Computer Networks

1. Introduction

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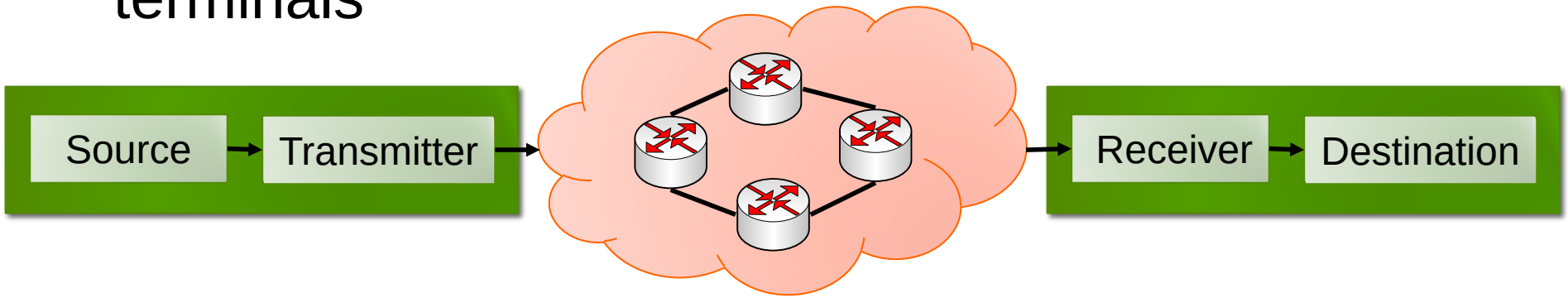
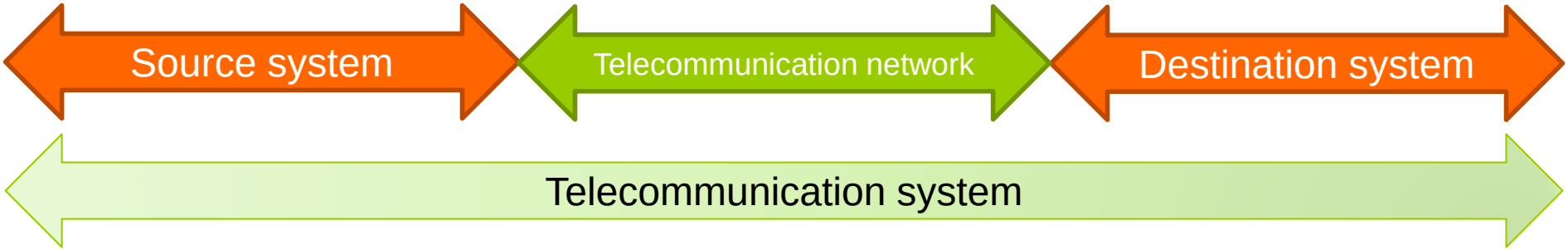
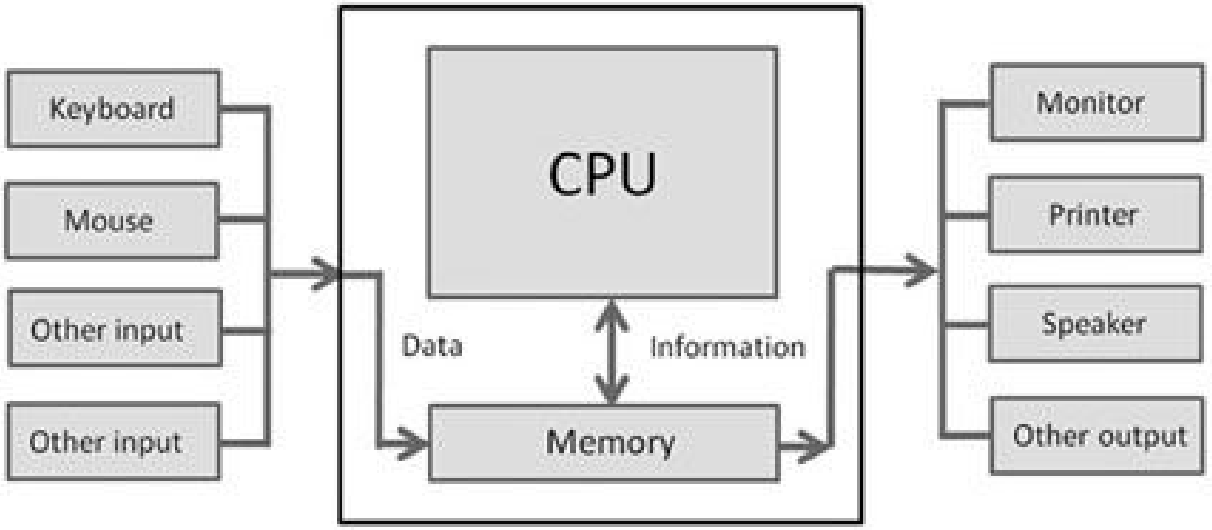
1. Basic concepts - Telecommunication network

- A **telecommunications network** is a collection of terminal **nodes** in which **links** (physical medium) are connected to enable communication between terminals





1. Basic concepts - Computer



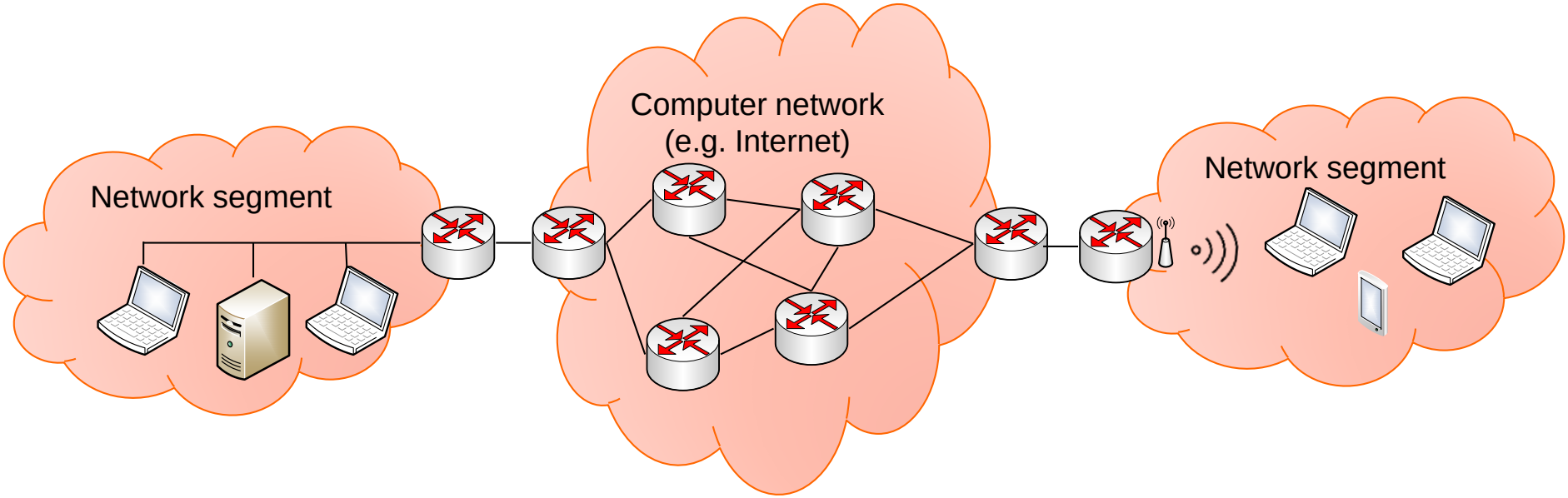
- A **computer** is an electronic device that receives data (*input*), processes it according to a sequence of instructions (*program*) and produces a result (*output*) in the form of information

