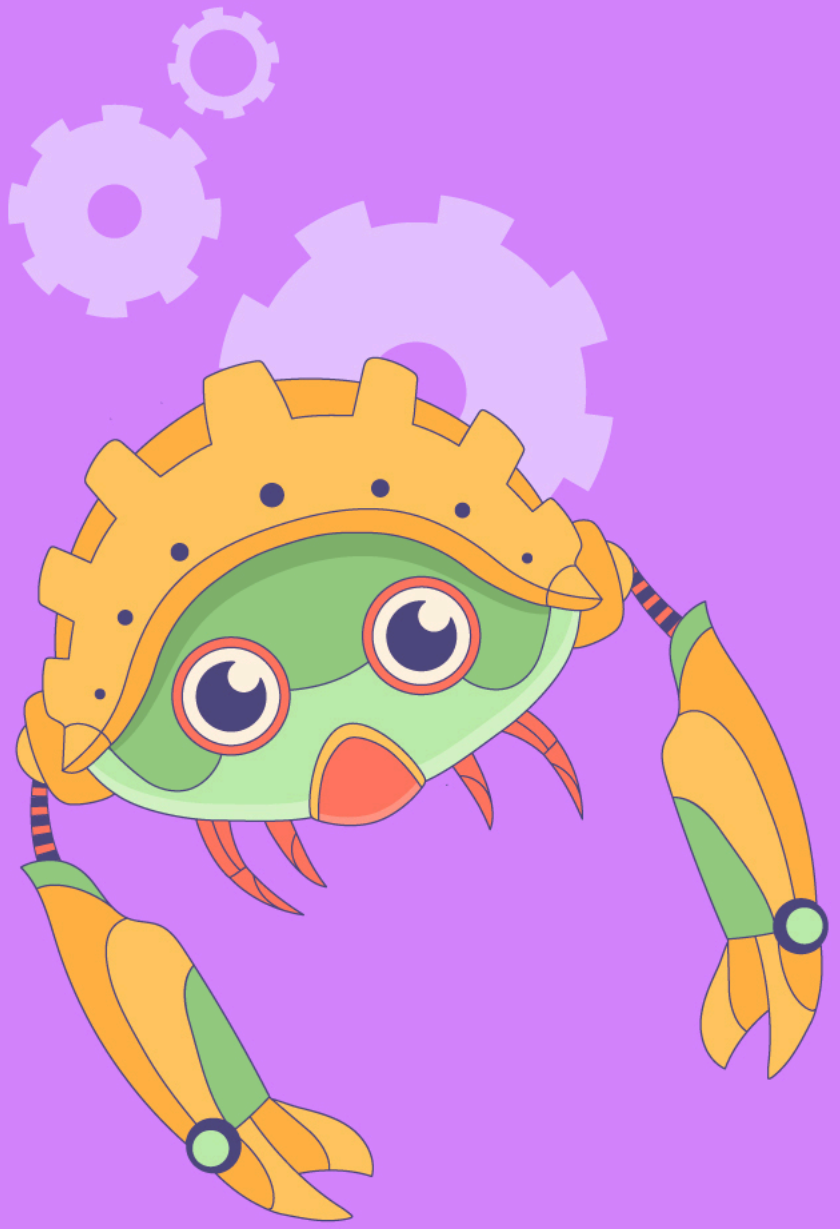
Network Interception in Rust
Building a MITM Tool from Scratch



Introduction

Agenda

- Introduction
- 0 - Training Goals
- 0bis - pnet library
- 1 - ARP Spoofing
- 2 - Intercept IPv4 packets
- 3 - TCP handshake
- 4 - Intercept HTTP requests
- 5 - Handle TLS handshake
- Bonus
- Real-life scenario
- Appendices

Introduction

Who are we ?

Thomas HALIPRÉ

Corentin LIAUD

- Working for Synacktiv
- French offensive security company
- ~200 ninjas: pentest, reverse engineering, development, DFIR
- 6 locations in France: Paris, Rennes, Lyon, Toulouse, Bordeaux, Lille

Introduction

What are we going to talk about?

- Rust ! 🦀
- Low level packet interception
- Network protocol overviews
- Offensive security (and applicable countermeasures when possible)

Introduction

What aren't we going to talk about?

- Rust basics
- IPv6
- Async

Introduction

Disclaimer(s)

- For educational purposes only
- Don't run this code on networks you aren't allowed to :)

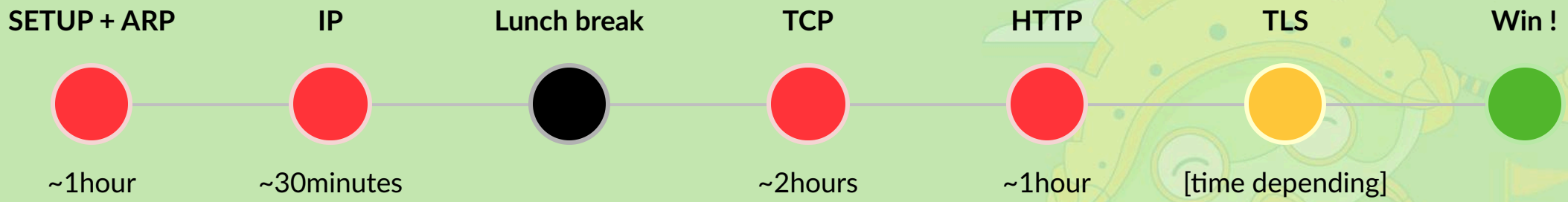
Introduction

Discord server

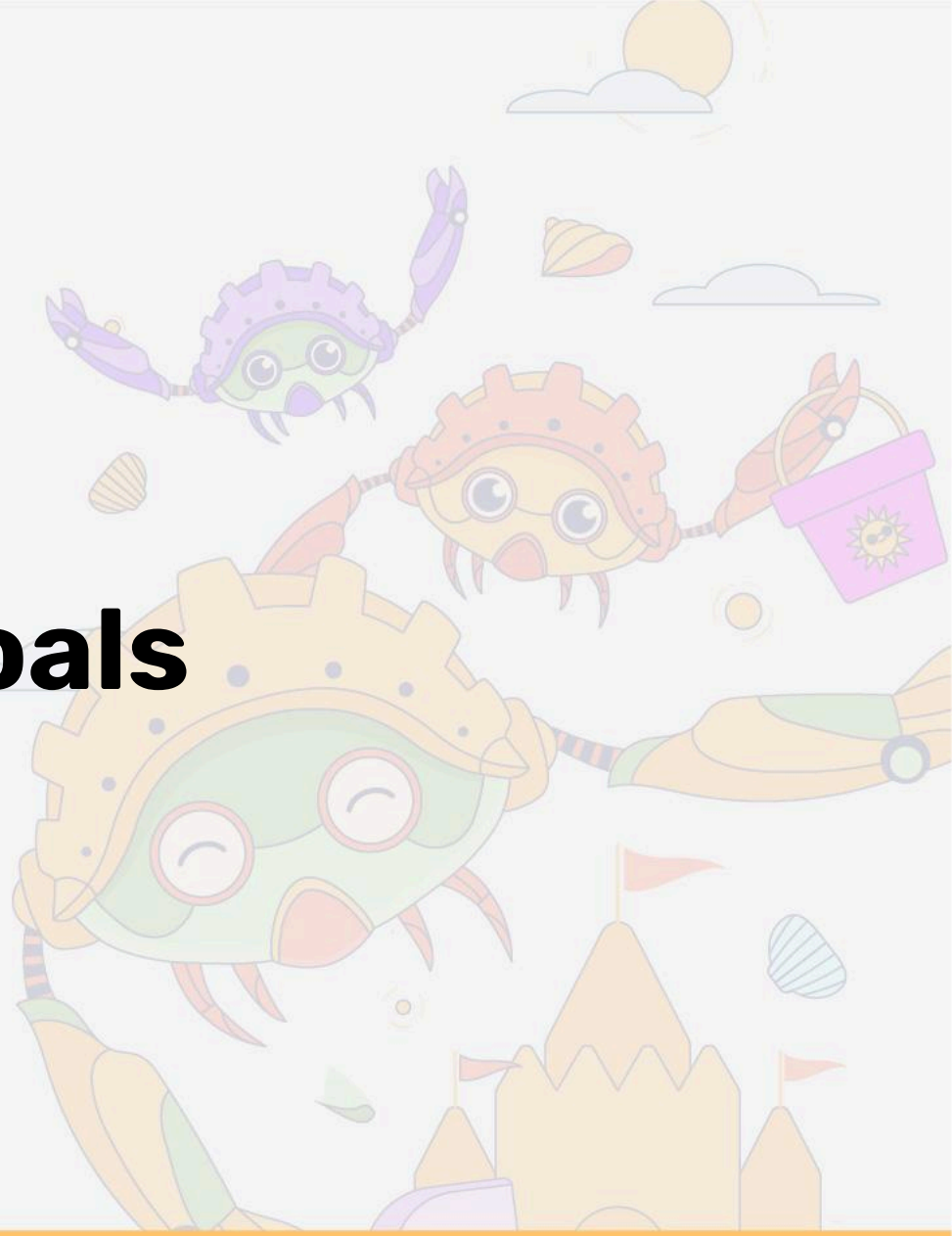
https://discord.gg/Y2ae88HneZ

Introduction

Expected schedule



0 - Training Goals



0 - Training Goals

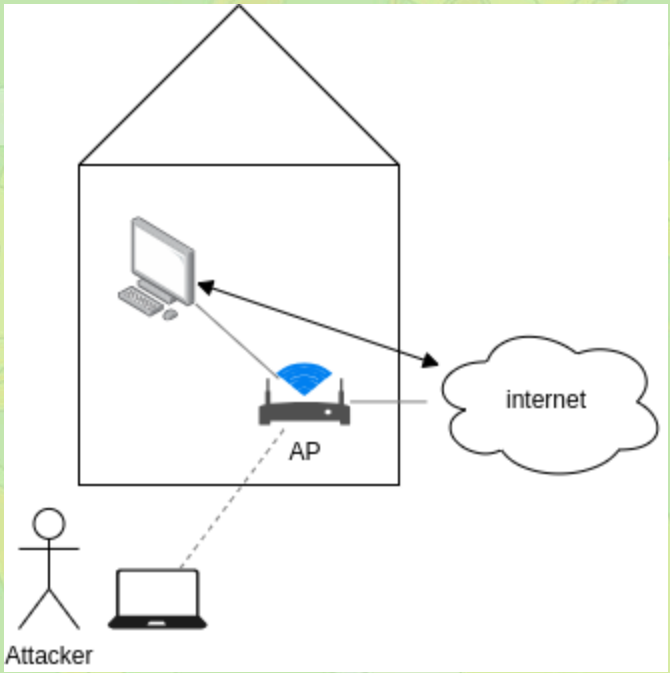
Initial Situation

- Two machines communicating on the same network (Ethernet or WIFI)
- They exchange data and assume their connection is private

As the attacker, we assume that we are connected to the same network.

Example

Your network at home!



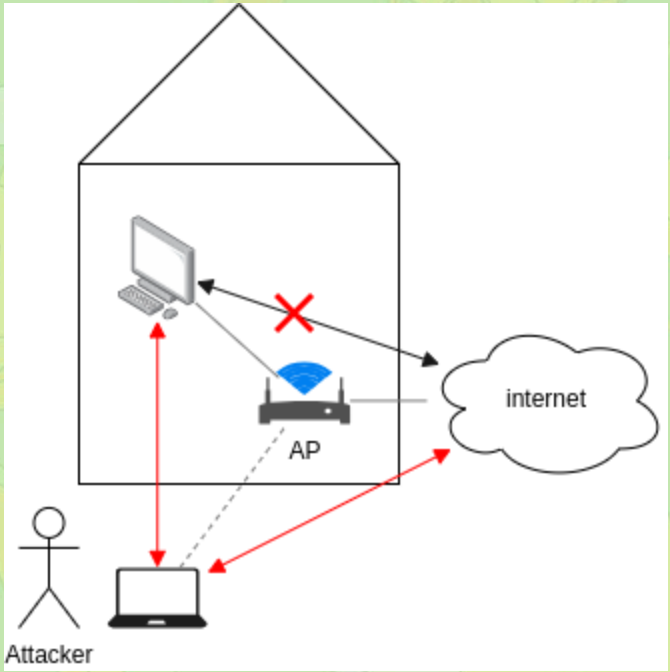
0 - Training Goals

Objectives

- **Read** the traffic between the two machines
  - Dump sensitive data (passwords, personal data...)
  - List requested websites
- **Modify** the data they are exchanging

Example

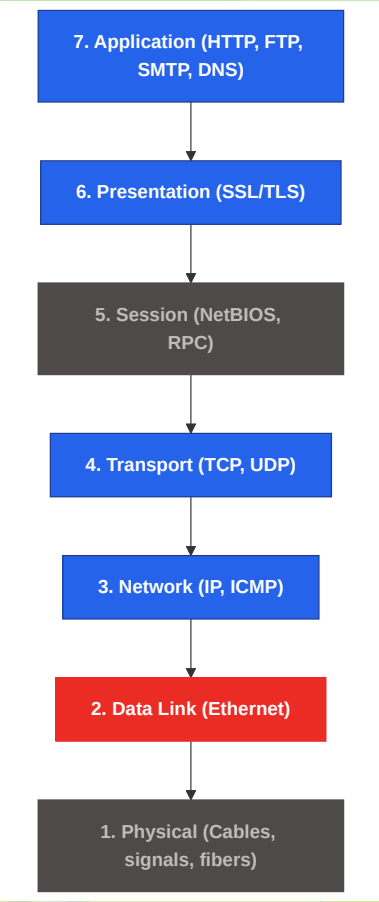
Your "hacked" network at home!



