Examination SS2016
Communication Systems and Protocols

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Communication Systems and Protocols

Date:	25.07.2016
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 31 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.

		Page	≈ Pts. [%]	Points
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Task 2:	Media Access	6	12	
Task 3:	Arbitration	11	11	
Task 4:	Error Protection	15	14	
Task 5:	Bus Systems	19	16	
Task 6:	FireWire	24	5	
Task 7:	Routing	26	11	
Task 8:	Network Topologies	29	12	
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Task 1: Physical Basics

Task 1.1: Signal Transmission

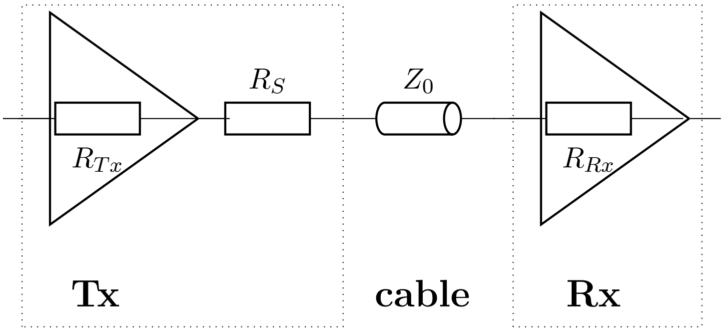


Figure 1.1: Test setup

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}.
In order to minimize reflections, the transmitter is matched to the line with an impedance of Z_0 by adding a series termination resistor R_S.
The impedances are $Z_0 = 50\ \Omega$, $R_{Tx} = 7\ \Omega$ and $R_{Rx} > 1\ M\Omega$.

A) How should the value of R_S be chosen in order to minimize reflections? Give the equation which describes this relation.

B) At which end of the line will be the least reflections for the case of the matched line in Figure 1.1?
Give the equation for the reflection factor in general. What does the equation look like at the selected end of the line where the least reflections are to be expected?

C) What does the equivalent circuit diagram look like for the setup depicted in Figure 1.1? How can the receiver side of the diagram be abstracted for the transmission line described in this task? Draw the diagram.

D) A step signal of $V_{Tx} = V_{step} = 2.5\text{V}$ 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 and give a reasoning: 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?

E) What will the signal look like at half of the cable's length (the middle) for the properly terminated transmission line from Figure 1.1 for an ideal cable (no attenuation per unit length)? Here it takes the time **T** for the step with $V_{Tx} = +V_{step}$ at the transmitter 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.
If you didn't get a result in the previous task, use $V_{cableIn} = +1/4^{*}V_{step}$.
Draw the signal curve into the diagram 1.2.

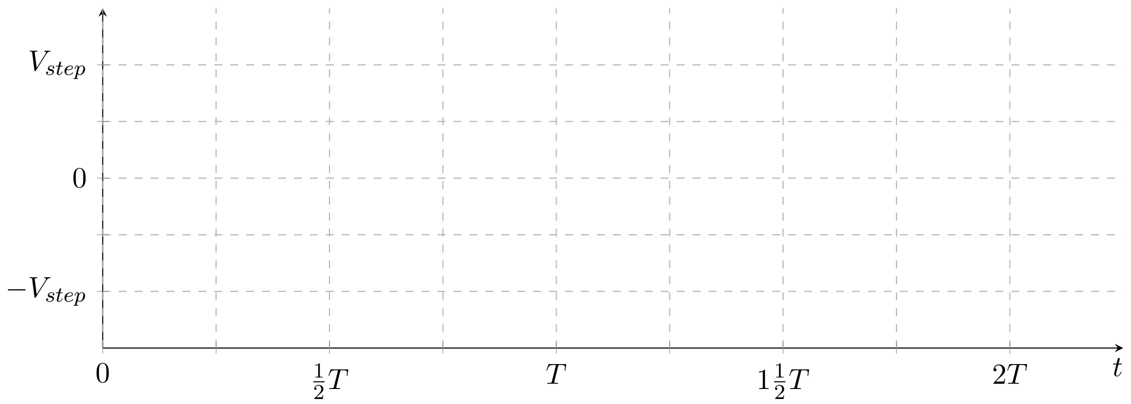


Figure 1.2: Diagram for drawing the voltage over time at half of the cable length

F) In this task, the voltages on the line have completely settled (steady state).
For the transmission line, a coaxial cable of 100 meter length is used which has an attenuation of A = -3.5 dB. The transmitter and receiver are LVCMOS components, where the transmitter's output signal has an high-voltage of 2.5V (V_{Tx}) and the receiver requires a minimum signal of 2V (V_{minRx}) for interpreting it as an high level.
An amplifier with how much gain G_{min} (in dB) will be required in order to allow the receiver to properly receive the signal at the far end of the cable?

Task 1.2: Sampling Theorem

A) What is the Nyquist theorem (explanation) and how is it defined in case of a non-baseband signal?

B) In the Figure 1.3 below you will find the bandwidth spectrum of an FM channel from a radio broadcast signal after downconversion.
If you were just interested in the **Audio Mono L+R** signal, how would you extract this signal's content from the spectrum (no FM demodulation in this step)?
Which are the components you will need in order to extract the signal?
What are the important properties of the required components and processing blocks regarding sampling rate and bandwidth?

