

Task 1: Design of a bus system

You want to design a bus system that is to be used in process automation. The system has to connect multiple sensors and actuators with different controllers. In order to reduce cost and effort for the wiring a serial bus system should be used. The arbitration of the system has to work without additional wires.

A) Which arbitration schemes could be used for that purpose? Name the pros and cons

2

Token-Passing

Advantages

- fair
- real-time capable

Disadvantages

- hard to assign different priorities to individual nodes
- each node has to know its neighbor, extension is complex
- failure of one node can block the bus

CSMA/CD

Advantages

- simple scheme
- easy to extend

Disadvantages

- channel can be blocked because of many transmission requests
- bad efficiency in terms of bandwidth usage

CSMA/CA

Advantages

- no collisions on the bus
- easy to prioritize because of individual identifiers
- partly real-time capable with additional rules
- efficient use of bandwidth

Disadvantages

- length of the bus and data transmission rate are limited because of simultaneity requirement

For the next subtasks we want to use the CSMA/CA scheme.

B) Which requirements have to be fulfilled in order to guaranty a faultless function of the system? The bus has to cover a maximum distance of 400m. Calculate the maximum baud rate that is achievable if the signal speed on the line equals to $0.66 \cdot c$.

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$$\left[t_s = \frac{l}{v} \right] \ll \left[t_B = \frac{1}{TR} \right], \text{ with } l = 400m, v = 0.66 \cdot c = 0.66 \cdot 3 \cdot 10^8 \frac{m}{s}$$

$$\Rightarrow TR \ll \frac{v}{l} = \frac{0.66 \cdot 3 \cdot 10^8 \frac{m}{s}}{400m} = 495000 \frac{1}{s}$$

- C) Assume a bus system with dominant '0' and '1' as recessive level. The data format uses a frame with a Start Of Frame bit (SOF) and an identifier with eight bits. Attached to this bus are four nodes. The identifiers can be taken from Table 1.1. Using Figure 1.1, draw the

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Node	Identifier
1	00110110
2	00101100
3	10010110
4	00100111

Table 1.1: Identifiers of the nodes

impulse diagram 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 4 is granted exclusive access to the bus.

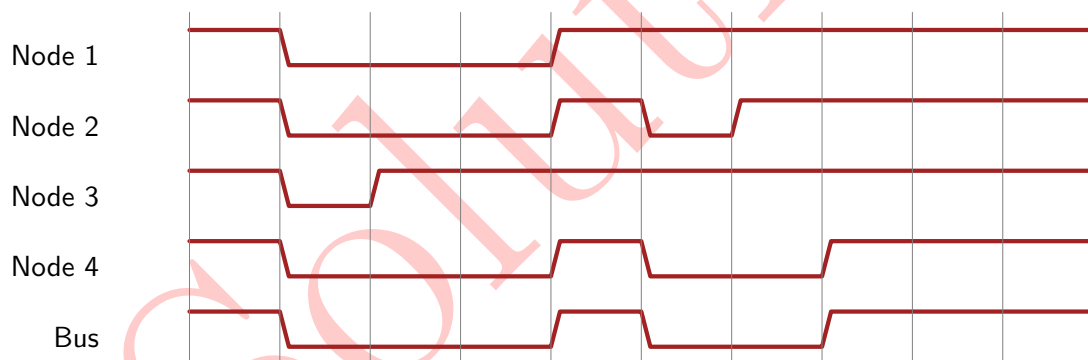


Figure 1.1: Bus Access

Task 2: Carrier Sense Multiple Access/Collision Detection (CSMA/CD)

2

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 2.1.

- 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 2.1.
- If a node willing to send detects that the bus is occupied it withdraws and waits for the time specified in Table 2.1 (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 2.1. If a node was already waiting before, its waiting time will be doubled. The waiting time is only reset to the initial value after a successful transmission of the respective node.

