521150A Introduction to Internet

Exercise 1B

Welcome to calculation exercises

In this non-mandatory part of the course, you will learn to

- answer concrete, numerical questions on the subject matter
- model different network scenarios
- use the presented algorithms and methods

Contact info for issues with these exercises

- email: lauri.haverinen@oulu.fi
- room: TS387 (prefer email for contacting)

Before the session

Complete pre-exercises in Moodle

- you will be better prepared for the exercise
- you can earn up to **1 point for final grading** (in Moodle, the points are scaled by 10)

During the session

Follow, participate and solve

- revisiting pre-exercises
- solving example problems together
- describing and going through how to solve the advanced problems

After the session

Solve the rest of the problems presented in this document

- return a scanned version (or good photo) as PDF of your hand-written solutions **with your name on it** to Moodle **before the next exercise**
- you can earn up to **0.5 points for each solved problem**, so a maximum of 1.5 points per exercise (in Moodle, the points are scaled by 10)

Pre-assignments

1. **Which of the following use odd parity? 9th (the last) bit is the parity bit.**
   a. 101101011 odd number of 1’s, odd parity bit should be 0
   b. 101010100 even number of 1’s, odd parity bit should be 1
   c. 111100011 odd number of 1’s, odd parity bit should be 0
   d. 010110110 odd number of 1’s, odd parity bit = 0
   e. 100000010 even number of 1’s, odd parity bit should be 1

2. **Which of the following use even parity? 9th (the last) bit is the parity bit.**
   a. 101101010 odd number of 1’s, even parity bit should be 1
   b. 101010101 even number of 1’s, even parity bit should be 0
   c. 111100011 odd number of 1’s, so even parity bit = 1
   d. 010110110 odd number of 1’s, even parity bit should be 1
   e. 100000011 even number of 1’s, even parity should be 0

3. **You received a 9x9 bit message that has a bit error. 9th bit of every row is the parity bit of that row. The 9th row contains parity bits of every column. Detect and correct the bit error!**

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

Pre-assignments

4. Calculate XOR for the following two 8-bit binary numbers.

1011 1110
1001 0010
↓
0010 1100

5. Encode generator polynomial x^3+1 to binary.

1*x^3 + 0*x^2 + 0*x + 1*1 => 1001

6. You are transmitting a message which can be presented as binary number 1100 0110 using CRC as error detection method with generator polynomial G=x^3+1. What is the transmitted frame, when it is formed by combining binary data and remainder?

remainder = 101, so transmitted binary is 1100 0110 101

```
           11011101
    1001)11000110000
         1001
          1010
          1001
           0111
           0000
            1111
            1001
             1100
             1001
              1010
              1001
               0110
               0000
                1100
                1001
                 101
```

Pre-assignments

7. **TDM (Time Division Multiplexing) channel has been divided into 5 time slots, one for each sender. Probability that a sender sends a packet on their own turn are shown for each sender below:**
   - **P(L1 has a packet): 1,0 (For example, the probability that L1 has a packet, which they send on their own turn is 100%)**
   - **P(L2 has a packet): 0,6**
   - **P(L3 has a packet): 0,6**
   - **P(L4 has a packet): 0,2**
   - **P(L5 has a packet): 0,1**

   What is the average efficiency of the channel (answer in range of 0,0 - 1,0)?

   There are on average 1,0+0,6+0,6+0,2+0,1=2,5 packets in the channel, divide that by amount of channels (=maximum number of packets at any given time) and you get 0,5

8. **FDM-based (Frequency Division Multiplexing) transmitter has maximum throughput (channel capacity) of 1Mbps. The transmitter uses four carriers, one for each sender:**
   - **L1 has bit rate of 10kbps**
   - **L2 has bit rate of 160kbps**
   - **L3 has bit rate of 30kbps**
   - **L4 has bit rate of 200kbps**

   Therefore, the channel does not have 100 % efficiency. What is the effective throughput (actually achieved throughput) of the channel (in Mbps)?

   10 kbps + 160 kbps + 30 kbps + 200 kbps = 400 kbps = 0,4 Mbps

Problem #3

Error detection

a) You have received a 9x9 bit message presented on the right. You notice that it has a bit error. 9th bit of every row is the even parity bit of that row and the 9th row contains even parity bits of every column. Detect and correct the bit error.

b) The following 8 bit messages have no errors. Which of them use even parity? 9th bit is the parity bit.

   i. 111111110
   ii. 000000001
   iii. 101010101
   iv. 010101010

c) You are transmitting a command to a wireless tag. To make sure that it is received correctly, you decide to use CRC-5 to detect possible errors. The command data can be presented as binary number 10101011, and the RFID protocol defines that the generator polynomial used is x^5+x^3+1. What is the transmitted data frame, when it is formed by combining binary data and the remainder?

