Exam in
SSY305 Kommunikationssystem

Department of Signals and systems

Exam date: March 13, 2014, 08:30–12:30
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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.

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 Results are posted no later than March 26, 2014. The grading reviews are on March 26 and April 2, 2014, 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!

1. Consider a PAM transmission system with symbol alphabet $\mathcal{A} = \{-3, -1, 1, 3\}$ and pulse shape $h(t)$,

$$h(t) = \begin{cases} 1, & 0 \leq t < 1\ \mu\text{s} \\ 0, & \text{otherwise} \end{cases}$$

   (a) Suppose we insist on ISI-free transmisssion. What is the maximum possible data rate? (3p)

   (b) Suppose the channel noise is neglible, $n(t) = 0$. Sketch the matched filter output if the matched filter is causal, the symbol rate is 0.5 Msymbol/s, and the transmitted symbols are $a_0 = 1$, $a_1 = -1$, and $a_2 = 3$. (3p)

   (c) Repeat part (b) when the symbol rate is 1 Msymbol/s. (3p)

   (d) Assume an additive white Gaussian noise channel and equally likely independent transmitted bits. Which is the systems in part (b) and part (c) will have the best symbol error probability? Motivate carefully. (3p)

2. (a) Explain why slotted Aloha has better maximum throughput compared to unslotted Aloha. (2p)

   (b) What is the purpose of the application layer in the OSI reference model? Give an example of a TCP/IP application layer protocol. (2p)

   (c) What is the purpose of the demodulator block in Shannon's model for digital communications? (2p)

   (d) Under what circumstances is Go-Back-N competitive with Selective Repeat? (2p)

   (e) Mention an ICT application that contributes to a sustainable society and motivate why. (2p)

   (f) What is the most important communication property for networked control systems: high data rates, low average delays, or low standard deviation of delays? Motivate. (2p)

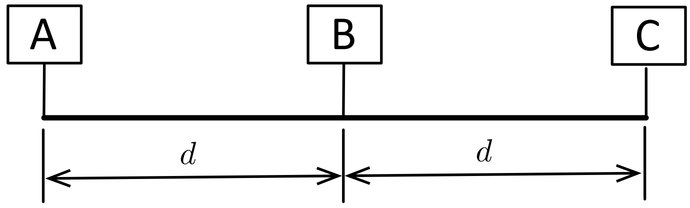
3. Consider a binary (n, k) code $\mathcal{C} = \{00000, 00101, 01011, 01110, 10010, 10111, 11001, 11100\}$, which is used for error detection when transmitting frames over a noisy channel. A frame is represented with a code word and consists of k equally likely and independent information bits and $n - k$ redudant bits (check bits). The channel introduces independent bit errors with probability p.

   (a) Suppose the coded bits are transmitted with a rate of $R = 1$ Mbit/s. What is the information bit rate when $p = 0$? (2p)

   (b) What is the frame error rate (before error detection) when $p = 0.01$? (4p)

   (c) Suppose that the transmitted bit pattern is [00000]. Compute the probability that an undetected frame error occurs when $p = 0.01$. (6p)

4. Consider a LAN with three connected hosts A, B, and C. Suppose that $d = 100$ m and that medium propagation speed is $c = 2c_0/3$, where $c_0 = 3 \times 10^8$ m/s is the speed of light in vacuum. The medium bit rate is $R = 100$ Mbit/s.



The link layer uses a stop-and-wait ARQ protocol to provide a reliable, in-sequence, packet transmission service for the network layer. The link layer information frames are n_f bits long, including a 26 byte header and 32 CRC parity bits. An acknowledgement frame is 74 byte long. The medium introduces independent bit errors with probability p.

We assume that the error-detection is perfect (i.e., that no erroneous frames are accepted by the receiver link layer) and the receiver and transmitter processing times are negligible. The ARQ protocol ignores any information frames or ACK frames with detected errors.

Nodes use persistent-CSMA with sensing time 4 μs to share the channel. For simplicity, we will assume that only host A has data to send. Hence, there will be no collisions on the medium.

