Examination (WS 2018/2019)
Communication Systems and Protocols

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Exam: Communication Systems and Protocols
Date: February 14, 2019

Participant:
Matr. №:
ID:

Lecure hall:
Seat №:

The following rules apply:

- The writing time of the examination is 120 minutes.
- No examination aids are permitted, except for
  - one double-sided DIN-A4 sheet of hand-written notes,
  - a non-programmable calculator and
  - a dictionary.
- Answers can be given in English or in German.
- Use **permanent ink** only. The usage of pencils or red color is prohibited.
- You are not permitted to use your own writing paper.
- Please do not write on the back sides of the sheets.
- Additional solution sheets are available from the examination supervisors.
  - Make sure that you label all such sheets with your matriculation number.
  - Each additional solution sheet needs to be assigned to exactly one task.

The examination comprises **41 sheets** and a two-page formulary.

		Page	≈ Pts. in %	Points
Task 1:	Physical Basics	2	10	**27**
Task 2:	Transmission Principles	8	13	**34**
Task 3:	Modulation and Spread Spectrum	14	12	**31**
Task 4:	Media Access	20	12	**32**
Task 5:	Error Protection	25	12	**31**
Task 6:	Protocols	30	12	**32**
Task 7:	Routing	34	13	**35**
Task 8:	Network Topologies	38	11	**30**
				$\sum$ **252**

Task 1: Physical Basics

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Task 1.1: Sampling and A/D conversion

A) Name the four classes of signals which exist in communication channels.

4

time-continuous, value-continuous (analog signal)
time-continuous, value-discrete (amplitude quantized signal)
time-discrete, value-continuous (sampled signal)
time-discrete, value-discrete (digital)

-1pt for each missing/incorrect class; both description and class name are valid

An exemplary signal is shown below.

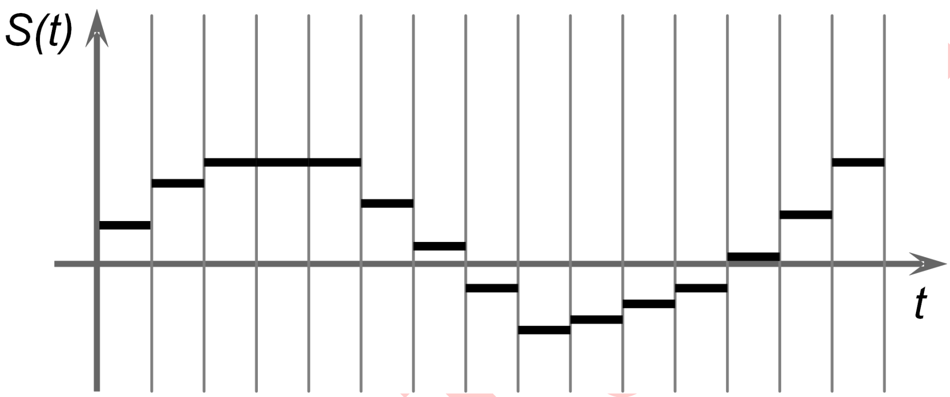

Figure 1.1: Exemplary signal

B) Which class does the signal shown in Figure 1.1 belong to?

2

time-continuous, value-discrete

2pt if correctly classified

C) An analog signal shall be converted into a digital signal. The maximum frequency occuring in the analog signal is $f_{max} = 40\,\text{kHz}$. What needs to be considered concerning sampling to be able to unambiguously reconstruct the signal? Give the name (of the rule) and calculate the resulting requirement concerning the sampling frequency.

2

Nyquist-Shannon sampling theorem;
$f_{sample} > 2 \cdot f_{max}$
$f_{sample} > 80\,\text{kHz}$

1pt for name
1pt for value

D) What is oversampling of digital signals? Give a definition and explain how the bit value is determined after sampling. What is the advantage of increasing the oversampling frequency?

4

Multiple sampling points are taken per bit/symbol that is transmitted. Among the sample values of one bit/symbol, a majority vote is done to determine the value that appears most often. This value is taken as the bit value.
With an increased oversampling frequency, more samples are available per bit/symbol. Therefore, more short distortions can be tolerated.

1pt for multiple sample points
1pt for majority vote
2pt for advantage of higher sampling frequency

E) Consider a transmission system for digital signals. Explain the concept of acceptance bands for digital signals. Why are acceptance bands needed? Which digital value is assumed if the signal is in the 'undefined' band?

3

In reality, digital signals are affected by noise or instable supply voltages, among others. Therefore, a receiver may not receive exactly the defined HIGH and LOW voltage levels. Therefore, the signal voltage scale is divided in three bands: HIGH, undefined, LOW. If the analog signal is within the HIGH band, digital 'high' is assumed. If it is within the LOW band, digital 'low' is assumed. While it is in the 'undefined' band, the previous value is assumed.

1pt for motivation (non-ideal signal voltages)
1pt for three bands
1pt for digital signal value explanation

Task 1.2: Channel Capacity

A digital transmission system has a bandwidth of $B = 20\,\text{kHz}$.

A) Assuming an ideal channel, calculate the maximum data rate achievable on this channel using quaternary signals? **2**

$D_{max} = 2 \cdot f_{limit} \cdot \log_2 V = 2 \cdot 20\,\text{kHz} \cdot \log_2 4 = 80\,\text{kbit/sec}$

1pt for general formula
1pt for correct value

B) Why can we not keep increasing the number of signal steps in a real channel to achieve a higher bit rate? **2**

With increasing number of signal steps, the voltage difference between these steps decreases. If this voltage difference is lower than the channel noise level, the noisy signal voltage may reach the voltage of the next higher or lower signal step, leading to an incorrect transmission.

1pt for noise preventing signal interpretation
1pt for detailed explanation (noise > distance)

Task 1.3: Signal Transmission

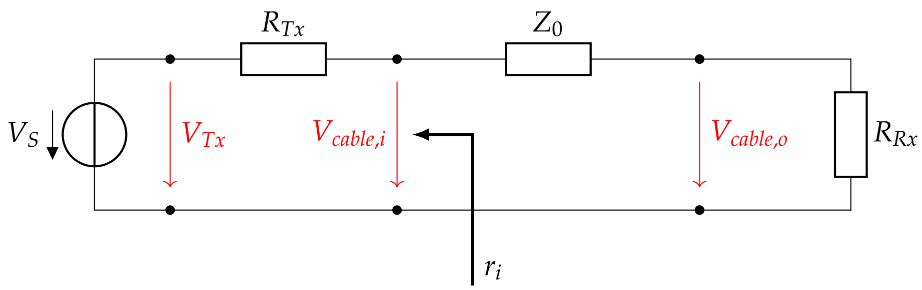

Figure 1.2: Test setup

In Figure 1.2, the equivalent circuit diagram of a transmission line is depicted. A transmitter having output impedance R_{Tx} is connected to a receiver with the input impedance R_{Rx} using a long cable.
The impedances are $Z_0 = 50\,\Omega$, $R_{Tx} = 10\,\Omega$. R_{Rx} is unknown.

A) Give the formula for calculating the reflection factors in general. Give the value of the reflection factor r_i at the beginning of the line. **2**

$r = (R_T - Z_0)/(R_T + Z_0)$

$r_i = (R_{Tx} - Z_0)/(R_{Tx} + Z_0) = -\frac{2}{3} = -0.\overline{6}$

1pt for abstract formular (a more general formula is also accepted)
1pt for correct r_{in} value (formula not needed)

At $t = 0$, the voltage V_S switches from 0 V to 6 V and is constant afterwards.

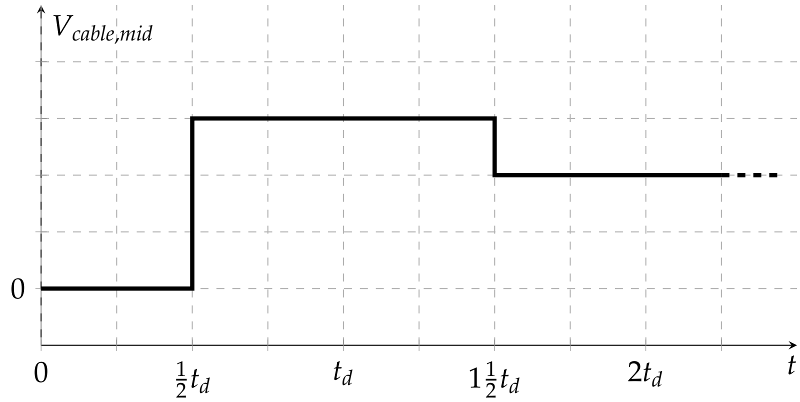

Figure 1.3: Voltage level in the middle of the line

B) An ideal cable (no attenuation per unit length) is assumed. The propagation times of the signal at the transmitter and receiver side of the cable are neglected. The propagation time of the signal from one end of the line to the other end is t_d.
Figure 1.3 shows the voltage signal at half of the cable's length (the middle). What is the reflection factor at the end of the line? Give a reasoning for your answer.
Determine the receiver's impedance R_{Rx}. **4**

The reflection at the end of the cable happens at $t = t_d$. The resulting change in voltage in the middle of the line can be seen at $t = 1\frac{1}{2}t_d$. It can be seen that $V_{cable,mid}$ decreases by $\frac{1}{3}$ at $t = 1\frac{1}{2}t_d$. Therefore, $r_{Rx} = -\frac{1}{3} = -0,\overline{3}$.

