Exam in
SSY305 Kommunikationssystem

Department of Electrical Engineering

Exam date: June 8, 2018, 14:00–18:00
Document updated: June 5, 2018

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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 June 13, 2017. The grading review is on June 14 and June 18, 2018, 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.

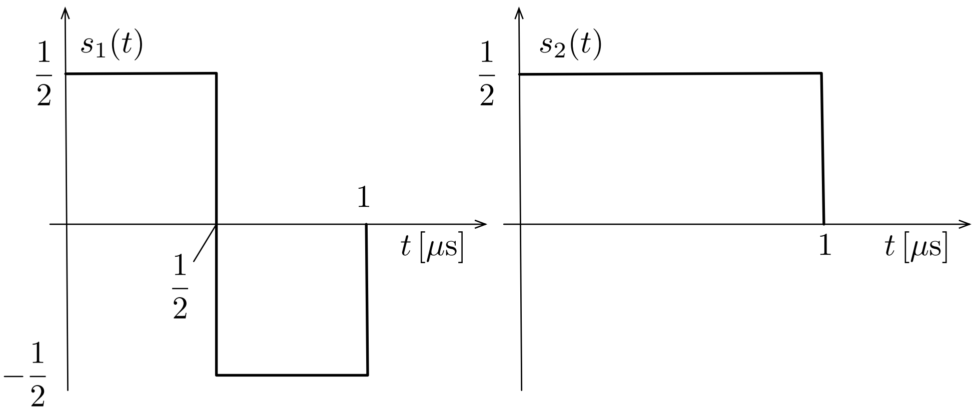
Total Score	0–39	40–69	70–79	≥ 80
Grade	Fail	3	4	5

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)	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	5.32	5.1880E-08
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	5.33	4.9110E-08
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	5.34	4.6470E-08
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	5.35	4.3980E-08
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	5.36	4.1610E-08
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	5.37	3.9370E-08
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	5.38	3.7240E-08
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	5.39	3.5230E-08
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	5.40	3.3320E-08
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	5.41	3.1510E-08
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	5.42	2.9800E-08
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	5.43	2.8180E-08
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	5.44	2.6640E-08
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	5.45	2.5180E-08
0.14	4.4430E-01	0.90	1.8410E-01	1.66	4.8460E-02	2.42	7.7600E-03	3.18	7.3640E-04	3.94	4.0740E-05	4.70	1.3010E-06	5.46	2.3810E-08
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	5.47	2.2500E-08
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	5.48	2.1270E-08
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	5.49	2.0100E-08
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	5.50	1.8990E-08
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	5.51	1.7940E-08
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	5.52	1.6950E-08
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	5.53	1.6010E-08
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	5.54	1.5120E-08
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	5.55	1.4280E-08
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	5.56	1.3490E-08
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	5.57	1.2740E-08
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	5.58	1.2030E-08
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	5.59	1.1350E-08
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	5.60	1.0720E-08
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	5.61	1.0120E-08
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	5.62	9.5480E-09
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	5.63	9.0100E-09
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	5.64	8.5030E-09
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	5.65	8.0220E-09
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	5.66	7.5690E-09
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	5.67	7.1400E-09
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	5.68	6.7350E-09
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	5.69	6.3520E-09
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	5.70	5.9900E-09
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	5.71	5.6490E-09
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	5.72	5.3260E-09
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	5.73	5.0220E-09
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	5.74	4.7340E-09
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	5.75	4.4620E-09
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	5.76	4.2060E-09
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	5.77	3.9640E-09
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	5.78	3.7350E-09
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	5.79	3.5190E-09
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	5.80	3.3160E-09
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	5.81	3.1240E-09
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	5.82	2.9420E-09
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	5.83	2.7710E-09
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	5.84	2.6100E-09
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	5.85	2.4580E-09
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	5.86	2.3140E-09
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	5.87	2.1790E-09
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	5.88	2.0510E-09
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	5.89	1.9310E-09
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	5.90	1.8180E-09
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	5.91	1.7110E-09
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	5.92	1.6100E-09
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	5.93	1.5150E-09
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	5.94	1.4250E-09
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	5.95	1.3410E-09
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	5.96	1.2610E-09
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	5.97	1.1860E-09
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	5.98	1.1160E-09
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	5.99	1.0490E-09
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	6.00	9.8660E-10
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	6.01	9.2760E-10
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	4.50	3.3980E-06	5.26	7.2030E-08	6.02	8.7210E-10
0.71	2.3890E-01	1.47	7.0780E-02	2.23	1.2870E-02	2.99	1.3950E-03	3.75	8.8420E-05	4.51	3.2410E-06	5.27	6.8210E-08	6.03	8.1980E-10
0.72	2.3580E-01	1.48	6.9440E-02	2.24	1.2550E-02	3.00	1.3500E-03	3.76	8.4960E-05	4.52	3.0920E-06	5.28	6.4590E-08	6.04	7.7060E-10
0.73	2.3270E-01	1.49	6.8110E-02	2.25	1.2220E-02	3.01	1.3060E-03	3.77	8.1620E-05	4.53	2.9490E-06	5.29	6.1160E-08	6.05	7.2420E-10
0.74	2.2960E-01	1.50	6.6810E-02	2.26	1.1910E-02	3.02	1.2640E-03	3.78	7.8410E-05	4.54	2.8130E-06	5.30	5.7900E-08	6.06	6.8060E-10
0.75	2.2660E-01	1.51	6.5520E-02	2.27	1.1600E-02	3.03	1.2230E-03	3.79	7.5320E-05	4.55	2.6820E-06	5.31	5.4810E-08	6.07	6.3960E-10