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

Problem #4

Consider an error-free 64 kbps satellite channel used to send 512 byte data frames in one direction, with very short acknowledgments (their transmission time is negligible) going back other way. The earth-satellite propagation time is 270 ms. Determine the maximum throughput and link utilisation for window sizes:

a) Stop-and-wait flow control (one frame in transit at any time, source waits for ACK before sending next frame)

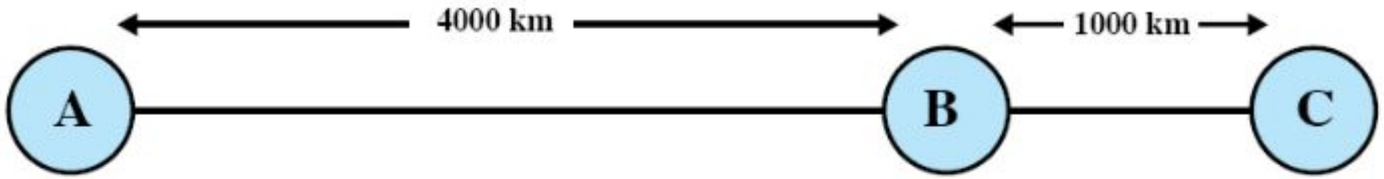
b) Continuous flow control with window size of 7 frames (transmitter can send up to 7 frames without ACK)

c) Continuous flow control with window size of 127 frames (transmitter can send up to 127 frames without ACK)

Problem #5

Consider the figure below where frames are generated at node A and sent to node C through node B. Determine the minimum data rate required in the link between nodes B and C so that the buffers of node B are not flooded given the following

- The data rate in the link between A and B is 200 kbps.
- The propagation delay is 5 μs/km in both links.
- The links are full duplex.
- All data frames are 2000 bits long.
- ACK frames are separate frames of negligible length.
- Between A and B, sliding window protocol with a window size of 3 is used.
- Between B and C, stop-and-wait protocol is used.
- There are no errors.



Problems 1B

Amount of 1's in message	Even parity bit	Odd parity bit
0	0	1
odd	1	0
even	0	1

$$d_{transmission} = \frac{message\ length\,(bits)}{link\ data\ rate\,(bps)} = \frac{L}{R}$$

$$d_{propagation} = \frac{link\ length\,(m)}{propagation\ speed\,(m/s)} = \frac{d}{v}$$

$$link\ utilization\ U = \frac{1}{1+2a}$$

$$a = \frac{frame\ propagation\ time\,(s)}{frame\ transmission\ time\,(s)} = \frac{T_p}{T_t}$$

$$throughput = \frac{window\ size\,(bits)}{round-trip-time\,(s)}$$

Problem #3: Error detection

a) You have received a 9x9 bit message presented on the right. You notice that it has a bit error. 9th bit of every row is the even parity bit of that row and the 9th row contains even parity bits of every column. Detect and correct the bit error.

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

b) The following 8 bit messages have no errors. Which of them use even parity? 9th bit is the parity bit.
- i) 111111110
- ii) 000000001
- iii) 101010101
- iv) 010101010

c) You are transmitting a command to a wireless tag. To make sure that it is received correctly, you decide to use CRC-5 to detect possible errors. The command data can be presented as binary number 10101011, and the RFID protocol defines that the generator polynomial used is x^5+x^3+1. What is the transmitted data frame, when it is formed by combining binary data and the remainder?

Problem #4: Consider an error-free 64 kbps satellite channel used to send 512 byte data frames in one direction, with very short acknowledgments (their transmission time is negligible) going back other way. The earth-satellite propagation time is 270 ms. Determine the maximum throughput and link utilisation for window sizes:

a) Stop-and-wait flow control (one frame in transit at any time, source waits for ACK before sending next frame)

b) Continuous flow control with window size of 7 frames (transmitter can send up to 7 frames without ACK)

c) Continuous flow control with window size of 127 frames (transmitter can send up to 127 frames without ACK)

Tips for #3

a, b) check the top table to refresh your memory on how parity bits are defined

c) Check pre-assignments 5 & 6 and example b) on how to solve the remainder using long division and generator polynomial

Tips for #4

a) Link utilization: propagation time given -> calculate transmission time -> calculate a => calculate U

Throughput: transferred data / round-trip-time (notice ACK propagation!)

b) Link utilization: U=7*...

c) Link utilization: U=127*... Notice link data rate!

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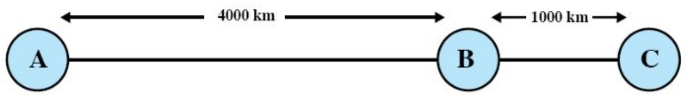


Tips for #5

- calculate transmission time for one frame from A
- calculate propagation time for A-B
- calculate RTT (round-trip-time) for A-B
- calculate throughput for A-B
- B-C uses stop-and-wait, so it would have to transmit frames as soon as they arrive
- solve frame transmission time (from throughput equation) -> solve minimum data rate

