

Examination Mobile & Wireless Networking (192620010)

April 7, 2016

13.45 – 16.45

Notes:

- *Only the overhead sheets used in the course, 2 double-sided sheets of notes (any font size/density!), and a dictionary are allowed as reference material. Use of the book by Bear and Stalling, the reader, or any other material is not allowed.*
- *Use of a calculator is allowed but not really needed.*
- *Use of PDA, laptop, mobile phone etc. is not allowed. Please switch off your mobile phone.*
- *Indications like “[10]” at questions mean that you can obtain 10 points for that question.*

Abbreviations

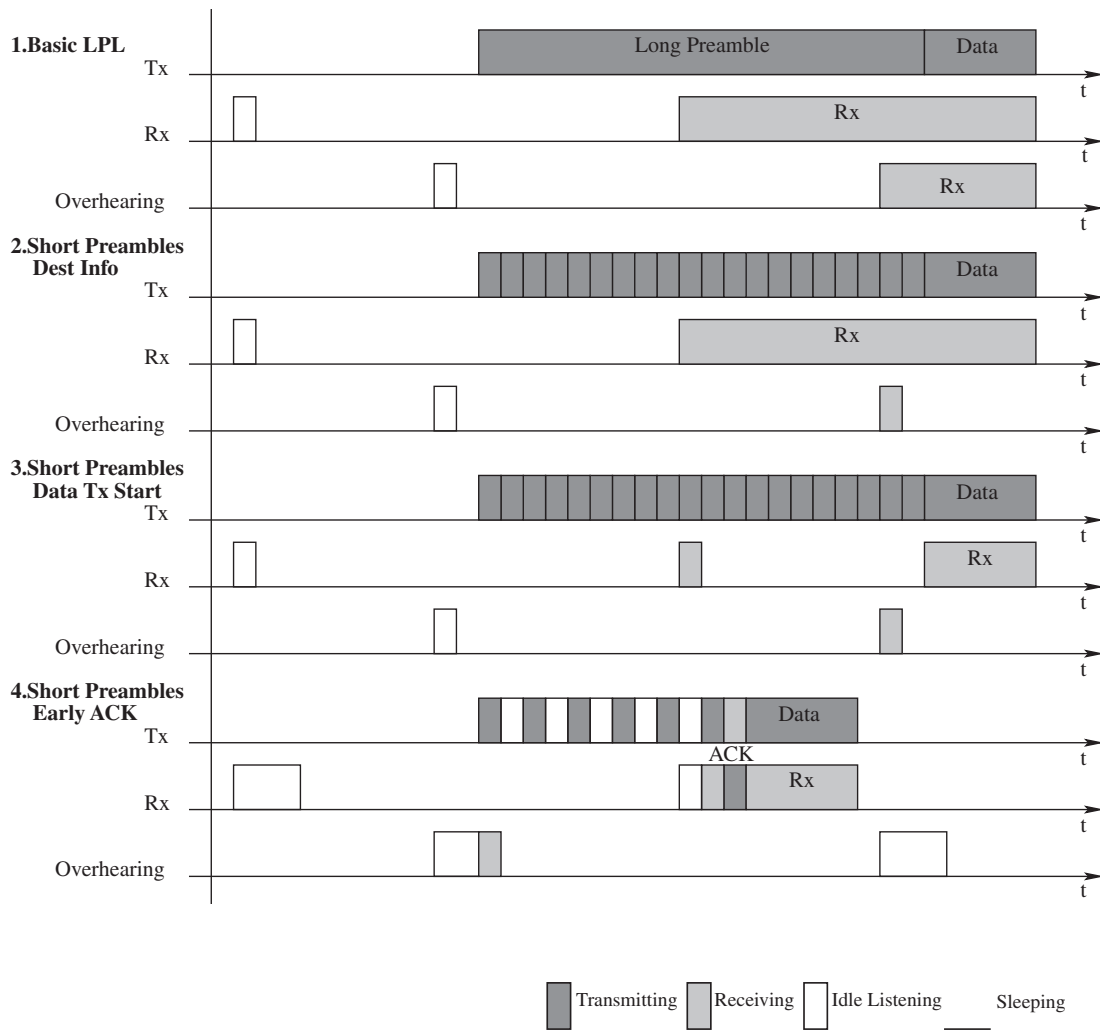
ACK	-	ACKnowledgement
ARQ	-	Automatic Repeat reQuest
CSMA	-	Carrier Sense Multiple Access
CSMA/CA	-	CSMA with Collision Avoidance
CTS	-	Clear To Send
CW	-	Contention Window
DCF	-	Distributed Coordination Function
Dest	-	Destination
DIFS	-	DCF Inter-Frame Space
FDD	-	Frequency Division Duplexing
FEC	-	Forward Error Correction
IEEE	-	Institute of Electrical and Electronics Engineers
LAN	-	Local Area Network
LPL	-	Low Power Listening
LTE	-	Long Term Evolution
MAC	-	Medium Access Control
MPR	-	Multi Point Relay
OFDM	-	Orthogonal Frequency Division Multiplexing
OLSR	-	Optimized Link State Routing
RTS	-	Request To Send
Rx	-	Receiver
SIFS	-	Short Inter-Frame Space
TDD	-	Time Division Duplexing
Tx	-	Transmitter