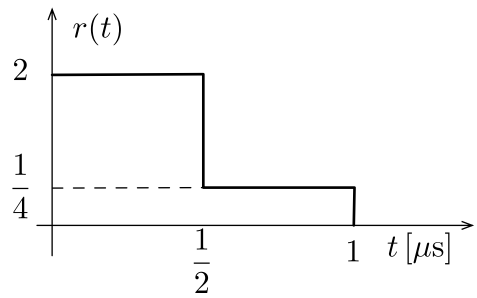
1. Consider a physical layer with signal alternatives $\{s_1(t), s_2(t), s_3(t), s_4(t)\}$, where $s_1(t)$ and $s_2(t)$ are defined in the figure below and where $s_3(t) = -s_1(t)$ and $s_4(t) = -s_2(t)$.



   (a) What is the maximum data rate that can be transmitted without ISI? (4p)

   (b) What is the average symbol energy, the average bit energy, and the transmit power when transmitting at the rate in Part (a)? (4p)

   (c) Suppose the received signal is $r(t) = s_m(t) + n(t)$, where $r(t)$ is defined in the figure below and m is the transmitted symbol. What decision on m would the minimum-distance receiver make? Motivate. (4p)



2. (a) Explain the purpose of the data link layer in the OSI model. (2p)

   (b) Define the security goals integrity and confidentiality. Give an example of an application when integrity is required but not confidentiality. (3p)

   (c) Discuss the advantages and disadvantages in using Ethernet for control applications. (3p)

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3. Consider a LAN with $M = 100$ attached stations. The protocol stack consist of a physical layer that provides a data rate $R = 100\,\text{Mbit/s}$, a network layer, and a link layer. We assume that the physical layer is quite robust: in the absence of collisions on the medium, we can neglect frame errors. The LAN medium length is 1000 m and the propagation speed is $c = 2 \times 10^8\,\text{m/s}$.

   The network layer SDUs have size 1000 byte and the link layer header and trailer are together 24 byte.

   (a) Suppose that the MAC layer is TDMA with slot duration T_s. We design the slot time such that (i) the bits transmitted in a slot can carry a whole network SDU, (ii) no collisions can occur at any receiving station, and (iii) to maximize the data rate for the stations. What is the (average) data rate R_u in bit/s that the network layer entity in a station can experience? Assume that the station has always have data to transmit. (3p)

   (b) Let $R_{\text{LAN},u}$ be the aggregated, useful data rate on the LAN, i.e., the average number of network SDU bits from all stations transmitted on the LAN per second. Suppose that N of the M stations have data to transmit. What is the normalized throughput, $\rho = R_{\text{LAN},u}/R$, for the TDMA scheme in Part (a) when $N = M$ and $N = M/10$, respectively? (3p)

   (c) Repeat Part (a) and (b) when $R = 1\,\text{Gbit/s}$. Comment on the results. (2p)

   (d) Suppose we replace the TDMA scheme with a simple reservation scheme. The reservation messages are 24 byte long and are transmitted in minislots of duration T_ms, which is designed such that (i) the bits transmitted in a slot can carry a whole reservation message, (ii) no collisions can occur at any receiving station, and (iii) to maximize the data rate for the stations. A cycle starts by that the M stations sends one reservation message each. Then, the N stations that have data to transmit sends a single network SDU each, which completes the cycle. What is the highest data rate R_u in bit/s that the network layer entity in a station can experience when $N = M$ and $N = M/10$, respectively? Assume $R = 1\,\text{Gbit/s}$. Comment on the results. (4p)

4. Consider a Stop-And-Wait ARQ protocol over a full-duplex physical medium of length 160 m and propagation speed 2×10^8 m/s. Data frames are 100 byte and ACK frames are 50 byte. The data rate on the medium is 1 Gbit/s. The protocol use binary state variable S_{last} and R_{next}, where S_{last} is the sequence number of the last transmitted frame and R_{next} is the sequence number of the frame that receiver expect to receive next. The state variables are initialized as $S_{\text{last}} = 1$ and $R_{\text{next}} = 0$.

