Computer Networks

Lecture 6

Introduction to Computer Networks

Theory

Topics:

1. Introduction, communication principles
2. Topology, components
3. OSI and TCP/IP models
4. LAN and IEEE 802.x standard
5. Network layer, IP protocol (IP v4, IPv6)
6. Transport layer, TCP and UDP protocols

Theory

Topics (continued):

7. WAN technology
8. Wireless LAN (IEEE 802.11x)
9. Routing protocols (OSPF, RIP)
10. Virtual LAN (VLAN)
11. Application layer and protocols (DNS, DHCP, ICMP, SMTP)
12. STP, aggregation, IEEE 802.1Q

Literature

- A. S. Tanenbaum, D. J. Wetherall. **Computer Networks**. Prentice Hall. 2010.
- J. F. Kurose, K. W. Ross. **Computer Networking. A Top Down Approach**. Addison Wesley. 2010.
- C. M. Kozierok. **The TCP/IP Guide**. 2005.
- A. Rodriguez, J. Gatrell, J. Karas, R. Peschke. **TCP/IP Tutorial and Technical Overview**. IBM Redbook, 2001.
- V. Olifer, N. Olifer. **Kompiuterių tinklai. Principai, technologijos, protokolai**. Piter, Sankt Peterburgas, 2006.
- https://www.coursera.org/#course/comnetworks

Communication

- Among all of the essentials for human existence, the need to interact with others ranks just below our need to sustain life. Communication is almost as important to us as our reliance on air, water, food, and shelter.
- The methods that we use to share ideas and information are constantly changing and evolving. Whereas the human network was once limited to face-to-face conversations, media breakthroughs continue to extend the reach of our communications. From the printing press to television, each new development has improved and enhanced our communication..

Duomenų perdavimo tinklai

Data networks are telecommunication network used to connect:

- Computers,
- Mobile devices,
- Voice and video devices,
- Other devices

Data types: text, video, audio.

Computer network = Data transferring network

History (1)

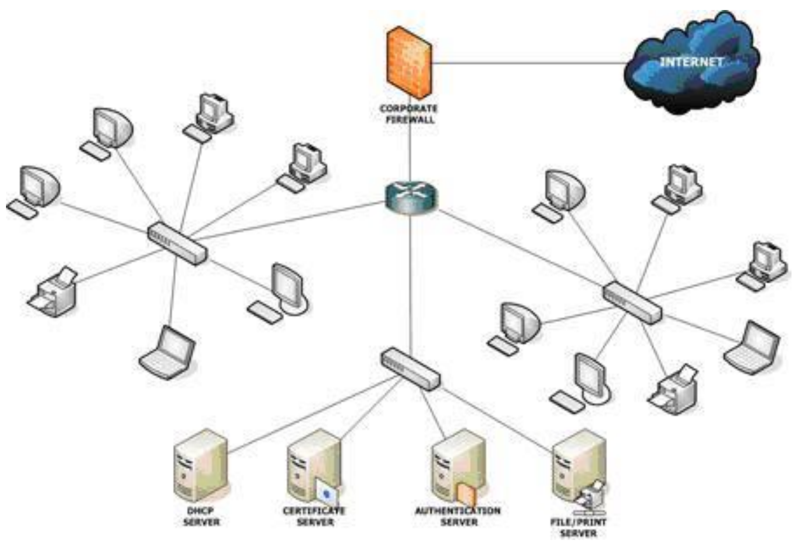
- Mainfraime and terminals (1960).
- Global networks (1960):
  - Telephone nework (~10 kbps)
  - Packet commutation
  - Network operating systems
  - File transfer, e-mail (off-line)
- ARPANET network (USA), 1969.

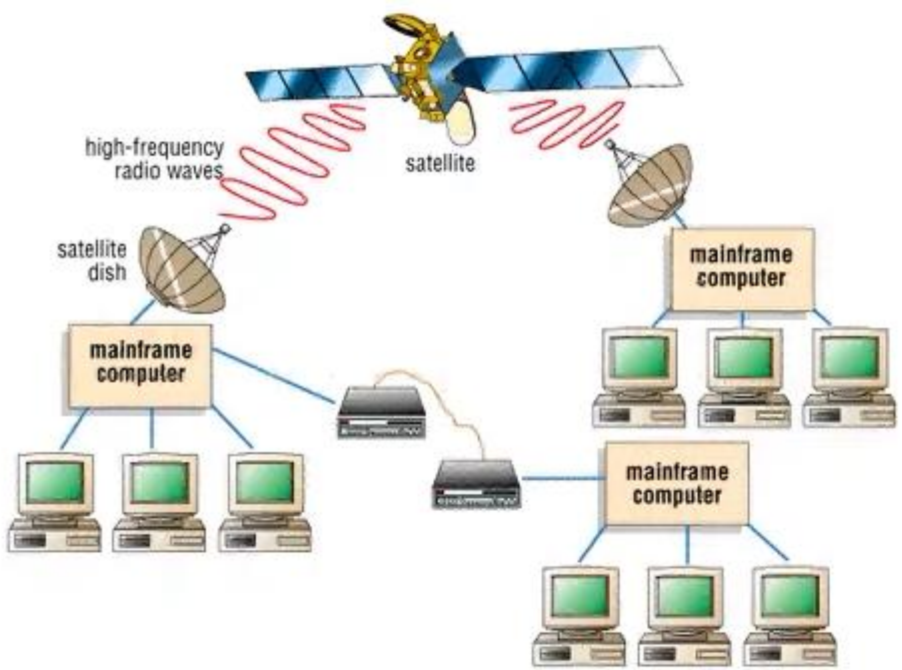
History (2)

- **LAN (1970)**.
  - No standard on LAN technologies.
  - Manufactures produce own HW/SW.
- **LAN (1980)**
  - Ethernet (1980 m.)
  - Token Ring (1985 m.)
  - Token Bus
  - FDDI (1985 m.)
- Internet based on TCP/IP (1980).
- Web, HTTP, 1991.

Network type

– Local area network (LAN)
– Municipality area network (MAN)
– Wide area network (WAN)





Local Area Network

Features

- Throughput (till 100 Gbps)
- Small number of users and nodes
- Topology based on star type
- No routing
- Network administrator
- Size of the area covered
- Limited number and types of services

Wide area network

Wide area network (WAN) is a set of LANs.

Features

- Common type communication lines
- Topology – P2P
- Routing

Communication principles

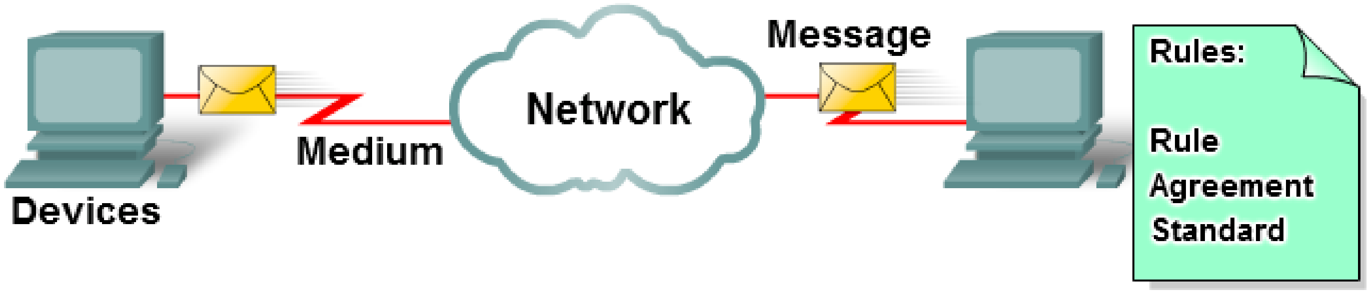
Before beginning to communicate with each other, we establish rules or agreements to govern the conversation. These rules, or protocols, must be followed in order for the message to be successfully delivered and understood. Among the protocols that govern successful human communication are:

- An identified sender and receiver
- Agreed upon method of communicating (face-to-face, telephone, letter, photograph)
- Common language and grammar
- Speed and timing of delivery
- Confirmation or acknowledgement requirements

Elements of the network

Four elements of the network

- Rules
- Medium
- Messages
- Devices



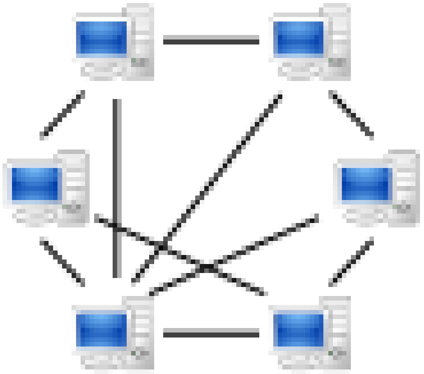
Models

Models of network architecture:

1. Peer-to-Peer
2. Client - Server
3. Hybrid

Peer to Peer

Peer-to-peer (**P2P**) computing or networking is a distributed application architecture that partitions tasks or work loads between peers. Peers are equally privileged, equipotent participants in the application. They are said to form a peer-to-peer network of nodes.



