Network & Protocols

TI602

Yessin NEGGAZ

Content

- Introduction to networks
- OSI architecture model
- Layers and thier functions
- Interconnection
- TCP/IP network protocols

Organization

- 7 CM - 1h30
- 6 TD - 1h30
- 3 TP - 3h30
- Evaluation : Writen exam + labs

Learning outcoms

At the end of this course the student will be able to:

- Explain how networking components work and how they can be put together to implement a system
- Explain and critically evaluate layered protocols (including OSI and TCP/IP), LAN and WAN standards, hardware and software components.
- Critically compare and evaluate LAN and WAN technology and architectures
- Design, implement and investigate networks using appropriate simulation software, internetworking tools and technology in multi-protocol environments

References

- Guy Pujolle - **Les réseaux**. - Eyrolles.
- **Cours Cicso CCNA1** – Cisco
- Richard Stevens - **TCP/IP illustré** - volume 1, Addison Wesley
- A. Tanenbaum "**Réseaux**", 5ème édition, Pearson Education, 2003

- To go further:
  - Gérard Mourier - **Guide des réseaux locaux** - Marabout
  - Mammeri - **Réseaux Locaux Industriels** - Eyrolles
  - Maurice Gagnaire - **Réseaux Hauts Débits ATM et RLI** – Interedition
  - J.K. Kurose, K.W. Ross : "**Computer Networking**", 4th edition, Addison-Wesley, 2007 et « **Analyse structurée des réseaux** », 2ème édition, Pearson Education, 2003
  - L.L. Peterson, B.S. Davie "**Computer Networks**", 4th edition, Elsevier, 2007
  - D. Dromard, D. Seret « **Architecture des réseaux**", Pearson Education, 2006
  - Cours CentralWeb, 2000
  - **Cours Cicso CCNA2,3,4** - Cisco.

What is a communication network ?

- **Definition :**
  - A communication network can be defined as the set of hardware and software resources related to the transmission and exchange of information between different entities.

- **Example :**
  - Internet
  - Mobile network
  - Drone fleets
  - Classical telephony network
  - Vehicular networks
  - Internet of Things
  - Etc.

What is a communication network ?

- Communication networks can be classified according to:
  - The type of information transported
  - The nature of the entities involved

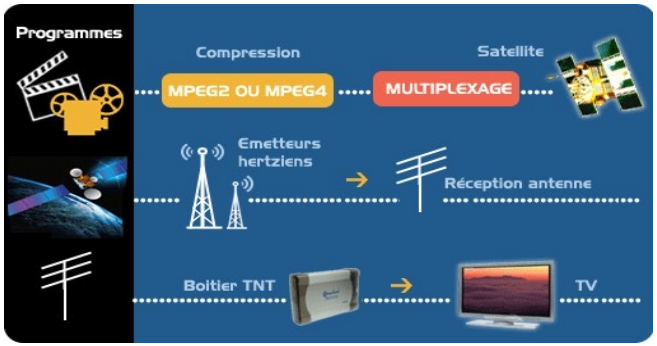
- There are three main categories of networks:
  - Telecommunications networks
  - Computer/computing networks
  - Broadcast networks

Telecommunication network

- These are the oldest communications networks
- Their purpose is to convey communications between individuals
- The raw information can be sent in the form of electromagnetic waves, this is called analog voice communication, or in the form of a series of binary information (‘0’ or ‘1’) after undergoing a processing called digitization

- Example : Public Switched Telephone Network, GSM mobile networks

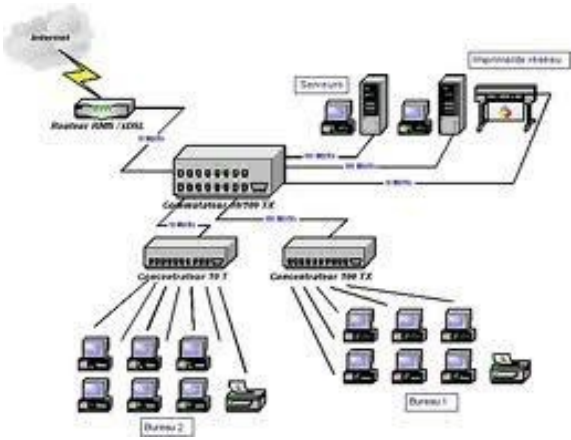
Broadcast networks



- More recent, it is used to broadcast television channels between studios and individuals. There are terrestrial wired distribution networks, wireless and satellite networks
- Notes:
  - One of the peculiarities of terrestrial networks is that they are operated in several cities in analog and not in digital
  - The digital migration started in 2009
  - Migration completed in Nov. 2011
  - the European Union has set a total shutdown of analogue broadcasts in Europe on January 1, 2012
  - TNT uses digital technology

Computer / computing Networks

- It is intended to connect computers (servers, terminals, printers, etc.)
- Exchange of binary data resulting from computer applications or processes such as video streaming, databases, Internet pages, resources sharing (printers, hard disks, etc.).
- Example: Internet, local networks, cloud, ETEBAC electronic banking network, sensor networks, Internet of Things, 5G, etc.



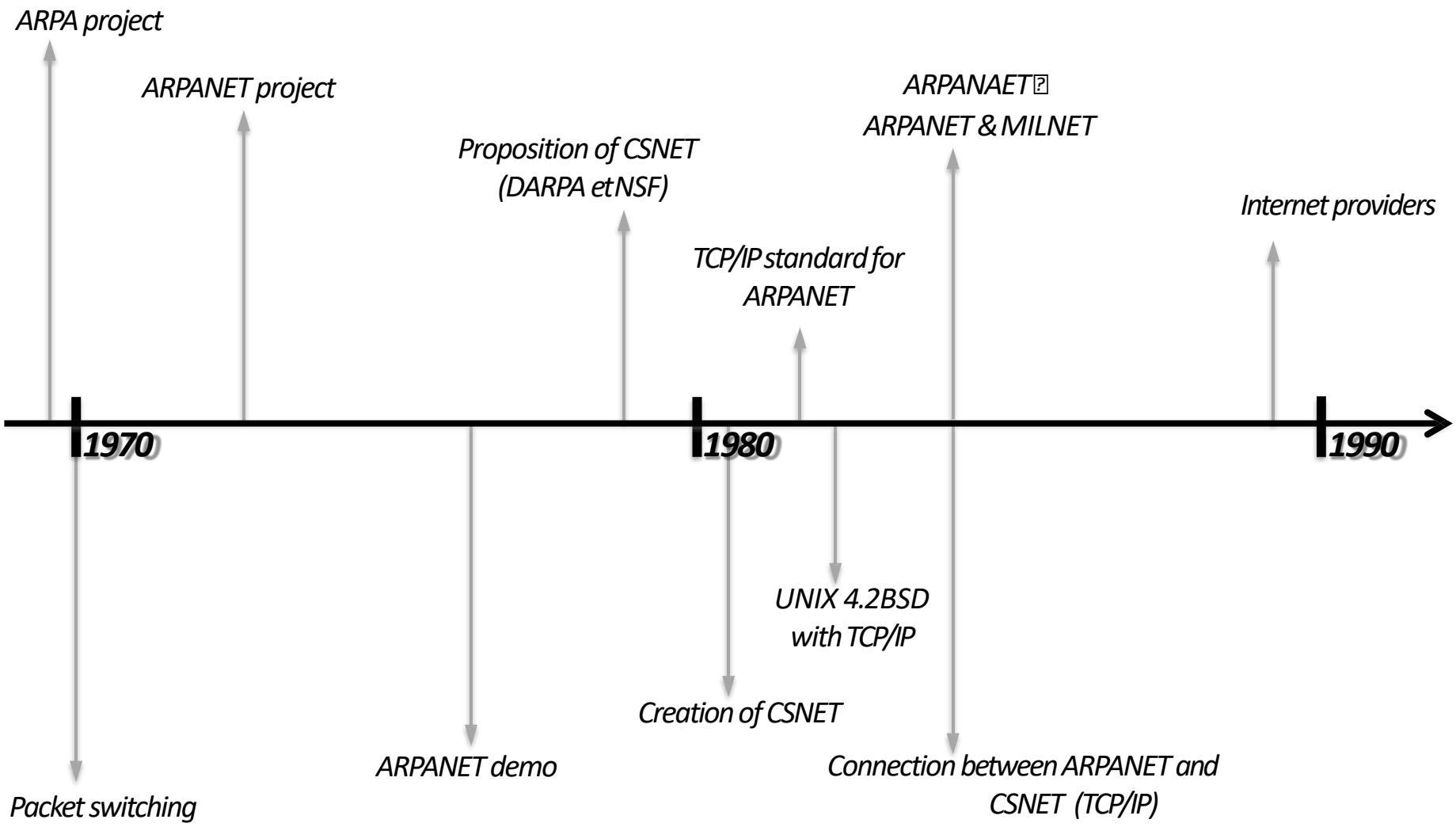
Quick Historique Internet

- February 7, 1958, creation of the ARPA (Advanced Research Projects Agency)

- 1969 development of the first packet transfer network or ARPANET (Advanced Research Projects Agency Network):
  - packet switching
  - point-to-point links
  - radio and satellite links

- Awareness of the authorities of the need for an interconnection network
- Mid-1970s: start of ARPA work on "internet technology"
- 1977-1979: emergence of the current form of TCP/IP internet protocols and architecture

Quick Historique Internet

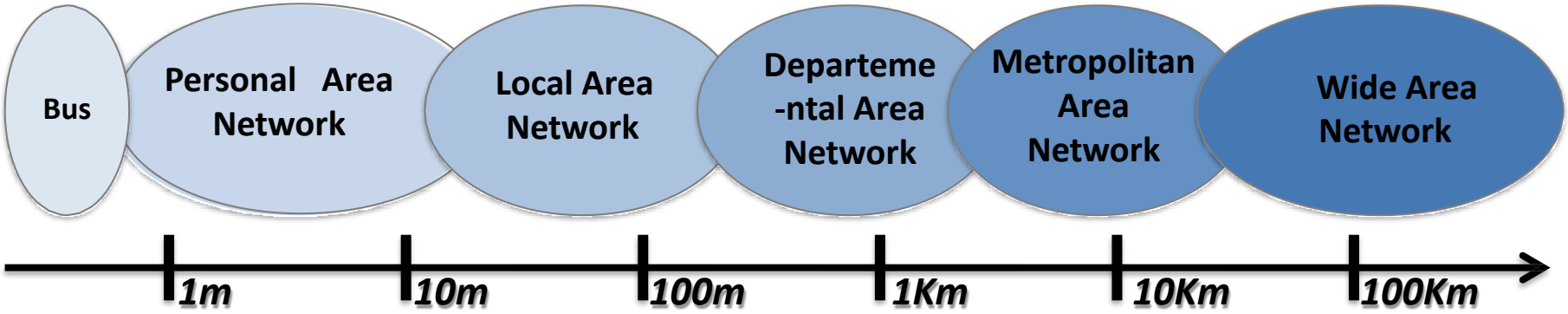


Network Classification

- Depending on their organization, or architecture, distances, transmission speeds and the nature of the information transmitted, networks are subject to a number of specifications and standards.

Network Classification : size

- **Network size**
  - Bus network — ISA, MCA, PCI
  - Personal Area Network (PAN) — Bluetooth, infrared, ZigBee
  - Local Area Network (LAN) — Ethernet, Token Ring, ATM
  - Departemental Area Network (DAN) — Fast Ethernet, Fast Token Ring, ATM
  - Metropolitan Area Network (MAN) — Metro Ethernet
  - Wide Area Network (WAN) — RTCP, RNIS, Internet, Frame Relay, ATM, Metro Ethernet



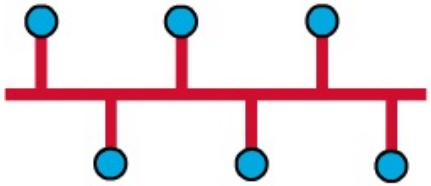
Network Classification : topology

Network topology: a communication network is made up of terminals, nodes and links

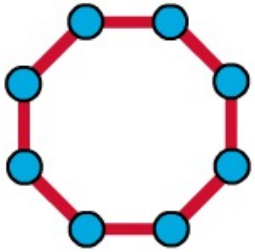
- Physical topology: describes how the different nodes are linked together
- Logical topology: describes how information is transmitted from one node to another

  - Bus
  - Star
  - Tree
  - Rings
  - Meshed

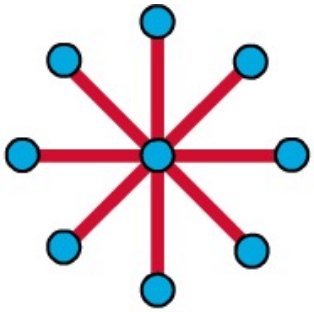
Network Classification : topology



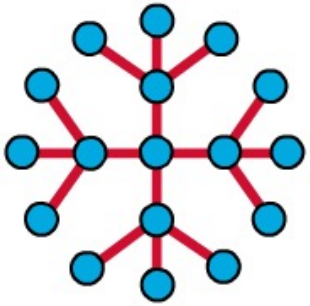
Bus topology



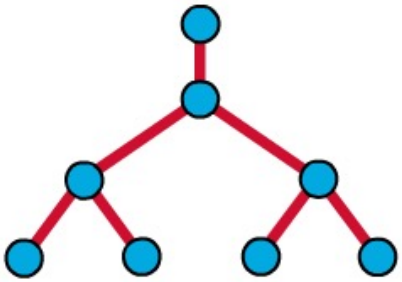
Ring topology



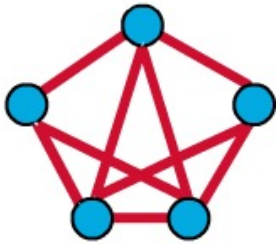
Star topology



Extended star topology



Hierarchy/tree topology



Mesh topology

Network Classification : connection mode

- Whatever the physical or logical architecture of a network, there are 2 different operating modes for computer terminals when transferring information:
  - Connected mode
  - Non-connected mode

Connected mode

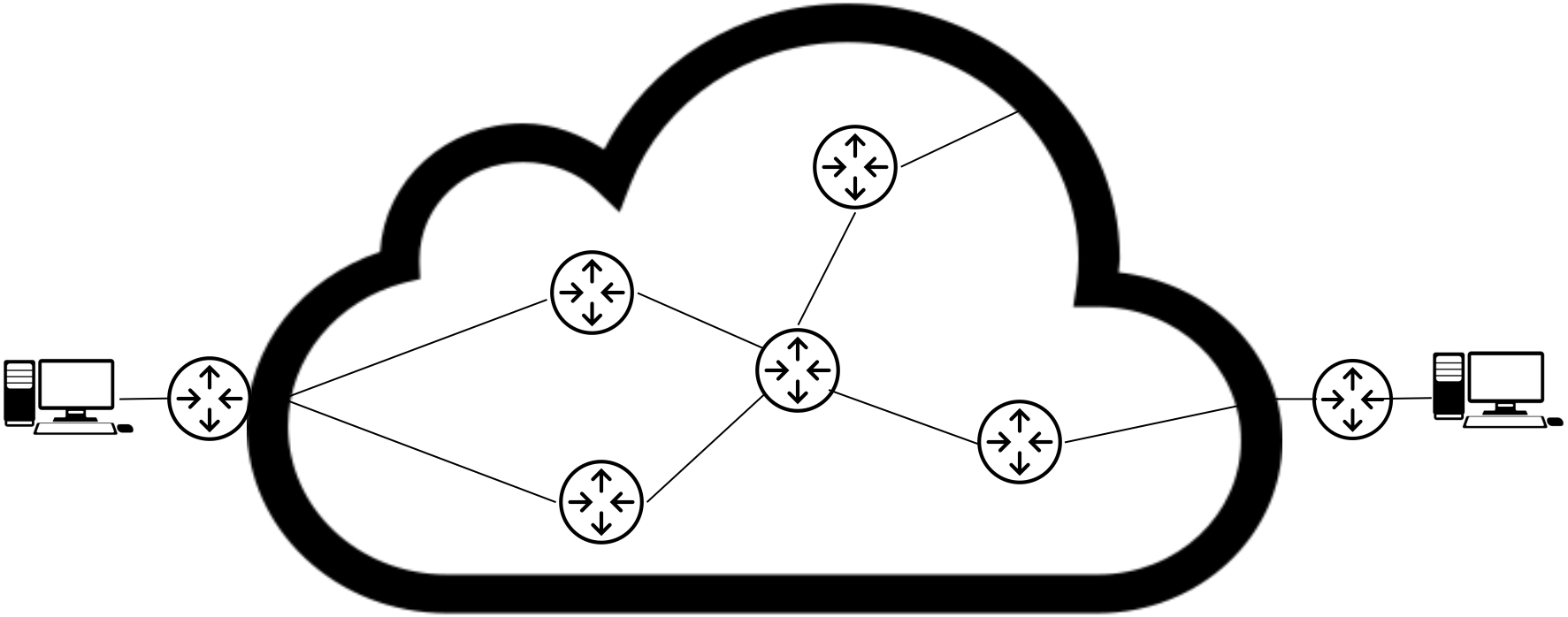
- Identical to the operating principle of the telephone: any communication between 2 network entities (A and B for example) follows the following process in 3 phases:

1. **Establishing the connection**
   - A requests a connection with B by sending a special message (packet call)
   - The call packet traces a path between A and B in the network
   - B confirms or not the connection with another special message (acknowledgment packet)

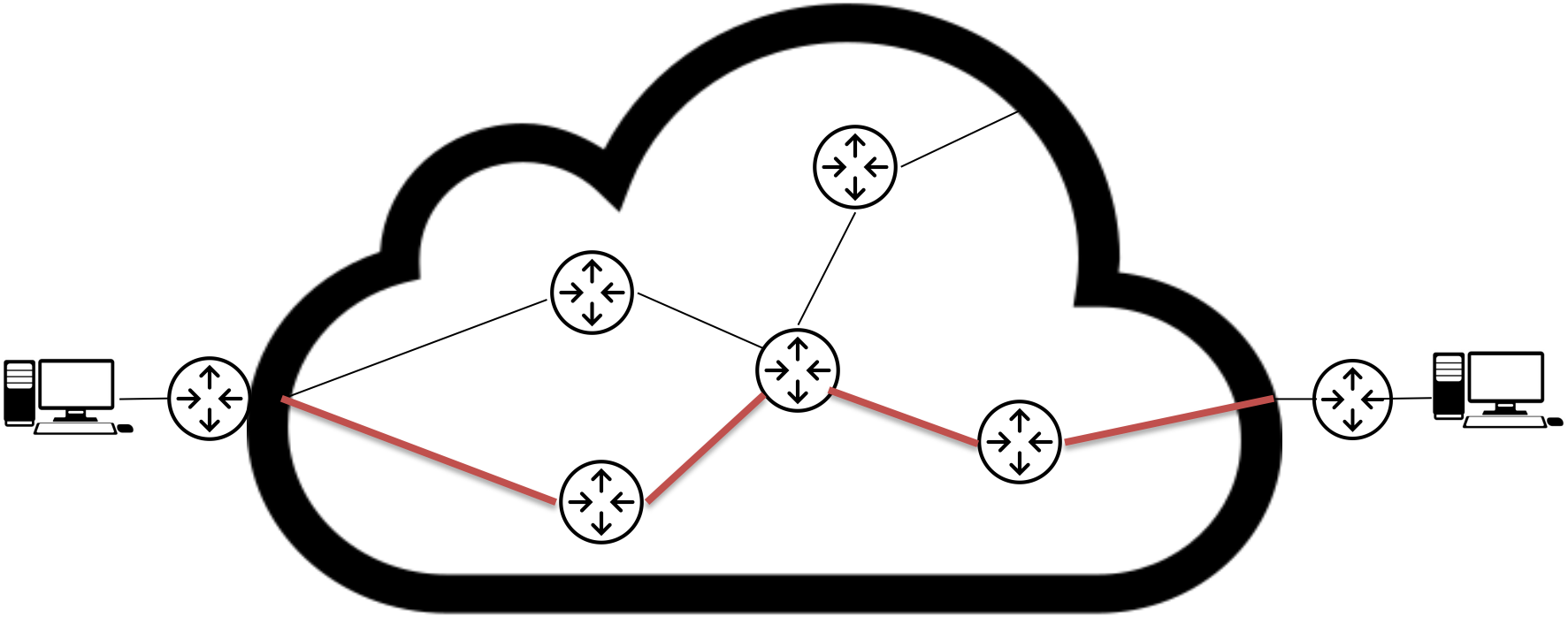
2. **Data transfer**
   - All packets in the message are sent to B following the same path in the network
   - The message packets contain the circuit number and no longer the address of B

3. **Releasing the connection**
   - a circuit release packet is sent at the initiative of A or B

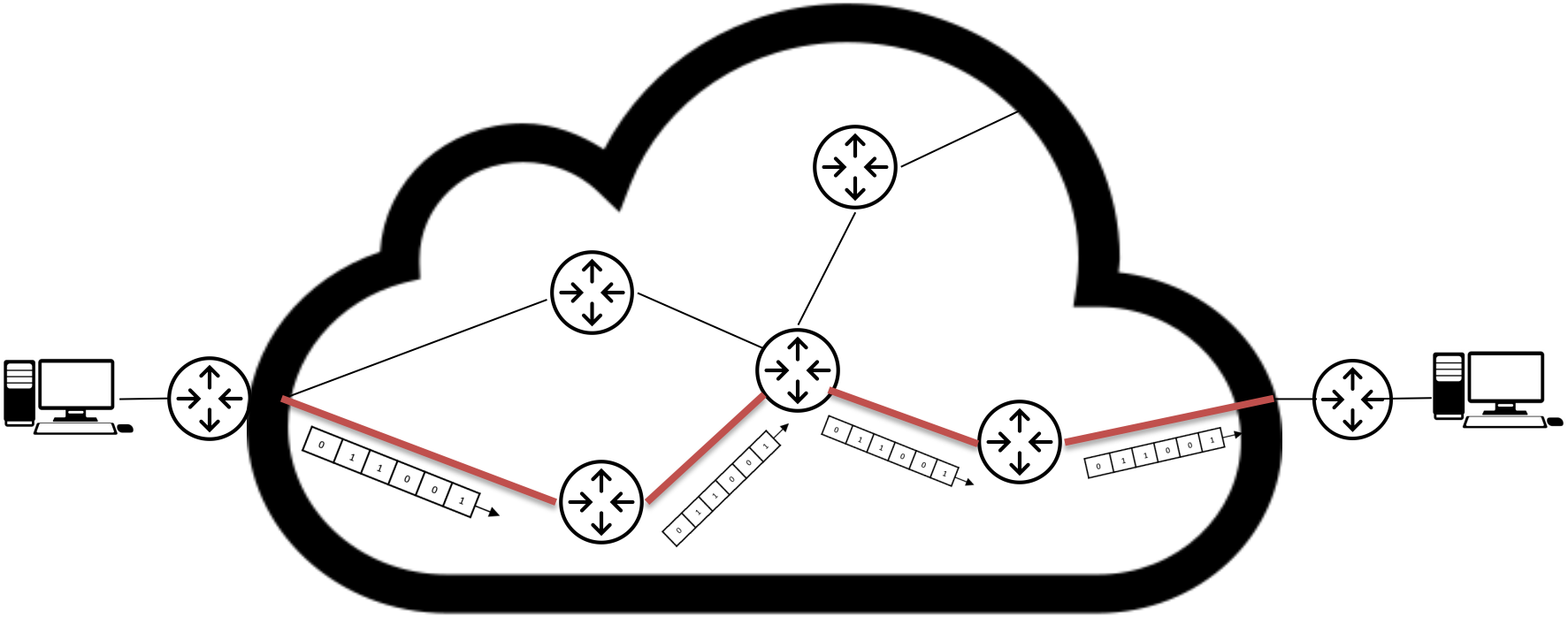
Connected mode



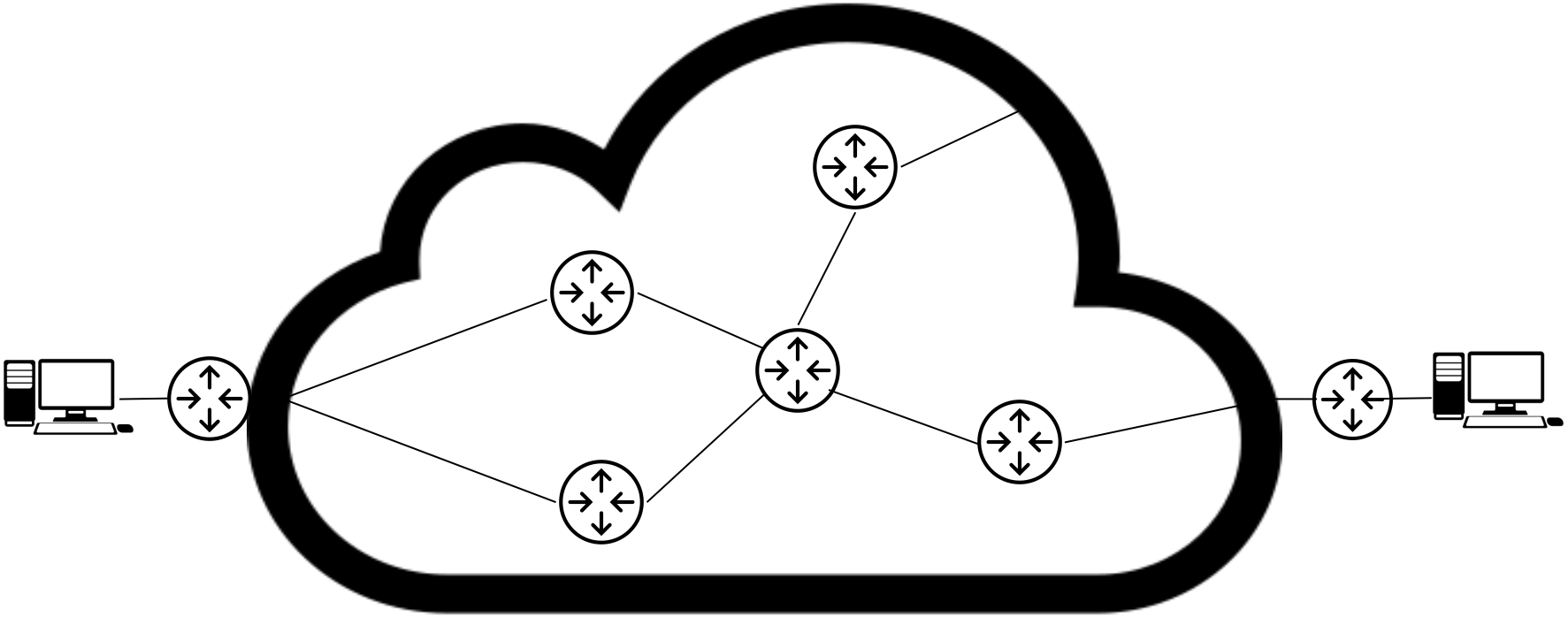
Connected mode



Connected mode



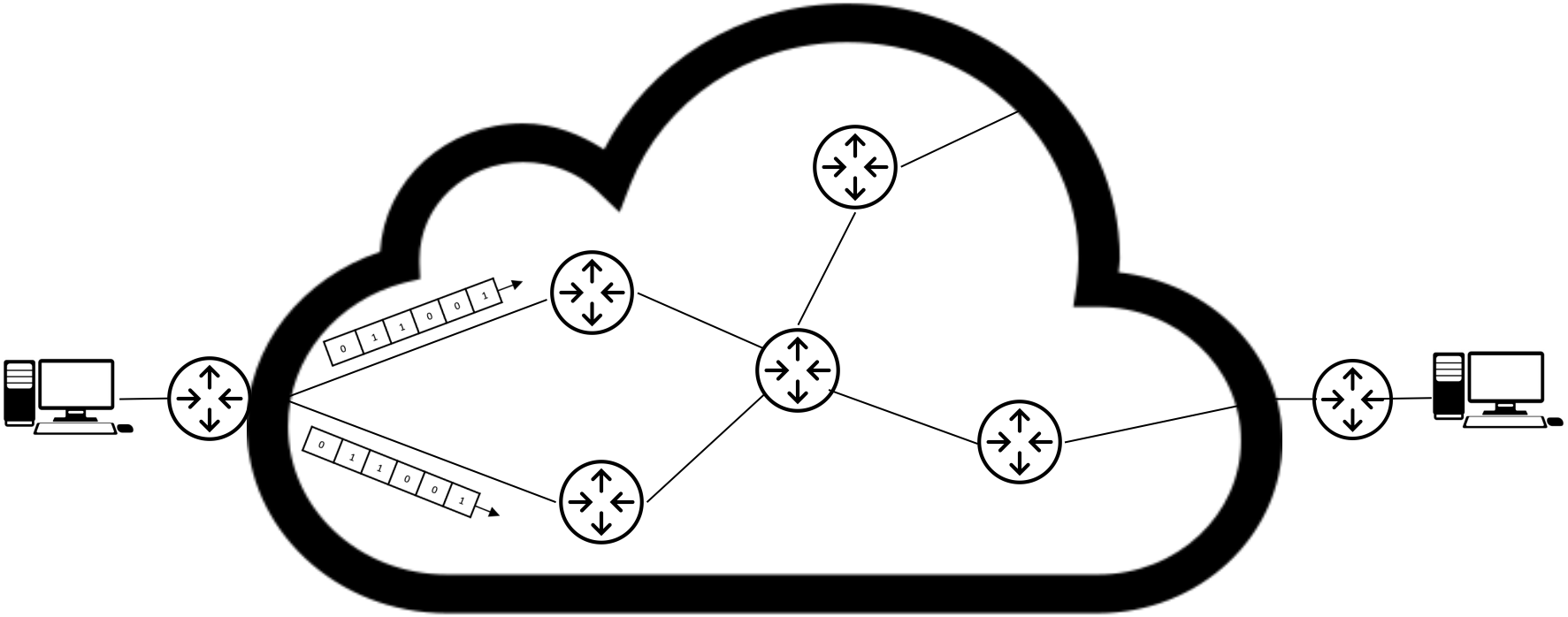
Connected mode



Non-connected mode

- Identical to the operating principle of postal mail
- Network application :
  - A sends to B the different messages (or packets of his message) with the destination address B without prior request for connection (no virtual circuit between A and B)
  - It is up to the network equipments to route these packets individually on paths that may be different, and by timing them if necessary
- Example: Internet, local networks

Non-connected mode



Connection mode: comparison

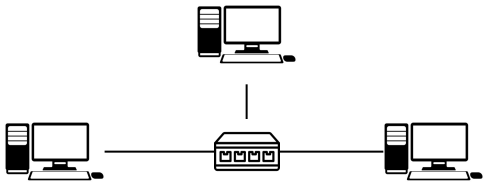
- Connected mode:
  - ☺ Security
  - ☺ Advance negotiation of communications parameters (speed, quality, etc.)
  - ☹ Long connection time
  - ☹ Multipoint not easy to set up

- Non connected mode:
  - ☺ Simplicity
  - ☺ Efficiency
  - ☺ Robustness to network failures
  - ☹ De-sequencing of incoming packets
  - ☹ Network buffer memory
  - ☹ Less negotiated quality

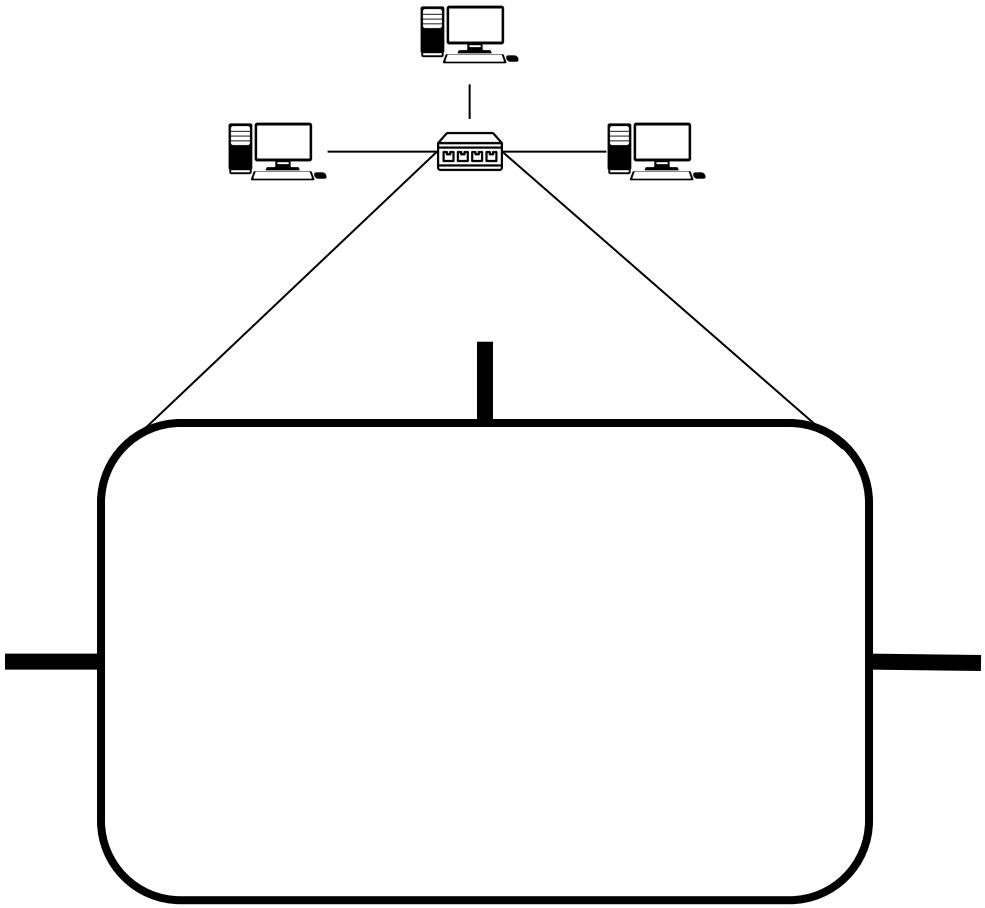
Network Classification : Switching techniques

- We are interested in the network nodes operation mode
- Switching: technique used by nodes in the network to route (direct) messages from the sender to the receiver
- There are several variants, example:
  - circuit switching
  - messages switching
  - packet switching

Network Classification : Switching techniques

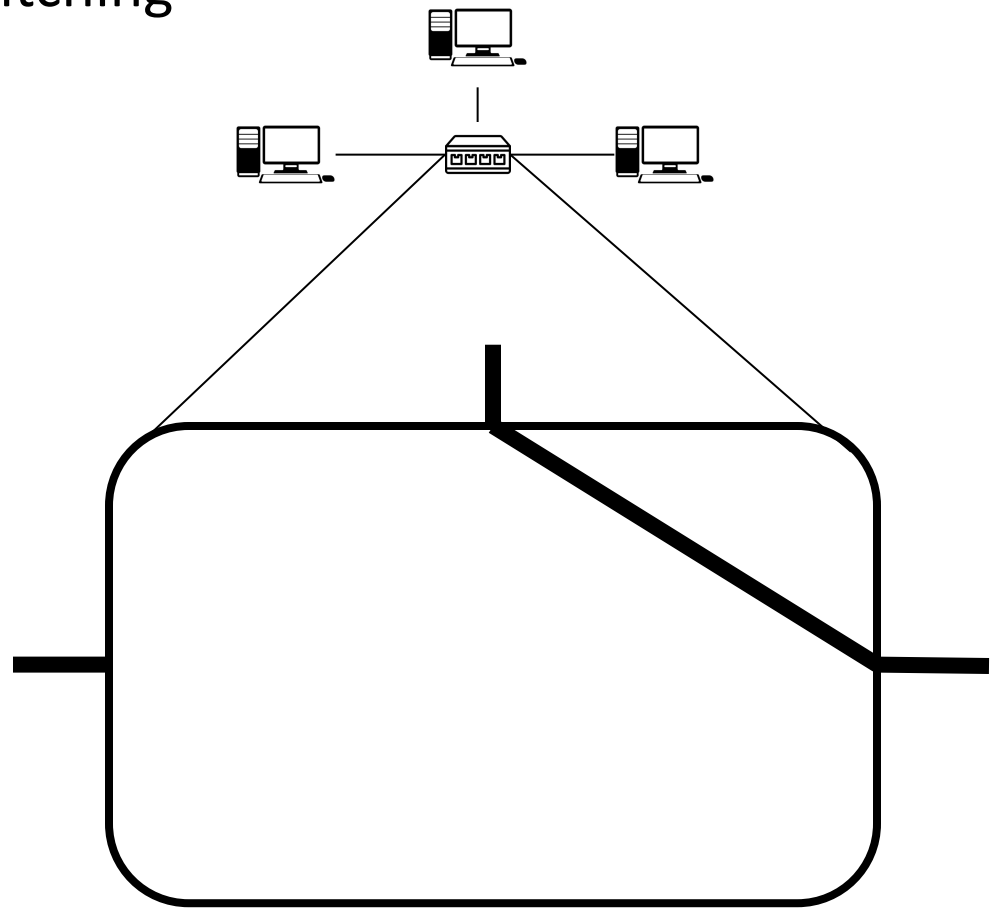


Network Classification : Switching techniques



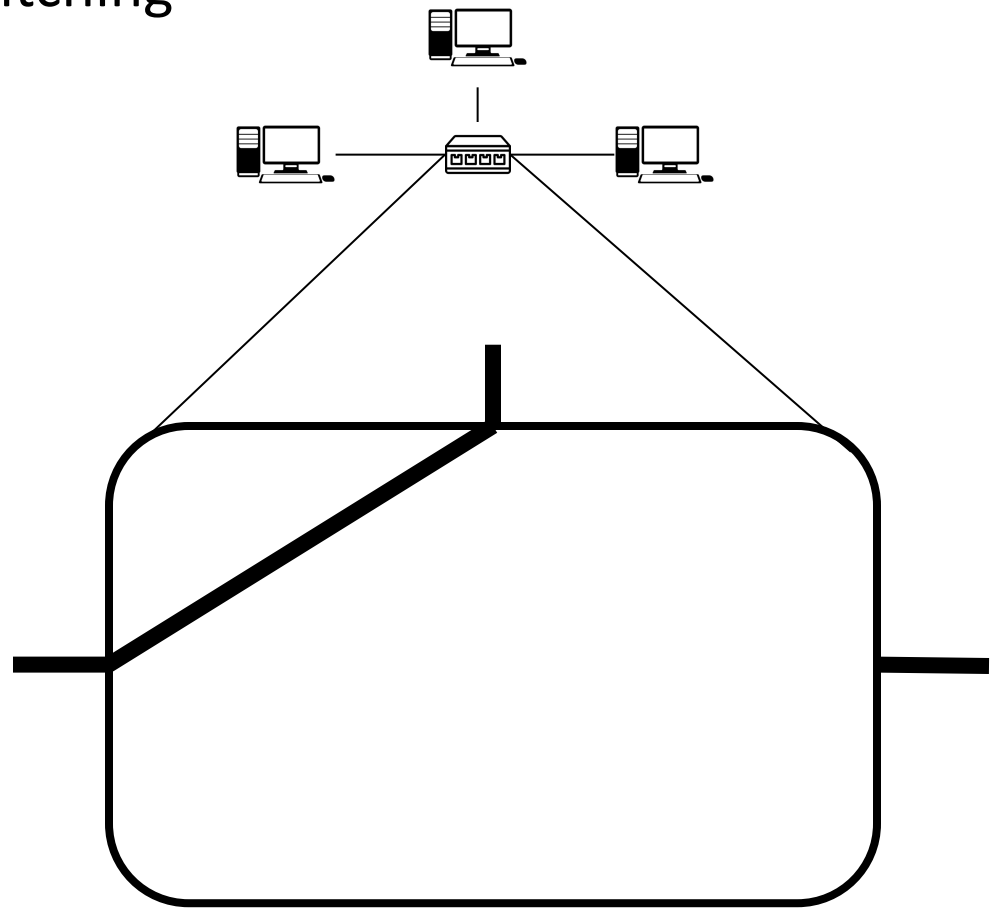
Network Classification : Switching techniques

- circuit switching



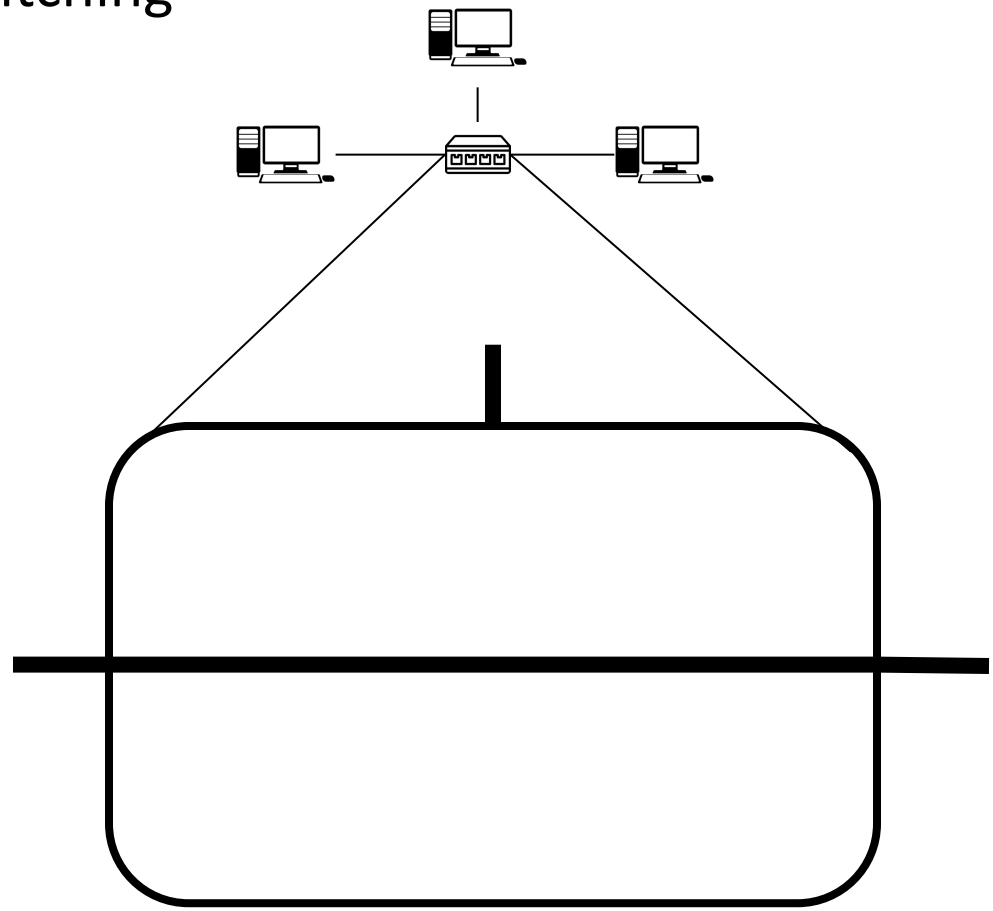
Network Classification : Switching techniques

- circuit switching



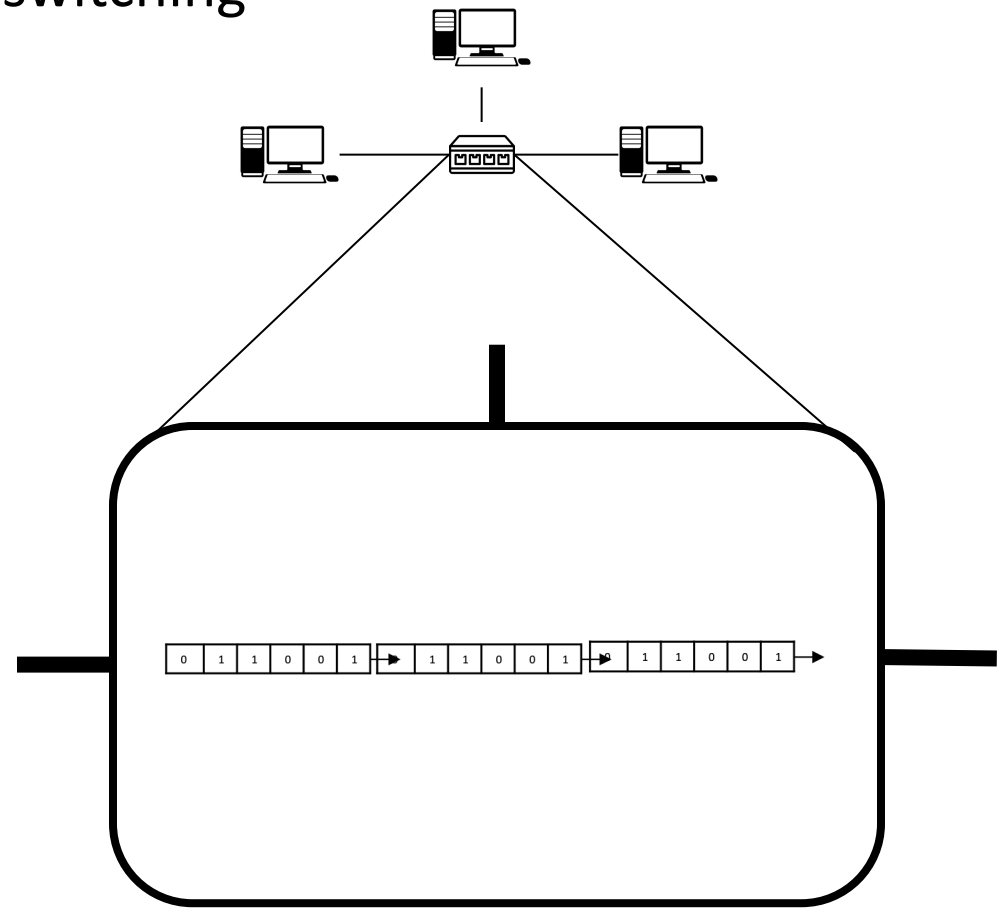
Network Classification : Switching techniques

- circuit switching



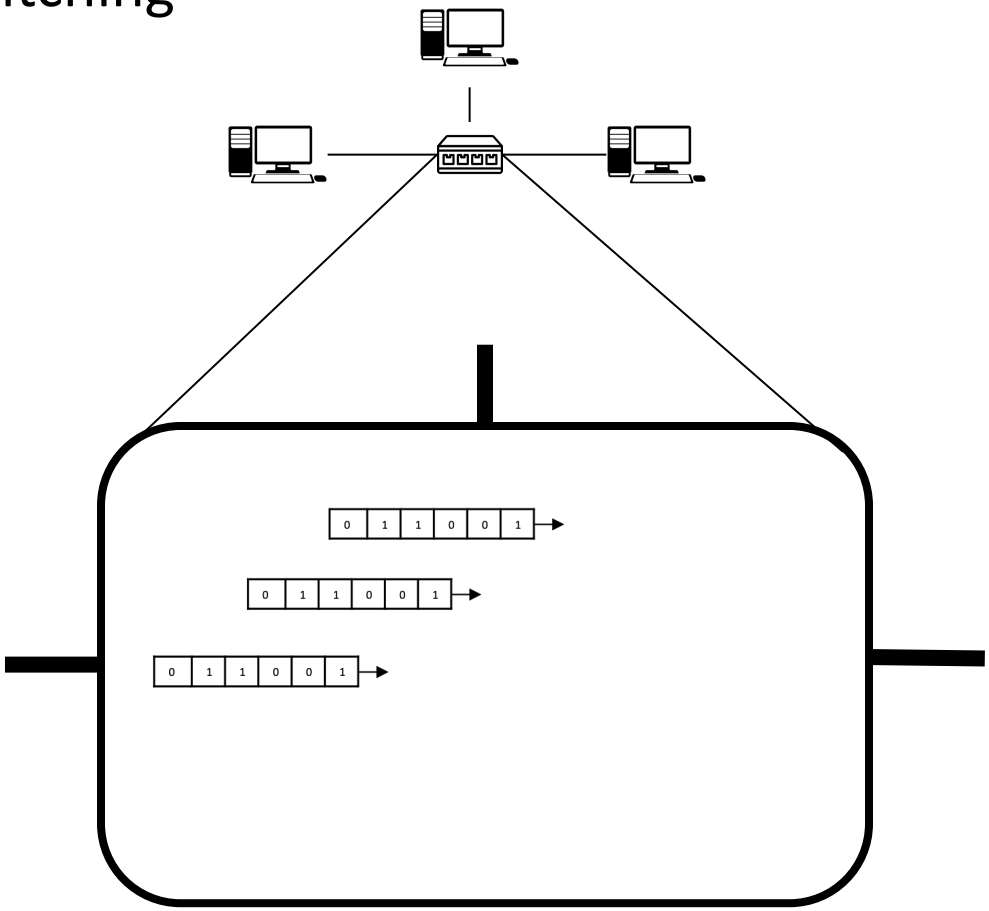
Network Classification : Switching techniques

- Message switching



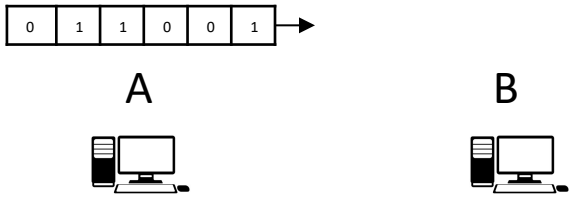
Network Classification : Switching techniques

- Packet switching



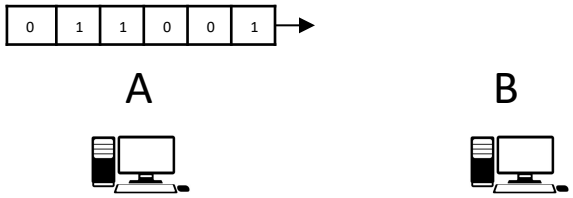
A Network as a System

A Network as a System



Goal : send an application information from A to B

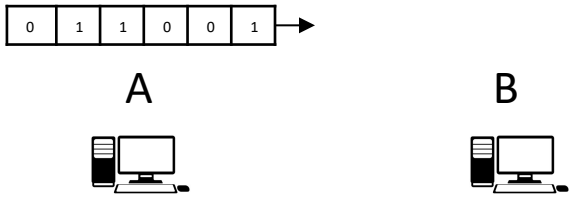
A Network as a System



Goal : send an application information from A to B

What do we need as functionality ?

A Network as a System

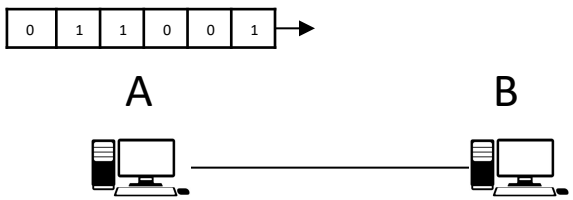


Goal : send an application information from A to B

What do we need as functionality ?

1. A mean to send signals - physical medium

A Network as a System

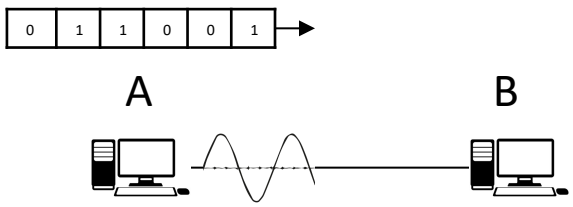


Goal : send an application information from A to B

What do we need as functionality ?

