Exam in
SSY305 Kommunikationssystem

Department of Electrical Engineering

Exam date: March 15, 2018, 14:00–18:00

Document updated: March 13, 2018

Teaching Staff

Erik Ström (examiner), 772 5182
Chouaib Bencheikh Lehocine, 073 742 6431

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 March 21 and March 26, 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

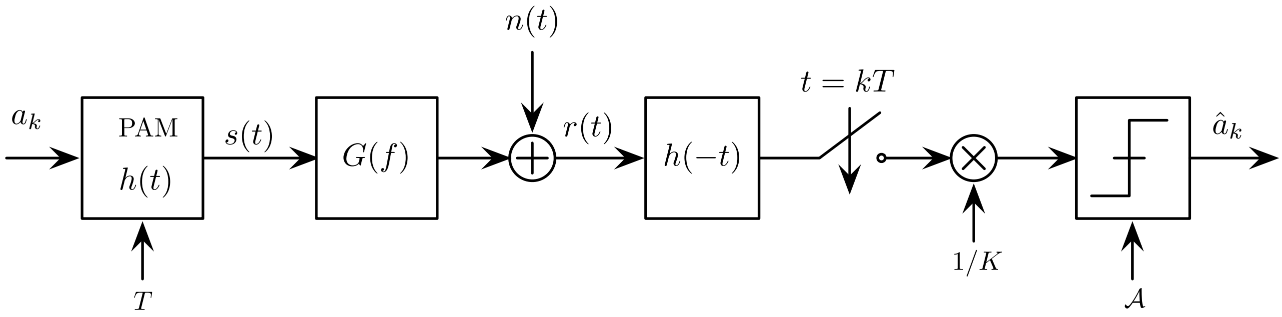
PLEASE NOTE THAT THE PROBLEMS ARE NOT NECESSARILY ORDERED IN DIFFICULTY.

Good luck!

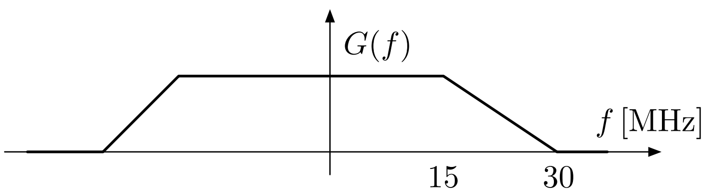
Table over the Q-function

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 transmission using 16-PAM over a bandlimited, additive white Gaussian noise channel. A block diagram is depicted below.



The channel frequency response is defined in the figure below.



We want to ensure ISI-free transmission, i.e., that $\hat{a}_k = a_k$ when $n(t) = 0$, by selecting the transmit pulse $h(t)$ and the scaling constant K wisely.

(a) What is the maximum data rate when $h(t)$ is a root-raised cosine pulse with roll-off factor 0? (4p)

(b) What is the maximum data rate when $h(t)$ is a root-raised cosine pulse with roll-off factor 0.5? (2p)

(c) What is the maximum data rate when $h(t)$ can be chosen freely? Define the transmit pulse (in the time domain or frequency domain). (6p)

Hint: Consider the signal $x(t)$ and its Fourier transform $X(f)$, then for any constant C

$$x(nT) = \begin{cases} C, & n = 0 \\ 0, & \text{otherwise} \end{cases} \Leftrightarrow \frac{1}{T} \sum_{k=-\infty}^{\infty} X(f - k/T) = C$$

The spectrum for a raised-cosine pulse is

$$X_{\text{rc}}(f) = \begin{cases} T, & |f| < \frac{1-\alpha}{2T} \\ \frac{T}{2}\left[1 + \cos\left(\frac{\pi T}{\alpha}\left(|f| - \frac{1-\alpha}{2T}\right)\right)\right], & \frac{1-\alpha}{2T} \leq |f| \leq \frac{1+\alpha}{2T} \\ 0, & \text{otherwise} \end{cases}$$

