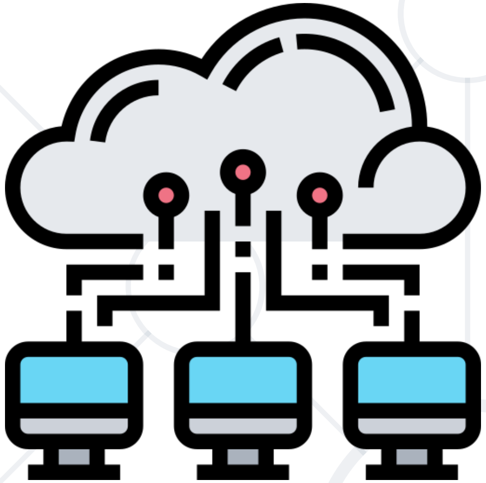
Networks, Internet and Protocols

Network Fundamentals, Network Services



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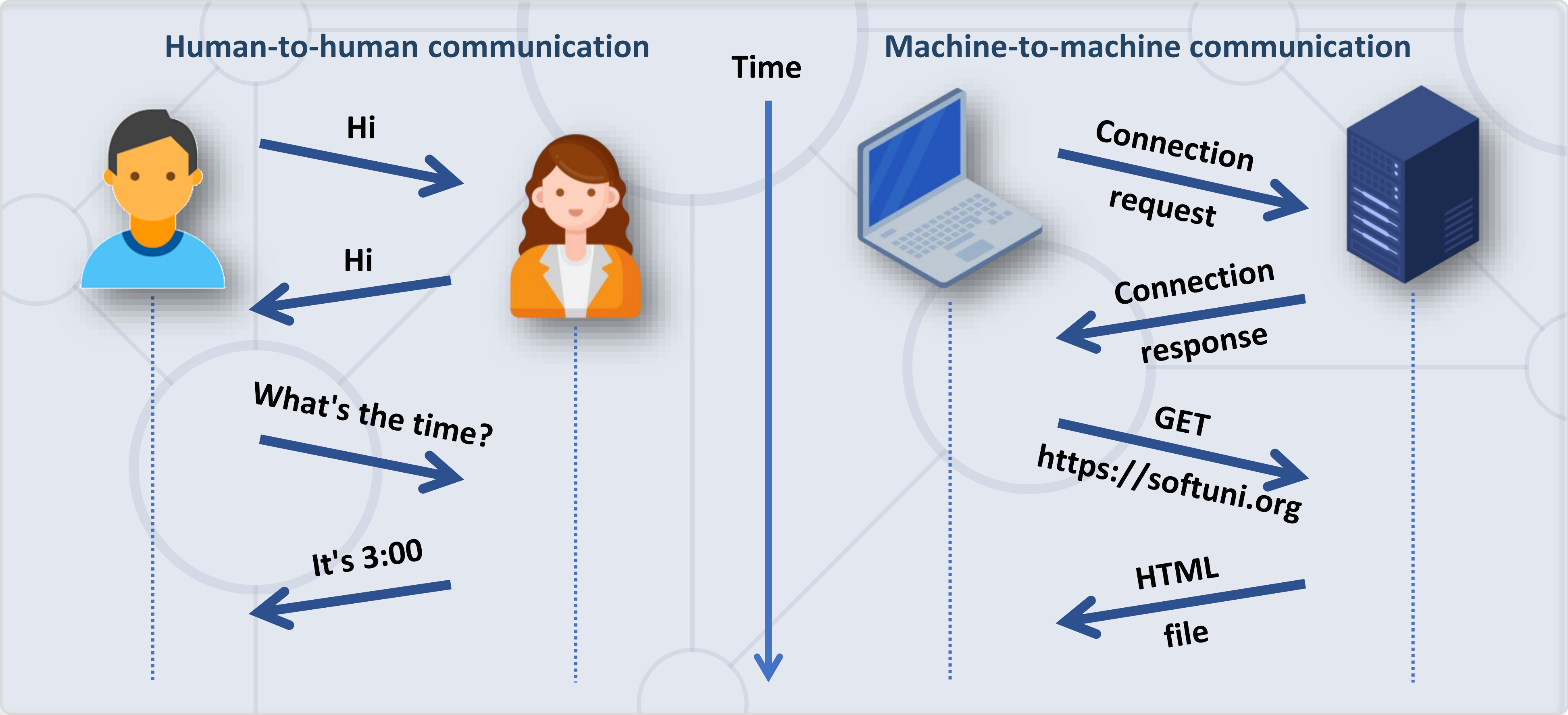
Network Fundamentals

OSI Model, MAC Address, IP Address, TCP and Ports

What is a Network Protocol?

- **Network protocol** - a **set of rules** that determine how data is transmitted between different devices on the same network

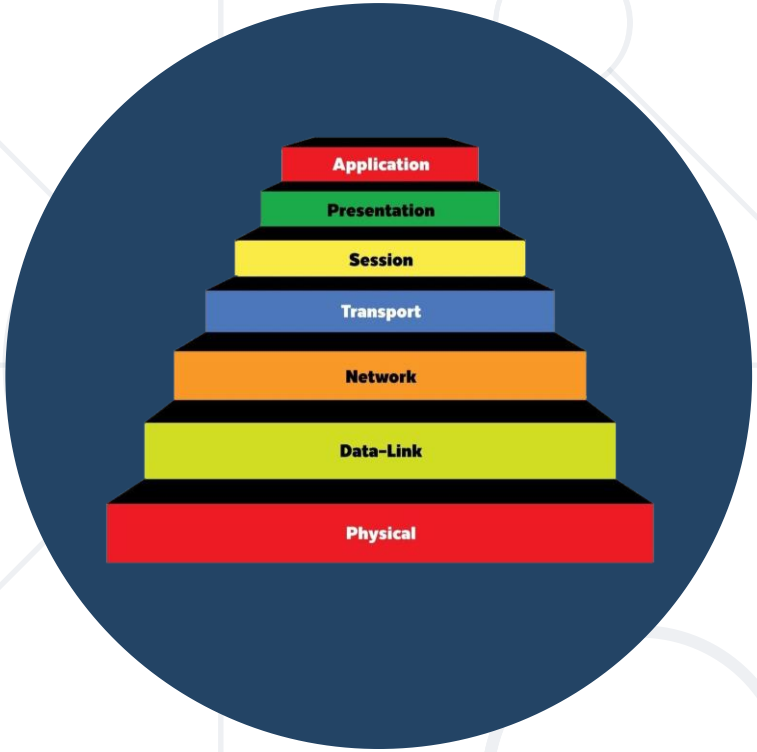


Network Protocols: Essentials

- **Network protocols** enable **standardized communication** between devices / programs
  - Typically, one party sends a **request** (command / question / other) and receives a **response** from the other party
- **Network protocols** govern aspects of **data transmission**, **addressing**, **routing**, **flow-control**, and **error handling**
- Most protocols are described in **public documents**
  - Example: https://www.rfc-editor.org/rfc/rfc5321

Network Layering Models

- **Layers** organize networking into a **structured framework**
  - Facilitate the understanding, design, and management of **complex networks**
  - **Simplifies** network communication and troubleshooting
  - Encourages protocol **interoperability** and **modularity**
- Examples:
  - **OSI** model (7 layers)
  - **TCP/IP** model (4 layers)

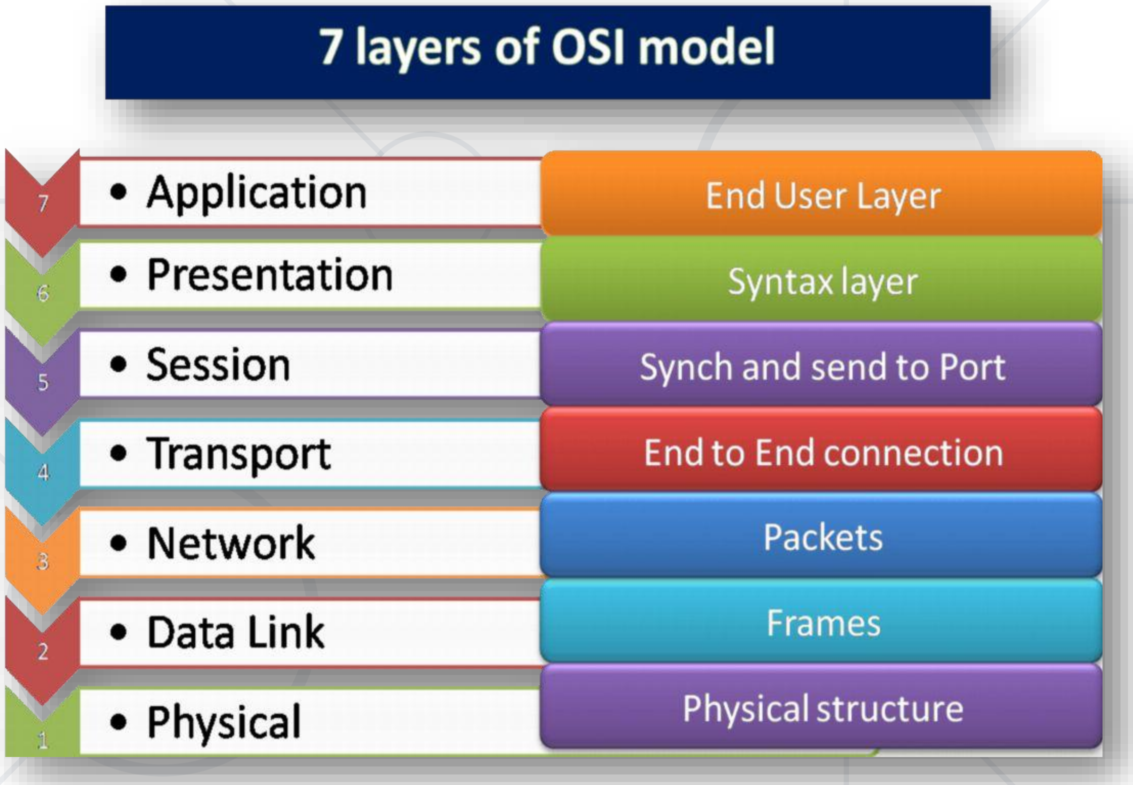


The OSI Model

Understanding the 7 Network Communication Layers

OSI Model Overview

- The **OSI Model** (**O**pen **S**ystems **I**nterconnection Model)
- Developed by the International Organization for Standardization (**ISO**) in the **1970s**
- **Framework** for understanding and designing network protocols and communication
- **7 layers** – each layer stacks on the previous and **adds functionality** to the data transmitted



7 layers of OSI model

7	Application	End User Layer
6	Presentation	Syntax layer
5	Session	Synch and send to Port
4	Transport	End to End connection
3	Network	Packets
2	Data Link	Frames
1	Physical	Physical structure

OSI Model Layers

- **Physical Layer** **(Layer 1)** – cables and radio
  - **Converts digital data** into electrical impulses, radio signals, or optical signals for transmission
  - **Devices**: hubs, repeaters, antennas
  - **Protocols**: **Ethernet**, **WiFi**, **Bluetooth**, **USB**, **RS-232**
- **Data Link Layer** **(Layer 2)** – MAC address, frames
  - **Manages data transmission**, error detection / correction
  - **MAC address**: unique identifier for network interfaces
  - **Devices**: switches, bridges, network interface cards (NICs)
  - **Protocols**: **Ethernet**, Point-to-Point Protocol (**PPP**)

OSI Model Layers

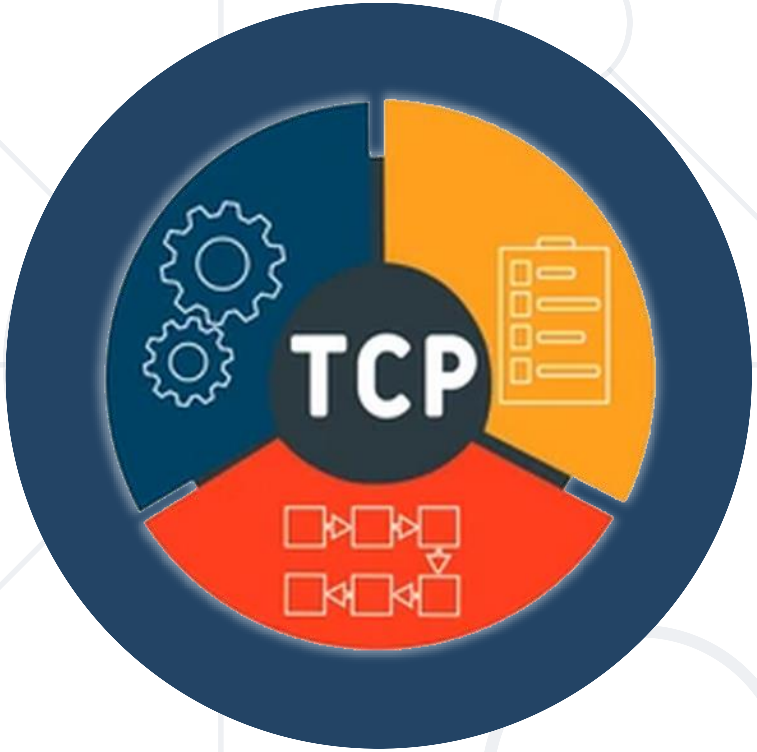
- **Network Layer (Layer 3)** – hosts and IP address, packets
  - **Packet routing:** host → router → router → … → end host, Shortest Path First (SPF), Distance Vector (DV), Link State (LS)
  - **Devices**: routers, layer 3 switches
  - **Protocols**: Internet Protocol (**IP**), **IPv6**, Internet Control Message Protocol (**ICMP**), **IPsec** (IP security), **ARP**
- **Transport Layer (Layer 4)** – ports
  - **Error checking**, flow control, congestion control, multiplexing
  - **TCP** – session-based bi-directional, reliable communication
  - **UDP** – fast, best-effort single packet delivery (connectionless)
  - **QUIC** – modern session-based protocol, multiplexed, low-latency

