Introduction

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COMPUTER ARCHITECTURES

FPGA

- **Field Programmable Gate Array,** it is an integrated circuit whose functions are programmable via software. Field Programmable Gate Arrays (FPGAs) are semiconductor devices based on a matrix of configurable logic blocks (CLBs) connected via programmable interconnections.
- FPGA they can be reprogrammed according to the desired application or functionality requirements after production. This feature distinguishes FPGAs from application-specific integrated circuits (ASICs), which are tailor-made for specific design tasks. While there are one-off programmable FPGAs (OTPs) available, the dominant types are SRAM based which can be reprogrammed as the design evolves
- **ASIC (Application Specific Integrated Circuit)**

UNIT OF MEASUREMENT AND PERFORMANCE

Performances

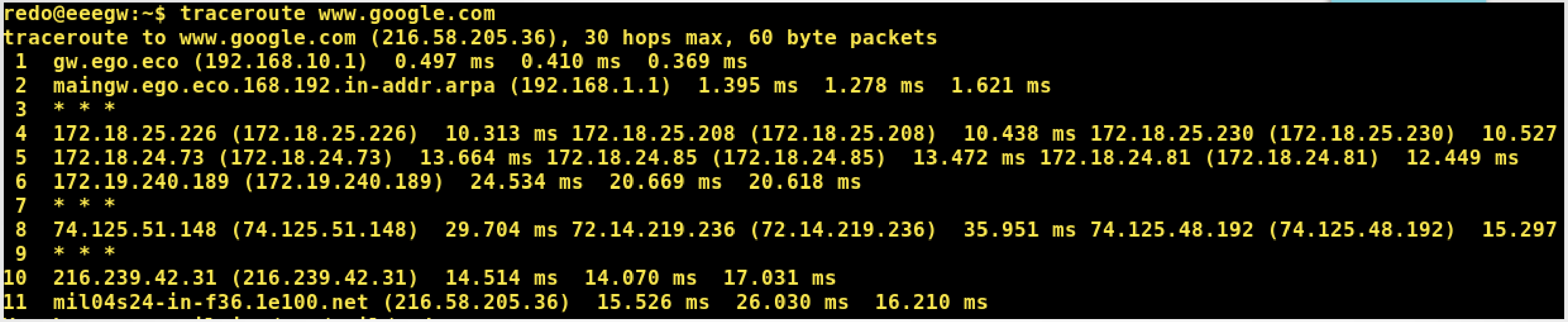
- **Bandwidth** the maximum amount of data (number of bits) of data that can be transmitted in a channel. It is often used as an approximation of the actual performance (unit of measurement for example **Mbps**)

- **Throughput** quantity of data (number of bits) transmitted on the channel in a certain period of time (unit of measurement for example **Mbps**)

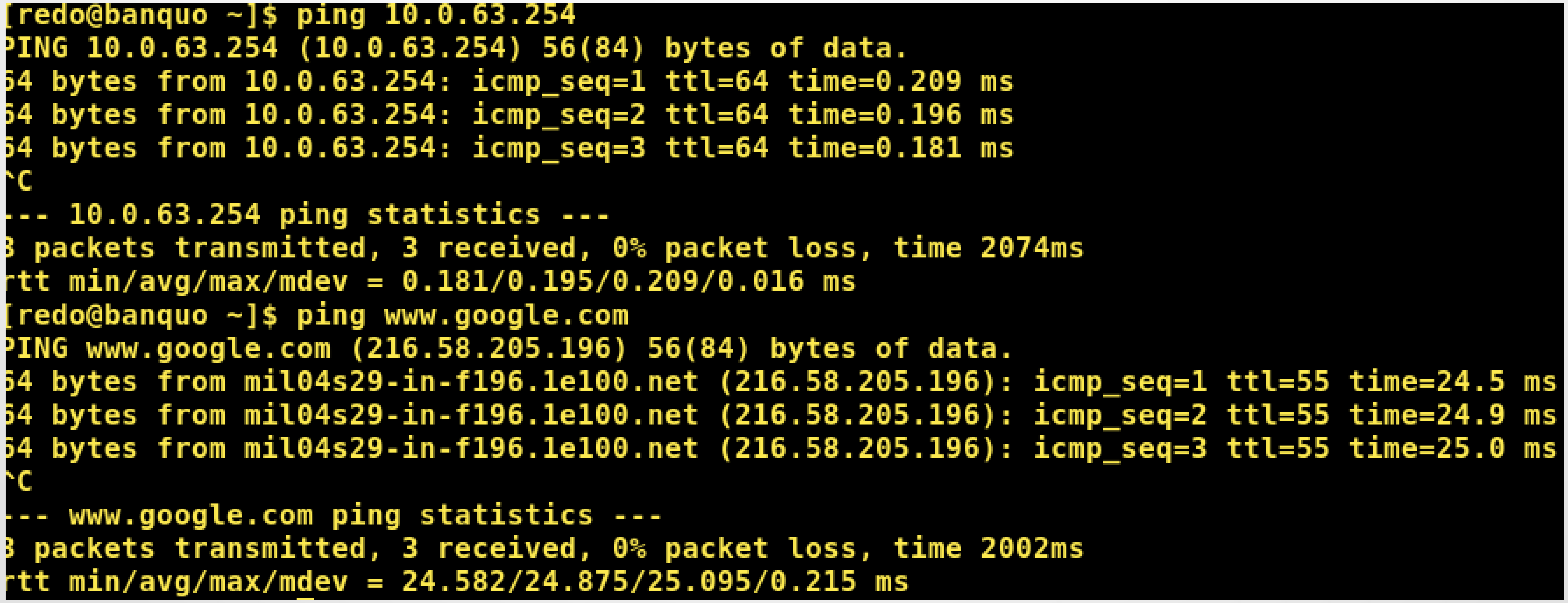
Performances

- **Llatencyor also delay is the time taken by a message to go from one point to another (unit of measurement time for example ms = millisecond = (1/1000) s)**
  - Transmission times due to the speed of signal propagation in the transmission medium, and therefore to the distance
  - Times required to process, for example, the header of the transmitted packets
- **Round Trip Time (RTT)** time taken by the message to go from point A to point B and back again from B to A **(ping and traceroute)**

Performances

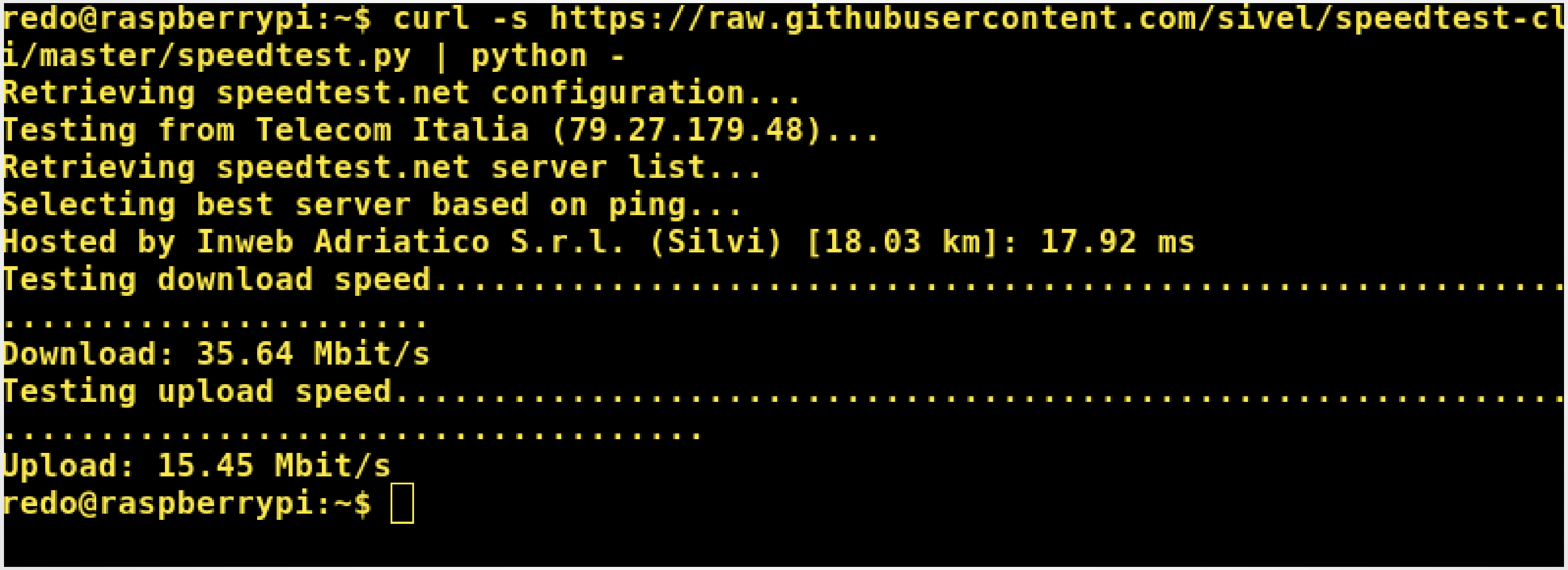


```
redo@eeegw:~$ traceroute www.google.com
traceroute to www.google.com (216.58.205.36), 30 hops max, 60 byte packets
 1  gw.ego.eco (192.168.10.1)  0.497 ms  0.410 ms  0.369 ms
 2  maingw.ego.eco.168.192.in-addr.arpa (192.168.1.1)  1.395 ms  1.278 ms  1.621 ms
 3  * * *
 4  172.18.25.226 (172.18.25.226)  10.313 ms 172.18.25.208 (172.18.25.208)  10.438 ms 172.18.25.230 (172.18.25.230)  10.527
 5  172.18.24.73 (172.18.24.73)  13.664 ms 172.18.24.85 (172.18.24.85)  13.472 ms 172.18.24.81 (172.18.24.81)  12.449 ms
 6  172.19.240.189 (172.19.240.189)  24.534 ms  20.669 ms  20.618 ms
 7  * * *
 8  74.125.51.148 (74.125.51.148)  29.704 ms 72.14.219.236 (72.14.219.236)  35.951 ms 74.125.48.192 (74.125.48.192)  15.297
 9  * * *
10  216.239.42.31 (216.239.42.31)  14.514 ms  14.070 ms  17.031 ms
11  mil04s24-in-f36.1e100.net (216.58.205.36)  15.526 ms  26.030 ms  16.210 ms
```