2. (a) Consider a systematic (8, 6) error-detection code where the parity bits p_0 and p_1 are formed as $p_0 = p_1 = b_0 \oplus b_1 \oplus \cdots \oplus b_5$, where b_i are the information bits. Suppose the received pattern is $\mathbf{y} = [01011100]$. Will an error be declared? Has an error occurred? (2p)

   (b) Compare the services provided by the Internet protocols TCP and UDP. In which layer do they reside? (3p)

   (c) Consider a LAN that use CSMA/CD over a coaxial cable medium with propagation speed 2×10^8 m/s and data rate 100 Mbit/s. If the frame length is fixed to 100 byte, what is the maximum cable length such that the MAC protocol works as intended? Suppose, by mistake, the cable is made longer then the maximum allowed, what will be the consequence for the MAC protocol? (4p)

   (d) Consider a vehicular traffic safety application based on broadcasting status messages (containing vehicle speed, heading, etc.). What combination of security goals (confidentiality, integrity, authentication) would be desirable? Motivate. (3p)

3. Consider the transmission of a 1 GB file with a Stop-And-Wait protocol over a physical link with data rate 100 Mbit/s. The information frame consist of a 20-byte header, the SDU, and 32 bit CRC bits. ACK frames have the same format, except that there is no SDU. The physical link propagation delay is 3 μs. Processing delays are small and can be neglected.

   Suppose that we transmit the file as M equal-size segments.

   We strive to minimize the file transfer time T, i.e., the time from when the first bit is transmitted until the time when the entire file has been delivered (error-free).

   (a) Determine the value of the time-out such that T is minimized. (2p)

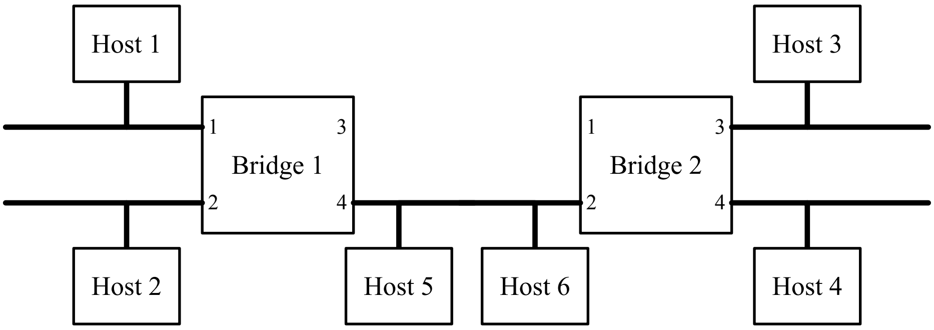
   (b) Suppose the transfer is error-free, what value of M minimizes T? What is the corresponding T? (3p)

   (c) Suppose the bit error occurs independently in the information frame with probability $P_b = 10^{-5}$. What value of M minimizes the average file transfer time $\mathrm{E}[T]$? Assume that ACK frames are transmitted error-free. (5p)

   (d) Repeat last part when bits in both information frames and ACK frames are subject to independent bit errors with probability $P_b = 10^{-5}$. (2p)

   Hint: For $0 < P < 1$ we have that $\sum_{i=1}^{\infty} i(1-P)P^{i-1} = 1/(1-P)$

4. Consider the following network topology where 5 LANs are interconnected with two bridges. Several hosts are connected to each LAN, but only 6 are depicted below.



Whenever a bridge receives a frame on one of its ports, the frame will subsequently be forwarded (transmitted) on none, one, or several of the bridge ports. For example, suppose that (i) H1 transmit a frame F, which is received by B1 on its port 1, and (ii) that the bridge forward the frame on its ports 2 and 4, which is received by H2, H5, H6, and B2 on port 2. The transmission-and-reception cycles (i) and (ii) can be described in table format as

	H1	H2	H3	H4	H5	H6	B1				B2			
							1	2	3	4	1	2	3	4
TX	F0													
RX							F0							
TX								F1		F2				
RX		F1			F2	F2						F2		

In the table, Fx denotes copy x of the frame F, i.e., F0 is the original frame, F1 and F2 are the copies of F0 that are created by B1. The notation is only for clarity—the frame copies are identical.

