Principles & Architecture

EPITA Bachelor of Science

Principles and Architecture of Information Systems

Chapter #5

Network

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Principles & Architecture

Structure

- **Chapter 1 : Introduction and Organisations**
- **Chapter 2 : Hardware**
- **Chapter 3 : Software**
- **Chapter 4 : Database Systems**
- **Chapter 5 : Network**
- **Chapter 6 : Internet and E-Commerce**
- **Chapter 7 : Major Information Systems**
- **Chapter 8 : Systems Development**
- **Chapter 9 : Security,Privacy and Ethical issues**

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Introduction

- **A computer network consists of communications media, devices, and software connecting two or more computer systems or devices**
- **Networks are an essential component of an organization's information technology infrastructure**
- **Effective communication: Essential to the success of every major human undertaking**

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Discussion

- **What are the applications that organizations benefit from the Network ?**

An Overview of Telecommunications

- **Telecommunications:**
  - **Electronic transmission of signals for communications**
- **Telecommunications medium:**
  - **Any material substance that carries an electronic signal to support communications between a sending and receiving device**
- **Networking protocol:**
  - **Set of rules, algorithms, messages, and other mechanisms that enable software and hardware in networked devices to communicate effectively**

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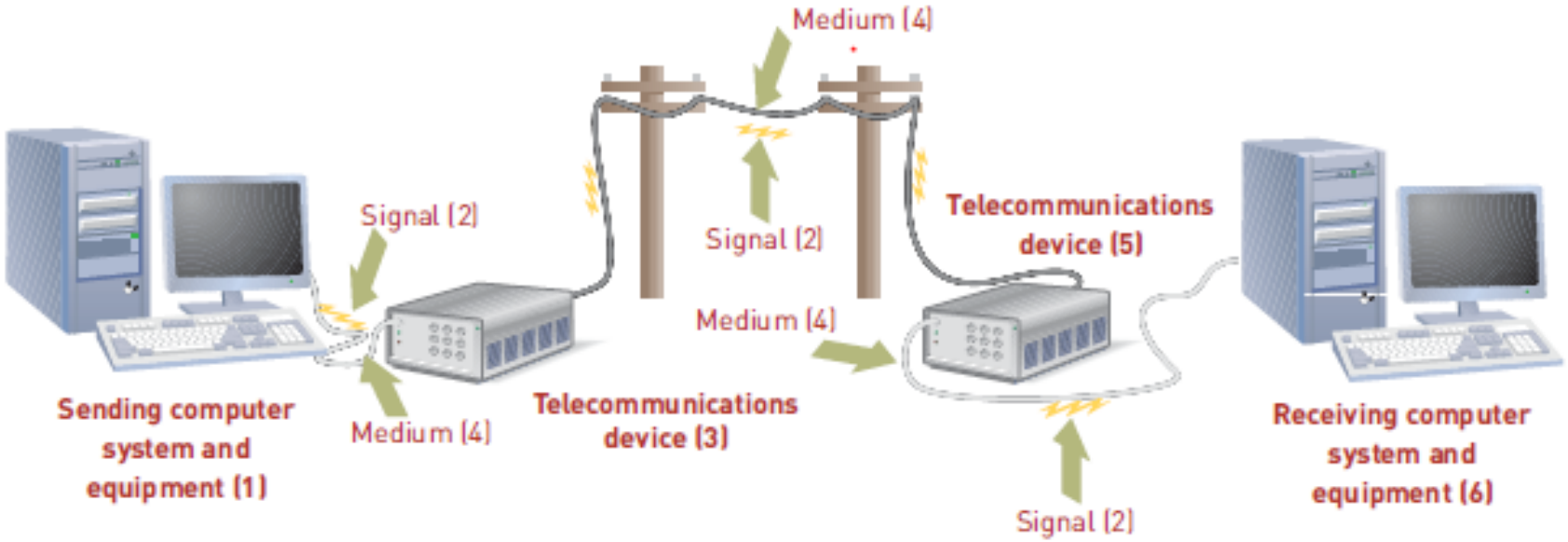
Elements of a Telecommunications System



Telecommunications devices relay signals between computer systems and transmission media

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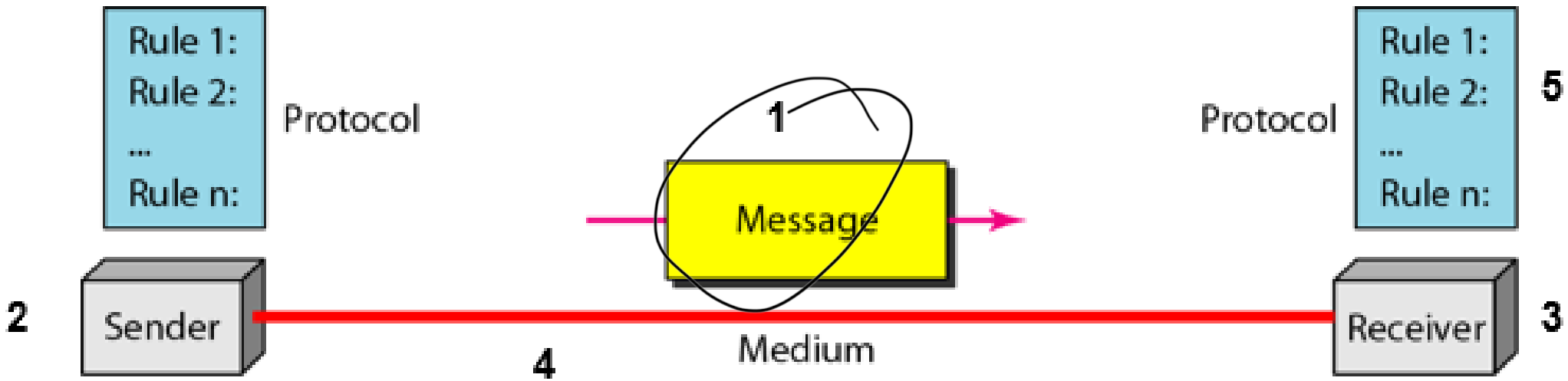
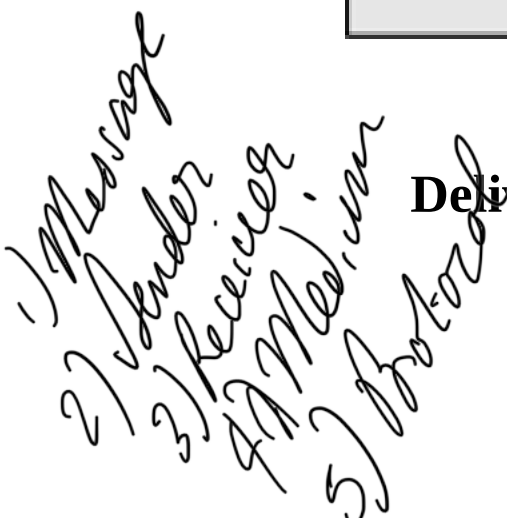
The 5 components of data communication

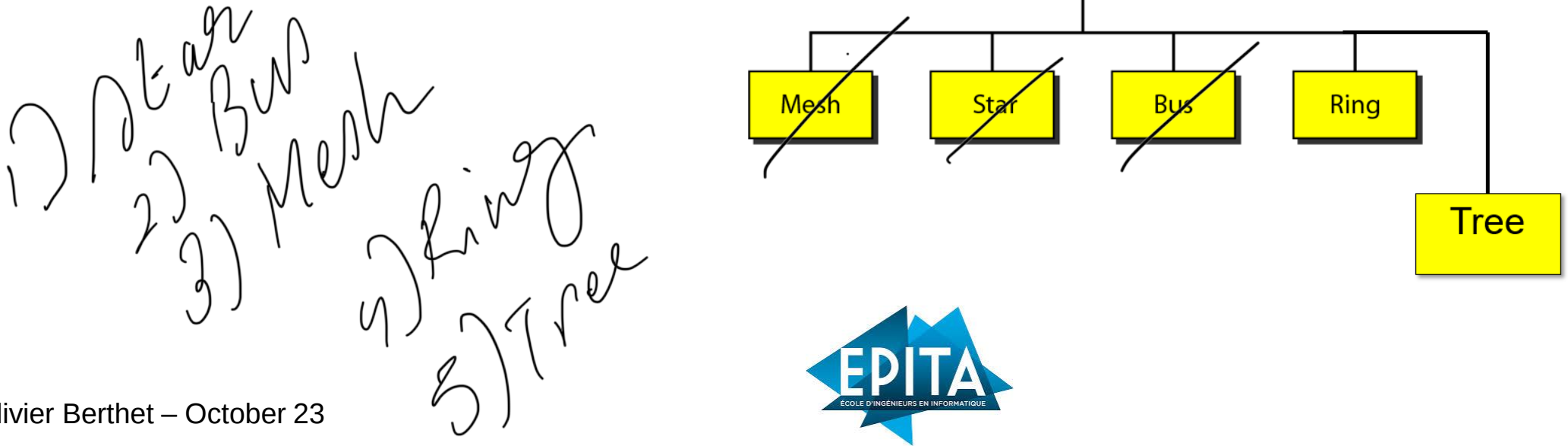




Delivery → Correct destination **Accuracy → Accurate data**

Network Topology

- **Network topology is the shape or structure of a network, including the arrangement of the communication links and hardware devices on the network**
- **The three most common network topologies in use today are the star, bus, and mesh.**



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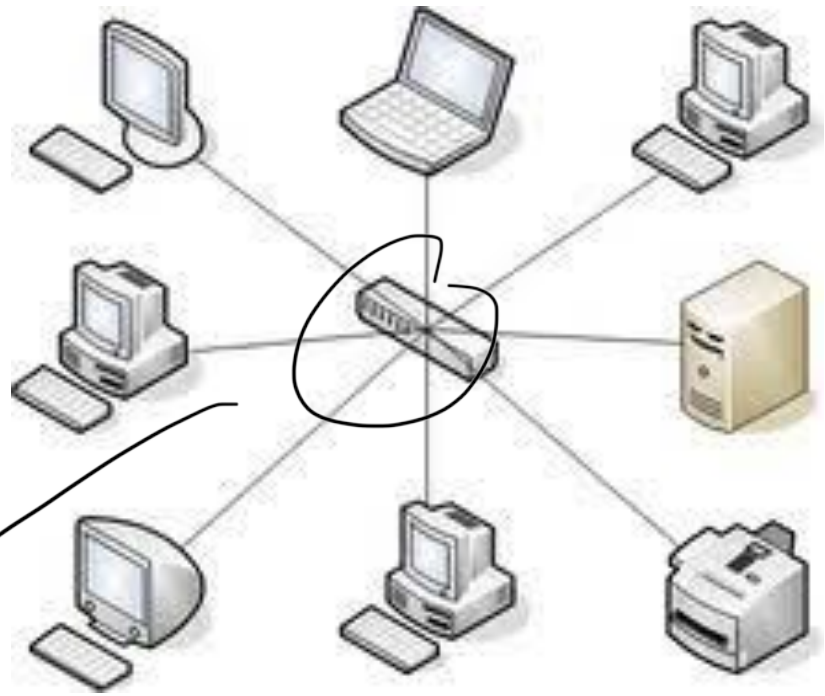
Star Network

- **In a star network, all network devices connect to one another through a single central device called the hub node.**
- **A failure in any link of the star network will isolate only the device connected to that link.**
- **However, should the hub fail, all devices on the entire network will be unable to communicate.**



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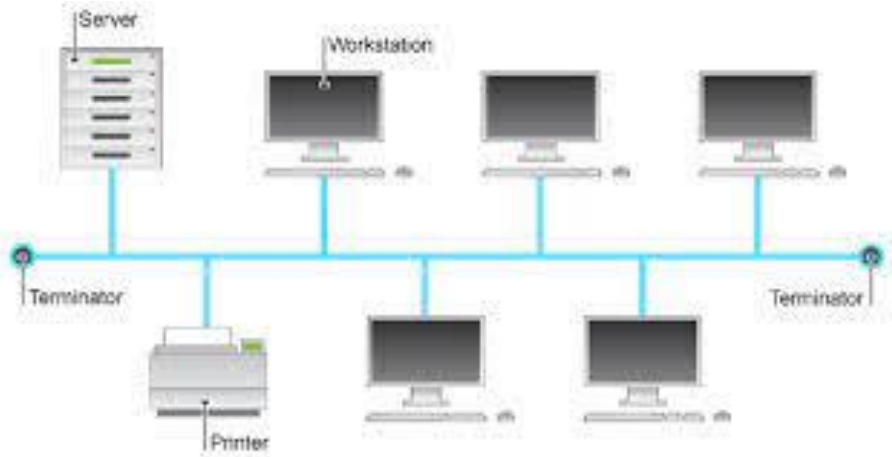
Bus Network

- **In a bus network, all network devices are connected to a common backbone that serves as a shared communications medium.**
- **To communicate with any other device on the network, a device sends a broadcast message onto the communications medium.**
- **All devices on the network can “see” the message, but only the intended recipient actually accepts and processes the message.**



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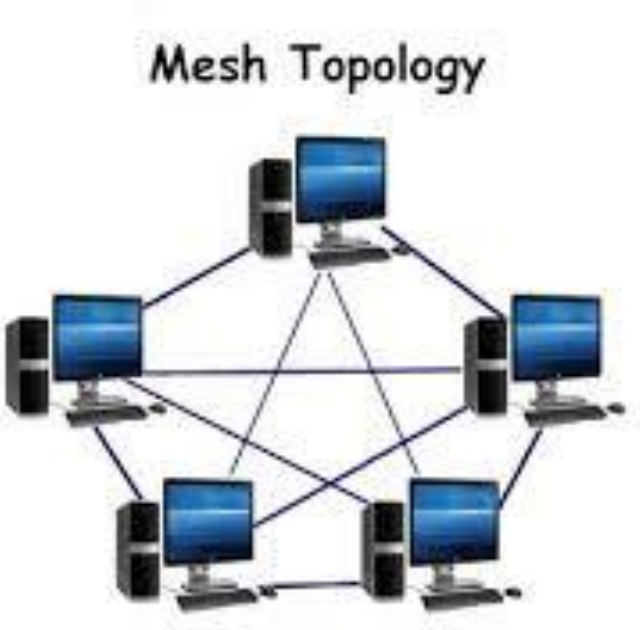
Mesh Network

- **Mesh networks use multiple access points to link a series of devices that speak to each other to form a network connection across a large area.**
- **Communications are routed among network nodes by allowing for continuous connections and by bypassing blocked paths by “hopping” from node to node until a connection can be established.**
- **Mesh networks are very robust: if one node fails, all the other nodes can still communicate with each other, directly or through one or more intermediate nodes.**



