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The Open System Interconnect model

Telecomunicazioni

Undergraduate course in Electrical Engineering

University of Rome La Sapienza

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Layered network design

- Data networks are usually designed according to a layered architecture, in order to allow independent design of protocols according to different layers.
- Designers of a specific layer will be well aware of the internal details and operations of a layer
- Designers of other layers and users of the whole network, on the other hand, will see the layer as a “black box” with clearly defined input and output interfaces
- This allows to use of standardized modules, and to change a layer without affecting the other ones

The OSI network model

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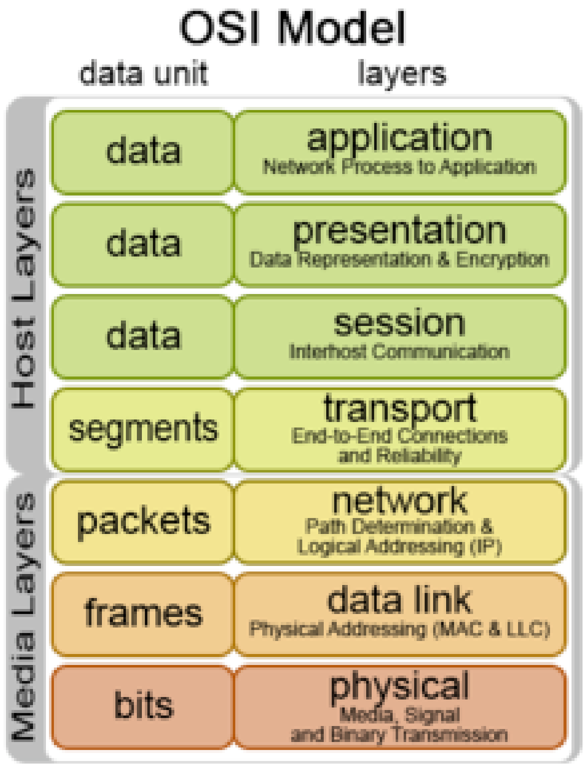
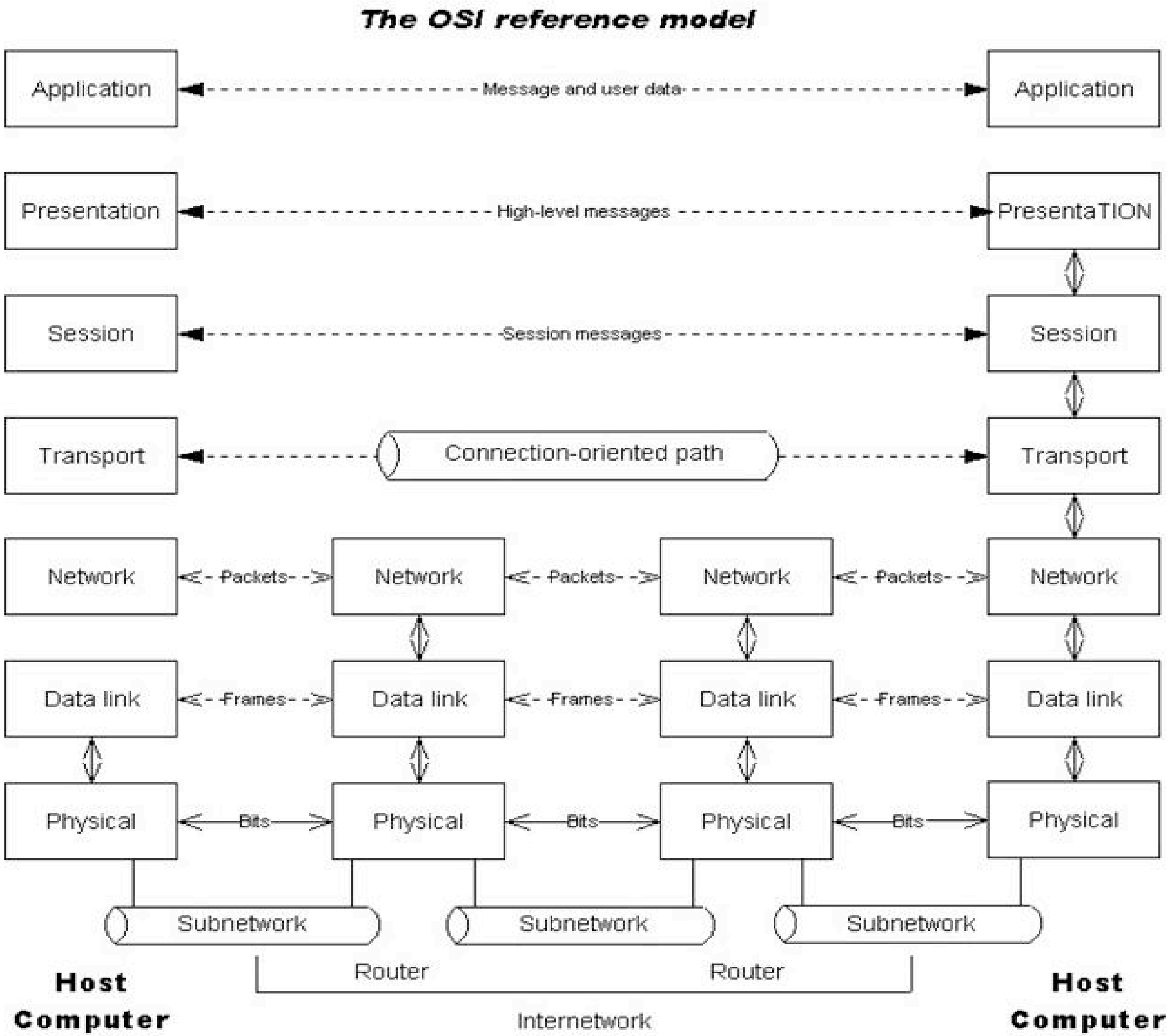
- The Open System Interconnect (OSI) was proposed in 1979 by the International Organization for Standardization (ISO)
- The OSI model is composed of two parts:
  - A 7-layer stack model (Basic Reference Model)
  - A set of original protocols for each layer



