Information page for written examinations at Linköping University

Examination date	2019-10-25
Room (2)	G35(1) TER4(30)
Time	14-18
Edu. code	TDDD66
Module	TEN1
Edu. code name **Module name**	Mobile Networks (Mobila nätverk) Written examination (Skriftlig tentamen)
Department	IDA
Number of questions in the examination	11
Teacher responsible/contact person during the exam time	Niklas Carlsson
Contact number during the exam time	013-282644
Visit to the examination room approximately	ca. 16:00
Name and contact details to the course administrator (name + phone nr + mail)	Annelie Almquist annelie.almquist@liu.se, 013-282934
Equipment permitted	None. (Well, please see cover page ...)
Other important information	
Number of exams in the bag	

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TDDD66 – Mobile Networks
Final Examination: 14:00-16:00, Friday, Oct. 25, 2019
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)
Instructor: Niklas Carlsson

Instructions:

- Read all instructions carefully, including these!
- Some questions have multiple tasks/parts. Please make sure to address *all* parts.
- The maximum possible points for each question is listed with each question.
- Be careful with the use of your time. The entire test will be graded out of 40. This gives you 10 marks per hour, or six minutes per mark. Since many of the questions on this exam can take time, please plan your time accordingly.
- This exam consists of a total of 10+1=11 questions. Check to ensure that this exam is complete.
- When applicable, please state assumptions and then show and explain how you derived your answers. Your final answers should also always be clearly stated.
- Write 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: Encapsulation (4)

Show (i) the link-layer frames of a *HTTP response* of a small Web page that fits in a single frame when the *response* first arrives at the network interface of the mobile client, (ii) a *DNS request* when the *request* first arrives to the access point used by the client, and (iii) a *DHCP offer* when the *offer* first arrives at to the access point used by the client. You can assume that the client is using 802.11. You do not have to show all the details of the different headers; however, you should (i) explain what protocols the different headers are associated with, and (ii) provide all address information associated with the source and destination fields for each of the different headers as well as the other *address information* included in the packets payload and headers. You can assume that the client machine uses 802.11, have a MAC address AA:AA:AA:AA:AA:AA, and obtains a dynamic IP address 111.111.11.11 when connecting with the network. The server providing this address has IP address 111.111.22.2 and MAC address CC.CC.CC.CC.CC.CC. The client uses a local DNS server (outside the gateway router) with IP address 111.222.1.1 and MAC address DD.EE.DD.EE.DD.EE. You can assume that the Web server is in a different continent than the client and that DNS messages go through at least one gateway router. The gateway router closest to the client has three interfaces, with the interface closest to the client having MAC and IP addresses BB:BB:BB:AA:AA:AA and 111.111.22.2, and the interface on the path to/from the Web server having MAC and IP addresses BB:BB:BB:BB:BB:BB and 111.111.11.222. The MAC address of the access point that the client is associated is AA:AA:AA:CC:CC:CC, and the access point is connected to the gateway router via layer-two Ethernet switches. Finally, the MAC and IP addresses of the HTTP server are DD:DD:DD:DD:DD:DD and 222.222.222.222. (Note: As explained on the cover page, if the necessary address information is not explicitly provided in the question, you are expected to make reasonable assumptions, and carefully motivate these assumptions.)

2) Question: CDMA and chipping codes (4)

With Code Division Multiple Access (CDMA), all users share the same frequency, but each user has its own "chipping" sequence (i.e., code) to encode data. Please use a concrete example in which you draw a figure that illustrates how a sender encodes a signal and how the receiver decodes the signal. First, use an example without competing traffic. Second, use an example with competing traffic (from a different sender but the same receiver, for example). In both scenarios, at least one of the clients should have a chipping code "0110".