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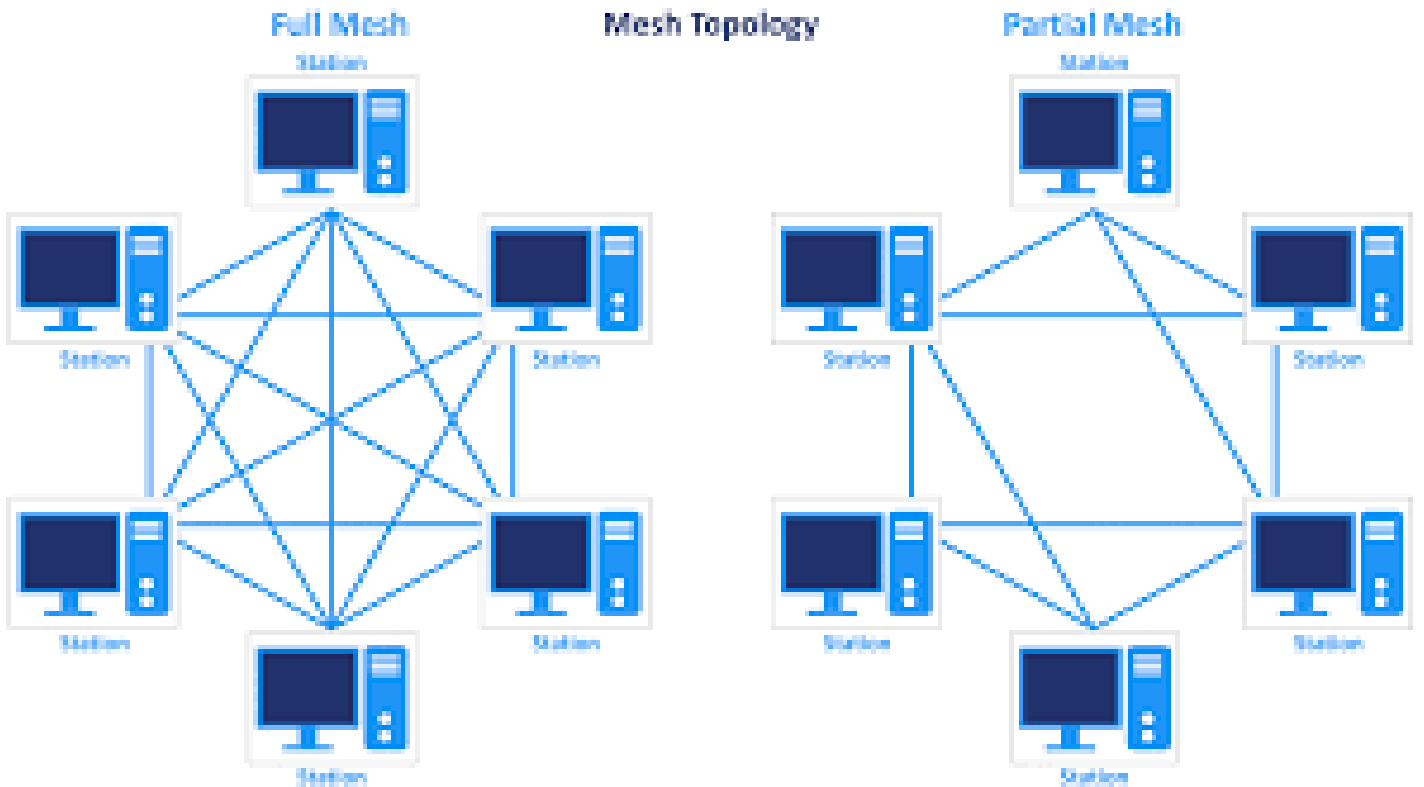
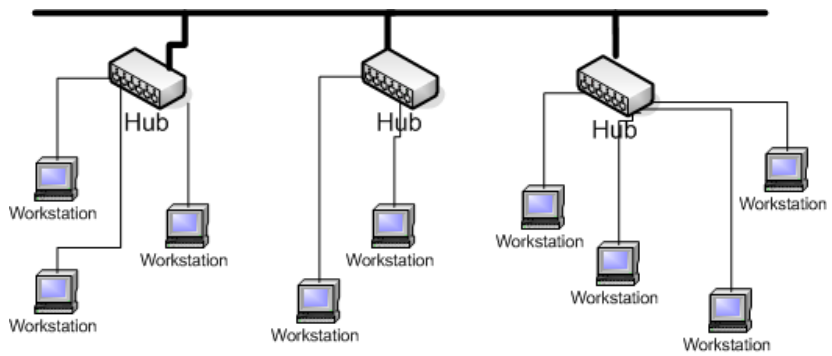
Full versus Partial Mesh Network



Tree topology

- **Tree topologies integrate multiple topologies together**
- **Advantages:**
  - **Point-to-point wiring for individual segments.**
  - **Supported by several hardware and software venders.**
- **Disadvantages:**
  - **Overall length of each segment is limited by the type of cabling used.**
  - **If the backbone line breaks, the entire segment goes down.**
  - **More difficult to configure and wire than other topologies.**



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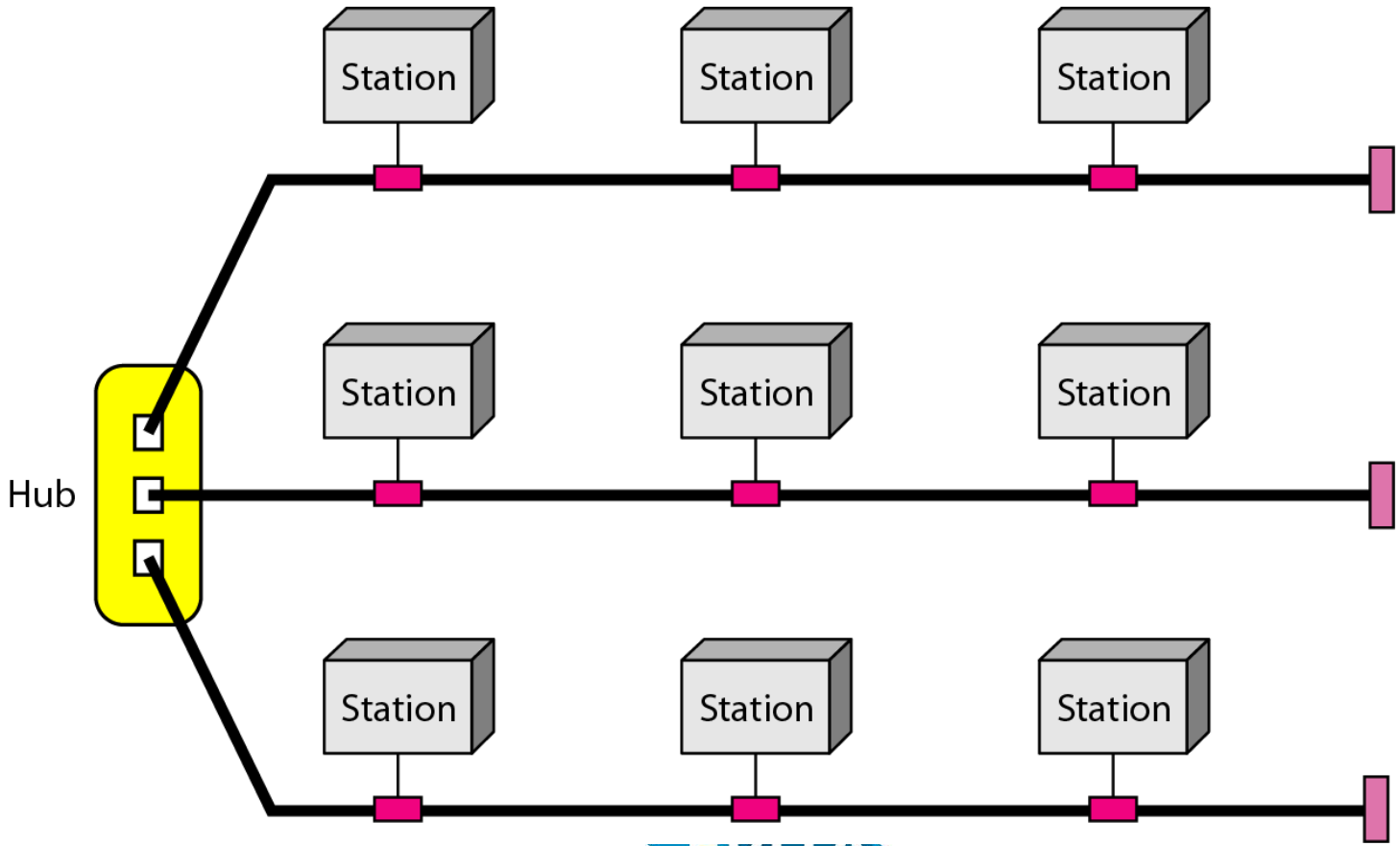
A hybrid topology: a star backbone with three bus networks



Synchronous versus Asynchronous

- **Synchronous communications:**
  - **Receiver gets message instantaneously**
- **Asynchronous communications:**
  - **Receiver gets message after some delay**

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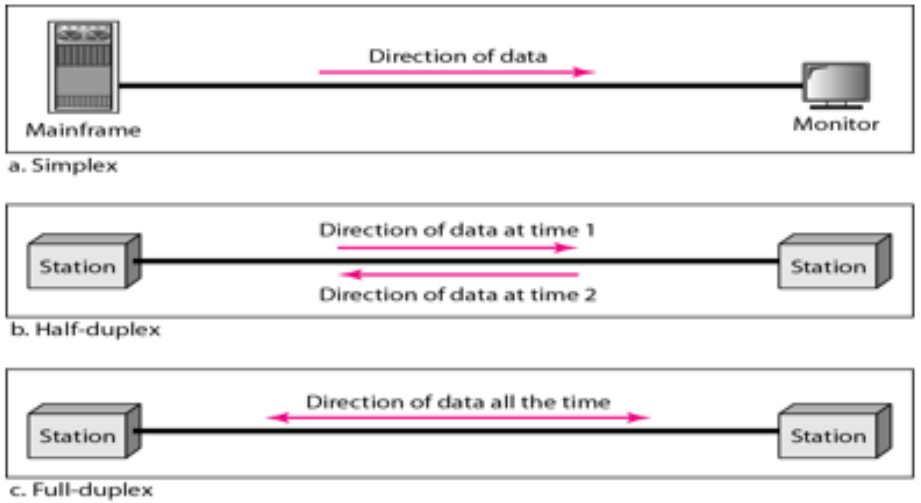
Basic Telecommunications Channel Characteristics

- **Simplex channel:**
  - **Transmits data in only one direction**
- **Half-duplex channel:**
  - **Transmits data in either direction, but not simultaneously**
- **Full-duplex channel:**
  - **Permits data transmission in both directions at the same time**



Protocol Concepts

- **Protocols are sets of rules.**
  - **What do you want to do? (Application)**
  - **Where are you going? (Addressing)**
  - **How do you get there? (Media types)**
  - **Did you get there? (Acknowledgments, Error checking)**

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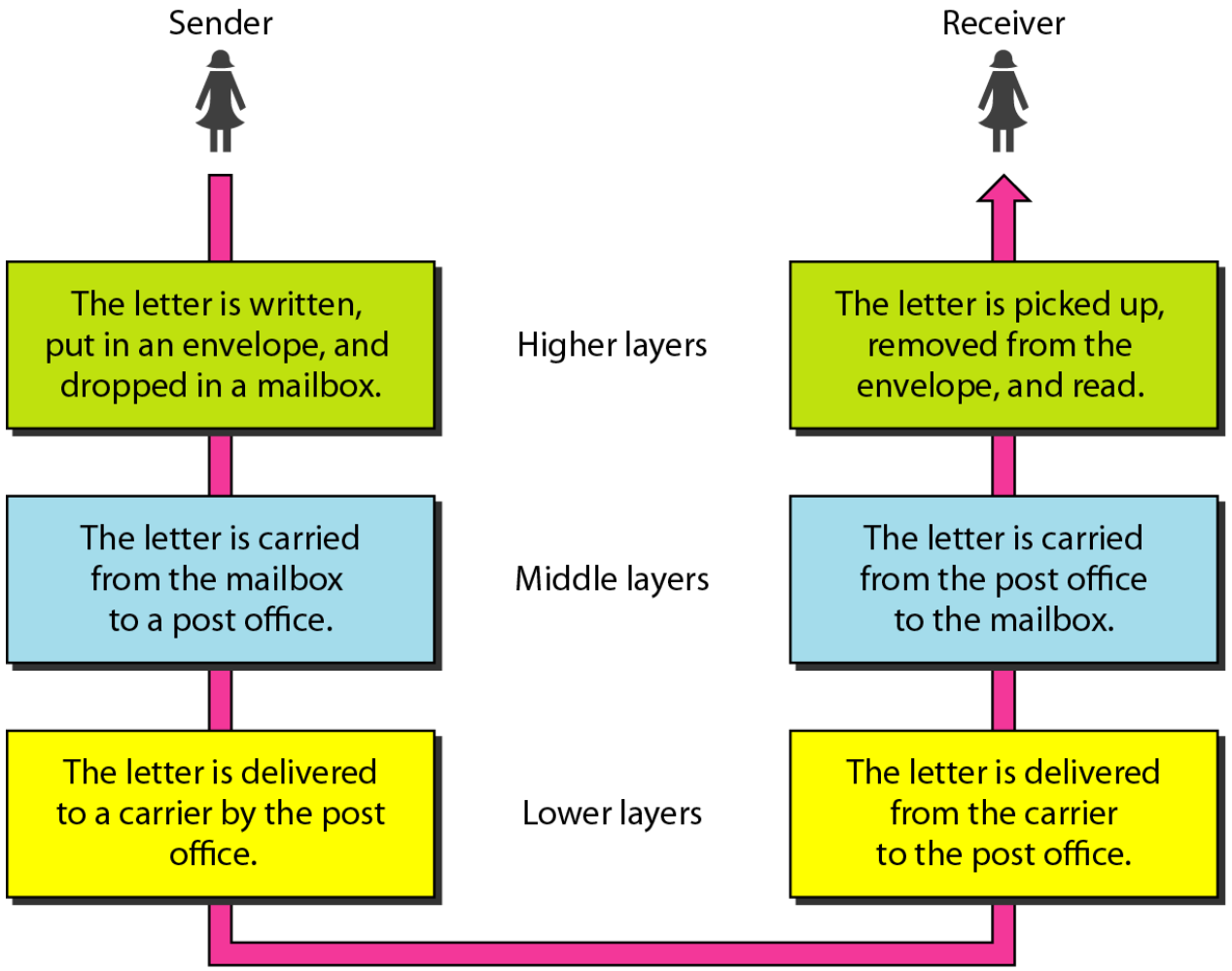
Tasks for a mail



The OSI model

- **Established in 1947, the International Standards Organization (ISO) is a multinational body dedicated to worldwide agreement on international standards.**
- **An ISO is the Open Systems Interconnection (OSI) model is the standard that covers all aspects of network communications from ISO. It was first introduced in the late 1970s.**
- **ISO is the organization. OSI is the model.**

Network Protocol

- **A network model is a layered architecture**
  - **Task broken into subtasks**
  - **Implemented separately in layers in stack**
  - **Functions need in both systems**
  - **Peer layers communicate**

- **Protocol:**
  - **A set of rules that governs data communication**
  - **It represents an agreement between the communicating devices**

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Layered architecture of the OSI model

