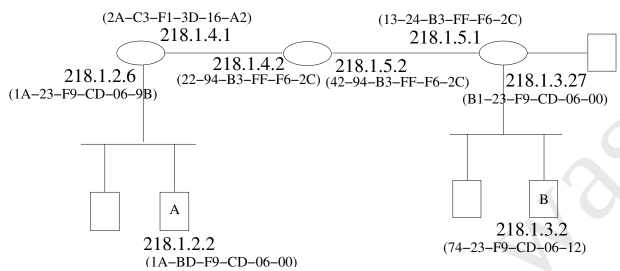
(b) In class, we saw that IP addresses are given in the so-called dotted-decimal notation. In the data link layer, we use LAN addresses (or also called physical addresses, Ethernet addresses, or MAC addresses). For most LANs (including Ethernet), the LAN address is six-bytes long. These six bytes are typically expressed in hexadecimal notation, with each byte of the address expressed as a pair of hexadecimal numbers. LAN address are given to adapters (interfaces) of a node. An adapters LAN address is permanent - when an adapter is is manufactured, a LAN address is burned into the adapter;s ROM. One interesting property of LAN addresses is that no two adapters have the same address.

The figure below gives a topology of hosts and routers with the corresponding LAN and IP addresses.



Assume that host A sends a message to host B, using the route that is indicated in the above figure. For each IP network over which the message travels, indicate addresses that is used in the frame (data link layer PDU), and in the datagram (network layer PDU).

Network 218.1.2.0/24:
IP-Source: 218.1.2.2
IP-Destination: 218.1.3.2
Frame-Source: 1A-BD-F9-CD-06-00
Frame-Destination: 1A-23-F9-CD-06-9B
Network 218.1.4.0/24:
IP-Source: 218.1.2.2
IP-Destination: 218.1.3.2
Frame-Source: 2A-C3-F1-3D-16-A2
Frame-Destination: 22-94-B3-FF-F6-2C
Network 218.1.5.0/24:
IP-Source: 218.1.2.2
IP-Destination: 218.1.3.2
Frame-Source: 42-94-B3-FF-F6-2C
Frame-Destination: 13-24-B3-FF-F6-2C
Network 218.1.3.0/24:
IP-Source: 218.1.2.2
IP-Destination: 218.1.3.2
Frame-Source: B1-23-F9-CD-06-00
Frame-Destination: 74-23-F9-CD-06-12

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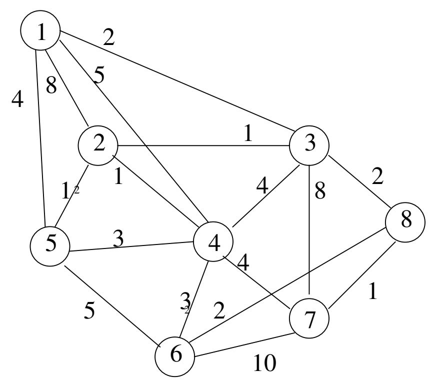
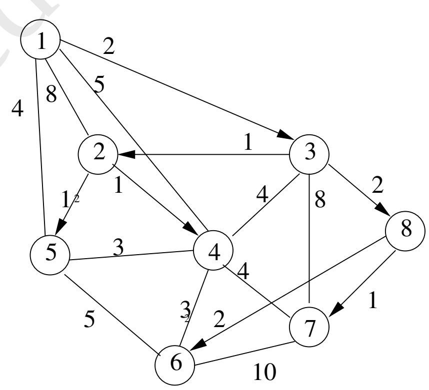
Question 2 (20 points)

Consider the network topology given below, where we assume that the costs are the same for both directions of the link. Use the Dijkstra algorithm to find the shortest path from



node 1 to the other nodes. Use a table with the following entries to illustrate each step of the algorithm.

Step	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	P
0	**0**	8	**2**	5	4	∞	∞	∞	{1}
1		**3**		5	4	∞	10	4	{1,3}
2				**4**	4	∞	10	4	{1,2,3}
3					**4**	7	8	4	{1,2,3,4}
4						7	8	**4**	{1,2,3,4,5}
5						6	**5**		{1,2,3,4,5,8}
6						**6**			{1,2,3,4,5,7,8}
7									{1,2,3,4,5,6,7,8}



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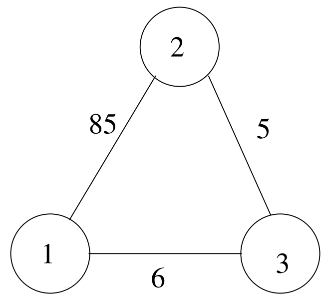
Question 3: Routing Algorithms(10 points)
Consider the network topology given below, where we assume that the costs are the same for both directions of the link.



(a) Use the Bellman-Ford algorithm to find the shortest path from node 2 and 3, to node 1. Use a table with the following entries to illustrate each step of the algorithm.

