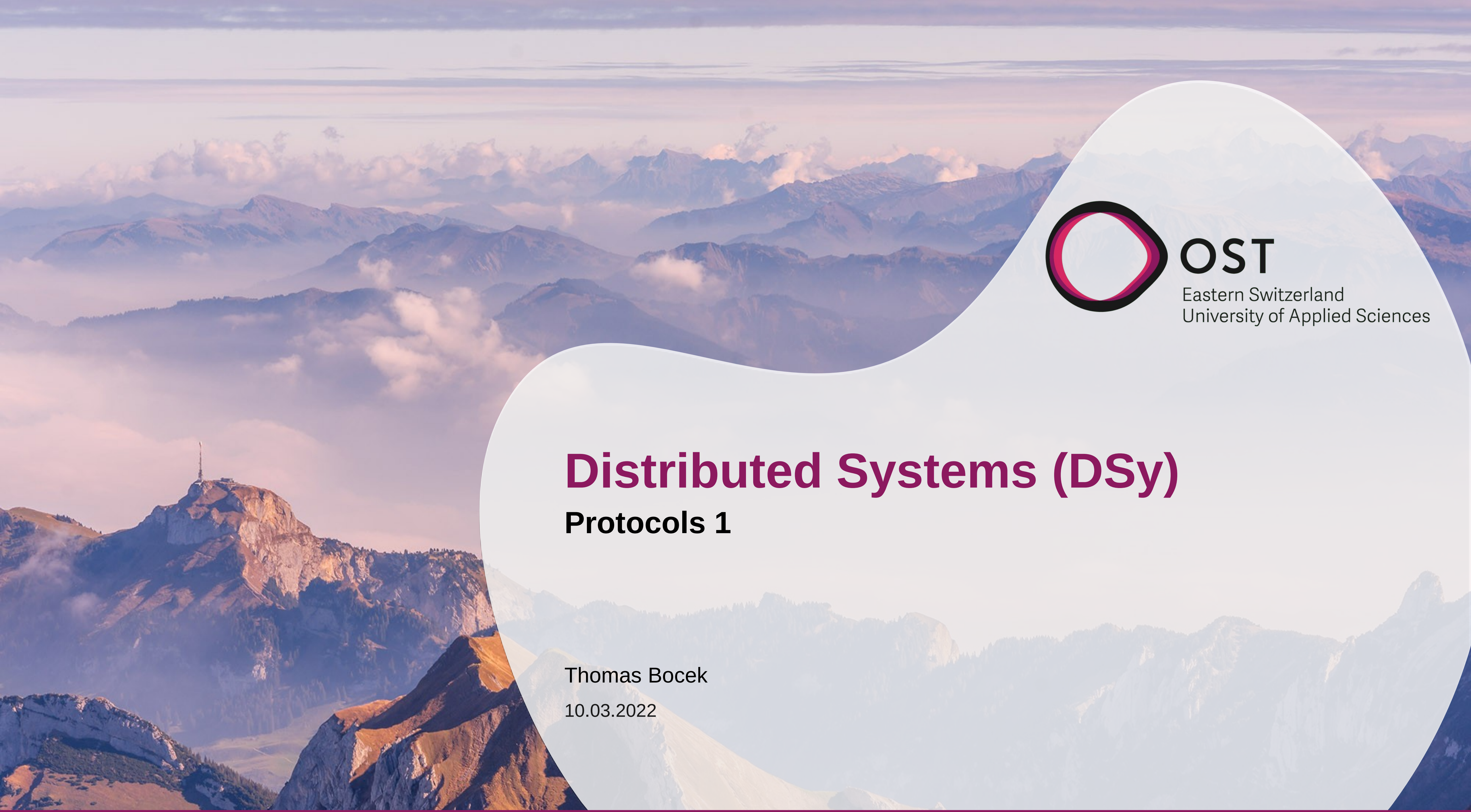

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# Distributed Systems (DSy)

## Protocols 1

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# Learning Goals

- Lecture 3 (Tor)
  - What is Tor?
  - How does it work?
  - Why do we need onion/hidden services?
  - How to setup an onion service?

