Karlsruher Institut für Technologie

ITIV

Examination WS 2013/2014

Communication Systems and Protocols

Prof. Dr.-Ing. Dr. h. c. Jürgen Becker ▪ Dr.-Ing. Alexander Klimm

Communication Systems and Protocols
Date: 17.02.2014
Name: «Vorname» «Nachname»
Matriculation ID: «Matrikelnummer»
ID-No.: «LaufNr»

Lecture Hall: «HS»
Seat No.: «PlatzNr»

Institut für Technik der Informationsverarbeitung (ITIV):
Prof. Dr.-Ing. Dr. h. c. Jürgen Becker
Prof. Dr.-Ing. Klaus Müller-Glaser
Prof. Dr. rer. nat. Wilhelm Stork

Engesserstr. 5

76131 Karlsruhe

Prerequisites for the examination

Aids

- Allowed aids for the examination are writing utensils, a ruler, a non-programmable calculator and a single sheet of A4 paper with self- and hand-written notes. Writing may be on a single side of the paper only. The use of own concept paper is not allowed.
- Use only indelible ink - use of pencils and red ink is prohibited.
- Other material than that mentioned above, is strictly forbidden. This includes any type of communication to other people.

Duration of the examination

120 minutes

Examination documents

The examination comprises 17 pages (including title page). Answers may be given in English or German. A mix of language within a single (sub)-task is not allowed. In your solution mark clearly which part of the task you are solving. Do not write on the backside of the solution sheets. If additional paper is needed ask the examination supervisor.
You will not be allowed to hand in your examination and leave the lecture hall in the last 30 minutes of the examination.
At the end of the examination: Stay at your seat and put all sheets into the envelope. Only sheets in the envelope will be corrected. We will collect the examination.

Task 1 Error Protection

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Task 1.1 CRC-Calculation

In figure the simplified implementation of a CRC module is given.

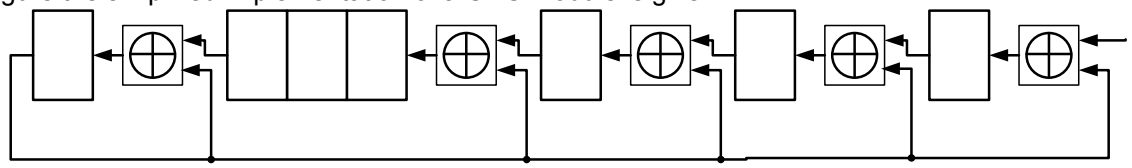

Figure 1.1: Simplified CRC Module

A) Name the polynomial g(x) used by the implementation

1

$g(x)= x^7+x^6+x^3+x^2+x+1.$

1pt: correct Polynomial

B) The dataword 11011011 is to be sent using the CRC protection as implemented in Figure 1.1. Give the bitstring as it is send over the bus. Give all steps of your solution.

4

Bitstring for polynomial: 11001111

Degree of generator polynomial = 7, hence seven zeros need to be appended

```
110110110000000 : 11001111
11001111
00010100000
   11001111
   011011110
    11001111
    00010001000
       11001111
       01000111
```

Remainder: 1000111

Bit stream as it is transmitted: 110110111000111

A: 1pt: bitstream appended with seven 0's
B: 2pts: calculation correct
ELSE:
0pts if systematic error
1pt if single calculation error
0pt more than 1 calc error
C: 1pt: correct bitstream that is being transmitted

Task 1.2 CRC-Error Protection

A) How and when does a receiving node detect a transmission error? **1**

1pt: result is not 0

The receiver divides the received bitstream with the bitstring as defined by the generator polynomial used within the receiver. If the result is not 0 than the receiver detects an erroneous transmission.

B) What possibilities exist in a CRC protection scheme to detect the position of the bit error within the received bitstream? Give a short explanation for your answer. **1**

CRC does not allow the detection of an error position. This can only be achieved by additional error detection measures

C) In a system, messages are sent over a bus with a datafield length of 17 bits. Each message is protected using CRC. If the datafield length is extended to 32 bits, in what way is it necessary to change the CRC implementation in order to still generally detect transmission errors? Explain your answer shortly. **1**

The same implementation can be used to detect errors. Nevertheless it might be possible that the detection quality is reduced as more errors can happen with more bits.

