Review problems (for no credit): Transport and Network Layer

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CS 653, Fall 2018
09/06/18

Transport layer

1. Protocol multiplexing:

   (a) If a web server has 100 open connections, how many sockets and ports does it have active?

   (b) What tuple uniquely identifies a TCP socket? A UDP socket?

   (c) Suppose you wrote a web server and client application program using just UDP implementing reliability yourself. If the server were serving data to 100 users simultaneously, how many sockets and ports would it have active?

   (d) Is the transport protocol being used part of the transport header or network header? Why?

2. Reliable transport:

   (a) Can you implement a reliable transport protocol without sequence numbers? Why or why not? What if protocol only had to tolerate corruption but not loss?

   (b) When are the pros and cons of cumulative acknowledgments, negative acknowledgments (NACKs), selective acknowledgments (SACKs) respectively? What does TCP use?

   (c) Timeouts are needed to tolerate loss, but not to tolerate only corruption. True/false?

   (d) The link, network, and transport headers each have a checksum-like error detection capability. Explain why a packet is not guaranteed to be correct even if it satisfies all three checks. How do you reconcile this design decision with the end-to-end principle?

3. Pipelined transport:

   (a) What is the window size required to saturate a 10Gbps link with a 50ms RTT assuming 1500KB packets?

   (b) What is the main benefit of Go-back-N (GBN) protocols compared to Selective Repeat (SR) protocols?

   (c) Consider the GBN protocol with a sender window size of 3 and a sequence number range of 1024. Suppose that at time T, the next in-order packet that the receiver is expecting has a sequence number of K. Assume that the medium does not reorder messages. Answer the following questions:

      (i) What are the possible sets of sequence numbers inside the sender’s window at time t? Justify your answer.
(ii) What are all possible values of the ACK field in all possible messages currently
propagating back to the sender at time T? Justify your answer.

(d) What is the relationship between the size of the sequence number space and window size
in order for the SR protocol to operate correctly?

4. TCP:

(a) How does TCP estimate the timeout after which it should retransmit a packet?

(b) What do triple duplicate ACKs and fast retransmit mean in TCP?

(c) If a TCP sends a packet of size 500B with a sequence number of 122 and an acknowledgment sequence number of 4344, what is the largest sequence number up to which it has received the byte stream reliably? Could it have received bytes beyond that number? If the packet is correctly received by the TCP at the other end and it responds immediately, what are the sequence numbers in the response packet?

(d) Why is it important for a TCP server to use a special initial sequence number in the SYNACK instead of just starting from 0?

(e) For estimating the RTT, why do you think TCP exclude the sampled RTTs of retransmitted packets?

5. Congestion control:

(a) Consider a network with N sender-receiver pairs. Suppose every link in the network has
greater capacity than the sum of the rates at which the applications at each of the N
senders is generating data. If the data has to be delivered reliably, is congestion control
necessary in this scenario?

(b) Can congestion collapse happen over a single link network? Over a chain network?

(c) Consider the following plot of TCP window size as a function of time. Assuming TCP
Reno is the protocol, answer the following questions.

![Figure 1: TCP window dynamics](image_url)
i. Identify the intervals of time when slow start is operating.
ii. Identify the intervals of time when TCP congestion avoidance is operating.
iii. After the 16th transmission round, is segment loss detected by a triple duplicate ACK or by a timeout?
iv. What is the initial value of \text{ssthresh} at the first transmission round?
v. What is the value of \text{ssthresh} at the 18th and 24th transmission round?
vi. During what transmission round is the 70th segment sent?
vii. Assuming a packet loss is detected after the 26th round by the receipt of a triple duplicate ACK, what will be the values of the congestion window size and of \text{ssthresh}?

(d) Consider the following simple model of TCP that varies the sending rate from $W/(2 \cdot RTT)$ to $W/RTT$. Assume that exactly one packet is lost at the very end of the period.

i. Show that the loss rate (fraction of packets lost) $L$ is equal to
   \[ L = \frac{1}{2W^2 + \frac{3}{4}W} \]
ii. Use the result above to show that if a connection has loss rate $L$, then its average rate is approximately given by $\approx \frac{1.22 \cdot MSS}{RTT \sqrt{L}}$.

Network layer

1. Quickies:

   (a) Does a virtual circuit network maintain connection state information? If a VC is required to use the same VC number on all links along the path, how could the number be assigned?

   (b) Give an example of how load-dependent link-state routing can lead to oscillations.

   (c) Derive an upper bound on the maximum number of iterations required for distance vector routing to converge in terms of the size of the underlying graph.