   (a) Draw a timing diagram (see example below) until three consecutive data frames have beed received correctly and acknowledged. The timeout is set to $10t_f$, where t_f is the data frame duration. Assume that no data frame or ACK frame errors occur. (2p)

   (b) Repeat Part (a) when the second transmitted data frame suffers a frame error. All other frame transmissions are successful. (2p)

   (c) Draw a timing diagram until three consecutive data frames have beed received correctly and acknowledged. The timeout is set to $2t_f$, where t_f is the data frame duration. Assume that no data frame or ACK frame errors occur. (2p)

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   (e) What is the value of the timeout that maximizes the effective rate when the frame error probability is nonzero? Motivate carefully. Discuss potential drawbacks. (4p)

The timing diagram should have two time axis, one for the transmitter events and one for the receiver events. On the axes, it should be noted when

- data frame and ACK frame transmission and reception start and end
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- state variables change

Make sure to label axis and draw carefully. See below for a (hypothetical) example that illustrates events in the table below

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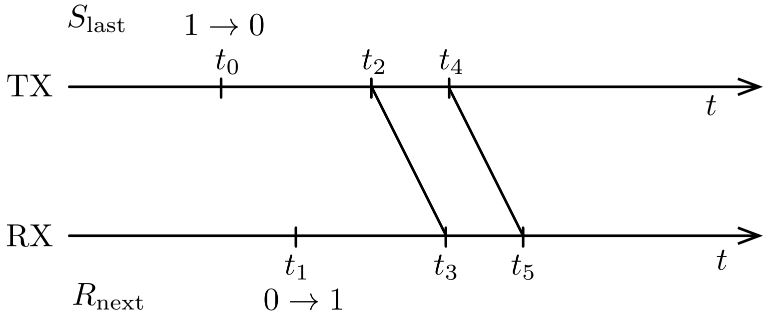

Exam in
SSY305 Kommunikationssystem

Department of Electrical Engineering

Exam date: June 8, 2018, 14:00–18:00

Document updated: June 12, 2018

Teaching Staff

Erik Ström (examiner), 031-772 5182
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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 June 13, 2017. The grading review is on June 14 and June 18, 2018, 12:00–13:00 in room 6414 in the ED-building.

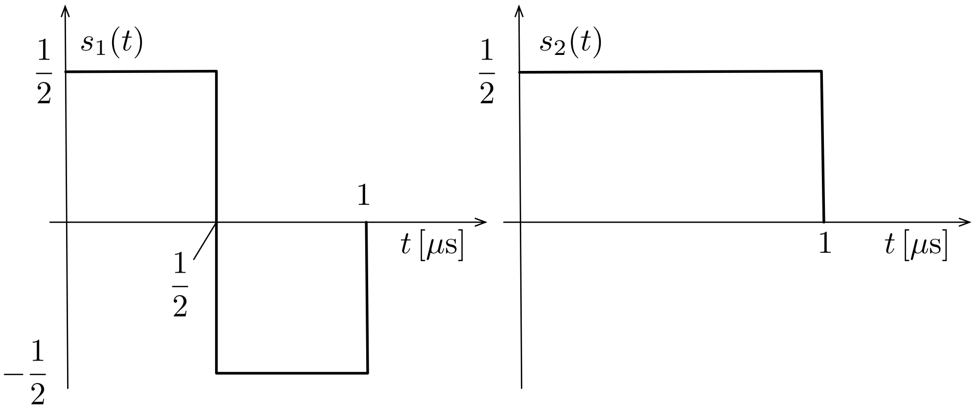
Grades The final grade on the course will be decided by the projects (maximum score 46), quizzes (maximum score 6), and final exam (maximum score 48). Project and exam must be passed (see course-PM for rules). The sum of all scores will decide the grade according to the following table.

Total Score	0–39	40–69	70–79	≥ 80
Grade	Fail	3	4	5

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

Good luck!