1pt for corr. reflection factor
1pt for reasoning
1pt for formula solved for R_{Rx}
1pt for corr. R_{Rx} value

Calculation of R_{Rx}: $r = (R_T - Z_0)/(R_T + Z_0)$
$r = (R_{Rx} - Z_0)/(R_{Rx} + Z_0)$
$r(R_{Rx} + Z_0) = (R_{Rx} - Z_0)$
$rR_{Rx} + rZ_0 = R_{Rx} - Z_0$
$(1 + r)Z_0 = (1 - r)R_{Rx}$
$R_{Rx} = Z_0(1 + r)/(1 - r)$
$R_{Rx} = 50\,\Omega(1 + (-\frac{1}{3}))/(1 - (-\frac{1}{3})) = 25\,\Omega$

C) What needs to be fulfilled to avoid reflection at the end of the line? Give the general formula and give a solution for proper termination, assuming that $R_{Rx} = 20\,\Omega$. **2**

Change Cable.
OR
The line impedance must match the termination resistance: $Z_0 = R_{Rx} + \ldots$

1pt for termination criteria (formula or explanation)
1pt for correct series resistor value

Since $R_{Rx} < Z_0$, a series resistor R_S needs to be added so that $Z_0 = R_{Rx} + R_S$.

$Z_0 = R_{Rx} + R_S$
$R_S = Z_0 - R_{Rx} = 50\,\Omega - 20\,\Omega = 30\,\Omega$

Task 2: Transmission Principles

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Task 2.1: Line Codes

A) We want to transmit the value 0110 0011 1001 through a serial wire communication channel. Complete Figure 2.1 with the digital signals transmitted using each given encoding scheme.

4

1p for each correct line code

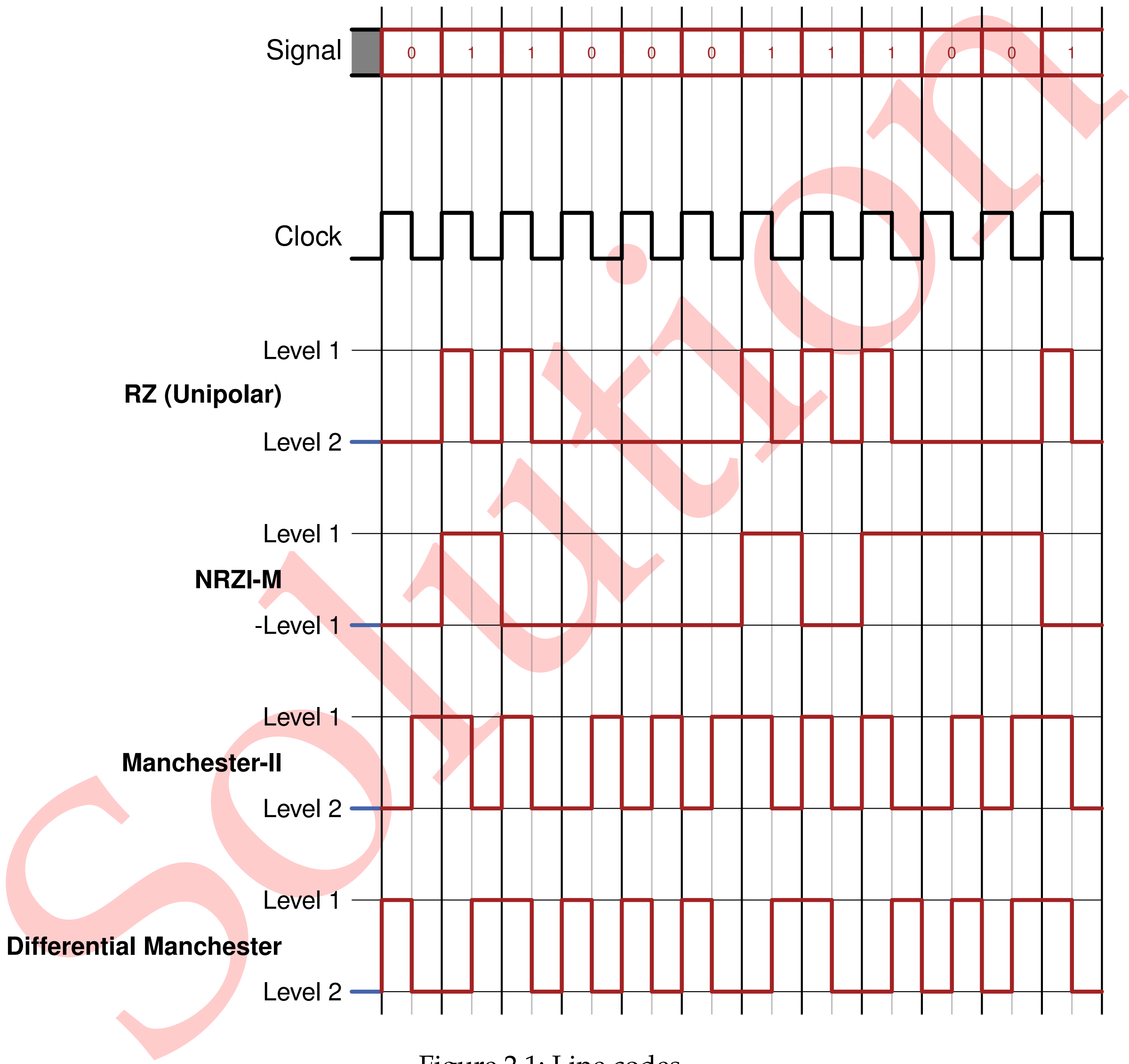

Figure 2.1: Line codes

B) Given the transmission of a random sample signal, which code(s) in Question A do NOT enable clock recovery of the transmitter's frequency? Justify your answer. **4**

Codes: RZ (Unipolar), NRZI-M.

2p for codes.
2p for explanation.

For each code, there is a possible input sequence that keeps the transmission line level constant, allowing for clock skew and loss of synchronization on the receiving end.

C) For the codes in Question A that enable clock recovery, what is a disadvantage that they share? Justify your answer. **2**

They need a larger bandwidth to transmit the signals as they require more transitions per bit interval.

2p for larger bandwidth due to more transitions.

D) An approach used to synchronize communication processes is the use of Handshakes. Complete the signals in figure 2.2 to perform two transmissions of DATA values 0x1 and 0x2 using a Full Duplex Handshake. A grey color symbolises that the DATA line is idle and that no value is being driven on the bus. Ignore delays and consider that a read occurs at the rising edge and signal change occurs at falling edge of the clock. **8**

1p for each correct transition in each clock edge:
- VALID and DATA (0x1 for first transmission and 0x2 for second) assert when ACCEPT=0
- ACCEPT assert the cycle after VALID=1
- VALID and DATA deassert the cycle after ACCEPT=1
- ACCEPT deassert the cycle after VALID=0

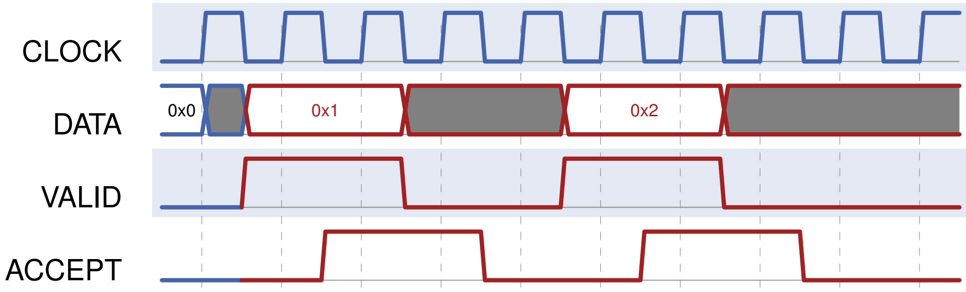

Figure 2.2: Signal sequence

Task 2.2: I^{2}C Communication

In this task we want to investigate the data transmission on the I^{2}C-Bus. The simplified frame format is given in Figure 2.3. Three master nodes are simultaneously trying to transmit or read one byte of data to or from different slaves over the I^{2}C-Bus.

S	ADDR	$R/\bar{W}$	A	DATA	A	DATA	$A/\bar{A}$	P

data transfered (n bytes + acknowledge)

term	description
S	start condition
ADDR	7-bit slave address
$R/\bar{W}$	read/write: read 1, write 0
A	acknowledge ('0')
$\bar{A}$	not acknowledge ('1')
DATA	8-bit data
P	stop Condition

Figure 2.3: I^{2}C-Bus frame format

A) Is I^{2}C a synchronous or asynchronous protocol? Justify your answer. **2**

It is a Synchronous Protocol because it sends the transmitter's clock through SCL.
OR
It is asynchronous because the point in time, where a new packet is send is not defined => start/stop condition

2p for SCL/presence of clock line or a resonable answer

B) Among the 3 transmission types presented in the lectures (Simplex, Half-Duplex, Full Duplex), what type does I^{2}C belong to? Justify your answer. **2**

I^2C is a Half-Duplex transmission as both Sender and Receiver share the same line of communication (SDA). (one possible justification) // as the Sender can only complete/confirm the transmission with an acknowledge from the Receiver. (other justification)

2p Half-Duplex with justification.