1. A mean to send signals - physical medium

A Network as a System

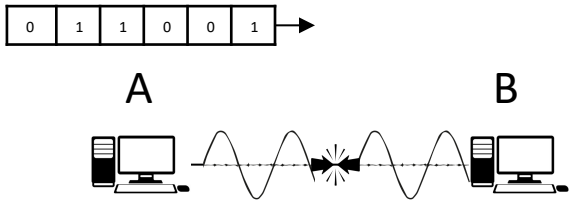


Goal : send an application information from A to B

What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal - encoding

A Network as a System

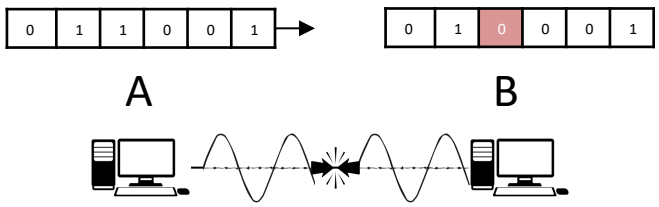


Goal : send an application information from A to B

What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control

A Network as a System

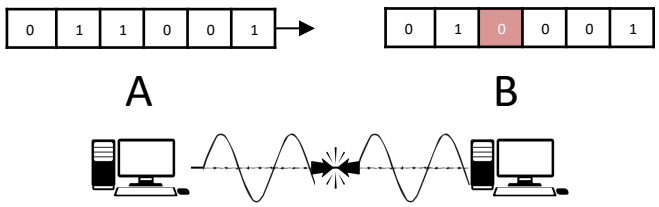


Goal : send an application information from A to B

What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control

A Network as a System

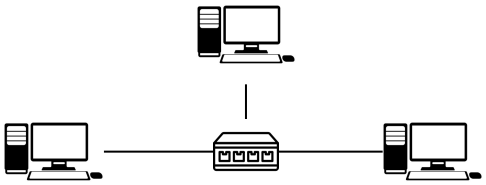


Goal : send an application information from A to B

What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching

A Network as a System

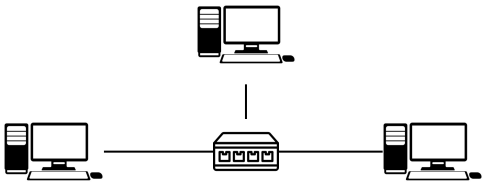


Goal : send an application information from A to B

What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching

A Network as a System

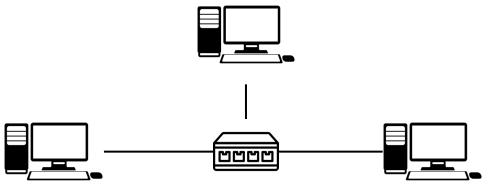


Goal : send an application information from A to B

What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress

A Network as a System

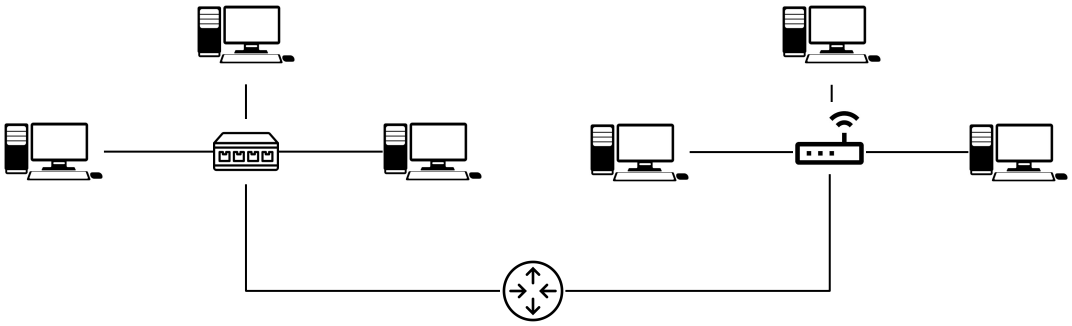


Goal : send an application information from A to B

What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress

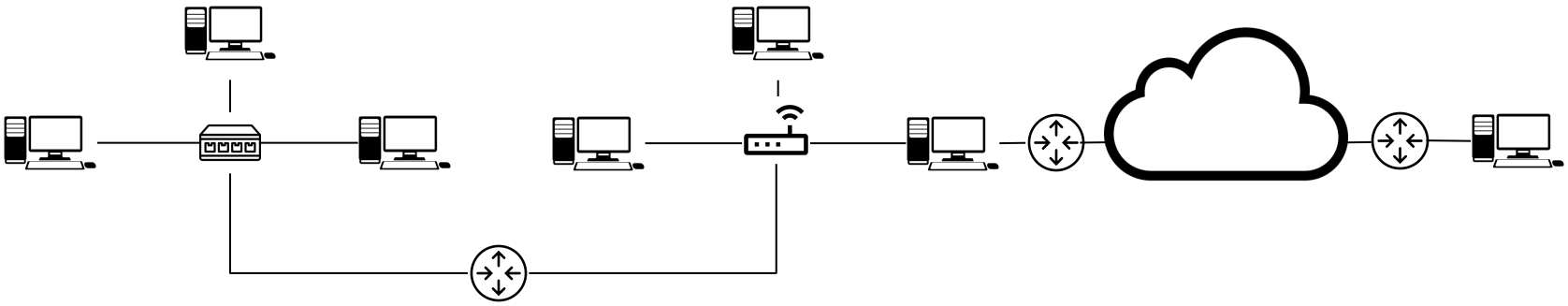
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress

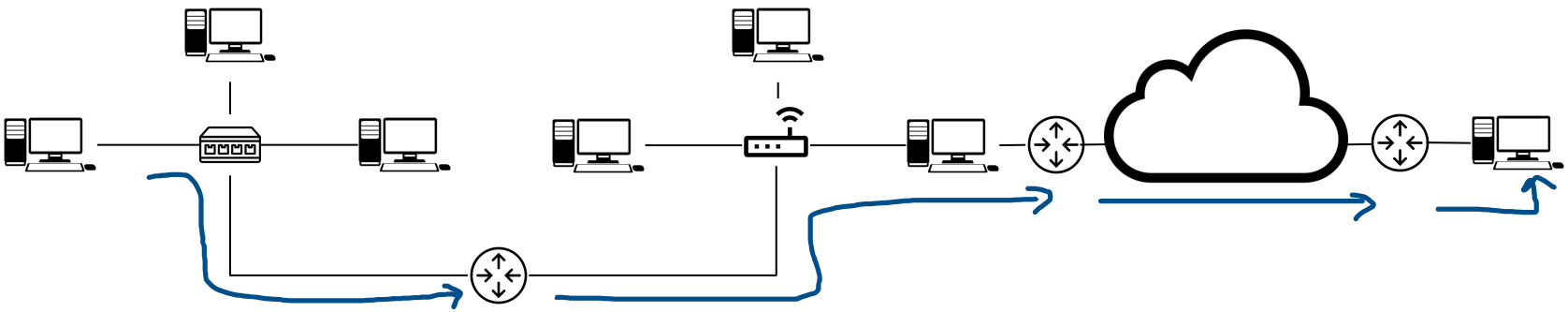
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress

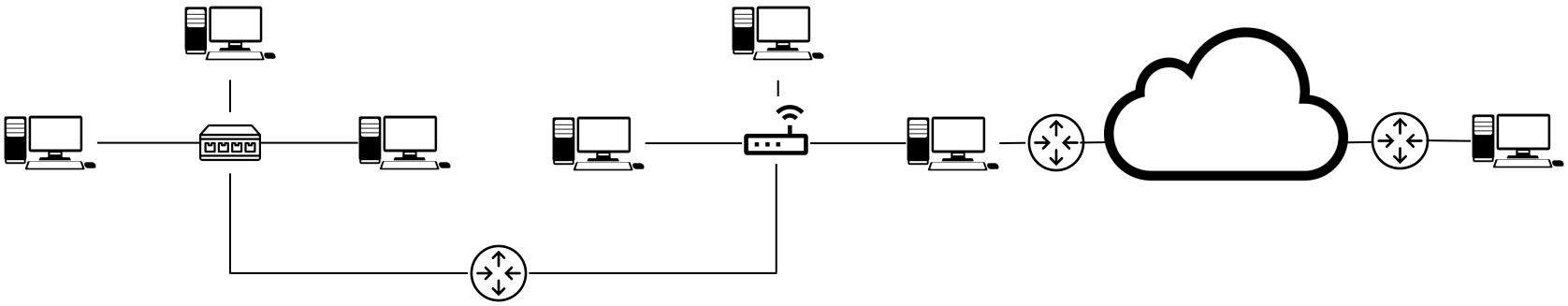
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress

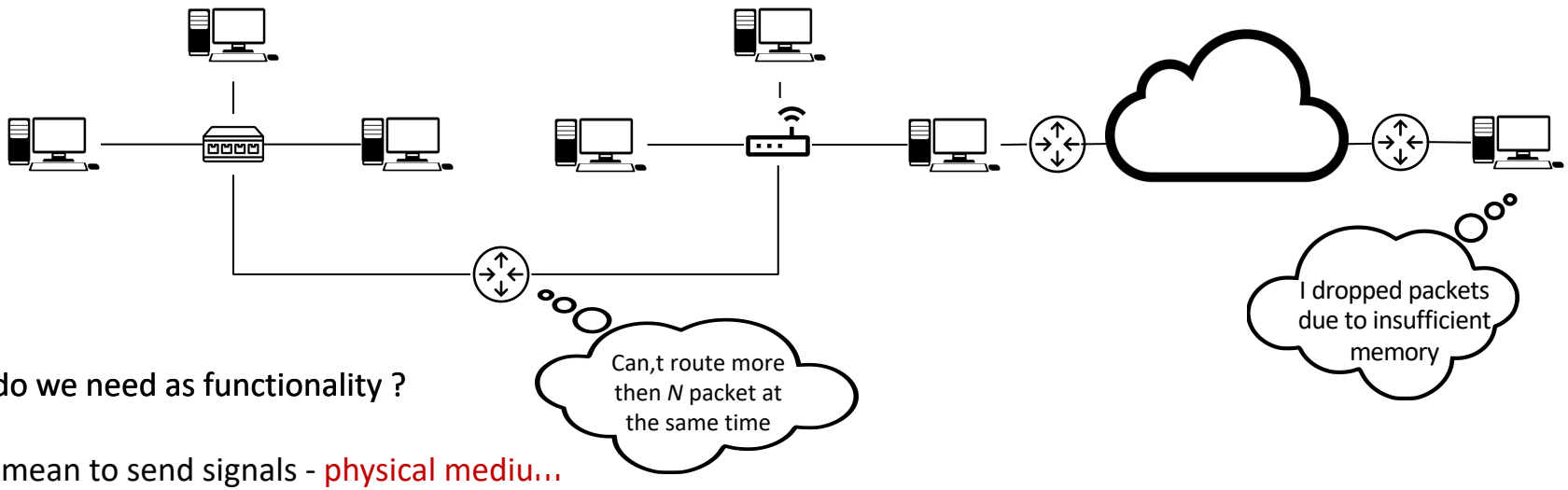
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress
8. Manage the amount of information sent based on receptors and network capacity – flow control

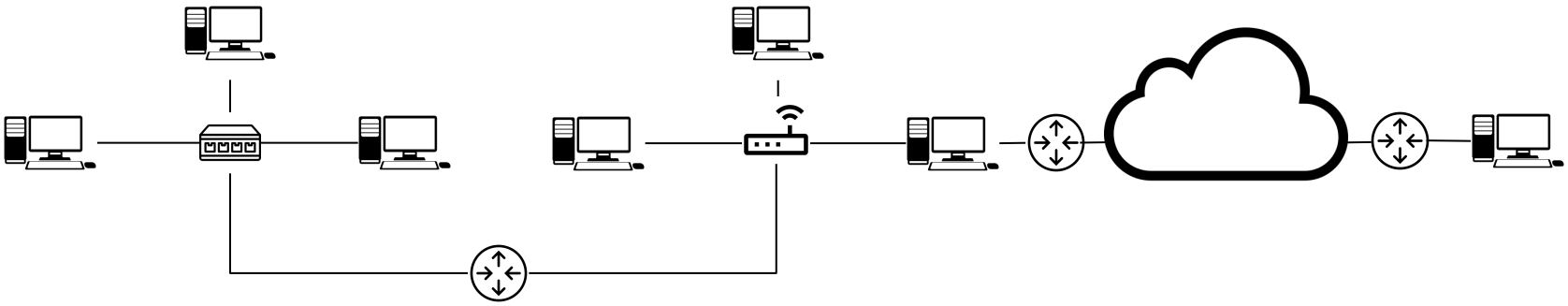
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical mediu…
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress
8. Manage the amount of information sent based on receptors and network capacity – flow control

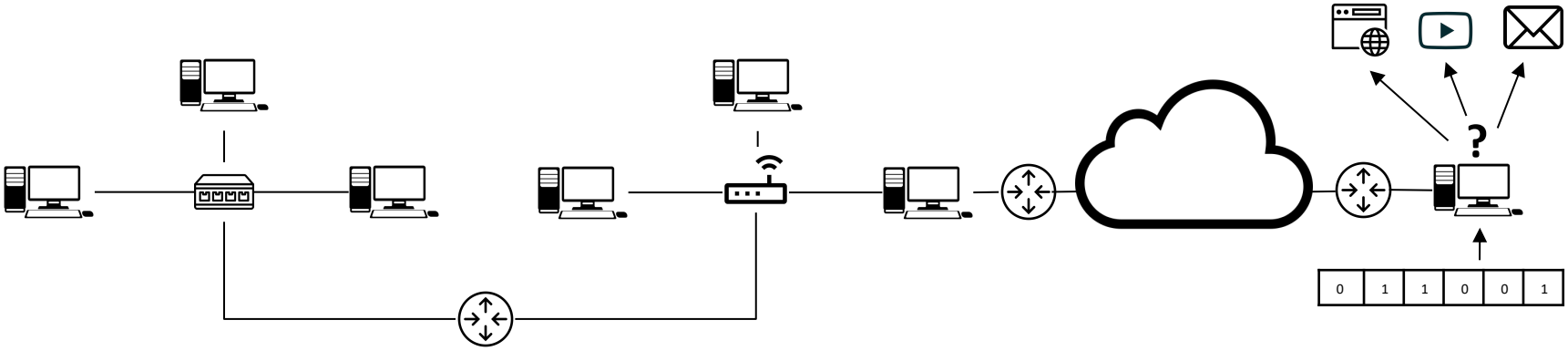
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress
8. Manage the amount of information sent based on receptors and network capacity – flow control
9. Deliver the message to the corresponding application – multiplexing using ports

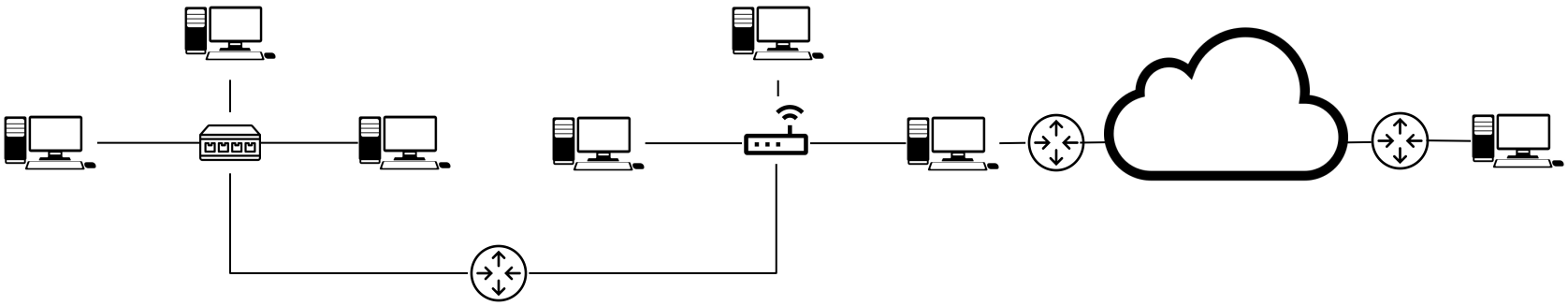
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress
8. Manage the amount of information sent based on receptors and network capacity – flow control
9. Deliver the message to the corresponding application – multiplexing using ports

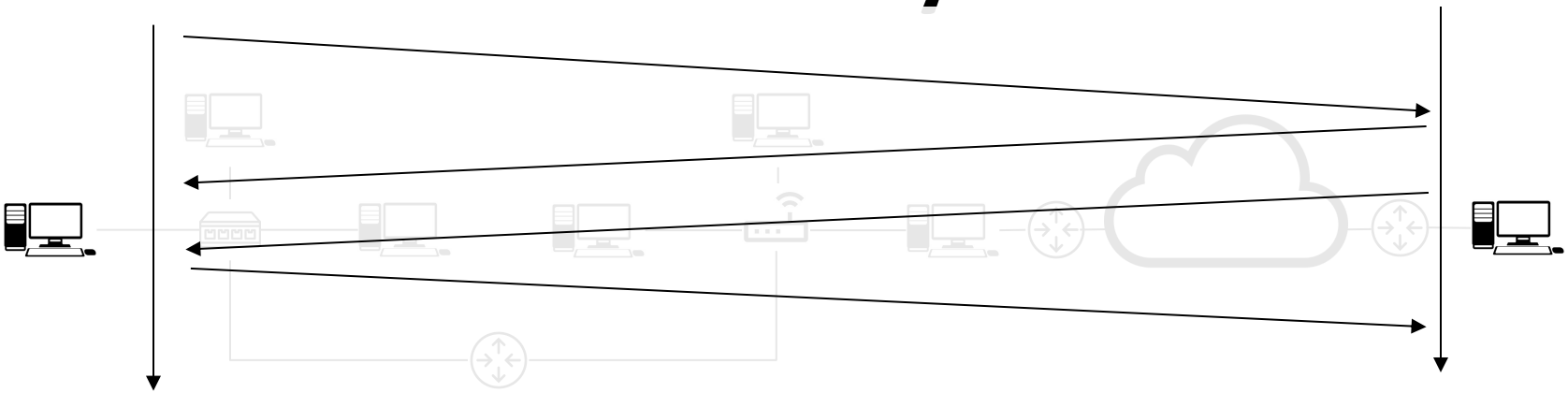
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress
8. Manage the amount of information sent based on receptors and network capacity – flow control
9. Deliver the message to the corresponding application – multiplexing using ports
10. Maintain an message exchange – connexion

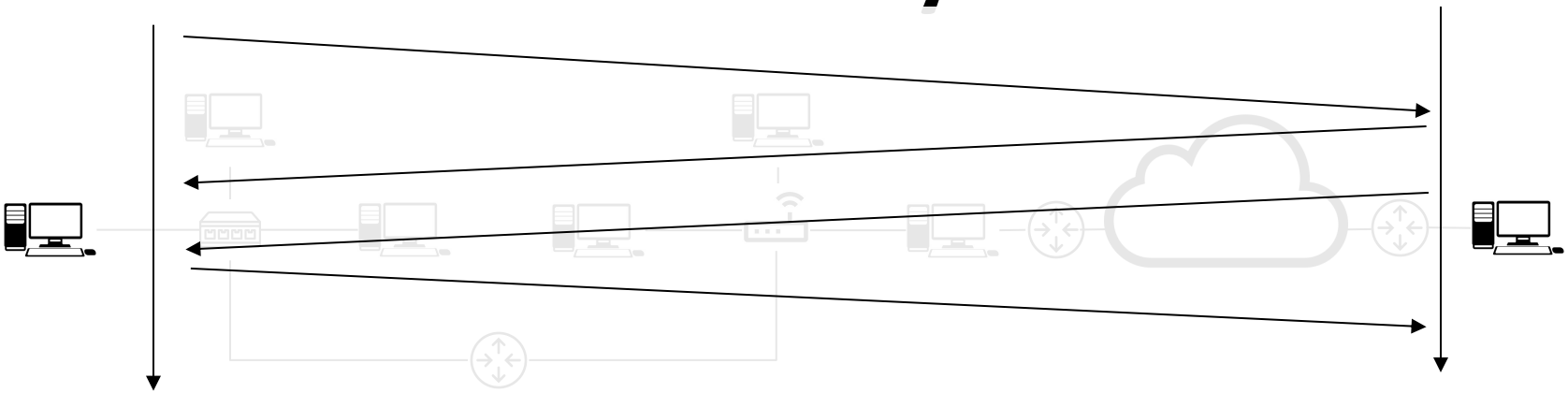
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress
8. Manage the amount of information sent based on receptors and network capacity – flow control
9. Deliver the message to the corresponding application – multiplexing using ports
10. Maintain an message exchange – connexion

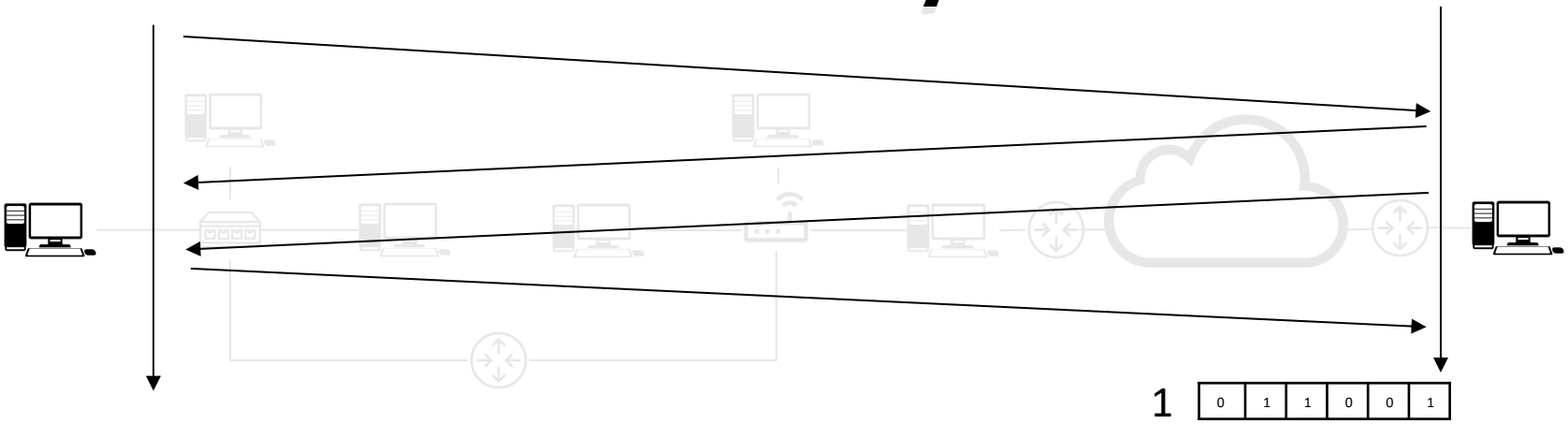
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress
8. Manage the amount of information sent based on receptors and network capacity – flow control
9. Deliver the message to the corresponding application – multiplexing using ports
10. Maintain an message exchange – connexion
11. Ensure message sequencing – sequence control

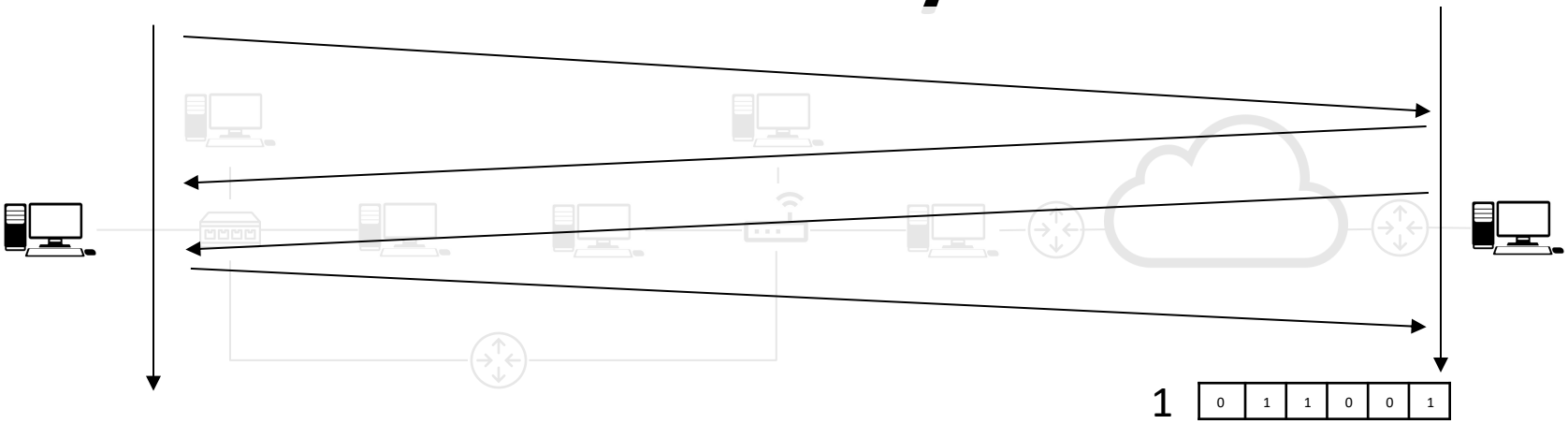
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress
8. Manage the amount of information sent based on receptors and network capacity – flow control
9. Deliver the message to the corresponding application – multiplexing using ports
10. Maintain an message exchange – connexion
11. Ensure message sequencing – sequence control

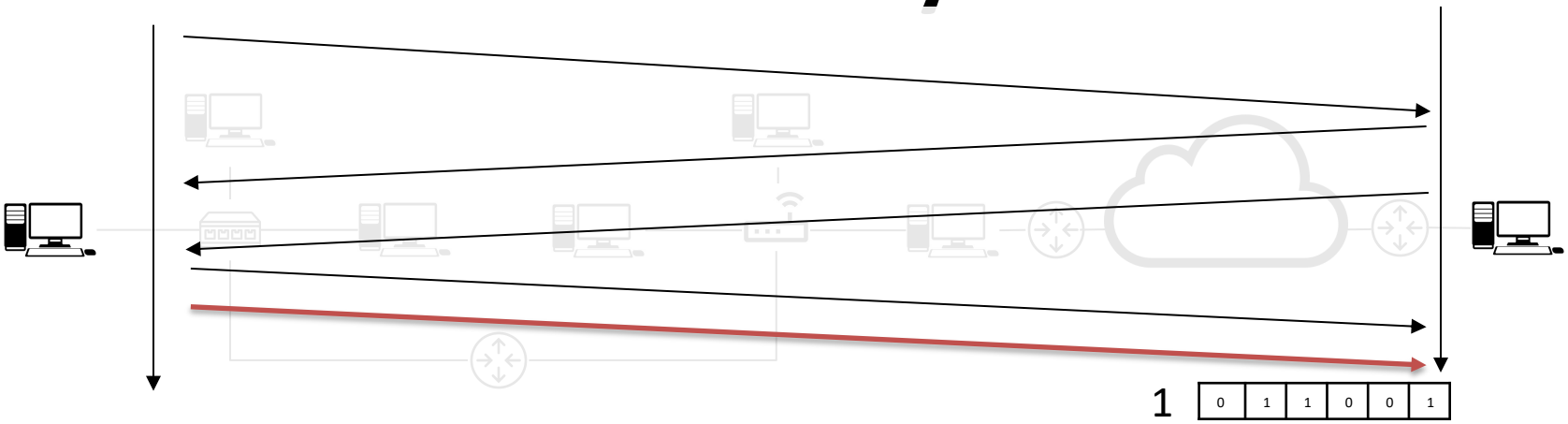
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress
8. Manage the amount of information sent based on receptors and network capacity – flow control
9. Deliver the message to the corresponding application – multiplexing using ports
10. Maintain an message exchange – connexion
11. Ensure message sequencing – sequence control
12. Ensure the arrival of the entire message – retransmission

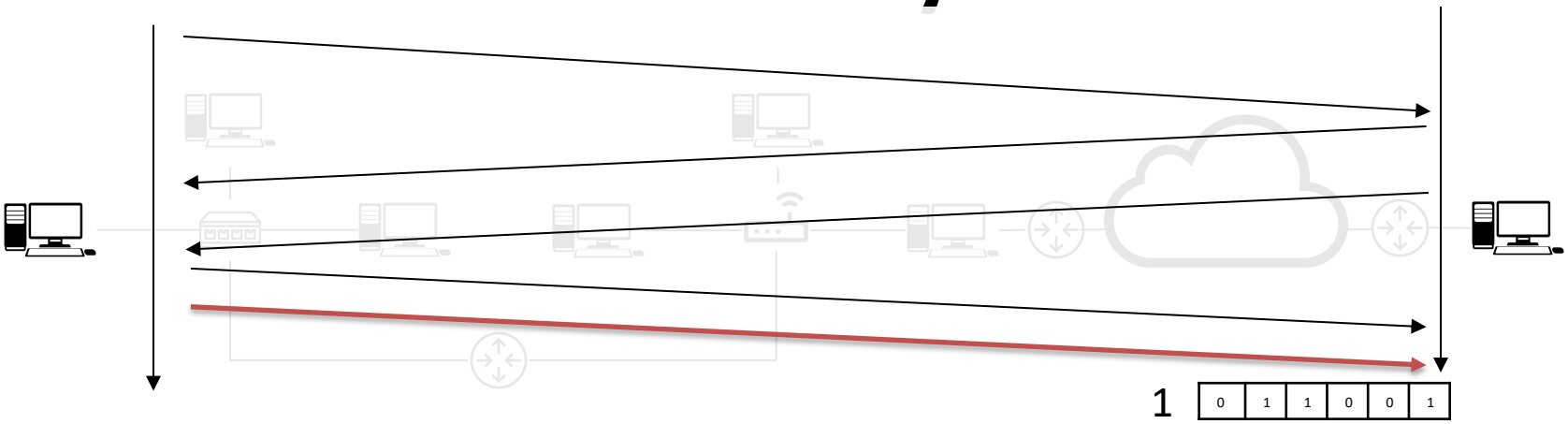
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress
8. Manage the amount of information sent based on receptors and network capacity – flow control
9. Deliver the message to the corresponding application – multiplexing using ports
10. Maintain an message exchange – connexion
11. Ensure message sequencing – sequence control
12. Ensure the arrival of the entire message – retransmission

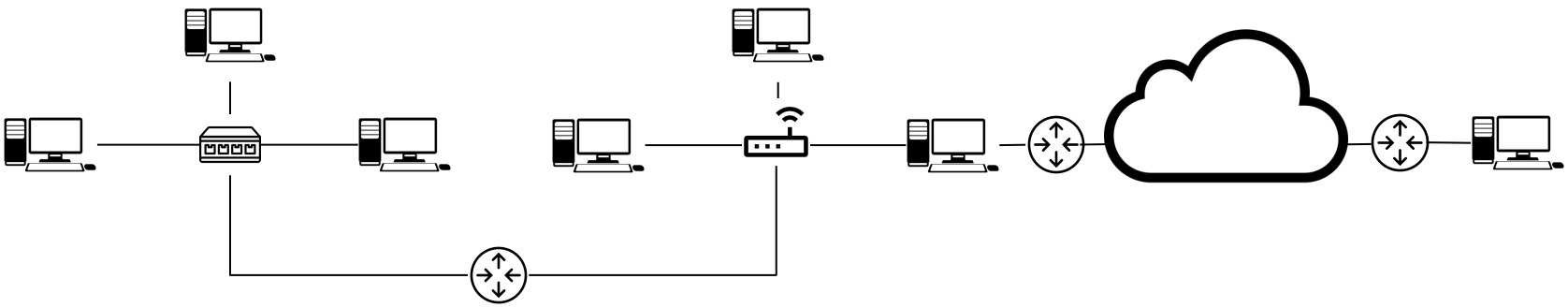
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress
8. Manage the amount of information sent based on receptors and network capacity – flow control
9. Deliver the message to the corresponding application – multiplexing using ports
10. Maintain an message exchange – connexion
11. Ensure message sequencing – sequence control
12. Ensure the arrival of the entire message – retransmission
13. Manage the progression of sessions – session management
14. Encoding data into a universal language – presentation
15. Manage application rules (depends on the application) - application

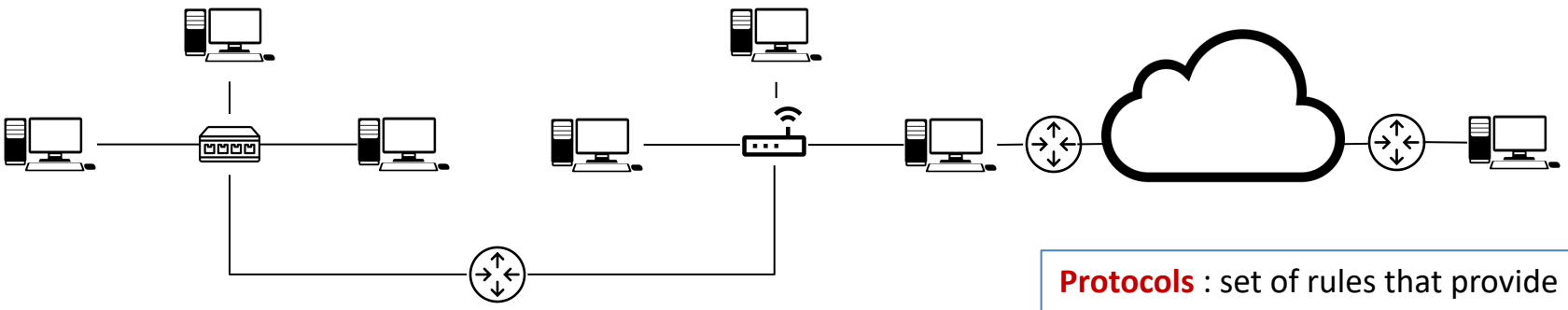
A Network as a System



What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress
8. Manage the amount of information sent based on receptors and network capacity – flow control
9. Deliver the message to the corresponding application – multiplexing using ports
10. Maintain an message exchange – connexion
11. Ensure message sequencing – sequence control
12. Ensure the arrival of the entire message – retransmission
13. Manage the progression of sessions – session management
14. Encoding data into a universal language – presentation
15. Manage application rules (depends on the application) - application

A Network as a System

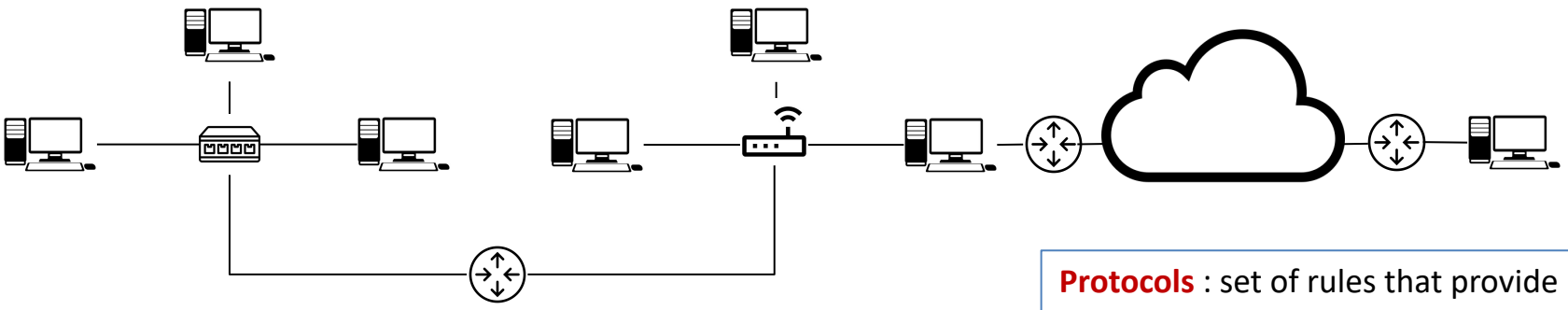


Protocols : set of rules that provide these functionalities
Standards and specifications

What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress
8. Manage the amount of information sent based on receptors and network capacity – flow control
9. Deliver the message to the corresponding application – multiplexing using ports
10. Maintain an message exchange – connexion
11. Ensure message sequencing – sequence control
12. Ensure the arrival of the entire message – retransmission
13. Manage the progression of sessions – session management
14. Encoding data into a universal language – presentation
15. Manage application rules (depends on the application) - application

A Network as a System

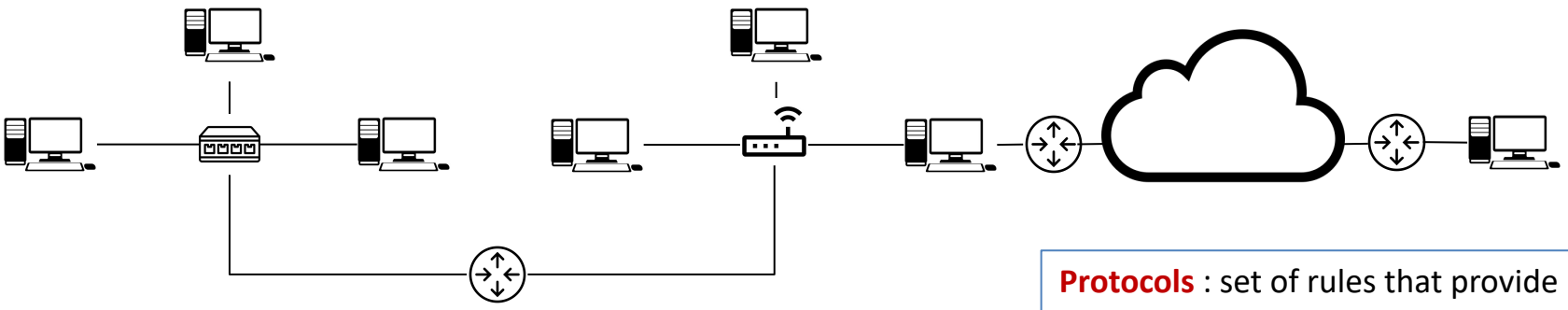


Protocols : set of rules that provide these functionalities
Standards and specifications

What do we need as functionality ?

1. A mean to send signals - physical medium
2. Convert information into signal – encoding
3. Manage the concuren access to the shared medium (avoid collision) – medium access control
4. Ensure that the information is sent correctly – error control
5. Connect more that 2 machines – switching
6. Identify a machine in a network – physical adress
7. Interconnect different networks – information routing & logical adress
8. Manage the amount of information sent based on receptors and network capacity – flow control
9. Deliver the message to the corresponding application – multiplexing using ports
10. Maintain an message exchange – connexion
11. Ensure message sequencing – sequence control
12. Ensure the arrival of the entire message – retransmission
13. Manage the progression of sessions – session management
14. Encoding data into a universal language – presentation
15. Manage application rules (depends on the application) - application

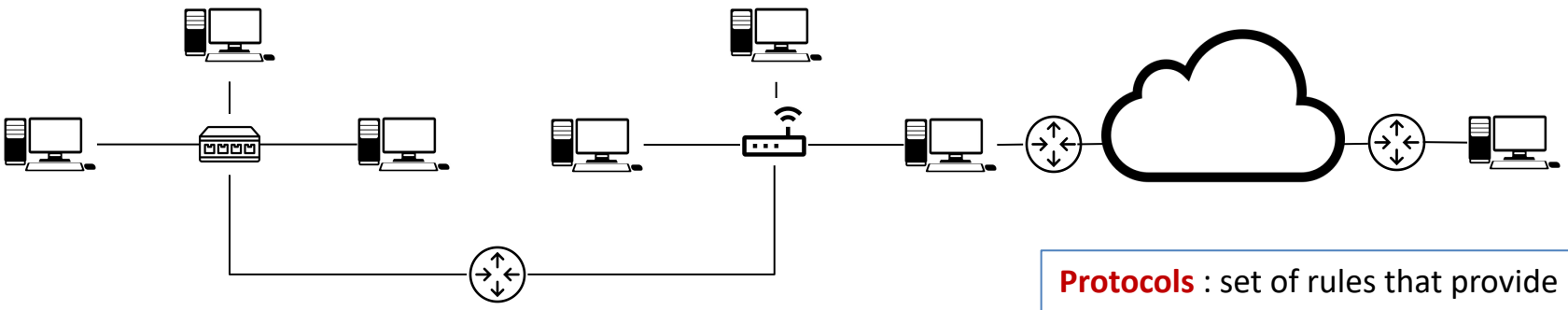
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

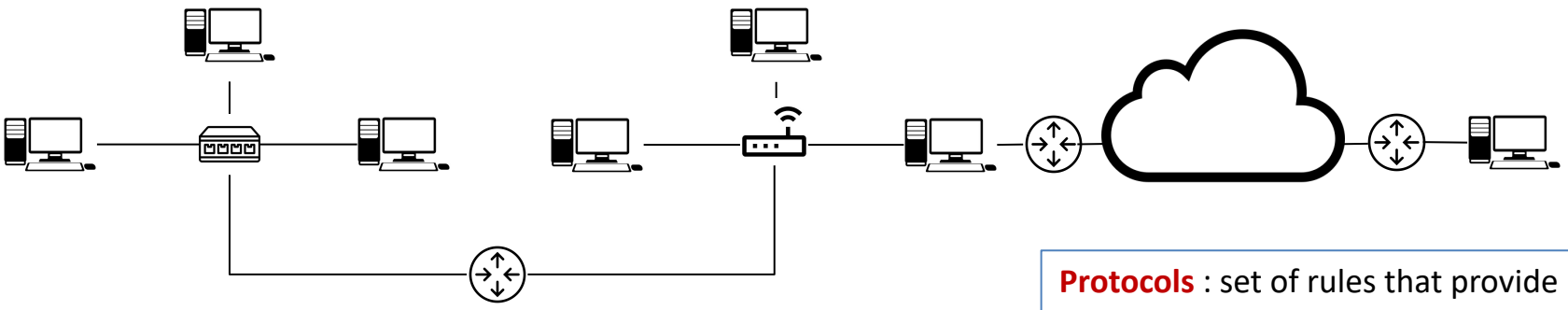
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

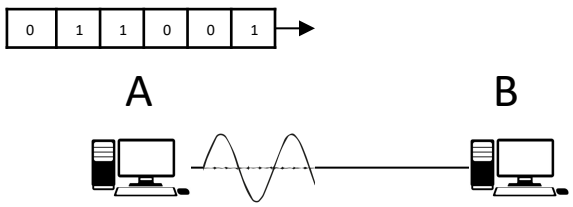
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

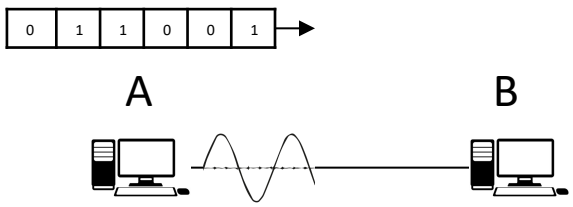
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

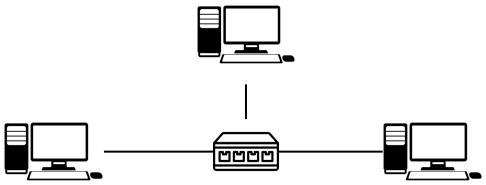
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

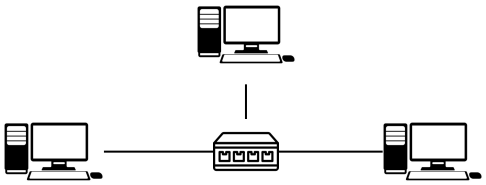
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

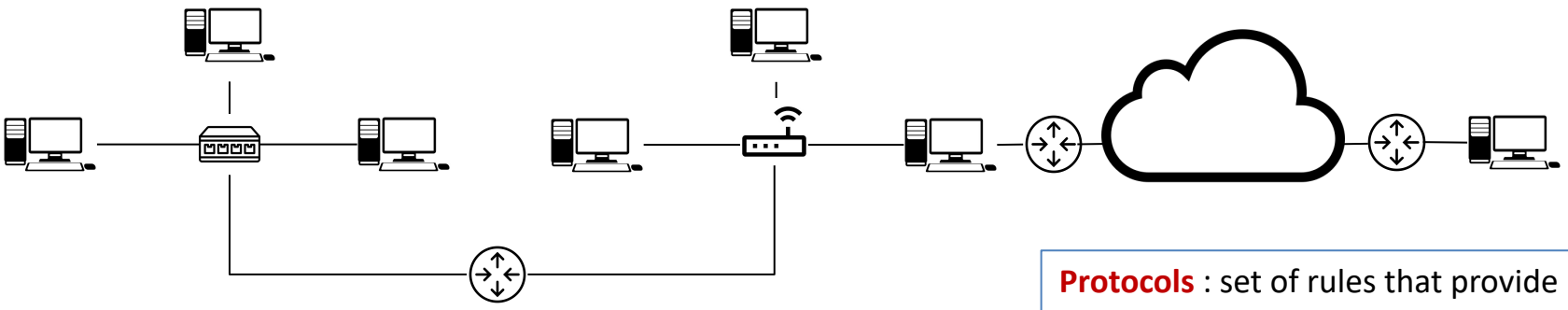
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

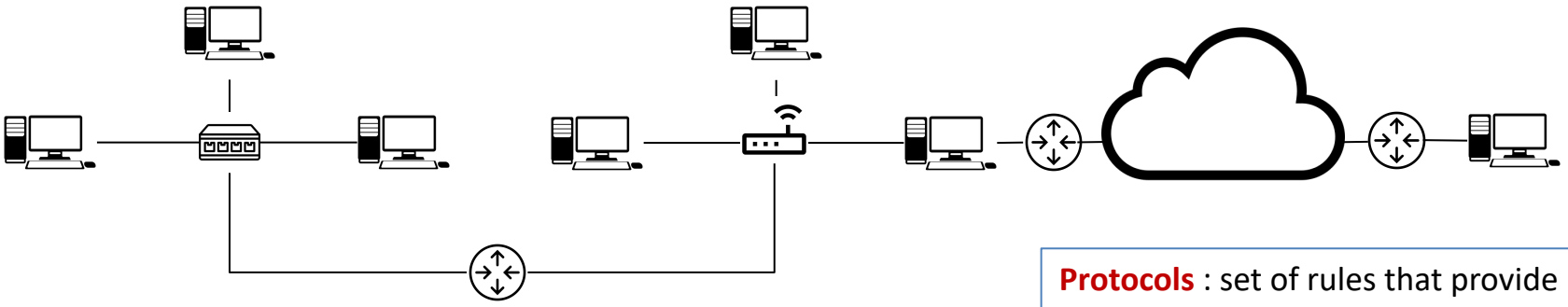
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

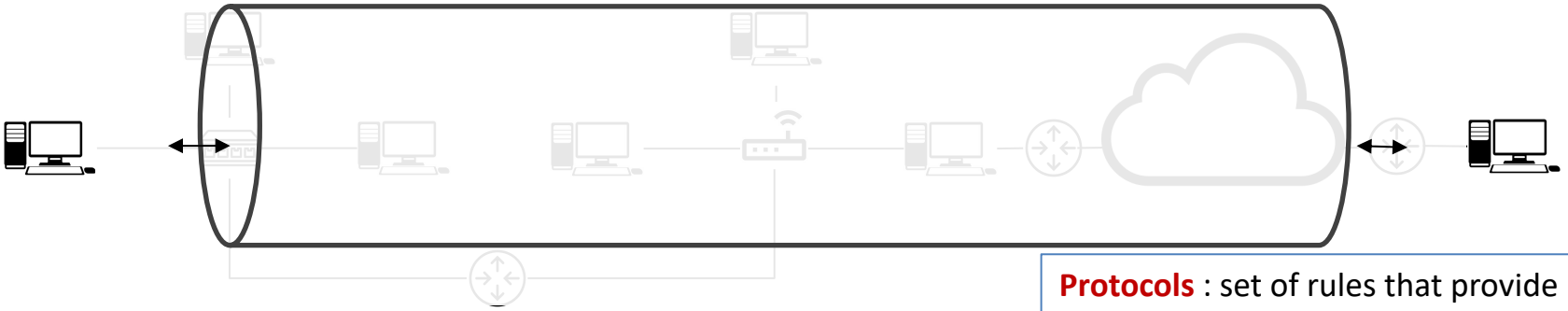
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

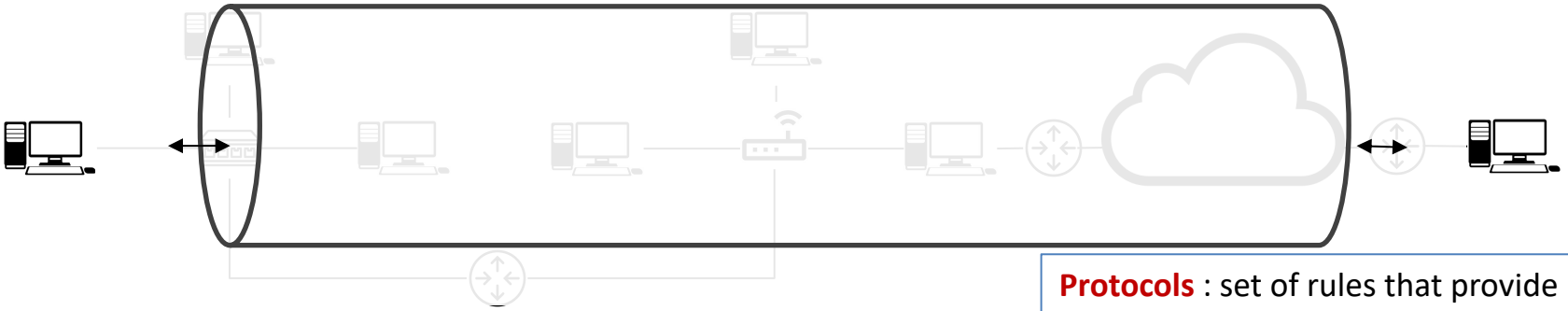
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

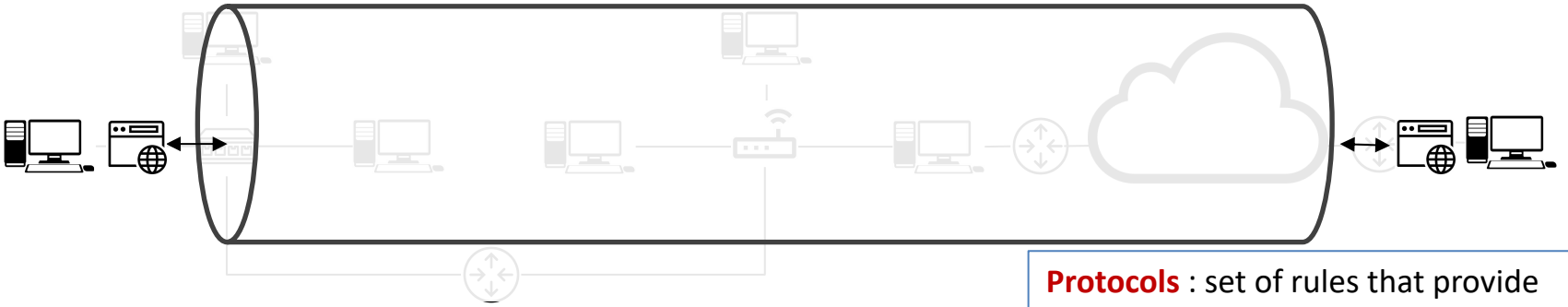
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

OSI Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

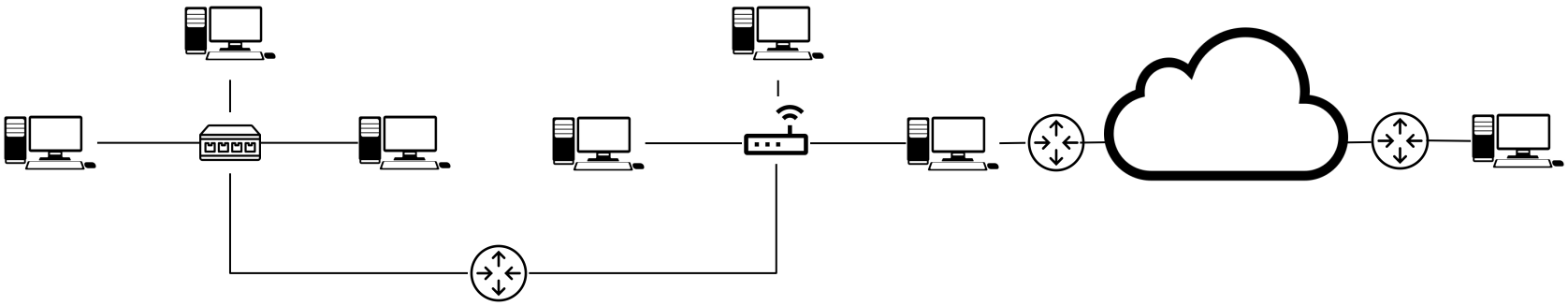
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

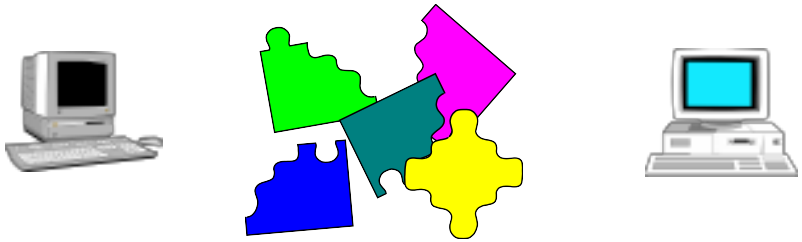
Why an architecture



- We need to :
  - Route bits,
  - Transport packets
  - Manage application exchanges
  - etc.
- Considering :
  - Data alterations
  - Data loss
  - Network congestion
  - Hardware failures
  - etc.

We must break down the problem!

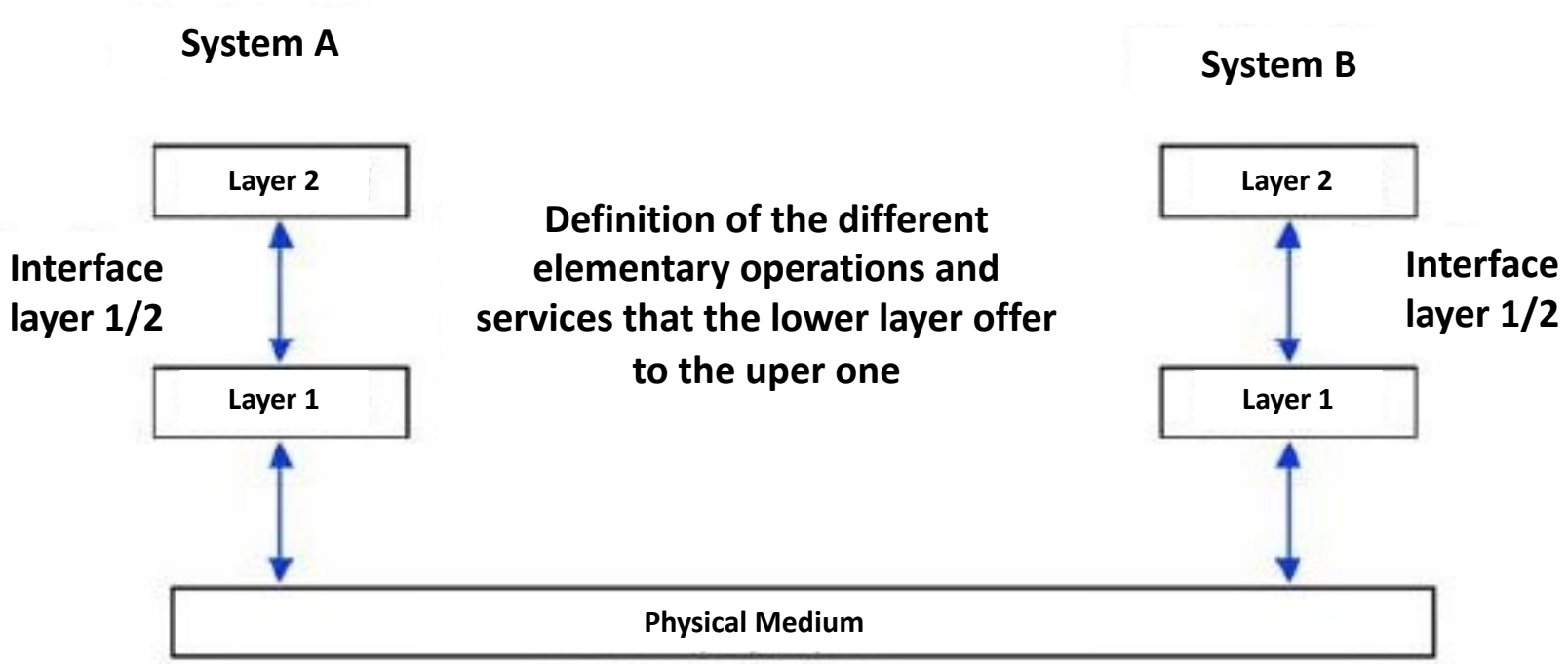
To break it down ?



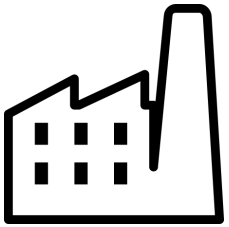
Principle: layered structure (levels)

- each layer is built on the previous one
- the number, name, content and functions of the layers differ from one architecture to another
- in all architectures, the role of each layer is to provide services to the upper layer

Layered model

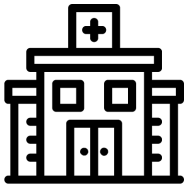


Analogy



Logistics	Logistics
Order preparation	Order preparation
Transport	Transport
Road law	Road law
Road infrastructure	Road infrastructure

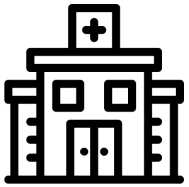
Analogy



Medical services	
Patient preparation	
Transport	
Road law	
Road infrastructure	

Medical services	
Patient preparation	
Transport	
Road law	
Road infrastructure	

Analogy

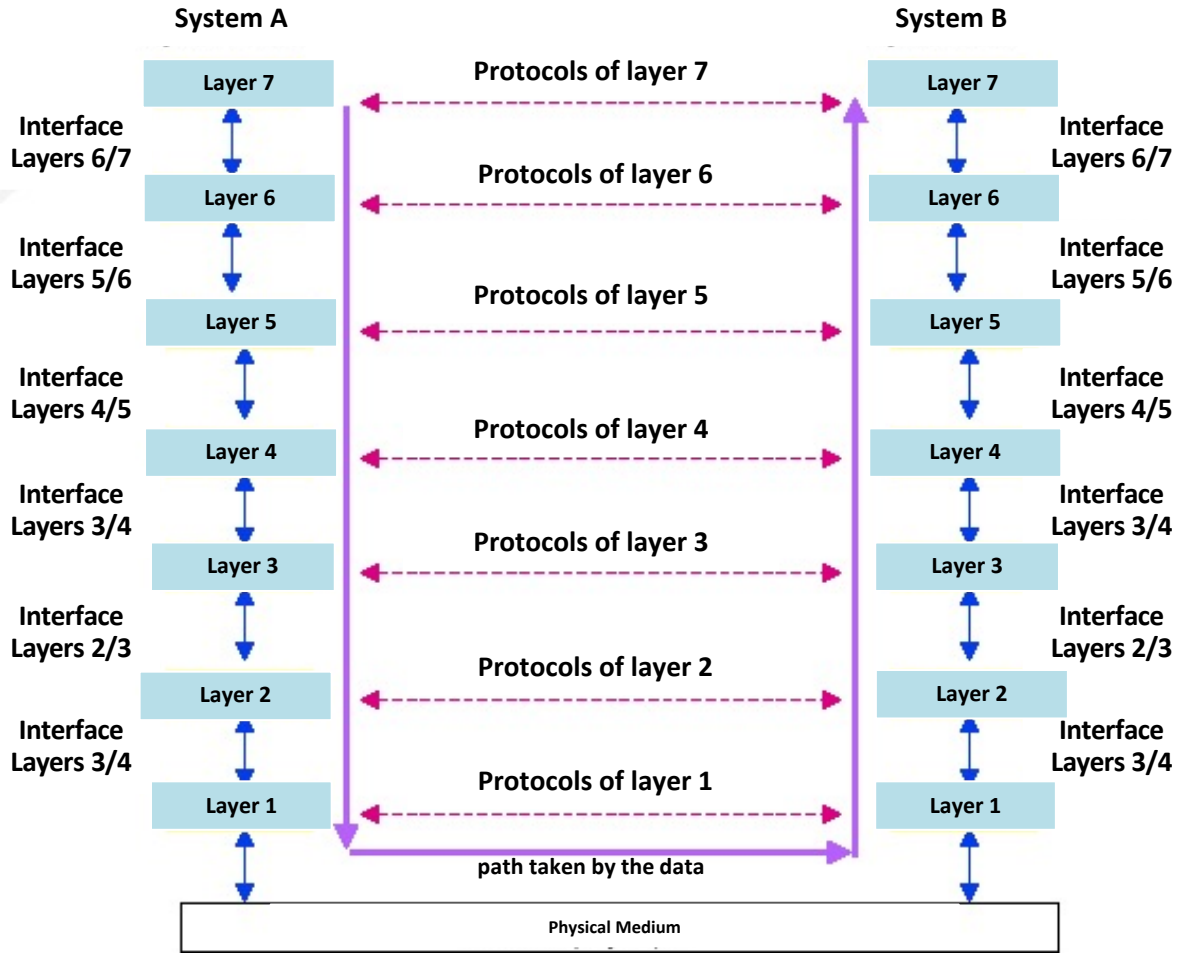


Medical services	
Patient preparation	
Transport	
Air trafic law	
Infrastructure	

Medical services	
Patient preparation	
Transport	
Air trafic law	
Infrastructure	

The OSI reference model (7 layers)

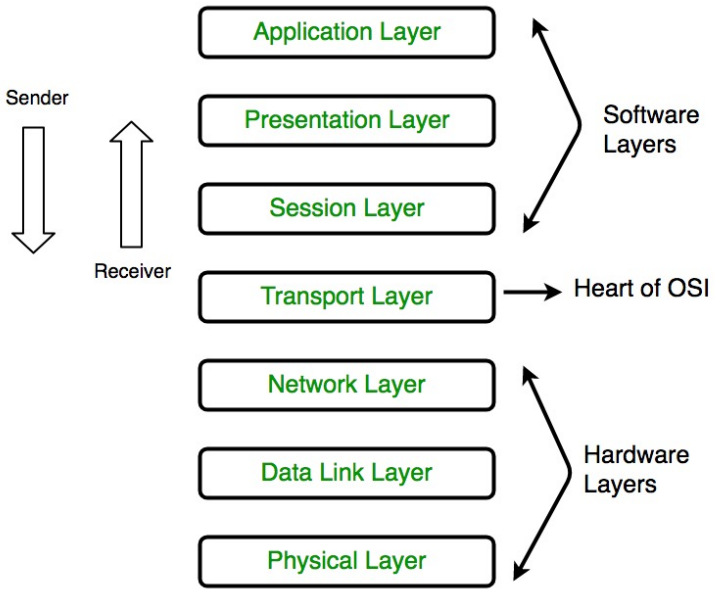
Open Systems Interconnection (OSI)



The OSI reference model

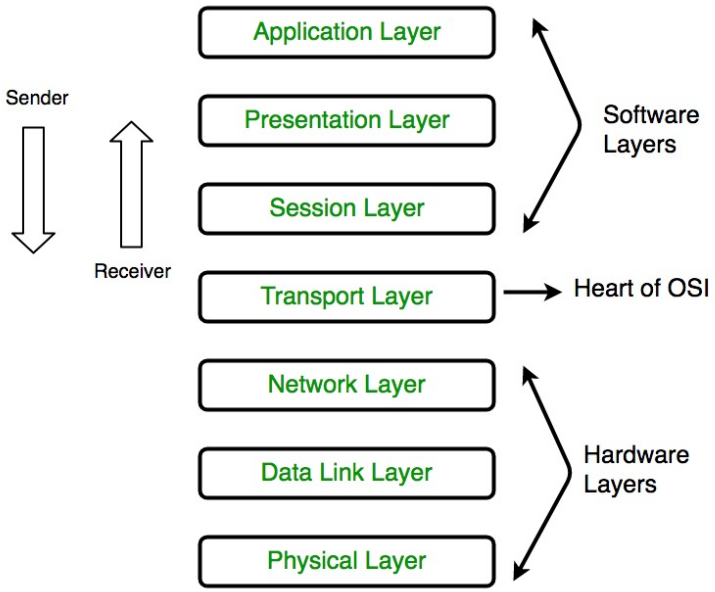
- The OSI Reference Model for Open Systems Interconnection was proposed in 1984 by ISO (ISO reference 7498):
  - Model based on a “Divide and Conquer” principle
- The main principle is the representation of networks in the form of a layer of functions.
- Their number, name and function vary depending on the network.
- The study of the communication system then returns to the study of its elements and offers :
  - Ease of study
  - Independence of layers
  - Flexibility of evolution

The OSI reference model (7 layers)



- data packets come from a source and are routed to a destination.
- Each layer is based on the service function of the underlying OSI layer.
- To provide a service, the lower layer uses encapsulation to place upper layer data in its data field

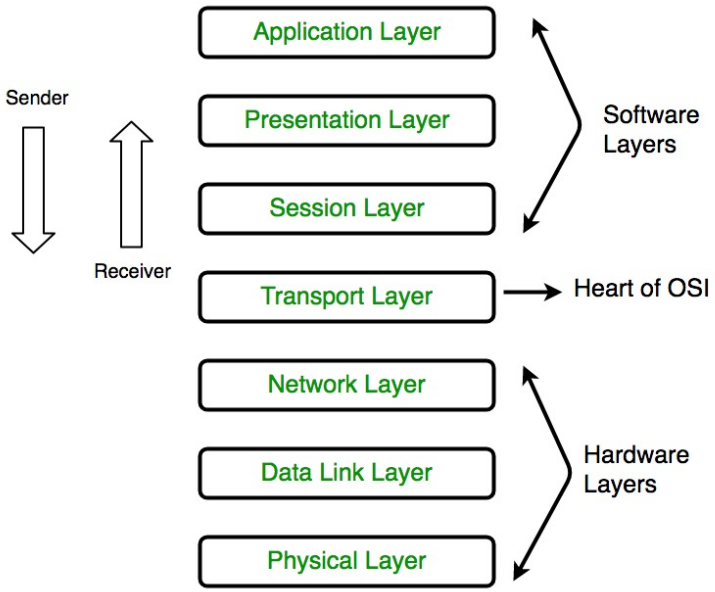
The OSI reference model



Application layer

- It represents the interface between the user/system applications and the protocol stack
- It contains a variety of protocols that are commonly needed by users, for instance :
  - HTTP for web pages
  - FTP for file transfert
  - SMTP for mail transfert
  - Etc.

