Network Security

Network Fundamentals Refresher

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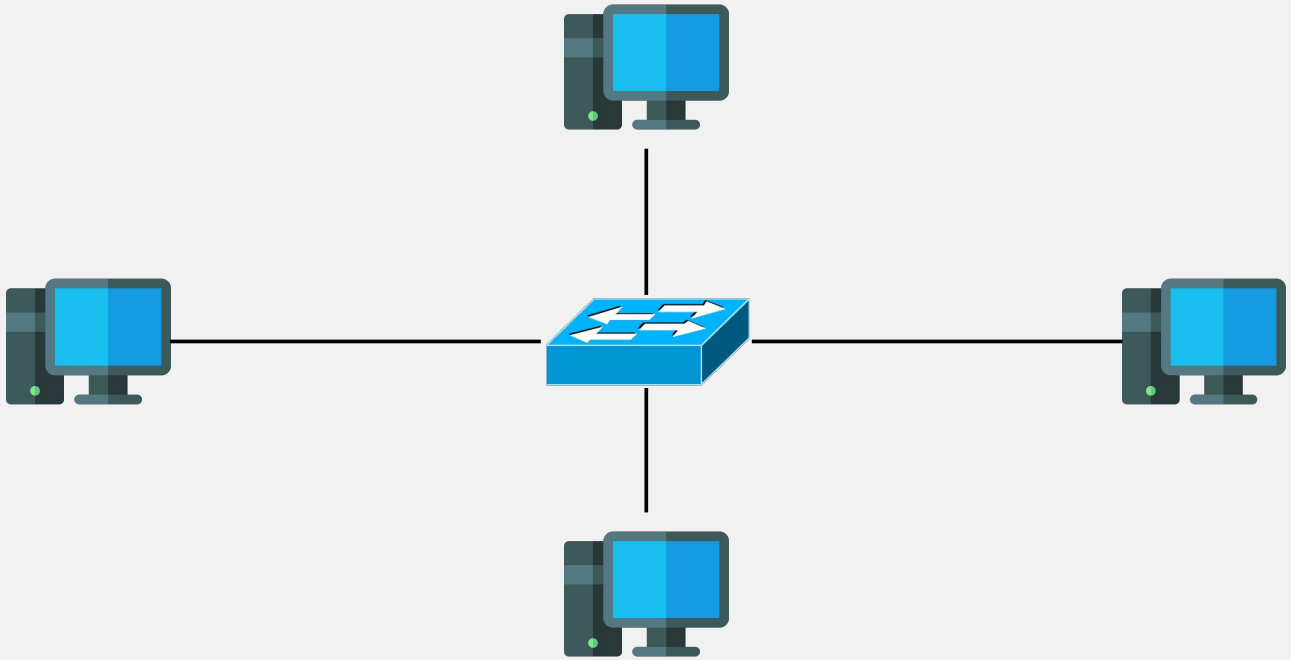
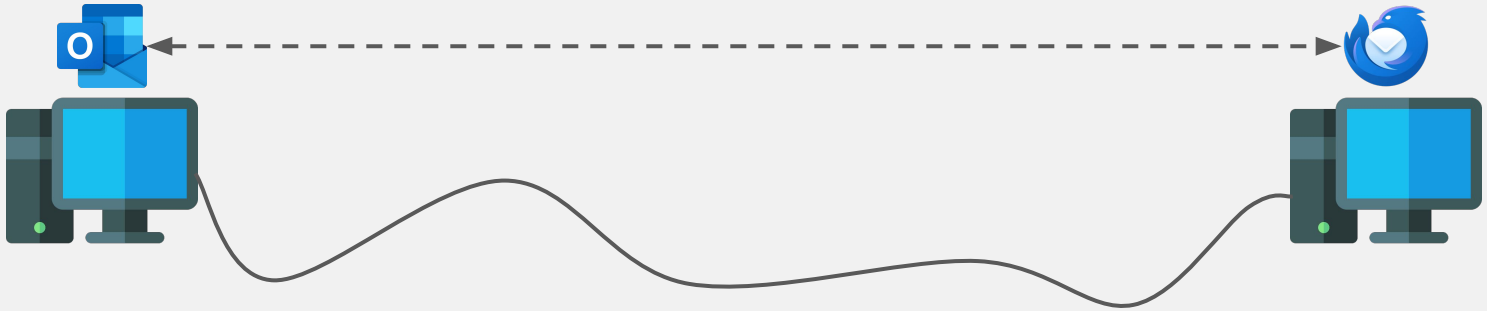
Main Goal: Connect Devices