0 - Training Goals

Steps

1. **ARP Spoofing**: Achieving the Man-in-the-Middle position.
2. **MitM on IP/TCP**: Intercepting raw data packets.
3. **MitM on HTTP**: Reading and modifying unencrypted web traffic.
4. **MitM on TLS (Optional)**: Attempting to intercept encrypted HTTPS traffic.



Obis - pnet library

> Cross-platform, low level networking in Rust[1]

- Sending, receive and craft packets
- Protocol parsing (Ethernet, IPv4, TCP, ARP, ...)
- Memory safety & idiomatic Rust API
- Supported platforms
  - Linux using raw `AF_PACKET` sockets
  - macOS/BSD using BPF (**B**erkeley **P**acket **F**ilter)
  - Windows using `winpcap` [2] or `npcap` [3] (its successor)

[1] pnet library - https://github.com/libpnet/libpnet
[2] winpcap library - https://www.winpcap.org
[3] npcap library - https://npcap.com

Obis - pnet library

Two different ways to manipulate packets:

> **Documentation**
>
> `pnet` documentation is a must-have for this training

Using "structures"

```
let arp = Arp {/* ARP params */};

let mut arp_data = vec![0u8; ArpPacket::packet_size(&arp)];

let mut arp_pkt = MutableArpPacket::new(&mut arp_data)
    .expect("cannot build arp packet");
arp_pkt.populate(&arp);

let ethernet = Ethernet {
    /* Ethernet params */
    payload: arp_data,
};

let mut eth_data = vec![0u8; EthernetPacket::packet_size(&ethernet)];

let mut eth_pkt = MutableEthernetPacket::new(&mut eth_data)
    .expect("cannot build ethernet packet");
eth_pkt.populate(&ethernet);
```

Using builder pattern

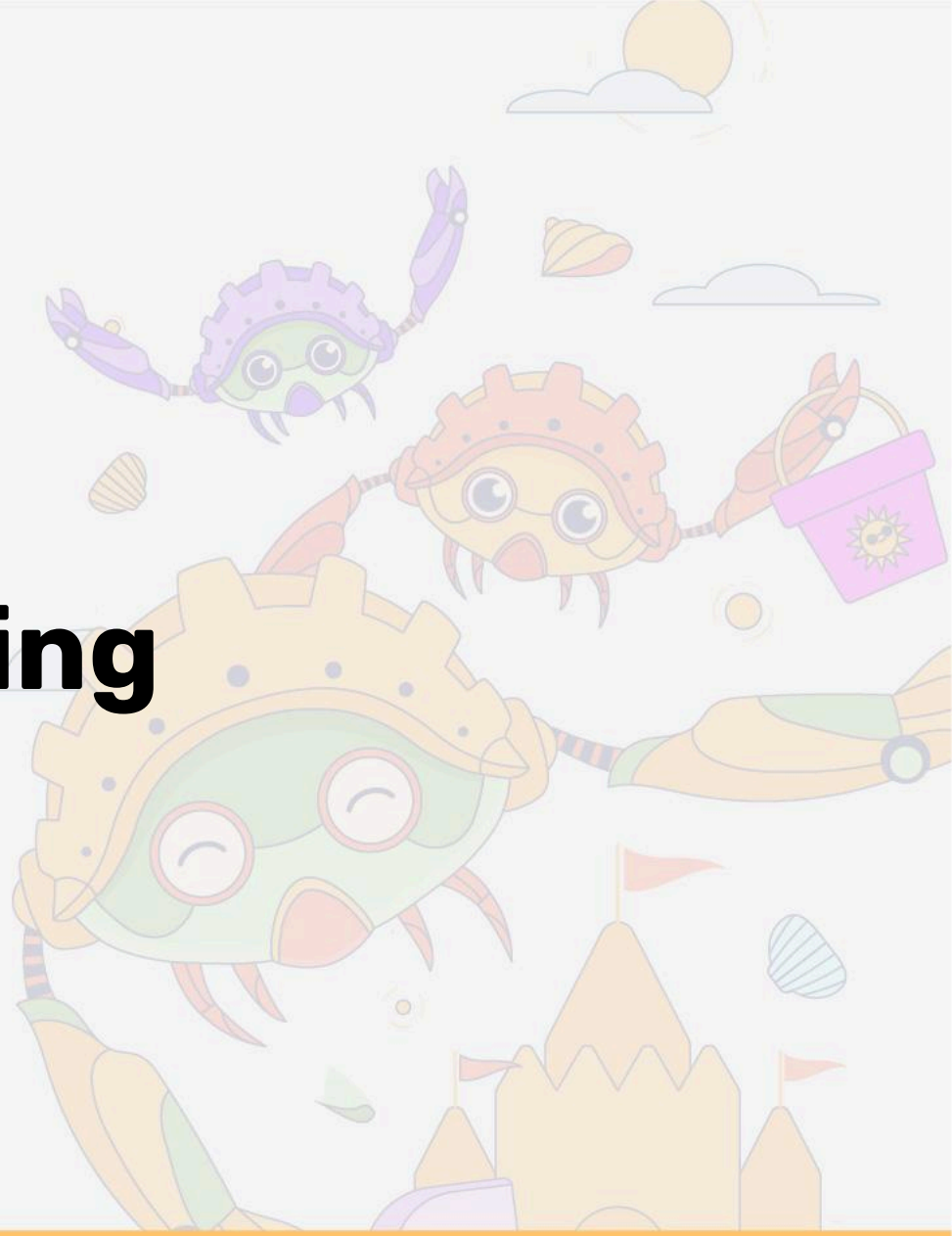
```
let mut arp_data = vec![0u8; ArpPacket::minimum_packet_size()];

let mut arp_pkt = MutableArpPacket::new(&mut arp_data)
    .expect("cannot build arp packet");
arp_pkt.set_hardware_type(ArpHardwareTypes::Ethernet);
arp_pkt.set_operation(ArpOperations::Reply);
/* keep building... */

let mut eth_data = vec![0u8;
    EthernetPacket::minimum_packet_size() + arp_data.len()];

let mut eth_pkt =
    MutableEthernetPacket::new(&mut eth_data)
        .expect("cannot build ethernet packet");
/* build ethernet packet... */
eth_pkt.set_payload(&mut arp_data);
```

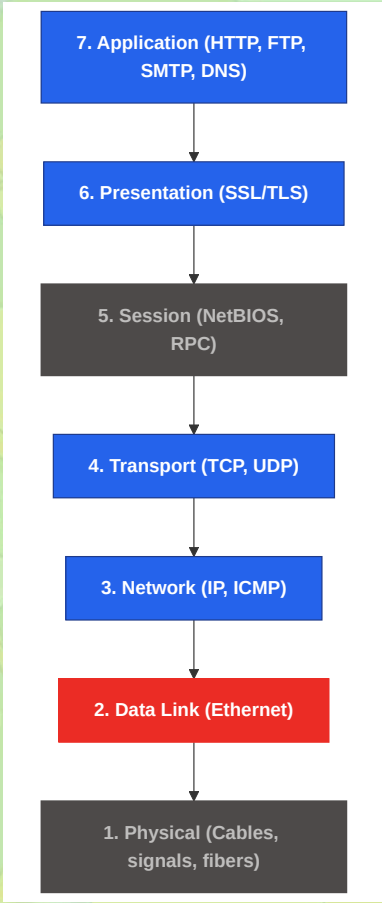
1 - ARP Spoofing



1 - ARP Spoofing

Ethernet protocol [1]

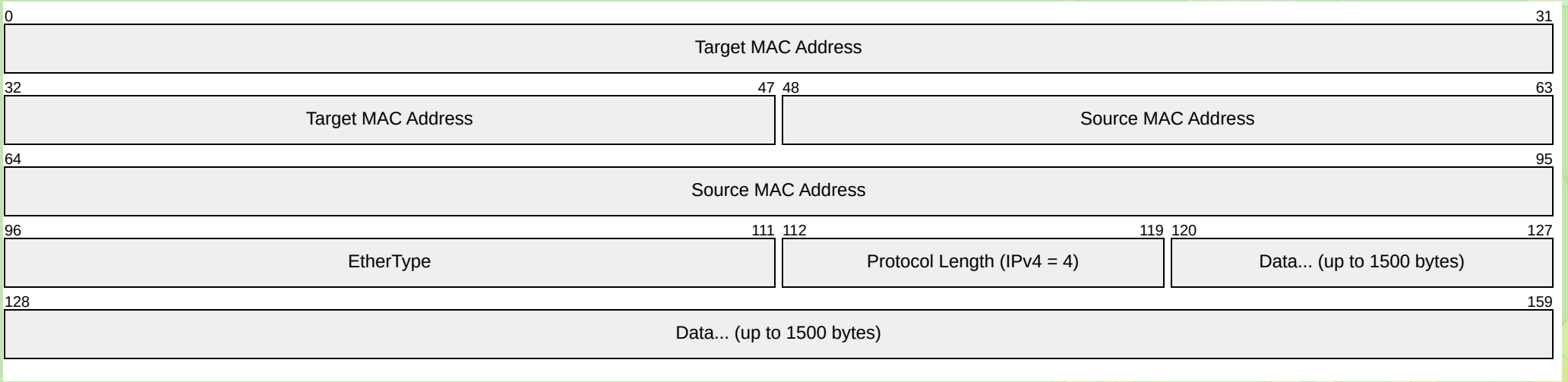
- Point-to-point communication
- Based on MAC addresses
- On LANs (**L**ocal **A**rea **N**etworks) only



[1] 802.3-2018 - IEEE Standard for Ethernet https://ieeexplore.ieee.org/document/8457469

1 - ARP Spoofing

Ethernet II frame format



Usual EtherTypes:

- IPv4 (*0x0800*)
- ARP (*0x0806*)
- Wake-On-Lan (*0x0842*)

1 - ARP Spoofing

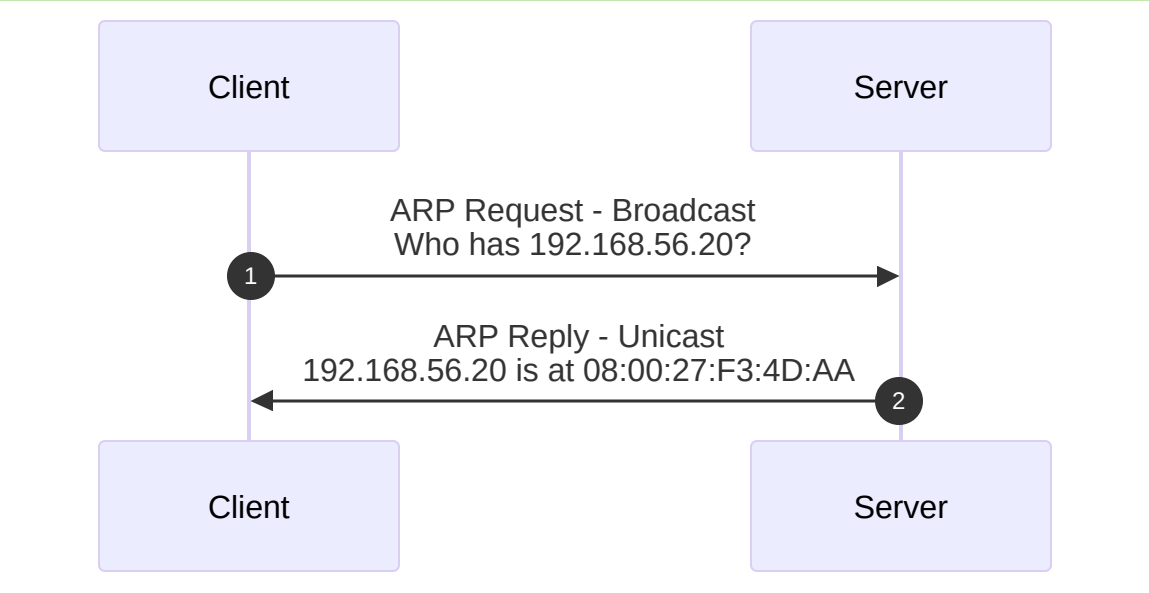
ARP protocol [1]

