Examination WS2016/17
Communication Systems and Protocols

Institute for Information Processing Technologies - ITIV
Prof. Dr.-Ing. Dr. h. c. Jürgen Becker

Communication Systems and Protocols

Date:	13.02.2017
Name:	Test Name
Matr. ID:	123456
ID:	1
Lecture Hall:	ITIV
Seat:	**1**

Prerequisites for the examination

Aids:

- writing utensils
- a non-programmable calculator
- a dictionary
- a single sheet of A4 paper with **self- and hand-written** notes. Writing may be on both sides
- 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:

The exam duration is 120 minutes.

Examination documents:

The examination comprises 32 pages (including title page, 8 blocks of tasks).

Answers may be given in English or German. A mix of language within a single (sub)-task is not allowed.

Please check your matriculation number and ID on every page before processing the tasks.

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.

End of Exam:

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 (including this title page) into the envelope. Only sheets in the envelope will be corrected. We will collect the examination.

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Task 2:	Media Access	7	10	
Task 3:	Arbitration	11	12	
Task 4:	Error Protection	15	15	
Task 5:	Bus Systems	19	11	
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Task 7:	Routing	26	10	
Task 8:	Network Topologies	29	14	
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Task 1: Physical Basics

Task 1.1: Signal Transmission

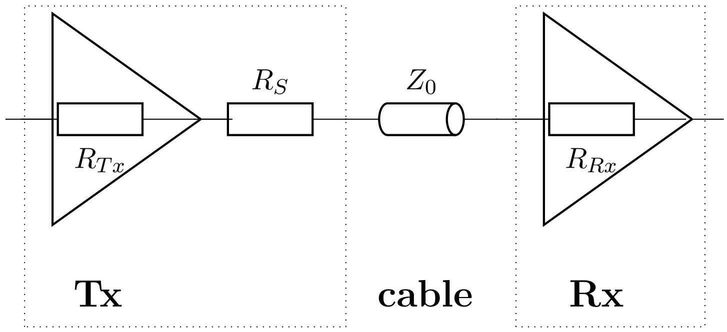


Figure 1.1: Test setup

In Figure 1.1, a transmission line is depicted. Here, a transmitter with the output impedance R_{Tx} is connected through a long cable to a receiver with input impedance R_{Rx}.
The transmitter is connected to the line with an impedance of Z_0.
The impedances are $R_{Tx} = 15\ \Omega$, $R_S = 60\ \Omega$, $Z_0 = 25\ \Omega$ and $R_{Rx} > 1\ M\Omega$.

A) What is the equation for calculating the reflection factor at an end of a line? Give the equation for the reflection factor in general.
Calculate the reflection factors at both the transmitter and the receiver side.

B) A step signal of $V_{Tx} = V_{step} = 4\text{V}$ amplitude is now being sent by the transmitter.
After the step has passed the transmitter circuit and the series termination resistor, it reaches the beginning of the long cable.
Explain or give the equation: What will be the voltage $V_{cableIn}$ for the point in time when the transmitted step reaches the beginning of the cable for the first time? Think about the equivalent circuit diagram of the electrical setup.
Calculate the value $V_{cableIn}$.

C) Since the transmission line is not properly terminated, there will be reflections after the injection of a step with $V_{Tx} = V_{step}$.
Explain by giving the formulas and calculate the values: what will be the voltage at the beginning of the cable on the side of the transmitter when the wave reaches this point for the first, the second and the third time?
For calculating the voltages $V_{Mid}(t_1)...V_{Mid}(t_3)$ use following values $V_{cableIn} = 2V$, $r_{Tx} = 0.25$ and $r_{Rx} = 0.5$.

D) What will the signal look like at half of the cable's length L/2 (the middle) for the transmission line from Figure 1.1 where the line is not perfectly terminated? Here, the cable does not attenuate the signal.
In this task it takes the time **T** for the step from the previous task to propagate from one end of the cable to the other. The propagation times of the signal at the transmitter and receiver side of the cable can be neglected.
Draw the signal curve into the diagram below up to the time t=3T.