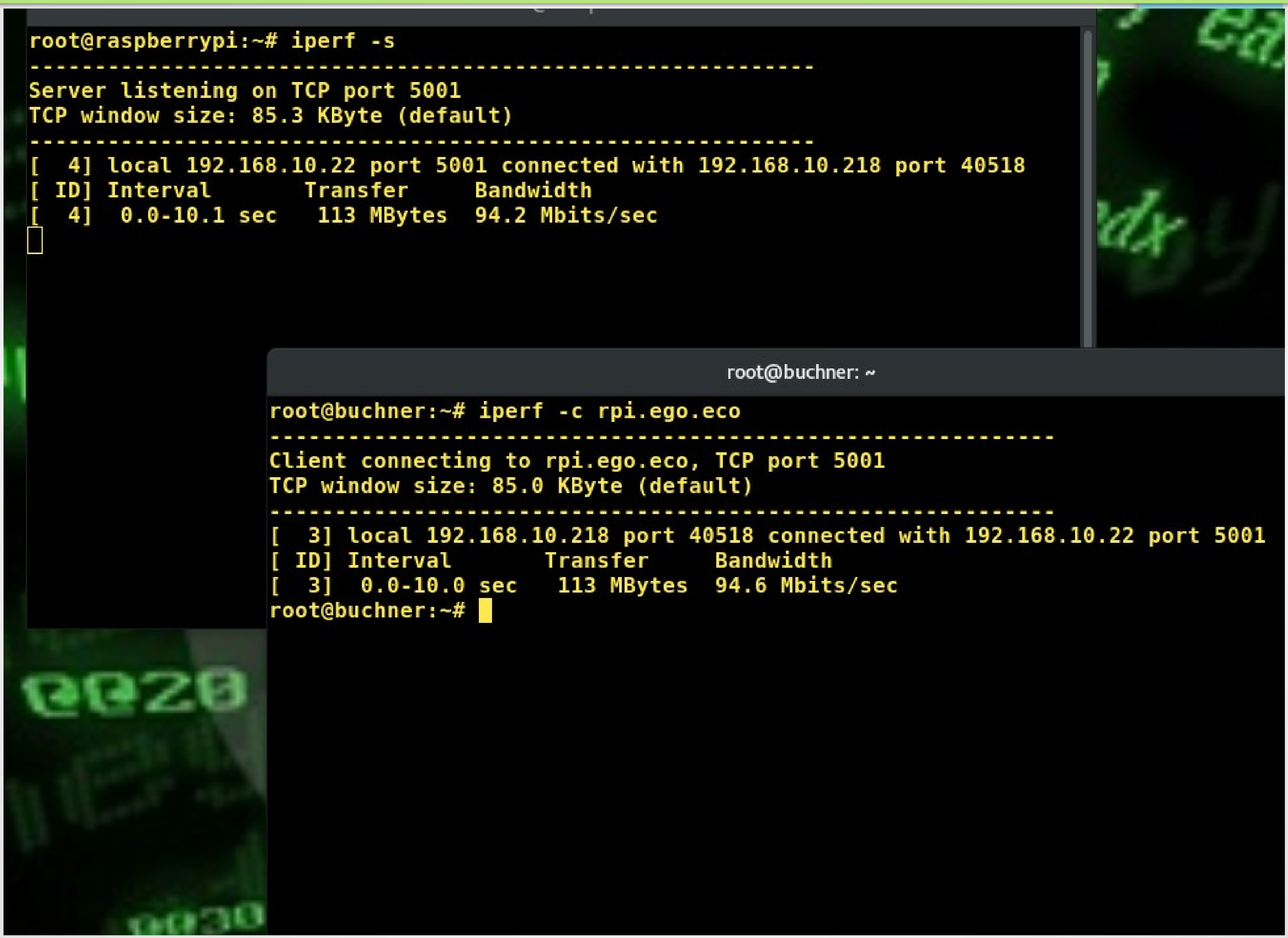
```
[redo@banquo ~]$ ping 10.0.63.254
PING 10.0.63.254 (10.0.63.254) 56(84) bytes of data.
64 bytes from 10.0.63.254: icmp_seq=1 ttl=64 time=0.209 ms
64 bytes from 10.0.63.254: icmp_seq=2 ttl=64 time=0.196 ms
64 bytes from 10.0.63.254: icmp_seq=3 ttl=64 time=0.181 ms
^C
--- 10.0.63.254 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2074ms
rtt min/avg/max/mdev = 0.181/0.195/0.209/0.016 ms
[redo@banquo ~]$ ping www.google.com
PING www.google.com (216.58.205.196) 56(84) bytes of data.
64 bytes from mil04s29-in-f196.1e100.net (216.58.205.196): icmp_seq=1 ttl=55 time=24.5 ms
64 bytes from mil04s29-in-f196.1e100.net (216.58.205.196): icmp_seq=2 ttl=55 time=24.9 ms
64 bytes from mil04s29-in-f196.1e100.net (216.58.205.196): icmp_seq=3 ttl=55 time=25.0 ms
^C
--- www.google.com ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2002ms
rtt min/avg/max/mdev = 24.582/24.875/25.095/0.215 ms
```

Performances



```
redo@raspberrypi:~$ curl -s https://raw.githubusercontent.com/sivel/speedtest-cl
i/master/speedtest.py | python -
Retrieving speedtest.net configuration...
Testing from Telecom Italia (79.27.179.48)...
Retrieving speedtest.net server list...
Selecting best server based on ping...
Hosted by Inweb Adriatico S.r.l. (Silvi) [18.03 km]: 17.92 ms
Testing download speed..................................................
......................
Download: 35.64 Mbit/s
Testing upload speed....................................................
....................................
Upload: 15.45 Mbit/s
redo@raspberrypi:~$ 
```

Performances



```
root@raspberrypi:~# iperf -s
------------------------------------------------------------
Server listening on TCP port 5001
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[  4] local 192.168.10.22 port 5001 connected with 192.168.10.218 port 40518
[ ID] Interval       Transfer     Bandwidth
[  4]  0.0-10.1 sec   113 MBytes  94.2 Mbits/sec
```

```
root@buchner:~# iperf -c rpi.ego.eco
------------------------------------------------------------
Client connecting to rpi.ego.eco, TCP port 5001
TCP window size: 85.0 KByte (default)
------------------------------------------------------------
[  3] local 192.168.10.218 port 40518 connected with 192.168.10.22 port 5001
[ ID] Interval       Transfer     Bandwidth
[  3]  0.0-10.0 sec   113 MBytes  94.6 Mbits/sec
root@buchner:~#
```

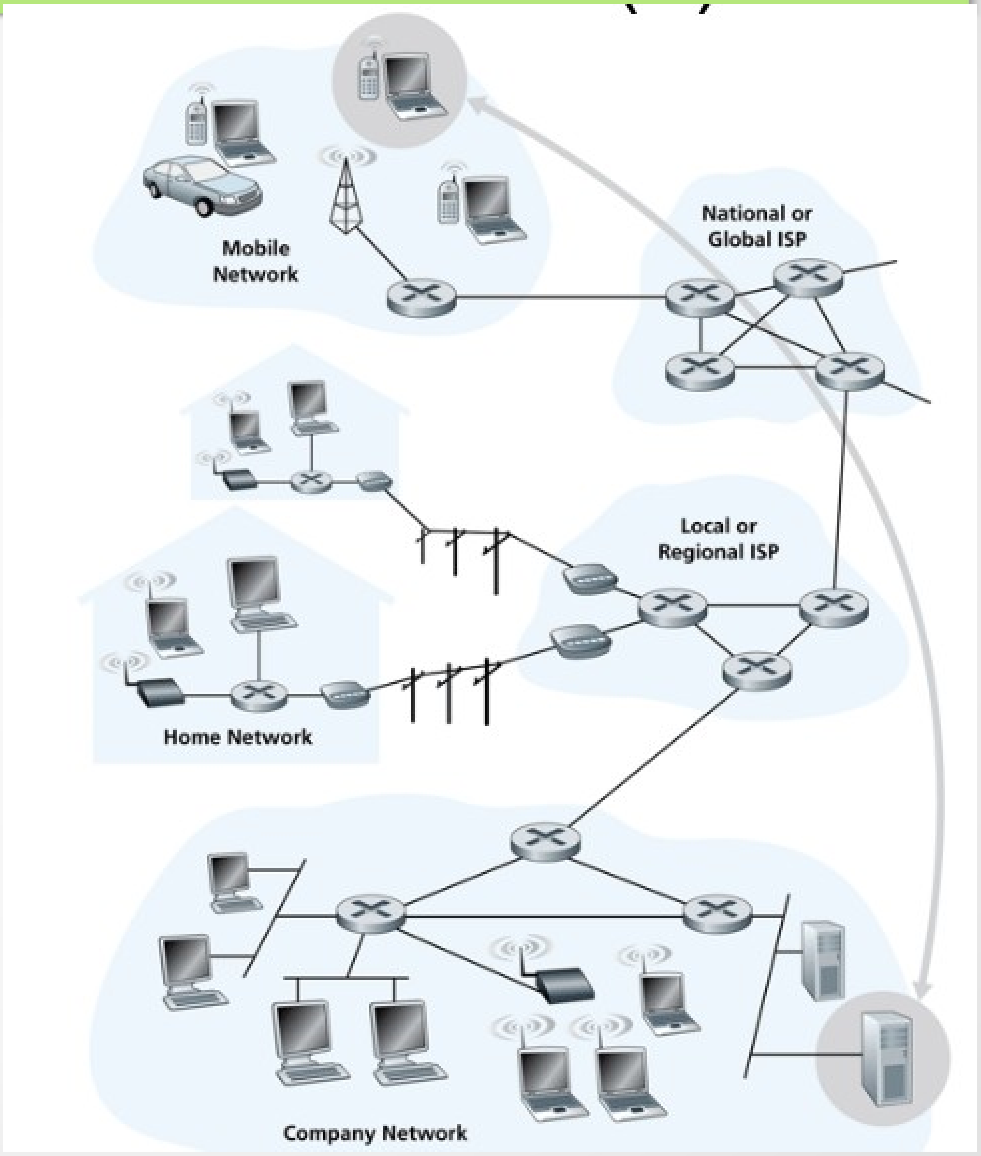
Unit of measurements

- **Data transmission speed = amount of information / transfer time**
- Generarly this speed is expressed in bits per second that is **bit / s (or bps also called bit rate**). Byte per second **byte / s (or Bps)** is also used.
- Then the standard prefixes **k (= kilo 10^3), M (= mega 10^6), G (= giga 109)** are used, therefore not the approximations based on the powers of two that are used in the computer field.
- Converting from **bps to Bps** is simple, just divide by 8. For example ADSL **10 Mbps = 10 Mbps / 8 = 1250 KBps**
- Having to transfer a **10 MiB file using a 5 Mbps line** it will take about (**10 * 1024 * 1024 * 8) / 5 10^6 = 16.8 s** (neglecting latency)

NETWORK

Network

A set of connected autonomous computers, the network is seen as a provider of logical channels through which the various applications can communicate with each other.

