

Exam in SSY305 Kommunikationssystem

Department of Signals and Systems

Exam date: March 16, 2017, 14:00–18:00

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Teaching Staff

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Material Allowed material is

- Chalmers-approved calculator
- L. Råde, B. Westergren. Beta, Mathematics Handbook, any edition.
- One A4 page with your own handwritten notes. Both sides of the page can be used. Photo copies, printouts, other students' notes, or any other material is not allowed.
- A paper-based dictionary, without added notes (electronic dictionaries are not allowed).

Grading A correct, clear and well-motivated solution gives a maximum of 12 points per problem.

An erroneous answer, unclear, incomplete or badly motivated solutions give point reductions down to a minimum of 0 points. No fractional points are awarded.

Answers in any other language than Swedish or English are ignored.

Solutions Are made available at the earliest at 19:00 on the course web page.

Results Exam results are posted on Ping-Pong no later than March 29, 2017. The grading review is on March 29 and April 5, 2017, 12:00–13:00 in room 6414 in the ED-building.

Grades The final grade on the course will be decided by the projects (maximum score 46), quizzes (maximum score 6), and final exam (maximum score 48). Project and exam must be passed (see course-PM for rules). The sum of all scores will decide the grade according to the following table.

Total Score	0–39	40–59	60–79	≥ 80
Grade	Fail	3	4	5

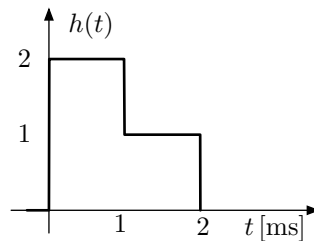
**PLEASE NOTE THAT THE PROBLEMS ARE NOT NECESSARILY
ORDERED IN DIFFICULTY.**

Good luck!

