TDDD66 – Mobile Networks
Final Examination: 8:00-12:00, Friday, Oct. 23, 2015
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)!!!!
- 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 10+1=11 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 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 request* of a small Web page that fits in a single frame when the *request* first arrives to the link layer at the gateway router closest to the client, and (ii) a *DNS response* when the *response* first arrives at the mobile 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 the address information associated with the source and destination fields for each of the different headers. You can assume that the client machine uses 802.11, have a MAC address AA:AA:AA:AA:AA:AA, and has obtained a dynamic IP address 111.111.11.11 from a DHCP server, which itself has IP address 111.111.22.2 and MAC address CC.CC.CC.CC.CC.CC. The client uses a local DNS server 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 the DNS request/query must go through a 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. 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: 802.11 collision avoidance (4)

The 802.11 protocol can handle some hidden-terminal problems using the RTS-CTS mechanism. Please illustrate the 802.11 communication sequence when two nodes A and C both want to communicate with an intermediate node B: (i) when the RTS-CTS mechanism is used, and (ii) when it is not being used. Also, please use a concrete example figure that shows the communication overhead as a function of packet size to discuss the performance tradeoffs of using RTS-CTS versus not using RTS-CTS.

3) Question: Handovers and indirect routing in cellular (4)

Explain and illustrate how handovers and indirect routing is used in the context of cell-phone networks (such as GSM) with a mobile client, such as to ensure that a user obtains seamless service. 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 scenario involving many base stations and mobile switching centers.

4) Question: CDMA and chipping codes (4)

With Code Division Multiple Access (CDMA), all users share same frequency, but each user has 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).

5) Question: LTE scheduling (4)

Within the context of the Long Term Evolution (LTE) down channel, please use a figure to show the relationship between (i) Orthogonal Frequency-Division Multiplexing (OFDM) symbols, (ii) resource elements, (iii) resource blocks, (iv) subcarriers, (v) time slots, and (vi) the total resources allocated to individual User Equipments (UEs). Also, please explain how different UEs are prioritized over time such as to maximize the effective throughput they receive.

6) 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.

7) Question: Bluetooth vs Microwaves vs WiFi (4)

Bluetooth, WiFi (802.11), and microwaves use the same frequency spectrum. Please compare (i) the frequency usage of the three technologies using a figure and (ii) explain how this channel usage behavior may impact other devices using the same spectrum. Finally, discuss the relative energy vs. data rate tradeoffs made by Bluetooth and WiFi, and put this tradeoff in the context of (i) and (ii).

8) Question: Packet losses and middle boxes (4)

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.

- **Part a:** Please draw a figure of the topology and explain where the delays and packet losses may occur in this scenario. Where are the loss probabilities bigger/smaller?
- **Part b:** 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.

9) 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 contact of cache performance, please explain the potential advantage of (i) splitting a file into multiple chunks, and (ii) using HTTP.

10) Question: Network coding (4)

Please provide a concrete example (e.g., 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.

11) Bonus Question: Buffers and Little's law (4)

Consider a long duration video streaming session between a client and a server, for which it was observed that the average round trip time (RTT) between the client and server was 200ms and the average TCP window size was 50 packets, each of which is 1.5kB. It was also measured that each video frame is buffered on average 10s at the player. Please estimate the average video encoding and buffer occupancy measured in bytes? **(Hint:** You may want to use Little's law twice.)

Good luck!