SINGAPORE UNIVERSITY OF
TECHNOLOGY AND DESIGN

50.012 Networks Mid-Term Fall 2017

Date of examination: 17.10.2017
Time: 9:00 am
Duration: 80 min
Name :
Student ID:

General Remarks

- This is a closed book exam. Do not use any digital or external material.
- This exam consists of 4 questions on 10 printed pages.
- The last 2 pages are empty, and can be used for (ungraded) notes.
- Each question has an assigned weight in points. There are 100 points in total.
- Write your answer below the questions, into the boxes.
- Answer all questions as thoroughly as you can.
- Please acknowledge the SUTD Honour Code by signing it on the handout.

Question	Points	Score
Foundations	25	
Shortest Path Finding	24	
Network Address Translation/IP/ Routing	26	
TCP	25	
Total:	100	

SINGAPORE UNIVERSITY OF
TECHNOLOGY AND DESIGN

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN
HONOUR CODE

“As a member of the SUTD community, I pledge to always uphold honourable conduct. I will be accountable for my words and actions, and be respectful to those around me.”

Introduction to the SUTD Honour Code

What is the SUTD Honour Code?

The SUTD Honour Code was established in conjunction with the school’s values and beliefs, in good faith that students are able to discern right from wrong, and to uphold honourable conduct. It is an agreement of trust between the students and the staf and faculty of SUTD, and serves as a moral compass for students to align themselves to. Being in a university that aspires to nurture the leaders of tomorrow, it calls for students to behave honourably, not just solely in their academic endeavours, but also in everyday life.

What the Honour Code encompasses

Integrity & Accountability

To be honourable is to do what is right even when nobody is watching, and to be accountable for the things one does. One should always be accountable for one’s words and actions, ensuring that they do not cause harm to others. Putting oneself in a favourable position at the expense of others is a compromise of integrity. We seek to create a community whereby we succeed together, and not at the expense of one another.

Respect

Part of being honourable is also respecting the beliefs and feelings of others, and to never demean or insult them. Should conf icts arise, the aim should always be to settle them in a manner that is non-confrontational, and try to reach a compromise. We will meet people of dif ering beliefs, backgrounds, opinions, and working styles. Understand that nobody is perfect, learn to accept others for who they are, and learn to appreciate diversity.

Community Responsibility

In addition to that, being honourable also involves showing care and concern for the community. Every individual has a duty to uphold honourable conduct, and to ensure that others in the community do likewise. The actions of others that display immoral or unethical conduct should not be condoned nor ignored. We should encourage each other to behave honourably, so as to build a community where we can trust one another to do what is right.

____
Student’s signature

Question 1: Foundations

(a) (8 points) Please provide examples for the addresses introduced by each layer (except Physical layer), and write a short comment on what they identify.

1 point for each correct address type (up to 4 points total), 1 point for correct brief description of meaning (up to 4 points total).

Solution:

- Application layer: Examples: URL or other resource name. URLs are uniquely identifying resources for that application, for example an image or webpage.
- Transport layer: Port number. TCP and UDP both use port numbers to identify the process on the destination machine
- Network layer: IP address. A (public) IP address uniquely identifies the respective host and allows routing.
- Link layer: MAC address. The MAC address identifies the network interface of a host.

(b) (6 points) For the following three applications, please comment on which Transport Layer protocol you would recommend to use, and provide a brief explanation why for each.

1 point per correct recommendation per protocol (up to 3 points total), 1 point for correct argument (up to 3 points total)

A. Protocol to locally broadcast measurement data
B. A time synchronization protocol, based on round-trip-time
C. Custom online-banking application protocol

Solution:

A. UDP, as broadcasting requires a connectionless protocol.
B. UDP, as TCP retransmissions could alter the measured RTT.
C. TCP, as no data should be lost, and timing or performance is not important.

(c) (8 points) Please list four types of information that are commonly supplied by a DHCP server to a client. Why is it usually a problem to have two non-collaborating DHCP servers in the same Link-Layer broadcast domain?

1 point for each type of information (up to 4 points total). Up to 4 points for correct comment on problem with two DHCP servers.

Solution: IP, net-mask, DNS, gateway/first hop. Other possible answers: lease time, +?

(d) (3 points) Given a network of three fully connected nodes (i.e. 3 links). In which of the following three scenarios can count-to-infinity occur?

A. The link between B and C gets cheaper
B. The link between B and C gets more expensive
C. All paths to C get cut

Solution: Count-to-infinity can only occur in case C, when all links are cut. In that case, the cost to reach becomes infinity, and other nodes will iteratively increase their path cost to reach that value.