- The main contribution of the OSI model was to propose the concept that each layer only interacts with the layer immediately above and below in the stack

Interaction between OSI layers

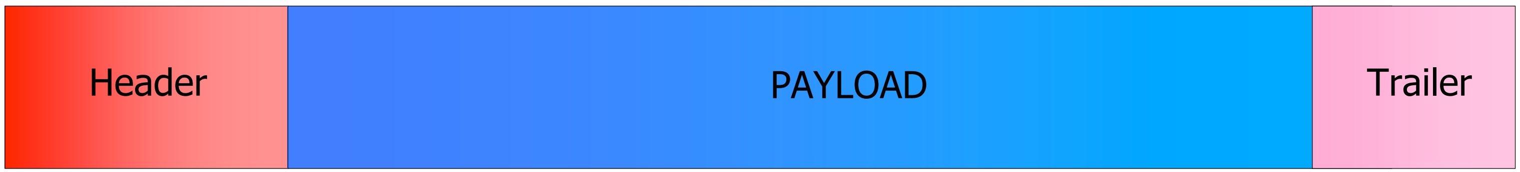


The physical layer

- The function of the physical layer is to provide a virtual link (*virtual bit pipe*) for transmitting a sequence of bits between any pair of nodes joined by a physical communication channel
- The conversion from bits coming from higher layer to signal suitable for the channel is performed by a *modem*
- The modem carries out the tasks that we carry out in the first part of the course
- The physical layer also defines wiring and connections with the upper layer...

The Data Link Control Layer

- The DLC layer has the goal to convert the unreliable bit pipe provided by PHY layer into a virtual communication link capable of sending packets asynchronously and error-free in both directions over the link
- A packet at this level is a string of bits received by the higher layer
- In order to correct errors introduced by the bit pipe at layer 1 the DLC must add control bits (header) to the packet:

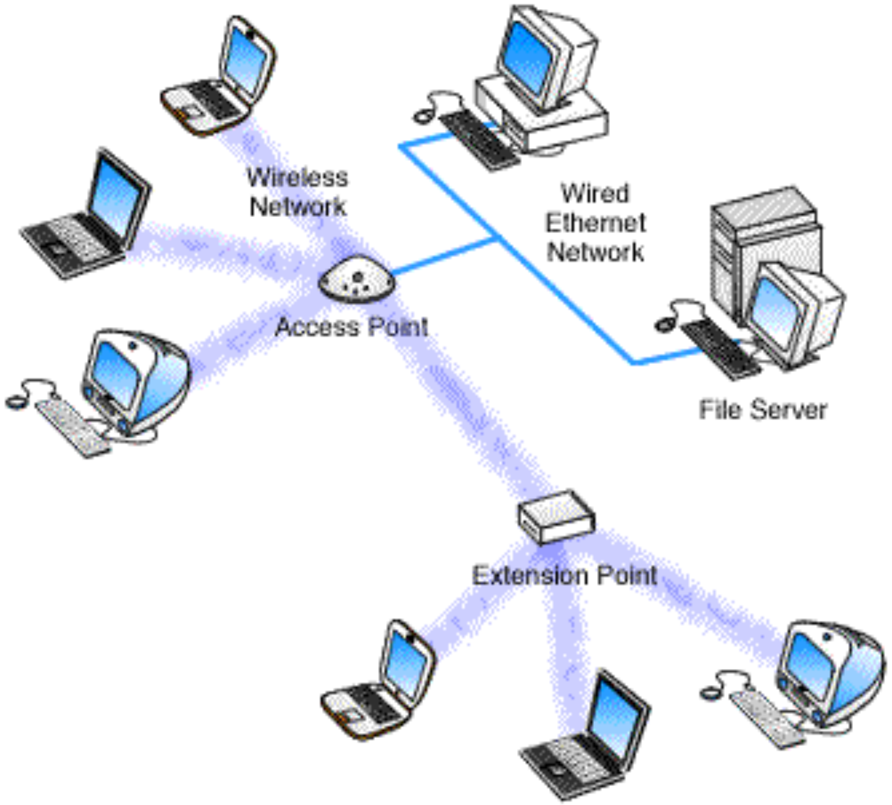


The Data Link Control Layer

- Data Link Control layer tasks and organization depend on the kind of communication links we consider:
  - Point-to-point communication links
  - Multi access communication links
- In the case of multi access links the DLC layer also takes care of managing and coordinating the condivision of the medium among multiple users
- This task is carried out by the Medium Access Control sublayer