OSI Model Layers

- **Session Layer (Layer 5)** – sessions
  - **Functions**: dialog control, token management, synchronization
  - **Protocols**: Secure Sockets Layer (**SSL**), Transport Layer Security (**TLS**), Remote Procedure Call (**RPC**), Session Initiation Protocol (**SIP**), Network File System (**NFS**)
- **Presentation Layer (Layer 6)** – data formats
  - **Functions**: data representation, encryption, decryption, compression, decompression
  - **Standards**: **ASCII**, **UTF-8**, **JPEG**, **MPEG**

OSI Model Layers

- **Application Layer (Layer 7)** – applications
  - **Networking for applications**, e. g. Web browsers use DNS, HTTP and HTTPS to open a Web site
  - Layer 7 **protocols**
    - Hypertext Transfer Protocol (**HTTP**) and **HTTPS** (secure HTTP over SSL)
    - File Transfer Protocol (**FTP**) – transfer files
    - Simple Mail Transfer Protocol (**SMTP**) and **IMAP** (mailbox access)
    - Domain Name System (**DNS**) – host to IP address
    - Telnet and Secure Shell (**SSH**) – session to a remote host

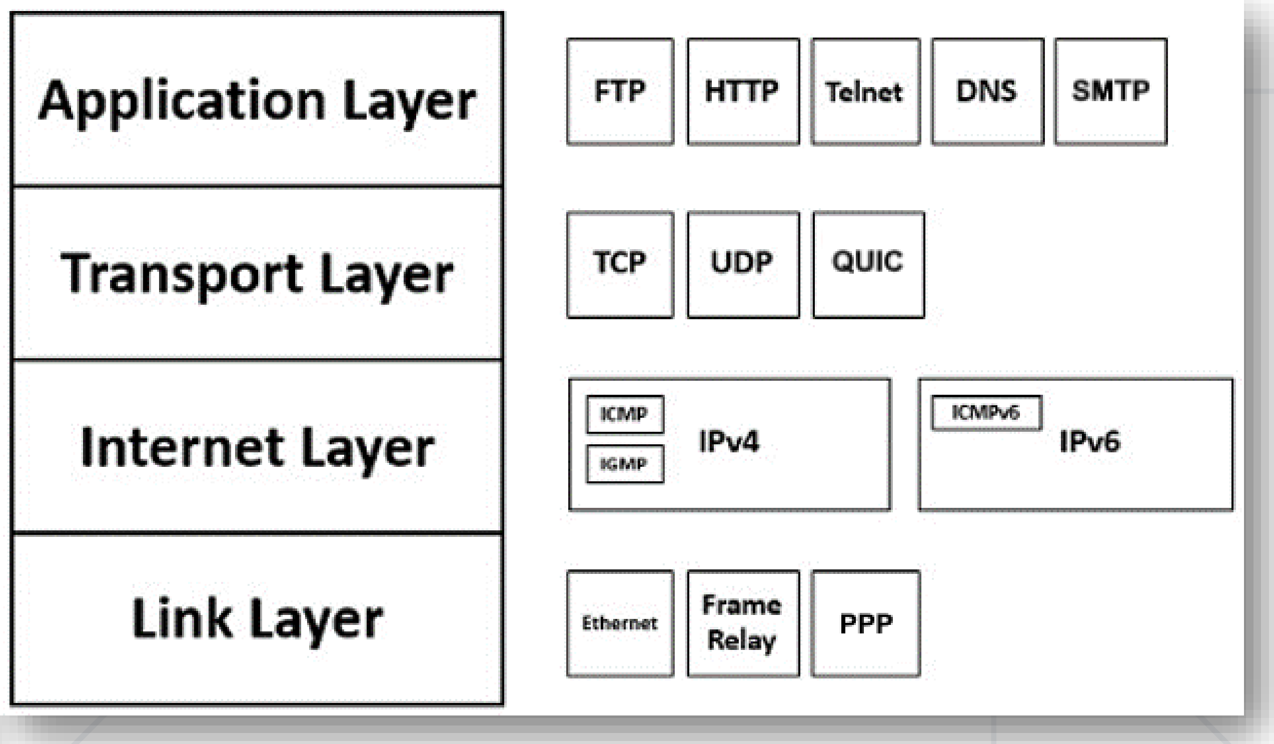


TCP/IP Model

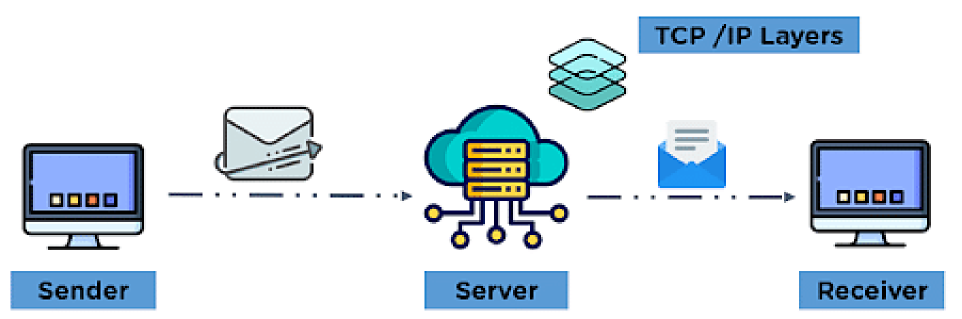
The 4 Layers in the TCP/IP Protocol Suite

TCP/IP Protocol Suite

- **TCP/IP Protocol Suite** (TCP/IP Model) == **Transmission Control Protocol** / **Internet Protocol**
  - **Simplified version of OSI**, with only 4 layers
  - Easier for developers, QAs and IT professionals



Application Layer	FTP, HTTP, Telnet, DNS, SMTP
Transport Layer	TCP, UDP, QUIC
Internet Layer	IPv4 (ICMP, IGMP), IPv6 (ICMPv6)
Link Layer	Ethernet, Frame Relay, PPP



TCP/IP Layers

- Link Layer
  - Combines the **functionalities of OSI Physical and Data Link layers**
  - Transmission and reception of data packets over a physical medium
  - Management of data link connections
- Internet Layer
  - **Corresponds to the OSI Network Layer**
  - Handling the logical addressing and routing of data packets

TCP/IP Layers

- **Transport Layer**
  - Closely **resembles the OSI Transport Layer**
- **Application Layer**
  - **Merges** the functionalities of **OSI Session, Presentation, and Application layers**

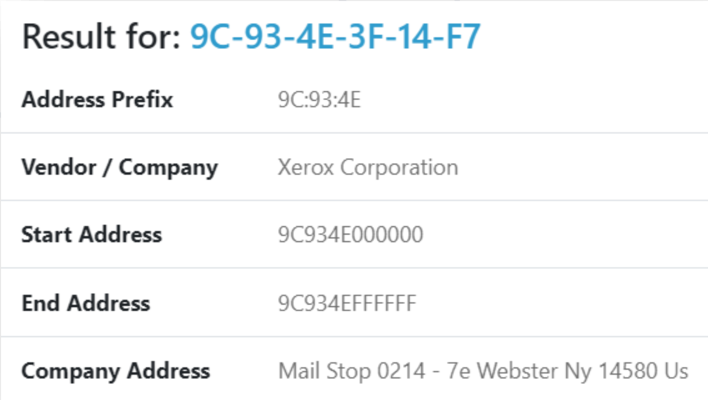
MAC, IP, Netmask, Gateway

Physical (MAC) Address, Network (IP) Address, Subnet Mask, Network Address and Gateway

Media Access Control (MAC) Address

- **MAC address** is a unique **hardware identifier** assigned to network interface cards (NICs)
  - **Format**: 48-bit (6 hex numbers), e. g. **9c-93-4e-3f-14-f7**
  - **Ethernet**, **WiFi** and **Bluetooth** devices have **MAC address**

- **Generally hardcoded** by the manufacturer
  - Decode a MAC address: https://dnschecker.org/mac-lookup.php
- Can be manually **changed** (depends)



Result for: 9C-93-4E-3F-14-F7

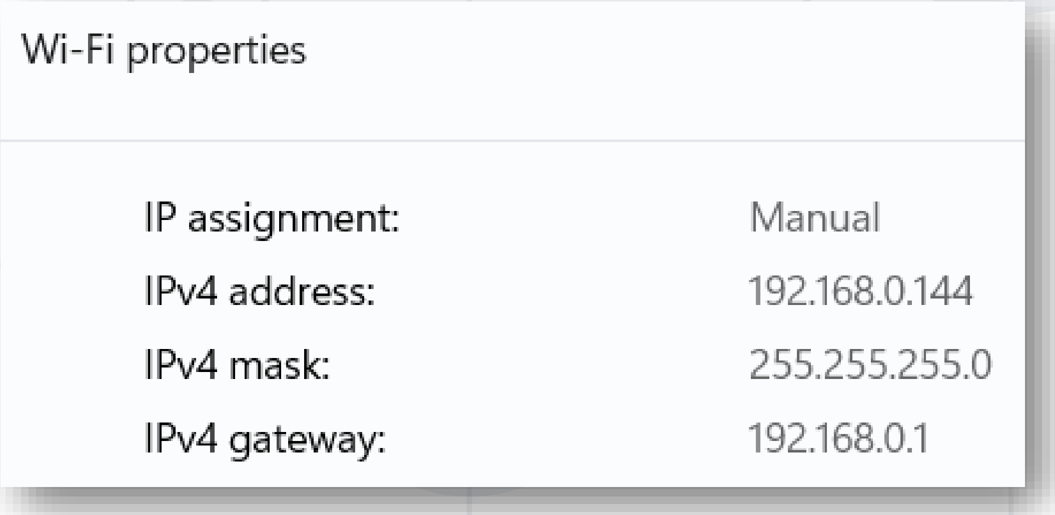
Address Prefix	9C:93:4E
Vendor / Company	Xerox Corporation
Start Address	9C934E000000
End Address	9C934EFFFFFF
Company Address	Mail Stop 0214 - 7e Webster Ny 14580 Us

Internet Protocol (IP) Address + Netmask

- **IP address** == 32-bit identifier (e. g. **192.168.0.61**) assigned to devices in a network for **addressing** and **routing** purposes
- **Netmask** (e. g. **255.255.255.0**) is a 32-bit number, used to masks out the **network part** of an IP address (IP bitwise AND mask == network address)
- **Network address + mask** (e. g. **192.168.0.0/24**) identifies the network
- **Gateway** (e. g. **192.168.0.1**) is the **router IP** used to access Internet
- **IPv6 address** == 128-bit address for the modern Internet (e. g. **2606:4700:0000:0000:0000:0000:6810:85e5**)
  - Not massively used, needs additional router configuration

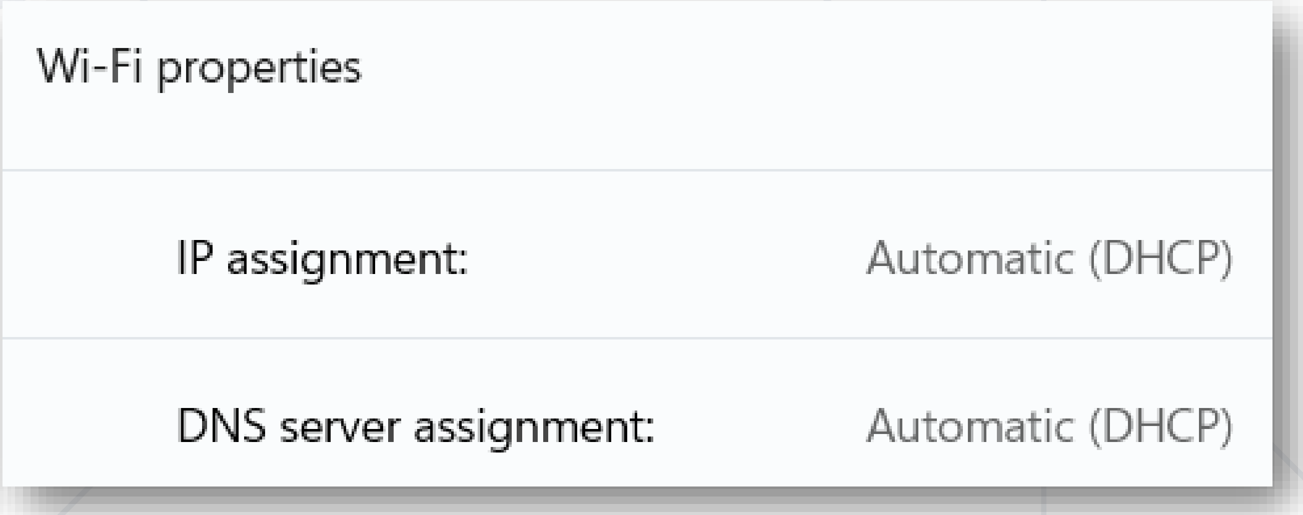
Internet Protocol (IP) Address + Netmask

- IP + netmask + gateway + DNS are assigned:
  - **Statically** (manually by hand)
  - **Dynamically** (by the router using the **DHCP protocol**)



Wi-Fi properties

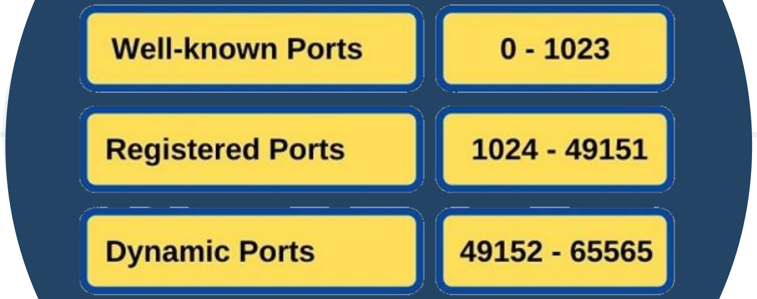
IP assignment: Manual
IPv4 address: 192.168.0.144
IPv4 mask: 255.255.255.0
IPv4 gateway: 192.168.0.1



Wi-Fi properties

IP assignment: Automatic (DHCP)

DNS server assignment: Automatic (DHCP)



Well-known Ports	0 - 1023
Registered Ports	1024 - 49151
Dynamic Ports	49152 - 65565