Layers

Layer 7. Application

Layer 6. Presentation

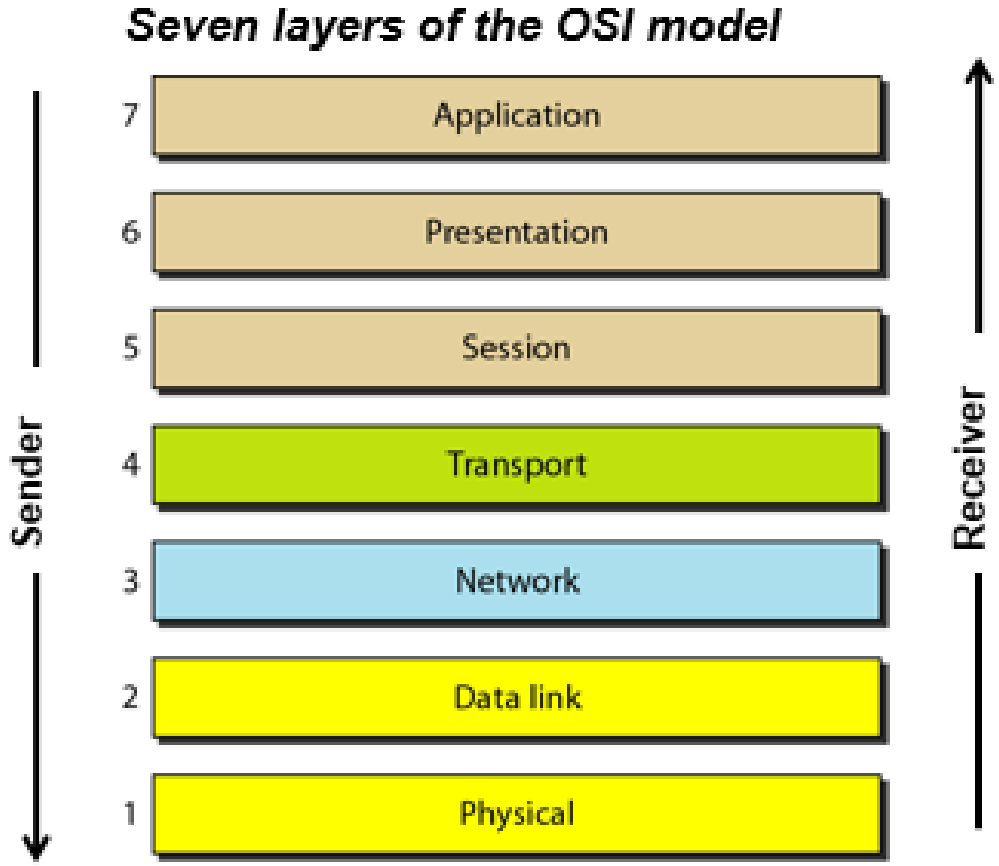
Layer 5. Session

Layer 4. Transport

Layer 3. Network

Layer 2. Data Link

Layer 1. Physical



A layered architecture

- **A layered model**
- **Each layer performs a subset of the required communication functions**
- **Each layer relies on the next lower layer to perform more primitive functions**
- **Each layer provides services to the next higher layer**
- **Changes in one layer should not require changes in other layers**
- **The processes on each machine at a given layer are called peer-to-peer process**

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Peer-to-peer process

- **Communication must move downward through the layers on the sending device, over the communication channel, and upward to the receiving device**
- **Each layer in the sending device adds its own information to the message it receives from the layer just above it and passes the whole package to the layer just below it**
- **At the receiving device, the message is unwrapped layer by layer, with each process receiving and removing the data meant for it**
- **The passing of the data and network information down through the layers of the sending device and backup through the layers of the receiving device is made possible by interface between each pair of adjacent layers**
- **Interface defines what information and services a layer must provide for the layer above it.**

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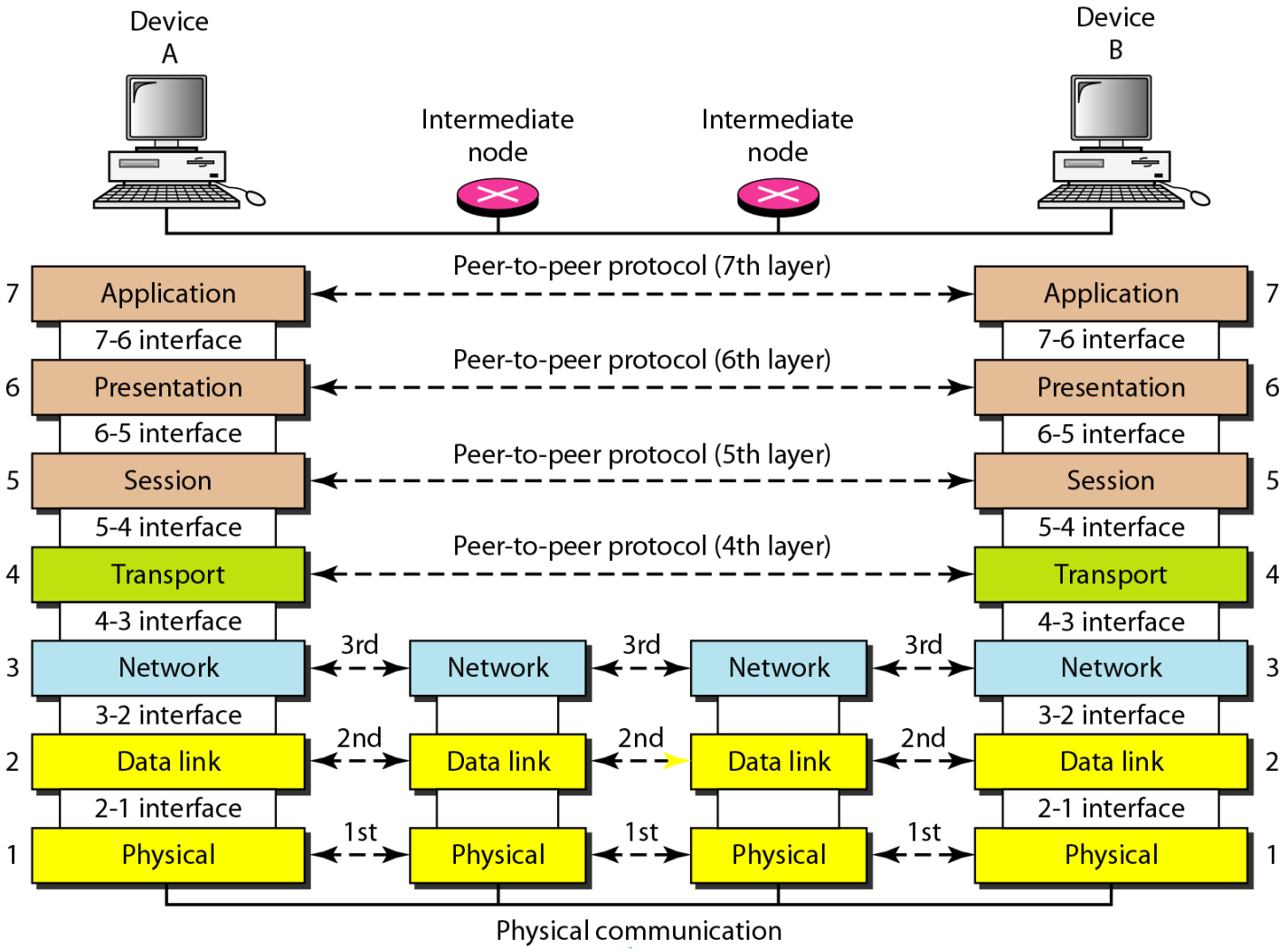
The interaction between layers in the OSI model



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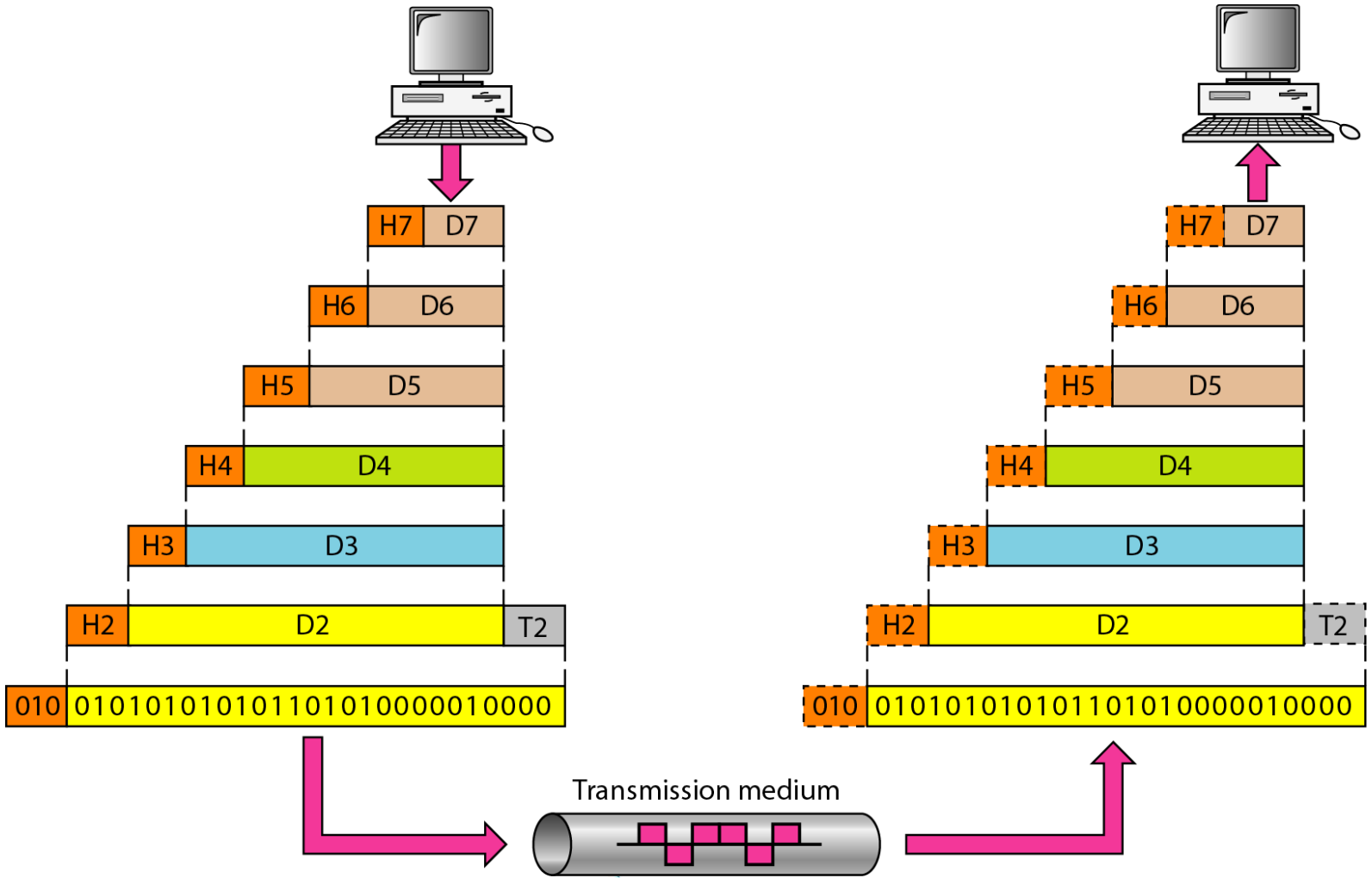
An exchange using the OSI model



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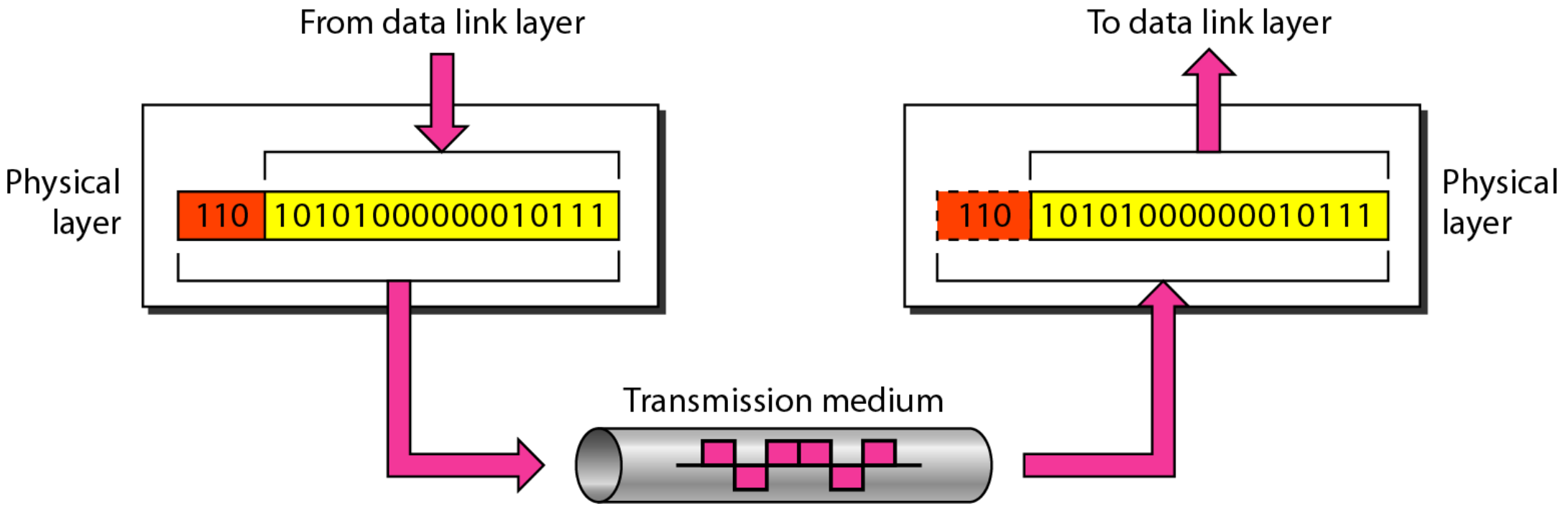
Physical layer



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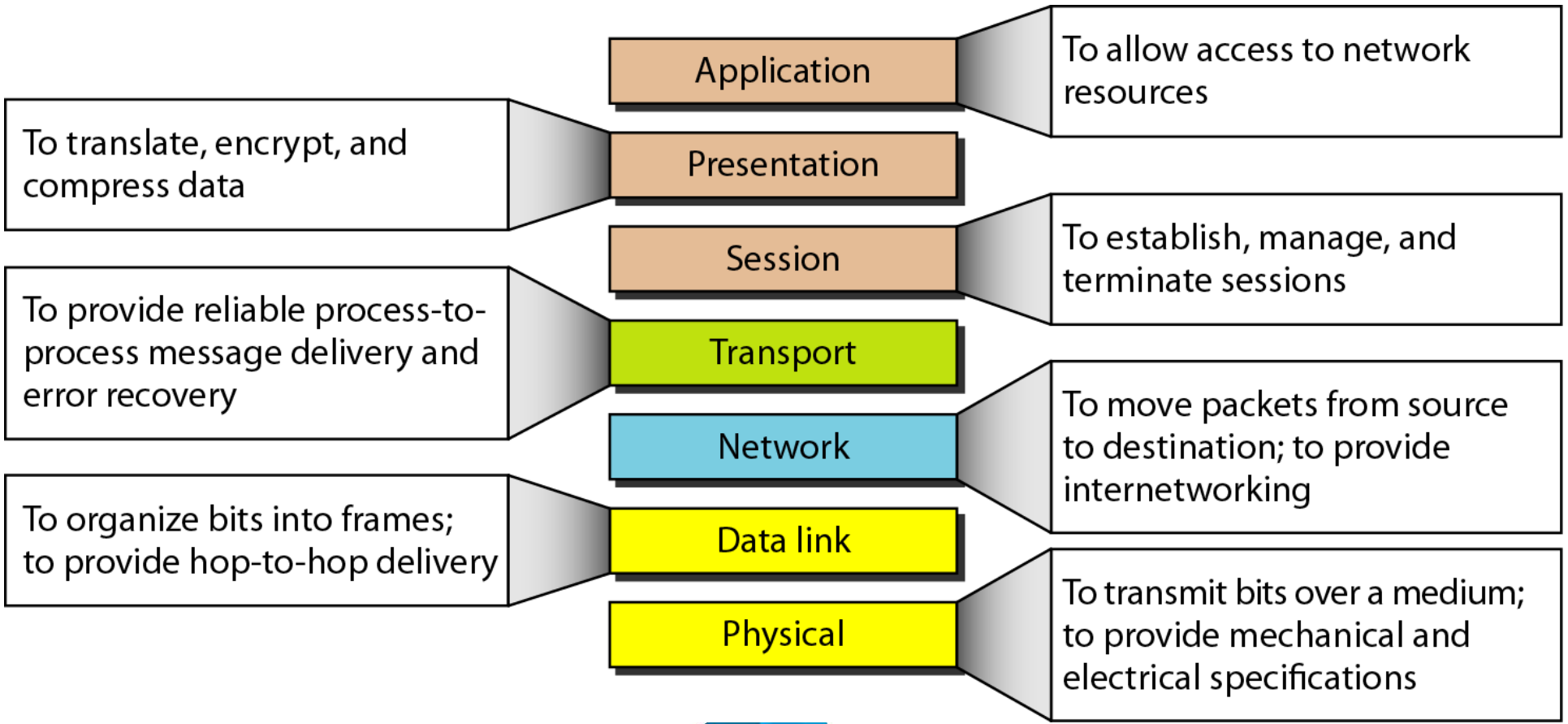
Summary of layers