Task 1.3 Error Handling

A) Name three different methods how a receiver reacts to detected errors. Name one advantage and one disadvantage of each method. **3**

Ignore Error:
+ no overhead is introduced into the communication
- errors are still in the system and can be propagated further

Dismiss Message:
+ no overhead introduced into the communication
- All data in the message is lost, although the error possibly did not affect all data

Inquire a resend:
+ only errorfree messages are accepted
- substantial overhead might be introduced

Correct Error:
+ data is errorfree after the correction
- possibly not all errors can be corrected
- additional overhead is introduced as some kind of redundancy has to be included into the transmission (Checksums, Hashes, special Coding, etc.)

1pt per method (together with one advantage and disadvantage)

B) Given are the following communication scenarios. What is the most suitable method for error handling for each scenario? Give a short reason for each of your choices (2-3 sentences). **4**

Scenario 1: Terrestrial Radio Reception

Ignore Error: With streaming data the errors tend to go unnoticed if limited in number. If the transmission is corrupted too much effort has to be spend on avoiding the introduction of errors in the first place (more robust sender, communication channel)

Scenario 2: Sending control commands to the mars rover

Error Correction: Commands MUST be correct in order to not put the mars rover in danger. To avoid long communication time to the rover a local and powerful error correction is carried out

Resend: Commands MUST be correct in order to not put the mars rover in danger. If long communication time is acceptable in the mission a resend is triggered until all commands are correct. This frees resources on board the rover for other important tasks.

Scenario 3: Data transmission for an online banking application

Resend: Data transmission MUST ALWAYS be correct. Aborting the communication transfer and restarting it (resending) is safe. Time is not the top priority in such a system.

Scenario 4: Sending commands from a remote control to a TV

Resend: a faulty behavior due to corrupted transmission will be noticed by the sender (TV user). He/she will resend the command

Task 2 Media Access

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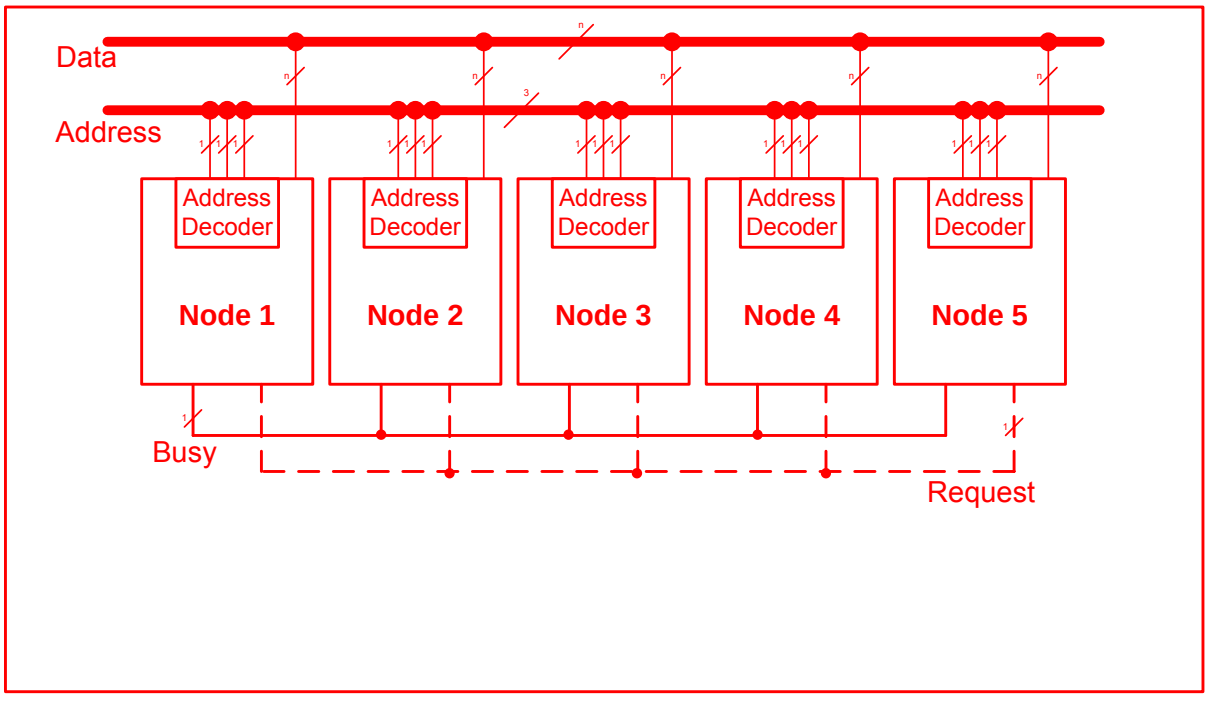
Task 2.1 Arbitration

A) What is arbitration? Why and in which cases is it necessary? Explain in 2-5 sentences. 2

It is necessary when multiple senders (masters) have to access the same common communication channel. It has to be decided which one may send. Otherwise the multiple signals overlap, the individual data is therefore corrupted and a correct data transmission may not be possible.
Arbitration can guarantee a collision free communication without the masters affecting each other or their data.