The OSI reference model

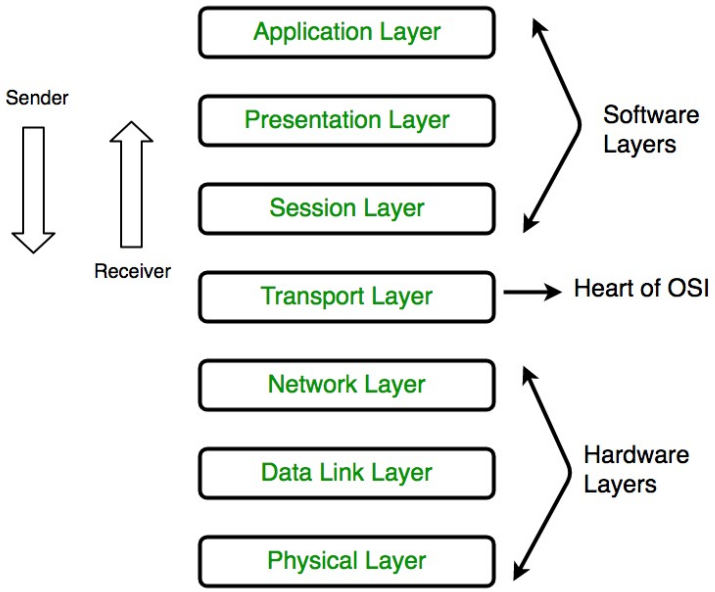


Presentation layer

- The primary goal of this layer is to take care of the **syntax** and **semantics** of the information exchanged between two communicating systems
- The presentation layer is responsible for interoperability between encoding methods as different computers use different encoding methods
- The main functions are :
  - Translation
  - Encryption
  - Compression

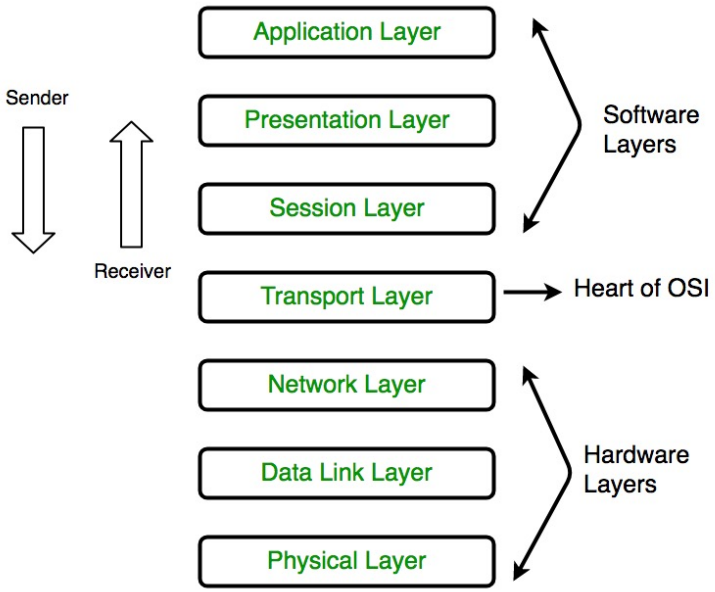
The OSI reference model

Session layer



- The Session Layer allows users on different machines to establish active communication sessions between them.
- Responsible for the synchronization of exchanges :
  - Dialogue control
  - Recovery points
  - Backtracking
  - Orchestration

The OSI reference model

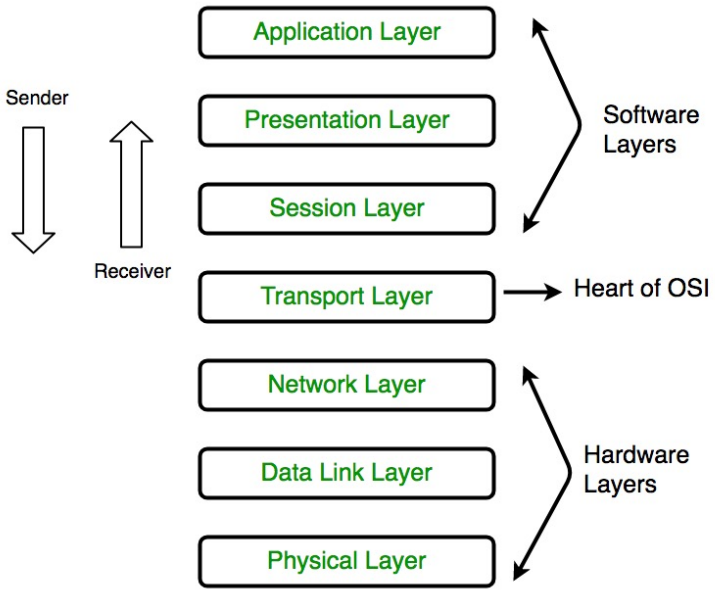


Transport layer

- The Transport Layer is responsible for end-to-end delivery over a network.
- It ensures that each message should reach its destination completely and in order.
- It establishes a connection between two end ports. A connection is a logical path from source to destination which is associated with all the packets in a message.

- The main functions are :
  - Segmentation and Reassembly of user messages
  - Connection Control
  - Multiplexing and Demultiplexing : link messages to services
  - Flow control
  - Error Control (at a message level)

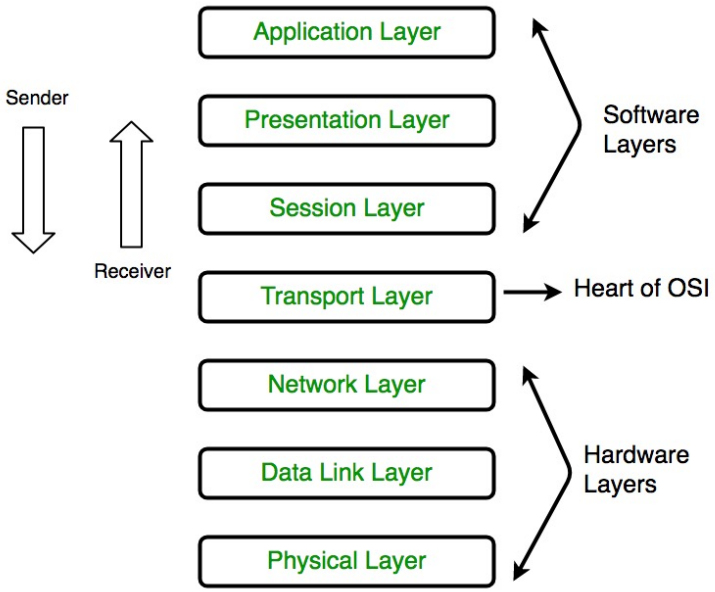
The OSI reference model



Network layer

- The network Layer controls the operation of the subnet.
- The main aim of this layer is to deliver packets from source to destination across multiple links (networks).
- If two computers (system) are connected on the same link, then there is no need for a network layer.
- It routes the signal through different channels to the other end and acts as a network controller.
- It also divides the outgoing messages into packets and to assemble incoming packets into messages for higher levels.
- In broadcast networks, the routing problem is simple, so the network layer is often thin or even non-existent.

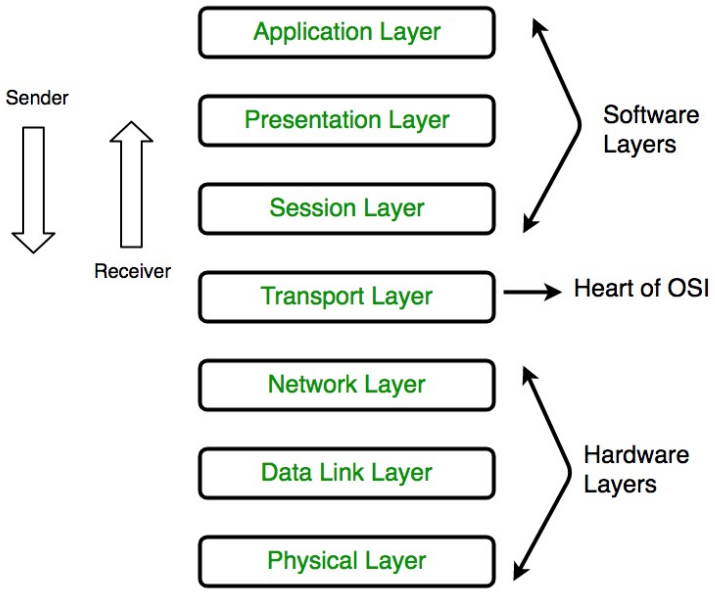
The OSI reference model



Data Link layer

- The data link layer provides the means necessary to establish, maintain and release data link connections between entities.
- it detects and corrects errors that may occur in the physical layer on reception
- the essential functions of the layer are:
  - Establishment and release of the link
  - delimitation and synchronization of data frames
  - sequence control
  - error detection and recovery
- For local networks this layer could be devided in two sublayers
  - MAC (Medium Access Control) sublayer: manages access to the channel
  - LLC (Logical Link Control) sublayer: manages error control, manages data frames and logical link

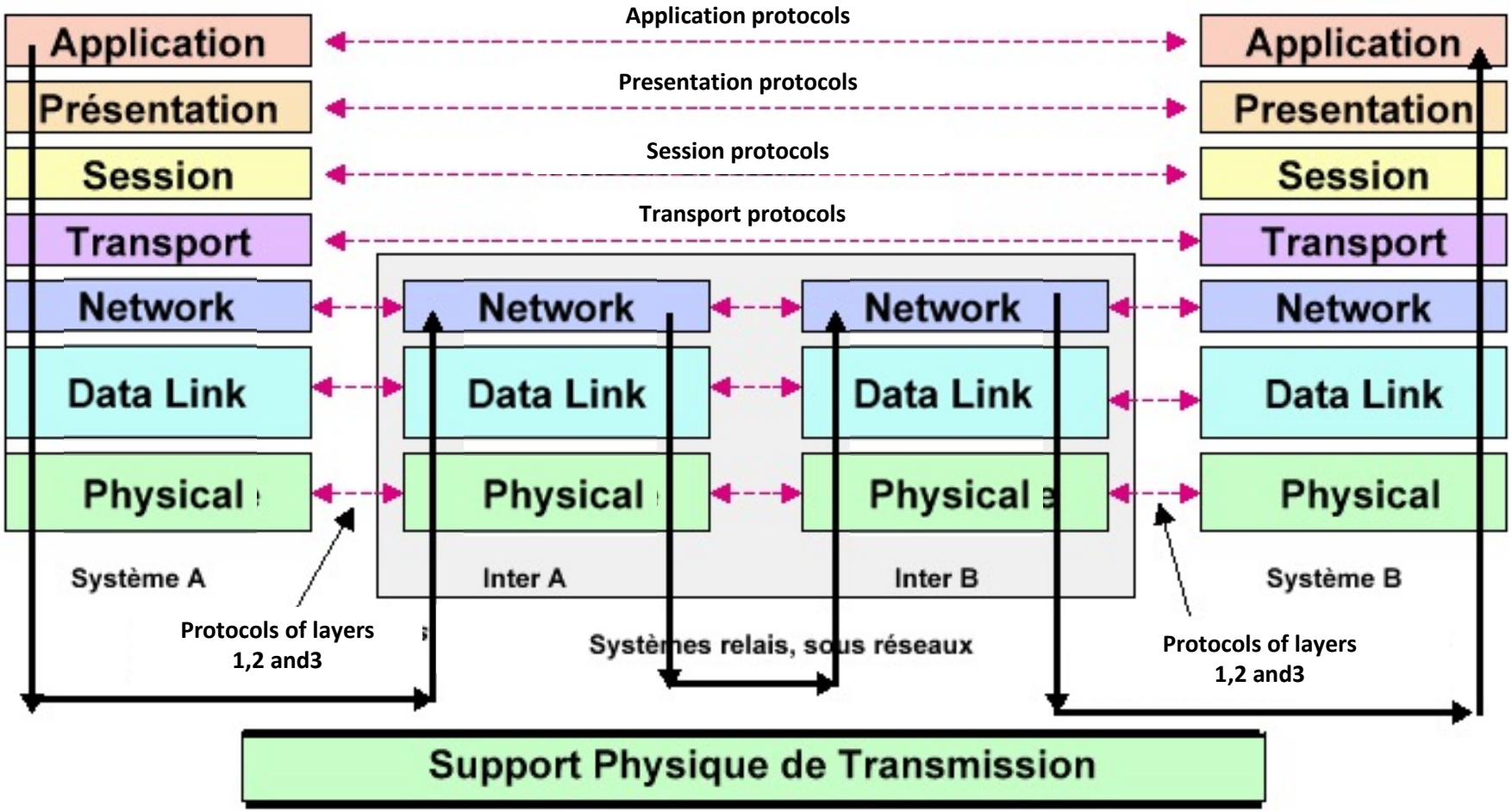
The OSI reference model



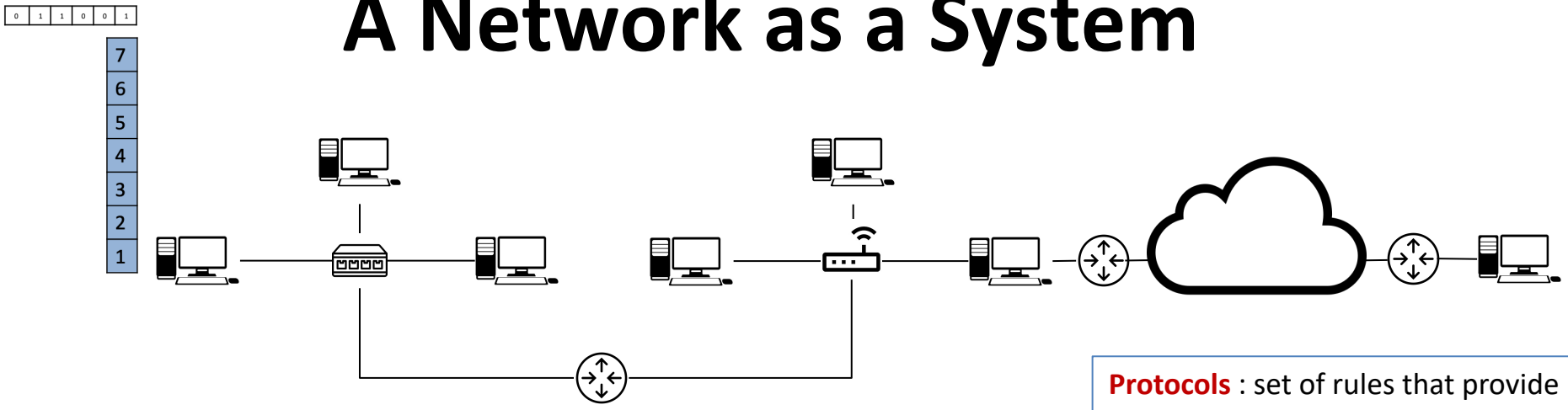
Physical layer

- it provides the mechanical, electrical and functional means necessary to maintain the physical connections intended for the transmission of digitized information between the entities
- transmission of bits on a communication circuit
- elements of the physical layer:
  - physical communication medium
  - encoder, modulator / demodulator
  - multiplexers, hubs
- The design of the elements of this layer could be considered as part of the electronics field.

Interconnection principle

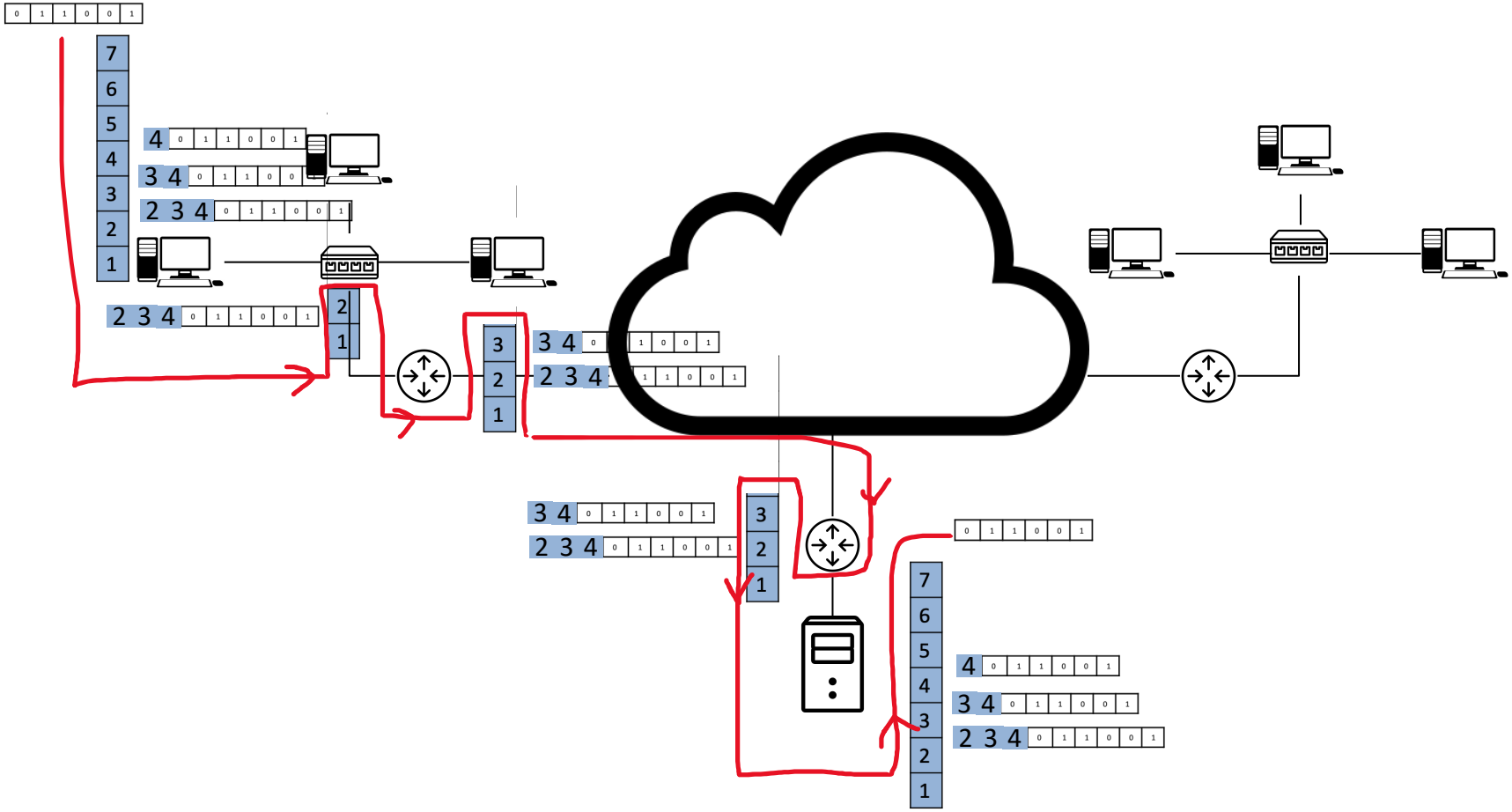


A Network as a System

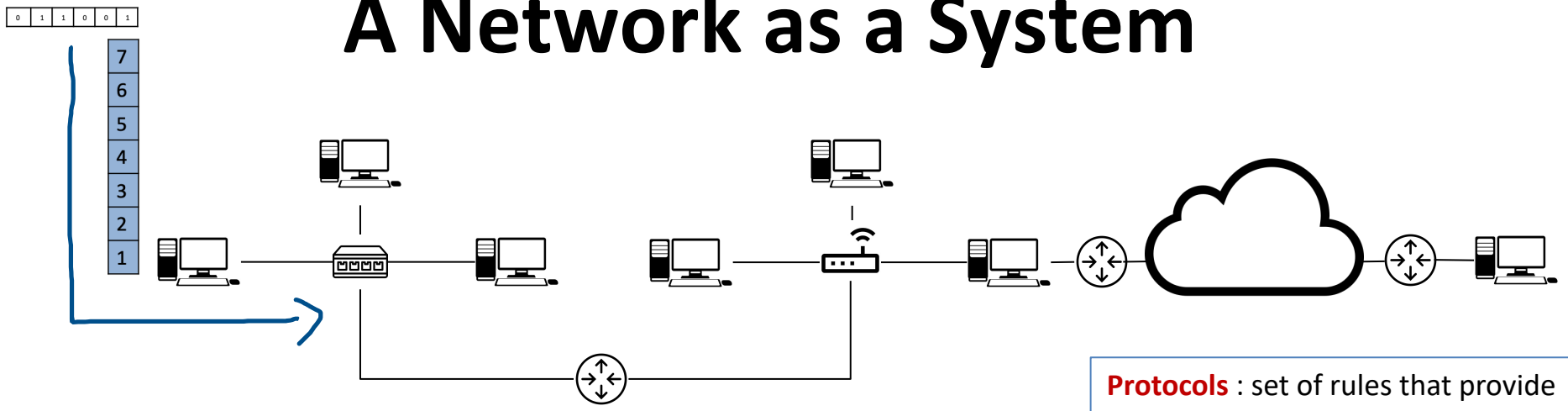


Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application


0 1 1 0 0 1
7
6
5
4
3
2
1
4 0 1 1 0 0 1
3 4 0 1 1 0 0
2 3 4 0 1 1 0 0 1
2 3 4 0 1 1 0 0 1
2
1
3 4 0 1 0 0 1
2 3 4 1 1 0 0 1
3
2
1
3 4 0 1 1 0 0 1
2 3 4 0 1 1 0 0 1
3
2
1
0 1 1 0 0 1
7
6
5
4
3
2
1
4 0 1 1 0 0 1
3 4 0 1 1 0 0 1
2 3 4 0 1 1 0 0 1

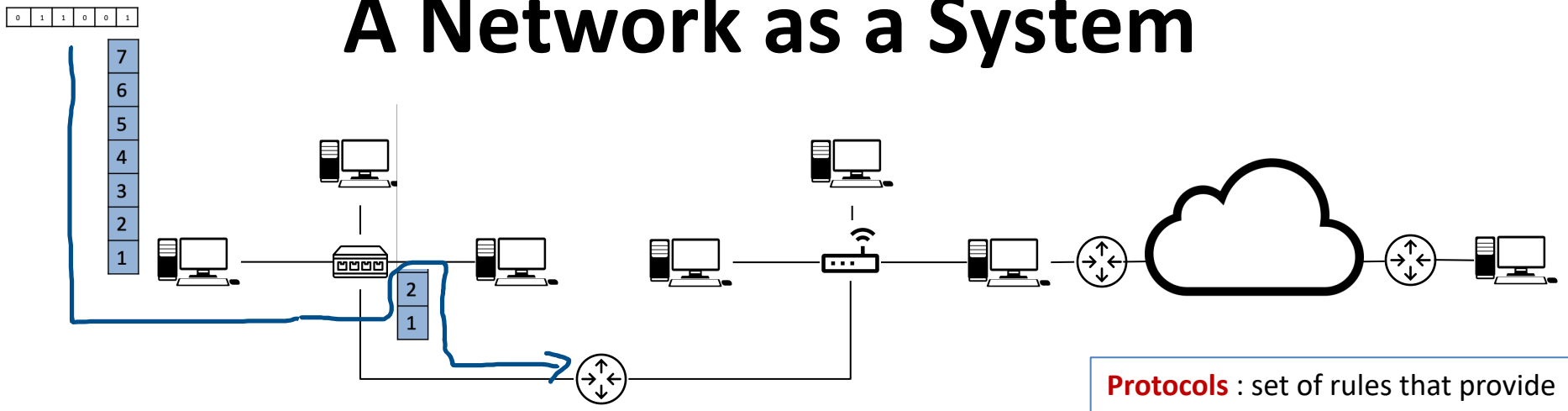
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

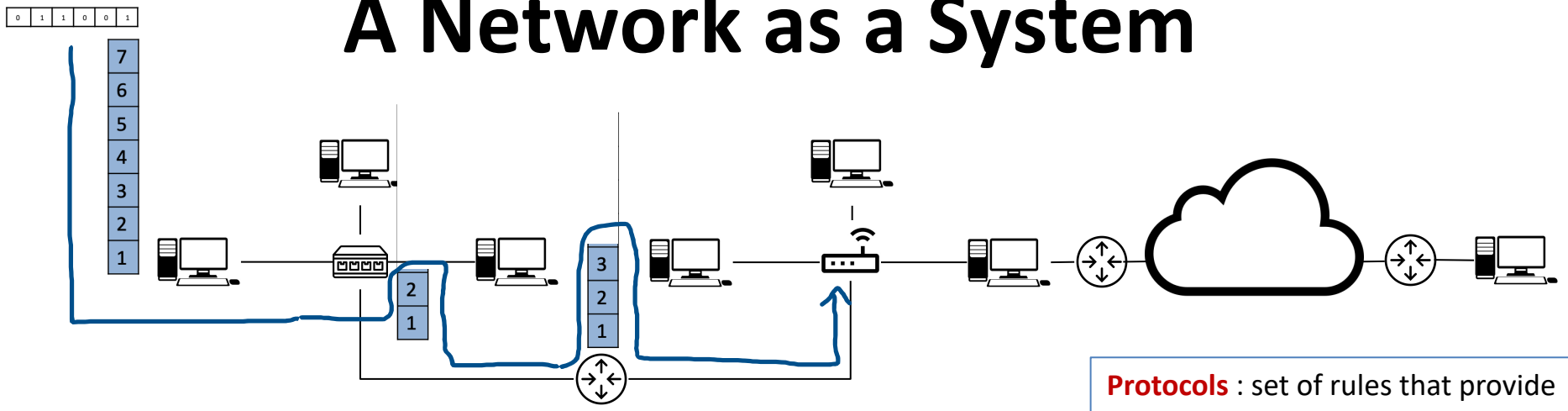
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

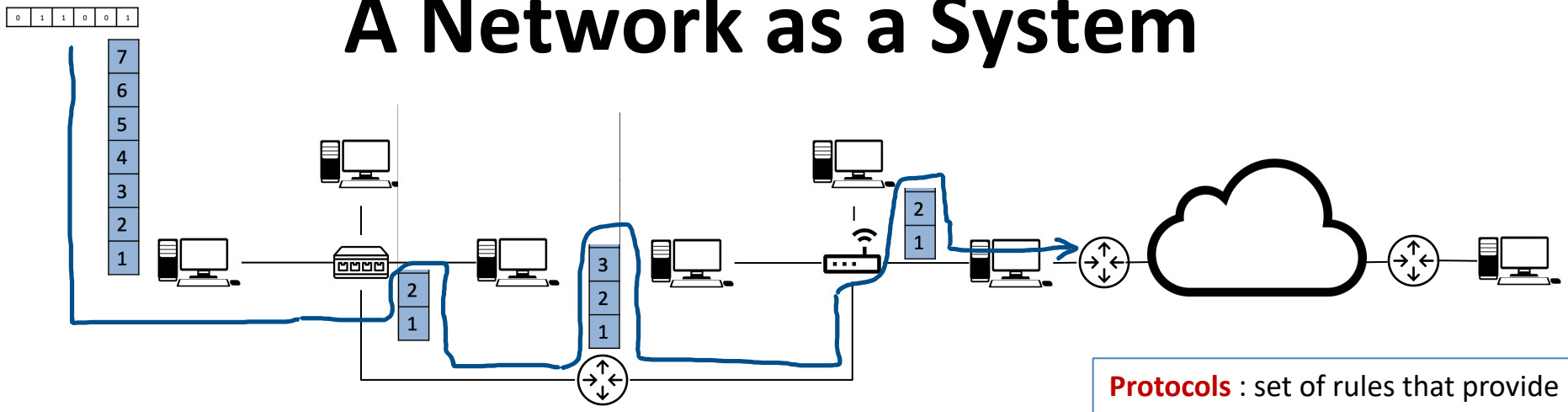
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

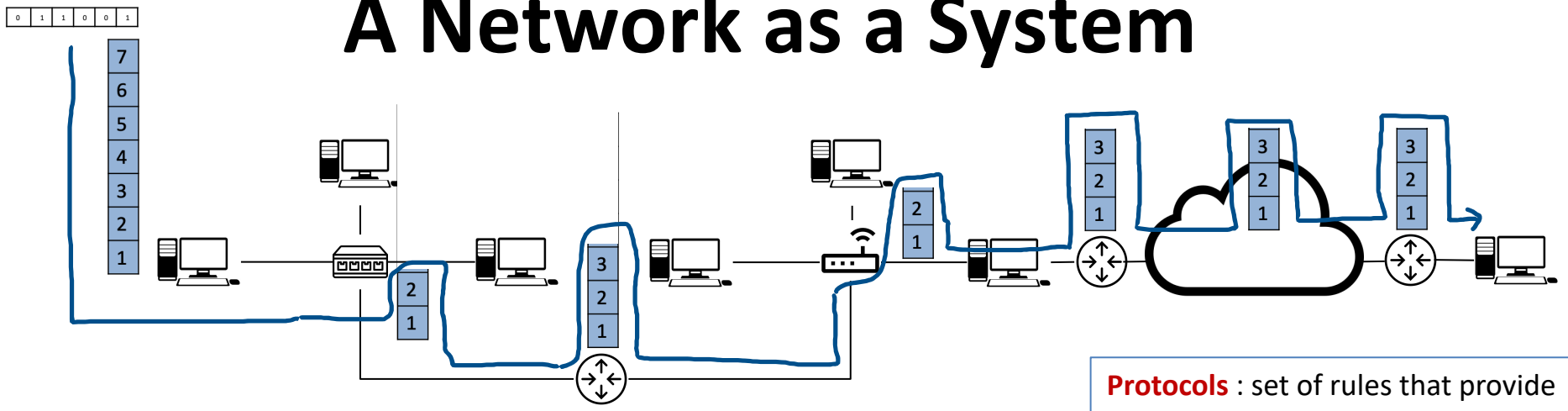
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

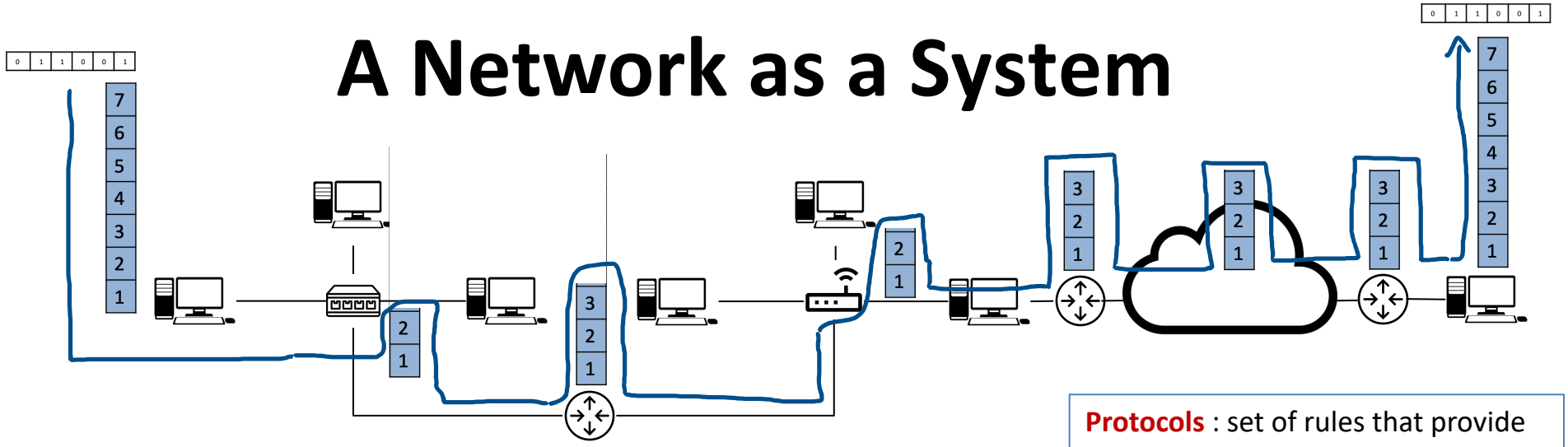
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

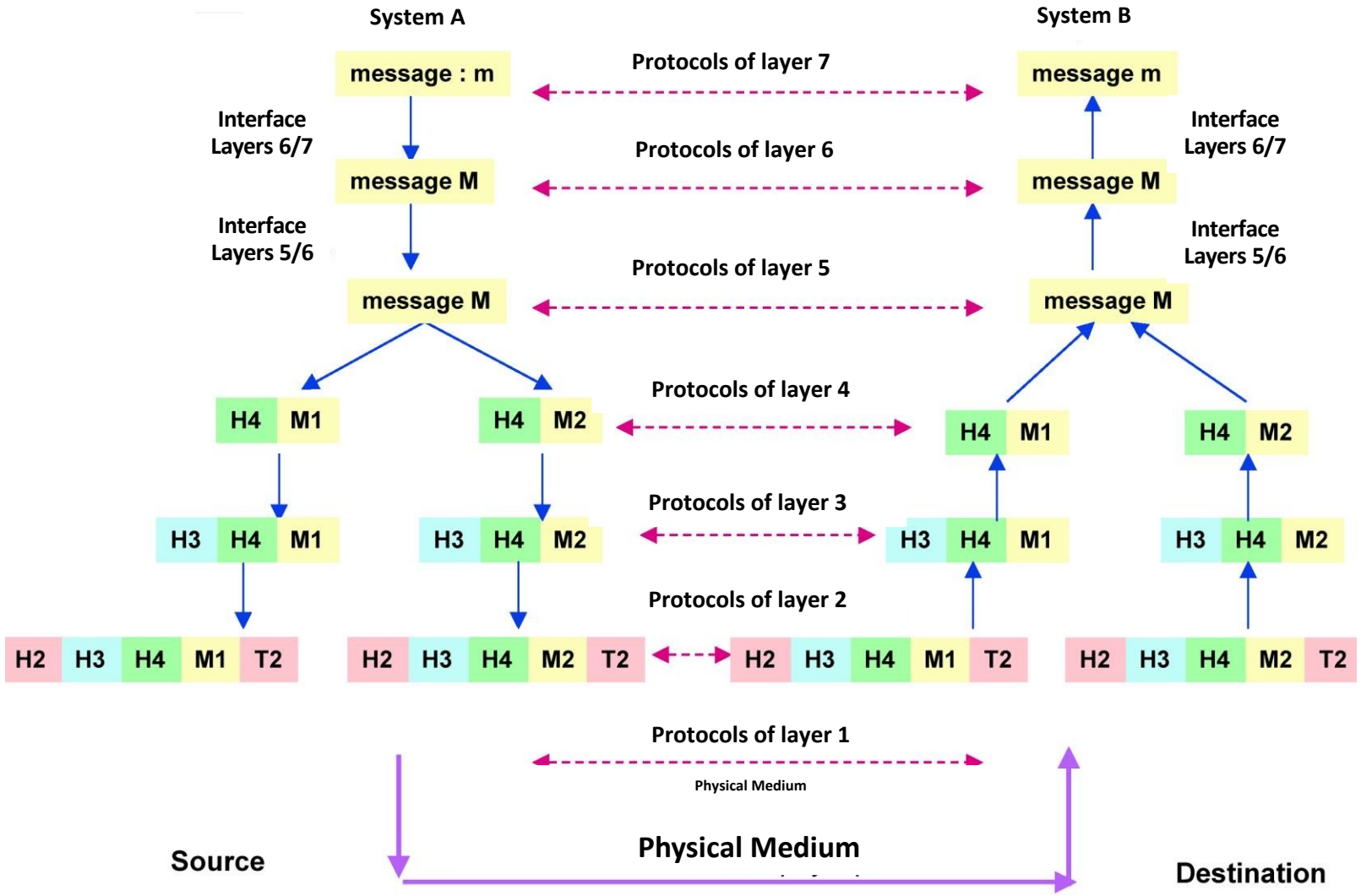
A Network as a System



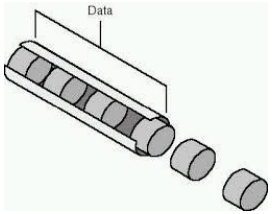
Protocols : set of rules that provide these functionalities
Standards and specifications

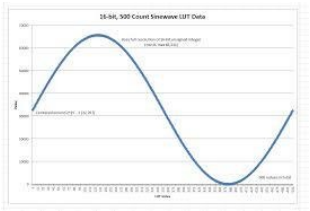
ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

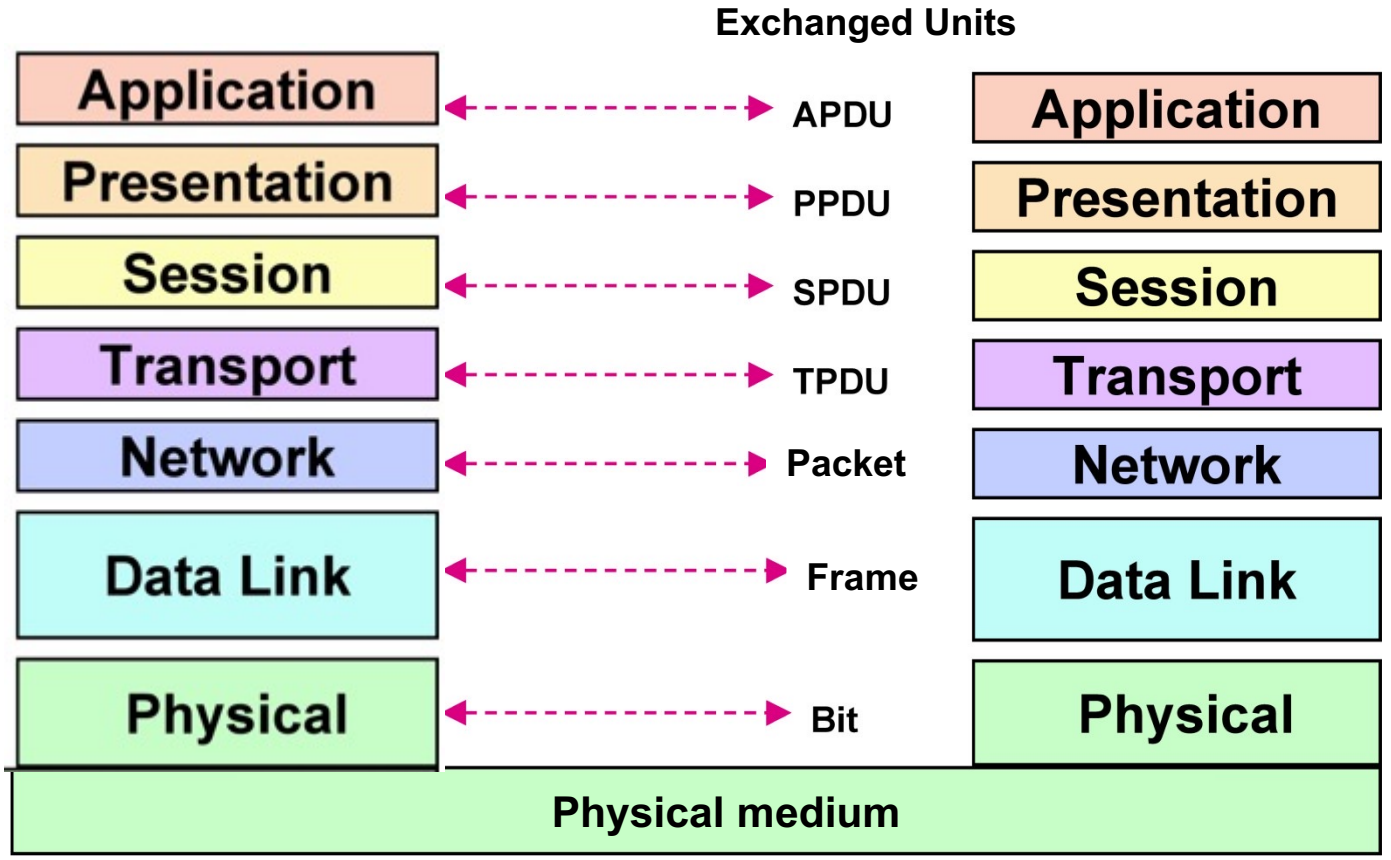
Encapsulation principle



Exchanged data structures

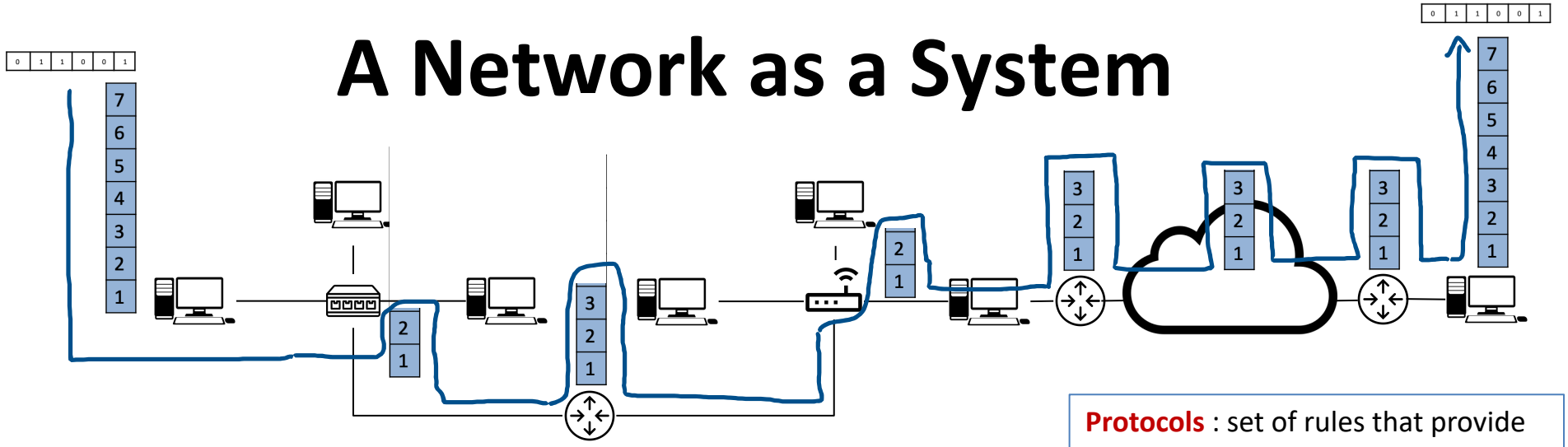






PDU : Protocol Data Unit

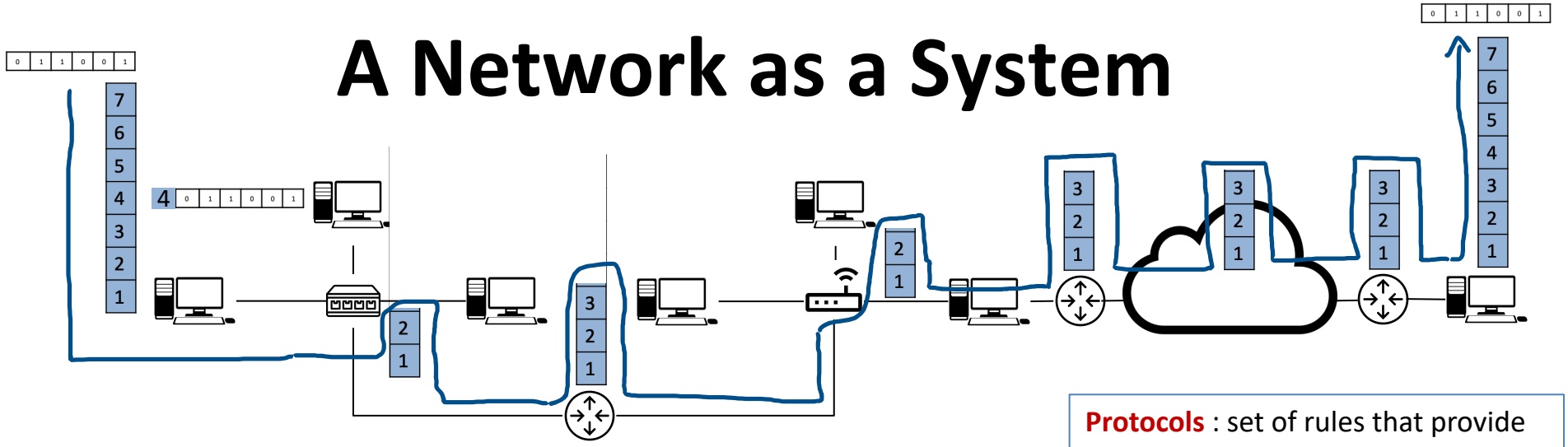
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

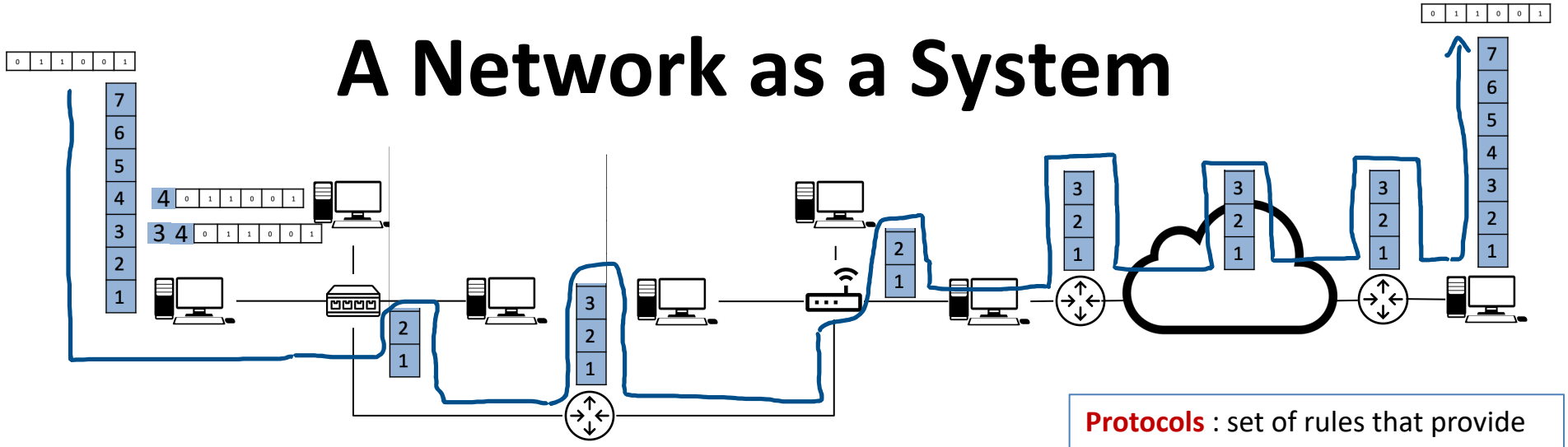
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

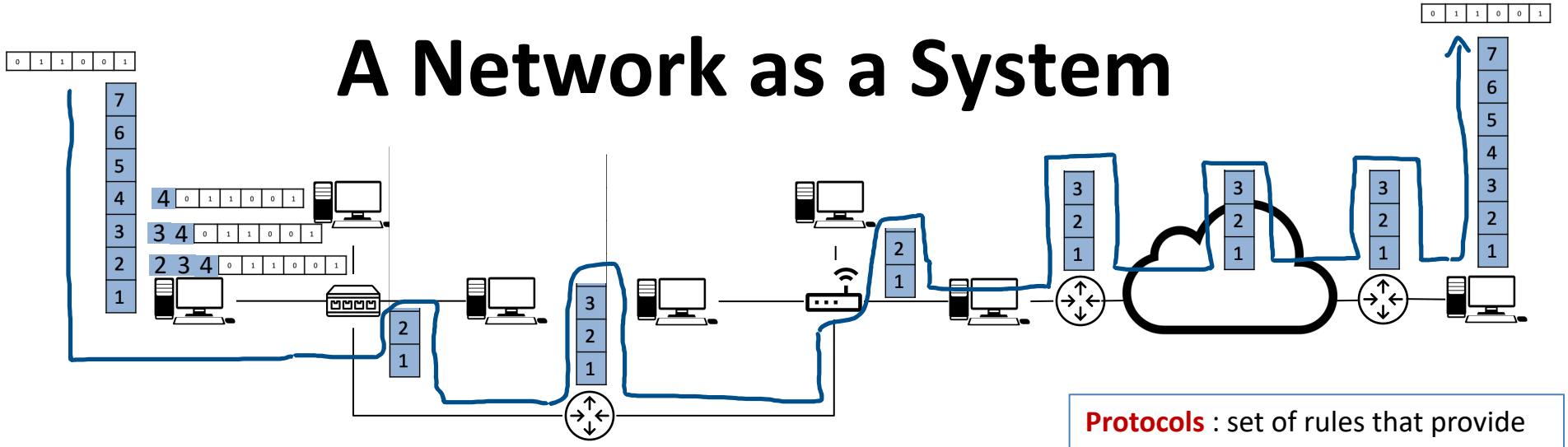
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

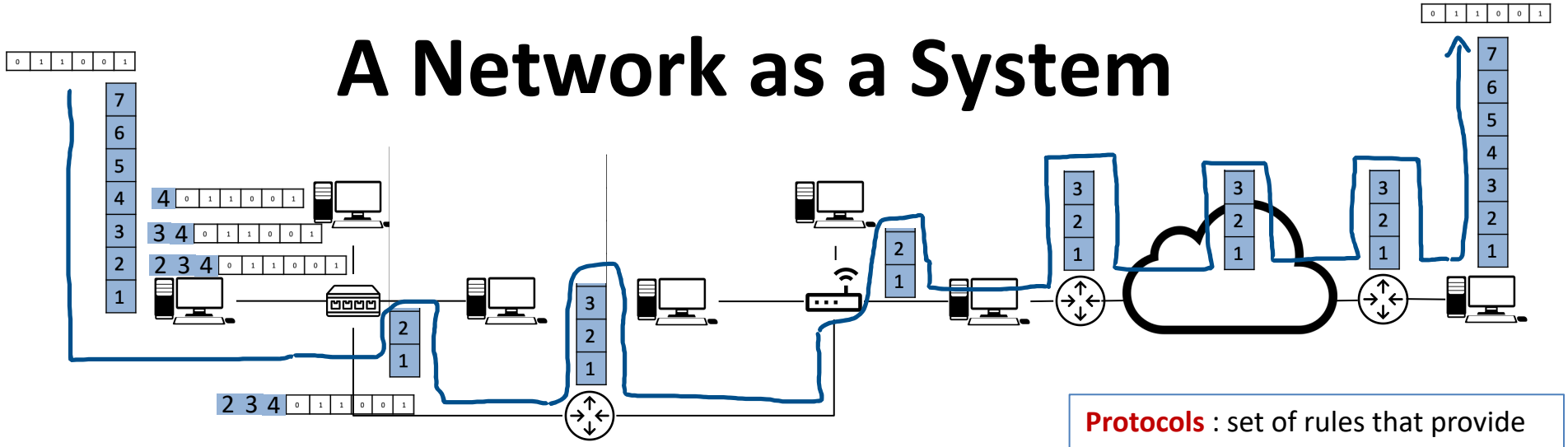
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

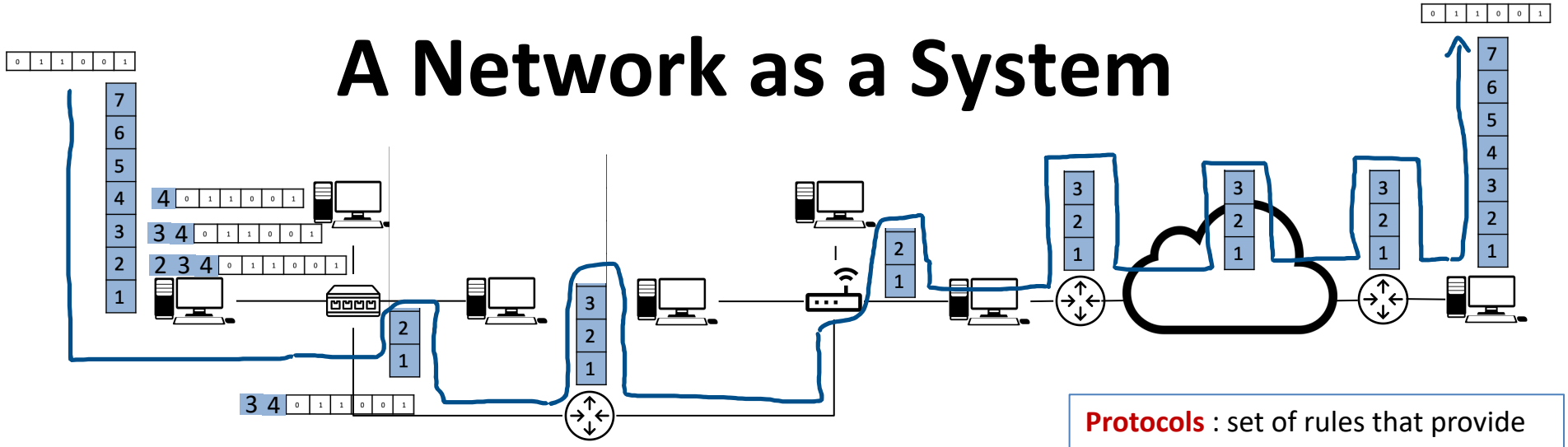
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