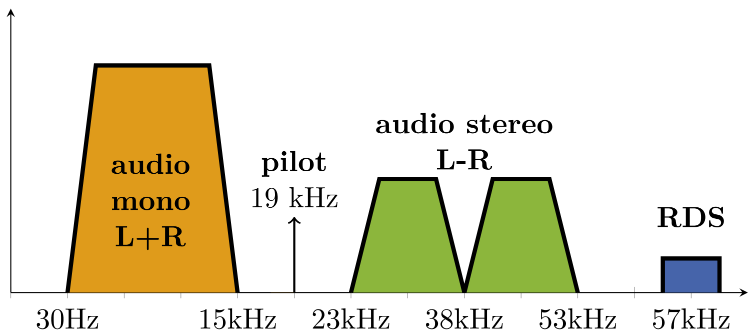


Figure 1.3: Base band spectrum of an radio broadcasting FM channel

Task 2: Media Access

Task 2.1: Multiplexing

A) Name two different types of multiplexing and explain the underlying principle.

B) Bus systems are often classified into serial and parallel buses. Please name one advantage and one disadvantage of parallel buses.

Task 2.2: Multiple Access

Eight different devices communicate on a shared bus-system using TDMA with static time-slot assignment. It can be assumed, that the clocks of each node are perfectly synchronized using a separate clock wire (i.e. clock wire delays are completely compensated). On the data wire, only payload data needs to be transmitted without any additional synchronization overhead. The TDMA cycles (time frames) last for $t_f = 5ms$ and contain exactly one time-slot for each of the 8 participants. The physical signal propagation delay (one-way delay) between the two most distant nodes on the bus is $\Delta_{max} = 50\mu s$. All TDMA time-slots are of equal length and each symbol has a fixed duration of $t_{sym} = 2.5\mu s$.

A) To avoid symbol interference, a guard interval is inserted at the end of each time-slot. How long should this guard interval be at least in order to fully prevent symbol interference in the given system? Calculate the length of the time-slots t_{sl} as well as the time t_{send} which can be used for data transmission during a time-slot.

B) Some of the devices may need to transmit larger amounts of data which can take several seconds. Calculate the average baud-rate f_s that can be achieved for such transmissions. (If you did not solve the previous question, assume that in each time-slot $t_{send} = 605\mu s$ can be used for data transmission.)

Task 2.3: Modulation

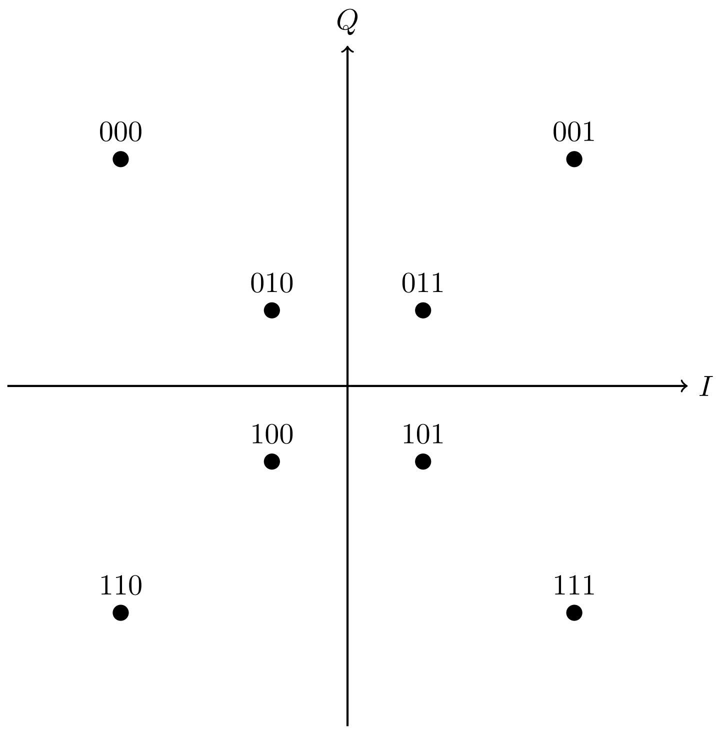


Figure 2.1: Constellation diagram

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. A receiver device now picks up the modulated signal which is plotted in Figure 2.3. Which bits have been transmitted by the sender? Demodulate the signal and write down the resulting bit-stream.

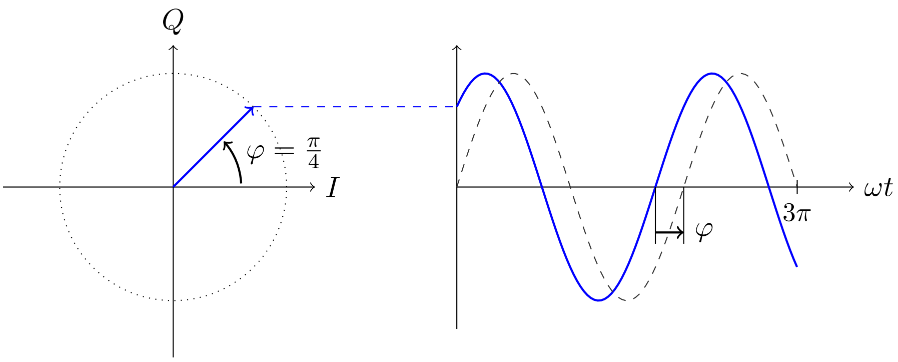


Figure 2.2: Phase difference of a sine signal compared to a reference signal (dashed line $\widehat{=}$ reference signal).