- **A**ddress **R**esolution **P**rotocol
  - Associates network address (IP) to link-layer address (MAC)
- Encapsulated in Ethernet frames
  - Can be carried out over Ethernet or Wifi transports
- Needed for IPv4 to work!
  - IPv6 counterpart is named NDP (**N**eighbor **D**iscovery **P**rotocol)
- Quite simple protocol
  - Sender broadcasts a request on a LAN (*Who Has IP ?*)
  - The *legitimate* machine should respond with its MAC address

[1] RFC 826: An Ethernet Address Resolution Protocol https://www.rfc-editor.org/rfc/rfc826

1 - ARP Spoofing

ARP sequence diagram



Client

- 08:00:27:1F:1B:F3
- 192.168.56.10

Server

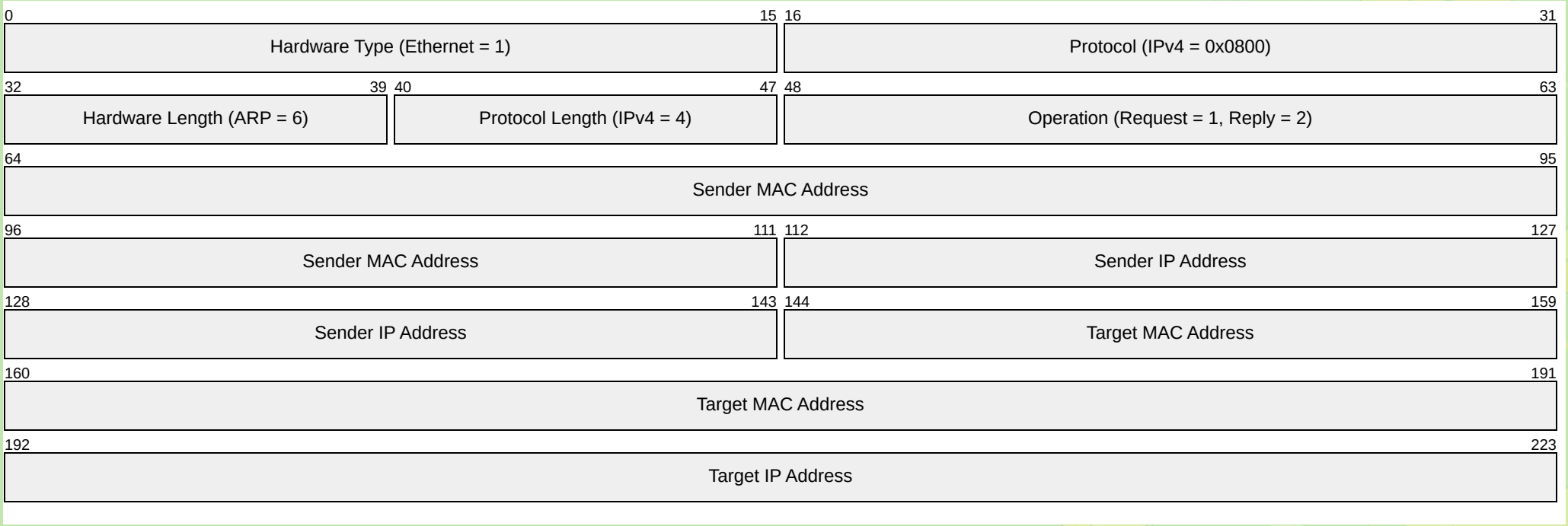
- 08:00:27:F3:4D:AA
- 192.168.56.20

Attacker

- 0A:00:27:00:00:00
- 192.168.56.1

1 - ARP Spoofing

ARP frame format



1 - ARP Spoofing

How to ?

Mainly 2 possibilities:

1. Respond to an actual ARP request ("Man On The Side") -- *preferred in our case*

- Less visible, targeted attack
- Relies on the fact that we can respond faster than the *real* host

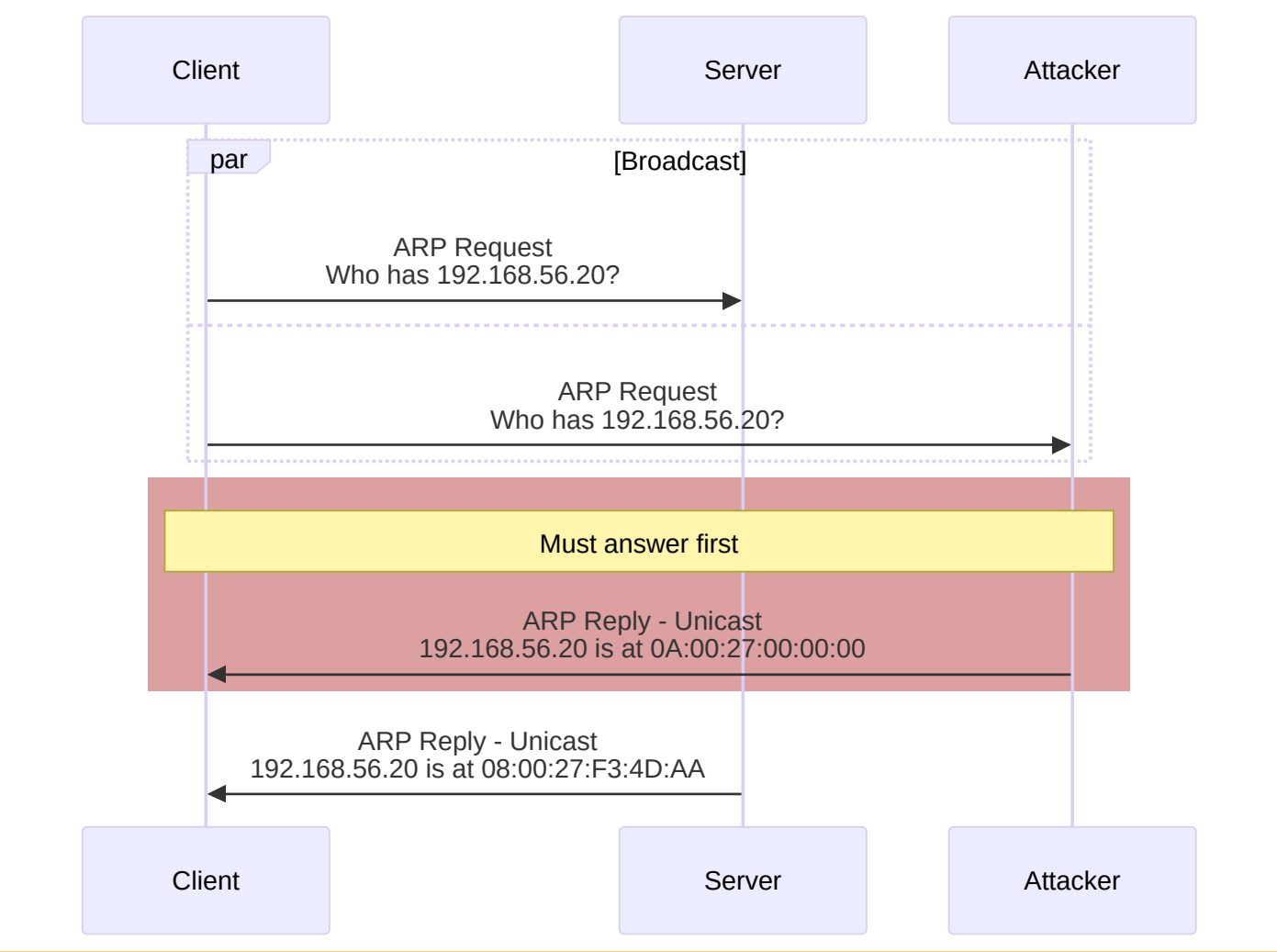
2. Gratuitous ARP [1]

- Broadcast data with our MAC but target IP address
- More visible

[1] RFC 5227: IPv4 Address Conflict Detection https://www.rfc-editor.org/rfc/rfc5227