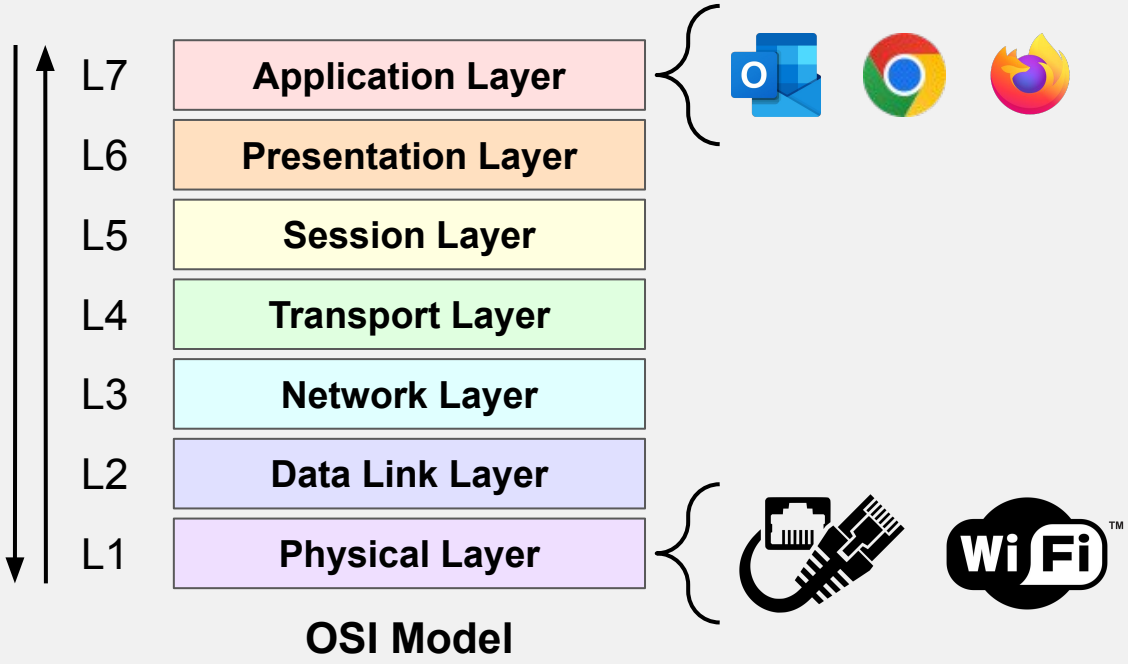
Send and receive messages



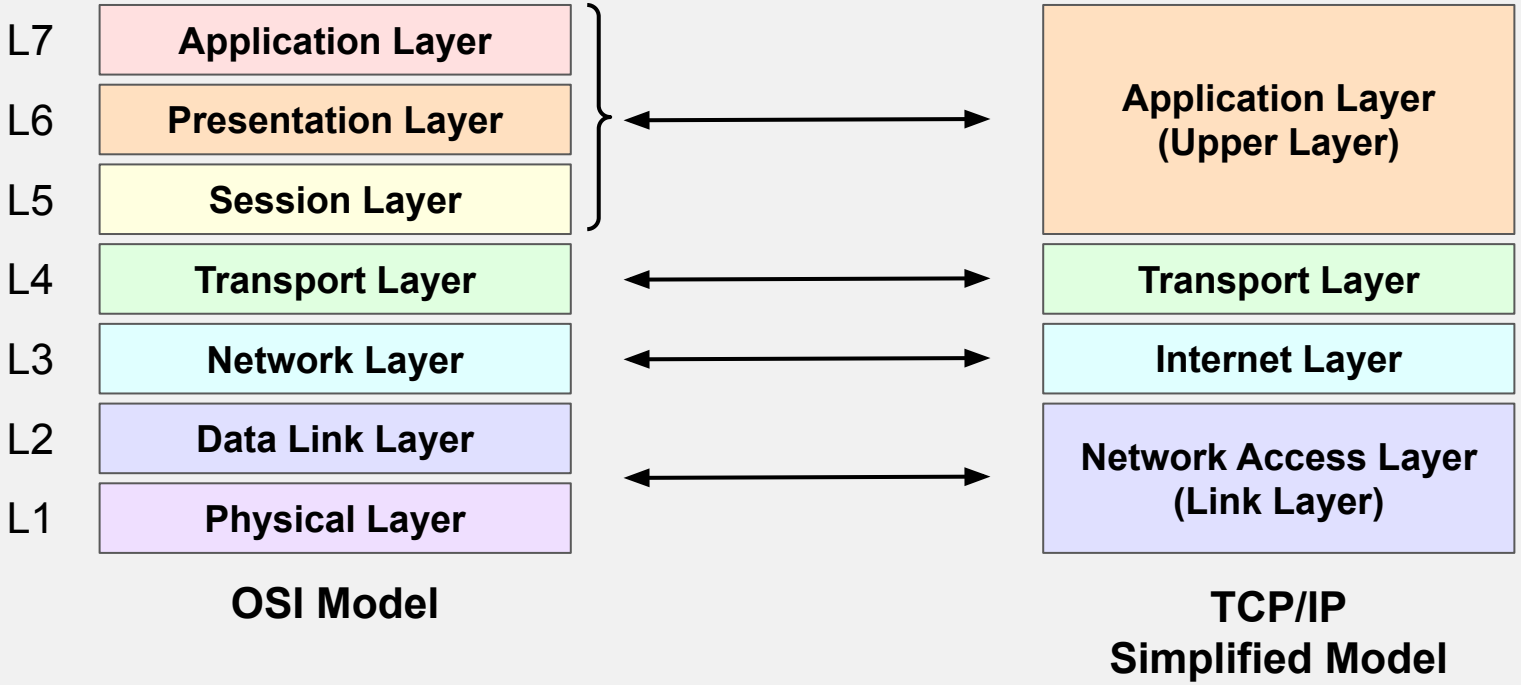
Problem to solve:

- Devices need to speak the same language.

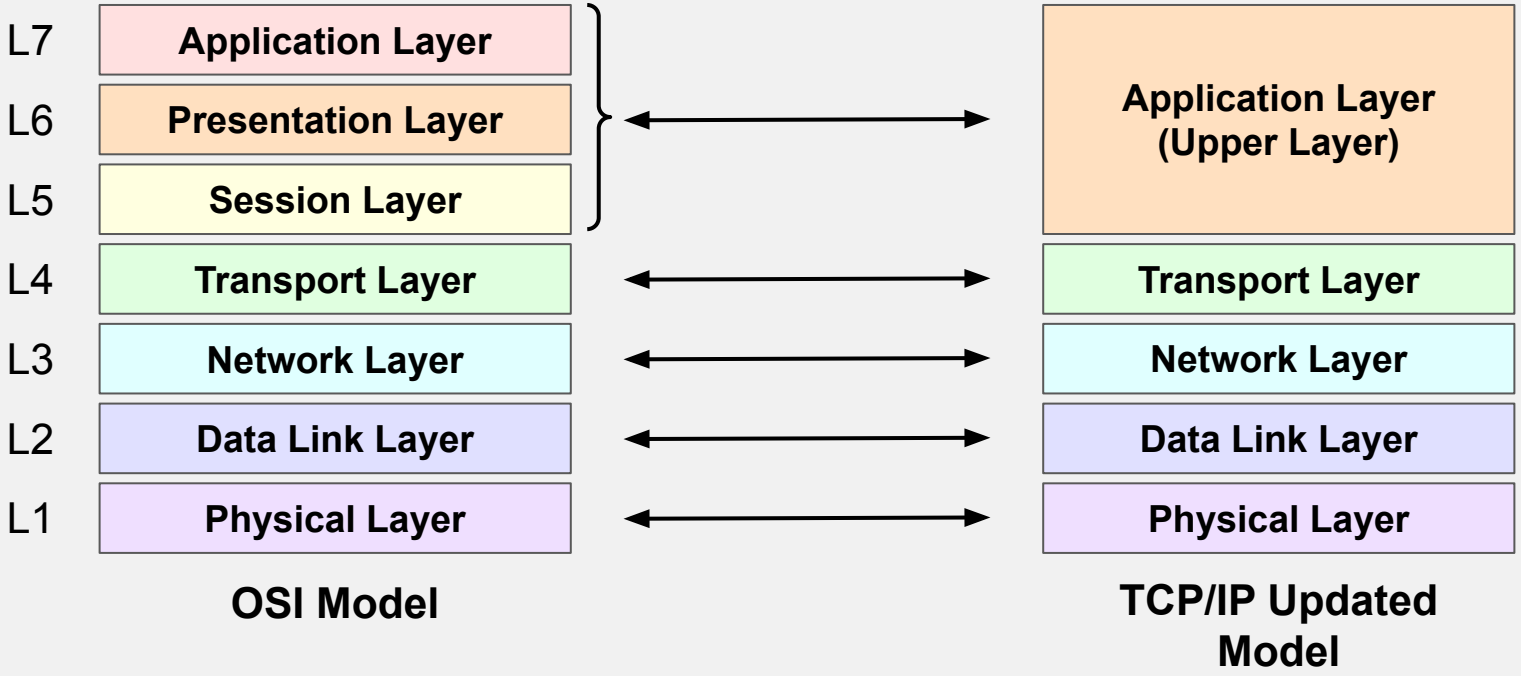
The Famous ISO OSI model



OSI vs TCP/IP Models



OSI vs TCP/IP Models



TCP/IP Model


Alice
Bob
Application Layer (Upper Layer)
Transport Layer
Network Layer
Data Link Layer
Physical Layer
Application Layer (Upper Layer)
Transport Layer
Network Layer
Data Link Layer
Physical Layer

Layer Overview

Layer 5: Application

- Abstraction level: Application-to-Application
- Addressing method: Application specific addressing (e.g. URLs for HTTP)

Layer 4: Transport

- Abstraction level: End-to-End
- Addressing method: Port

Layer 3: Network

- Abstraction level: Device-to-Device
- Addressing method: IP addresses

Layer 2: Data Link

- Abstraction level: Hop-to-Hop
- Addressing method: MAC addresses

Layer 1: Physical

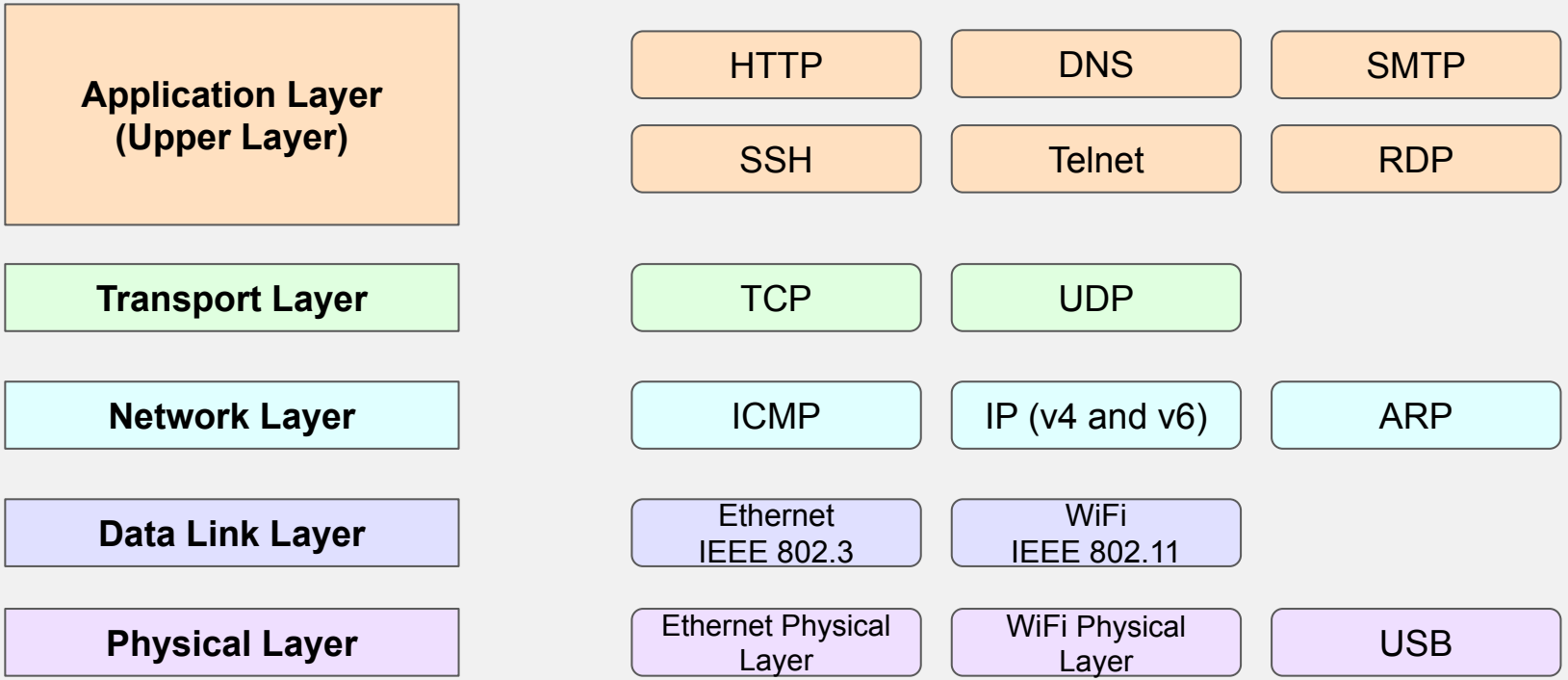
- Abstraction level: Physical transmission
- Addressing method: -

