Networks and Web technologies

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Network Protocols

I

1. TCP/IP: operation and main protocols (TCP, UDP, IP)

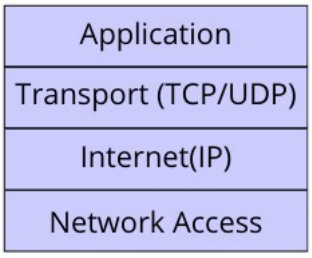
The TCP/IP* model is the **fundamental architecture used for communication on the Internet** and most modern networks. It defines how data is transmitted between devices and how different protocols interact to ensure reliable communication.
*

As seen in the previous chapter, TCP/IP* model is organized into four layers:

- Application layer
- Transport layer
- Internet layer
- Network access layer

Its main protocols are:

- TCP*
- UDP*
- IP*



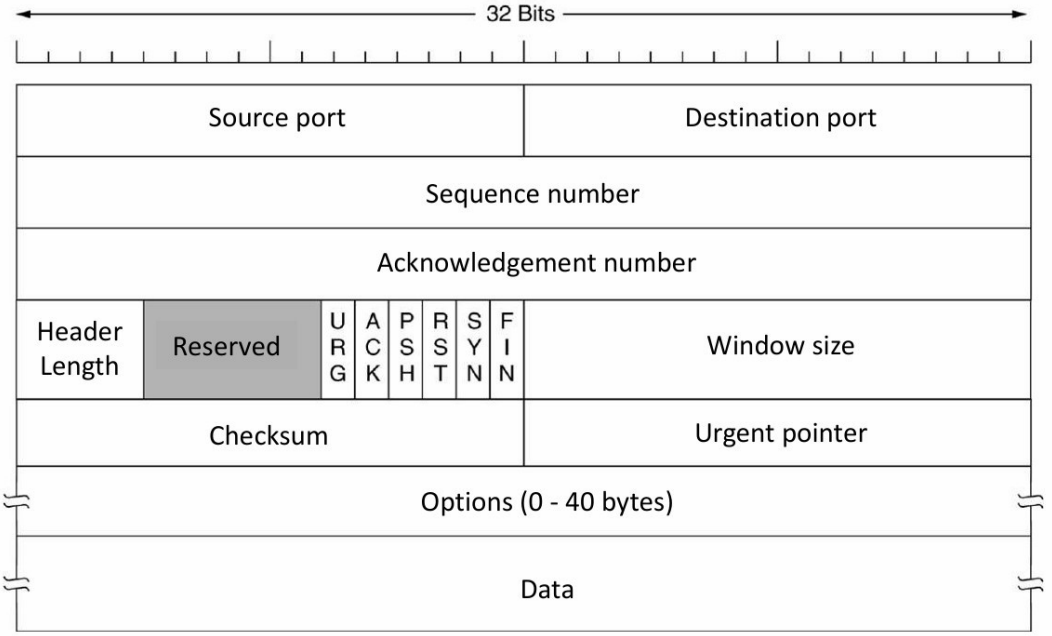
TCP/IP layers and main protocols

1.1. TCP

Définition

TCP* is a **reliable***, **connection-oriented*** transport protocol. Ensures **ordered delivery of packets**. Performs **error detection and retransmission**.

Complément : TCP Header



TCP Header

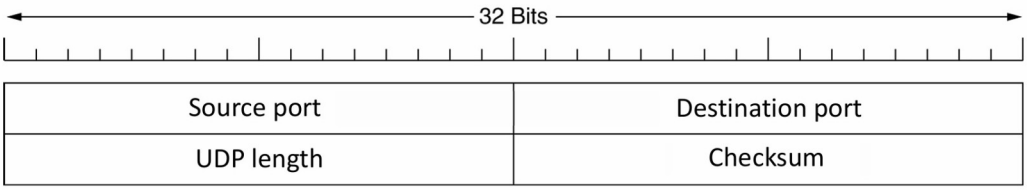
- The TCP* header is added to the data at the transport layer.
- It contains several fields used to control data transmission.
- The source port and destination port identify the application involved in the communication.