C) In an I^2C Multimaster configuration, how are bus access collisions among Masters resolved? Describe how a collision is detected by a Master. **2**

In case of collision detection whoever wrote '0' gets the line as '0' is the dominant value.
Each Master reads-back the SDA line. If it wrote a '1' but SDA is '0', another Master is also trying to access.
The Master who wrote a '1' then gives the priority.
If both masters wrote the same value, no collision will be detected.

1p for '0' dominant value. 1p for each master reading back the line and giving priority if a colision is detected.

D) What happens to the arbitration if 2 Masters try to access the same Slave? What happens if they try to perform the same or different operations (Read/Write)? Justify your answer for each of the three possible cases. **3**

If both Masters try to read, they both receive the same data from the Slave and no collision is detected.
If both try to write, the Master who writes the smallest value gets priority and completes the operation.
If they ask for different operations, the write (0) operation has priority.

1p for explanation

E) The diagram in Figure 2.4 corresponds to a connected I^2C Multimaster configuration. The system is composed of 3 Slave and 3 Master nodes. Complete the diagram with the signals generated by each node for the simultaneous transactions presented in Table 2.1 and for the resulting SDA line of this bus. The table shows for each master, the address of the slave it is accessing, the communication mode (R/W) and the data to be sent or read. **7**

2p for correct SDA line. 1p for correct address and R/W request for each Master (1,5p total for all 3). 1p for correct assignment of all A/not A by Slaves. 1p for correct assignment of Stop Condition.

node	slave address	$R/\overline{W}$	data
Master 1	1011101	1	$0x55$
Master 2	1010101	0	$0x5A$
Master 3	1011101	1	$0xAA$

Table 2.1: I^2C Communication Parameters

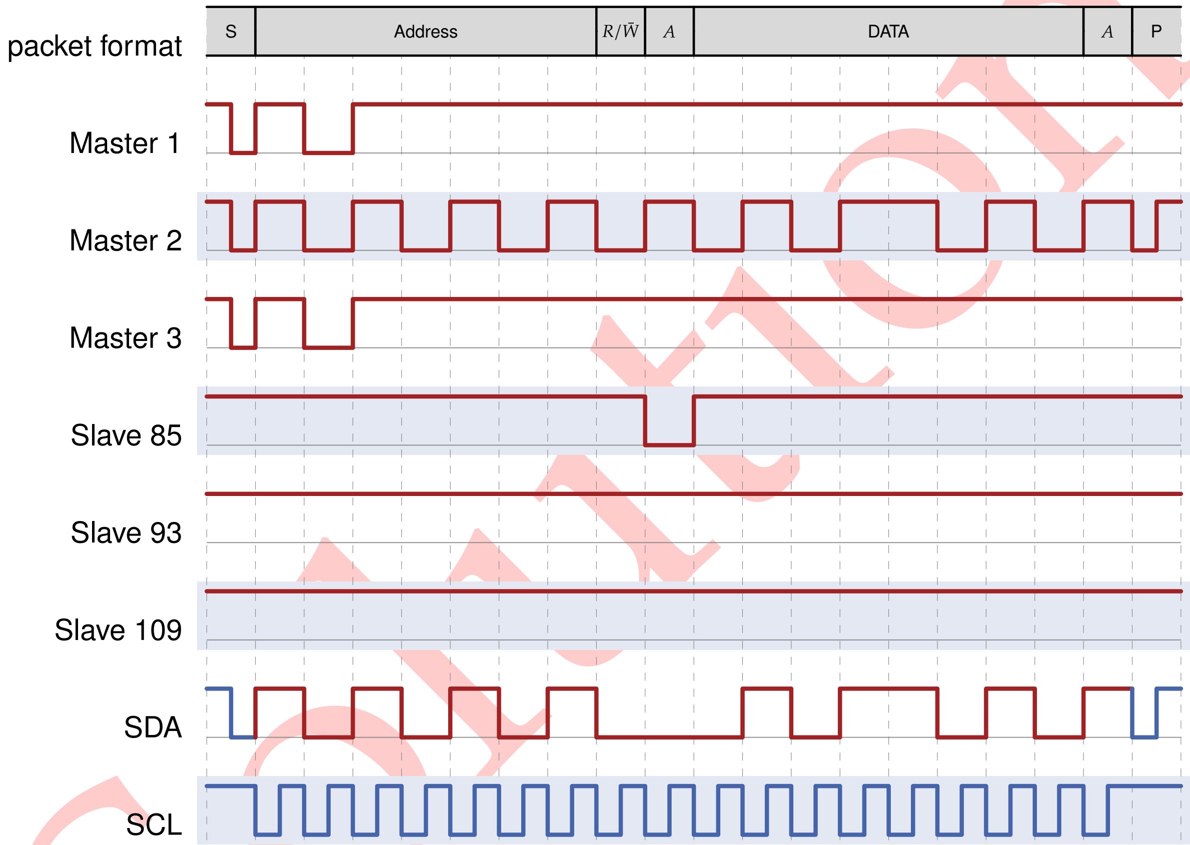

Figure 2.4: I²C Signal sequence

Task 3: Modulation and Spread Spectrum

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Task 3.1: Modulation

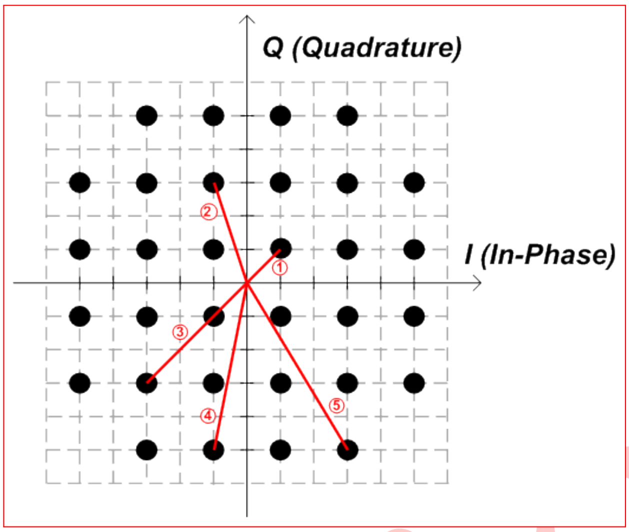


Figure 3.1: The constellation diagram of a certain modulation

A) The constellation diagram of a certain modulation is shown in Figure 3.1. How many possible absolute amplitude values can be used in that modulation? Sketch the amplitude values in the Figure 3.1!

3

Five values

1pt for mentioning five values and 2pt for complete sketch of the values in the figure. -1pt for each incorrect sketch, min point: 0pt for the sketch.

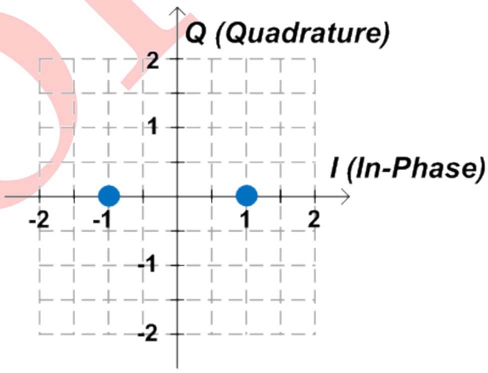


Figure 3.2: The constellation diagram of a digital modulation

B) What type of digital modulation scheme is shown in the Figure 3.2? Explain your answer based on the constellation diagram! Hint: the modulator does not have the quadrature component.

2

(Binary) Phase Shift Keying or BPSK. Two main properties are shown: equal absolute amplitude for both symbols, and two adjacent symbols have the same phase.

1pt for the correct answer and 1pt for corrent reasons/properties

C) What is the main difference between an absolute PSK and relative PSK?

2

In absolute psk, phase shift is compared to a reference phase. However, relative psk compares any phase shift to the phase of previous bit.

1pt for the definition of abs PSK, and 1pt for the definition of rel. PSK

D) A constellation diagram of 8-QAM is shown in Figure 3.3. The following bits are transmitted: **001000010100** which will be encoded from the left to the right. The Figure 3.4 (B) shows the in-phase carrier signal. Moreover, the Figure 3.5 (E) shows the quadrature carrier signal. Use the Figure 3.4 (A and C) and Figure 3.5 (D and F) to sketch the waveforms of symbol representations and modulated information signals based on in-phase and quadrature axes of the constellation diagram. The symbol period is twice as long as the period of carrier signal.