1 - ARP Spoofing

ARP Spoofing - Respond to ARP request



Client

- 08:00:27:1F:1B:F3
- 192.168.56.10

Server

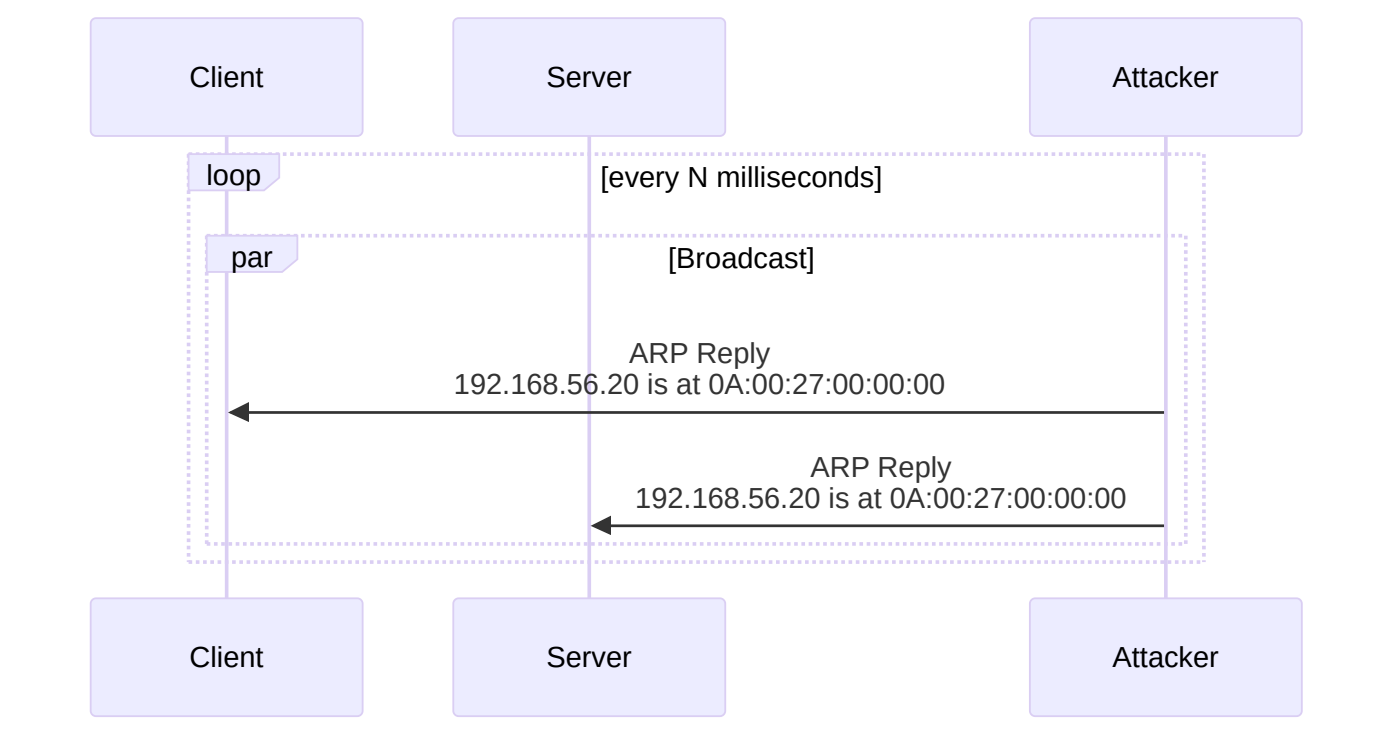
- 08:00:27:F3:4D:AA
- 192.168.56.20

Attacker

- 0A:00:27:00:00:00
- 192.168.56.1

1 - ARP Spoofing

ARP Spoofing - Gratuitous ARP



Client

- 08:00:27:1F:1B:F3
- 192.168.56.10

Server

- 08:00:27:F3:4D:AA
- 192.168.56.20

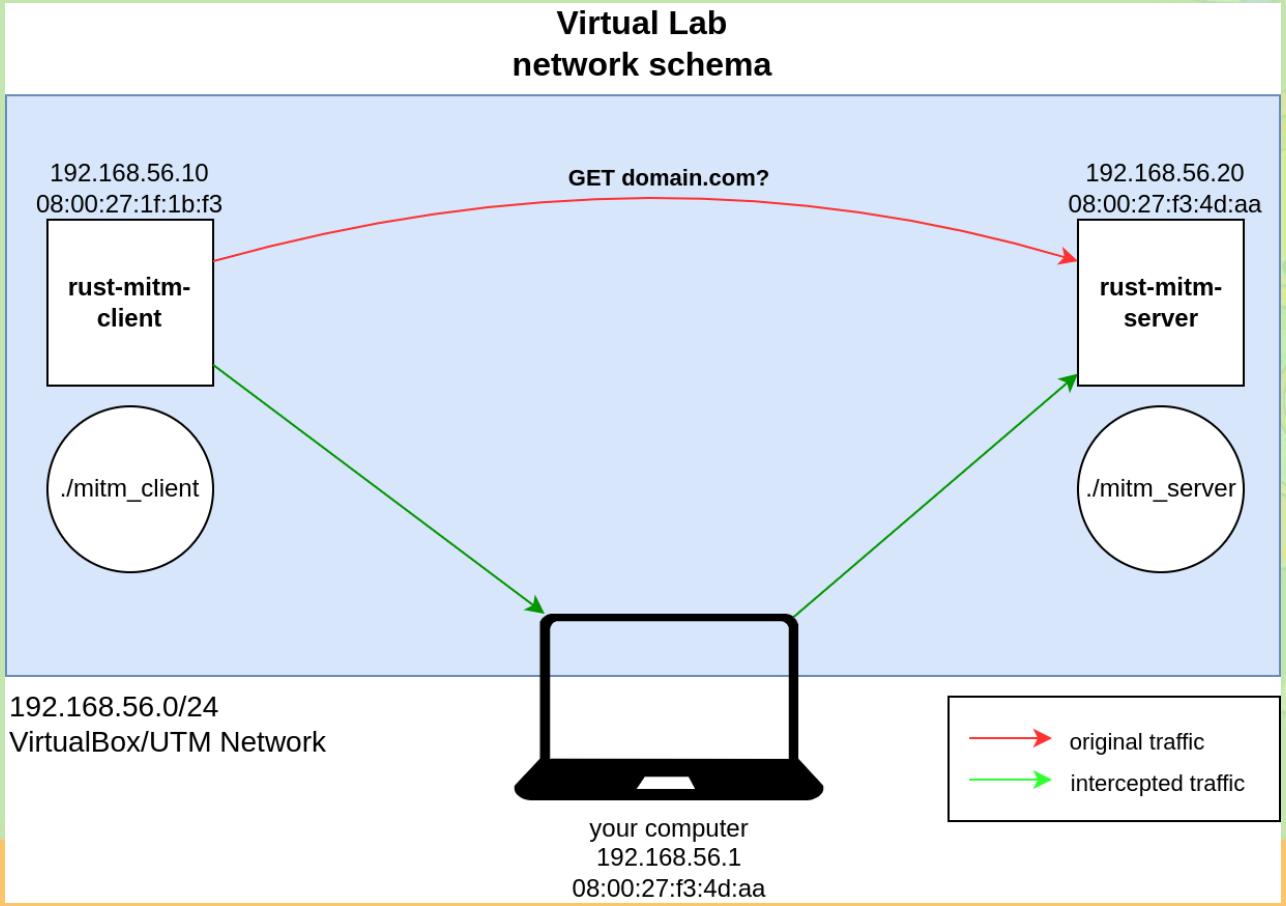
Attacker

- 0A:00:27:00:00:00
- 192.168.56.1

1 - ARP Spoofing

Virtual Lab running on your host

Follow the `setup.md`.



1 - ARP Spoofing

Exercises Ethernet & ARP

- Using `pnet` [1] crate and given code skeleton
- Complete the scenario to spoof the target by
  - Intercepting Ethernet frames
  - Sending valid ARP replies
    - Targeted client, asked IP addresses and listen interface must be configurable !
    - `wireshark` tool may help you for debugging
- `client` test binary may help you
  - You should pass tests #0 and #1 to validate this part
- You can also `ssh` into the client VM and run `ip neigh` command to check the association

[1]: pnet: A cross-platform API for low level networking https://github.com/libpnet/libpnet

1 - ARP Spoofing

Countermeasures

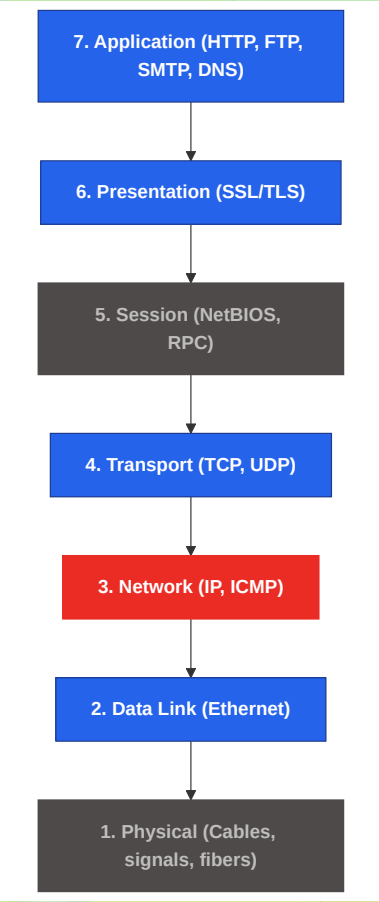
- Use encrypted protocols (more on that in the next Exercises)
- Add static ARP entries for known hosts (when feasible)
- On Linux, new cache entries are always validated when received (`STALE` state)

2 - Intercept IPv4 packets

2 - Intercept IPv4 packets

IPv4 protocol [1]

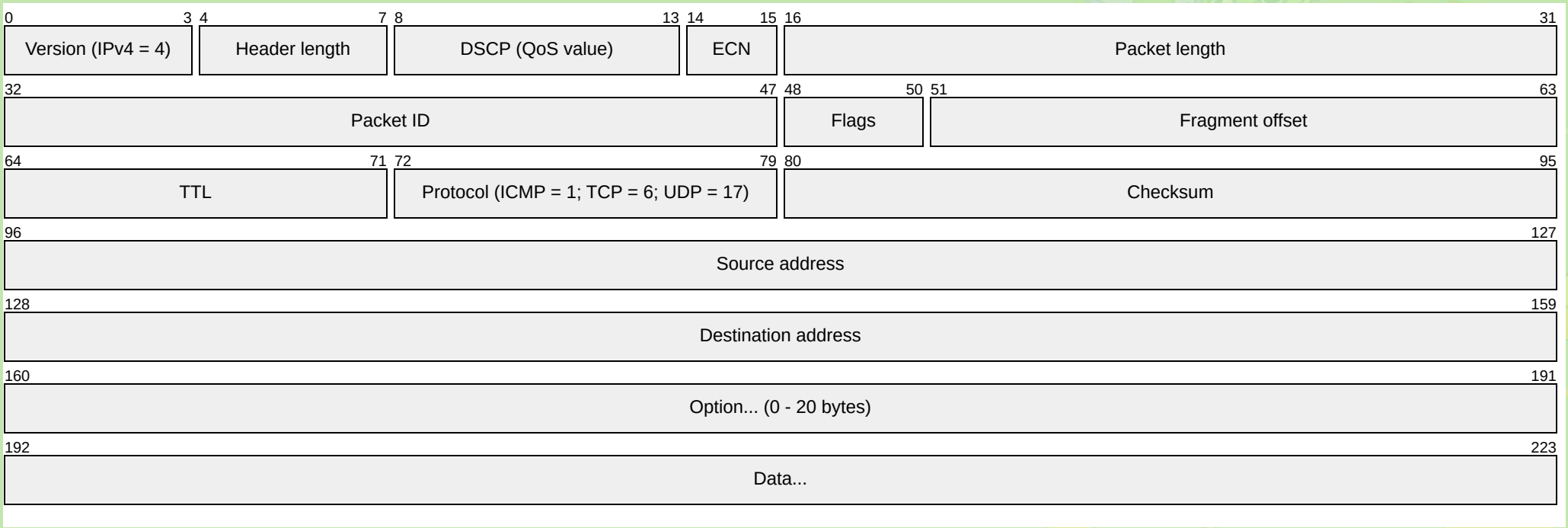
- Point to point and broadcast communication
- Each host has a unique IP address on a network
- Each address is 4 bytes long (4,294,967,296 addresses)
- Network masks are used to define private networks
- Many features:
  - Packet fragmentation
  - Quality of Service (QoS): packet priorization
  - Time-to-Live (TTL): prevent packet from being routed indefinitely
  - ...



[1] RFC791: Internet Protocol https://www.rfc-editor.org/rfc/rfc791

2 - Intercept IPv4 packets

IPv4 packet



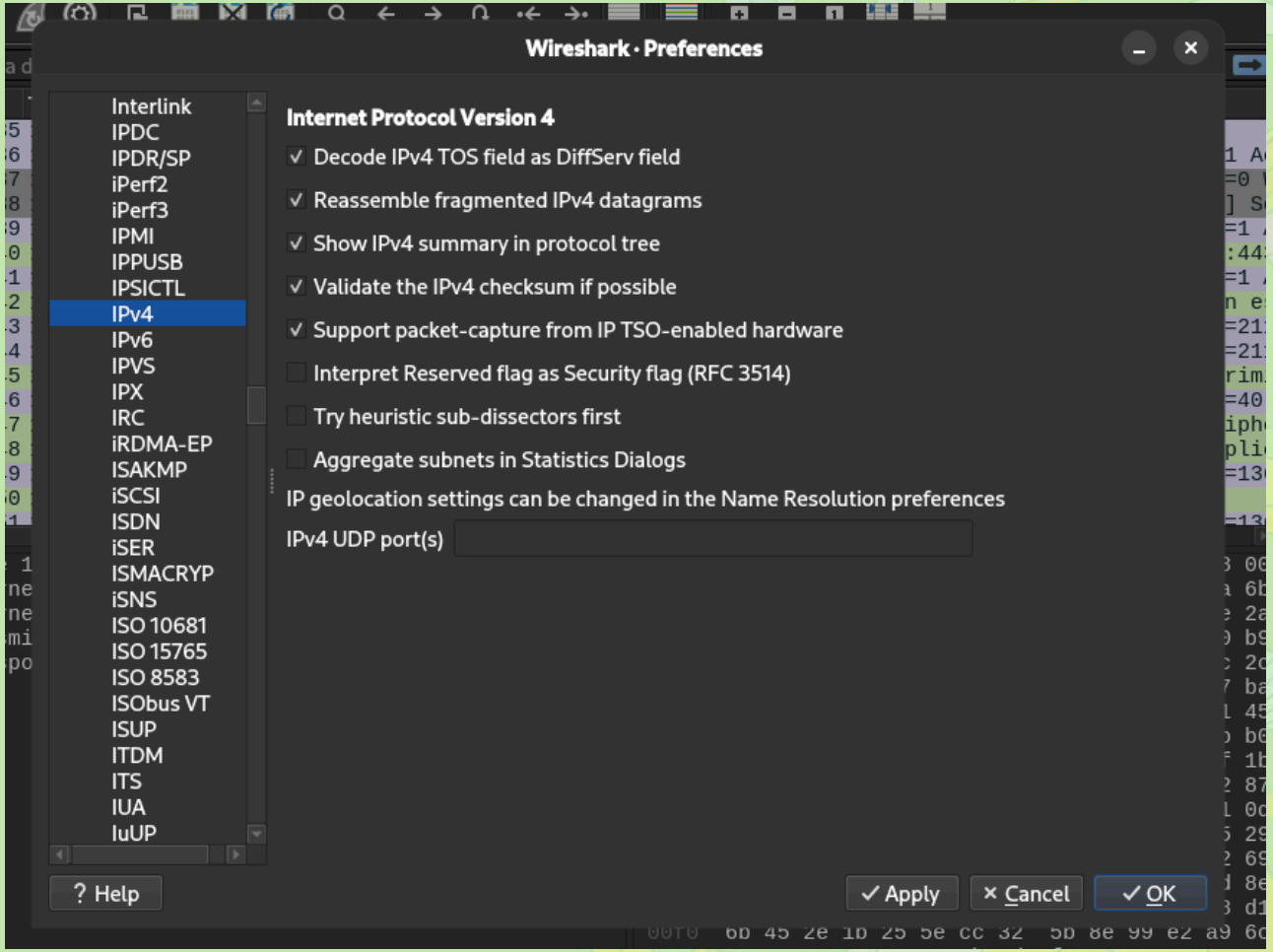
Max packet length: encoded on 2 bytes (up to 65,535 bytes)