Some Definitions

Protocol: Communication between **same-layer entities**

- Define **syntax** and **semantics**
- E.g. TCP

Some protocols



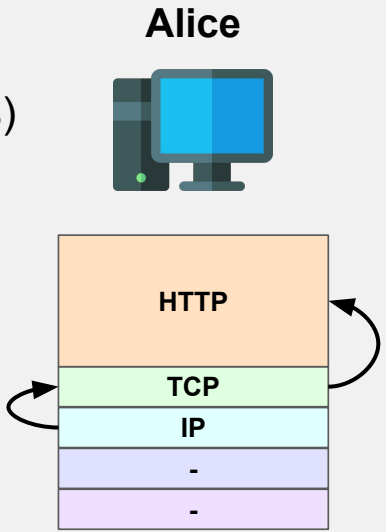
Some Definitions

Service: Communication between **adjacent layers**

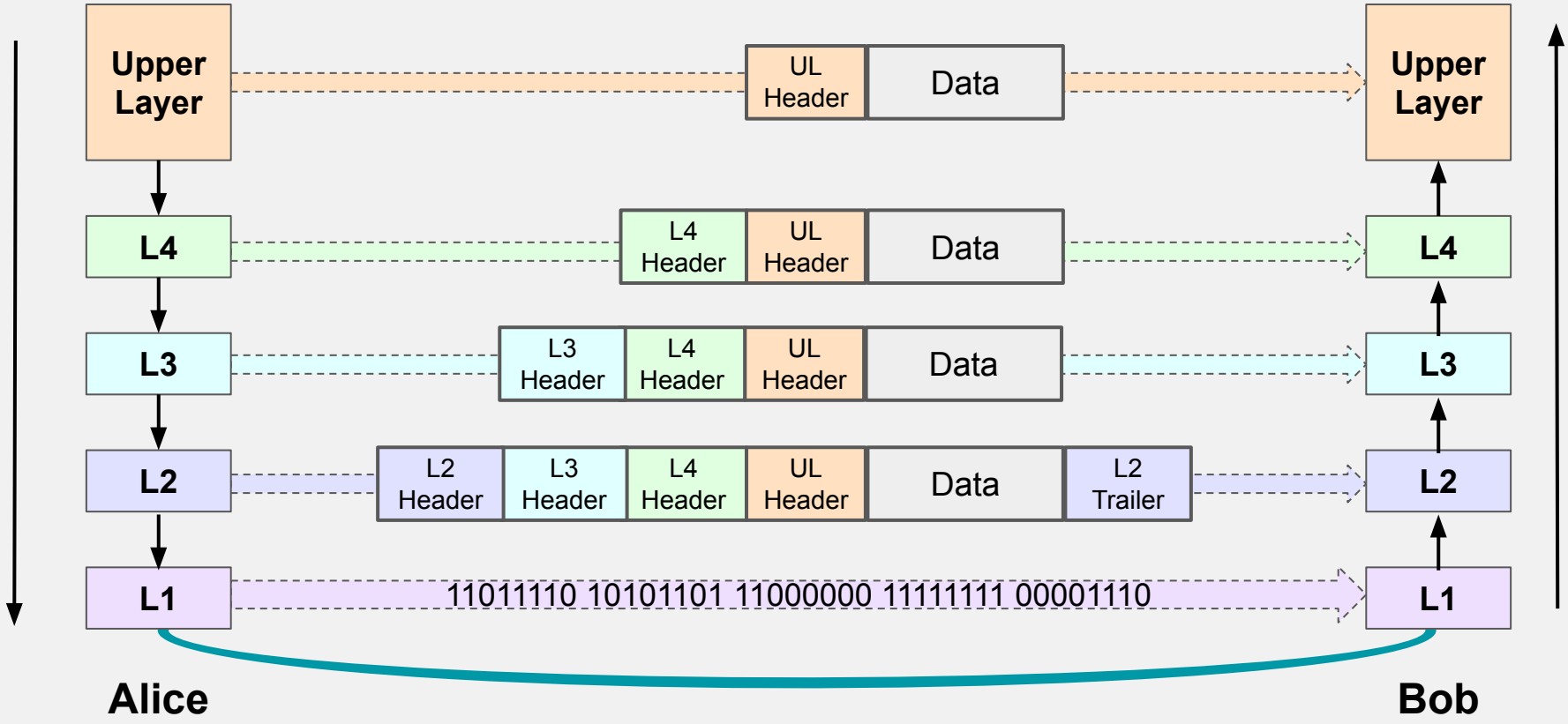
- Define interface between layers

In this example the following services can be identified:

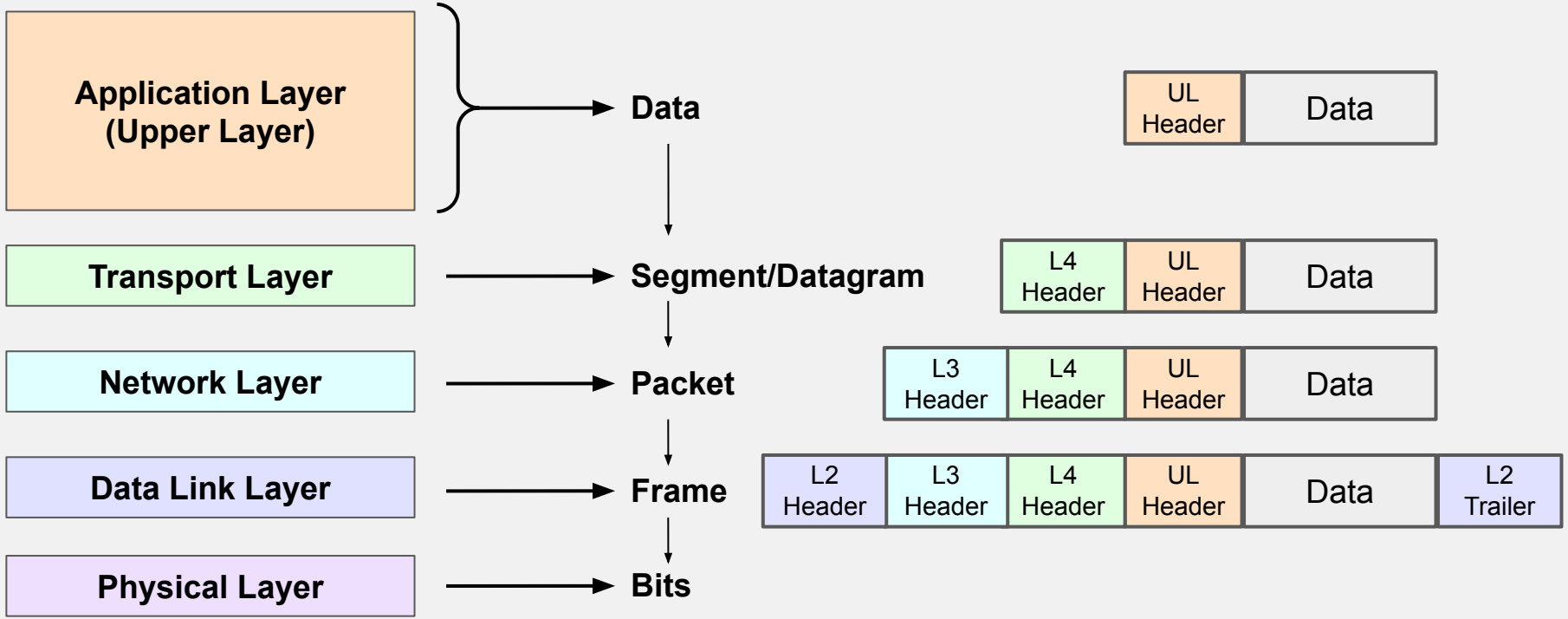
- IP provides a service for TCP (routing data between devices)
- TCP provides a service for HTTP (connexion reliability)



