**Ollscoil Mhá Nuad**

**Maynooth University**

**SEMESTER 1**

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# CS320

**Computer Networks**

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Time allowed: 2 hours

You must answer Question 1 and any three other questions.

Your mark will be based on Question 1 and your best three answers from the remaining questions

**All questions** carry equal marks

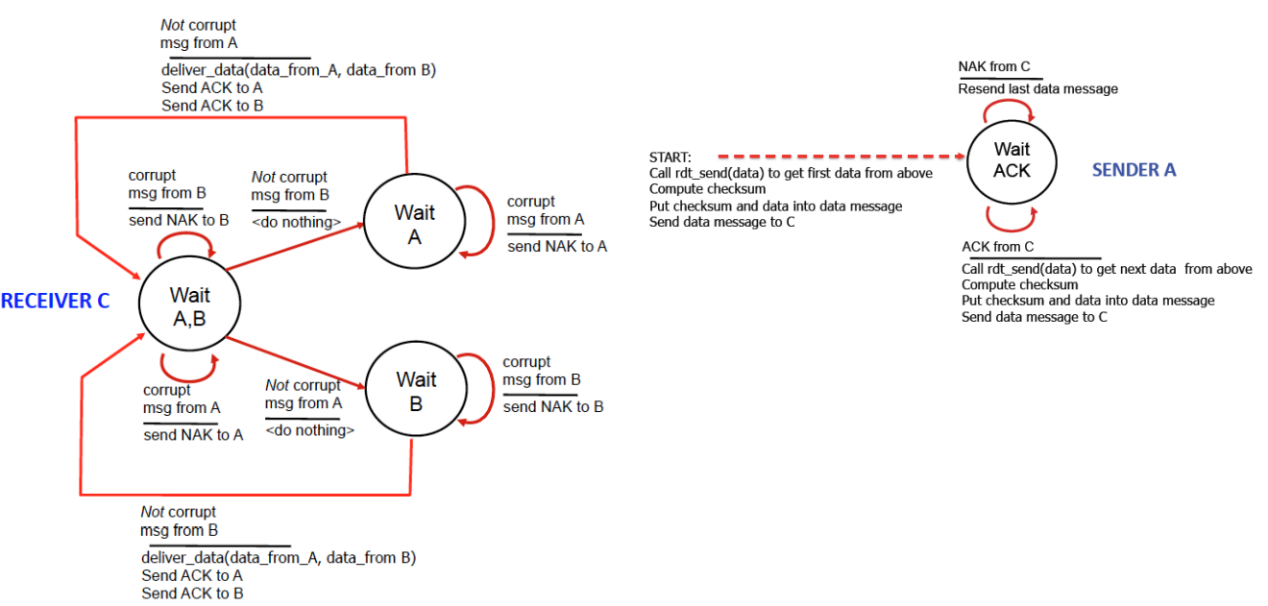
**Instructions**

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|  | **Yes** | **No** | **N/A** |
| Formulae and Tables book allowed *(i.e. available on request)* |  | x |  |
| Formulae and Tables book required *(i.e. distributed prior to exam commencing)* |  | x |  |
| Statistics Tables and Formulae allowed *(i.e. available on request)* |  | x |  |
| Statistics Tables and Formulae required *(i.e. distributed prior to exam commencing)* |  | x |  |
| Dictionary allowed *(supplied by the student)* |  | x |  |
| Non-programmable calculator allowed |  | x |  |
| Students required to write in and return the exam question paper |  | x |  |

