TDDD66 – Mobile Networks
Final Examination: 8:00-12:00, Thursday, Jan. 5, 2017
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* 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. Be careful with the use of your time. Many of the questions on this exam can take time.
- This examination consists of a total of 10 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: 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 network interface of 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 (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 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, 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: 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.

3) Handovers and indirect routing in cellular (4)

Explain and illustrate how handovers and indirect routing are 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 mobility 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 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).

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 each individual User Equipment (UE). 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: Mobile cloud computing and offloading (4)

In class, the concepts of mobile cloud computing (MCC) and offloading was discussed. Please draw a picture of the fraction of applications and services that could benefit from MCC as a function of the (i) amount of computing necessary and (ii) the amount of data that need to be transferred between the mobile device and the cloud. Also, for the different regions of the parameter space, please explain why MCC and offloading may be beneficial or not. (Note: It is not the absolute numbers that are of importance here, but the relationships between the different aspects and their constraints.)

8) Question: Roaming and energy (3)

In the context of roaming between 802.11 access points, for example, please explain the difference between active and passive scanning? Please discuss potential energy tradeoffs in this scenario.

9) Question: Packet losses and middle boxes (5)

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 frame/packet losses may occur in this scenario. Where are the loss probabilities bigger or smaller?
- **Part b:** Explain how the different layers in the network stack cause/handle these different frame/packet losses.
- **Part c:** 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) 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 (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. Now, please provide 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).

Good luck!