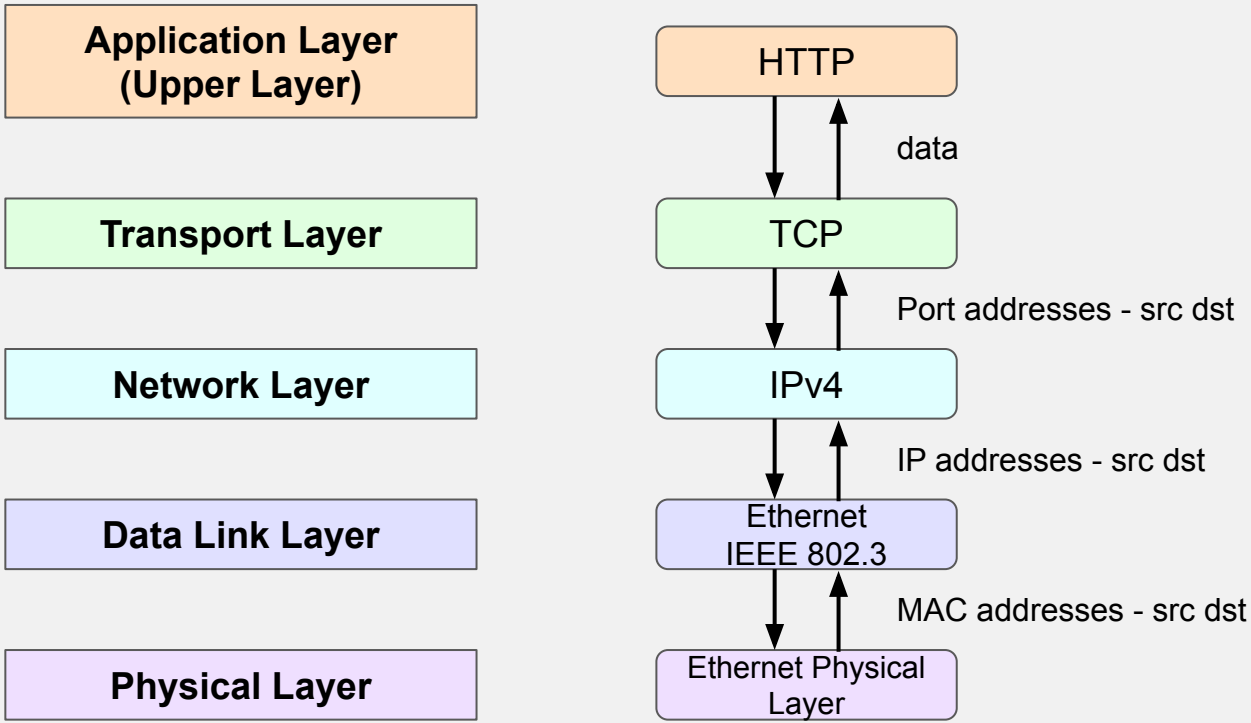
Encapsulation / Decapsulation



Protocol Data Unit: PDU



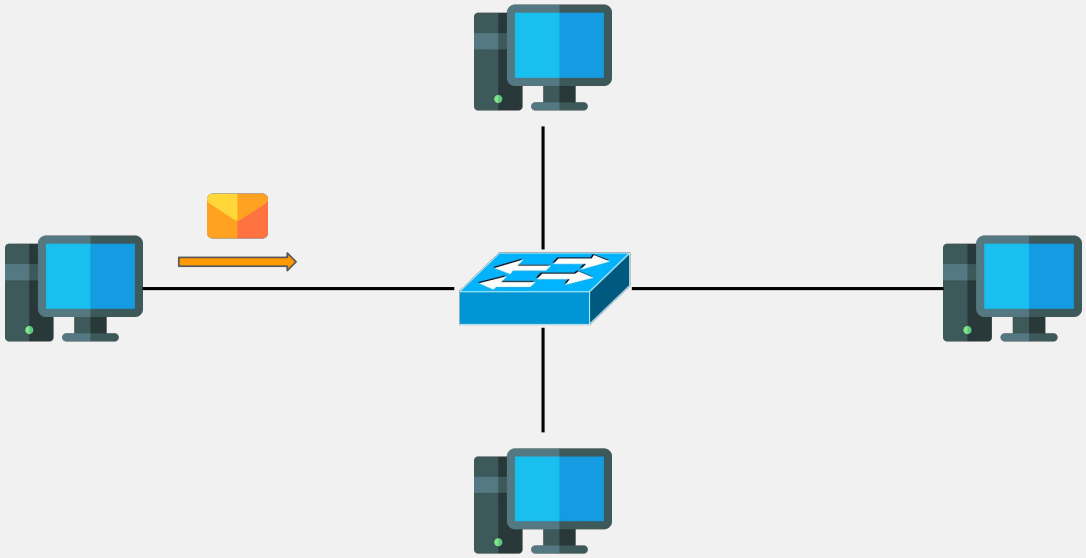
Top-down communication



Connecting Devices

Problems to solve:

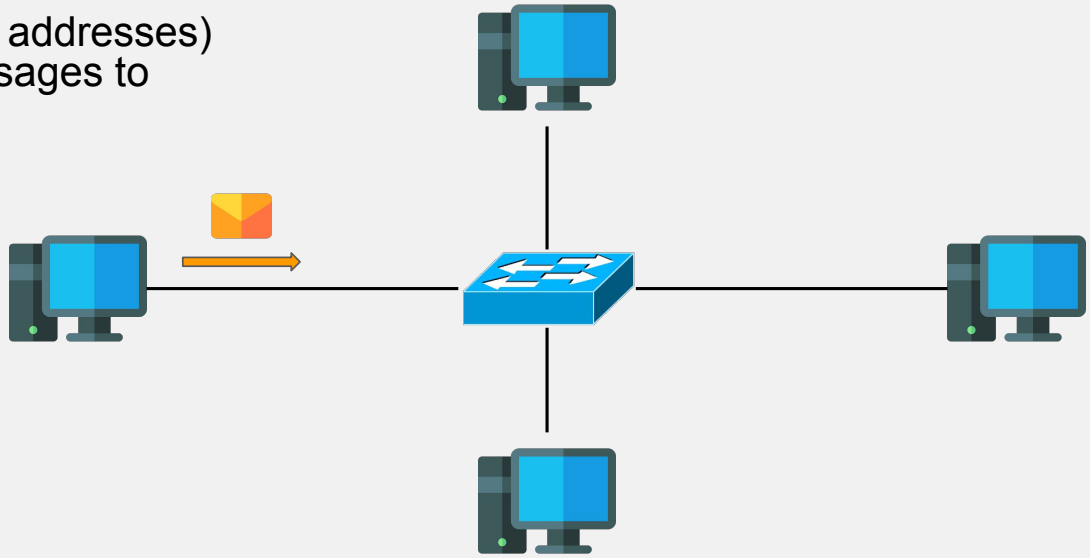
- How to send a message?
- How to route a message?