12

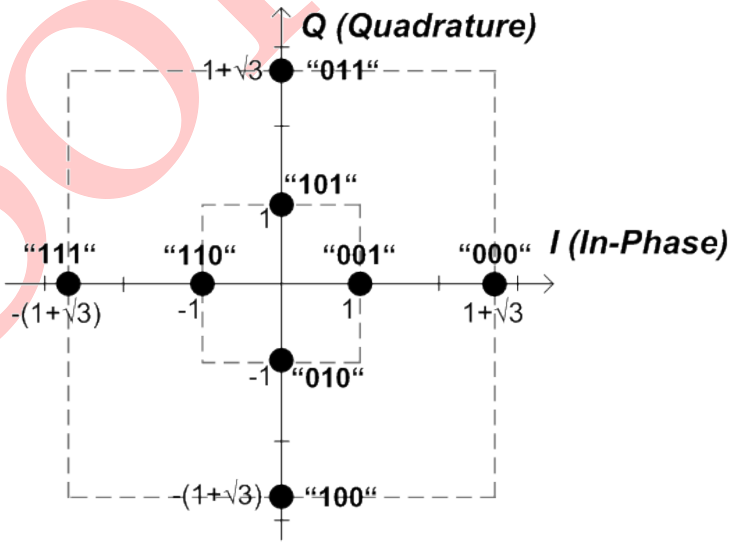
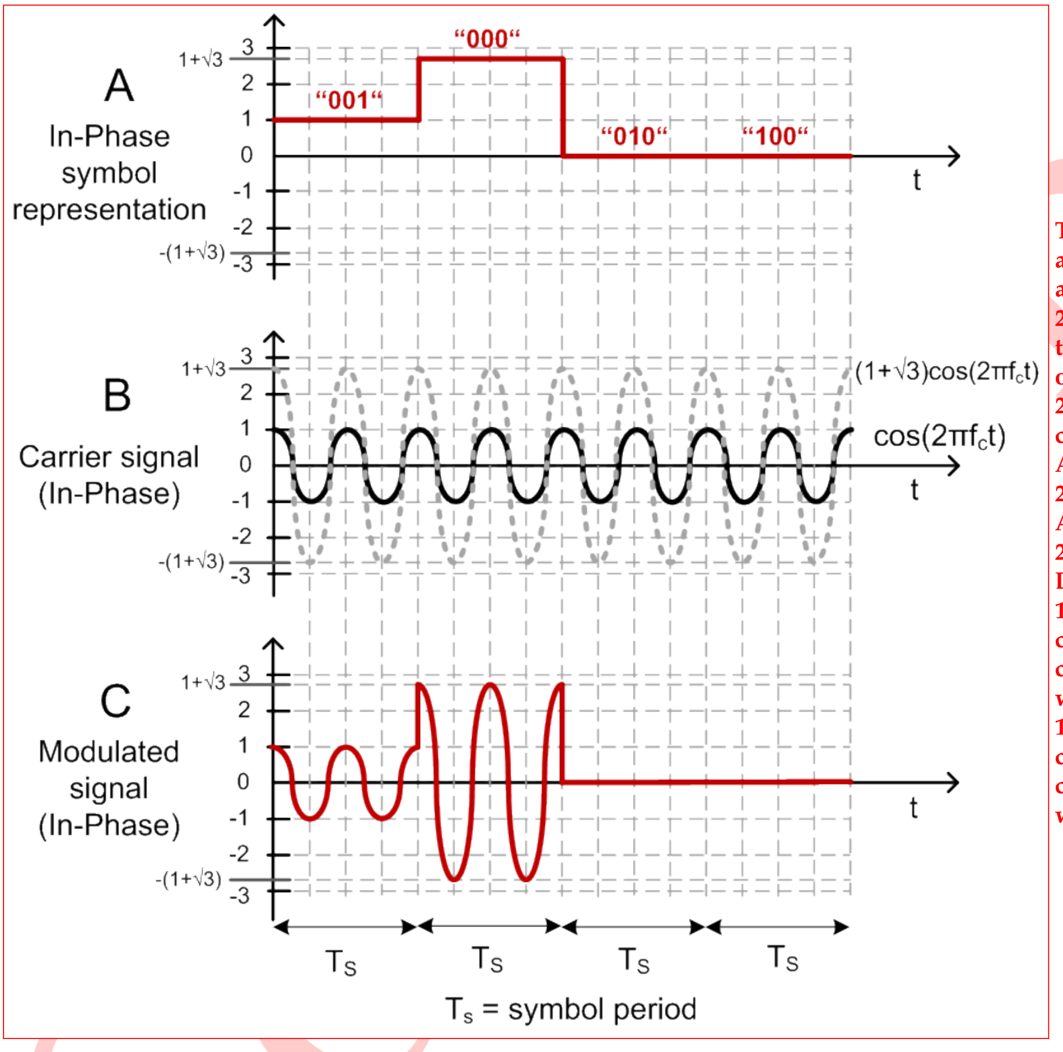


Figure 3.3: A constellation diagram of 8-QAM



These are the points allocation for Figure 3.4 and Figure 3.5 combined.
2pt if the symbol period is twice as long as the period of carrier signal.
2pt If the above is consistent for Sketch A,C,D,F
2pt for a complete sketch of A
2pt for a complete sketch of D
1pt if amplitude of C is correct, 1pt if phase of C is correct and is consistent with A
1pt if amplitude of F is correct, 1pt if phase of F is correct and is consistent with D

Figure 3.4: In-Phase symbol representation, carrier signal (in-phase), and modulated signal (in-phase)

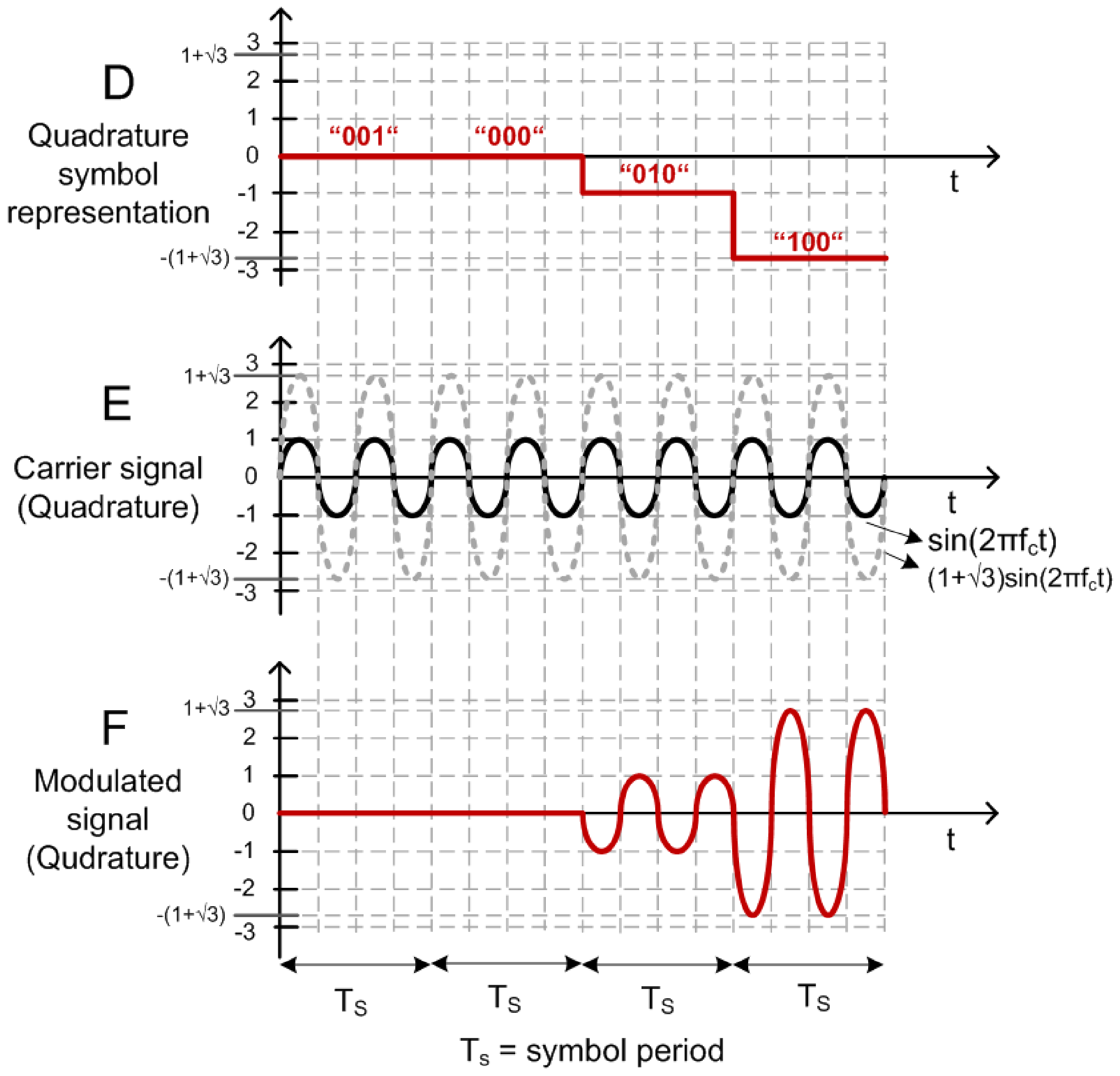


Figure 3.5: Quadrature symbol representation, carrier signal (quadrature), and modulated signal (quadrature)

Task 3.2: Spread Spectrum

A) For the simultaneous transmission of eight messages by eight nodes, the Walsh functions shown in Table 3.1 can be used. Complete the blank cells of Node 1, 2, 4, 7 and other nodes in Table 3.2 by using the Walsh functions.