(a) Suppose the forwarding tables in B1 and B2 are empty. Assume error-free transmission and that the bridges use backwards learning to fill out their forwarding tables. Suppose the following frame transmissions are initiated (in time order) H1→H3, H5→H1, and H6→H5. Describe how each transmission is completed using the table format described above (blank tables are available as separate sheets). Assume that all transmissions due to H1→H3 are completed before H5→H1 is initiated, and likewise for H5→H1 and H6→H5. (3p)

(b) Suppose the network is modified by connecting B1 port 3 and B2 port 1. If the spanning tree protocol has been executed and created a loop-free (logical) topology, which bridge will be the root bridge? What is the status of each bridge port (root port, designated port, or blocked port)? Assume that the cost associated with each LAN is the same. Motivate. (3p)

(c) Suppose the spanning tree protocol is disabled, i.e., that the logical topology is the same as the physical topology. Assume that the bridge forwarding tables are cleared. Explain what will happen if H1 sends a frame to H4 using the table format above. Why are loops in the topology not desirable? (6p)

Exam in
SSY305 Kommunikationssystem

Department of Electrical Engineering

Exam date: March 15, 2018, 14:00–18:00
Document updated: March 15, 2018

Teaching Staff
Erik Ström (examiner), 772 5182
Chouaib Bencheikh Lehocine, 073 742 6431

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.

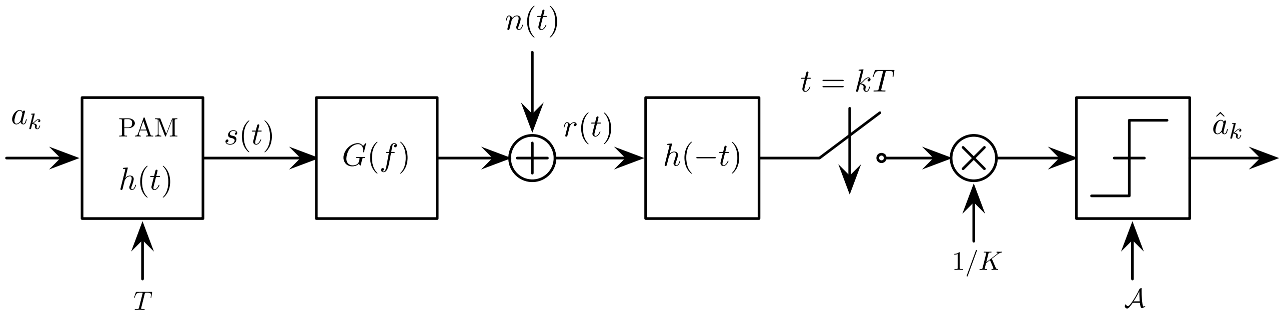
Results Exam results are posted on Ping-Pong no later than June 13, 2017. The grading review is on March 21 and March 26, 2018, 12:00–13:00 in room 6414 in the ED-building.

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.

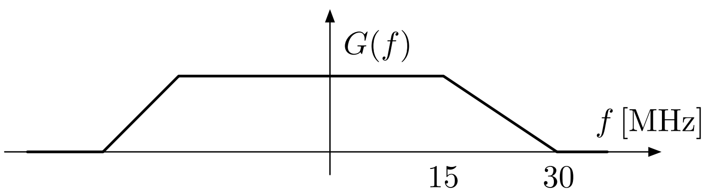
Total Score	0–39	40–69	70–79	≥ 80
Grade	Fail	3	4	5

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

1. Consider transmission using 16-PAM over a bandlimited, additive white Gaussian noise channel. A block diagram is depicted below.



The channel frequency response is defined in the figure below.



We want to ensure ISI-free transmission, i.e., that $\hat{a}_k = a_k$ when $n(t) = 0$, by selecting the transmit pulse $h(t)$ and the scaling constant K wisely.