(a) How should the frame length and timeout be chosen such that the bit rate experienced by the network layer is 80% of R when $p = 0$? (2p)

(b) Assuming $p = 10^{-5}$, what is the experienced bit rate for the network layer for the frame length and timeout calculated in part (a)? (4p)

(c) Assuming $p = 10^{-5}$ and that we double the timeout time calculated in part (a). The frame length is the same as calculated in part (a). What is the experienced bit rate for the network layer? (4p)

(d) Repeat part (c) with $p = 10^{-4}$. What can be said about the importance of choosing the time out? (2p)

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$A = \{-3, -1, 1, 3\}$

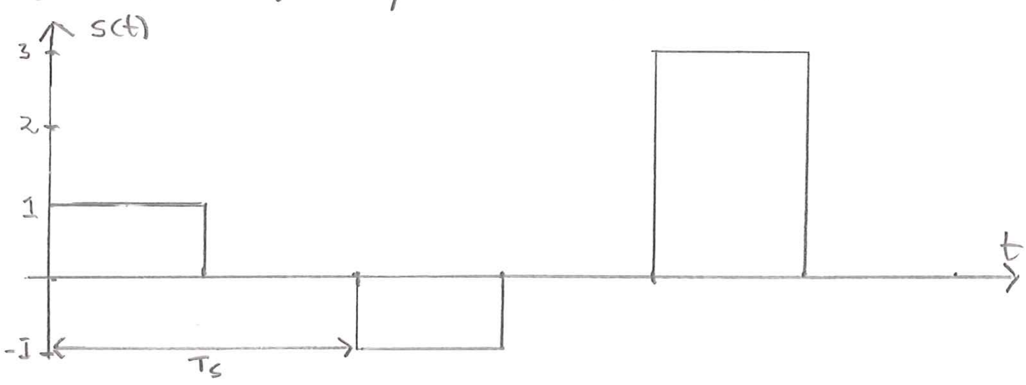
$$h(t) = \begin{cases} 1 & 0 \le t < 1\mu s \\ 0 & \text{otherwise} \end{cases}$$

a) To get ISI free transmission pulses can't overlap. Hence we need the symbol period to be larger than 1 μs, i.e., $T_s > 1\,\mu s$

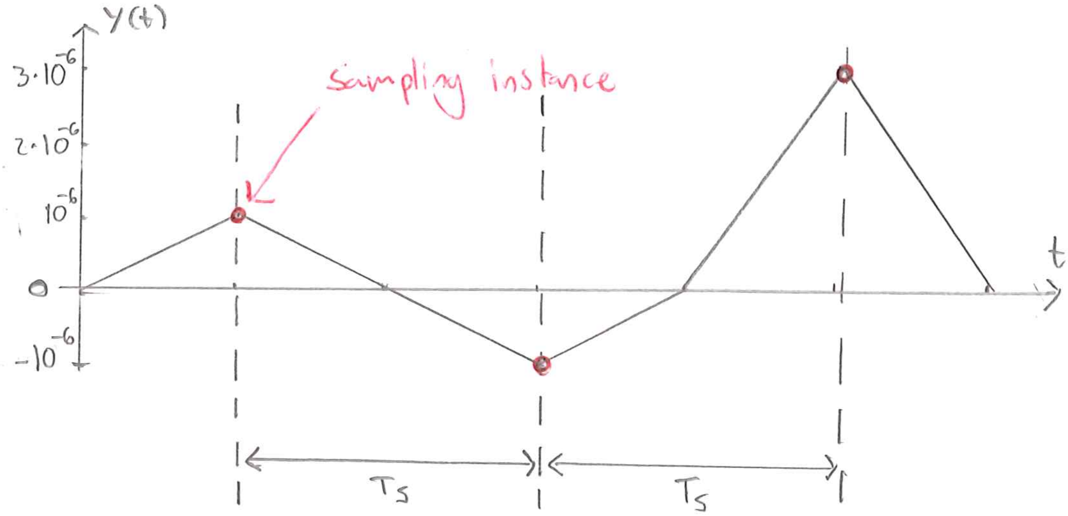
$$\left.\begin{array}{l} T_s > 1\,\mu s \\ R_b = R_s \log_2 M \end{array}\right\} \Rightarrow R_{b,max} = \frac{1}{10^{-6}} \cdot \log_2 4 = 2 \text{ Mbit/s}$$