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

Table 2.1: Specification of nodes

- A) Fill in the signal sequence of the bus nodes, resulting from the specification as given above (use Figure 2.1). Mark waiting times and collisions that occur.

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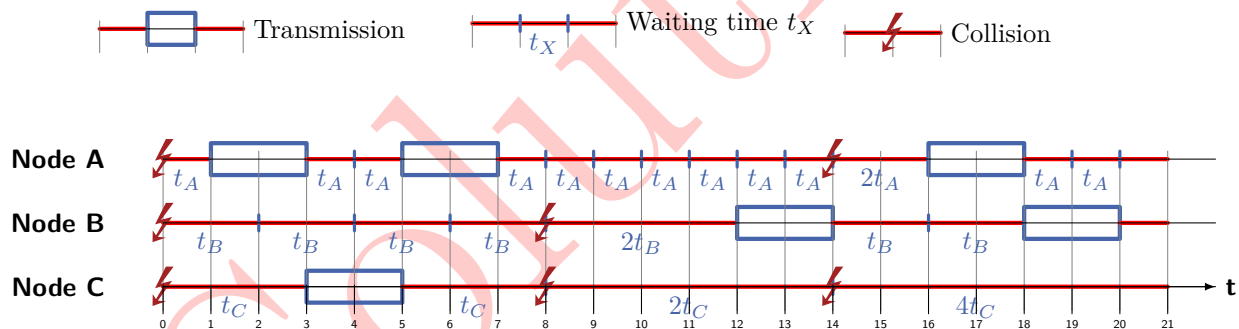


Figure 2.1: Signal sequence

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Task 3: Media Access

Task 3.1: 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 3.1
- 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 3.1.

- If a node willing to send detects that the bus is occupied it withdraws and waits for the time specified in table 3.1 (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 3.1.

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

Table 3.1: Specification of nodes

- A) Fill in the signal sequence of the bus nodes, resulting from the specification as given above (use Figure 3.1). Mark waiting times and collisions that occur.

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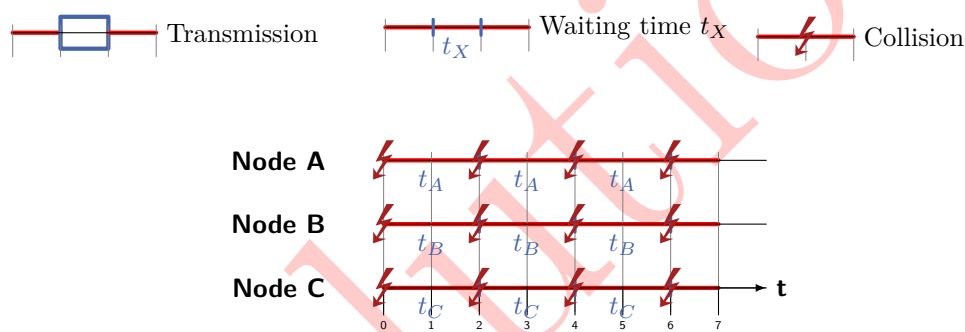


Figure 3.1: Signal sequence

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

1

Identical waiting time causes many collisions, transmitting is impossible. The waiting time has to be changed so that every node has a different waiting time.

- 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 3.2). 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 3.2). Mark waiting times and collisions that occur, label which graph should be evaluated with a cross.

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Node	Packet length	Waiting time
A	1	4
B	2	3
C	3	2