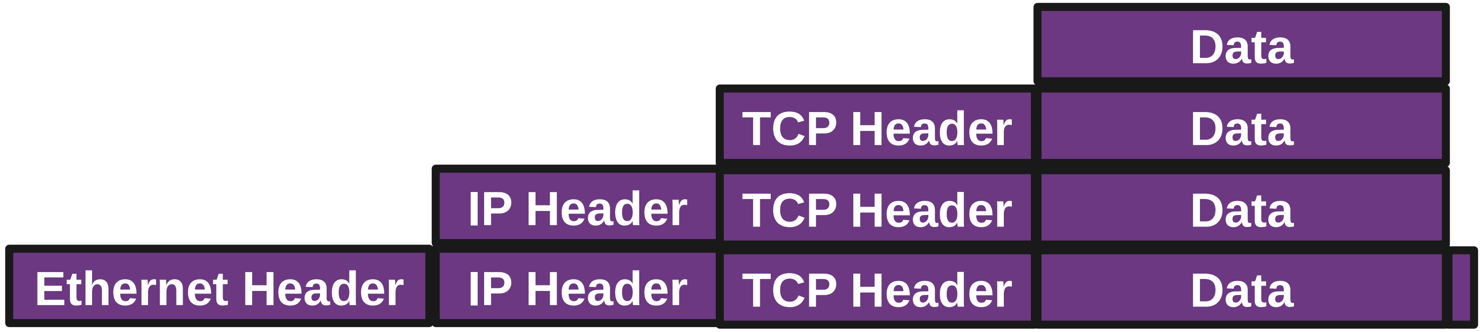
- Lecture 3 (Web Sockets)
  - What is a web socket?
  - How can I implement it?

- Lecture 3 (Protocols, part 1)
  - How do network layers work?
  - What are the TCP mechanisms?

# Networking: Layers

- Networking: Each vendor had its own proprietary solution - not compatible with another solution
  - IPX/SPX – 1983, AppleTalk 1985, DECnet 1975, XNS 1977
- Nowadays most vendors build compatible networks hardware/software from different vendors
  - Cisco, Dell, HP, Huawei, Juniper, Lenovo, Linksys, Netgear, MicroTik, Siemens, Ubiquiti, etc.
- Goal of layers: interoperability
  - 1984: ISO 7498 - The Basic Reference Model for Open Systems Interconnection

| OSI model | "Internet model" |
|---|---|
| Application | Application |
| Presentation | |
| Session | |
| Transport | Transport |
| Network | Internet |
| Data link | Link |
| Pysical | |



