# Communication Systems and Protocols
# Summer Term 2015

Institut für Technik der Informationsverarbeitung – ITIV
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**Communication Systems and Protocols**

Date: 20.07.2015
Name:
Matriculation-ID.:
ID:
Lecture Hall:

**Seat No.**.:

**Prerequisites for the examination**

**Aids**

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

**Duration of the examination**

120 minutes.

**Examination documents**

The examination comprises 28 pages (including title page). Answers may be given in English or German. A mix of language within a single (sub)-task is not allowed. In your solution mark clearly which part of the task you are solving. Do not write on the backside of the solution sheets. If additional paper is needed ask the examination supervisor.

You will not be allowed to hand in your examination and leave the lecture hall in the last 30 minutes of the examination.

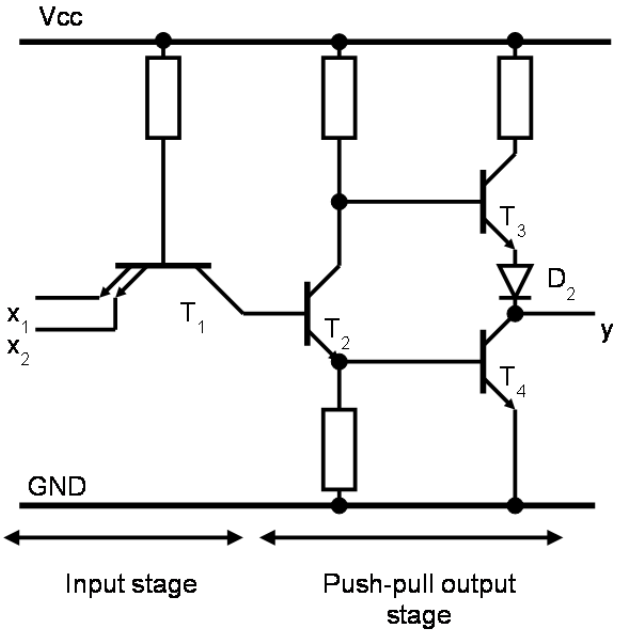
At the end of the examination: Stay at your seat and put all sheets into the envelope. Only sheets in the envelope will be corrected. We will collect the examination.

| | | | | |
|---|---|---|---|---|
| Task 1 | Physical Basics | 2 | | ~19% |
| Task 2 | Wiring | 7 | | ~11% |
| Task 3 | Data Transmission | 10 | | ~13% |
| Task 4 | Error Protection | 13 | | ~14% |
| Task 5 | Media Access | 17 | | ~13% |
| Task 6 | Practical Aspects of Communication Systems | 21 | | ~13% |
| Task 7 | Networks | 25 | | ~17% |
| | | | Σ | |

# Task 1 Physical Basics

## Task 1.1 TTL - Logic

A) Insert the logic level (HIGH, LOW) of the output and the state of the transistors (open, closed) into the table according to the input configuration x1 and x2 at the standard TTL output driver

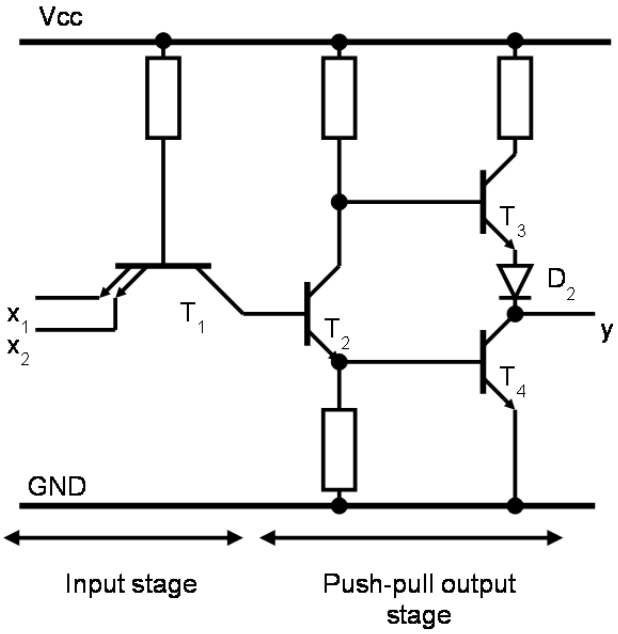



| $X_1$ | $X_2$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | y |
|---|---|---|---|---|---|---|
| 0 | 0 | | | | | |
| 0 | 1 | | | | | |
| 1 | 0 | | | | | |
| 1 | 1 | | | | | |

B) How would a transmission setup with TTL technology look like? (Drawing is not necessary, but when using a description, it has to be clear and distinct)

C) List two advantages for the use of TTL drivers.

D) How would it be possible to overcome the disadvantage of possible short circuits of a TTL driver? Which part of the TTL driver needs to be modified? Modify the drawing to get the solution and describe the purpose of the adjustments made.




## Task 1.2 Differential Signals

A) How could differential signal generation be realized?

B) What are the advantages for differential signal transmission? Name two.

# Task 1.3 Modulation

A) The signal in Figure 1.1 is received after a transmission. Which modulation scheme is used when assuming all possible modulations are transmitted in that signal?