Medium Access Control: basic principles

- The basic role of the MAC module is to allow <u>multiple users</u> to share a <u>common resource</u>.



Example of a network of multiple users using the same transmission resource (the wireless channel) for accessing the fixed infrastructure.

Medium Access Control: basic principles

- MAC key objectives are:
  - To maximize **throughput**.
  - To guarantee an acceptable **delay** to all terminals.
  - To guarantee a **fair** access to all terminals.

- The MAC should be capable of fulfilling the above goals in a dynamic environment.
- It should be flexible in adapting to different channel behaviors, traffic characteristics, and local network topologies.

Medium Access Control: basic principles

- MAC key tasks are:
  - Medium sharing
  - MAC organization
  - Admission Control
  - Packet Scheduling
  - Power Control
- MAC tasks often include:
  - Error detection
  - Forward Error Correction (FEC)
  - Handling of Automatic Repeat on reQuest (ARQ) algorithms

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What is the resource?

- The channel to be used for transmitting information will be further on called RESOURCE
- The resource might be defined in the frequency or time domains, as well as in other dimensions such as a code space

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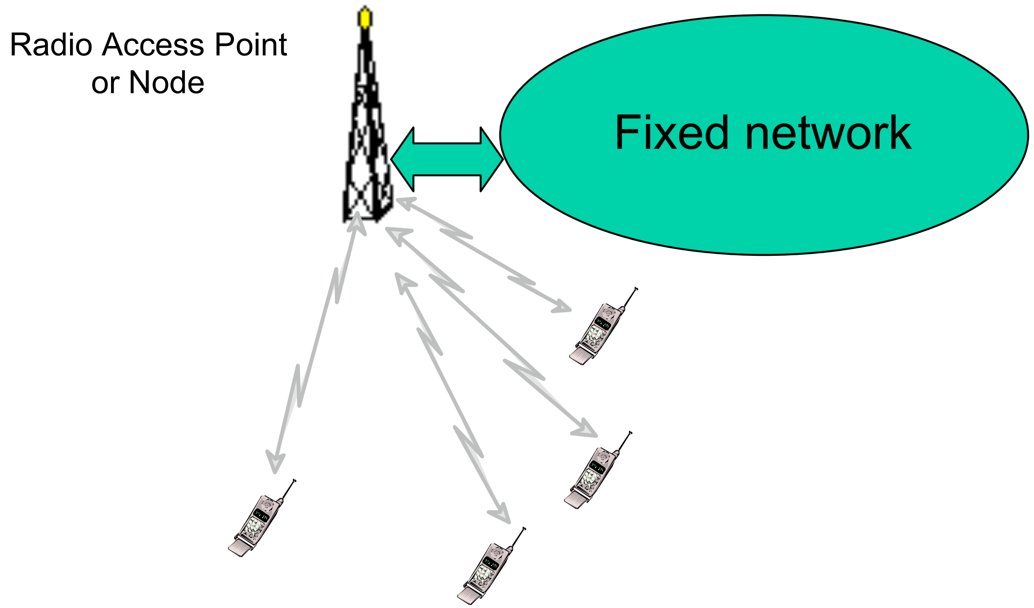
Topology of access: centralized vs. decentralized

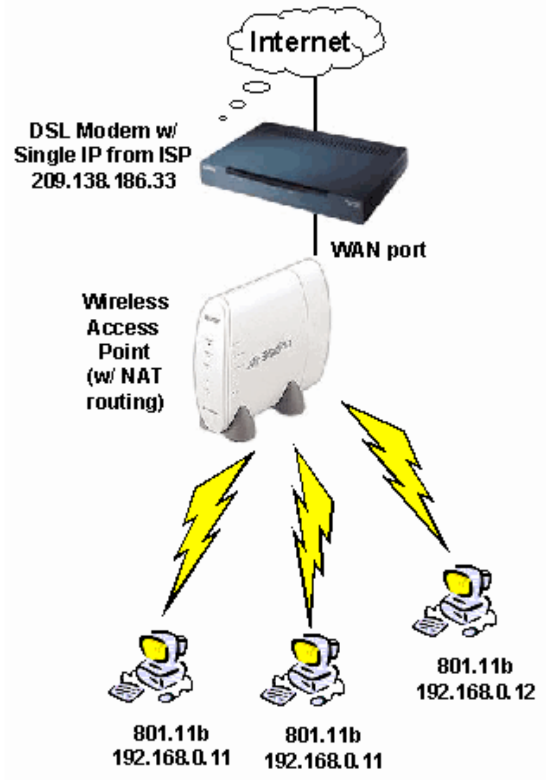
- In centralized access, the resource is managed and controlled by a central unit that acts as a coordinator
- In decentralized access, all nodes are hierarchically equivalent and a central unit does not necessarily exist. Nodes may eventually cooperate for the purpose of resource sharing and management