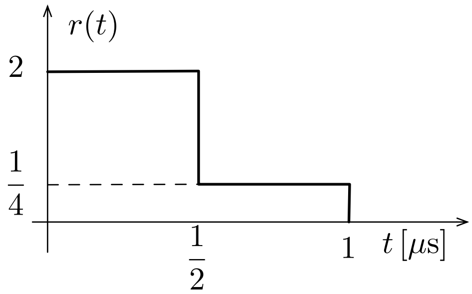
1. Consider a physical layer with signal alternatives $\{s_1(t), s_2(t), s_3(t), s_4(t)\}$, where $s_1(t)$ and $s_2(t)$ are defined in the figure below and where $s_3(t) = -s_1(t)$ and $s_4(t) = -s_2(t)$.



(a) What is the maximum data rate that can be transmitted without ISI? (4p)

(b) What is the average symbol energy, the average bit energy, and the transmit power when transmitting at the rate in Part (a)? (4p)

(c) Suppose the received signal is $r(t) = s_m(t) + n(t)$, where $r(t)$ is defined in the figure below and m is the transmitted symbol. What decision on m would the minimum-distance receiver make? Motivate. (4p)



Solution:

(a) The symbols duration is $T = 1\mu s$ and we have 4 signal alternatives $M = 4$. Thus the maximum symbol rate is $R_s = \frac{1}{T_s} = 1$ Msym/s.
And the maximum data rate is : $R_b = log_2(M)R_s = 2$ Mbit/S

(b) We have the energy of each symbol
$Es_i = \int_0^T |si(t)|^2 dt = \int_0^{10^{-6}} \frac{1}{4} dt = \frac{1}{4} 10^{-6} J \qquad \forall i = 1...4$
Thus, the avergae symbol energy is :$\sum_{i=1}^{4} p_i.Es_i = \frac{1}{4}10^{-6}$.
where pi corresponds to probability that symbol s_i is transmitted

The avergae bit energy is: $E_b = \frac{Es}{log_2(M)} = \frac{1}{8}.10^{-6}$

The average transmitted power is : $P = \frac{Es}{T} = 0.25$ W

(c) The miniumum distance receiver rule corresponds to:

$m^* = \arg\min_m ||r(t) - s_m(t)|| = \arg\min_m \sqrt{\int_{-\infty}^{\infty} |r(t) - s_m(t)|^2 dt}$
Which is equivalent to : $m^* = \arg\min_m ||r(t) - s_m(t)||^2$

We compute the distances' squares between $r(t)$ and the different signal alternatives:

$d_1^2 = \int_{-\infty}^{\infty} |r(t) - s_1(t)|^2 dt = \int_0^{T/2} (2 - 1/2)^2 dt + \int_{T/2}^{T} (1/4 + 1/2)^2 dt = \frac{45}{32} 10^{-6}$

$d_2^2 = \int_{-\infty}^{\infty} |r(t) - s_2(t)|^2 dt = \int_0^{T/2} (2 - 1/2)^2 dt + \int_{T/2}^{T} (1/4 - 1/2)^2 dt = \frac{37}{32} 10^{-6}$

$d_3^2 = \int_{-\infty}^{\infty} |r(t) - s_3(t)|^2 dt = \int_0^{T/2} (2 + 1/2)^2 dt + \int_{T/2}^{T} (1/4 - 1/2)^2 dt = \frac{101}{32} 10^{-6}$

$d_4^2 = \int_{-\infty}^{\infty} |r(t) - s_4(t)|^2 dt = \int_0^{T/2} (2 + 1/2)^2 dt + \int_{T/2}^{T} (1/4 + 1/2)^2 dt = \frac{109}{32} 10^{-6}$

Comparing these, we conclude that the receiver will decide for **m=2**.

2. (a) Explain the purpose of the data link layer in the OSI model. (2p)

   The data link is used to provide a reliable node-to-to node transfering service over the physical layer. The main functionalities implemenetd in this link are : Framing, flow control, error control (ARQs) and Medium Access Control (MAC).

   (b) Define the security goals integrity and confidentiality. Give an example of an application when integrity is required but not confidentiality. (3p)

   Integrity: The goal is to ensure that the message that has been transmitted hasn't been altered by a third party

   Confidentiality: the goal is to keep the content of a message private and confidential in such a way that only the communicating parties can have access to it.

   An example:

   In vehicular communication for safety, status messages that are sent in boradcast mode requires integrity but not confidentiality.