6

1pt for each correct line

Sender Node	Function							
0	+1	+1	+1	+1	+1	+1	+1	+1
1	+1	-1	+1	-1	+1	-1	+1	-1
2	+1	+1	-1	-1	+1	+1	-1	-1
3	+1	-1	-1	+1	+1	-1	-1	+1
4	+1	+1	+1	+1	-1	-1	-1	-1
5	+1	-1	+1	-1	-1	+1	-1	+1
6	+1	+1	-1	-1	-1	-1	+1	+1
7	+1	-1	-1	+1	-1	+1	+1	-1

Table 3.1: Functions for sender nodes

Node	Data	Signal							
1	"0"	-1	+1	-1	+1	-1	+1	-1	+1
2	"1"	+1	+1	-1	-1	+1	+1	-1	-1
4	"1"	+1	+1	+1	+1	-1	-1	-1	-1
7	"0"	-1	+1	+1	-1	+1	-1	-1	+1
other nodes	"silent"	0	0	0	0	0	0	0	0
Signal on media		0	+4	0	0	0	0	-4	0

Table 3.2: Transmission with CDMA

B) The following Signal has been received from a transmission using all the eight Walsh functions from this task.

6

-2.9 +0.7 +4.5 -0.2 +1.6 +3.3 -0.8 +1.0

As corruptions might happen during transmission, the receiver has a tolerance band for the detection. Indeed, all calculated values differing up to ±0.5 from the ideal values, i.e. -8 or +8, will still be accepted. Calculate the bit value that the receiver will detect for node 0 and node 7.

Node 0

Received	-2.9	+0.7	+4.5	-0.2	+1.6	+3.3	-0.8	+1.0
Node 0	+1	+1	+1	+1	-1	-1	-1	-1
	-2.9	+0.7	+4.5	-0.2	+1.6	+3.3	-0.8	+1.0

2pt for each correct sum of each node
1pt node 0: stating the undefined value
1pt node 7: in detecting "0"

Total= +7.2, and +7.2 is undefined value as out of the tolerance band, +8 ±0.5.

Node 7

Received	-2.9	+0.7	+4.5	-0.2	+1.6	+3.3	-0.8	+1.0
Node 7	+1	-1	-1	+1	-1	+1	+1	-1
	-2.9	-0.7	-4.5	-0.2	-1.6	+3.3	-0.8	-1.0

Total= -8.4, and -8.4 in the tolerance band of -8 ±0.5 → a "0" has been detected.

Task 4: Media Access

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Task 4.1: General questions

A) Name two advantages of CSMA/CD in contrast to Aloha. Explain your answers briefly. **2**

Less probability for disruption of ongoing transimissions: waiting for free medium
Fast collision detection: Alhoa - collisions can only be identified through a missing acknowledge

1P for correct disadvantage(only with explanation, faster than ALOHA detection is needed)

B) CSMA/CD ist used as transmission scheme. Is the length of the media related to the duration of sending? Give a short explanation. **2**

Yes, the data to be send has to be long enough for the signal to travel twice the media during sending time

2P for correct answer with explanation, no points if there is no explanation

C) Arrange the media access schemes CSMA/CR, CSMA/CD and Aloha according to their average channel utilization, start with the lowest channel utilization. **1**

Aloha (20%), CSMA/CD (30 – 70%), CSMA/CR (up to 100%)

1P for any order, 0pt otherwise

Task 4.2: Carrier Sense Multiple Access/Collision Resolution

A bus system of four nodes are using CSMA/CR as arbitration scheme and are connected via open collector drivers. Each node has a five Bit identifier and the bus has to cover a maximum distance of 600m.

A) Which is the dominant bus level? Give a short explanation. **1**

wired-AND: „0“ dominant, „1“ recessive

1p for zero (GND, LOW) as dominant bus level

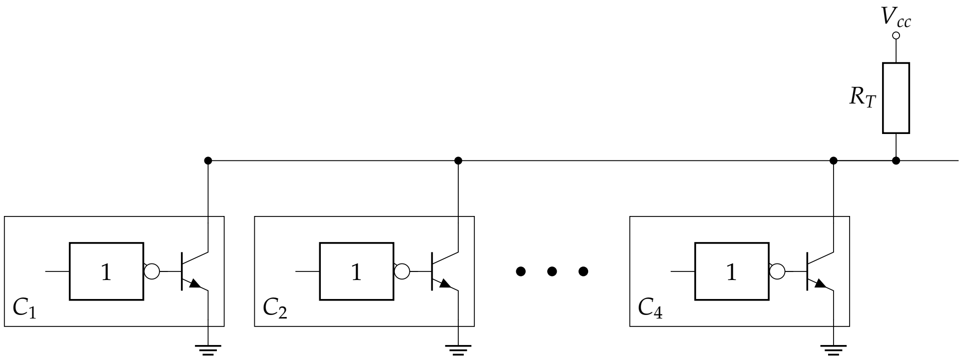

Figure 4.1: bus system

B) What are the requirements of the arbitration process of CSMA/CR? Give at least two requirements. **2**

- Unique ID per message/node
- All nodes start arbitration at the same time
- Bitwise arbitration
- Bit is long enough, so that all nodes can read it (Simultaneity)

1p for one correct requirement (max 2pt)

C) The data format uses a frame with a Start Of Frame bit (SOF) and an identifier with five bits. The identifiers can be taken from Table 4.1. Using Figure 4.2, draw the impulse diagram **7**

Node	Identifier
C_1	10010
C_2	10000
C_3	10001
C_4	11101

Table 4.1: Identifiers of the nodes

for the arbitration of the single nodes and the signal level of the shared bus line. Which node is granted exclusive access to the bus?

Node C_2 is granted exclusive access to the bus.

1p for correct dominant SOF
1p for each consecutive correct time step (max 5P)
1p for correct winning node and last time step

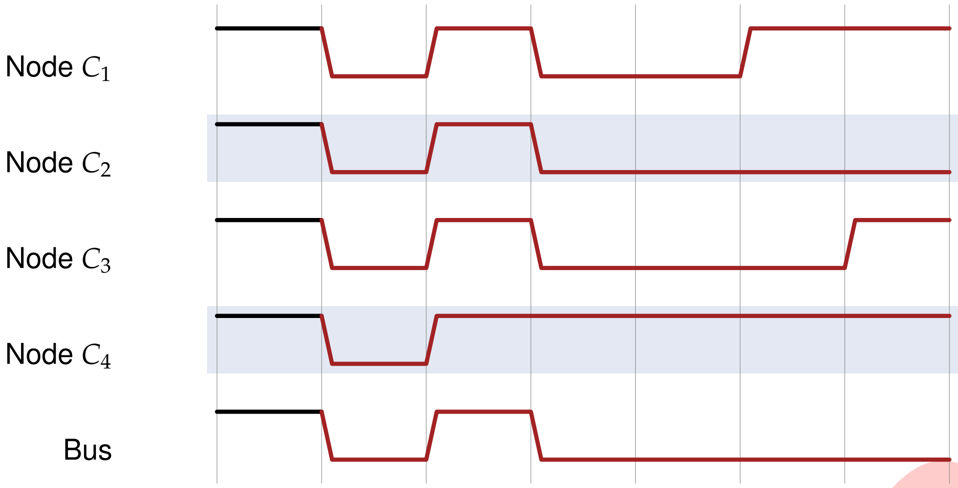

Figure 4.2: Bus Access

Task 4.3: Arbitration

A) Name one advantage of arbitration compared to static multiplexing schemes like CDMA. Justify your answer briefly. **2**

dynamic assignment - with static multiplexing an under-utilization off the channel can occur.

2P only with explanation, no points if explanation is missing

B) Explain the differences between centralized and decentralized arbitration schemes briefly. **2**

Centralized: One central arbiter is responsible for the arbitration.
Decentralized: all nodes participate in the selection of the next bus master (there is a rule to select one arbiter)

1P for one arbiter in centr scheme
1P for all nodes in decentr scheme or rule for master finding

C) Name two arbitration schemes mentioned in the lecture that use the decentralized approach. **2**

Daisy Chain, Polling, Self-Selection, Token-Passing

1P for each correct scheme
1p for each incorrect scheme

A decentralized Daisy-Chain is shown in Figure 4.3.