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(b) What is the maximum data rate when $h(t)$ is a root-raised cosine pulse with roll-off factor 0.5? (2p)

(c) What is the maximum data rate when $h(t)$ can be chosen freely? Define the transmit pulse (in the time domain or frequency domain). (6p)

Hint: Consider the signal $x(t)$ and its Fourier transform $X(f)$, then for any constant C

$$x(nT) = \begin{cases} C, & n = 0 \\ 0, & \text{otherwise} \end{cases} \Leftrightarrow \frac{1}{T} \sum_{k=-\infty}^{\infty} X(f - k/T) = C$$

The spectrum for a raised-cosine pulse is

$$X_{\text{rc}}(f) = \begin{cases} T, & |f| < \frac{1-\alpha}{2T} \\ \frac{T}{2}\left[1 + \cos\left(\frac{\pi T}{\alpha}\left(|f| - \frac{1-\alpha}{2T}\right)\right)\right], & \frac{1-\alpha}{2T} \le |f| \le \frac{1+\alpha}{2T} \\ 0, & \text{otherwise} \end{cases}$$

1.a

To ensure ISI free Transmission we want The resultant Pulse at The receiver $x(t)$

$$x(t) = h(t) * g(t) * h(-t)$$

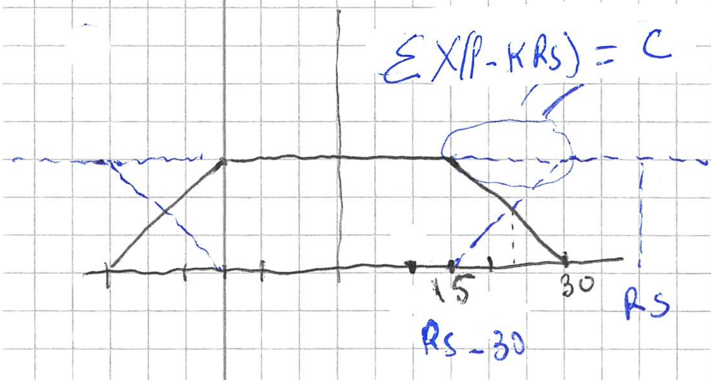
$$X(f) = H(f) . G(f) . H(-f)$$

To Be Nyquist.

for a RRC Pulse with $\alpha = 0$ we choose $H(f)$ as

$$H(f) = \begin{cases} 1 & |f| < 30 \\ 0 & \text{otherwise} \end{cases}$$

$$X(f) = H^2(f) . G(f) = G(f)$$



The Maximum data rate ensuring ISI free Transmission can be found setting:

$$R_s - 30 = 15$$

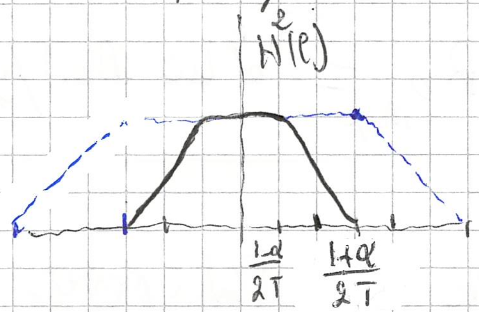
$$R_s = 45 \text{ Msymbol/s}$$

$$R_b = \log_2(16) . R_s$$

$$\boxed{R_b = 180 \text{ Mbit/s}}$$

1.b for a RRC with $\alpha = 0.5$

The Shape of $H^2(f)$ is



To ensure That The resultant Pulse $X(f)$ is Nyquist

i.e $\frac{1}{T_s} \Sigma X(f - KT_s) = c$

we restrict The rrc Pulse To The PassBand Region of $G(f)$ $|f| \leq 15$

following That

$$\frac{1+\alpha}{2T} = 15 \Rightarrow R_s = 20 \text{ Mbaud}$$

$$\boxed{R_b = 80 \text{ Mbit/s}}$$

1.c Since $G(f)$ has a Bandwidth

$W = 30\ MHz$

- we know that max symbol rate ensuring ISI free Transmission is (Nyquist Theorem)