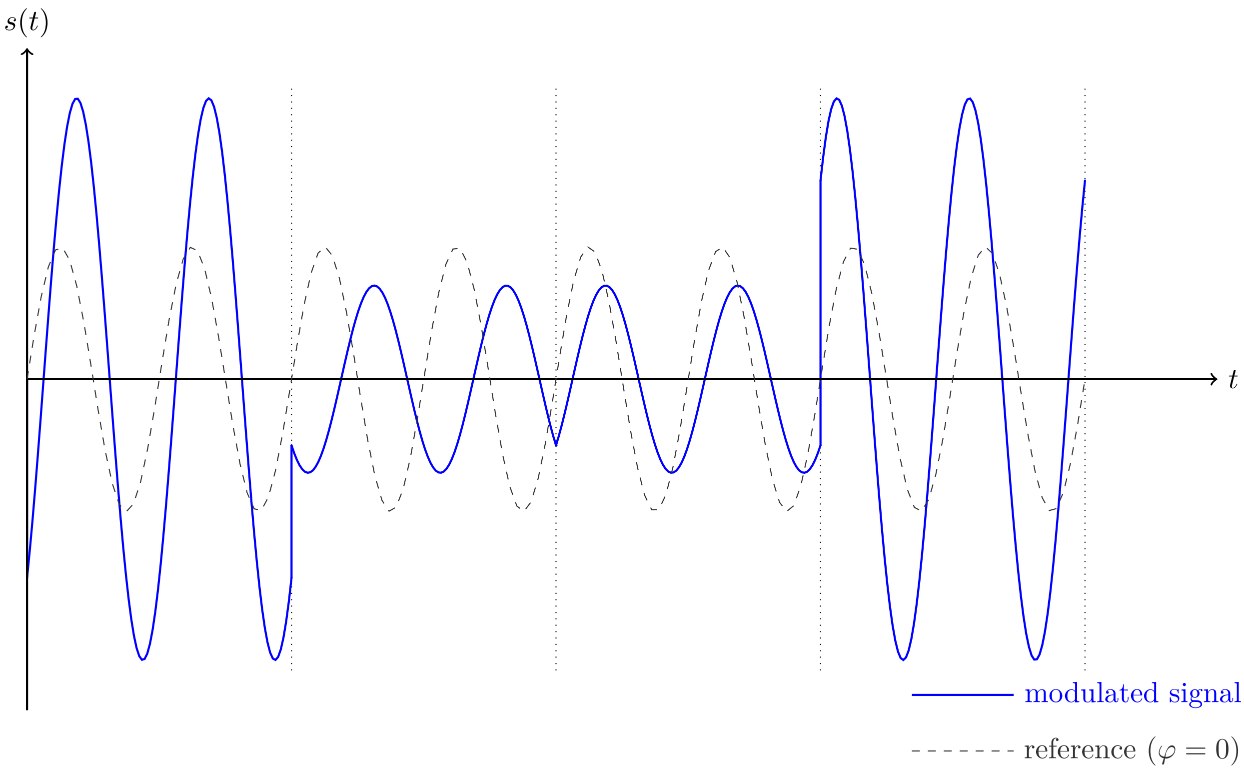


Figure 2.3: A modulated signal which uses the constellation from Figure 2.1 on the preceding page.

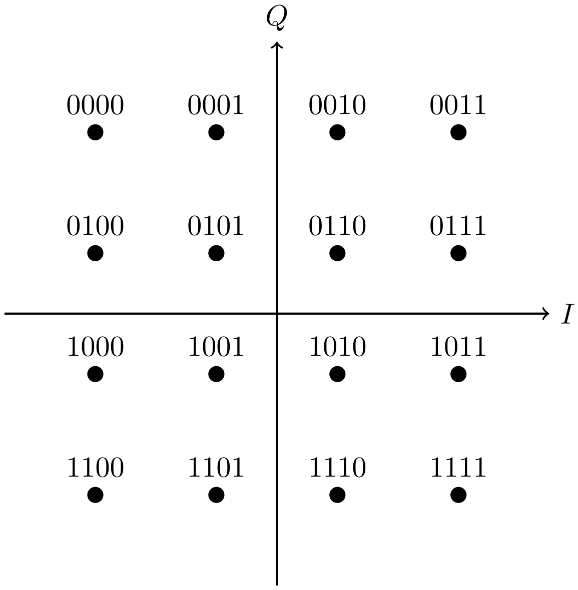


Figure 2.4: Constellation diagram

C) Now, a signal is modulated with the constellation diagram from Figure 2.4 and transmitted on a coaxial cable. The sender is able to generate a maximum voltage amplitude U_{max} of $\pm\sqrt{72}\,V$. Calculate the acceptance radius r_a for the symbols in the constellation diagram.

D) The symbol acceptance radius is a deciding factor for the symbol error probability. However the bit error probability also depends on the encoding of the symbols. The symbol-encoding in Figure 2.4 is not optimal because multiple bits can flip when neighboring symbols are mixed-up due to signal noise. Which kind of encoding could help to solve this problem?

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 600m.

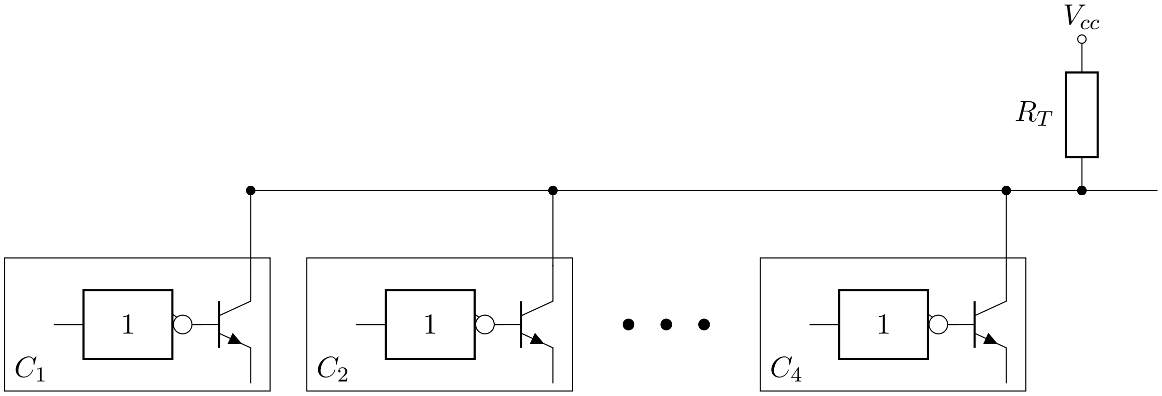


Figure 3.1: bus system

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

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

C) 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 $0.66 \cdot c$.