   (c) Discuss the advantages and disadvantages in using Ethernet for control applications. (3p)

   Advantages: High bandwidth- Relatively low cost

   Disadvnatges: No priorities among messages- High latency and jitter-Large minium packet size

   (d) What is the purpose of the modulator block in the Shannon communication model? (2p)

   The modulator block is used to convert digital signals to analog signals that are suitable for transmission over physical mediums (channels). The modulator is designed such that we maximize the data rate , minimize errors at the receiver and optimize the use of resources, that is : power and bandwidth

   (e) Describe the service provided by the IP protocol in the TCP/IP model. (2p)

   The main service provided by IP is Routing.And It provides that in datagram best-effort fashion.

3. Consider a LAN with $M = 100$ attached stations. The protocol stack consist of a physical layer that provides a data rate $R = 100\,\text{Mbit/s}$, a network layer, and a link layer. We assume that the physical layer is quite robust: in the absence of collisions on the medium, we can neglect frame errors. The LAN medium length is 1000 m and the propagation speed is $c = 2 \times 10^8\,\text{m/s}$.

   The network layer SDUs have size 1000 byte and the link layer header and trailer are together 24 byte.

   (a) Suppose that the MAC layer is TDMA with slot duration T_s. We design the slot time such that (i) the bits transmitted in a slot can carry a whole network SDU, (ii) no collisions can occur at any receiving station, and (iii) to maximize the data rate for the stations. What is the (average) data rate R_u in bit/s that the network layer entity in a station can experience? Assume that the station has always have data to transmit. (3p)

   To satisfy the requirements the slot duration is set to: $T_s = \tau_{max} + T_{tr}$, where τ_{max} corresponds to the maximum propagation delay on the LAN and T_{tr} is transmission time of an SDU.

   In this TDMA scheme, all stations are allocated time slots. Thus, the average data rate is $R_u = \frac{n_u}{M.T_S}$ where n_u is the size of an SDU in bits.

   We compute the different parameters:
   $\tau_{max} = \frac{L}{c} = \frac{1000}{2.10^8} = 5\,\mu\text{s}$
   $T_{tr} = \frac{n_u+n_o}{R} = \frac{(1000+24)(8)}{100.10^6} = 81.92\,\mu\text{s}$ (n_o corresponds to the size of header and trailer)
   $T_s = \tau_{max} + T_{tr} = 86.92\,\mu\text{s}$
   $R_u = \frac{1000(8)}{100.(81{,}92+0{,}2).10^{-6}} = 0.92\,\text{Mbit/s}$

   (b) Let $R_{\text{LAN},u}$ be the aggregated, useful data rate on the LAN, i.e., the average number of network SDU bits from all stations transmitted on the LAN per second. Suppose that N of the M stations have data to transmit. What is the normalized throughput, $\rho = R_{\text{LAN},u}/R$, for the TDMA scheme in Part (a) when $N = M$ and $N = M/10$, respectively? (3p)

   We have : $R_{LAN,u} = \frac{Nn_u}{MT_s}$

   When N= M

   $\rho = R_{LAN,u}/R = \frac{n_u}{TS} \cdot \frac{1}{R} = 92.04\%$

   When N=M/10

   $\rho = R_{LAN,u}/R = \frac{n_u}{10.TS} \cdot \frac{1}{R} = 9.2\%$

   (c) Repeat Part (a) and (b) when $R = 1\,\text{Gbit/s}$. Comment on the results. (2p)

   With $R = 1$ Gbit/s , $T_{tr} = 8{,}192\mu\text{s}$, τ_{max} is the same $5\mu s$
   $T_s = 13.192\,\mu\text{s}$
   $R_u = \frac{1000(8)}{100(8.192+5)\times 10^{-6}} = 6{,}06\text{Mbit/s}$

   The normalized throuput ρ is :

   When N= M

   $\rho = R_{LAN,u}/R = \frac{n_u}{T_s}\frac{1}{R} = 60.64\%$

   When N=M/10

   $\rho = R_{LAN,u}/R = \frac{n_u}{10T_s}\frac{1}{R} = 6.06\%$

   We notice that as the physical layer data rate increases, R_u goes up, but normalized throughput ρ goes down. The loss in normalized throughput is due to the fixed propagation time (guard time). As the data rate increases, a larger fraction of the slot time is allocated to guard time, which is not used for data transmission, and normalized throughput decreases. However, even more important for the normalized throughput is the number of active stations: ρ decreases quite fast as N decreases, which is due to the fact that $(M-N)$ slots does not carry data in the TDMA scheme.

We can conclude that the efficiency of this TDMA MAC is more sensitive to the number of active stations compared to the physical layer data rate. If only few stations have payloads to transmit in each cycle, this scheme is inefficient.