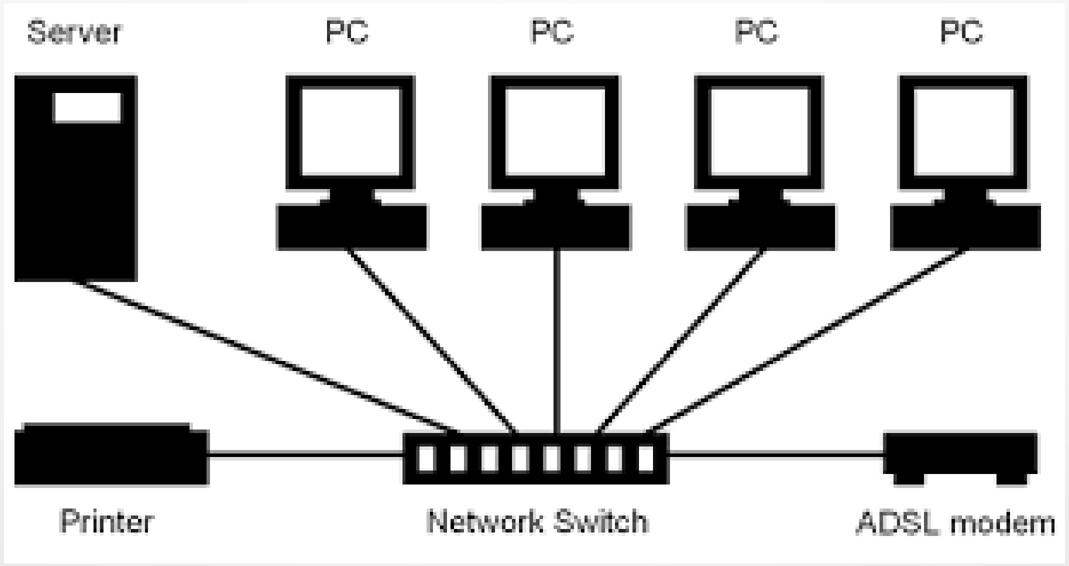


Network

- A set of connected standalone computers
  - **Nodes** (hosts) can be both servers and desktop PCs, or mobile devices or other
  - **Links**, are the channels that allow nodes to communicate. Obviously I can have very different means of transmission, for example the telephone pair, or optical fibers, or radio channels (wireless)
    - Can I have direct or indirect connections (switches)

Switch

- Network switch (also called switching hub, bridging hub) is a network device that connects devices together using computer packet switching to receive, process and forward data to the target device.



Network

I can characterize networks based on their extent

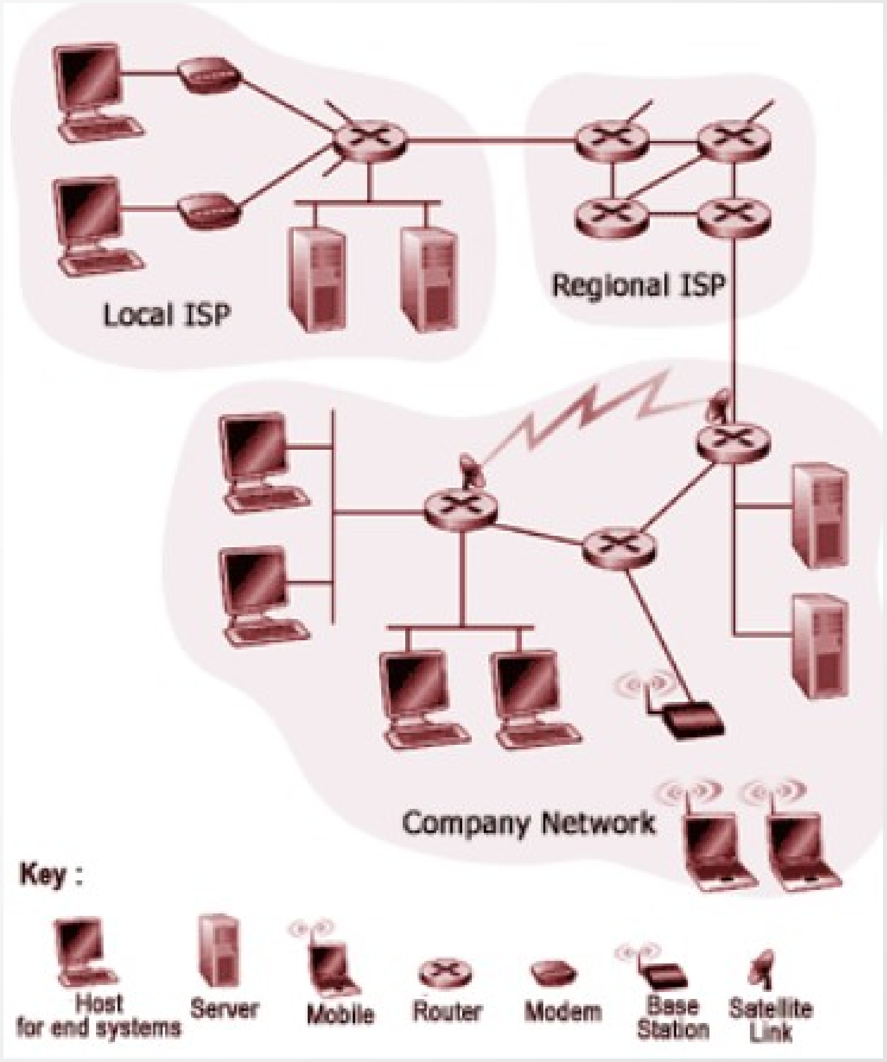
- LAN (Local Area Network): network on a local scale, these are networks extended to the level of a single room or at most of a building
- MAN (Metropolitan Area Network): it can for example connect several LANs
- WAN (Wide Area Network): networks spread over geographic areas. They connect LAN and MAN together (Internet is the WAN par excellence)

INTERNET

Internet

We can describe the internet first of all from the point of view of basic components.

The Internet interconnects millions of devices around the world, traditional desktop PCs, mobile devices, and the so-called servers (which store and transmit data, such as html pages, e-mails, etc.). These devices are called hosts or end systems

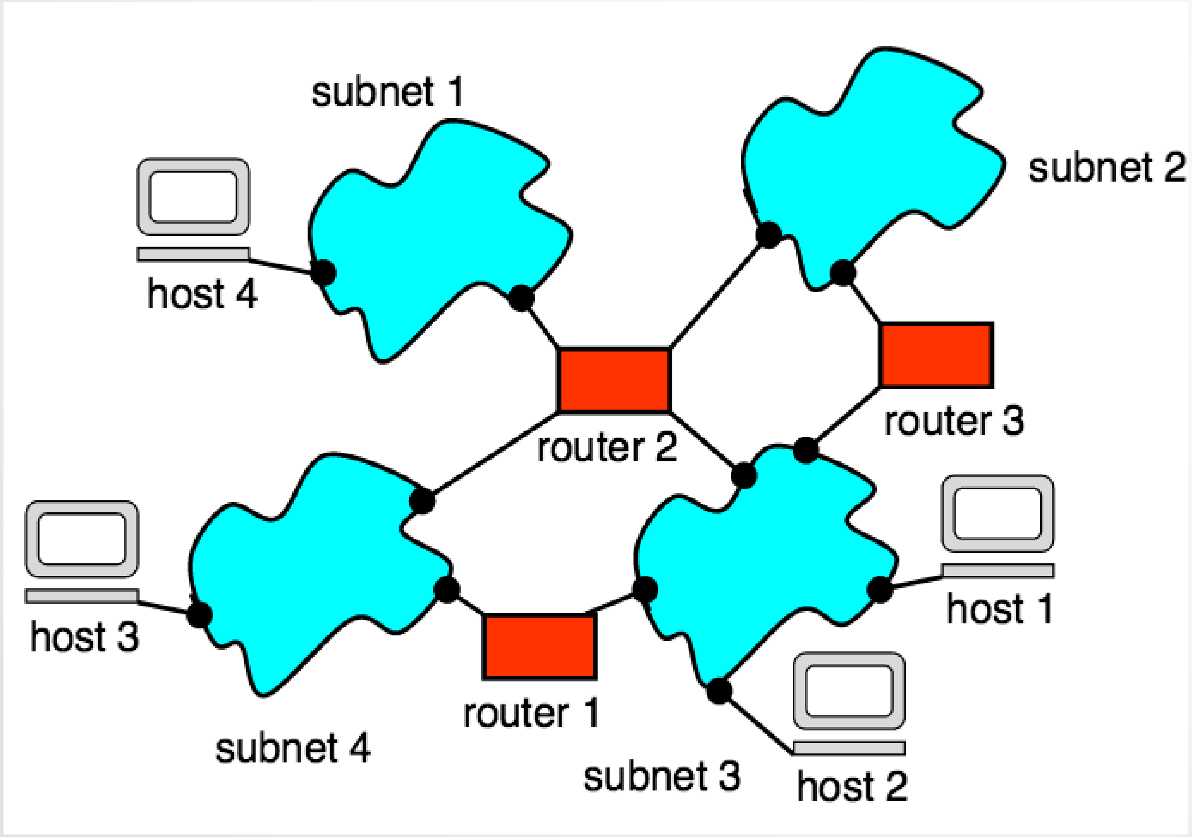


Internet

- **The various hosts are interconnected through communication channels**. These channels can be very different in nature, such as coaxial cables, copper wires, optical fibers or radio links
- **Generally the hosts are not directly interconnected but there are "switching" devices called routers.** Routers are used to route data traffic, and therefore take information arriving from one channel and send it to another channel
- **The Internet is a set of interconnected networks.** The various hosts, as well as other infrastructural devices communicate with each other using **common protocols (IP Internet Protocol and TCP Transmission Control Protocol are the two main protocols**)

Internet

The Internet today interconnects thousands of subnets



Host: computer connected to the internet, it can be either a client or an application-level server

Router: node ce is used to route traffic (a Layer 3 network gateway device,)

Subnet: set of hosts between which there is a layer 2 connection (for example a LAN)

To date, order of billions of hosts

Internet: History

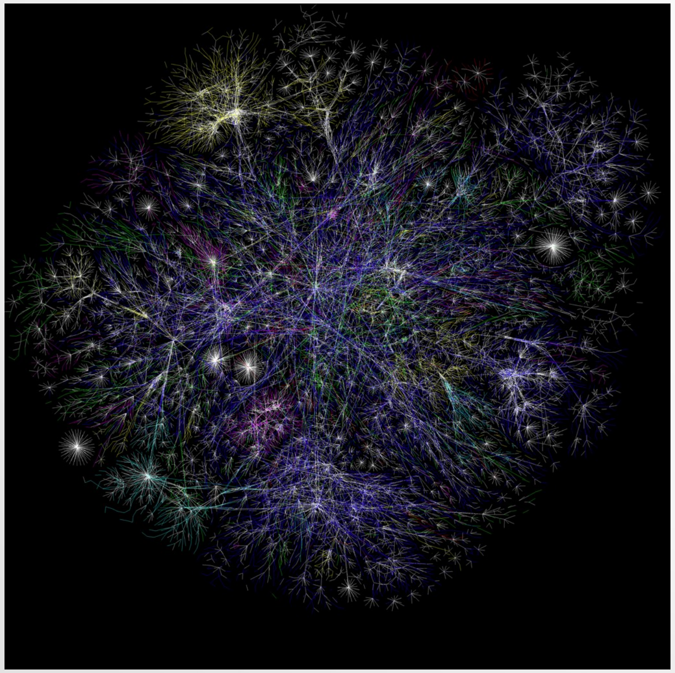
- **1969** starts the design of the **ARPANET military network**. Among other things, this network is designed with the aim of **resisting nuclear attacks.** In fact it was able in case of connecting the interconnected devices following in case of breakages different roads
- **1972 electronic mail (e-mail)** was born, file transfer via **FTP** and remote connection (**Remote Login**)
- **1974 the IP and TCP protocols are officially presented.**
- **1979 date of birth of the CSNet** network which interconnects the universities and **research centers** of the United States

Internet: History

- **1982 ARPANET and CSNet are linked**, this is considered the **official birth date, in some way, of the Internet**
- **1990 NSFNet, network linking supercomputers supplants Arpanet.** This paves the way for civil and commercial uses of the Internet.
- **1990 The same year Tim Bernes-Lee who then worked at CERN in Geneva invents HTML (Hyper Text Markup Language)** which allows the management of information of a different nature, text, images, etc. This is the first step towards the **WWW (World Wide Web)**

Internet: History

- **1993 the first browser is created Mosaic**
- **1994 born Yahoo!** The **first search engine**. In the second half of the 90s, many others were created up to the **1998 date of the birth of Google**.