1. Basic concepts - Computer

- Computers use the **binary system** internally
- *Bit*: Binary digit. Only two values allowed: 0 and 1
- *Byte*: Group of 8 bits operated on as a single unit
- *Word*: natural unit of data used by a particular processor design (*architecture*), handled as a unit by the processor (8,16,32,64,…)
- 1000 Bytes = 1 KB, 1000 KB = 1 MB, …
- 1024 Bytes = 1 KiB, 1024 KiB = 1 MiB, …

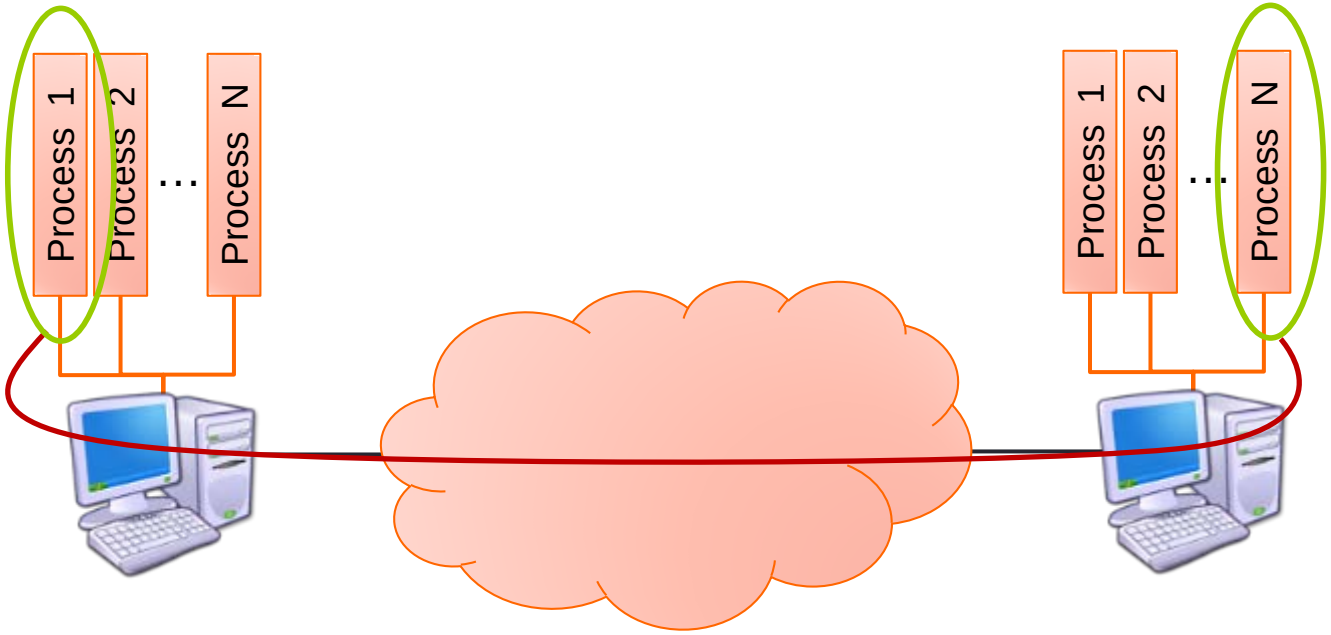
1. Basic concepts - Computer Network

- A **computer network** is a type of telecommunications network which allows nodes to exchange data
- A computers connected to the network is called **host**
- Hosts are interconnected in the same physical network (called segment) through **links** (wired or wireless)
- Different network segments can be connected with devices called **routers** (border routers are usually called **gateways**)



1. Basic concepts - Computer Network

- The final objective of a computer network is communicate **remote processes** (i.e. programs running in different computers)
- This is known as a **distributed service**

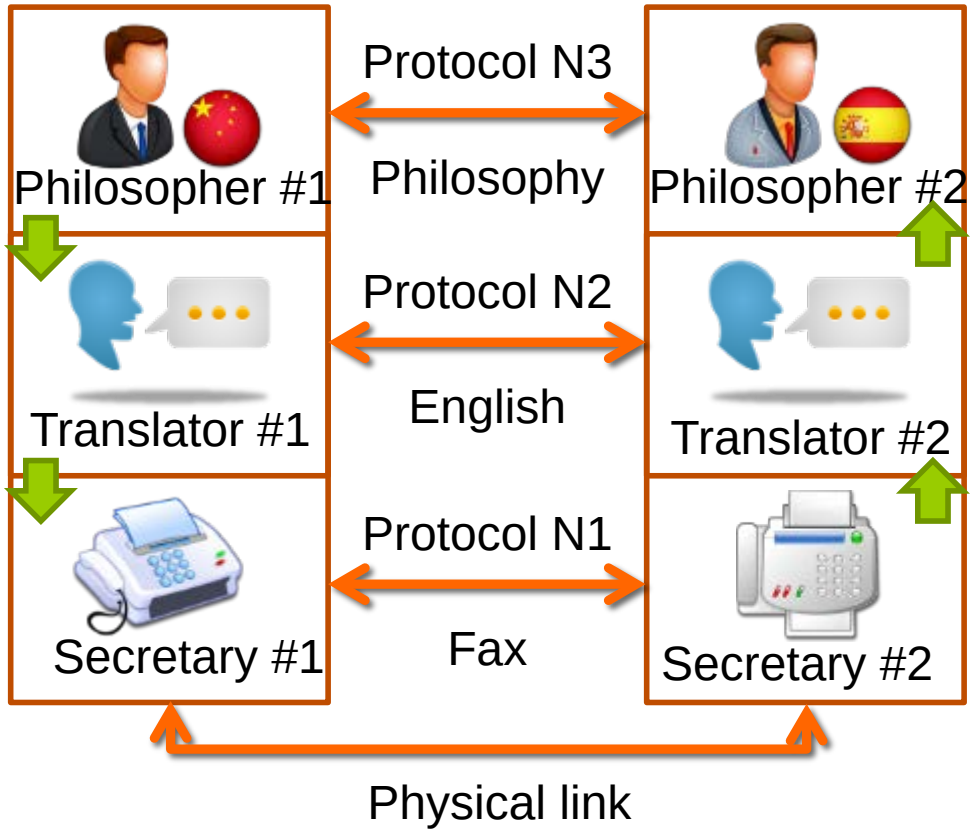


1. Basic concepts - Protocol stack

- In order to achieve this objective, we use the divide and conquer principle
- The communications architecture is divided in layer in the so-called protocol stack (also known as **reference model**)
- Each entity o a given level in a protocol stack is focused in a given problem and provides a **service** to the upper level
- Each entity communicates with a peer entity (i.e. of the same level) using a given **protocol**

1. Basic concepts - Protocol stack

- Analogy:



1. Basic concepts - Protocol stack

- **Service**:
  - It is the set of operations (primitives) that an entity of level N offers to the entity of level N + 1
  - An N-level entity uses the services provided by the N-1 entity
  - The services are available through its interface, and it has a unique address that identifies it
- **Protocol**:
  - It is the set of rules (message format, order, actions to be performed) that allow to communicate two or more remote entities
  - An entity is an element (software or hardware) that implements the protocol. The same level entities are called peer entities
  - The data units that are exchanged by the peer entities are known as the PDU (Protocol Data Unit)

1. Basic concepts - Standardization bodies

- Protocol stacks are effective if adopted by the different hosts in the communication
- To achieve this interoperability, there are different organizations that promote standards (**standardization bodies**), for example:
  - International Organization for Standardization (ISO)
  - Institute of Electrical and Electronics Engineers (IEEE)
  - International Telecommunication Union - Telecommunication Standardization Sector (ITU-T)
  - Internet Engineering Task Force (IEFT)
  - Internet Assigned Number Authority (IANA)

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2. Network types

- We can classify telecommunication networks (not only computer networks) using different criteria:

