TCP Protocol Specification

CPSC 441 - TUTORIAL 6

WINTER 2020

UNIVERSITY OF CALGARY

*Modified from slides by Reza Gholizadeh

What is TCP?

Transmission **C**ontrol **P**rotocol

Connection-Oriented and Reliable transport layer protocol

Features

Connection-Oriented

Byte Order Preservation

Flow and Congestion control

Reliability

TCP Header

10 requiring fields totaling 160 bits in size.

Options field is optional!

<table>
<tr><th>offset (bits)</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th><th>27</th><th>28</th><th>29</th><th>30</th><th>31</th></tr>
<tr><td><b>0</b></td><td colspan="16">Source Port Number</td><td colspan="16">Destination Port Number</td></tr>
<tr><td><b>32</b></td><td colspan="32">Sequence number</td></tr>
<tr><td><b>64</b></td><td colspan="32">Acknowledgment number (if ACK set)</td></tr>
<tr><td><b>96</b></td><td colspan="4">Data offset</td><td colspan="4">Reserved</td><td>C
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<tr><td><b>128</b></td><td colspan="16">Checksum</td><td colspan="16">Urgent pointer (if URG set)</td></tr>
<tr><td><b>160
…</b></td><td colspan="32">Options (if <i>data offset</i> > 5. Padded at the end with "0" bytes if necessary.)</td></tr>
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Source and **Destination Ports**

- Communication endpoints for sending and receiving data

Sequence number

- The accumulated sequence number of the first data byte of this segment
- Initial sequence number is random (When SYN is set)

Acknowledgment number

- Contains the next sequence number that the sender of ACK expects to receive. It acts as a receipt of all bytes in the previous segment (Works when ACK is set)

Data offset

- Represents the number 32-bit words in the TCP header. It should be 5 words at least and 15 words at most

TCP Header

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Reserved

- Should be set to zero

Flags

- CWR/ECE: Congestion Window Control
- URG: Shows that **Urgent pointer** field is active
- ACK: Indicates that **Acknowledgment** field is significant
- PSH: Activates **Push** function. Asks to push the buffered data to the receiving application
- RST: **Reset** the connection
- SYN: **Synchronize** sequence numbers (Only first packets of each end should have this flag set)
- FIN: Data from the sender is **Finished**

TCP Header

10 requiring fields totaling 160 bits in size.

Options field is optional!

offset (bits)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
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Window Size