1pt: principle of arbitration
1pt: Necessity

B) Draw a schematic of the system setup using decentralized polling as an arbitratrion scheme. Assume that there are 5 nodes in total in the system. Label each element in the schematic and give all bit widths. 3



1pt: Separate Address lines connected to every node (decentral Polling generally correct)
1pt: Correct control lines Busy, Request
1pt: 3bit address, 1bit Busy, 1 bit Request

Data Line is not necessary

C) Name three arbitration schemes that enable a fair arbitration by construction. Explain in one sentence per scheme why it is fair. **2**

Polling (centralized, decentralized): polling is done in a cyclic fashion. No node is prioritized

Decentral Daisy Chaining: Nodes pass access in a cyclic fashion

Tap Line: Every Node can be granted access directly in a cyclic fashion

Fair arbitration is possible if a node can not arbitrarily take the bus for itself without the other nodes having the opportunity to take the bus for their own communication as well.

2pt: 3 schemes + correct reasoning
or
1pt: at least 4 elements correct (of 3 schemes and 3 reasons)

Task 2.2 CSMA/CA

A communication system comprises four communication nodes that use CSMA/CA as arbitration scheme. In order to transmit data a node transmits a dominant start bit (‚0') followed by a 10 bit message identifier. After that, 7 bits of payload data is sent. The message identifiers are unique for each node and all data is sent MSB first.

A) Carry out the CSMA/CA arbitration assuming that the following data is to be send. **3**
Node 1: Payload Data: 0x11 / Message ID: 1001011011
Node 2: Payload Data: 0x02 / Message ID: 1001111010
Node 3: Payload Data: 0x09 / Message ID: 1000101011
Node 4: Payload Data: 0x07 / Message ID: 1000111111