Example of centralized access: the cellular network (GSM, UMTS)

- Systems that provide access to a fixed infrastructure, have usually a centralized topology of access.
- The central unit is the node that interfaces the fixed network

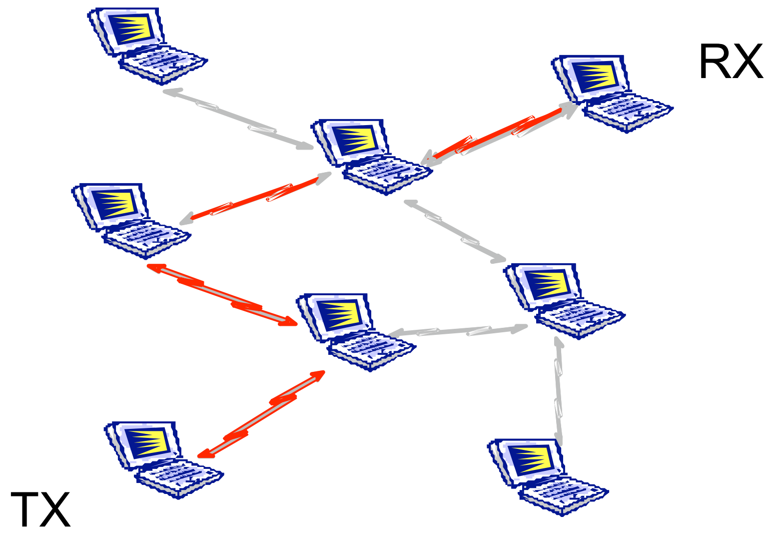


Another example of centralized access is Wi-Fi access points



- Access Control in these networks is typically demanded to the element connected to the fixed network, that coordinates the access of wireless devices by managing the resource

Example of decentralized access: self-organizing networks

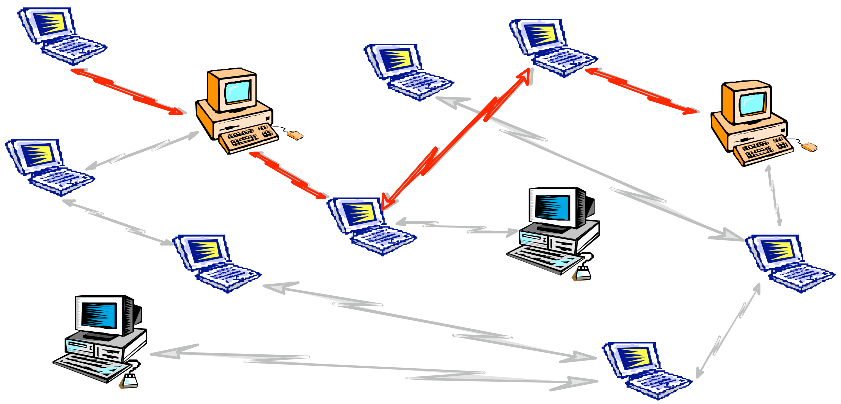


Decentralized access

Nodes might be cooperative or non-cooperative in finding end-to-end routes formed by multi-hop

Ad-hoc networks

- Self-organizing networks are a special case of **ad-hoc networks**
- Ad-hoc networks are sets of wireless terminals, capable of communicating in absence of fixed infrastructure



- Connectivity between two terminals can be obtained thanks to cooperative relaying terminals, based on multi-hop routes