b) $R_s = 0{,}5$ Msymbols/s $\Rightarrow T_s = 2\,\mu s$

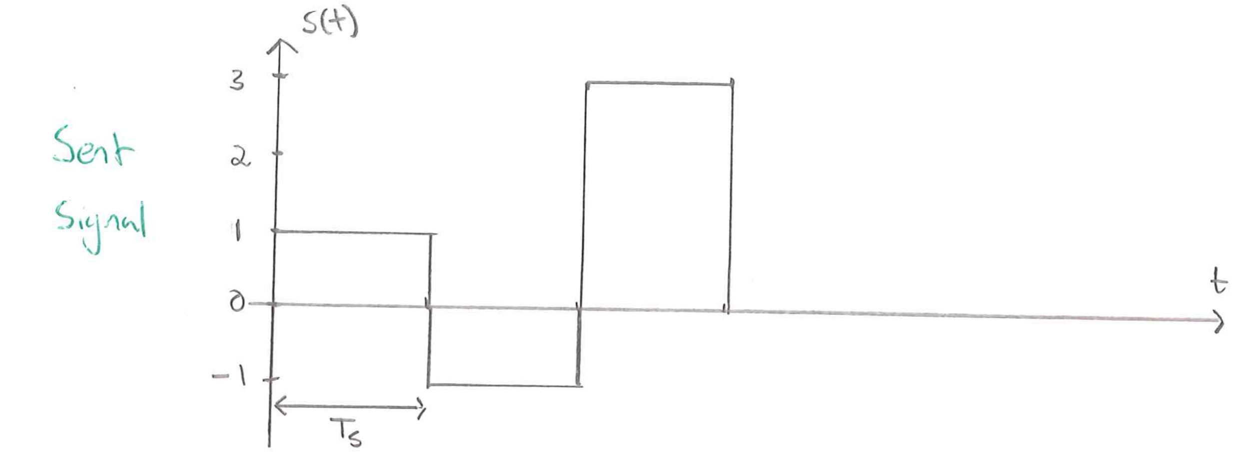
Sent Signal

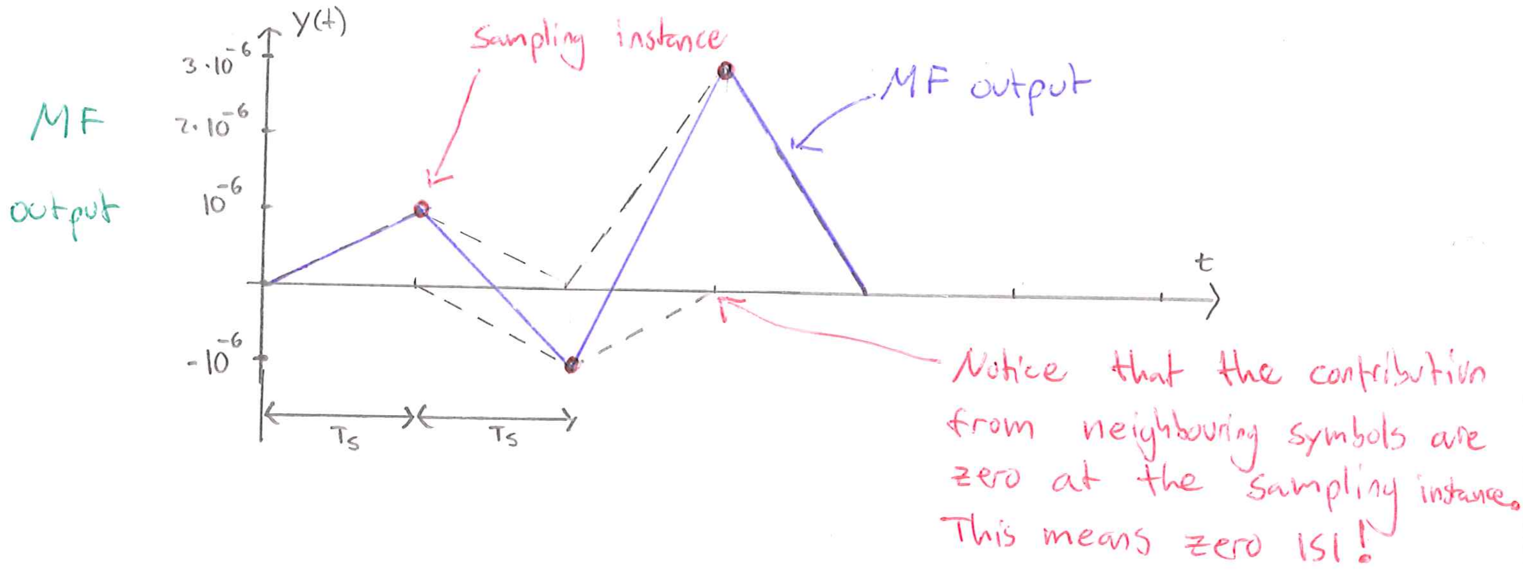


MF Output



c) $R_S = 1$ M symbol/s $\Rightarrow T_S = 1\ \mu s$





d) Both "(b)" and (c) are ISI free. This means that the only thing that could affect the symbol error probability is the enegy of h(t). As h(t) is the same in (b) and (c) they will have the same symbol error probability

2)

a) By restricting each station (transmitter) to only initiate transmissions at the beginning of each time slot the probability of collisions decreases. Hence the througput goes up. On the other hand slotted Aloha requires synchronization among the nodes. It also limits the frame length, as it is not allowed to extend outside one transmission slot.

b) • The purpose of the application layer is to provide services to application programs (eg. mail clients, web browsers etc.)

• Examples of application layer protocols in the TCP/IP protocol suite are SMTP and DNS

c) The purpose of the demodulator is to process the received signal in order to be able to decide on which symbols (bits) that were transmitted.

If for example PAM is used the demodulator would include the following steps

- Matched filtering
- down sampling and scaling
- Slicer
- (symbol to bit mapper)

d) The efficiencies for Go-Back-N and Selective Repeat are given by

$$\eta_{GBN} = \frac{1 - P_f}{1 + LP_f}$$

$$\eta_{SR} = 1 - P_f$$