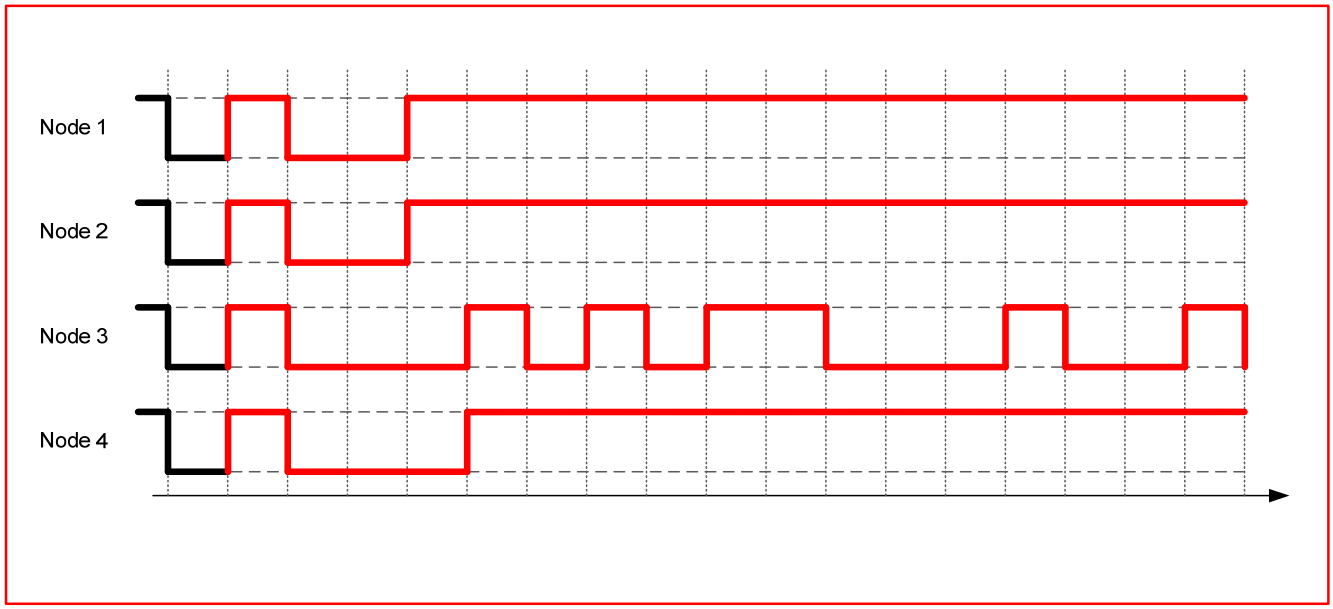


Figure 2.1: CSMA/CA Arbitration

3 points: everything correct
ELSE: 1pt: nodes that lost send out recessive level
1pt: dominant bit is 0

Task 3 Synchronization

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Task 3.1 General Questions

A) What is the goal of synchronization in a communication system? Explain in 1-2 sentences.

1

It is used to create a common understanding of time between all communicating nodes.

B) Name one suitable synchronization method for each of the quadrants given below

2

	Synchronous Transmission	Asynchronous Transmission
Serial Transmission	Line Code or Scrambler or shared clock	Start Stop Mode
Parallel Transmission	shared clock line	Hand Shake Mode

0,5 pts per correct quadrant

Task 3.2 Implementation of a synchronized node

Given is a distributed measuring system. A number of sensors have to transmit data over to a central control station. A serial transmission system is implemented, without a dedicated clock line. To avoid long sequences of ‚1's and ‚0' a bitstuffing scheme is implemented that inserts a ‚1' after 6 sequential ‚0's and a ‚0' after 5 sequential ‚1's.

Assume that 10 kbits/s of sensor data has to be transmitted. Per clock cycle exactly one bit is transmitted. The following clock generators are available for physical implementation of the nodes. Besides cost, the maximum frequency, the precision of the generator is given (the number of clock cycles after which the generator's frequency has drifted so much, that a bit cannot be detected correctly anymore).

A) Determine the best clock generator under technical and economical aspects. Justify your choice. (Hint: 1kbit = 1024bit) **3**

CLK generator	Precision [clock cycles]	max. Frequency [kHz]	Cost [Euro]
A	5	40	1,25
B	10	20	2,20
C	9	30	2,10
D	7	10	2,10

Table 1: Clock Generators available

Reasoning:

The longest sequence of indifferent bits occurs if a sensor sends out data consisting of all ‚0's. Therefore a precision of at least 7 is needed.

This rules out A

The bitstuffing rule introduces one additional bit after 5 bits of user data in the worst case. Thererfore 10kbit/5*6 = 12288 bits = 12 kbit have to be transmitted, a minimal clock frequency of 12 kbit/s is needed.

This rules out D

Generators B and C are left. The cheapest shall be chosen.

Generator C is chosen for implementation

3 pts: everything correct (including plausible reasoning)
ELSE: 0,5pt: correct reasoning why node is ruled out (despite calculation errors)

ALTERNATIVE
1 pt per correctly ruled out Clock generator

Task 3.3 Timing of a Synchronization Method

The half-duplex II (with busy signal) method is used for synchronization. A transmitting node puts out data sequentially. Each bit is put out for at least 10ms by the sender. The busy signal is sampled with a frequency of 1kHz. In between each bit an idle time of 4ms is mandatory for the bus to settle.
The receiving nodes can detect a valid signal immediately. They need 2.4 ms to sample the data off the bus and an additional 4.6 ms to store the data. The receivers have no knowledge of the timing behavior of the sender.
(Hints: 1 kHz = 1000 Hz | Assume that all signals are effective immediately, raise and fall times of signals are nonexistent)

A) What is the earliest time point at which the busy signal may be asserted if t_0 is the start of the transmission? Justify your answer. **1**

The busy signal shows that the slave is busy reading and processing the data currently residing on the bus.

As soon as the reading slave detects an asserted valid signal it starts reading data of the bus. At this time the busy signal is set.