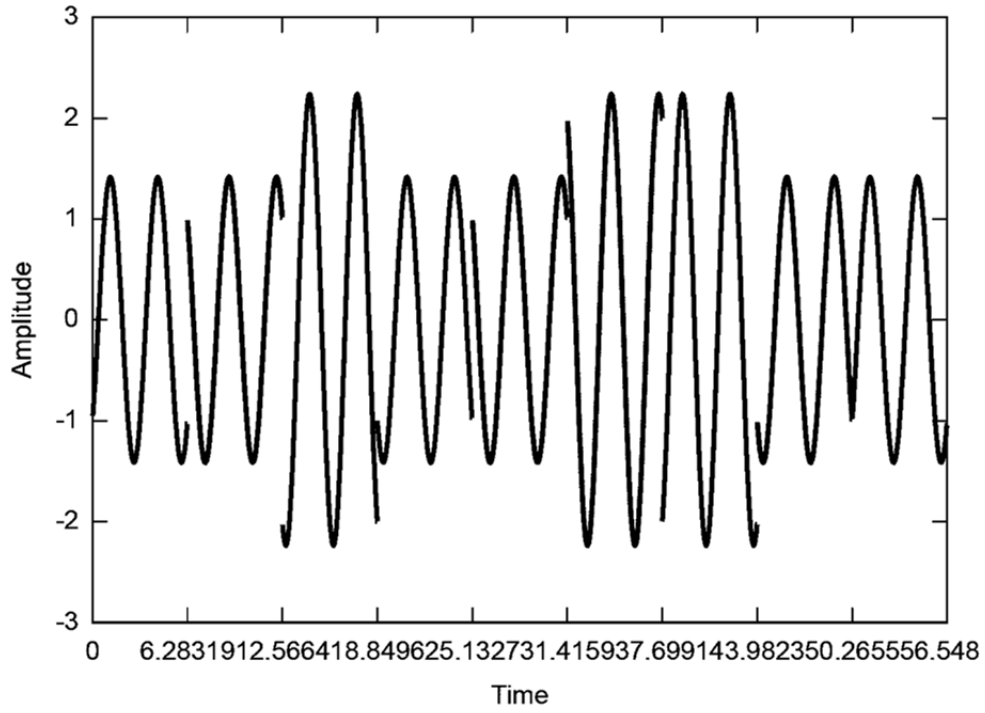



**Figure 1.1: Modulated signal**

B) Now consider that 8QAM is used. Give a possible coding for the modulation scheme.

| Phase / Amplitude | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |

C) Briefly describe ASK modulation and give one disadvantage.

## Task 1.4 Channel capacity, Bandwidth

A digital transmission system with a bandwidth of B=1,5*106 Hz has a channel capacity of C = 5 Mbit/s (according to Shannon).

A) What is the minimum for the signal-to-noise ratio (SNR) in dB?

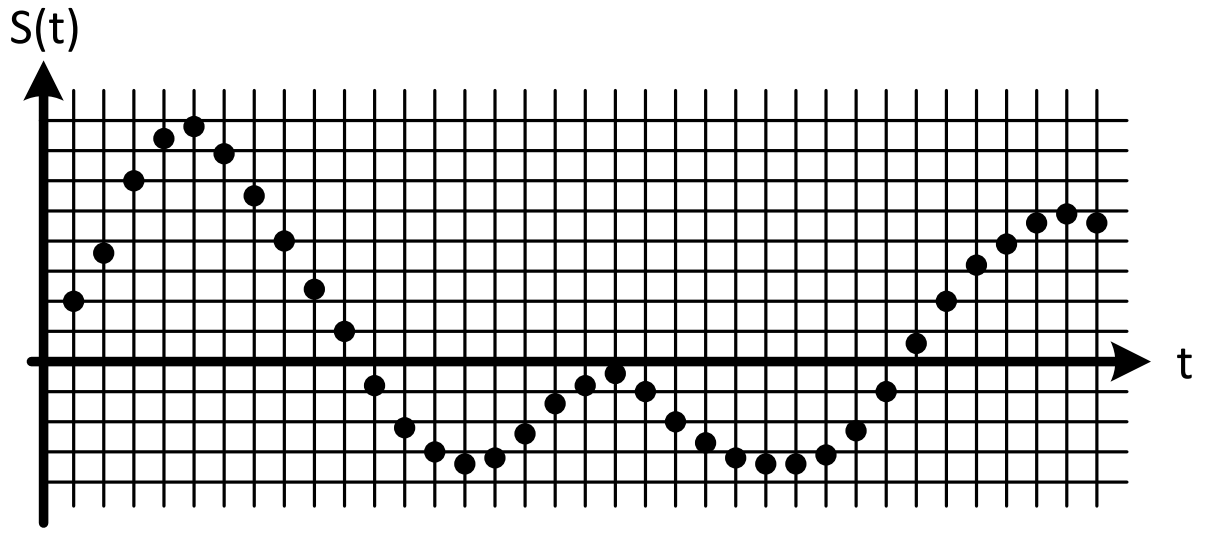
B) Give the definition for the Cut-Off-Frequency.

## Task 1.5 Signal Conversion

A) When converting analog signals into digital signals, what has to be considered in order to be able to achieve an unambiguously reconstruction of the signal (name and formula)?

B) Which classes of signals are used as analog and digital signals? Name 4 signal classes.

C) Which signal class does the following signal belong to? Briefly describe the generation of this signal class.