1.2. UDP

Définition

UDP* is a **connectionless*** and **unreliable*** transport protocol. It **does not guarantee packet delivery or ordering**, but it provides **faster transmission**.

Complément : UDP Header



UDP header

- When UDP* is used, the UDP* header is added at transport layer.
- It contains the source port and destination port, identifying the applications involved.
- The header is minimal (8 bytes), making UDP* faster and lightweight for real-time applications.

1.3. IP

TCP/UDP define the port to deliver the data, but where is the destination machine?

• To reach the correct host or computer, we need its address (IP address).

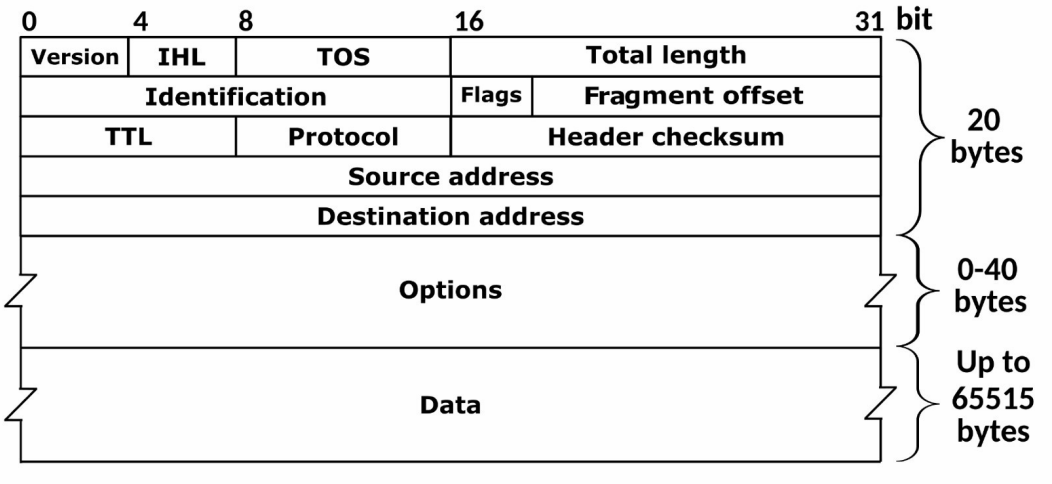
Définition

IP* handles the **addressing*** and **routing*** of packets across networks.

Versions: IPv4* (32-bit) and IPv6* (128-bit).

It **works with TCP* or UDP*** at the transport layer for end-to-end communication.

Complément : IPv4 packet header



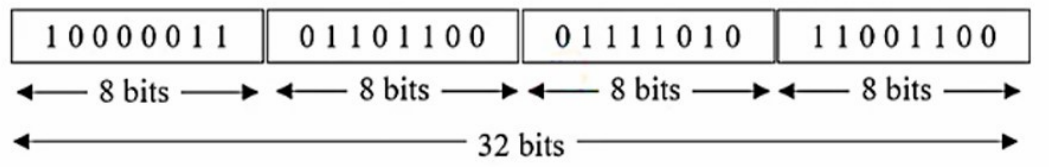
The IPv4* packet is the basic unit of data at the network layer. It contains an IP* header and a payload (data from transport layer).

The header includes key information such as:

- Source IP* address– the sender machine
- Destination IP* address– the receiver machine
- Protocol– indicates if payload is TCP*, UDP*, or another protocol

Complément : IPv4 addresses

Every host and router on the Internet network has an IP address. This combination is **unique**, two machines cannot have the sameIP* address in the same netwrok. IPv4* addresses are 32-bit encoded



Although an IPv4* address is a 32-bit binary number, it is usually written in dotted-decimal format (e.g., 192.168.1.10) for easier reading and configuration. IP* addresses are grouped into classes to adapt addressing to network size and number of hosts.