2. Consider a datagram network using 8-bit host addresses. Suppose a router uses longest prefix matching and has the forwarding table below. For each of the four interfaces, give the associated range of destination host addresses and the number of addresses in the range.

<table>
<thead>
<tr>
<th>Prefix match</th>
<th>Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>111</td>
<td>2</td>
</tr>
<tr>
<td>otherwise</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 1: Forwarding table using longest prefix matching.

3. Consider the network shown below. Suppose the cost of the link BC increases to 42. Assume that nodes exchange distance vectors once every 30 seconds.

   (a) Show how A’s cost to C increases in the next 3 minutes.

   (b) Do the same assuming poisoned reverse is being used.
4. You are hired by OIT to setup two routers, R1 and R2, as shown below. You have the network 128.119.248.0/21 at your disposal. Give an example of how this address space can be distributed in the domain by presenting the network identifiers for each of the four networks plus the forwarding tables for the two routers.

5. **Interdomain routing quickies**: Consider the AS topology in the figure below. Ignore the edges not fully shown in the figure. Answer the following questions with a one sentence explanation for each.

   (a) Suppose router 3a advertises the route [AS3 AS5 AS7] for the prefix 128.119.240/24 and router 2a advertises the route [AS2 AS9 AS13] for the same prefix. What is the AS-level route chosen by router 1d to reach the prefix assuming that AS1 uses RIP for intradomain routing and is a customer of both AS2 and AS3?

   (b) Suppose now that AS1 is a customer of AS2 and a peer of AS3. What is the route chosen by 1d?

   (c) Suppose now that router 3b also maintains a BGP session with AS1. What BGP route attribute would AS3 use to tell AS1 to send traffic to it through 3b as opposed to 3a? Hint: refer BGP notes on the class webpage.

   (d) Is the prefix 128.119.240/24 singly homed or multihomed?
(e) Can two routers in the same AS have different AS-level routes to the same prefix?
(f) Both BGP and RIP are fully decentralized, but there is no count-to-infinity problem in BGP. Why not?

6. Which of the following interdomain routes are possible with commonly used valley-free routing policies and which ones are not?

![AS relationships](image)

Figure 4: AS relationships: ASes higher up are providers of adjacent ASes below them and adjacent ASes are peers of each other.

7. **DV routing**: Consider a general topology and a synchronous version of the distance-vector algorithm. Suppose that at each iteration, a node sends its distance vectors to its neighbors and receives their distance vectors. Assuming that the algorithm begins with each node knowing only the cost to its immediate neighbors, what is the maximum number of iterations required before the distributed algorithm converges? Justify your answer.

8. **NAT**: Alice wishes to make a Skype call to Bob. Both Alice and Bob are at home behind their NAT routers, A and B respectively. Refer the picture below. Both Alice and Bob maintain keep alive connections with the skype server S. When Alice makes the call, the following steps occur: 1) Alice sends S a message requesting a call to Bob, 2) S sends Carols IP address and a port number to Alice, 3) S sends Carols IP address and the same port number to Bob, 4) Alice sends a call setup message to Carol, 5) Bob sends a call setup message to Carol and the call has been set up at this point, 6) Bob says Hello and the corresponding voice frame is sent to Carol, 7) Carol forwards the voice frame to Alice. All communication uses UDP.

![Skype call setup](image)

Figure 5: An example of a Skype call setup between two endpoints both behind NATs.

Alices IP address is 10.0.0.2 and As IP address is 44.56.78.90. Bobs IP address is 192.168.0.2 and Bs IP address is 88.76.54.32. Carols IP address is 128.83.83.20. She sends and receives all messages on port 5001. Ss IP address is 22.34.45.56. S sends and receives all messages on port 7001. Alices next unused local port number at step 4 is 3001. Bobs next unused local port number at step 5 is 4001. As next unused port number in its NAT table at step 4 is
6001. Bs next unused port number in its NAT table at step 5 is 7001. In the following, a 4-tuple refers to a source IP address, destination IP address, source port number, destination port number. [Note: This question is easier to answer than read.]

(a) In step 1, what are the source and destination IP addresses in the (i) packet from Alice to A, (ii) packet from A to S?
(b) In step 4, what is the (i) 4-tuple in the packet from Alice to A, (ii) from A to Carol?
(c) Just after step 4, what is the NAT table entry created at A? Assume the NAT table has two columns: each is a 2-tuple of the format IP address, port number.
(d) In step 7, what is the (i) 4-tuple in the packet from Carol to A, (ii) from A to Alice?