Question 2: Shortest Path Finding 24 points

Consider the network topology shown in Figure 1. The topology consists of multiple nodes interconnected by links. Each link has a static cost associated with it that represents the cost of sending data over that link.

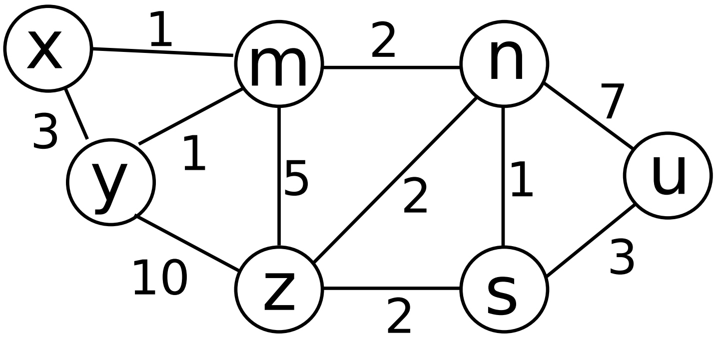

Figure 1: Setup for Dijkstra shorted path finding question.

Please use Dijkstra's shortest-path algorithm to compute the shortest path **from y** to all network nodes. Show your work by completing the table below.

Up to 3 points for correct d() and p() per destination (18 points total), up to 1 point for correct protocol round (6 points total).

Solution: Note: once found to be optimal, paths are not listed again. Best remaining path for each round is shown *emphasized*.

N'	d(x),p(x)	d(m),p(m)	d(z),p(z)	d(n),p(n)	d(s),p(s)	d(u),p(u)
y	3,y	*1,y*	10,y	∞,-	∞,-	∞,-
y,m	*2,m*		6,m	3,m	∞,-	∞,-
y,m,x			6,m	*3,m*	∞,-	∞,-
y,m,x,n			5,n		4,n	10,n
y,m,x,n,s			*5,n*			7,s
y,m,x,n,s,z						*7,s*
y,m,x,n						

Question 3: Network Address Translation/IP/ Routing

Consider the scenario in Figure 2. Note that all Link-layer addresses were shortened from xx:xx:xx:xx:xx:xx to xx:xx:xx:...

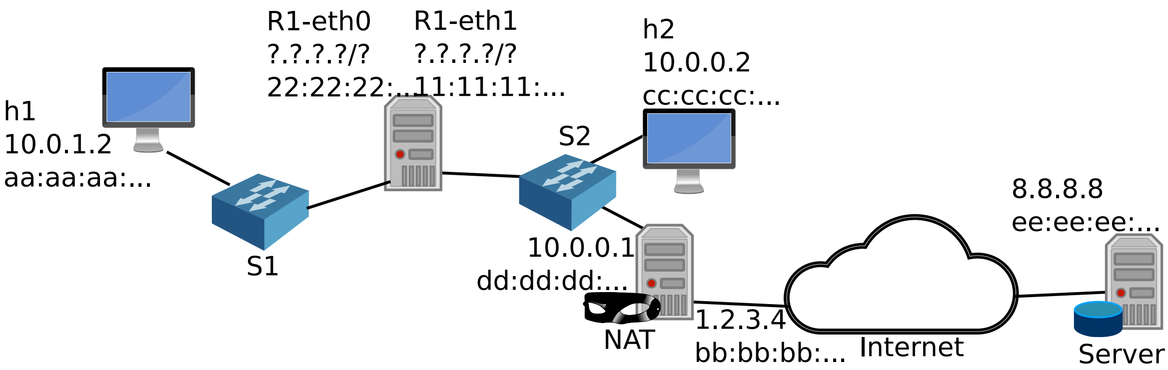

Figure 2: Setup for NAT+routing question.

(a) (10 points) Provide suitable IP addresses and subnet mask for the two interfaces of router R1. Also list the expected routing tables of h1, h2 to enable them to reach each other, and the Internet.

Up to 2 points per correct IP and subnet mask of R1 (4 points total). Up to 3 points per correct routing table for h1 and h2, listing destination network with subnet mask and gateway (6 points total).

Solution:

R1-eth0: 10.0.1.1/24 (or any IP in that range except 10.0.1.2)
R1-eth1: 10.0.0.3/24 (or any IP in that range except 10.0.0.1 or 10.0.0.2)

Routing table at h1:

destination	gateway
0.0.0.0	10.0.1.1 (IP that was provided for R1-eth0 above)
10.0.1.0/24	0.0.0.0 (local)

Routing table at h2:

destination	gateway
0.0.0.0	10.0.0.1
10.0.1.0/24	10.0.0.3 (IP that was provided for R1-eth3 above)
10.0.0.0/24	0.0.0.0 (local)

(b) (8 points) h1 sends a ping packet to h2. Please list source MAC address+IP, and destination MAC address+IP of the packet as transmitted by h1.