1 General [8]

- a) Why is reflection of radio waves both useful and harmful in a wireless system such as LTE? [2]
- b) Compare FEC, ARQ, and Hybrid ARQ with incremental redundancy. Which one performs better under which conditions? [3]
- c) To what extent do hidden terminal problems pose a problem in CSMA/CA, in Aloha, and in Bluetooth? [3]

2 Energy-efficient MAC protocols [7]

In the picture below the operation of 4 different Preamble Sampling Protocols is shown.



- a) Explain the operation of protocol 1, as shown in the picture (Basic Low Power Listening). Explain the behavior of the transmitter (Tx), the receiver (Rx), and the overhearers. [3]
- b) Explain how and why the behavior of the overhearers for protocol 2 (Short Preambles Dest Info) is different from protocol 1. [2]
- d) Explain how and why the behavior of the overhearers in protocol 4 (Short Preambles Early ACK) is different, compared to protocol 2. [2]

3 Cellular Systems [14]

- a) Mention 3 of the advantages and disadvantages of frequency and time division duplexing (FDD and TDD). [2]
- b) Consider a cellular system aiming at providing mobile telephony services with a grade of service of 0.02 (2%). It is composed of 4 different cells and a limited number of channels. We assume that each channel can only be used in one cell. Each user generates the traffic of 0.9 calls per hour with a mean holding time of 120 s. The number of subscribers residing in these cells is 1067, 2223, 1620, and 1260 respectively. We further assume that users are stationary. In this problem, you can use the Erlang B table that is given on the last page of this exam. The elements in this table give the amount of Erlang in traffic that can be supported given the number of available channels (leading column) and the required grade of service (leading row). Whenever necessary you can round the numbers down.

Answer the following subquestions. [3]

- i) Calculate the total traffic generated in the system
- ii) Calculate the number of channels required in each cell.
- iii) Now consider the situation where the users are not stationary, but can move freely through the entire service area of the system. Would the total number of channels required in each cell be higher or lower than the number of channels calculated in (ii)? Motivate your answer.
- c) Compare the three different types of carrier aggregation? What are their advantages and disadvantages? [2]
- d) What is the motivation of using OFDM in LTE systems? [2]
- e) What is cell breathing? Explain in which of the three generations (2G, 3G, 4G) of mobile networks it can occur and why? [2]
- f) Explain how in a cellular network the following factors affect each other: [3]
- Reuse factor/cluster size
 - Co-channel interference
 - Base-station antenna height
 - Network capacity
 - Network coverage

4 Wireless LAN [10]

- a) Why does the IEEE 802.11 CSMA/CA access mechanism use a number of different inter-frame spaces, such as SIFS and DIFS. [2]