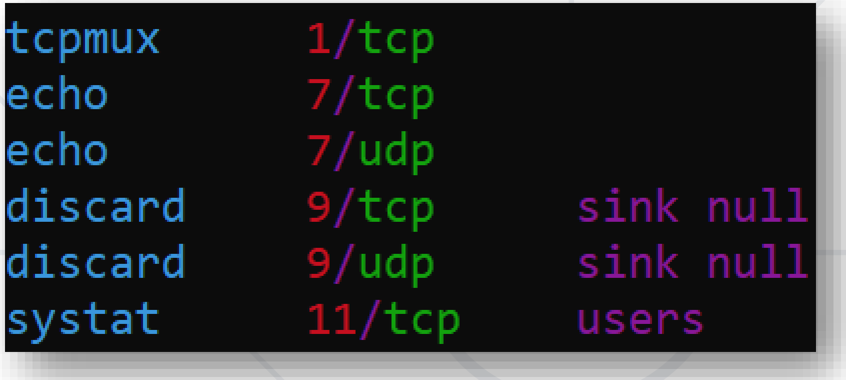
Ports

Ports Overview

- **Numerical identifiers** used to distinguish specific processes or services running on a device within a network
- Facilitate end-to-end communication between applications on different devices
- **Types of Ports**
  - **TCP ports -** Used for connection-oriented communication, ensuring reliability and data integrity
  - **UDP ports -** Used for connectionless communication, providing faster data transmission with minimal overhead

Port Numbers

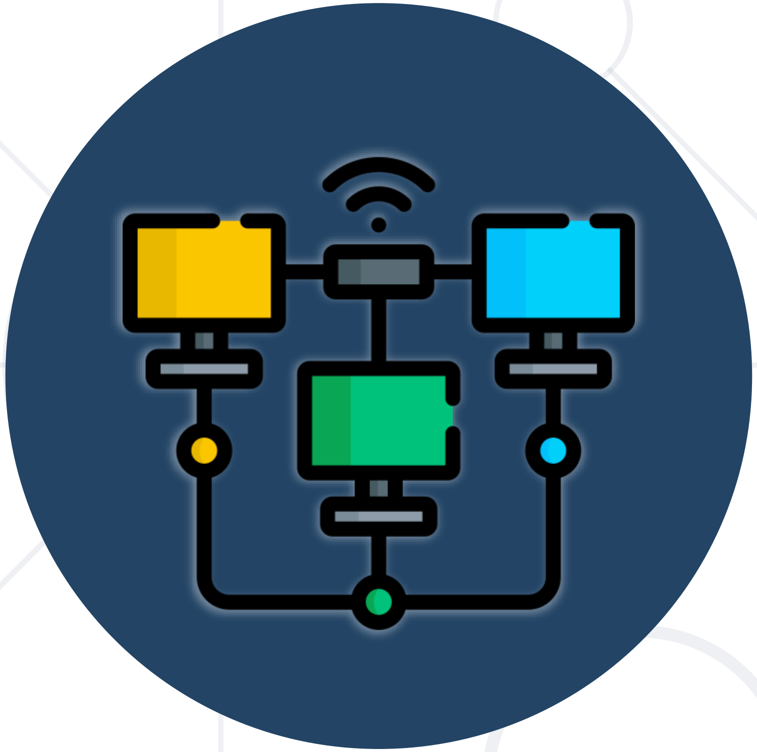
- Used to **identify** a network service
- Network services registry in **`/etc/services`**



```
tcpmux        1/tcp
echo          7/tcp
echo          7/udp
discard       9/tcp        sink null
discard       9/udp        sink null
systat        11/tcp       users
```

- Some of them are:
  - **22** – SSH, **53** – DNS, **80** – HTTP, **110** – POP3, **123** – NTP , **143** – IMAP

Ports	Port Numbers
Well-known (or system) ports	**0 – 1023**
Registered (or user) ports	**1024 – 49151**
Dynamic (and / or private) ports	**49152 – 65535**

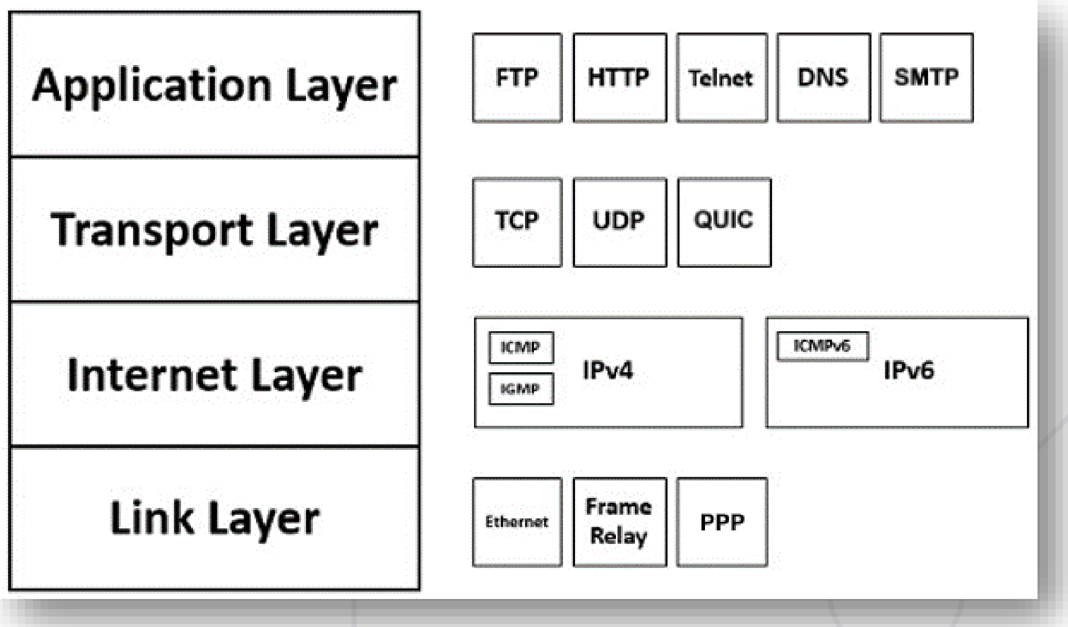


Networking: Summary

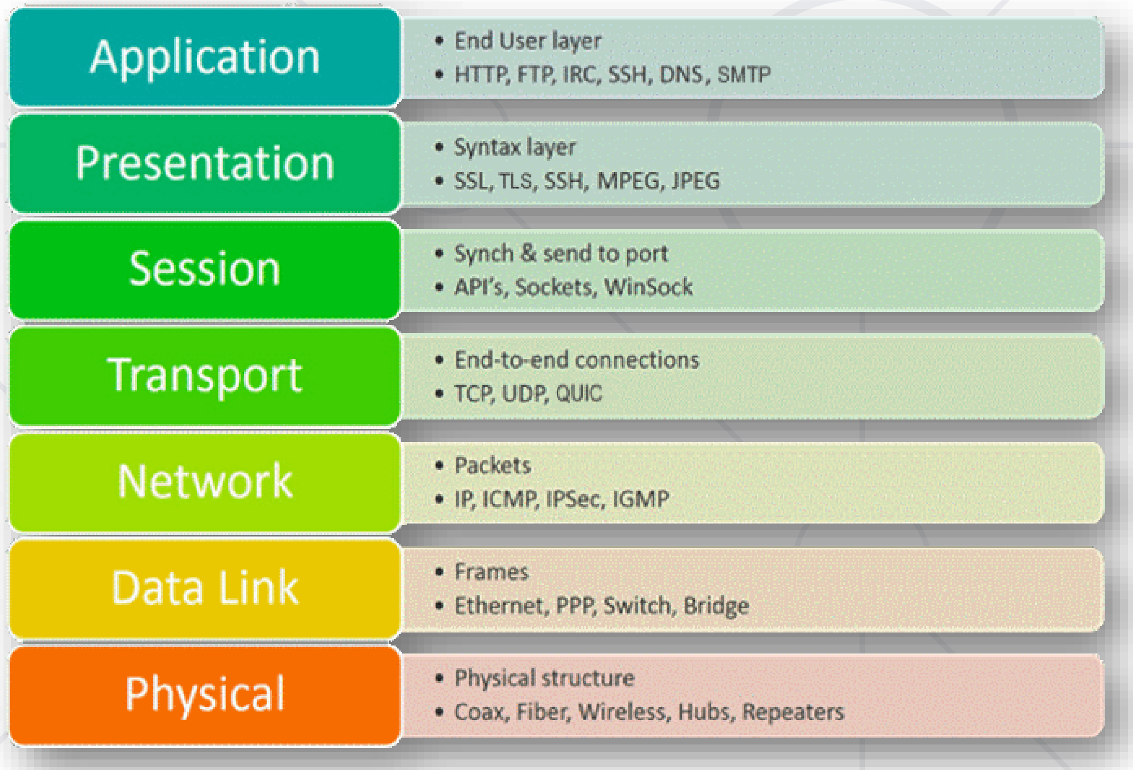
OSI Model, TCP/IP, Network Protocols

Networking and Internet Protocols Summary

- Communication in Internet uses **networking protocols**
  - The OSI model defines 7 layers of networking protocols
  - The TCP/IP model – 4 layers



Application Layer	FTP HTTP Telnet DNS SMTP
Transport Layer	TCP UDP QUIC
Internet Layer	ICMP IGMP IPv4 ICMPv6 IPv6
Link Layer	Ethernet Frame Relay PPP



Application	• End User layer • HTTP, FTP, IRC, SSH, DNS, SMTP
Presentation	• Syntax layer • SSL, TLS, SSH, MPEG, JPEG
Session	• Synch & send to port • API's, Sockets, WinSock
Transport	• End-to-end connections • TCP, UDP, QUIC
Network	• Packets • IP, ICMP, IPSec, IGMP
Data Link	• Frames • Ethernet, PPP, Switch, Bridge
Physical	• Physical structure • Coax, Fiber, Wireless, Hubs, Repeaters

Key Network Protocols

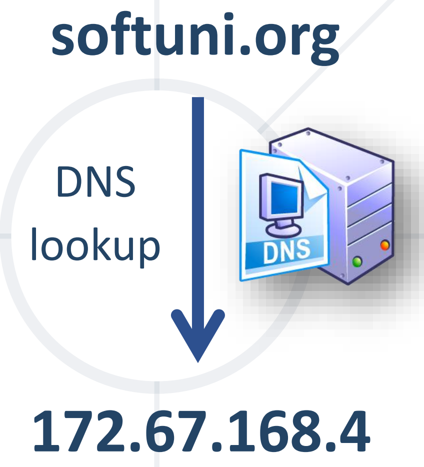
- **IP**: host-to-host communication in local networks and Internet
  - Uses **IP** address + **netmask** + **gateway** + **DNS**
- **TCP**: implements reliable transport of **data streams**; uses **ports** to distinguish connections
- **UDP**: transports **single packets**, connectionless, faster, has no error checking; uses **ports** to distinguish connections
- **QUIC**: modern fast transport for **multi-streams**, based on UDP + TLS; uses **ports** to distinguish connections
- **ICMP**: diagnostics protocol, used by **ping** and **traceroute**
- **DNS**: maps **hosts to IP** addresses (e. g. softuni.org → 172.67.168.4)
- **HTTP**: **request-response** text-based protocol for the **Web**

Web Fundamentals

WWW, Domains, DNS, URL

Domain Name System (DNS)

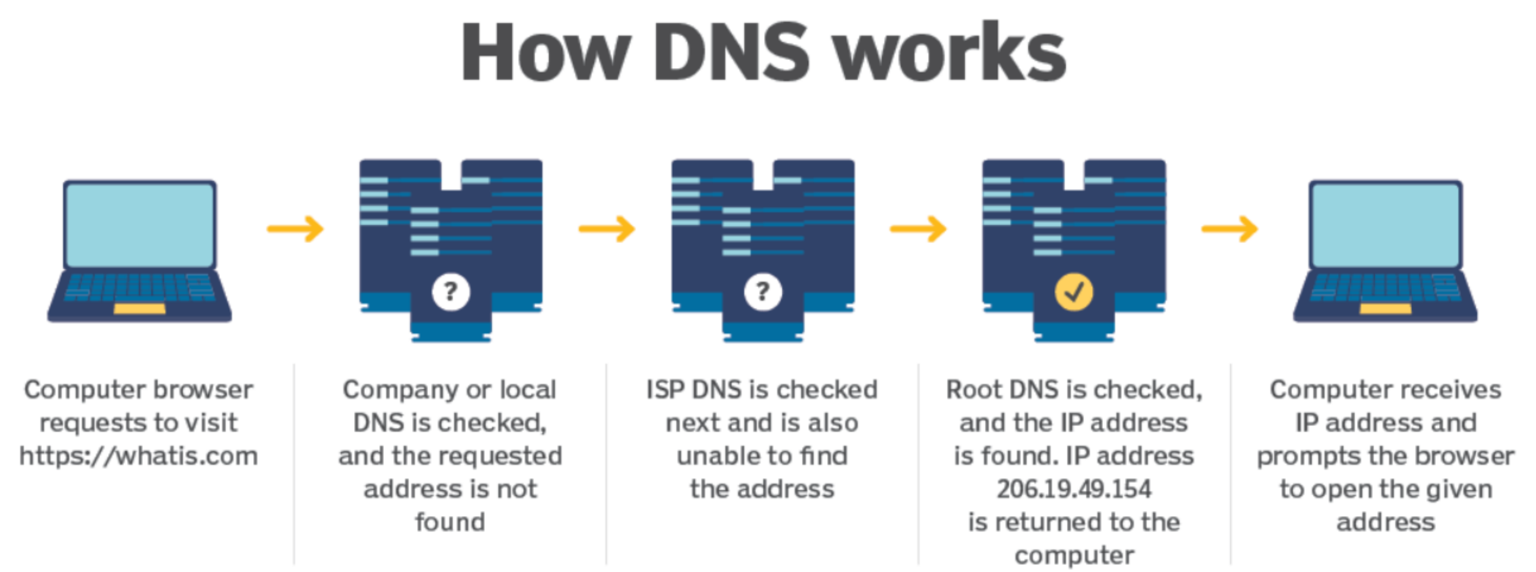
- A hierarchical, distributed system (part of Internet) that **translates domain names into IP addresses**
- Facilitates the resolution of human-readable **domain names** to machine-readable **IP addresses**