Key properties of ad-hoc networks

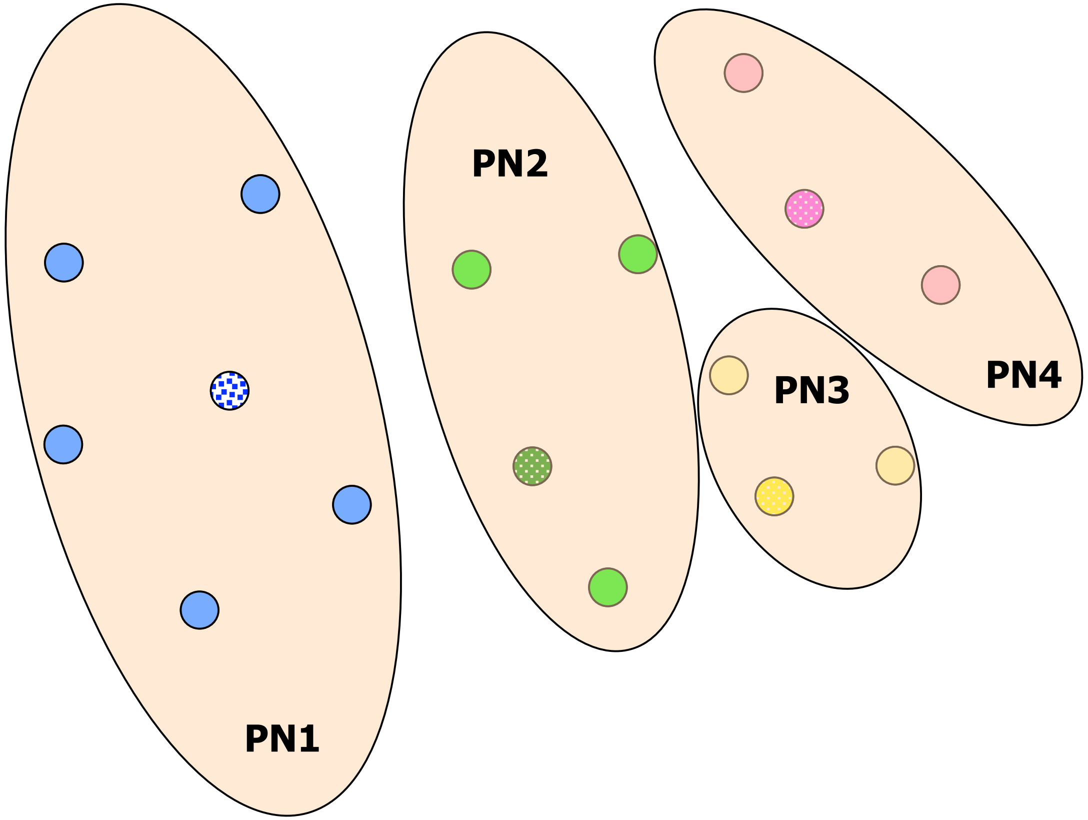
- Easy deployment:
  - No fixed infrastructure
  - Fast configuration
- Flexibility:
  - Adaptable to network variations (terminals going on/off, mobility, etc.)
- Scalability
  - Multi-hop allows geographical extension of ad-hoc networks
- Robustness:
  - No central control means no critical points

Network organization vs. network architecture

- Network organization and network architecture are two distinct concepts
- A network can be organized in either a centralized or distributed manner, independently of network architecture.
- 802.15.3 is an example of a network with a typical peer-to-peer distributed architecture, that self-organizes in a centralized way

Wireless networks organization vs. architecture
The 802.15.3/802.15.3a example

- 802.15.3 is a standard for Personal Area Networks (PAN)
- During start-up, the MAC organizes devices in PicoNets (PNs)
- Each PN is controlled by a PicoNet Coordinator (PNC)
- The standard completely defines MAC procedures for intra-PicoNet operations
- Procedures for inter-PicoNet exchanges are only drafted