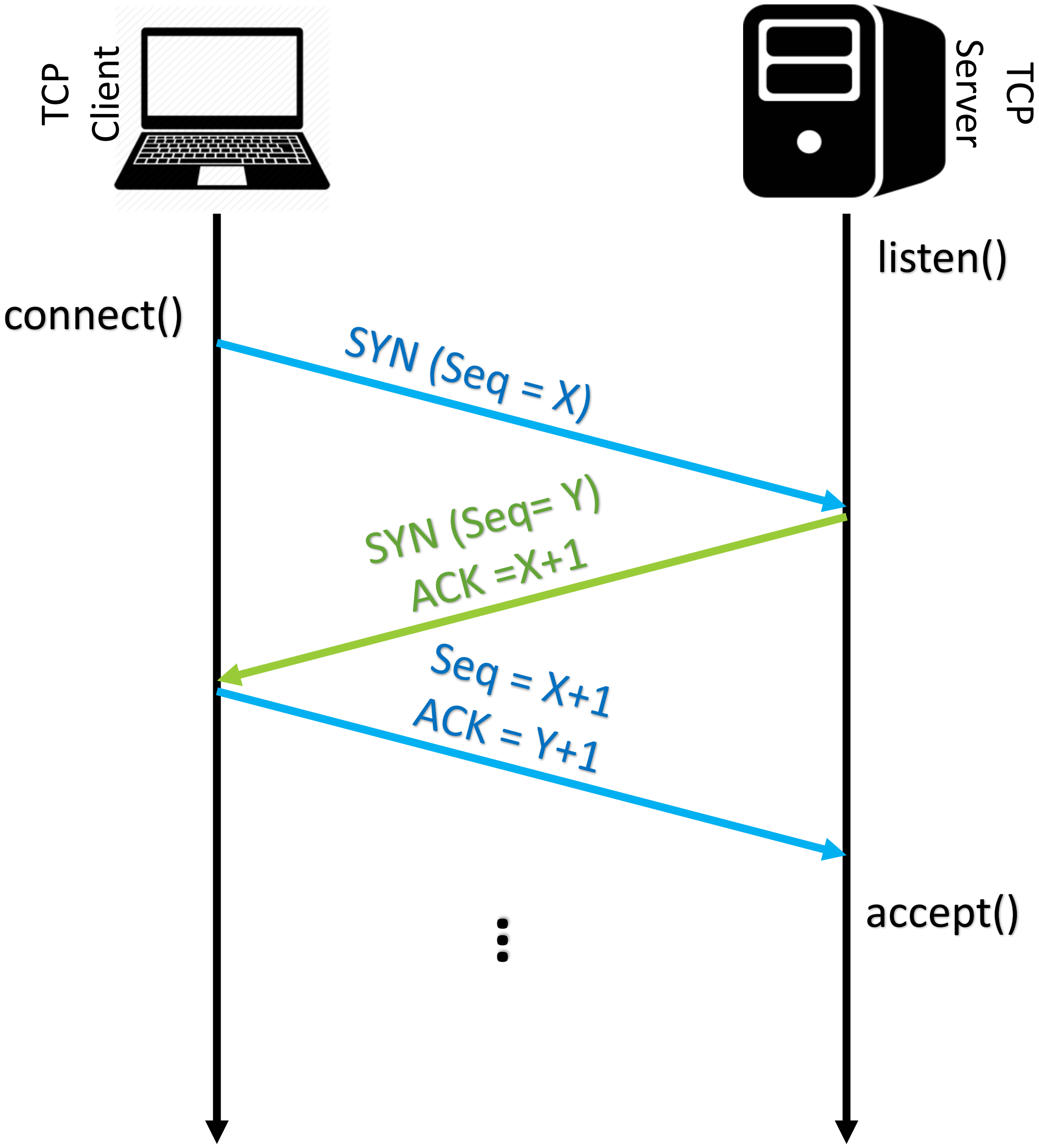
- The number of bytes that the receiver is currently willing to receive