Example of TCP/IP Protocol

- **The layers in the TCP/IP protocol suite do not exactly match those in the OSI model.**
- **The original TCP/IP protocol suite was defined as having four layers: host-to-network, internet, transport, and application.**
- **However, when TCP/IP is compared to OSI, we can say that the TCP/IP protocol suite is made of five layers: physical, data link, network, transport, and application.**

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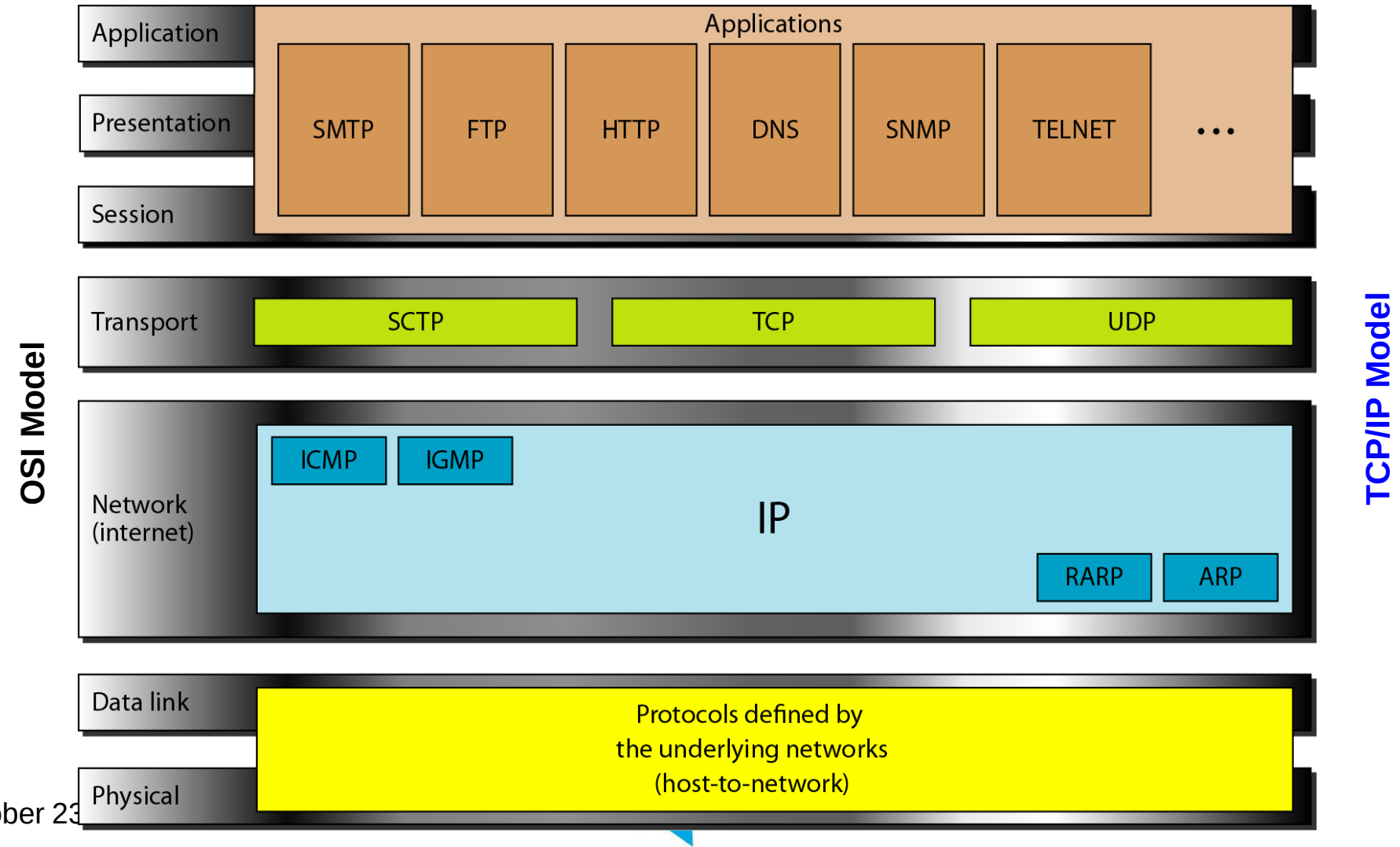
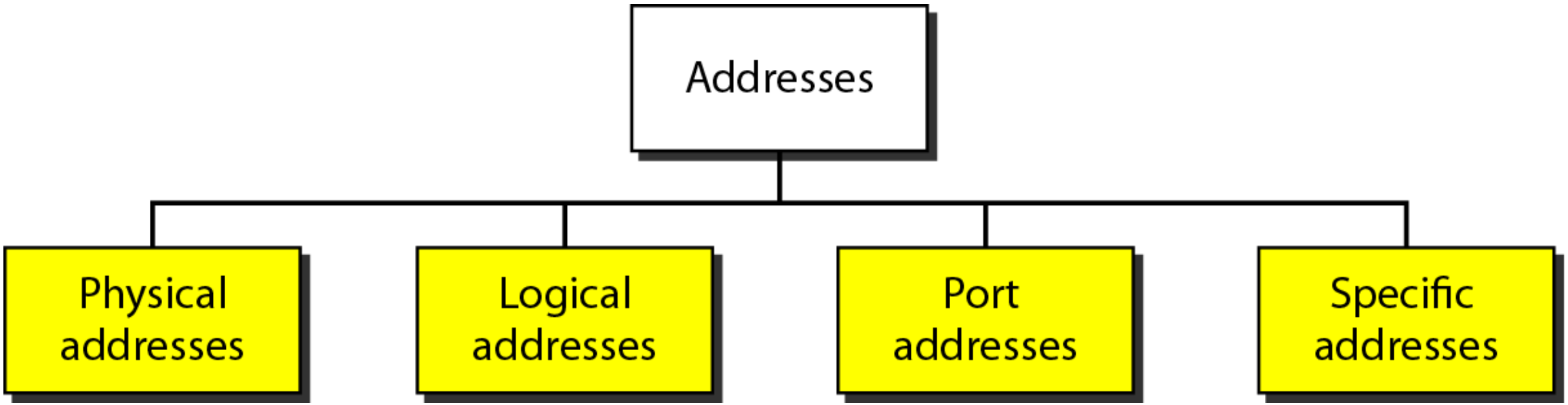
Example of TCP/IP Protocol



Addresses in TCP/IP



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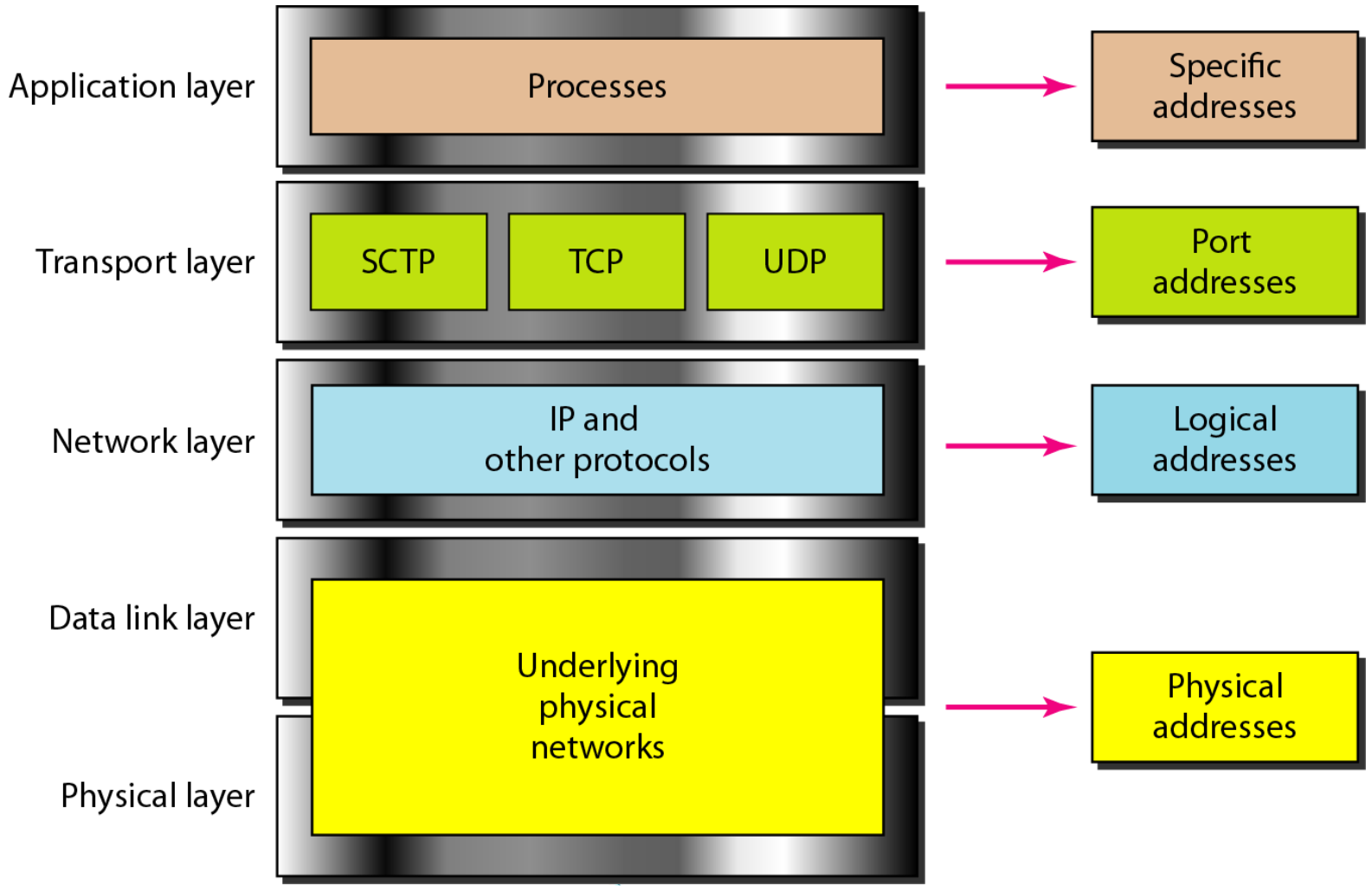
Relationship of layers and addresses in TCP/IP



Standard organizations

- **International Organization for Standardization (ISO)**
- **International Telecommunication Union - Telecommunication Standards (ITU-T)**
- **American National Standards Institute (ANSI)**
- **Institute of Electrical and Electronics Engineers (IEEE)**
- **Electronic Industries Association (EIA)**

Basic Telecommunications Channel Characteristics

- **Channel bandwidth:**
  - Rate at which data is exchanged usually in Mega Bits per second Mbps
- **Circuit switching network:**
  - Sets up a circuit between the sender and receiver before any communications can occur
- **Packet switching network:**
  - No fixed path is created between the communicating devices
- **Telecommunications media**
  - Categories: guided transmission media and wireless

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Network bandwith

56 kbit/s	Modem / Dialup
1.5 Mbit/s	ADSL Lite
1.544 Mbit/s	T1/DS1
2.048 Mbit/s	E1 / E-carrier
4 Mbit/s	ADSL1
10 Mbit/s	Ethernet
11 Mbit/s	Wireless 802.11b
24 Mbit/s	ADSL2+
44.736 Mbit/s	T3/DS3
54 Mbit/s	Wireless 802.11g
100 Mbit/s	Fast Ethernet
155 Mbit/s	OC3
600 Mbit/s	Wireless 802.11n
622 Mbit/s	OC12
1 Gbit/s	Gigabit Ethernet
1.3 Gbit/s	Wireless 802.11ac
2.5 Gbit/s	OC48
5 Gbit/s	SuperSpeed USB
7 Gbit/s	Wireless 802.11ad
9.6 Gbit/s	OC192
10 Gbit/s	10 Gigabit Ethernet, SuperSpeed USB 10 Gbit/s
20 Gbit/s	SuperSpeed USB 20 Gbit/s
40 Gbit/s	Thunderbolt 3
100 Gbit/s	100 Gigabit Ethernet

Basic Telecommunications Channel Characteristics

- **Guided transmission media types:**
  - Available in many types
- **Twisted-pair wire:**
  - Classified by category: category 2, 3, 5, 5E, and 6
- **Coaxial cable:**
  - Offers cleaner and crisper data transmission (less noise) than twisted-pair wire
- **Fiber-optic cable:**
  - Transmits signals with light beams

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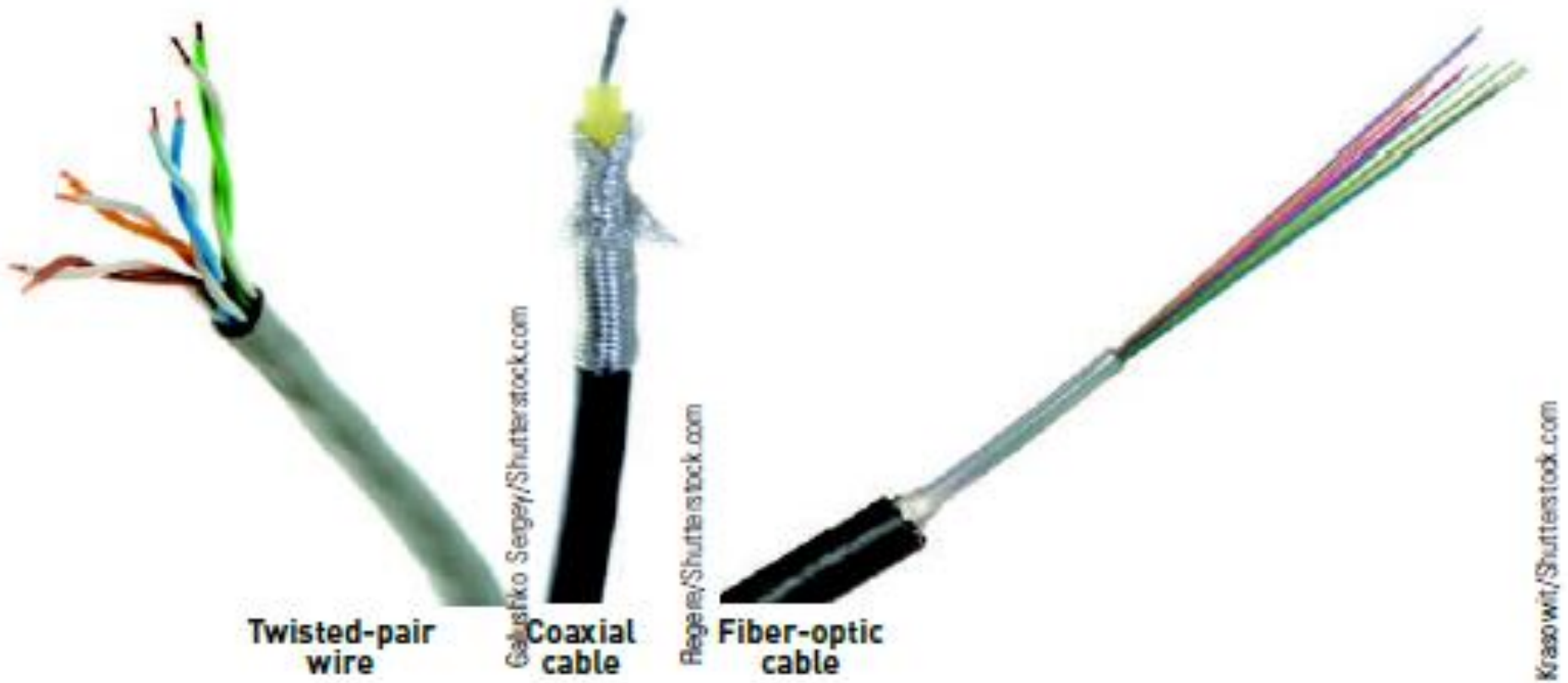
Type of guided transmission media