D) 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?

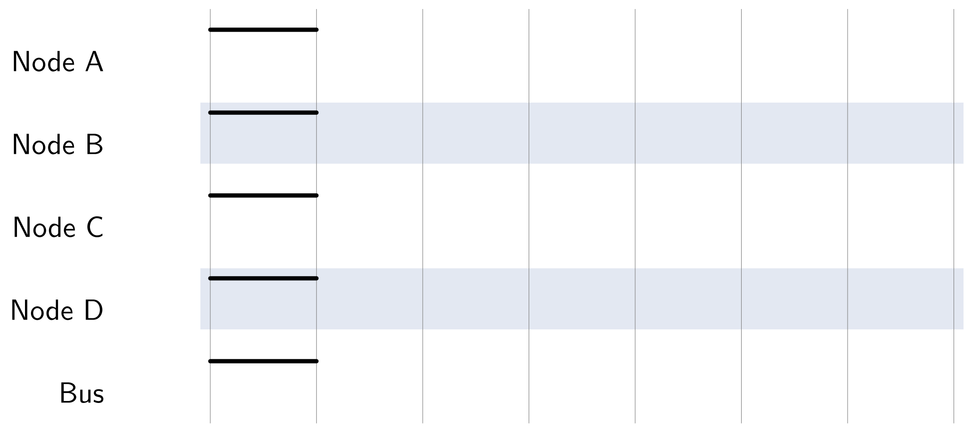


Figure 3.2: Bus Access

Task 3.2: Ethernet

Ethernet is a family of computer networking technologies commonly used in local area networks (LANs) and metropolitan area networks (MANs). Systems communicating over Ethernet divide a stream of data into shorter pieces called frames. Each frame contains source and destination addresses, and error-checking data so that damaged frames can be detected and discarded. The "Carrier Sense Multiple Access with Collision Detection" scheme is used to control access to the shared medium.

A bus system with several nodes is using the Ethernet standard with a transmission rate of $10 Mbit/s$ and a signal speed of $2 \cdot 10^8 m/s$. A maximum distance of $2.5 km$ for two nodes has to be considered.

A) Why is it necessary to establish minimal packet length?

B) Calculate the resulting minimal package length in bits for the bus system.

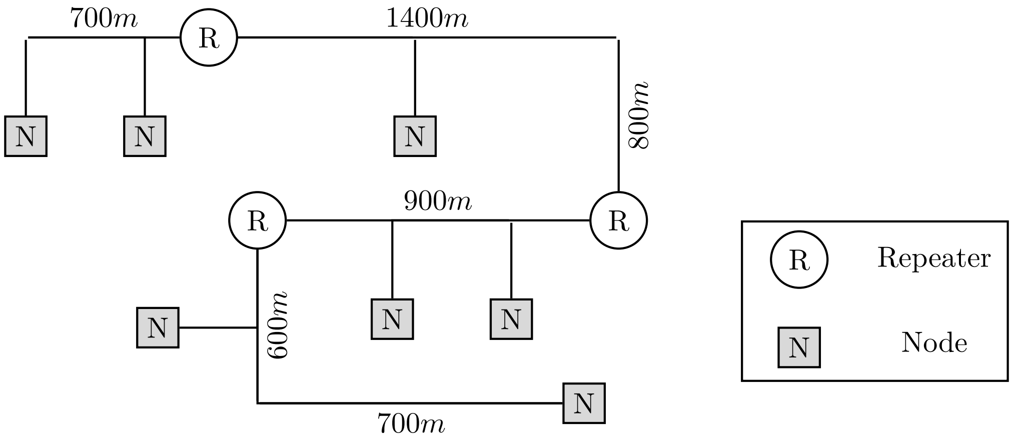


Figure 3.3: Ethernet topology

C) A minimal package length of 64 bytes for the bus system is determined. The bus system is illustrated in figure 3.3 and is used with a transmission rate of $10Mbit/s$ and a signal speed of $2 \cdot 10^8 m/s$. Each repeater will add a delay of three bits. Is this bus system working with these constraints? Give an explanation!

Task 4: Error Protection

Task 4.1: General Questions

A) What is external redundancy? What is natural redundancy? Why does it make sense to replace natural redundancy with a constructed one?

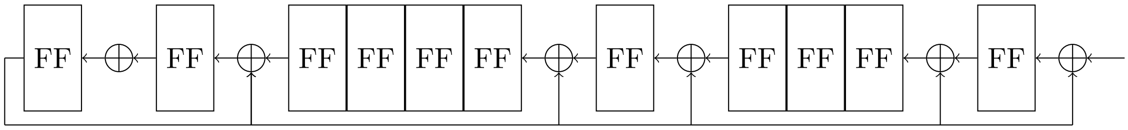
Task 4.2: Block Check

A) The following data was received. Check the even parity bits and mark the bits that can be possibly interpreted as erroneous bits.

	Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Parity
Byte 0	0	1	1	0	1	1	0	0	0
Byte 1	1	0	1	0	0	1	0	1	1
Byte 2	1	1	0	0	0	1	0	1	0
Byte 3	1	0	1	1	0	0	0	0	1
Byte 4	0	1	0	1	1	1	0	0	1
Byte 5	0	0	0	1	1	0	1	1	0
Byte 6	0	1	1	0	1	0	1	1	1
Byte 7	1	0	0	1	0	0	1	1	1
Parity	0	0	1	0	1	0	1	0	1

Task 4.3: Cyclic Redundancy Check

A) To protect data transmission in a mobile device, the following CRC scheme is to be implemented using linear feedback registers with XOR operators. Give the generator polynomial for this simplified hardware layout.



B) Calculate the data stream that will be transmitted if the following bit stream is to be protected, having a generator polynomial of $g(x) = x^3 + x + 1$:

1 1 0 1 0 0 1 1 1 0 1 1 0 0

C) The data string that has been calculated in Task 4.3 B) has been received with the 4th, 5th and 6th bits from the LSB being flipped due to channel errors. Assume that the generator polynomial of CRC-4 ($x^3 + x + 1$) has been used by the receiver for error detection. What is the received bit string and what does the receiver conclude from the result?

Task 4.4: CAN Bus Error Detection

A) Consider the following data frames at Node A (sender) and Node B (receiver).
Name the three errors that can be detected from the given information and also justify your answer.

Node A (Sender)

SOF	Arbitration Field												CTRL Field						Data Field								CRC Field								ACK Field		EOF			
1	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	1	2	3	4	5	6	7	8	1	2	3	..	..	..	14	15	1	2	1	..	..	7
	ID10										ID0	RTR																		..	..	..		DEL	ACK	DEL		..	..	
0	1	1	0	0	0	1	0	1	1	1	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	1	1	0	0	..	..	..	1	1	1	1	1	..	..	0

Node B (Receiver)

ACK Field		EOF			
1	2	1	..	..	7
ACK	DEL		..	..	
1	1	1	..	..	0

B) For the given CAN bus protocal in Task 4.4 A), the following error frame in Fig. 4.1 gets generated in order to cancel a faulty transmission.
Assume that there is a sender (Node 1) and two receivers (Node 2 and Node 3). Node 3 receives the data correctly, whereas Node 2 encounters a CRC error due to some data error. Complete the signal sequence in Fig. 4.2 with respect to the error frame generation of Node 2 and the consequence effect on Node 1, Node 3 and bus level.

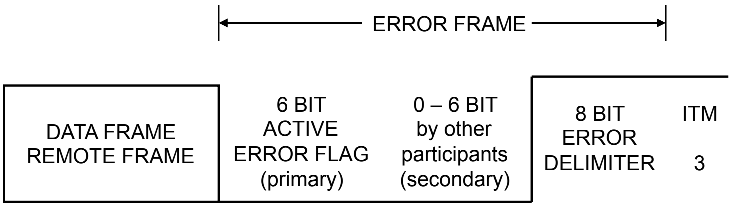


Figure 4.1: Error Frame

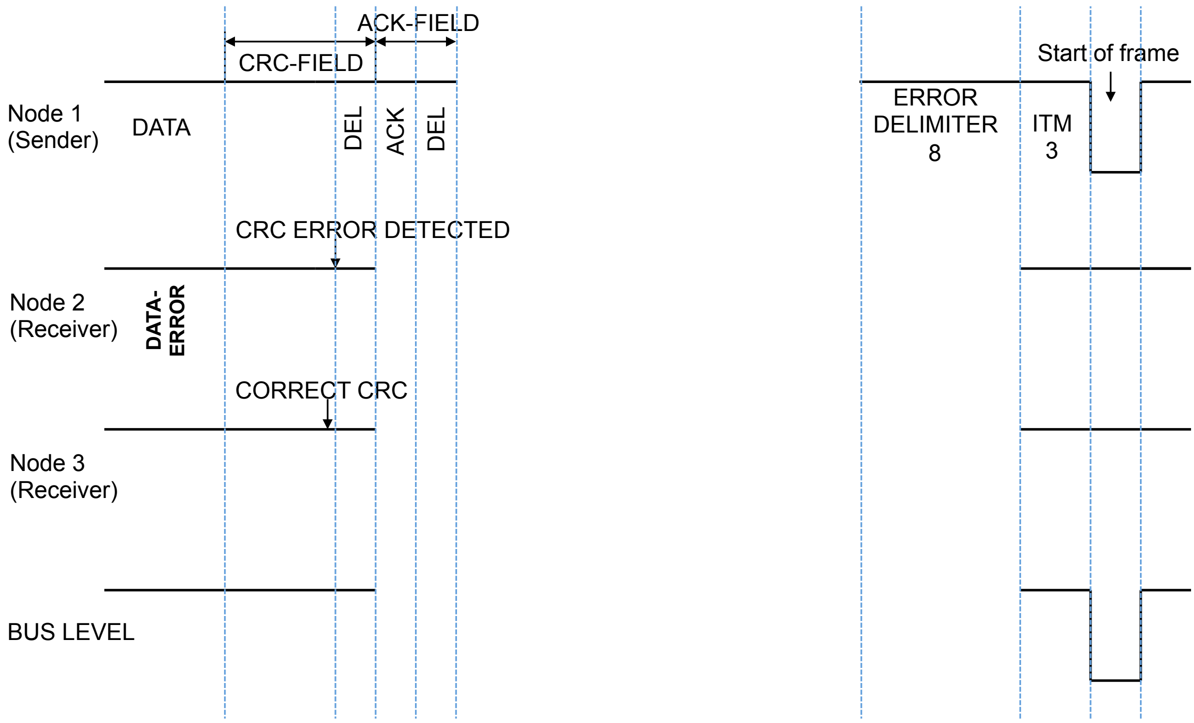


Figure 4.2: Signal sequence diagram of CAN bus

Task 5: Bus Systems

Task 5.1: I^2C: General Questions

A) Which arbitration scheme are used in I2C bus systems, when multiple senders wants to access the bus?