Checksum

- Used for error checking of the header and data

Urgent pointer

- Is an offset from the sequence number indicating the last urgent data byte

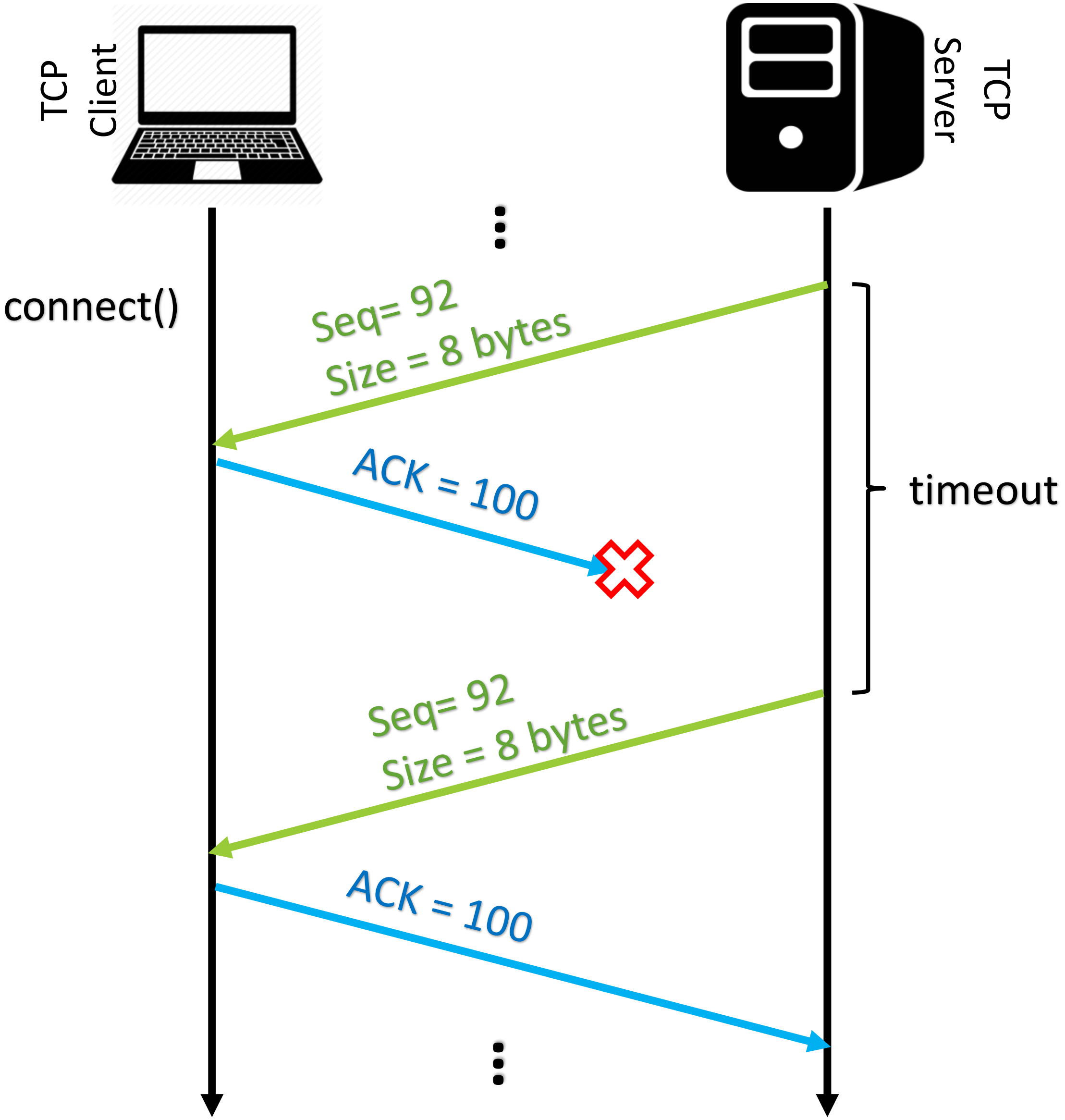


3-Way Handshake

Client sends SYN packet with initial sequence number of X