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Type of guided transmission media

Media Form	Description	Advantages	Disadvantages
Twisted-pair wire	Twisted pairs of copper wire, shielded or unshielded; used for telephone service	Widely available	Limitations on transmission speed and distance
Coaxial cable	Inner conductor wire surrounded by insulation	Cleaner and faster data transmission than twisted-pair wire	More expensive than twisted-pair wire
Fiber-optic cable	Many extremely thin strands of glass bound together in a sheathing; uses light beams to transmit signals	Diameter of cable is much smaller than coaxial cable; less distortion of signal; capable of high transmission rates	Expensive to purchase and install

Basic Telecommunications Channel Characteristics

- **Broadband over power lines:**
  - **Potential problem: transmitting data over unshielded power lines can interfere with both amateur (ham) radio broadcasts and police and fire radios**
- **Wireless communications options:**
  - **Wireless transmission involves the broadcast of communications in one of three frequency ranges : Radio, microwave, or infrared frequencies**

Wireless communication

- **Wireless communication is the transfer of information between two or more points that are not connected by an electrical conductor.**
- **All wireless communications signals are sent within a range of frequencies of the electromagnetic spectrum that represents the entire range of light that exists from long waves to gamma rays**
- **Like any other wave, light has two fundamental properties that describe it**
  - **frequency, measured in hertz (Hz), which counts the number of waves that pass by a stationary point in one second.**
  - **wavelength, which is the distance from the peak of one wave to the peak of the next.**
  - **These two attributes are inversely related so the higher the frequency, the shorter the wavelength.**

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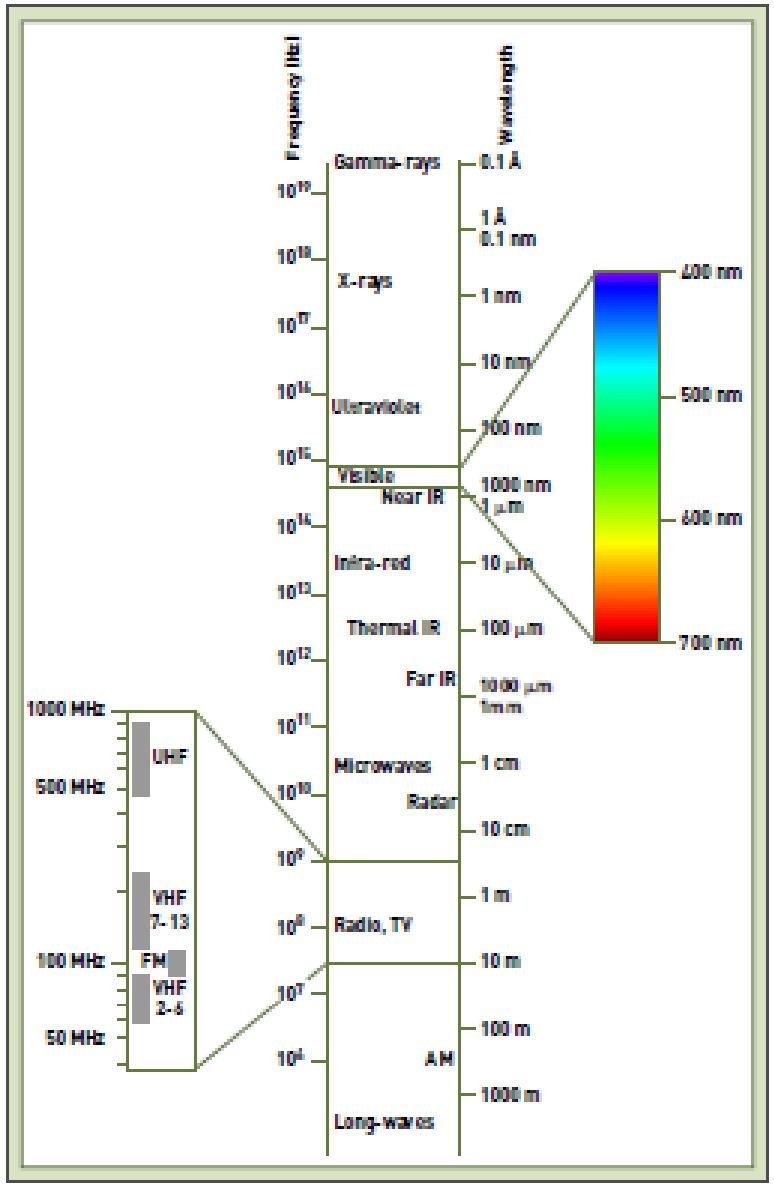

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Frequency ranges used for wireless communications

Technology	Description	Advantages	Disadvantages
Radio frequency range	Operates in the 3 KHz–300 MHz range	Supports mobile users; costs are dropping	Signal is highly susceptible to interception
Microwave—terrestrial and satellite frequency range	High-frequency radio signal (300 MHz–300 GHz) sent through the atmosphere and space (often involves communications satellites)	Avoids cost and effort to lay cable or wires; capable of high-speed transmission	Must have unobstructed line of sight between sender and receiver; signal is highly susceptible to interception
Infrared frequency range	Signals in the 300 GHz–400 THz frequency range	Lets you move, remove, and install devices without expensive wiring	Must have unobstructed line of sight between sender and receiver; transmission is effective only for short distances

Short Range Wireless Options

- **Near field communication (NFC)**
  - **Short-range wireless connectivity technology designed for cell phones and credit cards**
- **Bluetooth**
  - **Wireless communications specification that describes how cell phones, computers, personal digital assistants, etc., can be interconnected**
- **Infrared transmission**
  - **Sends signals at a frequency of 300 GHz and above**

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Medium-Range Wireless Options

- **Wi-Fi:**
  - Wireless telecommunications technology brand owned by the Wi-Fi Alliance
- **Wireless access point:**
  - Consists of a transmitter with an antenna
  - Receives the signal and decodes it
- **Wi-Fi access points:**
  - Have maximum range of about 300 feet outdoors and 100 feet within a dry-walled building

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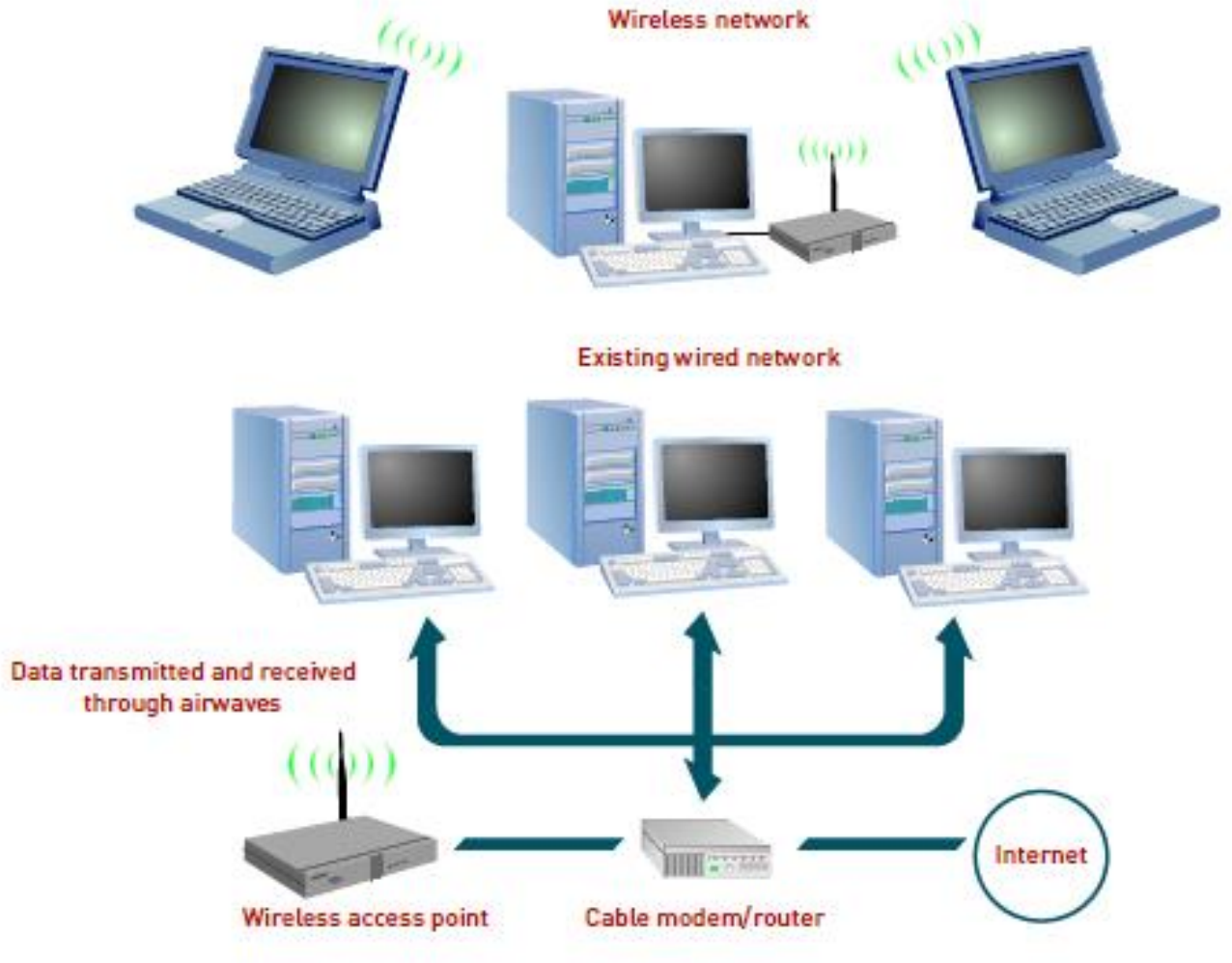
Wi-Fi network



Wide Area Wireless Network Types

- **Microwave transmission:**
  - **High-frequency (300 MHz–300 GHz) signal sent through the air**
- **Common forms of satellite communications:**
  - **Geostationary satellite**
  - **Low-earth orbit (LEO) satellite**
  - **Very small aperture terminal (VSAT)**

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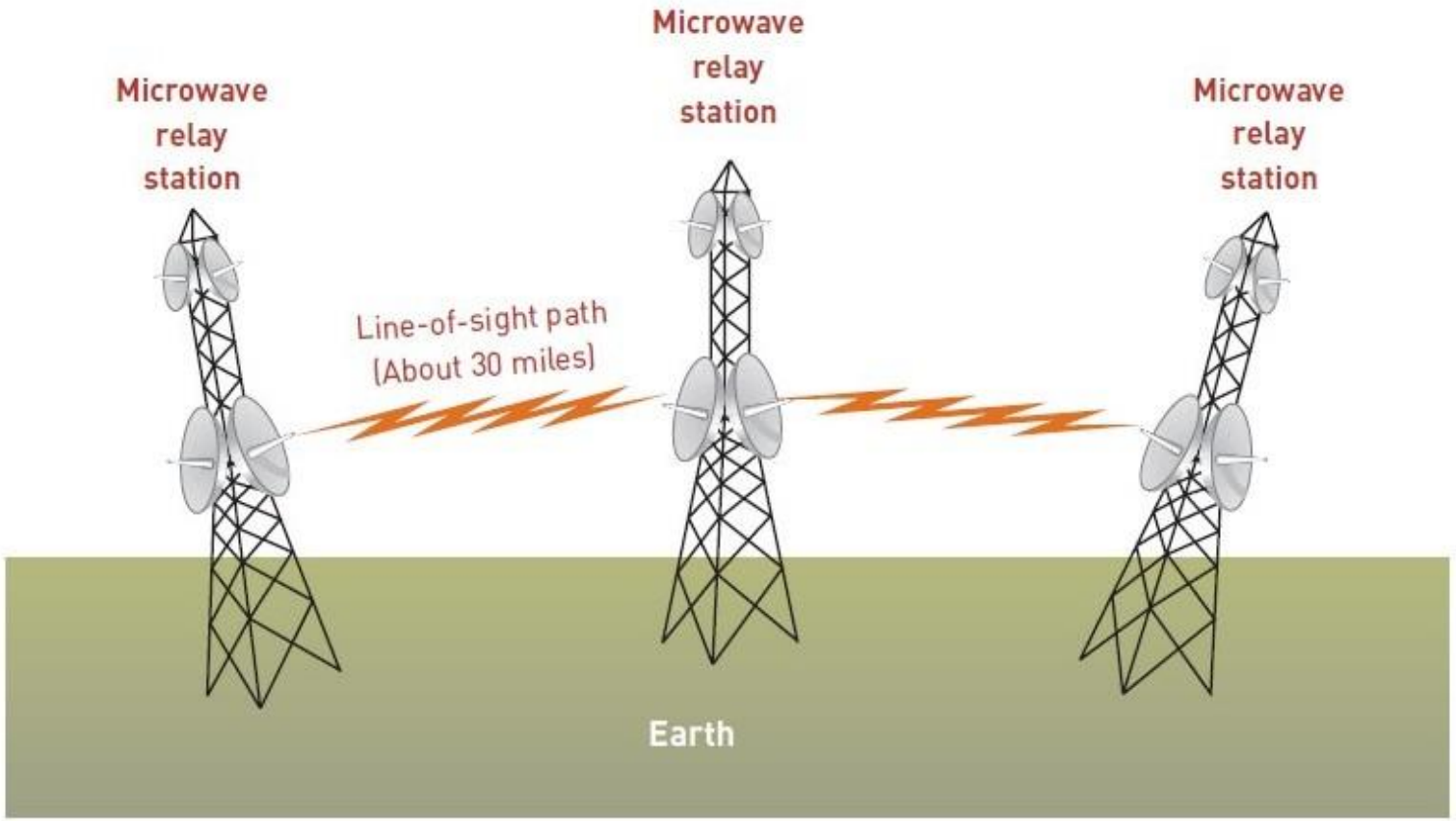
Microwave communications