Client - Server

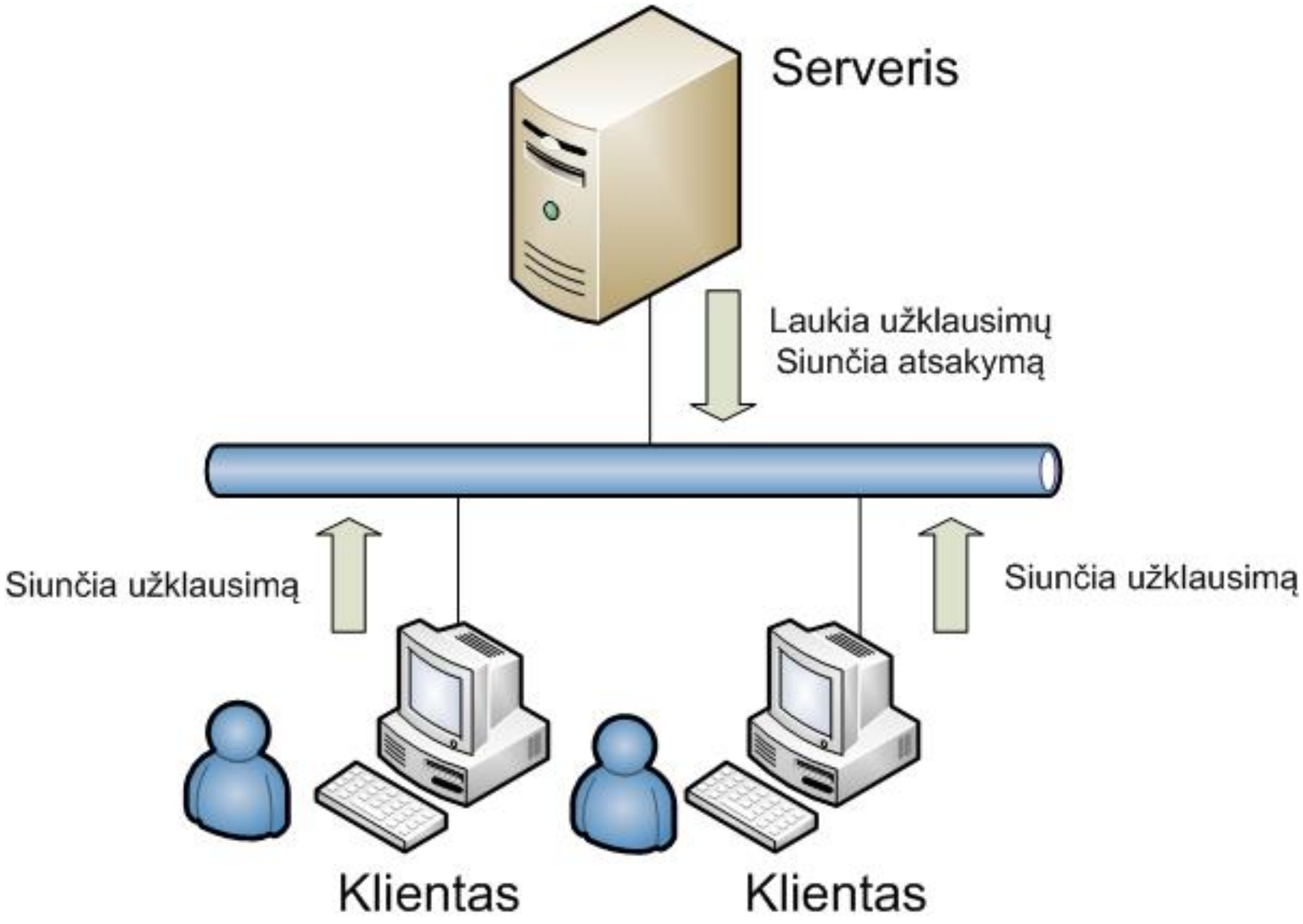
The client–server model of computing is a distributed application structure that partitions tasks or workloads between the providers of a resource or service, called servers, and service requesters, called clients.

Often clients and servers communicate over a computer network on separate hardware, but both client and server may reside in the same system.

A server host runs one or more server programs which share their resources with clients.

A client does not share any of its resources, but requests a server's content or service function. Clients therefore initiate communication sessions with servers which await incoming requests.

Client - Server



Komutacija

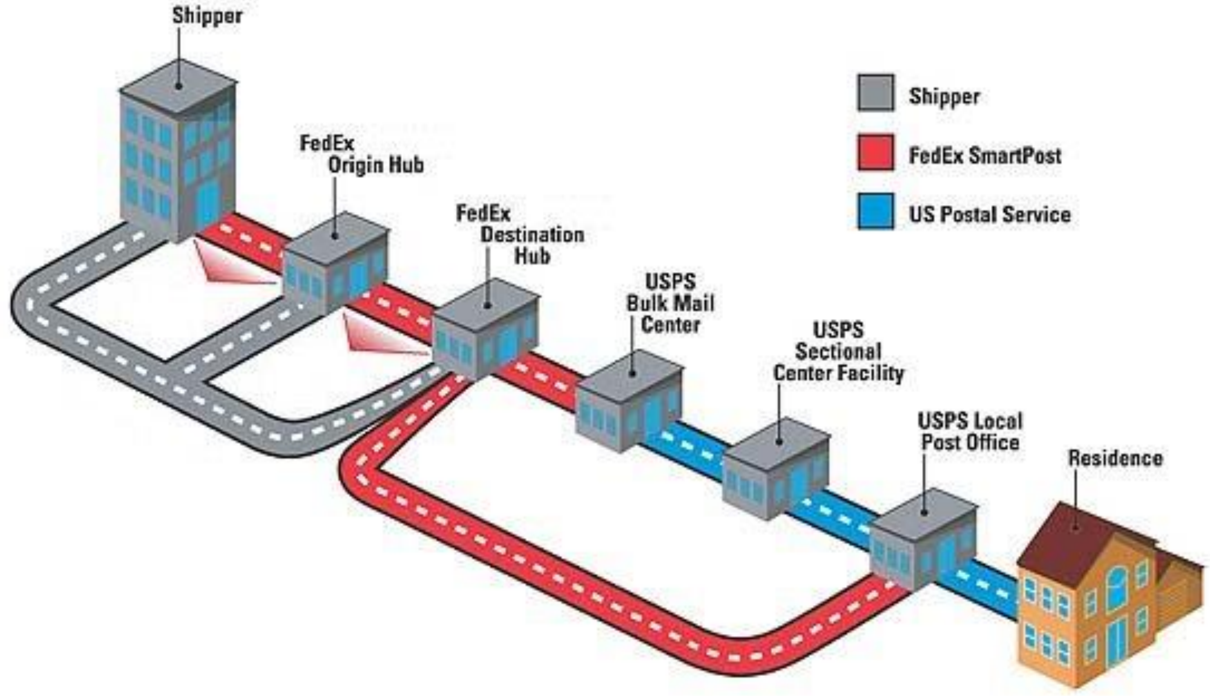
Pagrindinė kompiuterių tinklų užduotis – nusiųsti siuntėjo pranešimą gavėjui. Pranešimas siunčiamas duomenų perdavimo terpe: **kabeliais arba belaidžiu būdu.**

Tinkluose egzistuoja daug vartotojų. Jiems turi būti suteikta galimybė susijungti su bet kuriuo kitu vartotoju duomenų perdavimui.

Kiekvienas su kiekvienu tinklo topologija neįmanoma realizuoti dideliuose tinkluose, dėl didelio kabelių skaičiaus, todėl naudojami **komutatoriai.**

Commutation

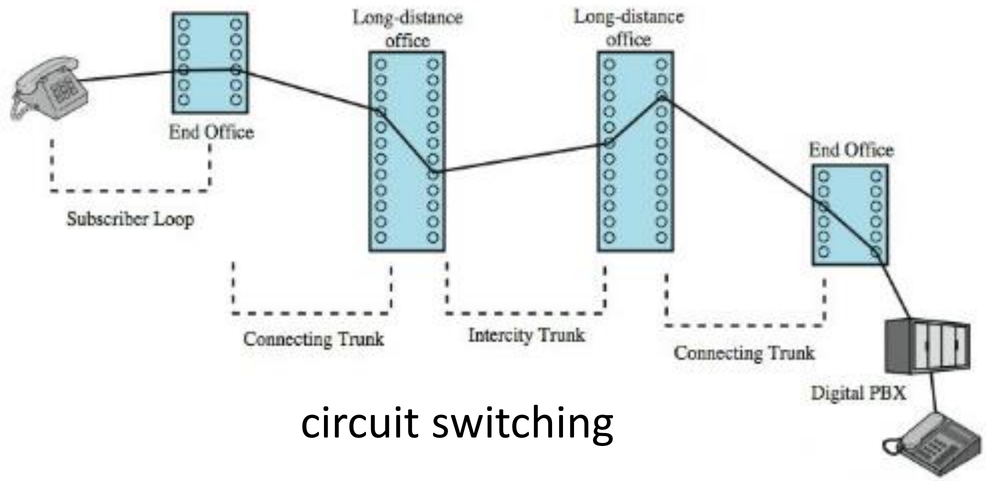
- Mail service
- Logistics
- etc.