3) Question: WiFi throughput (4)

Referring to our analysis of the 802.11 protocol, assume that you have measured (or through mathematical modeling have obtained estimates for) the average slot durations (measured in seconds) of a backoff period (T_b), collision period (T_c), and successful transmission (T_s). Furthermore, assume that the expected payload is L (measured in bytes), that you have estimated that there are N competing stations, and that the probability that a given station transmits in a slot is estimated to be τ. Given these assumptions, please derive an expression, using only the above quantities, for the expected WiFi throughput in that system.

Hint: Separately derive expressions of the probability P_t that there is at least one transmission in a timeslot and the probability P_s that a transmission is successful as a function of τ and N. As an intermediate step, you can then express the expected throughput using the probabilities P_t and P_s, before finally substituting in τ and N (instead of P_t and P_s).

4) Question: LTE scheduling (4)

Within the context of the Long Term Evolution (LTE) down channel, first use a figure to show the relationship between (i) Orthogonal Frequency-Division Multiplexing (OFDM) symbols, (ii) resource elements, (iii) resource blocks (RBs), (iv) subcarriers, (v) time slots, and (vi) the total resources allocated to each individual User Equipment (UE). Second, please use the example to estimate the throughput of a client that currently on average obtains 10 RBs in parallel and uses QPSK for the 75% of the time and 16 QAM for the other 25% of the time. (QPSK modulation allows 2 bits per OFDM symbol; 16 QAM allows 4 bits per OFDM symbol; and 64 QAM allows 6 bits per OFDM symbol.)

5) Question: Rate adaptation in contexts of 802.11 and LTE (5)

The wireless link characteristics can greatly impact the quality of a transmission. First, please explain the relationship between signal-to-noise ratio (SNR) and bit error rate (BER). Second, please explain how 802.11 leverage multiple physical layer encodings to adapt to changing link conditions. Third, in the context of scheduling in of the LTE downlink, please explain how different UEs are prioritized over time such as to maximize the effective throughput they receive. (Note that your answer could benefit from using some of the example values from Question 4, above.) Each of your three answers should include an explanatory figure together with a clear example scenario in which the client benefit from the use of rate adaptation.

6) 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.

7) Handovers and indirect routing in cellular 4G networks (4)

Explain and illustrate how handovers and indirect routing is used in the context of 4G/LTE networks with a mobile client. Please draw one or more figures that illustrate what happens with the routing of the network traffic as a mobile user that is away from its home network moves along a road, for example. Consider a mobility scenario involving many handovers and at least two of each of the following types of entities:

- Evolved Node B (eNB)
- Mobility Management Entity (MME)
- Serving Gateway (SGW)

Also, please try to separate control and data plane traffic.

8) Question: Geographic routing (4)

Illustrate and explain how routing takes place under the two different stages of greedy geographic routing protocols such as Greedy Perimeter Stateless Routing (GPSR): (i) when you are not at a "local minimum", and (ii) when you reach a "local minimum". Also, please use a figure to illustrate and discuss a scenario in which a packet is forwarded in both stages on its way to the final destination.

9) Question: Middle boxes (3)

Please consider a mobile client in Sweden watching video from a website in the US. Assume that the last link (closest to the user) is wireless link with much competing traffic on its WLAN. Please explain (using figures, example scenarios, and TCP fairness equations, for example) how the use of a middle-box can help improve the mobile end-users throughput when accessing this website.

10) 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 using HTTP-based adaptive streaming (HAS, used by Netflix, YouTube, DASH.js, Silverlight, Apple HLS, and most TV stations, for example) relative to using non-adaptive HTTP-based streaming. Second, please provide concrete examples, using one or more example figures, of the buffer conditions, network conditions, and playback quality, for example that illustrate these advantages (i.e., illustrate when and why HAS performs better in your example scenarios).

11) Bonus question: Network coding (4)

Please provide a concrete example (using figures) how network coding can be combined together with multicast to improve the *throughput* in a wireless multi-hop scenario with a single sender and two receivers compared to (i) naïve unicast, and (ii) naïve multicast.

Good luck!