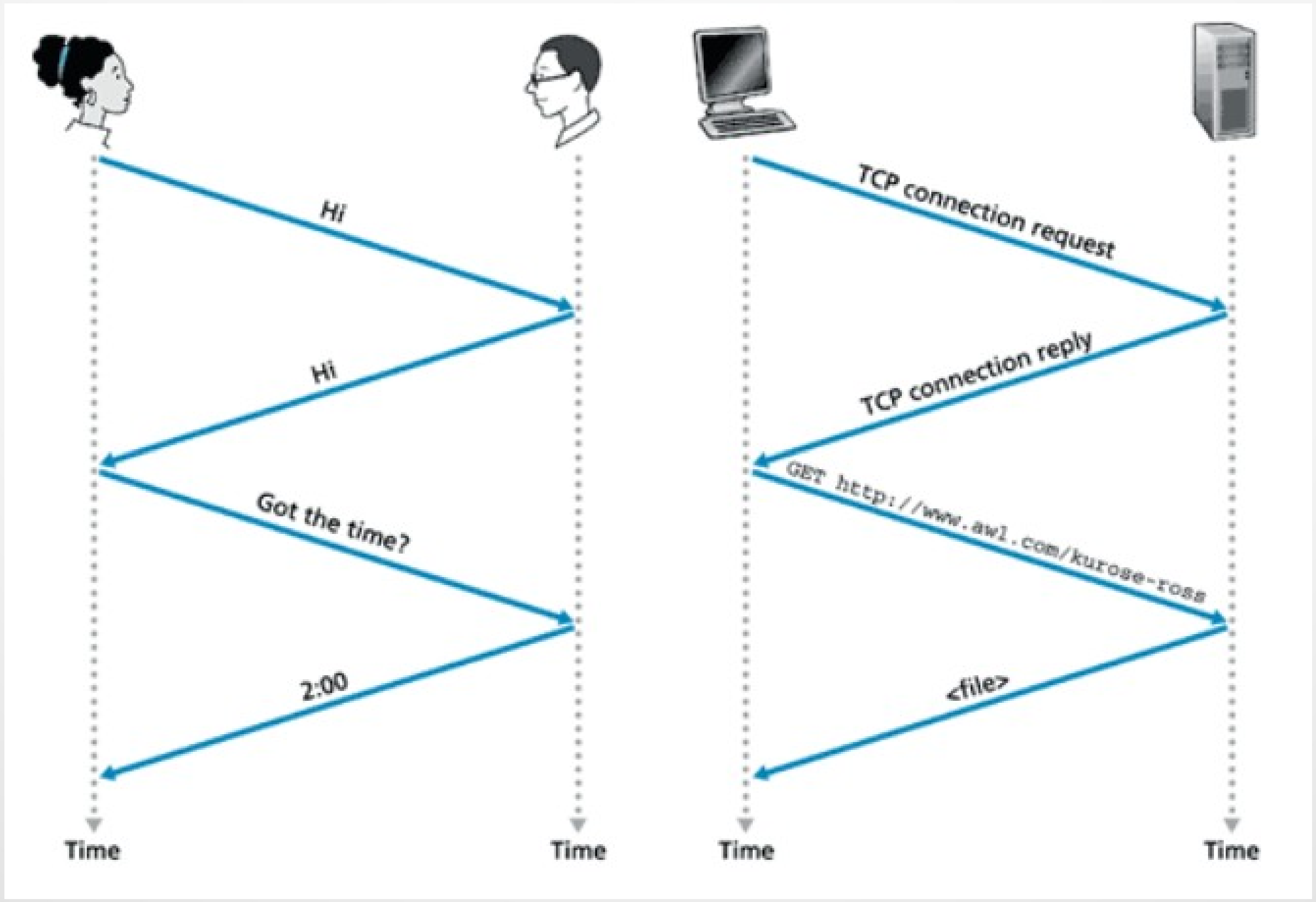
The internet today contains about 10 billion computers, each computer (device) contains on average a couple of billion transistors. So the internet interconnects 1019 transistors, in conclusion there are 10,000 times more transistors than synapses in the human brain

Internet today used in the sale of goods and services. Audio video transmission, network collaboration, work, network games, social interactions.

INTERNET

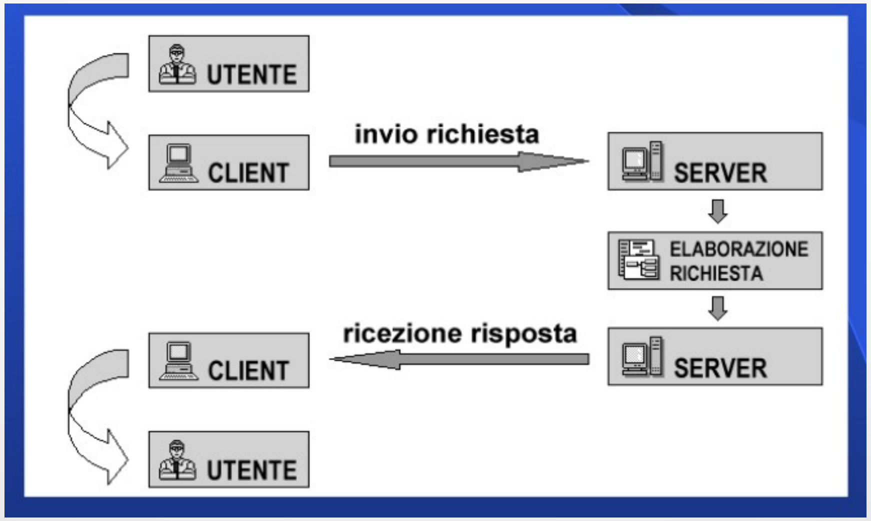
Communication protocol

- **Set of rules (formally described)** that define the methods of communication between two or more entities.



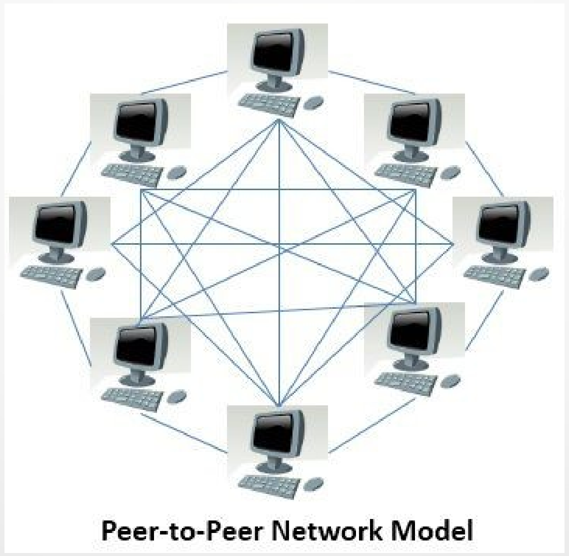
Network model: Client-Server

- Most of the telematic services offered by the Internet are based on the **client / server interaction mode** (different from P2P).
- The client is equipped with a particular client software able to send service requests to a server. The client formats the requests in an adequate and understandable way to the server, thus using a specific protocol (e.g. browser web server)



Network model: P2P Peer-to-Peer

- In this case **there is no distinction between client and server, each node can instead act as both client and server** depending on whether the single node is requesting or providing data
- To become part of the P2P network after the join, the node must start providing services and can in turn request services from other nodes (eg: BitTorrent)

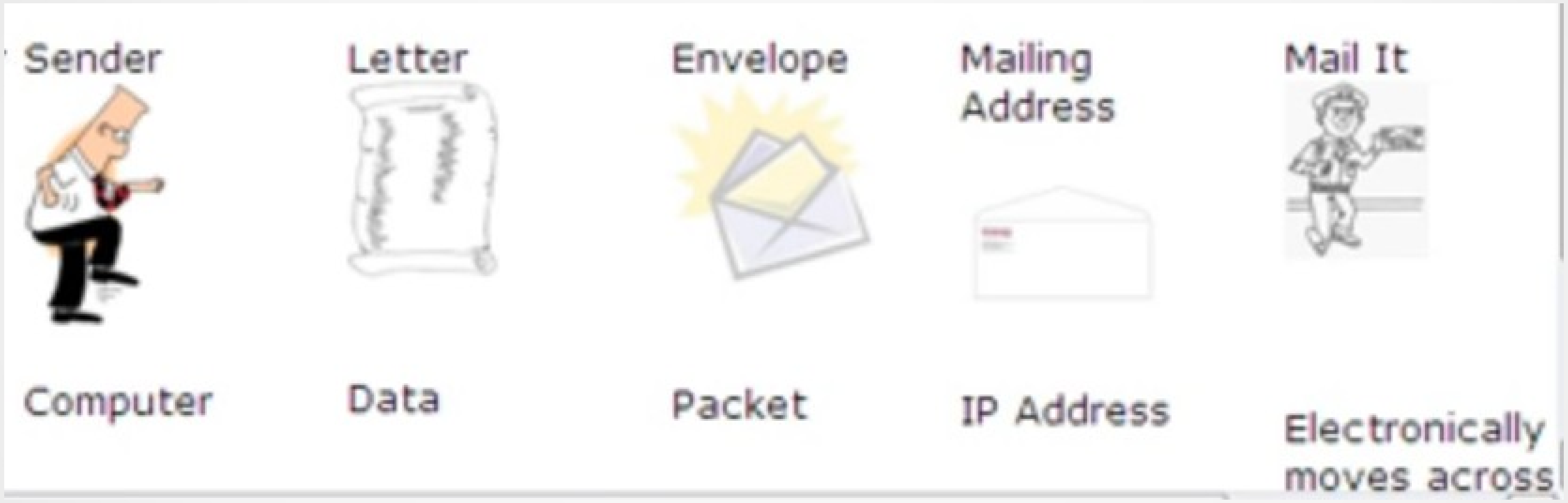


TCP/IP

TCP/IP

- A protocol is a set of rules that those who send data (sender) and those who receive them (recipient) must follow
- Trivial example of a **(non-formal) "protocol" that two people follow when they meet and one asks for the time**:
  - Bob greets Alice
  - Alice greets Bob
  - Bob asks for the time
  - Alice tells the time
  - Bob thanks and says hello
  - Alice greets