In the following subquestions, we explore the IEEE 802.11 CSMA/CA DCF access mechanism further. We make the following assumptions: 1 slot = 20 μ s; SIFS = 10 μ s; DIFS = 2 slots + SIFS; CW_{\min} = 7 slots; CW_{\max} = 255 slots; transmission of a complete data frame takes 1000 μ s; transmission of a complete acknowledgement frame takes 250 μ s; propagation delay is negligible, no transmission errors occur, and no RTS/CTS is used. Now, suppose two stations A and B want to transmit a data frame to an access point. Assume that A and B can hear each other's transmissions.

- b) How large is the probability that a collision occurs between the frames from A and B if A and B start the access procedure at exactly the same time, when the medium is idle? Explain your answer. [2]

Assume that the first transmission attempts of A and B, as discussed in the previous question resulted in a collision between the two.

- c) How do A and B know that a retransmission has occurred and that they have to do a retransmission? [2]
- d) How large is the probability that the first retransmission (i.e., the 2nd transmission) of station A collides with the one from station B? Explain your answer. [2]
- e) How large is the probability that the first retransmission of station A collides with the one from station B if A and B cannot hear each other's transmissions? Explain your answer. [2]

5 Ad-hoc networks [12]

- a) Explain what the principles are of proactive and reactive routing protocols and under what circumstances one is better than the other. [2]
- b) In the OLSR (Optimized Link State Routing) protocol, all nodes select a subset of their neighbors as MPRs (multipoint relays). This optimizes OLSR, as compared to pure link state protocols, in two different ways. Give these two different ways in which selection of MPRs optimizes OLSR. [3]

Please see the figure below. Four ad-hoc nodes, A, B, C, and D are running the OLSR protocol. Nodes A and B are neighbors, and can hear each other. The same applies to nodes B and C. Node A and C cannot hear each other. At time t_0 , no communication is possible between node D and any of the other nodes. Furthermore, node B has been selected as MPR by both node A and node C. At t_0 , the network is stable, and A, B, and C know routes to the other (2) nodes in the network (and not to node D).



At time t_1 , node D comes within communication range of node C (not A and B), i.e., from t_1 on, nodes C and D can hear each other's transmissions.

- c) How will node C learn about the existence of node D? [2]
- d) How will node B learn about the existence of node D? [2]
- e) In this topology, how does node A learn how to reach D? Give each relevant packet, transmitted between a pair of neighboring nodes, between t_1 , and t_2 (when A has learned the route to D), and why it was sent. [3]