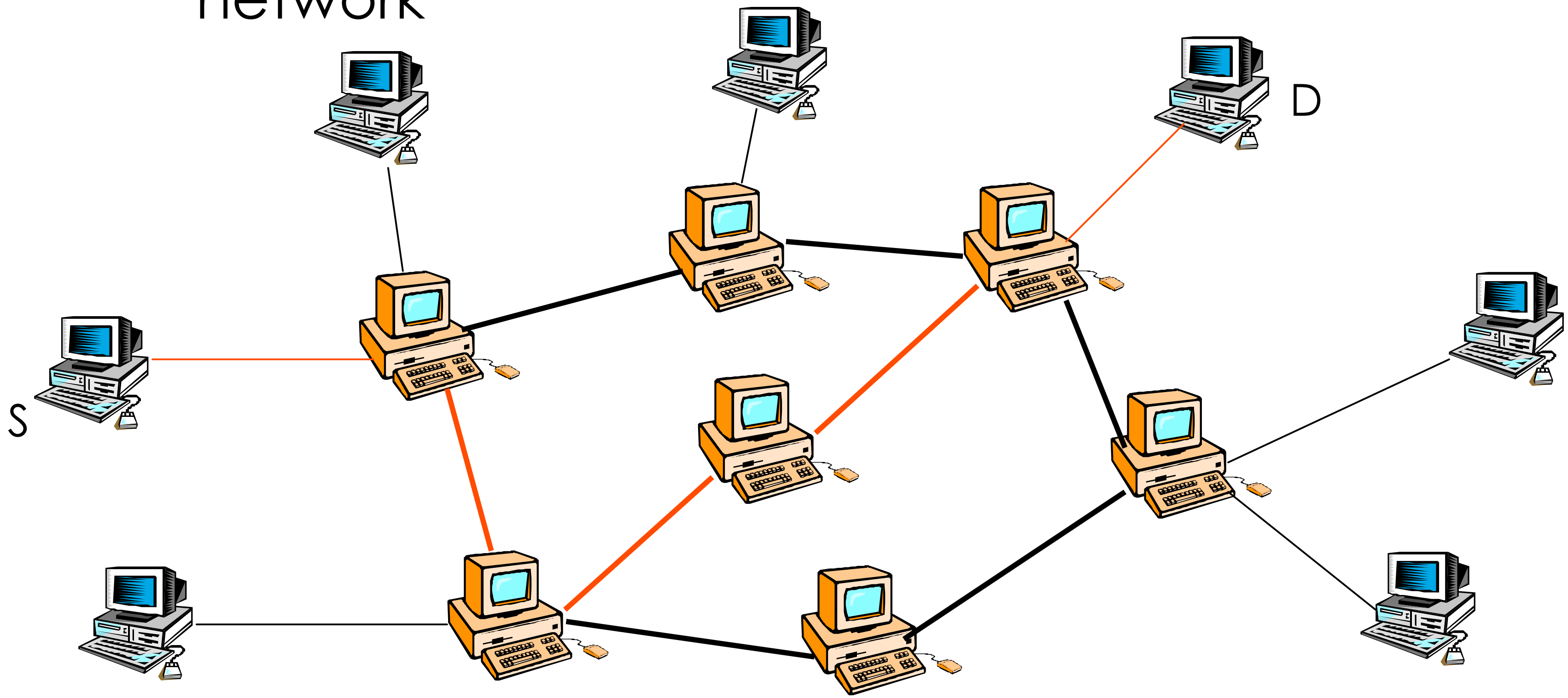


The network layer

- The network layer has two main tasks:
  - **Routing** - selecting the best path for a packet between a source and a destination
  - **Flow control** - regulating the access to the network, refusing traffic when network is not able to handle it

Routing in data networks
Goal

- Goal:
  - Find the best path between two nodes in the network



Routing in data networks
Strategies

- Routing can be done:
  - At the beginning of a communication, by creating a virtual circuit between source and destination, that will be followed by all packets (*virtual circuit networks*)
  - For each transferred packet (*datagram networks*): packets belonging to the same communication can follow different paths in the network

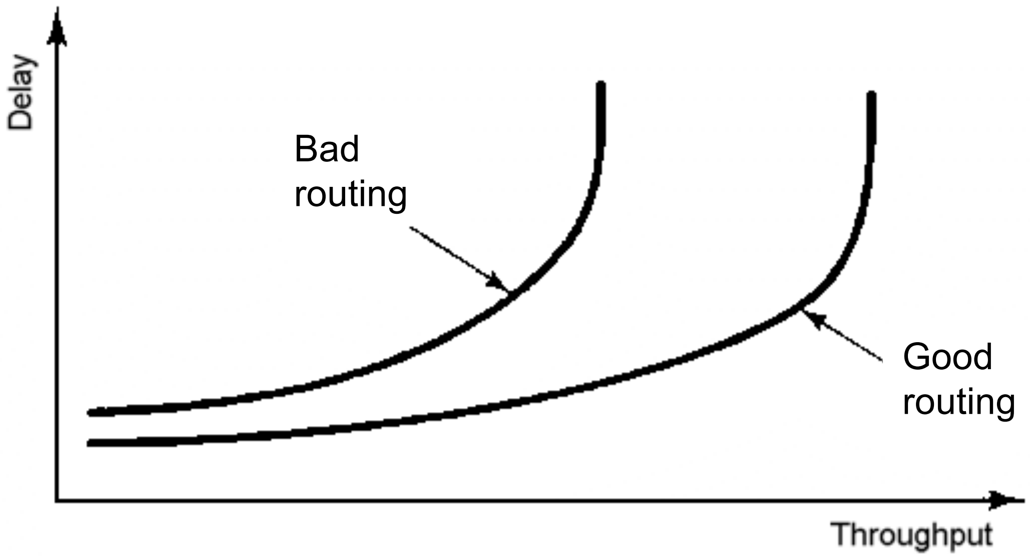
Routing in data networks
Effects (1/2)

- The routing algorithm determines:
  - directly: the *average packet delay*
  - Undirectly: the network *throughput*, defined as:

    Throughput=Offered Traffic – Refused Traffic
- Delay and throughput are linked by the **flow control algorithm**: if the average packet delay grows excessively, the flow control reacts by reducing the traffic allowed in the network and thus reducing the overall network throughput.