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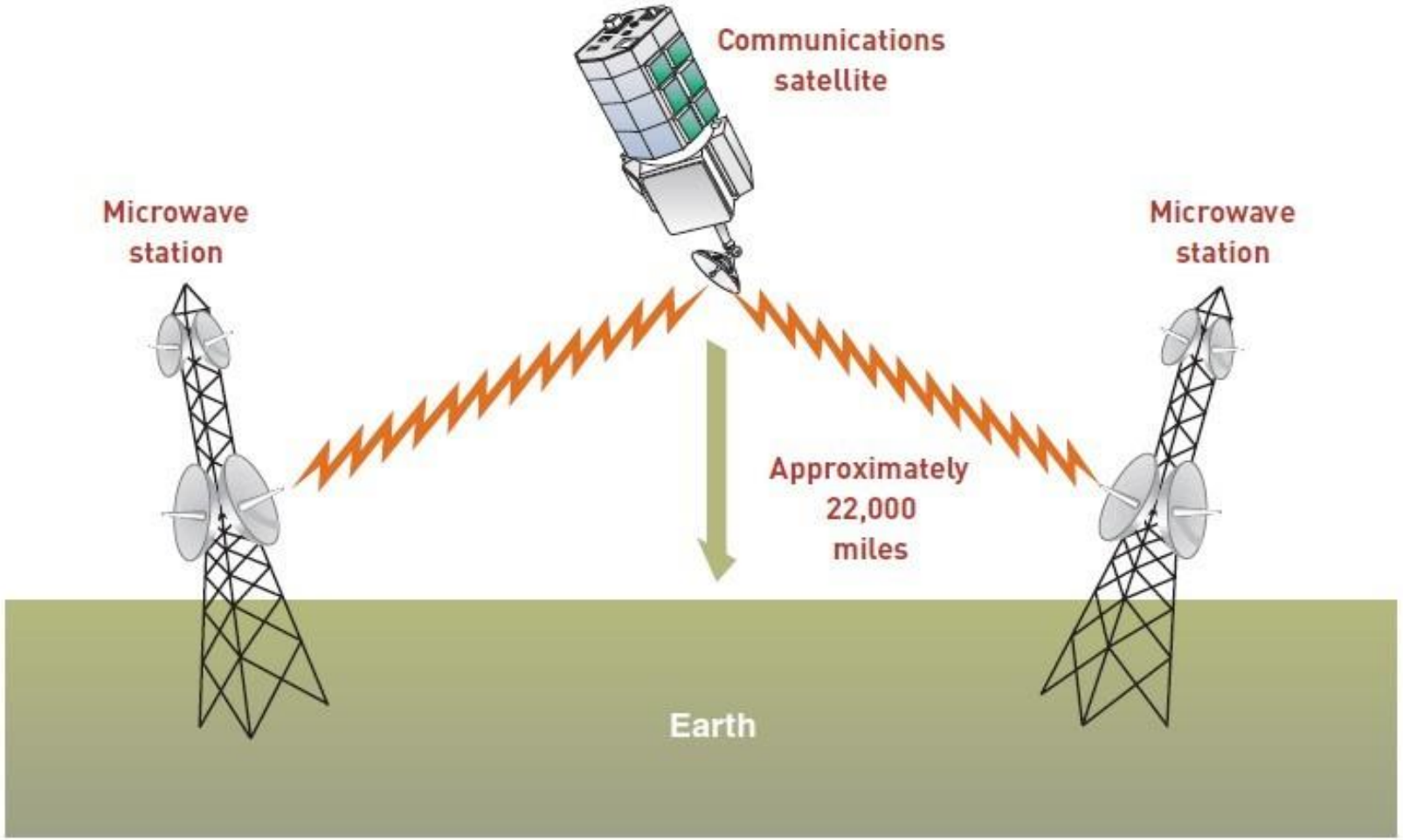
Satellite transmissions



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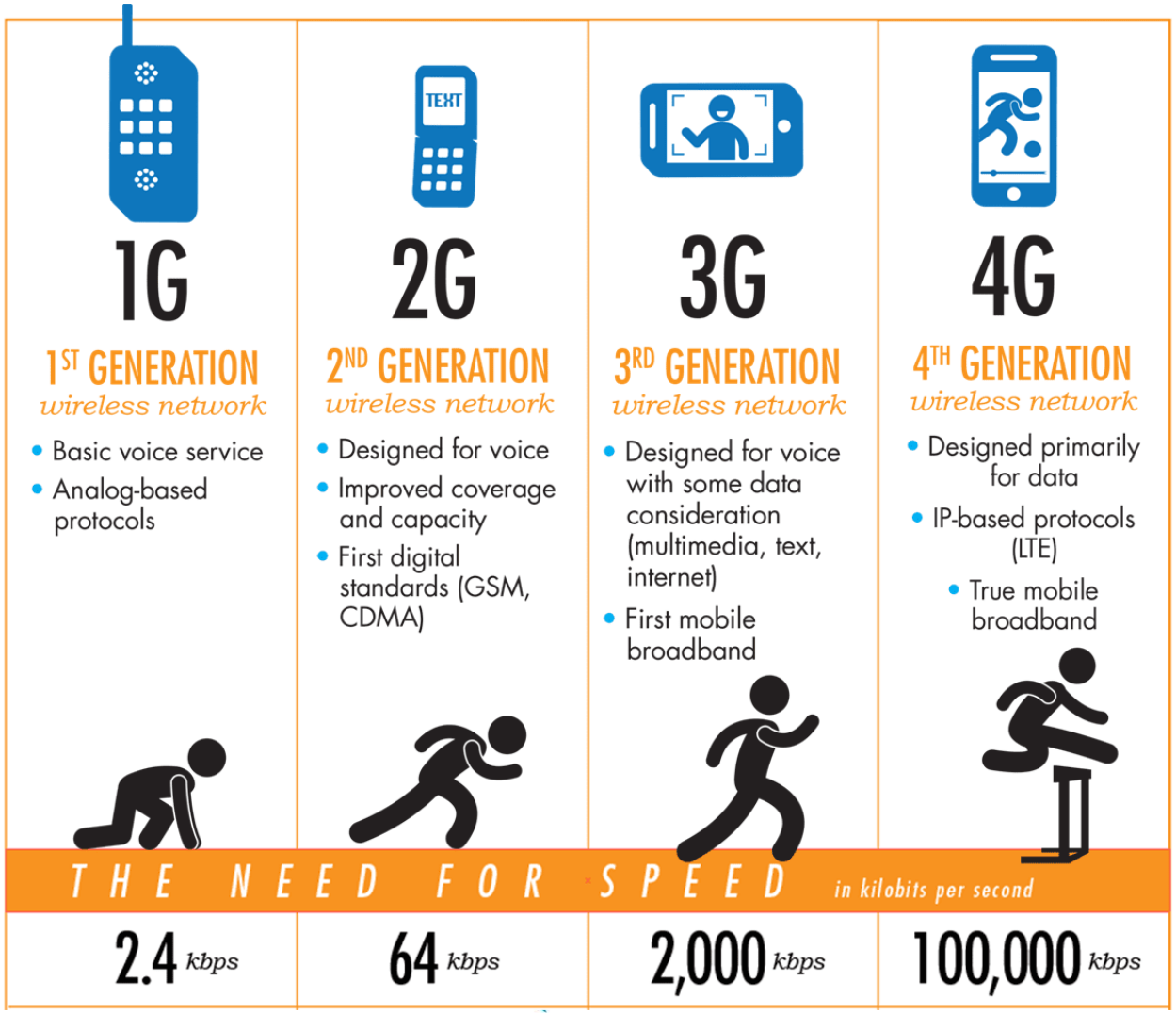
History of nG



History of nG

- **Wireless communications has evolved through four generations of technology and services.**
- **The first generation (1G) of wireless communications standards originated in the 1980s and was based on analog communications.**
- **The second-generation (2G) networks were fully digital, superseding 1G networks in the early 1990s.**
- **With 2G networks**
  - **phone conversations were encrypted**
  - **mobile phone usage was expanded, and short message services (SMS)—or texting—was introduced.**

History of nG

- **3G wireless communications supports wireless voice and broadband speed data communications in a mobile environment at speeds of 2 to 4 Mbps.**
- **Additional capabilities of 3G include mobile video, mobile e-commerce, location-based services, mobile gaming, and the downloading and playing of music**
- **4G wireless communications provides increased data transmission rates in the 20–40 Mbps range**
- **4G broadband mobile wireless delivers more advanced versions of enhanced multimedia, smooth streaming video, universal access, and portability across all types of devices; eventually 4G will also make possible worldwide roaming.**
- **4G can deliver 3 to 20 times the speed of 3G networks for mobile devices such as smartphones, tablets, and laptops.**

History of nG

- **The frequencies used for 4G are in the 700, 800 and 900 MHz, 1800, 2100 and 2600 MHz bands**
- **The 3.5 GHz frequency band (3.4 - 3.8 GHz) is the one that will be used primarily for the 5G mobile network. This is the core 5G band. Of the 400 MHz of spectrum width, 310 MHz was available for 5G and it was assigned exclusively to 5G**

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5G Wireless Communications

- **5G is a term used to identify the next major phase of mobile communications standards beyond 4G.**
- **5G will bring with it**
  - **higher data transmission rates**
  - **lower power consumption**
  - **higher connect reliability with fewer dropped calls**
  - **increased geographic coverage**
  - **lower infrastructure**

- **5G networks should meet the goal of a 50 times faster data rate than the most advanced Wi-Fi networks today, they will be able to stream a two-hourmovie in less than three seconds.**

Worldwide Area Network – WAN

- A wide area network (WAN) is a network that connects large geographic regions
- A WAN might be privately owned or rented and includes public (shared-users) networks.
- WANs usually consist of computer equipment owned by the user, together with data communications equipment and network links provided by various carriers and service providers.
- WANs often provide communications across national borders, which involves national and international laws regulating the electronic flow of data across international boundaries
- Some countries have strict laws limiting the use of networks and databases, making normal business transactions such as payroll processing costly, slow, or extremely difficult.

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WAN & LAN

Local Area Network – LAN

- **A network that connects computer systems and devices within a small area, such as an office, home, or several floors in a building is a local area network (LAN)**
- **Typically, LANs are wired into office buildings and factories**
- **Although LANs often use unshielded twisted-pair copper wire, other media—including fiber-optic cable—is also popular.**
- **LANs can be used to connect personal computers, laptop computers, or powerful**
- **mainframe computers.**

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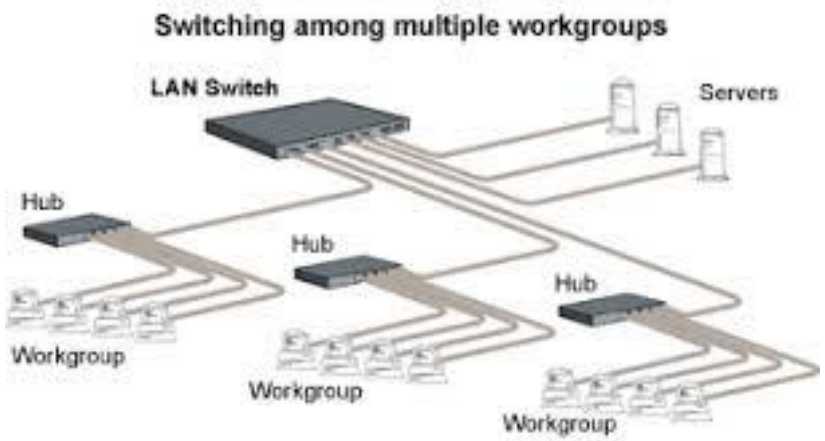
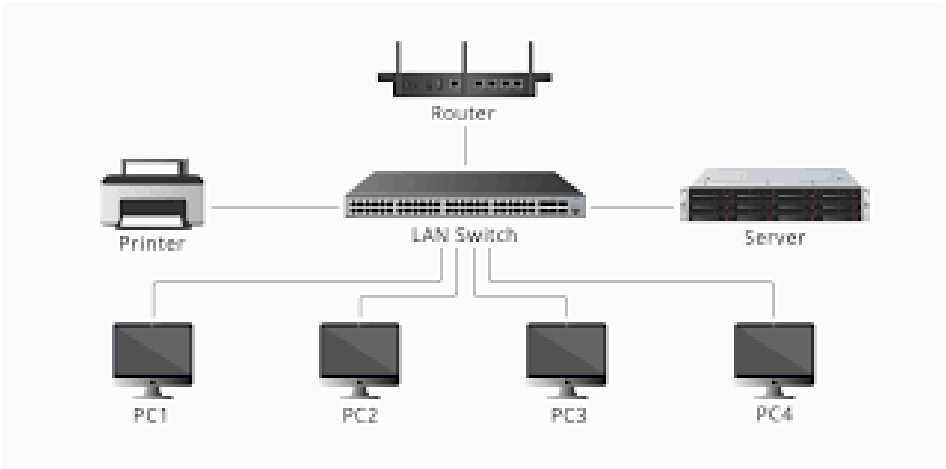
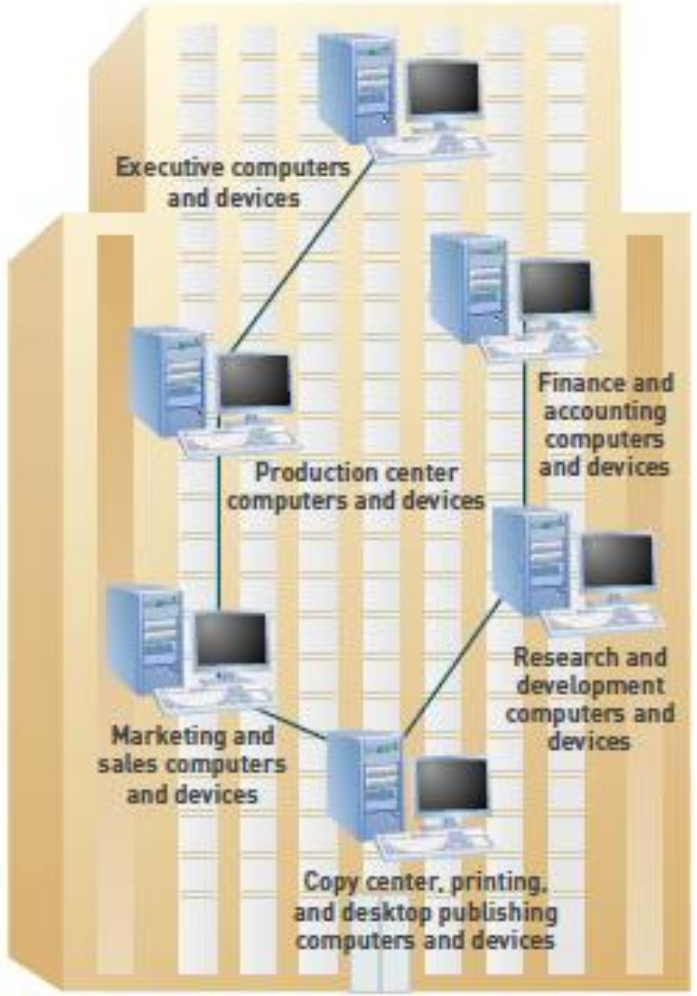