where P_f is the frame error probability and $L = 2(t_{prop} + t_{proc})\frac{R}{n_f}$. As can be seen the efficiency for Go-Back-N approaches the efficiency for Selective Repeat when $LP_f \to 0$. From this we can conclude that the efficiency of Go-Back-N and selective repeat are the same for low frame error probabilities, but they also approaches each other when $L \to 0$

e) Examples on ICT applications that contribute to a sustainable society are:

- Smart grids
  - better utalization of power grids (i.e. more efficient)
  - facilitates the incorporation of renewable enegy sources in the power grid
- Vehicular comm.
  - Safer traffic environment (less accidents)
  - traffic flow optimization (less fuel consumtion and time spent in traffic)

f) Low standard deviation of delays is the most important in network controled systems

- Latency decreases the stability margin
- jitter makes the analysis very hard.

Problem 3

a) One codeword has $n = 5$ bits, where only k of them are information bits: 2^k codewords $2^k = 8 \rightarrow k = 3$

$\Rightarrow$ the information bit rate R_i is given by:

$$R_i = \frac{k}{n} R = \frac{k}{5} \cdot 1 = \frac{3}{5} \text{ Mbit/s}$$

b) $Pr\{\text{error(s) in frame}\} = 1 - Pr\{\text{no error in frame}\}$

$$= 1 - (1-p)^5 = 0.0490$$

c) bit patterns that will lead to an undetected frame error (= another valid codeword) when [00000] was transmitted:

00101	$\rightarrow$ probability:	$(1-p)^3 p^2$
01011		$(1-p)^2 p^3$
01110		$(1-p)^2 p^3$
10010		$(1-p)^3 p^2$
10111		$(1-p) p^4$
11001		$(1-p)^2 p^3$
11100		$(1-p)^2 p^3$

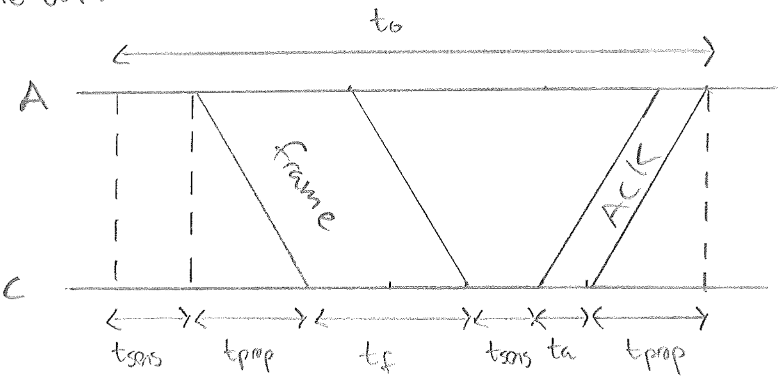
$\Rightarrow Pr\{\text{undetected frame error} \mid [00000] \text{ transmitted}\} =$

$$2(1-p)^3 p^2 + 4(1-p)^2 p^3 + (1-p) p^4 = 0.0098$$

Problem 4

a)

time-out:



($t_{proc} = 0$!)