# Task 2 Wiring

## Task 2.1 General Questions

A) What is an asymmetric line? Name one example for its application.

B) How does the wire length affect the wave impedance ZW?

C) Name four causes for distortions of real data signals.

## Task 2.2 Twisted Pair

A) How does a twisted pair cable help against interferences from external sources?

B) Is using a twisted pair cable more beneficial against interferences of small sources close to the wire or ones that are farther away? Explain your answer.

## Task 2.3 Reflection on wires

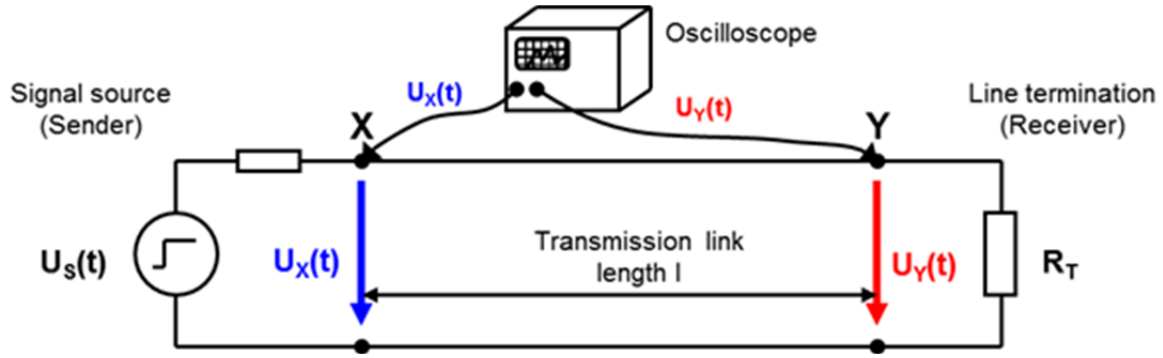



**Figure 2.1: Test setup**

You have found a transmission link in the basement and want to find out the wave impedance. With the setup given in Figure 2.1 you make the measurements that can be seen in Figure 2.2. The signal source is stuck at an unknown output voltage and has an internal resistance of 33 Ω. The termination resistance is RT = 200Ω. You can assume that the DC resistance is zero. When using numbers from Figure 2.2, only use one decimal place and only use values where the voltage is mostly constant.

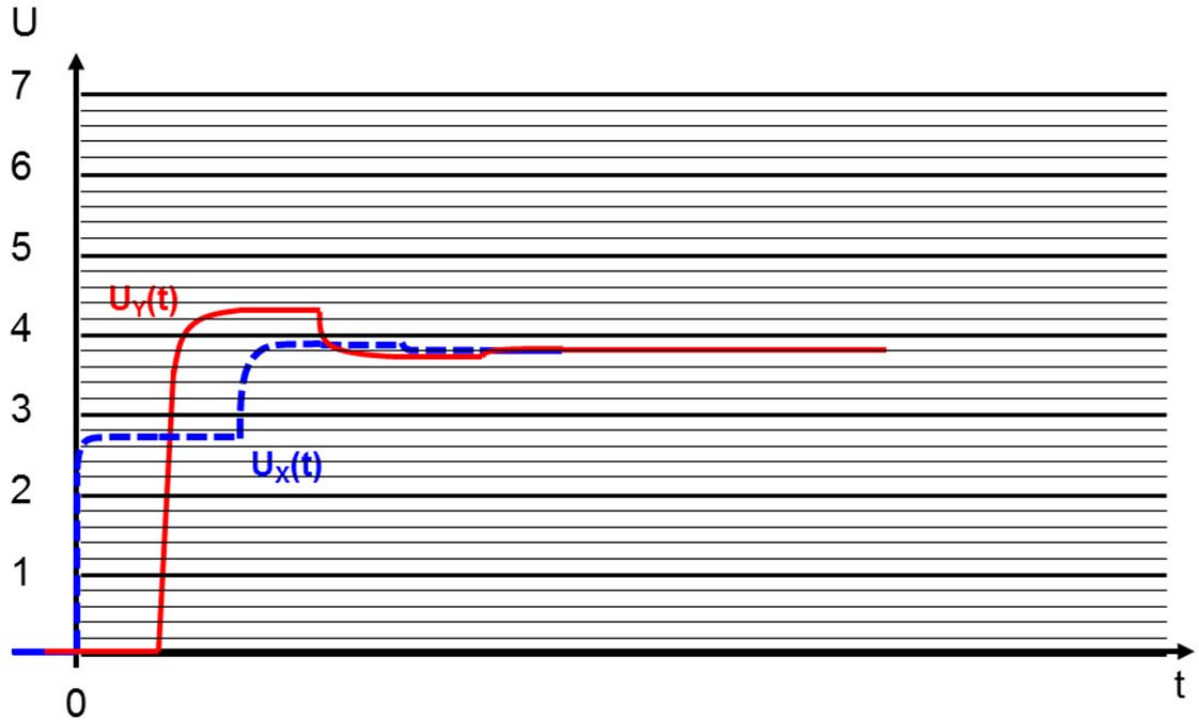



**Figure 2.2: Measurement**

A) How would you divide the timeline? Explain and mark at least four points on the timeline.

B) Without calculation, make a quantitative statement about the reflection factors at the start and at the end.

C) Calculate the wave impedance (characteristic impedance) and the reflection factors at the start and at the end.