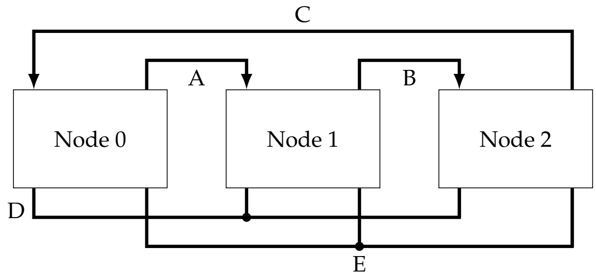

Figure 4.3: Decentralized Daisy-Chain

D) Explain the purpose of the five signal lines A-E of the decentralized Daisy-Chain with a few sentences. **3**

A-C GRANT lines - to pass the GRANT signal to each node
D REQUEST line - indicates a sending request -> GRANT signal has to pass
E BUSY line - indicates a transmission, busy line

1P for A-C
1P for D
1pt for E
no points without explanation
D and E can be switched

E) An exemplary arbitration cycle of the system is shown in Figure 4.4. The transmission is ongoing and at the time t_0 node 0 and node 2 want to send further data. At time t_1 node 1 wants to send data again. The sending time for all data packages of all senders are equal. The time steps are shown at the top of the Figure 4.4, complete this diagram accordingly. Mark down the sending nodes and the signal curves of each signal line. **8**

1P for node2 as first sender
1p for sequence node0 and node2
1P for correct GRANT passing after t_0
2P for correct GRANT passing after t_1
2P for correct request line D

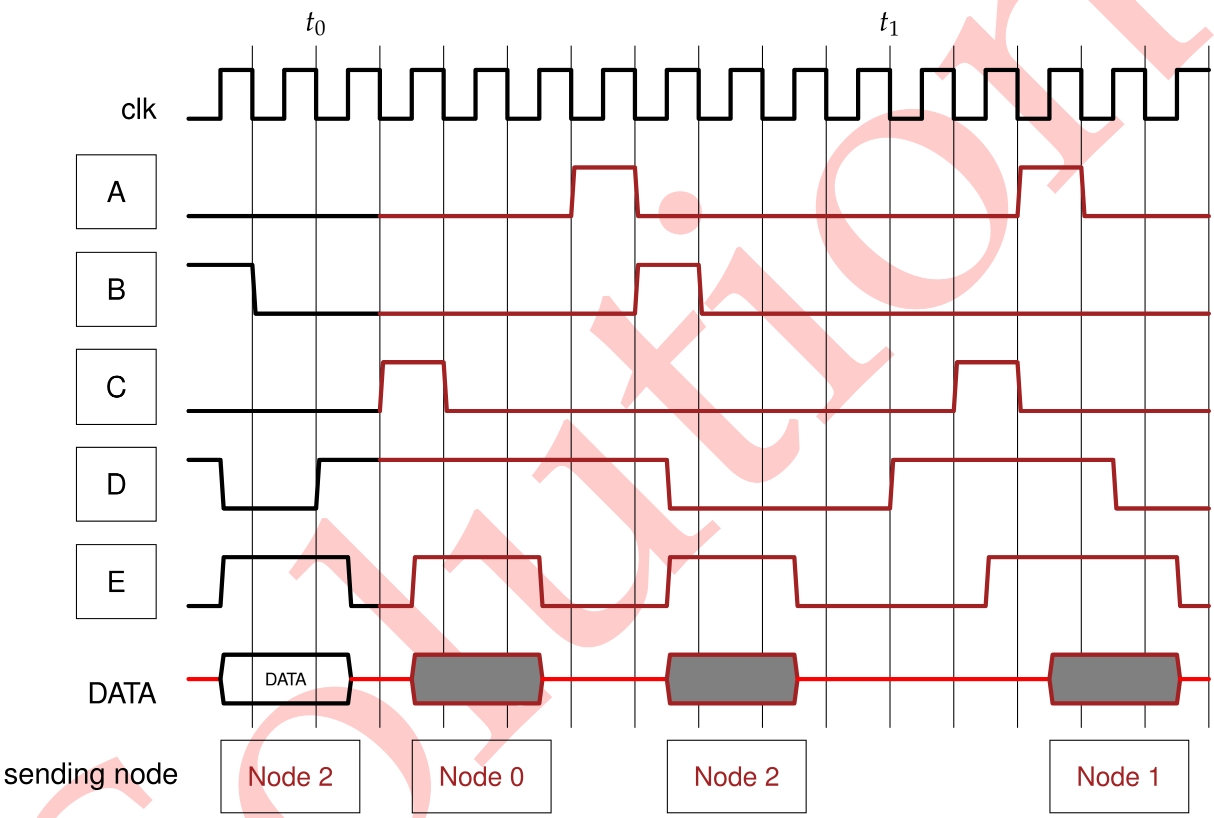

Figure 4.4: Signal flow for Daisy-chain

Task 5: Error Protection

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Task 5.1: General Questions

A) How many data bytes can a normal CAN data transmission transfer at most? In addition, explicitly specify the four bit DLC field that must be selected for this purpose. **1**

8 Bytes, DLC must be 8 –> 1000

+1p everything is correct

B) How many different priorities can be realized on the CAN bus? (Indicate calculations) **1**

2 11 = 2048

+1P for 2 11

C) Name two errors that can be detected with the CRC and describe additionally which conditions the generator polynomial must have. **2**

- All single-bit errors
- Odd number of bit errors if G(x) contains factor (x+1)
- All error bursts <= degree of generator polynomial
- Two single-bit errors if $(x^k + 1)$ is not divisible by the generator polynomial (k <= frame size)

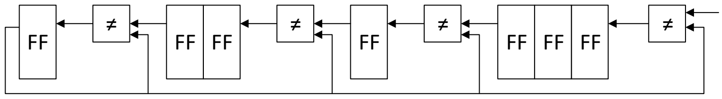
1p for each correct answer

Task 5.2: CRC-Calculation

A) To protect data transmission in a mobile device, the given CRC generator polynomial should be implemented. Draw the short form of the linear feedback registers with XOR operators for the given generator polynomial. **3**

Given CRC generator polynomial: $x^7 + x^6 + x^4 + x^3 + 1$

+3P everything is correct
2P if one error



B) Calculate the data stream that will be transmitted if the following bit stream is to be protected using the CRC generator polynomial given in task 5.2 A): $x^7 + x^6 + x^4 + x^3 + 1$.
Data stream for transmission: **1011 1000 0000**

6

```
 1011  1000  0000  0000  000  :  1101  1001
 1101  1001
 ----------------
 0110  0001  0
  110  1100  1
 ----------------
  000  1101  1000
       1101  1001
 ----------------------
       0000  0001  0000  000
             0001  1011  001
       ----------------------
             0000  1011  001
```

Bit stream as it is transmitted: 1011 1000 0000 1011 001

4p calculation correct
0p if systematic error (hint: it is allowed to use 0000 0000 rows)
2p if single calculation error
0p if more than 1 calculation error
2p for correct complete transmitted bitstream

C) In a transmission system that uses CRC for error detection, a receiver receives the following bitstream: **1011 1010 0011**
Carry out the CRC error detection scheme of the receiver, assuming that the generator polynomial $x^5 + x^3 + x + 1$ has been used to generate the checksum at the sender. What does the receiver conclude from the result?

4

```
 1011  1010  0011  :  101011
 1010  11
 ----------------
 0001  0110  0
    1  0101  1
 ----------------
    0  0011  1011
       0010  1011
       ----------
       0001  0000
```

The receiver assumes that an error occured during transmission.

3p calculation correct
0p if systematic error
1p if single calculation error
0p if more than 1 calculation error
1p for the correct statement

D) Specify the correct bit stream, assuming that only one bit error has occurred in the transmitted bitstream of the task 5.2 C).

2

correct bitstream: 1011 101<u>1</u> 0011

2p if correct

Task 5.3: CAN Bus

A) For a given CAN bus protocol, the following error frame in Fig. 5.1 gets generated in order to cancel a faulty transmission. Assume that there is a sender (Node1) and two receivers (Node 2 and Node 3). Node 2 receives the data corretly, whereas Node 3 encounters a CRC error due to some data error. Complete the signal sequence in Fig. 5.2 with respect to the error frame generation of Node 3 and the consequence effect on Node 1, Node 2 an bus level. In addition, clearly mark where Node 2, Node 3 and Node 1 detects the error.

8

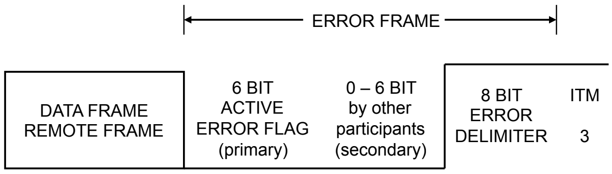
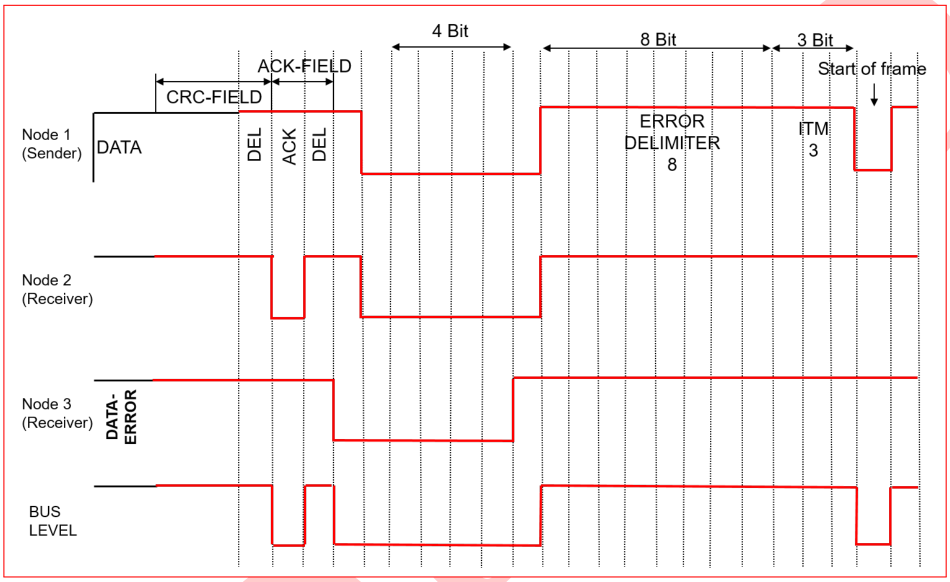


Figure 5.1: Error Frame



2p for primary error flag in sender without a change in receivers
2p for correct marking where N2+3 detects the error
2p for the correct bus level
-1p for simple mistakes

Figure 5.2: Signal sequence diagram of CAN bus

B) Consider the following CAN data stream at Node A (sender). Name four errors that can be detected from the given data stream and justify your answer.