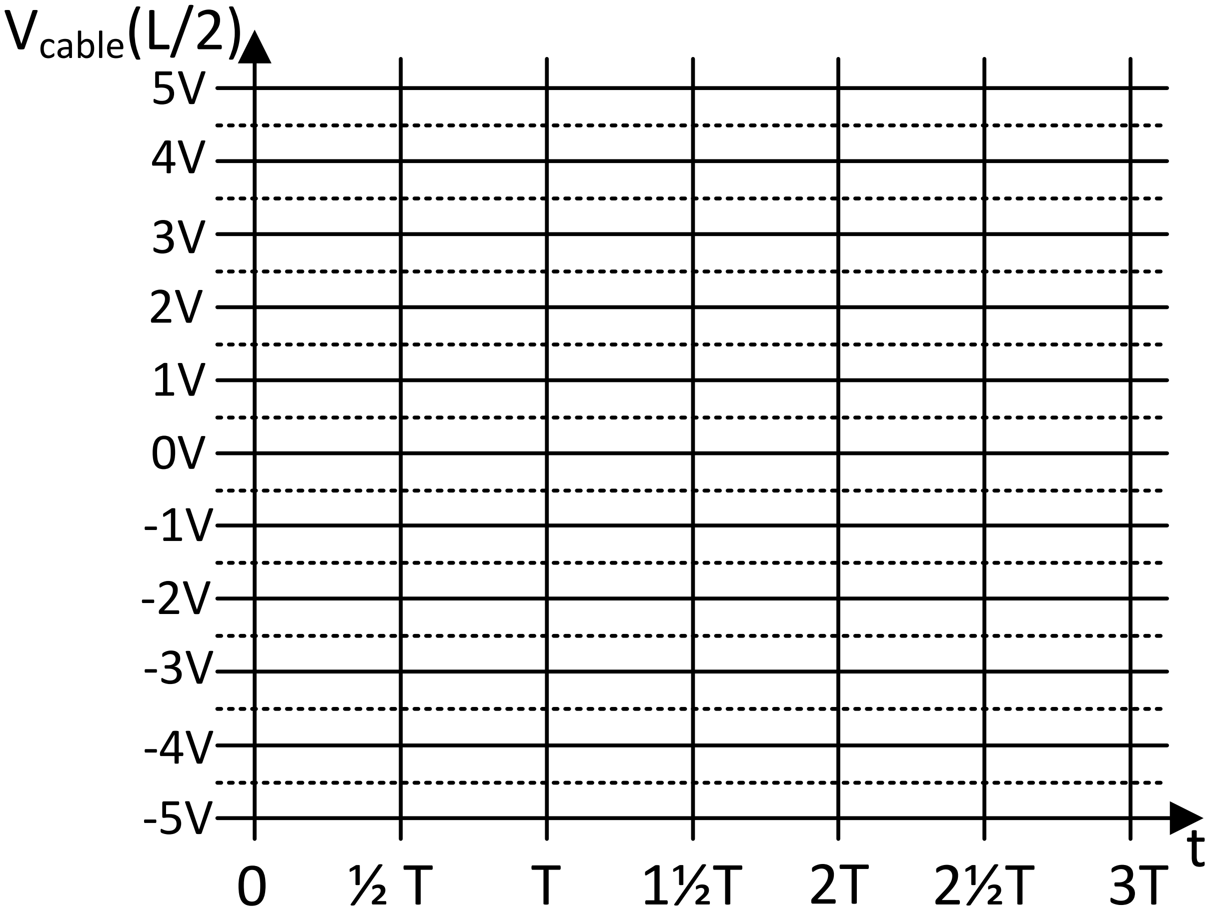


Figure 1.2: Diagram for drawing the voltage over time at half of the cable length

E) In this task, the line has the same setup as depicted in figure 1.1 but the resistor R_S has been properly chosen for a perfectly terminated line. Also, the voltages on the line have now completely settled (steady state).
For the transmission line, a coaxial cable of 100 meter length is used which has an attenuation of A = -5 dB. The transmitter inputs a signal of $V_{in} = 5V$ into the cable.
An amplifier (G_{amp}) after the transmission line at the receiver side, brings the signal to a voltage level of $V_{out} = 4V$.
What is the gain G_{amp} of the amplifier in dB?

Task 1.2: Sampling Theorem

A) In the Figure below the spectrum of an RF channel and the associated receiver chain are depicted. The receiver is interested in obtaining the Rx Data of user U2. Here, only one analog mixer, one ADC, one analog Low-Pass etc. are being used.

1) First, the spectrum of interest U1 to U5 is mixed in a way (f_{LO}), that the leftmost frequency of U1 will be at the DC frequency by using an analog RF mixer.
2) After that, the frequency content of the other spectra outside U1 to U5 is suppressed by a Low-pass filter (B_{LP1}).
3) An ADC afterwards converts the spectrum of U1 to U5 into the digital domain (f_{Sample}).
4) In order to receive data from an arbitrary user, the signal is digitally mixed using a Digital Downconversion (DDC) (f_{DDC_U2}). In the case of extracting user U2, it mixes the signal so that the leftmost frequency of the desired user U2 is at the DC frequency.
5) At the end of this block, a digital Low-Pass filter removes the frequency content of the other groups (B_{LP2}).

What are the frequencies f_{LO}, f_{Sample} and f_{DDC_U2} and the bandwidths B_{LP1} and B_{LP2} for correctly extracting the Rx Data of user **U2**?

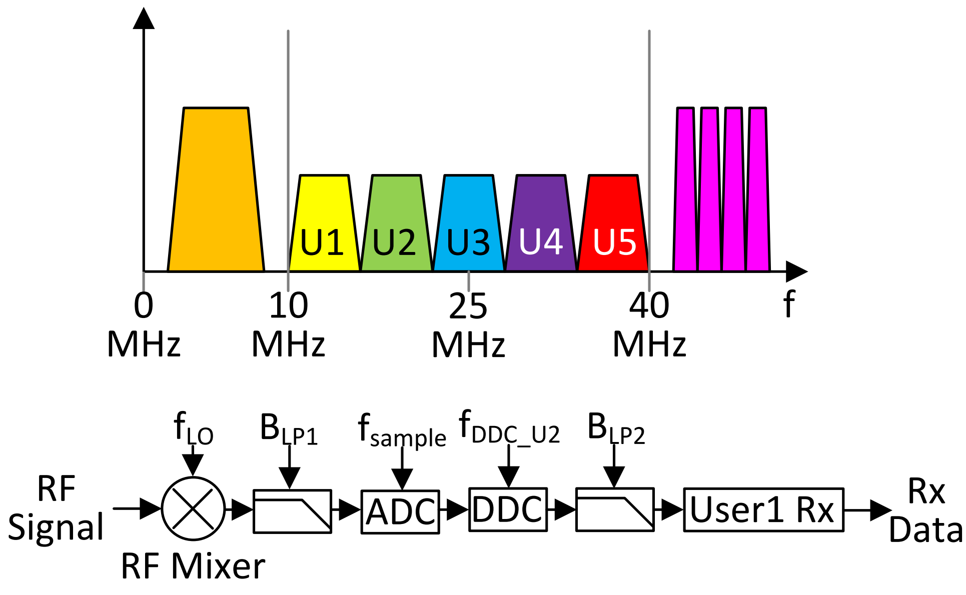


Figure 1.3: Base band spectrum and receiver chain of an RF signal

Task 2: Media Access

Task 2.1: Multiplexing

A) What is the main difference between half-duplex and full-duplex transmission? Explain in 1-2 sentences.