D) Calculate the internal sender voltage us

# Task 3 Data Transmission

## Task 3.1 Line Codes

A sensor node has to be connected to your existing system. To lower costs and complexity, only one line is available for data transmission. Nonetheless, timing recovery without additional measures should be possible.

A) Name two line codes that fulfill these requirements.

B) Your channel's signal power is 500 times higher than its noise, its maximum frequency amounts to 4500 Hz. Your sensor node delivers its data with 5 Kbit/s. Which line code that fulfills the requirements above would you use? Justify your answer by comparing it with its alternatives you mentioned in the preceding task.

## Task 3.2 CDMA

GPS and mobile phones use CDMA to distinguish their participants.

A) CDMA is using a special class of codes, one example are Walsh-Codes. How is this class of codes named and why are they called like that?

B) Which influence does this have on the bandwidth of the transmitted signal?

The so-called Gold code is an alternative to the method of generating these codes presented in the lecture. It uses two different linear feedback shift registers (LFSR) whose outputs are XOR-ed. The start value of the LFSRs is called “seed”. The different codes are obtained by using different seeds for LFSR1 while LFSR2’s seed is left unchanged.

The gold code generator in Figure 3.1 shall be used in the following. The seed of LFSR2 is fixed to “001”

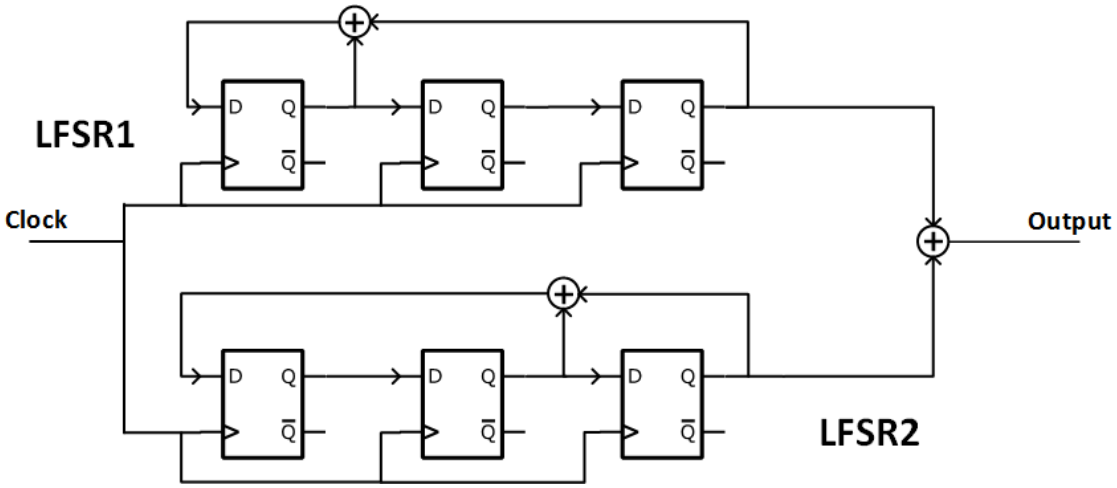



**Figure 3.1: Gold code generator**

C) How many Gold codes can be generated in this way?

D) List the first two gold codes generated by this generator (start seeds 001 and 010), how many different participants does the generator allow on your channel?

E) What would happen if you used the seed “000” in one of the LFSRs?

## Task 3.3 Symbol Stuffing

You want to transmit formatted text but due to limitations of your transmission system you can only use the uppercase letters A-Z and whitespace. However, it should be possible to transmit italic, bold and strike-through text.

To achieve this, the command character „C“ is used which denotes the beginning and the end of a command sequence. The commands are then applied to all following characters until the command sequence is repeated. If the character “C” is to be send as part of the text, it therefore has to be escaped by doubling it at sender site.

Available commands are “B” for bold text, “I” for italic text, “L” for lowercase letters and “S” for strike-through text.

A) Format the following text according to these rules:

This task is ~~**stupid**~~ *COOL*

B) What could happen if you did not use a separate command word?

# Task 4 Error Protection

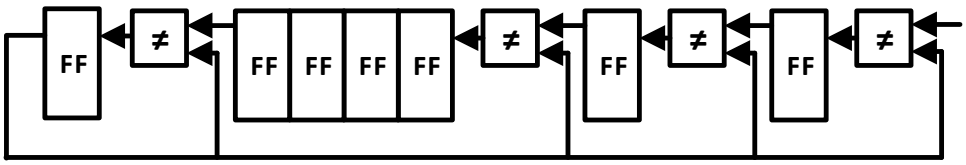
## Task 4.1 Error Detection

A) What is the general difference between Safety and Security?

B) Name two properties of a good hash function (for communication purposes)?

## Task 4.2 CRC-Calculation

To protect data transmissions, the given CRC scheme is implemented using linear feedback registers with XOR operations.