Up to 2 points per correct value (8 total points).

Solution:

Source MAC:	aa:aa:aa:...
Source IP:	10.0.1.2
Dest. MAC	22:22:22:...
Dest. IP	10.0.0.2

(c) (8 points) A user wants to use his laptop at home (connected through the Internet) to send network-layer traffic to h1. How could this be achieved without port forwarding at NAT? If a service is required for this, on which device should this service run? What would the source IP of traffic sent by the home user be (give valid example value)?

Up to 3 points for correct location of the service. Up to 3 points for explanation of what that service should be, and 2 points for correct source IP.

> **Solution:**
> A VPN server should be located at NAT (needs public IP+private IP that can reach h1). VPN should be network layer, and give home user IP in a suitable network range, e.g. 10.0.3.0/24 (not in 10.0.1.0/24). Note: if link-layer VPN is chosen (uncommon, but possible), IP of home user could be in 10.0.0.0/24. IP should never be in 10.0.1.0/24 range.

Question 4: TCP

Assume a link between RouterA and RouterB is used by four parallel TCP streams. The streams are sending data traffic in the direction of RouterB. The link has a capacity of 10Gbps (in each direction). All streams send an infinite amount of data. The ACK timeout (time waited for ACKs before re-transmission) for all streams is round-trip-time (RTT)+500ms.

(a) (4 points) What is the expected average rate for each of the streams towards RouterB?

> **Solution:** Ideal long-term average: 10/4 Gbps per stream. In practise, will be slightly less due to TCP congestion control mechanism. For grading, 2.5Gbps or values slightly less are given full points.

(b) (5 points) A fifth stream is added, in the opposite direction (sending data traffic towards RouterA), with infinite data to send and same timeout value. Lets assume that each segment has size 1kB, and ACK messages have size 100B. What is your estimate on the resulting average rate possible for all five streams? Ignore overhead introduced by TCP/IP/Link layer headers.

Solution: The fifth stream will compete with the ACKs of the other four streams. As ACKs are 10% of the traffic of data, this means that 4 streams with total of 10Gbps cause 1Gbps of ACK traffic. That would imply approximately 9Gbps for the fifth stream. The 900Mbps of the fifth stream reduces rate of original 4 streams as well. Overall, the original four streams will be reduced to $\approx 9.1/4$ Gbps= 2.275Gbps. The fifth stream will have rate of ≈ 9.09 Gbps. Could also be solved analytically for more precise values, but these are enough for full points.

(c) (6 points) Let us assume that all streams have a RTT of 1s. How big should each stream's flow control window be at least to not slow down data transfer? Please explain why!

Solution: Flow control window needs to be at least RTT*rate, so 2.275 Gbit =285 MB for the first 4 flows. The fifth flow will need at least 9.09 Gbit=1.136 GB. Such buffer sizes will allow the receiver to buffer all segments in case the first was lost in transmission.

(d) (5 points) For a short time, an additional UDP connection will transmit data over the connection towards RouterA. The source will send 5GB with 10Gbps. What is the expected effect on each of the five TCP connections? In which state will the congestion control of the streams be immediately after the finish of the UDP transmission?

Solution: The new UDP connection will lead to massive packet losses for the fifth stream, and massive ACK losses for the first 4 streams. The fifth stream will likely be in congestion avoidance mode (as triple duplicate ACKs are received by sender). The first four streams will be in slow start mode as no ACKs/duplicate ACKs are received, and timeouts occur.

(e) (5 points) Assume a single TCP stream has a constant rate of 1Mbps. How long will it (approximately) take until the Segment IDs will wrap around (e.g. reach 0 again, if IDs started with 0 at the beginning). To simplify calculations, assume that $2^{10} = 1000$

Solution: The segment IDs are 32 bit long and denote Bytes transmitted. To transmit $2^{32} = 4,294,967,296$ Bytes (roughly 32Gbit) with 1Mbps, it takes around 32,000 seconds (34.459s if not assumed that $2^{10} = 1000$). Hint: length of ID will always be in multiples of 8 bit (due to header alignment). 16 bit is much too small, so 32 bit is next better guess.

[END OF PAPER]

[THIS PAGE IS INTENTIONALLY LEFT BLANK]

[THIS PAGE IS INTENTIONALLY LEFT BLANK]