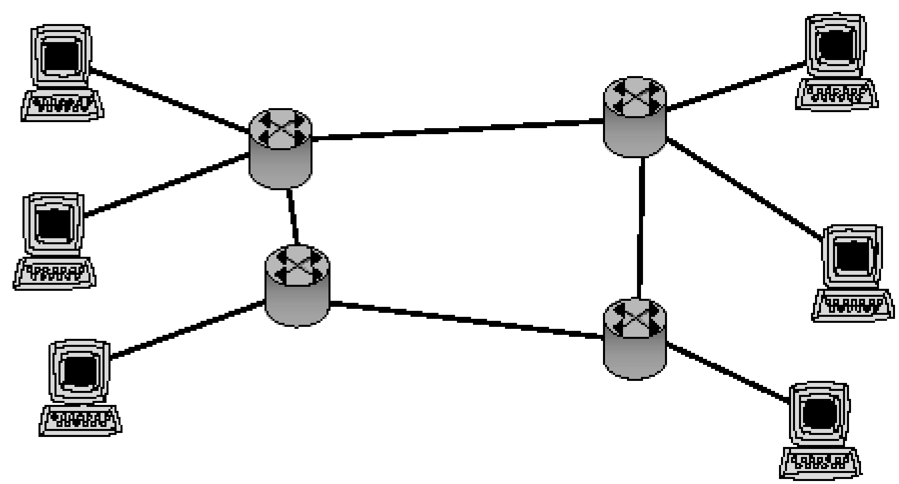
Commutation

Commutation types**:**

- circuit switching
- Packet switching
- Message switching



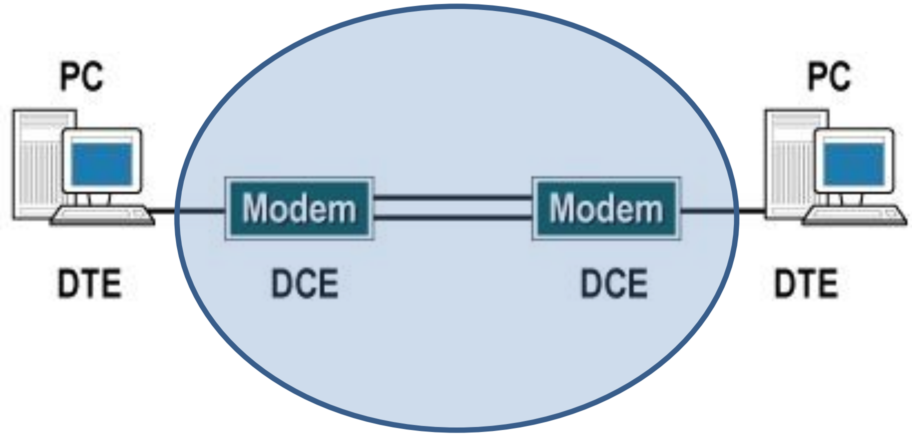
circuit switching



Duomenų perdavimo linijos

Duomenų perdavimo linijos (arba kanalai) užtikrina fizinį ryšį tarp tinklo įrenginių. Jos susideda iš:

- Fizinės elektrinių signalų perdavimo terpės (*media*)
- Duomenų (el.signalų) perdavimo įrenginių (DCE – *data circuit equipment*) (DTE – *data terminal equipment*)
- Tarpinių įrenginių.



Network media

Modern networks primarily use three types of media to interconnect devices and to provide the pathway over which data can be transmitted. These media are:

- Metallic wires within cables
- Glass or plastic fibers (fiber optic cable)
- Wireless transmission

The signal encoding that must occur for the message to be transmitted is different for each media type. On metallic wires, the data is encoded into electrical impulses that match specific patterns. Fiber optic transmissions rely on pulses of light, within either infrared or visible light ranges. In wireless transmission, patterns of electromagnetic waves depict the various bit values.

Standards

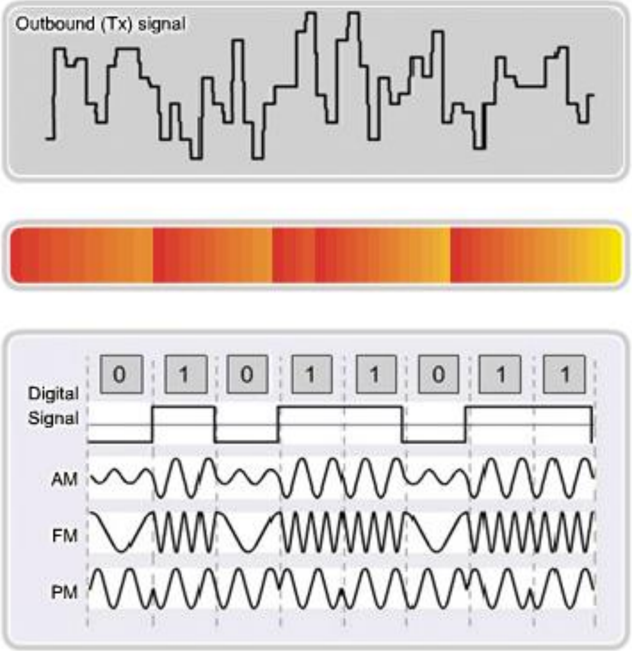
Organizations for networking standartization:

- **ISO** - International Organization for Standardization
- **ANSI** - American National Standards Institute
- **IEEE** - Institute of Electrical and Electronics Engineers
- **ITU** - International Telecommunication Union
- **EIA/TIA** - Electronic Industries Alliance / Telecommunications Industry Association

Physical layer

There are three basic forms of network media on which data is represented: Copper cable, Fiber, Wireless

The representation of the bits - that is, the type of signal - depends on the type of media. For copper cable media, the signals are patterns of electrical pulses. For fiber, the signals are patterns of light. For wireless media, the signals are patterns of radio transmissions.



Physical layer

The three fundamental functions of the Physical layer are:

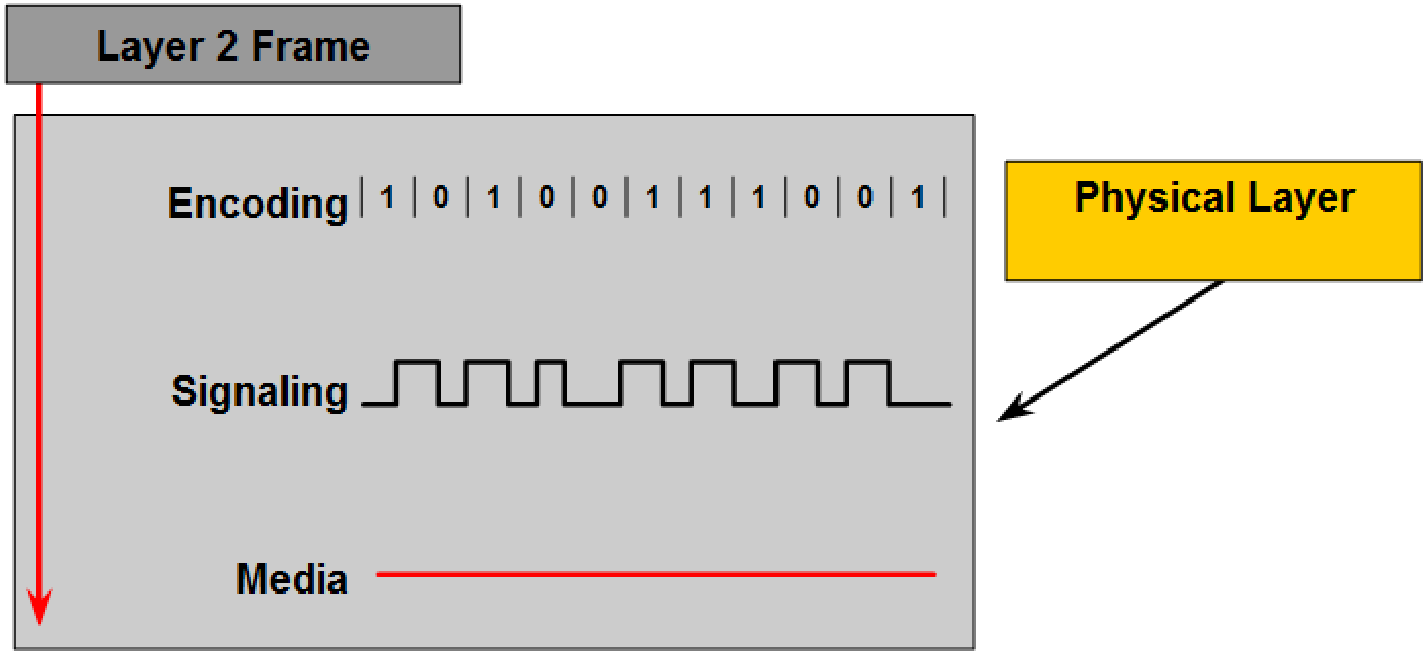
- The physical components
- Data encoding
- Signaling

The physical elements are the electronic hardware devices, media and connectors other that transmit and carry the signals to represent the bits.

