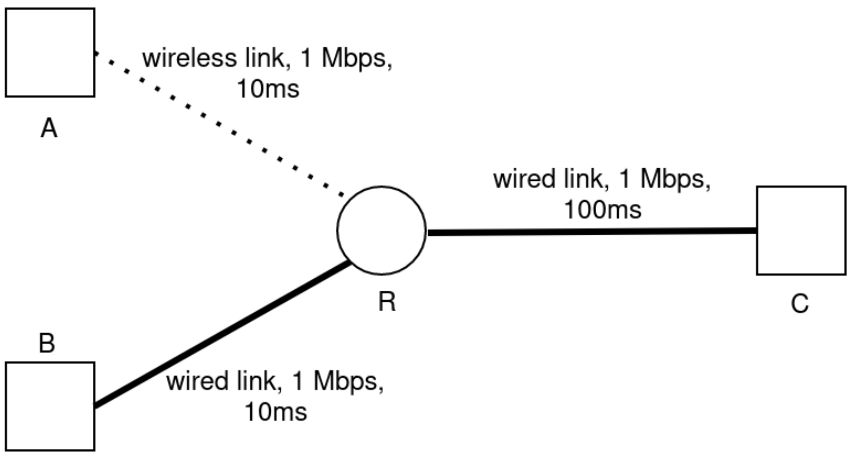
CS224M End-Semester Exam
Max. Marks: 64

1. (12 marks) Answer the following questions regarding **TCP Reno**.
    a. (2 marks) State the conditions for TCP Reno to be in Slow Start and also how and when Congestion Window (CW) is modified in Slow start phase.
    b. (2 marks) State the conditions for TCP Reno to be in Congestion Avoidance (AI) phase and also how and when CW is modified in the congestion avoidance phase.
    c. (2 marks) If Timeout occurs for a particular TCP segment, state how CW and the parameter `ss_thresh` are modified.
    d. (2 marks) If the sender of a TCP segment gets 3 DUP ACKs for that particular TCP segment, state how CW and the parameter `ss_thresh` are then modified.
    e. (4 marks) Consider the network topology shown below. A, B, and C are three hosts connected via router R. All links are assumed to be full-duplex, and the speed-of-light delays and link capacities between A--R, B--R and R–C are given in the diagram. We assume that the speed of light delays and link capacities in the opposite directions, that is, R--A, R--B, and C--R are the same as that of A--R, B--R and R--C respectively. Router R has a FIFO output queue (of size 1 MB) at each output interface.



Suppose at time t=0, “A” starts a TCP Reno connection with C, and at the same time B starts a TCP Reno connection with C. Both TCP connections transfer files of infinite size. In other words, because of the infinite file size, the TCP connections never end. Assume that the wireless link A--R has a fixed packet drop probability of “p” (where 0<p<1). This means that when the PHY layer at A transmits a frame to R, then that frame is corrupted due to wireless interference with probability “p” (independent of whether other frames were corrupted), and does not reach R. Assume that there are no retransmissions at **the DLL** layer, that is, the DLL at A tries to transmit a frame only once and gives up if it does not reach R. The wireless link R–A has the same properties as that of A–R. Assume that there is no other data traffic besides these two TCP connections in the network.

Suppose T_A and T_B are the goodputs observed by the TCP connections which have senders A and B respectively after 1 hour has elapsed. Recall that the goodput is the data (excluding retransmissions and overheads) received per unit time.

Explain which of T_A and T_B would be higher and why. Use a diagram to show how the CW of both connections might vary over time, in order to justify your answer. In your diagram, indicate clearly the various phases of slow start, congestion avoidance, and also show clearly when CW at "A" changes due to wireless packet loss or due to a queue at router R overflowing. **Note:** Your diagram does not have to show exact timings of when packets or ACKs reach various nodes. A rough diagram, such as those drawn in class, which qualitatively explains which of T_A and T_B would be higher, will suffice.