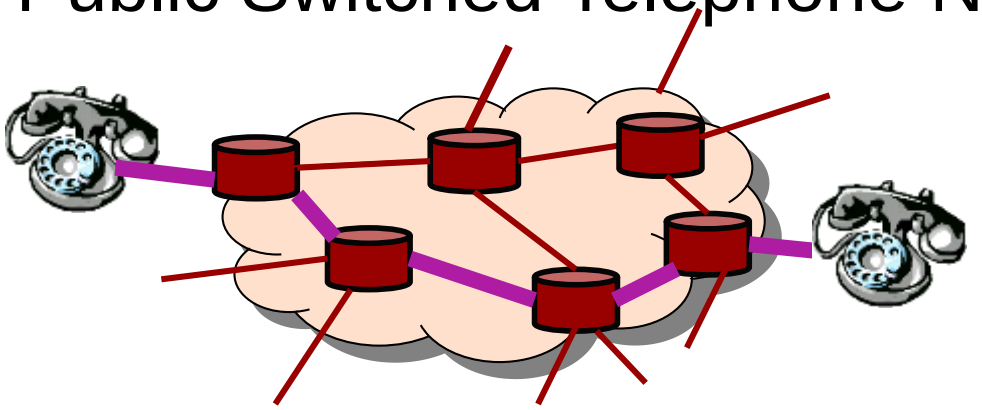
1. **Switching technique** (how the data traverses the path between the source and destination node in the network)
2. **Size** (extension of the network)
3. **Topology** (structure of the network)

2. Network types - Switching technique

- There are two main types of switching techniques:
  - **Circuit switching** is a switching technique that establishes a dedicated path between sender and receiver
  - The **packet switching** is a switching technique in which the message is divided into smaller pieces (known as **packages**), and they are sent individually. Packet switching is divided into 2 sub-categories:
    - Connection-oriented
    - Connectionless

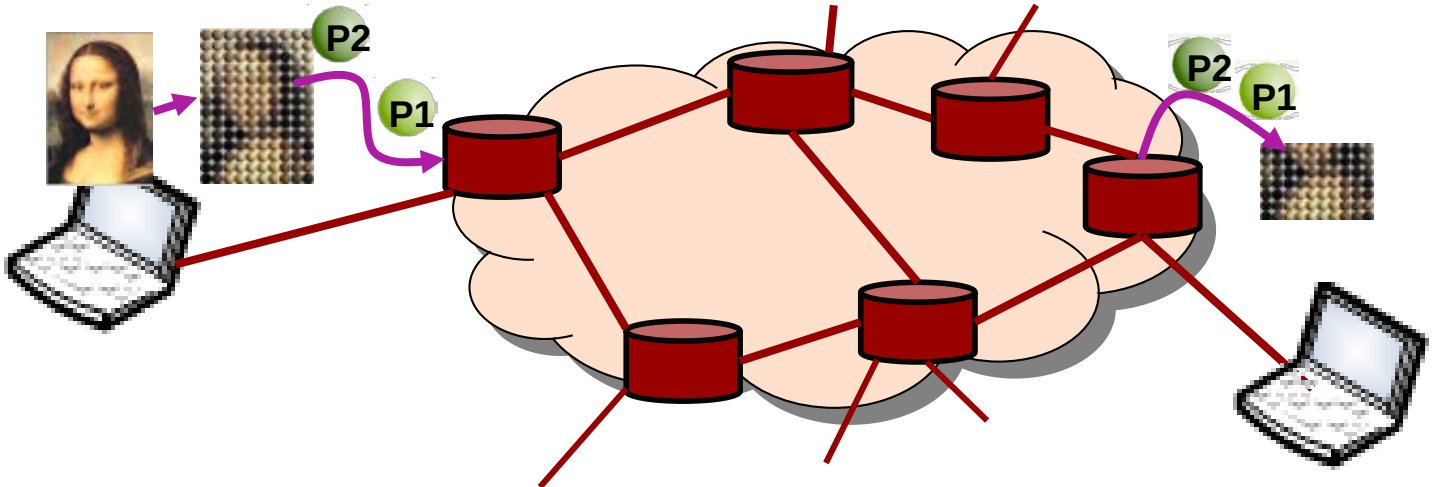
2. Network types - Switching technique

- In a **circuit switching** network there is a dedicated path (**circuit**) between the terminal nodes
- All information follows the same path
- The circuit is established using **signaling**
- Example: Public Switched Telephone Network (PSTN)



2. Network types - Switching technique

- In a packet switching network the messages are spited in smaller pieces called **packets**
- The intermediate nodes (routers) **store and forward** the packages, routing them to the destination
- Once the packages reach their destination, the message is reassembled



2. Network types - Switching technique

- Circuit vs packet switching:

Circuit switching	Packet switching
✔ Convenient for real-time communication services (e.g. voice calls)	✔ More efficient resource sharing
✘ Inefficiency in resource management (dedicated circuits are actually used or not)	✘ It may be inappropriate for real-time services because delays are variable and unpredictable (queue delays)

2. Network types - Switching technique

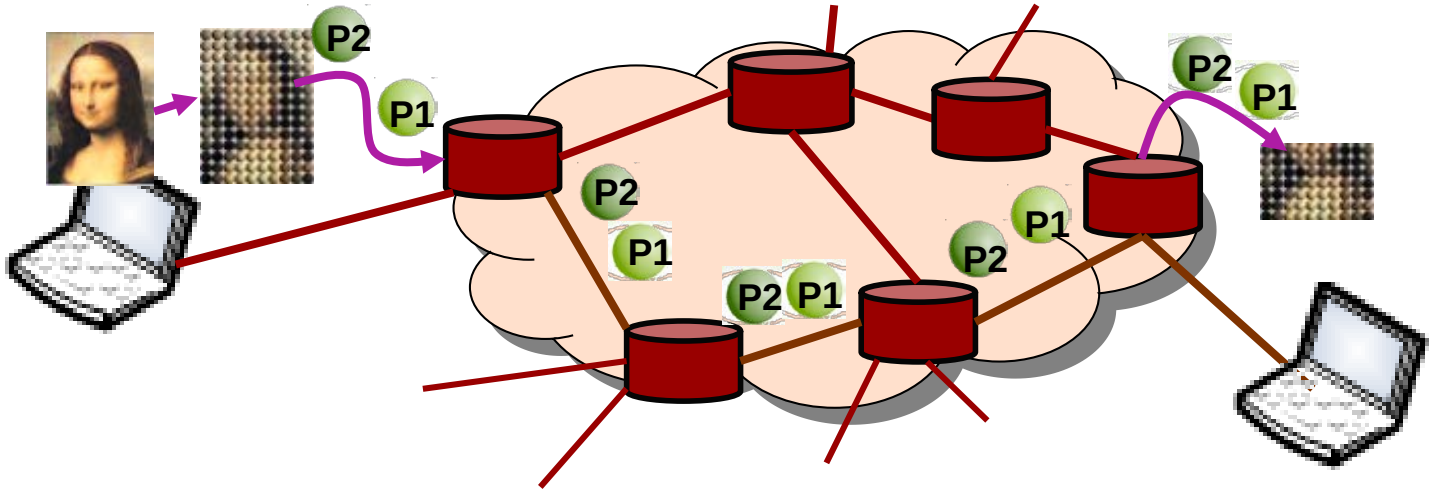
- There are two types of packet switching technique:

1. **Connection-oriented**:
   - Also known as virtual circuit switching
   - For example, X.25, ATM, Frame Relay networks
2. **Connectionless**:
   - Also known as datagram switching
   - Each packet contains the information to reach the destination
   - For example: IP networks, such as the Internet

2. Network types - Switching technique

- There are two types of packet switching networks:

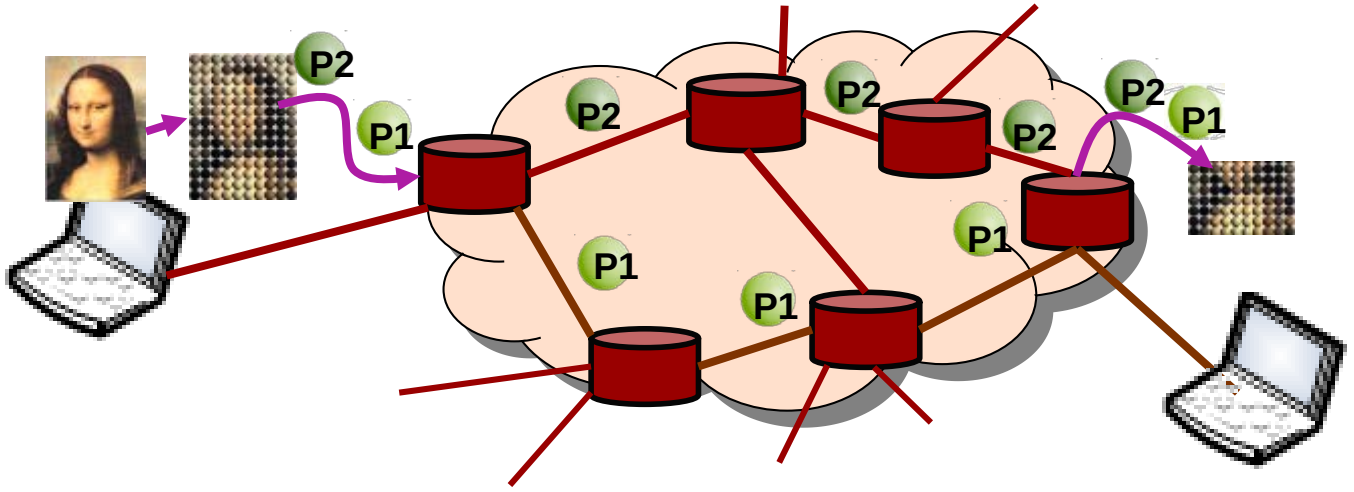
1. **Connection-oriented**:
   - Also known as virtual circuit switching
   - There are three phases in a communication: setup, transfer and release
   - Only setup packets contains source and destination address
   - The route is determined in the setup phase and all packages follow the same path
   - For example: X.25, ATM, Frame Relay



2. Network types - Switching technique

- There are two types of packet switching networks:

2. **Connectionless**:
   - Also known as datagram switching
   - There are no setup nor release phases
   - Each packet contains the information to reach the destination
   - Packages can follow different routes
   - Packages can reach destination unordered or even get lost (*best-effort* network)
   - For example: IP networks, such as the Internet



2. Network types - Switching technique

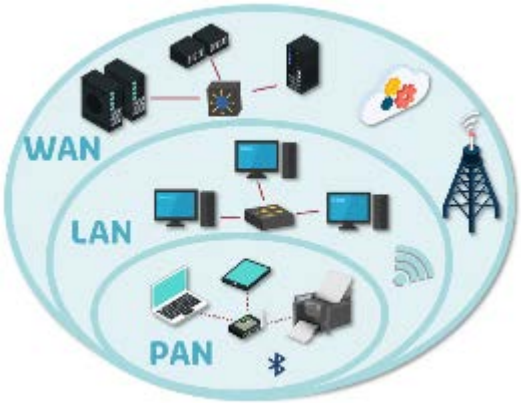
- Connection-oriented vs connectionless:

Connection-oriented	Connectionless
✔ The network provides error control. Since there is a virtual circuit, packets are sent faster (switching can be done even by hardware, for example in ATM)	✔ Very flexible (if a node fails, alternative routes can be found)
✘ Less flexible (if a node fails, all virtual circuits of that node fail)	✘ It may be inappropriate for real-time services because delays are variable and unpredictable.

2. Network types - Size

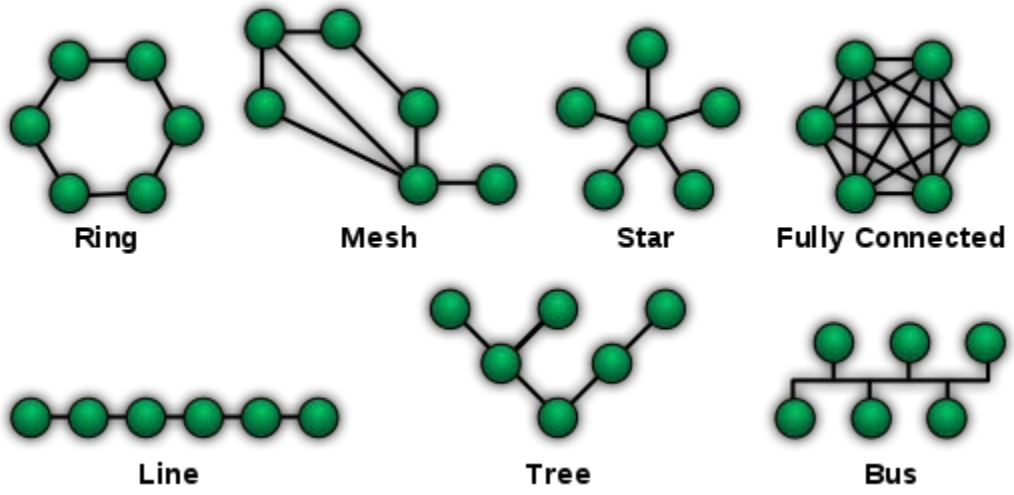
- The most relevant network types depending of its size are:

Network type	Distance	Coverage
Personal Area Network (**PAN**)	10 m	Room, person
Local Area Network (**LAN**)	100 - 1000 m	Home, company
Wide Area Network (**WAN**)	1 - 1000 km	City, country, continent
Internet	10000 km	Planet



2. Network types - Topology

- Network topology is the layout of the connections (links, nodes) of a computer network



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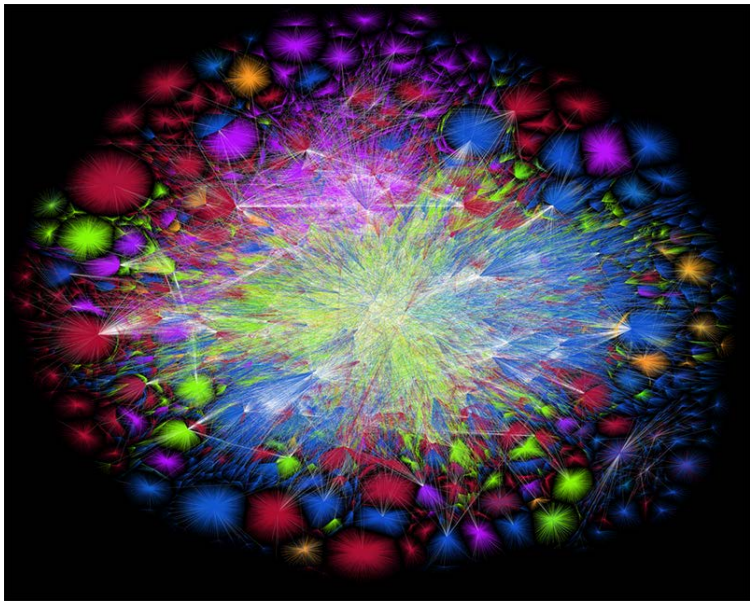
3. Internet - Definition