softuni.org

DNS lookup

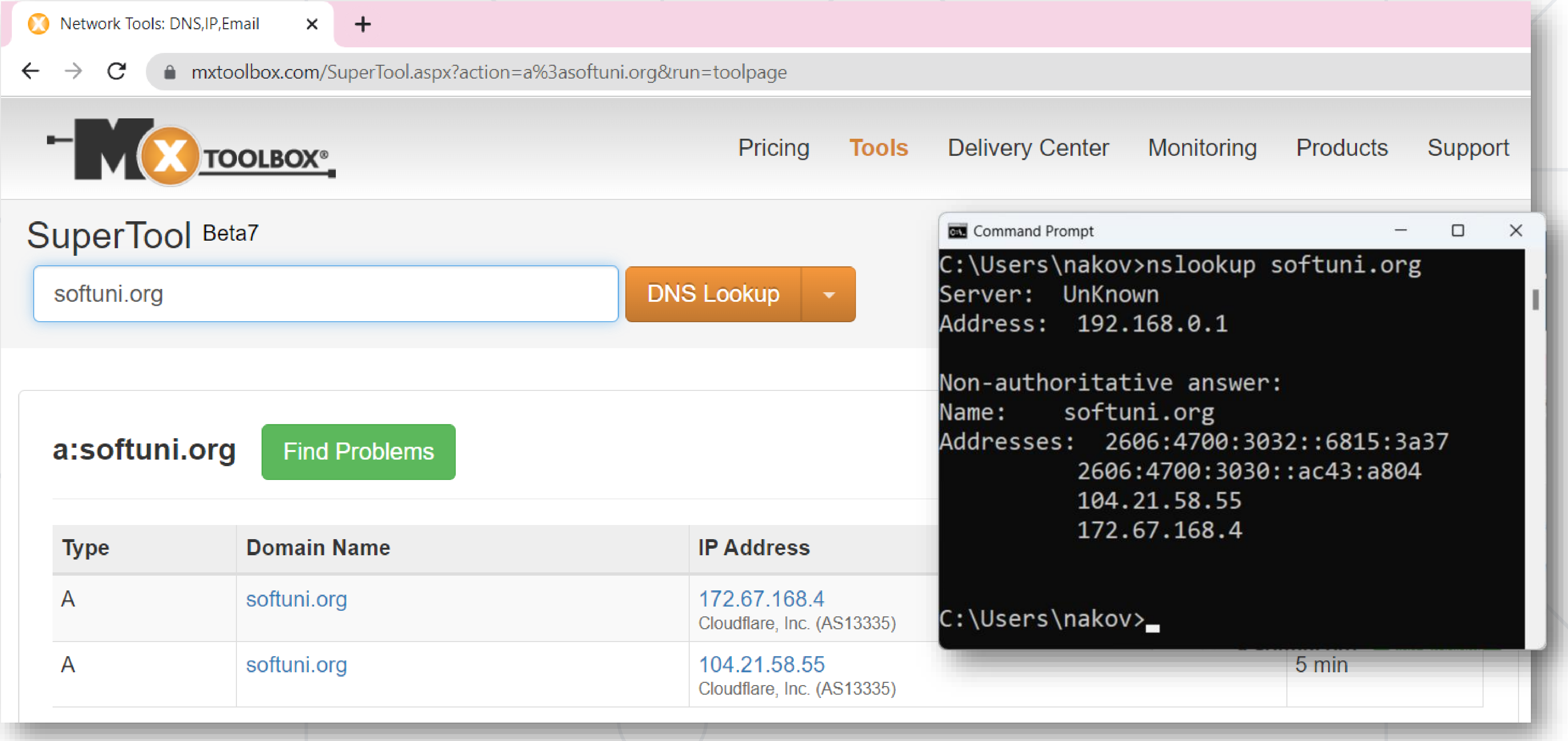
172.67.168.4



How DNS works

1. Computer browser requests to visit https://whatis.com
2. Company or local DNS is checked, and the requested address is not found
3. ISP DNS is checked next and is also unable to find the address
4. Root DNS is checked, and the IP address is found. IP address 206.19.49.154 is returned to the computer
5. Computer receives IP address and prompts the browser to open the given address

DNS Lookup – Example



a:softuni.org

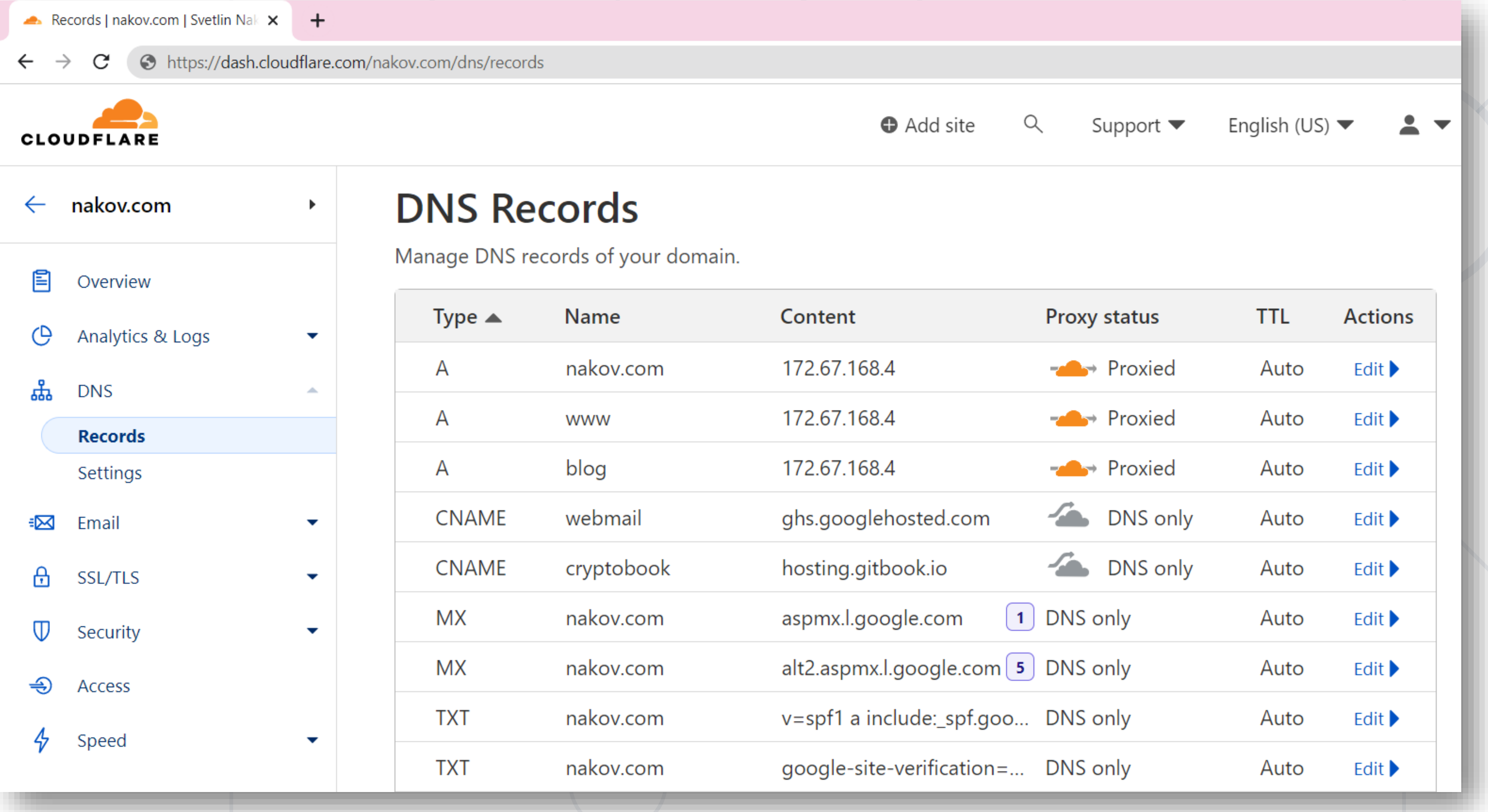
Type	Domain Name	IP Address	
A	softuni.org	172.67.168.4 Cloudflare, Inc. (AS13335)	
A	softuni.org	104.21.58.55 Cloudflare, Inc. (AS13335)	5 min

```
C:\Users\nakov>nslookup softuni.org
Server:  UnKnown
Address:  192.168.0.1

Non-authoritative answer:
Name:    softuni.org
Addresses:  2606:4700:3032::6815:3a37
          2606:4700:3030::ac43:a804
          104.21.58.55
          172.67.168.4


C:\Users\nakov>_
```

DNS Configuration – Example



DNS Records

Manage DNS records of your domain.

Type	Name	Content	Proxy status	TTL	Actions
A	nakov.com	172.67.168.4	Proxied	Auto	Edit
A	www	172.67.168.4	Proxied	Auto	Edit
A	blog	172.67.168.4	Proxied	Auto	Edit
CNAME	webmail	ghs.googlehosted.com	DNS only	Auto	Edit
CNAME	cryptobook	hosting.gitbook.io	DNS only	Auto	Edit
MX	nakov.com	aspmx.l.google.com 1	DNS only	Auto	Edit
MX	nakov.com	alt2.aspmx.l.google.com 5	DNS only	Auto	Edit
TXT	nakov.com	v=spf1 a include:_spf.goo...	DNS only	Auto	Edit
TXT	nakov.com	google-site-verification=...	DNS only	Auto	Edit

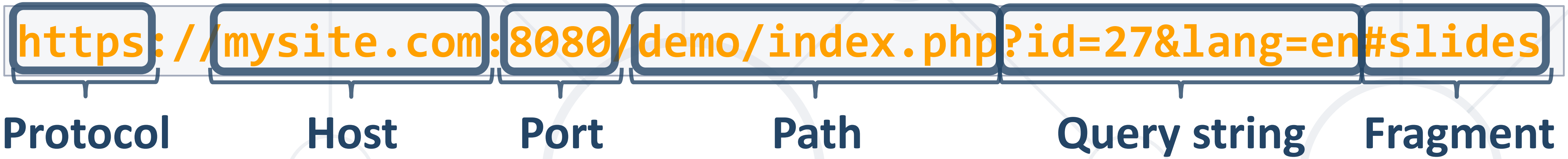
Domain Names

- **Domain name** == a **unique**, human-readable name for **Internet host** / machine / web site
  - Examples: softuni.org, www.cloudflare.com, students.softuni.bg
  - **Simplify navigation** to websites, easier to remember and share
- Domain structure
  - **Top-level domains (TLDs)** – .com, .net, .org, .info, .us, .uk, .de, .uk
  - **Second-level domains (SLDs)** – website's name, softuni.org
  - **Subdomains** – inner hosts, e. g. blog.nakov.com

What is a URL?

- A **URL** (Uniform Resource Locator) is a **unique address** pointing to a **website**, a **web page**, or a **document** on the Internet
  - Example: https://java-book.softuni.org/home?lang=en
- **Structure-wise**, a URL consists of multiple **elements**
  - Communication protocol, e. g. **https://**
  - Subdomain, e. g. **java-book**
  - Domain name, e. g. **softuni.org**
  - Path to the resource, e. g. **/home**
  - Parameters, e. g. **?lang=en**

Uniform Resource Locator (URL) Example

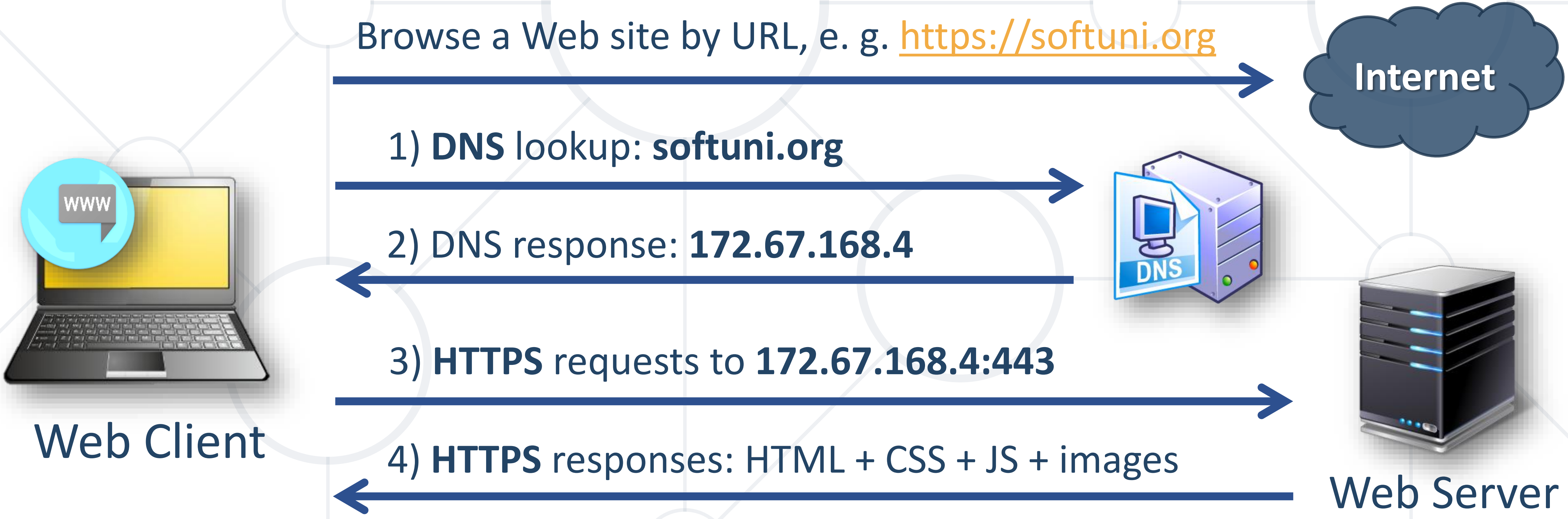


`https://mysite.com:8080/demo/index.php?id=27&lang=en#slides`

- **Network protocol** (**`https`**, **`http`**, **`ftp`**, …) – HTTPS in most cases
- **Domain**, **host**, or **IP** address (**`softuni.org`**, **`mail.yahoo.com`**, **`127.0.0.1`**, **`[::1]`**, **`[2606:4700::6810:85e5]`**, **`webmail`**)
- **Port** (the default HTTPS port is **443**) – integer [0…65535]
- **Path** (**`/forum`**, **`/path/index.php`**) – a script / page on the Web server
- **Query string** (**`?id=27&lang=en`**) – parameters in format **key=value**
- **Fragment** (**`#slides`**) – navigate to certain section in the page