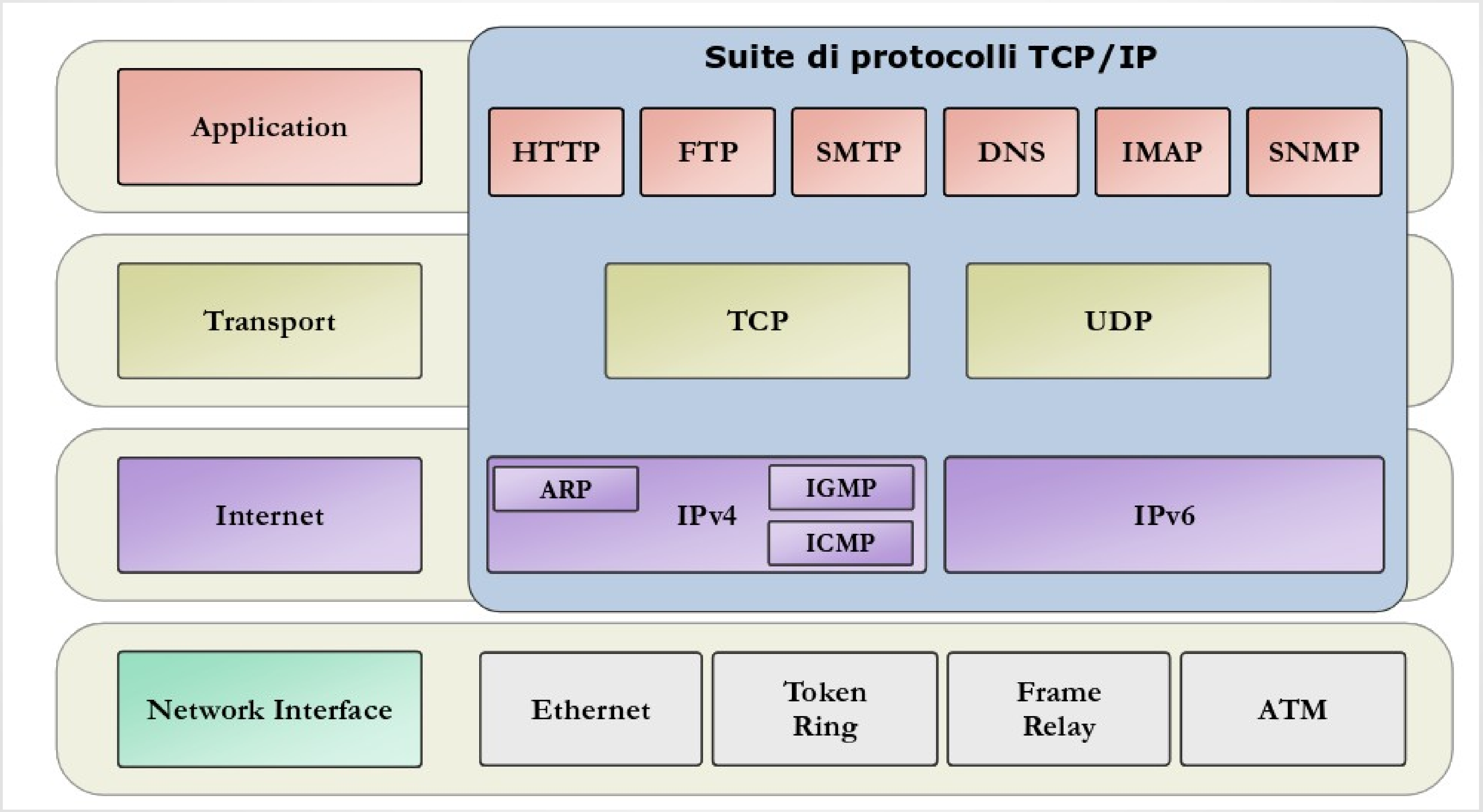
TCP/IP



Sender	Letter	Envelope	Mailing Address	Mail It
Computer	Data	Packet	IP Address	Electronically moves across

And finally a receipt of receipt (ACK)

TCP/IP


Suite di protocolli TCP/IP
Application
HTTP
FTP
SMTP
DNS
IMAP
SNMP
Transport
TCP
UDP
Internet
ARP
IPv4
IGMP
ICMP
IPv6
Network Interface
Ethernet
Token Ring
Frame Relay
ATM

TCP/IP: basic concepts

- **Layering** idea. **For example, the HTTP protocol is built on top of TCP. A browser doesn't have to worry about how TCP is implemented, it just needs to know that it works.**
- **The data that the transport layer receives from the application layer is fragmented into packets**. **The data packets are recomposed at their destination (each packet can follow different paths)**
- The TCP adds additional information to each packet such as in particular the order number of the sequence of which the packet is part.
- **The packet is then passed to the network layer where IP routes the packets to the destination host in the most appropriate way**

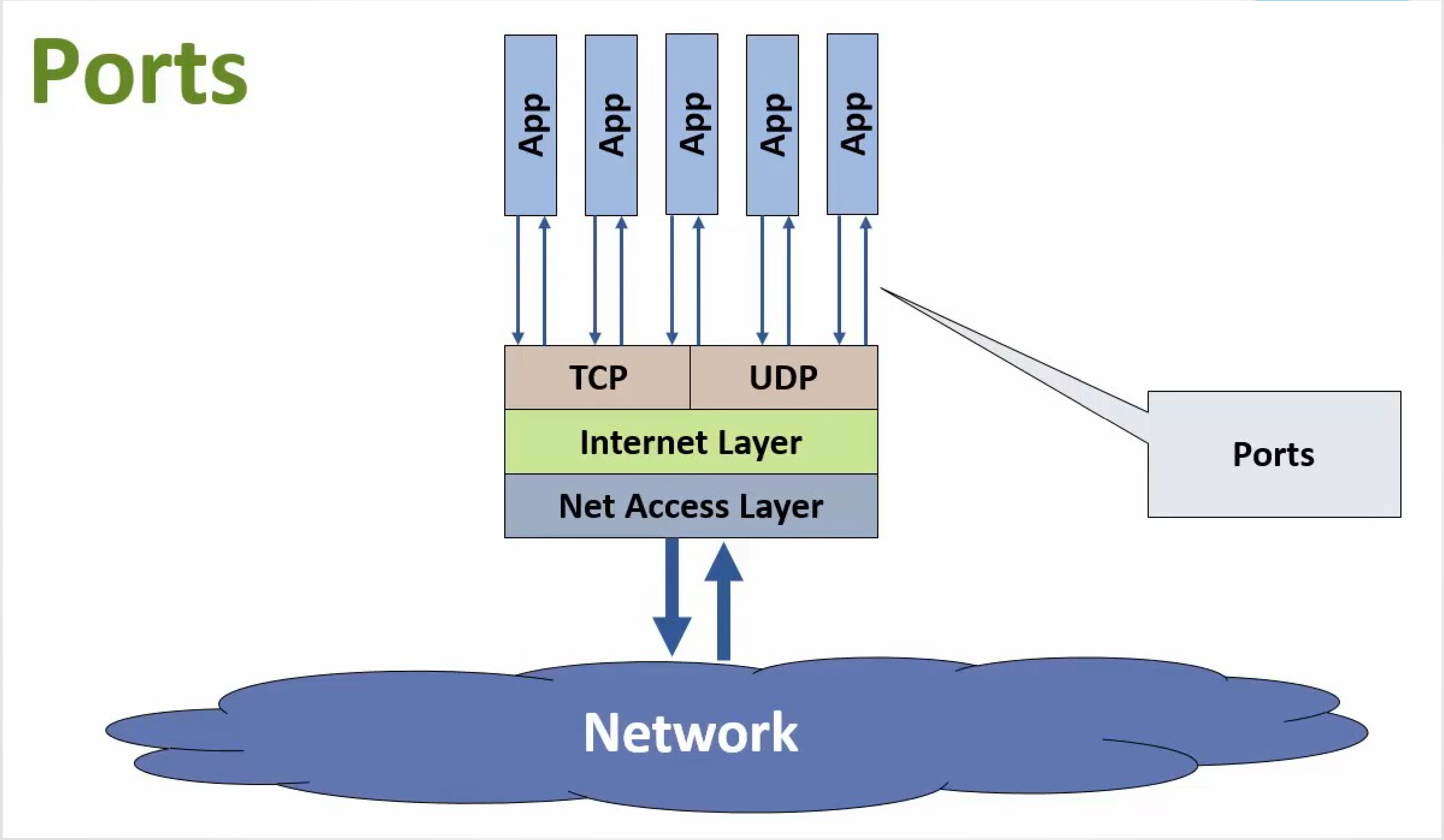
STACK TCP/IP: Application layer

- **Application level**: we have numerous protocols such as **HTTP, FTP, DNS, SMTP, etc etc. At this level, two applications exchange messages without worrying about how they will be delivered.**
- This is the interface with the user, for example if we consult a web page the protocol manages the interaction session between our browser (client) and the web server

STACK TCP/IP: Transport layer

- **Transport layer**: at this layer we find the **two basic protocols TCP and UDP**, at this layer two hosts exchange segments.
- The protocols at this level offer the transport service at the application level. For example, **to manage multiple active sessions simultaneously, TCP and UDP use different port numbers (logical ports)**
- TCP
  - At each window of packets sent, the **TCP starts a time counte**r
  - **The receiver sends an ACK** if they have received the packet
  - **If the sender does not receive an ACK before time runs out (or…). The transmitter takes care, for example, of re-sending the data**

STACK TCP/IP: Ports



STACK TCP/IP: Network layer

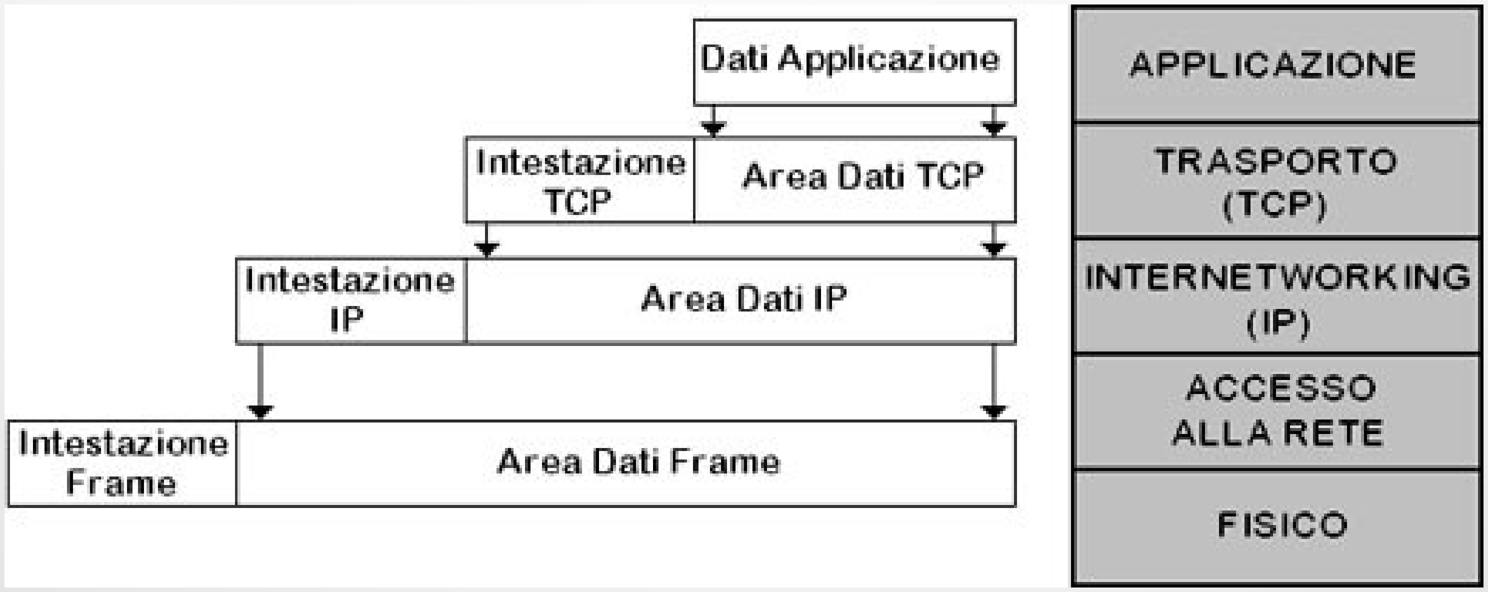
- **Network Level:** at this level we find the **IP protocol**. This protocol deals with the **addressing and routing of packets** between sender and recipient.
- **Addressing**: **Each node is unambiguously identified by an IP address**
- **Routing**: this feature allows to select the best path to follow to transport data from the sender to the recipient