In a Local Network (LAN)

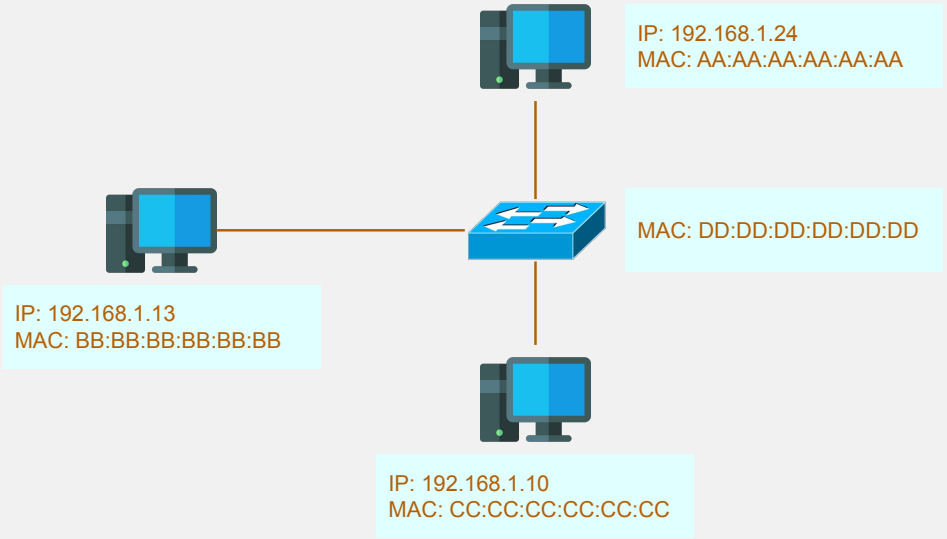
In a local network:

- Layer 1 and 2 are required (MAC addresses)
- Devices can broadcast ARP messages to discover MAC addresses.



ARP: Routing in the LAN

- **ARP:** Address Resolution Protocol
- Used to get the MAC address associated to an IP address.



ARP Broadcast

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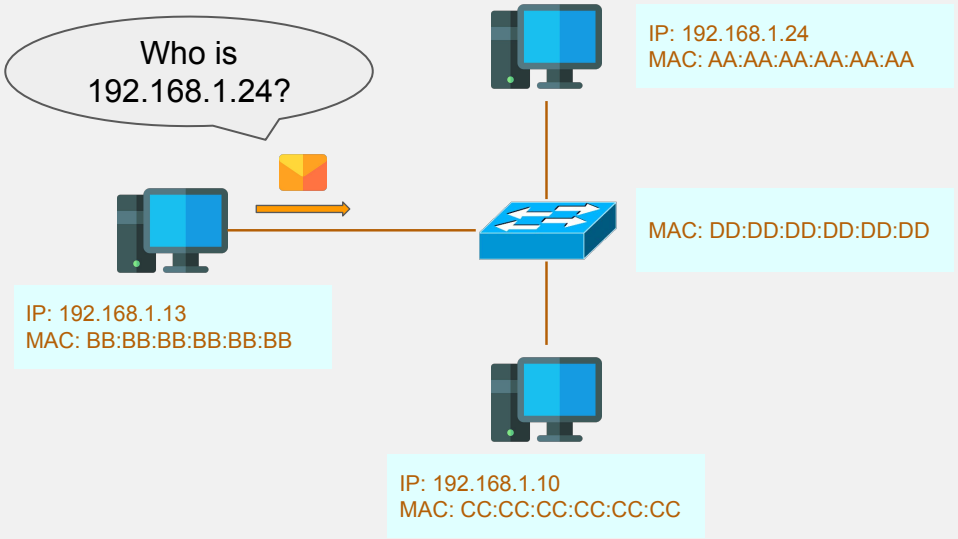

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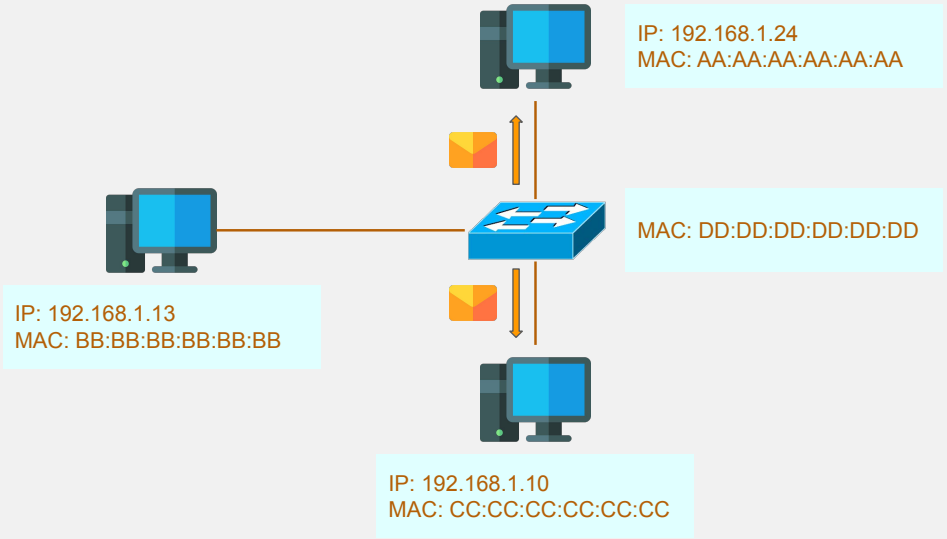
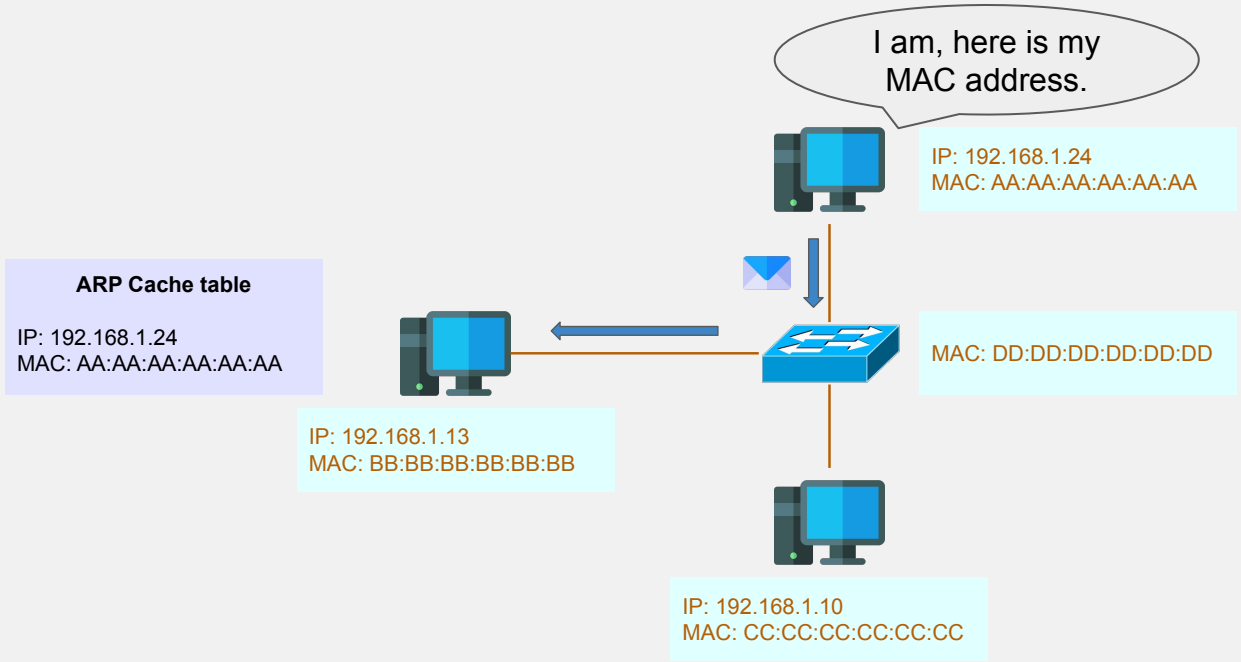
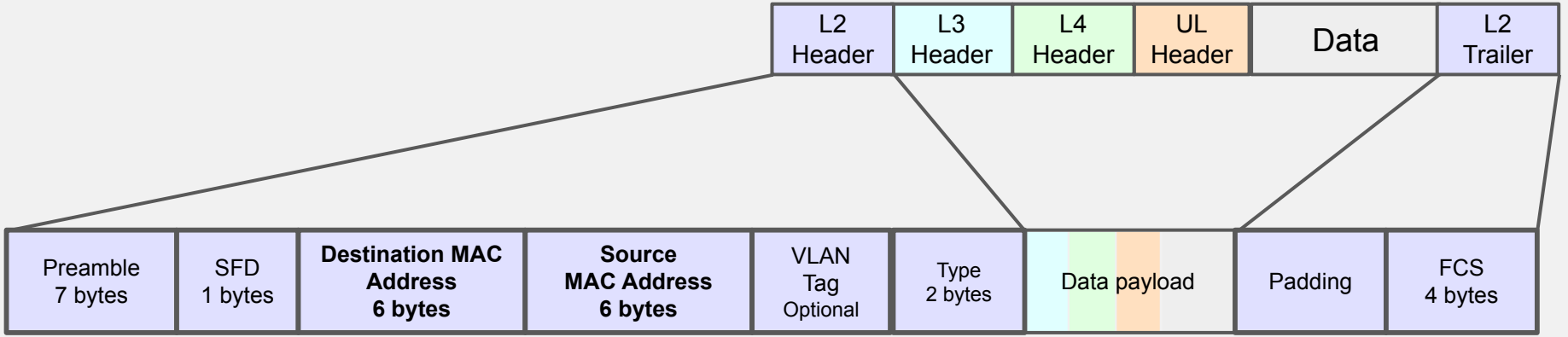


ARP Response

- **ARP:** Address Resolution Protocol
- Used to get the MAC address associated to an IP address.