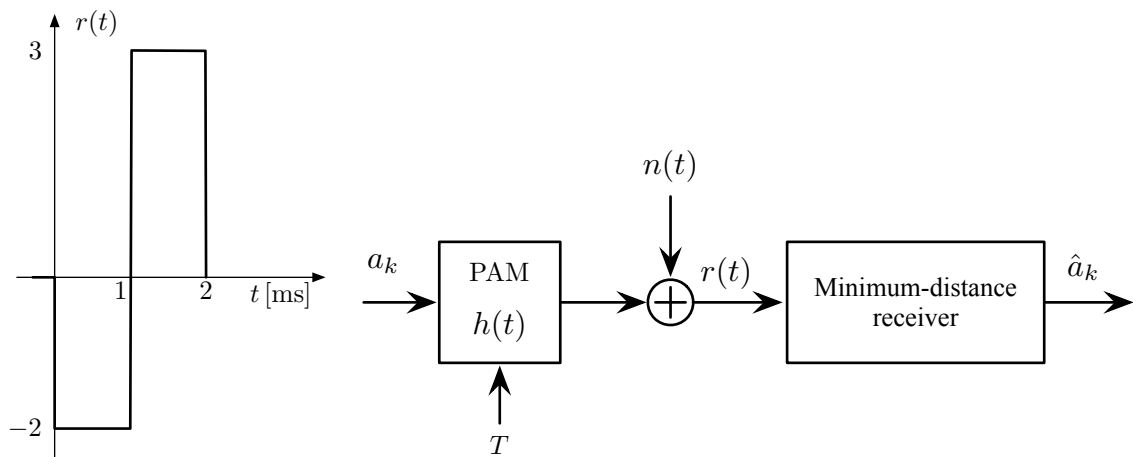
Table over the Q-function

x	Q(x)	x	Q(x)	x	Q(x)	x	Q(x)	x	Q(x)	x	Q(x)	x	Q(x)
0.00	5.0000E-01	0.76	2.2360E-01	1.52	6.4260E-02	2.28	1.1300E-02	3.04	1.1830E-03	3.80	7.2350E-05	4.56	2.5580E-06
0.01	4.9600E-01	0.77	2.2060E-01	1.53	6.3010E-02	2.29	1.1010E-02	3.05	1.1440E-03	3.81	6.9480E-05	4.57	2.4390E-06
0.02	4.9200E-01	0.78	2.1770E-01	1.54	6.1780E-02	2.30	1.0720E-02	3.06	1.1070E-03	3.82	6.6730E-05	4.58	2.3250E-06
0.03	4.8800E-01	0.79	2.1480E-01	1.55	6.0570E-02	2.31	1.0440E-02	3.07	1.0700E-03	3.83	6.4070E-05	4.59	2.2160E-06
0.04	4.8400E-01	0.80	2.1190E-01	1.56	5.9380E-02	2.32	1.0170E-02	3.08	1.0350E-03	3.84	6.1520E-05	4.60	2.1120E-06
0.05	4.8010E-01	0.81	2.0900E-01	1.57	5.8210E-02	2.33	9.9030E-03	3.09	1.0010E-03	3.85	5.9060E-05	4.61	2.0130E-06
0.06	4.7610E-01	0.82	2.0610E-01	1.58	5.7050E-02	2.34	9.6420E-03	3.10	9.6760E-04	3.86	5.6690E-05	4.62	1.9190E-06
0.07	4.7210E-01	0.83	2.0330E-01	1.59	5.5920E-02	2.35	9.3870E-03	3.11	9.3540E-04	3.87	5.4420E-05	4.63	1.8280E-06
0.08	4.6810E-01	0.84	2.0050E-01	1.60	5.4800E-02	2.36	9.1370E-03	3.12	9.0430E-04	3.88	5.2230E-05	4.64	1.7420E-06
0.09	4.6410E-01	0.85	1.9770E-01	1.61	5.3700E-02	2.37	8.8940E-03	3.13	8.7400E-04	3.89	5.0120E-05	4.65	1.6600E-06
0.10	4.6020E-01	0.86	1.9490E-01	1.62	5.2620E-02	2.38	8.6560E-03	3.14	8.4470E-04	3.90	4.8100E-05	4.66	1.5810E-06
0.11	4.5620E-01	0.87	1.9220E-01	1.63	5.1550E-02	2.39	8.4240E-03	3.15	8.1640E-04	3.91	4.6150E-05	4.67	1.5060E-06
0.12	4.5220E-01	0.88	1.8940E-01	1.64	5.0500E-02	2.40	8.1980E-03	3.16	7.8880E-04	3.92	4.4270E-05	4.68	1.4340E-06
0.13	4.4830E-01	0.89	1.8670E-01	1.65	4.9470E-02	2.41	7.9760E-03	3.17	7.6220E-04	3.93	4.2470E-05	4.69	1.3660E-06
0.14	4.4430E-01	0.90	1.8410E-01	1.66	4.8460E-02	2.42	7.7600E-03	3.18	7.3620E-04	3.94	4.0740E-05	4.70	1.3010E-06
0.15	4.4040E-01	0.91	1.8140E-01	1.67	4.7460E-02	2.43	7.5490E-03	3.19	7.1140E-04	3.95	3.9080E-05	4.71	1.2390E-06
0.16	4.3640E-01	0.92	1.7880E-01	1.68	4.6480E-02	2.44	7.3440E-03	3.20	6.8710E-04	3.96	3.7470E-05	4.72	1.1790E-06
0.17	4.3250E-01	0.93	1.7620E-01	1.69	4.5510E-02	2.45	7.1430E-03	3.21	6.6370E-04	3.97	3.5940E-05	4.73	1.1230E-06
0.18	4.2860E-01	0.94	1.7360E-01	1.70	4.4570E-02	2.46	6.9470E-03	3.22	6.4100E-04	3.98	3.4460E-05	4.74	1.0690E-06
0.19	4.2470E-01	0.95	1.7110E-01	1.71	4.3630E-02	2.47	6.7560E-03	3.23	6.1900E-04	3.99	3.3040E-05	4.75	1.0170E-06
0.20	4.2070E-01	0.96	1.6850E-01	1.72	4.2720E-02	2.48	6.5690E-03	3.24	5.9760E-04	4.00	3.1670E-05	4.76	9.6800E-07
0.21	4.1680E-01	0.97	1.6600E-01	1.73	4.1820E-02	2.49	6.3870E-03	3.25	5.7700E-04	4.01	3.0360E-05	4.77	9.2110E-07
0.22	4.1290E-01	0.98	1.6350E-01	1.74	4.0930E-02	2.50	6.2100E-03	3.26	5.5710E-04	4.02	2.9100E-05	4.78	8.7650E-07
0.23	4.0900E-01	0.99	1.6110E-01	1.75	4.0060E-02	2.51	6.0370E-03	3.27	5.3770E-04	4.03	2.7890E-05	4.79	8.3390E-07
0.24	4.0520E-01	1.00	1.5870E-01	1.76	3.9200E-02	2.52	5.8680E-03	3.28	5.1900E-04	4.04	2.6730E-05	4.80	7.9330E-07
0.25	4.0130E-01	1.01	1.5620E-01	1.77	3.8360E-02	2.53	5.7030E-03	3.29	5.0090E-04	4.05	2.5610E-05	4.81	7.5470E-07
0.26	3.9740E-01	1.02	1.5390E-01	1.78	3.7540E-02	2.54	5.5430E-03	3.30	4.8340E-04	4.06	2.4540E-05	4.82	7.1780E-07
0.27	3.9360E-01	1.03	1.5150E-01	1.79	3.6730E-02	2.55	5.3860E-03	3.31	4.6650E-04	4.07	2.3510E-05	4.83	6.8270E-07
0.28	3.8970E-01	1.04	1.4920E-01	1.80	3.5930E-02	2.56	5.2340E-03	3.32	4.5010E-04	4.08	2.2520E-05	4.84	6.4920E-07
0.29	3.8590E-01	1.05	1.4690E-01	1.81	3.5150E-02	2.57	5.0850E-03	3.33	4.3420E-04	4.09	2.1570E-05	4.85	6.1730E-07
0.30	3.8210E-01	1.06	1.4460E-01	1.82	3.4380E-02	2.58	4.9400E-03	3.34	4.1890E-04	4.10	2.0660E-05	4.86	5.8690E-07
0.31	3.7830E-01	1.07	1.4230E-01	1.83	3.3620E-02	2.59	4.7990E-03	3.35	4.0410E-04	4.11	1.9780E-05	4.87	5.5800E-07
0.32	3.7450E-01	1.08	1.4010E-01	1.84	3.2880E-02	2.60	4.6610E-03	3.36	3.8970E-04	4.12	1.8940E-05	4.88	5.3040E-07
0.33	3.7070E-01	1.09	1.3790E-01	1.85	3.2160E-02	2.61	4.5270E-03	3.37	3.7580E-04	4.13	1.8140E-05	4.89	5.0420E-07
0.34	3.6690E-01	1.10	1.3570E-01	1.86	3.1440E-02	2.62	4.3960E-03	3.38	3.6240E-04	4.14	1.7370E-05	4.90	4.7920E-07