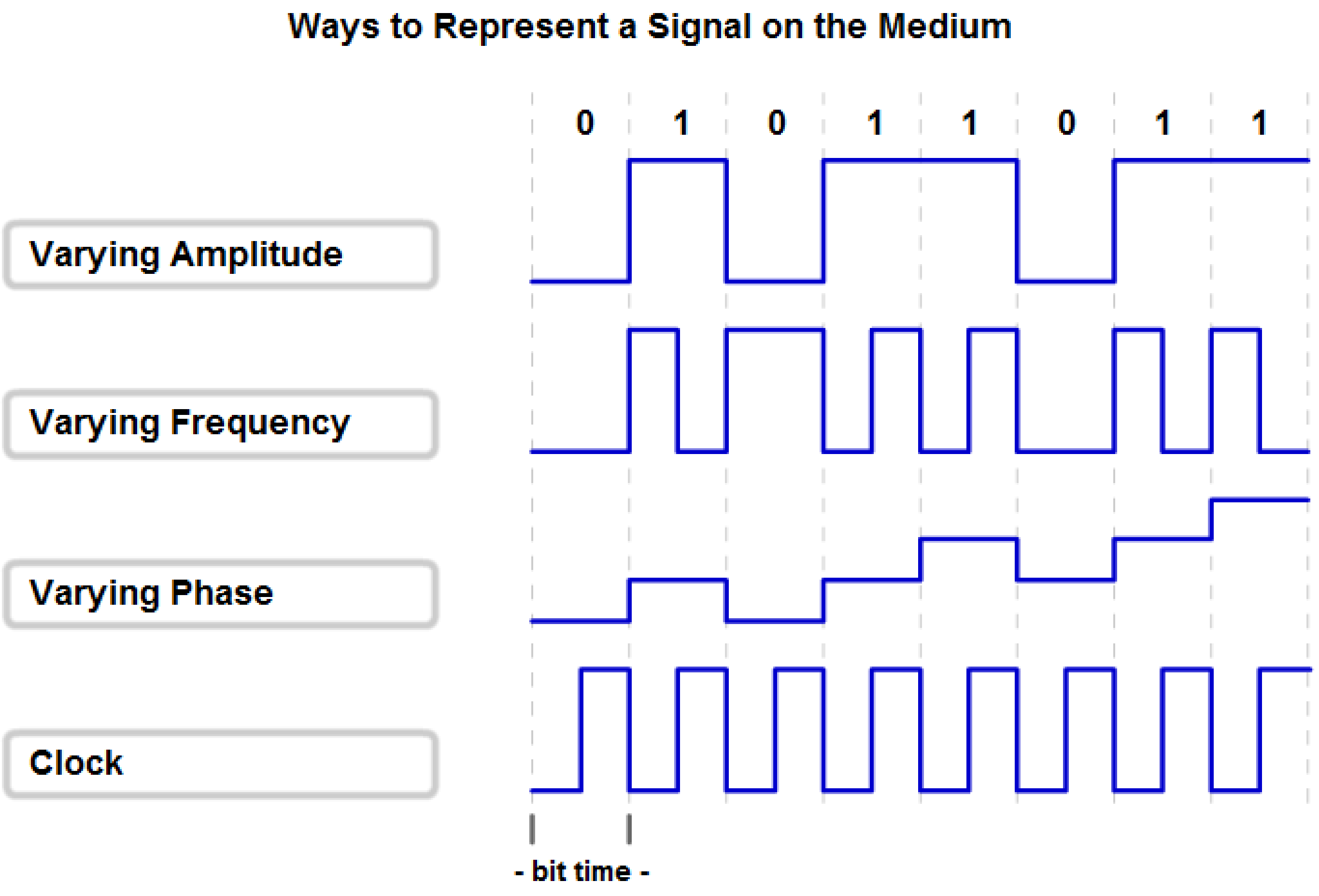
Encoding is a method of converting a stream of data bits into a predefined "code.

The Physical layer must generate the electrical, optical, or wireless signals that represent the "1" and "0" on the media. The method of representing the bits is called the signaling method. The Physical layer standards must define what type of signal represents a "1" and a "0". This can be as simple as a change in the level of an electrical signal or optical pulse or a more complex signaling method.

Physical layer



Signaling Methods



Bandwidth

Different physical media support the transfer of bits at different speeds. Data transfer can be measured in three ways:

- Bandwidth
- Throughput

The capacity of a medium to carry data is described as the raw data bandwidth of the media. Digital bandwidth measures the amount of information that can flow from one place to another in a given amount of time.

Bandwidth is typically measured in kilobits per second (kbps) or megabits per second (Mbps).

The practical bandwidth of a network is determined by a combination of factors: the properties of the physical media and the technologies chosen for signaling and detecting network signals.

Cabling

The most commonly used media for data communications is cabling that uses copper wires to signal data and control bits between network devices.

Cabling used for data communications usually consists of a series of individual copper wires that form circuits dedicated to specific signaling purposes.

Other types of copper cabling, known as coaxial cable, have a single conductor that runs through the center of the cable that is encased by, but insulated from, the other shield.

The copper media type chosen is specified by the Physical layer standard required to link the Data Link layers of two or more network devices.

Cabling

Resistance

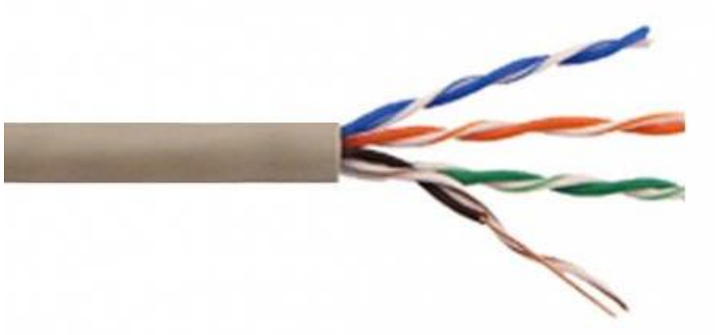
$$R = \frac{l \cdot \rho}{S}\ , \qquad \rho = \rho_0(1+\alpha t)$$

Specific resistance ρ (Ω*m):

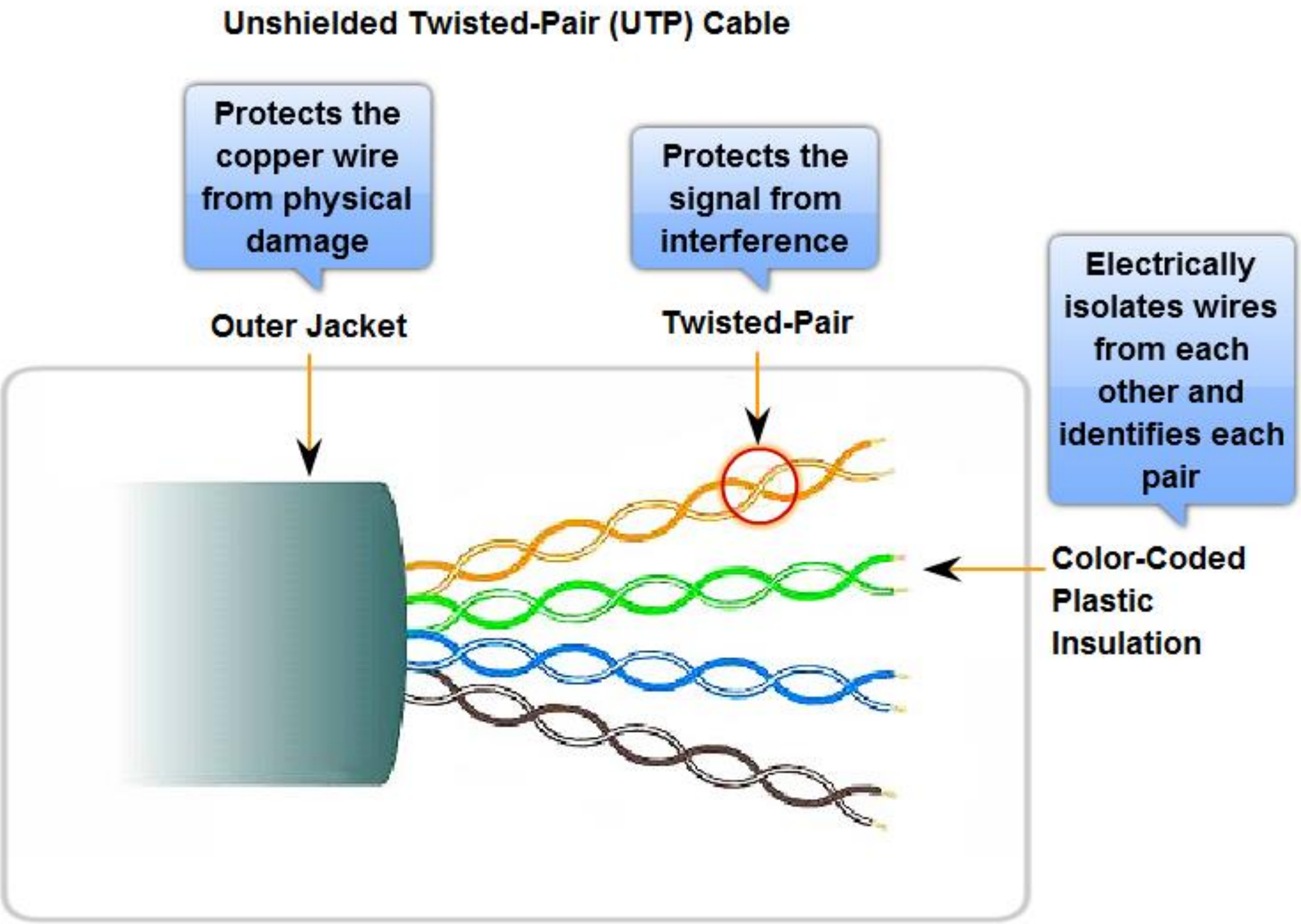
Cooper = 1,7 e-8 steel = 12,0 e-8 aluminium = 2,8 e-8