Step	D_2	D_3
0	∞	∞
1	85	6
2	11	6
3	11	6

(b) Assume that the link cost for the link between node 1 and 2 is decreased to $d_{12} = d_{21} = 1$. Use again the Bellman-Ford algorithm to find the shortest path from node 2 and 3, to node 1. However, as initial values for the estimates D_2^0 and D_3^0 for the shortest path use the final values of (a) (and not ∞). This examples shows that in the Bellman-Ford algorithm, "good news" travels fast.

Step	D_2	D_3
0	11	6
1	1	6
2	1	6

(c) Assume that the link cost for the link between node 1 and 3 is increased to $d_{13} = d_{31} = 120$. Use again the Bellman-Ford algorithm to find the shortest path from node 2 and 3, to node 1. As initial values for the estimates D_2^0 and D_3^0 for the shortest path use the again final values of (a) (and not ∞). This examples shows that in the Bellman-Ford algorithm, "bad news" travels slow (you can stop after 6 iterations).

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Step	D_2	D_3
0	11	6
1	11	16
2	21	16
3	21	26
4	31	26
5	31	36
6	41	36
$\vdots$	$\vdots$	$\vdots$

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Question 4 (10 points)
Consider the following model for slotted Aloha where nodes attempt to transmit a frame with different probabilities. There are n_1 nodes of type 1, and n_2 nodes of type 2. In each time-slot, every type 1 node attempts to transmit a frame with probability p_1 (independent of all other nodes) and every type 2 node attempts to transmit a frame with probability p_2 (independent of all other nodes). We assume that each time slot has length 1 (equal to the transmission delay of a packet). We say that a given node has successfully transmitted a frame when only this node (and not other node) made a transmission attempt during a time-slot. We say that a given slot is an idle slot when no transmission attempt occurs during this slot.

(a) What is the probability that a given slot is an idle slot? This is equal to the probability that no type 1, or type 2, nodes are transmitting. The probability that no type 1 node is sending is equal to

$$(1 - p_1)^{n_1},$$

and the probability that no type 2 node is sending is equal to

$$(1 - p_2)^{n_2}.$$

Therefore, the probability that a slot is an idle slot is equal to

$$(1 - p_1)^{n_1}(1 - p_2)^{n_2}.$$

(b) Consider a fixed node of type 1. Assume that at time t_0 this node finished a successful transmission and let t_1 be the the next time when the node begins a successful transmission. What is the expected time $E[t_1 - t_0]$ between two successful transmissions of this node?

The probability that a given node of type has successfully transmits a frame is equal to

$$P_1 = p_1(1 - p_1)^{n_1 - 1}(1 - p_2)^{n_2}.$$

The probability that a node has to try k slots pass until the next successful tranmission is equal to

$$P_1(1 - P_1)^k.$$

Therefore, we have

$$E[t_1 - t_0] = \frac{1}{P_1} - 1.$$

(c) Compute the throughput of this system.

The throughput of the system is

$$n_1 p_1 (1 - p_1)^{n_1 - 1}(1 - p_2)^{n_2} + n_2 p_2 (1 - p_1)^{n_1}(1 - p_2)^{n_2 - 1}.$$

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Question 5 (10 points)
In this question, we consider the following slotted Aloha model. Suppose that there is a fixed set of N nodes that access the channel. In each time slot, each nodes attempts to transmit a frame with probability p, $0 < p < 1$, independently of all other nodes. Again, we rescale time such that each time slot has length 1.

(a) For a fixed N, what is the throughput of the system? Compute the exact probability, i.e. without using the approximations that we used for the analysis in class.

The probability that exactly one out of the N hosts makes a transmission attempt in a given slot is equal to

$$Np(1-p)^{N-1}.$$

As all time-slots are of lenght 1. this is also equal to the throughput.

(b) Using the result of (a), as a function of the number of nodes N that access the channel, what value of p maximizes the throughput?

We have

$$\frac{d}{dp}Np(1-p)^{N-1} = N\Big[(1-p)^{N-1}\Big(1-p(1-p)^{-1}(N-1)\Big)\Big],$$

and it follows that

$$\frac{d}{dp}Np(1-p)^{N-1} = 0,$$

when

$$p = 1 \qquad \text{or} \qquad p = \frac{1}{N}.$$

With $p = 1$, the probability that exactly one device is active is equal to 0. The optimal probability is therefore

$$p_{opt}(N) = \frac{1}{N}.$$

(c) Using the value of p found in (b), find the maximal throughput by letting N approach infinity. Hint: use the result that $\lim_{x\to 0}(1-x)^{1/x} = e^{-1}$.

Using the above solutions, the maximal throughput for N nodes is given by

$$\left(1-\frac{1}{N}\right)^{N-1},$$

and we have that

$$\lim_{N\to\infty}\left(1-\frac{1}{N}\right)^{N-1} = \lim_{N\to\infty}\left(1-\frac{1}{N}\right)^{N} = 1/e.$$

Note that this is the same result that we received for the analysis that we did in class.

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