B) In general what is the theoretical minimum and maximum length of any busy signal? Justify your answer. **2**

Theoretically: Minimum Length 0 sec – Infinity sec
(In this system at least 2.4 + 4.6 ms = 7 ms)

1 pt: Correct Minimum
1 pt: Correct Maximum

The busy signal has to be asserted at least for the duration of the reading node's processing time needed to retrieve the data from the bus and to store it within the receiving node. In theory the maximum length is not limited, but it makes sense to limit the time to the duration of a read/store

C) What is the theoretic maximum guaranteeable data rate of the system given? Justify your answer **1**

As the receiving node is faster than the 10 ms that valid data is available:

1 / (10 ms + 4 ms) = 71.42857 bits/s

D) Assume that an additional receiving node is introduced into the system. The node needs 8.3 ms to sample the data off the bus and an additional 14.1 ms to be ready for a new transmission cycle. Does this change the guaranteeable data rate? If yes: to what datarate? If not: Why not? **3**

Datarate is decreased, because the additional node needs 22.4 ms which exceeds the 10 ms that the transmitter holds the data valid on the bus.

1 / (10 ms + 4 ms + upperbound(22.4 -10 ms)

= 1 / (10 ms + 4 ms + 13 ms)

= 1 / 27 ms = 37.037037037037 Hz

A) 1 pt: Datarate changes
B) 1 pt: correct calculation
C) 1pt: upperbound necessary because it is sampled exactly every 1ms

Task 4 Data Transmission

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Task 4.1 General Questions

A) Describe the difference between node based adressing and message based adressing. 1

In Message based addressing the messages are marked directly with an ID. They are sent out over the bus and each node filters out the messages based on the ID

In node based addressing the sender decides who is supposed to retrieve the message and addresses the recipient directly by appending the receiving node's address to the data.

B) In what scenario is a node based adressing scheme andvantagous over a message based adressing scheme and vice versa? Give a short example for both cases and give the reason why your choice has advantages over the second possibility. 2

For broadcasting one data set to multiple receiving nodes message based addressing is beneficial. The data has to be sent only once thus saving bandwidth on the channel. Otherwise one message for each recipient would need to be sent.

Node based addressing can be used if data could be processed by different nodes in the system, but shall be processed by a dedicated unit which is chosen by the sender of the data. The sender can distribute data over a number of nodes directly. Using message based addressing would make additional coding necessary within the payload data.

1 pt per scenario (including plausible reasoning)

Task 4.2 Line Codes

A) Name two line codes that do not demand a separate clock line within a communication system. Justify your answer. 1

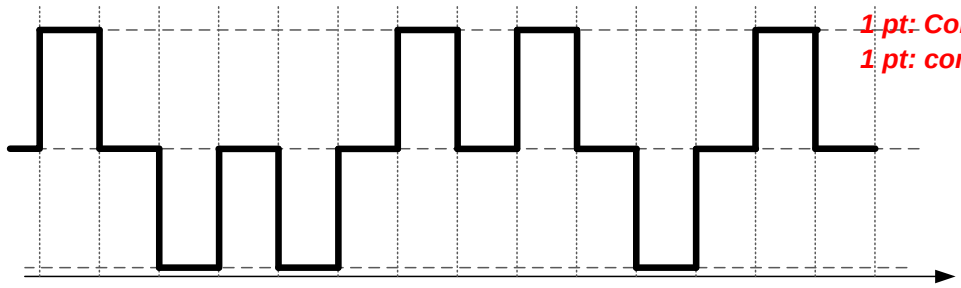
Manchester Code

Bi-Polar Return-to-Zero

In both cases there are signal transistions within each bittime. These can be used for clock recovery.

1 pt for both codes and reasoning

B) The figure below shows the signal diagram of a transmission. What coding scheme has been used in the transmission? Give the data being transmitted. **2**



1 pt: Correct Code
1 pt: correct data

Figure 4.1: Signal Diagram

RZ – bipolar Code is used. The data 1001101 was sent.

C) Encode the same data using the differential manchester code in the diagram given below. Mark the bits and their value in the diagram. **2**

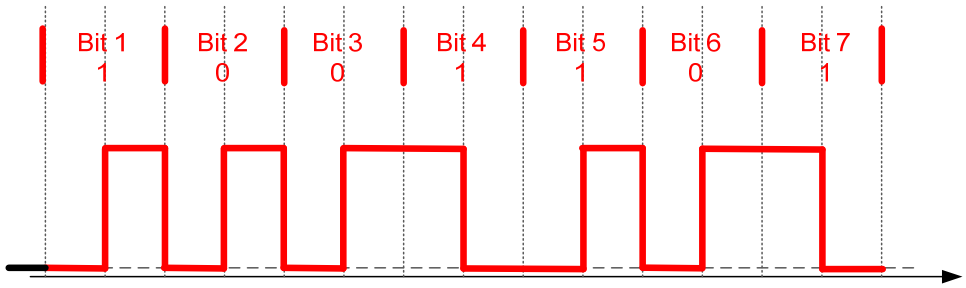


Figure 4.2: Differential Manchester Code

2 pts everything correct
ELSE
- ***A) 0,5 pt: generally correct Code***
- ***B) 0,5 pt: edges in the middle of bit time***
- ***C) 0,5 ps: phase shift for ‚0‘s***