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| **1** |  | **SHORT QUESTIONS** | **[25 marks]** |
|  | (a) | What are the five layers in the Internet protocol stack? What are the principal responsibilities of the top and bottom layers?  *Answer: The five layers in the Internet protocol stack are – from top to bottom – the application layer, the transport layer, the network layer, the link layer, and the physical layer. The principal responsibilities are outlined in lectures (section 1 - intro). Once sentence max for each one is sufficient.* | [2.5 marks] |
|  | (b) | Suppose there is 12 packet switches between a sending host and a receiving host. The transmission rates of all links are R = 15Mbs and the propagation delay a link is 1ms. Assuming that the switch uses store-and-forward packet switching, what is the total end-to-end delay to send a packet of length L=6Mbytes? (Ignore queuing, propagation delay, and processing delay.)  Answer: For 1 link Trans delay+prop delay = 6\*8\*M/15M + 1ms = 3.201s. For 13 links it is 13\*3.201s | [2.5 marks] |
|  | (c) | What is a difference between an authoritative DNS name server and a TLD name server?  *Answer: The authoritative name server for a given name is the one server in the Internet that must know the name-to-IP-address translation for than name. A TLD name server will know the IP address of name servers for names in that domain. E.g., a .edu server will know the IP address of name servers for the various .edu names* | [2.5 marks] |
|  | (d) | What are two important differences between a client-server and peer-peer model of communication?  *Answer: A client-server model requires that the server that is providing a service is always on; a peer providing a service may come and go (this is called “churn”). In Peer-to-peer, more workload (peers) also means more service capacity (peers to provide service). In client-server, more clients means more work for the server to do, so more service capacity must be provisioned.* | [2.5 marks] |
|  | (e) | Suppose a web server has 2 ongoing TCP connections. How many server-side welcoming sockets are used? How many server-side port numbers are used? Briefly (two sentences at most each) explain your answer  Answer: There are 3 including the welcoming socker | [2.5 marks] |
|  | (f) | *Consider two TCP senders are sharing a single congested link. The first sender is initially the only sender, and uses the link as in the question above. The second sender then becomes active. The first TCP sender will initially be sending at a higher rate than the second TCP sender, since the first sender has had a chance to increase (and perhaps decrease) its sending rate over time. Will the first TCP sender be able to maintain a higher sending rate than the second TCP sender over time? Briefly explain your answer.*  *Answer: The TCP senders will eventually share the bandwidth fairly. We saw that two TCP senders will eventually fairly share a link given AIMD.* | [2.5 marks] |
|  | (g) | Suppose that you have a laptop connected to a LAN and you friend has a server with a permanent IP address in some distant network. You and your friend are both skilled in wireshark. How could you and your friend decide whether or not there is a NAT router between your laptop and your friend’s server?  *Answer: look at the laptops source address as observed at the laptop and at the server. If they’re different, there is an intervening NAT.* | [2.5 marks] |
|  | (h) | Describe two differences between IPv4 and IPv6  *Answer: Address space increases from 32 bits to 128 bits and fixed header size* | [2.5 marks] |
|  | (i) | Briefly describe how Ethernet’s exponential backoff works. What is one reason why Ethernet’s exponential backoff might be better than randomizing retransmission attempts over a fixed-length time interval?  *Answer: Ethernet maintains an interval of time T over which is will randomize when it will attempt a retransmission. After each collision for the same packet, it doubles the length of T up to some fixed max. This is better than just a single, fixed value of T since when there are a lot of collisions the interval over which randomization is done will be large, allowing just one node to successfully being transmitting. When there are only a small number of colliding nodes, the retransmission will be randomized initially over a small T, allowing a node to transmit more quickly.* | [2.5 marks] |
|  | (j) | Suppose one is interested in bounding the amount of time it takes to send a packet from one host to another on the network. Would you recommend CSMA or token passing for such a network? | [2.5 marks] |