- The **Internet** is a decentralized global system of interconnected computer networks that use the Internet protocol stack (**TCP/IP**) to connect hosts worldwide
- Internet is based on the network protocol IP (**connectionless packet switching**)



http://www.opte.org/

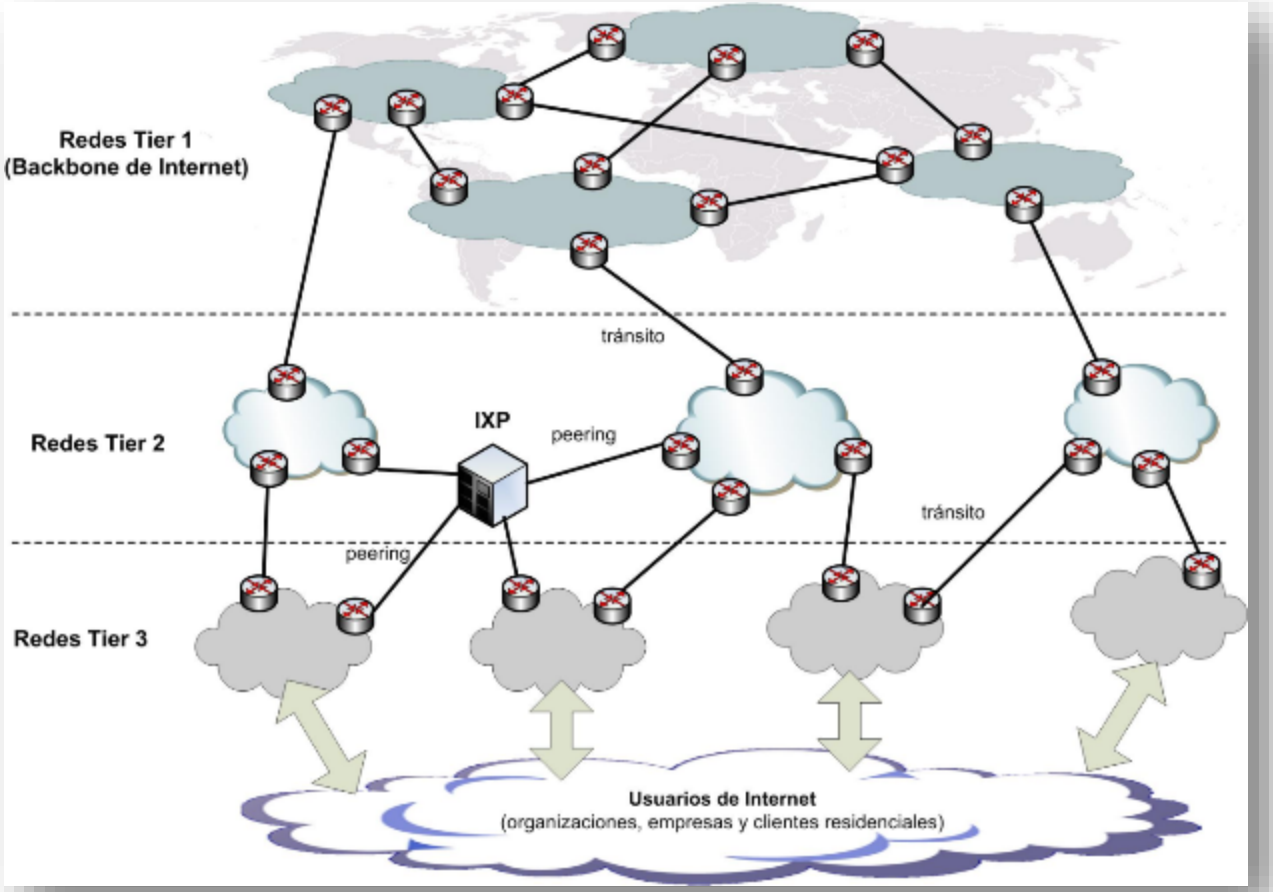
Internet = network of networks

3. Internet - Structure

- Internet is structured in 3 tiers:

Network core

Access network

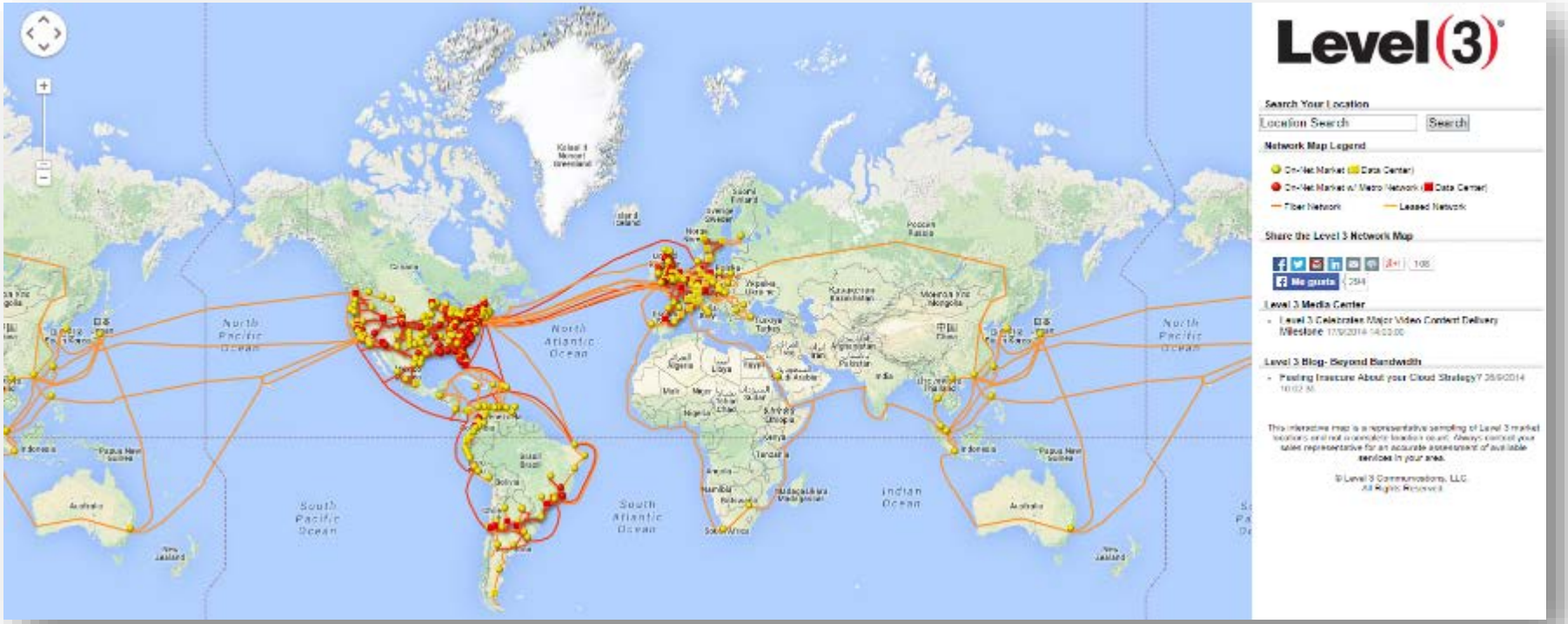


3. Internet - Structure - Tier-1

- The **Internet backbones** (tier-1) networks are composed of a large number of **core routers** (usually between continents and countries)
- Core routers are connected to a large number of tier-2 routers
- The companies that manage tier-1 routers are:
  - Sprint, Verizon, MCI (formerly UUNet / WorldCom), AT&T, NTT, Level3, Qwest and Cable & Wireless