Table 3.2: Modified waiting time

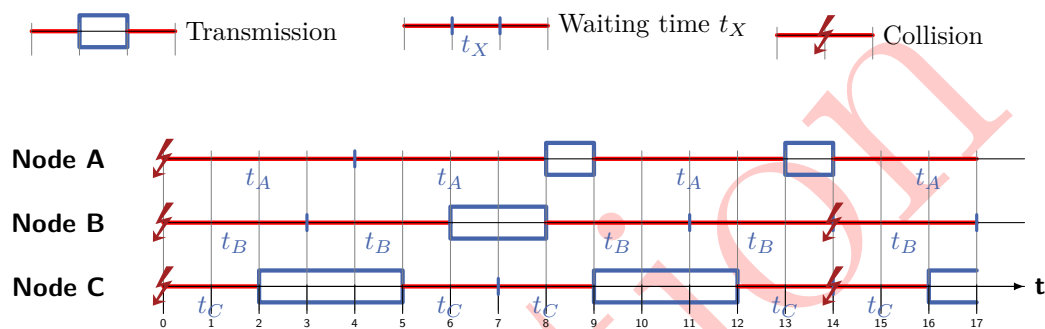


Figure 3.2: Signal sequence

Task 3.2: 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.

2

Advantages

- no collisions on the bus
- easy to prioritize because of individual identifiers
- partly real-time capable with additional rules
- efficient use of bandwidth

Disadvantages

- length of the bus and data transmission rate are limited because of simultaneity requirement

- 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?

1

The requirement of simultaneity has to be fulfilled.

The signal propagation time t_s is much smaller compared to the digit length (bit time) t_b :

$$\left[t_s = \frac{l}{v} \right] \ll \left[t_b = \frac{1}{TR} \right].$$

- C) Calculate the maximum payload data rate of this bus. Assume a propagation time of $0.66c$ ($c = 3 \cdot 10^8 \frac{m}{s}$).

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Transmission rate:

$$\left[t_s = \frac{l}{v} \right] \ll \left[t_b = \frac{1}{TR} \right] \text{ with } l = 500m, v = 0.66 \cdot 3 \cdot 10^8 \frac{m}{s}$$

$$TR \ll \frac{v}{l} = \frac{0.66 \cdot 3 \cdot 10^8 \frac{m}{s}}{500m} = 396000 \frac{1}{s}$$

Start bit + 5 bit message identifier and 10 bits data:

$$\text{payload data rate} = \frac{10}{16} \cdot TR = 247500 \frac{1}{s}$$

- D) Figure 3.3 shows a timing diagram for the bus system described above. Indicate the identifiers of the given nodes as far as possible (use Table 3.3). Mark undetermined identifiers bits as X!

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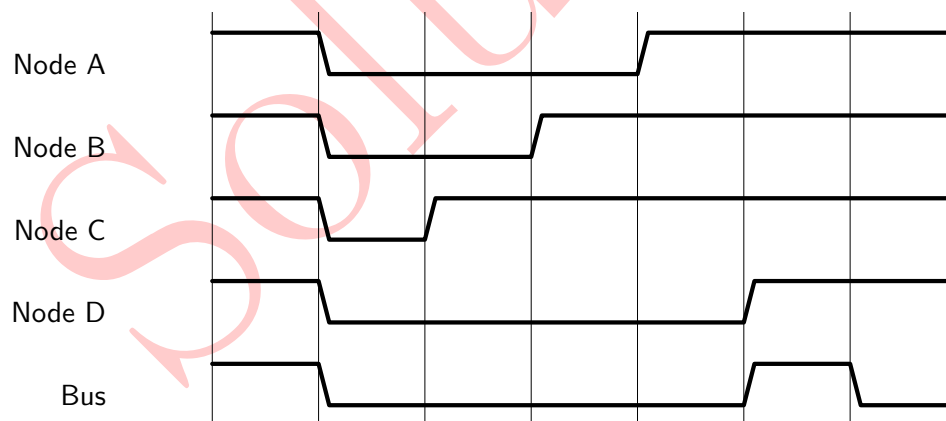


Figure 3.3: Bus Access

Node	Bit 0	Bit 1	Bit 2	Bit 3	Bit 4
A	0	0	1	X	X
B	0	1	X	X	X
C	1	X	X	X	X
D	0	0	0	1	1

Table 3.3: Identifiers of the nodes

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

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Node E (five nodes are mentioned in the task) is able to send data.

OR: No one of the four nodes A-D is allowed to send data.