B) Name two different multiplexing schemes that can be used if only one single physical line is available for a communication of multiple users.

C) Which property of a spreading code is needed in order to be able to do multiple transmissions at the same time? Explain the effect of this property for the reception process.

Task 2.2: Modulation

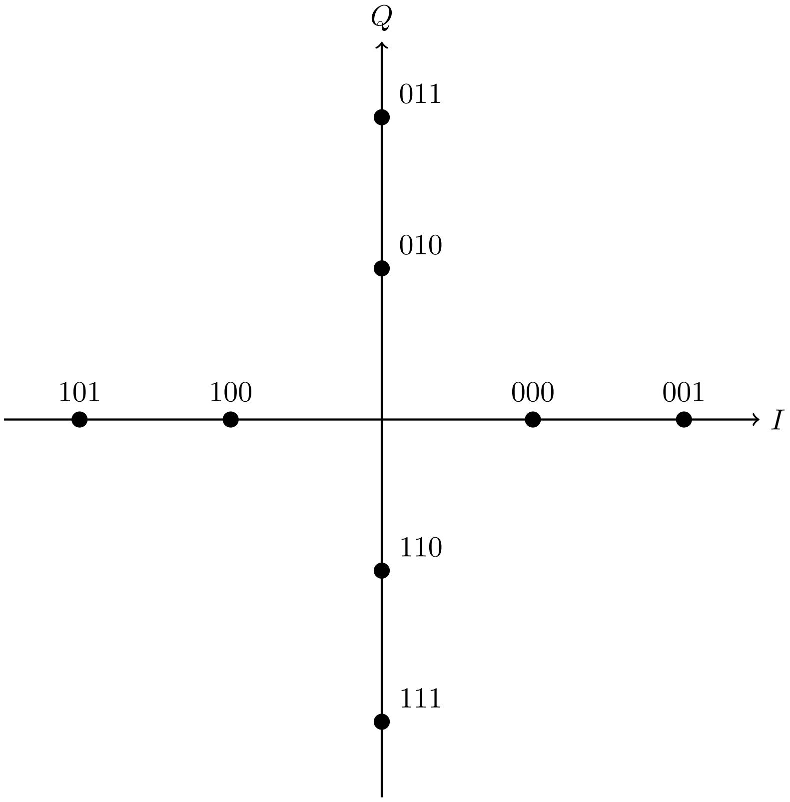


Figure 2.1: Constellation diagram

A) Figure 2.1 shows a constellation diagram for a digital modulation technique. Which type of modulation is used here? Which properties of the signal can be varied with this modulation type?

B) The symbol constellation from Figure 2.1 is now used by a transmitter to modulate data bits on a carrier. The phase φ of the signal is defined relative to a sine reference signal as shown in Figure 2.2. Determine the coding for each point in the constellation diagram and write it down in Table

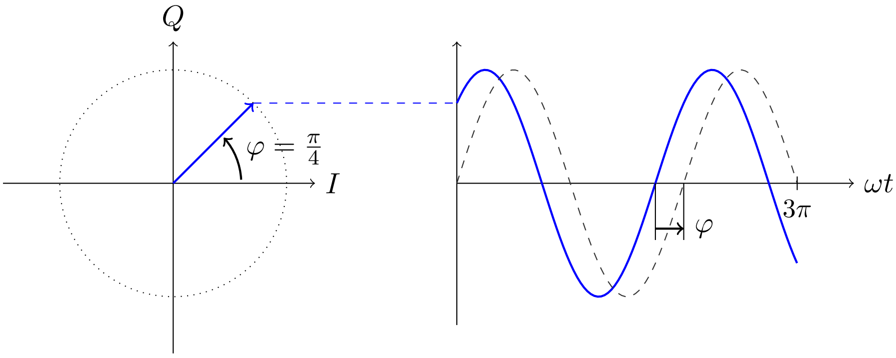


Figure 2.2: Phase difference of a sine signal compared to a reference signal (dashed line $\widehat{=}$ reference signal).

Bitvalue	Amplitude	Phaseshift
000		
001		
010		
011		
100		
101		
110		
111		

C) Now the symbols from Figure 2.1 should be used to transmit data. The signal is given in Figure 2.3. Assume that each symbol has the duration of two periods of the signal. Determine the bit sequence that has been transmitted.

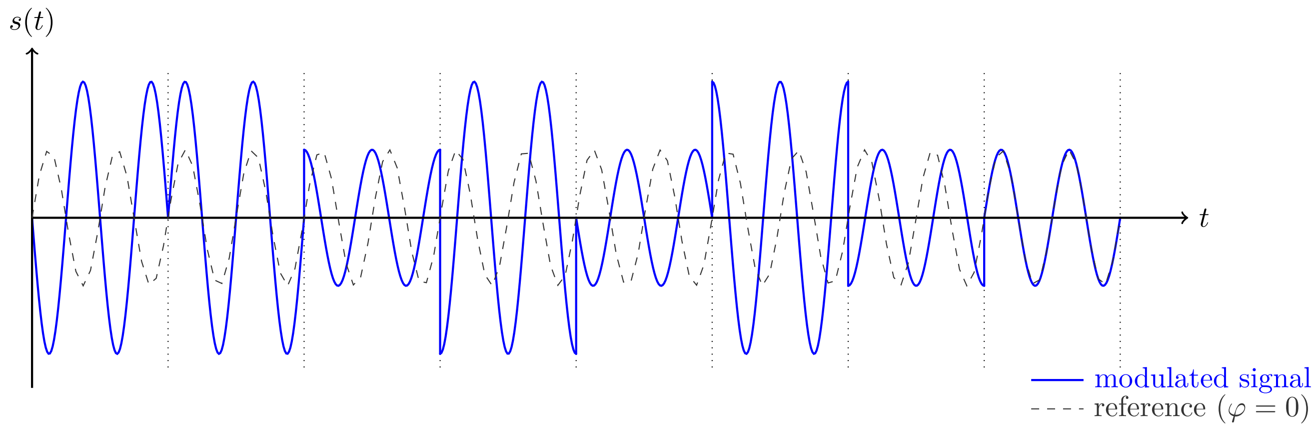


Figure 2.3: A modulated signal which uses the constellation from Figure 2.1 on page 8.