Examples

Amount of 1's in message	Even parity bit	Odd parity bit
0	0	1
odd	1	0
even	0	1

$$d_{transmission} = \frac{message\ length\,(bits)}{link\ data\ rate\,(bps)} = \frac{L}{R}$$

$$d_{propagation} = \frac{link\ length\,(m)}{propagation\ speed\,(m/s)} = \frac{d}{v}$$

$$link\ utilization\ U = \frac{1}{1+2a}$$

$$a = \frac{frame\ propagation\ time\,(s)}{frame\ transmission\ time\,(s)} = \frac{T_p}{T_t}$$

$$throughput = \frac{window\ size\,(bits)}{round-trip-time\,(s)}$$

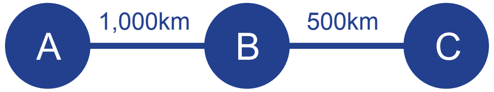
Problems

a) The following 8-bit long messages have no errors. What parity is used for their error correction?
   - i) 100000001
   - ii) 110000001
   - iii) 111000001
   - iv) 111111111
   - v) 000000001

b) You are transmitting a binary message 10101010 using CRC with generator polynomial x^5+x^2+1 for error detection. What is the transmitted data frame containing the message and error detection bits (remainder)?

c) A 56kbps link is used to send 128 byte data frames in one direction. Acknowledgements to those frames are very short so their transmission time can be ignored. The propagation time in the link is 100 ms. What is the maximum throughput and link utilization, when
   - i) stop-and-wait flow control is used?
   - ii) continuous flow control (sliding window) with window size 5 is used?
   - iii) continuous flow control with window size of 1,000 frames is used?

d) Computer A generates continuously 1 kb long data frames and sends them to computer C through router B. Data rate in the link A-B is 1Mbps, so what is the minimum data rate required for link B-C so that buffer in B will not be flooded. Assume the following:
   - links are full duplex
   - propagation delay is 2µs/km in both links
   - ACK frames are small so their transmission delay can be ignored
   - stop-and-wait protocol is used in both links
   - there are no errors



Solutions

a) check the table above to refresh your memory on how parity bits are defined
   - i) even parity
   - ii) odd parity
   - iii) even parity
   - iv) odd parity
   - v) odd parity

b) generator polynomial in binary form is 100101, so remainder is 11000 (solved on right). The transferred data consisting of both message 10101010 and error detection bits 11000 is 1010 1010 1100 0.

```
              101  1100  0
100101)1010  1010  0000  0
       1001  01
        011  111
        000  000
         11  1110
         10  0101
          1  1011  0
          1  0010  1
             1001  10
             1001  01
              000  110
              000  000
               00  1100
               00  0000
                0  1100  0
                0  0000  0
                   1100  0
```

c)

i)
$$Utilization = \frac{1}{1+2\left(\frac{100\cdot 10^{-3}\ s}{128\ B\cdot 8/56\ kbps}\right)} = \frac{1}{1+2\left(\frac{100\cdot 10^{-3} s}{1{,}024\ b/56{,}000\ bps}\right)} = \frac{1}{1+2\left(\frac{100\cdot 10^{-3}}{18.3\cdot 10^{-3}}s\right)} \approx 0.084$$

$$Throughput = \frac{128\ B\cdot 8}{18.3\cdot 10^{-3}\ s + 2\cdot 100\cdot 10^{-3} s} = \frac{1{,}024\ b}{218.3\cdot 10^{-3} s} \approx 4691\ bps \approx 4.7\ kbps$$

ii)
$$Utilization = 5\cdot\frac{1}{1+2\left(\frac{100\cdot 10^{-3}\ s}{128\ B\cdot 8/56\ kbps}\right)} = \frac{5}{1+2\left(\frac{100\cdot 10^{-3} s}{1{,}024\ b/56{,}000\ bps}\right)} = \frac{5}{1+2\left(\frac{100\cdot 10^{-3}}{18.3\cdot 10^{-3}}s\right)} \approx 0.42$$

$$Throughput = \frac{5\cdot 128\ B\cdot 8}{18.3\cdot 10^{-3}\ s + 2\cdot 100\cdot 10^{-3} s} = \frac{5{,}120\ b}{218.3\cdot 10^{-3} s} \approx 23{,}455\ bps \approx 23.5\ kbps$$

iii)
$$Utilization = \frac{1{,}000\cdot 1}{1+2\left(\frac{100\cdot 10^{-3}\ s}{128\ B\cdot 8/56\ kbps}\right)} \approx 84 \text{ which is } > 1\text{, so } U = 1 \text{ and throughput} = 56\ kbps$$

d)
$$RTT_{AB} = T_t + 2T_p = \frac{1{,}000\ b}{1\ Mbps} + 2\cdot 1{,}000\ km\cdot 2\ \mu s/km = 0.005\ s, \quad throughput_{AB} = \frac{1{,}000\ b}{0.005\ s} = 200{,}000\ bps$$

B-C uses stop-and-wait, so it would have to transmit frames as soon as they arrive. the throughput of B-C has to be equal or greater than A-B throughput

$$throughput_{BC} = \frac{1{,}000\ b}{T_t + 2\cdot 500\ km\cdot 2\ \mu s/km} = 200{,}000\ bps \Rightarrow T_t = 0.003\ s = \frac{1{,}000\ b}{x\ bps} \Rightarrow x = 333{,}333.333\ bps \approx 333.3\ kbps$$