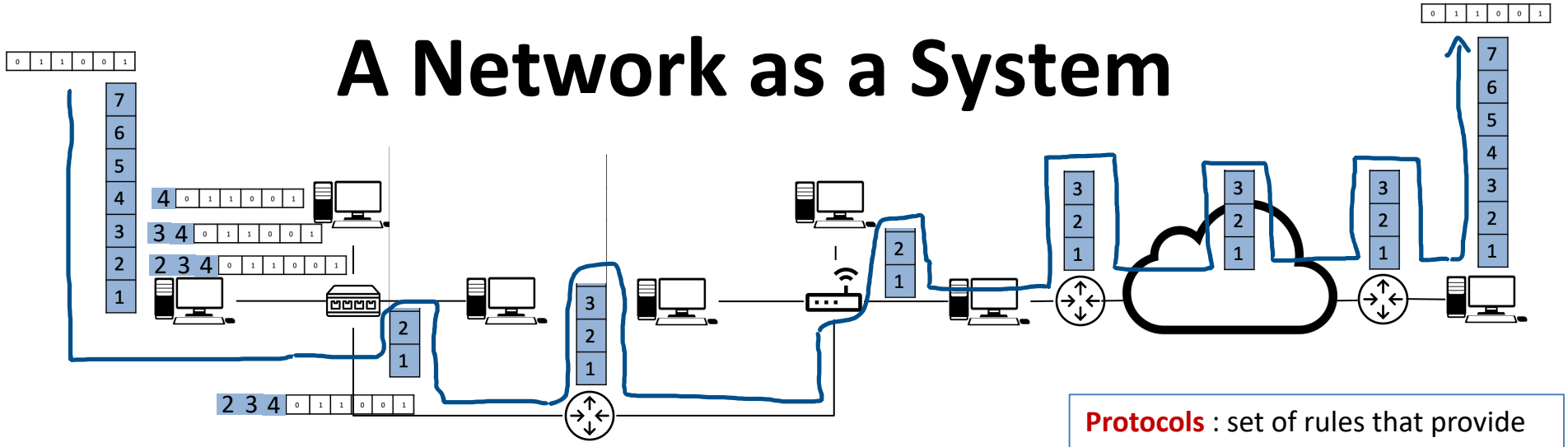
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

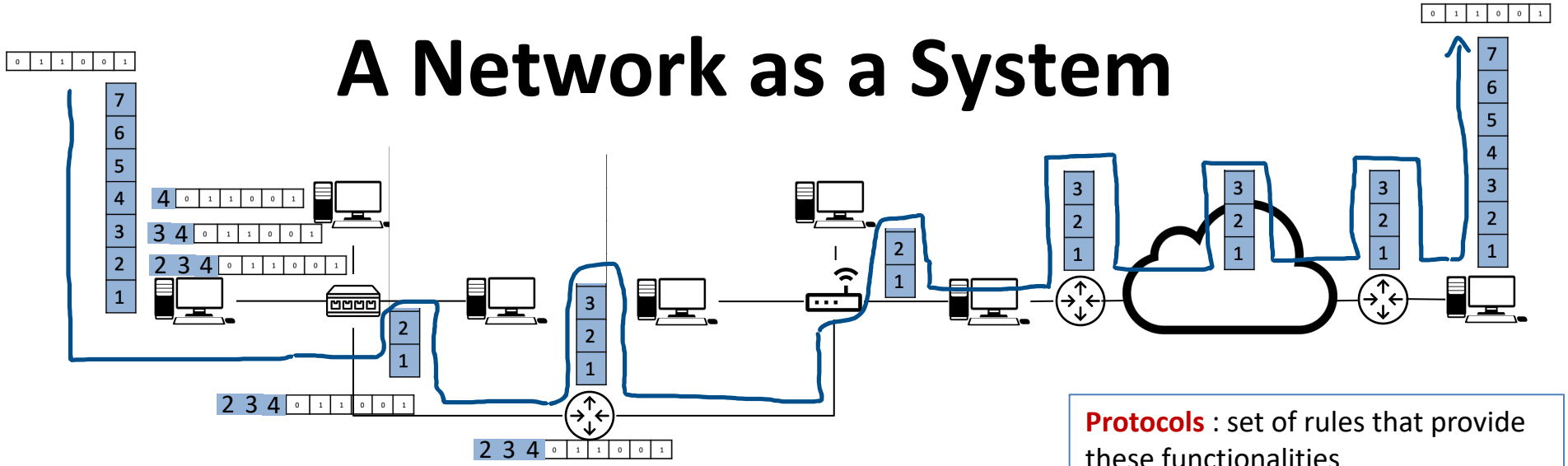
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

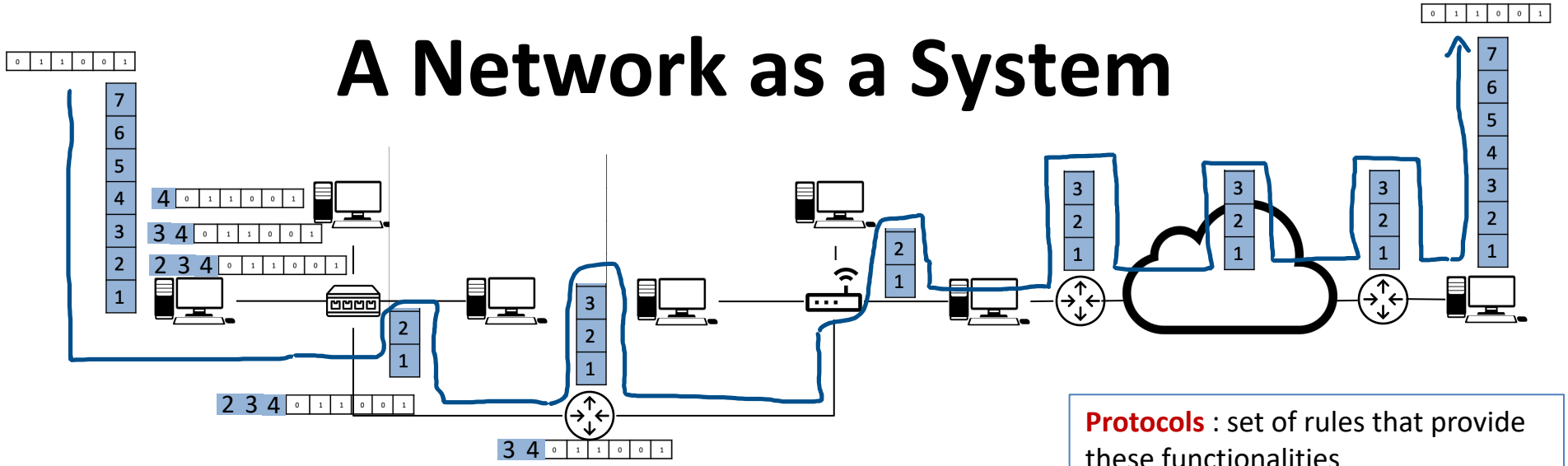
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

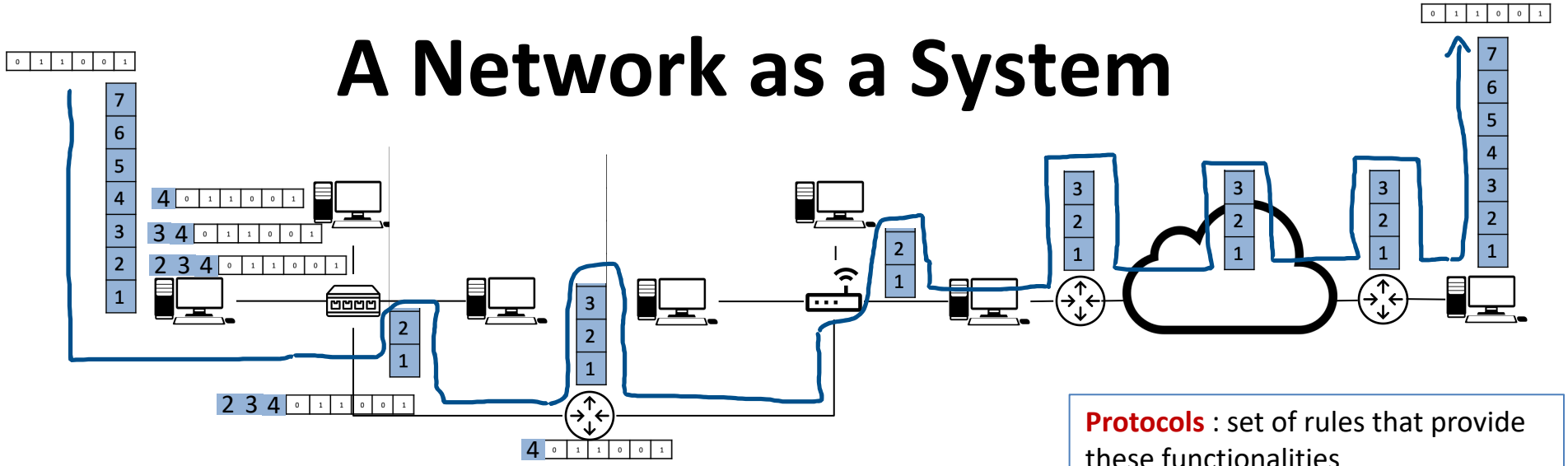
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

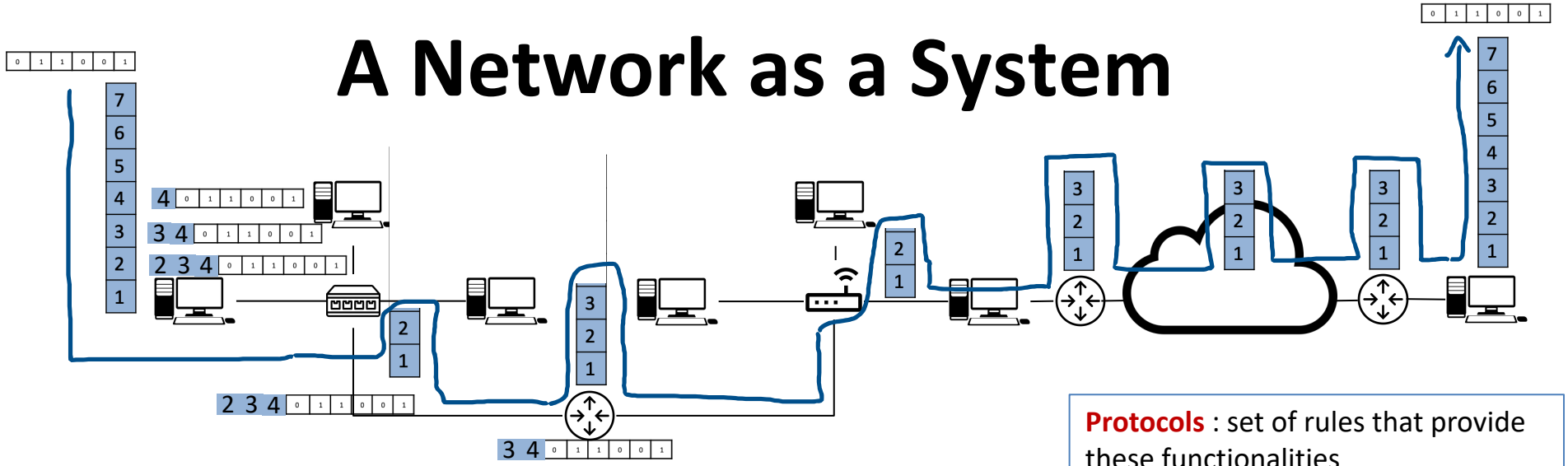
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

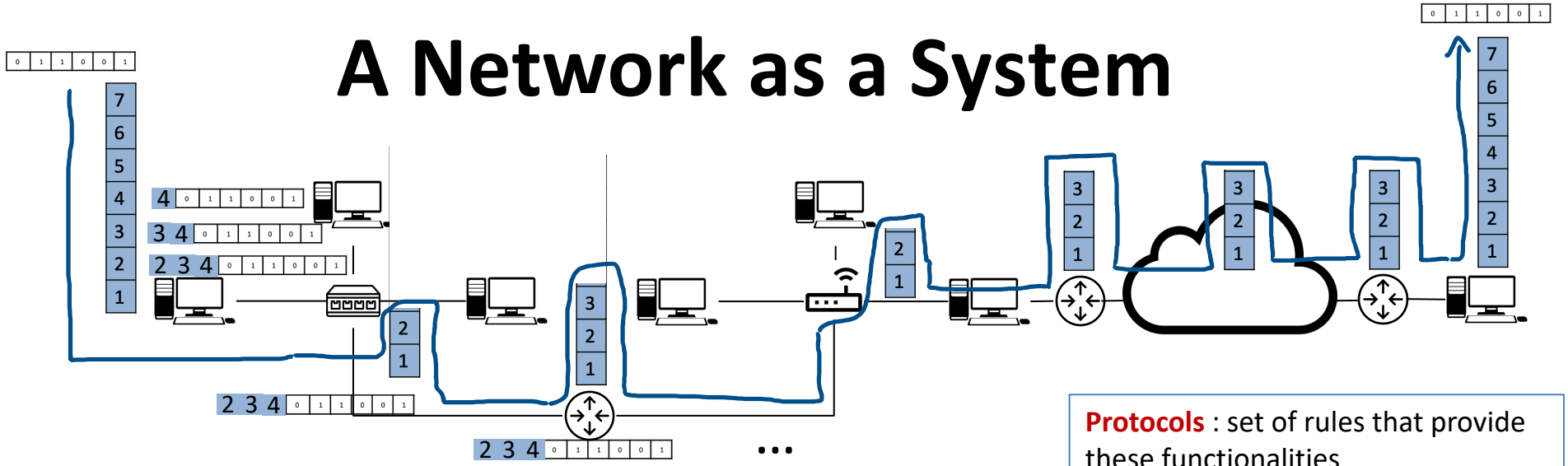
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

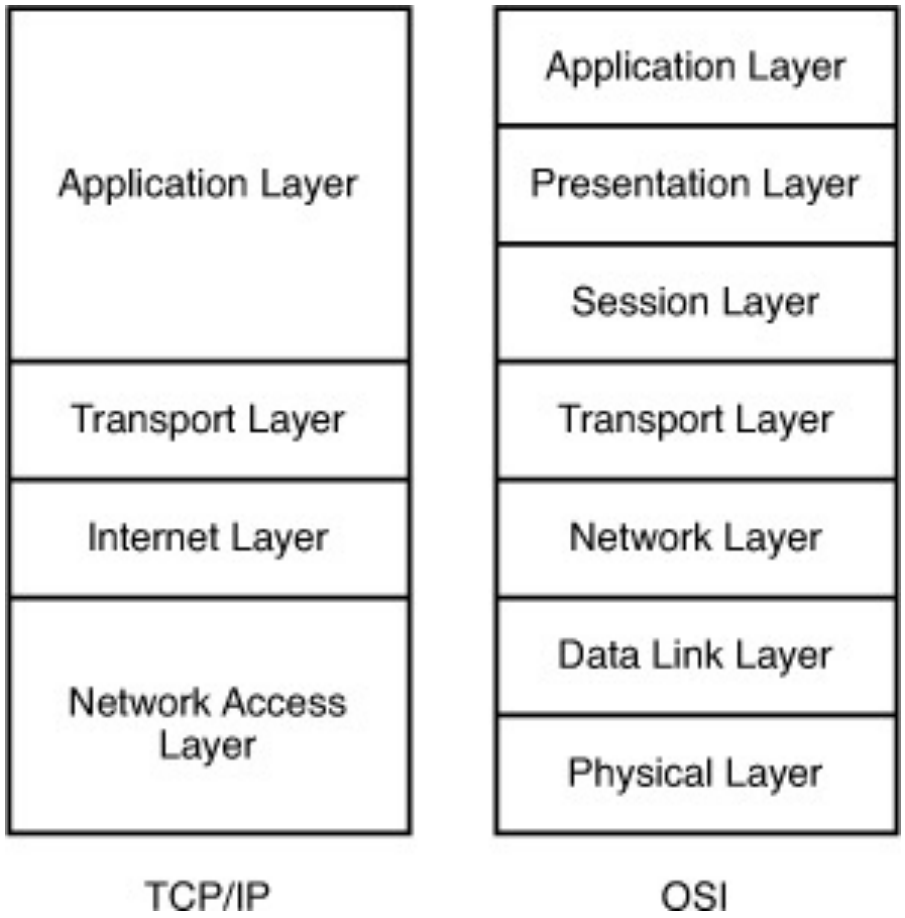
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

OSI Model v.s. TCP/IP Model



OSI Model v.s. TCP/IP Model

- The main differences are:
  - TCP / IP integrates the presentation layer and the session layer in its application layer
  - TCP / IP merges the physical layer and the data link layer of the OSI model in the network access layer
  - TCP / IP has a simpler conception because it has fewer layers
  - TCP / IP protocols are the standard on which the Internet has developed

Network standardization organisms

- International :
  - ISO (International Organisation for Standardisation)
  - ITU (International Teecommunication union)
  - CCITT (Comité Consultatif International Télégraphique et Téléphonique)

- Les Organismes Privés :
  - DARPA du DoD (USA);
  - IEEE (Institute of Electrical and Electronics Engineers) (USA)
  - IETF (Internet Engineering Task Force) (USA)

- Les Organismes Nationaux :
  - AFNOR (Association Française de Normalisation)
  - ANSI (American National Standart Institute) (USA)

ISO International Organization for Standardization IEEE afnor NORMALISATION ANSI American National Standards Institute ITU IETF

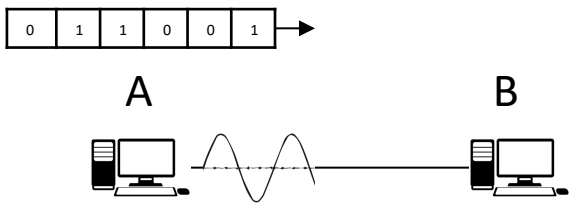
Network & Protocols

TI602

Yessin NEGGAZ

Physical layer (Layer 1)

A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

Physical layer (Layer 1)

Offers mecanical, electrical and electronical procedures and functions :

- to establish, maintain and release the physical connections between devices.
- represents everything that constitutes the physical medium.

Ensures data transmission in the form of electrical signals :

- according to a permanent or dynamic connection
- full duplex, simplex or half duplex
- in series or in parallel
- between one or more end points: point to point or multipoint.

Ensures interface compatibility:

- for baseband encoding (without transposition) or modulation for signal
- for signal amplification
- For multiplexing several signals from different sources

Data transmission

Transmission consists of passing information on the communication medium in the form of digital or analogical signals.

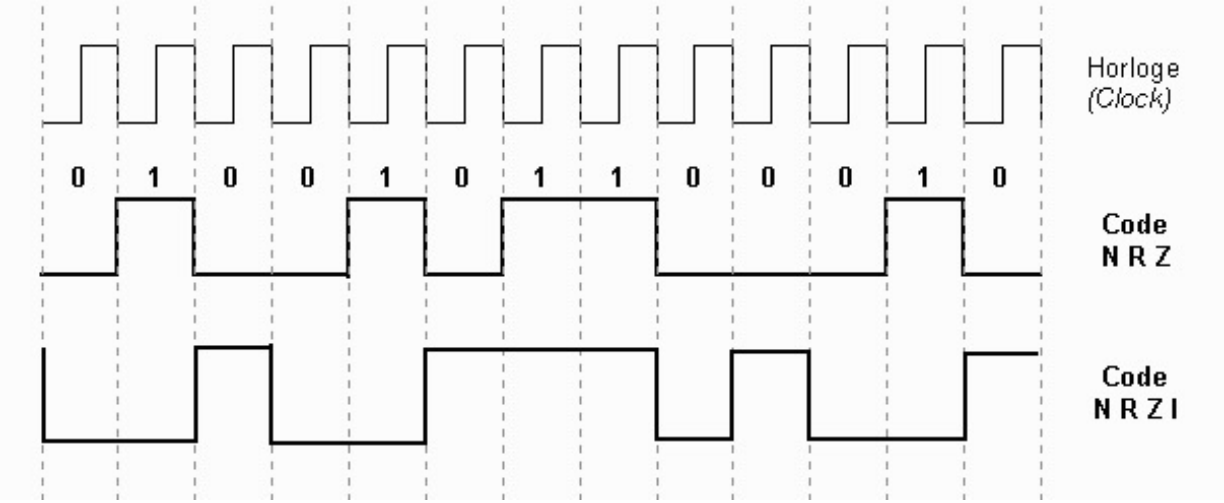
For the transmission to be optimal, the signal must be encoded so as to facilitate its transmission on the physical medium.

Data transmission

- **Digital Data – digital signals**
  - How to represent information bits (encoding)
  - Example : Local networks (LAN)
  - NRZ (non-return to zero) encoding , NRZI, Manchester, etc.

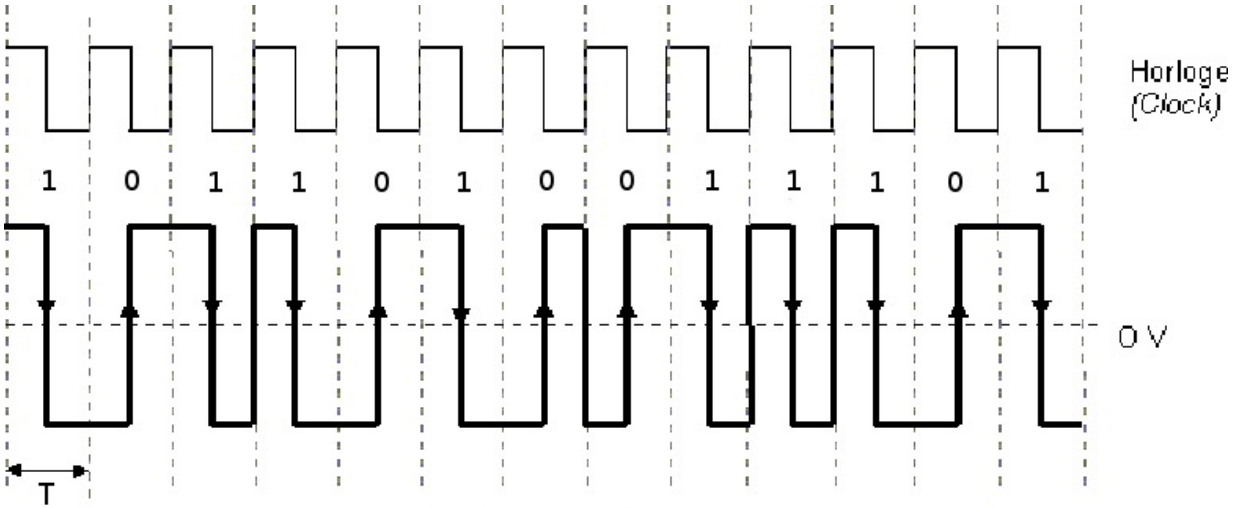
Example : NRZ and NRZI

- NRZ (no return to zero) ➔ encoding « 1 » by +V Volt and 0 by -V Volt
- NRZI (no return to zero inverted) ➔ The encoding of the current bit depends on the precedent one : 0 is represented by a polarity change, no change for 1



Example Manchester

- Duplicates the amount of information to ensure a transition
- Used in the classical local networks transmission
- Encoding rules :
  - 0 ➔ 01
  - 1 ➔ 10



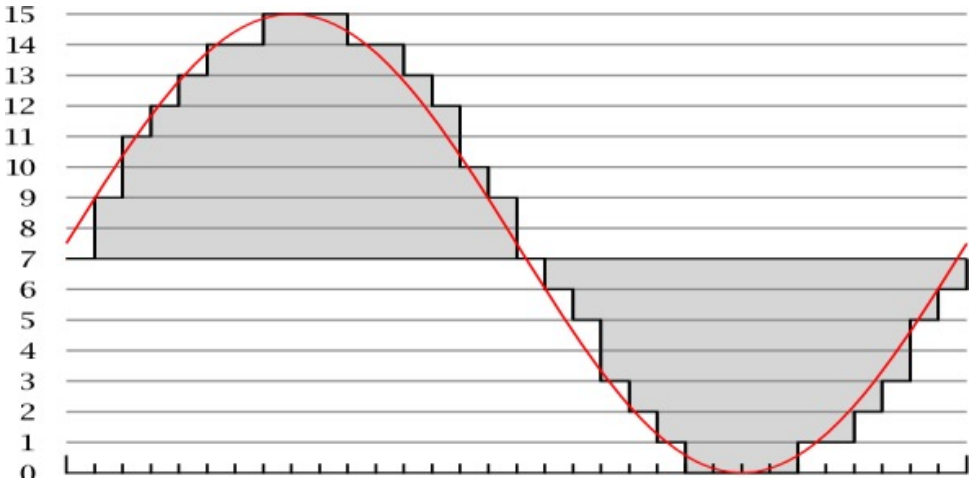
Codage Manchester

Which one should I use ?

- **NRZ :**
  - Good noise resistance
  - Bad adaptation to the support (spectrum centered on the zero frequency)
  - Few transitions => clock synchronization difficulty
- **NRZI**
  - Good synchrinization if the signal stays on 0 for longer periods
- **Manchester**
  - Good noise resistance (2 voltage levels)
  - Good adaptation to wide bandwidth media
  - Lot of transitions => easy clock synchronization

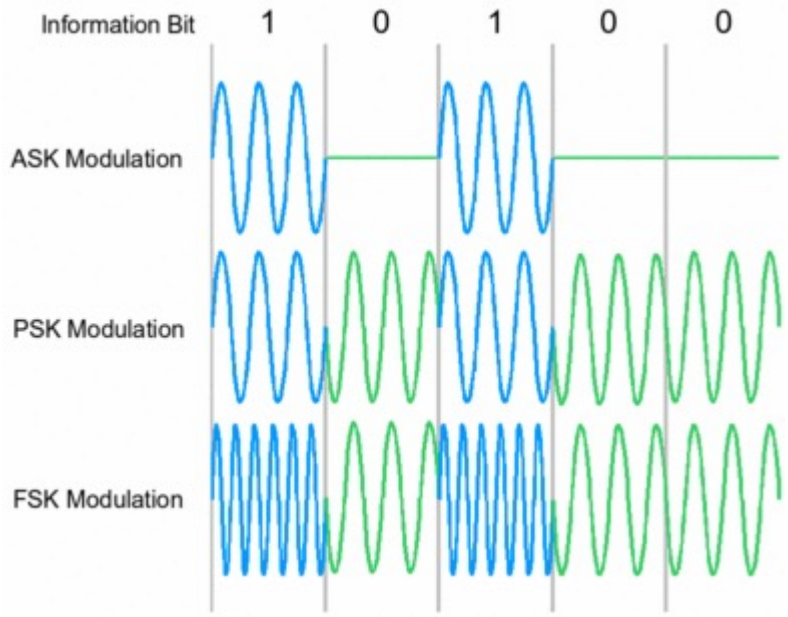
Data transmission

- **Analogical data - digital signals**
  - How to represent a voltage (sampling)
  - Example: Transmitting voice on a digital channel
  - Encoding at 8KH or 64Kbits/s



Data transmission

- **Digital data – analogical signal**
  - How to represent bits (modulation)
  - Example: Digital data transmission over a telephone channel
  - amplitude (ASK: Amplitude Shift Keying), frequency (FSK: Frequency Shift Keying) and phase (PSK: Phase Shift Keying) modulation



Cable specifications

At what **speeds** can data transmission be carried out?

- The speed at which bits are transmitted in a cable is extremely important.
- The type of the medium used influences the transmission speed.

Should transmissions be **digital** or **analog** ?

- Digital (or baseband) transmission requires different types of cable than those used for analog (or broadband) transmission.

•How **far** can a signal travel before attenuation affects transmission?

- If the signal is degraded, network equipment cannot receive or interpret it.
- The distance traveled by the signal in the cable influences the attenuation of the signal.
- The degradation is directly related to the distance traveled by the signal and the type of cable used.

Bandwidth

- Bandwidth represents the amount of information that can flow from one node to another in a given period of time on a given medium. The unit is "bit/s"

- The effective speed of a connection is less than the bandwidth of the cable or physical medium

- Analogy:
  - Bandwidth is like the diameter of a water pipe.
  - Bandwidth can be compared to the number of channels in a highway

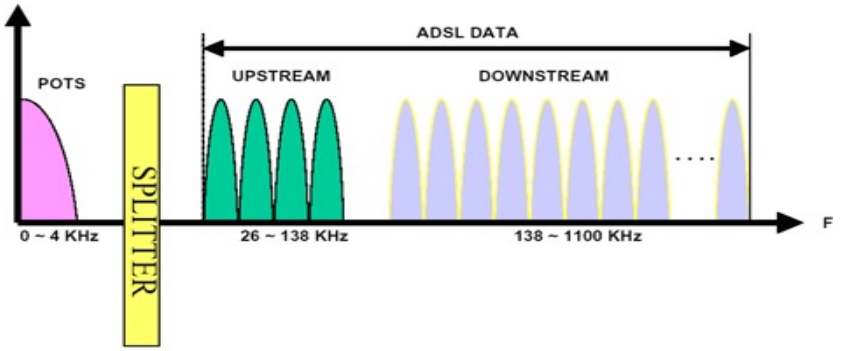
Example : ADSL (Asymmetric Digital Subscriber Line)

Use :

- Asymmetric mode (uplink rate different from downlink rate)
- Permanent connection mode
- Simultaneous voice and data communications

Characteristics :

- Spectrum divided into 3 regions, for example:
  - Telephone: 4 Khz (between 0 and 4 kHz)
  - Upstream data channel: 100 Khz (between 10 kHz and 130 kHz)
  - Descending data channel: 1 Mhz (between 130 Khz and 1.1 Mhz)

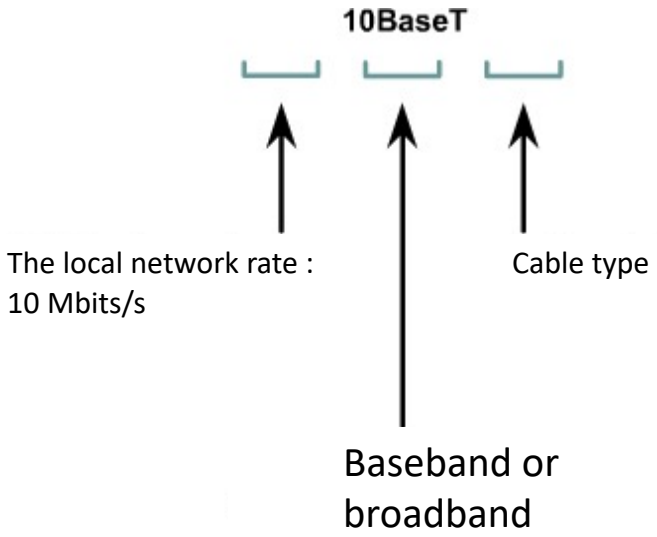


Ethernet

•Several Ethernet variants exist

•Example **10 Base T** :

- 802.3 CSMA/CD
- Full and Half-Duplex
- Base Band
- Manchester Coding
- Twisted Pair



•The Ethernet variants differ in:

- The **type of support** (UTP " *Unshielded twisted Pair* ", STP " *Shielded Twisted Pair* ", Coax, Optical fiber)
- The **type of topology** (*bus, star, tree*)
- The **rate** (*1, 5, 10, 100 Mbps, 1Gbps, 10 Gbps, 100 Gbps, etc.*)

Ethernet 802.3 Examples

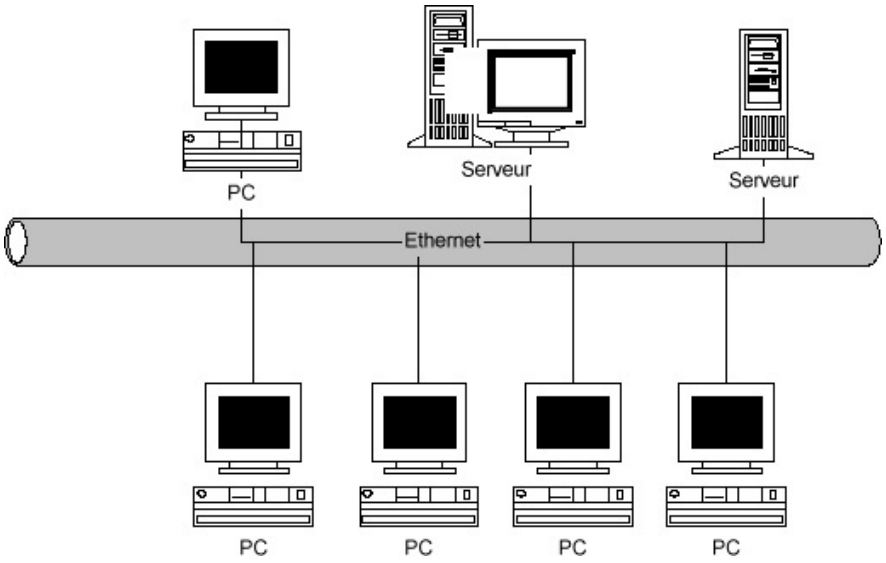
- 10 Base 2 (coax thin)
- 10 Base 5 (coax thick)
- 100 Base T (copper)
- 100 Base F (optical fiber)
- 1 Base 5 (copper)
- 10 Broad 36 (CATV)
- 1000 Base TX/SX/LX (copper, small / long wave laser on fiber)

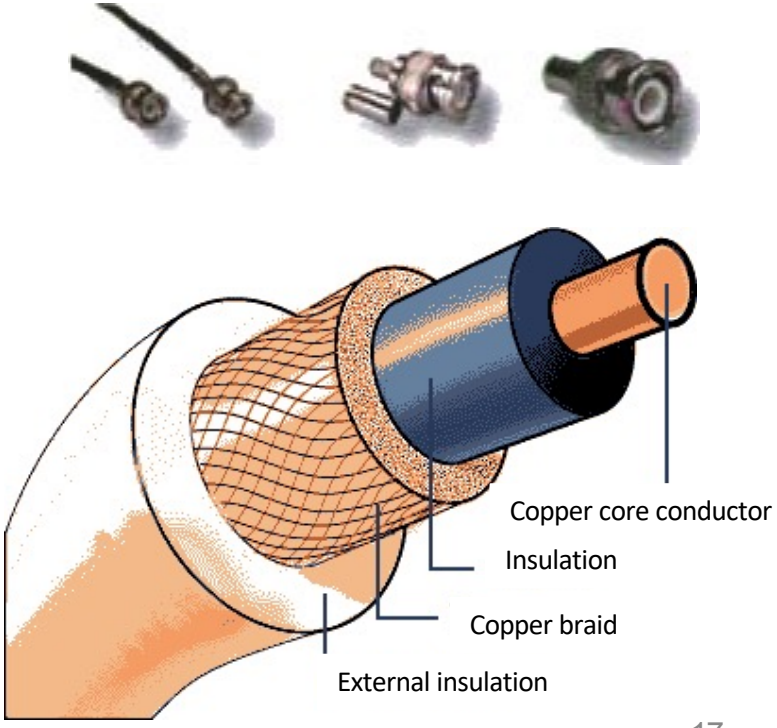
Speed/rate	Signalization method	Medium
10	BASE	2
100	LARGE	5
1000		-T
10G		-TX
		-SX
		-LX

Ethernet 802.3a - 10 base 2 (*Thinnet* ou *Cheapernet*)

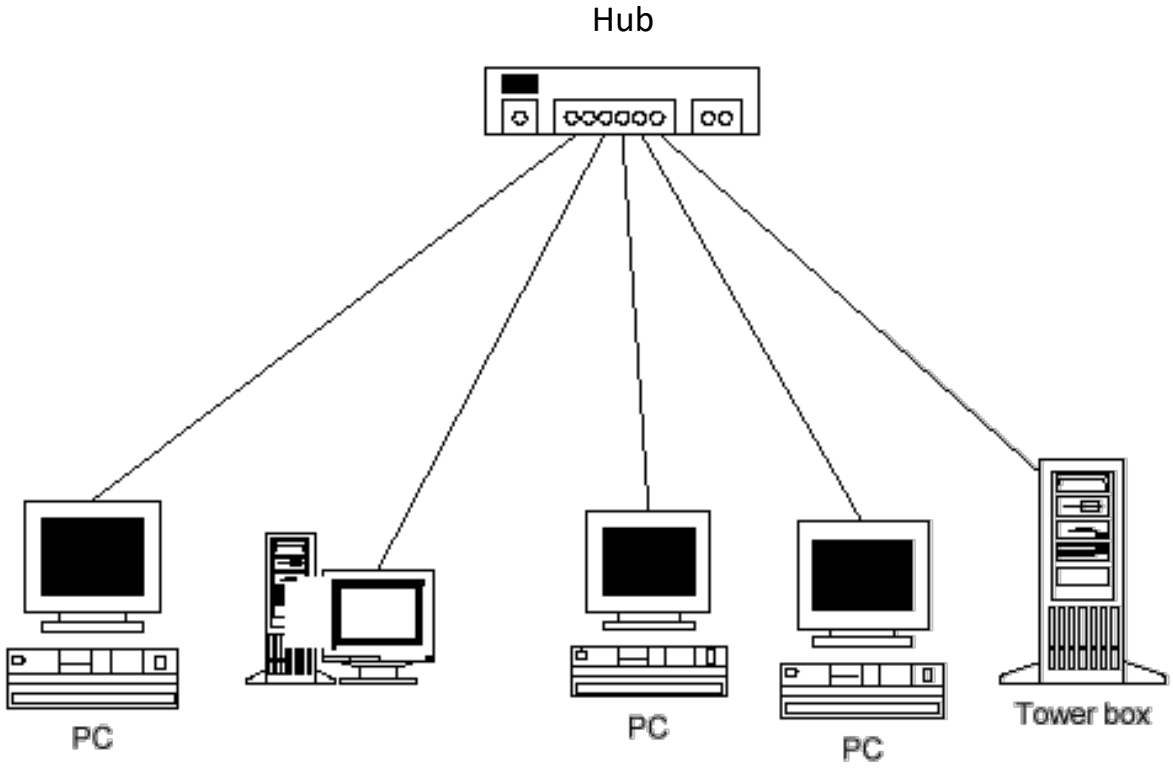
•The components of a thin Ethernet cabling (*thinnet*) are as follows:

- BNC (*Bayonet Neill–Concelman connector*) extenders
- BNC T connectors
- BNC termination plugs





Ethernet 802.3 - 1000 base T



•Advantages :
- Cheaper cables,
- Simple and clean wiring (RJ45 sockets to the BNC connector link),

•Using twisted wire pair (UTP) cables

Twisted Pair Cables

STP

UTP

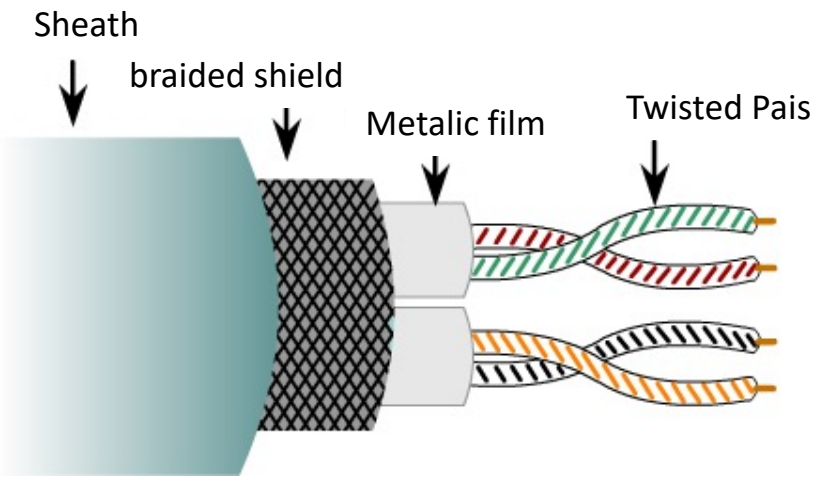
- Two pairs (transmission & reception)
- Distance maintained between the two pairs to reduce **crosstalk**
- More twists => less crosstalk

Shielded Twisted Pair Cable
(STP: Shielded Twisted Pair)

•Each pair of wires is wrapped in metal foil and the two pairs are wrapped together in a braided covering or metallic film.

•This is usually a cable of **150 ohms.**

•As indicated the instructions of the Token Ring network installation, the shielded twisted pairs reduce electrical noise inside the cable (crosstalk), as well as outside (electromagnetic interference and radio).

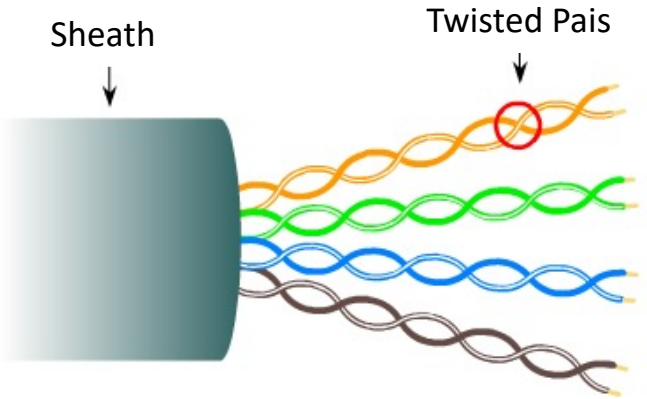


Unshielded Twisted Pair Cable
(UTP: Unshielded Twisted Pair)

•Unshielded Twisted Pair (UTP) cable is a medium consisting of four pairs of wires, found in various types of networks.

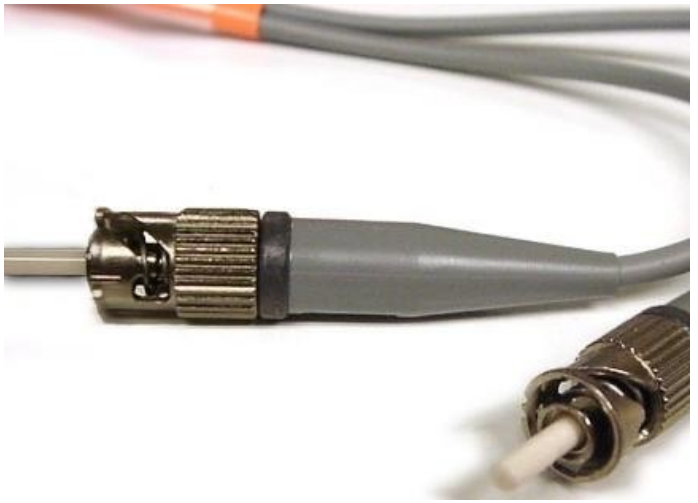
•Each of the eight copper is protected by an insulating material.

•In addition, the pairs are braided together. This type of cable relies only on the twisted pairs technique to limit signal degradation due to electromagnetic and radio interference.

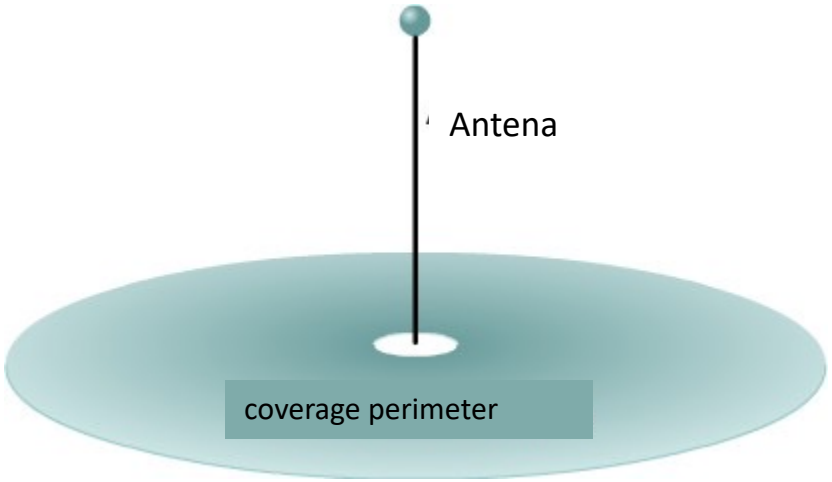


Other physical mediums

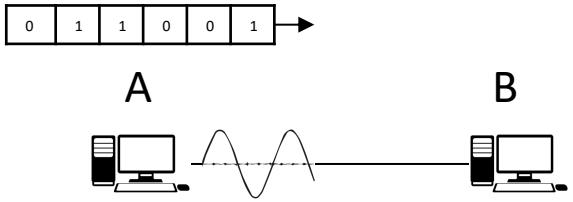
- Optical fibers



- Wireless medium

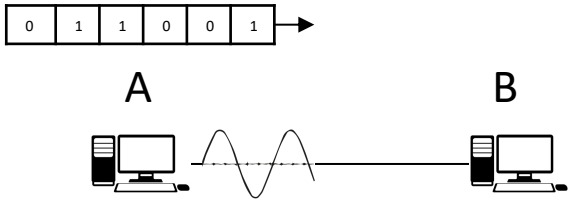


Network transmission parameters



What are the main transmission parameters ?

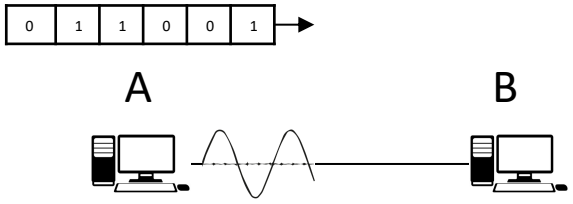
Network transmission parameters



What are the main transmission parameters ?

Propagation time is the time a signal takes to cross a given medium of a given length, limited by its propagation speed (depends on the type of the medium) and its length.

Network transmission parameters

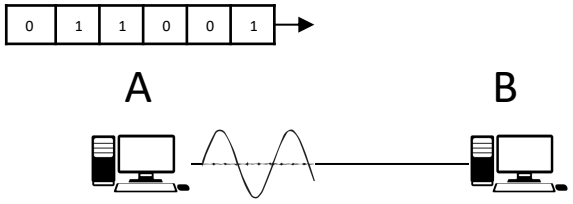


What are the main transmission parameters ?

Propagation time is the time a signal takes to cross a given medium of a given length, limited by its propagation speed (depends on the type of the medium) and its length.

Data emission rate is the amount of data provided by a computer in a given time unit before the transmission, limited by the capacity of this later and its network card.

Network transmission parameters



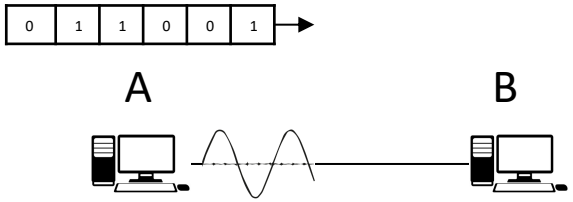
What are the main transmission parameters ?

Propagation time is the time a signal takes to cross a given medium of a given length, limited by its propagation speed (depends on the type of the medium) and its length.

Data emission rate is the amount of data provided by a computer in a given time unit before the transmission, limited by the capacity of this later and its network card.

Emission time is the time necessary for the emission of a given amount of data, limited by the data emission rate

Network transmission parameters



What are the main transmission parameters ?

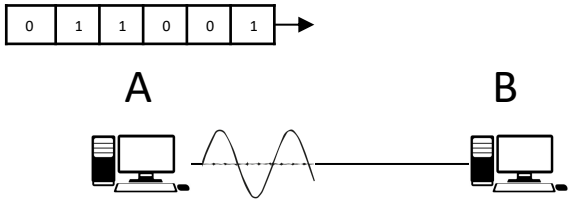
Propagation time is the time a signal takes to cross a given medium of a given length, limited by its propagation speed (depends on the type of the medium) and its length.

Data emission rate is the amount of data provided by a computer in a given time unit before the transmission, limited by the capacity of this later and its network card.

Emission time is the time necessary for the emission of a given amount of data, limited by the data emission rate

Data transfer rate is the amount of data that is moved from a source to a destination in a given time unit, limited by the bandwidth of the meduim and the data emission rate.

Network transmission parameters



What are the main transmission parameters ?

Propagation time is the time a signal takes to cross a given medium of a given length, limited by its propagation speed (depends on the type of the medium) and its length.

Data emission rate is the amount of data provided by a computer in a given time unit before the transmission, limited by the capacity of this later and its network card.

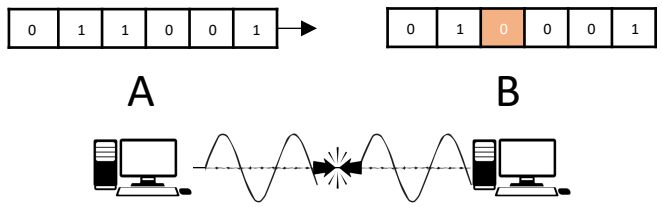
Emission time is the time necessary for the emission of a given amount of data, limited by the data emission rate.

Data transfer rate is the amount of data that is moved from a source to a destination in a given time unit, limited by the bandwidth of the meduim and the data emission rate.

Transfer time is the time necessary for the transfer of a given amount of data, limited by the data transfer rate

Medium access control method (layers 1,2)

A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	**3. Manage the concuren access to the shared medium (avoid collision) – medium access control** 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

Medium access protocols

• Depending on the way in which requests for access to the communications medium are managed, there are essentially two approaches:

- **Random allocation** : the access time is not limited
  - Example of dynamic access policies with random allocation
    - Aloha
    - Carrier Sense Multiple Access - CSMA

- **Deterministic allocation** : it is possible to limit the access time
  - Example of dynamic access policies with deterministic allocation
    - Polling
    - the token

• Ethernet exploits the technique of **random access** to the medium

Ethernet ancestor : Alohanet

•The idea was to allow at least **two hosts to use the same media** without any interference between the signals.

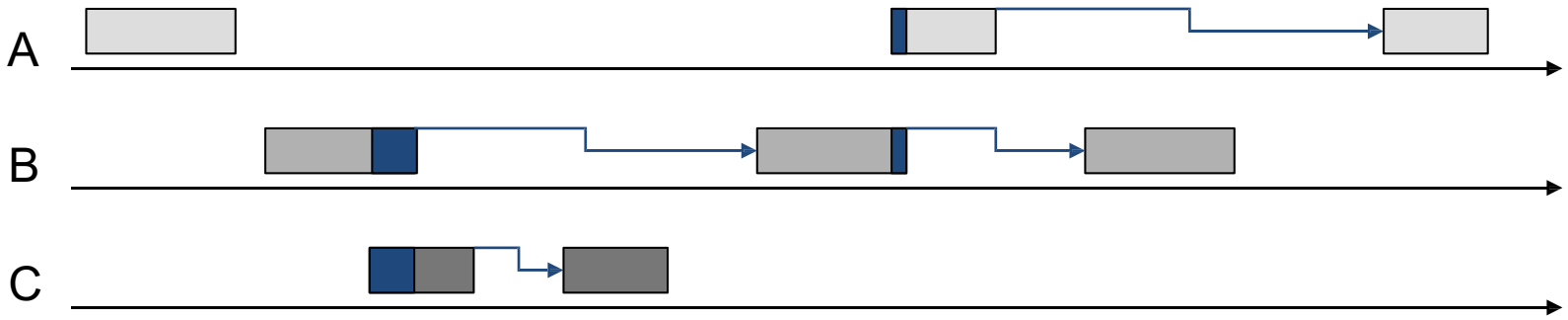
•This problem of multiple user access to shared media was investigated in the early 1970s at the University of Hawaii.

•A system called **Alohanet** was developed to give several stations in the Hawaiian Islands structured access to the shared radio frequency in the atmosphere.

•This work subsequently **formed the basis of the Ethernet access method** known by the acronym **CSMA / CD**.

(Pure) Aloha

- **Principle**
  - a station send whenever it wishes
  - in the event of a collision, the station will send again its frame at the end of a random delay,
  - after *N* successive collisions, the station abandons



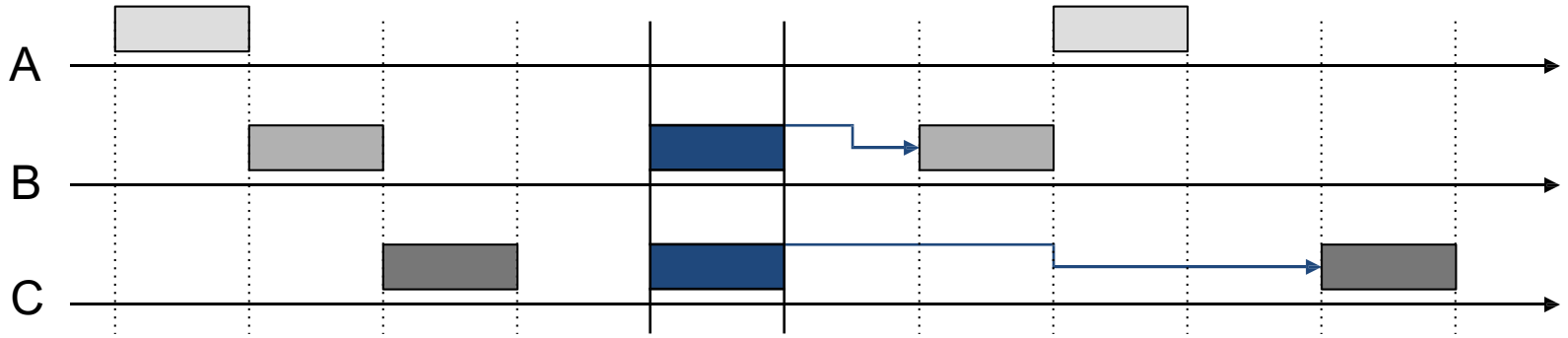
- Very low efficiency: **18%** !
- The efficiency of a channel is defined by the ratio:
  effective rate / theoretical rate

Slotted Aloha

- **Principle**
  - time is **discretized** and divided into time slices called **slots**
- slot = maximum round trip delay
- Stations are synchronized
- A station sends a packet at the start of a slot

Slotted Aloha

- Enhanced version of Aloha since 2 frames overlap only on one slot at most, instead of 2 slots (because they start at the beginning of the same slot).
- Problem: Incorrect (not optimized) use of the channel



CSMA Technique IEEE 802.3

- Random access with carrier listening: **CSMA** (*Carrier Sense Multiple Access*).
  - a station that wishes to send starts listening to the channel;
  - if it detects a signal online, it defers the transmission of its frame.

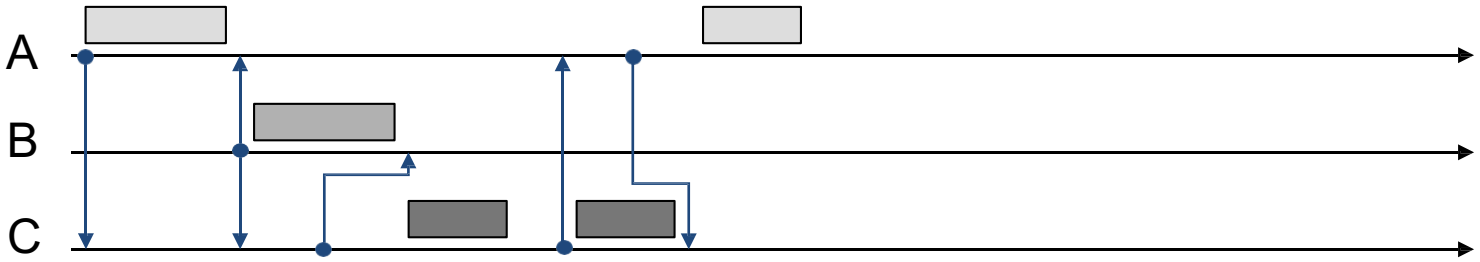
- Different variants depending on the type of decision made when the channel is detected busy :

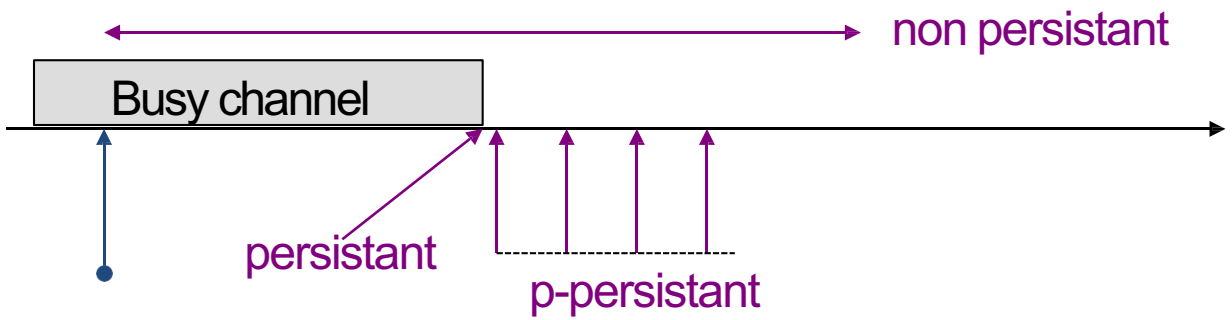
  - **Non-persistent CSMA** : when the station detects a signal, it waits for a random delay before repeating the procedure (listening to the carrier, etc.);

  - **Persisting CSMA** the station persists in listening to the channel until it becomes free, then sends;

  - **P-persistent CSMA** : when the channel becomes free, the station sends with a probability p, and defers its transmission with a probability (1-p). This makes it possible to reduce the probability of collision.

CSMA





CSMA / CD Technique

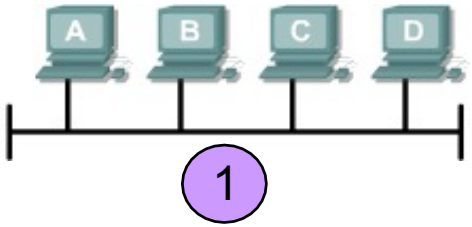
- Vulnerability period: the propagation time between the pair of the most distant stations.

- If the duration of the frames is considerably greater than the vulnerability period then the connection rate can approach 100%.

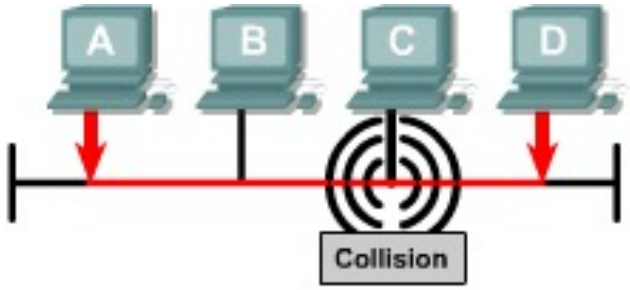
- **CSMA / CD** (**CSMA** with collision detection)
  - CD = *Collision Detection*
  - The most used technique among random access disciplines.
  - This is the method standardized by ISO.