A) Determine the given generator polynomial

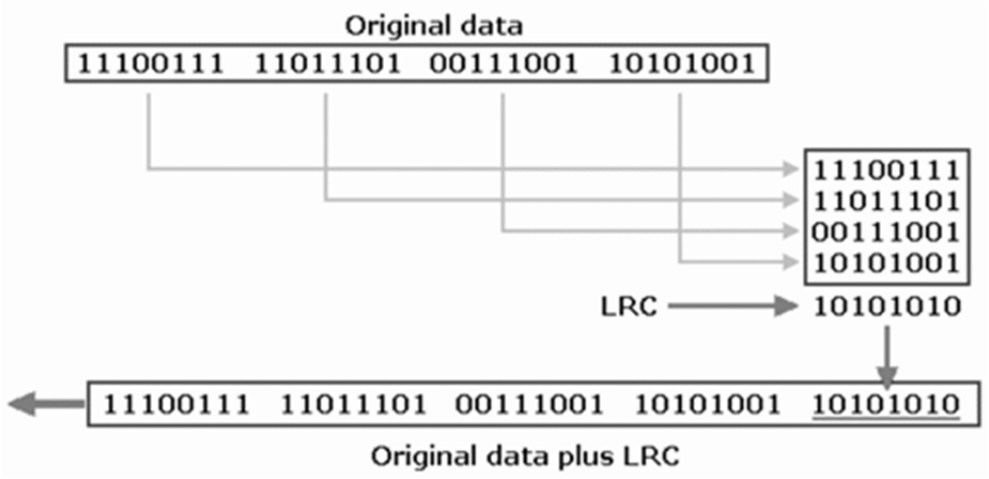
B) Calculate the data stream that will be transmitted if the following bit string is to be protected:

**10101110**

C) With a transmission system that uses CRC for error protection, a sender transmits the following bitstream: **10011000 00100011 011**
Carry out the CRC error detection scheme of the receiver, assuming that the generator polynomial CRC-4 (x3+1) has been used. What does the receiver conclude from the result?

## Task 4.3 Comparison of LRC and CRC

In Longitudinal Redundancy Check (LRC), a block of bits is organized in a table with rows and columns. Then the parity bit for each column is calculated and used to create a new row of an additional parity data word. After that the new calculated parity bits are attached to the original data and sent to the receiver.




A) With a transmission system that uses LRC for error protection, the following bitstream was received: **00011000 10100011 10111011**
Carry out the LRC error detection scheme of the receiver, assuming that even parity has been used. What does the receiver conclude from the result?

B) Assuming that the sender has sent the following bitstream instead of the bitstream in Task 4.3A): **10011000 00100011 10111011**
Would these errors be detected by using LRC? Determine the Hamming Distance (HD) of the LRC method.
Note: Hamming Distance (HD) is lowest weight of any undetectable error. For example, HD=4 means **all** 1, 2, 3 bit errors detected.

C) Could these errors from Task 4.3A)-B) be detected by using the CRC method with a “good” selected CRC polynomial? Name an example from the given table where the CRC would guarantee detection of these errors. Explain your answer.
Note: Hamming Distance (HD) is lowest weight of any undetectable error. For example, HD=4 means **all** 1, 2, 3 bit errors detected.

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

**Table 4.1: "Good" polynomials for HD at given CRC size and data length**

D) Compare LRC against CRC on the following criteria:

- Error detection
- Implementation

Which detection scheme would you prefer regarding these criteria? Explain your answer!

# Task 5 Media Access

## Task 5.1 CSMA/CD

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 5.1.
- A node is not allowed to send twice in a row. 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 5.1.
- If a node willing to send detects that the bus is occupied it withdraws and waits for the time specified in Table 5.1 (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 5.1.

| Node | Packet length | Waiting time |
|---|---|---|
| A | 1 | 2 |
| B | 2 | 2 |
| C | 3 | 2 |

**Table 5.1: Specifications of nodes**

A) Fill in the signal sequence of the bus nodes, resulting from the specification as given above (use Figure 5.1). Mark waiting times and collisions that occur.

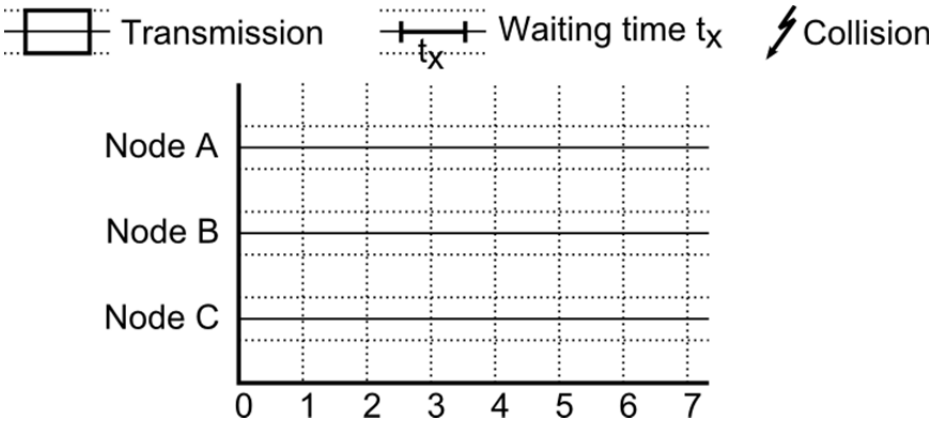



**Figure 5.1: Signal sequence**

B) Which problem occurs and how could it be solved?