WWW (World Wide Web)

- A **global**, **interconnected system** of documents, images, and other resources, accessed through the Internet using **Web browsers**



Browse a Web site by URL, e. g. https://softuni.org

1) **DNS** lookup: **softuni.org**

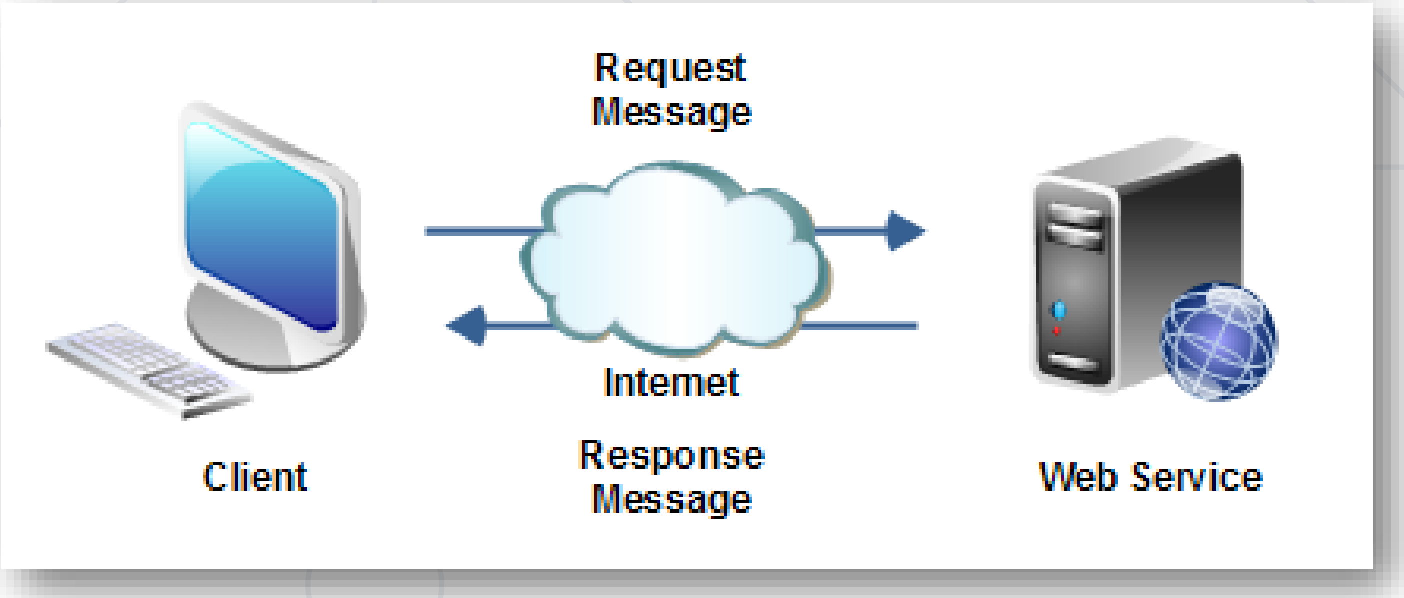
2) DNS response: **172.67.168.4**

3) **HTTPS** requests to **172.67.168.4:443**

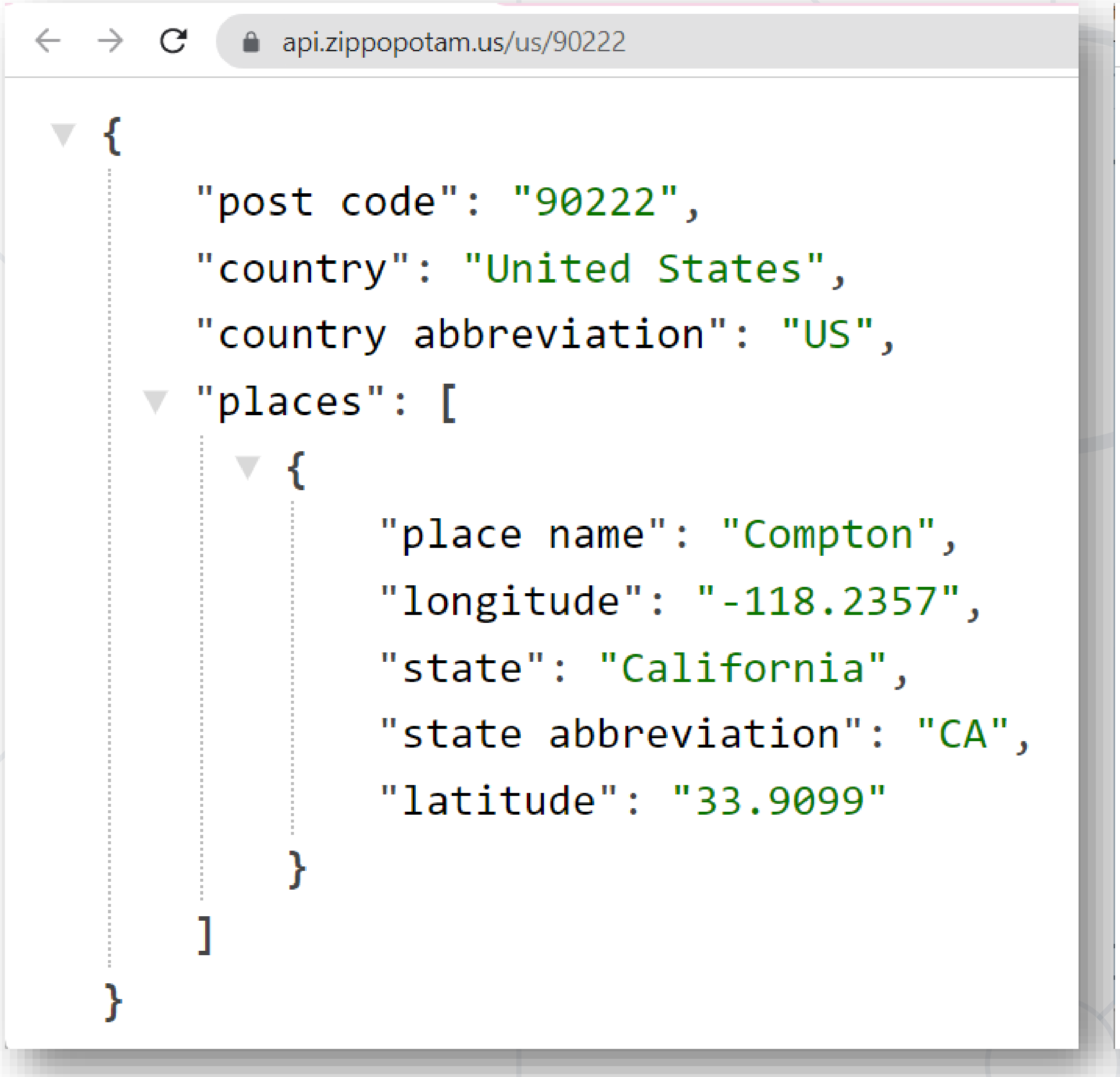
4) **HTTPS** responses: HTML + CSS + JS + images

What is a Web Service?

- **Web services** implement **communication** between software **systems** or **components** of over the **network**
  - Using standard **protocols**, such as HTTP, JSON and XML
  - Exchanging **messages**, holding data and operations

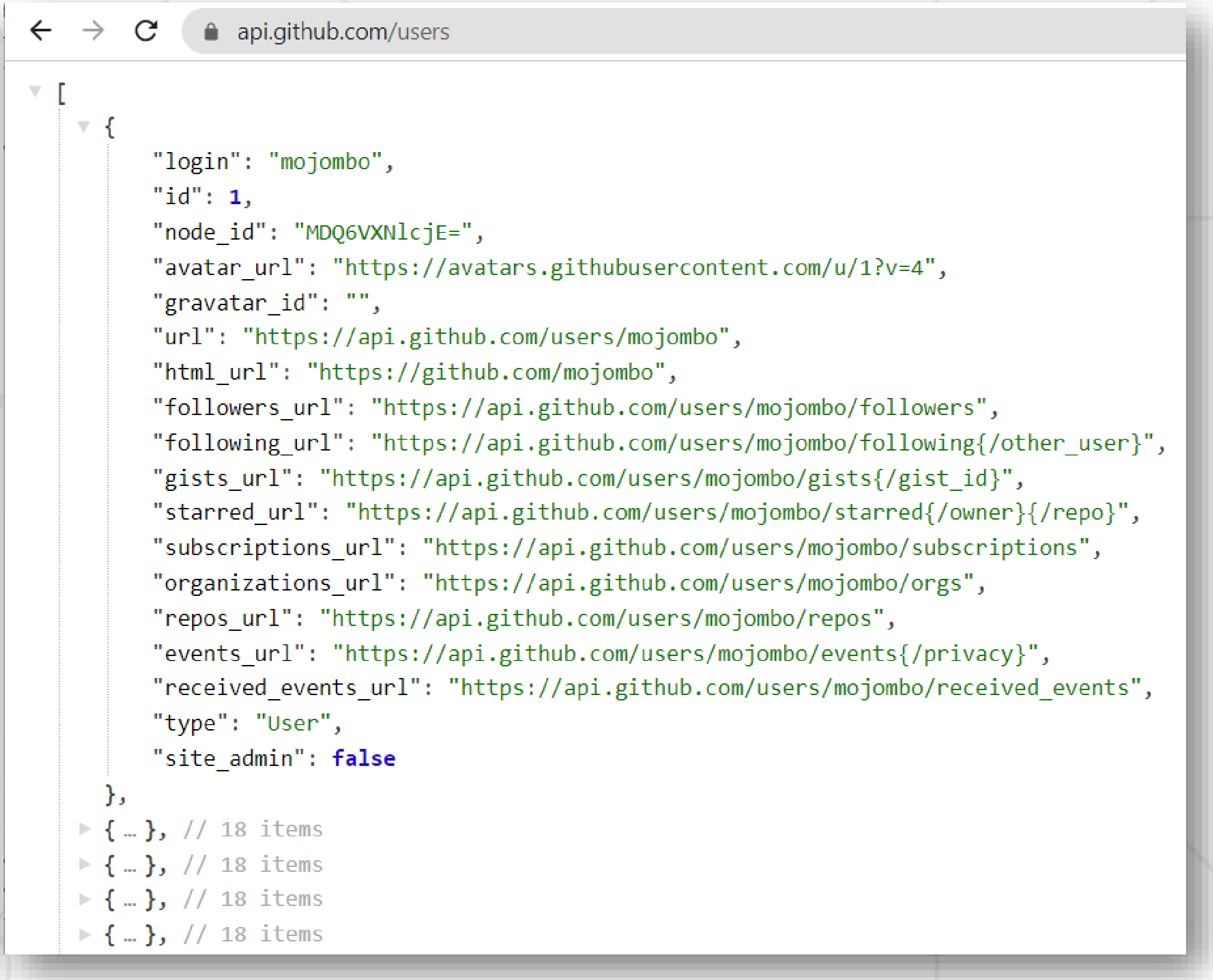


Web Service Call – Examples



api.zippopotam.us/us/90222

```
{
    "post code": "90222",
    "country": "United States",
    "country abbreviation": "US",
    "places": [
        {
            "place name": "Compton",
            "longitude": "-118.2357",
            "state": "California",
            "state abbreviation": "CA",
            "latitude": "33.9099"
        }
    ]
}
```



api.github.com/users

```
[
  {
    "login": "mojombo",
    "id": 1,
    "node_id": "MDQ6VXNlcjE=",
    "avatar_url": "https://avatars.githubusercontent.com/u/1?v=4",
    "gravatar_id": "",
    "url": "https://api.github.com/users/mojombo",
    "html_url": "https://github.com/mojombo",
    "followers_url": "https://api.github.com/users/mojombo/followers",
    "following_url": "https://api.github.com/users/mojombo/following{/other_user}",
    "gists_url": "https://api.github.com/users/mojombo/gists{/gist_id}",
    "starred_url": "https://api.github.com/users/mojombo/starred{/owner}{/repo}",
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    "received_events_url": "https://api.github.com/users/mojombo/received_events",
    "type": "User",
    "site_admin": false
  },
  { … }, // 18 items
  { … }, // 18 items
  { … }, // 18 items
  { … }, // 18 items
```
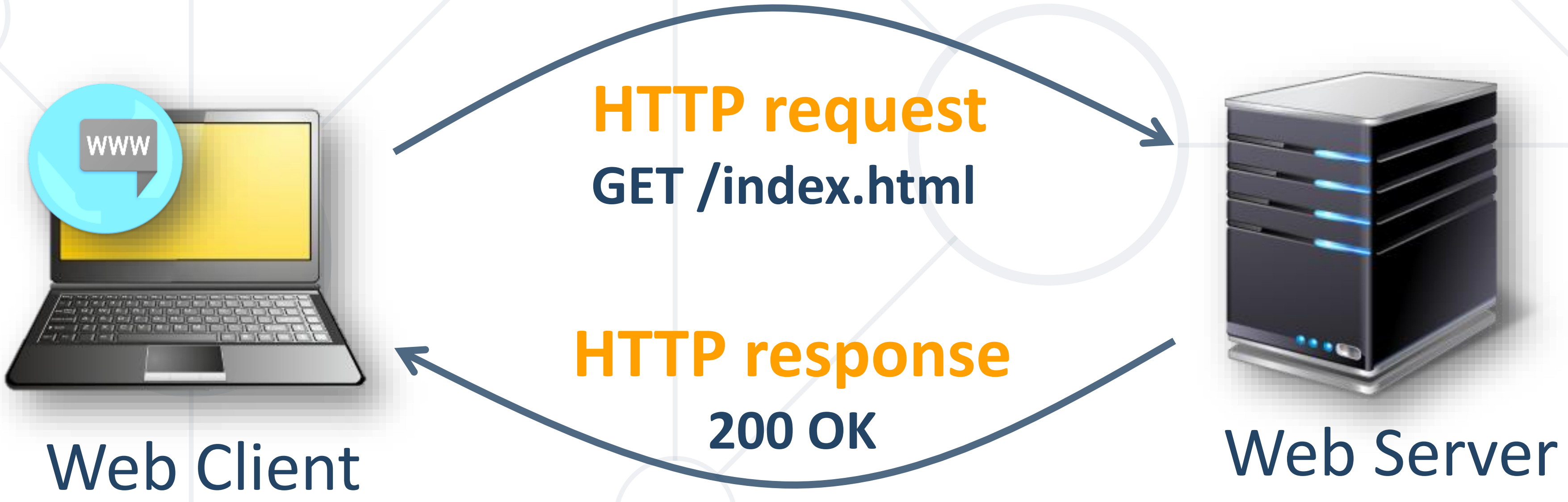

