Computer Networks
Jacobs University Bremen
Dr. Jürgen Schönwälder

Course: 320301
Date: 2014-09-15
Due: 2014-09-22

Problem Sheet #1

Problem 1.1: *transmission vs. propagation delay* (1 point)

Signals propagate in space with the speed of light (about $3 \cdot 10^8 \frac{m}{s}$). Electric wires (twisted pair copper cables, coax cables) achieve a signal propagation speed of about $2 \cdot 10^8 \frac{m}{s}$. Consider the transmission of a 1000 bit frame over three different channels and determine for each channel the transmission delay T_x and the propagation delay T_p. Which delay component is dominating?

a) 100 m twisted pair cable with a bit rate of 10 kbps
b) 200 km coax cable with a bit rate of 1 mbps
c) 50000 km space with a bit rate of 10 mbps

Solution:

a) 100 m twisted pair cable with 10 kbps:

$$T_p = \frac{100ms}{2 \cdot 10^8 m} = 5 \cdot 10^{-7} \qquad T_x = \frac{1000Bit\ s}{10 \cdot 10^3 Bit} = 0.1s$$

The transmission delay is dominating and the propagation delay over the short distance can be neglected.

b) 200 km coax cable with 1 mbps:

$$T_p = \frac{2 \cdot 10^5 ms}{2 \cdot 10^8 m} = 10^{-3}s \qquad T_x = \frac{1000Bit\ s}{10^6 Bit} = 10^{-3}s$$

The transmission delay and the propagation delay have the same impact.

c) 50000 km space with 10 mbps:

$$T_p = \frac{5 \cdot 10^7 ms}{3 \cdot 10^8 m} = \frac{5}{3}10^{-1}s \qquad T_x = \frac{1000Bit\ s}{10^7 Bit} = 10^{-4}s$$

The propagation delay is dominating and the transmission delay over the long distance can be neglected.

Problem 1.2: *cyclic redundancy check* (1+1 = 2 points)

A cyclic redundancy check (CRC) code with the generator polynomial $G(x) = x^5 + x^3 + x + 1$ is used to detect transmission errors.

a) Write the binary representation of $G(x)$ down. How long (in bits) is the CRC code to be appended to binary messages?
b) The binary message 1010 1001 0101 1000 should be transmitted. Compute the CRC code and show the bit sequence that is actually transmitted.

Solution:

a) $G(x)$ can be written as 101011. The length of the CRC code is 5 bits (the degree of the polynomial).

b) The calculation:

```
1010 1001 0101 1000 00000 : 101011
1010 11
-------
      101 010
      101 011
      -------
            11 1000
            10 1011
            -------
             1 0011 0
             1 0101 1
             --------
                110 100
                101 011
                -------
                 11 1110
                 10 1011
                 -------
                  1 01010
                  1 01011
                  -------
                        1
```

The message to transmit: 1010 1001 0101 1000 00001

Problem 1.3: *csma/cd media access protocol* (3+4 = 7 points)

The CSMA/CD protocol used by the classic Ethernet works as follows:

1. If the channel is idle (no signal energy for 96 bit times), start the transmission of the frame. Otherwise, wait until the channel is idle (no signal energy for 96 bit times) and then start the transmission of the frame.
2. While transmitting, monitor the presence of signal energy from other adapters. If the adapter transmits the entire frame without detecting signal energy from other adapters, the adapter is finished with the frame.
3. If the adapter detects signal energy from other adapters while transmitting, it stops transmitting and instead transmits a 48-bit jam signal.
4. After aborting (that is, transmitting the jam signal), the adapter enters an exponential backoff phase. Specifically, when transmitting a given frame, after experiencing the nth collision in a row for this frame, the adapter chooses a value for K at random from $\{0, 1, 2, \ldots 2^{m-1}\}$ where $m = min(n, 10)$. The adapter then waits $K \cdot 512$ bit times and then returns to step 1.