Data

TCP Header | Data

IP Header | TCP Header | Data

Ethernet Header | IP Header | TCP Header | Data

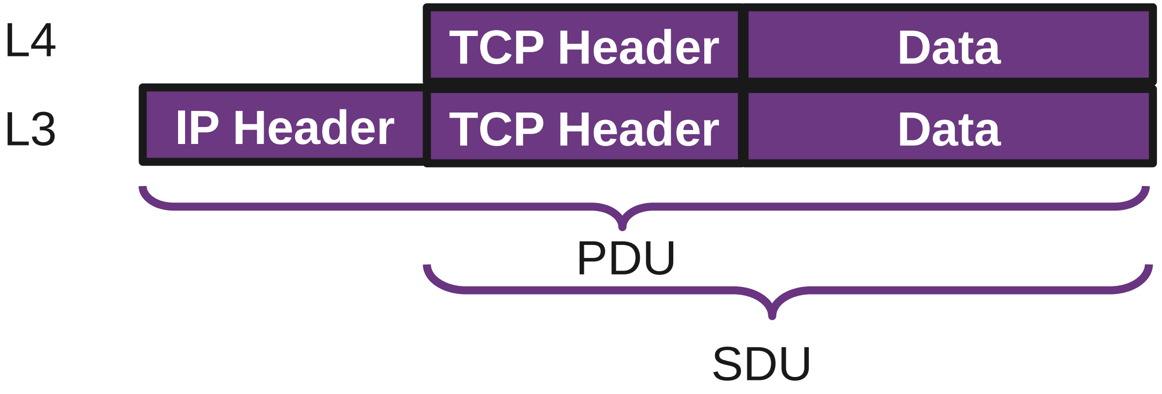
# Networking: Definitions

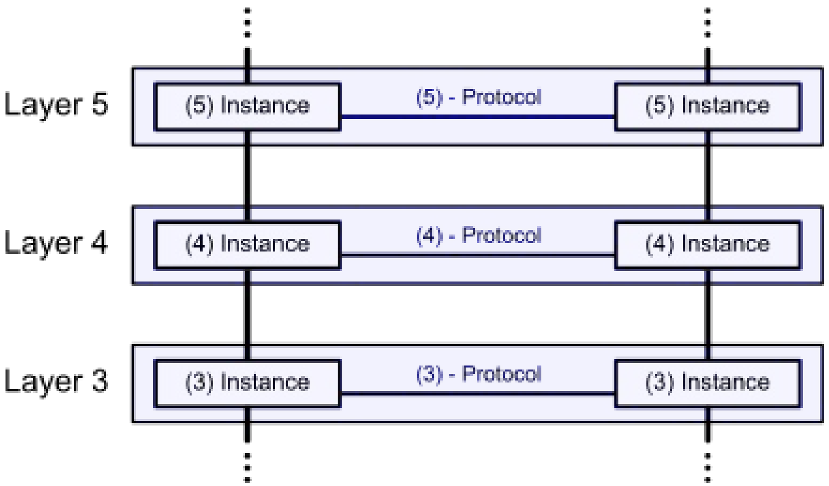
| RFC 1122, Internet STD 3 (1989) | OSI model |
|---|---|
| Four layers | Seven layers |
| "Internet model" | OSI model |
| Application | Application |
| | Presentation |
| | Session |
| Transport | Transport |
| Internet | Network |
| Link | Data link |
| | Physical |

source: https://en.wikipedia.org/wiki/Internet_protocol_suite

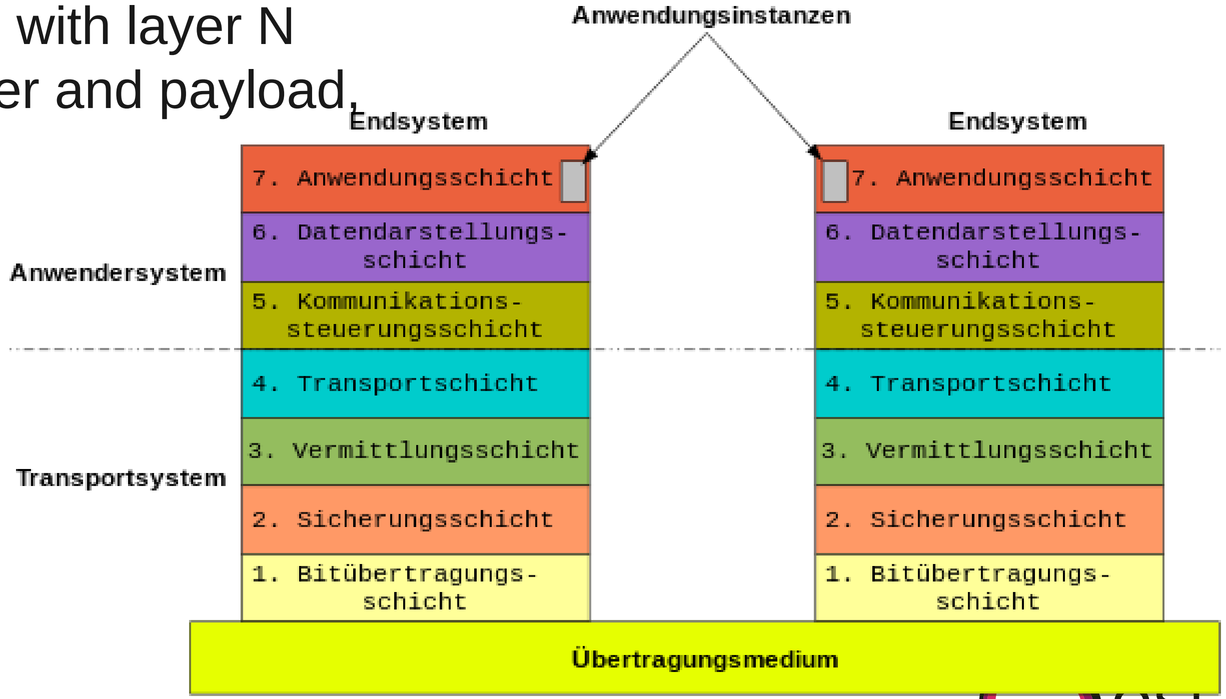
# Layer Abstraction

- Protocols enable an entity/instance to interact with an entity/instance at the same layer in another host
- Service definitions: provide functionality to an (N)-layer by an (N-1) layer
- Layer N exchange protocol data units (PDUs) with layer N protocol. Each PDU contains a protocol header and payload, the service data unit (SDU). E.g. PDU of L3:





source: https://en.wikipedia.org/wiki/OSI_model



source: https://de.wikipedia.org/wiki/OSI-Modell

# Layer 4 - Transport

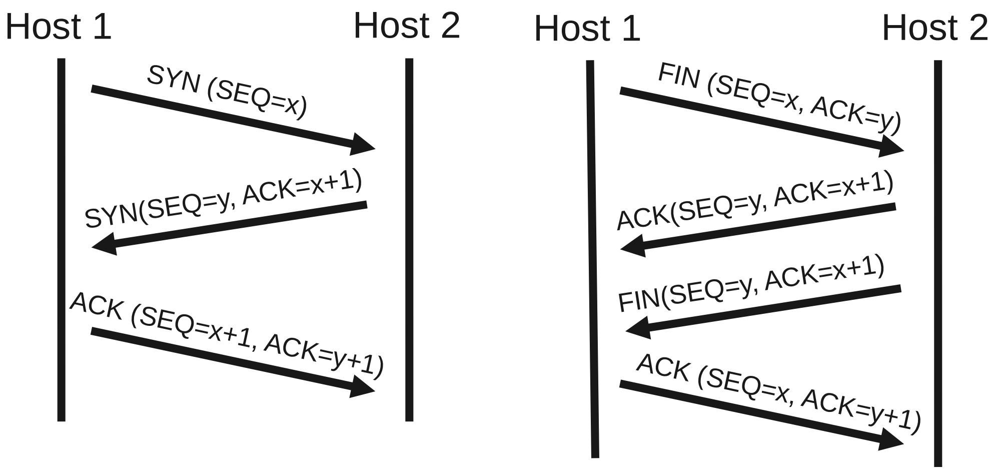
- TCP (Transmission Control Protocol)
  - Reliable (retransmission)
  - Ordered
  - Window – capacity of receiver
  - Checksum – 16bit (crc16)
  - TCP overhead: 20bytes
    - IP overhead: 20bytes
    - Ethernet frame: 18bytes (crc32)
- TCP tries to correct errors; you don't need to worry…
  - Sometimes, you need to worry…

```
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Source Port          |       Destination Port        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Sequence Number                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Acknowledgment Number                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Data |           |U|A|P|R|S|F|                               |
| Offset| Reserved  |R|C|S|S|Y|I|            Window             |
|       |           |G|K|H|T|N|N|                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Checksum            |         Urgent Pointer        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Options                    |    Padding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                             data                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

source: http://freesoft.org/CIE/Course/Section4/8.htm

# Layer 4 - TCP

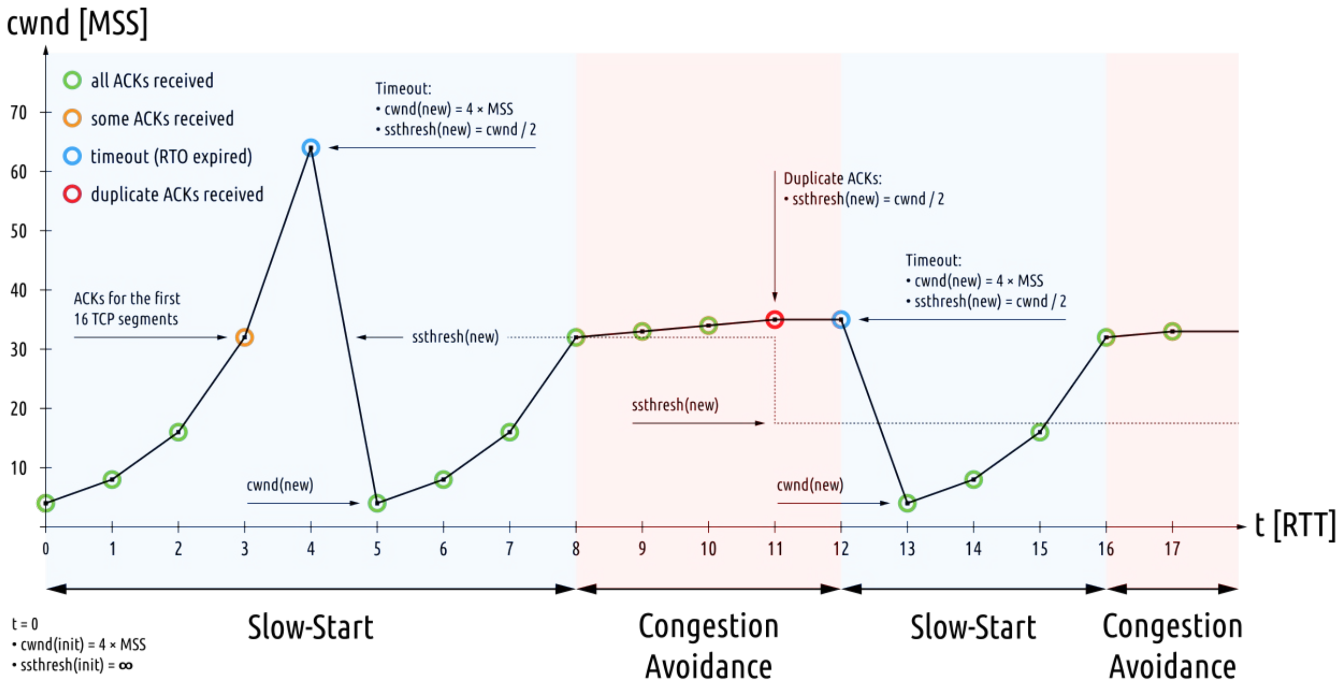
- Connection establishment
  - SYN, SYN-ACK, ACK (three way)
  - Initiates TCP session: initial sequence number is ~ random
- Connection termination
  - FIN, ACK + FIN, ACK (three/four way)
  - 3-way handshake, when host 1 sends a FIN and host 2 replies with a FIN & ACK
- Sequences and ACKs
  - Identification each byte of data
  - Order of the bytes → reconstruction
  - Detecting lost data: RTO, DupACK:



- Retransmission timeout
  - If no ACK is received aftert timout (e.g. 2xRTT), resend.