0.35	3.6320E-01	1.11	1.3350E-01	1.87	3.0740E-02	2.63	4.2690E-03	3.39	3.4950E-04	4.15	1.6620E-05	4.91	4.5540E-07
0.36	3.5940E-01	1.12	1.3140E-01	1.88	3.0050E-02	2.64	4.1450E-03	3.40	3.3690E-04	4.16	1.5910E-05	4.92	4.3270E-07
0.37	3.5570E-01	1.13	1.2920E-01	1.89	2.9380E-02	2.65	4.0250E-03	3.41	3.2480E-04	4.17	1.5230E-05	4.93	4.1110E-07
0.38	3.5200E-01	1.14	1.2710E-01	1.90	2.8720E-02	2.66	3.9070E-03	3.42	3.1310E-04	4.18	1.4580E-05	4.94	3.9060E-07
0.39	3.4830E-01	1.15	1.2510E-01	1.91	2.8070E-02	2.67	3.7930E-03	3.43	3.0180E-04	4.19	1.3950E-05	4.95	3.7110E-07
0.40	3.4460E-01	1.16	1.2300E-01	1.92	2.7430E-02	2.68	3.6810E-03	3.44	2.9090E-04	4.20	1.3350E-05	4.96	3.5250E-07
0.41	3.4090E-01	1.17	1.2100E-01	1.93	2.6800E-02	2.69	3.5730E-03	3.45	2.8030E-04	4.21	1.2770E-05	4.97	3.3480E-07
0.42	3.3720E-01	1.18	1.1900E-01	1.94	2.6190E-02	2.70	3.4670E-03	3.46	2.7010E-04	4.22	1.2220E-05	4.98	3.1790E-07
0.43	3.3360E-01	1.19	1.1700E-01	1.95	2.5590E-02	2.71	3.3640E-03	3.47	2.6020E-04	4.23	1.1680E-05	4.99	3.0190E-07
0.44	3.3000E-01	1.20	1.1510E-01	1.96	2.5000E-02	2.72	3.2640E-03	3.48	2.5070E-04	4.24	1.1180E-05	5.00	2.8670E-07
0.45	3.2640E-01	1.21	1.1310E-01	1.97	2.4420E-02	2.73	3.1670E-03	3.49	2.4150E-04	4.25	1.0690E-05	5.01	2.7220E-07
0.46	3.2280E-01	1.22	1.1120E-01	1.98	2.3850E-02	2.74	3.0720E-03	3.50	2.3260E-04	4.26	1.0220E-05	5.02	2.5840E-07
0.47	3.1920E-01	1.23	1.0930E-01	1.99	2.3300E-02	2.75	2.9800E-03	3.51	2.2410E-04	4.27	9.7740E-06	5.03	2.4520E-07
0.48	3.1560E-01	1.24	1.0750E-01	2.00	2.2750E-02	2.76	2.8900E-03	3.52	2.1580E-04	4.28	9.3450E-06	5.04	2.3280E-07
0.49	3.1210E-01	1.25	1.0560E-01	2.01	2.2220E-02	2.77	2.8030E-03	3.53	2.0780E-04	4.29	8.9340E-06	5.05	2.2090E-07
0.50	3.0850E-01	1.26	1.0380E-01	2.02	2.1690E-02	2.78	2.7180E-03	3.54	2.0010E-04	4.30	8.5400E-06	5.06	2.0960E-07
0.51	3.0500E-01	1.27	1.0200E-01	2.03	2.1180E-02	2.79	2.6350E-03	3.55	1.9260E-04	4.31	8.1630E-06	5.07	1.9890E-07
0.52	3.0150E-01	1.28	1.0030E-01	2.04	2.0680E-02	2.80	2.5550E-03	3.56	1.8540E-04	4.32	7.8010E-06	5.08	1.8870E-07
0.53	2.9810E-01	1.29	9.8530E-02	2.05	2.0180E-02	2.81	2.4770E-03	3.57	1.7850E-04	4.33	7.4550E-06	5.09	1.7900E-07
0.54	2.9460E-01	1.30	9.6800E-02	2.06	1.9700E-02	2.82	2.4010E-03	3.58	1.7180E-04	4.34	7.1240E-06	5.10	1.6980E-07
0.55	2.9120E-01	1.31	9.5100E-02	2.07	1.9230E-02	2.83	2.3270E-03	3.59	1.6530E-04	4.35	6.8070E-06	5.11	1.6110E-07
0.56	2.8770E-01	1.32	9.3420E-02	2.08	1.8760E-02	2.84	2.2560E-03	3.60	1.5910E-04	4.36	6.5030E-06	5.12	1.5280E-07
0.57	2.8430E-01	1.33	9.1760E-02	2.09	1.8310E-02	2.85	2.1860E-03	3.61	1.5310E-04	4.37	6.2120E-06	5.13	1.4490E-07
0.58	2.8100E-01	1.34	9.0120E-02	2.10	1.7860E-02	2.86	2.1180E-03	3.62	1.4730E-04	4.38	5.9340E-06	5.14	1.3740E-07
0.59	2.7760E-01	1.35	8.8510E-02	2.11	1.7430E-02	2.87	2.0520E-03	3.63	1.4170E-04	4.39	5.6680E-06	5.15	1.3020E-07
0.60	2.7430E-01	1.36	8.6910E-02	2.12	1.7000E-02	2.88	1.9880E-03	3.64	1.3630E-04	4.40	5.4130E-06	5.16	1.2350E-07
0.61	2.7090E-01	1.37	8.5340E-02	2.13	1.6590E-02	2.89	1.9260E-03	3.65	1.3110E-04	4.41	5.1690E-06	5.17	1.1700E-07
0.62	2.6760E-01	1.38	8.3790E-02	2.14	1.6180E-02	2.90	1.8660E-03	3.66	1.2610E-04	4.42	4.9350E-06	5.18	1.1090E-07
0.63	2.6430E-01	1.39	8.2260E-02	2.15	1.5780E-02	2.91	1.8070E-03	3.67	1.2130E-04	4.43	4.7120E-06	5.19	1.0510E-07
0.64	2.6110E-01	1.40	8.0760E-02	2.16	1.5390E-02	2.92	1.7500E-03	3.68	1.1660E-04	4.44	4.4980E-06	5.20	9.9640E-08
0.65	2.5780E-01	1.41	7.9270E-02	2.17	1.5000E-02	2.93	1.6950E-03	3.69	1.1210E-04	4.45	4.2940E-06	5.21	9.4420E-08
0.66	2.5460E-01	1.42	7.7800E-02	2.18	1.4630E-02	2.94	1.6410E-03	3.70	1.0780E-04	4.46	4.0980E-06	5.22	8.9460E-08
0.67	2.5140E-01	1.43	7.6360E-02	2.19	1.4260E-02	2.95	1.5890E-03	3.71	1.0360E-04	4.47	3.9110E-06	5.23	8.4760E-08
0.68	2.4830E-01	1.44	7.4930E-02	2.20	1.3900E-02	2.96	1.5380E-03	3.72	9.9610E-05	4.48	3.7320E-06	5.24	8.0290E-08
0.69	2.4510E-01	1.45	7.3530E-02	2.21	1.3550E-02	2.97	1.4890E-03	3.73	9.5740E-05	4.49	3.5610E-06	5.25	7.6050E-08
0.70	2.4200E-01	1.46	7.2150E-02	2.22	1.3210E-02	2.98	1.4410E-03	3.74	9.2010E-05				