(d) Suppose we replace the TDMA scheme with a simple reservation scheme. The reservation messages are 24 byte long and are transmitted in minislots of duration T_{ms}, which is designed such that (i) the bits transmitted in a slot can carry a whole reservation message, (ii) no collisions can occur at any receiving station, and (iii) to maximize the data rate for the stations. A cycle starts by that the M stations sends one reservation message each. Then, the N stations that have data to transmit sends a single network SDU each, which completes the cycle. What is the highest data rate R_u in bit/s that the network layer entity in a station can experience when $N = M$ and $N = M/10$, respectively? Assume $R = 1\,\text{Gbit/s}$. Comment on the results. (4p)

$T_{ms} = \tau_{max} + \frac{no}{R} = 5.10^{-6} + \frac{24(8)}{10^9} = 5.192\,\mu\text{s}$
$T_s = 5 + 8.192 = 13.192\,\mu\text{s}$

Computing the data rate:

When N= M
$R_u = \frac{n_u}{MT_{ms}+NT_s} = 4.35\,\text{Mbit/s}$
When N=M/10
$R_u = \frac{n_u}{MT_{ms}+NT_s} = 12.29\,\text{Mbit/s}$

Comparing the results of this scheme with that of TDMA for the same $R = 1\,\text{Gbit/S}$ we see that when we have few number of transmitting nodes the rate experienced in this scheme, $R_{u,resr} = 12.29\,\text{Mbit/s}$, is higher than the rate experienced by stations in the TDMA scheme $R_{u,TDMA} = 6.06\,\text{Mbit/s}$. While when we have large number of transmitting nodes $(N = M)$ in each cylce the performance is lower compared to that of TDMA. This shows that the reservation scheme is more efficient than TDMA scheme when we have only few active nodes in each cycle. TDMA is better in case that all the nodes allocated slots have data to transmit in each cycle.

4. Consider a Stop-And-Wait ARQ protocol over a full-duplex physical medium of length 160 m and propagation speed 2×10^8 m/s. Data frames are 100 byte and ACK frames are 50 byte. The data rate on the medium is 1 Gbit/s. The protocol use binary state variable S_{last} and R_{next}, where S_{last} is the sequence number of the last transmitted frame and R_{next} is the sequence number of the frame that receiver expect to receive next. The state variables are initialized as $S_{\text{last}} = 1$ and $R_{\text{next}} = 0$.