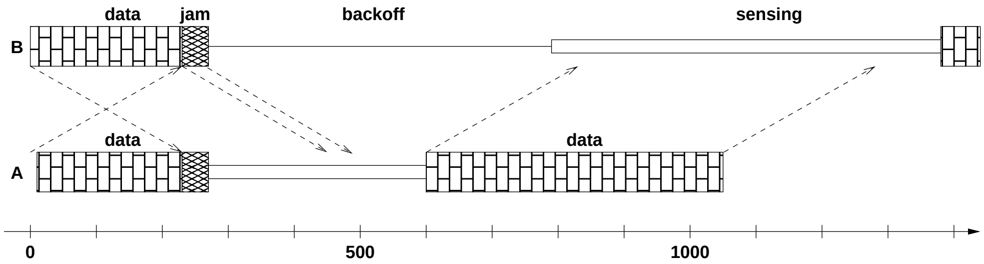
The bit time is the time needed to transmit a single bit. (For a 10 Mbps Ethernet, a bit time is 0.1 microsecond.) Recall that an Ethernet frame is at least 64 bytes long (including the header and the CRC code) and the preamble used to synchronize the receiver is 8 bytes long.

a) Suppose nodes A and B are on the same Ethernet segment and the propagation delay between the two nodes is 225 bit times. Suppose A and B send frames at time $t_0 = 0$ bit times. The frames collide and A and B finish transmitting a jam signal at $t = 225 + 48 = 273$ bit times. A and B now choose different values of K in the CSMA/CD algorithm. Suppose $K_A = 0$ and $K_B = 1$. Will the retransmissions of A and B collide again? Explain why or why not.

b) In a), we assumed that A and B start the original transmission at $t_0 = 0$ bit times so the collision of the signals happens in the middle between A and B. Suppose A sends before B such that the collision happens exactly when node B starts its transmission. Suppose A chooses $K_A = 0$ and B chooses $K_B = 1$ like in a). Will the retransmissions of A and B collide again? Explain why or why not.

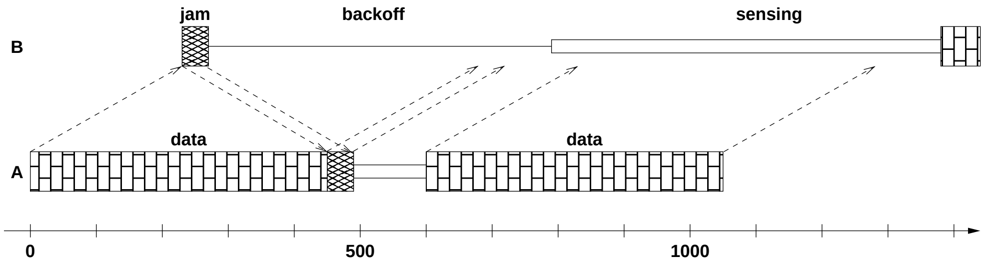
Solution:

a) Node A starts sensing the channel at $t = 273$. The channel carries B's transmission until $t = 273 + 225 = 498$. The channel is idle for 96 bit times at $t = 498 + 96 = 594$ and A starts sending the frame. With a propagation delay of 225 bit times, node B will receive A's transmission at $t = 594 + 225 = 819$.



Node B has to wait 512 bit times until $t = 273 + 512 = 785$ before starting to sense the channel. Since A's transmission is received before 96 bit times have passed, B will detect a busy channel and wait before starting its own transmission.

b) In this case, A detects the collision at bit time $t = 2 \cdot 225 = 450$ bit times and finishes transmitting a jam signal at $t = 450 + 48 = 498$. With the 96 bit times wait time, A starts retransmitting the frame at $t = 498 + 96 = 594$. Since the minimum frame size including preamble is $64 + 8$ bytes or 576 bits, A will transmit at least until $t = 594 + 576 = 1170$ if there is no further collision.



Node B starts sending at $t = 225$ and immediately detects the collision. B finishes transmitting its jam signal at $t = 225 + 48 = 273$ bit times. Node B afterwards waits 512 bit times until $t = 273 + 512 = 785$ bit times. At $t = 785$, B starts sensing the channel. A started sending data at $t = 594$ and consequently A's signal will reach B at $t = 594 + 225 = 819$, well before B can decide that the channel is free at $t = 785 + 96 = 881$. B therefore concludes that the channel is not idle and waits until A's transmission is complete before sending its own data. No second collision occurs.