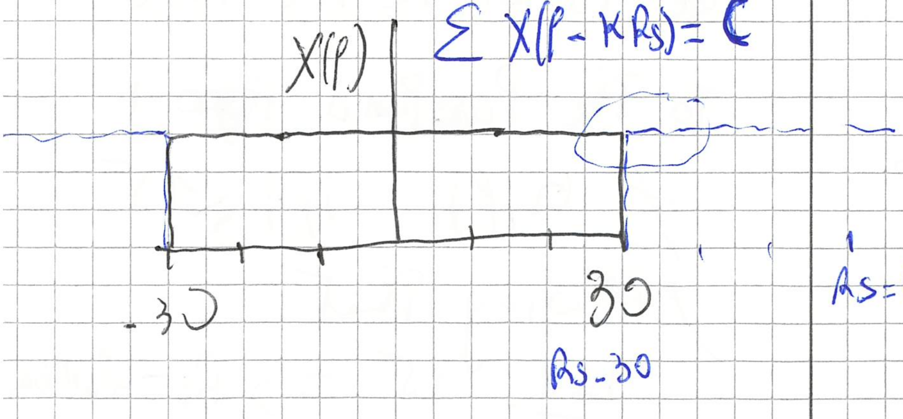
$R_S \leq 2W$

$R_{S_{max}} = 60\ MHz$

$$\boxed{R_{b_{max}} = 240\ Mbit/s}$$

- The Pulse that results in Nyquist rate is

$$X(f) = \begin{cases} 1 & |f| \leq 30 \\ 0 & \text{otherwise} \end{cases}$$



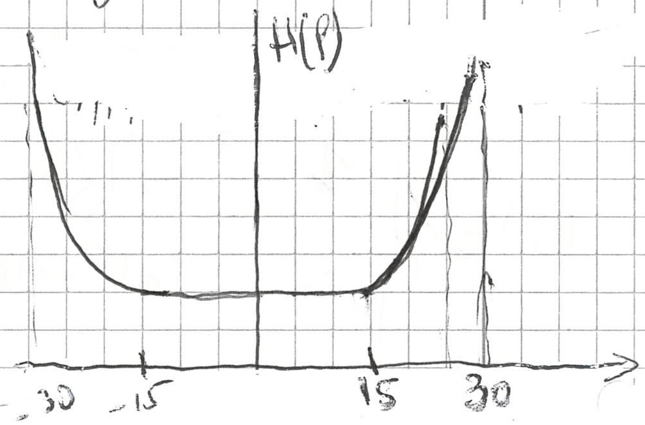
we have

$X(f) = H^2(f) \cdot G(f)$

$$H(f) = \sqrt{\frac{X(f)}{G(f)}}$$

$$H(f) = \begin{cases} 1 & |f| \leq 15\ MHz \\ \sqrt{\frac{15}{(|f|-30)}} & 15 \leq |f| \leq 30\ MHz \\ 0 & |f| \geq 30\ MHz \end{cases}$$

assuming that $G(f) = 1$ when $|f| \leq 15$



1. (a) Consider a systematic (8, 6) error-detection code where the parity bits p_0 and p_1 are formed as $p_0 = p_1 = b_0 \oplus b_1 \oplus \cdots \oplus b_5$, where b_i are the information bits. Suppose the received pattern is $\mathbf{y} = [01011100]$. Will an error be declared? Has an error occurred? (2p)

We have an even number of ones in the information bits [010111] , this corresponds to $p_0 = p_1 = 0$. So, no error will be declared.

It is possible that an error occured. An example of undetcted error pattern could be $\mathbf{e} = [01001000]$

(b) Compare the services provided by the Internet protocols TCP and UDP. In which layer do they reside? (3p)

Both prtocols are transport layer protocols

TCP	UDP
Connection Oriented	Connectionless
It provides Reliable Service	Best effort service
It uses Error detection, Acks and retransmissions	It uses only Error detection, erroneous packets are just dropped, No acks are used
It applies Flow control and congestion control mechanisms	No flow or congestion control
Slow transfer of data	Fast transfer of data
Good for reliable transfer of data e.g. Tranfer of files	Good for real time transfer of data (VoIP , video chat)
Provides services for: HTTP, FTP...	Provides services for: RTP, DNS...