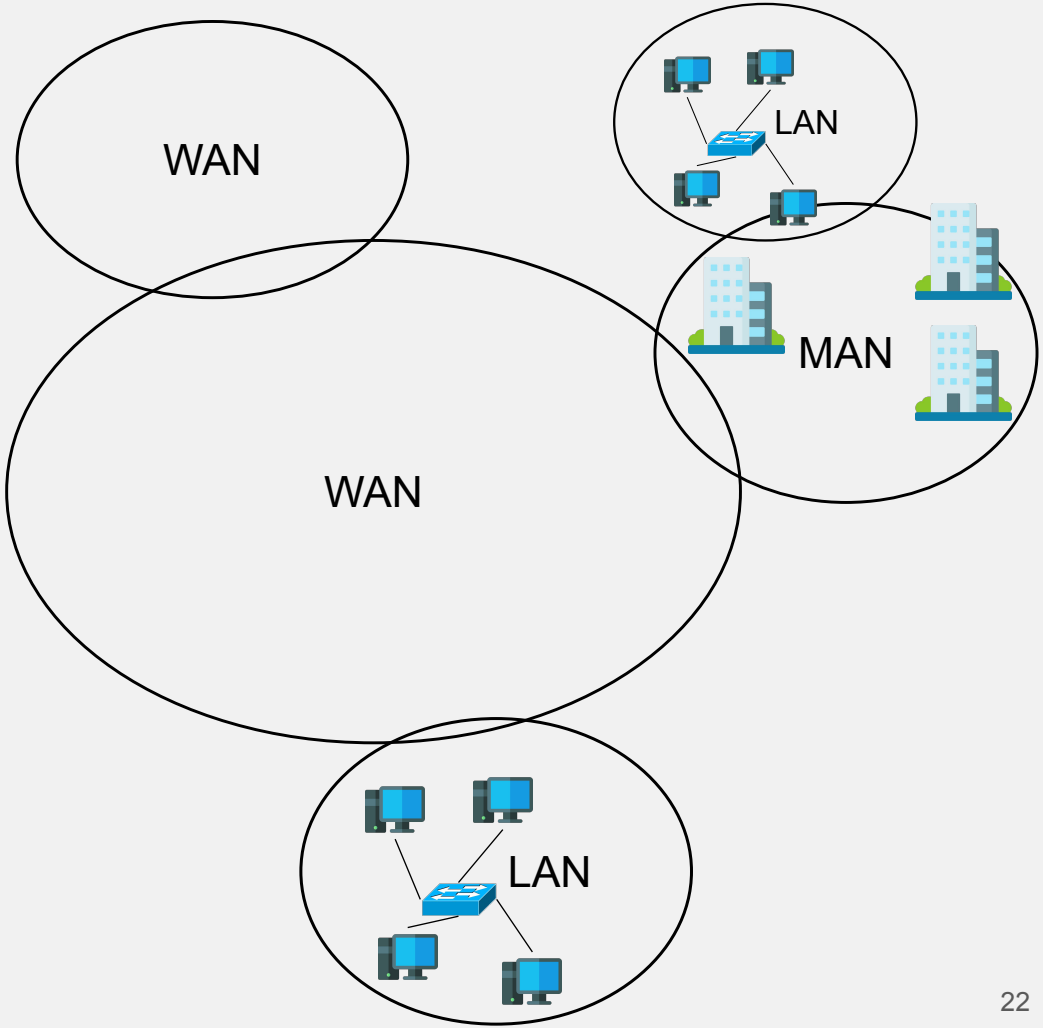
Frame Header/Trailer: Ethernet example



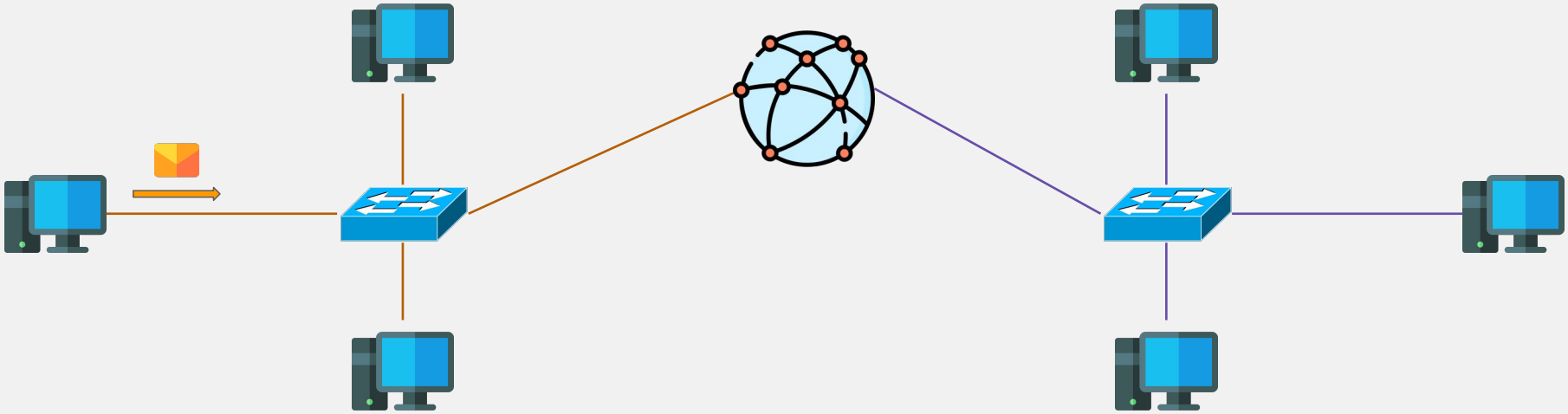
- SFD (Start Frame Delimiter)
- **Source** and **destination MAC addresses** for device specific identification.
- Optional VLAN tags for logical segmentation (more on this later).
- FCS (Frame Check Sequence) in the trailer, used to detect transmission errors.

Types of Network

- **LAN:** Local Area Network
  - Up to ~1 km.
  - Home, Office, Building, etc…
- **MAN:** Metropolitan Area Network
  - Up to ~50 km.
  - Within one city
- **WAN:** Wide Area Network
  - Above 50 km.
  - Within countries



Routing outside the LAN: Layer 3



Internet Protocol version 4 (IPv4)

- IPv4 still performs most of the routing on the internet
  - Designed in the 70s
  - Was redefined, fixed, over the years.
    - IPSec for security.
    - NAT for intranet and to resolve address shortage.
    - …
- Was here to be the main protocol for the Internet layer.
  - Many to one to Many.
  - Maximize interoperability
  - Minimize number of service interfaces

IPv4 Structure

An **IPv4 address** consists of two parts:

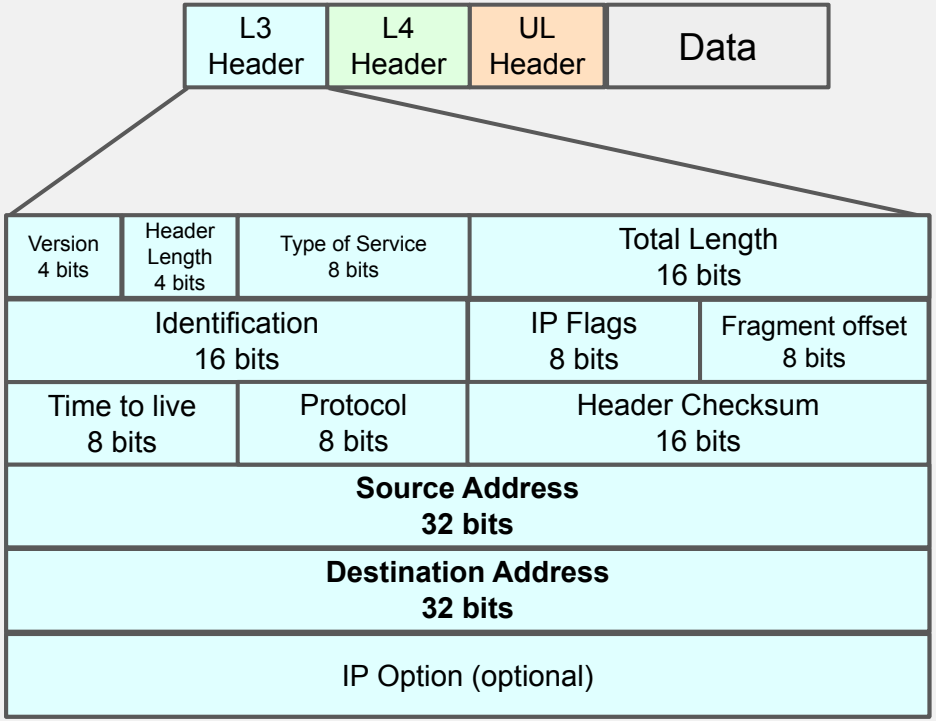
- **Network part**: identifies the network.
- **Host part**: identifies a device within that network.

The **subnet mask** specifies which bits belong to the network and which to the host.
Example:

- IP: 192.168.1.10
- Mask: 255.255.255.0 (or /24)
- Network: 192.168.1.0
  Host range: 192.168.1.1 to 192.168.1.254
- Broadcast: 192.168.1.255

Packet Header: IPv4 example

- **Source** and **destination *IPv4 addresses***.
- Upper-layer protocol identification (TCP, UDP, ICMP…).
- Checksum to verify header validity.

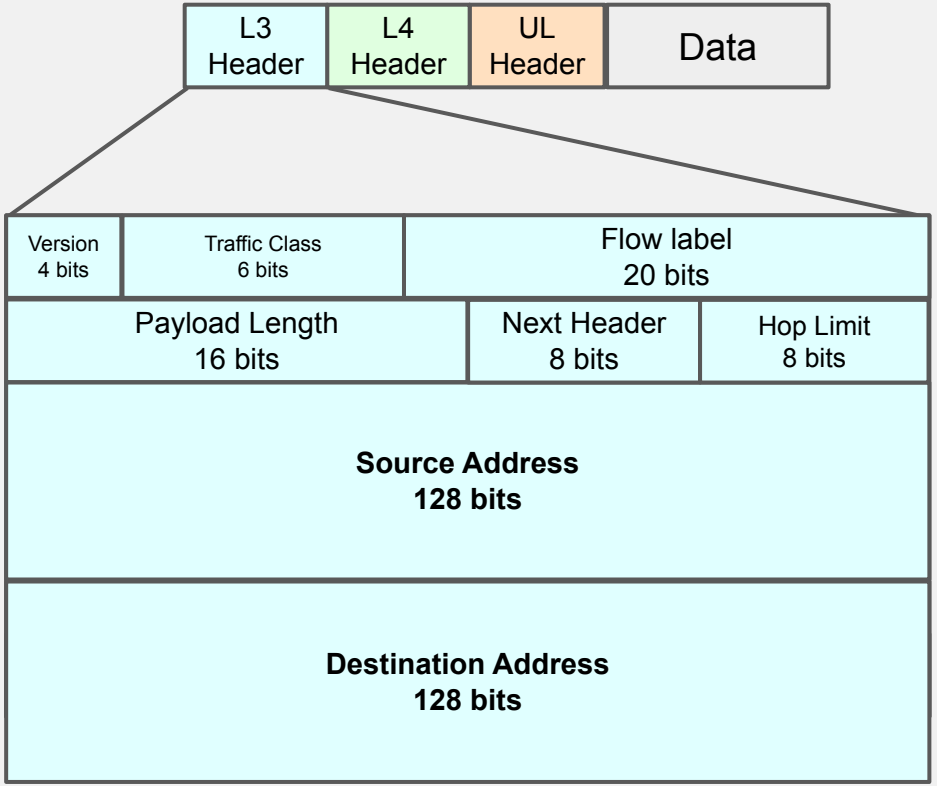


Internet Protocol version 6 (IPv6)

- Developed in the 90s to address IPv4 limitations.
  - Built-in improvements rather than incremental fixes.
  - IPSec support is native, part of the base specification.
  - No need for NAT thanks to a vastly larger address space.
  - 2^{32} addresses maximum for IPv4 against 2^{128} for IPv6.
- Simplified packet header for more efficient routing.
- Better support for mobile devices and IoT.
- Aimed to be the new main protocol for the Internet layer.
- Designed to maintain interoperability while enabling future scalability.
- Adoption is progressing, but still slow in some regions due to legacy infrastructure and transition costs.

Packet Header: IPv6 example

- **Source** and **destination *IPv6 addresses***.
- Upper-layer protocol identification (TCP, UDP, ICMP…).
- No checksum anymore. We rely on the Data Link Layer to provide sufficient protection.



IPv6 Structure

IPv6 uses a **prefix length** instead of a subnet mask.

The prefix length defines the number of bits representing the network.

Example:

- IPv6: 2001:db8:abcd:0012::1/64
- /64 means the first 64 bits are the network identifier.
- The remaining 64 bits are used for host addresses.

Now for the connection

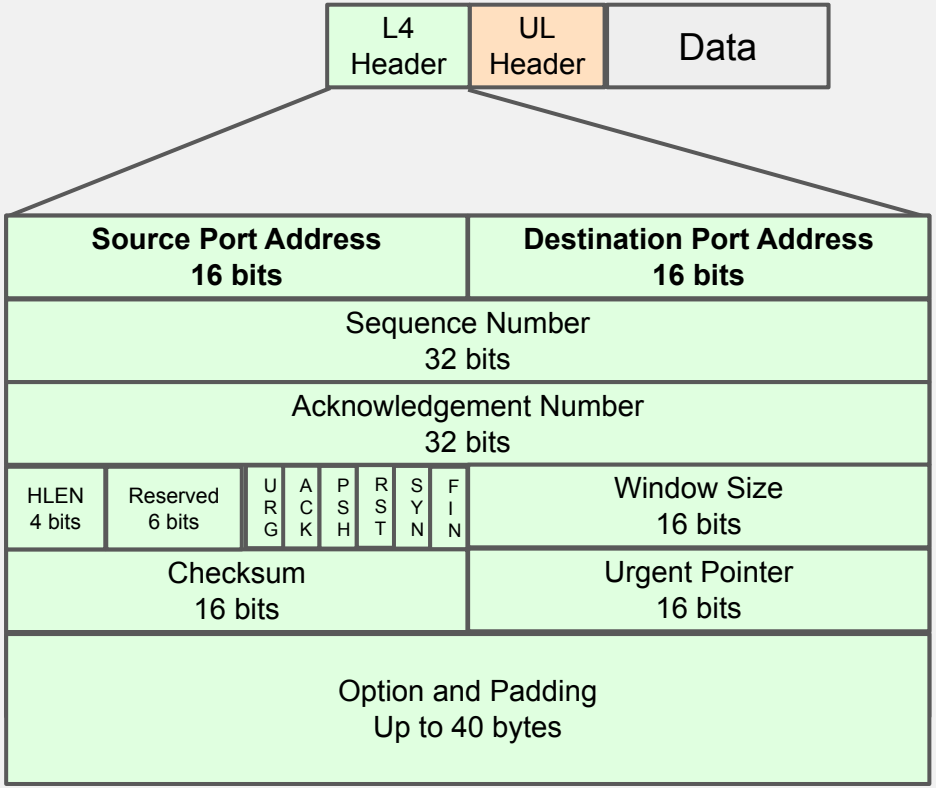
With addresses, devices can talk to each other.