----- end of exam -----

P(B) = Trunks	0.005	0.01	0.015	0.02	0.03	0.05	0.07	0.1
20	11.092	12.041	12.680	13.188	14.002	15.252	16.273	17.614
21	11.860	12.848	13.514	14.042	14.890	16.191	17.255	18.652
22	12.635	13.660	14.352	14.902	15.782	17.134	18.240	19.693
23	13.429	14.479	15.196	15.766	16.679	18.082	19.229	20.737
24	14.214	15.303	16.046	16.636	17.581	19.033	20.221	21.784
25	15.007	16.132	16.900	17.509	18.486	19.987	21.216	22.834
26	15.804	16.966	17.758	18.387	19.395	20.945	22.214	23.885
27	16.607	17.804	18.621	19.269	20.308	21.905	23.214	24.939
28	17.414	18.646	19.487	20.154	21.224	22.869	24.217	25.995
29	18.226	19.493	20.357	21.043	22.143	23.835	25.222	27.053
30	19.041	20.343	21.230	21.935	23.065	24.803	26.229	28.113
31	19.861	21.196	22.107	22.830	23.989	25.774	27.239	29.174
32	20.685	22.053	22.987	23.728	24.917	26.747	28.250	30.237
33	21.512	22.913	23.869	24.629	25.846	27.722	29.263	31.302
34	22.342	23.776	24.755	25.532	26.778	28.699	30.277	32.367
35	23.175	24.642	25.643	26.438	27.712	29.678	31.294	33.435
36	24.012	25.511	26.534	27.346	28.649	30.658	32.312	34.503
37	24.852	26.382	27.427	28.256	29.587	31.641	33.331	35.572
38	25.694	27.256	28.322	29.168	30.527	32.624	34.351	36.643
39	26.539	28.132	29.219	30.083	31.469	33.610	35.373	37.715
40	27.387	29.011	30.119	30.999	32.413	34.597	36.397	38.788
41	28.237	29.891	31.021	31.918	33.359	35.585	37.421	39.861
42	29.089	30.774	31.924	32.838	34.306	36.575	38.447	40.936
43	29.944	31.659	32.830	33.760	35.255	37.565	39.473	42.012
44	30.801	32.546	33.737	34.683	36.205	38.558	40.501	43.088
45	31.660	33.435	34.646	35.609	37.156	39.551	41.530	44.165
46	32.521	34.325	35.556	36.535	38.109	40.545	42.559	45.243
47	33.385	35.217	36.468	37.463	39.063	41.541	43.590	46.322
48	34.250	36.111	37.382	38.393	40.019	42.537	44.621	47.401
49	35.116	37.007	38.297	39.324	40.976	43.535	45.654	48.481
50	35.985	37.904	39.214	40.257	41.934	44.534	46.687	49.562
51	36.856	38.802	40.132	41.190	42.893	45.533	47.721	50.644
52	37.728	39.702	41.052	42.125	43.853	46.533	48.756	51.726
53	38.601	40.604	41.972	43.061	44.814	47.535	49.791	52.808
54	39.477	41.507	42.894	43.999	45.777	48.537	50.827	53.891
55	40.354	42.411	43.817	44.937	46.740	49.540	51.864	54.975
56	41.232	43.317	44.742	45.877	47.704	50.544	52.902	56.059
57	42.112	44.224	45.667	46.817	48.689	51.548	53.940	57.144
58	42.993	45.132	46.594	47.759	49.636	52.553	54.979	58.229
59	43.875	46.041	47.522	48.701	50.603	53.559	56.018	59.315
60	44.759	46.951	48.451	49.645	51.570	54.566	57.058	60.401
61	45.644	47.863	49.381	50.590	52.539	55.573	58.099	61.488
62	46.531	48.776	50.311	51.535	53.509	56.581	59.140	62.575
63	47.418	49.689	51.243	52.482	54.479	57.590	60.181	63.663
64	48.307	50.604	52.176	53.429	55.450	58.599	61.224	64.750
65	49.197	51.520	53.110	54.377	56.422	59.609	62.266	65.839
66	50.088	52.437	54.044	55.326	57.395	60.620	63.309	66.927
67	50.980	53.355	54.980	56.276	58.368	61.631	64.353	68.016
68	51.874	54.273	55.916	57.226	59.342	62.642	65.397	69.106
69	52.768	55.193	56.853	58.178	60.316	63.654	66.442	70.196
70	53.663	56.113	57.791	59.130	61.292	64.667	67.487	71.286
71	54.560	57.035	58.730	60.083	62.268	65.680	68.532	72.376
72	55.457	57.957	59.670	61.036	63.244	66.694	69.578	73.467
73	56.356	58.880	60.610	61.991	64.222	67.708	70.624	74.558
74	57.255	59.804	61.551	62.945	65.199	68.723	71.671	75.649
75	58.155	60.729	62.493	63.901	66.178	69.738	72.718	76.741
76	59.056	61.654	63.435	64.857	67.157	70.753	73.765	77.833
77	59.958	62.581	64.379	65.814	68.136	71.769	74.813	78.925
78	60.861	63.508	65.322	66.772	69.116	72.786	75.861	80.018
79	61.765	64.435	66.267	67.730	70.097	73.803	76.909	81.110
80	62.669	65.364	67.212	68.689	71.078	74.820	77.958	82.203