(c) Consider a LAN that use CSMA/CD over a coaxial cable medium with propagation speed 2×10^8 m/s and data rate 100 Mbit/s. If the frame length is fixed to 100 byte, what is the maximum cable length such that the MAC protocol works as intended? Suppose, by mistake, the cable is made longer then the maximum allowed, what will be the consequence for the MAC protocol? (4p)

For proper functionality of Collision Detection mechanism, $X \geq 2 * t_{prop}$

where X is the frame transmission time and t_{prop} is the maximum propgataion time on the cable.

$\frac{L}{R} \geq 2.\frac{D}{2/3.C_0}$

$D \leq 800m$

Where L is the frame length and R is the data rate

In case the cable is made longer, some tranmissions between nodes will have a propagation delay that doesn't satisfy the condition $X \geq 2 * t_{prop}$, and thus the CD mechansim will not be fully functional and communication between these nodes can't be guaranteed.(i.e. collisions may occur which results in frame losses, but the transmitting node won't be aware of that.)

(d) Consider a vehicular traffic safety application based on broadcasting status messages (containing vehicle speed, heading, etc.). What combination of security goals (confidentiality, integrity, authentication) would be desirable? Motivate. (3p)

Confidentiality:

This is not an important goal in this application, as the shared information (vehicle speed, heading, etc.) will be broadcasted to all cars that are nearby. So, the content is not confidential between particular users.

Integrity and Authentication:

Integrity is important, to ensure that the messages sent hasn't been altered by an intruder. Authentication is also important to ensure that only authorized users can send these messages. The combination of these two cancels the possibility of sending false messages that can trigger an unecessary safety measure (e.g. braking) or false messages that results in non taking safety measre in a dangereous situation.

2. Consider the transmission of a 1 GB file with a Stop-And-Wait protocol over a physical link with data rate 100 Mbit/s. The information frame consist of a 20-byte header, the SDU, and 32 bit CRC bits. ACK frames have the same format, except that there is no SDU. The physical link propagation delay is 3 μs. Processing delays are small and can be neglected.

   Suppose that we transmit the file as M equal-size segments.

   We strive to minimize the file transfer time T, i.e., the time from when the first bit is transmitted until the time when the entire file has been delivered (error-free).

   (a) Determine the value of the time-out such that T is minimized. (2p)

   (b) Suppose the transfer is error-free, what value of M minimizes T? What is the corresponding T? (3p)

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   (d) Repeat last part when bits in both information frames and ACK frames are subject to independent bit errors with probability $P_b = 10^{-5}$. (2p)

   Hint: For $0 < P < 1$ we have that $\sum_{i=1}^{\infty} i(1-P)P^{i-1} = 1/(1-P)$

   Let $N_f = 8 \times 10^9$ be the file size in bits, $R = 100 \times 10^6$ be the data rate in bit/s. The number over overhead bits is $n_0 = 192$ bit, which is also the number of bits in the ACK frame.

   (a) The timeout should be set to the reaction time, i.e., $t_{\text{out}} = n_u/R + 2n_0/R + 2t_{\text{prop}}$, where n_u is the number of payload bits in a segment. For M segments, $n_u = \lceil N_f/M \rceil$ (here $\lceil x \rceil$ is rounding x up to the closest integer). Hence,

   $$t_{\text{out}} = \frac{1}{R}(\lceil N_f/M \rceil + 2(n_0 + Rt_{\text{prop}}))$$

   For simplicity, we will from now on assume that $n_u = N_f/M$ is an integer for all M.

   (b) The transfer time per segment is $n_u/R + 2(n_0/R + t_{\text{prop}})$ and the whole file transfer time is

   $$T = M[n_u/R + 2(n_0/R + t_{\text{prop}})] = N_f/R + 2M(n_0/R + t_{\text{prop}}).$$

   It is easily checked that $M = 1$ gives the smallast T, namely $T = N_f/R + 2(n_0/R + t_{\text{prop}})$. (This also holds for $n_u = \lceil N_f/M \rceil$.)