Server responds with its own SYN packet with initial sequence number of Y and acknowledgment number of X+1 (which is next expected byte)

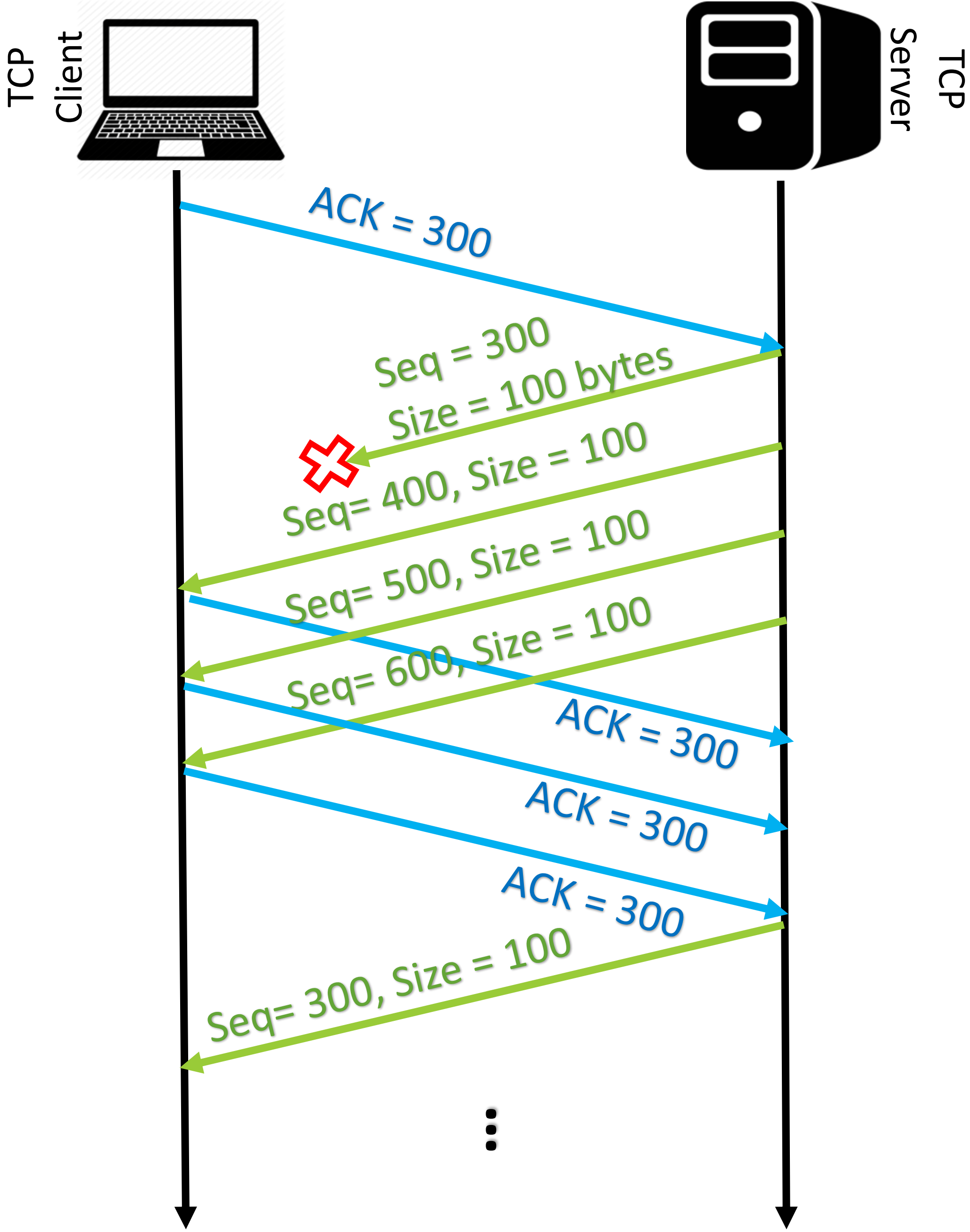
Client send a packet with sequence number of X+1 and acknowledgment number of Y+1