STACK TCP/IP: Network access level

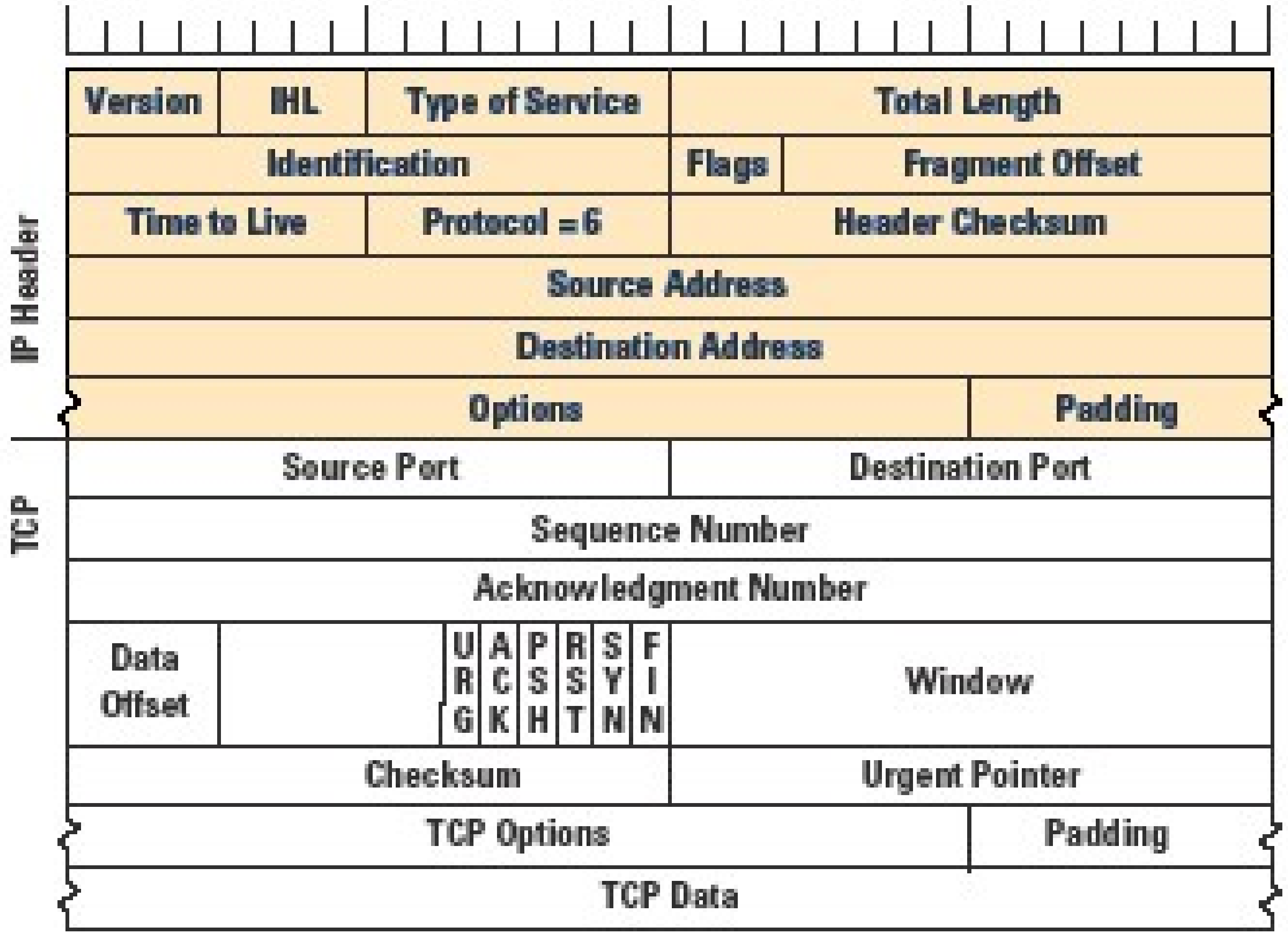
- The TCP / IP model only specifies that below the IP layer there must be a network access layer that **actively deals with sending packets.**
- At the link layer, the protocols decide how the message is to be transferred for each section of the path. So, for example, how to go from the first host to the first router and so on (**MAC addresses, and ethernet)**
- **On a physical level, then the data are converted into electrical or electromagnetic signals or ...**

STACK TCP/IP

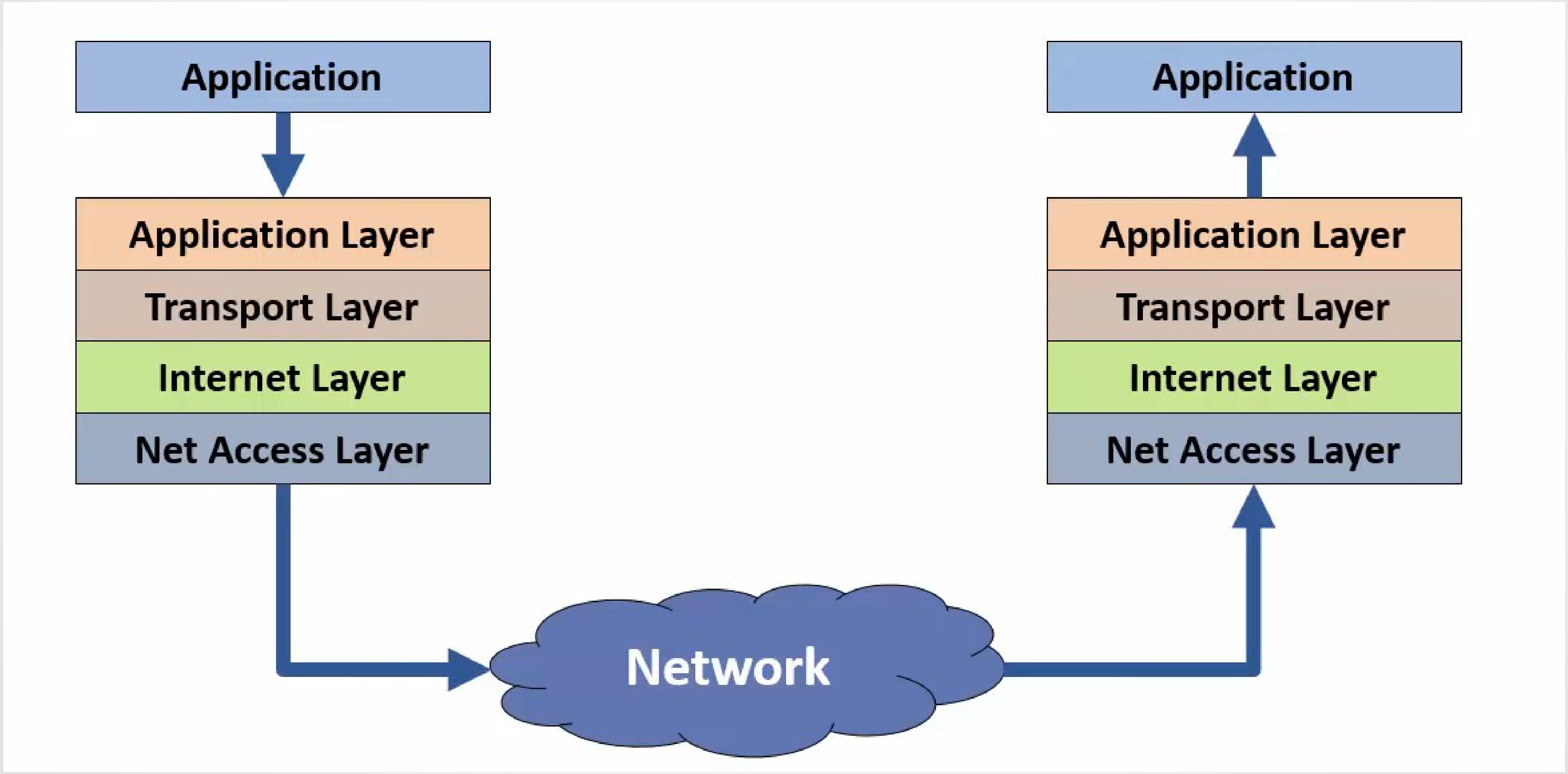
- When an application has to send data, these are passed to the lower level, from time to time until they reach the underlying physical network. During this process, each layer adds information to the data, to create a "network frame" (encapsulation):



TCP/IP: headers



TCP/IP: headers



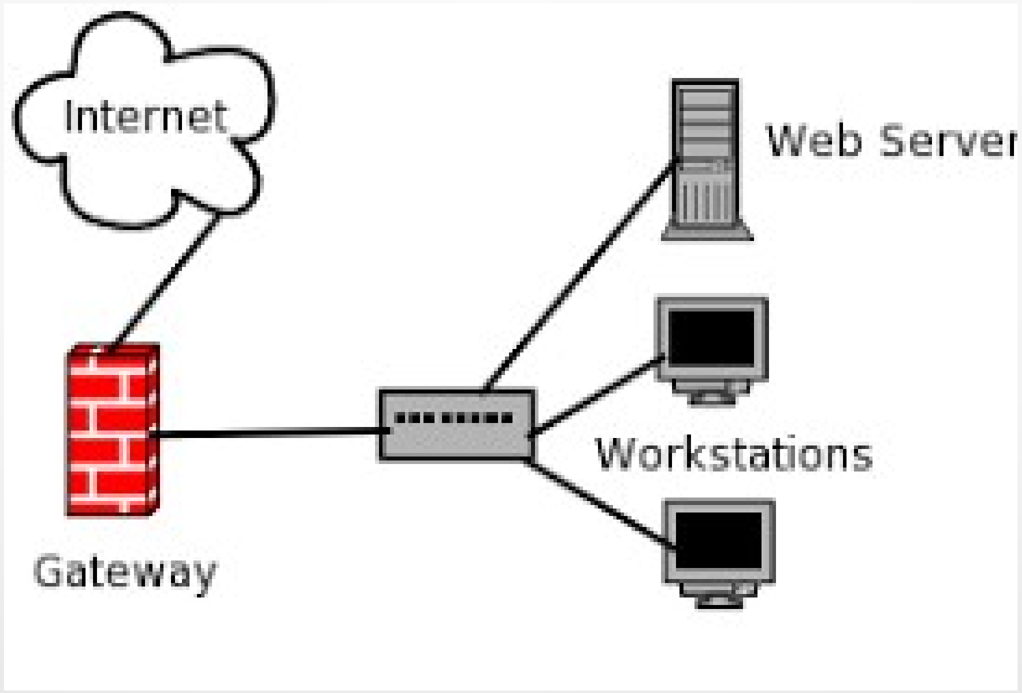
IP ADDRESSES, DNS, DHCP AND ...