IPv4* classes:

- Class A: 0.0.0.0 – 126.255.255.255 (very large networks)

- Class B: 128.0.0.0 – 191.255.255.255 (medium networks)
- Class C: 192.0.0.0 – 223.255.255.255 (small networks)
- Class D: 224.0.0.0 – 239.255.255.255 (multicast)
- Class E: 240.0.0.0 – 255.255.255.255 (reserved)

Exceptions:

- 127.0.0.0/8: loopback (localhost, e.g., 127.0.0.1)
- 0.0.0.0 : special, often used for default route

Complément : Subnet Mask

The subnet mask defines **which part of an IP* address identifies the network** and **which part identifies the host**.

IP Address	Subnet Mask	Network / Host
192.168.1.10	255.255.255.0	Network: 192.168.1 / Host: 10
172.16.5.20	255.255.0.0	Network: 172.16 / Host: 5.20
10.2.3.4	255.0.0.0	Network: 10 / Host: 2.3.4

The **host part** identifies the specific machine in that network.

Machines can communicate directly only if their network part is the same.

Méthode : Finding a Subnetwork

Network Address =IP* Address AND Subnet Mask

PC1: IP* address= 192.168.1.10, Subnet Mask = 255.255.255.0

1. Convert to binary:
   IP* address: 11000000.10101000.00000001.00001010
   Mask: 11111111.11111111.11111111.00000000
2. Apply logical AND:
   IP* address AND MASK = Network Address: 11000000.10101000.00000001.00000000 = 192.168.1.0

The network address of PC1 is 192.168.1.0.

Méthode : Check if two machines can communicate directly

PC1: IP* address= 192.168.1.10, Subnet Mask = 255.255.255.0

PC2: IP* address= 192.168.1.20, Subnet Mask = 255.255.255.0

1. Find the network address of each machine
   Convert to binary and perform AND with subnet mask:
   PC1: 11000000.10101000.00000001.00001010 AND 11111111.11111111.11111111.00000000 = 192.168.1.0
   PC2: 11000000.10101000.00000001.00010100 AND 11111111.11111111.11111111.00000000 = 192.168.1.0
2. Compare network addresses

- **If network addresses are the same = direct communication possible**
- **If network addresses differ = communication requires a router**

  PC1 Network = 192.168.1.0

  PC2 Network = 192.168.1.0

PC1 and PC2 -> same network -> direct communication.

2. Transport protocols (TCP vs. UDP)

UDP and TCP comparaison

TCP* and UDP* are both transport layer protocols, but they serve different purposes:

Feature	TCP	UDP
Connection	Connection-oriented	Connectionless
Reliability	Reliable	Unreliable
Ordering	In order	May be out of order
Acknowledgment	ACK for each packet	None
Retransmission	Retransmits lost packets	None
Speed	Slower	Faster
Common uses	HTTP, TFP, Email	DNS, VoIP, Streaming

TCP vs UDP

The choice between TCP* and UDP* depends on whether reliability or speed is more important for the application.

3. Routing protocols (RIP, OSPF, BGP)

Now that we have the logical address. How do we send the data, and which path should it take ? How do we know if data is received ?

A network protocol is similar to a human protocol, except that the entities exchanging messages and taking actions are hardware or software components of some device (for example, computer, smartphone, tablet, router, or other network-capable device).

* Routing protocols determine how data packets travel from a source to a destination across multiple networks. They allow routers to exchange information and dynamically update their routing tables to find the best paths.

In this chapter we will see:

3.1. RIP

Définition

RIP* is a simple distance-vector protocol that allows routers to share information about network reachability using hop counts. It is suitable for small networks but has limitations in scalability.