Cabling

- Twisted pair cable
  - UTP
  - STP
- Coaxial cable



Twisted pair cable



Categories

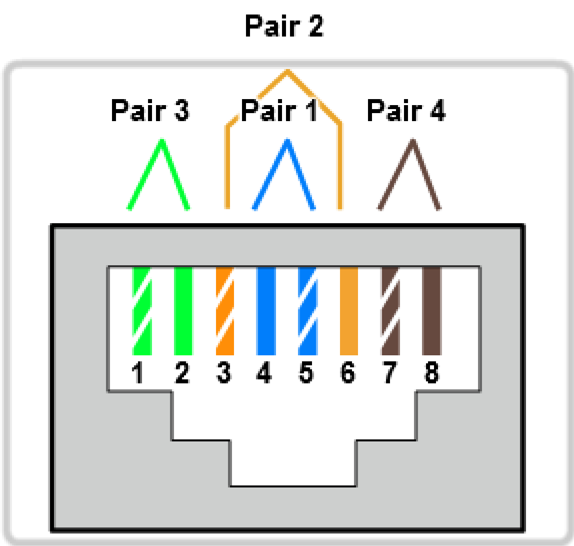
TP categories (EIA/TIA):

- Kategorija 1 – tik telefono tinklams, greitis iki 20 Kbps (iki 1983);
- Kategorija 2 – tik IBM reikmės, dažnis iki 1MHz (nebegaminama);
- Kategorija 3 – dažnis iki 16 MHz, telefoniniams tinklams ir Ethernet (10 Mbps), Token Ring (4 Mbps) ir kt.;
- Kategorija 4 – pagerinta 3 kat., dažnis iki 20 MHz
- Kategorija 5 – dažnis iki 100 MHz, Fast Ethernet (100 Mbps), naudojamas šiuolaikiniame tinkle;
- Kategorija 5e – Gigabit Ethernet (1000 Mbps) tinklams.
- Kategorija 6 – dažnis iki 250MHz, Gigabit Ethernet (1000 Mbps)
- Kategorija 7 – dažnis iki 600MHz (tik STP)

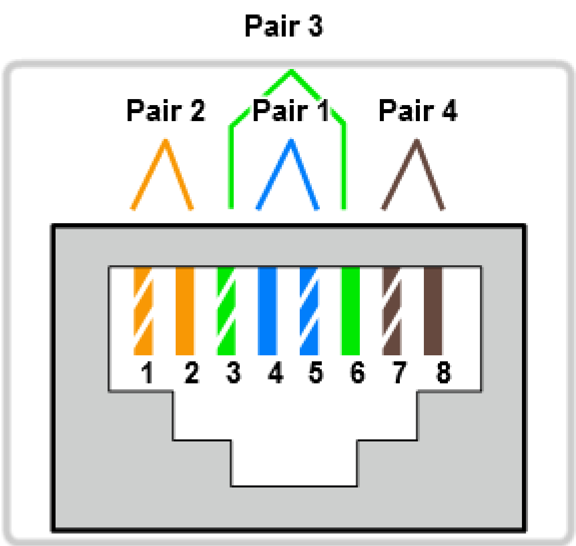
TIA/EIA 568

Straight-through, Crossover, and Rollover Cable Types

Cable Type	Standard	Application
Ethernet Straight-through	Both end T568A or both end T568B	Connecting a network host to a network device such as a switch or hub.
Ethernet Crossover	One end T568A, other end T568B	Connecting two network hosts. Connecting two network intermediary devices (switch to switch, or router to router).
Rollover	Cisco proprietary	Connect a workstation serial port to a router console port, using an adapter.

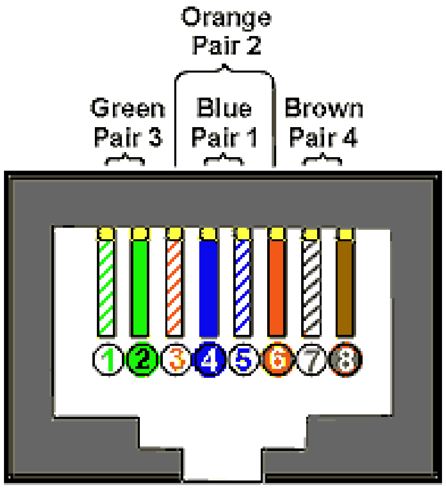


T568A

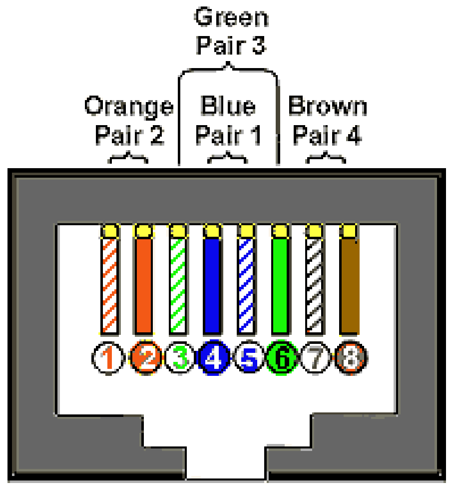


T568B

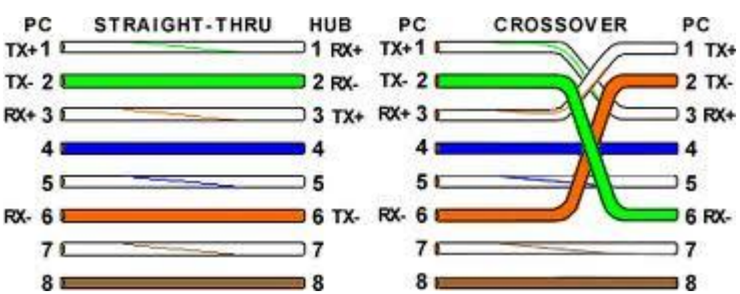
TIA/EIA 568



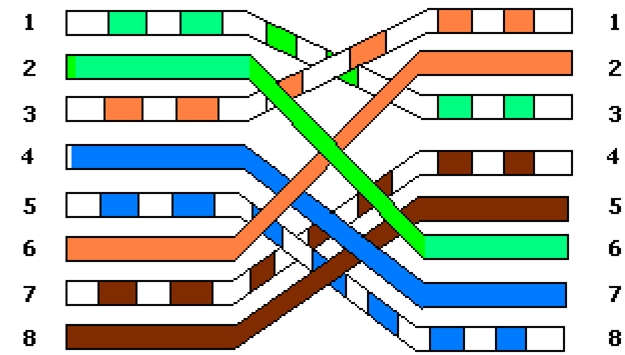
RJ-45 JACK
TIA/EIA 568A STANDARD



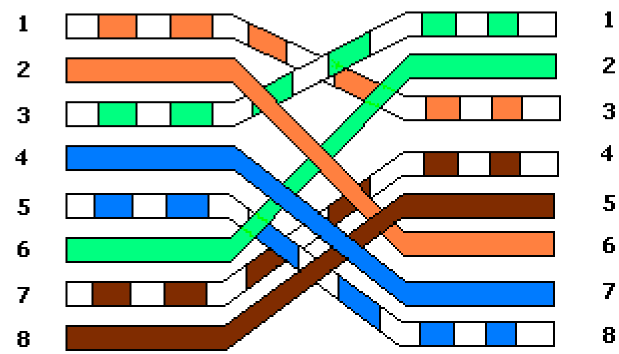
RJ-45 JACK
TIA/EIA 568B STANDARD



TIA/EIA 568A kryzminis

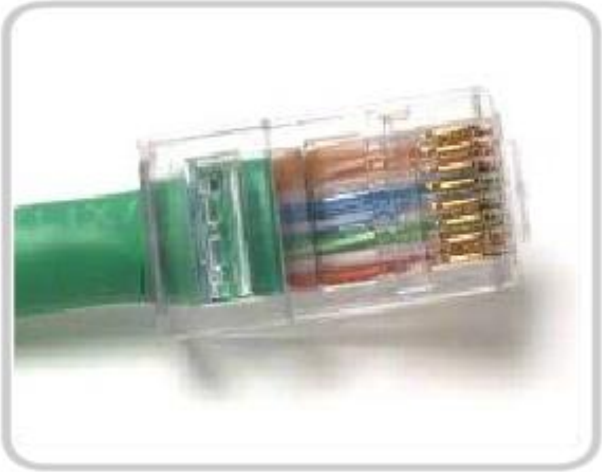


TIA/EIA 568B kryzminis



RJ-45 connector

Bad connector - Wires are untwisted for too great a length.



Good connector - Wires are untwisted to the extent necessary to attach the connector.

Coaxial cable

Coaxial cable consists of a copper conductor surrounded by a layer of flexible insulation, as shown in the figure.