- Duplicate cumulative acknowledgements, selective ACK [link]
  - ACKs for last consecutive packets
  - 3 times same ACK → retransmit missing packets (fast retransmit)

# Layer 4 - TCP

- Flow control
  - Sender is not overwhelming a receiver
  - Back pressure
  - Sliding window:
    - Receiver specifies the amount of additionally received data in bytes that can be buffered
    - Sender up to that amount of data before ACK
- Congestion control
  - slow-start
  - congestion avoidance
- Difference flow/congestion control



source:
https://upload.wikimedia.org/wikipedia/commons/thumb/2/24/TCP_Slow-Start_and_Congestion_Avoidance.svg/1280px-TCP_Slow-Start_and_Congestion_Avoidance.svg.png

# TCP/IP from an Application Developer View

- Server in golang (repo)
  - git clone https://github.com/tbocek/DSy
  - Download GoLand, or others
  - go run server.go → server
- Listening on TCP port 8081
  - Return string in uppercase
- Node.js version
  - Download WebStorm, or other
- Client:
  - nc localhost 8081

```
const net = require('net');
const server = new net.Server();
server.listen(8081, function() {
   console.log('Launching server...');
});

server.on('connection', function(socket) {
   socket.on('data', function(chunk) {
      console.log(`Data received from client: $
{chunk.toString()}`);
      socket.write(chunk.toString().toUpperCase() +
"\n");
   });
});
```

```
package main
import ("bufio"
     "fmt"
     "net"
     "strings")
func main() {
     fmt.Println("Launching server...")
     ln, _ := net.Listen("tcp", ":8081") // listen
on all interfaces
     for {
          conn, _ := ln.Accept() // accept
connection on port
          message, _ :=
bufio.NewReader(conn).ReadString('\n') //read line
          fmt.Print("Message Received:",
string(message))
          newMessage := strings.ToUpper(message)
//change to upper
          conn.Write([]byte(newMessage + "\n"))
//send upper string back
     }
}
```