B) Which mechanism is used to synchronize a master communicating with a slower slave node? Which signal of the I2C bus is involved in this mechanism?

Task 5.2: I^2C Arbitration

In this task we want to investigate the data transmission on the I^2C-Bus. The simplified packet format is given in Figure 5.1. Three master nodes are simultaneously trying to transmit or read one byte of data to or from different slaves over the I^2C-Bus.

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

data transfered (n bytes + acknowledge)

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

Figure 5.1: I^2C-Bus frame format

A) The addresses of the slaves, communication mode (R/$\overline{W}$) and the data to be send or read to or from them is shown in the Table 5.1. Complete the signal diagram in the Figure 5.2.

node	slave address	R/$\overline{W}$	data
Master 1	1001001	0	$0x15$
Master 2	0101101	0	$0x81$
Master 3	0101100	1	$0x45$

Table 5.1: I2C Communication Parameters

B) Which Master is winning the arbitration? Justify your answer!

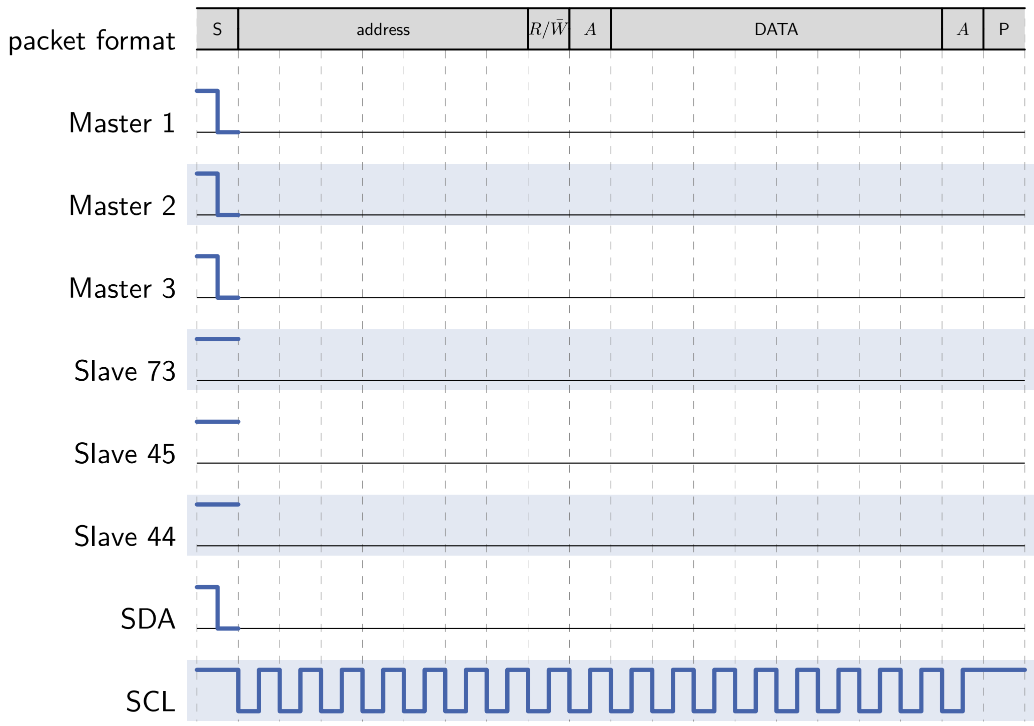


Figure 5.2: Signal sequence

Task 5.3: Flexray: General Questions

A) What is the main goal of Flexray in automotive network topologies compared to conventional bus systems? 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 is used in the different segments in order to cope with multiple senders?

Static Segment	Dynamic Segment

Task 5.4: Flexray: Bus Access

In this task we want to investigate the data transmission and scheduling with Flexray. The used topology is shown in Figure 5.3. Additionally, the slot durations for the scheduling are given in Table 5.2.

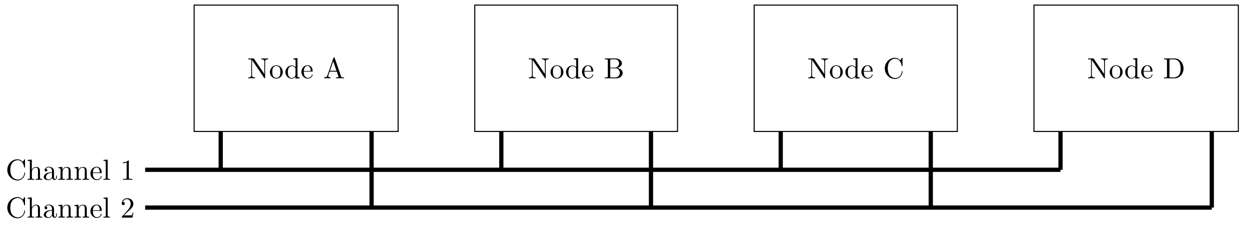


Figure 5.3: Flexray Topology

Static slots	Dynamic slots
$10\mu s$	$1\mu s$

Table 5.2: Slot durations

A) In Table 5.3 the nodes shown in Figure 5.3 and the assignment of their available frames to the static slots are given. Complete the signal diagram in the Figure 5.4 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