HTTP Protocol – Basics

Request-Response Text-Based Protocol for the Web

HTTP Basics

- **HTTP** (HyperText Transfer Protocol)
  - **Text-based** client-server protocol for the Internet
  - For transferring **Web resources** (HTML files, images, styles, etc.)
  - **Request-response** based



HTTP request

GET /index.html

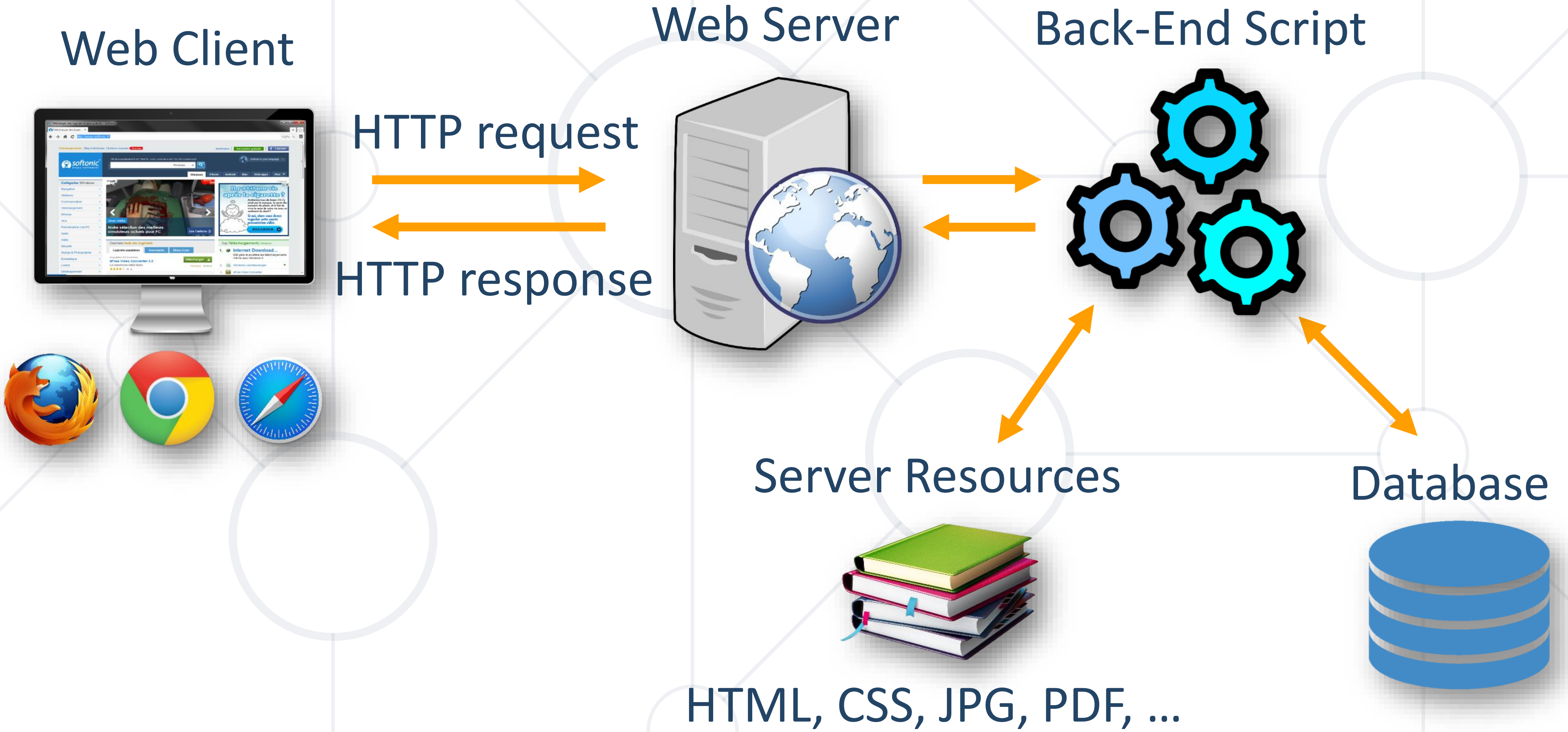
HTTP response

200 OK

Web Client

Web Server

Web Server: How It Works?



Web Client

HTTP request

HTTP response

Web Server

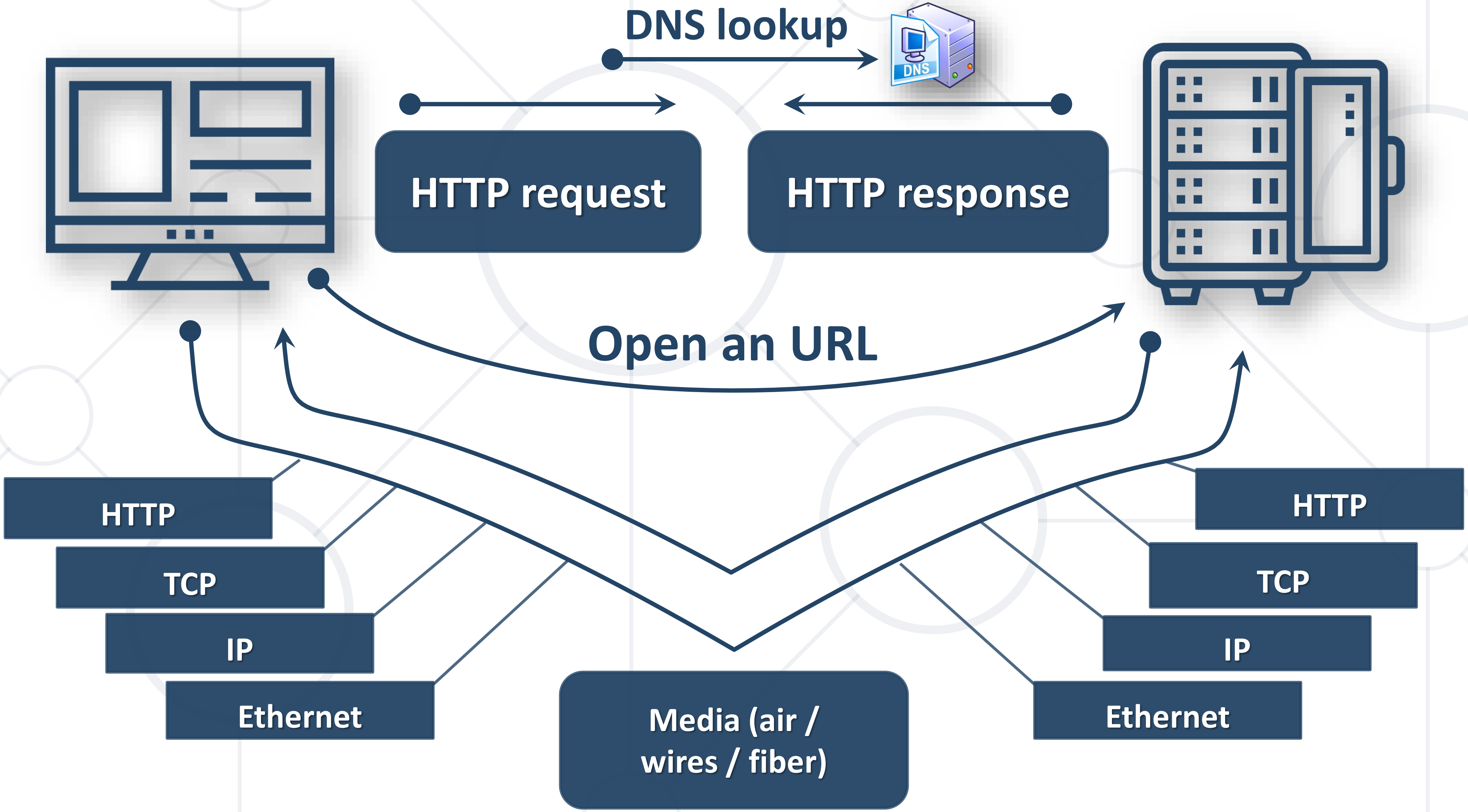
Back-End Script

Server Resources

HTML, CSS, JPG, PDF, …

Database

Network Layers and HTTP



HTTP Request Methods

- **HTTP request methods** specify the desired **action** to be performed on the requested resource (identified by URL)

Method	Description
GET	Retrieve a resource
POST	Create / store a resource
PUT	Update (replace) a resource
DELETE	Delete (remove) a resource
PATCH	Update resource partially (modify)
HEAD	Retrieve the resource's headers

CRUD == the four main functions of persistent storage

Other Methods
CONNECT
OPTIONS
TRACE

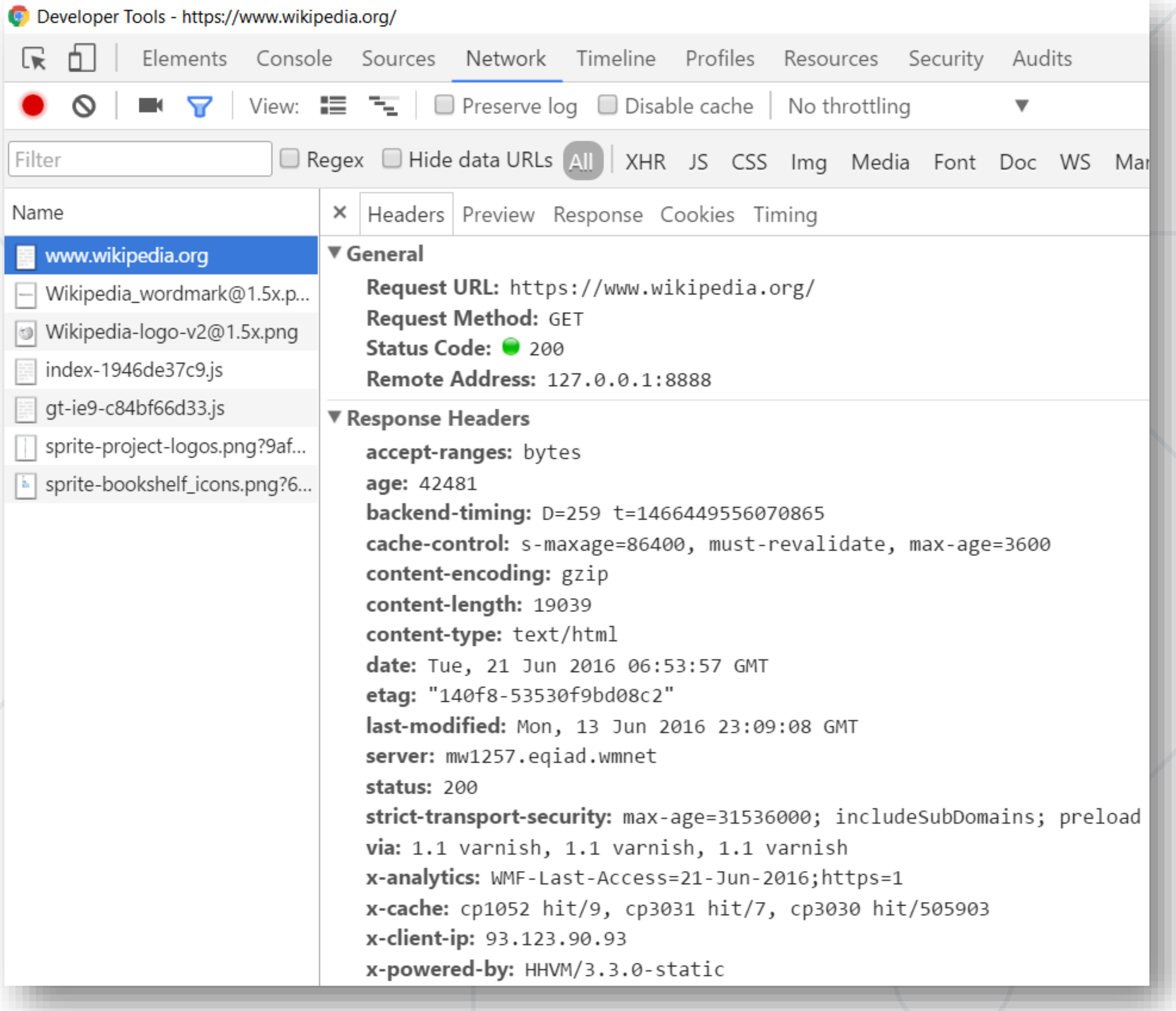
HTTP Response Status Codes

Status Code	Action	Description	
200	OK	Successfully retrieved resource	**Success**
201	Created	A new resource was created	
204	No Content	Request has nothing to return	
301 / 302	Moved	Moved to another location (redirect)	**Redirect**
400	Bad Request	Invalid request / syntax error	**Error**
401 / 403	Unauthorized	Authentication failed / access denied	
404	Not Found	Invalid resource requested	
409	Conflict	Conflict detected, e.g. duplicated email	
500 / 503	Server Error	Internal server error / service unavailable	

HTTP Dev Tools

In-Browser Tools for Developers and QAs

HTTP Developer Tools: Network Inspector



▼ General

Request URL: `https://www.wikipedia.org/`
Request Method: `GET`
Status Code: ● `200`
Remote Address: `127.0.0.1:8888`