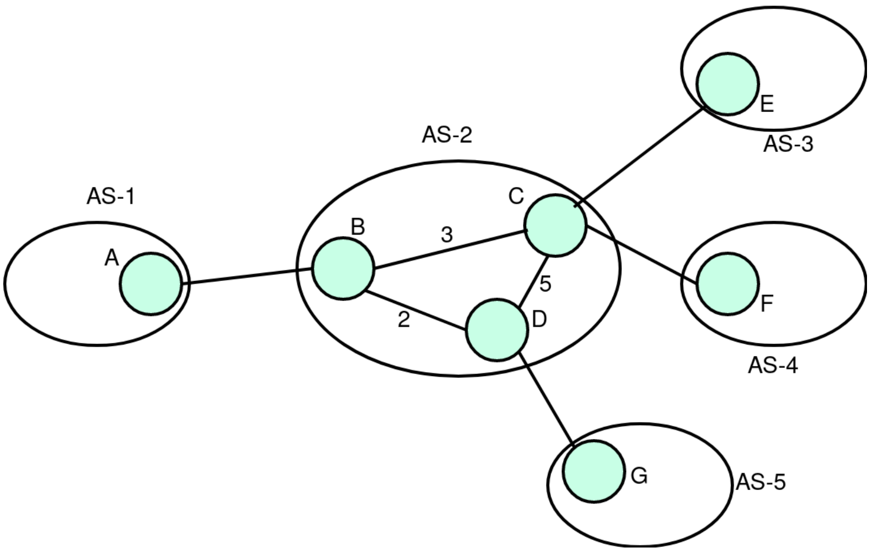
2. (9 marks) The following figure shows 5 Autonomous Systems (AS) and their BGP routers. Assume that there are no other layer-3 routers in the ASes other than the ones shown. The link costs for links in AS-2 for intra-domain routing (which uses any shortest path algorithm) are shown. Suppose that the IP prefixes 1.1/16, 2.2/16, 3.3/16, 4.4/16, and 5.5/16 belong to AS-1, AS-2, AS-3, AS-4, and AS-5 respectively. Assume that router ID of B is smaller than that of C, which is in turn smaller than that of D.

The following BGP advertisements are sent out using eBGP.

A sends to B: 1.1/16, AS_PATH= AS-1, MED=100
B sends to A: 2.2/16, AS_PATH= AS-2, MED=50
D sends to G: 2.2/16, AS_PATH= AS-2, MED=50
C sends to F: 2.2/16, AS_PATH= AS-2, MED=50
C sends to E: 2.2/16, AS_PATH= AS-2, MED=50
G sends to D: 5.5/16, AS_PATH= AS-5, MED=50
F sends to C: 4.4/16, AS_PATH= AS-4, MED=50
E sends to C: 3.3/16, AS_PATH= AS-3, MED=50

Now due to improper BGP configuration, router "A" sends out the following incorrect BGP advertisements to router "B". These messages are incorrect because they imply that the prefixes 3.3/16, 4.4/16, and 5.5/16 belong to AS-1 when in fact they do not. Such incorrect messages may be sent out in the real Internet too due to misconfiguration of BGP routers.

A sends to B: 3.3/16, AS_PATH= AS-1, MED=50
A sends to B: 4.4/16, AS_PATH= AS-1, MED=50
A sends to B: 5.5/16, AS_PATH= AS-1, MED=30



Suppose that AS-2 accepts all BGP advertisements received by its routers and is unaware that any of them have incorrect information. Given this information, routers in AS-2 decide on which paths to use for different IP prefixes using standard BGP rules. We assume that AS-2 <u>compares MED across all advertisements for the same prefix</u>, no matter which AS it heard the announcement from. Assume that the network administrator of AS-2 sets LOCAL_PREF to the same value for all BGP advertisements heard by AS-2 from routers in external ASes.

a. (3 marks) Explain which is the EXIT router chosen by router D for prefix 3.3/16. Recall that EXIT router is the last router in AS-2 for the path that is chosen (chosen by D, in this case). You must explain using BGP rules for choosing paths.
b. (3 marks) Explain which is the EXIT router chosen by router C for prefix 5.5/16.
c. (3 marks) Explain which is the EXIT router chosen by router B for prefix 4.4/16.