Collision detection and prevention with CSMA / CD

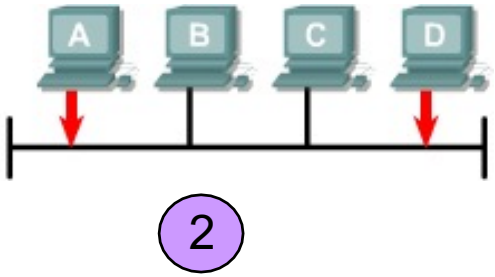
Free medium detection



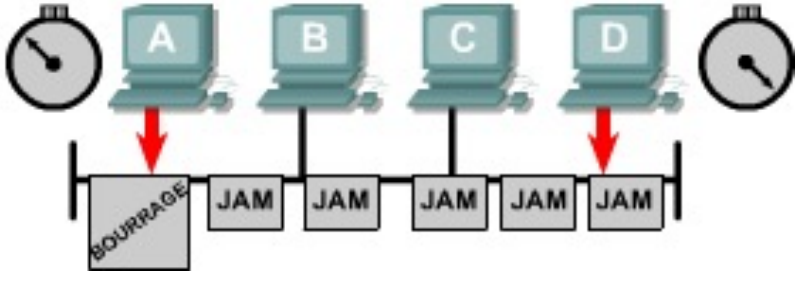
Collision



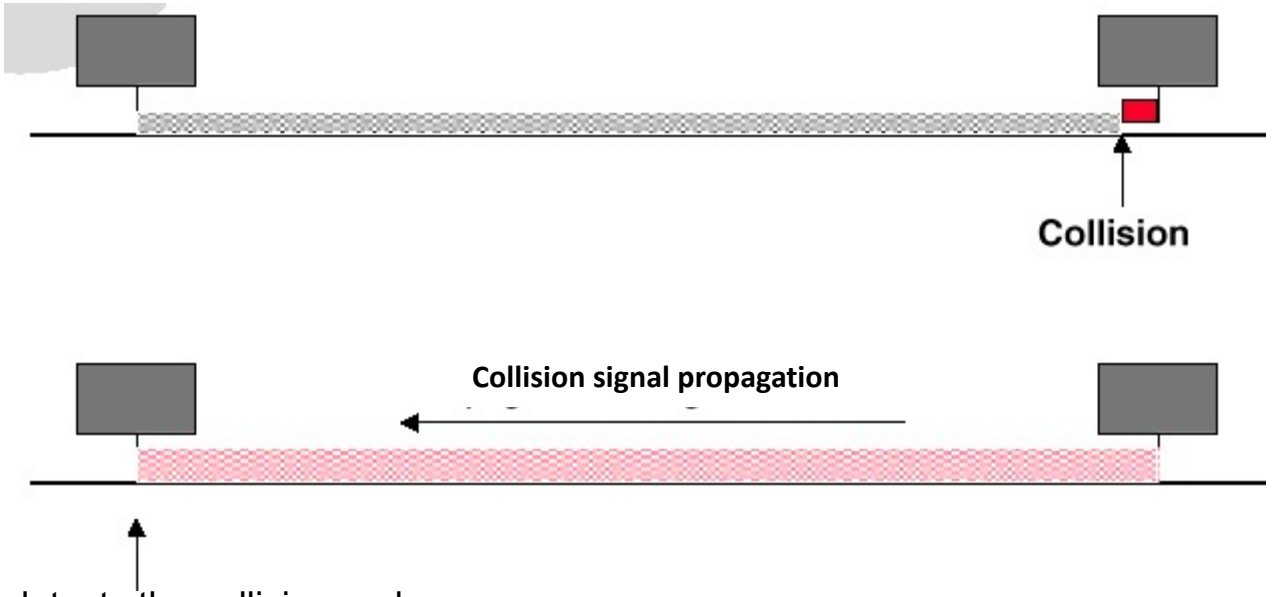
Multiple access



Collision detection



Collision detection and prevention with CSMA / CD

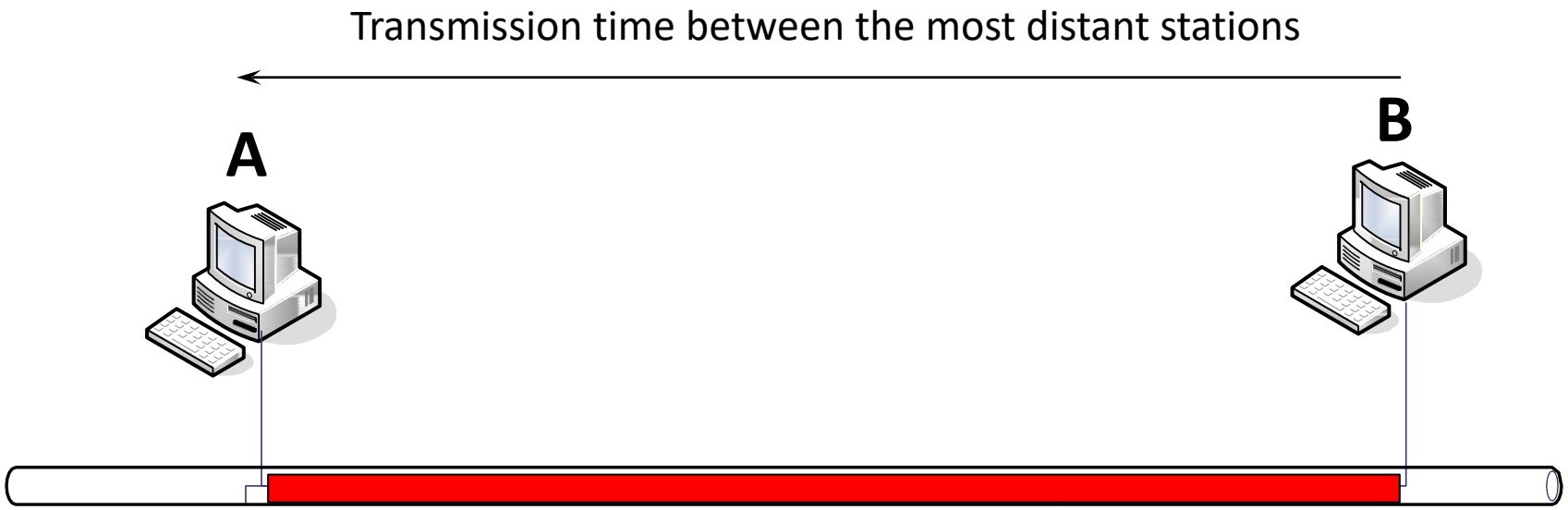


A detects the collision and
stops the transmission

Max duration = Round Trip Time (RTT) = Distance / Speed
Frame emission time = Frame length / Channel rate

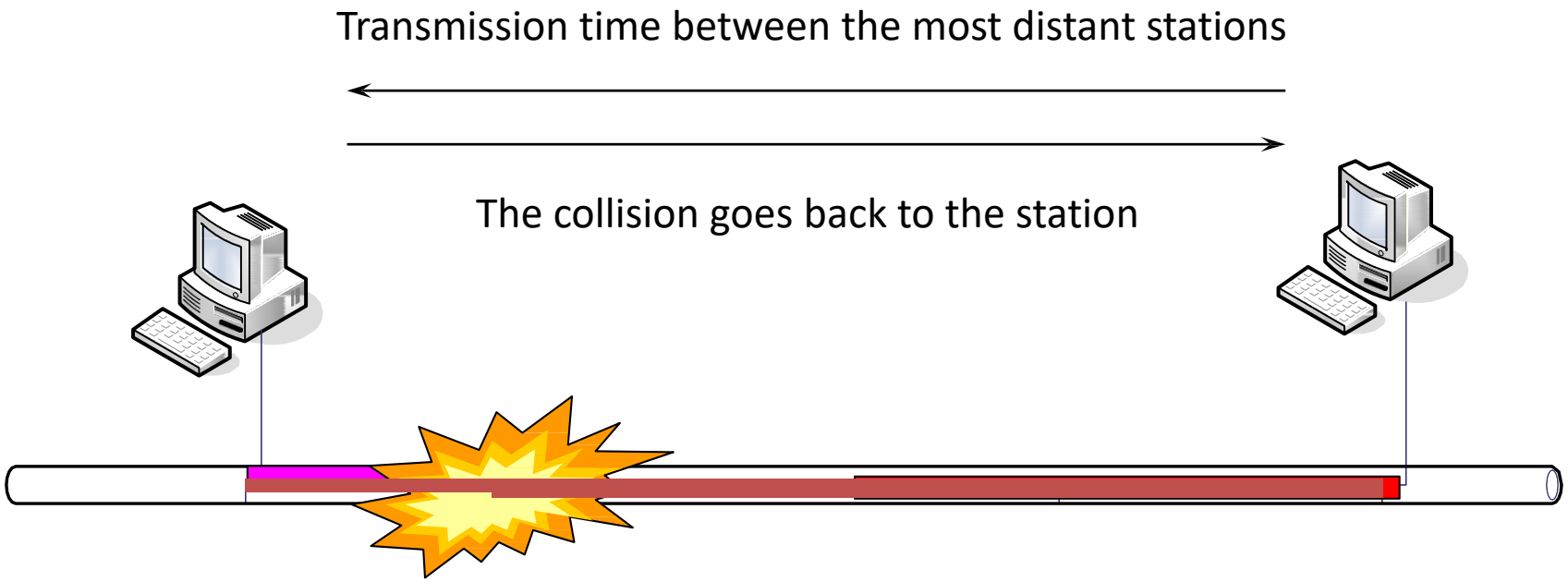
What is the condition for CSMA / CD to work properly ?

CSMA / CD time interval



Channel occupancy must be long enough to ensure that no other station transmits at the same time

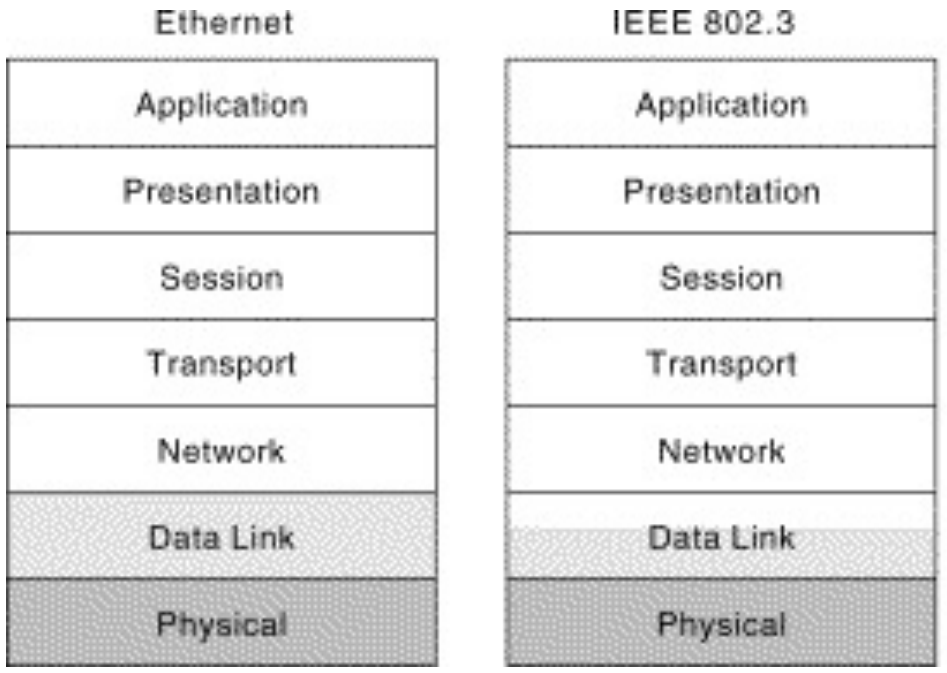
Intervalle de temps CSMA/CD



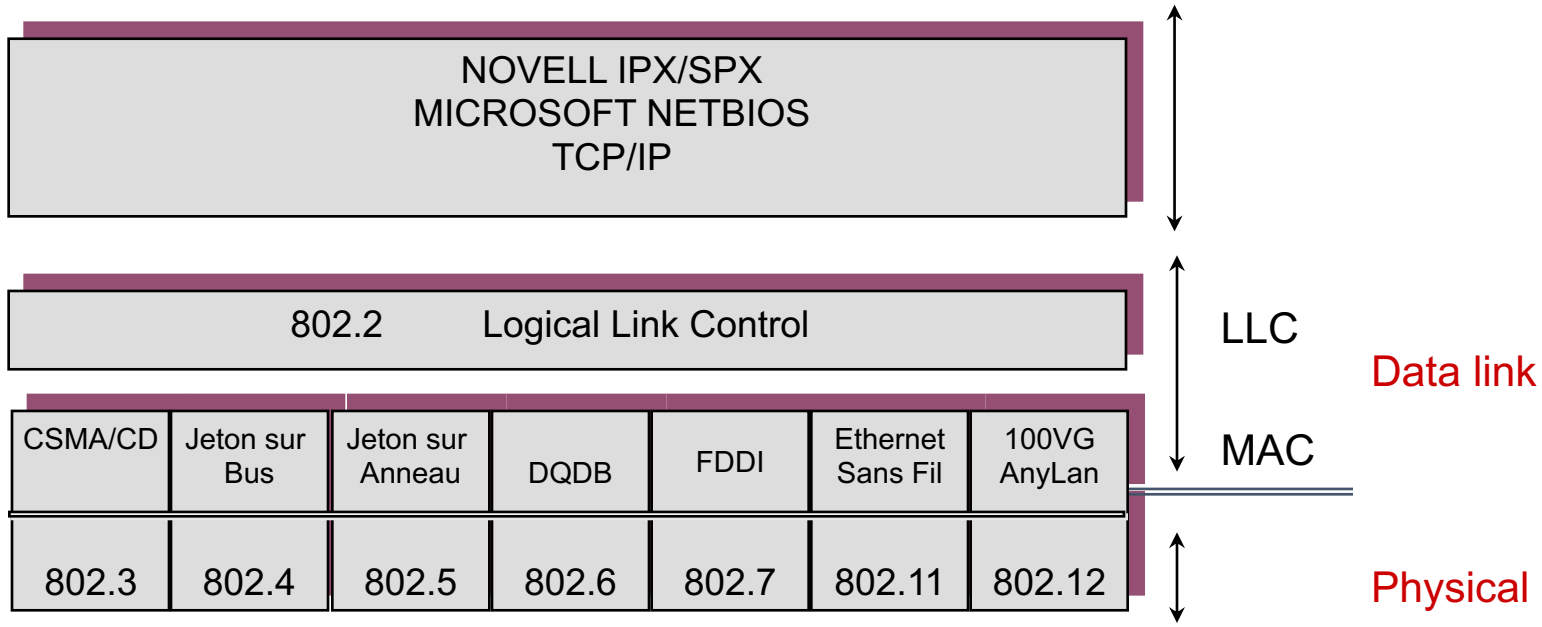
This collision is not perceived by the transmitter
→ channel occupancy problem

Differences between Ethernet and IEEE802.3

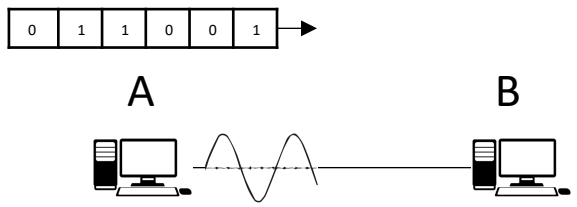
- Remark :
  - 802.3 : Concerns only the physical layer and MAC sublayer
  - Ethernet : Physical layer+ MAC + LLC + topologie + Meduim + transmission techniques = the complete specification of a LAN



IEEE 802 general architecture



A Network as a System



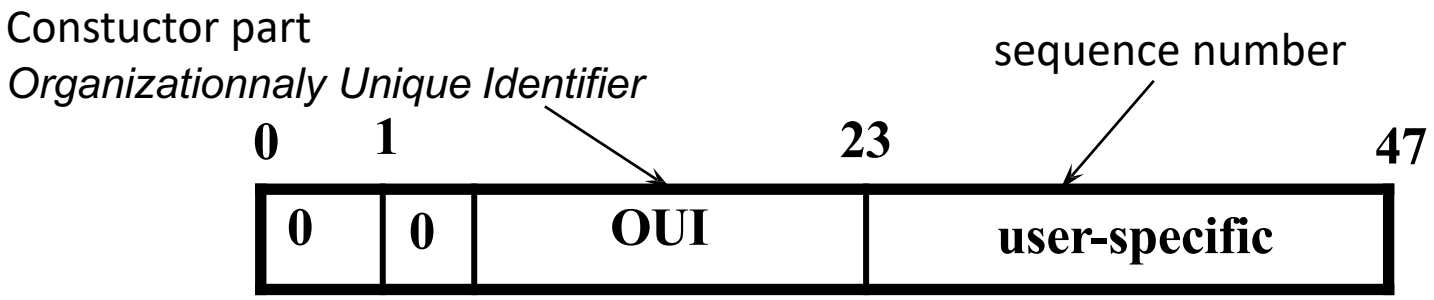
Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching **6. Identify a machine in a network – physical adress**
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

Universal Address MAC 802

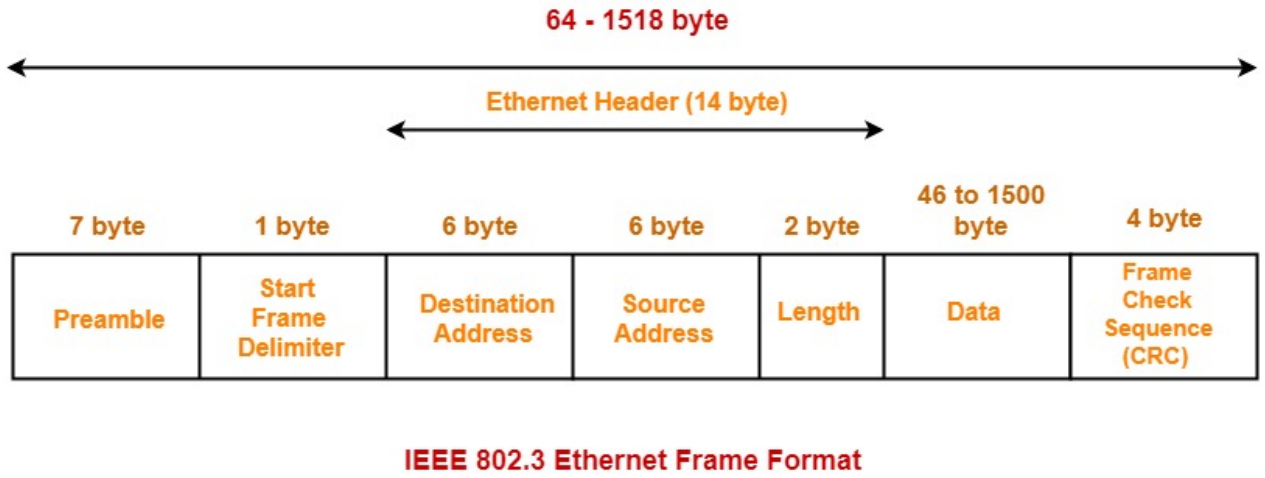
- 6 bytes address (48bits)
- Unique to each network card
- MAC address = Constuctor part + a sequence number

– **00:00:0C**:XX:XX:XX : **Cisco**
– **08:00:20**:XX:XX:XX : **Sun**
– **08:00:09**:XX:XX:XX : **HP**
– **08:00:14**:XX:XX:XX : **Excelan**



- The address **FF:FF:FF:FF:FF:FF** Is used to broadcast the message to all the machines on the network

Ethernet frame structure



IEEE 802.3 Ethernet Frame Format

- Ethernet 802.3 frame contains the following mandatory fields:
  - **Preambule**
  - **Start Frame Delimiter (SFD)**
  - **Destination address**
  - **Source address**
  - **Type/length** (type if < 1500, length otherwise)
  - **Data** : the uper layer packet
  - **Frame check sequence (FCS)** : error control

- 0800 IP
- 0806 ARP
- 6000 à 6009 DEC (6004 LAT)
- 8019 DOMAIN (Apollo)
- 8038 DEC LANBridge management

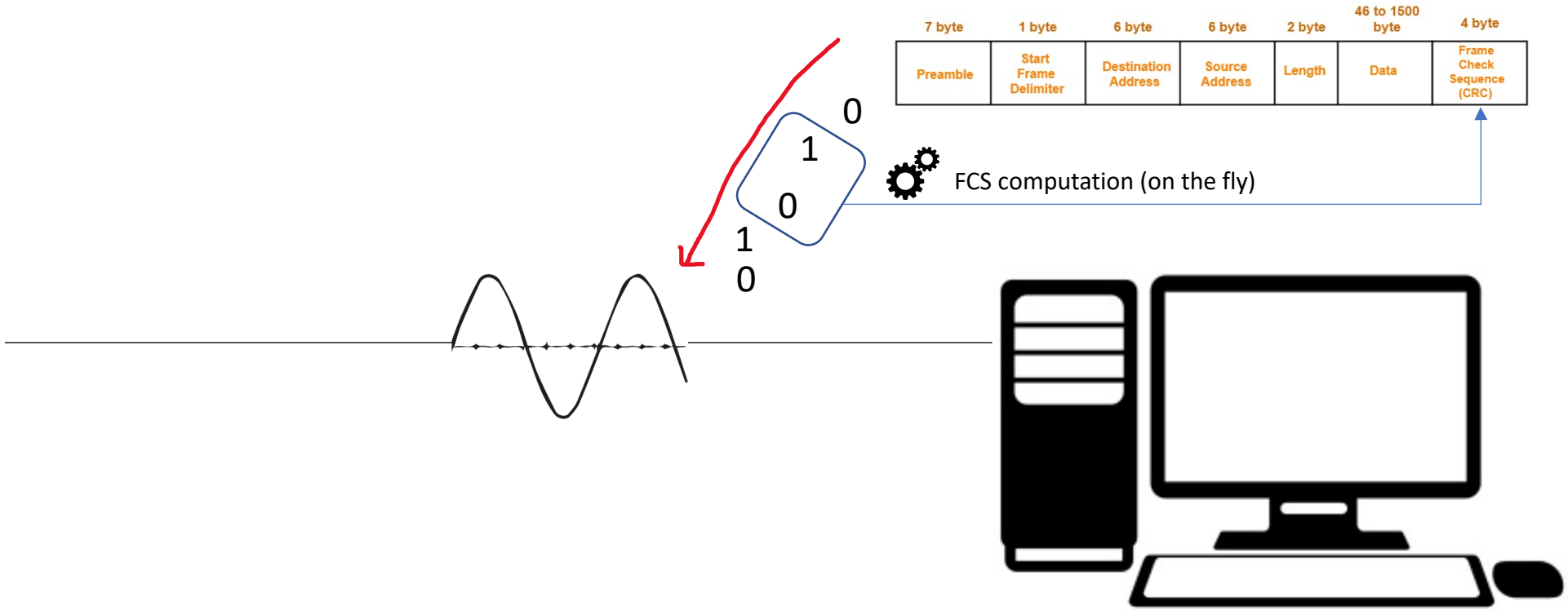
Whow does it work ?

- The sender machine sends 64 bits of synchronization data called preambule (7 X 10101010 followed by 10101011 as a SFD delimiter). Then it sends the other fields information in this order :
  - Information on the MAC source and destination address
  - The type of the network layer protocol
  - The payload containing the upper layer data (network layer packet)
  - To optimisze the transmission time, the Frame Check Sequence value FCS (CRC) is computed as these data are sent (on the fly). That explain why it is located at the end of the frame (tail).

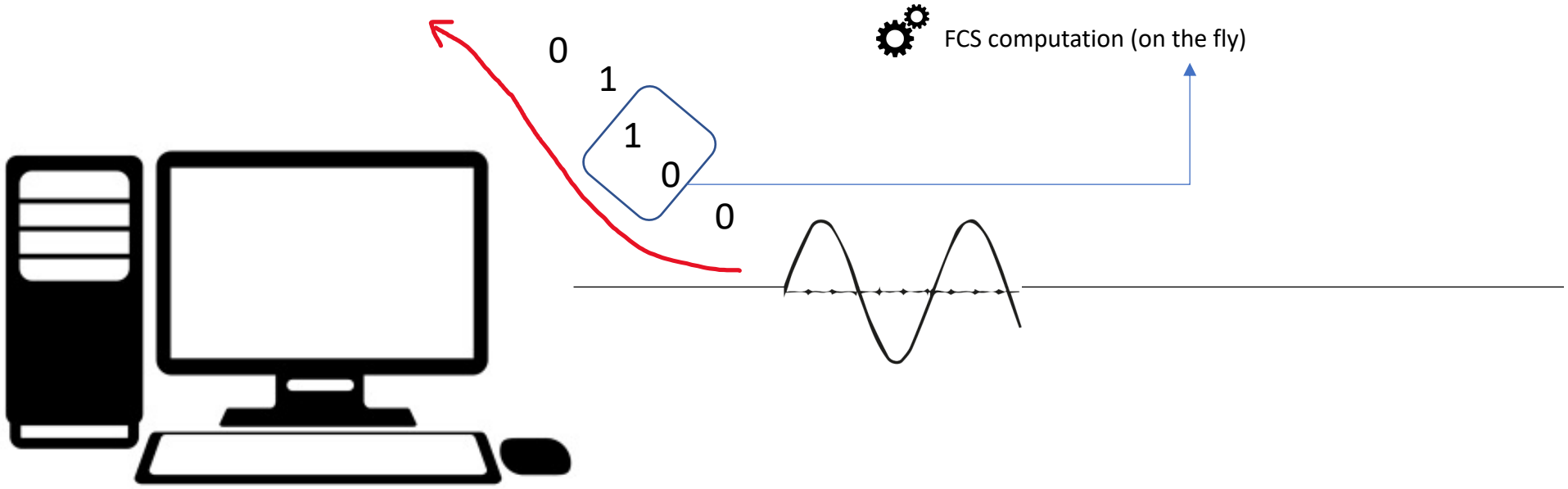
- Any station that receives the frame reads this information :
  - verify first if the message is intended for it by checking the destination MAC address
  - While receiving the data the machine recalculates the FCS (CRC) and compare it to the received FCS, to determine if the incoming message is valid
  - If the message is vald then the data payload is forwarded to the next upper layer (network layer). Otherwise, the message is dropped.

- Note: The maximum size of a Data Link frame (level 2) is called MTU (Maximum Transmission Unit) and it is specific to each network based on its capacity.

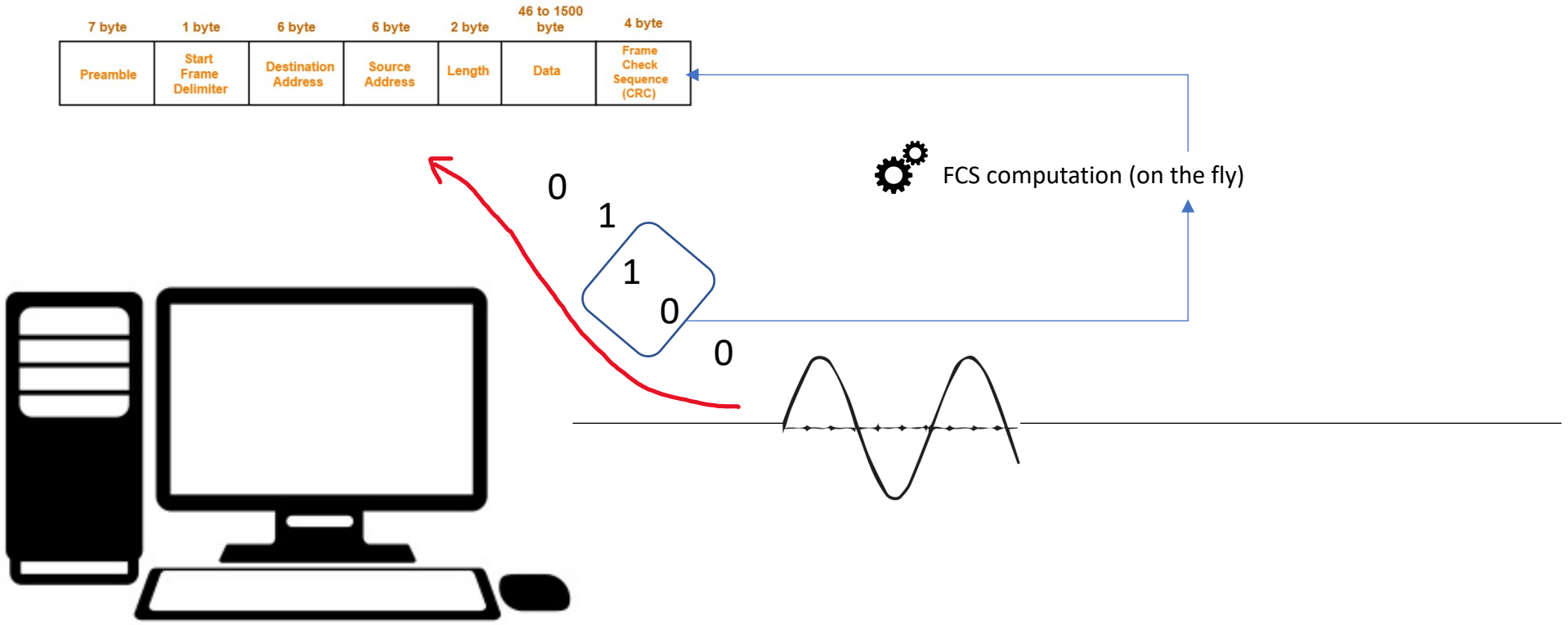
Sending Ethernet frame



Receiving Ethernet frame



Receiving Ethernet frame



Ethernet

- Ethernet is today the **dominant** local area network technology
- Ethernet is a family of local area network technologies that the OSI reference model makes easier to understand
- All local networks must deal with the basic problem of **assigning names to each station** or node
- Ethernet specifications **support different media**.

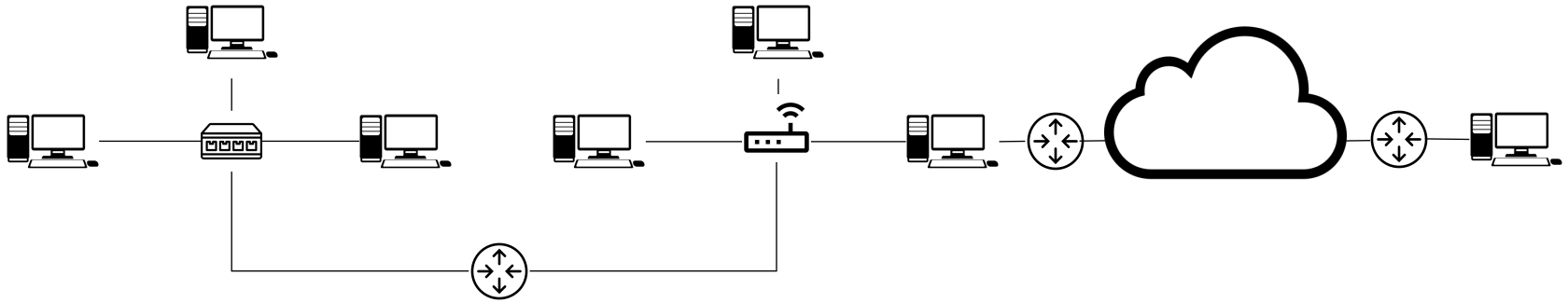
The seccess of ethernet

- The success of Ethernet is due to the following factors:
  - Simplicity and ease of maintenance
  - Ability to incorporate new technologies
  - Reliability
  - Low cost of installation and upgrade

- The introduction of Gigabit Ethernet extended the original LAN technology to such an extent that Ethernet is now a standard in MAN and WAN networks.

Interconnexion

Interconnexion



Network interconnection

- Diversity and variety of communication media (layers 1 and 2)
- Technological evolution
- Different needs
- Different costs
- Different logical configurations

- Problems
  - Need to connect several machines while limiting the areas of collisions
  - communication between entities connected to different media
  - interoperability of applications operating in this context

- Solutions
  - use of a single type of media (impossible)
  - interconnection

Interconnection means

- Interconnection makes it possible to federate several networks with physical or protocol differences in order to allow communications between their entities
- Divide and conquer: segment a network into parts for performance, administration or security purposes
- Adaptation of physical signals
- Protocol adaptation by extraction / encapsulation
- Filtering by processing information from different layers
- Several levels of interconnection possible (level n interconnection)

Interconnection means

- Level 1 interconnection
  - **Repeater, Hub**: signal amplification and broadcast
- Level 2 interconnection
  - **Bridge, switch**: signal amplifier and level 2 processing (frame switching)
- Level 3 interconnection
  - **Router**
- Level 4 to 7 interconnection
  - **Gateway**

Layer 1 Interconnection equipments

- Layer 1 equipment: **repeaters and hubs**, are primarily used to extend Ethernet cable segments.
- They allow you to add more hosts.
- However, each added host increases the amount of potential traffic on the network.
- Layer 1 equipment transmits all of the data that is received on the media.
- The denser the traffic in a segment, the greater the risk of collision.
- Layer 1 equipment can be the cause of collisions due to too much traffic in the LAN.

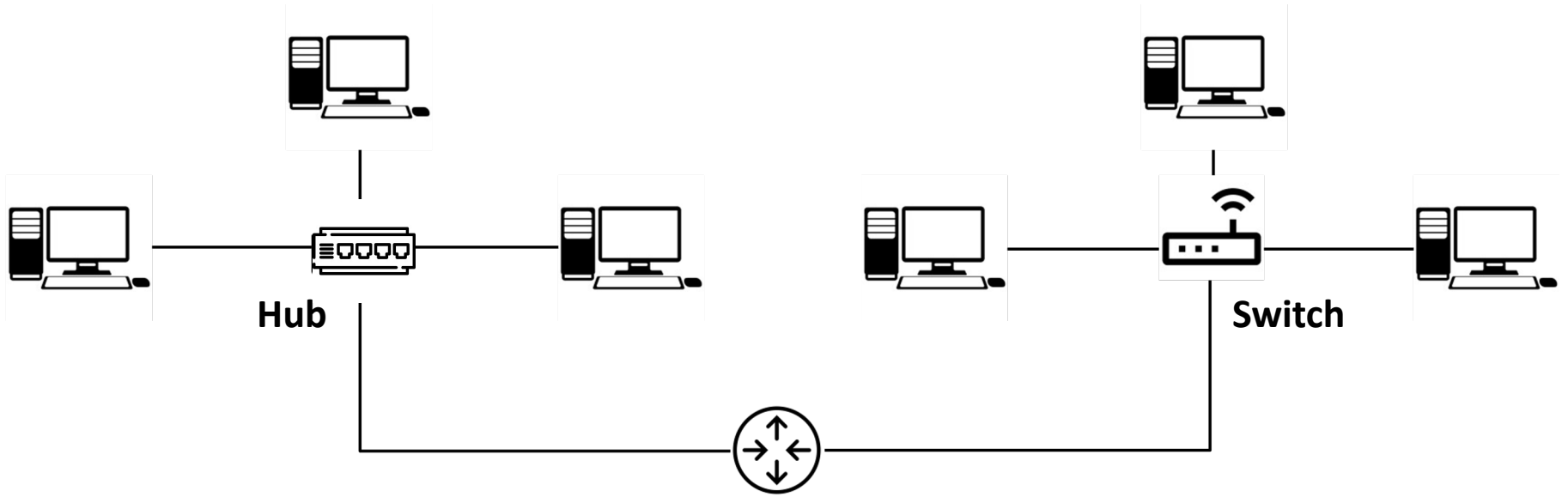
Ethernet Switching

- A shared Ethernet network (bus) works perfectly under optimal conditions of use.
- When the number of devices attempting to access the network is low, the number of collisions remains at an acceptable level.
- On the other hand, as the number of machines increases, the increasing number of collisions can significantly reduce network performance.
- In order to limit the effects, collision and broadcast domains must be created by installing **bridges (Bridge) or switches (Switch)**

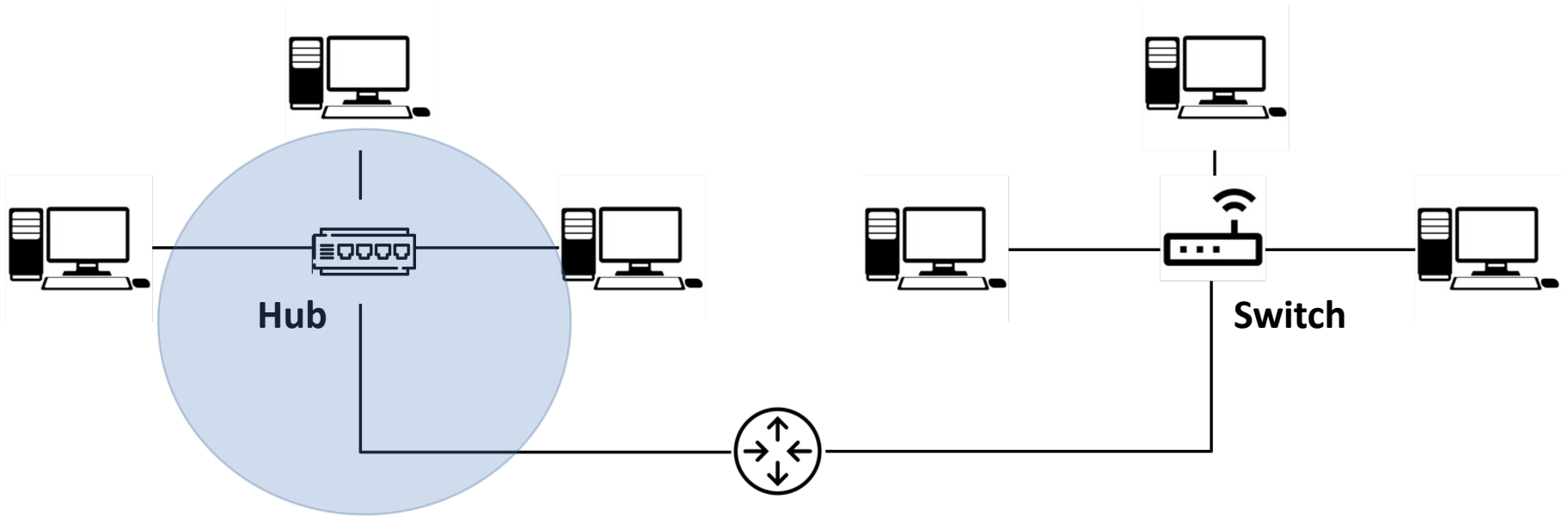
Collision domaines

- Segments of the physical network in which collisions can occur are called collision domains.
- Collisions make the network inefficient.
- Whenever a collision occurs on a network, transmissions stop momentarily.
- The duration of this interruption is variable and depends on a timed re-transmission algorithm for each device in the network.
- The types of equipment interconnecting the media segments define the collision domains.

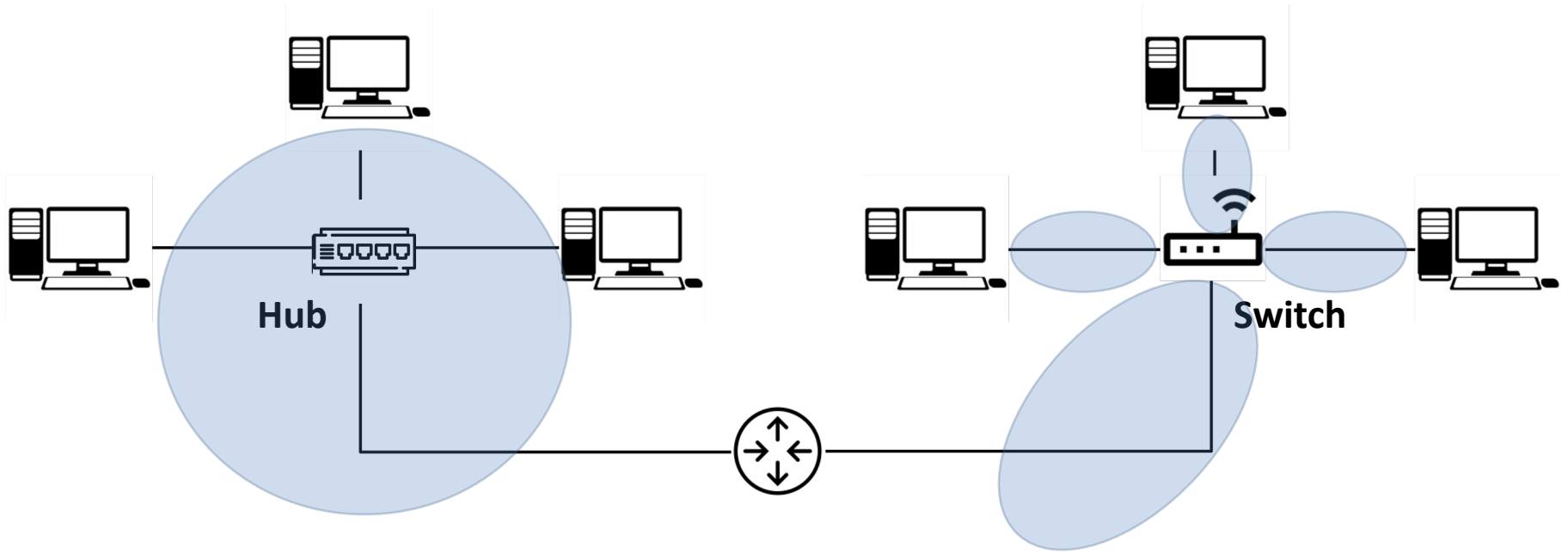
Collision domaines



Collision domaines



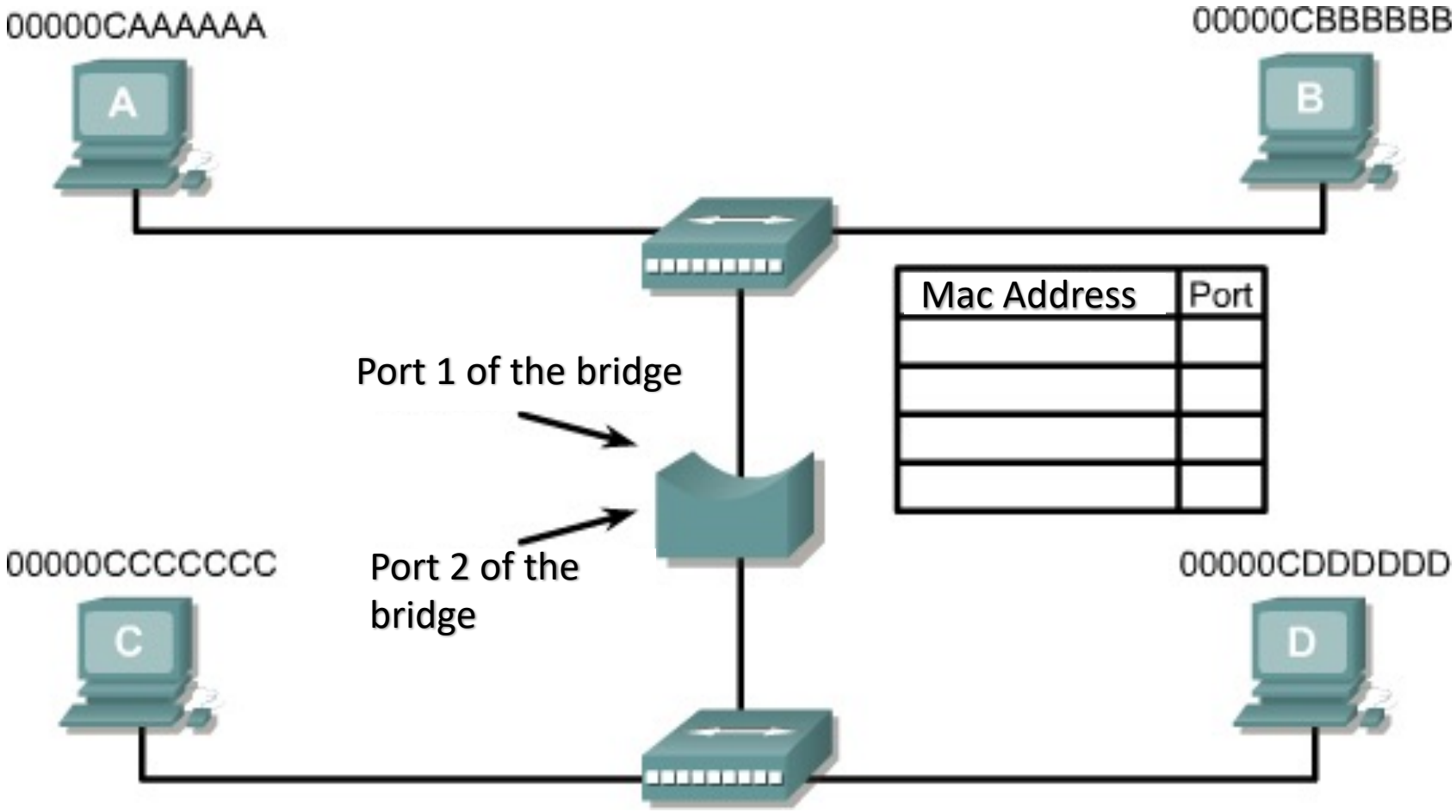
Collision domaines



Bridges

- The more nodes that are on an Ethernet segment, the more the medium is used.
- In a shared medium configuration, only one node can transmit data at a time.
- Adding more nodes increases the need for bandwidth and places additional tension on the medium. In addition, the probability of collisions is higher, resulting in more retransmissions.
- One solution is to split the main segment into several parts and **divide it into separate collision domains**.

Bridges


00000CAAAAAA
A
00000CBBBBBB
B
Mac Address
Port
Port 1 of the bridge
Port 2 of the bridge
00000CCCCCCC
C
00000CDDDDDD
D

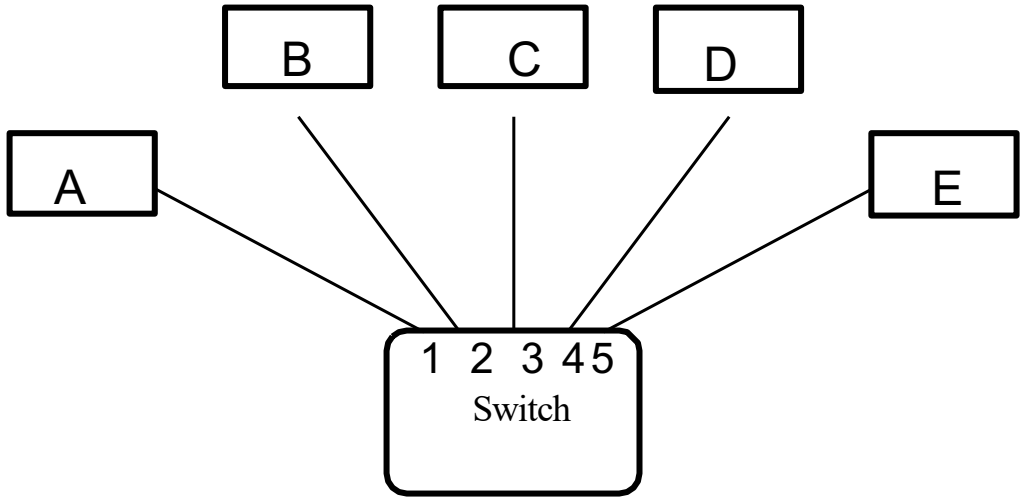
Bridges

- When a bridge has just been installed, its table is empty. The bridge waits for the data transfer on the segments.
- If a host A sends a frame on port 1, the bridge associates host A MAC address (source address) with port 1 in the table.
- At each reception, the destination address of the frame is compared to all addresses of the bridging table. If the destination address is not found in the table, the frame is transferred to the next segment.
- If the destination and source addresses are associated with the same port then the frame is ignored, otherwise it is transfered on the next port

Bridges and switches

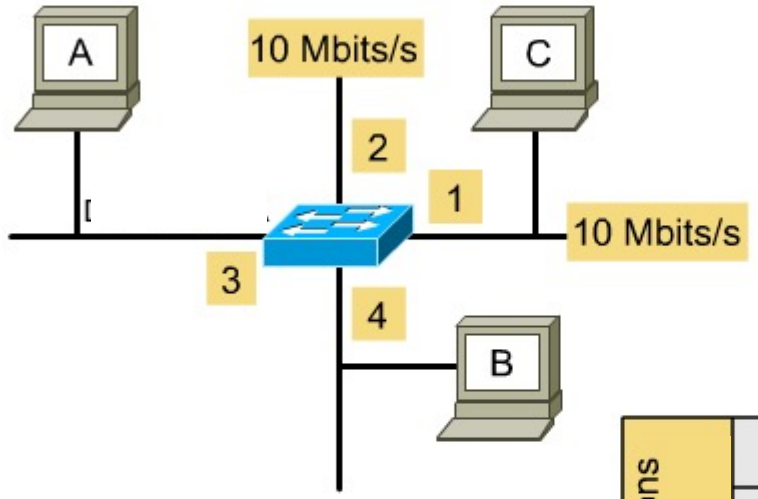
- Typically, a bridge has two ports and subdivides a collision domain into two segments.
- Decisions made by a bridge depend only on MAC addresses (or Layer 2 addresses) and do not affect Layer 3 addresses (or logical addresses).
- A switch is actually a very fast multiport bridge that can hold dozens of ports. Each port defines its own collision domain
- When a network has 20 nodes, 20 collision domains must exist if each node is connected to its own switch port.
- A switch dynamically creates and manages an Associative Memory Table (CAM, Content Addressable Memory), which contains all of the MAC information associated with the ports.

Switch principle



- Reduces collisions to increase the data rate
- Replaces central passive nodes (HUB)
- Low cost virtual networks (VLANS)

Address learning by a switch



Stations	Interface 1	2	3	4
A			✓	
B				✓
C	✓			

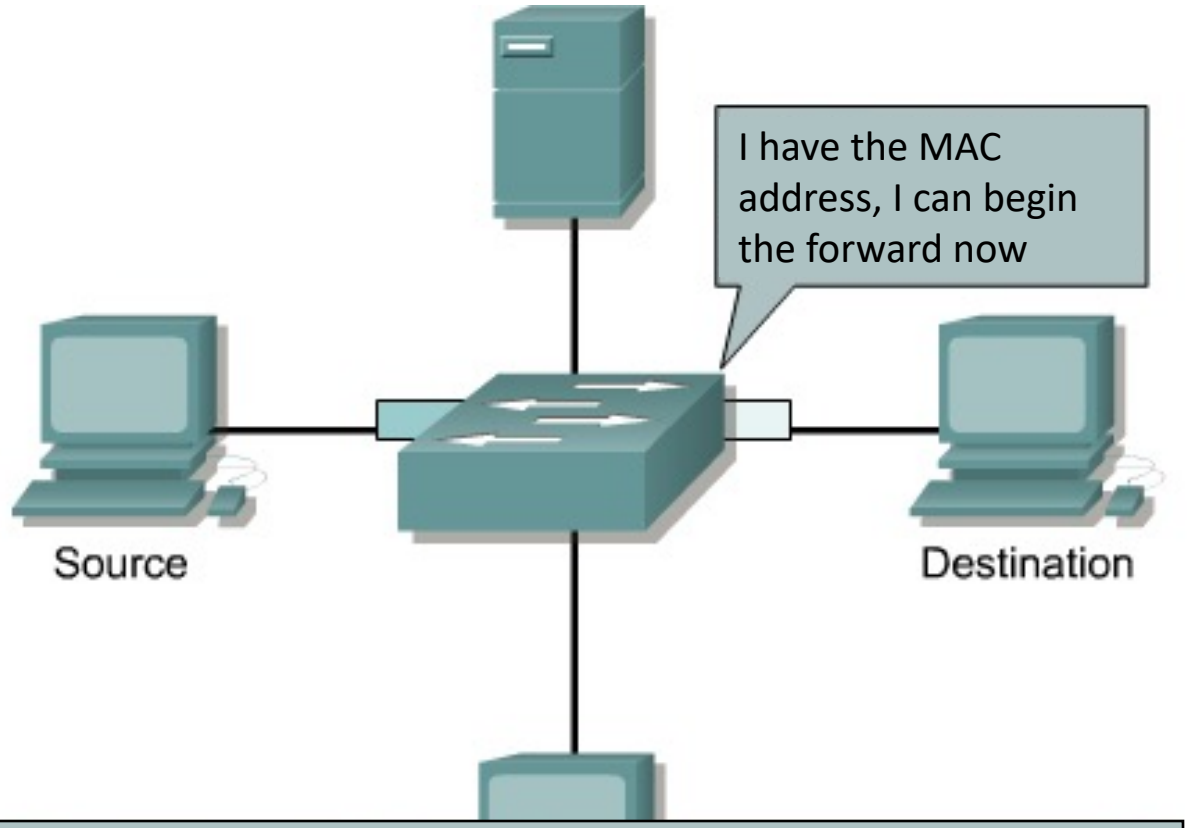
2000

- Learns the address from the source address field in the frame, and associates it to the port
- Sends the frame on all ports (except the one on which the frame is received) if the association is not done for the destination address
- Forward on the associated port otherwise
- Drop the frame when the source and destination address are associated with the same port

Switching modes

- Switching a frame to a destination port depends on the level of latency and reliability.
- A switch can start forwarding the frame as soon as the MAC address is received. This mode of packet switching is called «**Cut-through**».
- With the Cut-through switching mode, the emission rates of the source and destination ports must be identical to avoid damaging the frame.

« CUT-THROUGH » Mode

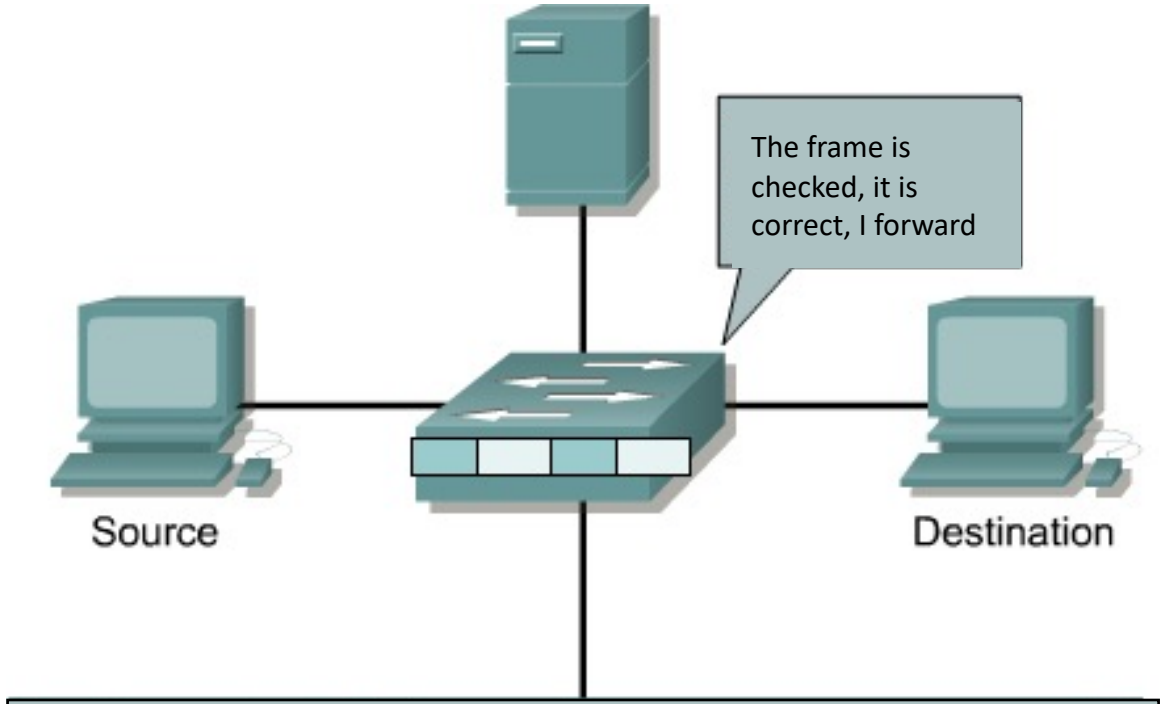


A cut-through switch begins the transmission of the frame on the correspnding port as soos as the MAC address is read

Switching modes

- A switch can also wait until the all the frame is received to switch it
- This allows the switch to tcheck the *Frame Check Sequence (error control)*.
- If an error is detected, then the frame is rejected on the switch. This switchnig mod is called «**Store-and-Forward**».