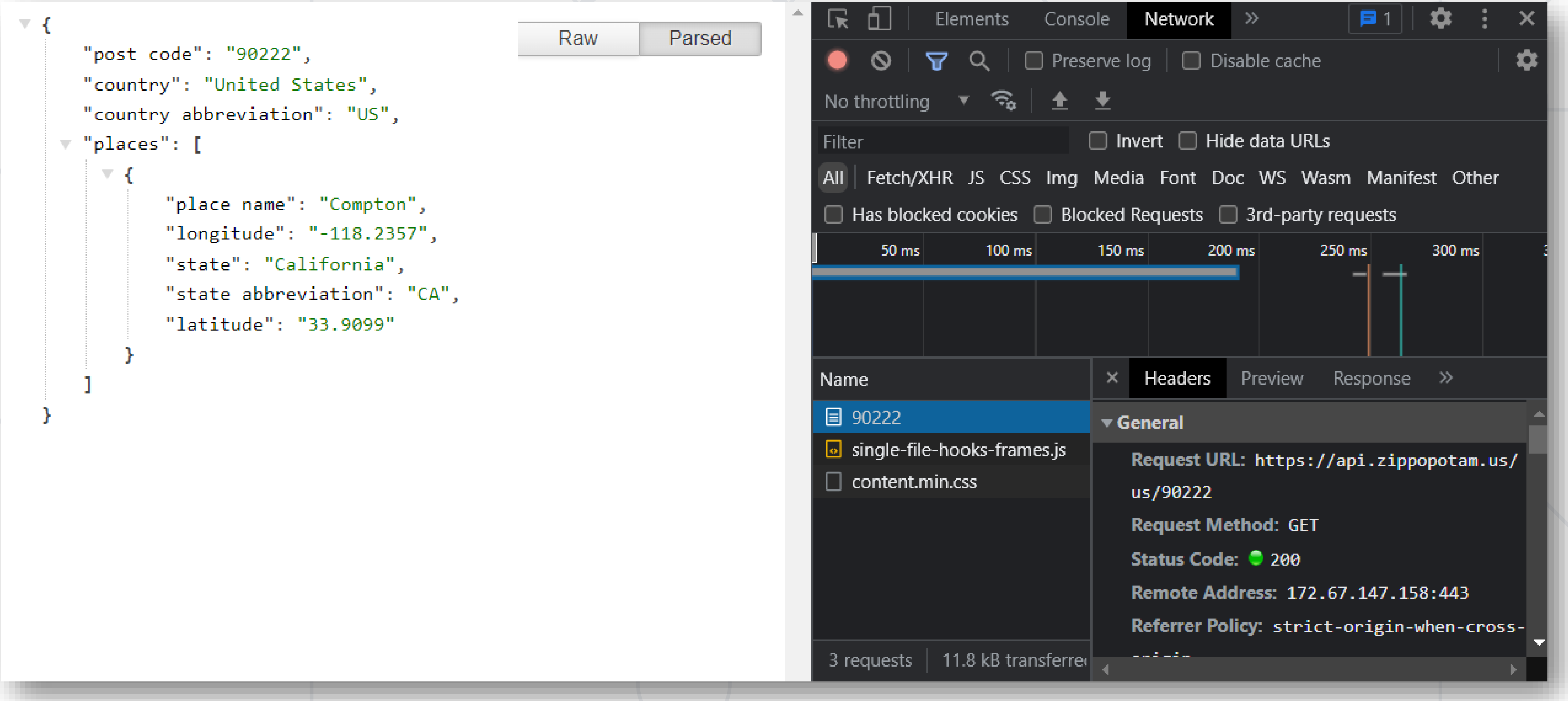
▼ Response Headers

accept-ranges: `bytes`
age: `42481`
backend-timing: `D=259 t=1466449556070865`
cache-control: `s-maxage=86400, must-revalidate, max-age=3600`
content-encoding: `gzip`
content-length: `19039`
content-type: `text/html`
date: `Tue, 21 Jun 2016 06:53:57 GMT`
etag: `"140f8-53530f9bd08c2"`
last-modified: `Mon, 13 Jun 2016 23:09:08 GMT`
server: `mw1257.eqiad.wmnet`
status: `200`
strict-transport-security: `max-age=31536000; includeSubDomains; preload`
via: `1.1 varnish, 1.1 varnish, 1.1 varnish`
x-analytics: `WMF-Last-Access=21-Jun-2016;https=1`
x-cache: `cp1052 hit/9, cp3031 hit/7, cp3030 hit/505903`
x-client-ip: `93.123.90.93`
x-powered-by: `HHVM/3.3.0-static`

- Chrome Developer Tools
  - Press **[F12]** in Chrome
  - Open the [Network] tab
  - Inspect the HTTP traffic

HTTP Requests and DevTools – Example

- https://api.zippopotam.us/us/90222



```
{
    "post code": "90222",
    "country": "United States",
    "country abbreviation": "US",
    "places": [
        {
            "place name": "Compton",
            "longitude": "-118.2357",
            "state": "California",
            "state abbreviation": "CA",
            "latitude": "33.9099"
        }
    ]
}
```

Name
- 90222
- single-file-hooks-frames.js
- content.min.css

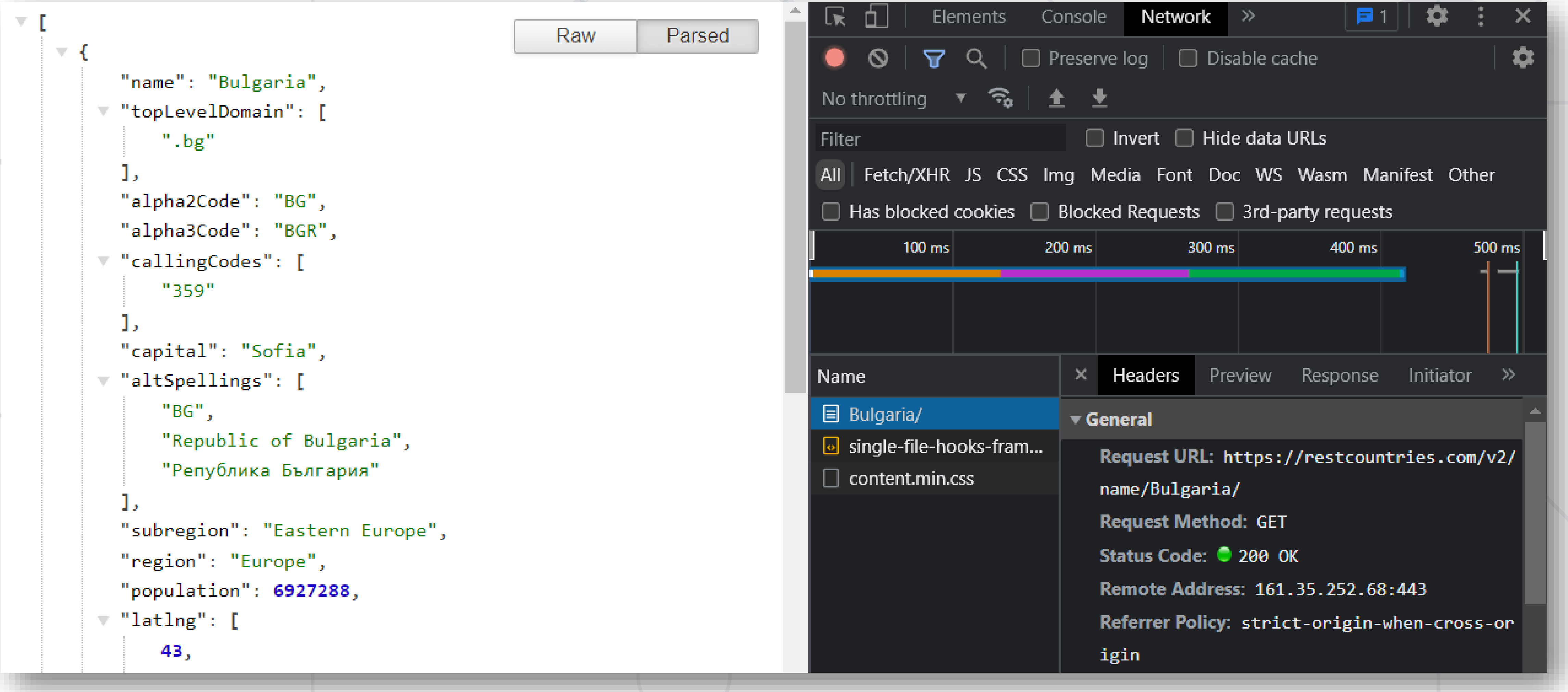
3 requests | 11.8 kB transferre

General

Request URL: https://api.zippopotam.us/us/90222
Request Method: GET
Status Code: ● 200
Remote Address: 172.67.147.158:443
Referrer Policy: strict-origin-when-cross-origin

HTTP Requests and DevTools – Example

- https://restcountries.com/v2/name/Bulgaria



```
[
  {
    "name": "Bulgaria",
    "topLevelDomain": [
      ".bg"
    ],
    "alpha2Code": "BG",
    "alpha3Code": "BGR",
    "callingCodes": [
      "359"
    ],
    "capital": "Sofia",
    "altSpellings": [
      "BG",
      "Republic of Bulgaria",
      "Република България"
    ],
    "subregion": "Eastern Europe",
    "region": "Europe",
    "population": 6927288,
    "latlng": [
      43,
```

Name:

- Bulgaria/
- single-file-hooks-fram...
- content.min.css

General

Request URL: https://restcountries.com/v2/name/Bulgaria/

Request Method: GET

Status Code: ● 200 OK

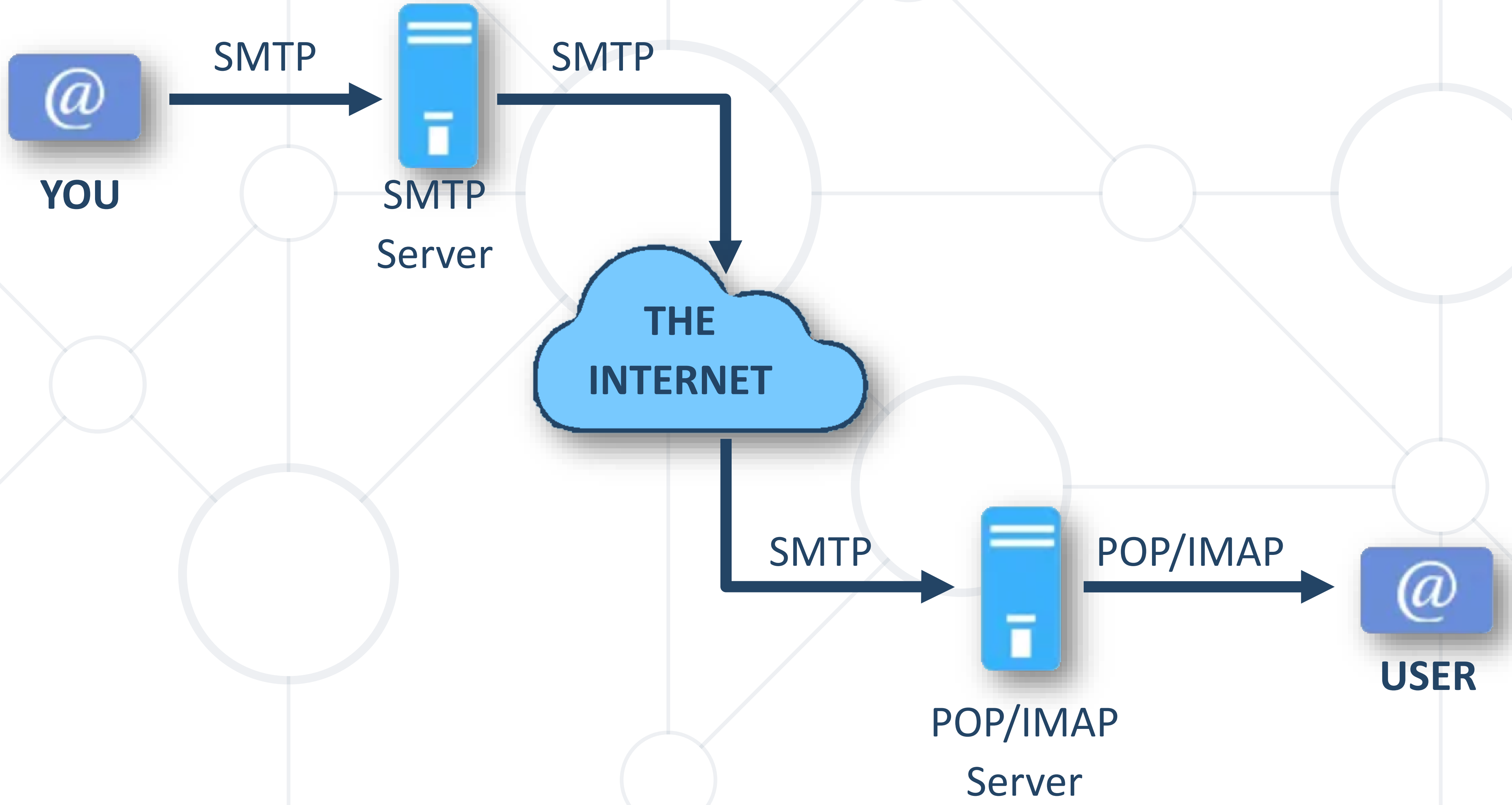
Remote Address: 161.35.252.68:443

Referrer Policy: strict-origin-when-cross-origin

Email

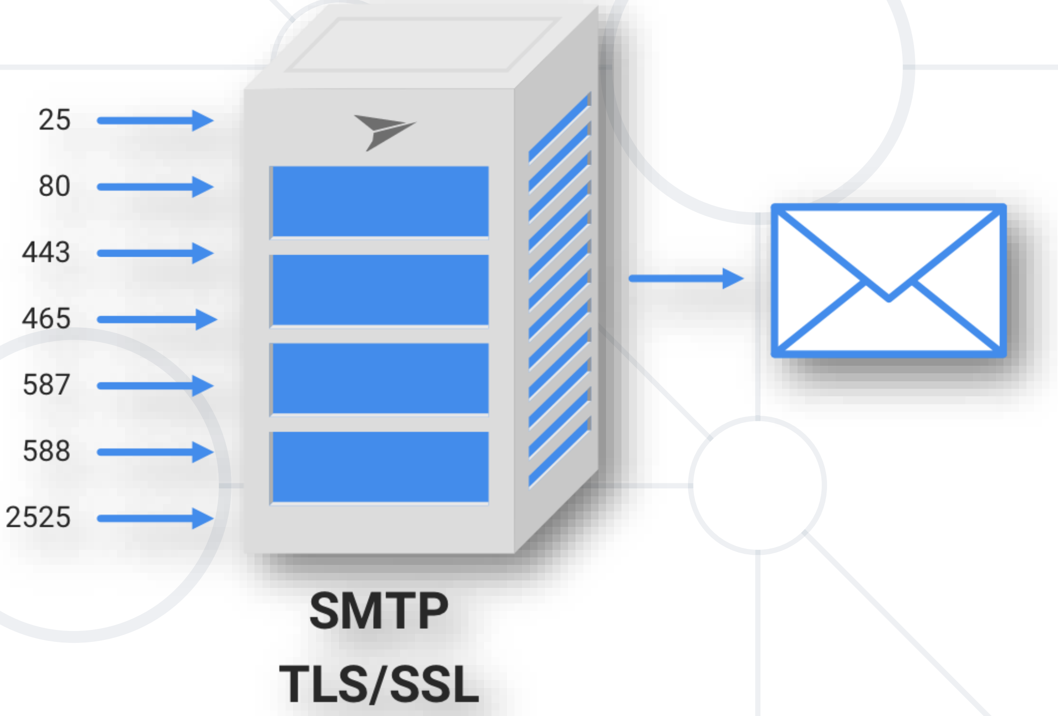
Email Protocols: SMTP and IMAP

How Does Email Work?