2 - Intercept IPv4 packets

Tooling - Wireshark configuration

Activate checksum verification in wireshark to make sure your implementation is correct

- Edit > Preferences > Protocols > IPv4 > Check Validate the IPv4 checksum if possible > Ok



2 - Intercept IPv4 packets

Exercises IPv4 & IPv4 Test1

> After the ARP spoofing developped during Exercise 1 you should now receive IP data from the victim

- Using special `Protocol Number` 0xFD (253 - *Test1*), implement IP protocol interception
- `client` test binary may help you
  - It expects your implementation to respond with the sent data ("echo")
  - You should pass test #2 to validate this part

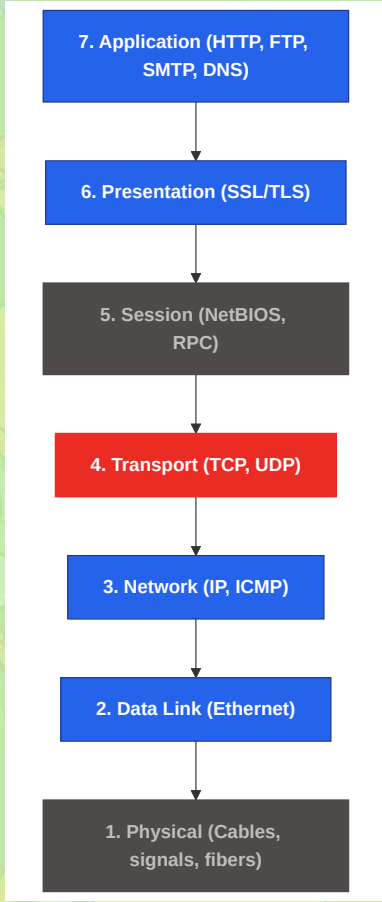
3 - TCP handshake

3 - TCP handshake

TCP protocol [1]

- Designed to exchange data over congested or unpredictable networks
  - Reliable, Ordered & Error checked
- Bidirectionnal
- Point-to-Point communication
- Usually paired with IP
- Relies on **port number** to identify different services on a single host with a unique IP address

Focus on **correct** data delivery more than *fast* data delivery.



[1] RFC 9293: Transmission Control Protocol (TCP) https://www.rfc-editor.org/rfc/rfc9293

3 - TCP handshake

TCP message types

The TCP protocol defines different flags to identify the semantic of each message

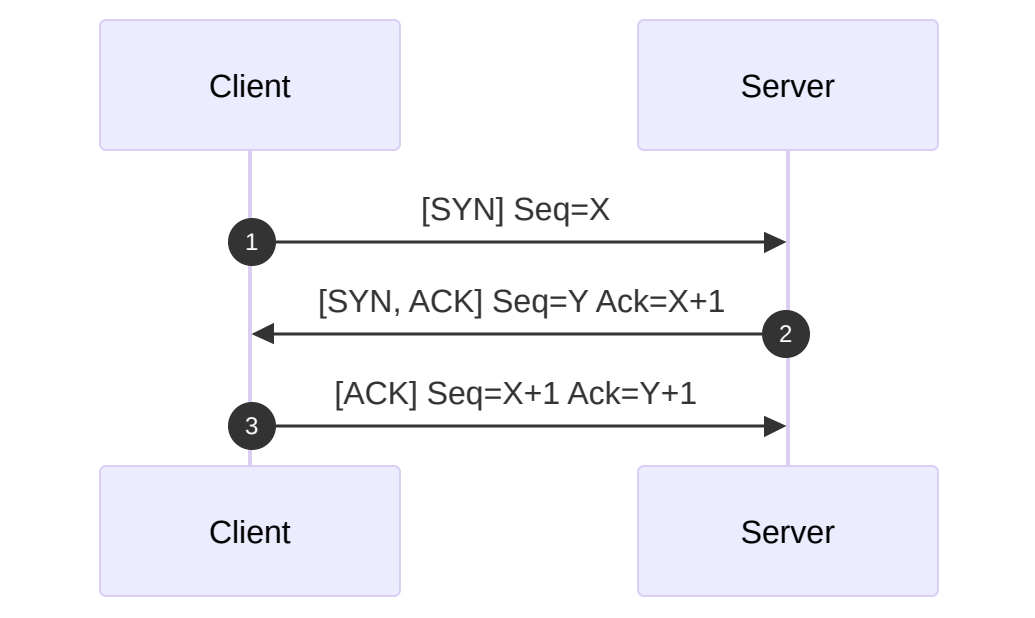
- **SYN**: Sent by each party on the first message of a new communication
- **ACK**: Acknowledge bytes sent by the peer
- **PSH**: Push data on the connection
- **FIN**: Request to close the sender sides of the connection
- **RST**: Reset the connection (closing it immediately)
- ...

TCP uses two sequence numbers (one for each direction) to keep track of the amount of data correctly received by the peer.

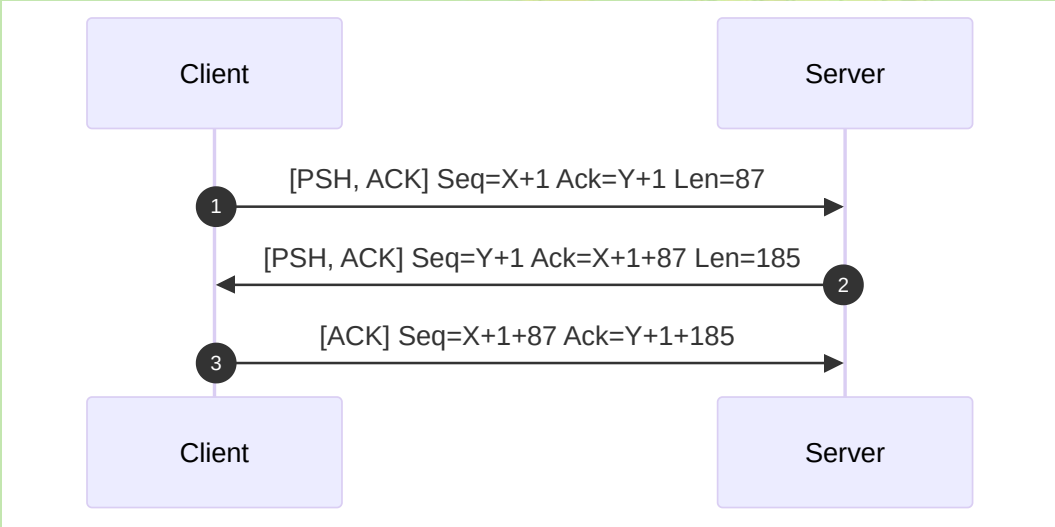
3 - TCP handshake

TCP sequence diagram - 1

New communication (handshake)



Bidirectionnal data exchange (after handshake)

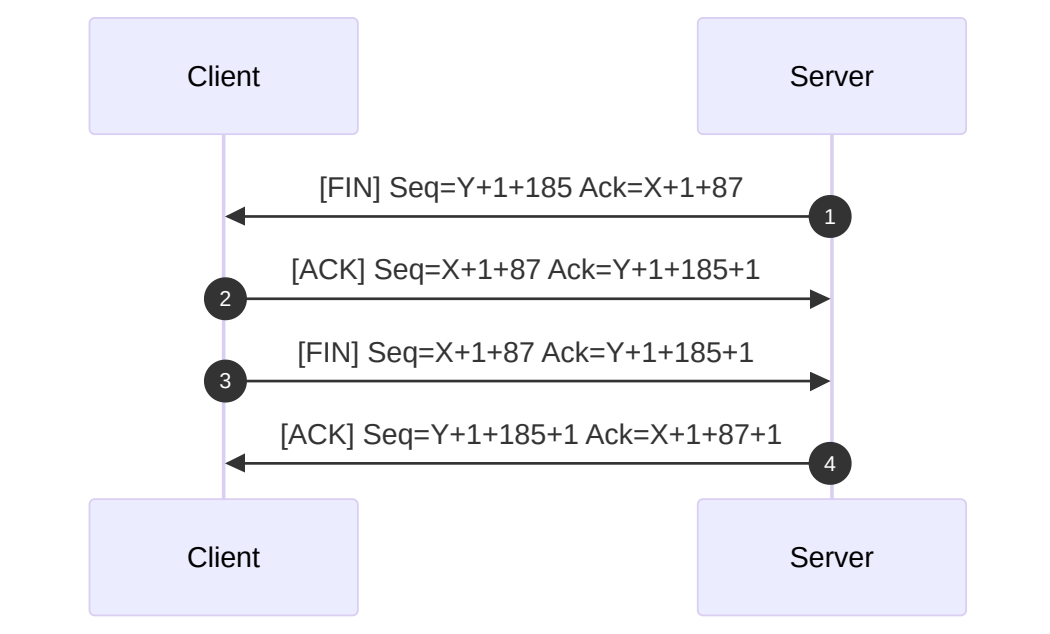


The values of `X` and `Y` are randomly generated on each new connection.

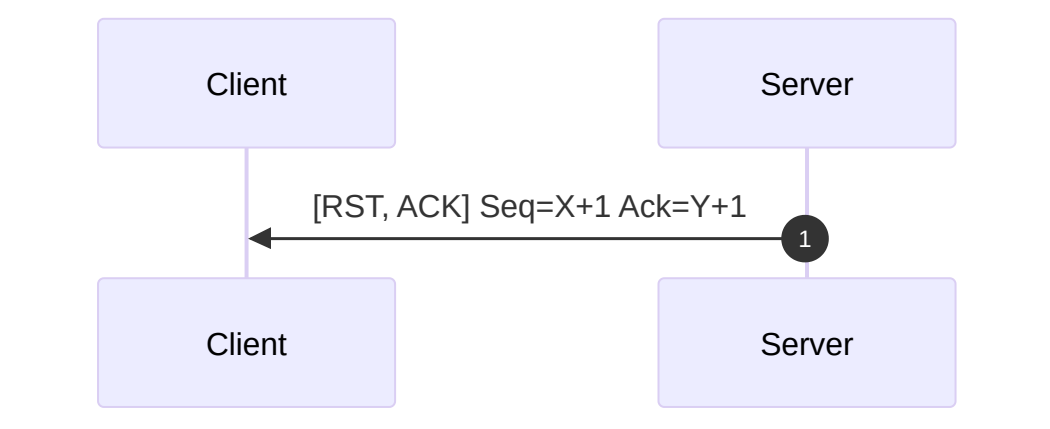
3 - TCP handshake

TCP sequence diagram - 2

Close connection (gracefully)