« STORE-AND-FORWARD » mode



A store-and-forward switch copie the frame check its length and if the is an error (FCS). If the frame is correct, then it forwards it to the corresponding port. The frame is rejected otherwise

Switching modes

- An intermediate packet switching solution is the «**Fragment-Free**»
- This mode reads the first 64 bytes, including the header of the frame, and then starts transmitting the frame before it has even finished reading the data field and checksum.
- This mode checks the reliability of addresses and higher-level protocol information to ensure that the data is processed correctly and is routed to the correct destination.
- Allows collision detection (detected during the first 64 bytes according to the Ethernet standard. This size corresponds to the number of bytes required to occupy the bus during the round trip between the most distant stations)

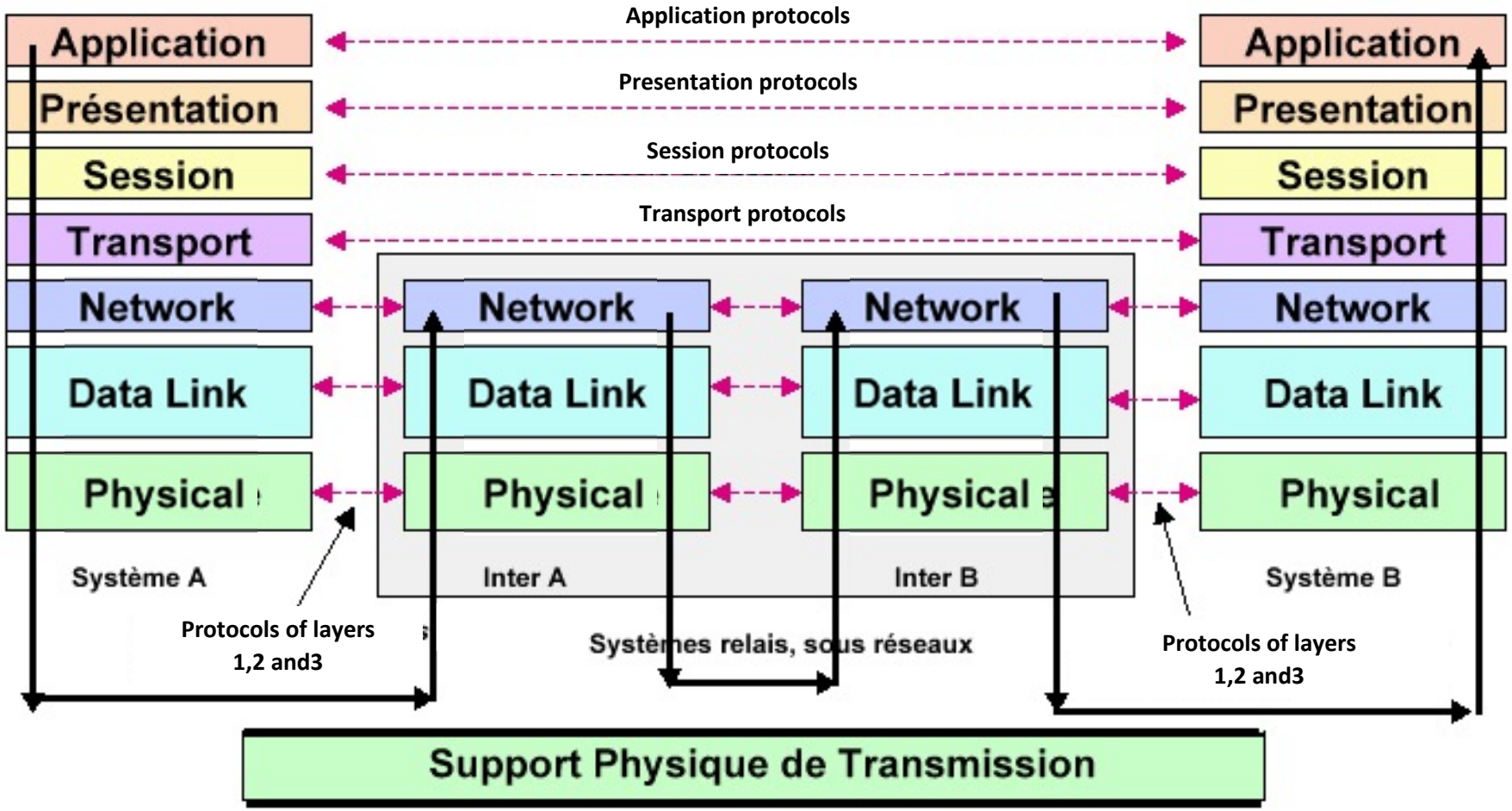
Layer 2 interconnection devices

- Layer 2 devices segment or divide collision domains.
- Bridges and switches break down collision domains into smaller pieces.
- Each element then becomes its own collision domain.
- They use the MAC addresses assigned to each Ethernet device to carry out the transmission control of the frame.
- Layer 2 devices are bridges and switches
- These devices can control the traffic flow at the layer 2 level.
- Thanks to this characteristic, networks are more efficient.
- Carry data simultaneously on different segments without collisions.

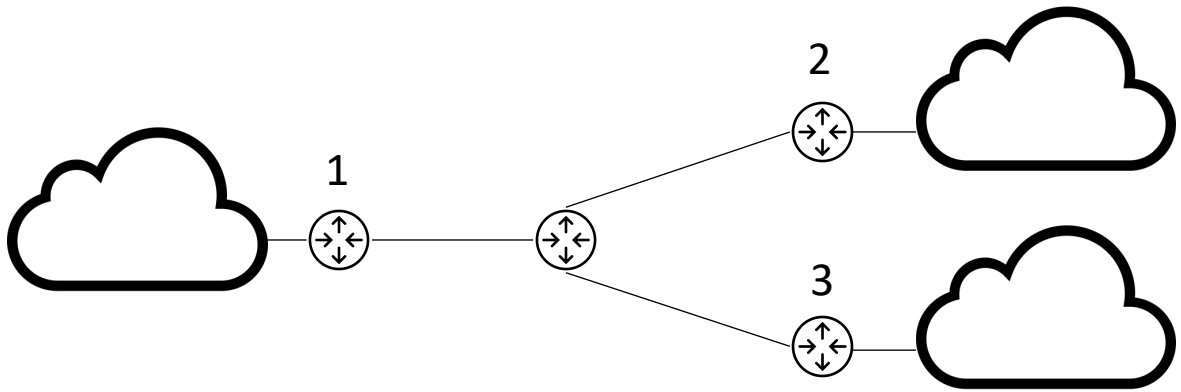
Network interconnection

- Layer 3 interconnection (network layer of the OSI model) :
  - The goal is to hide the heterogeneity of the supports by federating them
  - enable a unified communication service
  - identification of entities by IP addresses
  - access to services
  - Provide a network layer protocol suitable for many media
- IP (Internet Protocol) works on (very) varied media and offers services to the layer 4 (transport)

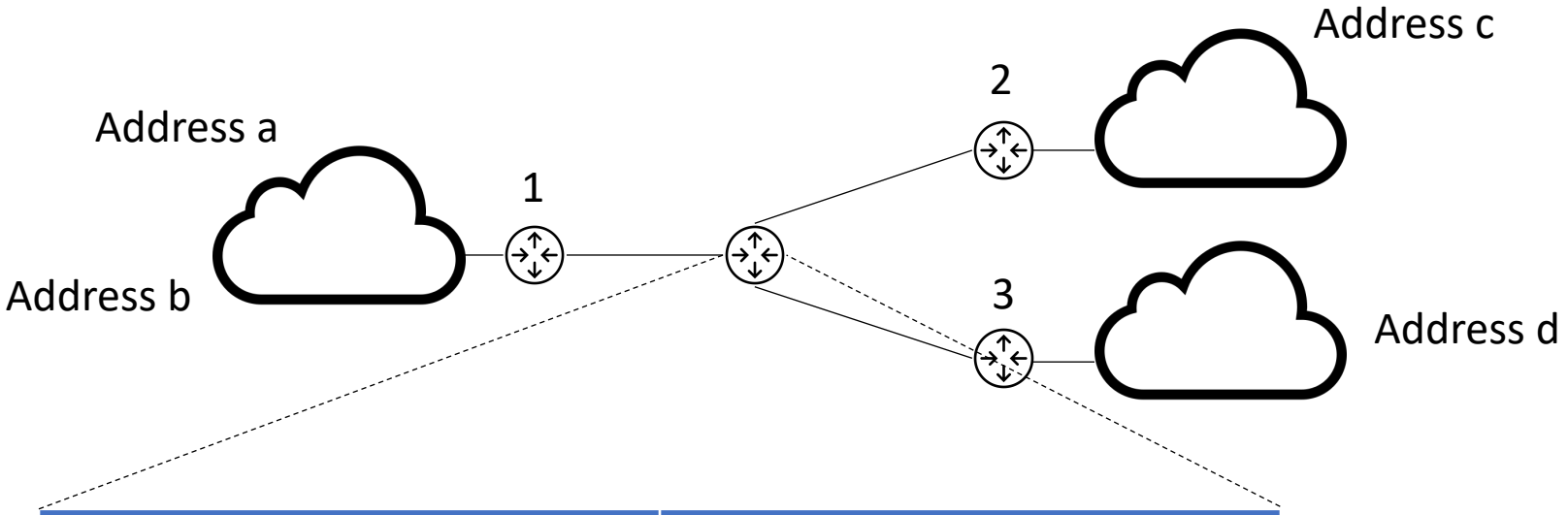
Interconnection principle



Routers



Routers



Destination IP address	Next hop
Address a	Address next 1
Address b	Address next 1
Address c	Address next 2
Address d	Address next 3
Default	Address next 3

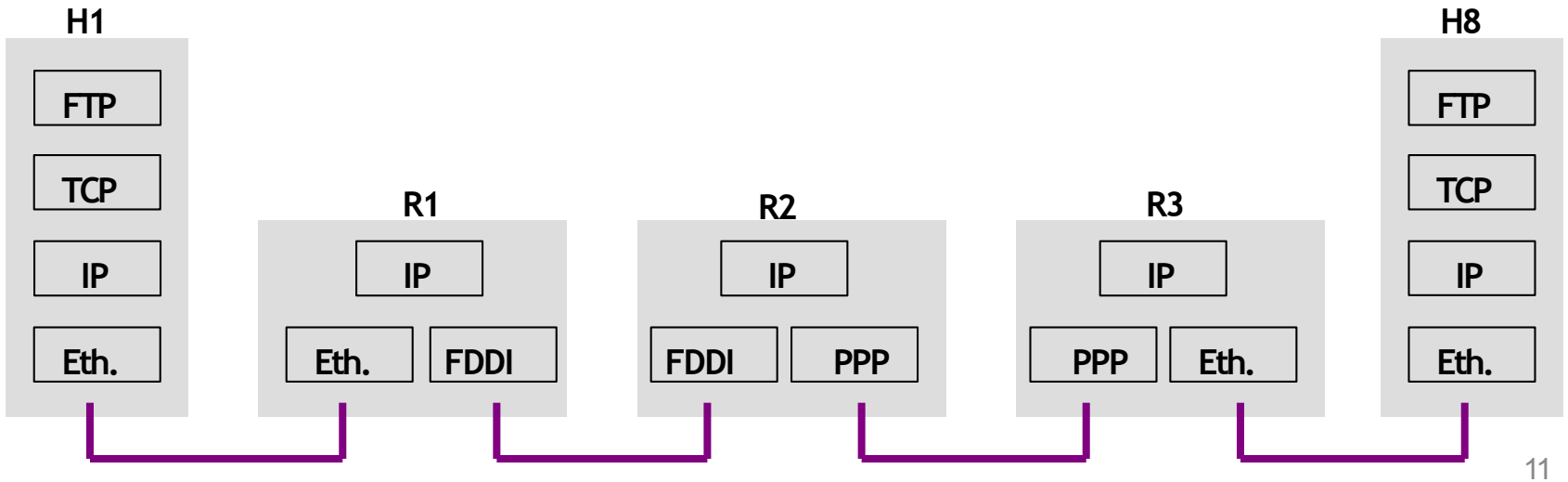
Routing table

IP address

IP addresses

- Used to uniquely identify each machine on the network
- Starting point for all Internet communication
- In the Internet network each machine is identified by an IP address
- A machine also has other addresses!

IP protocol



- The glue that binds the Internet together: the *Internet Protocol* (IP)
- Several access and transport protocols exist - but only one from the network layer
- We are talking about logical addressing

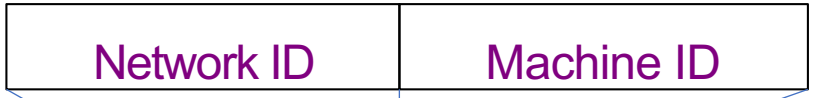
Physical and logical addresses

- Data-link layer address => physical address
  - Fixed by the manufacturer
  - Often not modifiable
  - Used only on physical networks (Ethernet)
  - Flat address
  - Physically identifies an item of equipment

- IP address => logical address chosen by the network administrator

IP address

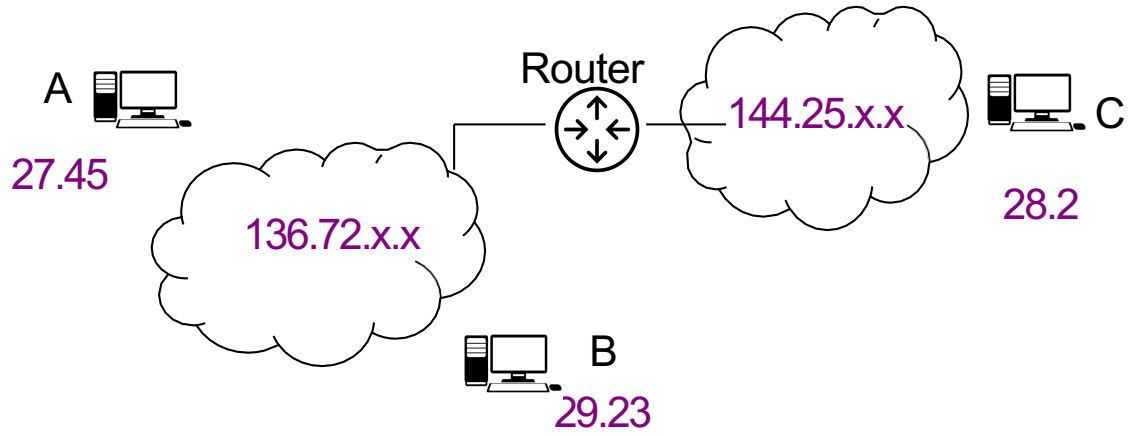
- Address
  - for the identification of network devices
  - for routing
- Homogeneous addressing plan
  - format: 4 bytes => 4.3 billion addresses
  - dotted decimal notation: x1.x2.x3.x4
- Globally unique and hierarchical address
- Format: <network> <machine>
  - network prefix: network identifier
  - identifier: machine identifier



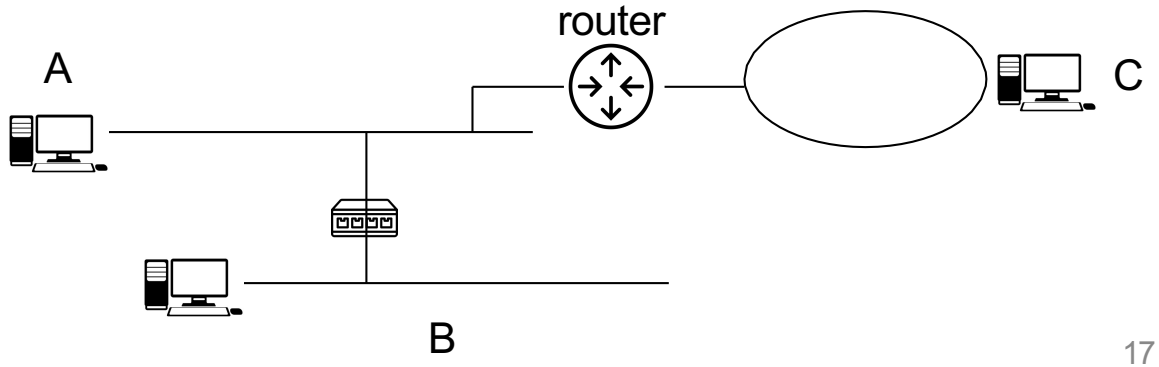
Example 192.168.4.5

IP address

- One network ID per physical network
  - IP level



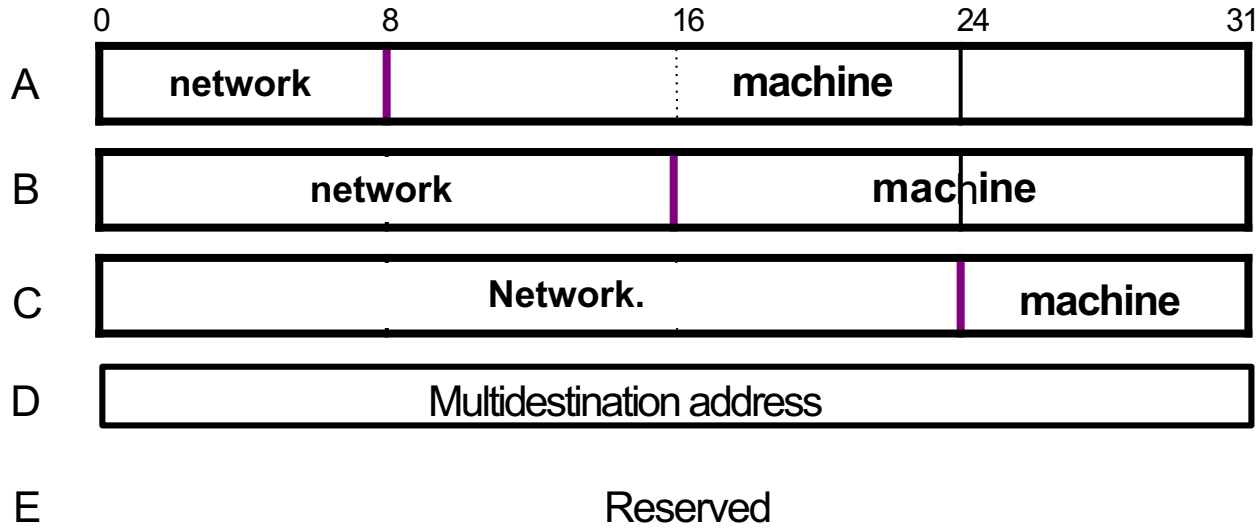
  - Physical and data link level



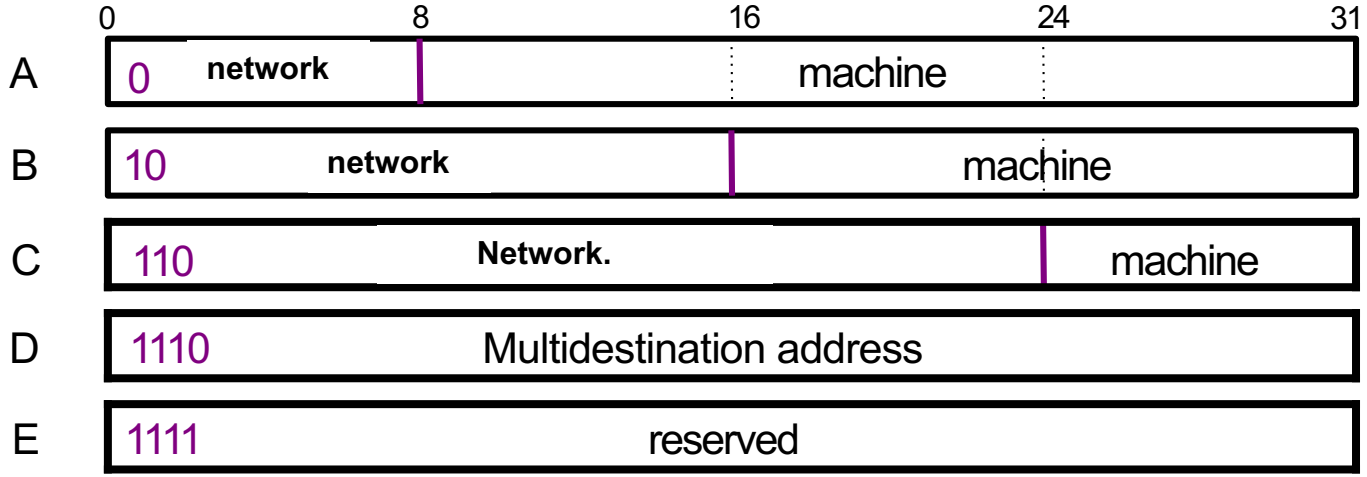
Address classes

- the <network> / <machine> split is not fix

↳ 5 classes exist

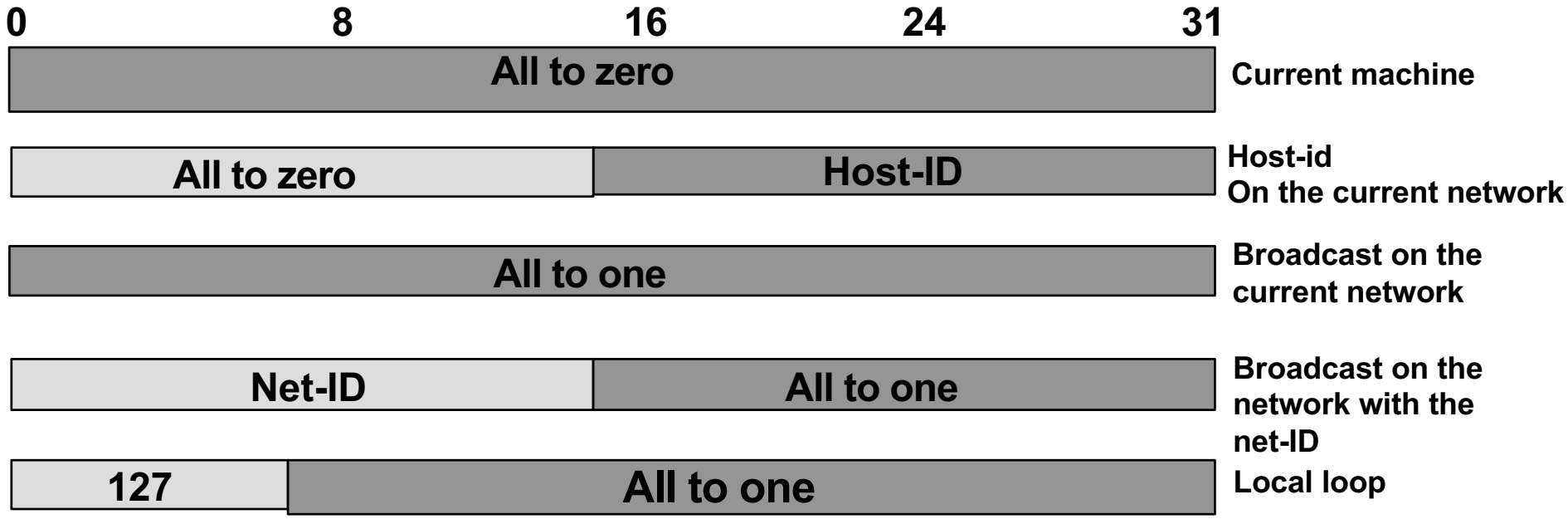


Address classes



- class A = 0.0.0.0 to 127.255.255.255
- class B = 128.0.0.0 to 191.255.255.255
- class C = 192.0.0.0 to 223.255.255.255
- class D = 224.0.0.0 to 239.255.255.255 ➔ reserved for IP multicast
- class E = 240.0.0.0 to 255.255.255.255 ➔ Reserved for future use

Specific addresses



- an IP address whose hostid value includes only 1 cannot be assigned to a real machine => it is a directed broadcast address

- an IP address whose hostid value only includes 0 cannot be assigned to a real machine => it is a network address

Address mask

- The mask indicates the border between the <network> part and the <machine>
- The mask lentgh is 32 bits => 4 bytes
- Network Mask bits (*mask*)
  - positioned at 1 => network part
  - positioned at 0 => machine part

- Example

  11111111 11111111 11111111 00000000

  => 3 bytes for the network field, 1 byte for the machine field

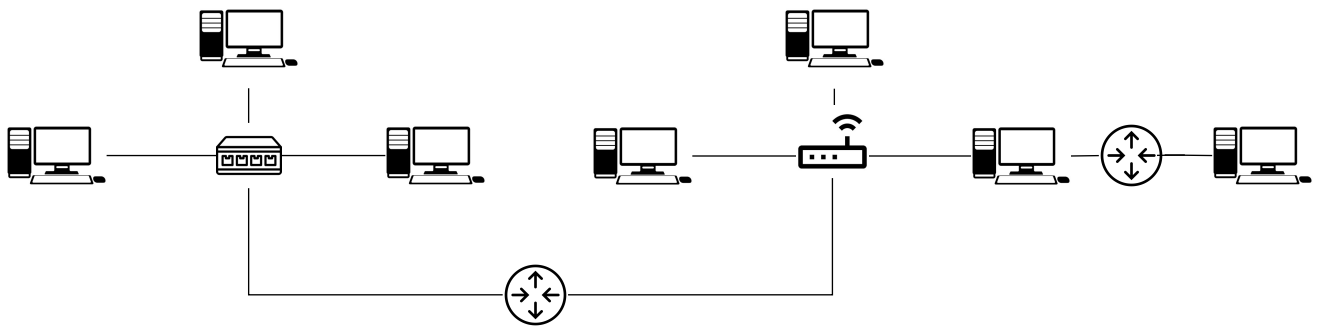
- Notations
  - Dotted decimal

    example: 255.255.255.0

  - Network-address/mask

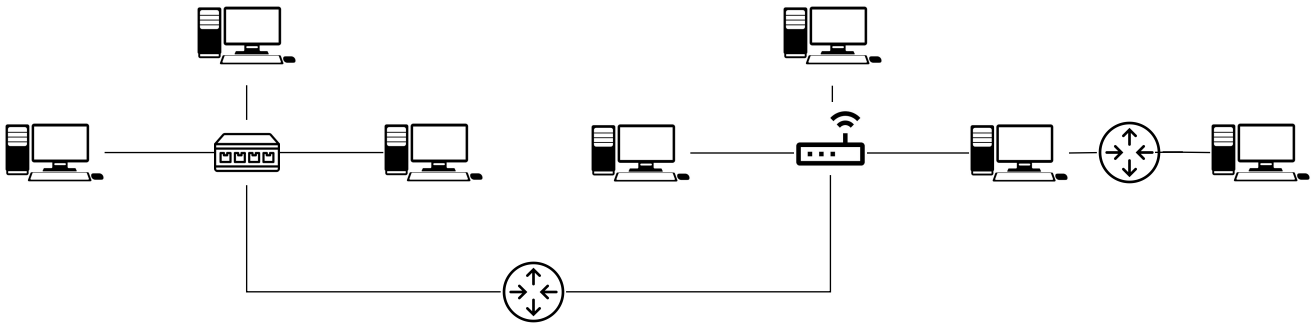
    example: 193.49.60.0/24 (24 = number of contiguous bits of the mask)

IP addresses



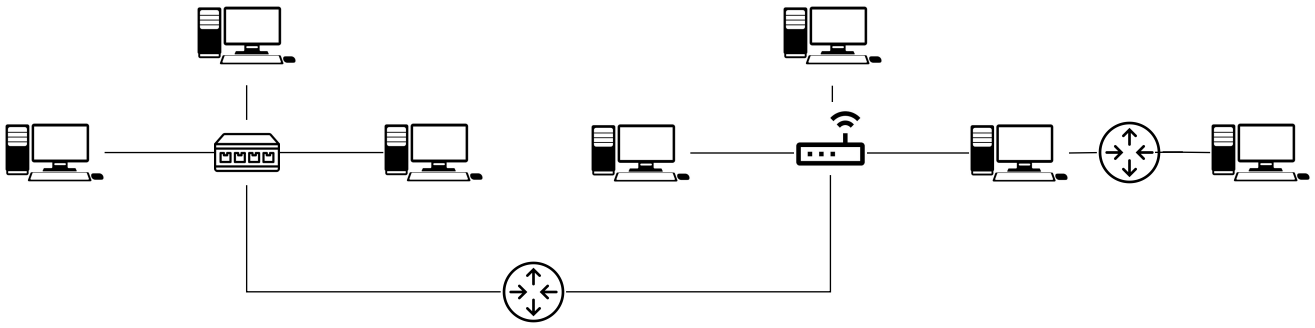
IP addresses

- How many physical network do we have ?



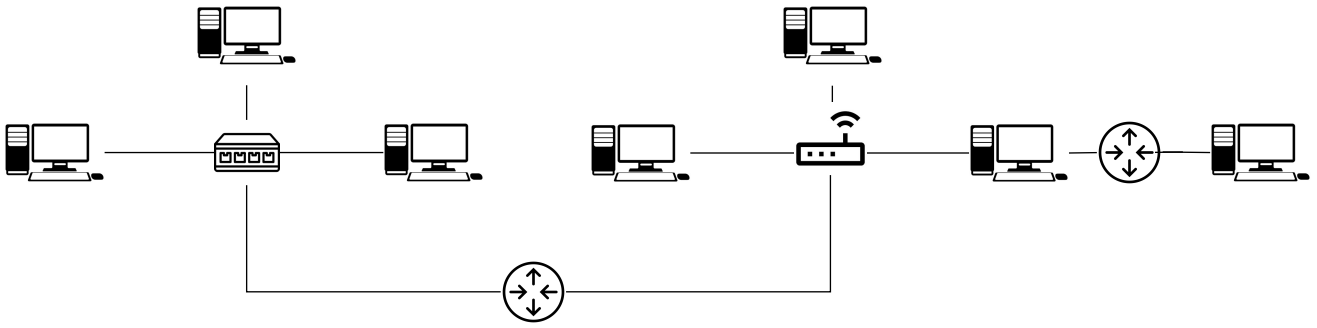
IP addresses

- How many physical network do we have ?
  - **3 networks**



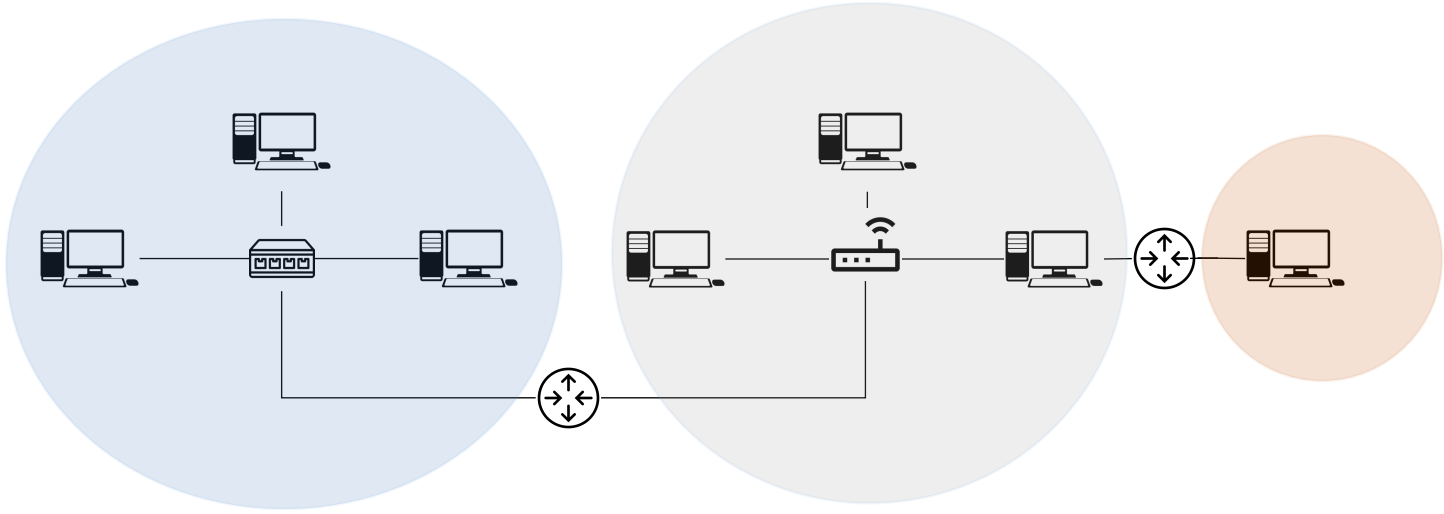
IP addresses

- How many physical network do we have ?
  - **3 networks**
- How many network adress do we need



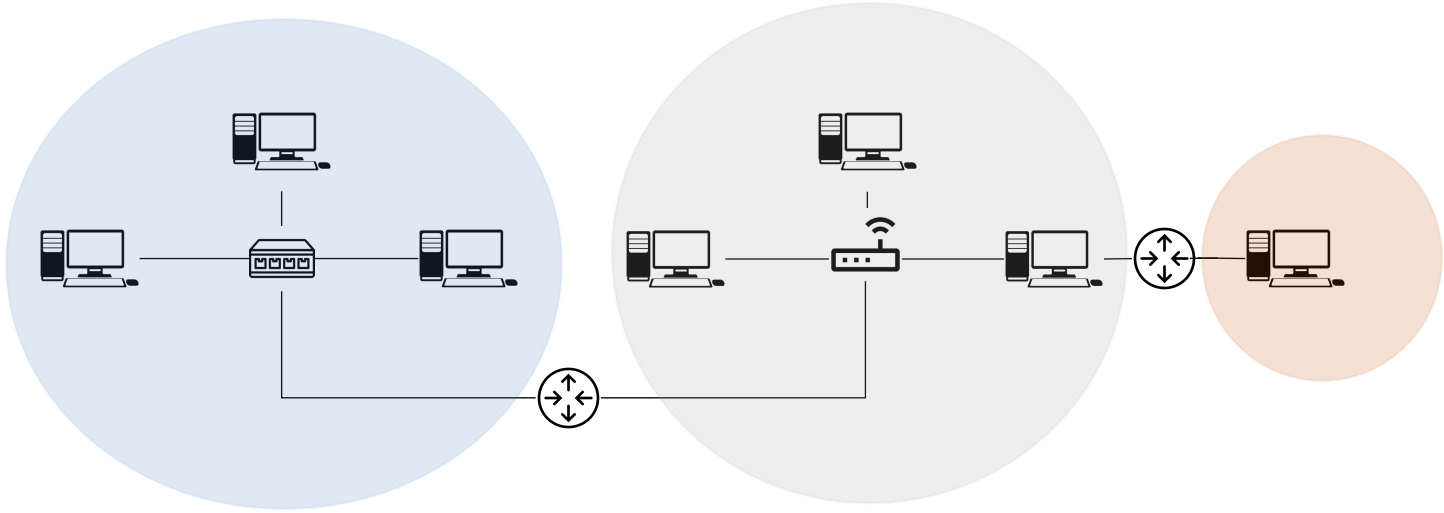
IP addresses

- How many physical network do we have ?
  - **3 networks**
- How many network adress do we need
  - **3 networks => 3 network addresses**



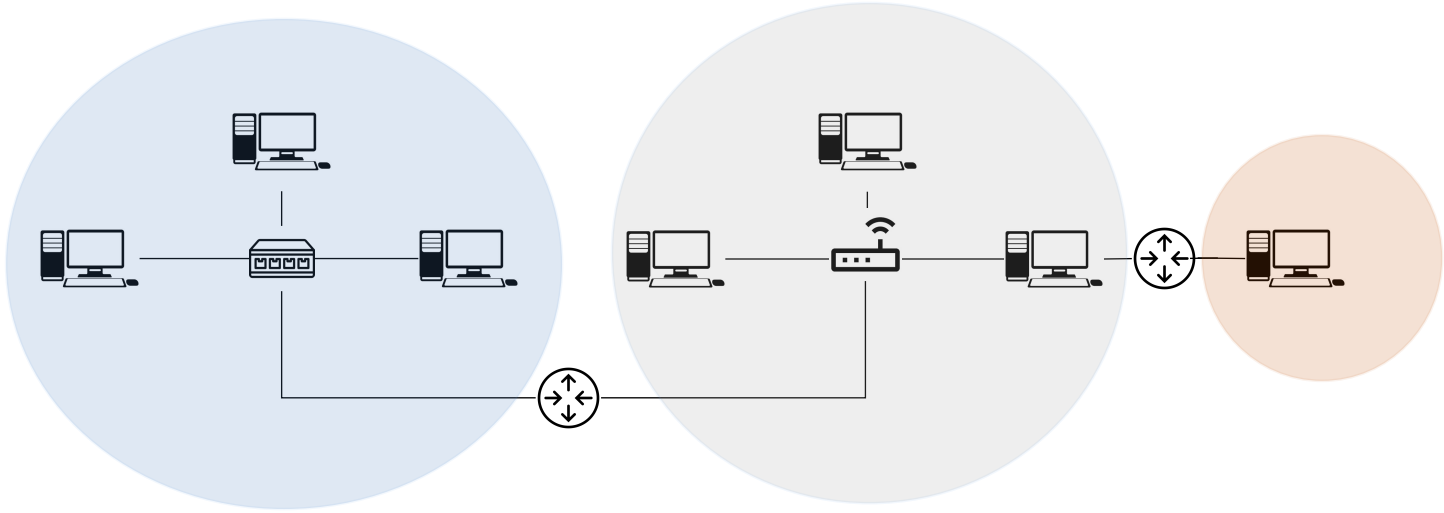
IP addresses

- How many physical network do we have ?
  - **3 networks**
- How many network adress do we need
  - **3 networks => 3 network addresses**
- How to split the addresses



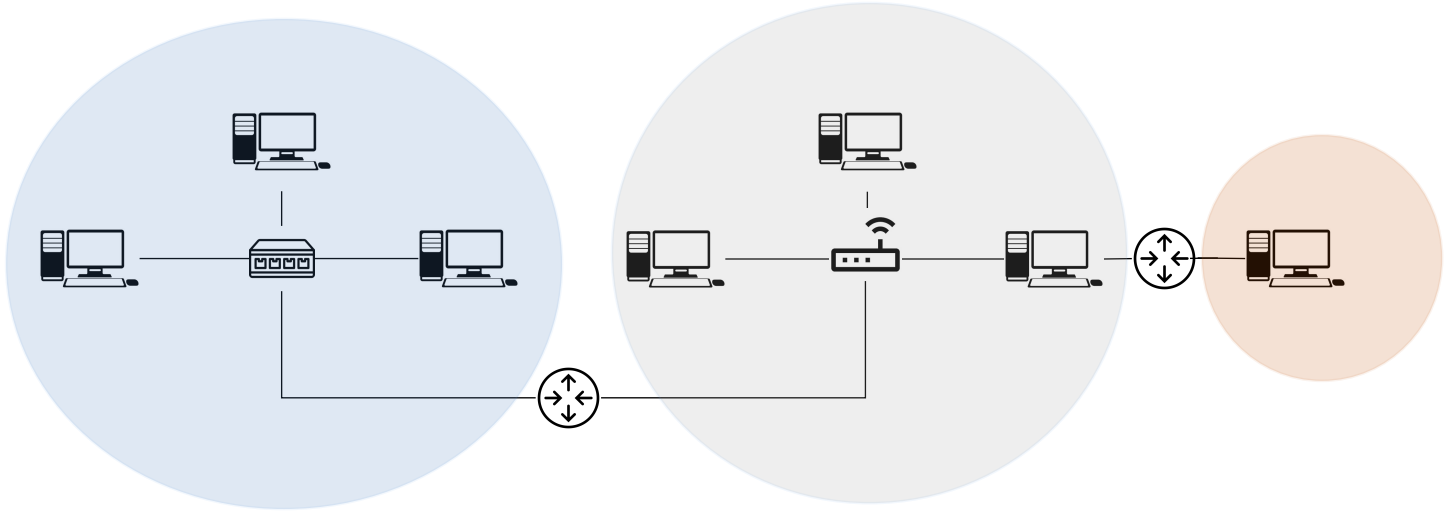
IP addresses

- How many physical network do we have ?
  - **3 networks**
- How many network adress do we need
  - **3 networks => 3 network addresses**
- How to split the addresses
  - **Based on machine number on the networks**
  - **Few machines => short machine ID part**



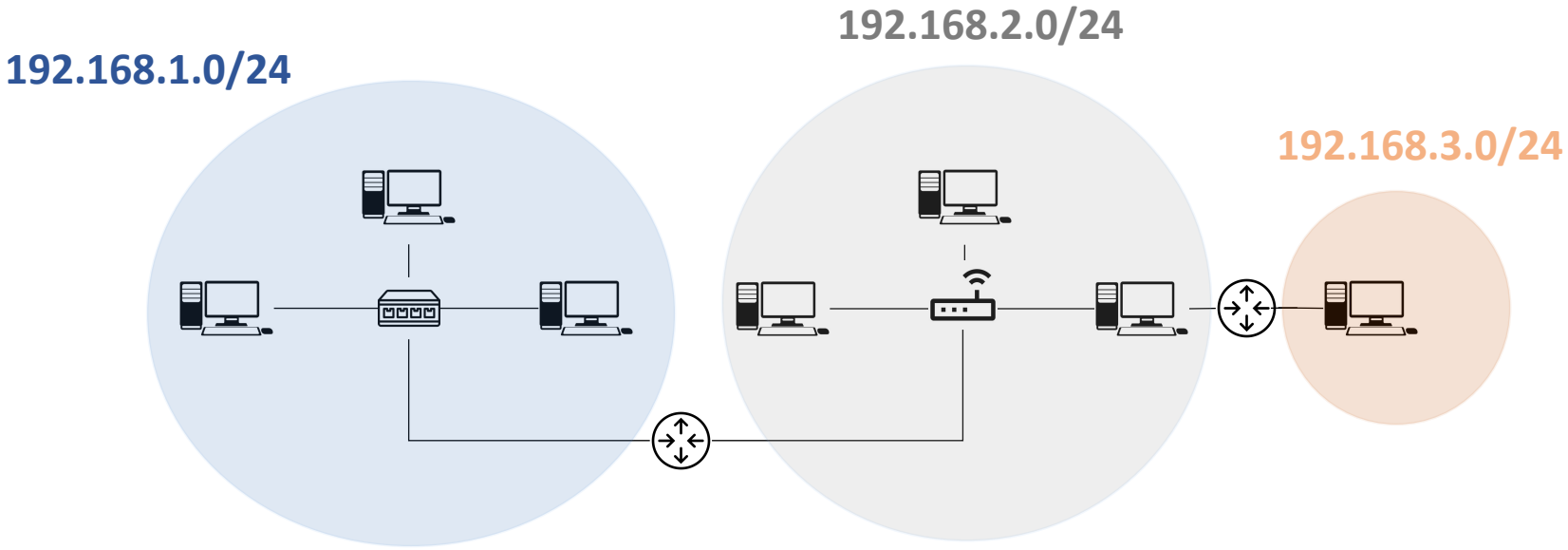
IP addresses

- How many physical network do we have ?
  - **3 networks**
- How many network adress do we need
  - **3 networks => 3 network addresses**
- How to split the addresses
  - **Based on machine number on the networks**
  - **Few machines => short machine ID part**
  - **for example 255.255.255.0 mask => 3 bytes for network ID and 1 byte for Machine ID**



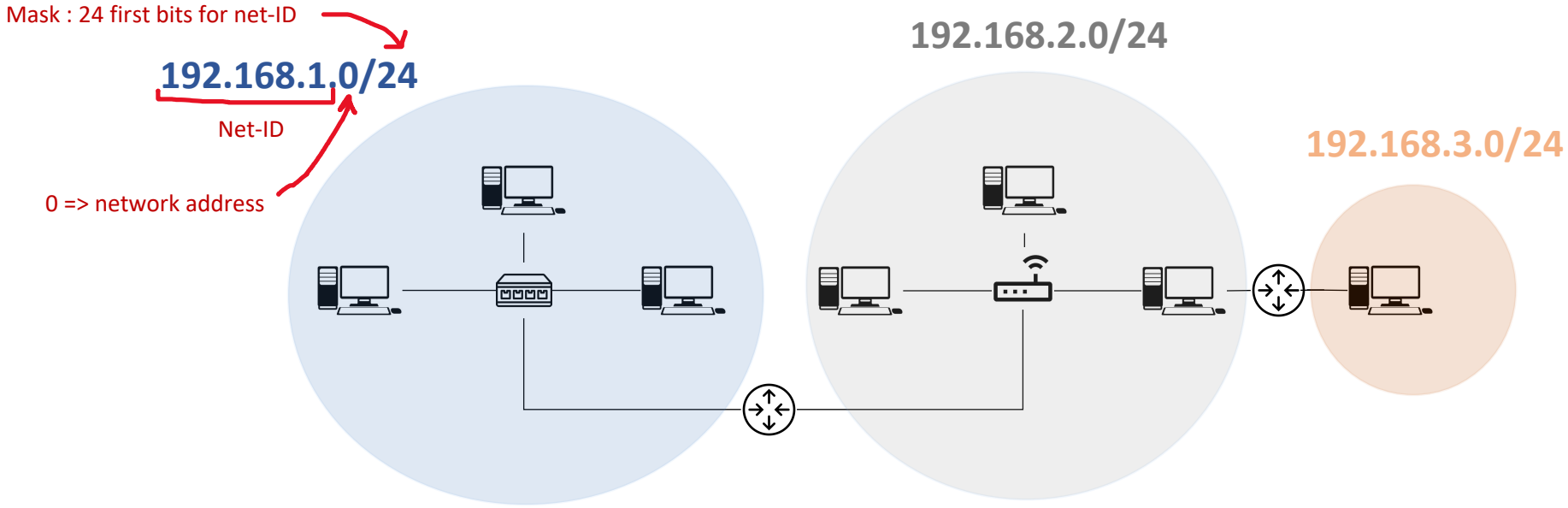
IP addresses

- How many physical network do we have ?
  - **3 networks**
- How many network adress do we need
  - **3 networks => 3 network addresses**
- How to split the addresses
  - **Based on machine number on the networks**
  - **Few machines => short machine ID part**
  - **for example 255.255.255.0 mask => 3 bytes for network ID and 1 byte for Machine ID**



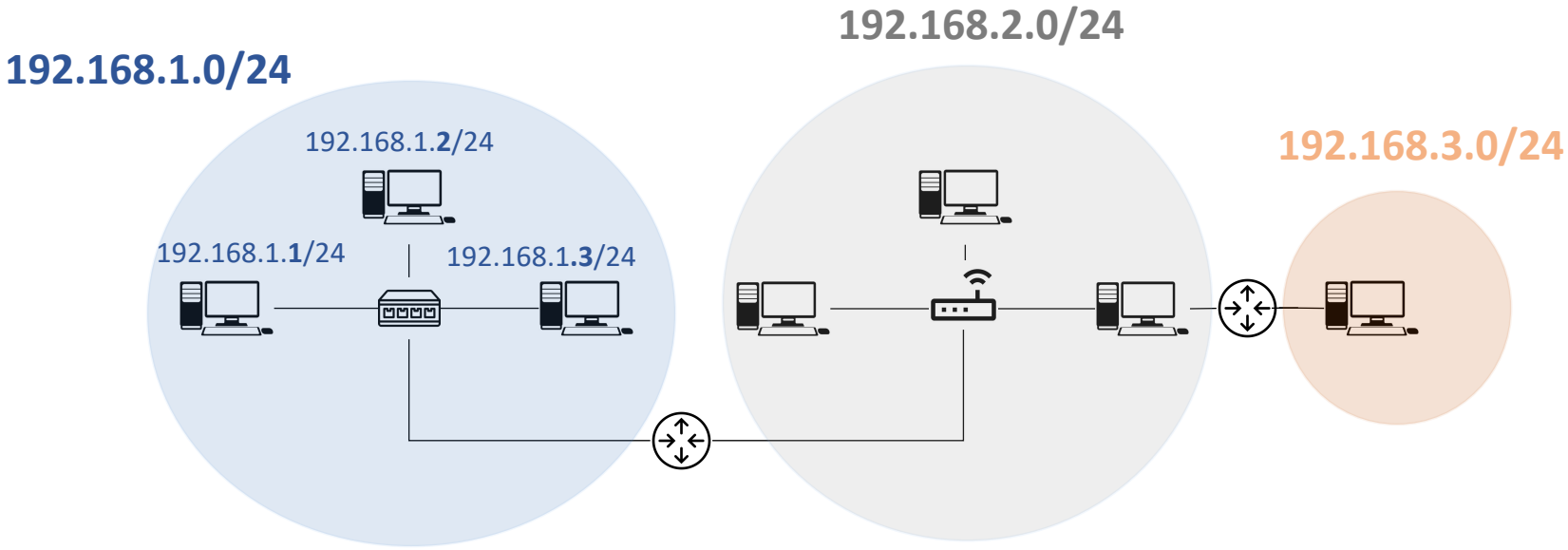
IP addresses

- How many physical network do we have ?
  - **3 networks**
- How many network adress do we need
  - **3 networks => 3 network addresses**
- How to split the addresses
  - **Based on machine number on the networks**
  - **Few machines => short machine ID part**
  - **for example 255.255.255.0 mask => 3 bytes for network ID and 1 byte for Machine ID**



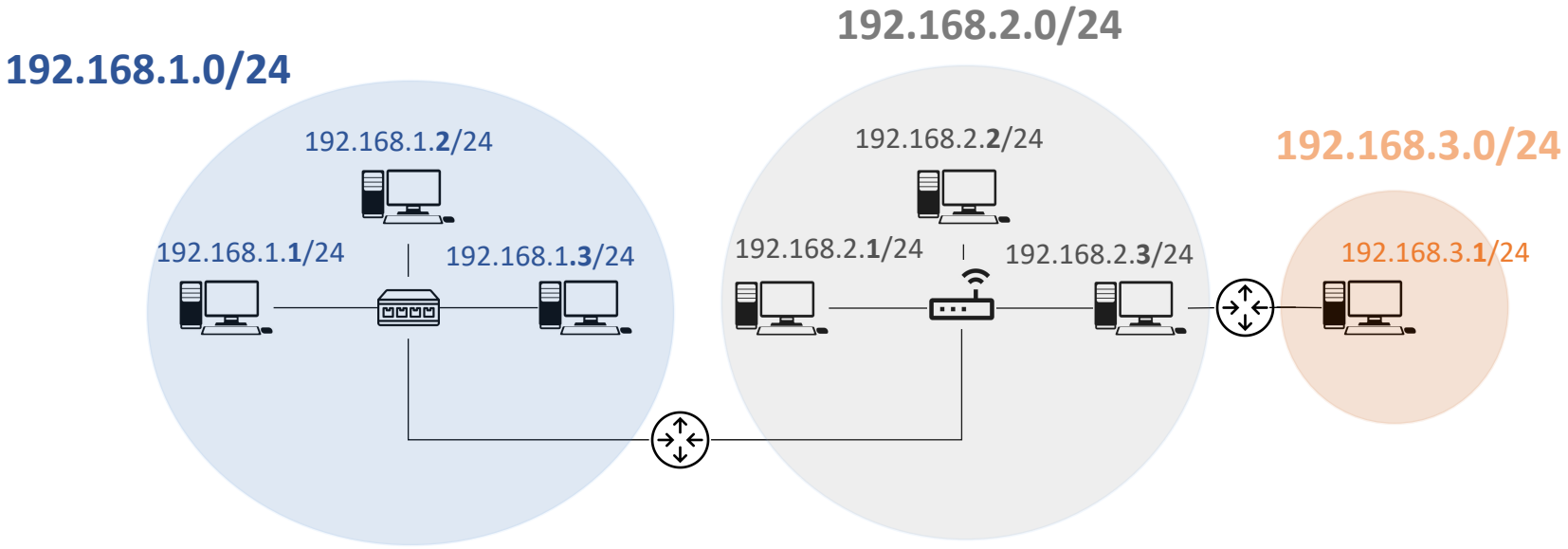
IP addresses

- How many physical network do we have ?
  - **3 networks**
- How many network adress do we need
  - **3 networks => 3 network addresses**
- How to split the addresses
  - **Based on machine number on the networks**
  - **Few machines => short machine ID part**
  - **for example 255.255.255.0 mask => 3 bytes for network ID and 1 byte for Machine ID**



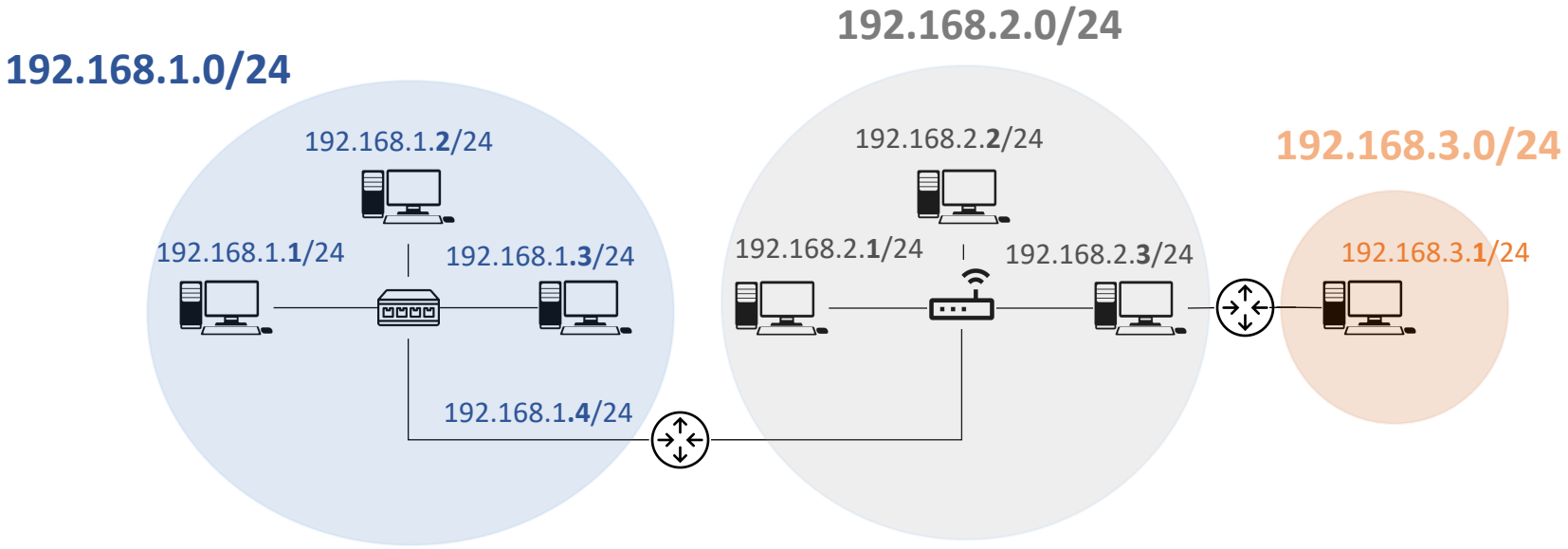
IP addresses

- How many physical network do we have ?
  - **3 networks**
- How many network adress do we need
  - **3 networks => 3 network addresses**
- How to split the addresses
  - **Based on machine number on the networks**
  - **Few machines => short machine ID part**
  - **for example 255.255.255.0 mask => 3 bytes for network ID and 1 byte for Machine ID**



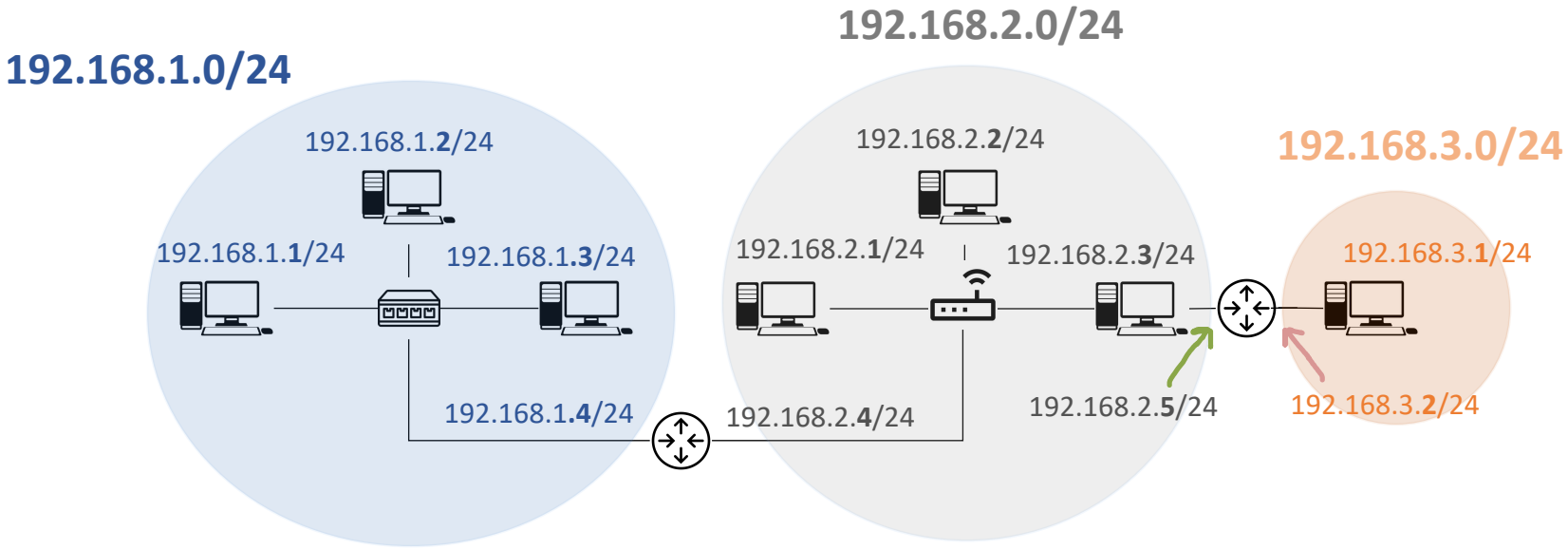
IP addresses

- How many physical network do we have ?
  - **3 networks**
- How many network adress do we need
  - **3 networks => 3 network addresses**
- How to split the addresses
  - **Based on machine number on the networks**
  - **Few machines => short machine ID part**
  - **for example 255.255.255.0 mask => 3 bytes for network ID and 1 byte for Machine ID**