Task 3: Arbitration

Task 3.1: CSMA/CA

A bus system of four nodes are using CSMA/CA as arbitration scheme and are connected via open collector drivers (see figure 3.1). Each node has a five Bit identifier and the bus has to cover a maximum distance of 800m.

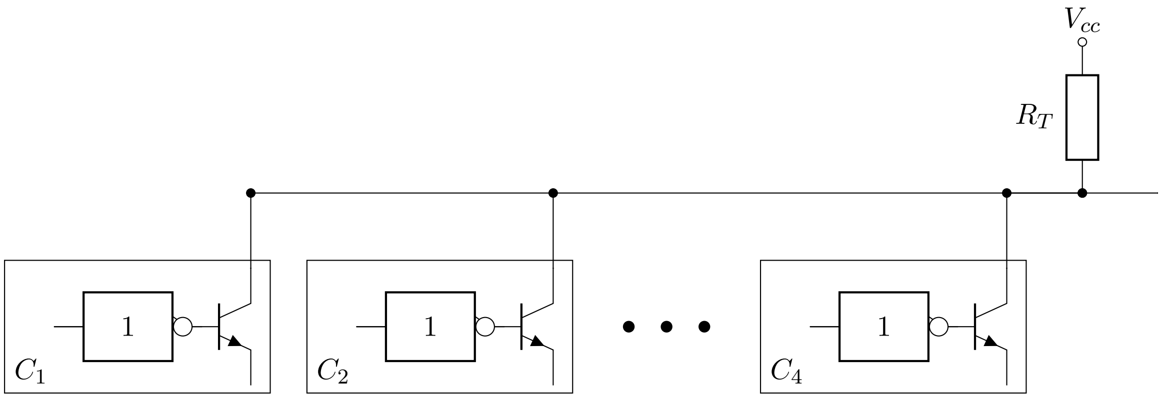


Figure 3.1: bus system

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

B) Name two advantages and two disadvantages of CSMA/CA.

C) Is it possible to extend this bus system with any number of nodes? Give a short explanation.

D) Which requirement has to be fulfilled in order to guaranty a faultless function of the bus system? Calculate the maximum bitrate that is achievable if the signal speed on the line equals to $0.66 \cdot c$. (Speed of light $c = 3 \cdot 10^8 \frac{m}{s}$)

E) 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 3.1. Using Figure 3.2, draw the impulse diagram

Node	Identifier
A	00101
B	01001
C	00100
D	00110

Table 3.1: 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?

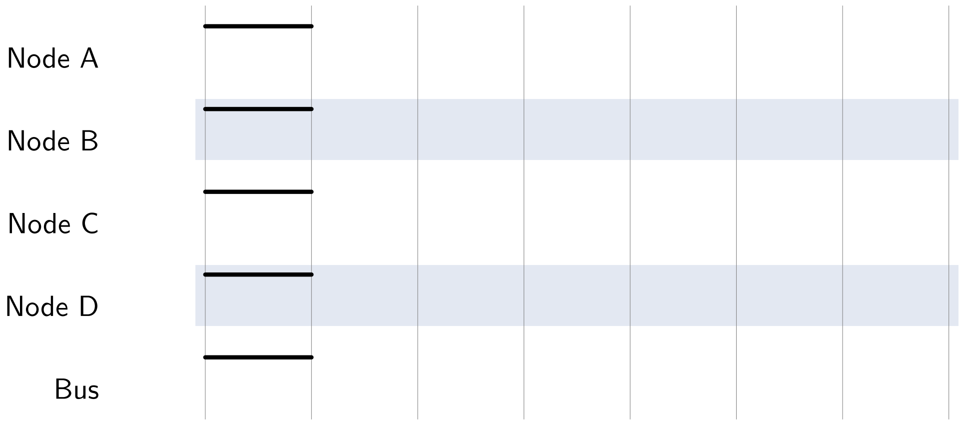


Figure 3.2: Bus Access

Task 3.2: Carrier Sense Multiple Access/Collision Detection

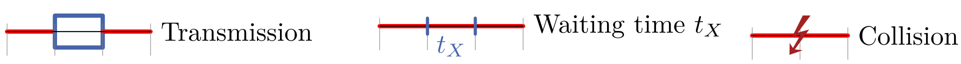
In this task we have a look at a bus system with arbitration that is derived from CSMA/CD. The following rules apply:

- All nodes want to send as many messages as possible. The length of each message is given in Table 3.2.
- A node is not allowed to send twice in a row even if the bus is free. After each successful transmission it has to wait until another node has finished its transmission. The values of the assigned waiting times for each node are given in Table 3.2.
- If a node willing to send detects that the bus is occupied it withdraws and waits for the time specified in Table 3.2 (waiting time) until it will retry to transmit. Any ongoing transmission is not influenced.
- If two or more nodes want to start a transmission on the free bus at the same time there is a collision. All involved nodes withdraw from the bus and wait for the time given in Table 3.2.

Node	Packet length	Waiting time
A	2	2
B	3	3
C	4	4

Table 3.2: Specification of nodes

A) Fill in the signal sequence of the bus nodes, resulting from the specification as given above (use Figure 3.3). Mark waiting times and collisions that occur.