   (c) Let n_t be the number of transmissions needed to complete the transmission of a segment. We assume for simplicity that $n_u = N_f/M$ is an integer. Then the number of bits in an information frame (segment) is $n_f = n_u + n_o = N_f/M + n_o$, and the frame error probability is $P_f = 1 - (1 - P_b)^{n_f}$. The average number of transmissions needed to complete the transmission of a segment $\mathrm{E}[n_t] = \sum_{i=1}^{\infty} i(1-P_f)P_f^{i-1} = 1/(1-P_f) = 1/P_s$, where P_s is the probability of successful frame transmission,

$P_s = (1-P_b)^{n_f} = P_{b,s}^{-n_f} = P_{b,s}^{-N_f/M-n_o}$, where $P_{b,s} = 1 - P_b$. The (random) transfer time is

$$T = [n_u/R + 2(n_0/R + t_{\text{prop}})] \sum_{m=1}^{M} n_{t,m}$$

where $n_{t,m}$ is the number of transmissions needed for the mth segment. The average transfer time is then

$$\begin{aligned}
\bar{T} &= \mathrm{E}[T] \\
&= [n_u/R + 2(n_0/R + t_{\text{prop}})] \sum_{m=1}^{M} \mathrm{E}[n_{t,m}] \\
&= [n_u/R + 2(n_0/R + t_{\text{prop}})] M P_{b,s}^{-n_f} \\
&= [M n_u/R + M2(n_0/R + t_{\text{prop}})] P_{b,s}^{-N_f/M-n_o} \\
&= [N_f/R + M2(n_0/R + t_{\text{prop}})] P_{b,s}^{-n_o} P_{b,s}^{-N_f/M} \\
&= [A + MB] C P_{b,s}^{-N_f/M},
\end{aligned}$$

where A, B, C are constants with respect to M. Assuming for the moment that is M is a real number, we can differentiate $\bar{T}$ with respect to M, which yields

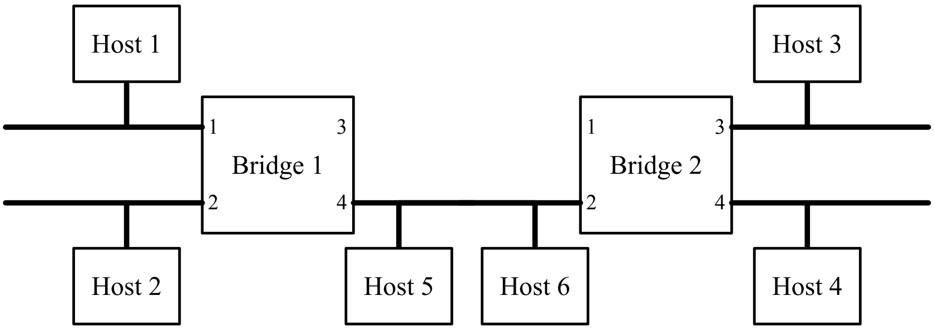
$$\begin{aligned}
\frac{d}{dM}\bar{T} &= BCP_{b,s}^{-N_f/M} + [A + MB]C\frac{N_f}{M^2}P_{b,s}^{-N_f/M}\ln P_{b,s} \\
&= \frac{BCP_{b,s}^{-N_f/M}}{M^2}(M^2 + [A/B + M]N_f \ln P_{b,s}) \\
&= \frac{BCP_{b,s}^{-N_f/M}}{M^2}\left(M^2 + MN_f \ln P_{b,s} + \frac{AN_f}{B}\ln P_{b,s}\right)
\end{aligned}$$

We find the extreme points by setting the derivative equal to 0 and solving for M. This is equivalent to finding the roots of the inside the parenthesis above. It is easily verified that the positive root is the value of M that minimizes $\bar{T}$, i.e.,

$$M^\star = -\frac{N_f \ln P_{b,s}}{2} + \sqrt{\left(\frac{N_f \ln P_{b,s}}{2}\right)^2 - \frac{AN_f}{B}\ln P_{b,s}} \approx 847471$$

(d) A frame is successfully transmitted if both the information frame and the ACK frame are transmitted correctly. That is, the probability of successful transmission is $P_s = (1-P_f)(1-P_a)$, where P_a is the probability of error in an ACK frame. Hence, $P_s = P_{b,s}^{n_f+n_o} P_{b,s}^{n_o} = P_{b,s}^{n_f} P_{b,s}^{2n_o}$. The derivation above holds also for the case when ACK frames are also subject to bit errors. The only difference is that we replace $C = P_{b,s}^{n_o}$ with $C' = P_{b,s}^{2n_o}$ in the above equation for $\bar{T}$. This will change $\bar{T}$, but the M that minimizes $\bar{T}$ is still $M^\star$.