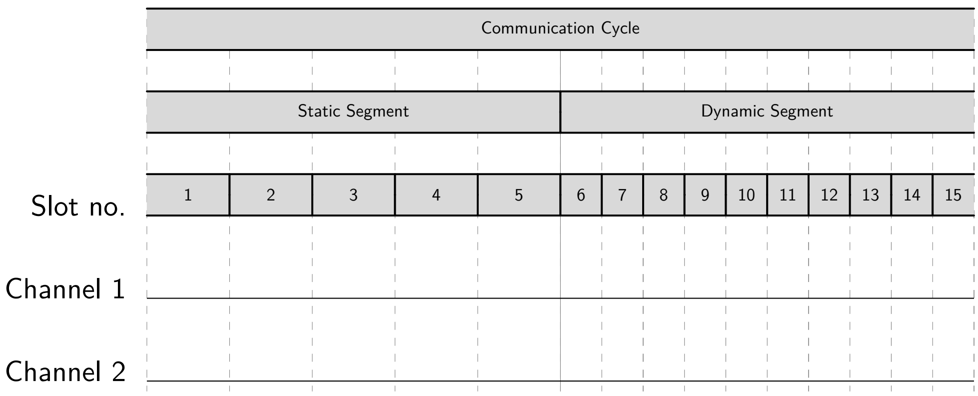


Figure 5.4: Signal sequence

B) Calculate the duration of a complete communication cycle!

C) In Table 5.4 the parameters for the dynamic segment are given. Complete the signal diagram in the Figure 5.4 and perform the dynamic scheduling of the frames according to the Table 5.4

Node	Frames	Slot-ID	Frame Duration
A	A7	7	$1\mu s$
B	B9	9	$6\mu s$
C	C8	8	$5\mu s$
D	D6	6	$4\mu s$
	D11	11	$2\mu s$

Table 5.4: Dynamic Segment Parameters

D) Is the dynamic scheduling feasible in the sense that all dynamic frames could be served in one communication cycle? Justify your answer!

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 state if the FireWire systems given below are working correct. Mark the roots, if the systems are correct. Give a reason, if the FireWire system is not working correctly.

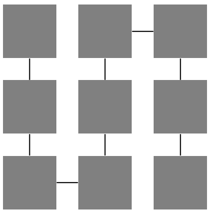
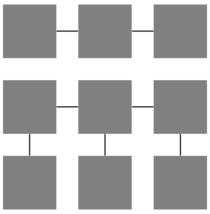
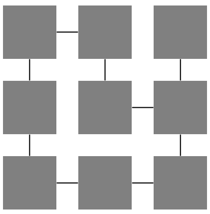
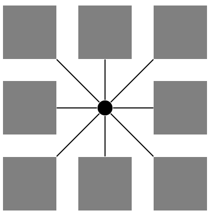
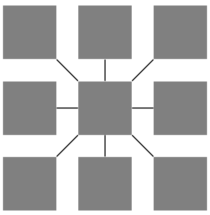
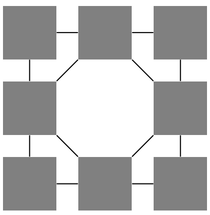
	Correct	Wrong	Reason
			
			
			
			
			
			

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.

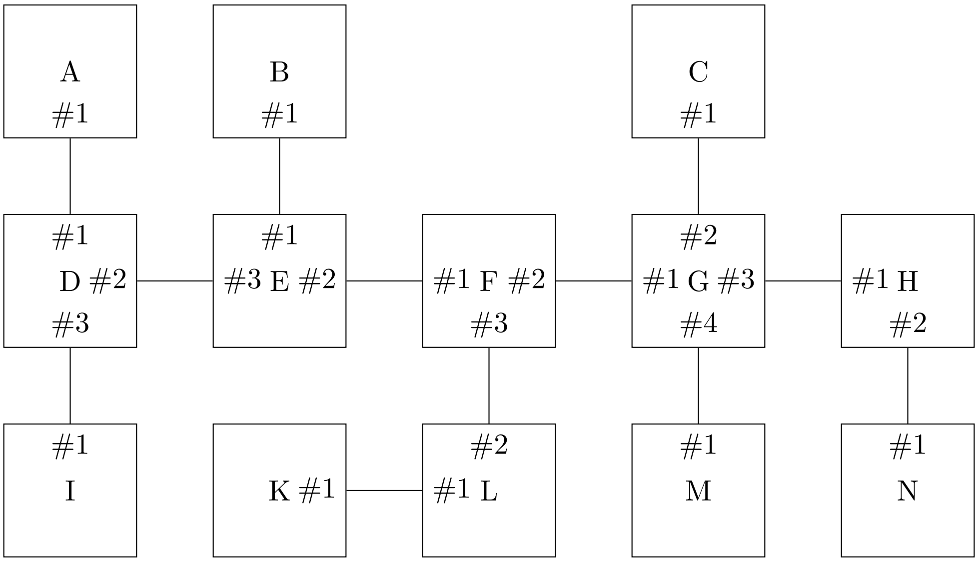


Figure 6.1: FireWire network

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 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.

Task 7: Routing

Task 7.1: General Questions

A) Comparing online or predetermined routing, which one is more suitable when low latency is required ? Justify you answer !

B) Comparing wormhole routing and traditional routing, which one is more suitable when low memory consumption in each node is desired? Justify your answer !

C) Describe the difference between adaptive and deterministic routing. Additionally describe an application in which deterministic routing is more suitable than adaptive. Justify your answers !