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| **2** |  | **Question 2. Throughput, HTTP CACHE/CDN**  Consider the scenario shown in the figure below. N=10 clients and a CDN node (explained below) are in a local area network with a Gbps (1,000,000,000) path with a 1 msec RTT between any two hosts in the LAN. The client LAN is connected to another network containing an origin server, netflix.com, via a 1 Mbps (1,000,000 bps) link between routers R1 and R2 with a 100 ms RTT delay. All web pages being served by netlix.com are 500Kbits in size. You can assume that any other messages involved below are very short, and thus have a transmission time of zero, but do experience propagation delays. | **[25 marks]** |
|  | (a) | Suppose that the 10 clients each make a request to the netlix.com server. If all clients make these repeated requests at the same rate, and ignoring web browsers and web caches, what is the average throughput that neflix content (in pages per second) can be delivered to a single client. You can ignore the TCP setup and the request messages in your answer.  *Answer: Time taken to download one page by one client = transmission delay + propagation delay = 0.5M(1/1G + 1/1M****/10*** *+ 1/1G) + 0.5\*(1ms + 100ms +1ms) = (0.5ms + 5s + 0.5ms) + 51ms=5052ms. Throughout is 1/5.052 pages/second* | [5 marks] |
|  | (b) | Now suppose the propagation delay of the R1-to-R2 link increases by a factor of 10. How does your answer to a) change?  *Answer: Time taken to download one page by one client = transmission delay + propagation delay = 0.5M(1/1G + 1/1M****/10*** *+ 1/1G) + 0.5\*(1ms +* ***10\*****100ms +1ms) = (0.5ms + 5s + 0.5ms) + 501ms=5052ms. Throughout is 1/5.502 pages/second* | [5 marks] |
|  | (c) | Suppose only a single client makes a HTTP request to the netflix.com web server. How much time is required from when the user first enters the netflix.com URL into a browser and when the page is received at that client. Ignore browser caching. You need not consider DNS delays but should take into account delays involving transport layer messages that are sent.  *Answer: 102 msec propagation delay for TCP handshake with netflix.com server (SYN and SYN-ACK segments). 102 msec propagation delay for HTTP GET (within first ACK)and reply netflix.com server. 500 msec transmission delay on the 1Mbps link + .5msec transmission delay on each of the LAN links. Total delay: 704. Msecs*  The CDN (content distribution network) node in the client LAN contains copies of a fixed set of pages from the neflix web site (intentionally placed there by the CDN). If a client requests content from the CNN server (via a traditional HTTP GET) that is available in the CDN node, the CNN server will respond to the GET request with a short “redirection” reply that tells the requesting client to get the content from the CDN node. | [5 marks] |
|  | (d) | Suppose that the CDN node, which can hold x pages of content, is filled with the most popular content on the cnn.com site, and the result is that 50% of the requests made to the cnn.com server are for content that is available in the CDN node. How does you answer to a) change?  *Answer: Since only half the pages need be delivered over the bottleneck link, the throughput = 0.5 times the throughput in (a) + 0.5 times the throughput from CDN server. Time for one page from CDN server is 0.5M/1G + 0.5\*1ms = 1ms so throughput from CDN server is 1000 pages/s. Average throughput = 0.5\*(1/5.052)+500 pages/sec* | [5 marks] |
|  | (e) | Now suppose that the CDN node is replaced by a traditional web cache that can also hold x pages (where x here is the same x as in d)). Assuming the client request characteristics are unchanged from d), would you expect that the fraction of time that content is found in the web cache is greater than, equal to, or less than 50%? Briefly explain your answer.  *Answer: the fraction of time that the content would be found in the cache would be less because sometimes unpopular content would be requested, causing content that is more popular to be flushed out of the cache, causing more misses.* | [5 marks] |

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| **3** |  | **RELIABLE DATA TRANSFER PROTOCOL**  Consider the diagram below, which shows three nodes, A, B, and C. A and C are connected by a bi-directional channel with variable and known delay; B and C are connected by a separate independent bi-directional channel. A and B cannot communicate with each other. The A-to-C and B-to-C channels may corrupt but **will not** lose messages. The C-to-A and C-to-B channels are perfect (they will not lose or corrupt messages). Advice: re-read the channel models and make sure you understand them!    You are to design a protocol that operates as follows. A and B each receive data from their upper layer, via a call to **rdt\_send(data)**, which returns the data to be sent, exactly the same as we studied in the rdt protocols in class. A and B are to reliably send the sequence of data obtained via subsequent calls from **rdt\_send(data)**to C. Whenever node C has received a data value each from A and B, it will then pass the two values up to the upper layer at C at the same time via a call to **deliver\_data(data\_from\_A, data\_from B)**. Node C’s job should thus pair together the ith data item from A with the *ith* data item from B, and to deliver this pair (exactly once, with pairs being delivered in their proper order) to the upper layer at C. Node A and node B should NOT begin sending the next data item until they know that C has delivered the current data item (paired with the current data item from the other node). | **[25 marks]** |
|  |  | Using finite state machine diagrams design a rdt protocol at C and at A. Briefly describe (a sentence each) why you use (or do not use) the following reliability mechanisms: (i) checksums, (ii) ACKs and/or NACKs, (iii) timers, and (iv) sequence numbers. | [25 marks] |

*Answer*:

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| **4** |  | **PIPELINED PROTOCOLS** | **[25 marks]** | | |
|  |  | In this question we’ll explore several aspects of pipelined protocols (Go-Back-N and Selective Repeat). |  | | |
|  | (a) | Suppose that a sender is connected to a receiver over a 1 Gbps (1,000,000,000 bits per second) link, with an RTT propagation delay of 10 milliseconds. Packets are 10,000 bits long. What size window is needed to ensure that this link’s utilization is at least 50 percent?  *Answer: A packet takes 10-5 secs to transmit, so at full utilization, a sender can send 1000 packets in 10 msec. At 50% utilization, that would thus be 500 packets*. | [5 marks] | | |
|  | (b) | Consider a window of size N and the Go-Back-N protocol. Suppose the current sender window at time t starts at sequence number x (i.e., that the sender window covers sequence numbers x to x+N-1). Is it possible that the receiver window at time t start at (i) a sequence number less than x, (ii) equal to x, or (iii) greater than x? Explain your answers briefly [Hint: more than one of cases (i) – (iii) may be true].  *Answer:*  *(i) can’t happen.*  *(ii) suppose every packet sent by the sender has been ACKed by the receiver and all ACKs have been received by the sender. In this case, the windows are aligned.*  *(iii) Let x be the smallest sequence number of a packet sent by the sender and received and ACK by the receiver, but for which the sender has yet to receive this ACK. In this case, the sender window being at x, and the receivers window is larger than x (since x has been ACKed).* | [3 marks] | | |
|  | (c) | Does your answer to b) change for the case of Selective Repeat?  *Answer: No. The arguments above hold in both cases.* | [3 marks] | | |
|  | (d) | Consider the GBN protocol and assume that the window size, N (which you can choose), is equal to the size of the sequence number space. Given an example (in the form of a sender/receiver timing diagram showing data and ACK messages being exchanged) showing that the receiver may deliver duplicate copies of data to the application layer above.  *Answer: see below for the case of N=2, for d) and e):* | [6 marks] | | |
|  | (e) | Again consider the GBN protocol and assume that the window size, N, is equal to the size of the sequence number space. Given an example (in the form of a sender/receiver timing diagram showing data and ACK messages being exchanged) showing that the receiver may not deliver some of the data sent by the sender to the application layer above.  *Answer: can use answer from 2d above.* | [6 marks] | | |
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| |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | **5** |  | **ROUTING ALGORITHMS** | **[25 marks]** | | | |  |  | Consider the 6-node network shown below, with the given link costs. Notice that one of the links has two different costs depending on the direction. |  | | | |  | (a) | Using Dijkstra's algorithm, find the least cost path from source node u to all other destinations. Show your work in tabular format, as we did in class.  *Answer:*   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | |  |  | *D(v)* | *D(w)* | *D(x)* | *D(y)* | *D(z)* | | *STEP* | *N* | *P(v)* | *P(w)* | *P(x)* | *P(y)* | *P(z)* | | *0* | *u* | *7,u* | *13,u* | *8,u* | *Inf* | *inf* | | *1* | *uv* |  | *10,v* | *8,u* | *8,v* | *Inf* | | *2* | *uvx* |  | *10,v* |  | *8,v* | *17,x* | | *3* | *uvxy* |  | *9,y* |  |  | *10,y* | | *4* | *uvxyw* |  |  |  |  | *10,y* | | *5* | *Uvxywz* |  |  |  |  |  | | [15 marks] | | | |  | (b) | What is the least cost path from u to z?  *Answer: work backwards z->y->v->u* | [3 marks] | | | |  | (c) | What is the difference between eBGP and iBGP? | [7 marks] | | | |  |  |  | |  | |  |  |  |

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| **6** |  | **LANS** | **[25 marks]** |
|  |  | Consider the figure below. There are three learning switches S1, S2, and S3, with the numbered interfaces shown, a router (R1) and a number of hosts. Now suppose that host C wants to send an IP UDP datagram to host A. |  |
|  | (a) | Consider the first ARP request sent by C. Whose IP-to-MAC-address-translation is being queried? Explain briefly.  *Answer: the right router interface. Need to know MAC of gateway router* | [3 marks] |
|  | (b) | What is the destination MAC address on the frame containing the ARP request?  *Answer: FF-FF-FF-FF-FF-FF flooding address* | [3 marks] |
|  | (c) | After C receives the ARP reply, what is contained in switch S3’s switch table?  *Answer: s3 knows that C is reachable via interface 2 (as a result of the ARP request sent by C) and that R1 is reachable via interface 3 (as a result of the ARP reply sent by R1).* | [5 marks] |
|  | (d) | Now consider the frame containing C-to-A IP datagram. What are the MAC source and destination addresses on this frame (i.e., to which network components do the source and destination MAC addresses belong), and the source and IP destination addresses in the encapsulated IP datagram when it is sent by C?  *Answer: The MAC addresses are for C (sender) and router R1s right interface (destination). The IP source address is that of C and the IP destination address is that of A.* | [5 marks] |
|  | (e) | Now consider the frame containing C-to-A IP datagram that is eventually received at A. What are the MAC addresses of the source and destination on this frame (i.e., to which network components do the source and destination MAC addresses belong) when it is received by A? What are the source and IP destination addresses in the encapsulated IP datagram.  *Answer: MAC source: router left interface, MAC destination A. IP source: C’s IP address. IP destination: C’s IP address.* | [5 marks] |
|  | (f) | Which other hosts, if any, besides A receive the frame containing the C-to-A IP datagram? Explain your answer.  *Answer: none. Because the router had to issue an ARP request and then receive an ARP reply from A, the switch already knows the interface leading to A when the switch sends the frame containing the IP datagram.* | [4 marks] |