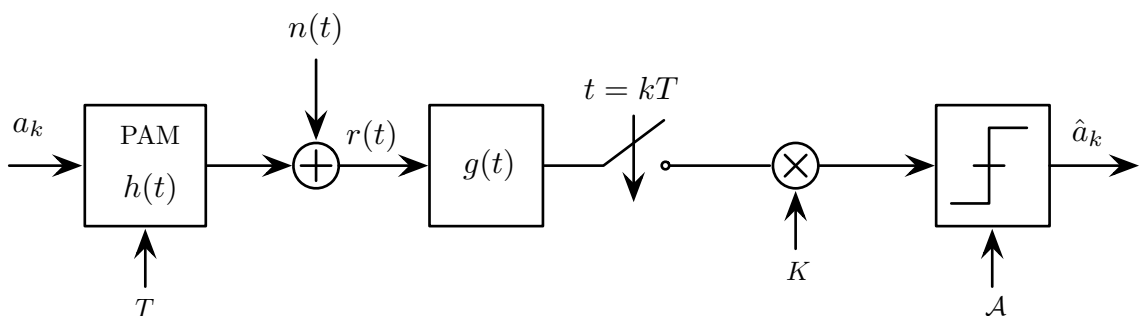
1. Consider transmission of independent, equally likely symbols $a_k \in \mathcal{A} = \{-3, -1, 1, 3\}$ for $k = 0, \pm 1, \pm 2, \dots$ over an AWGN channel using PAM with transmit pulse $h(t)$.



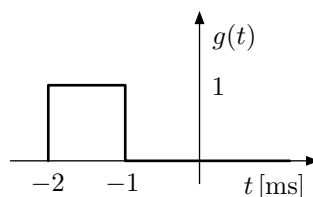
- (a) What is the maximum data rate that can be achieved without introducing intersymbol interference? Assume that the receiver is a minimum-distance receiver. (2p)
- (b) Suppose the received signal is $r(t)$ and that we use a minimum-distance receiver. What would be the decision on a_0 ? (3p)



- (c) Consider the receiver structure in the figure below. Suppose $K = 1$, determine $g(t)$ such that the symbol error probability is minimized. (3p)

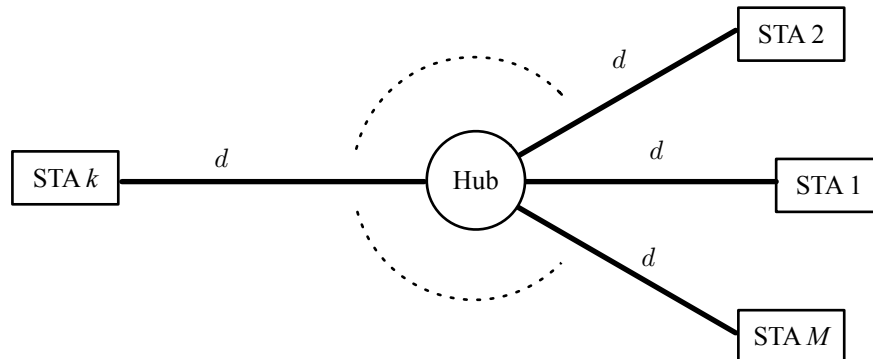


- (d) For the receiver structure in part (c), suppose the receiver impulse response is as in the figure below. What is the value of K that minimizes the probability of symbol error? (4p)