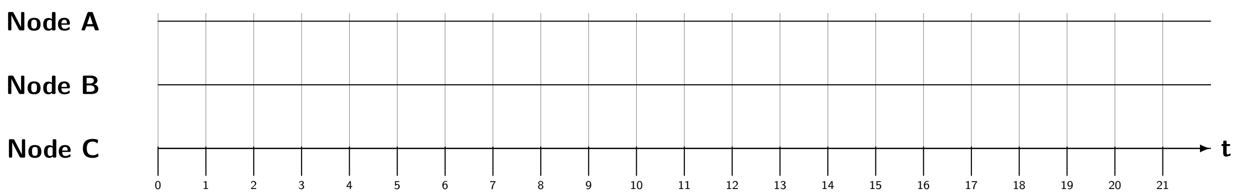


Figure 3.3: Signal sequence

B) Is the length of the media related to the duration of sending? Give a short explanation

Task 4: Error Protection

Task 4.1: Multiple Choice

A) Specify whether the statements in table 4.1 are true or wrong.
Hint: Wrong answers will be penalised. The task will be evaluated with a minimum of 0 points.

Statements	True	Wrong
Security is the protection against malicious errors caused by attackers		
In a good hash function for communication purposes, a small change in input value results in a small change in hash value		
“Natural” redundancy has no dependable information value		
All even number of errors with even number of bit errors per row/column are detectable by Block Check methode for error detection		
All error bursts > degree of CRC generator polynomial are detectable		
A CRC generator polynomial must have ‚1‘ in most significant bit (MSB)		

Table 4.1: Multiple Choice

Task 4.2: CRC-Calculation

A) To protect data transmission in a mobile device, a given CRC generator polynomial should be implemented. Draw the linear feedback registers with XOR operators for the given generator polynomial.
Given CRC generator polynomial: $x^7 + x^6 + x^5 + x^2 + 1$

B) Calculate the data stream that will be transmitted if the following bit string is to be protected: **10101110**

C) With a transmission system that uses CRC for error detection, a sender transmits the following bitstream: **1001 1101 0001**
Carry out the CRC error detection scheme of the receiver, assuming that the generator polynomial $x^4 + x^1 + 1$ has been used to generate the checksum at the sender. What does the receiver conclude from the result?

D) In a system, data has to be transmitted from a mobile device to a server. The raw data consists of three bytes that are sent every 40 ms. Assume that in every transmission a maximum of three bits (not obligatory as a burst error) could flip. Could every possible error be detected by using CRC with a well chosen CRC polynomial? If so, give the shortest possible CRC polynomial from the table 4.2 which would guarantee detection of these errors. Explain your answer.
Note: Hamming Distance (HD) is the lowest weight of any undetectable error. For example, HD = 3 means that all 1 and 2 bit errors can be detected.

#	CRC Polynomial	Guaranteed HD	Up to max. data length (in bits)
1	CRC-3 ($x^2 + 1$)	HD=2	2048
2	CRC-4 ($x^3 + 1$)	HD=3	11
3	CRC-5 ($x^4 + x^1$)	HD=3	26
4	CRC-5 ($x^4 + x^2 + 1$)	HD=4	10
5	CRC-8 ($x^7 + x^4 + x^3 + x^1 + 1$)	HD=4	119
6	CRC-8 ($x^7 + x^4 + x^3 + x^2$)	HD=5	9

Table 4.2: CRC polynomial with guaranteed HD

Task 4.3: CAN Bus

A) Consider the following data frame at Node A (sender).
Find and mark three errors in the given data stream and give a short explanation of each error.

Node A (Sender)

<table>
<tr><td>SOF</td><td colspan="6">ARB Field</td><td colspan="6">CTRL Field</td><td colspan="8">Data Field</td><td colspan="6">CRC Field</td><td colspan="2">ACK Field</td><td colspan="7">EOF</td><td colspan="3">ITM</td></tr>
<tr><td>SOF</td><td colspan="5">ID 10 .. 0</td><td>RTR</td><td colspan="2">res.</td><td colspan="4">DLC 3 .. 0</td><td colspan="8">DB 7 .. 0</td><td colspan="5">CRC 14 .. 0</td><td>DEL</td><td>ACK</td><td>DEL</td><td colspan="7">EOF 6 .. 0</td><td colspan="3">IFS 2 .. 0</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>..</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>..</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
</table>

B) In CAN bus communication it is very important that every participant is able to count the errors. Please give a short explanation why any erroneous participant must be recognized and deactivated.

C) Please name the three different error states in CAN communication and explain the limitations of the participant in each error state.

Task 5: Bus Systems

Task 5.1: I²C-Bus Synchronization

Three I²C Bus Masters want to send data to one slave. Each node needs one time step to read in data from external signal lines (SCL, SDA). The reaction time within each node is neglectably small (0 time steps). The individual masters want to establish a clock signal according to the following table 5.1:

Master	Low period	High period
A	4	8
B	12	4
C	8	12

Table 5.1: clock signals

Assume that Master B is initiating the communication cycle.

A) Complete the waveforms of the signals that result from the interaction between the nodes on the SCL signal.