4

Node A (sender)

SOF	Arbitration Field				CTRL Field						Data Field								CRC Field				ACK Field		EOF			
1	1	..	11	12	1	2	3	4	5	6	1	2	3	4	5	6	7	8	1	..	15	16	1	2	1	2	..	7
	ID10	..	ID0	RTR	Ext.	Res.	DL3	...		DL0	DB7			...				DB0	CRC14	..	CRC0	DEL	ACK	DEL	EOF6	EOF5	..	EOF0
1	1	..	0	0	0	0	0	1	1	0	1	1	1	0	0	0	0	1	1	..	1	0	0	0	0	1	..	1

(I) SOF error. The SOF must be a dominant bit.
(II) only 1 Byte is sending, but the CTRL Field implied 6
(III) Form error as a dominant has been found in the EOF
(IV) ACK must be a recessive bit for the sending unit
(V) DEL must be a recessive bit
(VI) CRC DEL must be a recessive bit

1p for each correct error identification and justification

Task 6: Protocols

32

Task 6.1: FireWire Arbitration

The FireWire network shown below is given. The complete self-configuration of the network is already done including initialization, tree identification and self identification.

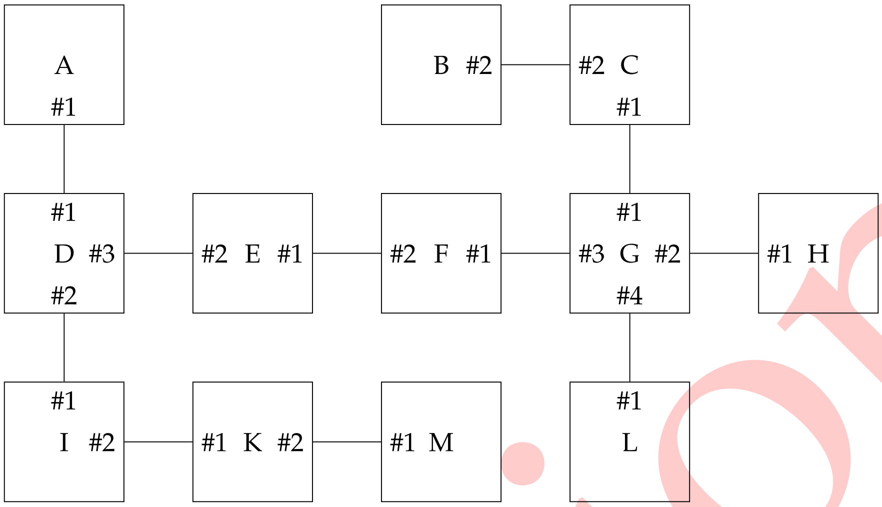


Figure 6.1: FireWire network

Now a normal FireWire bus cycle should be considered. For simplification, several assumptions should be taken into account:

- A list of nodes wanting to send is given.
- All nodes start requesting the bus at the same time.
- Processing of arbitration requests are done in zero time. There are no delays for propagation of the arbitration decision.
- If a node receives multiple bus requests, it will always forward the request that it receives from the port with the lowest number.

A) Mark the root of the FireWire network in Figure 6.1!
The following nodes request access to the bus: **A, B, G, F, K, L**. Determine the order in which the nodes will be granted access to the bus.

6

root is node E; access order = F, G, B, L, A, K

2pt for root
4pt for correct order
check order for wrong root

B) If the root sends continuously, it would always grant access to the bus. How does FireWire preserve fairness?

2

every node is only allowed to acquire the bus once in a cycle. Therefore every node has an arbitration enable bit, that is cleared after a successful access

2pt for correct

Task 6.2: FireWire Structures

A) Different FireWire structures were built during a student laboratory. During test phase you notice that not all FireWire systems are working. Please state if the FireWire systems given below are working correctly. Mark the roots, if the systems are correct. Give a reason, if the FireWire system is not working correctly.

6

1Pt each row
- when marked as wrong, reason is necessary.
- when marked as correct root is necessary.

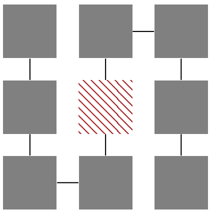
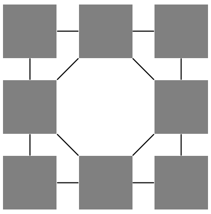
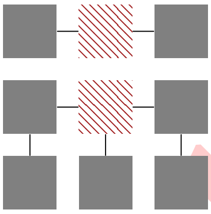
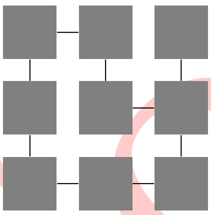
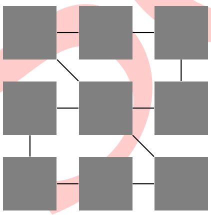
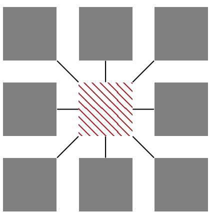
	Correct	Wrong	Reason
	x		
		x	Rings are note allowed in FireWire
	x	x	wrong: two individual systems, correct two roots
		x	Rings are not allowed in FireWire
		x	Rings are not allowed in FireWire
	x		

Table 6.1: FireWire structures

Task 6.3: ITIV-Protocol

The ITIV want to transmit data bidirectional from campus south to campus north with multiple clients. Therefore a customized protocol is build by the ITIV for transmission of information with id, data and a check sum. The bus should use Manchester coding to transmit the raw data. Use the Manchester code where data bit '1' is represented by signal transition from low level to high level. The voltage level on the bus is induced by an open-collector that is connected to the output stage of the microcontroller (see Figure 6.2). The transmission is initialized by a start-bit (low) and finished with a stop-bit (high).

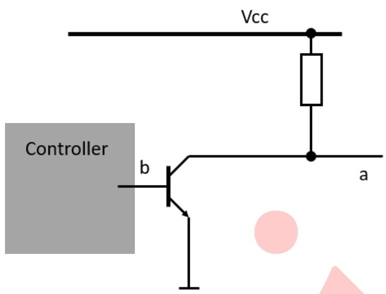


Figure 6.2: Open collector schematics

A) How can data integrity be checked on physical layer without changing the protocol? **2**

Check for start-bit and stop-bit or
Macnchester needs to change at least once every clock cycle

1pt each

B) The transmitted data-field will have variable length. Name two ways of determining the data-field length within a transmission. **4**

Length specification in length field of frame
Use of delimiter for data field

2pt each

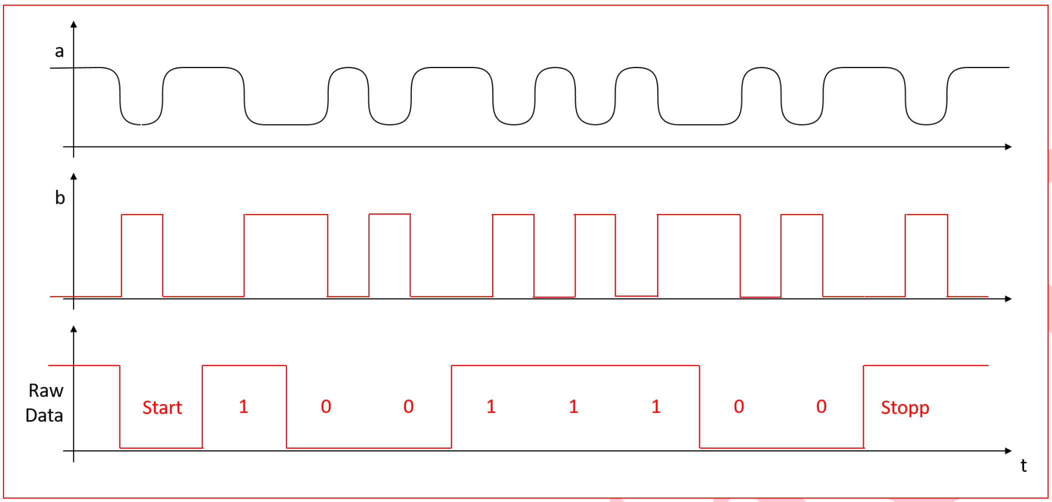
C) Can the clock be recovered within this system? Justify your answer. If clock recovery is not working give a possible solution. **2**

Yes. Manchester-II is used, therefor a change of level for every bit.