Typical LAN



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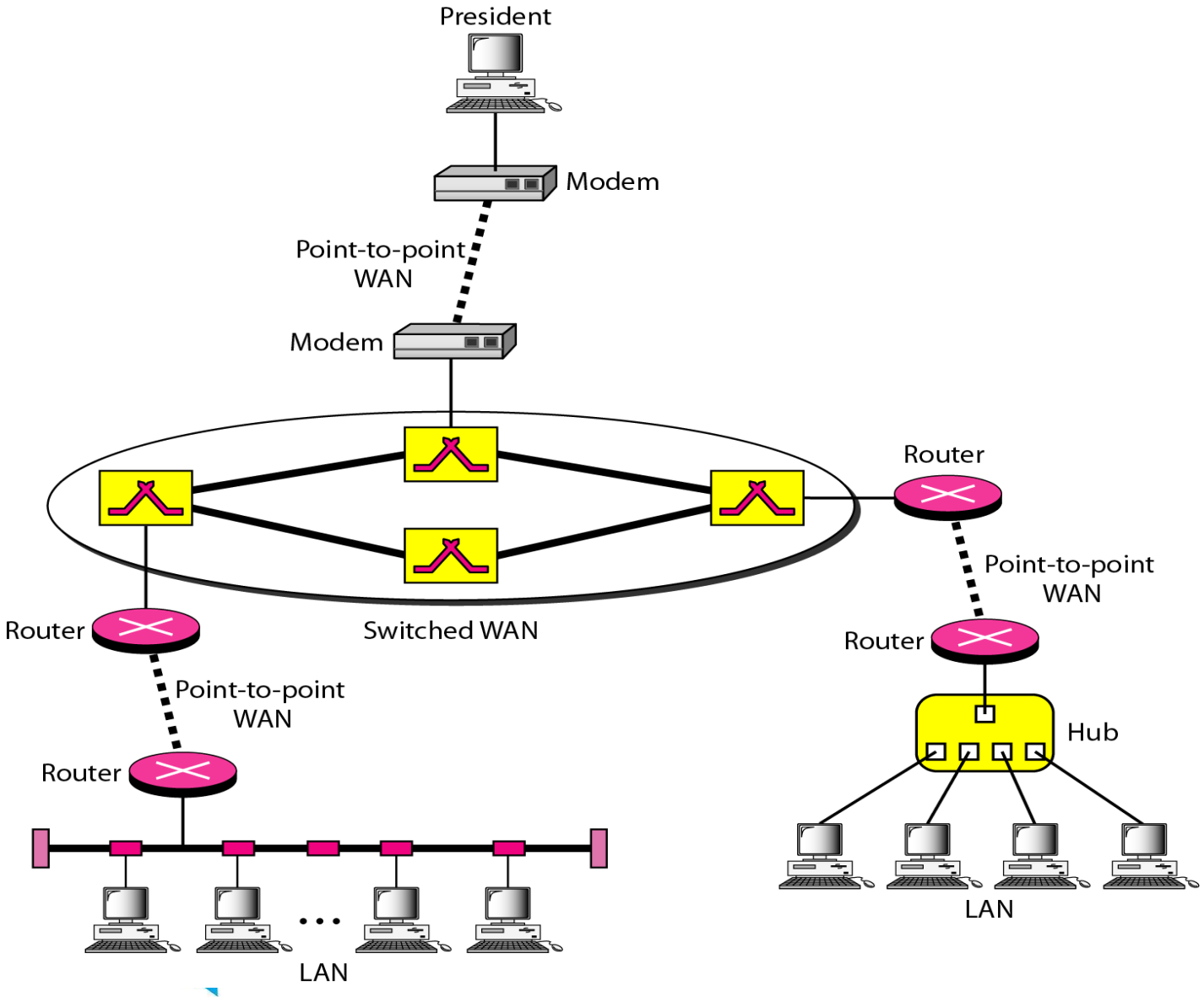
A heterogeneous network made of four WANs and two LANs



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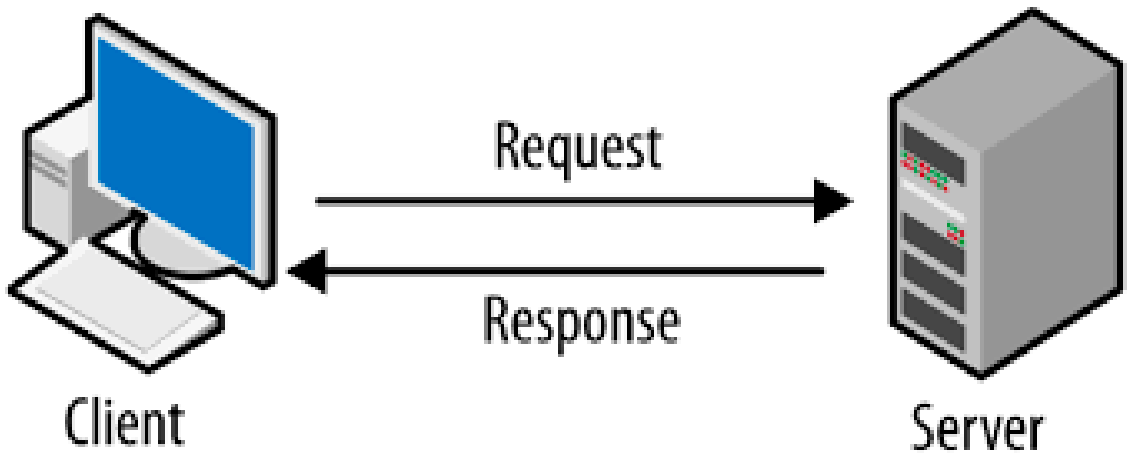
Client/Server Systems

- **A client is any computer (often a user's personal computer) that sends messages requesting services from the servers on the network.**
- **A client can converse with many servers concurrently.**
- **The client or the server might do the actual data processing.**

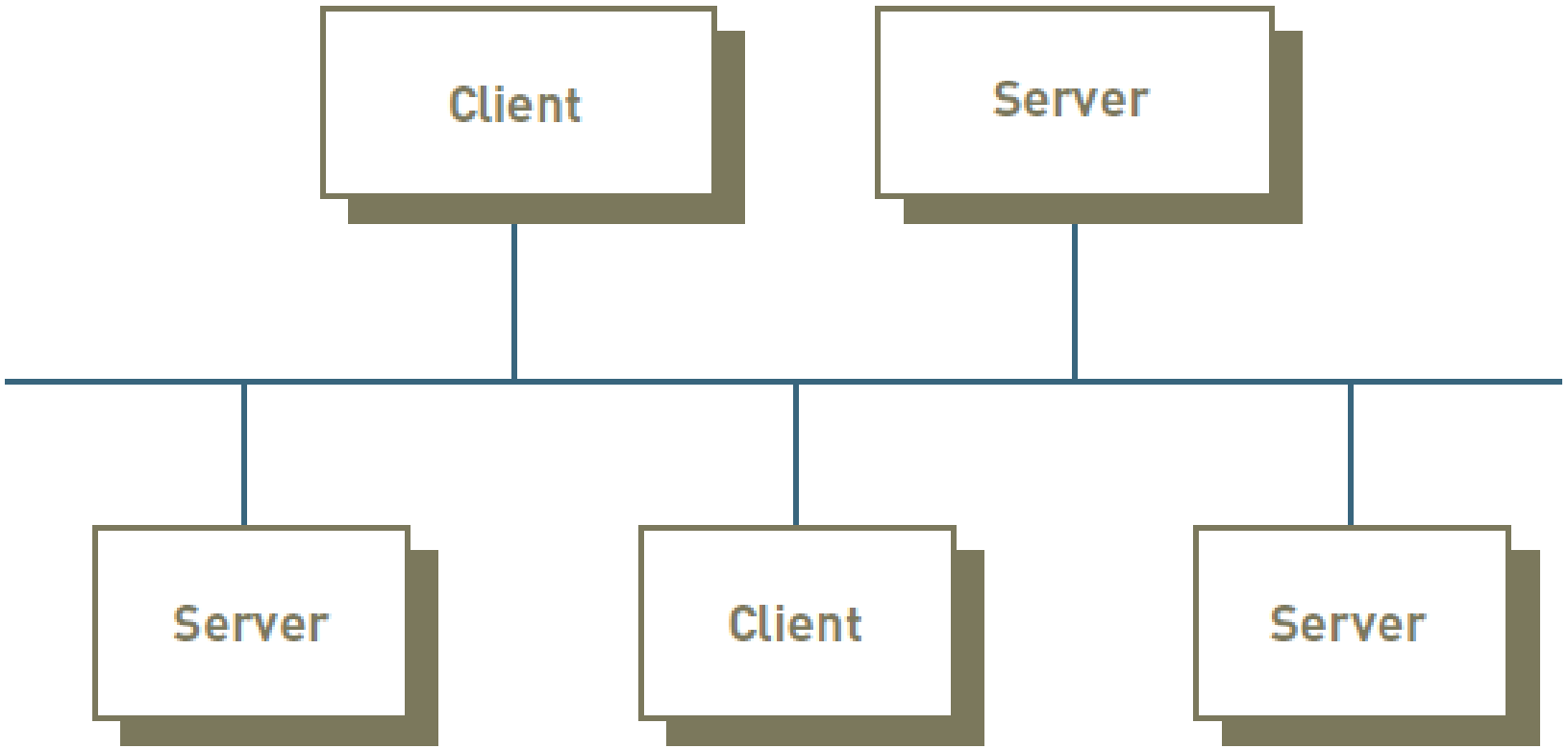


Client/Server Systems

- **In client/server architecture, multiple computer platforms are dedicated to special functions, such as database management, printing, communications, and program execution.**
- **These platforms are called servers.**
  - **Each server is accessible by all computers on the network.**
  - **Servers can be computers of all sizes;**
  - **Servers store both application programs and data files and are equipped with operating system software to manage the activities of the network.**
  - **The server distributes programs and data to the other computers (clients) on them network as they request them.**
  - **An application server holds the programs and data files for a particular application, such as an inventory database.**
  - **A Database server sends only the data that satisfies a specific query, not the entire file**

Principles & Architecture

Client/Server Systems



Principles & Architecture

Telecommunications Hardware

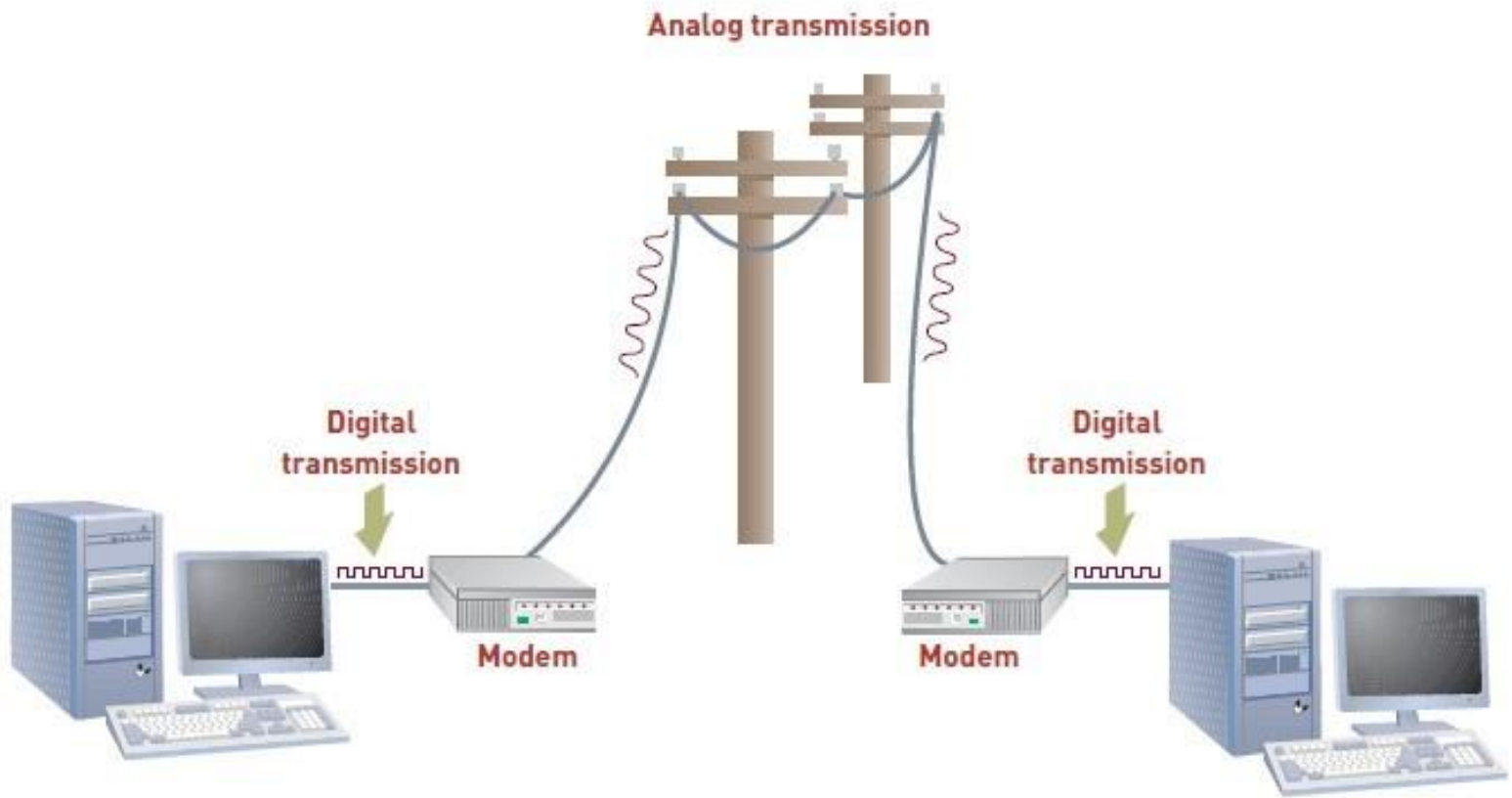
- **Smartphones**
  - Combine the functionality of a mobile phone, camera, Web browser, e-mail tool, MP3 player, and other devices
  - Have their own software operating systems
- **Modems**
  - Modulation/demodulation devices
- **Multiplexers**
  - Combine data from multiple data sources into a single output signal that carries multiple channels

Telecommunications Hardware

- **Switch**
  - uses the physical device address in each incoming message on the network
- **Bridge**
  - connects two LANs together using the same telecommunications protocol
- **Router**
  - forwards data packets across two or more distinct networks toward their destinations
- **Gateway**
  - serves as an entrance to another network