IP addresses

- **Each computer connected to the Internet is identified by its IP address**, consisting of 4 groups of one byte each (overall 32-bit). Each number can assume values from 0 to 255
- For example: **192.167.12.66** (static or dynamic IP, private IP ...)
- **The last number usually identifies a Host, the numbers preceding the subnet to which this Host belongs.**
- The maximum number of IPv4 addresses is therefore 255 * 255 * 255 * 255
- IPv6: 128-bit and therefore 2^{128} approximately 3.4 x 10^{38} addresses (IoT: Internet of things)

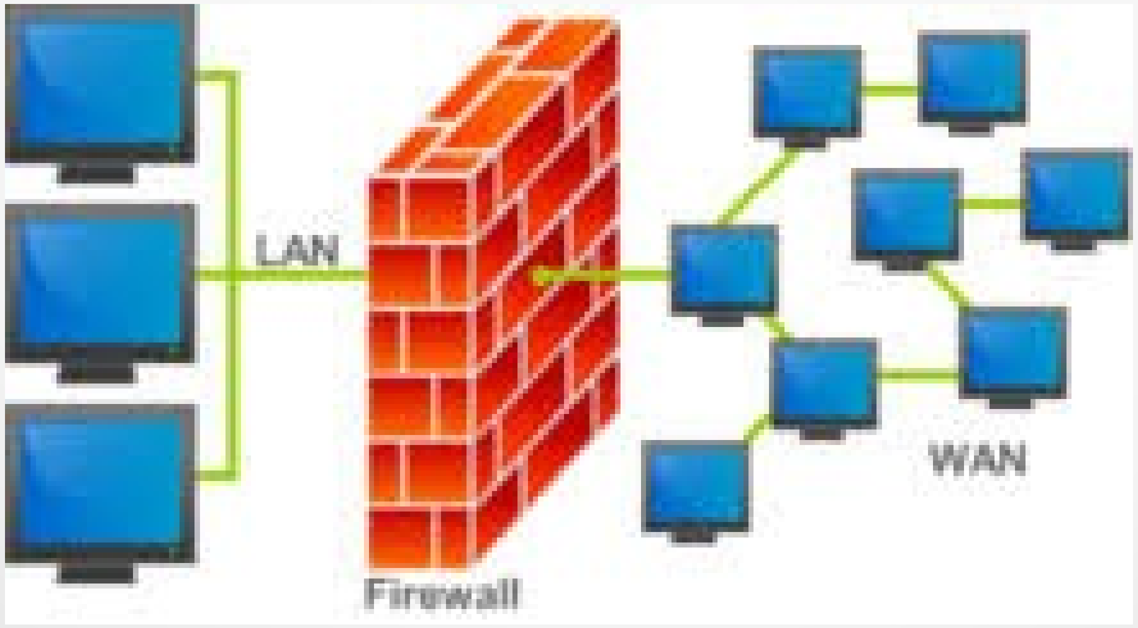
IP addresses: gateway

- The default gateway is used to route packets to other destinations
- DHCP is almost always used to automatically provide the client with the IP address of the default gateway



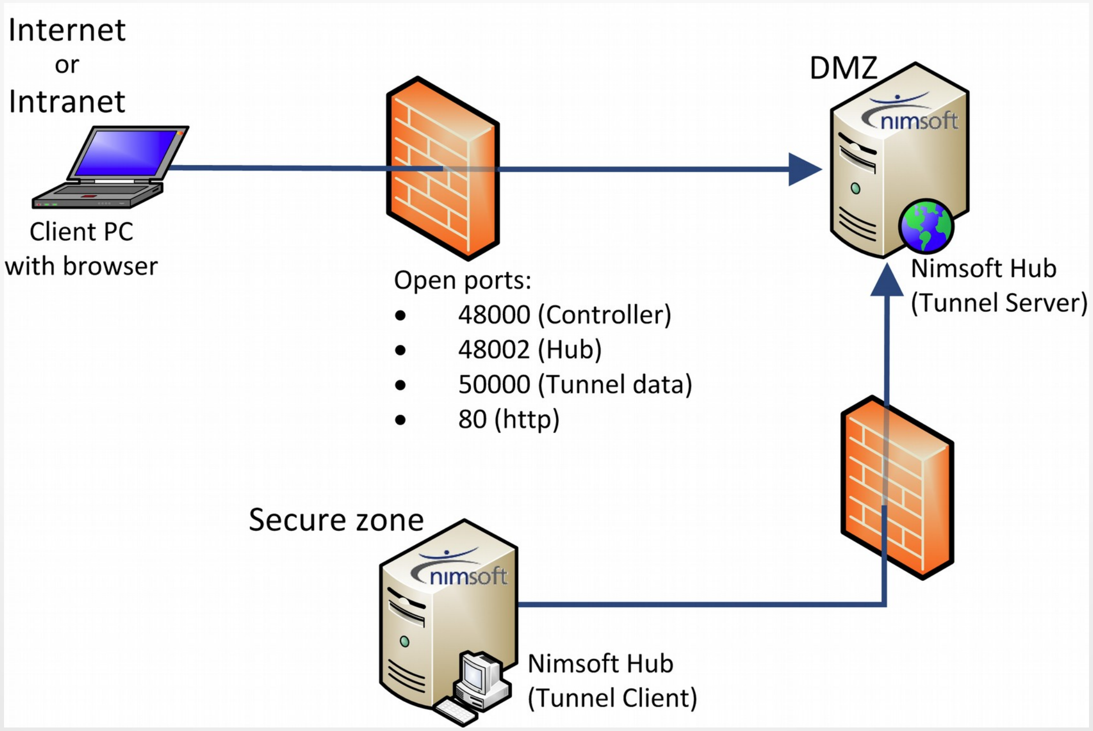
Firewall

- The firewall is a network security system that controls all incoming and outgoing traffic according to well-defined rules



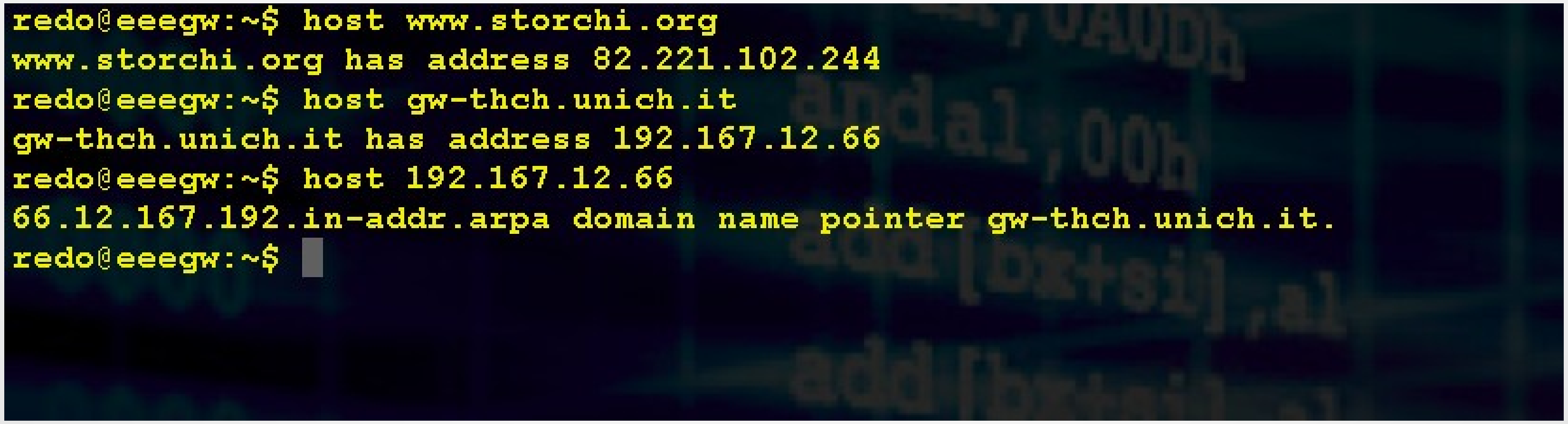
DMZ

- A **DMZ** (demilitarized zone)is a physical or logical subnet that contains and exposes the services of an external organization to an unsecured network, usually a larger network such as the Internet



DNS

- It's difficult for a human to memorize numbers, much easier for names. So there are **DNS (Domain Name System) services**. So systems that are useful for translating names and addresses in one direction and the other.



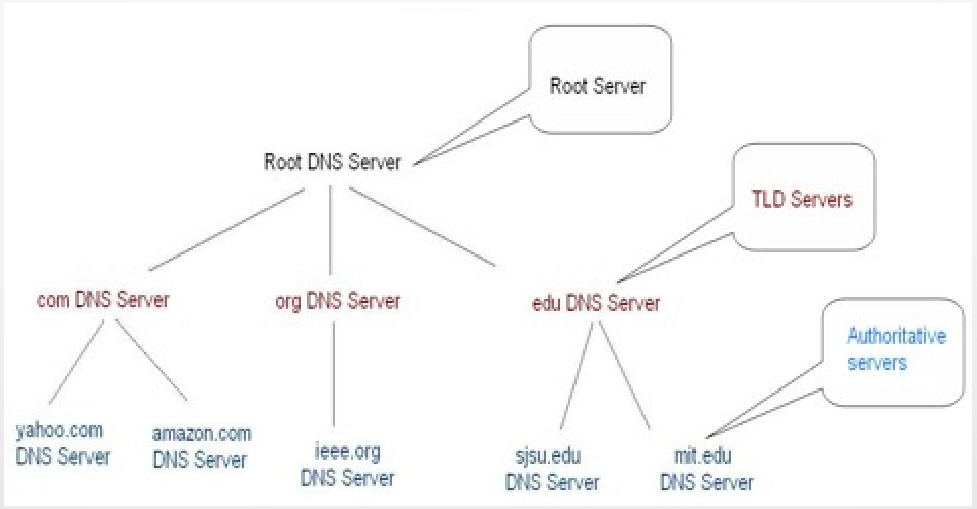
```
redo@eeegw:~$ host www.storchi.org
www.storchi.org has address 82.221.102.244
redo@eeegw:~$ host gw-thch.unich.it
gw-thch.unich.it has address 192.167.12.66
redo@eeegw:~$ host 192.167.12.66
66.12.167.192.in-addr.arpa domain name pointer gw-thch.unich.it.
redo@eeegw:~$
```

DNS

- Each host is therefore identified by the user by a symbolic name:
  - gw-thch.unich.it
- The names are uniquely assigned and administratively managed in a hierarchical manner
- Names uniquely identify a host within a domain:
  - it is the domain
  - unich is the subdomain inside it
- The main domains are:
  - .gov .edu .com essentially in USA associated with the type of organization
  - The various countries instead have domains of the type: .it, .uk, .fr, .de….