2Pt for yes with reson,
0Pt if wrong or no reason

D) Draw the Manchester coded and raw data (8-bit of information) transmitted over the channel in the following graphic. The signal names correspont to the names from Figure 6.2. Please write down the transmitted data.

6



2pt: for correct b
-1pt if inverted (wrong start bit)
4pt: for correct raw data
-1pt each error

E) Because of license reasons the Manchester coding cannot be used. Why can't differential Manchester be used for the system? Please name the Problem and a possible solution. Hint: What happens to the bus line after transmission.

4

Differential Manchester is alternating, therefor last level depends on number of '0's and '1's. This means the stop bit ends not always at recessive level.
For odd parity a second stop-bit or parity-bit has to be added.

2pt: for Problem
2pt: for possible Solution

Task 7: Routing

35

Task 7.1: Router and Switching

A) Which approach, Network-on-Chip or a Bus system, is better suited for a large number of nodes that can act as a master, with regards to scalability? Justify your answer.

2

Network-on-Chip provides better scalability than busses due to the possibilities to have parallel communication. Network-on-Chip is more suitable due to its capabilities for arbitration.

2 Point for correct choice and justification, as long as justification is reasonable

B) Describe the main and at least one reasonable additional function that is provided by routers in networks.

4

Main : Choose paths for data transmission in the network
Additional : Error Correction, Storage

2 Point for each ; Additional is very open, as long as it makes "sense"

C) One of the major components of a router is the switch matrix. Describe its purpose and name the unit inside the router that is configuring the matrix. Additionally describe how that unit can be implemented when using static routing algorithms.

6

The switch matrix connects the inputs of the routers with the respective outputs.
The configuration itself is determined by the routing control.
It can be implemented as a look up table.
Alternative : Crossbar valid as well, if student thought about switch matrix

each 2 Point

D) Are all flits of a message routed through the same path in a network when using circuit switching? Additionally describe the situation when using packet switching. Justify your answer relative to the characteristics of the switching scheme.

2

The path taken in circuit is always the same for every message
The path taken in packet switching can be different for each packet of a message

2 point

E) Describe the two routing algorithms Hot Potato and XY Routing. Additionally provide an advantage and disadvantage for each algorithm.

8

X-Y Routing : Route in X at first then in Y
Deadlock free
only works in meshes
Hot Potato Routing : Like XY but find an unoccupied port in case ot contention in one direction
Can deal with busy ports
Livelocks are possible

2 point for each description
2 point each for advantage and disadvantage

Task 7.2: Routing

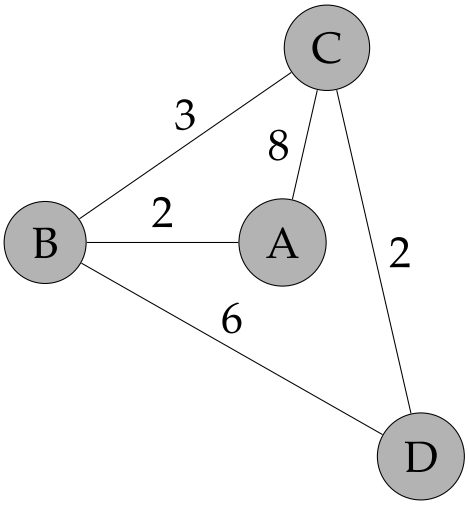


Figure 7.1: Given network topology

A) Figure 7.1 represents a network for which an optimal routing has to be found. The weights of each connection represent an abstract metric that is to be minimized through routing. Combining the weights across connections, is done by addition. Node A represents the starting point from which optimal routes are to be determined. Calculate the paths with the smallest accumulated weights in the given network by using Dijkstra's algorithm. For that write down which node is visited in each step. Fill out the given table that contains the optimal paths after each step. **7**

	step 1		step 2		step 3		step 4		step 5	
node	**A**		A		B		C		D	
vertex	dist.	pred.	dist.	pred.	dist.	pred.	dist.	pred.	dist.	pred.
A	∞	A	0	A	0	A	0	A	0	A
B	∞	-	2	A	2	A	2	A	2	A
C	∞	-	8	A	5	B	5	B	5	B
D	∞	-	∞	-	8	B	7	C	7	C

Table 7.1: Dijkstra's algorithm

step 2,3,4 2p
step 5 and correct nodes in the node row 1 point

B) Name and describe at least 3 optimization goals of routing algorithms! Provide and explain a suitable metric for each goal!

6

minimum latency : worst case transfer time, ms , ...
short routing path : hops
balanced network load : mbit/s or similar
throughput : packets/s, mbit/s

2 point for each

Task 8: Network Topologies

30

Task 8.1: General Questions

A) Which network topology is more suitable when there is a high possibility of link failure, ring, mesh or torus? Justify your decision.

2

Torus is more suitable as it has higher edge connectivity.

Alternative solutions are possible. The reasoning needs to be sound. No points without reasoning!

B) What is the edge connectivity and diameter of a 16 node network which uses 4x4 2-D Torus topology

2

Edge connectivity = 4. Diameter = 4

1 point for each answer

C) There are four topologies given: Mesh, Star, Ring. Assume for each topology a network with 16 nodes. Order the topologies in the given table from best (top) to worst (bottom) regarding the given metric. Metrics: edge connectivity, diameter, resource cost(i.e. in this case the total amount of links in the network). Hint: Think about what is desirable for each metric in a network when deciding the order.

6

Edge Connectivity	Diameter	Resource Cost
Mesh	Star	Star
Ring	Mesh	Ring
Star	Ring	Mesh

for each collumn: +2 in case all correct

Table 8.1: Metrics and topologies

Task 8.2: 3D Topology

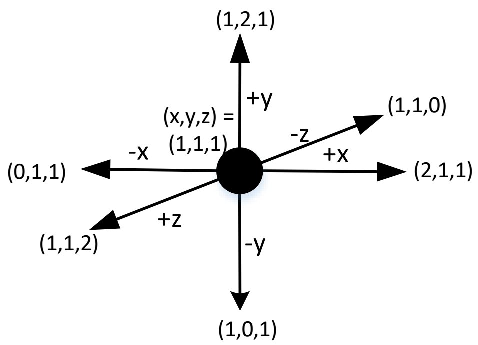


Figure 8.1: Node at (x,y,z) = (1,1,1)

A) Consider a 5x4x7 mesh topology for this task. In the network, a fault occurs in router at node (x,y,z) = (4,2,5) and at (x,y,z) = (4,3,4) and these two routers stop working. Due to this, a packet needs to avoid both these routers to reach its destination. Find a path from the source point (x,y,z) = (1,2,5) to the destination point (x,y,z) = (4,3,5) using the adaptive XYZ routing algorithm described below: **7**

Rule1 Try to first route in the X direction towards the destination. Then the Y direction, and then the Z direction.

Rule2 If a link chosen leads you to a faulty router, disregard it and choose among the remaining directions from the local position towards the destination, prioritising first X, then Y, then Z.

Rule3 If the direction chosen leads you to an already visited node, disregard it and choose among the remaining directions from the local position towards the destination, prioritising first X, then Y, then Z.

Rule4 In case none of the above rules is possible, choose among the remaining directions in the decreasing order of priority -x,-y,-z,+x,+y,+z. Use Figure 8.1 as a guide .Here it is possible for the packet to go away from the destination.

In your answer please name all traversed nodes (i.e. their coordinates) in the correct sequence. Mention which of the above rules you used at each step to go to the next node.

(1,2,5)(R1) -> (2,2,5) (R1) -> (3,2,5) (R2) -> (3,3,5) (R1) -> (4,3,5)

+2 pt per correct intermediate node with rule (start and end point are optional and don't give extra points)
-1 if no rule is mentioned
+1 pt for a full solution with no errors

B) Now find the path from the source point (4,3,5) to the destination point (4,3,3). The two faulty routers still exist at nodes (x,y,z) = (4,2,5) and at (x,y,z) = (4,3,4). In your answer please name all traversed nodes (i.e. their coordinates) in the correct sequence. Mention which rule you used at each step to go to the next node.. **7**

(4,3,5) (R4) -> (3,3,5) (R3) -> (3,3,4) (R2) -> (3,3,3) (R1) -> (4,3,3)

+2 pt per correct intermediate node with rule (start and end point are optional and don't give extra points)
-1 if no rule is mentioned
+1 pt for a full solution with no errors

C) If Rule 3 in the above algorithm was not present and a packet travels from the source point (4,3,5) to the destination point (4,3,3), does it reach the destination ? Explain your answer. **2**

The packet does not reach the destination. Because a Livelock occurs.

+2 points for answer and explanation. Alternative explanations are possible. The reasoning needs to be sound. No points without reasoning!

D) What is the diameter and edge connectivity in a 5x4x7 3D Mesh topology? **2**

Diameter = 4+3+6=13
Edge connectivity = 3

+1 pt for each correct answer

E) Explain livelock and deadlock in a network. **2**

In a livelock, the system still continues but a transmission never reaches its destination (due to e.g. circles) while in a deadlock, the system is stuck due to mutual blocking of links.

+1 pt for each correct explanation

Additional sheet for task ☐ :