Retransmission Time-Out

Lost ACK Scenario:

- Sender sends a packet with data and waits for the receiver’s ACK
- Receiver send the ACK but somehow the packet is lost
- After waiting for a specific **amount of time** and not getting the ACK, sender retransmit the same packet of data. The event is called a **Retransmission Time-Out** (RTO)
- Receiver sends the ACK again



Fast Retransmission

Receiver expects N, gets N+1:

- Immediately sends ACK(N)
- This is called a duplicate ACK
- Does NOT delay ACKs here!
- Continue sending dup ACKs for each subsequent packet (not N)

Sender gets 3 duplicate ACKs:

- Infers N is lost and resends
- 3 is chosen so out-of-order packets don’t trigger Fast Retransmit accidentally
- Called “fast” since we don’t need to wait for a full RTT

Connection Termination

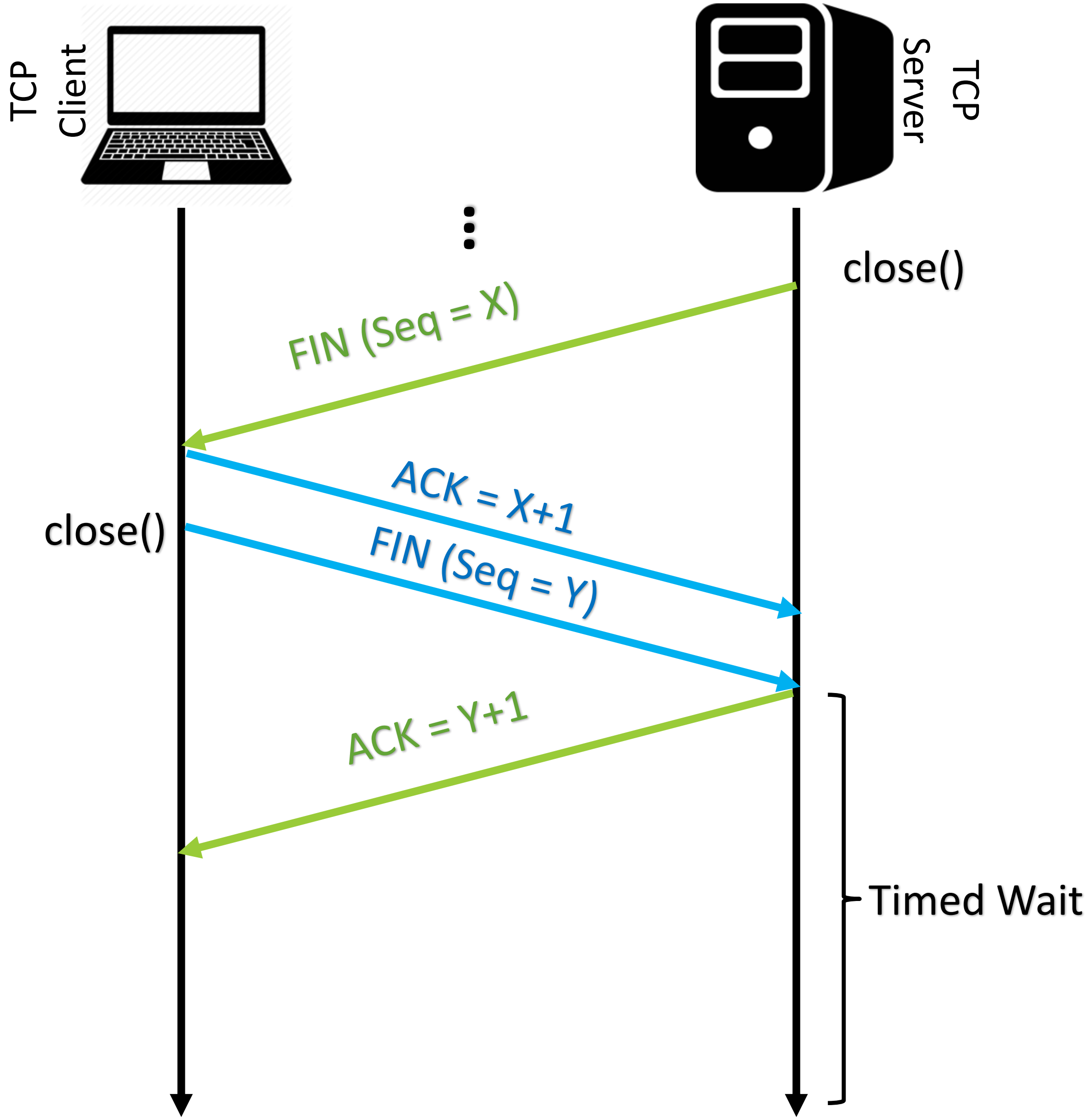
Either side may terminate a connection. (In fact, connection can stay half-closed.) Let's say the server closes (typical in WWW)

