TDTS11/TEN1 – Computer networks and Internet protocols
TDDD93/TEN1 – Large-scale distributed systems and networks

Final Examination: 14:00-18:00, Wednesday, March 23, 2016
Time: 240 minutes
Total Marks: 40
Grade Requirements: Three (20/40); four (28/40); and five (36/40).
Assistance: None (closed book, closed notes, and no electronics)
Examiner: Niklas Carlsson

Instructions:

- Read all instructions carefully (including these)!!!! Some questions have multiple tasks/parts. Please make sure to address *all* of these.
- The total possible marks granted for each question are given in parentheses. The entire test will be graded out of 40. This gives you 10 marks per hour, or six minutes per mark, plan your time accordingly.
- This examination consists of a total of 9+1=10 questions. Check to ensure that this exam is complete.
- When applicable, please explain how you derived your answers. Your final answers should be clearly stated.
- Write answers legibly; no marks will be given for answers that cannot be read easily.
- Where a discourse or discussion is called for, be concise and precise.
- If necessary, state any assumptions you made in answering a question. However, remember to read the instructions for each question carefully and answer the questions as precisely as possible. Solving the *wrong* question may result in deductions! It is better to solve the *right* question incorrectly, than the *wrong* question correctly.
- Please write your AID number, exam code, page numbers (even if the questions indicate numbers as well), etc. at the top/header of each page. (This ensures that marks always can be accredited to the correct individual, while ensuring that the exam is anonymous.)
- Please answer in English to largest possible extent, and try to use Swedish or ”Swenglish” only as backup when not finding words or needing to further support your answers. In general, questions are designed to be answered using figures/tables.
- If needed, feel free to bring a dictionary from an official publisher. Hardcopy, not electronic!! Also, your dictionary is not allowed to contain any notes; only the printed text by the publisher.
- Good luck with the exam.

1) Question: Forwarding (6)

Show, illustrate, and explain the path of (i) the *first HTTP request* and (ii) the *first HTTP response* between a Web client (browser) and a Web server. You can make the following assumptions:

- The client is located in Sweden and the server in USA.
- The client machine uses Ethernet, has a single interface with a MAC address AA:AA:AA:AA:AA:AA.
- The GET request is for a webpage: www.aa.com/index.html.
- The client has obtained a dynamic IP address 187.187.123.123 from a DHCP server, which is running on the closest gateway router.
- The client uses a local DNS server with IP address 187.187.1.1 and MAC address EE.EE.EE.EE.EE.EE.
- The MAC and IP addresses of the Web server are DD:DD:DD:DD:DD:DD and 229.222.111.111. Similar to the client, the server has a single interface.
- The gateway router closest to the client has four interfaces. The first is the interface closest to the client and has MAC and IP addresses B1:B1:B1:B1:B1:B1 and 187.187.111.1. The second interface has MAC and IP addresses B2:B2:B2:B2:B2:B2 and 187.187.111.2. The third interface has MAC and IP addresses B3:B3:B3:B3:B3:B3 and 187.187.111.3. Finally, the fourth interface has MAC and IP addresses B4:B4:B4:B4:B4:B4 and 187.187.111.4.
- The gateway router closest to the server has four interfaces. The first is the interface closest to the server and has MAC and IP addresses C1:C1:C1:C1:C1:C1 and 228.222.111.1. The second interface has MAC and IP addresses C2:C2:C2:C2:C2:C2 and 228.222.111.2. The third interface has MAC and IP addresses C3:C3:C3:C3:C3:C3 and 228.222.111.3. Finally, the fourth interface has MAC and IP addresses C4:C4:C4:C4:C4:C4 and 228.222.111.4.
- The forwarding table at the gateway router closest to the client has many entries. However, for this question, the four most closely related entries states: 229.0.0.0/8 over interface 2, 228.0.0.0/6 over interface 3, 229.128.0.0/9 over interface 4, and 229.222.0.0/18 over interface 2.
- The forwarding table at the gateway router closest to the server has many entries. However, for this question, the four most closely related entries states: 187.187.192.0/18 over interface 2, 187.187.0.0/18 over interface 3, 187.187.64.0/18 over interface 4, and 187.187.0.0/24 over interface 2.

For this question you should also draw a picture of the topology, clearly indicate the path taken by the packet in this topology, and clearly state any assumptions you make about the topology (including parts of the networks not explained above) or anything else needed to solve the question. As with all your answers it is important that you also explain how you derived your answer. For example, why was the packet taking this particular route and not some other route?

2) Question: Encapsulation (6)

Consider the same scenario as above (Q1). Please use a series of figures to show and illustrate each messages (and their encapsulated address information) that the client need to *send* and *receive* (e.g., DHCP, ARP, and DNS) to obtain all the necessary IP and MAC addresses to complete the above web transaction. Your series of figures should capture all frames (both incoming and outgoing) from the time the client connects its laptop to the network up to and including the transfer of the webpage itself (which you can assume fits in a single packet). Each such message should clearly show the encapsulation and protocols used for each link-layer frame and all the encapsulated address information (including both addressing information for upper layer headers and addresses in the payload) *as it passes through the gateways router's network interface that is closest to the client.* You can assume that the only address information that the client initially knows is its own MAC address.

