TDTS04 – Computer networks and distributed systems (TEN1)
Final Examination: 14:00-18:00, Monday, Mar. 21, 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 8+1=9 questions. Check to ensure that this exam is complete.
- When applicable, please state assumptions and show/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.
- 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.
- Yet, some question(s) may be ambiguous or have contradicting information. If necessary, please clearly identify any such instance and clearly state any additional necessary assumptions needed in answering such a question.
- 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 needed to support your answers.
- 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 123.123.123.123 from a DHCP server, which is running on the closest gateway router.
- The client uses a local DNS server with IP address 123.123.1.1 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 123.123.111.1. The second interface has MAC and IP addresses B2:B2:B2:B2:B2:B2 and 123.123.111.2. The third interface has MAC and IP addresses B3:B3:B3:B3:B3:B3 and 123.123.111.3. Finally, the fourth interface has MAC and IP addresses B4:B4:B4:B4:B4:B4 and 123.123.111.4.
- 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: 123.123.192.0/18 over interface 2, 123.123.0.0/18 over interface 3, 123.123.64.0/18 over interface 4, and 123.123.0.0/24 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 network interface of 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 fifteen (15) 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. 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 HTML page and each of the images are 5.5KB each, 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, 2, 3, 4, 5] and an updated distance vector from neighbor C which looks as follows [∞, 1, 0, 5, 4, 3, 2]. 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	2
C	1 (C)	2	0	2
D	1 (D)	7	4	0
E	? (?)	6	8	7
F	? (?)	2	11	6
G	? (?)	10	5	7

6) Question: Transparency and multi-tier systems (6)

Transparency plays a central role in some distributed systems. Consider a simple multi-tier system with three levels: a user interface, an application server, and two replicated database servers. Assume these layers are implemented as a distributed cloud service at different geographic locations and that the average round trip time (RTT) between the machines used in the consecutive layers (starting with the top-tier layer) is 30ms and 20ms, respectively. Consider a workload (set of calls) with two different types of "jobs" (call types). The first type results in fully synchronized calls in which the application server requires 50ms total processing and the database requires 100ms processing to satisfy the request. The second type does not require any database access, is fully synchronized and requires 50ms processing at the application server.

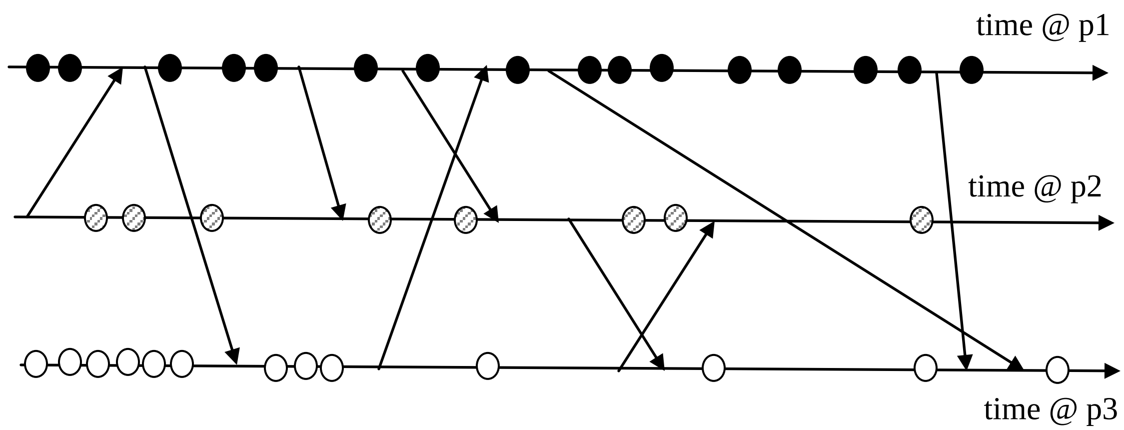
(a) For each of the two types of jobs, how much time is the client process locked from the moment it makes the request to the application server? You can assume that no large data is transferred between the layers such that the call and responses fits within a single package, and that messages do not need to be acknowledged. Please explain your answer and illustrate with a figure.

(b) Assuming 50% of the clients make each type of requests, what is the average response time (assuming no competing jobs or other reasons for queuing).

Please give concrete examples of two types of transparency that are provided in the above example. Remember to explain your answers.

7) Question: Lamport's clock (4)

Assume that you have three processes p1, p2, and p3 which are implementing Lamport's clocks. There are many events that take place at these processes, including both internal in-process events (shown as circles) and messages being sent between the processes (shown as arrows). Please provide the logical timestamps associated with each event. You can assume that all three clocks start at zero, at the left-most point in time. (Also, explain how the processes would adjust their clocks if using Lamport's logical clocks.)



8) Question: Power save mode (4)

Illustrate and explain how the power save mode in 802.11 can be used to save energy of the mobile nodes. What is the role of the access point? Also, sketch and explain the tradeoffs between latency (x-axis) and energy usage (y-axis), as well as between the latency (x-axis) and buffer size (y-axis) at the access point.

9) Bonus Question: IP fragmentation (4)

Consider a 4,000 byte IPv4 datagram which traverses 10 links on its path from A to B. Assume that links 1, 2, 5 and 8 have a maximum transmission unit (MTU) of 5,000 bytes and the other links have an MTU of 1,500 bytes.

(a) Please use a figure and explain when fragmentations occurs, and into how many fragments the datagram is fragmented/defragmented as it traverses each link of the forwarding path from A to B.

(b) Please use a figure and explain how this scenario will change if all routers on the path used IPv6. You can assume that the MTUs are the same as for the IPv4 case.

Good luck!!