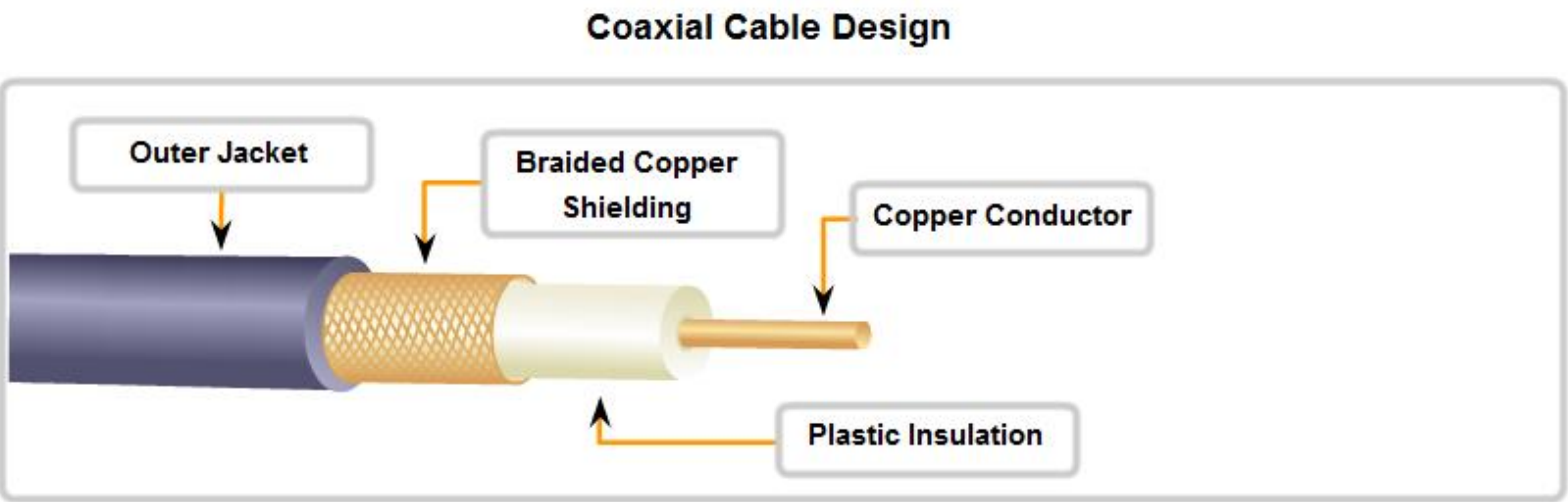
Over this insulating material is a woven copper braid, or metallic foil, that acts as the second wire in the circuit and as a shield for the inner conductor. This second layer, or shield, also reduces the amount of outside electromagnetic interference. Covering the shield is the cable jacket.

All the elements of the coaxial cable encircle the center conductor. Because they all share the same axis, this construction is called coaxial, or coax for short.

Coaxial cable type:

- **RG58** – Thin coaxial. 185 m, 50 Om, 10Base-2;
- **RG8** – Thick coaxial. 500 m, 50 Om 10Base-5.

Coaxial cable

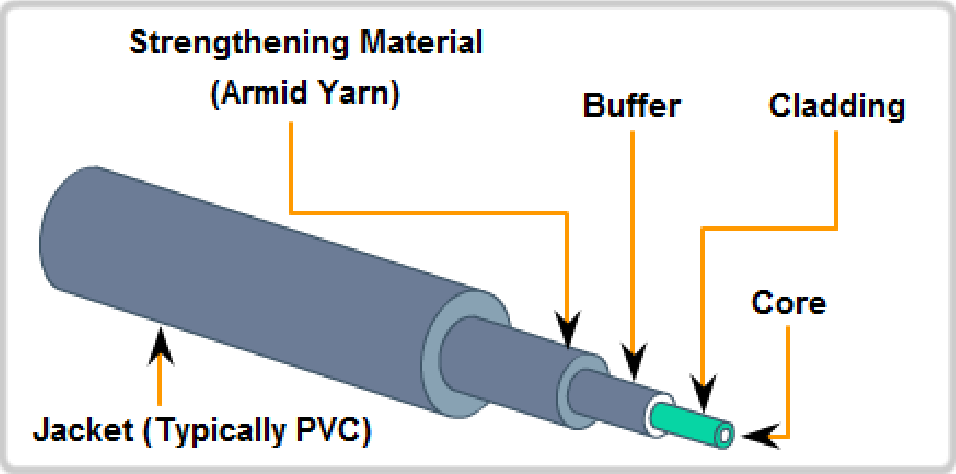


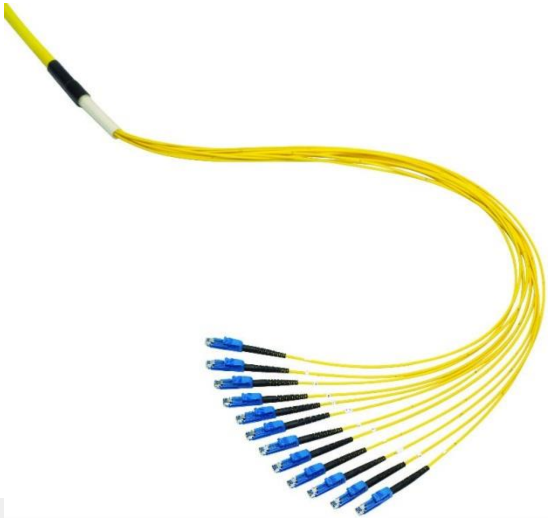
Fiber-optic cable

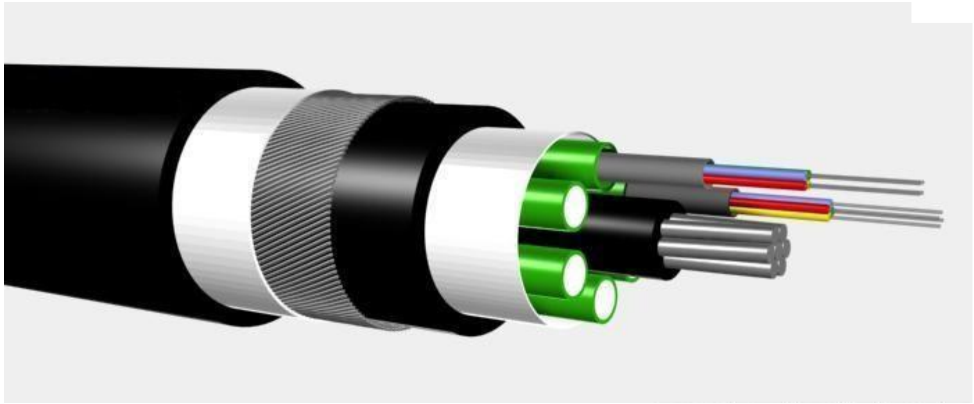
Fiber-optic cabling uses either glass or plastic fibers to guide light impulses from source to destination. The bits are encoded on the fiber as light impulses . Optical fiber cabling is capable of very large raw data bandwidth rates. Most current transmission standards have yet to approach the potential bandwidth of this media.

The fibers used in fiber-optic media are not electrical conductors, the media is immune to electromagnetic interference and will not conduct unwanted electrical currents due to grounding issues. Because optical fibers are thin and have relatively low signal loss, they can be operated at much greater lengths than copper media, without the need for signal regeneration. Some optical fiber Physical layer specifications allow lengths that can reach multiple kilometers.