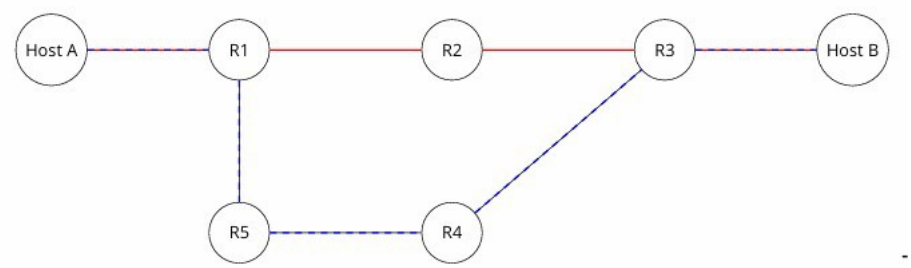
Key characteristics of RIP**:

- Distance-vector protocol

- Uses hop count as metric, each link between routers = 1 hop
- Maximum allowed hops = 15 (16 = unreachable)
- RIP* chooses the path with least hops to route packets
- Simple, suitable for small networks

Exemple

RIP* selects the path with the least number of hops. Each link = 1 hop (implicit).



RIP illustration

Red line = shortest path (3 hops)

Blue dashed line = alternative path (4 hops)

RIP chooses the path with the least number of hops -> red line

3.2. OSPF

Définition

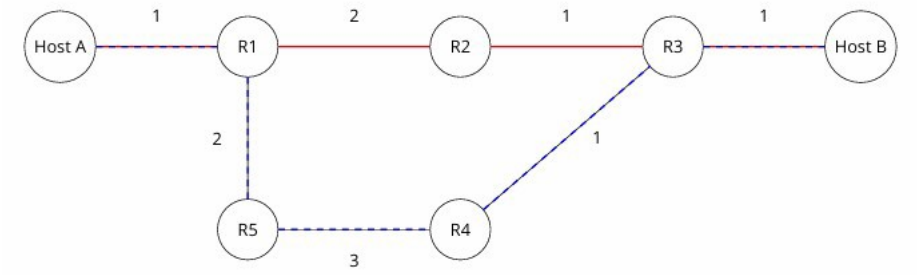
OSPF* is a link-state protocol that builds a complete map of the network topology, allowing routers to calculate the shortest paths efficiently.

Key characteristics of OSPF*:

- Link-state protocol, each router maintains a map of the network topology
- Uses costas metric
- Fast convergence, suitable for medium/large networks

Exemple

OSPF* selects the path with the lowest total cost. Each link has a cost (weight).



OSPF illustration

Red path = lowest total cost = 1 + 2 + 1 + 1 = 5 → selected by OSPF*

Blue dashed path = total cost = 1 + 2 + 3 + 1 + 1=8 → not selected

OSPF* considers link costs instead of just hop count

3.3. BGP

Définition

BGP* is a path-vector protocol used to exchange routing information between different AS* on the Internet.

Key characteristics of BGP:

- Path-vector protocol used between AS*
- Exchanges reachability information
- Each route contains the AS*-PATH (list of AS* numbers the route passes through)
- Route selection is based on policies, AS*-PATH length, and attributes
- It is the main protocol that connects large networks on the Internet
- Suitable for very large networks (Internet)

4. MAC addressing and operation of the Ethernet frame

We used logical addresses (IP addresses) to identify machines in the network. Routing protocols determine the path to reach the destination network, but there is important questions:

• An IP address identifies the destination logically, but what is the real hardware address of the machine?

• How does a device find the physical address of the destination?

• Where will the data be finally delivered on the local network?

• Can we track data delivery?

Fondamental : Ethernet protocol

Ethernet protocol defines **frames** for sending data over a physical medium.

Complément

Each frame contains:

- Destination MAC* address**
- Source MAC* address
- Payload (data)
- Frame FCS* for error detection

MAC addresses are unique 48-bit identifiers for each network interface a MAC address is assigned to a network interface card. They are usually written in hexadecimal format.