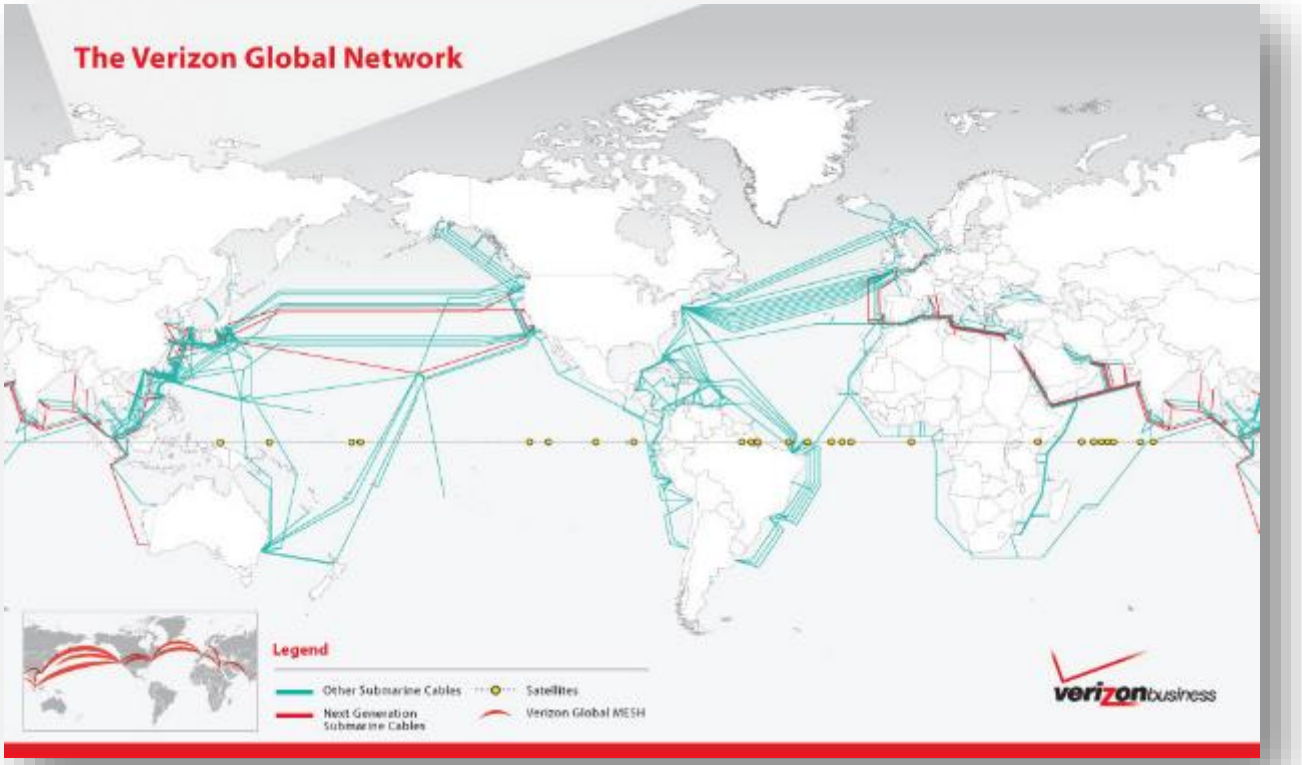
3. Internet - Structure - Tier-1

- Internet backbones (Level3):



3. Internet - Structure - Tier-1

- Internet backbones (Verizon):



3. Internet - Structure - Tier-1

- Internet backbones (Verizon):

3. Internet - Structure - Tier-2

- Tier-2 are regional Internet Service Providers (ISPs) which connects tiers 1 and 3
- Tier-2 providers will exchange Internet traffic through two types of connections:
  - **Transit**: Connection between operators of different tiers. The ISP supplier sells traffic ISP consumer
  - **Peering**: Connection between the same tier. This connection can be public (using an IXP, Internet Exchange Point) or private (using a direct link between ISPs)
- Examples of tier 2 ISPs: British Telecom, SingTel, Cable&Wireless, …

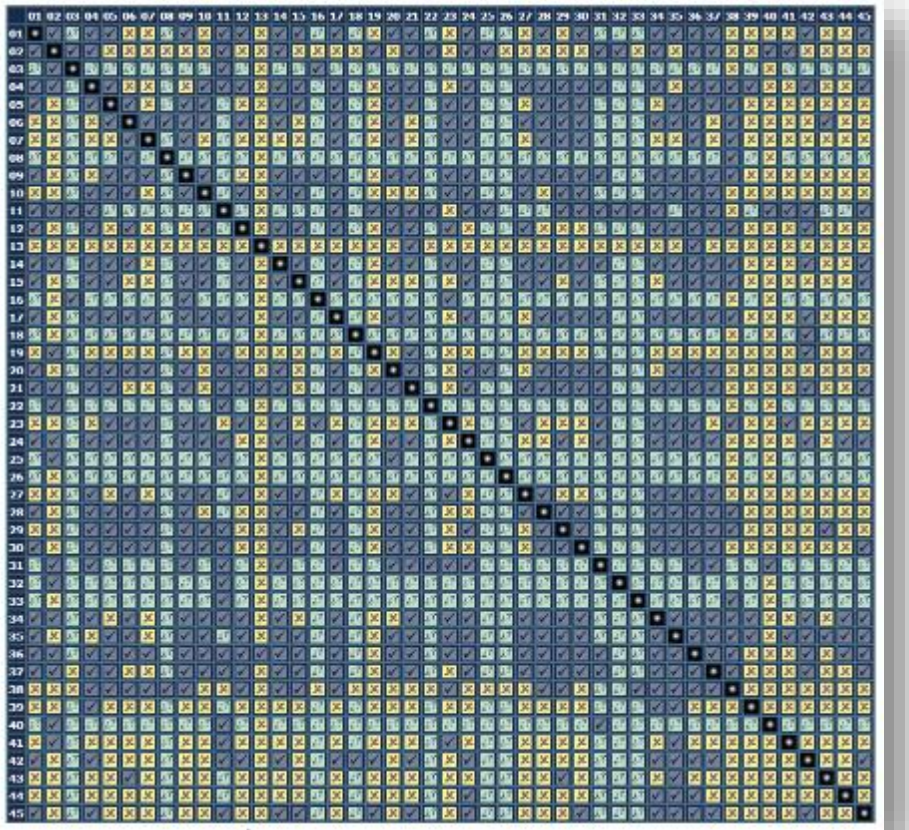
3. Internet - Structure - Tier-2

- An IXP (Internet Exchange Point) is a physical infrastructure that allows different ISPs to exchange traffic
- Map of IXPs: https://www.internetexchangemap.com/
- Spanish IXP examples:
  - ESPANIX (Madrid)
  - CATNIX (Barcelona)
  - NIXVAL-ix (Valencia)

3. Internet - Structure - Tier-2

- ESPANIX peering:

01	Acens AS 16371
02	Adamo AS 35699
03	Akamai AS 20940
04	Arsys AS 20718
05	AT&T GNS AS 2686
06	BT Global Services AS 8903 - AS 5400
07	BT IGS AS 12541
08	Cable & Wireless AS 1273
09	COLT Telecom AS 8220
10	Cogent Communications AS 174
11	Comvive AS 39020
12	Datagrama AS 9019
13	Dinahosting AS 42612
14	Easynet AS 4589
15	Euskaltel AS 12338
16	Flag Telecom AS 15412
17	Fujitsu AS 3324
18	Gas Natural AS 42325
19	Genetsis AS 16168
20	GRN Serveis Telematics AS 20815
21	Ibercom AS 15915
22	Init7 AS 13030
23	Interoute AS 8928
24	Jazztel AS 12715
25	Leaseweb AS 16265
26	Level 3 AS 3356
27	NTT Communications AS 2914
28	Ono AS 12457
29	Ono (Auna) AS 16338
30	Orange AS 12479
31	OVH AS 16276
32	Panther Express AS 36408
33	Produban AS 2134
34	RedIRIS AS 766
35	Relco AS 12359
36	SAREnet AS 3262
37	Servicom2000 AS 9165
38	Telefónica AS 3352
39	Teleglobe AS 6453
40	Teremark AS 23148
41	T-Systems España AS 3257
42	Veloxia AS 28842
43	Verizon AS 702
44	Vodafone AS 12430
45	Ya.com Internet Factory AS 20838



3. Internet - Structure - Tier-3

- Tier-3 ISPs are companies that provide Internet access to final users
- Users are connected to Internet with the so-called **access networks**
- Examples of ISPs in Spain: Movistar, Vodafone, Orange, Yoigo, Ono, Jazztel, Euskaltel, ...
- The main technologies of access networks are:
  - Dial-up access (through the telephone network)
  - Digital Subscriber Line (DSL)
  - Cable Internet access
  - Fiber To The Home (FTTH)
  - Satellite
  - Mobile networks (2.5G / 3G / 4G / 5G)