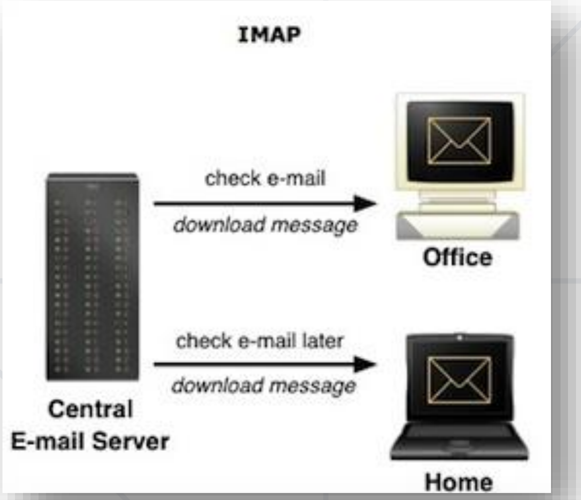
Sending Email: the SMTP Protocol

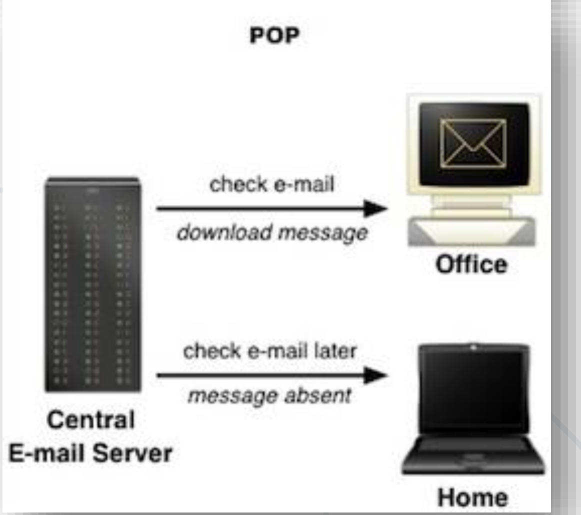
- SMTP (Simple Mail Transfer Protocol)
  - Send / receive email messages between mail servers
- Mail client apps (like Thunderbird) use SMTP to send emails
- **SMTPS** (secure SMTP) uses additional SSL for security
  - **SMTP** – port **25**, **SMTPS** – port **587**



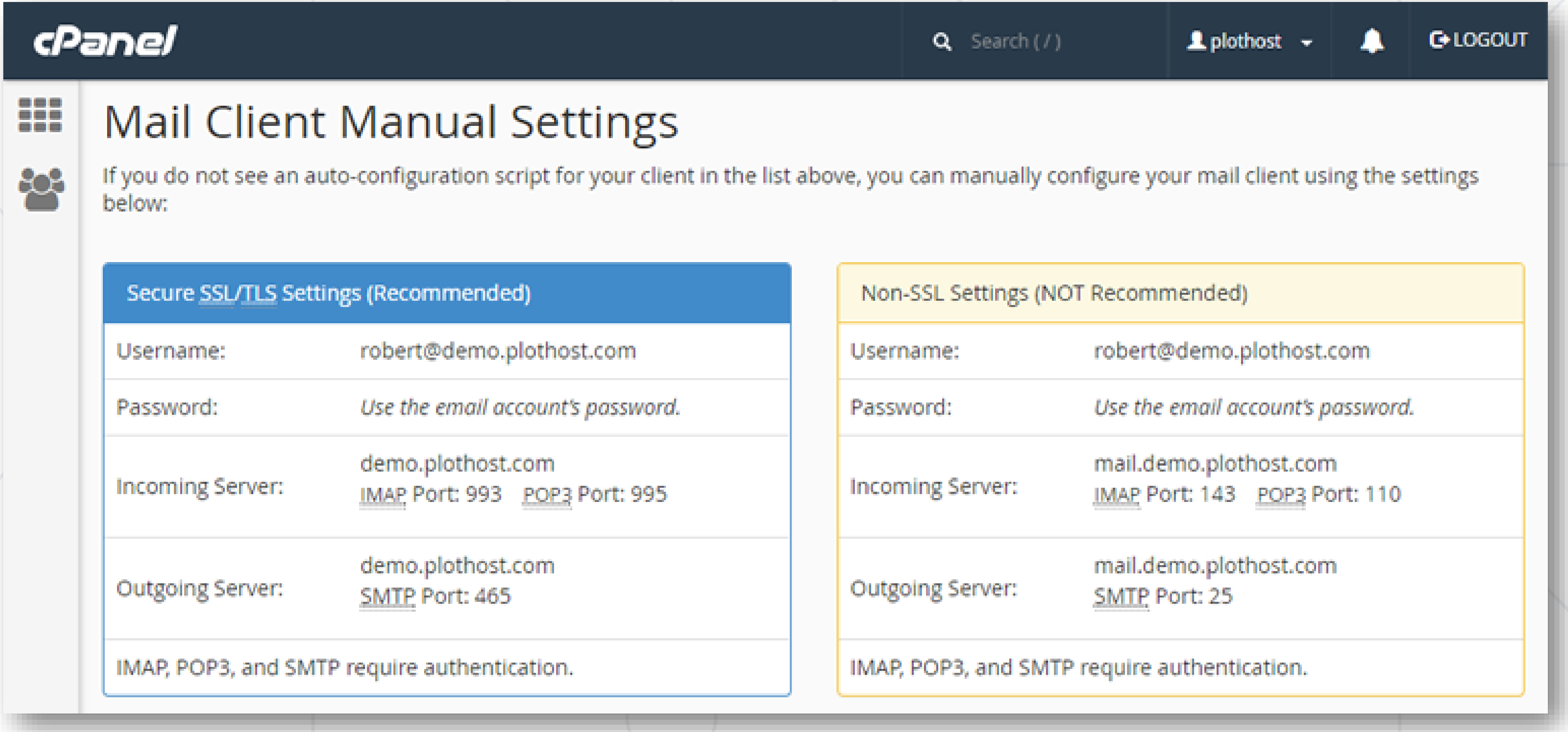
IMAP/POP

- IMAP (Internet Message Access Protocol)
  - Retrieve email messages from server mailbox
  - Allows management of email messages on the server from different devices (**sync and delete**)
  - More popular and flexible
- POP (Post Office Protocol)
  - Once downloaded to a client, the message is removed from the server (**download and delete**)
  - Difficult to access email messages from different devices or locations





Configuring an Email Client



Mail Client Manual Settings

If you do not see an auto-configuration script for your client in the list above, you can manually configure your mail client using the settings below:

Secure SSL/TLS Settings (Recommended)	
Username:	robert@demo.plothost.com
Password:	*Use the email account's password.*
Incoming Server:	demo.plothost.com IMAP Port: 993 POP3 Port: 995
Outgoing Server:	demo.plothost.com SMTP Port: 465
IMAP, POP3, and SMTP require authentication.	

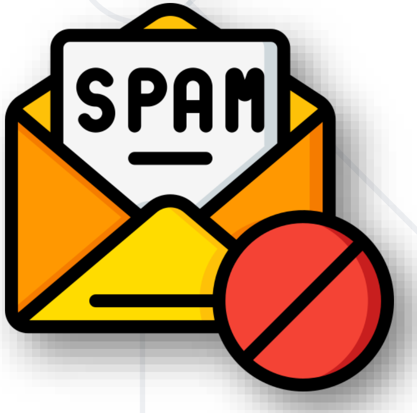
Non-SSL Settings (NOT Recommended)	
Username:	robert@demo.plothost.com
Password:	*Use the email account's password.*
Incoming Server:	mail.demo.plothost.com IMAP Port: 143 POP3 Port: 110
Outgoing Server:	mail.demo.plothost.com SMTP Port: 25
IMAP, POP3, and SMTP require authentication.	

Email Forwarding

- **Redirect** incoming emails to another email address
  - E. g. peter@softuni.org → peter1997@gmail.com
- Useful for managing multiple email accounts
  - **Server-based forwarding** –the mail server automatically forward incoming messages to another email address
  - **Client-based forwarding** – setting up email forwarding using the email client settings
  - **Email filters** – setting up filters to forward messages that match specific criteria

Spam Filters

- **Detect** and **filter** out unwanted or harmful email messages
  - Typically, move spam emails to the "SPAM" folder
- **Rule-based** filtering and **Machine learning-based** filtering
- Some filtering is usually conducted automatically by an SMTP
- **Reject**, **redirect**, or **quarantine** based on the email content
- **Customizable** for individual needs and preferences
- Setting up rules to **block/allow** emails from specific senders or domains

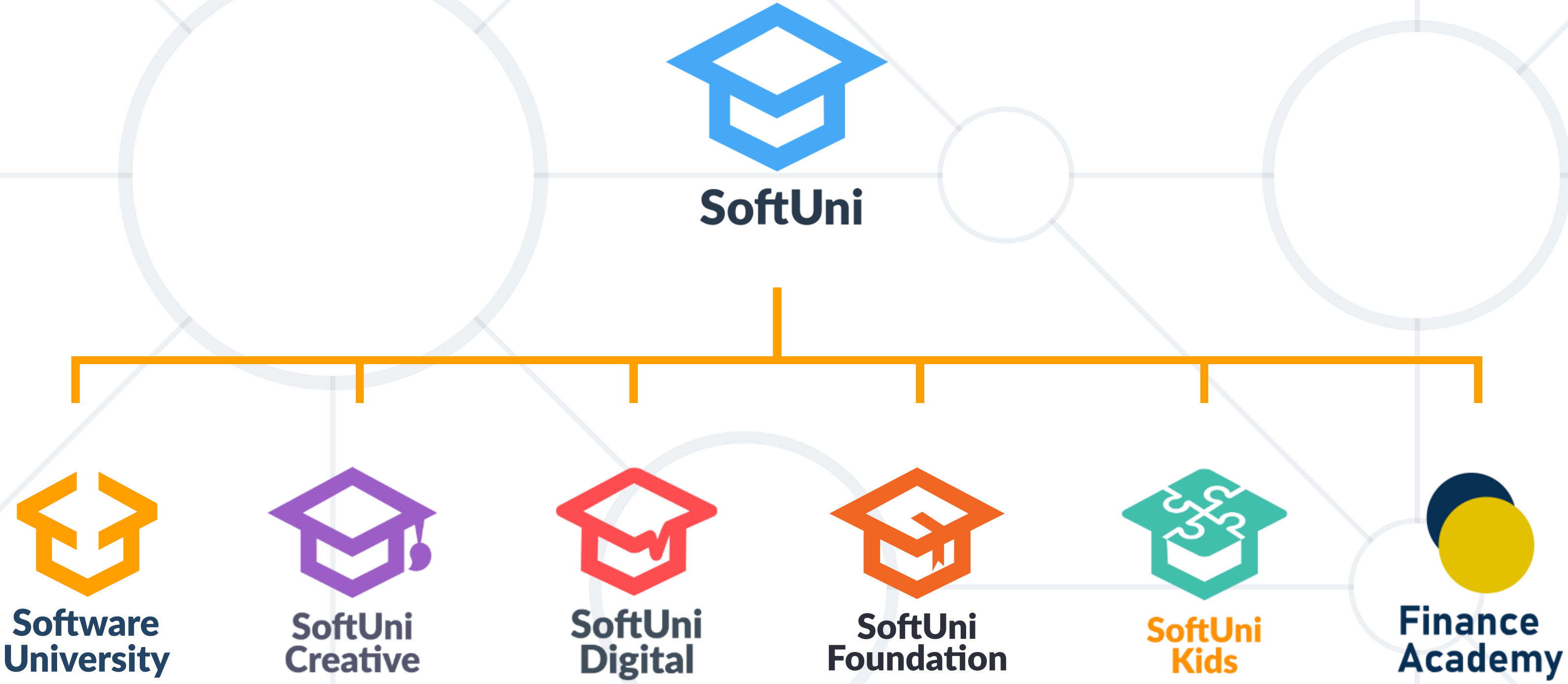


Summary

Software University

- **Networking protocols**: rules for communication
- **Network layer models**: OSI Model, TCP/IP
- **MAC** address, **IP** address, **netmask**, **ports**
- **Domains** and **DNS**, **WWW**
- **HTTP** request (GET, POST) + HTTP response
- Browser **Dev Tools**: in-browser debugging
- How does an email work? **SMTP** / **IMAP**

Questions?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SoftUni Digital
SoftUni Foundation
SoftUni Kids
Finance Academy

SoftUni Diamond Partners

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- Software University Foundation
  - softuni.foundation
- Software University @ Facebook
  - facebook.com/SoftwareUniversity
- Software University Forums
  - forum.softuni.bg