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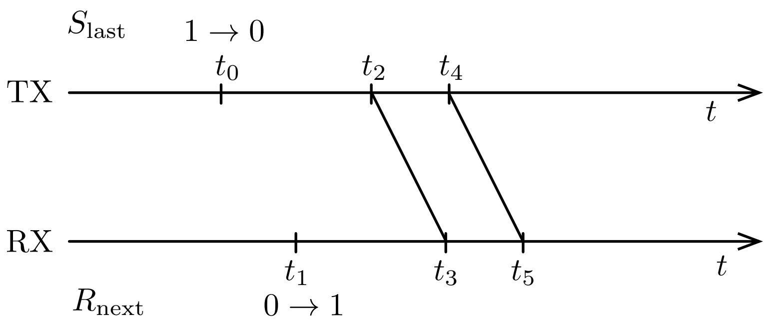
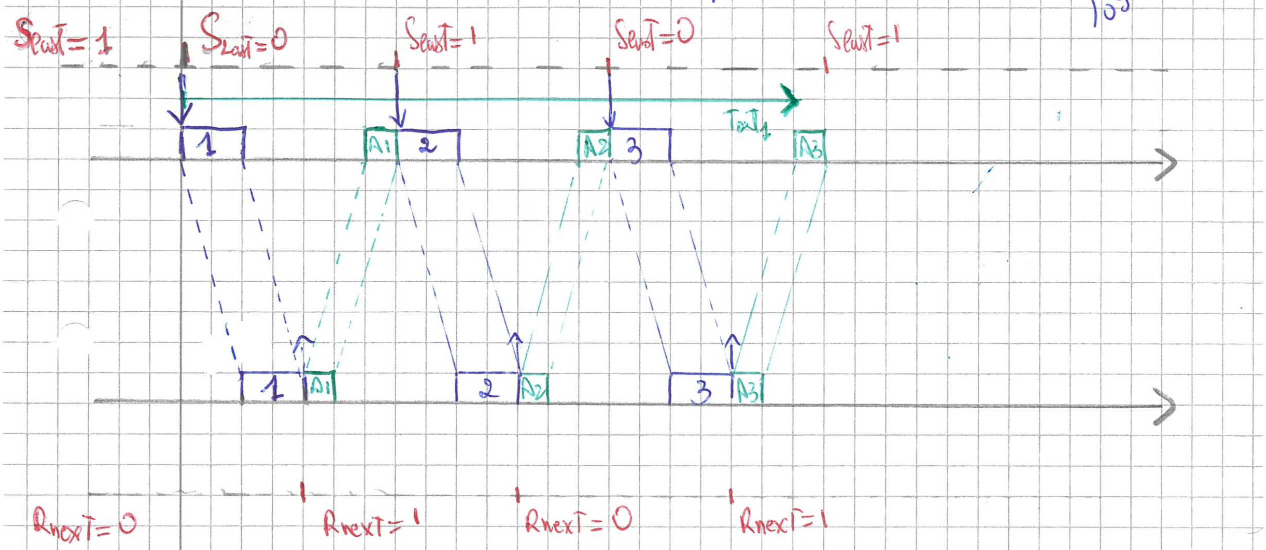
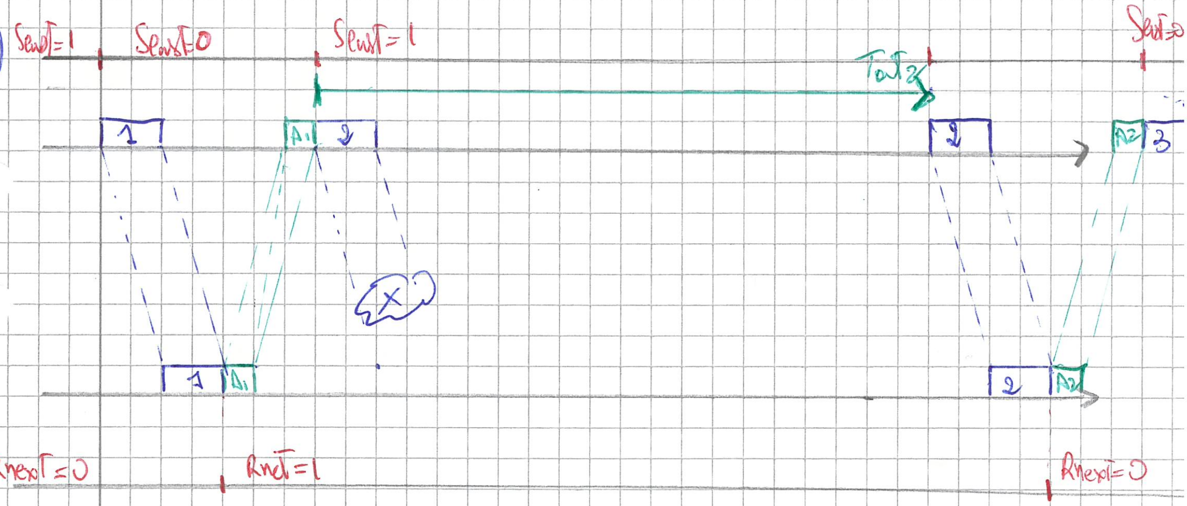


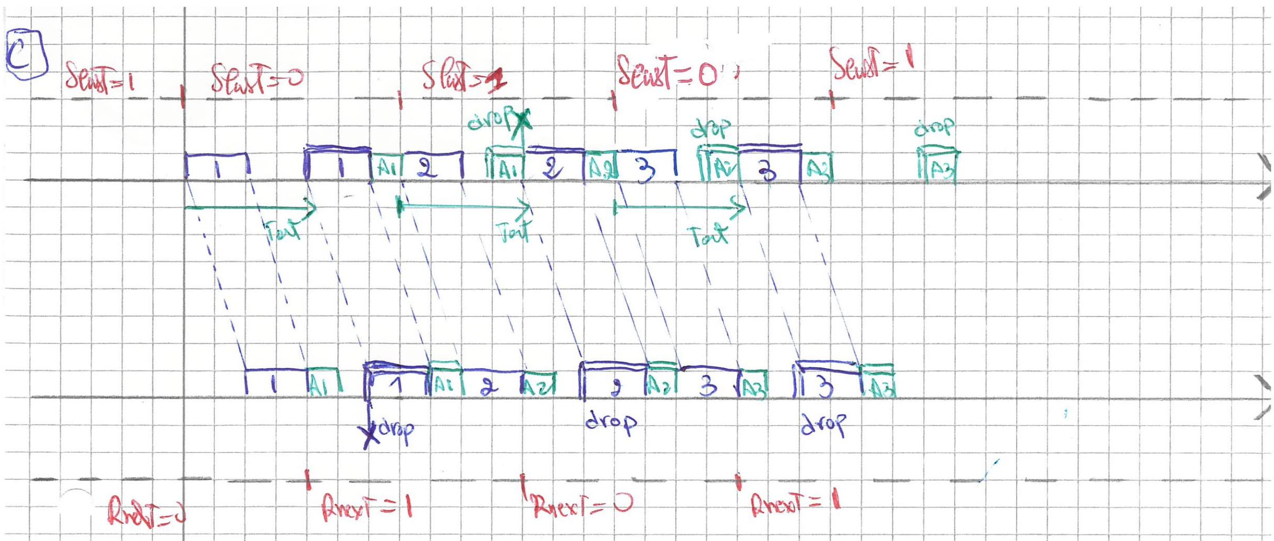
(a) We compute :

