In-person session

We will teach the last exercise session (03.06.2021) at ETH as well as online via Zoom.

In the coming days you will receive a Doodle link via email. Please register for the in-person session (max 50 students).

The Q&A session before the exam will also be in-person, more details follow later.
Communication Networks

Exercise 10

Transport project (with demo)

Overview current assignment

Solutions will be published next week
Soon the first week is over

<table>
<thead>
<tr>
<th>Part 1</th>
<th>Complete a simple Go-Back-N implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.05.2021</td>
<td>Retransmit all packets after a timeout</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 2</th>
<th>Add support for Selective Repeat</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.05.2021</td>
<td>Fast retransmission after duplicated ACKs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 3</th>
<th>Add support for Selective Acknowledgements (SACK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>04.06.2021</td>
<td>SACK contains blocks of correctly received segments</td>
</tr>
</tbody>
</table>

| Bonus | Implement your own congestion control algorithm |
Sequence number overflow

<table>
<thead>
<tr>
<th>NBITS</th>
<th>controls the maximum sequence number</th>
</tr>
</thead>
<tbody>
<tr>
<td>maximum</td>
<td>assuming NBITS=3: $2^{NBITS} - 1 = 7$</td>
</tr>
<tr>
<td>overflow</td>
<td>... 5, 6, 7, 0, 1, 2, ...</td>
</tr>
<tr>
<td>application examples</td>
<td>ACK number, SACK header blocks, retransmission, ...</td>
</tr>
</tbody>
</table>
The Go-Back-N sender waits for a timeout before segments are retransmitted.

- **Sent segments:** 0 1 2 3 4 5
- **Receiver behavior:** 0 - 2 3 4 5
  - Out-of-order segments are dropped
- **Sent ACKs:** 1 - 1 1 1 1 1

**Retransmission:**
The Go-Back-N sender waits for a **timeout** before segments are retransmitted.

- **Sent segments:** 0 1 2 3 4 5
- **Receiver behavior:** 0 - 2 3 4 5
  - Out-of-order segments are **dropped**
- **Sent ACKs:** 1 - 1 1 1 1
- **Retransmission:**
  - **timeout**
Selective Repeat can increase the performance

Sent segments:  0 1 2 3 4 5

Receiver behavior:  0 - 2 3 4 5  Out-of-order segments are buffered

Sent ACKs:  1 - 1 1 1 1 1

Retransmission:
Selective Repeat can increase the performance.
Selective Repeat can increase the performance
For SACK we need an *optional* header

Maximal 3 SACK blocks in the optional header
SACK example - Receiver

Correctly received segments: 0, 1, 2

Buffered out-of-order segments: 4, 5, 8, 10, 11, 12, 13, 15, 16, 17

Mandatory header:

SACK header:
SACK example - Receiver

Correctly received segments: 0, 1, 2

Buffered out-of-order segments: 4, 5, 8, 10, 11, 12, 13, 15, 16, 17

Mandatory header: ACK number: 3

SACK header:
SACK example - Receiver

Correctly received segments: 0, 1, 2

Buffered out-of-order segments: 4, 5, 8, 10, 11, 12, 13, 15, 16, 17

Mandatory header: ACK number: 3

SACK header:

<table>
<thead>
<tr>
<th>#blocks</th>
<th>start b1</th>
<th>size b1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Padding</td>
<td>start b2</td>
<td>size b2</td>
</tr>
<tr>
<td>Padding</td>
<td>start b3</td>
<td>size b3</td>
</tr>
</tbody>
</table>
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<th>2</th>
</tr>
</thead>
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<td>size b2</td>
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Buffered out-of-order segments: 4, 5, 8, 10, 11, 12, 13, 15, 16, 17

Mandatory header: ACK number: 3

SACK header:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
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SACK example - Sender

Receiver SACK header:

<p>| | | |</p>
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</tr>
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ACK number: 3

ACK - block 1:
block 1 - block 2:
block 2 - block 3:
after block 3:
SACK example - Sender

Receiver SACK header:

<table>
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<th></th>
<th>3</th>
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<th>2</th>
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Receiver SACK header:

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ACK number: 3

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block 2 - block 3:

after block 3:
SACK example - Sender

Receiver SACK header:

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<td>Padding</td>
<td>10</td>
<td>4</td>
</tr>
</tbody>
</table>

ACK number: 3

ACK - block 1:

block 1 - block 2:

block 2 - block 3:

after block 3:

3

6, 7

9
SACK example - Sender

Receiver SACK header:

<table>
<thead>
<tr>
<th></th>
<th>3</th>
<th>4</th>
<th>2</th>
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</tr>
<tr>
<td>Padding</td>
<td>10</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

ACK number: 3

ACK - block 1:
3

block 1 - block 2:
6, 7

block 2 - block 3:
9

after block 3:
no retransmission
Let’s see how we can use Git to collaborate and remotely edit your files on the VM

Watch the live session or the recorded video!
Transport project (with demo)

**Overview current assignment**

Solutions will be published next week
Task 1: TCP Warm-up

True/false question from the 2019 exam

In the exam, you cannot give an explanation

Every wrong answer results in a point deduction!
Task 2: Fairness

Consider the situation in which two hosts, A and B, are concurrently using a 1 Mbps link with a Maximum Segment Size (MSS) of 100 kb. Assuming that B starts with 500 kbps and A with 200 kbps (see left picture). Describe the evolution of the throughput of the two hosts when:

a) A and B rely on Additive Increase Multiplicative Decrease (AIMD).

b) A and B rely on Multiplicative Increase Additive Decrease (MIAD).

Assume now that only A is malicious, and wants to cheat congestion control to get more throughput. Describe two distinct ways A could do so and what would be the net effect on B’s throughput.

10.3 Congestion Window

Consider the following plot which depicts the evolution of the TCP congestion window of the sender.

What kind of network conditions is this flow seeing? Describe briefly:

a) What happens at point B?

b) Does the event happening at point B require the network to discard packets? Why or why not?

c) What happens at point E?

d) Does the event happening at point E require the network to discard packets? Why or why not?

Compare slides 04b page 52+
Task 3: Congestion Window

Hint: TCP performs a Three-Way-Handshake at the beginning

10.2 Fairness
A’s throughput
B’s throughput

1
0.5

Are you getting a fair share?

Consider the situation in which two hosts, A and B, are concurrently using a 1 Mbps link with a Maximum Segment Size (MSS) of 100 kb. Assuming that B starts with 500 kbps and A with 200 kbps (see left picture). Describe the evolution of the throughput of the two hosts when:

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Assume now that only A is malicious, and wants to cheat congestion control to get more throughput. Describe two distinct ways A could do so and what would be the net effect on B’s throughput.

10.3 Congestion Window
Consider the following plot which depicts the evolution of the size of the TCP congestion window of the sender.

Hint: TCP performs a Three-Way-Handshake at the beginning
Task 4: Drawing practice (Exam 2018)

Goal: Draw the CWND given a changing link capacity

Part of the correct CWND
Task 4: Reaction if link capacity is exceed by at most 2kB

We assume that we would receive 3 duplicates in this case
Task 4: Reaction if link capacity is exceed by more than 2kB

We assume that we reach a timeout.

Consider that the Maximum Segment Size (MSS) of the connection is 1 kB and the Round-Trip Time (RTT) between the two end points is 100 milliseconds. The sender opens the connection at time $t = 0$. Transmission delay in this network is negligible, so you should only consider the propagation delay in the following.

- How much time has elapsed at point A?
- How much time has elapsed between point C and D?
- How much time has elapsed between point F and point G?

Briefly explain how come point D is higher than point B. Would you expect this to happen often?

10.4 Drawing practice

(Exam Question 2018)

Will receive 3 duplicate ACKs Will reach timeout

$\text{ssthresh} = \frac{\text{cwnd}}{2}$

$cwnd = 1$
Transport project (with demo)

Overview current assignment

Solutions will be published next week