3. Consider the following network topology where 5 LANs are interconnected with two bridges. Several hosts are connected to each LAN, but only 6 are depicted below.



Whenever a bridge receives a frame on one of its ports, the frame will subsequently be forwarded (transmitted) on none, one, or several of the bridge ports. For example, suppose that (i) H1 transmit a frame F, which is received by B1 on its port 1, and (ii) that the bridge forward the frame on its ports 2 and 4, which is received by H2, H5, H6, and B2 on port 2. The transmission-and-reception cycles (i) and (ii) can be described in table format as

	H1	H2	H3	H4	H5	H6	B1				B2			
							1	2	3	4	1	2	3	4
TX	F0													
RX							F0							
TX								F1		F2				
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In the table, Fx denotes copy x of the frame F, i.e., F0 is the original frame, F1 and F2 are the copies of F0 that are created by B1. The notation is only for clarity—the frame copies are identical.

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(b) Suppose the network is modified by connecting B1 port 3 and B2 port 1. If the spanning tree protocol has been executed and created a loop-free (logical) topology, which bridge will be the root bridge? What is the status of each bridge port (root port, designated port, or blocked port)? Assume that the cost associated with each LAN is the same. Motivate. (3p)

(c) Suppose the spanning tree protocol is disabled, i.e., that the logical topology is the same as the physical topology. Assume that the bridge forwarding tables are cleared. Explain what will happen if H1 sends a frame to H4 using the table format above. Why are loops in the topology not desirable? (6p)

Problem 4(a)

	H1	H2	H3	H4	H5	H6	B1				B2			
							1	2	3	4	1	2	3	4
	H1→ H3, Bridge 1 learns that H1 is on port 1, Bridge 2 learns that H1 is on port 2													
TX	F0													
RX							F0							
TX								F1		F1				
RX		F1			F1	F1						F1		
TX													F2	F2
RX			F2	F2										
TX														
RX														
	H5→H1, Bridge 1 learns that H5 is on port 4, Bridge 2 learns that H5 is on port 2													
TX					F0									
RX						F0				F0		F0		
TX							F1						F1	F1
RX	F1		F1	F1										
TX														
RX														
	H6→H5. Both bridges know that H6 is on the incoming port, and frame is not forwarded													
TX						F0								
RX					F0					F0		F0		
TX														
RX														

Problem 4(b)

Bridge 1 will be the root bridge. All its ports are designated ports.
Bridge 2 will not be the root. B2:1 will be root port, B2:2 will be disabled, B2:3 and B2:4 will be designated ports.

Problem 4(c)

	H1	H2	H3	H4	H5	H6	B1				B2			
							1	2	3	4	1	2	3	4
	H1→ H4													
TX	F0													
RX							F0							
TX								F1	F1	F1				
RX		F1			F1	F1					F1	F1		
TX											F3	F2	F2,F3	F2,F3
RX			F2,F3	F2,F3	F2	F2			F3	F2				
TX							F4,F5	F4,F5	F4	F5				
RX	F4,F5	F4,F5			F5	F5					F4	F5		
TX											F7	F6	F6,F7	F6,F7
RX			F6,F7	F6,F7	F6	F6			F7	F6				
TX							F8,F9	F8,F9	F8	F9				
RX			F8,F9	F8,F9	F9	F9					F8	F9		
	Packets are circling around the loop between bridges indefinitely. One packet goes clockwise and the other goes counterclockwise. The packet keeps on being broadcasted to hosts without end. This is called a broadcast storm and could bring down the network by flooding it with useless traffic													