$t_{sens} = 4\ \mu s$

$t_{prop} = \frac{2d}{c} = \frac{200 \cdot 3}{2 \cdot 3 \cdot 10^8} = 10^{-6}$ s (max distance is 2 d m)

$t_f = \frac{n_f}{R}$ s

$t_a = \frac{n_a}{R} = \frac{74 \cdot 8}{100 \cdot 10^6} = \frac{592}{10^8}$ s

The basic time to send a frame is

$$t_0 = 2(t_{sens} + t_{prop}) + t_f + t_a =$$
$$= 2 \cdot (4 \cdot 10^{-6} + 10^{-6}) + \frac{n_f}{10^8} + \frac{592}{10^8}$$
$$= \frac{10^3 + n_f + 592}{10^8}$$

Minimum value for time-out is t_0. Hence we set $t_{out} = t_0$

frame length:

$$\left.\begin{aligned} R^0_{eff} &= 0{,}8R \\ R^0_{eff} &= \frac{n_f - n_0}{t_0} \end{aligned}\right\} \Rightarrow \quad 0{,}8 \cdot 10^8 = \frac{n_f - (26 \cdot 8 + 32)}{10^3 + 592 + n_f} \cdot 10^8$$

$$0{,}8 \cdot 1592 + 0{,}8 n_f = n_f - 240$$

$$0{,}2 n_f = 1273 + 240$$

$$n_f = \frac{1273 + 240}{0{,}2} = 7565 \text{ bits}$$

$$\Rightarrow t_{out} = 9157 \cdot 10^{-8} = 91{,}57 \cdot 10^{-6} = 91{,}57\ \mu s$$

The frame length n_f should be 7565 bits and the time-out should be 91,57 μs

b) We know that the probability of a frame error is

$$P_F = 1 - Pr\{\text{no error in frame}\} = 1-(1-p)^{n_f}$$

Furthermore the effective transmission rate for stop-and-wait ARQ is given by

$$R_{eff} = \frac{n_f - n_o}{E[t_{sw}]}$$

where the average total time to transmit a frame is

$$E[t_{sw}] = t_o + \frac{t_{out} P_F}{1-P_f}$$

Hence when $t_{out} = t_o$ we get

$$R_{eff} = \frac{n_f - n_o}{t_o}(1-P_f) = R^o_{eff}(1-P_f) =$$

$$= R^o_{eff}(1-p)^{n_f} = 0{,}8 \cdot 10^8 (1-10^{-5})^{7565} =$$

$$= 74{,}17 \text{ Mbit/s} \quad \text{for } p = 10^{-5}$$

c) time-out $t_{out} = 2t_o$

$$E[t_{sw}] = t_o + \frac{t_{out} P_F}{1-P_F} = \frac{t_o(1-P_F) + 2t_o P_F}{1-P_F} = \frac{t_o(1+P_F)}{(1-P_F)}$$

Hence

$$R_{eff} = \frac{n_f - n_o}{t_o\left(\frac{1+P_F}{1-P_f}\right)} = R^o_{eff}\frac{1-P_F}{1+P_F} = \frac{R^o_{eff}(1-p)^{n_f}}{2-(1-p)^{n_f}} =$$

$$= \frac{0{,}8 \cdot 10^8 (1-10^{-5})^{7565}}{2-(1-10^{-5})^{7565}} = 69{,}13 \text{ Mbit/s}$$

for $p = 10^{-5}$

d) $R_{eff} = 24{,}52$ Mbit/s for $p = 10^{-4}$

In stop-and-wait ARQ the time-out value determines the time when a frame is retransmitted in case an error occured in the transmission. The time-out value has a huge influence on the average time it takes for a frame to be transmitted, which in turn has has an influence on the effective rate of the System. If the time-out is chosen too short, unnecessary retransmissions will occur. If the time-out value is too long, the effective rate will decrease, especially for high bit error rates, where more retransmissions are required.