2. (a) What is the difference between a physical address, a network address, and a domain name? Give examples of each of them. (2p)
 - (b) Compare message authentication codes and digital signatures. What security properties do they provide? What are the advantages and disadvantages with them? (3p)
 - (c) Explain the purpose of the spanning tree algorithm in the context of transparent bridges. (2p)
 - (d) Explain why 802.11 DCF use CSMA/CA rather than CSMA/CD. (2p)
 - (e) Suppose vehicles (cars, buses, trucks, etc.) use 802.11 to enable cooperative traffic safety applications. Explain why “communication outside the context of an BSS” is preferable compared to using BSS-based communication. (2p)
 - (f) Given an example of a channelization scheme in which the channels can be accessed at all times. (1p)
3. Consider two stations, A and B, that are communicating over a 10^4 m long full-duplex optical cable. The propagation speed in the optical cable is $2c_0/3$, where $c_0 = 3 \times 10^8$ m/s. The physical layer has data rate of $R = 10$ Gbit/s. The data link (DL) protocol is capable of multiplexing and is currently serving two network protocol entities, NET1 and NET2. NET1 has 100-byte PDUs and NET2 has 1000-byte PDUs. For fairness reasons, the transmitter DL protocol entity accepts data from NET1 and NET2 in a round-robin fashion, i.e., the first DL SDU comes from NET1, the second DL SDU comes from NET2, the third DL SDU from NET1, etc. We assume that both NET1 and NET2 always have data to send. The DL data frame header and trailer are together 50 bytes, and an DL ACK frame is 40 byte long. The DL processing delay (for error detection etc.) is $2 \mu\text{s}$. Assume that there are no transmission errors.
 - (a) Suppose the DL layer use Stop-And-Wait ARQ. What is the data rate experienced by the NET1 and NET2 protocol entities? (4p)
 - (b) Suppose the DL layer aggregates one NET1 PDU and one NET2 PDU and transmit them in single DL PDU. What is the data rate experienced by the NET1 and NET2 protocol entities? Assume that there are no transmission errors. (4p)
 - (c) Repeat part (a) and (b) when using Go-Back-N (with a send window size that maximizes efficiency). (4p)

4. Consider a LAN with M users in a star topology as depicted in the figure below. Each station is connected with a cable of length $d = 100$ m to a central hub. The hub connects the stations on the physical layer. Hence, an incoming frame from station k is broadcasted out to all other stations. The delay imposed by the hub is $1 \mu\text{s}$ and the propagation speed in the cables is 2×10^8 m/s.



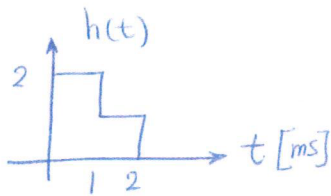
Suppose the MAC protocol is variation of p -persistent CSMA with collision detection. In particular, each station executes the following protocol

- Step 1* Wait until ready (i.e., until a new frame is ready to be transmitted)
- Step 2* Sense medium, if idle goto to *Step 5*, otherwise continue with next step
- Step 3* Wait one slot time, sense medium, and repeat until medium is idle
- Step 4* With probability $1 - p$ repeat previous step, otherwise continue with next step
- Step 5* Start transmission of frame. If collision is detected during the contention period, abort transmission and goto *Step 3* to attempt to retransmit the frame.
- Step 6* Medium is captured, complete transmission of frame.

We assume that the carrier sensing is instantaneous (i.e., take negligible time) and that the slot time is equal to the LAN contention time.

- Suppose the physical layer data rate is 1 Mbit/s. What is the minimum frame length in bytes for collision detection to work as intended (i.e., that all collisions are detected)? (2p)
- Suppose that the channel is idle for $t < 0$. At time $t = 0$, N stations becomes ready (which will generate a collision). Find the success probability, i.e., the probability that one of the stations captures the medium at the *first* possible time after the collision. Give the answer as a function of p and N . (4p)
- For a given N , what is the p that maximizes the success probability? (2p)
- Suppose p is the probability calculated in part (c), what is the success probability as N becomes very large? (2p)
Hint: $\lim_{x \rightarrow \infty} (1 - t/x)^x = e^{-t}$.
- What would be the advantage of replacing the hub with a link-layer switch? (2p)

1. (a)

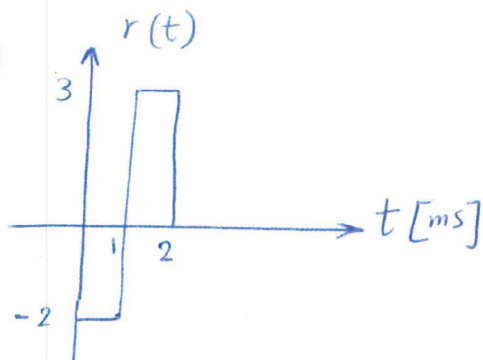


$$T_s = 2 \text{ ms} = 2 \times 10^{-3} \text{ s} \rightarrow R_s = \frac{1}{T_s} = 500 \text{ symbols/sec}$$

$$M = 4 \rightarrow k = \log_2(M) = 2$$

$$R_b = k R_s = 2 \times 500 = 1000 \text{ bits/sec}$$

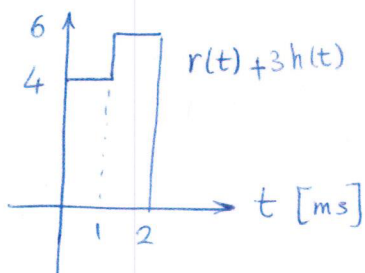
1. (b)