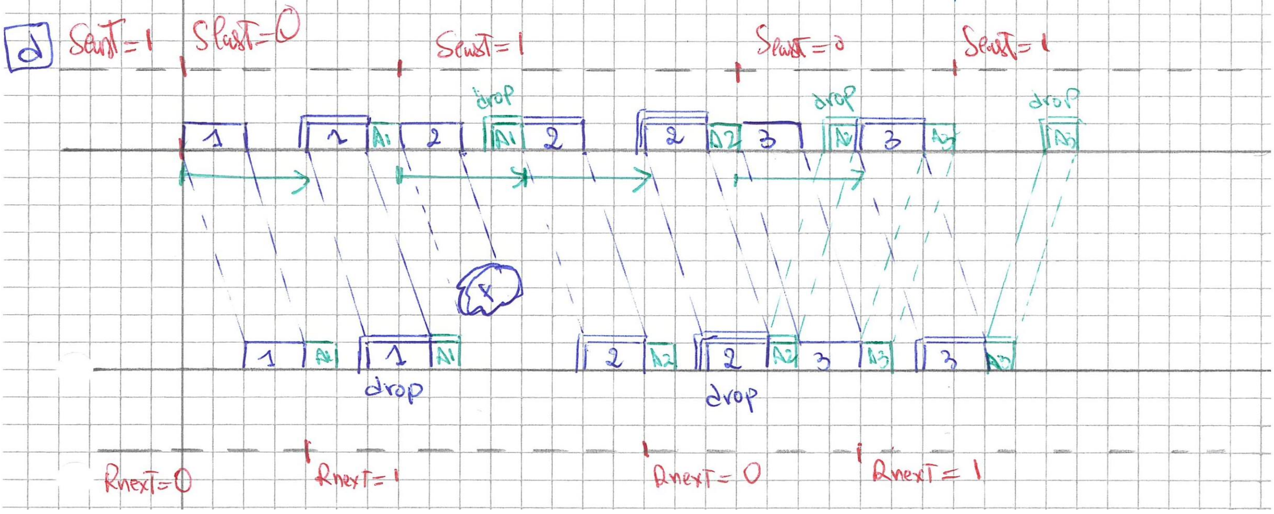
- The Propagation Time $T_{prop} = \frac{160}{2.10^8} = 0.8\,ms$
- Transmission Time of a data Packet $T_p = \frac{100(8)}{10^9} = 0.8\,ms$
- Transmission Time of an Ack $T_{Ack} = \frac{50(8)}{10^9} = 0.4\,ms$



(b)







4(e) The effective rate is maximized by minimizing the time for completing the delivery of a frame. That is, the time from when a frame is first started to be transmitted until it has been acknowledged, at which point the transmitter can move on and transmit the next frame. In the absence of frame errors, the completion time is equal to the reaction time

$$t_0 = t_f + t_{\text{prop}} + t_a + t_{\text{prop}},$$

where t_f is the information frame duration, t_a is the ACK frame duration, and t_{prop} is the propagation time. When there is a frame error, the frame will be retransmitted after the timeout time t_{out}. Suppose it takes i transmissions to complete the frame delivery, then there are $(i-1)$ consecutive frame errors followed by one successful frame transmission. The total time for this is $(i-1)t_{\text{out}} + t_0$. Clearly, this is minimized by selecting t_{out} to the smallest possible value, which is $t_{\text{out}} = t_f$. (We assume here that the transmitter aborts any on-going retransmission of an information frame upon reception of an ACK for that information frame.) With this timeout, the transmitter will continuously transmit information frames (since the timeout expires immediately after the corresponding information frame has been transmitted). This will continue until the ACK is received. This is clearly a waste of transmit power and channel bandwidth, since frames are retransmitted even when there is no frame error. In the given example, suppose that the first frame is error-free. Regardless of this, three complete copies and one partial copy of the information frame will be transmitted before the ACK for the first frame has been delivered to receiver.