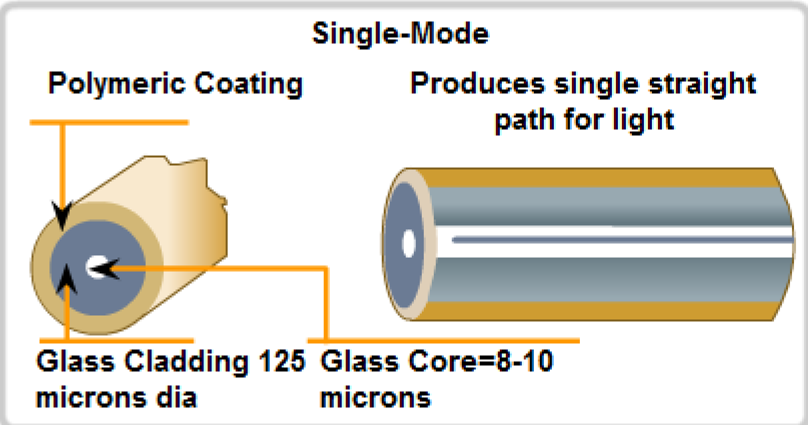
Fiber-optic cable

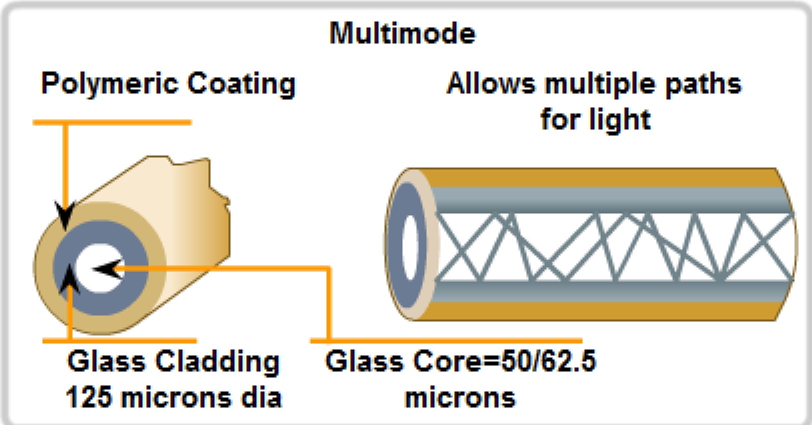






Fiber media modes

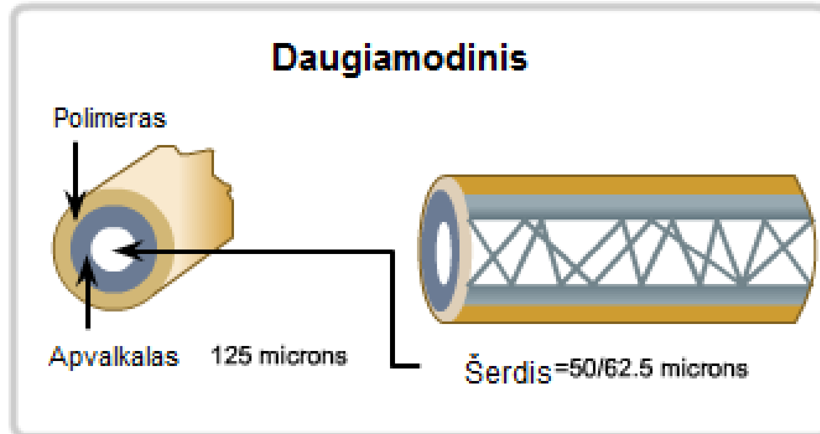




- Small Core
- Less Despersion
- Suited for long distance applications (up to 100 km, 62,14 mi.)
- Uses lasers as the light source often within campus backbones for distance of several thousand meters

- Larger core than single-mode cable (50 microns or greater)
- Allows greater dipersion and therefore, loss of signal
- Used for long distance appllication, but shorter than single-mode (up to ~2km, 6560 ft)
- Uses LEDs as the light source often within LANs or distances of couple hundred meters within a campus network

Optinis kabelis



Vienos modos kabelio savybės

- Vienos spalvos šviesos spindulys
- Mažo diametro šerdis
- Maža dispersija
- Šaltinis - lazeris
- Atstumas iki 100 km

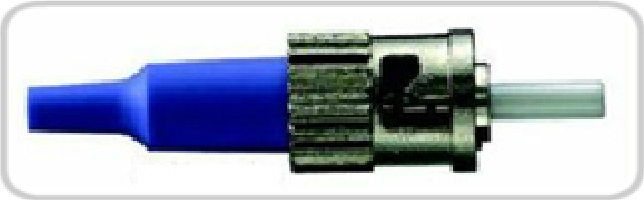
Daugiamodinio kabelio savybės

- Keletas šviesos spindulių
- Didesnio diametro šerdis
- Didesnė dispersija
- Šaltinis - LED
- Atstumas iki 2 km

Fiber-optic cable connectors

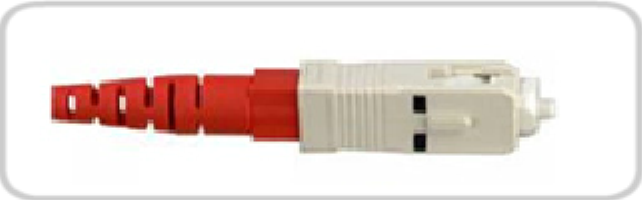
Fiber Media Connectors

ST Connector



Straight Tip (ST) connector is used with single-mode fiber

SC Connector



Subscriber Connector (SC) is used with multimode fiber

Single-Mode (LC)

Single-Mode Lucent Connector (LC)

Multimode (LC)

Multimode LC Connector

Duplex Multimode (LC)

Duplex Multimode LC Connector

Wireless media

Wireless media carry electromagnetic signals at radio and microwave frequencies that represent the binary digits of data communications. As a networking medium, wireless is not restricted to conductors or pathways, as are copper and fiber media.

Wireless data communication technologies work well in open environments. However, certain construction materials used in buildings and structures, and the local terrain, will limit the effective coverage. In addition, wireless is susceptible to interference and can be disrupted by such common devices as household cordless phones, some types of fluorescent lights, microwave ovens, and other wireless communications.

Types of Wireless Networks

Four common data communications standards that apply to wireless media are:

- Standard **IEEE 802.11** - Commonly referred to as Wi-Fi, is a Wireless LAN (WLAN) technology that uses a contention or non-deterministic system with a Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) media access process.
- Standard **IEEE 802.15** - Wireless Personal Area Network (WPAN) standard, commonly known as "Bluetooth", uses a device pairing process to communicate over distances from 1 to 100 meters.
- Standard **IEEE 802.16** - Commonly known as WiMAX (Worldwide Interoperability for Microwave Access), uses a point-to-multipoint topology to provide wireless broadband access.
- Global System for Mobile Communications (**GSM**) - Includes Physical layer specifications that enable the implementation of the Layer 2 General Packet Radio Service (GPRS) protocol to provide data transfer over mobile cellular telephony networks.

Wireless LAN

IEEE 802.11a - Operates in the 5 GHz frequency band and offers speeds of up to 54 Mbps. Because this standard operates at higher frequencies, it has a smaller coverage area and is less effective at penetrating building structures. Devices operating under this standard are not interoperable with the 802.11b and 802.11g standards described below.

IEEE 802.11b - Operates in the 2.4 GHz frequency band and offers speeds of up to 11 Mbps. Devices implementing this standard have a longer range and are better able to penetrate building structures than devices based on 802.11a.

IEEE 802.11g - Operates in the 2.4 GHz frequency band and offers speeds of up to 54 Mbps. Devices implementing this standard therefore operate at the same radio frequency and range as 802.11b but with the bandwidth of 802.11a.

The IEEE 802.11n standard is currently in draft form. The proposed standard defines frequency of 2.4 Ghz or 5 GHz. The typical expected data rates are 100 Mbps to 210 Mbps with a distance range of up to 70 meters.

Network devices

Network devices:

- Hub
- Bridge
- Switch
- Router
- Modem
- Access point

Hub

A network hub, repeater hub is a device for connecting multiple Ethernet devices together and making them act as a single network segment.

It has multiple input/output (I/O) ports, in which a signal introduced at the input of any port appears at the output of every port except the original incoming.

A hub works at the physical layer (layer 1) of the OSI model.

Repeater hubs also participate in collision detection, forwarding a jam signal to all ports if it detects a collision. In addition to standard 8P8C ("RJ45") ports, some hubs may also come with a BNC and/or Attachment Unit Interface (AUI) connector to allow connection to legacy 10BASE2 or 10BASE5 network segments

Bridge

Network bridging is the action taken by network equipment to create an aggregate network from either two or more communication networks, or two or more network segments. If one or more segments of the bridged network are wireless, it is known as wireless bridging. Bridging is distinct from routing, which allows multiple different networks to communicate independently while remaining separate.

A network bridge is a network device that connects multiple network segments. In the OSI model, bridging is performed in the first two layers, below the network layer.

There are four types of network bridging technologies: simple bridging, multiport bridging, learning or transparent bridging, and source route bridging.

Switch

A network switch (also called switching hub) is a computer networking device that connects devices together on a computer network, by using packet switching to receive, process and forward data to the destination device. Unlike less advanced network hubs, a network switch forwards data only to one or multiple devices that need to receive it, rather than broadcasting the same data out of each of its ports.

A network switch is a multiport network bridge that uses hardware addresses to process and forward data at the data link layer (layer 2) of the OSI model.

Router

A router is a networking device that forwards data packets between computer networks.

A router is connected to two or more data lines from different networks (as opposed to a network switch, which connects data lines from one single network). When a data packet comes in one of the lines, the router reads the address information in the packet to determine its ultimate destination. Then, using information in its routing table or routing policy, it directs the packet to the next network on its journey. This creates an overlay internetwork.

Routers perform the "traffic directing" functions on the Internet. A data packet is typically forwarded from one router to another through the networks that constitute the internetwork until it reaches its destination node.

Wireless Access Point

Wireless Access Point (AP) is a device that allows wireless devices to connect to a wired network using Wi-Fi, or related standards. The AP usually connects to a router (via a wired network) as a standalone device, but it can also be an integral component of the router itself. An AP is differentiated from a hotspot, which is the physical space where the wireless service is provided.

Topology

Network topology is the arrangement of the various elements (links, nodes, etc.) of a computer network.

Essentially, it is the topological structure of a network and may be depicted physically or logically.

Physical topology is the placement of the various components of a network, including device location and cable installation, while **logical topology** illustrates how data flows within a network, regardless of its physical design.

Topology

Topology

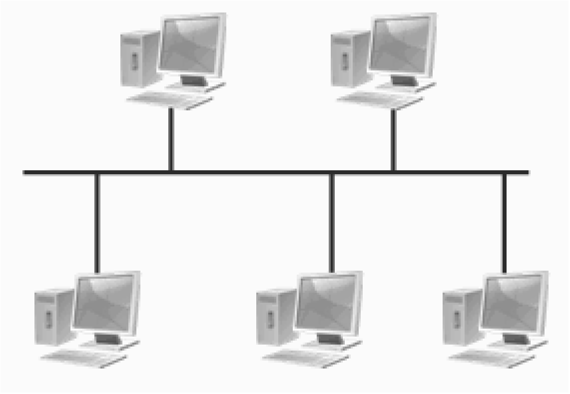
- Point-to-point
- Bus
- Star
- Ring
- Mesh
- Tree
- Hybrid
- Daisy chain

Bus topology

Each computer or server is connected to the single bus cable. A signal from the source travels in both directions to all machines connected on the bus cable until it finds the intended recipient.