3. (16 marks) A peer-to-peer file-sharing network has the following properties.
   - Each file is stored (replicated) in <u>at least</u> 5 peer nodes. Assume that there are more than 5 nodes in the network at all times. Assume that every file name is a single unique keyword.
   - Unlike Napster, this application uses no centralized server that stores the location(s) of different files.
   - Any peer (person wanting a file) may download a *chunk* (i.e. a portion) of a file using TCP-Reno from another peer who has this file. He can specify the starting and ending byte of the chunk he wants. For example, he can state that he wants a particular file from byte 1200 to byte 1999. We assume byte 0 represents the first byte of a file.
   - Every client wishes to download a file from his peers as fast as possible. Simultaneous downloads from multiple peers is allowed.
   - The peer may not know the exact bit-rate in the near future for data transfer from another peer to itself but can predict this from recent downloads from that peer.
   - Nodes may occasionally join and leave the P2P network.

   Design such a P2P network and describe briefly the following aspects of your design. State any assumptions you make clearly. Solutions which are more elegant will receive more marks. **Note:** You cannot simply state that you use a particular protocol described in class; even if you do re-use such a protocol, you must describe its details in your answer. If you are reusing some algorithm which you have already described earlier in your answer, then you need not repeat all the details again – just state which part of your answer from an earlier sub-question you are reusing.

   a. (3 marks) How does a node join the P2P network? How many messages (at application layer) are sent overall when a node joins? You can give the answer in big-O notation, assuming there are “N” peers in the network.
   b. (2 marks) How is a given file stored in multiple locations?
   c. (3 marks) How does a client wanting a file determine which peer(s) possess it? How many messages (at application layer) are sent overall in the network to determine which nodes possess the file?
   d. (2 marks) How is the P2P network robust to node failure or node leaving the network?

e. (6 marks) How does a client (i.e. peer wanting a file) minimize the total time to obtain a particular file? You should state what information a peer stores and give the algorithm it uses to determine which chunks to download from which peer.

4. (10 marks) Answer the following questions about HTTP.
   a. (2 marks) Give the general formatting structure of a HTTP message. State clearly what is there on each line and how each line is terminated.
   b. (3 marks) What are requests GET, HEAD, and POST used for?
   c. (3 marks) Suppose a particular webpage on a server consists of 2 different objects (for example, the first object could be a text file and the second one an image). The server supports both HTTP-1.0 and HTTP-1.1. The server transfers the page (i.e. the 2 objects) to client B using HTTP-1.0 and the server transfers the same page to another client C using HTTP-1.1. Explain with the help of timing diagrams, how the two HTTP protocols transfer the page to B and C using TCP connections. The timing diagram should show how many TCP connections are opened by the two HTTP protocols, and which object(s) are requested and downloaded in which TCP connections. Assume that the various TCP connections are started and terminated by three-way handshakes. Show these handshakes in the diagrams.
   d. (2 marks) Mention two advantages of the method used by HTTP-1.1 over the method of HTTP-1.0. Be brief, do not give lengthy explanations.

5. (7 marks) Explain the following regarding Distance Vector routing protocols.
   a. (4 marks) Using an example, explain the “count to infinity” problem.
   b. (3 marks) Explain what is the “split horizon” method. Give an example where the split horizon method prevents a particular count-to-infinity problem (you may reuse the example in part-a or give a new example if required).

6. (10 marks) Short answer questions. You need not give lengthy explanations. Answer to the point.
   a. (3 marks) Construct DNS resource records (RRs) which mean the following. Each RR should be of the form `(Name, Value, Type, Class).`
      i. The IP address of `penguin.cs.princeton.edu` is `128.112.155.166.`
      ii. The Email Server of domain `cs.princeton.edu` is `mail.cs.princeton.edu.`
      iii. An alias of `www.cs.princeton.edu` is `coreweb.cs.princeton.edu.`
   b. (2 marks) Give any two reasons for why Ethernet has a maximum frame size and does not allow arbitrarily large frame sizes.
   c. (3 marks) Explain what the Exposed Terminal problem is in the context of WiFi. Does the virtual carrier sensing protocol of WiFi which uses RTS-CTS solve the exposed terminal problem? Why or why not?
   d. (2 marks) State any two technical reasons why Ethernet’s spanning tree protocol does not scale to networks consisting of many thousands of switches. You need not give a very detailed explanation. A short explanation will do.