Task 5 Physics

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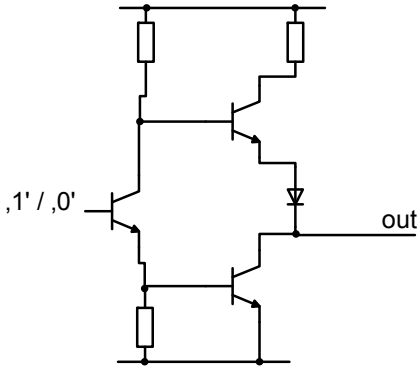
Task 5.1 General Questions

The figure below shows a TTL driver for bus systems.



A) Give one advantage of TTL drivers and one disadvantage. 1

Advantage: Relatively high current can be put out to the bus. This makes the signals very robust

Disadvantage: more than on active driver results in a short circuit in the system

.

B) How can the main disadvantage of TTL drivers be overcome? 1

Only a single driver may be active at any time, while all others must have high impedance. This can be achieved with an additional signal conditioning stage (an additional transistor in front of the actual driver)

C) What is the benefit of signal modulation? 1

It allows circumvention bandlimitations of a carrier medium

D) A QAM-4 modulation is given. How much may phase (φ) and amplitude (A) of the signal vary without introducing errors into the transmission. Justify your answer. **1**

In QAM-4 only 4 points are used vor encoding data. They can be differentied by only their phase. Therefore any amplitude shift may be allowed (Amplitudes are positive).

As the phase difference in the 4 points is 90° the phase may only vary with $\Delta \varphi < \pm 45°$

Point only given with correct reasoning

E) Differential signaling is implemented. A logic '1' is detected with a ΔU1 = +4.2 V...+5V. A logic '0' is detected with ΔU2 = -4.0 V...-5.5V. Due to EMR issues voltage spikes are introduced onto the signaling lines. **2**
What is the minimal voltage of the spikes that results in the misinterpretation of a '0' bit being send over the bus line? Explain your answer!

Due to the nature of differential signaling the voltage spikes affect both signaling lines. A receiver determines the voltage difference of the two lines. Therefore ΔU will still be in the same even with errors.

Only f the voltage spike is too large and destroys the receiver an erroneous reading of the bit might occur

1 pt: no effect of spikes
1 pt: Reasoning (destruction must not be a part of the explanation

Task 5.2 Oversampling

A communication system uses oversampling and majority voting to compensate for errors introduced by physical sources (crosstalk, EMR, etc). The duration of one bit is 5 ms. The frequency at which errors occur is 1 Hz.

A) How much of one bit time may be corrupted if the nodes shall still be able to read the correct bit value? Give the maximum value per bit. **1**

Less than 50% per bit time may contain a corrupted signal (less than 2.5 ms) if only one error occurs.

B) Under the assumption that only a single error with a maximum duration of 1.2ms occurs during on bit time:
What is the minimal number of samples per bit time in order to be able to detect a correct value by majority voting?
What is the minimal sampling frequency needed?
Justify your answer. **2**

Sampling points are always equidistant. Therefore 3 samples are sufficient. They have a distance of 5ms/3 = 1.66666 ms to each other. One error can affect on sample point the most.

The sampling frequency has to be at least:
f(sample) = 1 / (5ms / 3) = 600 Hz

1 pt: minimal number of sampling points
1 pt: correct calculation of sampling frequency

Task 6 Practical Aspects of Communication Systems

4

Seven different control units are interconnected over a bus. They each send out cyclic messages consisting of 32 bits, including payload data and and all overhead. The cycle frequency for the transmission is 100 Hz.