Wired

Wireless

3. Internet - Net neutrality

- **Net neutrality** (or network neutrality) is the principle that ISPs must treat all Internet communications equally, and not discriminate or charge differently based on user, content, application, equipment, etc.
- This principle is in the Internet since its origins
- It is applied by regulatory entities (governments) and must be met primarily by ISP
- Example of not respecting the principle of net neutrality: in 2008 the North American ISP Comcast reduced the upload speed of applications that used P2P to share files

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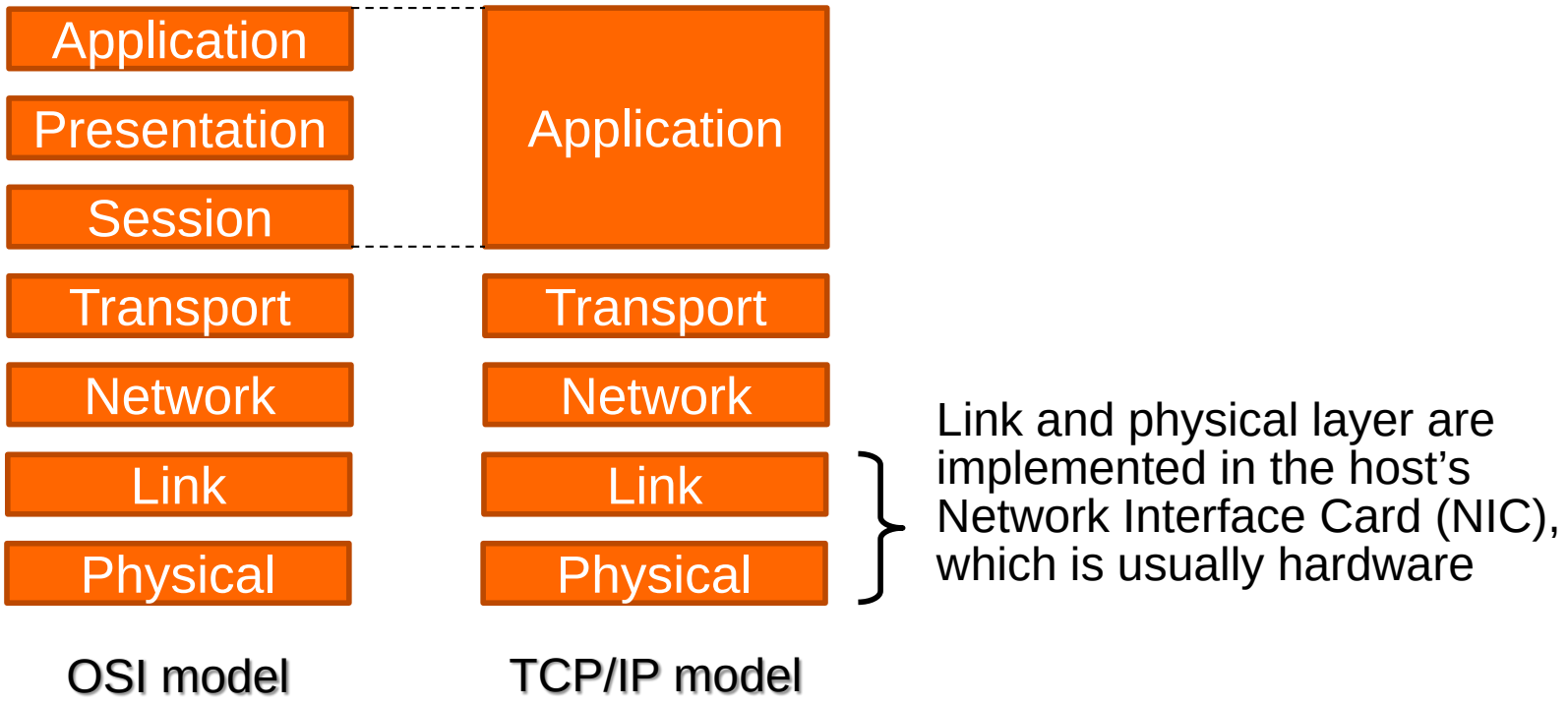
4. Protocol stacks - TCP/IP

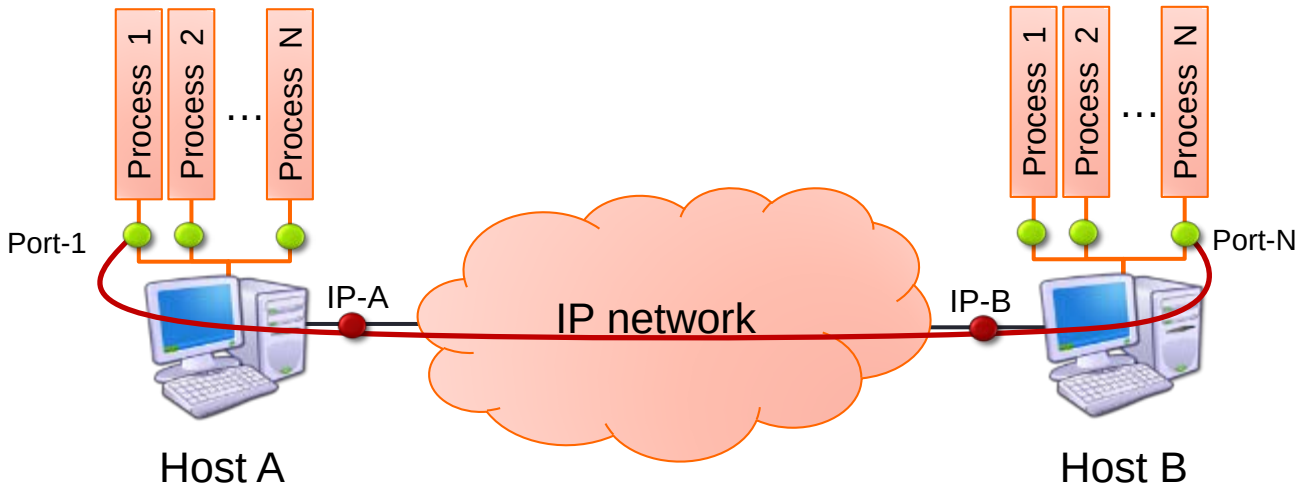
- The TCP/IP protocol stack (also kwon as Internet model) is divided in 5 layers:



4. Protocol stacks - TCP/IP

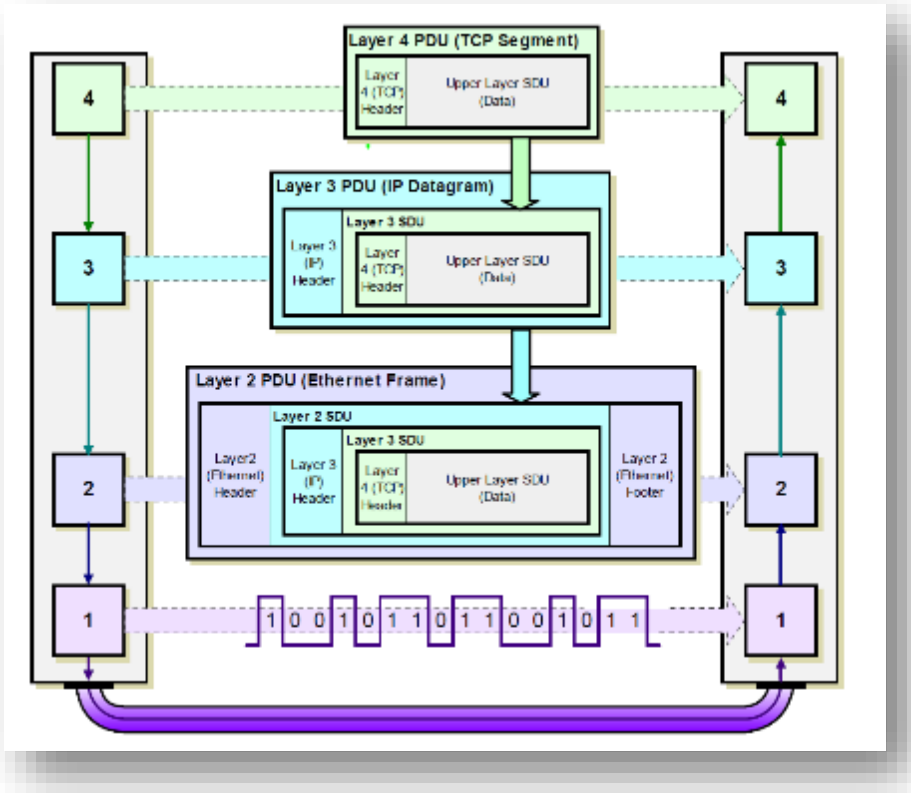
- TCP/IP protocol stack in a nutshell:

Level	Features	PDU	Address
Physical + Link	Communication in the same physical network (segment)	Frame	MAC address
Network	Communication between hosts	Packet	IP address
Transport	Communication between processes	Segment/datagram	Port
Application	Distributed services	Message	-



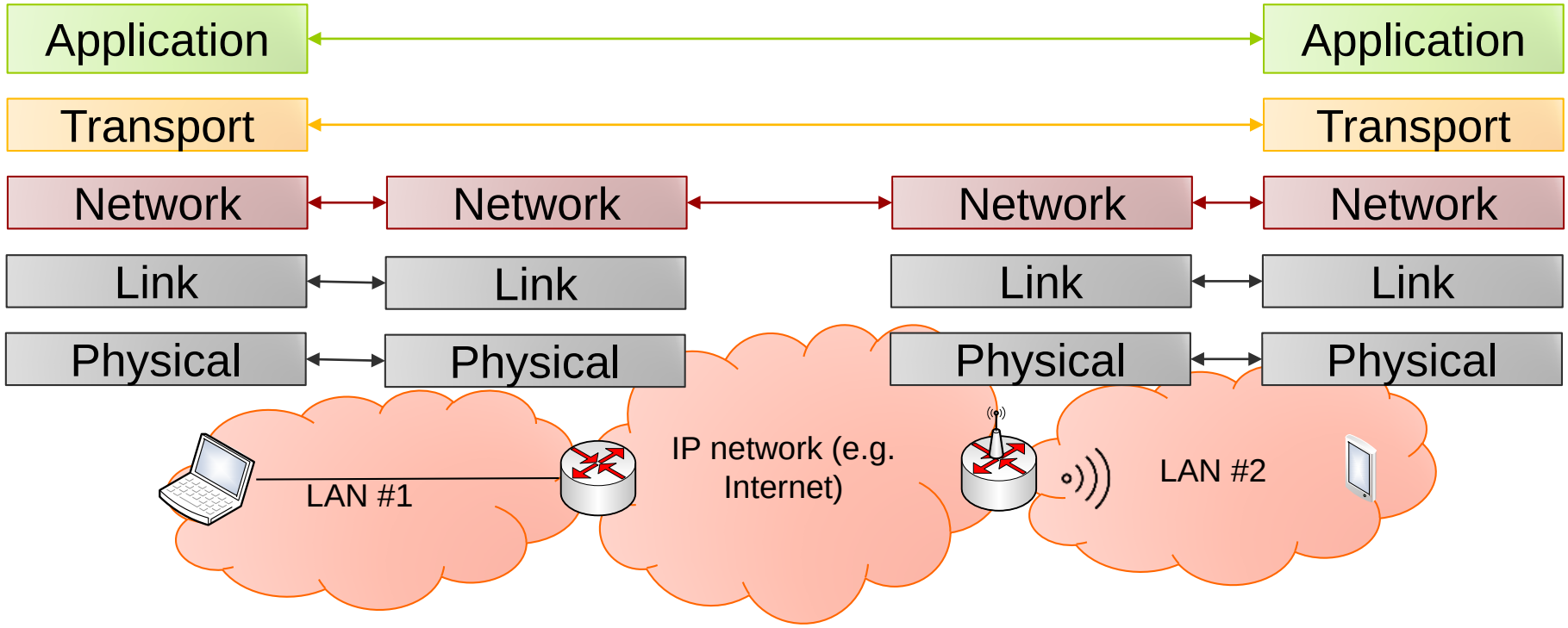
4. Protocol stacks - TCP/IP

- A **PDU** is made up by:
  - **Payload**: Actual data to be transmitted
  - **Header**: Extra data aimed to implement the protocol
- **Encapsulation** is the process in which a PDU becomes the payload of its upper layer PDU



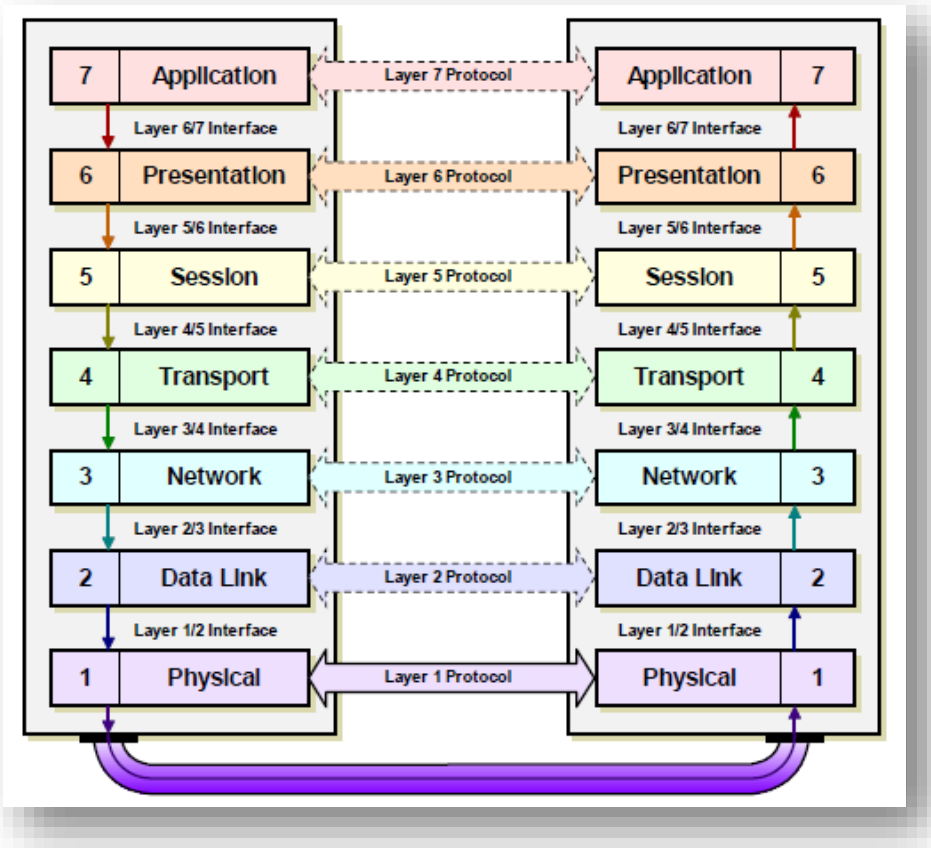
4. Protocol stacks - TCP/IP

- **Hosts** in the TCP/IP model implements the full stack (5 levels)
- Intermediate nodes (**routers**) implements up to network (3 levels)



4. Protocol stacks - OSI

- The **OSI** (Open System Interconnection) protocol stack is a reference model created by the ISO in 1980
- Nowadays few networks implements this model, although it is very valuable as conceptual model
- In the TCP/IP model, the session (temporary relationship) and presentation (encoding and compression) are implemented at application level (if required)



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5. Takeaways

- A **computer network** is a set of devices (e.g. **routers**) and **links** which allows to exchange binary data between computers (**hosts**)
- **Internet** is a **connectionless packet switching** global computer network based on the **TCP/IP** protocol stack
- The TCP/IP reference model is made up by 5 levels: **physical** + **link** (communication in the same network segment), **network** (communication in the whole network), **transport** (end-to-end communication between process), **application** (specific service)