Now choosing the layer 4 protocol:

- TCP
  - Reliable but slow, perfect for HTTP
- UDP
  - Fast but no reliability
  - Perfect for video streaming

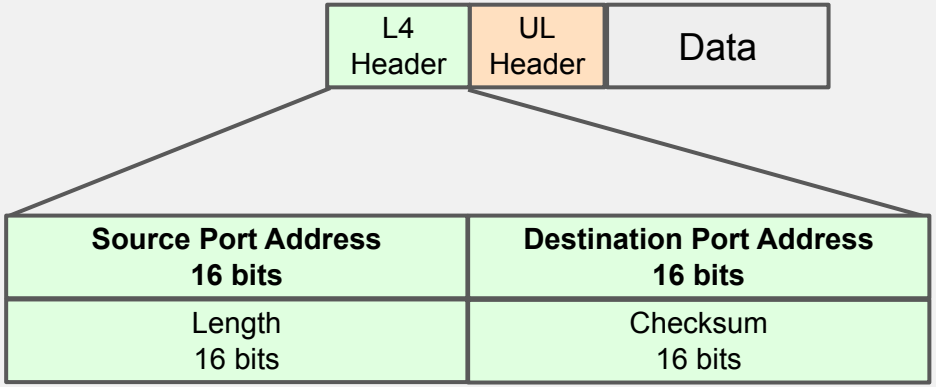
Segment Header: TCP example

- Application identification through **source** and **destination *ports***.
- Reliability via sequence and acknowledgment (ACK) numbers.
- Flow control through the window size.
- Integrity with the checksum.
- Additional functions (SYN, FIN, RST, etc.) that handle connection establishment, termination, or reset.



Segment Header: UDP example

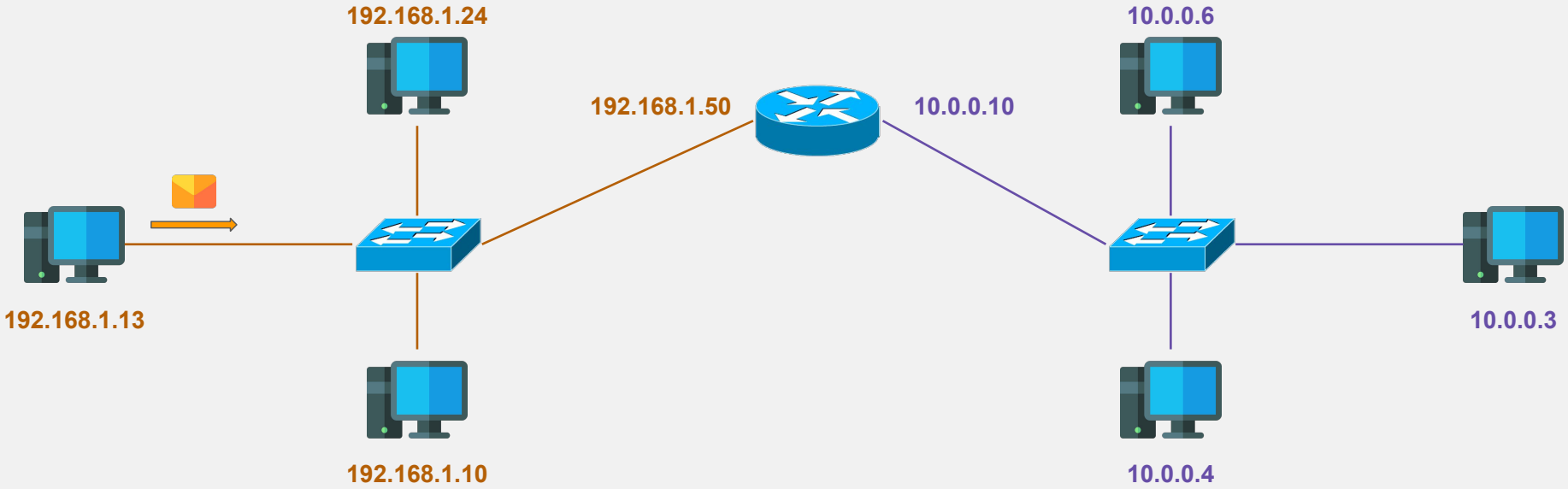
- Application identification through **source** and **destination *ports***.
- An additional layer with IP addresses is added when used with IPv4 or IPv6, for checksum calculation.



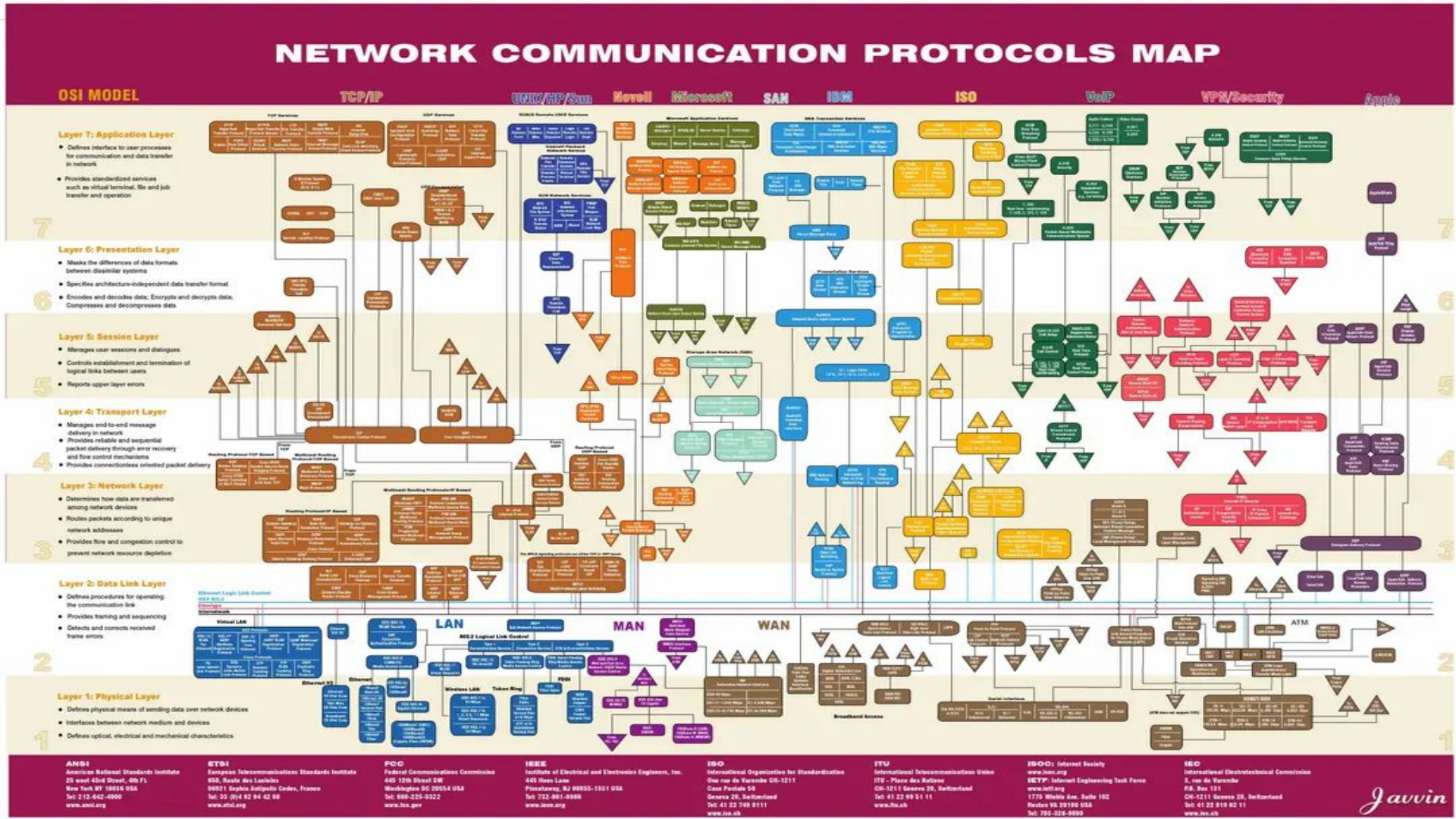
Common Network Devices and Servers

- **Switch:** Forwards network traffic between devices within the same local network.
- **Router:** Connects different networks together and directs network traffic between them.
- **Getaway:** Serves as the access point that connects a local network to another network. Most of the time a router.
- **DNS (Domain Name System):** Translate a Domain Name to its IP address.
- **DHCP (Dynamic Host Configuration Protocol):** Gives an IP address to a device in the network.

Routing outside the LAN



NETWORK COMMUNICATION PROTOCOLS MAP



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ITU
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