Routing in data networks
Effects (2/2)

- A good routing algorithm can:
  - increase the throughput while keeping the delay constant (for high values of offered traffic)
  - Decrease ddelay while keeping the throughput constant ed a diminuire il delay a parità di throughput (for low values of offered traffic)



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Routing in data networks

Classification

- Routing algorithms can be divided in:

Centralized	**Distributed**
The path between source and destination is selected by a central node that communicates the path to the involved node	The path selection is carried out by all nodes by cooperation; nodes exchange information in order to take decisions

- And also in:

Static	**Adaptive**
The selected path between a source and a destination is only modified when there is a failure or a topology variation	The selected path between a source and a destination adapts to network conditions (e.g. traffic)

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Routing in data networks
Shortest path algorithms (1/2)

- A key family of algorithms is formed by the **shortest path routing algorithms**:
  1. A cost is associated to each link in the network;
  2. The algorithm considers all possible paths and selects the one for which the sum of the link costs is minimum.
- The cost associated to each link can be:
  – Equal to one: the algorithm selects the *minimum-hop path*
  – Based on link capacity and on the expected traffic on the link
  – Variable in time according to instantaneous link conditions.

Routing in data networks
Shortest path algorithms (2/2)

- Shortest path algorithms:
  - **Dijkstra**:
    - + in a network of N nodes has complexity equal to $O(N^2)$
  - **Bellman-Ford**:
    - + It is distributed and does not require synchronism among nodes
    - - in a network of N nodes has complexity $O(N^3)$
  - **Floyd-Warshall**:
    - + Evaluates at the same time the best path betwween all sources and all destinations
    - - has complexity $O(N^3)$

Routing in data networks
Flooding (1/3)

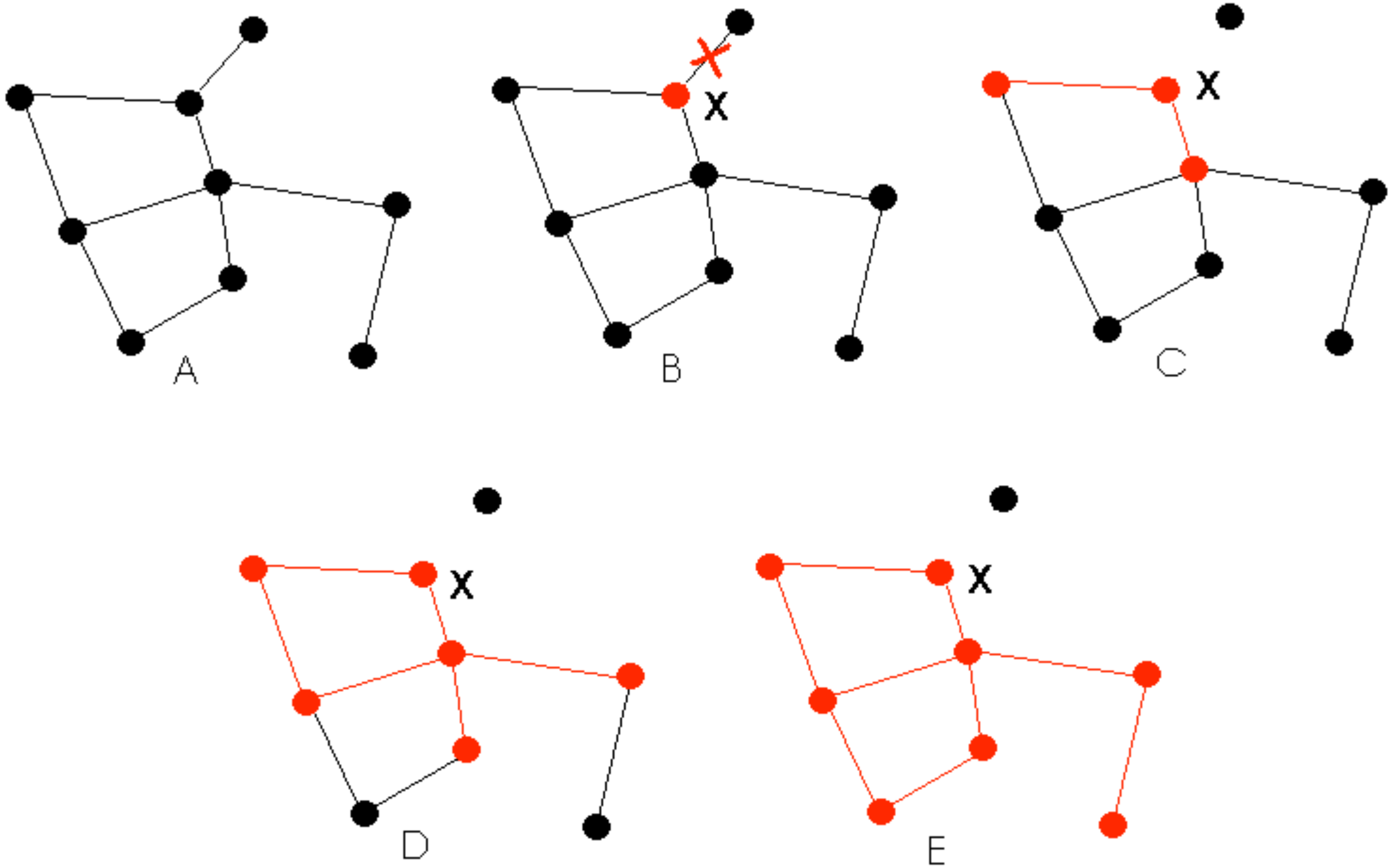
- It is sometimes necessary (in order to communicate failures or topology variations) transfer information from a node **x** in the network to all other nodes (*broadcasting*)
- A simple solution for broadcasting is the so-called **flooding**:

1. **x** sends the information (that is a data packet) to its neighbors (that is the nodes that are physically reachable);
2. Every neighbor repeats the operation, by retransmitting the packet to all its neighbors, excluding **x**;
3. Every packet is identified by a growing sequence number and by the ID of node **x**, in order to avoid that a node transmits the same packet more than one time.