If the machine address does not match the intended address for the data, the machine ignores the data. Alternatively, if the data matches the machine address, the data is accepted.

Because the bus topology consists of only one wire, it is rather inexpensive to implement when compared to other topologies. Because only one cable is utilized, it can be the single point of failure.

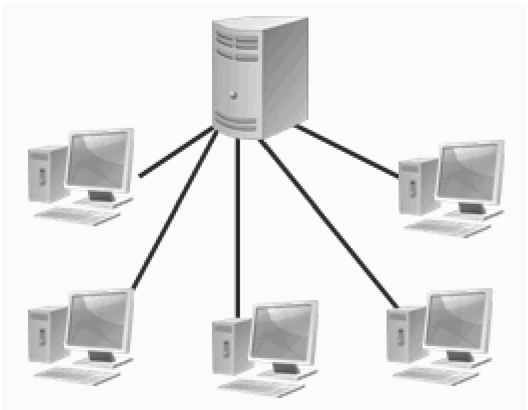


Star topology

In Star topology every node is connected to a central node called hub or switch.

The switch is the server and the peripherals are the clients. All traffic that traverses the network passes through the central hub. The hub acts as a signal repeater. The star topology is considered the easiest topology to design and implement. An advantage of the star topology is the simplicity of adding additional nodes.

The primary disadvantage of the star topology is that the hub represents a single point of failure.



Ring topology

A network topology that is set up in a circular fashion in which data travels around the ring in one direction and each device on the ring acts as a repeater to keep the signal strong as it travels.

Each device incorporates a receiver for the incoming signal and a transmitter to send the data on to the next device in the ring.

The network is dependent on the ability of the signal to travel around the ring. When a device sends data, it must travel through each device on the ring until it reaches its destination. Every node is a critical link.

In a ring topology, there is no server computer present; all nodes work as a server and repeat the signal.

The disadvantage of this topology is that if one node stops working, the entire network is affected or stops working.

Fully connected mesh topology

A fully connected network is a communication network in which each of the nodes is connected to each other.

In graph theory it known as a complete graph.

A fully connected network doesn't need to use switching or broadcasting. However, its major disadvantage is that the number of connections grows quadratically with the number of nodes, and so it is extremely impractical for large networks.

$$c = \frac{n(n-1)}{2}.$$

Tree topology

- A tree topology is essentially a combination of bus topology and star topology. The nodes of bus topology are replaced with standalone star topology networks. This results in both disadvantages of bus topology and advantages of star topology.
- For example, if the connection between two groups of networks is broken down due to breaking of the connection on the central linear core, then those two groups cannot communicate, much like nodes of a bus topology.
- However, the star topology nodes will effectively communicate with each other.

Hybrid topology

Hybrid networks use a combination of any two or more topologies, in such a way that the resulting network does not exhibit one of the standard topologies (e.g., bus, star, ring, etc.). For example a tree network connected to a tree network is still a tree network topology.

A hybrid topology is always produced when two different basic network topologies

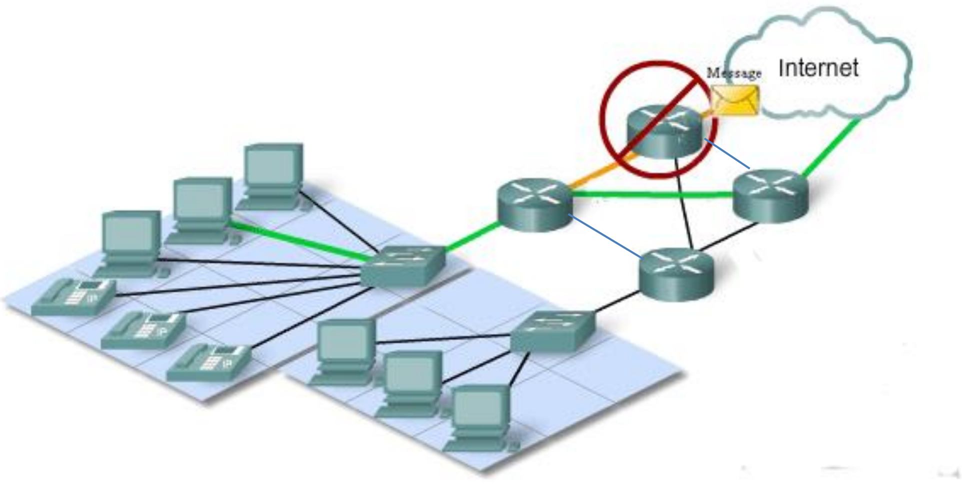
are connected.

Two common examples

for Hybrid network are:

star ring network and

star bus network.

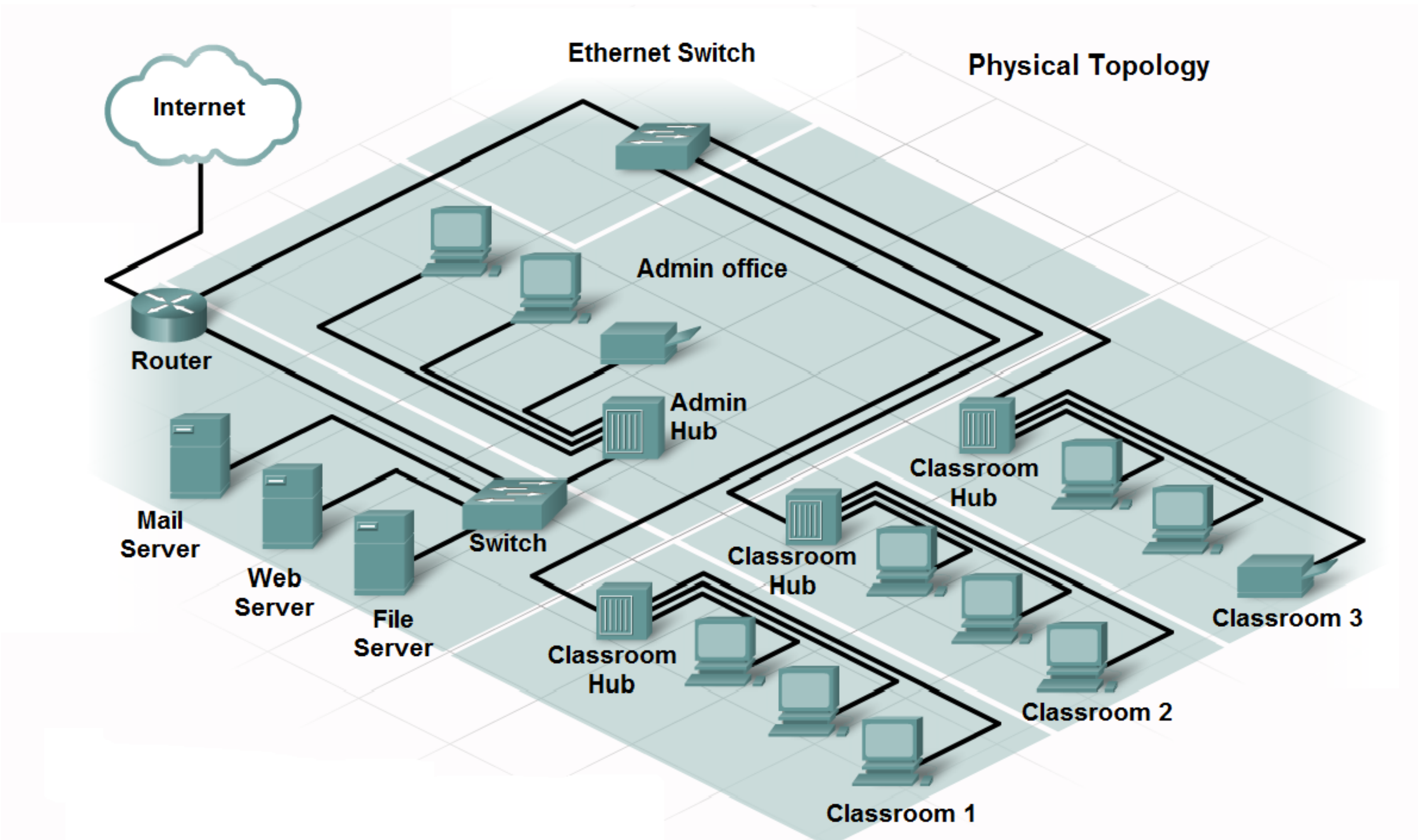


Physical topology

The cabling layout used to link devices is the physical topology of the network. This refers to the layout of cabling, the locations of nodes, and the interconnections between the nodes and the cabling.

The physical topology of a network is determined by the capabilities of the network access devices and media, the level of control or fault tolerance desired, and the cost associated with cabling or telecommunications circuits.

Physical topology



Logical topology

The logical topology is the way that the signals act on the network media, or the way that the data passes through the network from one device to the next without regard to the physical interconnection of the devices.

A network's logical topology is not necessarily the same as its physical topology.

For example, the original twisted pair Ethernet using repeater hubs was a logical bus topology with a physical star topology layout. Token Ring is a logical ring topology, but is wired a physical star from the Media Access Unit.

Logical topology