A) Using baseband transmission on an ideal channel with unlimited bandwidth, TDMA (Time Division Multiple Access) is implemented as a bus access and scheduling scheme. With what minimal frequency has a sender to be able to change the level on the bus (switching frequency)? Justify your answer and give all calculation steps to your solution. **1**

M * n * t 1/s

7 * 32 * 100 Hz = 22400 Hz

= 22.4 kHz (1k = 1000)

= 21.875 kHz (1k = 1024)

B) Under the same assumptions, what is the minimal frequency that a receiver has to sample the bits with? (Hint: Assume error free transmission). **1**

The same frequency as the data is being sent out with.

C) CDMA with Walsh codes is now used as a bus access and scheduling scheme. All nodes shall send their data simultaneously. With what minimal frequency has a sender to be able to change the level on the bus (switching frequency)? Justify your answer and give all calculation steps to your solution. **2**

7 nodes → upperbound [ld(7)] ➔ 8 chips per bit

32 Bits are send by each node per cycle ➔ 32 * 8 = 256 chips per cycle

➔ 256 * 100 Hz = 25600 Hz

= 25.6 kHz

= 25 kHz

1pt: upperbound when calculating chips
1pt: correct result

Task 7 Networks

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Task 7.1 OSI Layers

A) Name all the layers of the OSI model. Give the name and the number of each layer. 1

7: Application Layer

6: Presentation Layer

5: Session Layer

4: Transport Layer

3: Network Layer

2: Data Link Layer

1: Physical Layer

0.5 pt: names of all layers given
0.5 pt: layer names connected to correct layer no.

Data with an 8 bit destination address and 8 bit of payload data is send over a network. Framing consists always of a 4 bit header and a 2-8 bit trailer segment. A node transmits a payload of 10011011 over the network. The following message can be seen on the network:

0101 0010 0101 0001 0100 0100 0111 1001 1011 1011 0001 1100 1110 01

B) How many layers of the OSI have been implemented in the system? Justify your answer 2

5 Layers have been implemented.

The data that is sent appears from bit position 29 on. The 28 bits prior to the data must therefore be the message's address (8 bit) and headers resulting from the framing: 5 x 4 bit + 8 bit = 28 bit

Alternative solution:

6 layers have been implemented.

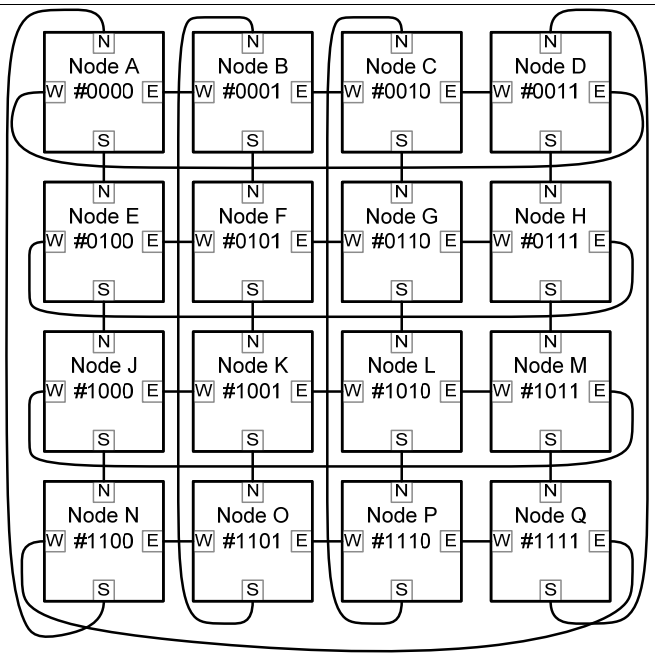
Same calculation as above but data with address is interpreted as one additional layer.

1pt: 5 Layers or 6 layers
1pt: Reasoning

Task 7.2 Routing

A) What is a disadvantage of using circuit switching in a network, if the number of hops is increasing? 1

It may block off other connections



In the network structure given above the routing control is embedded into the messages send over the network. For each routing decision a header is appended to the data packet. A node will read the first routing information, remove the header and send the data packet according to the command that has been removed.
The routing commands are the following:

000	Send data to North (N)
010	Send data to East (E)
100	Send date to South (S)
110	Send data to West (W)
111	Send data to Network Adapter

Node F sends out the following stream: 010100010010000111110000111

B) Give the sequence of the nodes as they are passed by the message **2**

F -> G -> L -> M -> J -> E

A) 1pt: Routing Carried out correctly (111 terminates routing)
B) 1pt: Route correct

C) What is the content of the message? **1**

110000111