C) The packet length is unchanged and node C has the highest priority. Modify the waiting times so that all nodes have send data after nine clock cycles (use Table 5.2). The waiting times should be as short as possible. Fill in the signal sequence of the bus nodes, resulting from the modified waiting times (use Figure 5.2). Mark waiting times and collisions that occur, label which graph should be evaluated with a cross.

| Node | Packet length | Waiting time |
|---|---|---|
| A | 1 | |
| B | 2 | |
| C | 3 | |

**Table 5.2: Modified waiting time**

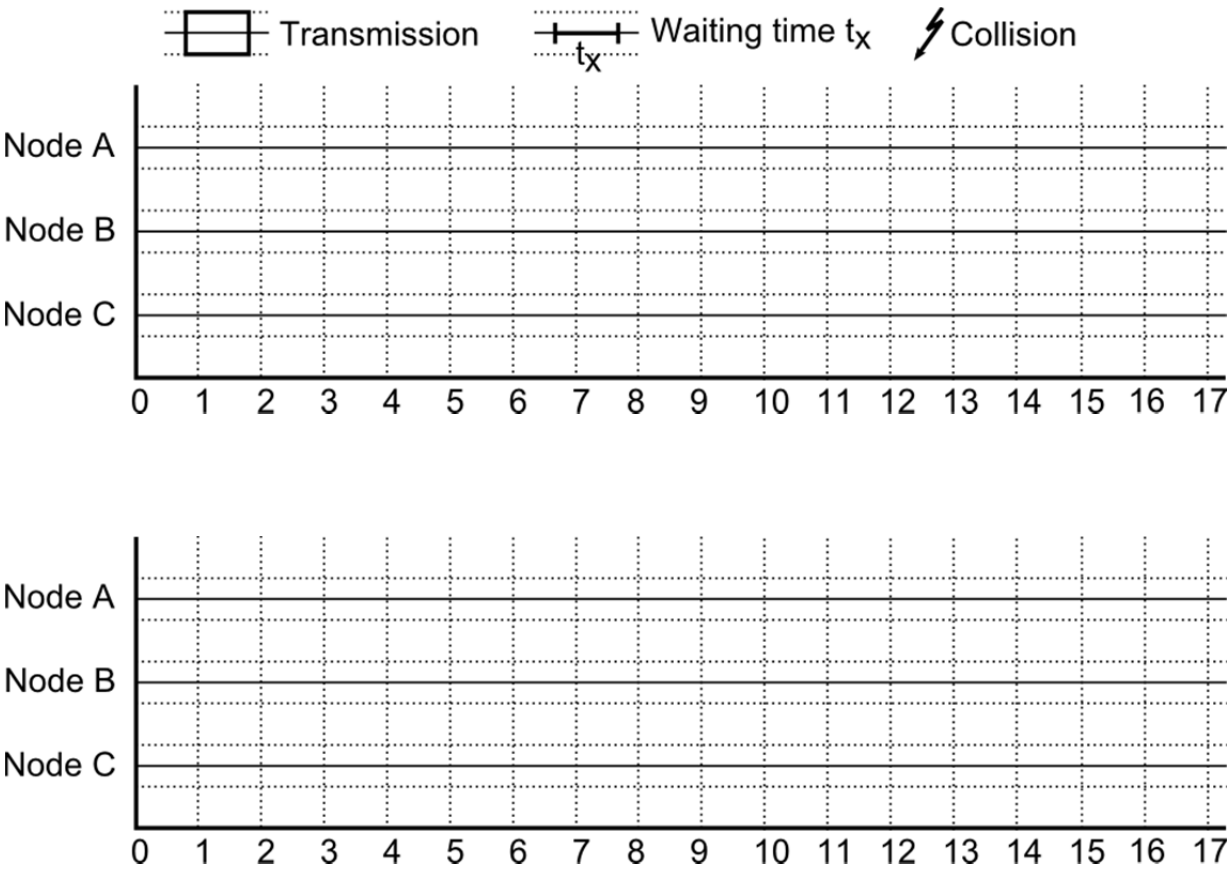



**Figure 5.2: Signal sequence**

## Task 5.2 CSMA/CA

A communication system comprises five communication nodes that use CSMA/CA as arbitration scheme. In order to transmit data a node transmits a dominant start bit (‚0') for synchronization purpose. After that a 5 bit message identifier followed and 10 bits of payload data is sent. The message identifiers are unique for each node and all data is sent MSB first. The bus has to cover a maximum distance of 500m.

A) Name two advantages and two disadvantages of CSMA/CA

B) Which requirements have to be fulfilled in order to guaranty a faultless function of the system? What are the implications for the transmission rate?

C) Calculate the maximum payload data rate of this bus. Assume a propagation time of 0.66·c (c=3·10^8 m/s).

D) Figure 5.3 shows an impulse diagram for the bus system described above and the signal level of the shared bus line. Indicate the identifiers of the given nodes as far as possible (use Table 5.3, mark uncertain identifier bits as X).