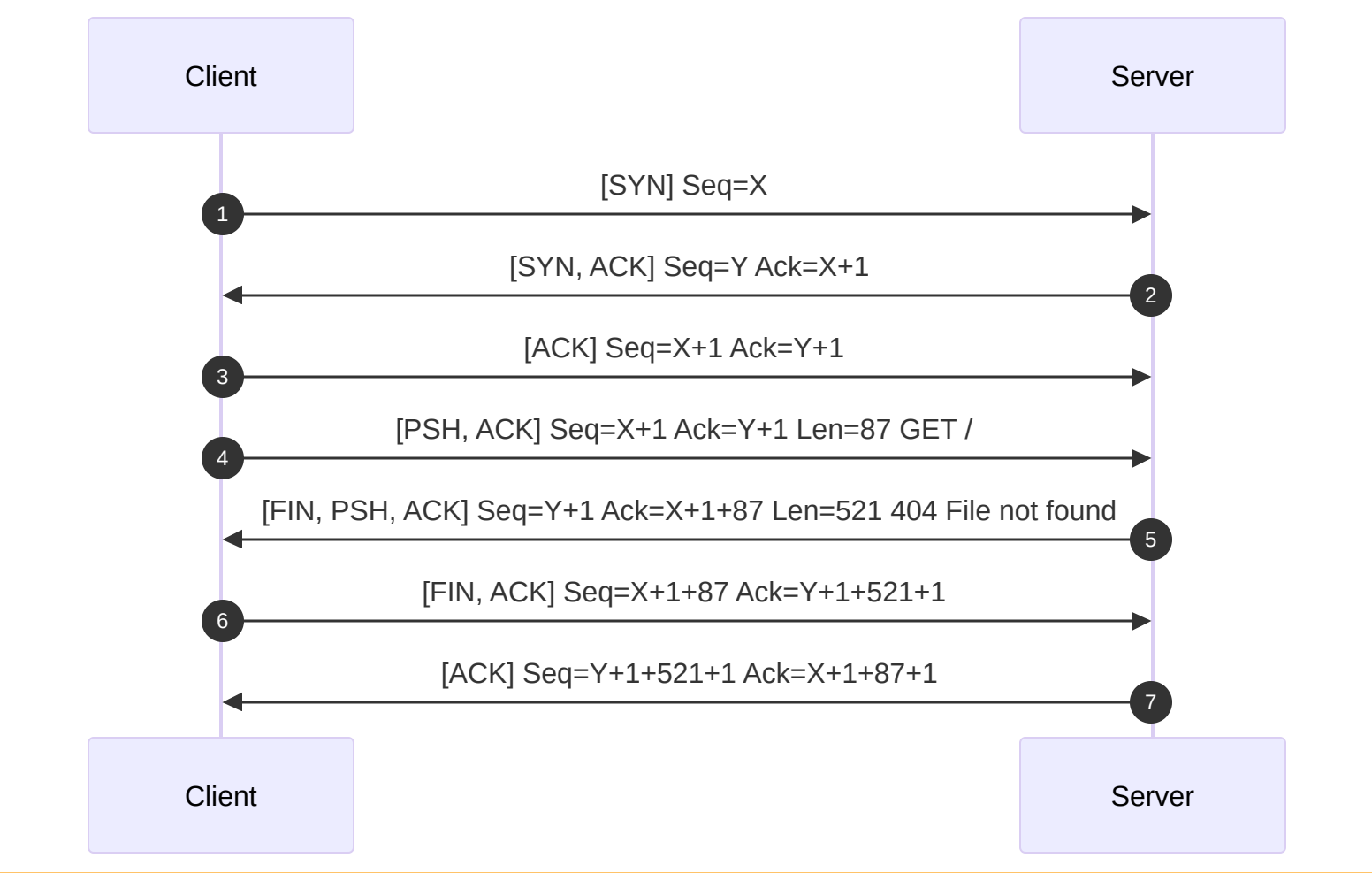
Close connection (force)



> Note: It is possible to close the connection in 3 messages instead of 4, if the receiving end of the first FIN merges his FIN and ACK messages.

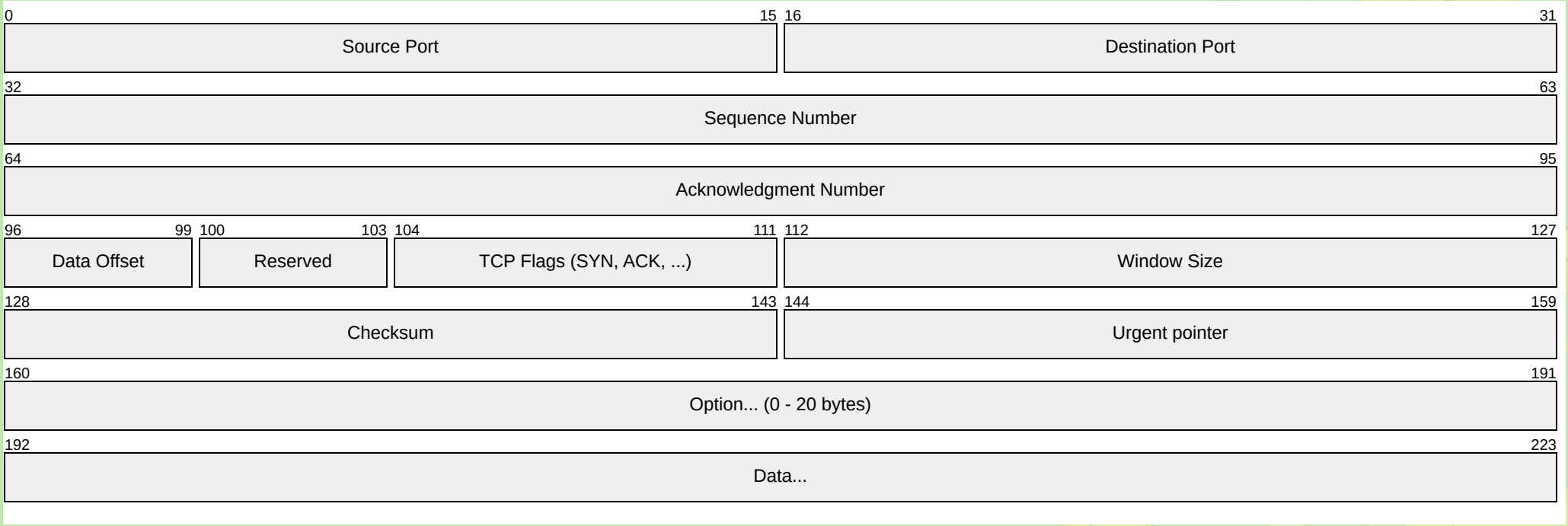
3 - TCP handshake

Example - Full HTTP GET / communication



3 - TCP handshake

TCP packet

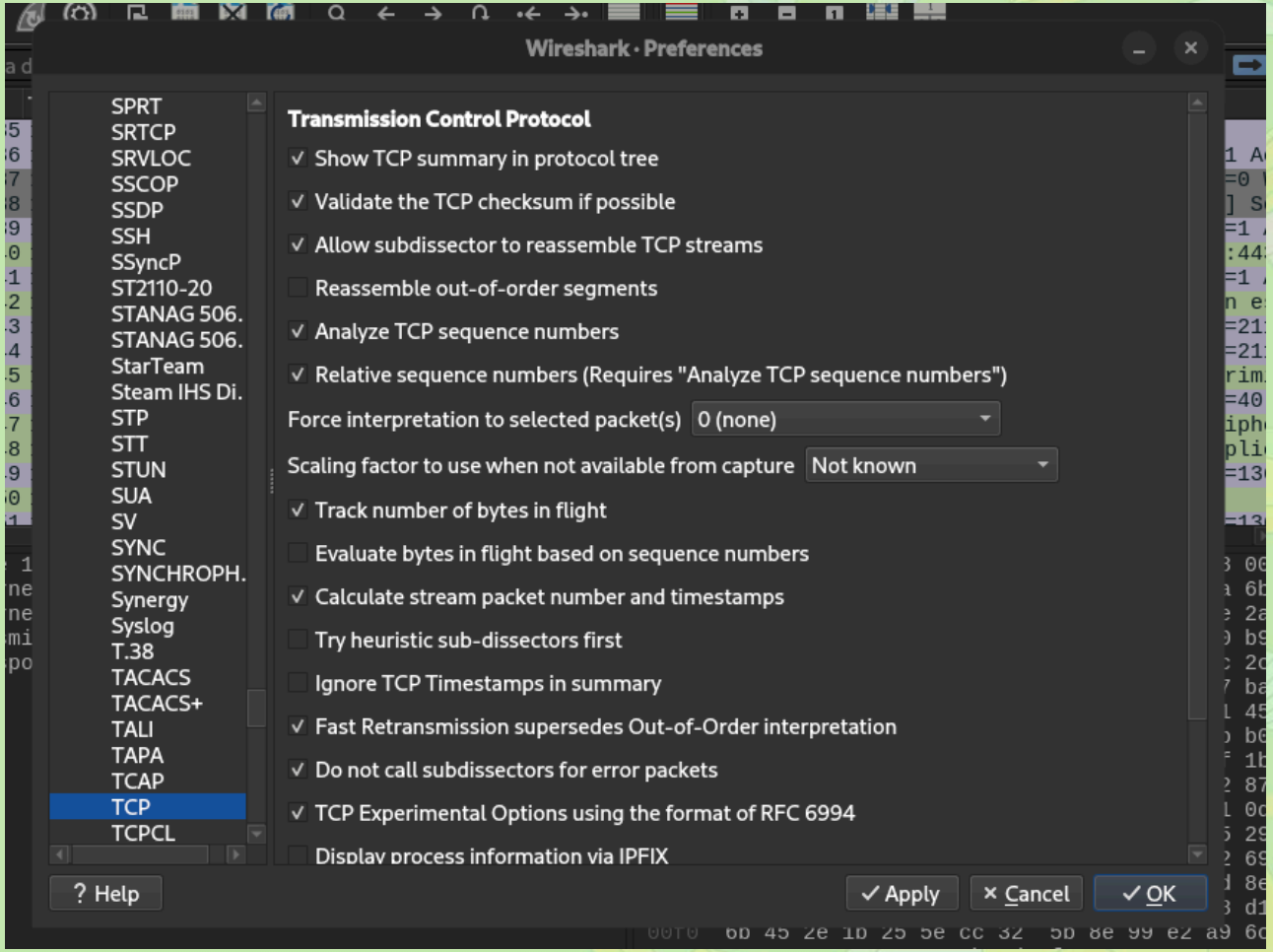


3 - TCP handshake

Tooling - Wireshark configuration

Activate checksum verification in wireshark to make sure your implementation is correct

- Edit > Preferences > Protocols > TCP > Check Validate the TCP checksum if possible > Ok



3 - TCP handshake

Exercises TCP & TCP Echo

> After the IPv4 interception developped in Exercise 2, you should now receive TCP data from the victim.

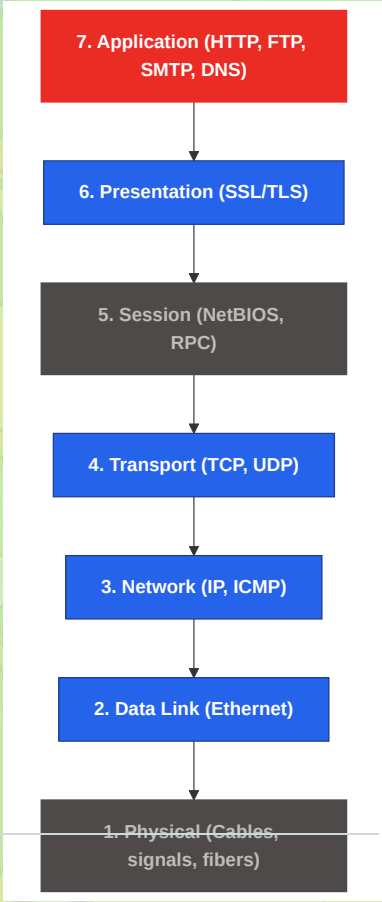
- Using custom port `4000`, implement TCP protocol interception
- `client` test binary may help you
  - It also expects your implementation to respond with the sent data ("echo")
  - You should pass tests #3 and #4 to validate this part