Server sends FIN with seq Number (SN+1) (i.e., FIN is a byte in sequence)

Client ACK's the FIN with SN+2 ("next expected")

Client sends it's own FIN when ready

Server ACK's client FIN as well with SN+1



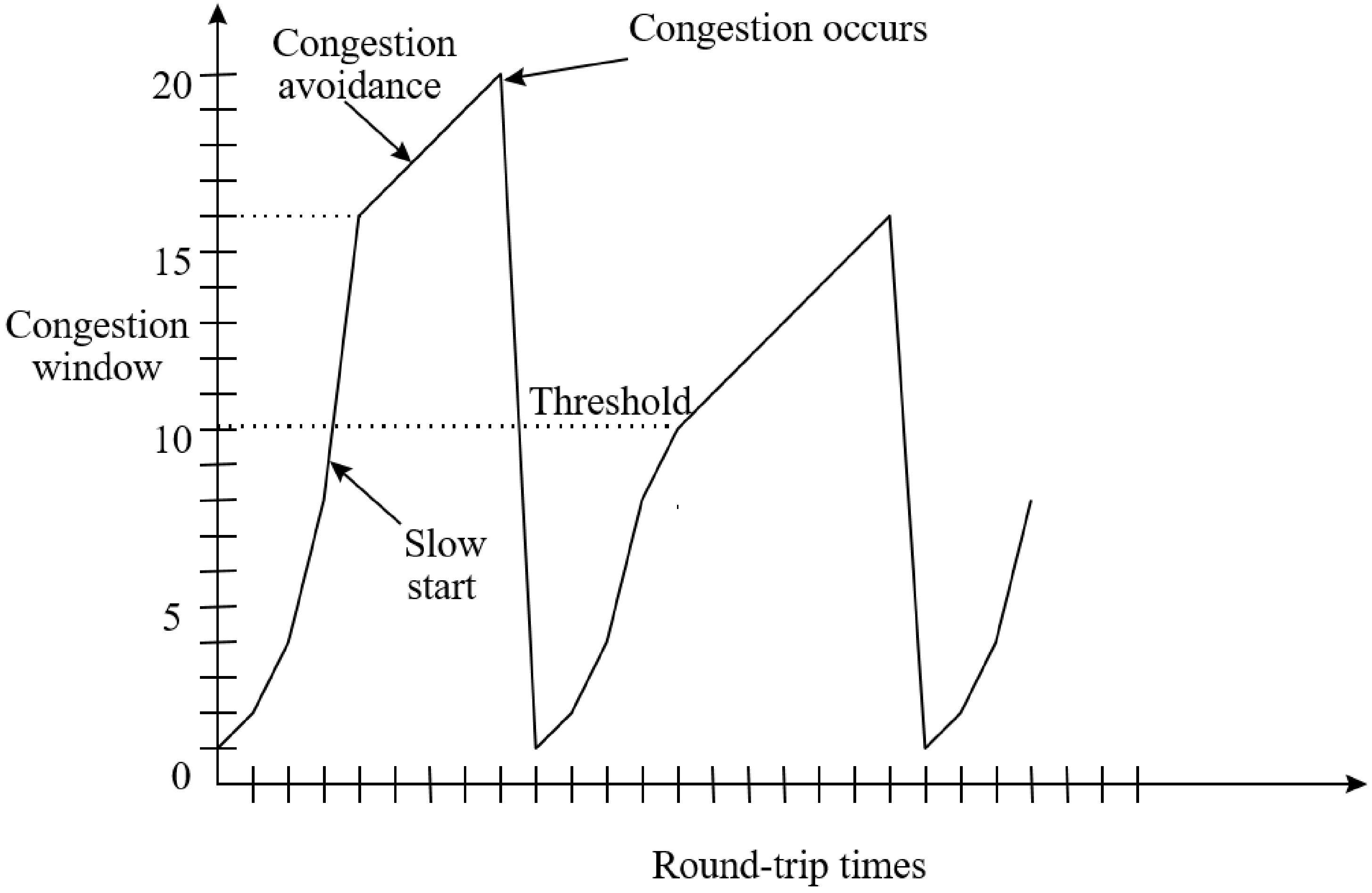
Congestion Control

Server perceives that there is congestion if:

- Timeout happens or
- The receipt of three duplicate ACKs

So then:

- It decreases the rate
- When it gets ACKs, starts increasing rate again



Congestion Control Algorithm

Three major components:

Slow start (mandatory)

Congestion avoidance (mandatory)

Fast recovery

We go to this state, when 3 duplicate ACKS happens

Timer in C

Library:
`#include <time.h>`

Function:
`clock()`

`CLOCKS_PER_SEC`

```
void setTimeout(int milliseconds)
{
     if (milliseconds <= 0)
     {
          printf("Count milliseconds for timeout is less or equal to
          0\n");
          return;
     }
     // a current time of milliseconds
     int milliseconds_since = clock() * 1000 / CLOCKS_PER_SEC; //
     needed count milliseconds of return from this timeout
     int end = milliseconds_since + milliseconds;
     // wait while until needed time comes
      do {
          milliseconds_since = clock() * 1000 / CLOCKS_PER_SEC;
      } while (milliseconds_since <= end);
 }
```

```
//c
void wait(long seconds)
{
 sleep(seconds);
}
```

Timer in C++

Library:
`#include <time.h>`

Function:
`clock()`

Type:
`clock_t`

`CLOCKS_PER_SEC`

```
void setTimeout(int milliseconds)
{
     clock_t start, end;

     // a current time of milliseconds
     clock_t start = clock() * 1000 / CLOCKS_PER_SEC;
     int gap;
      do {
          end = clock() * 1000 / CLOCKS_PER_SEC;
          gap = (int) end-start;
     } while (gap < milliseconds);
 }
```

```
//waits for 1 second or 1000 milliseconds
//c++
void wait(long seconds)
{
 seconds = seconds * 1000;
 Sleep(seconds);
}
```

Multi-process/multi-thread

C Programming:

`fork`

C++ Programming:

`thread`

```
#include <stdio.h>
#include <string.h>
#include <sys/types.h>

void main(void)
{
  pid_t pid;
  int i;
  fork();
  pid = getpid();
  if (pid>0)
  {
     for (i = 1; i <= 10; i++)
     {
          printf("This line is from pid %d\n", pid);
     }
  }
  else
  {
          printf("This line is from the parent process\n");
  }
}
```

References

https://en.wikipedia.org/wiki/Transmission_Control_Protocol

https://www.tutorialspoint.com/c_standard_library/time_h.htm

http://www.cplusplus.com/forum/general/8255/

http://www.cplusplus.com/reference/thread