Routing in data networks

Flooding (2/3)

Example of application of flooding:



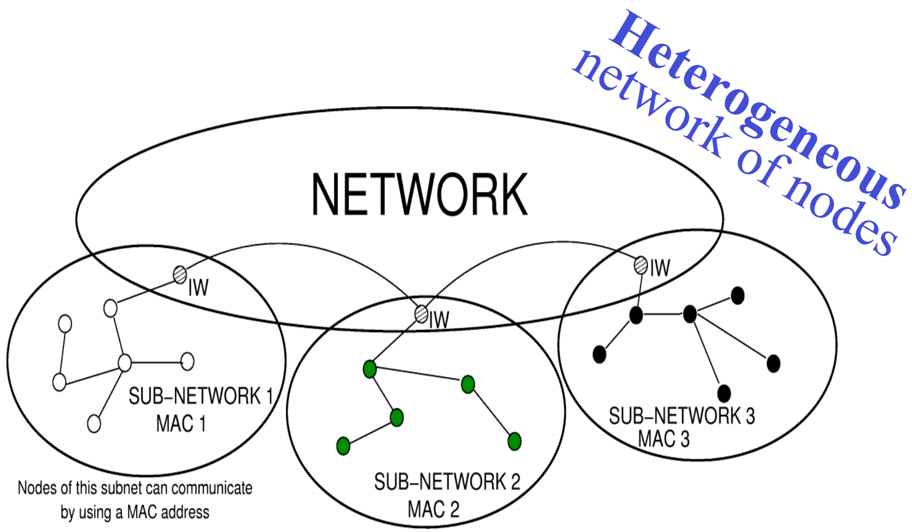
Routing in data networks

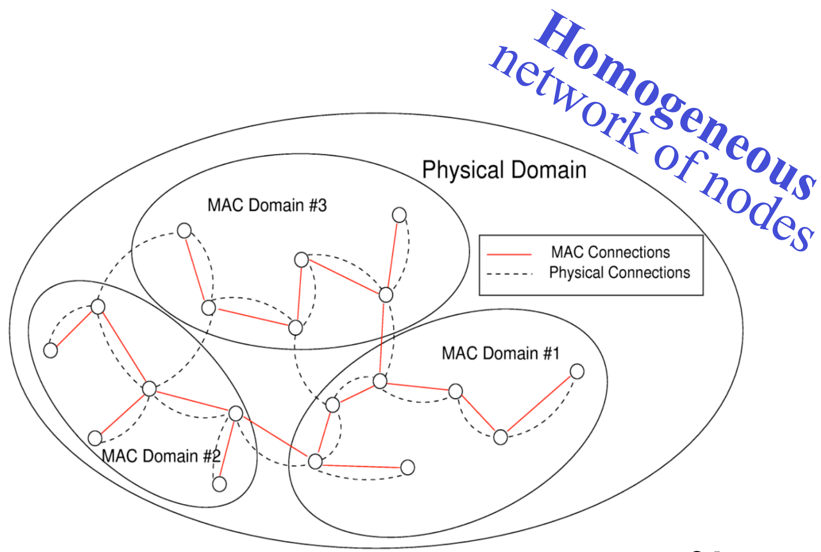
Flooding (3/3)

- Flooding has two main drawbacks:
  - The number of packets transmitted for each update depends on the number L of links in the network
  - The algorithm must foresee special information (sequence numbers) in order to guarantee that information is always correct and up to date

Analogies between Network and MAC layer

- Routing, addressing and flow control are functions commonly associated with the network module.
- Such functions can be also defined as functions of the MAC module in the case of a homogenous network of nodes.





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The Transport layer

- The Transport layer manages a virtual end-to-end link
- Main tasks of the Transport layer
  - Message breaking / reassembly (required to meet maximum data size for network layer)
  - Multiplexing of several low-rate sessions in a single network layer stream
  - Splitting a high-rate session in several low-rate network streams
  - If necessary, correct residual errors

The Session layer

- The Session layer manages a virtual end-to-end link
- Main tasks of the Session layer
  - "Directory service": indicates to transport layer where a service is located
  - Access rights management: regulates access to information

The Presentation and Application layers

- Main tasks of the Presentation layer
  - Data compression
  - Data encryption
  - Code conversion

- Main tasks of the Application layer
  - Application-specific tasks (software)