4 - Intercept HTTP requests

4 - Intercept HTTP requests

HTTP Protocol

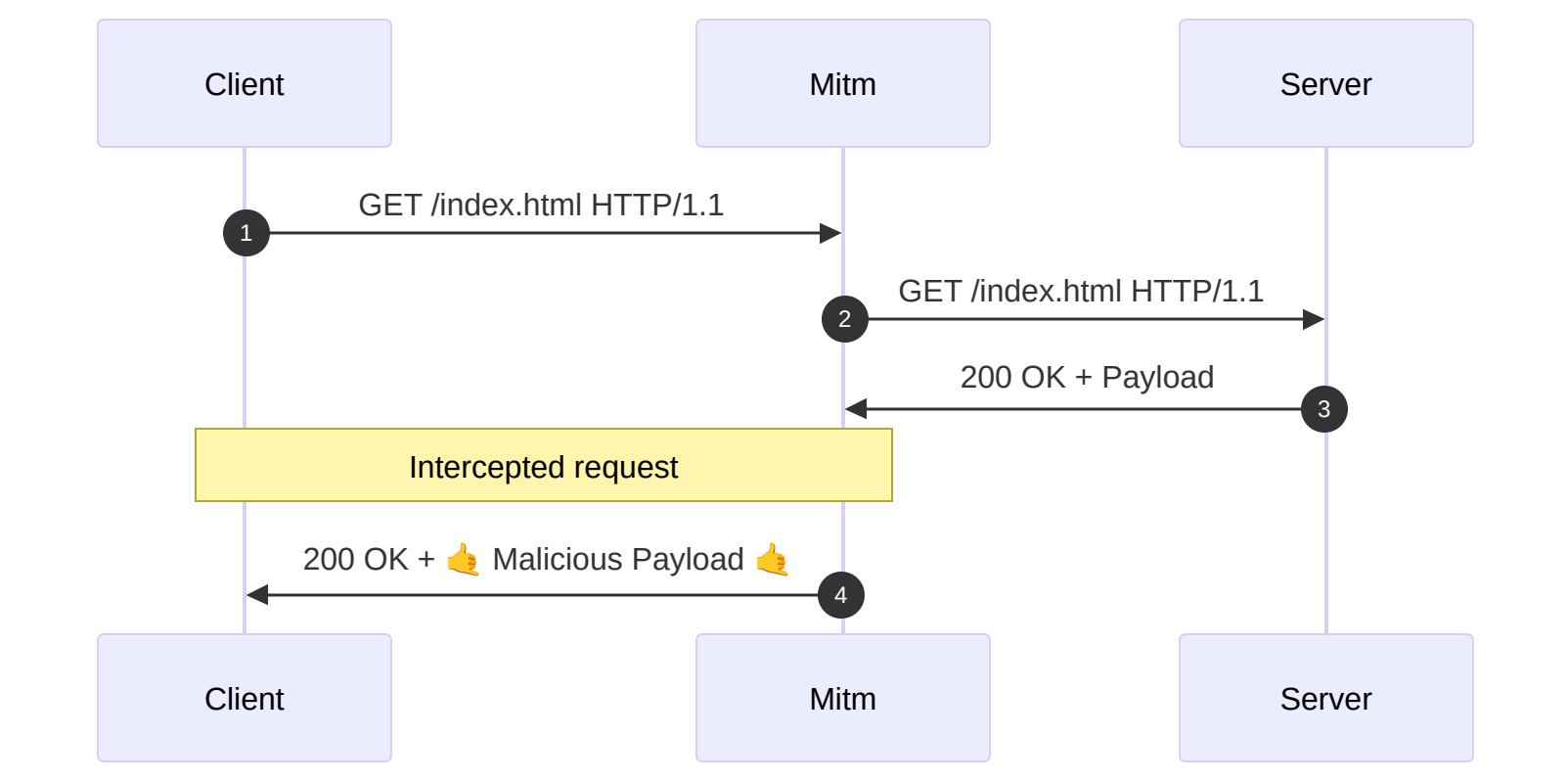
- Request-response point to point protocol
- Client-server model
- Multiple version still in use
  - HTTP/1.0[1]: text frame over TCP (deprecated)
  - HTTP/1.1[2]: Host header required, OPTIONS, persistent connections, ...
  - HTTP/2.0[3]: binary frame, simulatenous request, ...
  - HTTP/3.0[4]: uses UDP and QUIC instead of TCP



[1]: RFC 1945: Hypertext Transfer Protocol -- HTTP/1.0 https://www.rfc-editor.org/rfc/rfc1945
[2]: RFC 9112: HTTP/1.1 https://www.rfc-editor.org/rfc/rfc9112
[3]: RFC 9113: HTTP/2 https://www.rfc-editor.org/rfc/rfc9113
[4]: RFC 9114: HTTP/3 https://www.rfc-editor.org/rfc/rfc9114

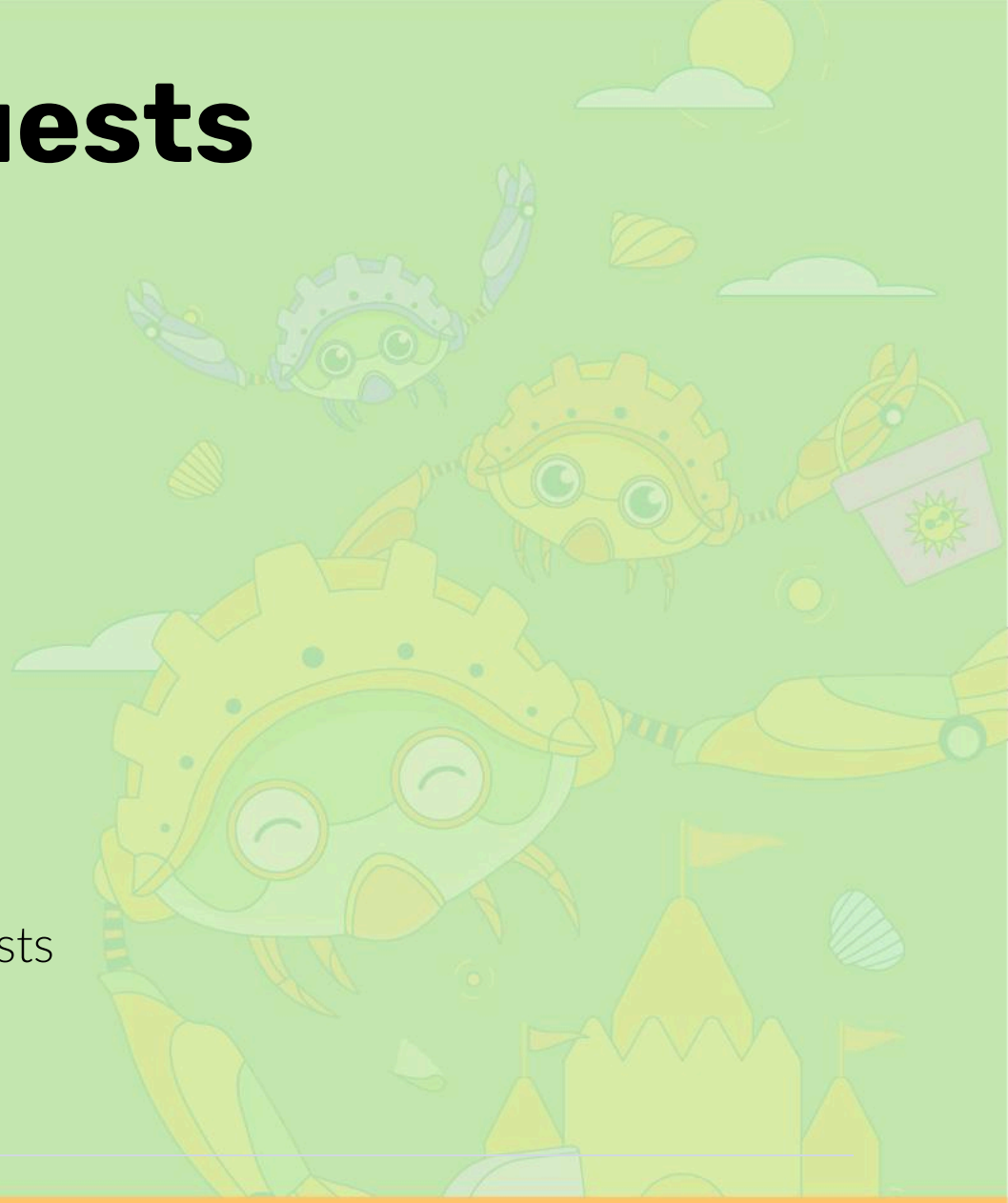
4 - Intercept HTTP requests

HTTP Protocol



4 - Intercept HTTP requests

Recommended libraries



- `ureq` [1]
  - Fully synchronous HTTP client
- `httparse` [2]
  - HTTP parsing library
  - Only supports HTTP/1.1
  - Hints about `Partial` or `Complete` HTTP requests

[1]: `ureq` documentation https://docs.rs/ureq/latest/ureq

[2]: `httparse` documentation https://docs.rs/httparse/latest/httparse/

4 - Intercept HTTP requests

Exercise HTTP

> After the TCP interception from Exercise 3 you should now receive HTTP requests from the victim.

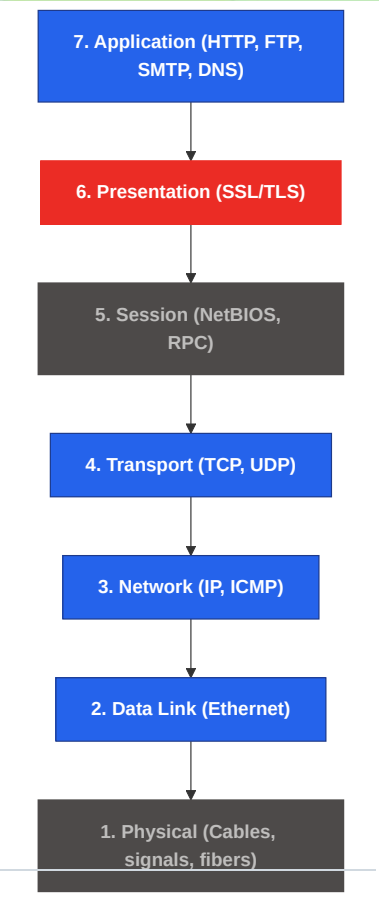
- The victim tries to connect to a website using HTTP. Can you figure out what domain it is using your MITM?
- The victim also seems to connect using credentials, can you intercept and log the username and password?
- Implement HTTP interception by logging credentials & forwarding data from the upstream server to the client
- You can use `client` binary to test your implementation
- You should pass test #5 to validate this part

5 - Handle TLS handshake

5 - Handle TLS handshake

TLS Protocol

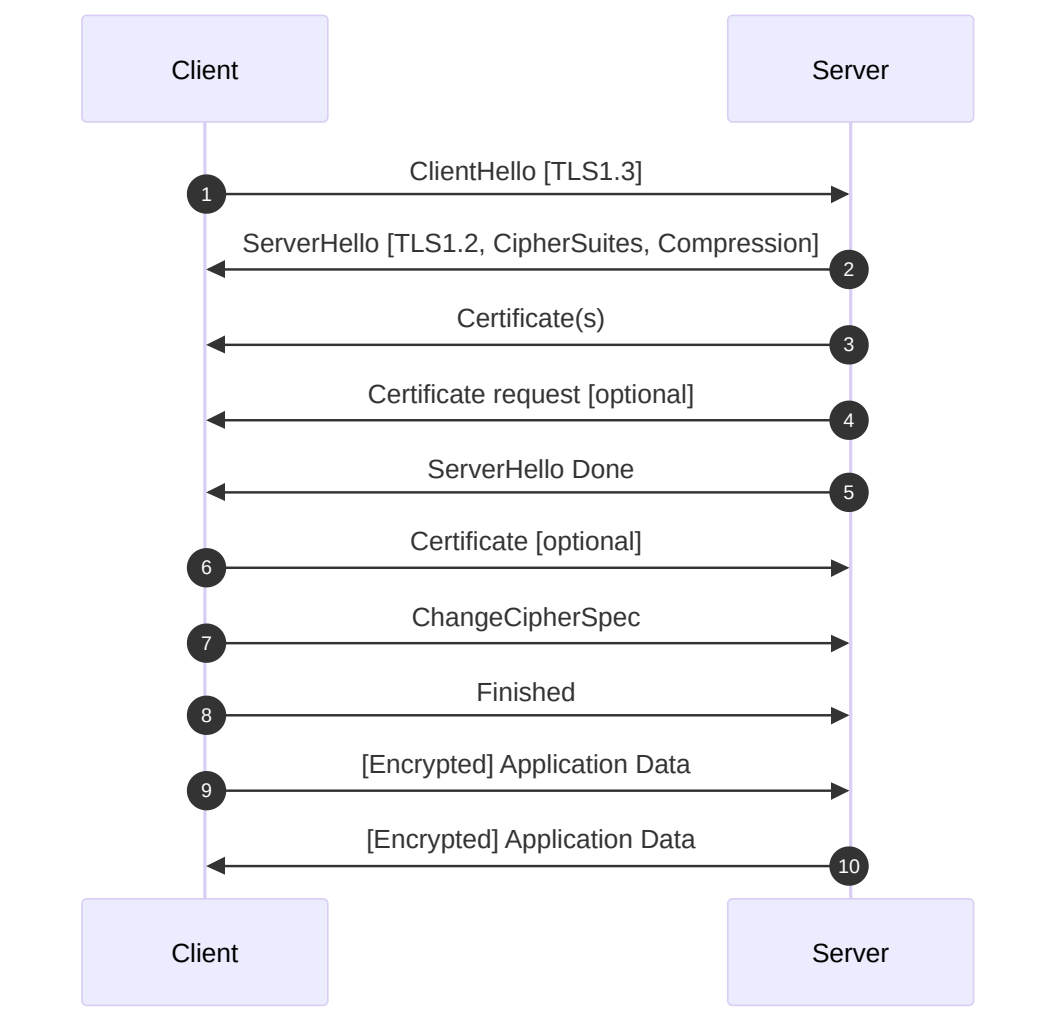
- Provide security to communications, including confidentiality, integrity, and authenticity (CIA) over various transports
- Based on asymmetric cryptography (via certificates)
- Different versions
  - SSL1.0-3.0 (1994 to 1996): deprecated
  - TLS1.0 / TLS1.1[1] (2006): deprecated since March 2021
  - TLS1.2[2] (2008)
  - TLS1.3[3] (2018)