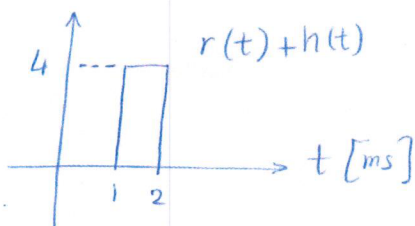
$$\hat{a}_0 = \arg \min_{a_0 \in \mathcal{A}} \|r(t) - a_0 h(t)\|_2^2 \rightarrow \text{Minimum Distance detector}$$

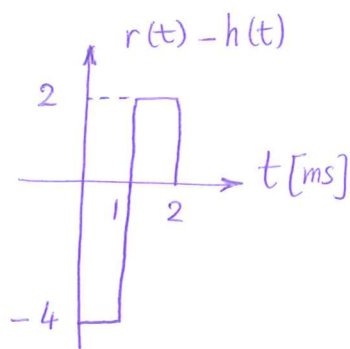
$$a_0 \in \mathcal{A} = \{-3, -1, 1, 3\} \rightarrow$$

$$a_0 = -3 \rightarrow D_1 = \|r(t) + 3h(t)\|_2^2 = \int_{-\infty}^{+\infty} |r(t) + 3h(t)|^2 dt = \sqrt{52 \times 10^{-3}}$$



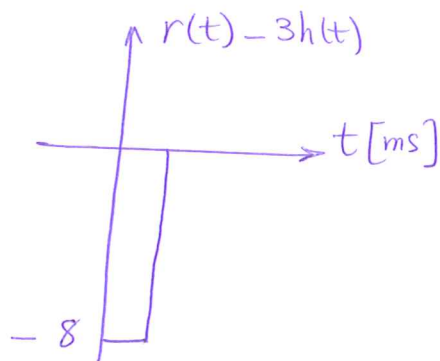
$$a_0 = -1 \rightarrow D_2 = \|r(t) + h(t)\| = \sqrt{16 \times 10^{-3}}$$





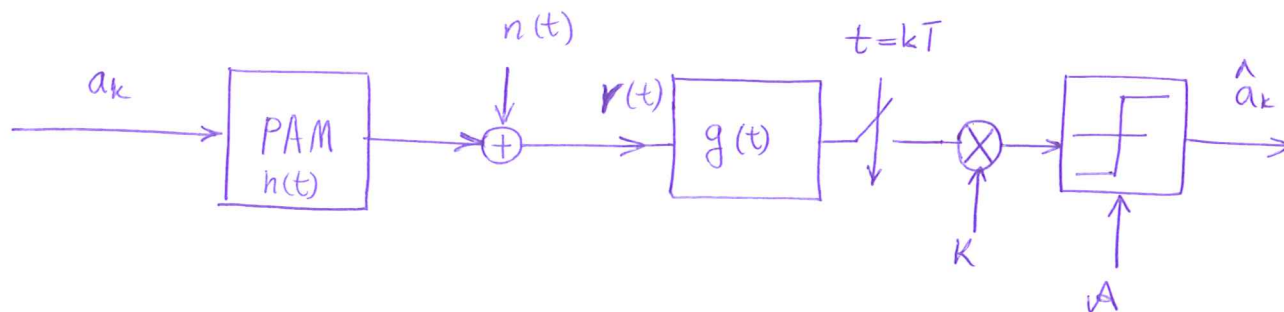
$$a_0 = 1 \rightarrow D_3 = \|r(t) - h(t)\|_2 = \sqrt{20 \times 10^{-3}}$$

$$a_0 = 3 \rightarrow D_4 = \|r(t) - 3h(t)\|_2 = \sqrt{64 \times 10^{-3}}$$



$$\hat{a}_0 = \arg \min_{a_0 \in A} \|r(t) - a_0 h(t)\| = -1$$

1.(c)



For AWGN Channel, the minimum distance receiver is Matched Filter.

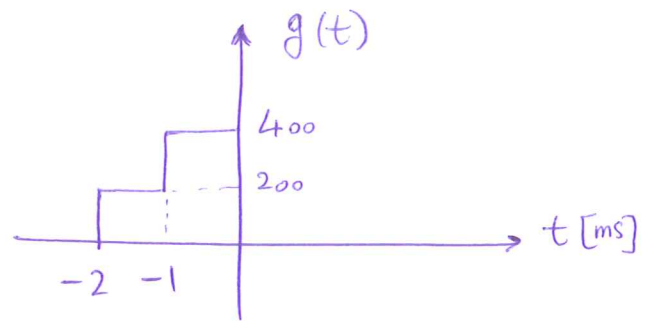
$$\text{ISI-free} \rightarrow h(t) * g(t) \Big|_{t=kT} = \begin{cases} \frac{1}{K}, & k=0 \\ 0, & k \neq 0 \end{cases}$$