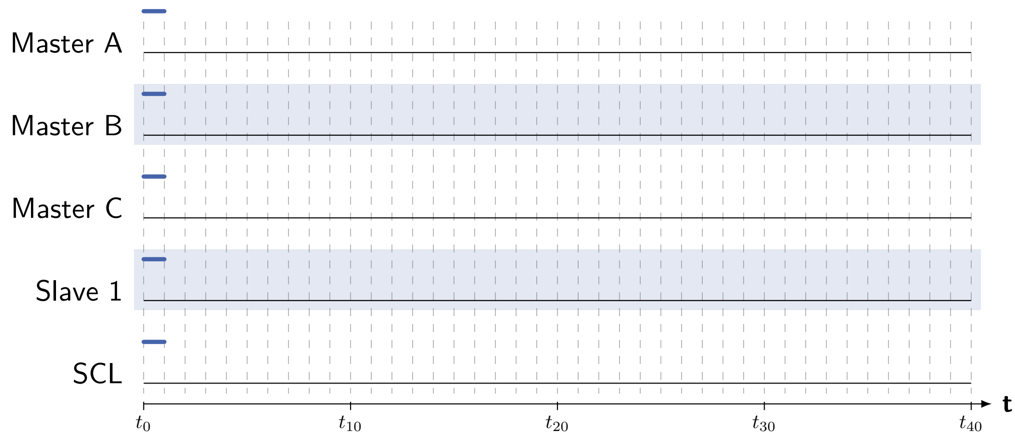


Figure 5.1: Signal sequence

Task 5.2: Flexray: General Questions

A) What were the main goals during the development of Flexray in automotive network topologies? Name at least two features to fulfill this goal.

B) With Flexray it's possible to run the system in dual-channel mode. Explain the advantage and disadvantage of the dual-channel mode over single channel mode.

C) Which arbitration schemes are used in the different available Flexray segments in order to cope with multiple senders?

Static Segment	Dynamic Segment

Task 5.3: Flexray: Bus Access

In this task we want to investigate the data transmission and scheduling with Flexray. The used topology is shown in Figure 5.2. Additionally, the slot durations for the scheduling are given in Table 5.2.

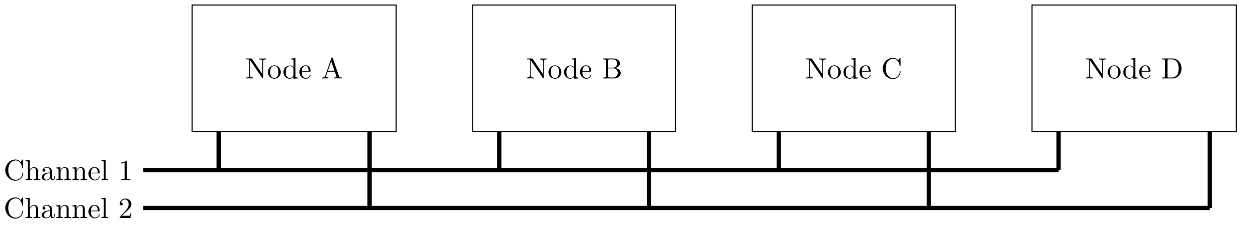


Figure 5.2: Flexray Topology

Static slots	Minislots
$5\mu s$	$100ns$

Table 5.2: Slot durations

A) In Table 5.3 the nodes shown in Figure 5.2 and the assignment of their available frames to the static slots are given. Complete the signal diagram in the Figure 5.3 and perform the static scheduling of the frames according to the Table 5.3.

Node	Static Slots	Frames	Redundant Frames
A	1, 3, 5	A1, A2, A3	A2
B	2, 4	B1, B2	B2
C	1, 4	C1, C2	—
D	5	D1	—

Table 5.3: Static Node Assignments

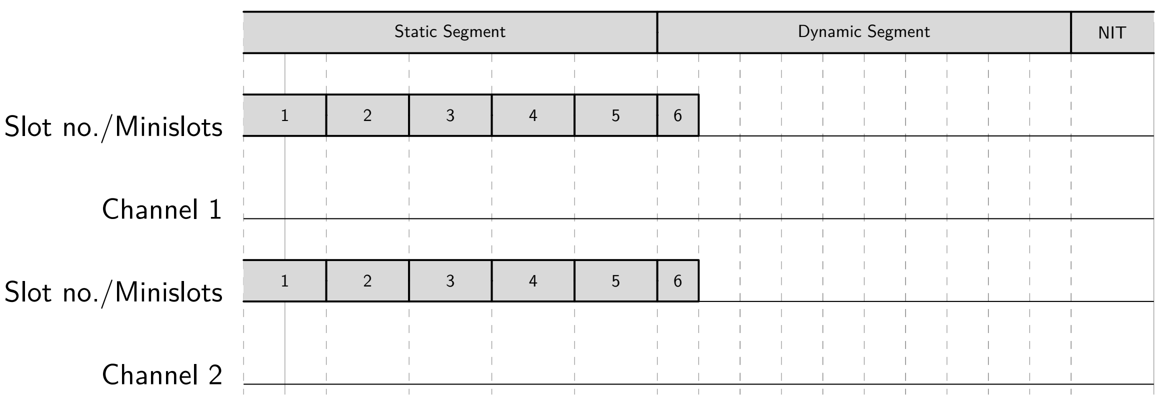


Figure 5.3: Signal sequence

B) Calculate the duration of a complete communication cycle! Assume a Network Idle Time (NIT) of $1\mu s$ and that all minislots depicted in Figure 5.3 are idle!

C) What is the purpose of the minislots with regard to bus access, which are used in the dynamic segment of the communication cycle? Is it possible that multiple nodes can own the same minislot? Justify your answer!

D) In Table 5.4 the parameters for the dynamic segment are given. Complete the signal diagram in the Figure 5.3 and perform the dynamic scheduling of the frames for Channel 1 and Channel 2 according to the Table 5.4. Number the minislots with slot IDs dependent on the length of your scheduled frames. Note that each channel offer its own minislots for transmission.