IP addresses

- How many physical network do we have ?
  - **3 networks**
- How many network adress do we need
  - **3 networks => 3 network addresses**
- How to split the addresses
  - **Based on machine number on the networks**
  - **Few machines => short machine ID part**
  - **for example 255.255.255.0 mask => 3 bytes for network ID and 1 byte for Machine ID**



Public v.s. private address

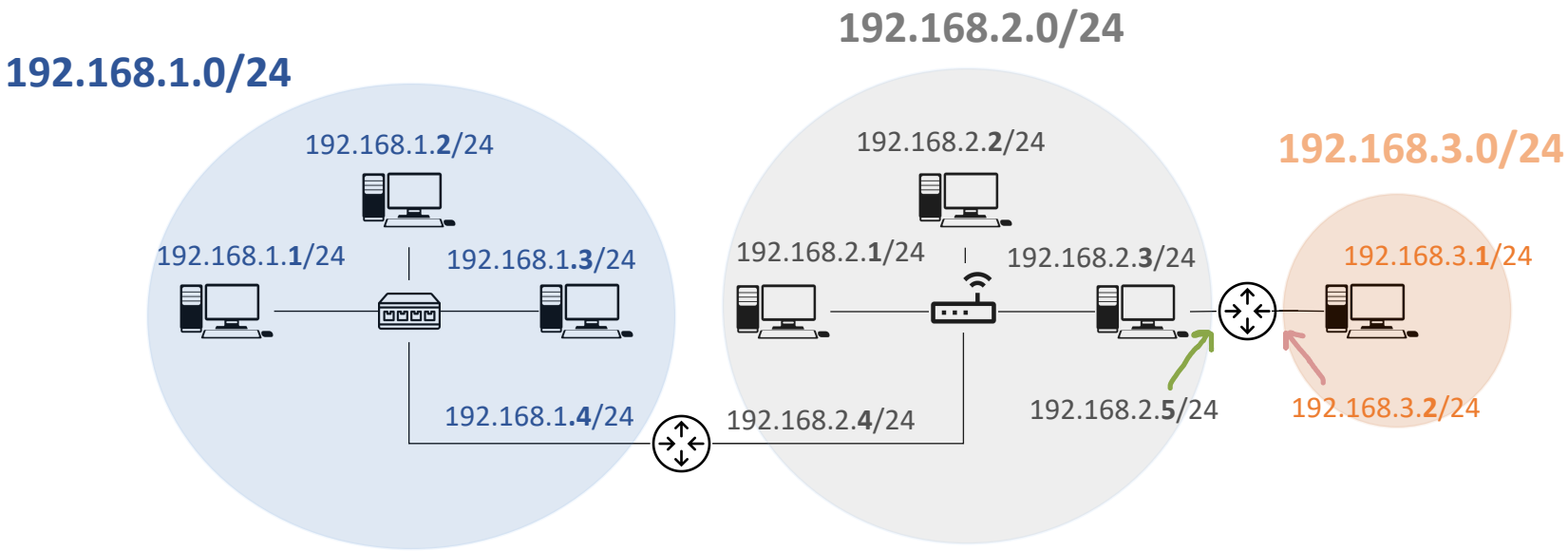
- Need to connect multiple IP addresses to the Internet
- Example: several machines but a single Internet subscription
- Need to configure a local network to use private addresses locally (internal) and a single public address for the Internet (external)

Public v.s. private address

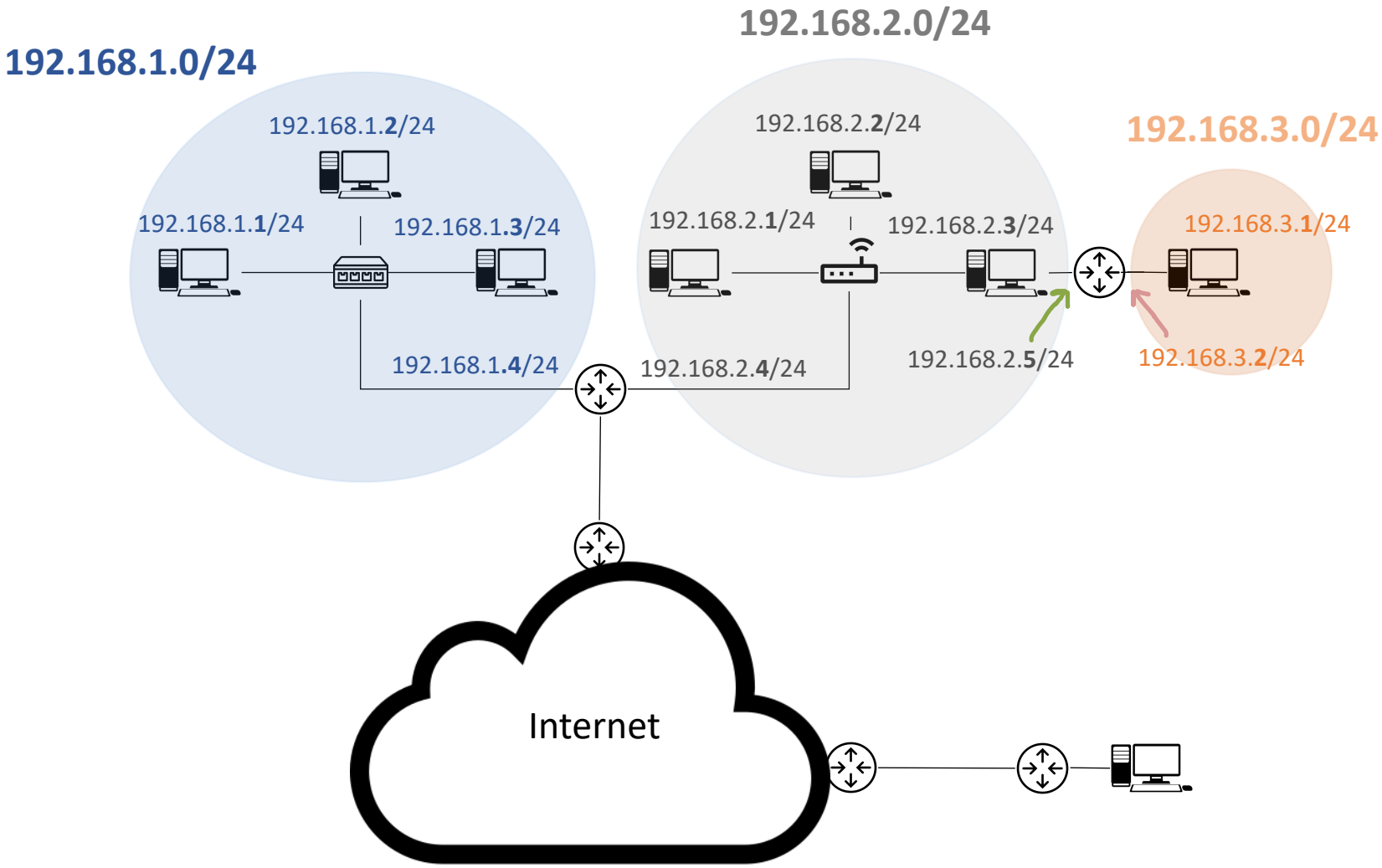
- Among the available IP addresses, some can only be used for local use : **private address**
- These addresses do not allow Internet access
- Useful for setting up local networks
- 3 address ranges - see RFC 5735
  - Class A: 10.0.0.1 -> 10.255.255.254
  - Class B: 172.16.0.1 -> 172.31.255.254
  - Class C: 192.168.0.1-> 192.168.255.25

- Others are public, used in the internet and known by internet routers : **public address**

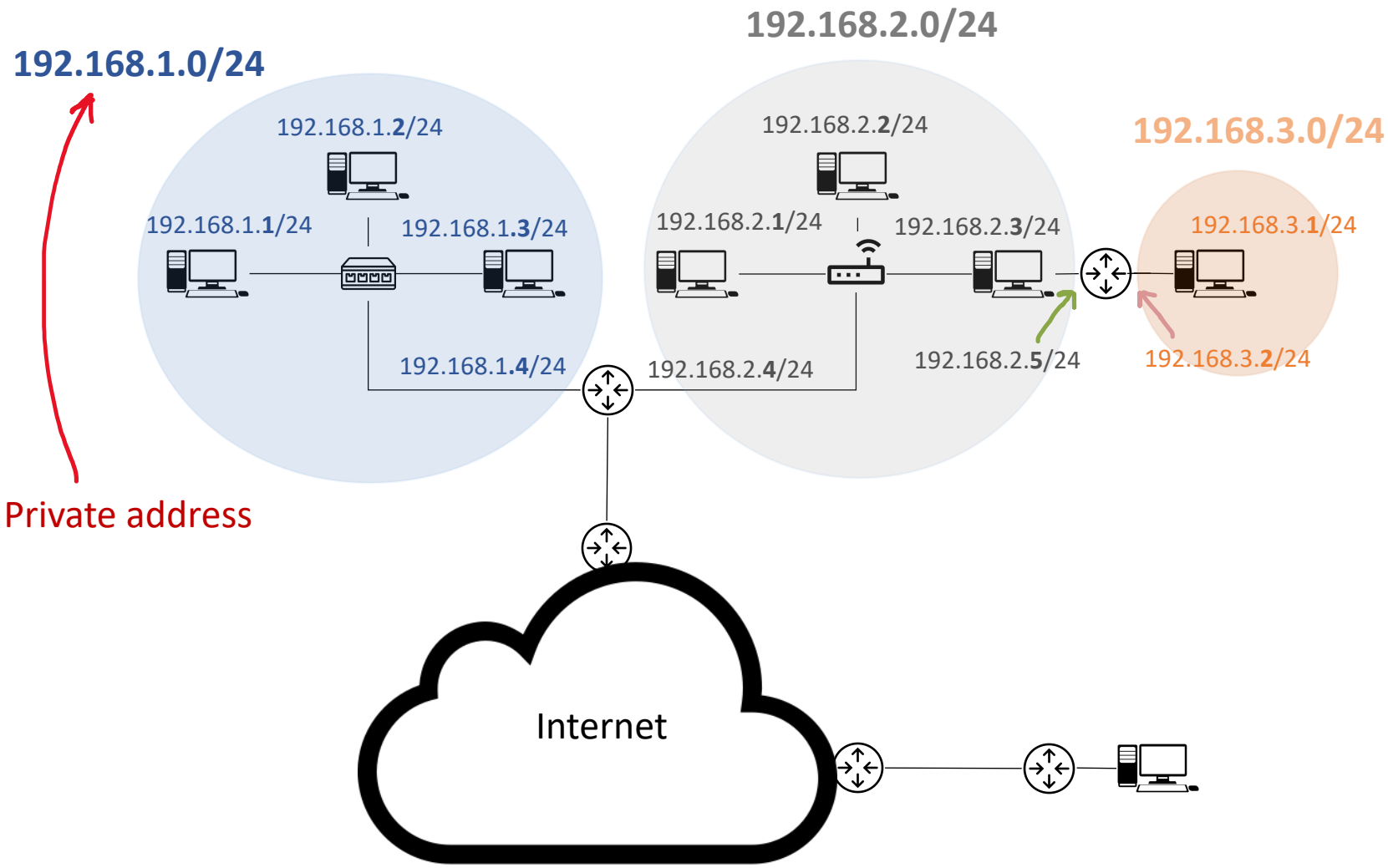
Public v.s. private address



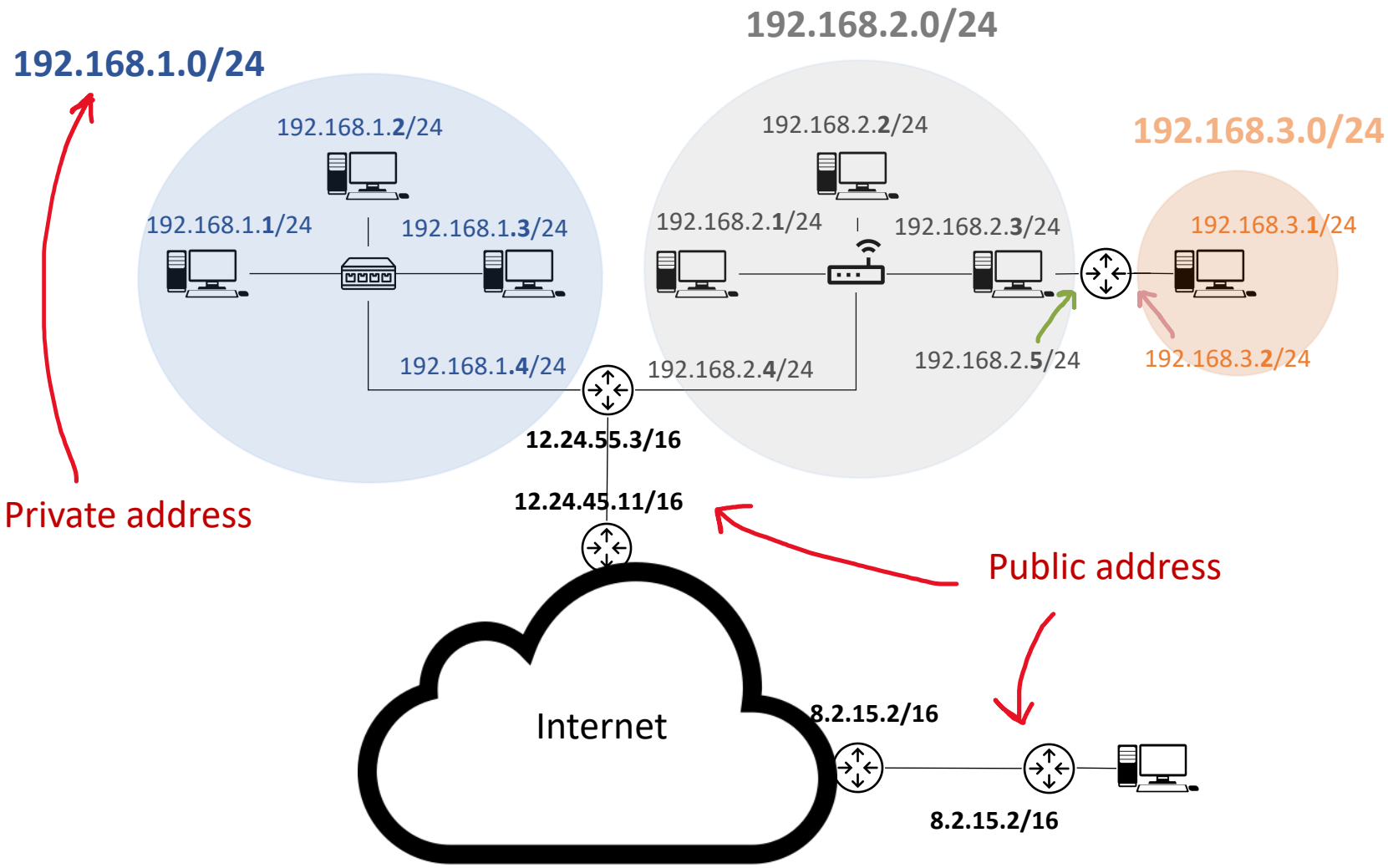
Public v.s. private address



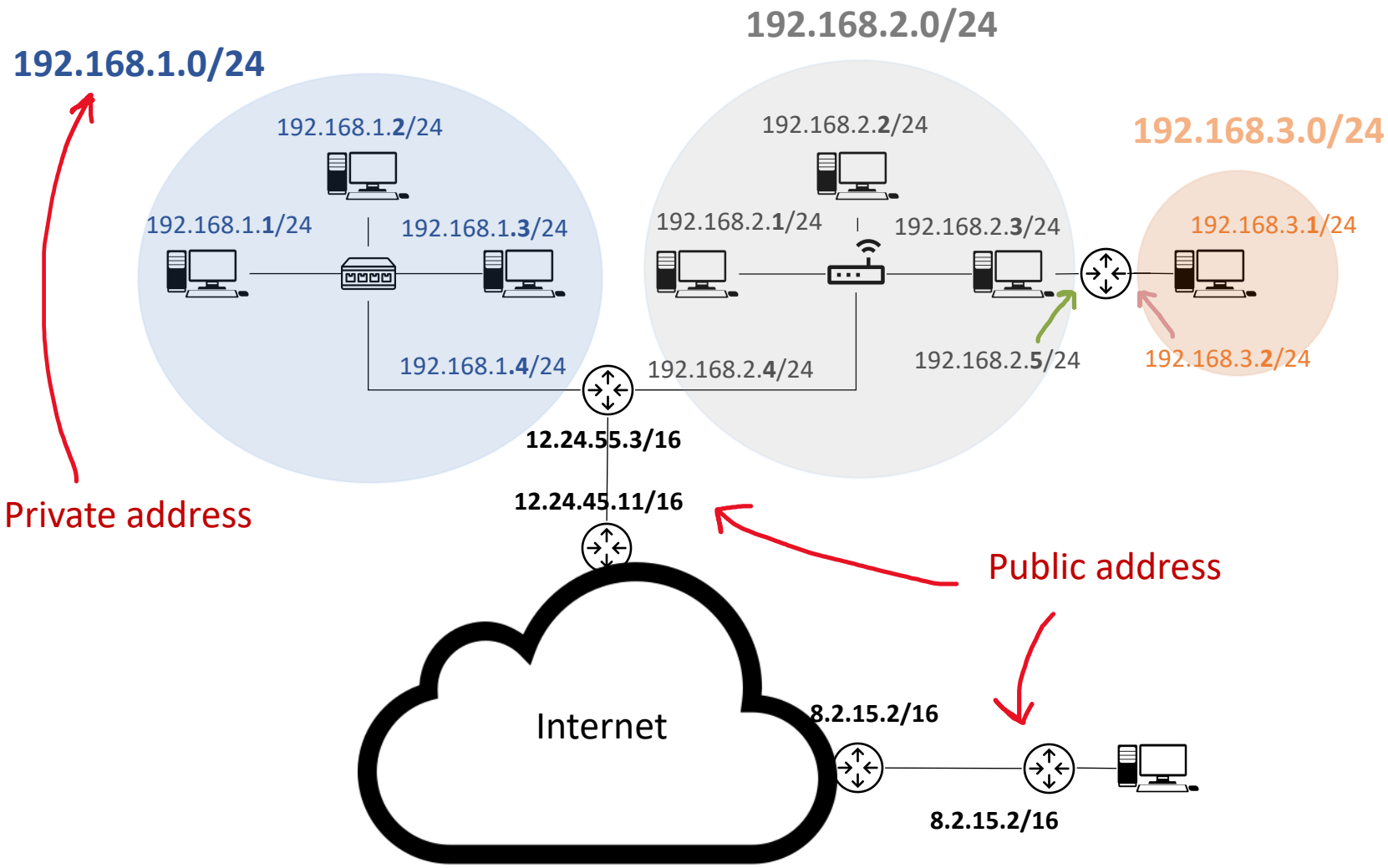
Public v.s. private address



Public v.s. private address



Public v.s. private address



NAT - Network address Translation

- Any user can create a local network with a single public address
- So how can I send a message to the different local machines from internet if there is only one public address ?

=> The router will do the **translation**, i.e. replace the source and/or destination address with its public address

=> NAT (Network Address Translation)

Address assignment

- The prefixes of the IPv4 network addresses are assigned by the IANA: Internet Assigned Numbers Authority whose role is the management of shared resources (address, number of protocols and ports, AS operator number, etc.)

- The IANA assigns addresses to the RIRs (Regional Internet Registry) which then allocates them to the LIRs (local Internet registry) or Internet access providers

IP Addresses

- I have 192.168.1.0/24 as a network
- In the case of one network :
  - I keep the same mask
  - I keep the same network ID
  - I change the host ID part to attribute addresses to machines

IP Addresses

- I have 192.168.1.0/24 as a network
- In the case of one network :
  - I keep the same mask
  - I keep the same network ID
  - I change the host ID part to attribute addresses to machines

Network address	192.168.1.0/24
Machine 1	192.168.1.1/24
Machine 2	192.168.1.2/24
Machine 1	192.168.1.3/24
…	…
Broadcast address	192.168.1.255/24

IP Addresses

- I have 192.168.1.0/24 as a network
- In the case of one network :
  - I keep the same mask
  - I keep the same network ID
  - I change the host ID part to attribute addresses to machines

Network address	192.168.1.0/24
Machine 1	192.168.1.1/24
Machine 2	192.168.1.2/24
Machine 3	192.168.1.3/24
…	…
Broadcast address	192.168.1.255/24

With the same mask I can configure 2^8 – 2 machines

Subneting

- Subneting is an extension of the initial addressing plan

- Allows to optimize:
  - administrative management of IP addresses
  - the size of the routing information
  - limit broadcast domains
  - the processing carried out at the gateways

- Principles
  - Several physical networks share this IP address
  - These physical networks are then said to be *subnetworks* of the IP address network

Subneting

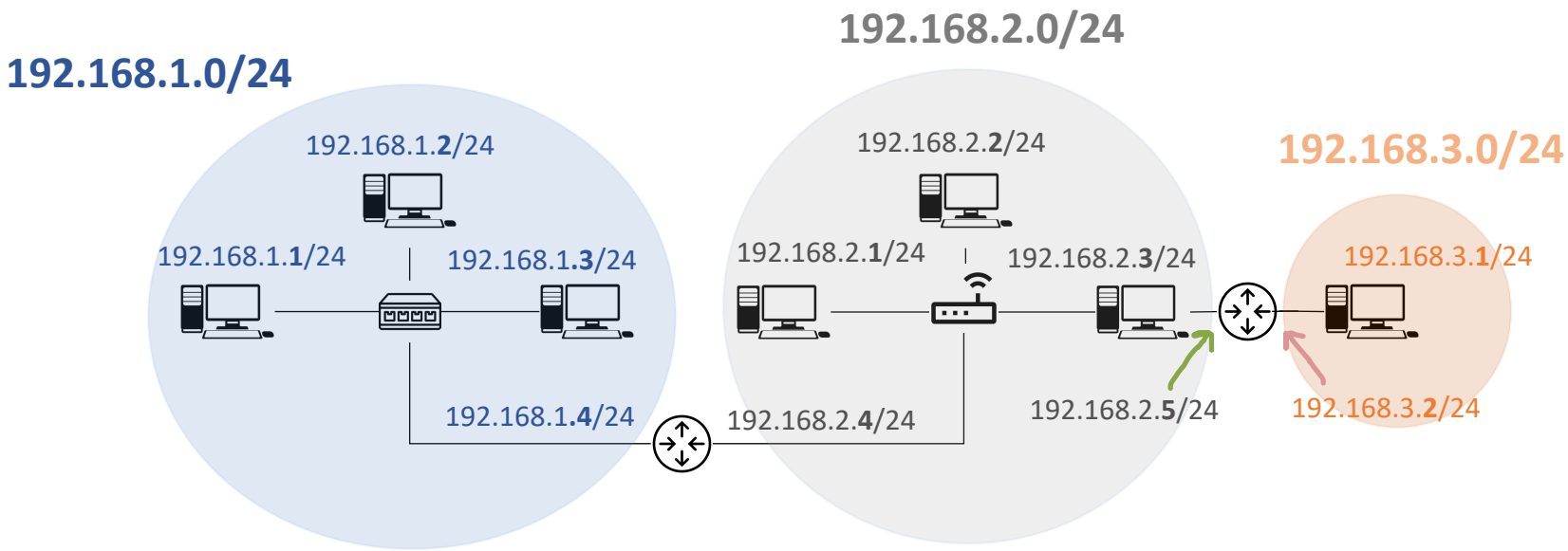
- Splitting a network into subnets using the network mask

- Mask :
  - Binary "1" in <network-number> <subnet-number>
  - Binary "0" in <host-number>

- Example
  - Class B network address: 130.25.0.0
  - Network mask 255.255.0.0
  - 3 subnets => 3 <2^2
  - Subnet mask: 255.255. 11000000

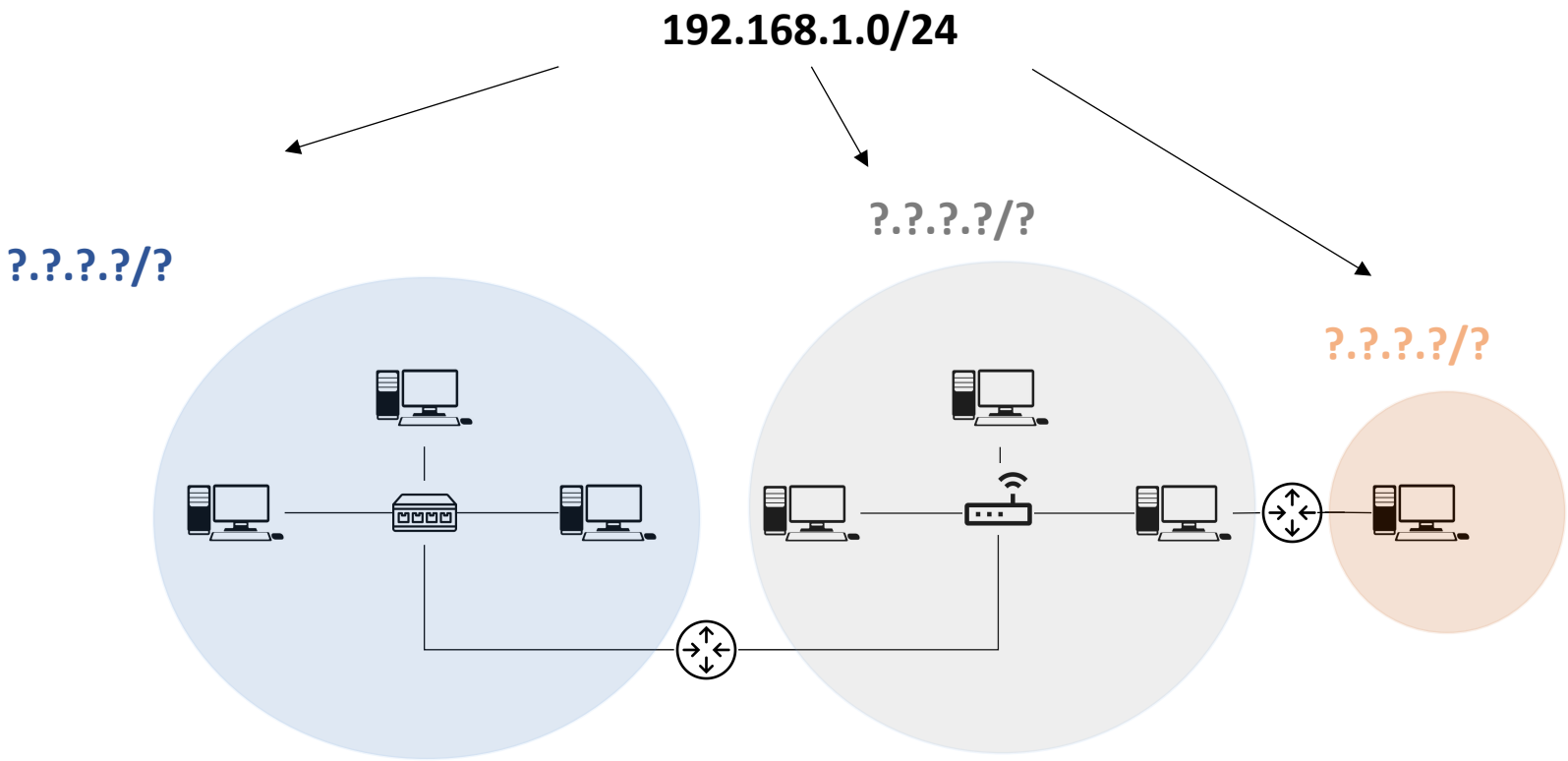
Subneting

- We used different addresses of mask 24 in the previous example
  => some machine adresses are not used
- We want to use only 192.168.1.0/24 for all networks to optimise



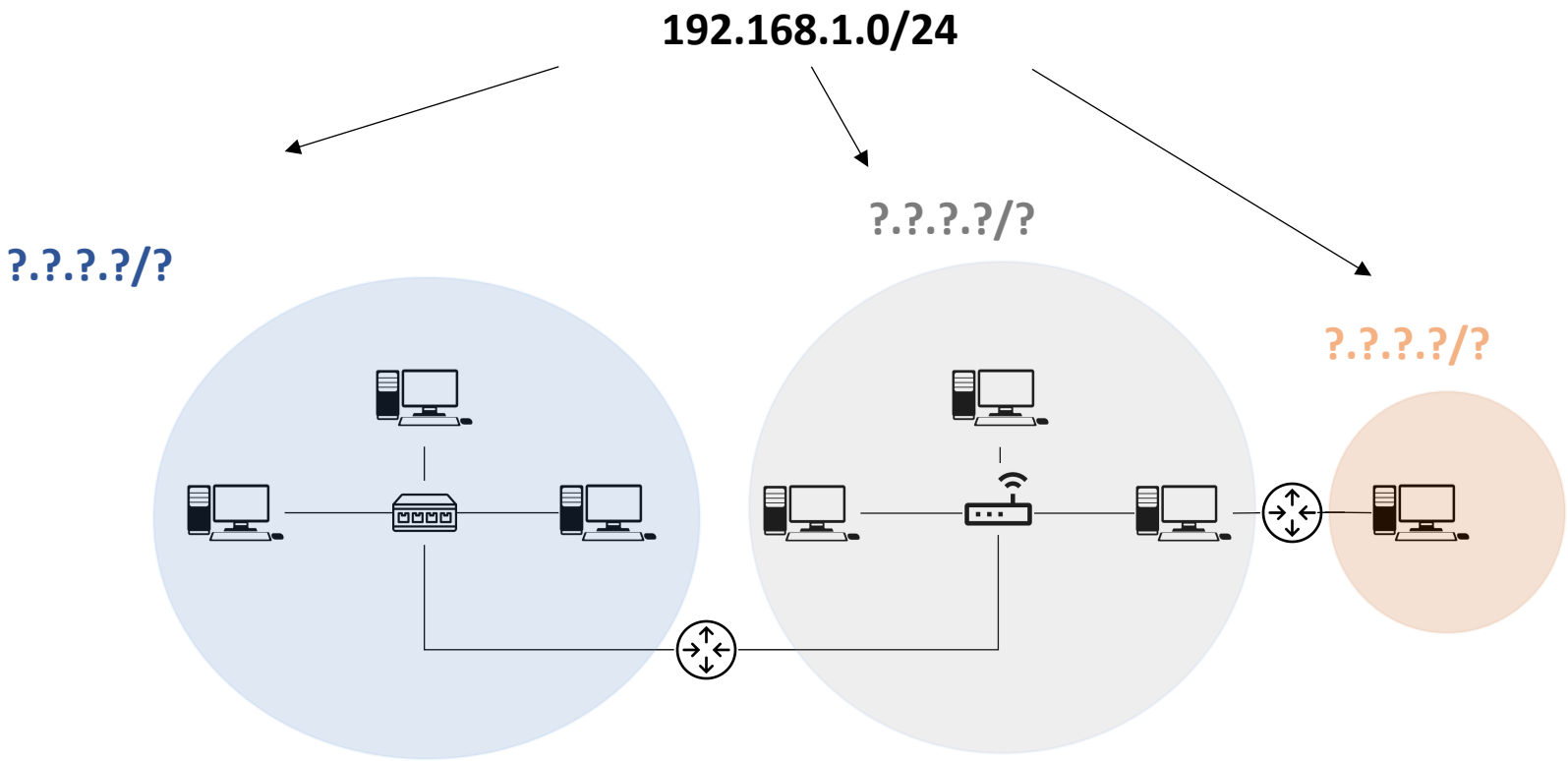
Subneting

- We used different addresses of mask 24 in the previous example
  => some machine adresses are not used
- We want to use only 192.168.1.0/24 for all networks to optimise



Subneting

192	168	1	0	/24



Subneting

192	168	1	0	/24

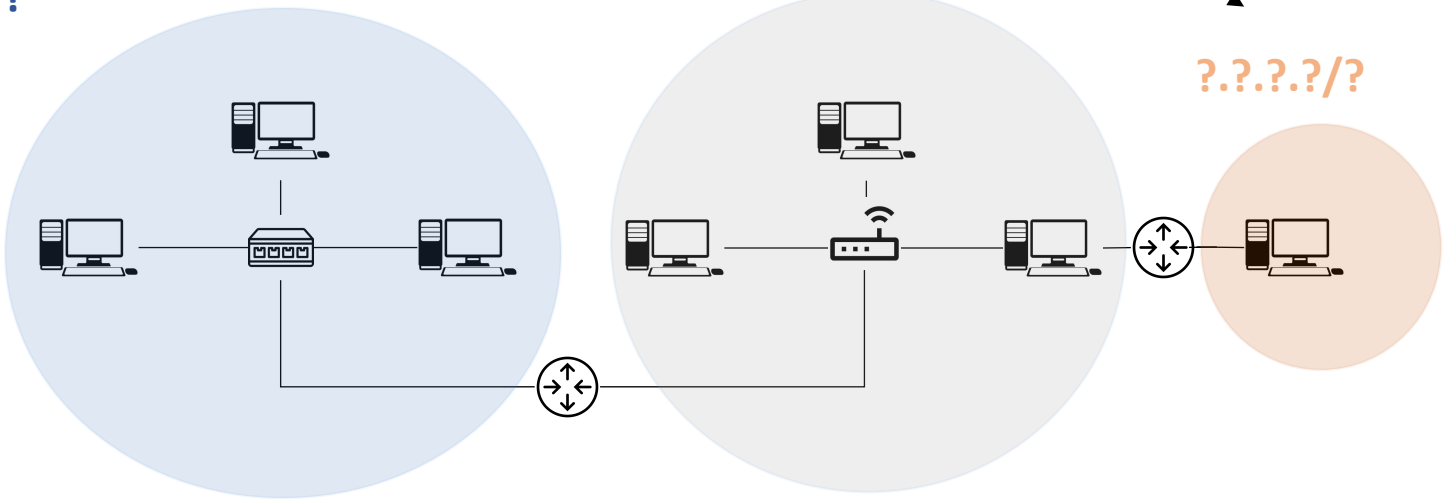
0 0 0 0 0 0 0 0

192.168.1.0/24

?.?.?.?/?

?.?.?.?/?

?.?.?.?/?



Subneting

192	168	1	0	/24

3 subnetworks => 2 bits

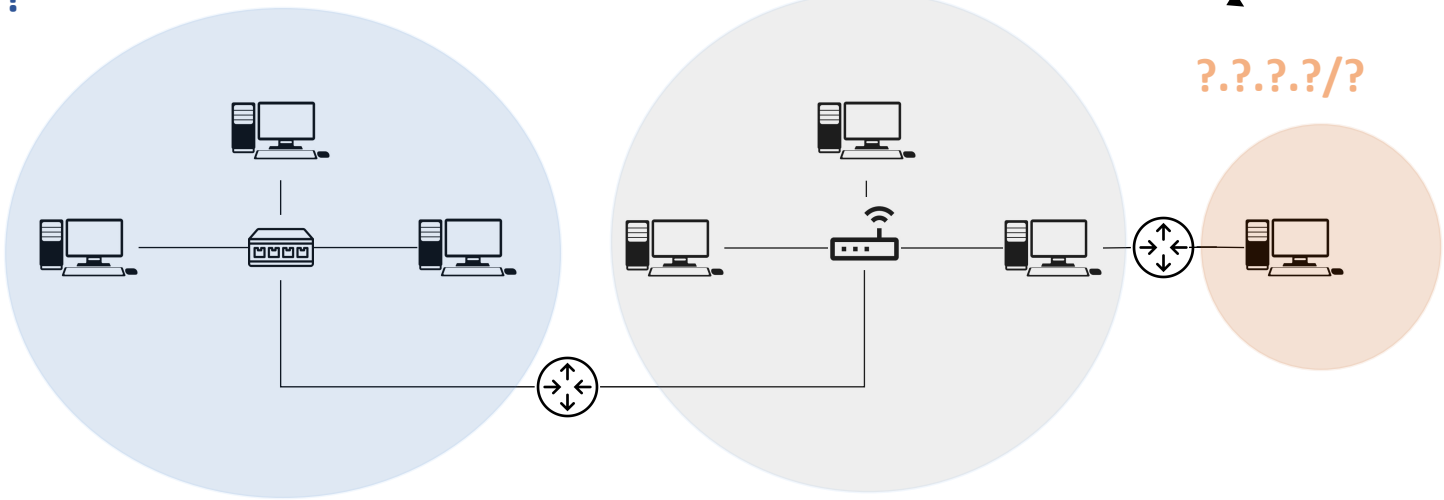
0	0	0	0	0	0	0	0	/26

192.168.1.0/24

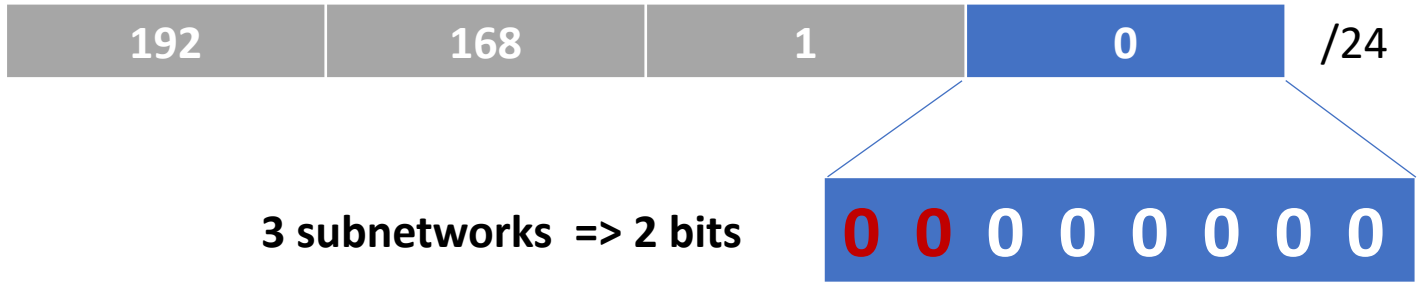
?.?.?.?/?

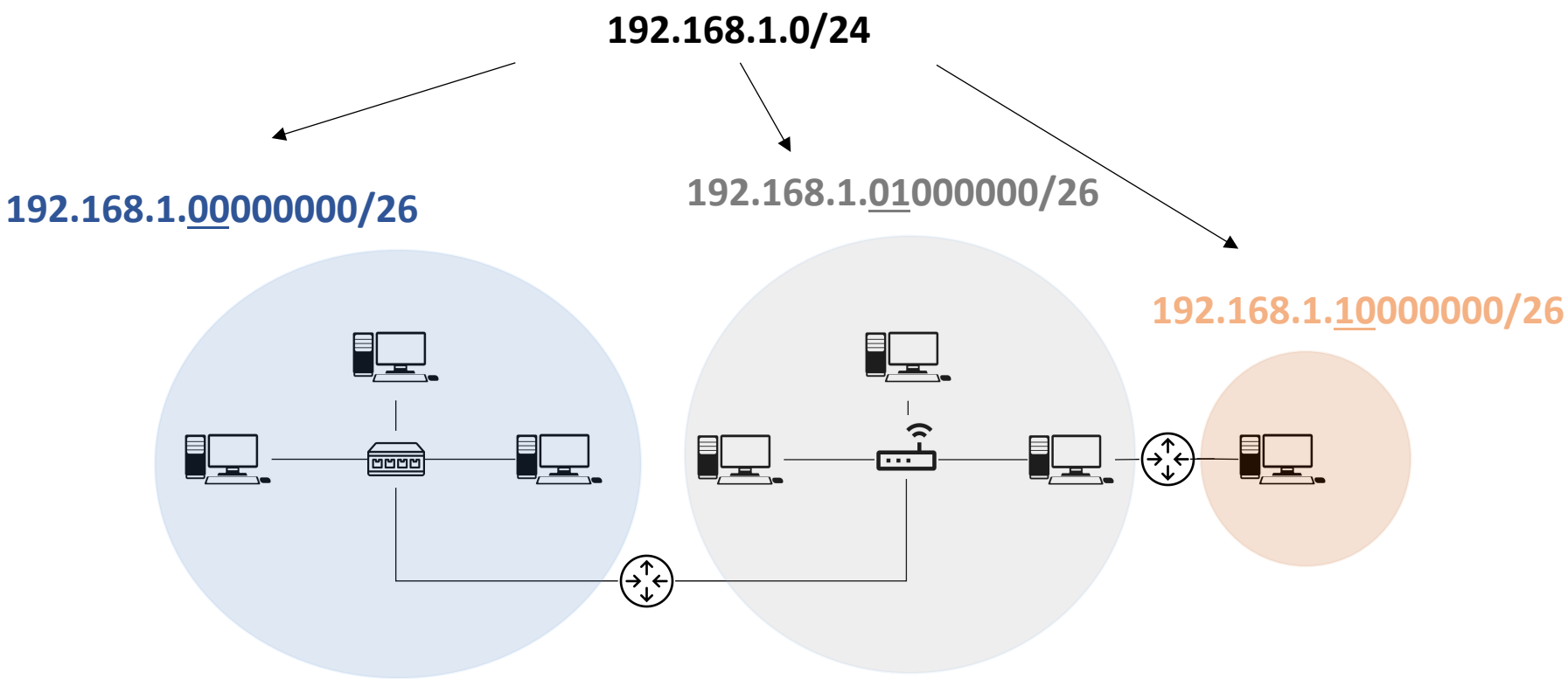
?.?.?.?/?

?.?.?.?/?



Subneting


192
168
1
0
/24
3 subnetworks => 2 bits
0 0 0 0 0 0 0 0
/26

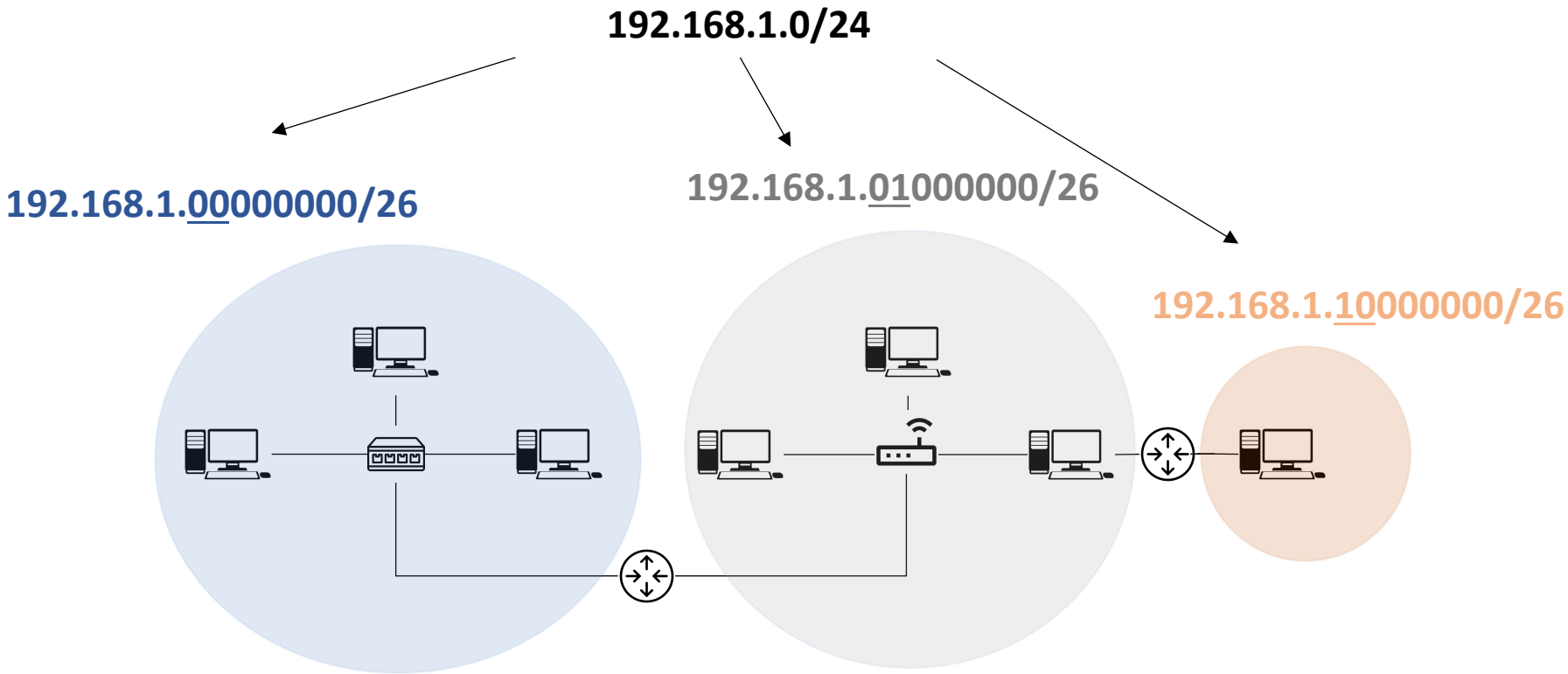

192.168.1.0/24
192.168.1.00000000/26
192.168.1.01000000/26
192.168.1.10000000/26

Subneting

- Ok, this optimizes the use of a general address in the case of subnets of a similar size
- What if we have a significant difference in subnets size ?

  Example : subnet 1 with 50 machine and subnet 2 with 2 machines

⇒ Taking a mask based on subnet 1 wil give to subnet 2 a large unused machine address range



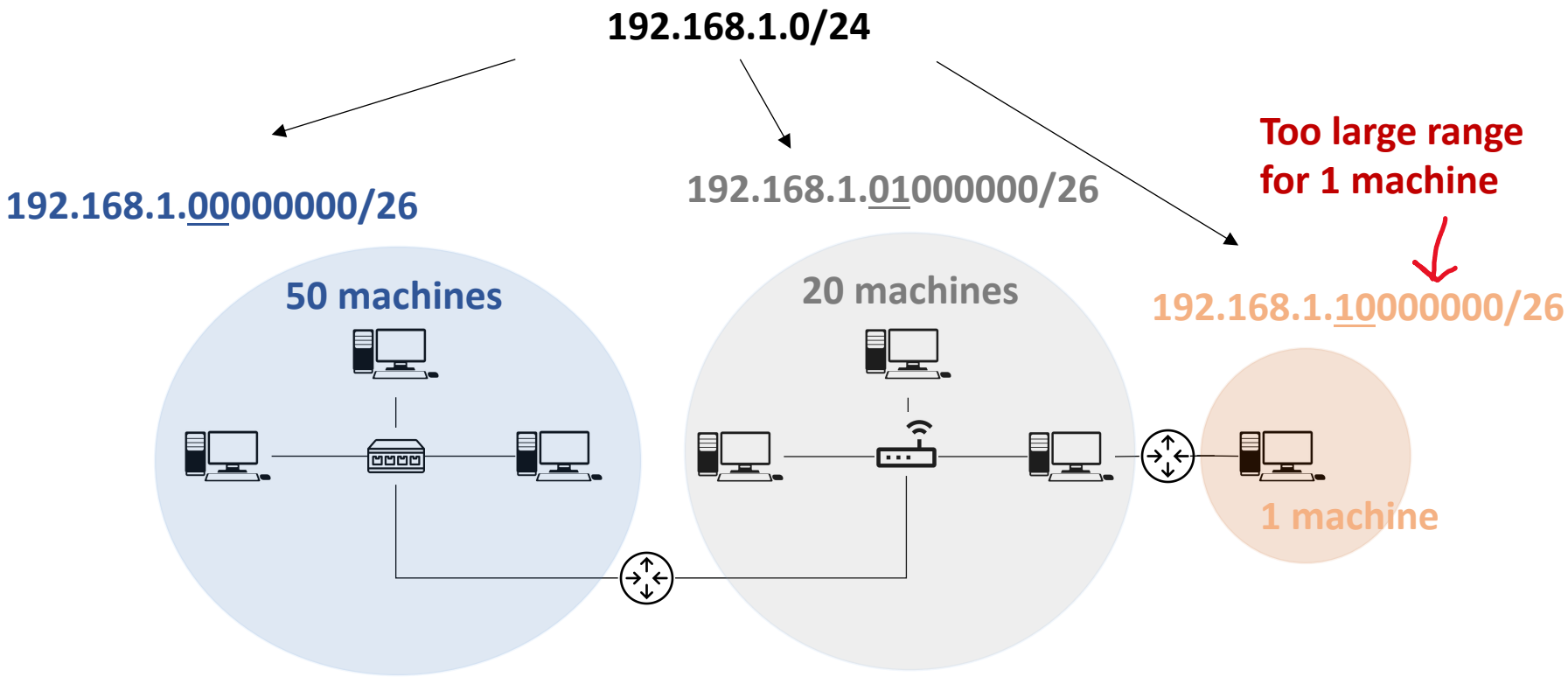
Variable Length Subnet Masks (VLSM)

- An IP network can have several different masks
- => Variable Length Subnet Masks (VLSM) network

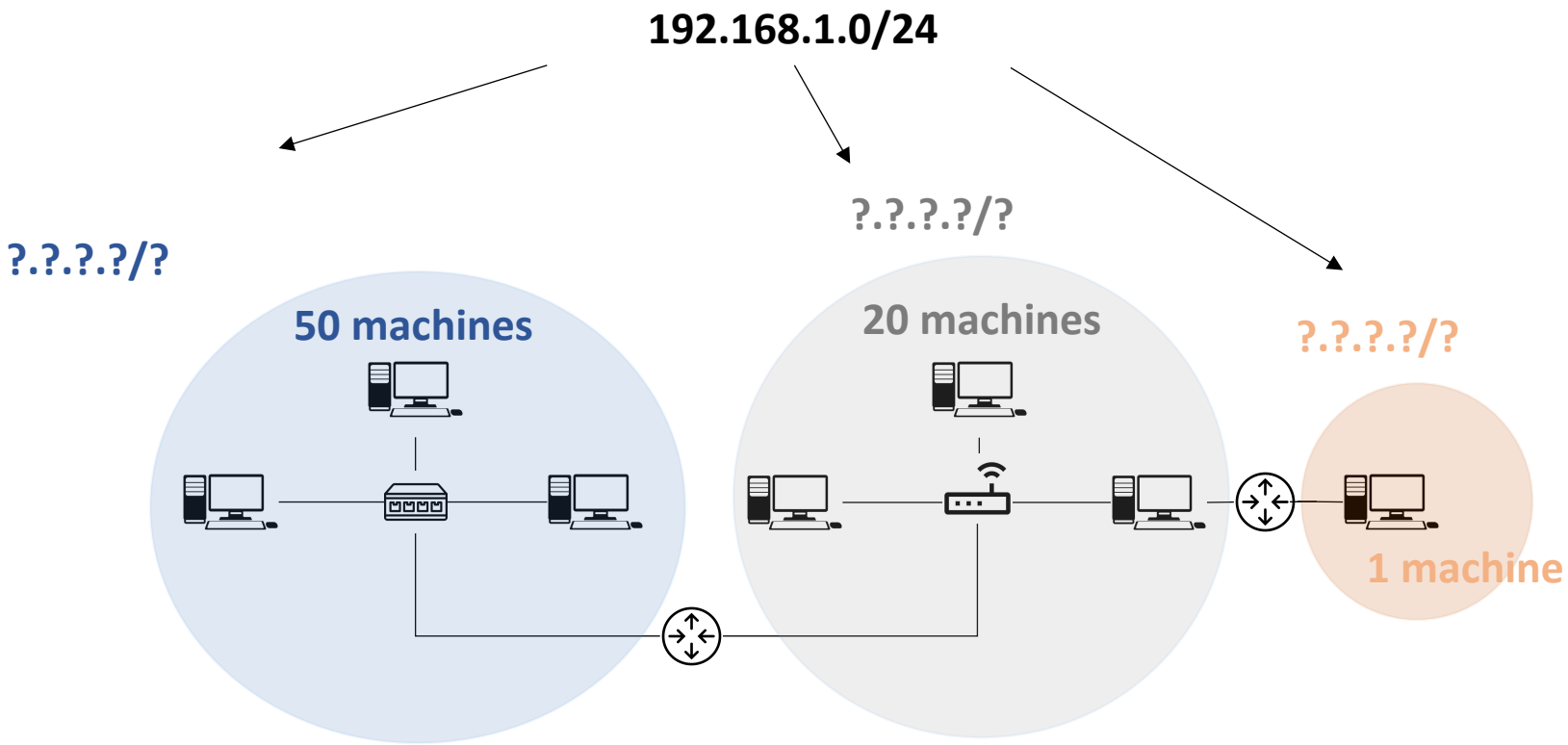
- Avoids the rigidity of the fixed mask which imposes:
  - Example:
  - 130.5.0.0/22 ==> 64 subnets and 1022 machines per subnetwork
    - Unsuitable for small subnets of a few machines;
    - Example 30 machines on a subnet ==> 992 IP addresses lost

- Allows the adaptation of IP addressing to the size of the subnets
  - Previous example: cohabitation of large and small subnets
    - 130.5.0.0/22 (64 subnets and 1022 machines / subnetwork)
    - 130.5.0.0/26 (1024 subnets of 62 machines / subnet)

Variable Length Subnet Masks (VLSM)

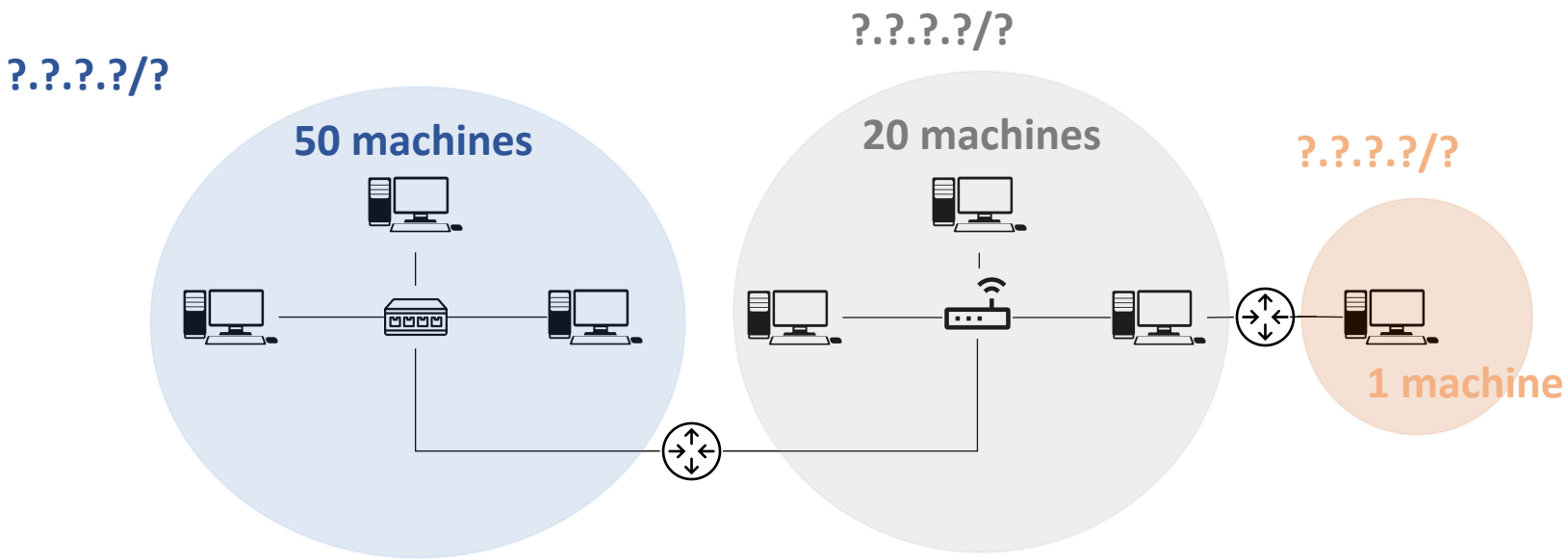


Variable Length Subnet Masks (VLSM)



Variable Length Subnet Masks (VLSM)

192.168.1.0/24

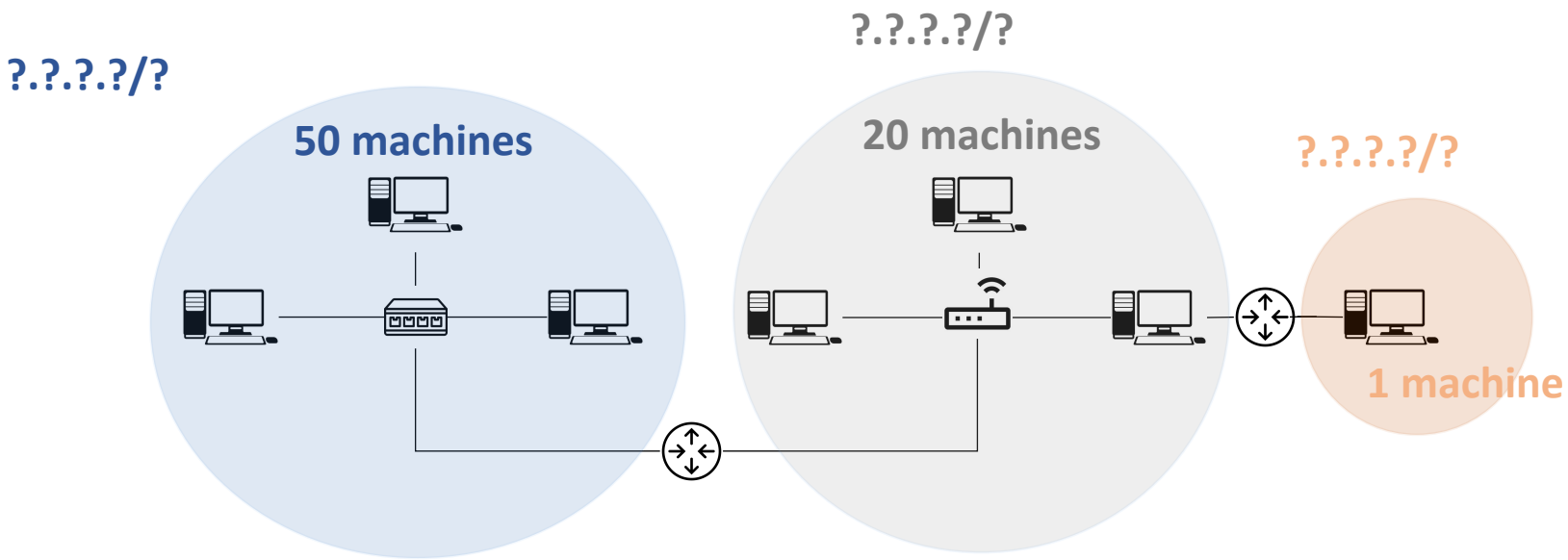


Variable Length Subnet Masks (VLSM)