Exemple : MAC address example

00:1A:2B:3C:4D:5E

5. ARP (Address Resolution Protocol): resolving IP addresses to MAC addresses

Fondamental : ARP Protocol

Devices communicate using IP* addresses, however, Ethernet usesMAC* addresses*. **How does a device send a frame if it only knows the destination IP*?** A mechanism is required to map -> ARP* resolves IP* addresses to MAC* addresses.

Méthode : ARP process

- Device sends ARP* request on the network
- Target responds with its MAC*
- MAC* cached for future communication

6. ICMP (Internet Control Message Protocol): managing control and diagnostic messages in IP

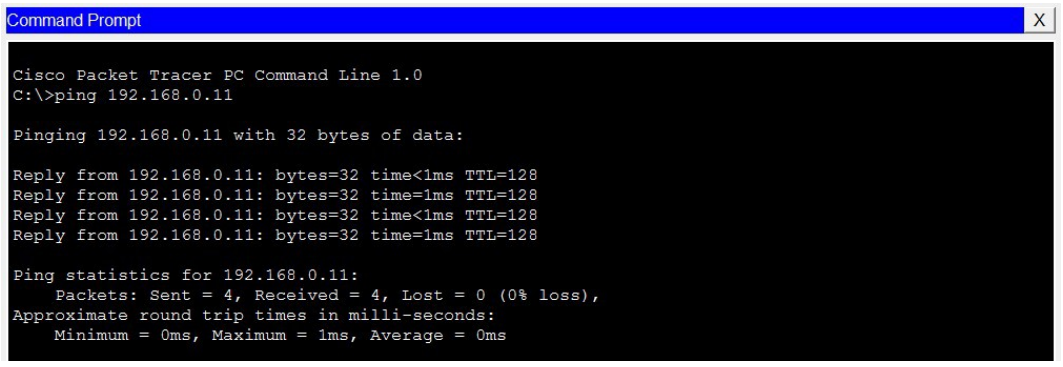
Fondamental

IP* provides logical addressing and routing, while Ethernet and ARP* handle physical delivery within a local network.

However, **when sending packets across multiple networks, packets may be lost, a destination may be unreachable, or a route may not exist**. To handle these situations, **the network needs a protocol to report errors and provide diagnostic information** -> ICMP* provides this control, it is used for network diagnostics and management.

Exemple

Check connectivity between PC1 with IP* address 192.168.0.10 and PC2 with IP* address 192.168.0.11 using ping* command.



Glossaire

Addressing

Addressing is the process of assigning unique identifiers to devices on a network so that data can be sent from a source to the correct destination

Connectionless Protocol

In a connectionless protocol No dedicated connection is established before sending data.

Connection-oriented protocol

A connection-oriented protocol establishes a dedicated connection between sender and receiver before transmitting data.

MAC address

A MAC address is a unique hardware identifier assigned to a NIC or network device. It operates at the Data Link layer (Layer 2) of the OSI model and is used for local network communication.

Ping

Ping is a network utility that uses ICMP to test the reachability of a host on an IP network.

Reliable protocol

A reliable protocol guarantee packet delivery

Routing

Routing is the process of selecting a path to send packets from source to destination.

Unreliable protocol

An unreliable protocol does not guarantee packet delivery

Abréviations

ARP : Address Resolution Protocol

AS : Autonomous Systems

BGP : Border Gateway Protocol

FCS : Frame Check Sequence

HTTPs : HyperText Transfer Protocol Secure

ICMP : Internet Control Message Protocol

IP : Internet protocol

IPv4 : Internet Protocol Version 4

IPv6 : Internet Protocol Version 6

MAC : Media Access Control

OSPF : Open Shortest Path First

RIP : Routing Information Protocol

TCP : Transmission Control Protocol

TCP/IP : Transmission Control Protocol / Internet Protocol

UDP : User Datagram Protocol

Bibliographie

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