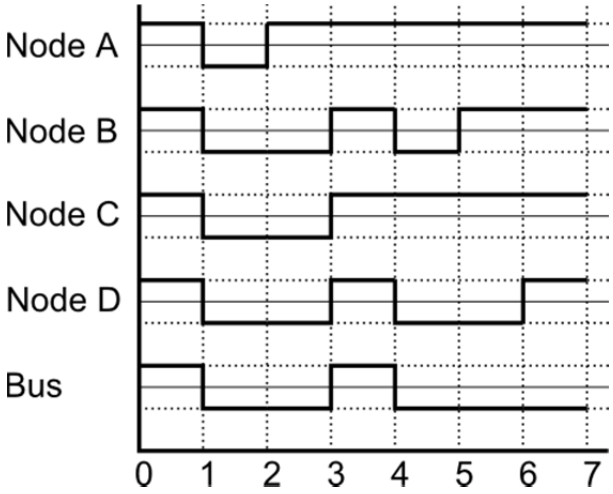



**Figure 5.3: Bus Access**

| Node | Bit 0 | Bit 1 | Bit 2 | Bit 3 | Bit 4 |
|---|---|---|---|---|---|
| A | | | | | |
| B | | | | | |
| C | | | | | |
| D | | | | | |

**Table 5.3: Identifiers of the nodes**

E) Which node is granted exclusive access to the bus?

# Task 6 Practical Aspects of Communication Systems

## Task 6.1 General Questions

A student wants to transmit data over a very long distance. Because of budget reasons, a connection with one single wire has to be used for this transmission. The transmission should use Aloha with unipolar NRZI.

A) How can clock recovery be done for the above network?

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

C) What needs to be changed in order to make the network real time capable?

# Task 6.2 Physical Layer of Customized Bus

A customized bus should code the raw data with Manchester. The voltage level on the bus is generated by an inductivity. This inductivity is driven by an open-collector that is connected to the output stage of the microcontroller. The transmission is initialized by a logical Zero (start-bit) and ended by a logical One (stop-bit).

A) What is the advantage of the induced voltage levels?

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

C) Draw the Manchester coded and raw data (information) transmitted over the wire in the following graphic. Please write down the transmitted data. The figure shows the transmission of a complete frame.

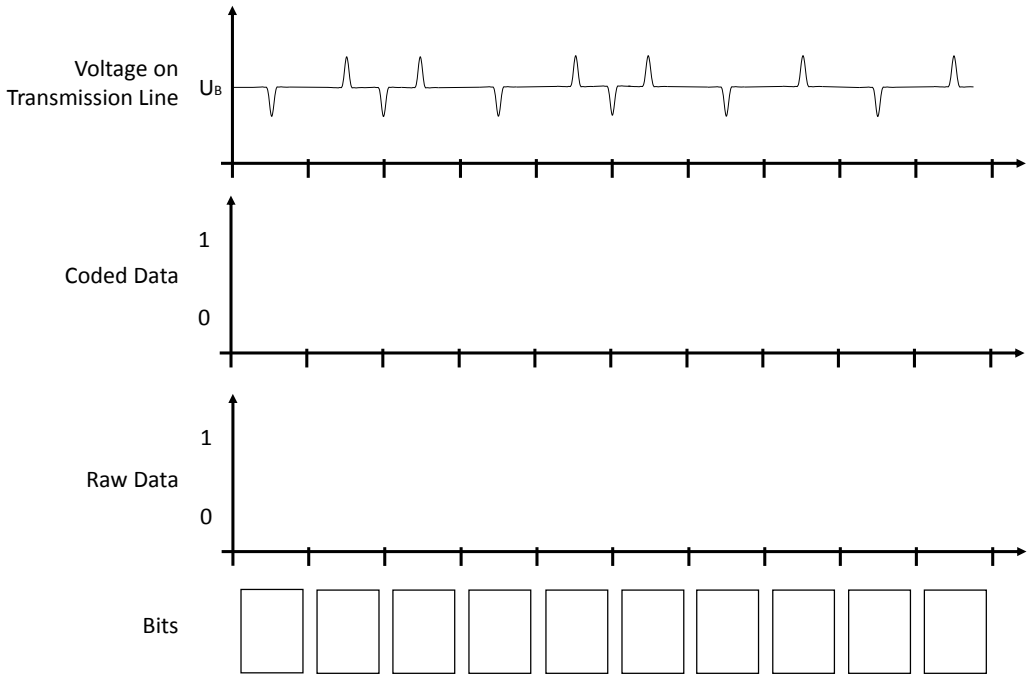


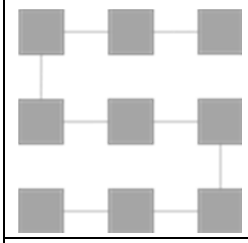
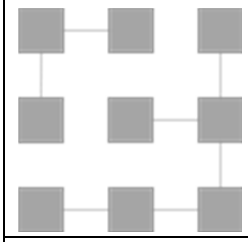
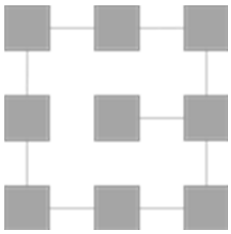
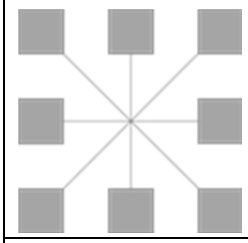
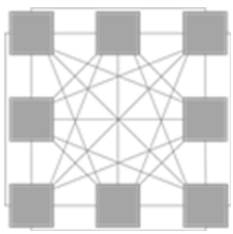

**Figure 6.1: Transmission on customized bus**

D) How can data integrity be checked purely on physical layer? (Name two)

E) Because of license reasons Manchester coding cannot be used. Why can't differential Manchester be used for the system? Please name the Problem and a possible solution.