192.168.1.0/24

192.168.1.000000000/26

50 machines
⇒ 6 host bits
⇒ 2 subnet bits

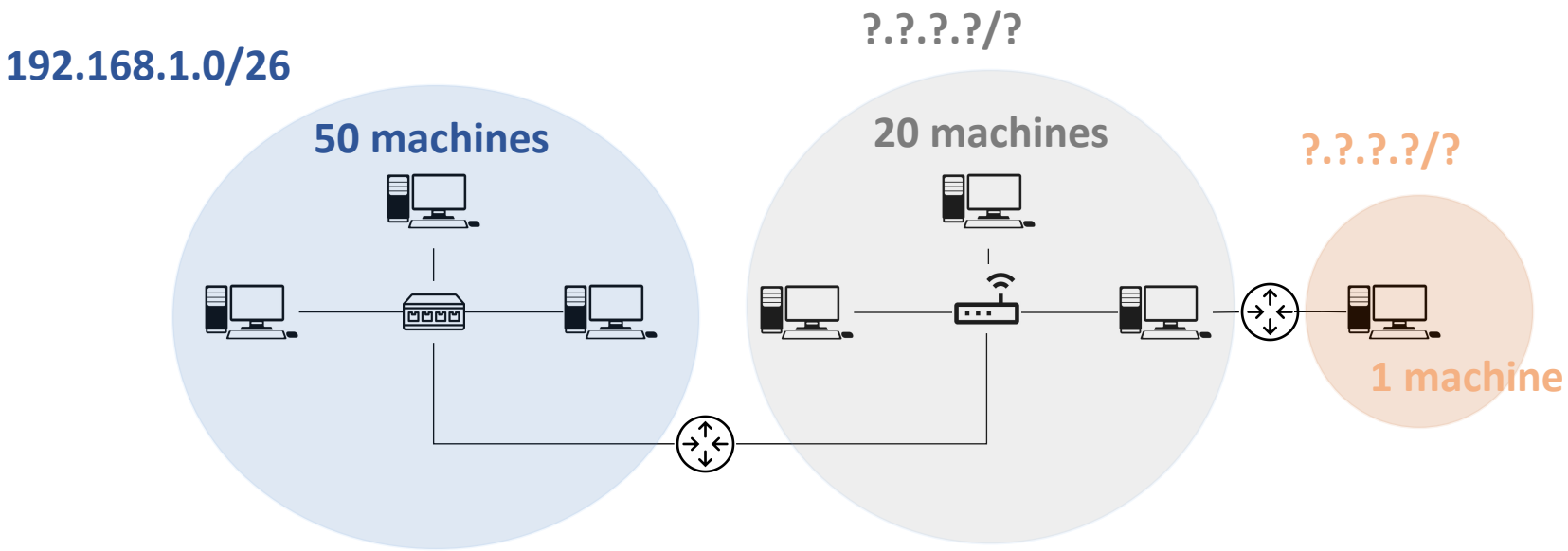


Variable Length Subnet Masks (VLSM)

192.168.1.0/24

192.168.1.000000000/26

50 machines
⇒ 6 host bits
⇒ 2 subnet bits

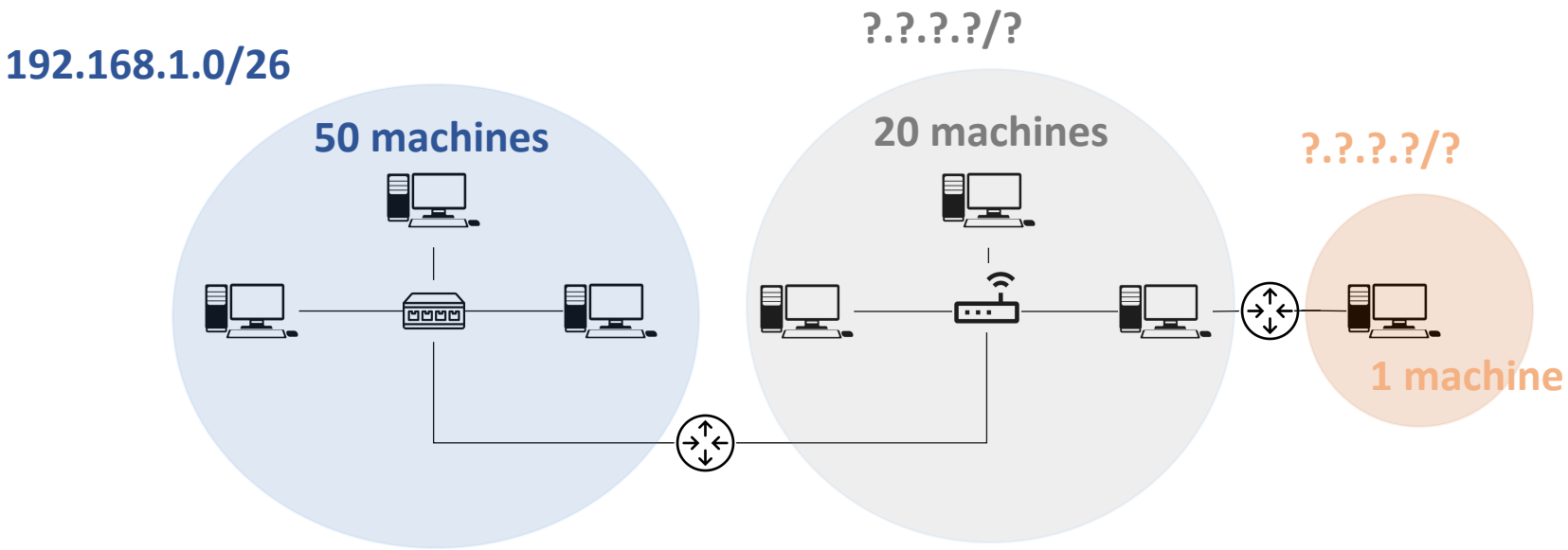


Variable Length Subnet Masks (VLSM)

192.168.1.0/24

192.168.1.000000000/26 **192.168.1.01000000/26**

50 machines
⇒ 6 host bits
⇒ 2 subnet bits



Variable Length Subnet Masks (VLSM)

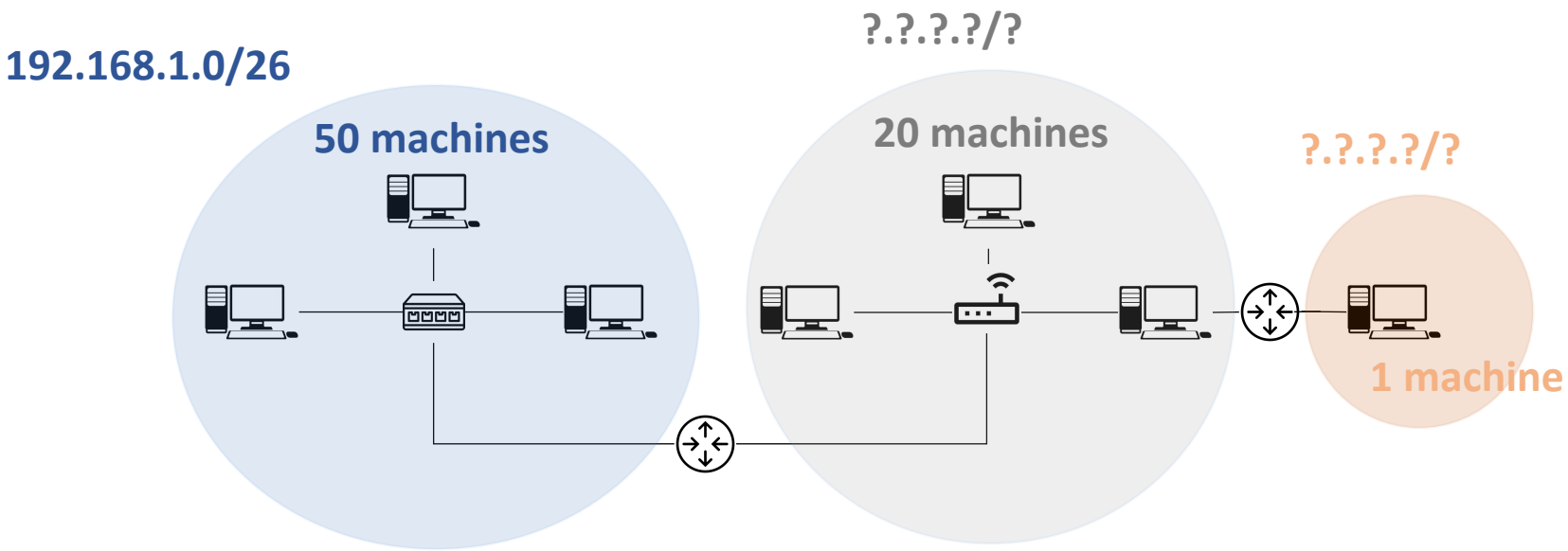
192.168.1.0/24

192.168.1.000000000/26

50 machines
⇒ 6 host bits
⇒ 2 subnet bits

192.168.1.01000000/26

20 machines
⇒ 5 host bits
⇒ 3 subnet bits



Variable Length Subnet Masks (VLSM)

192.168.1.0/24

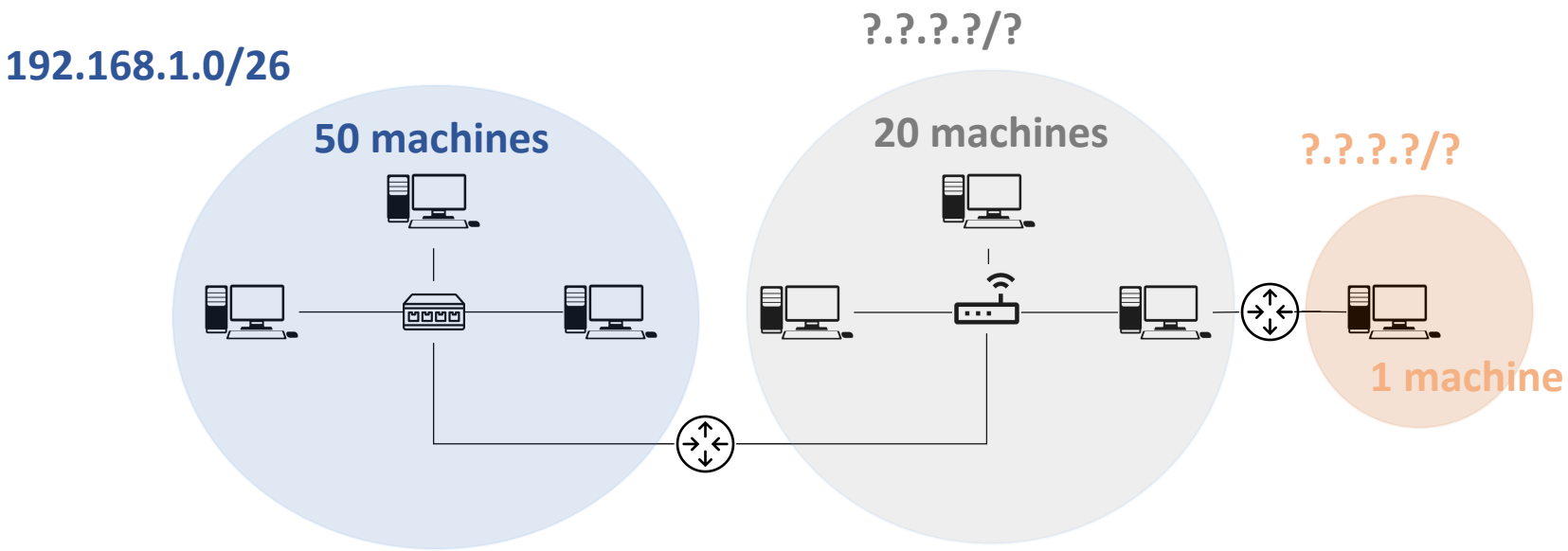
192.168.1.000000000/26

50 machines
⇒ 6 host bits
⇒ 2 subnet bits

192.168.1.01000000/26

20 machines
⇒ 5 host bits
⇒ 3 subnet bits

192.168.1.01000000/27



Variable Length Subnet Masks (VLSM)

192.168.1.0/24

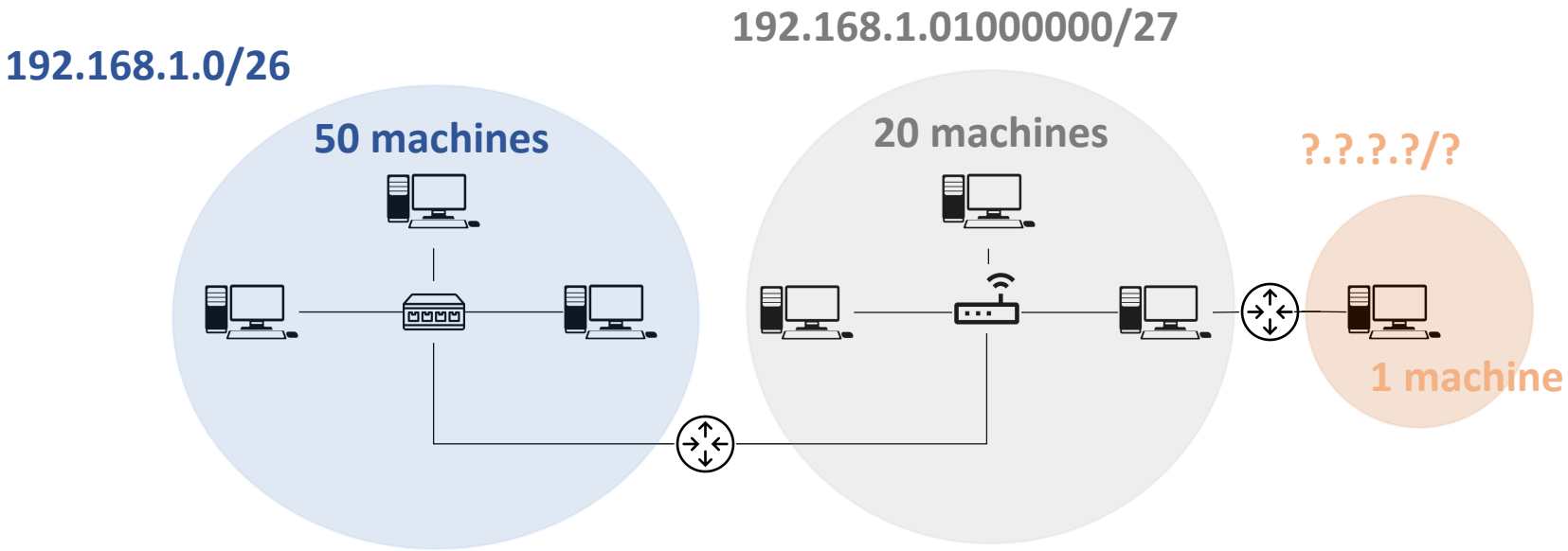
192.168.1.000000000/26

50 machines
⇒ 6 host bits
⇒ 2 subnet bits

192.168.1.01000000/26

20 machines
⇒ 5 host bits
⇒ 3 subnet bits

192.168.1.01000000/27



Variable Length Subnet Masks (VLSM)

192.168.1.0/24

192.168.1.000000000/26

50 machines
⇒ 6 host bits
⇒ 2 subnet bits

192.168.1.01000000/26

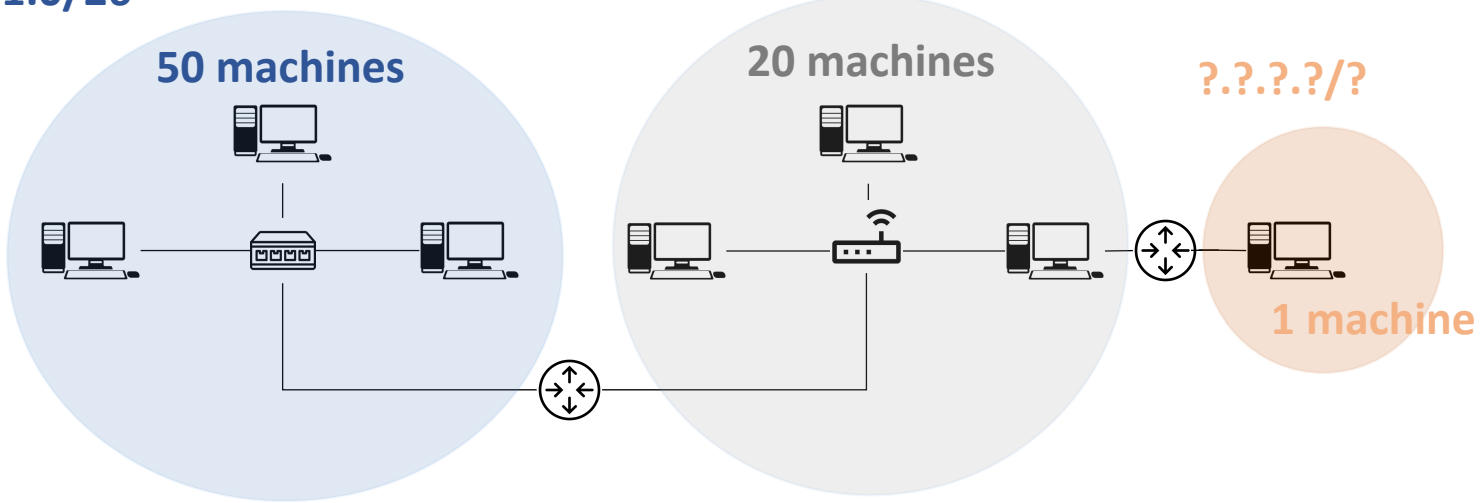
20 machines
⇒ 5 host bits
⇒ 3 subnet bits

192.168.1.01000000/27

192.168.1.01100000/27

192.168.1.0/26

192.168.1.01000000/27



Variable Length Subnet Masks (VLSM)

192.168.1.0/24

192.168.1.000000000/26

50 machines
⇒ 6 host bits
⇒ 2 subnet bits

192.168.1.01000000/26

20 machines
⇒ 5 host bits
⇒ 3 subnet bits

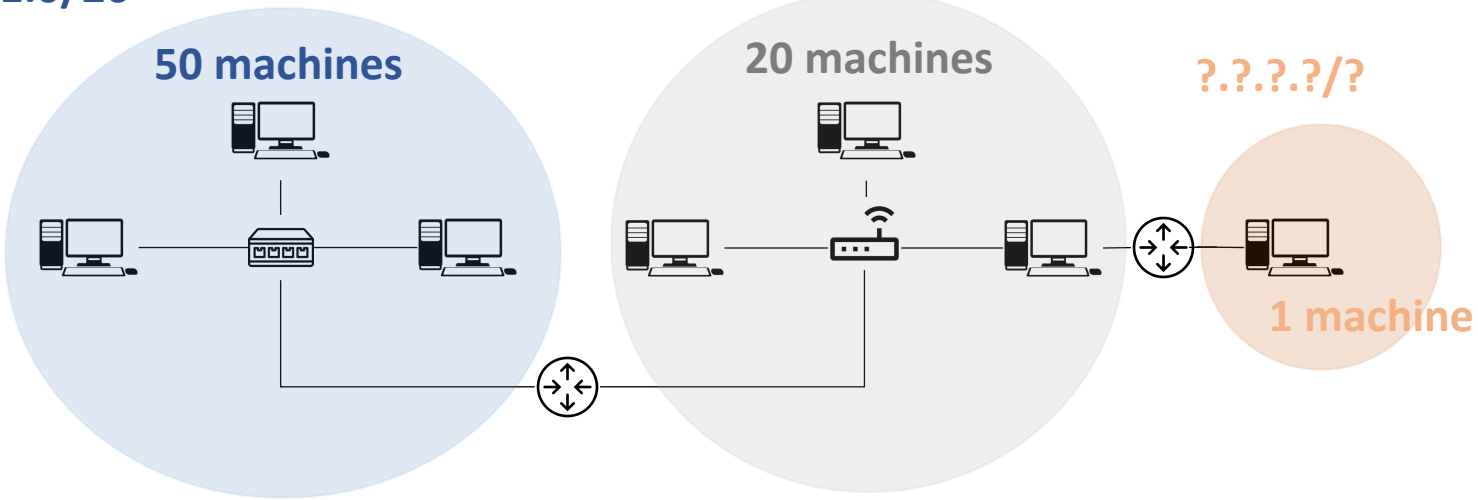
1 machines
⇒ 2 host bits
⇒ 6 subnet bits

192.168.1.01000000/27

192.168.1.01100000/27

192.168.1.0/26

192.168.1.01000000/27



Variable Length Subnet Masks (VLSM)

192.168.1.0/24

192.168.1.000000000/26

50 machines
⇒ 6 host bits
⇒ 2 subnet bits

192.168.1.01000000/26

20 machines
⇒ 5 host bits
⇒ 3 subnet bits

1 machines
⇒ 2 host bits
⇒ 6 subnet bits

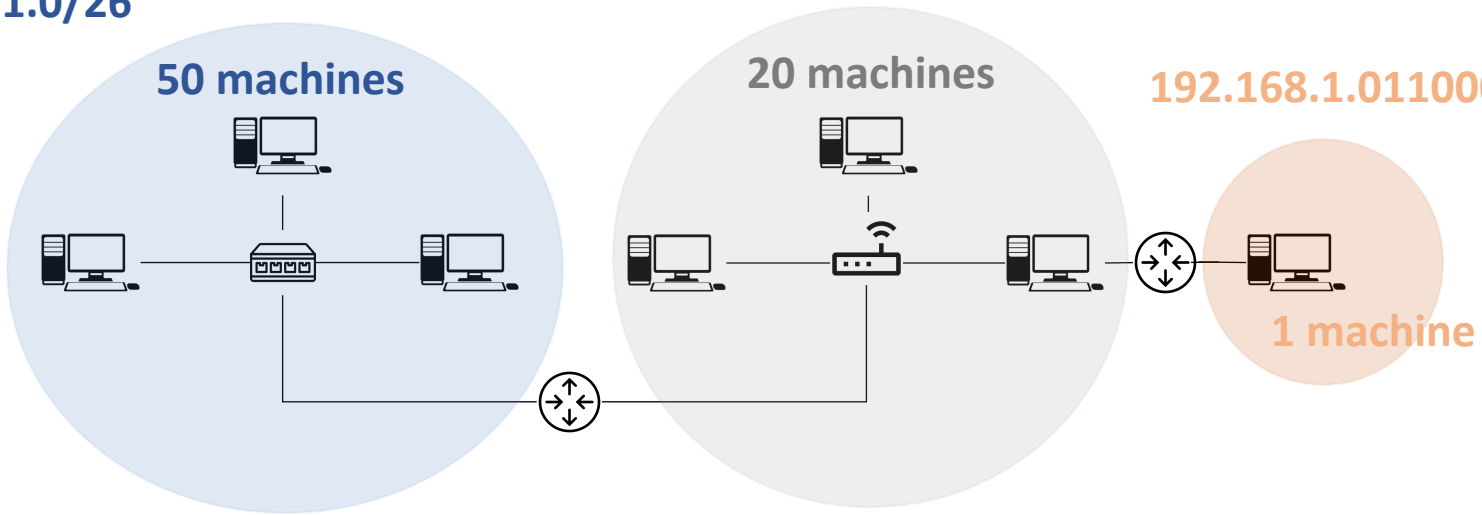
192.168.1.01000000/27

192.168.1.01100000/27

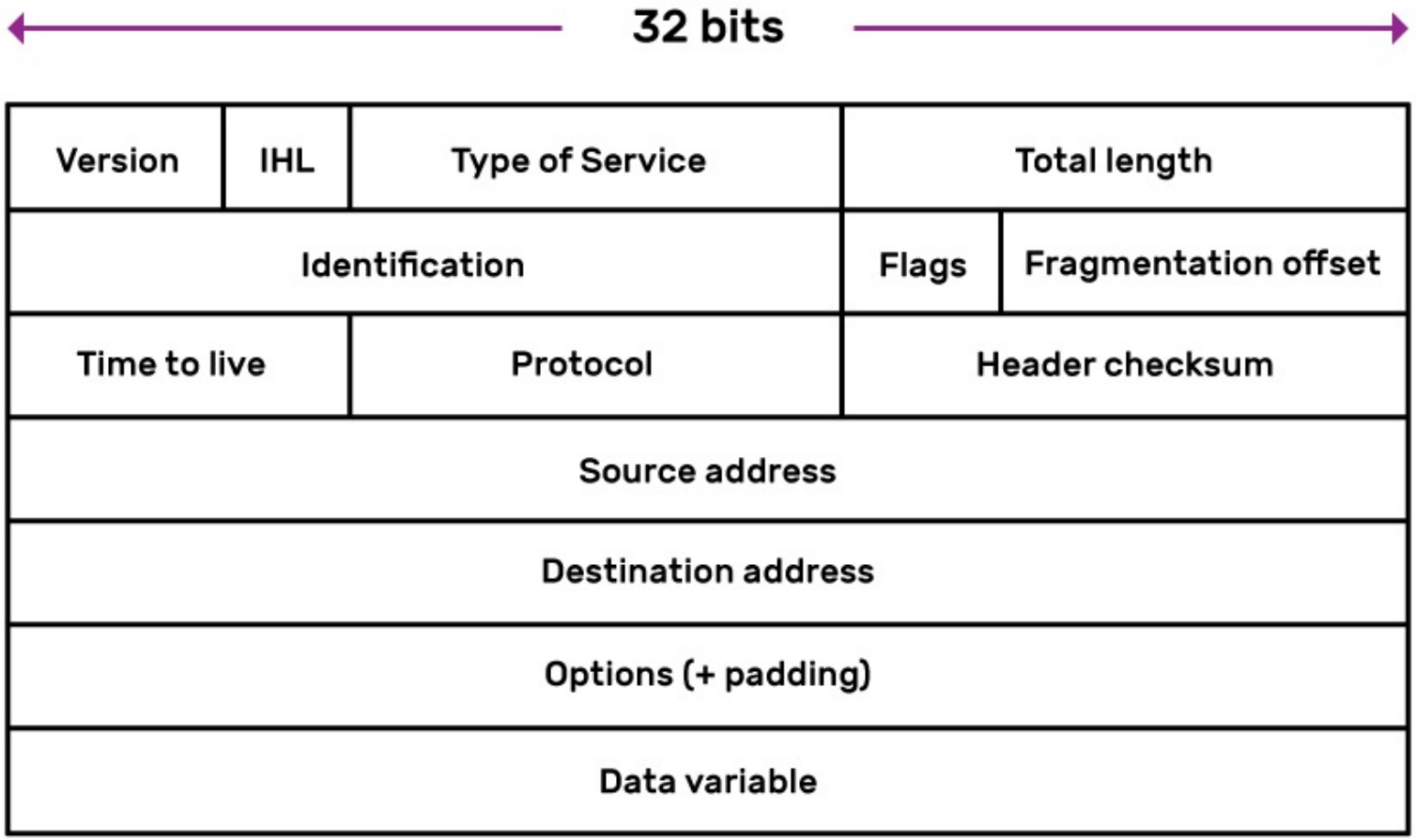
192.168.1.01100000/30

192.168.1.0/26

192.168.1.01000000/27



IP packet structure



IP packet structure

- `Version` (4 bits) : IP protocol version, 4 in our case
- `Internet Header Length` (IHL) (4bits) : header length, in multiples of 4 bytes (≥ 5)
- `Total Length` : total length of the packet (or fragment)
- `Protocol` : number of the protocol to which the data in the Data zone belong
- `Header Checksum` : used for check the integrity/correctness of the header
- `Source Address` : source IP address
- `Destination Address` : destination IP address
- `Time to Live (TTL)` : remaining lifetime of the packet, in terms of router hops

IP packet structure

- Packet lifetime
  - Implemented thanks to the TTL field indicating the remaining packet lifetime
  - TTL coded on 8 bits: traverses of routers initialized by the sender of the packet decremented by 1 by any equipment processing the packet at level 3
  - Destruction of datagrams received with TTL = 0

Fragmentation principle

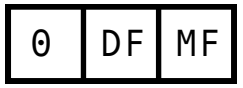
- Goal : to adapt to the MTU (Maximum transfer unit) of the networks, a packet is splited into smaller fragments

- Principle :
- Fragmentation by level 3 entities (sender and routers)
- Reassembly by final recipient only
- time-bound reassembly: destruction of incomplete datagrams after expiration of a timer

Fragmentation principle

- `Identification` : value completing the Protocol, Source Address and Destination Address fields in order to form a unique identifier for a given complete datagram (copied in all its fragments)

- `Flags` (3 bits) : binary flags required for fragmentation



  - `0` : reserved
  - `DF` : Dont Fragment indicator
  - `MF` : More fragment indicator

- `Offset` : position, in multiples of 8 bytes, of the first data byte of this fragment among all the bytes of the complete datagram (significant only in case of fragmentation)

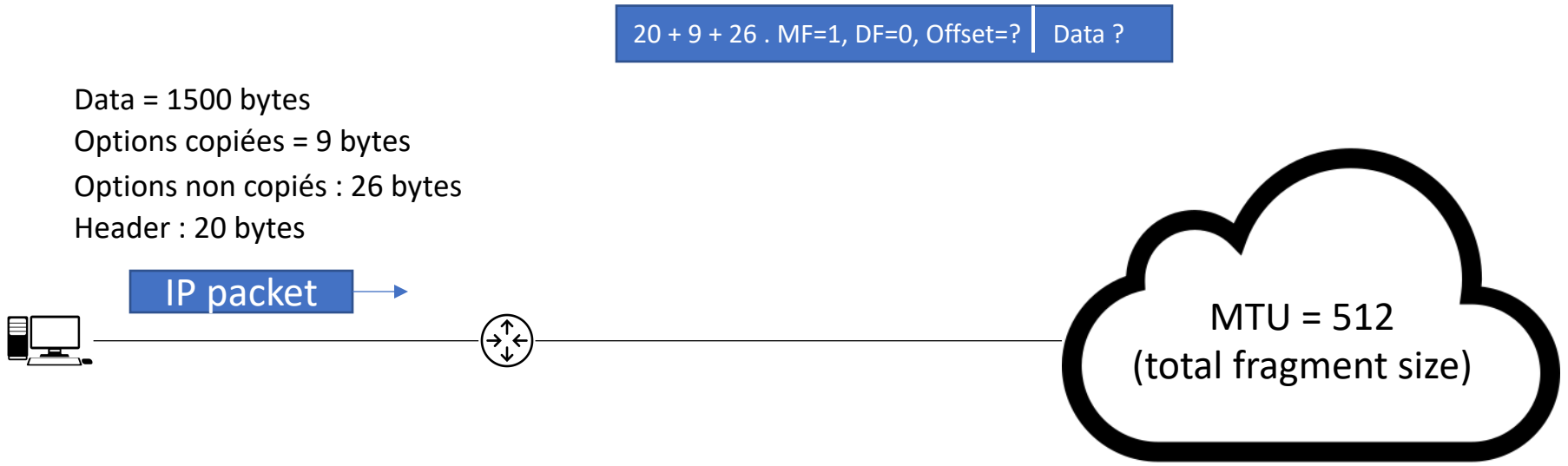
Fragment structure

- Structure of the fragments
  - Similar to that of the original full packet
  - Data size multiple of 8 bytes (except for the last one)
  - Identification of the data of the fragment by an offset, also a multiple of 8 bytes, relative to the start of the complete datagram and the MF indicator (More Fragment)
  - Identification of fragments of the same complete datagram by Protocol, Source Address, Destination Address and Identification
- Note: request for non-fragmentation
  - DF (Don't Fragment) indicator

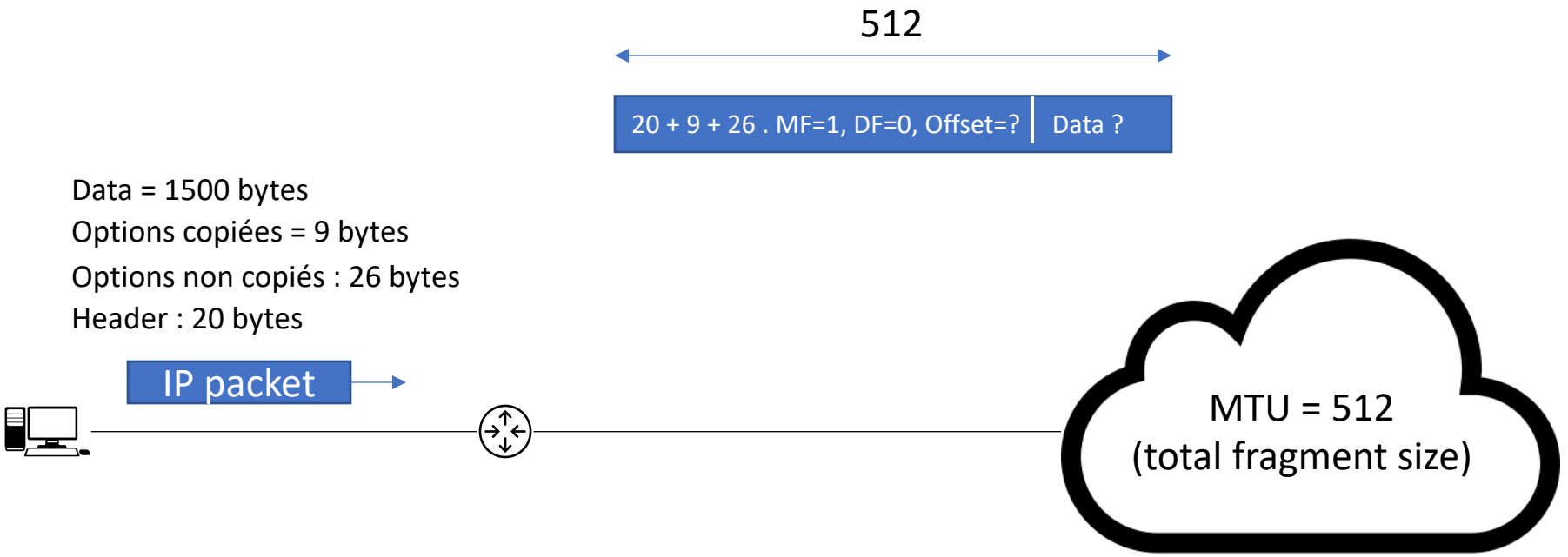
Fragmentation principle

Data = 1500 bytes
Options copiées = 9 bytes
Options non copiés : 26 bytes
Header : 20 bytes

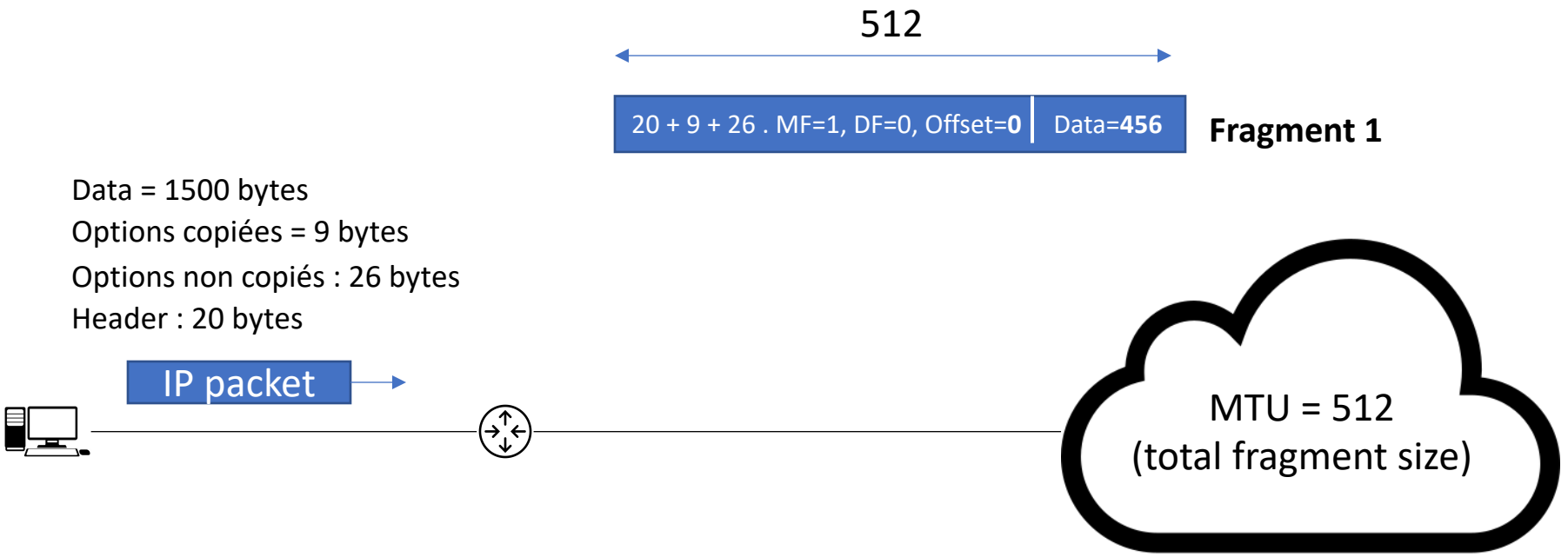
Fragmentation principle



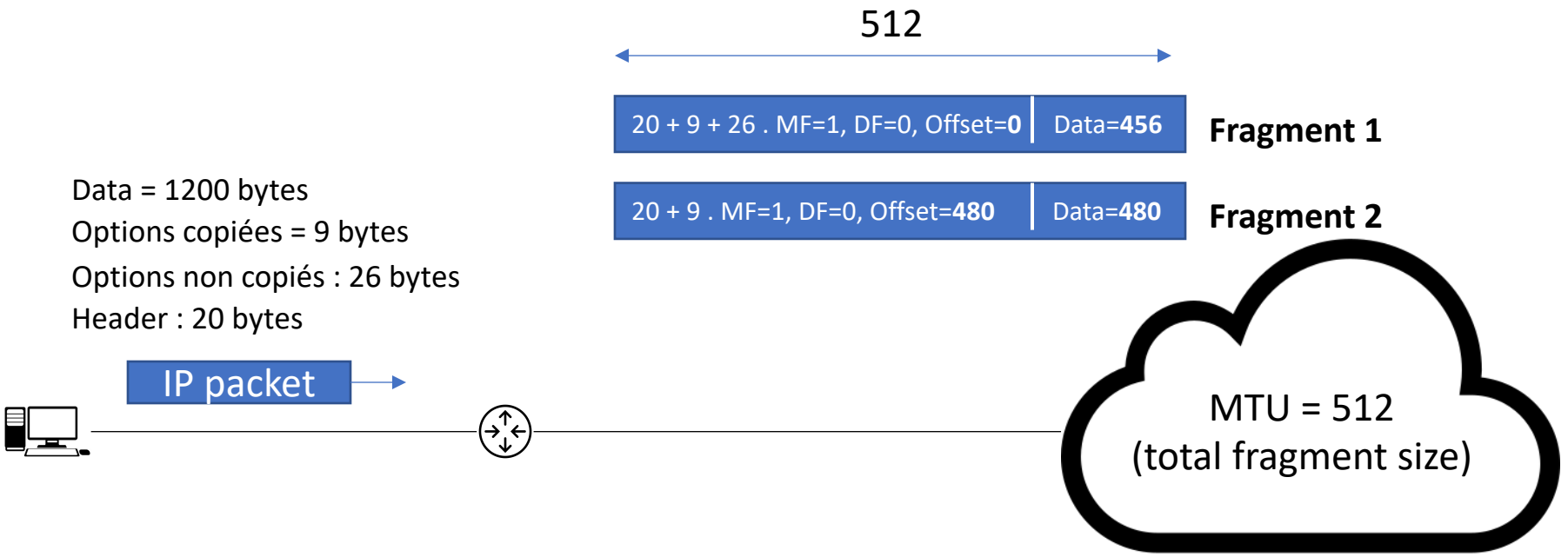
Fragmentation principle



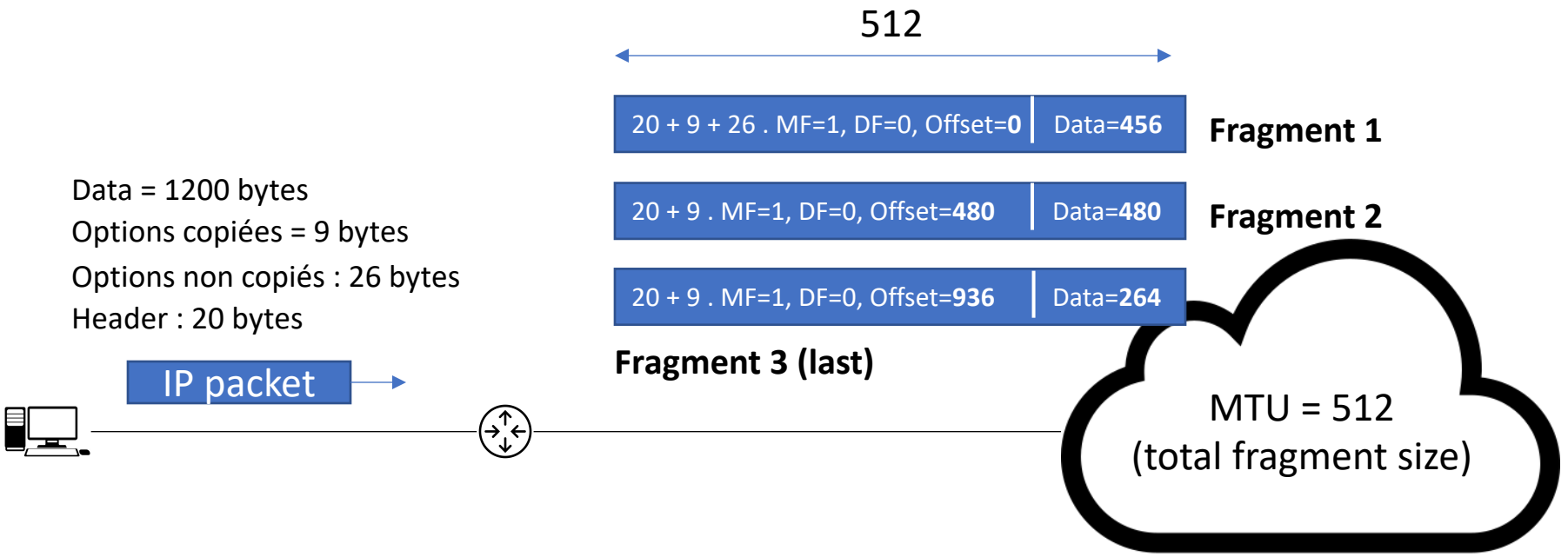
Fragmentation principle



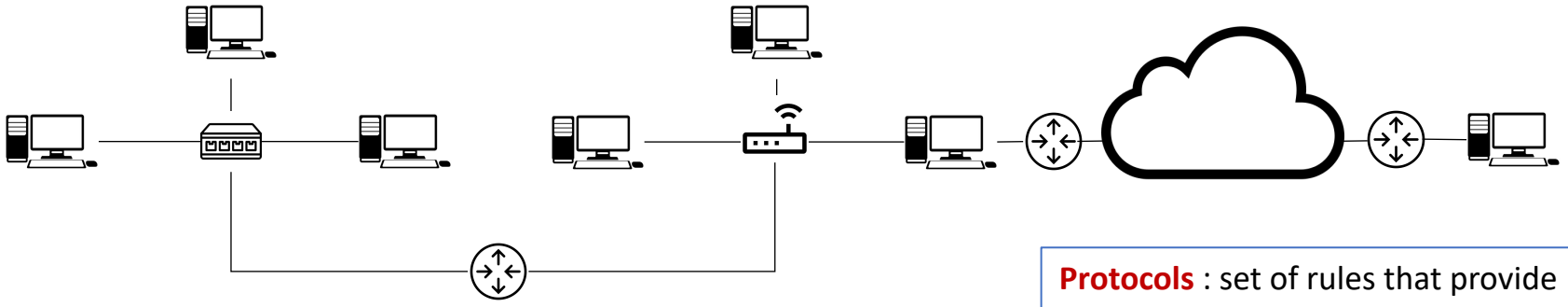
Fragmentation principle



Fragmentation principle



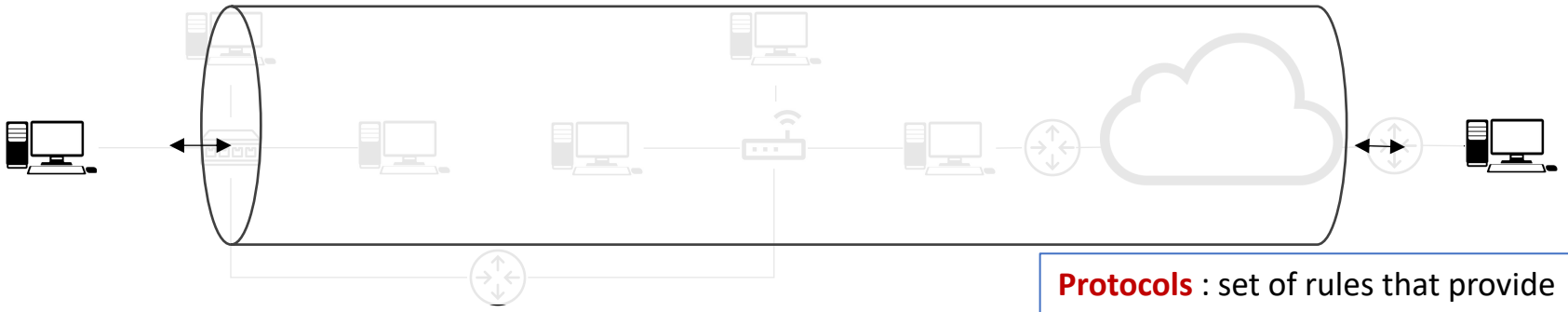
A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receptors and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application

A Network as a System



Protocols : set of rules that provide these functionalities
Standards and specifications

ISO Layer architecture	What do we need as functionality ?
1 - Physical	1. A mean to send signals - physical medium 2. Convert information into signal – encoding
2 – Data link	3. Manage the concuren access to the shared medium (avoid collision) – medium access control 4. Ensure that the information is sent correctly – error control 5. Connect more that 2 machines – switching 6. Identify a machine in a network – physical adress
3 - Network	7. Interconnect different networks – information routing & logical adress
4 - Transport	8. Manage the amount of information sent based on receiver and network capacity – flow control 9. Deliver the message to the corresponding application – multiplexing using ports 10. Maintain an message exchange – connexion 11. Ensure message sequencing – sequence control 12. Ensure the arrival of the entire message – retransmission
5 - Session	13. Manage the progression of sessions – session management
6 - Presentation	14. Encoding data into a universal language – presentation
7 - Application	15. Manage application rules (depends on the application) - application 2

Transport Layer
UDP / TCP

Transport Layer

- How the transport layer works
- UDP protocol study
- TCP protocol study

Transport Layer

- The "transport" layer is particularly concerned with ensuring the transfer of the payload between different points of a communications network

- Purpose of the transport layer:

    - End-to-end data transmission
    - Checking that the data arrives in the correct order (TCP)
    - Determines which application each data is delivered to

- Two main protocols
    - UDP basic and light service
    - TCP sophisticated reliable but heavy service

UDP: User Datagram Protocol

- **UDP**: connectionless transport protocol
  - transmission of application messages: without prior connection establishment
  - the arrival of messages as well as the scheduling are not guaranteed
- **Ports** : identification of the service and management of multiplexing
- IP addresses designate the machines between which communications are established.
- Application process management
  - processes are created and destroyed dynamically on machines
  - you have to be able to replace one process by another without the remote application noticing
  - destinations must be identified according to the services offered, without knowing the processes that implement them

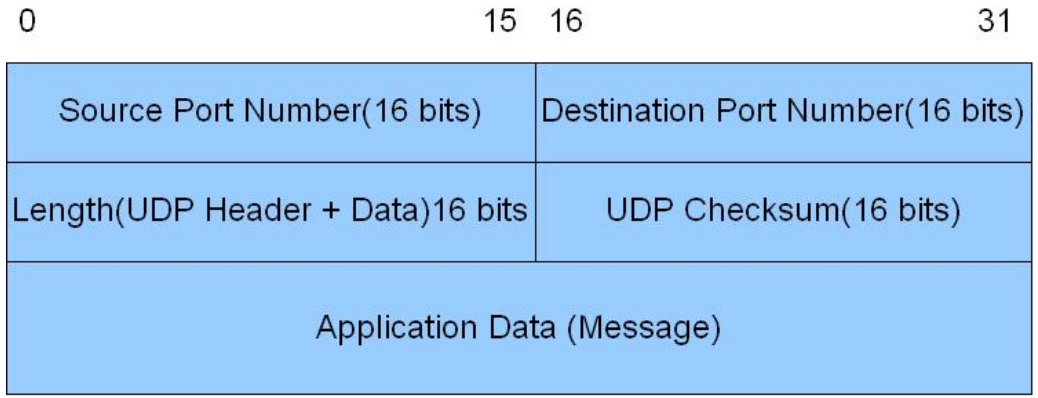
Port

- The transmission of a message is done on the basis of a source port and a destination port.
- Application processes have a system interface allowing them to specify a port or access it (socket API)
- Port access is generally synchronous, port operations are buffered (queues)

UDP datagram

- UDP packets are also called UDP datagrams.
- They contain two parts: a UDP header and the UDP data
- Protocol number is 17
- Communication service
  - with data protection
  - without guarantee of delivery (loss, duplication, de-sequencing, etc.)
- Level 4 multiplexing (port)

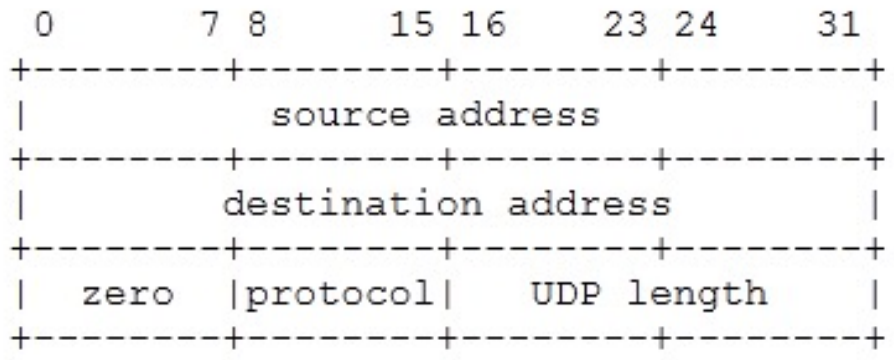
UDP datagram



- `Source Port` : source port number
- `Destination Port` : Destination port number
- `Length` : total length of the UDP datagram
- `Checksum` : checksum for error control (0 if not used)
- `Data`: data transported by UDP (coming from upper layer)

UDP Pseudo Header

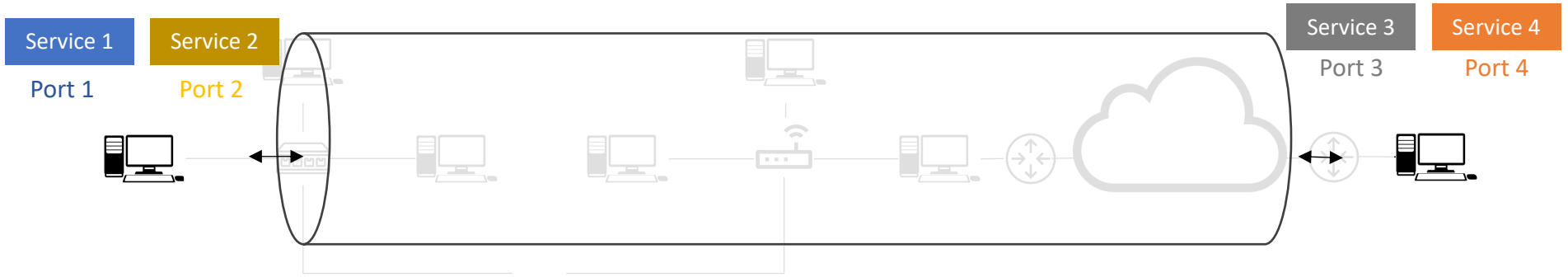
- The checksum is calculated using the UDP header and a pseudo header not transmitted in the datagram:
- The Protocol field indicates the protocol identifier (17 = UDP)
- The UDP length field specifies the length of the UDP datagram without the pse
-



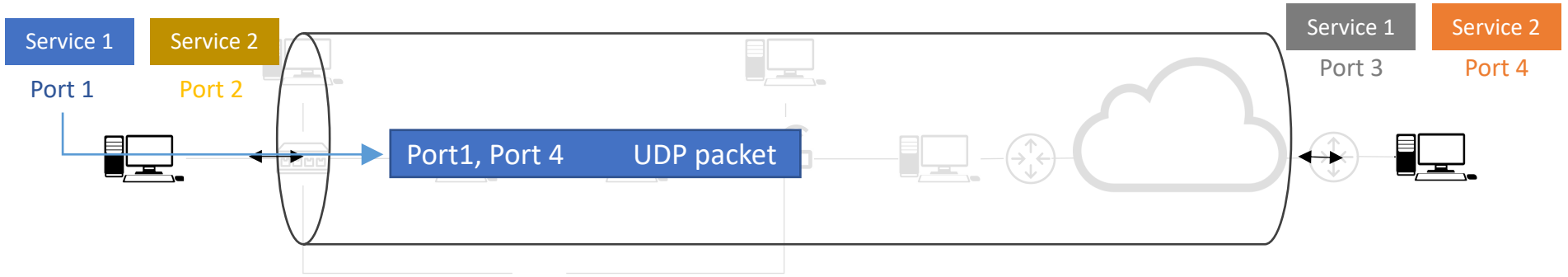
Multiplexing

- UDP multiplexes and demultiplexes datagrams by selecting the port numbers:
  - an application obtains a port number from the local machine; as soon as the application sends a message via this port, the PORT SOURCE field of the UDP datagram contains this port number,
  - an application knows (or obtains) a remote port number in order to communicate with the desired service.
- When UDP receives a datagram, it checks that it is one of the currently active ports (associated with an application) and delivers it to the corresponding application (queuing)
- if not, it issues an ICMP *port unreachable* message, and destroys the datagram.

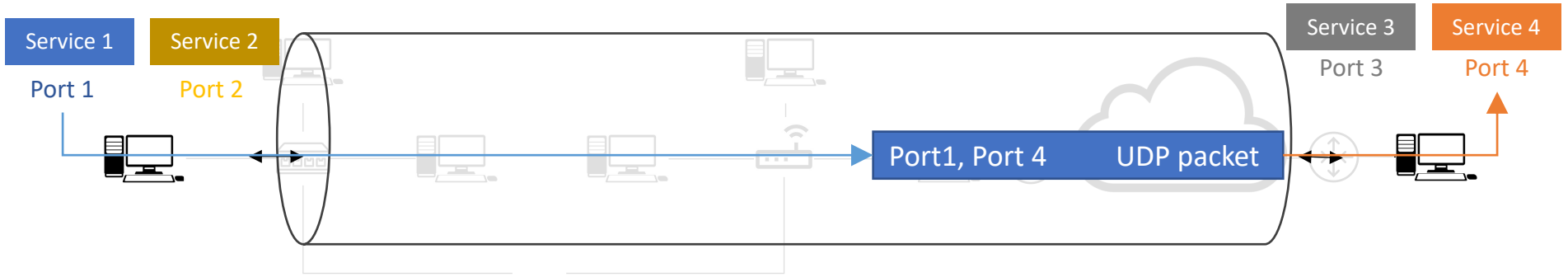
Multiplexing



Multiplexing



Multiplexing



UDP Standard Ports

- Some ports are reserved (*well-kown port assignments*):
  - 7 ECHO Echo
  - 11 USERS Active Users
  - 13 DAYTIME Daytime
  - 37 TIME Time
  - 42 NAMESERVER Host Name Server
  - 53 DOMAIN Domain Name Server
  - 67 BOOTPS Boot protocol server
  - 68 BOOTPC Boot protocol client
  - 69 TFTP Trivial File transfer protocol
  - 123 NTP Network Time Protocol
  - 161 SNMP Simple Network Management prot.
- Other (non-reserved) port numbers can be dynamically assigned to applications.