$$g(t) = c h^*(-t)$$

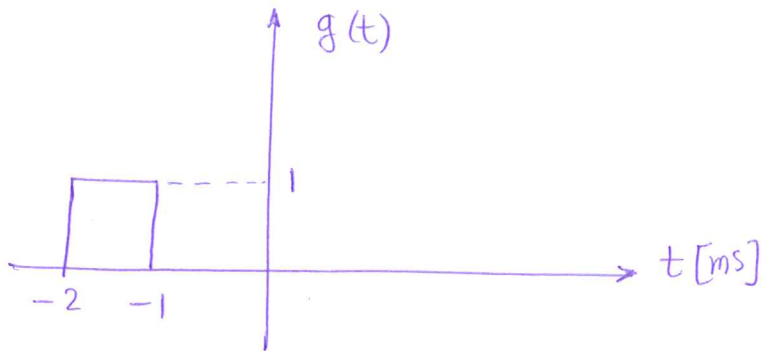
$$(h * g)(t) \Big|_{t=0} = 1 \rightarrow \int_{-\infty}^{+\infty} h(\tau) g(-\tau) d\tau = 1$$

$$c \int_{-\infty}^{+\infty} h(\tau) h^*(\tau) d\tau = 1 \rightarrow c E_h = 1 \rightarrow c = \frac{1}{E_h} = \frac{1}{5 \times 10^{-3}} = 200$$

$$\rightarrow g(t) = 200 h^*(-t)$$



1. (d)



$$f(t) = (h * g)(t) \Big|_{t=kT} = \begin{cases} \frac{1}{K} & k=0 \\ 0 & k \neq 0 \end{cases}$$

$$f(0) = \int_{-\infty}^{+\infty} h(\tau) g(-\tau) d\tau = \int_{10^{-3}}^{2 \times 10^{-3}} h(\tau) d\tau = 10^{-3}$$

$$f(0) = \frac{1}{K} \rightarrow K = 10^3$$

P2:

(a) What is the difference between a physical address, a network address, and a domain name? Give examples of each of them.

-A physical address is the hardware address used by the network to transfer packets to the appropriate destination on the same network. It identifies an interface of a machine on a physical network such as a LAN.

Example: Ethernet uses 6-byte addresses. Each Ethernet network interface card has globally unique physical address. The first 24 bits identify NIC manufacturer; second 24 bits are serial number

-A network address is a network-layer address that is used by networking software to allow packets to be independent of the physical connection of the network, that is, to work with different network topologies and types of media. A network address uniquely identifies a network interface card. A node can have several network addresses, e.g., if attached to several networks

-The physical and network address are hard for human beings to remember. The domain name are symbolic names that are unique and easy to remember. They are independent of the physical location

Example: www.chalmers.se-> chalmers.se is the domain name and www is the host name. The DNS translates the host name + domain name to an IP address: 129.16.17.21 (the first part is the net id, the second one is the host id)

(b) Compare message authentication codes and digital signatures. What security properties do they provide? What are the advantages and disadvantages with them?

Suppose Alice and Bob are the honest parties that communicate over an open channel, and suppose Trudy is an active malicious party that can intercept and possibly change messages from Alice before delivery to Bob. Message authentication codes and digital signatures provide *integrity*, i.e., it is computationally infeasible for Trudy to forge a message that Bob will accept as a genuine message from Alice. Message authentication codes use symmetric cryptography and signature use asymmetric cryptography. Hence, the advantage of message authentication codes is that they are less computationally demanding than digital signatures. On the other hand, key distribution for digital signatures is easier, since Bob only needs to know Alice's public key to verify that the message is from Alice. (In contrast, Alice and Bob need to share a common secret key to use message authentication codes.) Due to the shared key, Bob can be certain that a message that is not tampered with is indeed from Alice. Hence a level of *authentication* is provided. However, for message authentication codes, the level of authentication is not high, since Bob cannot prove to a third party (e.g., Charlie) that the message is from Alice. However, with digital signatures, a message is verified with Alice's public key. Hence, anyone (including Charlie) can verify that the message is from Alice.

(c) Explain the purpose of the spanning tree algorithm in the context of transparent bridges.

In the context of transparent bridges, the purpose of the spanning tree algorithm is to create a loop-free logical network topology from a physical topology that may have loops. This will enable bridges to create valid forwarding tables (i.e., tables that will ensure that frames reach their destinations) by backwards learning, i.e., by inspecting the destination addresses of data traffic on the attached LANs. The spanning tree algorithm logically disables links (bridge ports) such that the resulting topology is a spanning tree.

(d) Explain why 802.11 DCF use CSMA/CA rather than CSMA/CD.

Collision detection is very hard to use in wireless, since the transmitted signal has much higher power than the received signal. Moreover, carrier sensing in wireless is not perfect since stations that belong to the same LAN might not be in radio range.

(e) Suppose vehicles (cars, buses, trucks, etc.) use 802.11 to enable cooperative traffic safety applications. Explain why “communication outside the context of an BSS” is preferable compared to using BSS-based communication.

Traffic safety with 802.11p is one example of ad-hoc communication that uses outside the context of an BSS (OCB). In the OCB operation mode, the delay due to the process of authentication and association for establishing a BSS is avoided, and therefore the setup procedure is simplified which allows low-latency communication, that is fundamental in safety applications.

(f) Given an example of a channelization scheme in which the channels can be accessed at all times.

FDMA and CDMA are two examples of channelization scheme in which the channels can be accessed at all times.