## Task 6.3 FireWire

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 below FireWire systems are working correct. Mark the roots, if the systems are correct and all nodes starting at the same time. Give a reason, if the FireWire is not working correctly.

| | Correct | Wrong | Reason |
|---|---|---|---|
|  | | | |
|  | | | |
|  | | | |
|  | | | |
|  | | | |
|  | | | |

# Task 7 Networks

## Task 7.1 General Questions

A) Your task is to decide on which type of connection to be used in a network consisting of components in need of predictable latencies. Justify your decision.

B) Your task is to decide on which type of connection to be used in a network consisting of components that mainly communicate by streaming data, thus in need of high and guaranteed throughput. Justify your decision.

C) Name the three components of a network on chip node in the basic setup and their respective task

D) How do networks and busses differ from each other?

# Task 7.2 Routing

Figure 1 2 shows a 4x4 meshed network with bidirectional links for wormhole packet-switching communication.

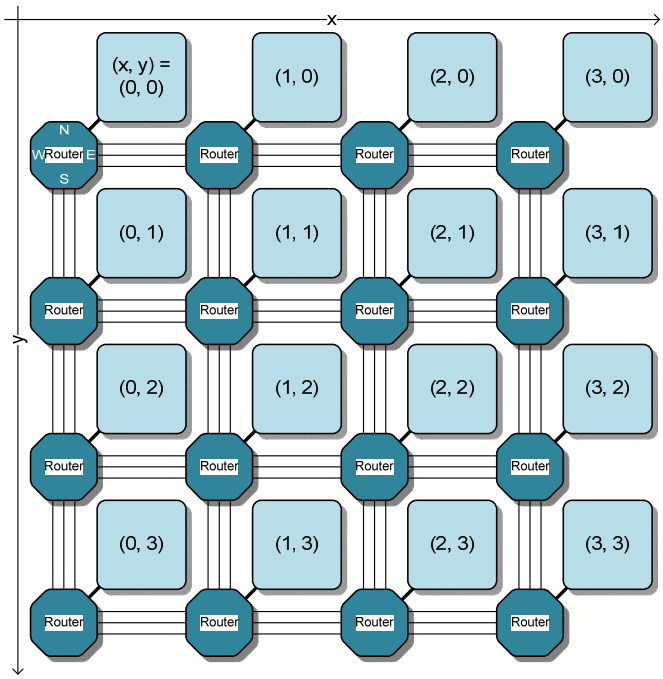



**Figure 7.1: 4x4 meshed network**

A) Which routers are passed by a packet sent from (x, y) = (1, 0) to (3, 3) using XY-Routing. Please provide the coordinates of the passed router in the order given by the transmission process.

B) The routers (1, 0) and (2, 1) are experiencing heavy traffic towards their east port, such that packets have to wait before being forwarded. As an alternative “hot potato XY-Routing” is used. If a port is occupied the opposite dimension is used, so in case of X towards Y and in case of Y towards X. If no heavy traffic is present common XY Routing is used. Which routers are passed by a packet sent from (x, y) = (1, 0) to (3, 3) for that routing

C) Which classes of routing algorithms is hot potato XY-Routing associated with?

D) Describe two scenarios: one in which common XY Routing is preferable and one in which “hot potato XY Routing”.

E) Instead of XY-Routing, Flooding is considered for the given network.
How many times is a packet forwarded when flooding is used, with router (1, 0) being the origin and router (2, 2) the destination

F) How many times is a packet forwarded by routers, using Flooding with a time to live of 2, when router (1, 0) is the origin and router (2, 2) the destination?

G) What is the minimal time to live for a packet sent by router (1,0) to reach router (2,2) ?

# Task 7.3 Communication Models

This task focuses on Communication Models like the OSI reference model.

A) The (notional) company “Simple Communications” has taken the position that layered communication models are unnecessary. Name one reason why they would fare better with a layered model and justify your answer.

B) What is the purpose of the presentation layer in the OSI reference model?

The following Latencies for data processing within each layer of the OSI reference model can be assumed for all devices in the following:

[1] Physical Layer: 1 us

[2] Data Link Layer: 10 us

[3] Network Layer: 100 us

[4] Transport Layer: 500 us

[5] Session Layer: 1 ms

[6] Presentation Layer: 1.5 ms

[7] Application Layer: 2.5 ms

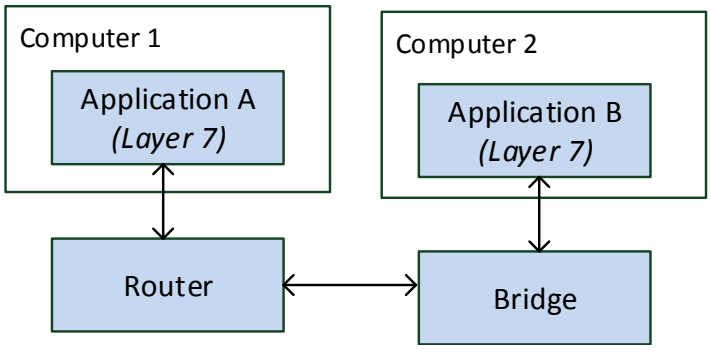



**Figure 7.2: Data Transmission Scenario**

C) Please calculate the communication latency for the router, bridge and for Computer 1. The payload size can be assumed as small. Thus, data transmission latency is assumed to be independent from the payload size.