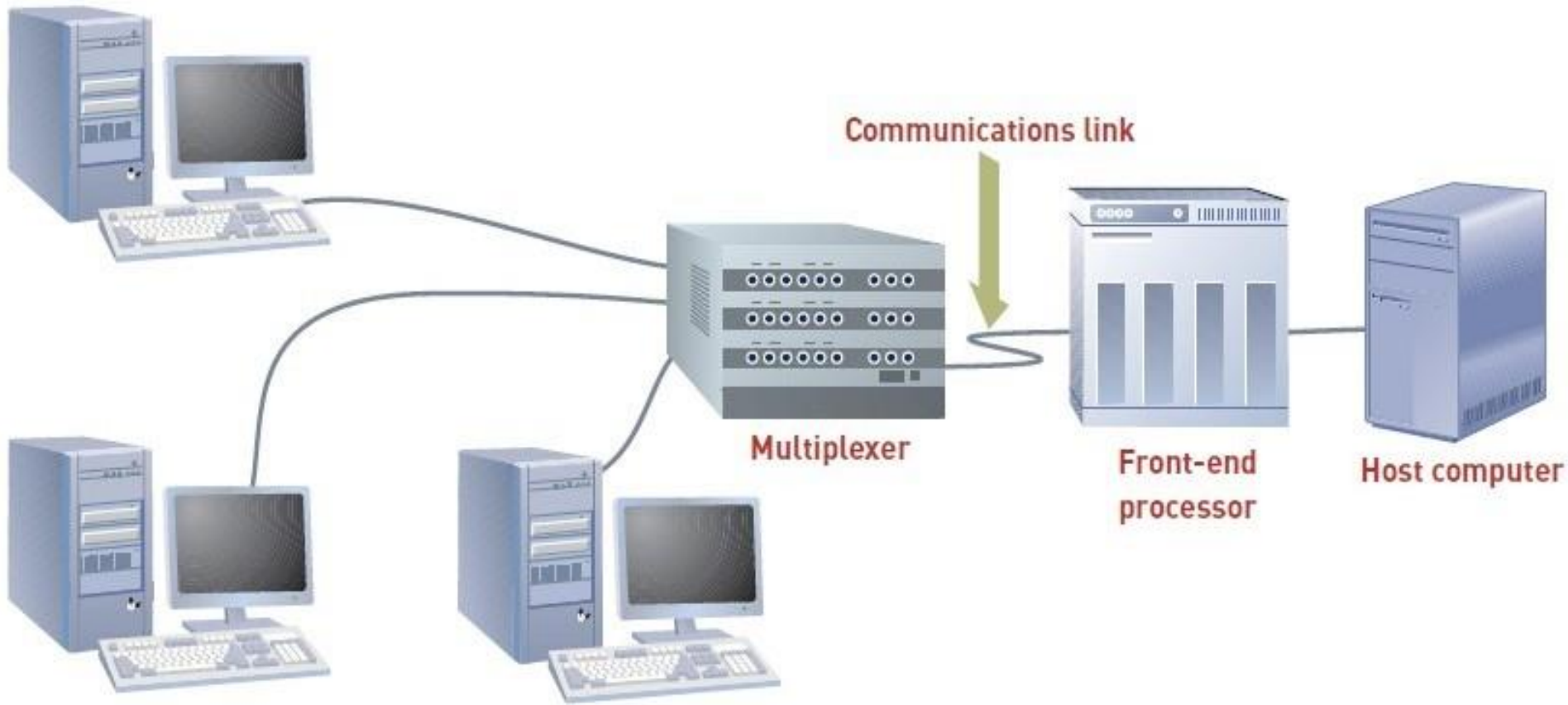
Principles & Architecture

Telecommunications Hardware



Principles & Architecture

Telecommunications Hardware



Communications Software

- **Network operating system (NOS):**
  - **Systems software that controls the computer systems and devices on a network**
- **Network management software:**
  - **Protects software from being copied, modified, or downloaded illegally**
  - **Locates telecommunications errors and potential network problems**

Principles & Architecture

Software Defined Network (SDN)

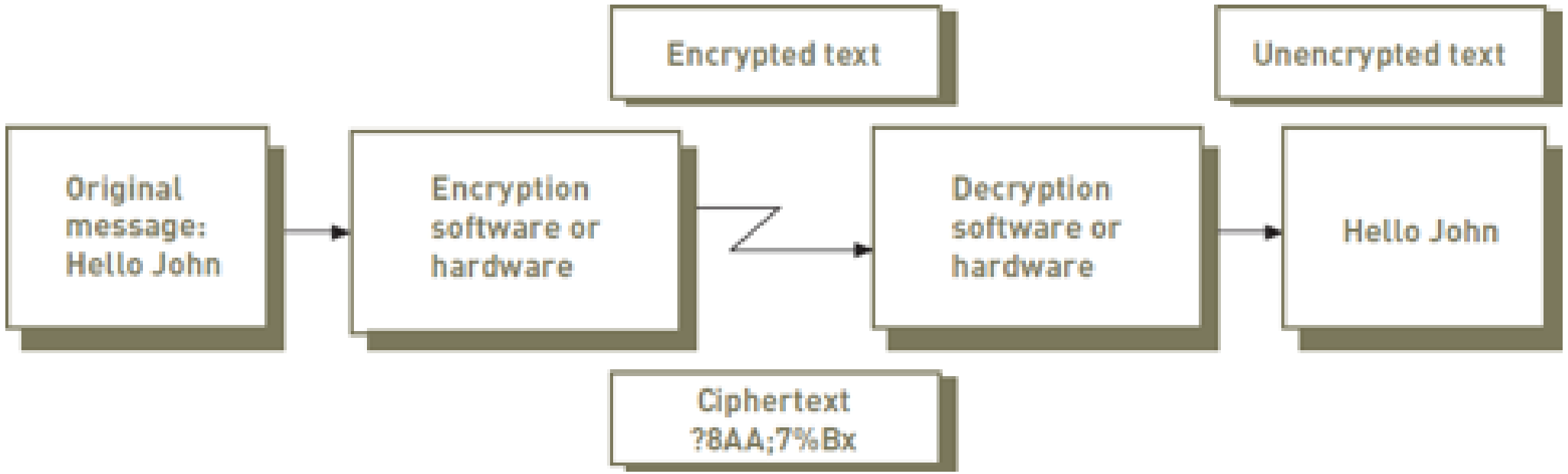
- **Hundreds or thousands of network devices to perform such tasks as routing and switching of data through the network, providing network access and control**
- **Each network device must be configured individually and manually**
- **Labor-intensive and error prone effort, making it difficult to change the network so it can meet the changing needs of the organization.**
- **Software-defined networking (SDN) is an emerging approach to networking that allows network administrators to manage a network via a controller that does not require physical access to all the network devices.**
- **This approach automates tasks such as configuration and policy management and enables the network to dynamically respond to application requirements.**
- **Google is implementing Andromeda, Microsoft and Amazon also employ software-defined networks**

Securing Data Transmission

- **Encryption:**
  - **Converting an original message into a form that can only be understood by the intended receiver**
- **Encryption key:**
  - **Variable value that is applied (using an algorithm) to a set of unencrypted text to produce encrypted text or to decrypt encrypted text**

Principles & Architecture

Securing Data Transmission



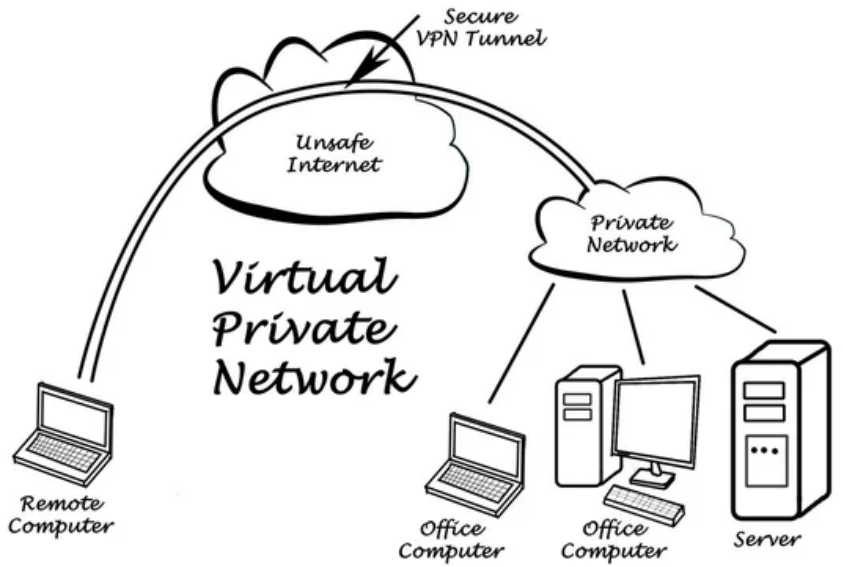
Securing wireless networks

- **Wired equivalent privacy (WEP):**
  - Used encryption based on 64-bit key, which has been upgraded to a 128-bit key
- **Wi-Fi Protected Access (WPA):**
  - Security protocol that offers significantly improved protection over WEP
- **War driving:**
  - Involves hackers driving around with a laptop and antenna trying to detect insecure wireless access points

Principles & Architecture

Virtual Private Network (VPN)

- **Private network that uses a public network (usually the Internet) to connect multiple remote locations**
- **Provides network connectivity over a potentially long physical distance**
- **Supports secure, encrypted connections between a company's private network and remote users**

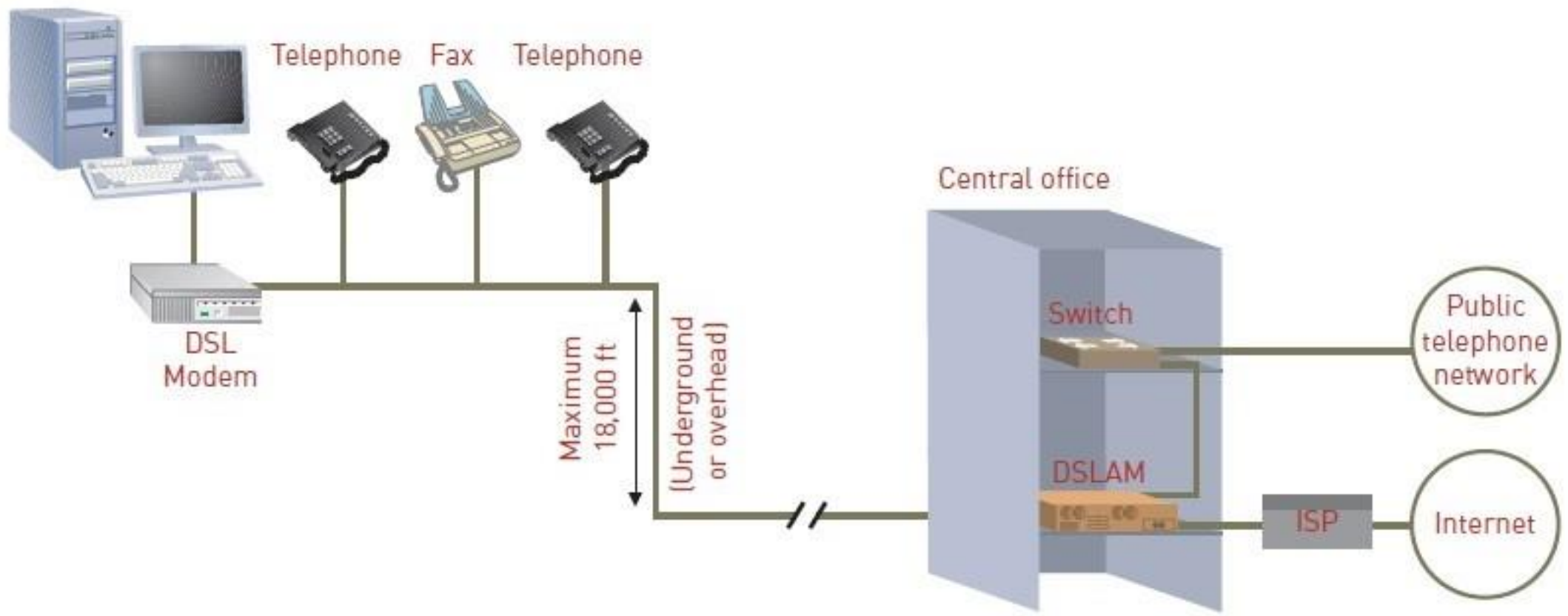


Digital subscriber line (DSL) service

- **Telecommunications service that delivers high- speed Internet access**
- **Asymmetric DSL (ADSL) line:**
  - **Designed to provide download speed that is three to four times faster than upload speed**
- **Symmetric DSL (SDSL):**
  - **Used mainly by small businesses**
  - **Does not allow you to use the phone at the same time**
  - **The speed of receiving and sending data is the same**

Principles & Architecture

Digital subscriber line (DSL) service



Home and Small Business Networks

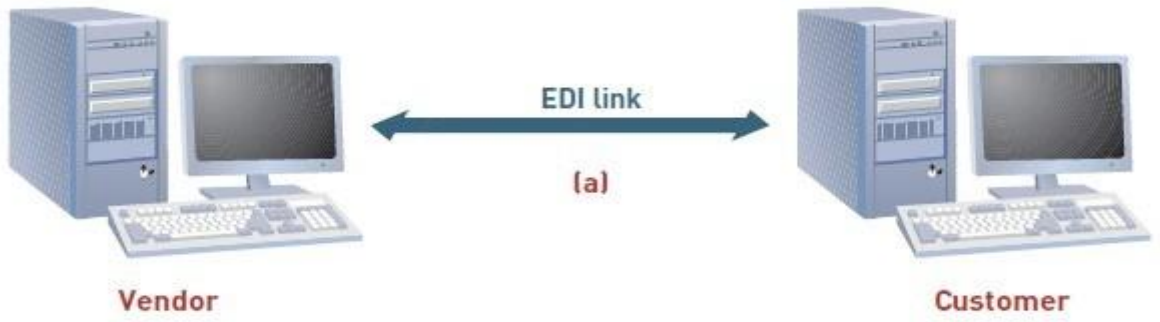
- **DSL modem:**
  - Enables each computer in the network to access the Internet
- **Firewall:**
  - Filters the information coming from the Internet into your network
- **Router:**
  - Encrypts all wireless communications to keep your network secure

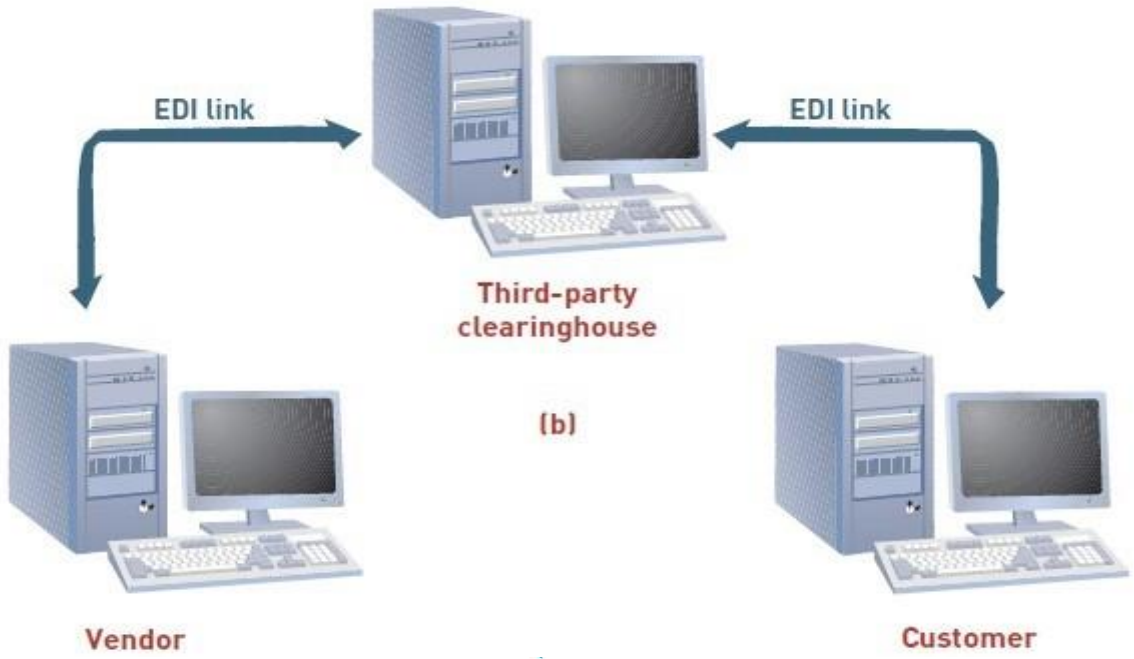
Electronic Data Interchange (EDI)

- **Idea behind EDI:**
  - Connecting corporate computers among organizations
- **EDI:**
  - Can link the computers of customers, manufacturers, and suppliers
  - Eliminates the need for paper documents and substantially cuts down on costly errors

Principles & Architecture

Electronic Data Interchange (EDI)





Electronic funds transfer

- **System of transferring money from one bank account directly to another without any paper money changing hands**
- **Used for:**
  - **Credit transfers, such as payroll payments**
  - **Debit transfers, such as mortgage payments**
- **Benefits:**
  - **Reduced administrative costs**
  - **Increased efficiency**
  - **Simplified bookkeeping and greater security**