3) Question: TCP slow start (4)

Consider the download of the above file *index.html*, located on the server hosting *www.aa.com*. Assume that the client and server are using non-persistent HTTP/1.0, and that there is a 100ms round trip time (RTT) between them. Please draw a figure and explain the entire communication sequence associated with the file download, including the TCP handshake and connection teardown. You can assume that the payload is 20 packets, that each packet can be sent in 1ms, and that both payload packet two (2) and payload packet sixteen (16) are lost. You can also assume that the TCP version is implementing fast retransmit and fast recovery, that the initially *ssthresh* value is 4, and that the timeout period is (approximately) constant at 400ms. You should include a figure that clearly show when each packet is sent and received.

4) Question: HTTP and replication (6)

Performance and personalized service are important aspects of building good Web services. Please draw a picture illustrating the communication sequence when the client above downloads a smaller version of the above file *www.aa.com/index.html*, which in this question is only 3.5KB, but the webpage also include four embedded images (each 7KB in size). The main document and two of the embedded images can be found on the original Web server *www.aa.com* and the final two embedded images can be found on the server *www.bb.com*. You can assume that no proxy cache is used and the client communicates directly with the server *www.aa.com using pipelined HTTP* and directly with the server *www.bb.com using non-persistent HTTP*. Your picture should illustrate the client, all involved Web servers, and the communication sequence. Your picture should also clearly show connection establishment and teardown messages, as well as any other messages needed for the file transfer. You can assume that the MSS is 1.5KB, and both webservers have the same RTT and loss rates to the client. Also, how many packets are being sent between each of the two servers and the client? Which connections are likely to terminate last?

5) Question: Distance vector routing (4)

Consider a node A with neighbors B, C, and D. Node A currently has the distance table below. (Note that the network currently is not in a very good shape, and a few routing table updates will be needed to get the network back into shape.) Assume that it receives an updated distance vector from neighbor B which looks as follows [∞, 0, 1, 3, 8, 3, 7] and an updated distance vector from neighbor C which looks as follows [∞, 2, 0, 6, 3, 6, 3]. First, update the table below, including A's own distance vector. Second, assume that poison reverse is implemented, and show and explain exactly what information the node sends to each its neighbors (after the table has been updated).

	Costs			
Destination	A (via)	B	C	D
A	0 (A)	∞	∞	∞
B	1 (B)	0	4	5
C	1 (C)	2	0	7
D	1 (D)	7	4	0
E	? (?)	6	8	7
F	? (?)	2	11	5
G	? (?)	10	5	7

6) Question: End-to-end delay (4)

A common mistake when designing distributed systems or applications is to ignore the network delay. Consider a message of size L = 1,000 bytes that will be routed between two machines in a distributed system using a regular store-and-forward network, such as the Internet. Along its path, the message will traverse ten (10) routers, each requiring a packet processing delay t_p = 1ms and a queening delay that depends on the number of packets ahead of it in the outgoing send queue. For simplicity, let us assume that each link i (i = 1,2,3, ... 11) on the path has a propagation speed $s_i = 2.5 \cdot 10^8$ m/s, length l_i = 1,000 km, and transmission rate R_i = 100 Mbps. Please (i) draw the topology, (ii) list the different delays associated with the end-to-end path, (iii) derive an expression for the end-to-end delay, and (iv) calculate an estimate of the end-to-end delay. Four your answers to (iii) and (iv) you should consider two cases:

1. Assume that the message do not experience any queuing delays (e.g., the network is empty or there is minimal competing traffic).
2. Assume that the message on average is queued behind 1.5 packets per router.

7) Question: TCP fairness (4)

Use figures and examples to illustrate why TCP's additive increase and multiplicative decrease (AIMD) mechanism provides some stability and fairness.

8) Question: HTTP-based Adaptive Streaming (4)

In mobile environments, the network conditions experienced by a client may vary significantly over the duration of a session. In this context, you should first explain what the main advantages of HTTP-based adaptive streaming (HAS), used by Netflix, for example, is relative to non-adaptive HTTP-based streaming. Your answer should provide concrete examples (preferably using a figure of buffer conditions, network conditions, and playback quality, for example) of when and why HAS performs better in your example scenarios. Second, in the context of client playback performance, please explain the potential advantages of (i) splitting a file into multiple chunks, and (ii) using HTTP.

9) Question: BitTorrent (2)

One of the more important mechanisms in BitTorrent is the rarest-first policy. Please explain what this policy does, what it achieves, and why it is important for the success of BitTorrent.

10) Bonus questions: Confidentiality, message integrity, authentication (4)

Consider a sender that wants to provide efficient confidentiality, message integrity, and sender authentication with the help of a combination of symmetric keys (e.g., as with message authentication codes) and public keys (e.g., as with signed message digests).

1. Please clearly and briefly explain what confidentiality, message integrity, and authentication are.
2. Please draw a figure/diagram explaining how a sender can combine these different techniques to provide efficient confidentiality, message integrity, and sender authentication when sending one large message between two nodes (say from Alice to Bob). Ideally, your solution should be both secure and fast.
3. Briefly and clearly explain how your solution satisfies each of the above properties. Also, please list the main advantages/disadvantages with your solution compared to alternative approaches that try to use only one of the two types of keys separately.

Good luck!!