Node	Frames	Slot-ID	Frame Duration
A	A7	7	$100ns$
B	B9	9	$300ns$
C	C8	8	$500ns$
D	D6	6	$400ns$
	D11	11	$200ns$

Table 5.4: Dynamic Segment Parameters

Task 6: FireWire

Task 6.1: FireWire Structures

A) Different FireWire structures were built during a student laboratory. During test phase you notice that not all FireWire systems are working correctly. Please modify the FireWire systems given below by adding or removing as few connections as possible to get one correct FireWire system each. Draw the corrected system in column 2 (*Corrected System*) and give a reason, why the system has to be modified in column 3 (*Reason*).

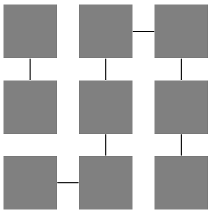
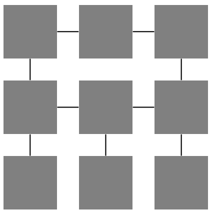
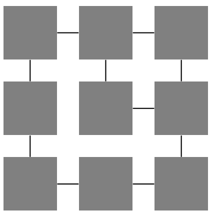
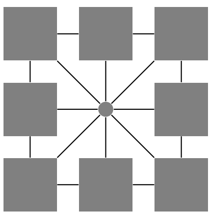
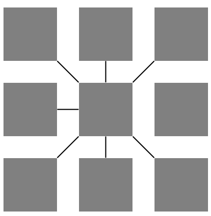
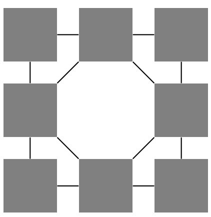
	Corrected System	Reason
		
		
		
		
		
		

Table 6.1: FireWire structures

Task 6.2: 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.

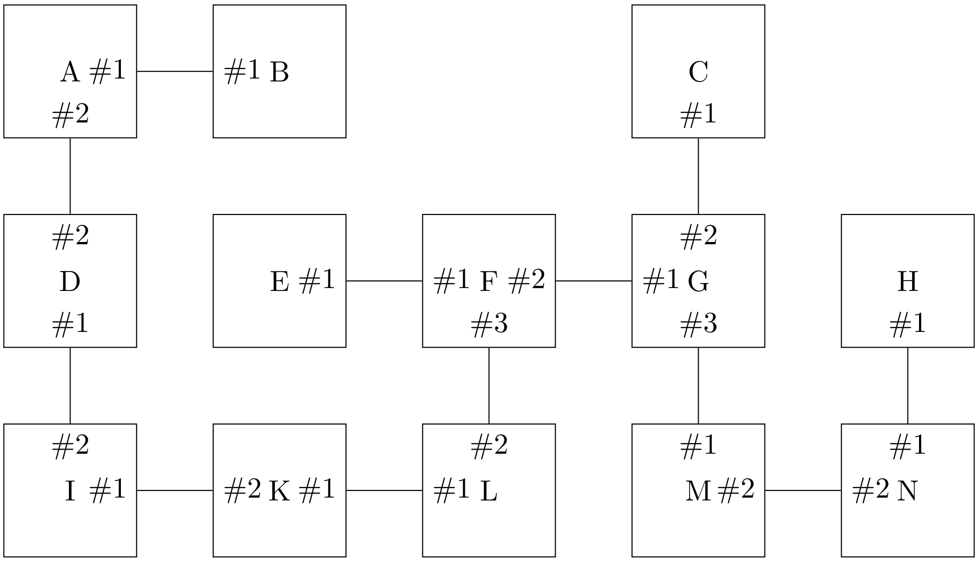


Figure 6.1: FireWire network

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 request is done in zero time. There are no additional delays for propagation of the arbitration decision.
- If a node receives multiple bus request, it will always forward the request that it receives from the port with the lowest number.

A) Mark the root of the FireWire Network!
The following nodes request access to the bus: **A, E, F, I, M**. Determine the order in which the nodes will be granted access to the bus.

B) What happens if two nodes send their parent requests at the same time during the tree identification process? Does this influence the decision which node becomes the root node? Justify your answer.

Task 6.3: FireWire Encoding

A) FireWire uses a special coding scheme with an additional STROBE signal. Explain the purpose of the this signal and a possible implementation.

B) Indicate the impulse diagram for the case that the following bit sequence (given in binary notation) should be transmitted. Use figure 6.2.

$$110011100100010100110100_b$$

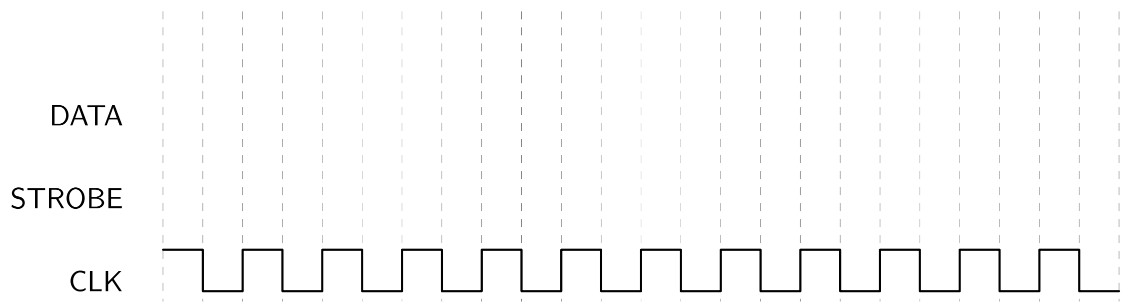


Figure 6.2: FireWire impulse diagram

Task 7: Routing

Task 7.1: General Questions

A) Explain the term hop in context of routing.

B) Describe 2 possible reasonable goals of a routing algorithm.

C) Describe the difference between a deadlock and a livelock.

D) Your Task is to find a routing solution that minimizes packet sizes. Decide whether source or distributed routing is more suitable in this context and justify your answer.