Task 7.2: Dijkstra's Algorithm

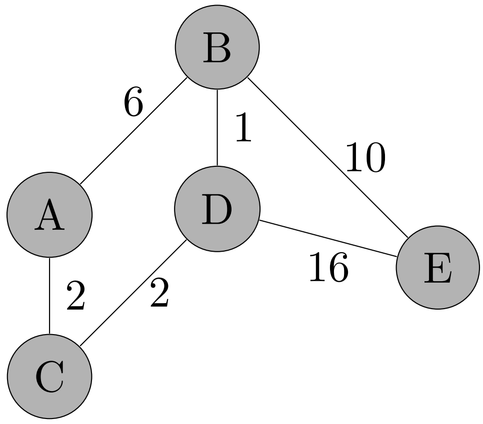


Figure 7.1: Given network topology

A) With node A as the starting point, calculate the shortest paths in the network shown in 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 **A**		step 2		step 3		step 4		step 5	
vertex	dist.	pred.	dist.	pred.	dist.	pred.	dist.	pred.	dist.	pred.
A	0	A								
B	∞	-								
C	∞	-								
D	∞	-								
E	∞	-								

Table 7.1: Dijkstra algorithm

B) Describe a network in which Dijkstra's algorithm is more suitable than XY-Routing and justify your answer.

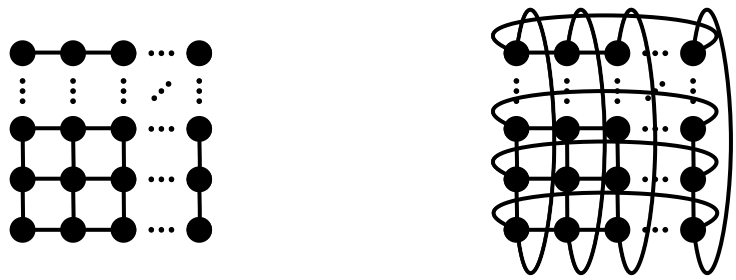
C) Write down at least 2 reasonable examples for the meaning of the weights in a topology commonly routed with Dijkstra's algorithm

D) Suppose a failure occurs in a network in which a communication path between 2 nodes is not available anymore. Under the assumption that routing was created using Dijkstra's algorithm, is communication between these nodes still possible even after the failure? Justify your answer !

Task 8: Network Topologies

Task 8.1: General Questions

A) Which network topology is more suitable in a safety critical system, star or ring topology? Justify your decision!



(a) Mesh (b) 2D torus

Figure 8.1: General structure of a) mesh and b) 2D torus network topologies

B) The flexibility F describes the number of possible directions in which a network node can transmit. What is the average flexibility F_avg in a 10x10 mesh topology? *Hint: the general structure of a mesh network topology is depicted in Fig. 8.1a.*

C) The flexibility F describes the number of possible directions a network node can transmit to. What is the average flexibility F_avg in a 10x10 2D torus topology? *Hint: the general structure of a 2D torus network topology is depicted in Fig. 8.1b.*

D) Explain one possible case or system where a bus is preferable over a network.

E) Explain one possible case or system where a network is preferable over a bus.

Task 8.2: 3D Mesh Topology

A) Comparing a 6x3 2D-mesh topology with a 3x3x2 3D-mesh topology, which has the lower maximum latency when using a shortest path routing strategy and how much is the relative improvement when replacing one topology with the other? Assume that there is no heavy traffic or congestions and that all routing segments have the same delay!

B) In Fig. 8.2 a 4x4x3 mesh topology is given. Find the shortest path from the source point (0,2,0) to the destination point (3,3,2). 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 (Δx, Δy or Δz) from the local position towards the destination.
2. In case a segment is congested, disregard the respective direction and choose among the remaining directions the one of the next largest vector component from the local position towards the destination.
3. In case there are multiple directions with the same largest value for the respective vector components possible, choose the direction of the previous step.
4. In case none of the above rules is possible, prioritize first x then y then z.

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

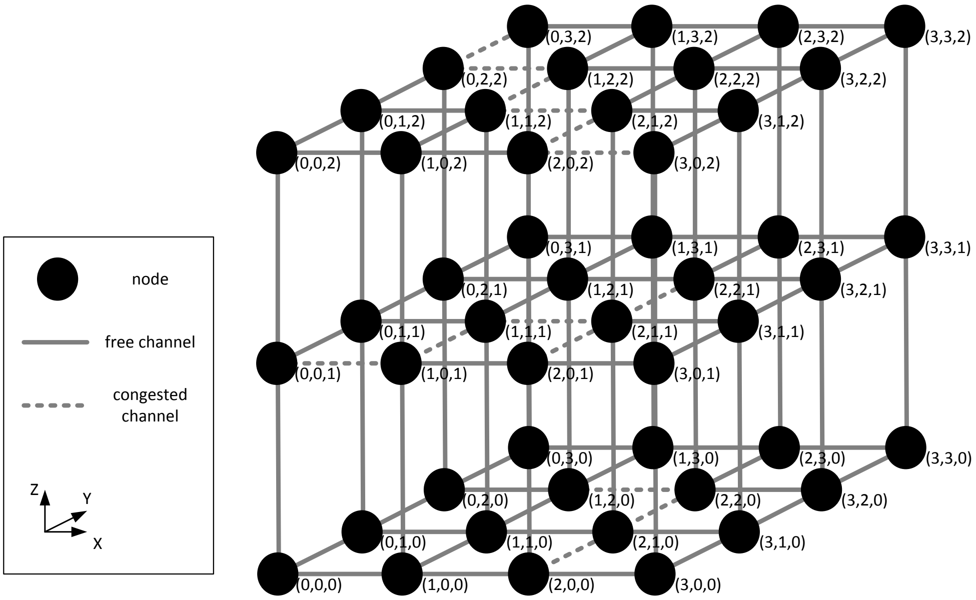


Figure 8.2: Structure of a 3D mesh network topology

C) The network nodes in Fig. 8.2 support simultaneous multipath communication, while each channel has a bandwidth of 1Gbit/s. What is the maximum communication throughput between the nodes (1,1,1) and (3,2,2)? Assume that there are no congestions. Justify your answer.

D) Explain one possible extension of the topology in Fig. 8.2 to further reduce the maximum latency.