Midterm Exam
CMPSCI 653: Advanced Computer Networks
Fall 2015
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Instructions:
• There are 3 questions on this exam.
• Put your name and student number on the exam book NOW!
• The exam is closed book.
• **You have 75 minutes** to complete the exam. **Be a smart exam taker** - if you get stuck on one problem go on to another problem. Also, don't waste your time giving irrelevant (or not requested) details.
• The total number of points for each question is given in parenthesis. There are 100 points total. An approximate amount of time that would be reasonable to spend on each question is also given; if you follow the suggested time guidelines, you should finish with 15 minutes to spare. The exam is 75 minutes long.
• Show all your work. Partial credit is possible for an answer, but only if you show the intermediate steps in obtaining the answer.
• Good luck.

PLEASE WRITE NEATLY
I need to be able to read your answers!

**Question 1: "Quickies" (24 points, 20 minutes)**

Answer each of the following questions briefly, i.e., in at most a few sentences.

• Briefly (in a couple of sentences each) describe the roles of the signaling switching point (SSP), the signaling transfer point (STP), and the signaling control point (SCP) in SS7.
• Are Q.2931 (ATM signaling protocol) and RSVP hard state or soft state protocols? Give a couple of sentence explanation of your answer for each of these protocols.
• Describe the role of the OpenFlow protocol in an SDN. Which network elements are involved in the communication that takes place using OpenFlow?
• What is meant by a customer premise VPN? What is meant by a network-based VPN?
• Consider the Ethernet CSMA/CD algorithm and compare it to the TDMA (time division multiplexed access) algorithm. What are the pros and cons of each of these and what role does randomization play in your answer?
• Briefly describe indirect routing and direct routing in Mobile IP? What are the pros and cons of each?
Question 2: Openflow (26 points, 20 minutes)
Consider the 3-subnet, 3-switch/router, 15-host Openflow network shown in the figure below. The MAC address for a host with IP address 10.0.i.j is 00:00:00:i.j.

Specify the 11-tuple flow table entries, and indicate at which switch/router the rules are installed to obtain the following forwarding behaviors. In the case that you have multiple entries a flow table, indicate their priority order.

a) Static counter-clockwise routing. All hosts can route to all other hosts; if the destination is not attached to the same switch/router as the source forward the packet clockwise. For switch S1 only, specify this rule using IP addresses rather than MAC addresses. You can use a wildcard (*) in addresses in your rules to specify a full range of addresses (e.g., 10.0.1.*) refers to all addresses in the range 10.0.1.0 through 10.0.1.255.

b) In your answer to a) above, what would happen at a router if a packet were to arrive on an incoming link in the clockwise direction? Explain.

c) Given your answer in a), what happens when a packet is sent from a host in 10.0.0.* to an address not shown in the 15 hosts in the figure above? (You can assume that S2 and S3 have rules that are similar in spirit to those you have specified in a) for S1). Explain you answer in a few sentences.

d) Static counter-clockwise switching. All hosts can forward to all other hosts; if the destination is not attached to the same switch/router as the source, forward the frame counter-clockwise. For switch S2 only, specify this rule using MAC addresses rather than IP addresses. (Here again, you can use wildcards in your MAC addresses as well).

e) Specify a rule in S1 so that only UDP packets can be delivered to hosts attached to S1. There should be no restrictions on S3-to-S2 traffic routed through S1.

f) Specify a rule in S1 so that only packets sent from 10.0.2.* can be delivered to hosts attached to S1.
QUESTION 3: Randomization (25 points, 25 minutes)
Consider the network below. Traffic arrives from sources $s_1$ and $s_2$ to the left routers $R_1$ and $R_3$ via a link of capacity of $C$ (packets/sec). Thus the maximum arrival rate of packets at each left-side router is $C$ packets/sec. The interior links have capacities $x$ and $y$, as illustrated below. The link between $R_2$ and $R_4$ has a capacity $y$ in both directions. An arriving packet is destined for destination $d_1$ or $d_2$.

<table>
<thead>
<tr>
<th>Source</th>
<th>Link Capacity</th>
<th>Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_1$</td>
<td>$C$</td>
<td>$R_1$</td>
</tr>
<tr>
<td>$s_2$</td>
<td>$C$</td>
<td>$R_3$</td>
</tr>
<tr>
<td>$R_1$</td>
<td>$x$</td>
<td>$R_2$</td>
</tr>
<tr>
<td>$R_2$</td>
<td>$y$</td>
<td>$R_4$</td>
</tr>
<tr>
<td>$R_3$</td>
<td>$x$</td>
<td>$R_4$</td>
</tr>
</tbody>
</table>

a) Suppose that arriving traffic is routed to its destination along the direct-hop (shortest path) route, i.e., an arriving packet at $R_1$ destined to $d_1$ is routed directly to $R_2$, and a packet arriving at $R_1$ destined for $d_2$ is routed directly to $R_4$, and then delivered to the destination. Suppose that traffic arriving at $R_1$ and $R_3$ can have any possible mix of destinations (ranging from all traffic destined to $d_1$, to a mix of $d_1$ and $d_2$, to all traffic destined to $d_2$). What are the capacities $x$ and $y$ that need to be assigned to links so that all possible mixes can be supported (i.e., that the output traffic rate at each router never exceeds that link’s capacity, given how traffic is routed)? Express your answer for $x$ and $y$ in terms of $C$, and briefly explain your answer.

b) Now suppose that arriving traffic is randomly routed from the ingress router ($R_1, R_3$) to $R_2$ or $R_4$ with equal probability. If $R_2$ or $R_4$ is attached to the destination, then the packet exits the network there, otherwise it is routed to the other right side router and exits the network there. What are the capacities $x$ and $y$ that need to be assigned to links so that all possible mixes can be supported? Express your answer in terms of $C$, and briefly explain your answer.

c) Suppose that the cost of link bandwidth is $a \times z$ where the link bandwidth is $z$ and the cost per unit bandwidth is $a$. How do the above two routing strategies compare in terms of total link bandwidth cost? Which is preferable?