[1]: RFC 4346: The Transport Layer Security (TLS) Protocol Version 1.1 https://www.rfc-editor.org/rfc/rfc4346
[2]: RFC 5246: The Transport Layer Security (TLS) Protocol Version 1.2 https://www.rfc-editor.org/rfc/rfc5246
[3]: RFC 8446: The Transport Layer Security (TLS) Protocol Version 1.3 https://www.rfc-editor.org/rfc/rfc8446

5 - Handle TLS handshake

TLS Protocol

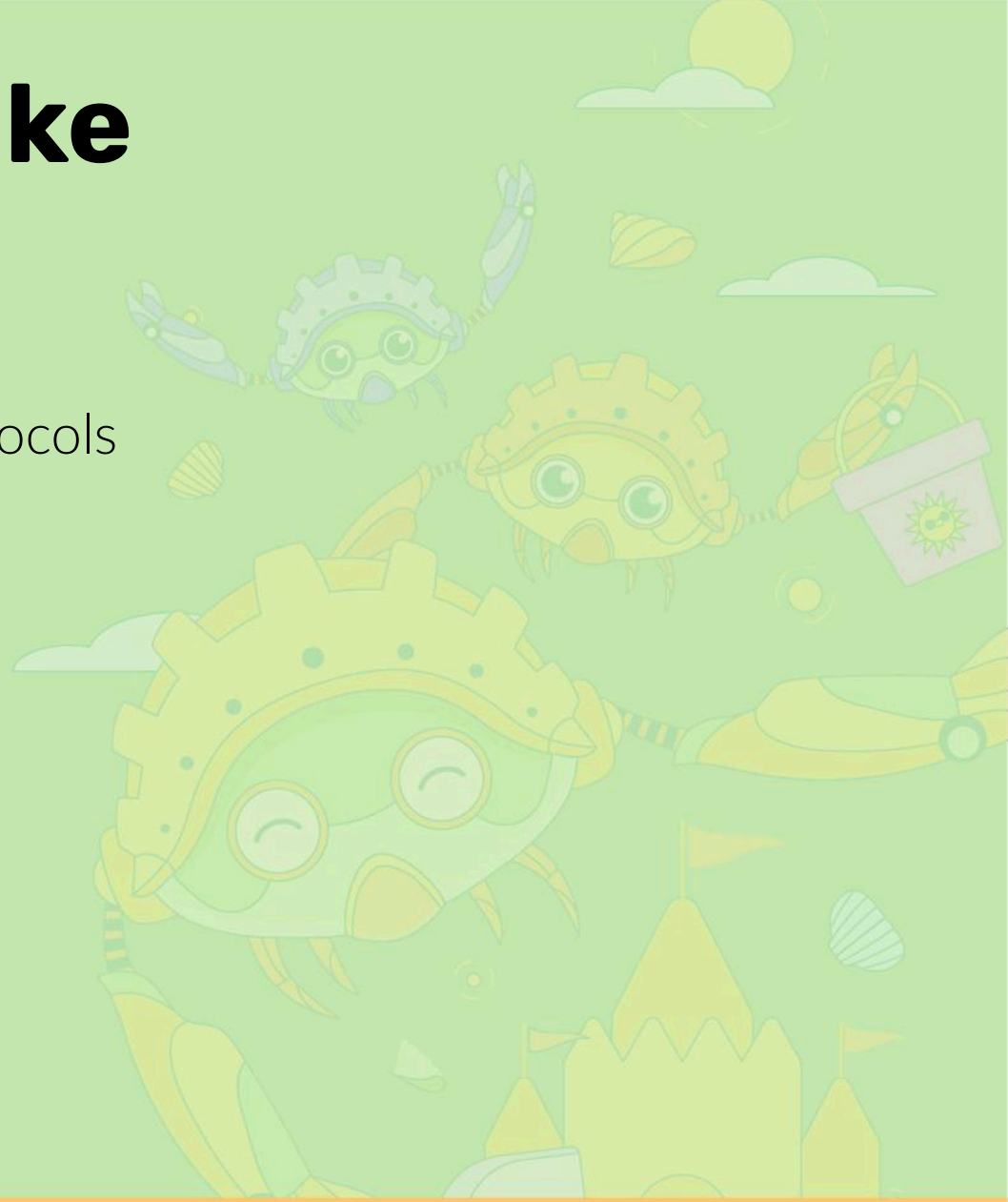


- Client initiates the handshake with its TLS version and ciphersuites
- The server responds with various information like its certificate, TLS version, chosen ciphersuite / compression...
- This is then validated by the client using a `ChangeCipherSpec` message.

5 - Handle TLS handshake

TLS Protocol

- TLS sessions can be negociated over various protocols
  - TCP (our use-case)
  - UDP
- Protocols using TLS
  - HTTPS (over TCP or UDP via QUIC)
  - DOT (*DNS Over TLS*)
  - SMTPS
  - ...



5 - Handle TLS handshake

Exercise TLS

> Using the HTTP interception from Exercise 4 we will now try to intercept TLS from our victim.

- The TLS configuration of the victim is bad and does not check provided certificates.
- You can MITM the victim by providing a self-signed certificate:
  - Either on-the-fly (generating it for the asked domain)
  - Or one-time (using `openssl req -x509 -newkey rsa:4096 -keyout key.pem -out cert.pem -days 365 -nodes -subj "/CN=mitm.com"`)
- TLS layer should then call on your previous HTTP layer :)
- `rustls`[1] library is a good choice to manage the TLS session
- You can use `client` binary to test your implementation
  - You should pass test #6 to validate this part

[1]: rustls: A modern TLS library https://github.com/rustls/rustls

Bonus

Bonus

Capture The Flag

You can now inject data into the *real* HTTP server response before forwarding it to the client, either from TLS or HTTP connections.

- This can be done by adding e.g a `<script>alert("pwned")</script>` .
- You can use `client` binary to test your implementation
- You can also open firefox on the client VM and navigate to http://FOUND_DOMAIN.com/index.html
- You should pass test #7 to validate this part

Bonus

Advanced tests

A few "advanced" tests have been implemented to experiment more protocol features.

They can be activated using `--advanced` option of `client`

- **[IP]** Packet with options
- **[TCP]** Echo with large payloads (validating MTU handling)
- **[TCP]** Maximum Segment Size handling
- **[HTTP]** Content-Encoding: gzip upstream responses

Real-life scenario

- Implement IPv6 features
- Implement missing TCP features
  - MTU management
  - Window size
  - Retransmission
- Multithreading treatments to improve performances
- Attack a gateway + dhcp spoofing
- In 2025, around 90%[1] of internet trafic is encrypted
  - Real-life clients (should?[2]) not have insecure TLS activated

[1] Traffic initiated by Google Chrome https://transparencyreport.google.com/https/overview
[2] CVE-2024-2466 in libcurl https://nvd.nist.gov/vuln/detail/cve-2024-2466

Appendices

Appendices

Physical lab

- SSID: `RUSTLAB-MITM`
- WPA2
- Password: `KhiXSvrrbCj634eXmstvcWVisw`

> **Note:** A DHCP is running on the access point, you should have an IP in range `172.16.100.[50-99]`

⚠ Exposed services

Lab is setup at layer 2, be careful to not expose local ports on your device :)

Appendices

Known IPv4 protocol numbers

Number	Protocol	Description
1	**ICMP**	Internet Control Message Protocol, used for error messages and diagnostics (e.g., ping)
6	**TCP**	Transmission Control Protocol, connection-oriented protocol for reliable communication
17	**UDP**	User Datagram Protocol, connectionless protocol for fast but unreliable communication
41	**IPv6**	IPv6 encapsulation within IPv4
58	**ICMPv6**	ICMP for IPv6, error messages and diagnostics for IPv6
89	**OSPF**	Open Shortest Path First, an internal routing protocol (IGP)

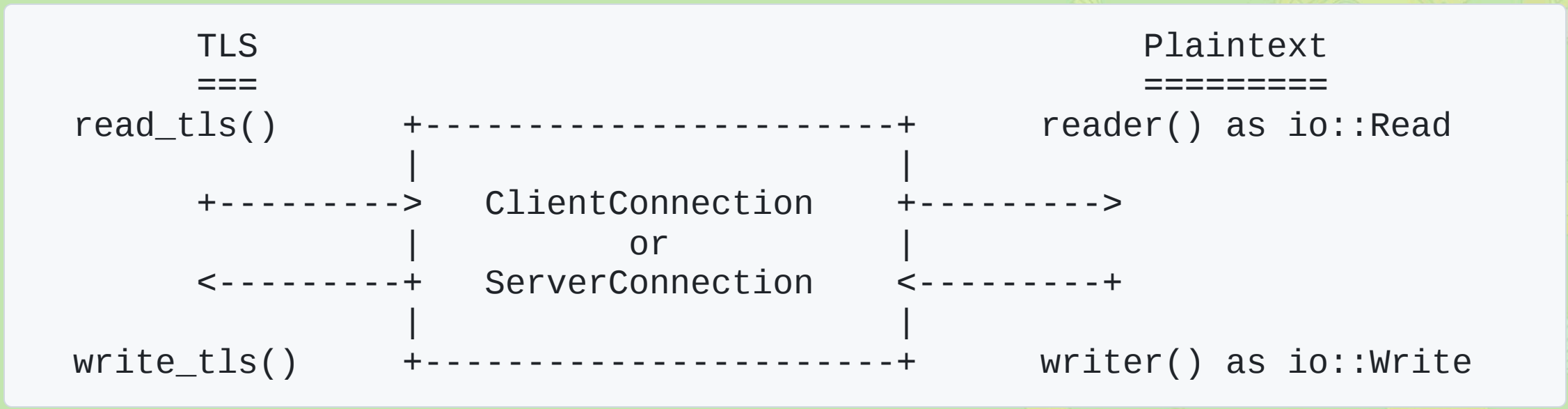
Appendices

Known TCP port numbers

Port	Service	Description
22	**SSH**	Secure Shell, for secure remote login and file transfer
25	**SMTP**	Simple Mail Transfer Protocol, for sending email
53	**DNS**	Domain Name System, resolving hostnames to IP addresses
80	**HTTP**	Hypertext Transfer Protocol, web traffic
443	**HTTPS**	HTTP over TLS/SSL, secure web traffic
465	**SMTPS**	SMTP over SSL, secure email sending

Appendices

rustls `ServerConnection` workflow



From https://docs.rs/rustls/0.23.31/rustls/index.html#rustls-provides-encrypted-pipes

Appendices

Force MAC address for a given host

> This command can be run on the `client` to "fake" the ARP spoofing part

```
CLIENT_IFACE_NAME=enp1s0
MITM_MAC_ADDRESS=0A:00:27:00:00:00
SERVER_IP_ADDR=192.168.56.20

# Linux
sudo ip neigh add $SERVER_IP_ADDR lladdr $MITM_MAC_ADDRESS dev $CLIENT_IFACE_NAME permanent
```

```
set MITM_MAC_ADDR = 08-00-27-f3-4d-aa
set MITM_IP_ADDR = 192.168.56.1
set SERVER_IP_ADDR = 192.168.56.20

:: Windows
arp -s %SERVER_IP_ADDR% %MITM_MAC_ADDR% %MITM_IP_ADDR%
```