E) Your Task is to find a routing solution in which overhead is scaling well. Decide whether source or distributed routing is more suitable in this context and justify your answer.

Task 7.2: Dijkstra's Algorithm

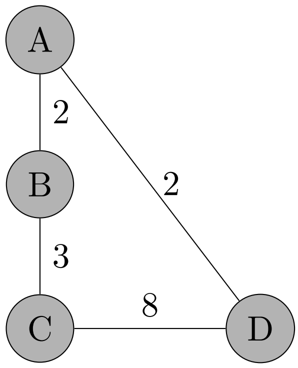


Figure 7.1: Given network topology

A) With node C as the starting point, calculate the shortest paths in the network shown in Figure 7.1, by using Dijkstra's algorithm. For that write down the order in which nodes are visited in each bracket under the current step and fill out the given tables that encompass the shortest paths after each visitation of a node.

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

Table 7.1: Dijkstra's algorithm

B) How many times does Dijkstra's algorithm in general have to be calculated in order to generate a complete routing table ?

C) Write down at least 2 reasonable examples for the meaning of the weights in a topology commonly routed with Dijkstra's algorithm.

D) Name two characteristics of a given network that would lead you to consider Dijkstra's algorithm instead of others presented in the lecture. Additionally justify your decision.

E) Explain the term Time-To-live that is used in Flooding and the reason for using it.

Task 8: Network Topologies

Task 8.1: General Questions

A) Which topology is better suited for safety-critical applications, torus or tree? Justify your decision!

B) The term "broadcast" refers to a style of communication where one node needs to send a message to all other nodes reachable over its connected communication structure. Discuss a bus versus a network regarding broadcast capabilities. Which topology is better suited? Explain your answer!

C) Name an algorithm you know from the lecture that can be used to enable broadcast transmissions in an irregular network topology (i.e. a topology without a clear structure like ring or mesh) and shortly summarize its procedure.

Task 8.2: 4D Topology

Meshed topologies offer a very suitable solution for future many-core architectures, especially because of the easy routing scheme available (x,y-based routing). When we increase the amount of nodes in a mesh, it can be useful to scale the mesh into a higher dimension instead of adding the nodes in the same dimension. A higher dimension keeps the diameter low while increasing the flexibility of the nodes.

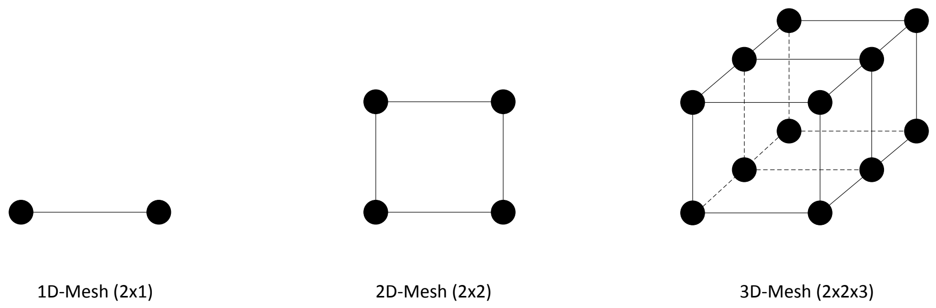


Figure 8.1: Drawing higher-dimensional meshed networks

Mathematically speaking, higher dimensional meshed topologies behave the same as lower dimensional topologies. For drawing them on a sheet of paper, some techniques exist. If we consider a 1-dimensional topology consisting of two nodes and want to move towards a 2-dimensional (2x2) topology, we simply copy our original nodes and connect each node with their exact copy. For a 2x2x3 topology, we copy the existing 2x2-rectangle two times (resulting in 3 rectangles) and connect each original node with their first copy and their first copy with the second copy. The same technique can be applied to a 4D topology, where we copy our 3D cubes and connect each node to its next copy.

A) A 2x2x5x5 mesh topology is given. Each node can be described by the tuple (x1,x2,x3,x4). Find the shortest path from the source point (0,1,0,1) to the destination point (1,0,2,4). Thereby, the routing policy that each node has to obey is described as follows:

1. Try first to route in the direction of the largest vector component ($\|\Delta x1\|$, $\|\Delta x2\|$, $\|\Delta x3\|$ or $\|\Delta x4\|$) from the local position towards the destination.
2. In case there are multiple directions with the same largest value for the respective vector components possible, choose the direction of the previous step.
3. In case none of the above rules is possible, prioritize first x1 then x2 then x3 and finally x4 among the directions with the largest vector components.

In your answer please name all traversed nodes (i.e. their coordinates) in the correct sequence.

B) Can the routing policy described in the previous question A result in a lifelock? Justify your answer!

C) Explain the difference between a lifelock and a deadlock in a network.

D) Assume now that there may be broken nodes which may not be selected by a routing algorithm. To cope with these broken nodes, there is an additional rule that extends the first rule and which says:

1. In case a selected direction is not routable (due to the target node being broken), choose among the remaining directions the one of the next largest vector component from the local position towards the destination.

Furthermore assume that there are two broken nodes: (0,1,0,3) and (0,1,1,2). Route a packet again starting from (0,1,0,1) towards (1,0,2,4) and name all visited nodes on the way.

A tesseract is a 2x2x2x2 Topology, also labeled "4d-cube". It can be drawn with two 3D cubes next to each other or with an "inner"-cube and an "outer"-cube.

Figure 8.2: Two ways of drawing a Tesseract (i.e. a 4-d cube)

E) What is the average flexibility (average number of connections of each node) and the diameter of a tesseract? Shortly explain why your answer is correct.

F) What is the minimal amount of nodes/links that must fail, so that there is no route between any two nodes in a 2x2x5x5 meshed topology? Explain your answer.