3. (a) $d = 10^4 \text{ m}$

$v = \frac{2}{3} c = 2 \times 10^8 \text{ m/s}$

$R = 10 \text{ Gbps} = 10^{10} \text{ bit/sec}$

$\text{SDU1} = 100 \text{ byte} = 800 \text{ bit} \rightarrow \text{SDU of NET1}$

$\text{SDU2} = 1000 \text{ byte} = 8000 \text{ bit} \rightarrow \text{SDU of NET2}$

$t_{\text{prop}} = \frac{d}{v} = 50 \mu\text{s}$

$t_{\text{SDU1}} = \frac{800}{10^{10}} = 0.08 \mu\text{s}$

$t_{\text{proc}} = 2 \mu\text{s}$

$t_{\text{SDU2}} = \frac{8000}{10^{10}} = 0.8 \mu\text{s}$

$t_{\text{ack}} = \frac{40 \times 8}{10^{10}} = 0.032 \mu\text{s}$

$t_{\text{over}} = \frac{50 \times 8}{10^{10}} = 0.04 \mu\text{s}$

$t_1 = 2(t_{\text{prop}} + t_{\text{proc}}) + t_{\text{ack}} + t_{\text{over}} + t_{\text{SDU1}} = 104.152 \mu\text{s}$

$t_2 = 2(t_{\text{prop}} + t_{\text{proc}}) + t_{\text{ack}} + t_{\text{over}} + t_{\text{SDU2}} = 104.872 \mu\text{s}$

$R_1 = \frac{t_{\text{SDU1}}}{t_1 + t_2} \times R = \frac{0.08 \times 10^{10}}{104.152 + 104.872} = 3.8273 \times 10^6 \text{ bits/sec}$

$R_2 = \frac{t_{\text{SDU2}}}{t_1 + t_2} \times R = \frac{0.8 \times 10^{10}}{209.024} = 3.827 \times 10^7 \text{ bits/sec}$

3. (b)



$t = 2(t_{\text{prop}} + t_{\text{proc}}) + t_{\text{ack}} + t_{\text{over}} + t_{\text{SDU1}} + t_{\text{SDU2}} = 104.952 \mu\text{s}$

$R_1 = \frac{t_{\text{SDU1}}}{t} \times R = \frac{0.08}{104.952} \times 10^{10} = 7.62 \times 10^6 \text{ bits/sec}$

$R_2 = \frac{t_{\text{SDU2}}}{t} \times R = \frac{0.8}{104.952} \times 10^{10} = 7.62 \times 10^7 \text{ bits/sec}$

3. (c) Go back N.

* without aggregation

$$t_{GBN} = t_f \left(1 + \frac{P_f W_s}{1 - P_f} \right) \xrightarrow{(P_f=0)} = t_f$$

$$W_s > 2 (t_{prop} + t_{proc}) \frac{R}{n_f} \rightarrow \text{number of bits in a frame}$$

$$R_{GBN1} = \frac{n_{f1} - n_{over}}{t_{f1} + t_{f2}} = \frac{800}{t_{SDU1} + t_{over} + t_{SDU2} + t_{over}}$$

$$= \frac{800}{(0.12 + 0.84) \times 10^{-6}} = 8.33 \times 10^8 \text{ bits/sec}$$

$$R_{GBN2} = \frac{n_{f2} - n_{over}}{t_{f1} + t_{f2}} = \frac{8000}{0.96 \times 10^{-6}} = 8.33 \times 10^9 \text{ bits/sec}$$

3. (c) with aggregation

$$t_f = t_{SDU1} + t_{SDU2} + t_{over} = 0.92 \mu s$$

$$R_1 = \frac{800}{t_f} = 8.69 \times 10^8 \text{ bit/s}$$

$$R_2 = \frac{8000}{t_f} = 8.69 \times 10^9 \text{ bit/s}$$

4.(a)

$$t_f \geq \text{round-trip delay}$$

$$\frac{n_f}{R} \geq 2 (\text{Hub-delay} + \text{Propagation delay})$$

$$= 2 \left(10^{-6} + \frac{2d}{v} \right)$$

$$= 2 \left(10^{-6} + \frac{200}{2 \times 10^8} \right) = 4 \times 10^{-6}$$

$$n_f \geq 4 \times 10^{-6} \times 10^6 = 4 \text{ bit}$$

$$n_f \geq 1 \text{ byte}$$

4.(b)

$$P_{\text{succ}} = \binom{N}{1} P (1-P)^{N-1}$$

4.(c)

$$\frac{\partial P_{\text{succ}}}{\partial P} = N(1-P)^{N-1} + NP(-1)(N-1)(1-P)^{N-2}$$

$$= N(1-P)^{N-2} [1-P - P(N-1)]$$

$$= N(1-P)^{N-2} (1-NP) = 0$$

$$\begin{cases} 1-NP=0 \longrightarrow P^* = \frac{1}{N} \checkmark \\ 1-P=0 \longrightarrow P=1 \text{ X} \end{cases}$$

4.(d)

$$P_{\text{succ}} = N P^* (1-P^*)^{N-1} = N \times \frac{1}{N} \left(1 - \frac{1}{N}\right)^{N-1}$$

$$= \left(1 - \frac{1}{N}\right)^{N-1}$$

$$\lim_{N \rightarrow \infty} P_{\text{succ}} = \lim_{N \rightarrow \infty} \left(1 - \frac{1}{N}\right)^{N-1} = \lim_{N \rightarrow \infty} \left(1 - \frac{1}{N}\right)^N \xrightarrow{\text{Hint}} e^{-1}$$

4.(e) A link-layer switch remove all collisions, as frames are buffered in the switch. If there are no buffer overruns, there will be no collisions, more over, simultaneous communication is possible.
 $A \rightarrow B$, $C \rightarrow D$, etc.