DNS

- Before the introduction of the DNS system, the correspondence between IP addresses and names was managed by the SRI-NIC which essentially kept a list in a hosts.txt file
- In practice, DNS is a distributed database. **The information is in fact distributed on many computers, DNS servers, each of which is responsible for a certain portion of the name, called domain.**

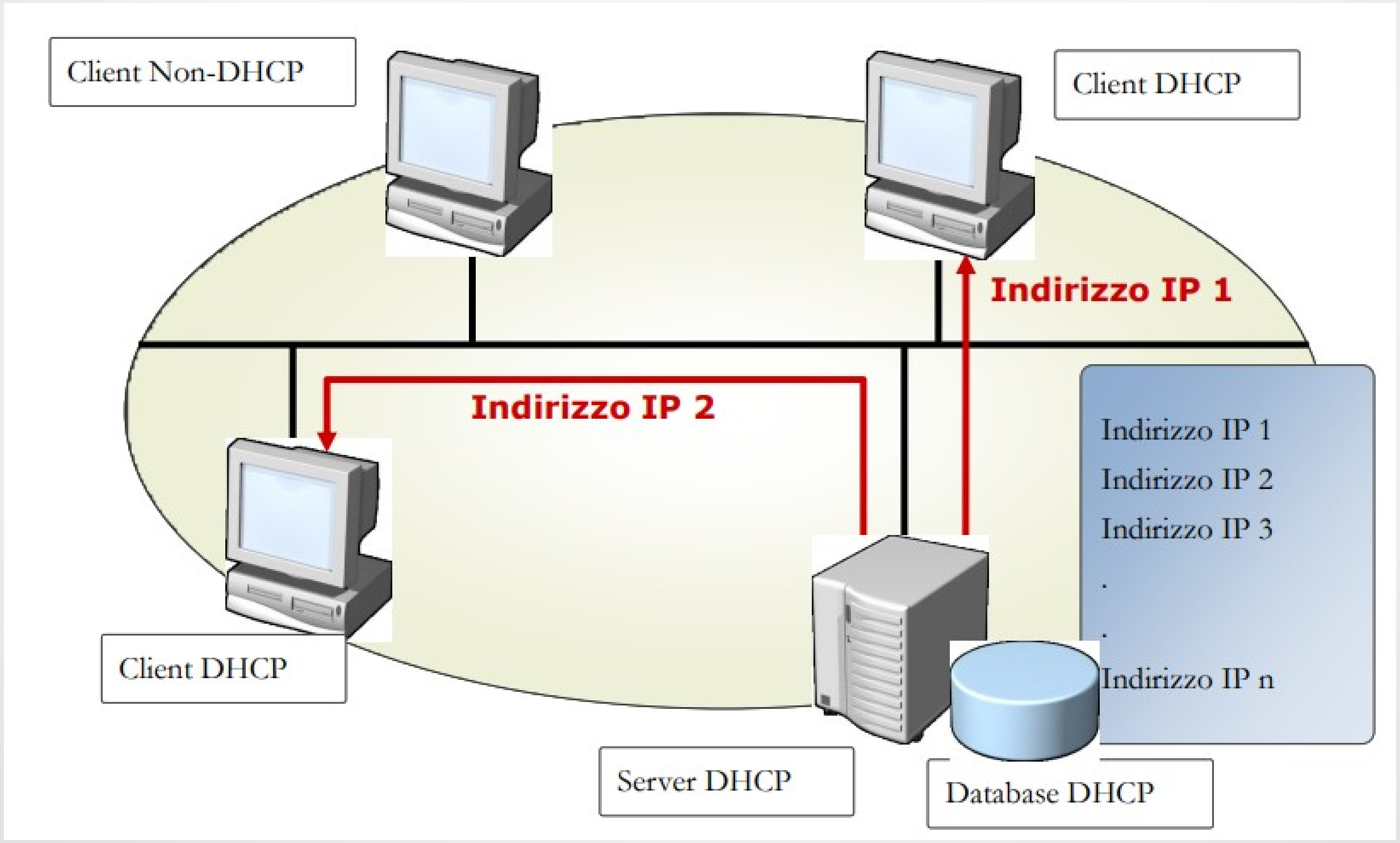


DNS

- The servers are organized in a hierarchical tree structure
- When requesting a given address, for example www.storchi.org, the DNS server of "your network" checks if the address corresponding to the name is present in the cache.
- If it is not present, contact the Root servers (those that manage the .org, .it, .edu extensions ...), in this case .org which will return a list of servers that manage the storchi.org domain
- The latter server will return the IP address corresponding to "WWW" (Domain Name System (DNS) names are "case insensitive")
-
-

DHCP

- For example the ADSL router you have at home



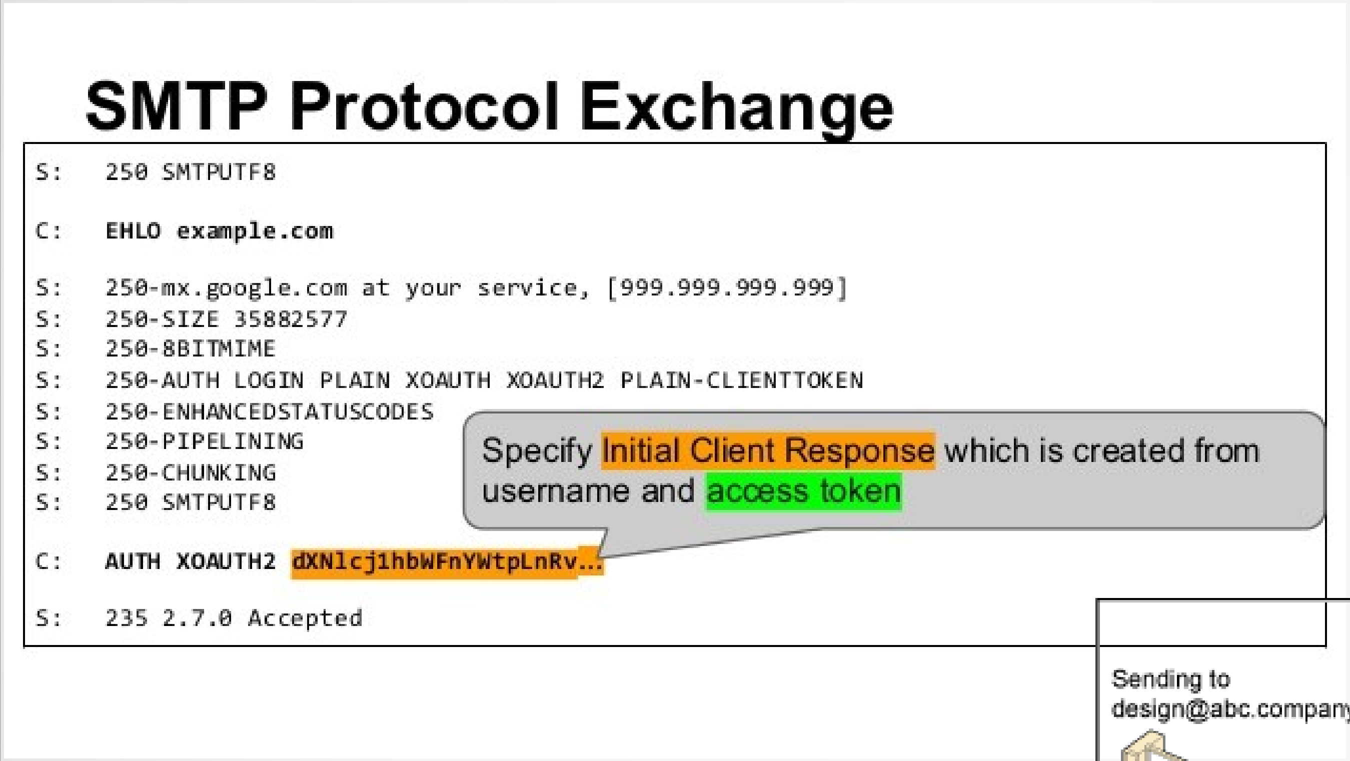
High level protocols

- Different types of protocol are used each for each specific service:
  - **HTTP** (HyperText Transfer Protocol) Access to hypertext pages (WEB) within the WWW (https encrypted)
  - **FTP** (File Transfer Protocol) transfer and copy files
  - **Simple Mail Transfer Protocol (SMTP)** Send POP3 email messages (email) to download email messages to your computer. IMAP useful when viewing messages from multiple devices

A resource on the network is therefore "identified" by the URL:

http://nomehost.it/index.html

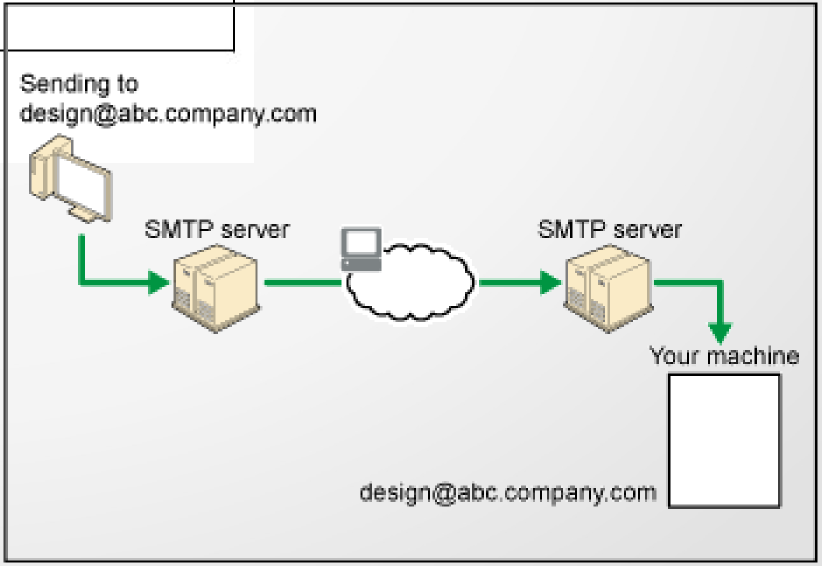
SMTP esempio



SMTP Protocol Exchange

```
S:   250 SMTPUTF8

C:   EHLO example.com

S:   250-mx.google.com at your service, [999.999.999.999]
S:   250-SIZE 35882577
S:   250-8BITMIME
S:   250-AUTH LOGIN PLAIN XOAUTH XOAUTH2 PLAIN-CLIENTTOKEN
S:   250-ENHANCEDSTATUSCODES
S:   250-PIPELINING
S:   250-CHUNKING
S:   250 SMTPUTF8

C:   AUTH XOAUTH2 dXNlcj1hbWFnYWtpLnRv...

S:   235 2.7.0 Accepted
```

Specify Initial Client Response which is created from username and access token


Sending to
design@abc.company.com
SMTP server
SMTP server
Your machine
design@abc.company.com
CJN014