

Chapter 1

Networking Fundamentals

What is a Computer Network?

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A **computer network** (or communication network) is a set of interconnected **devices** (both hardware and software components) that are **linked together** to **exchange information and share resources**.

These devices can be connected through **wired connections** (such as Ethernet cables) or **wireless links** (such as Wi-Fi or radio signals).



Advantages of Computer Networks?

Advantages of Computer Networks

Computer networks offers many advantages, including

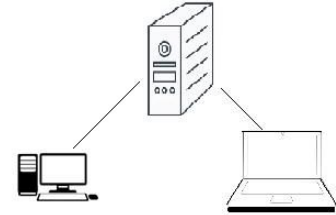
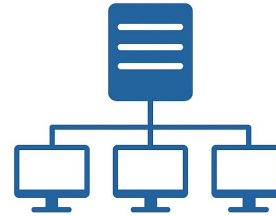
- **Data sharing:** easy exchange of files and information between users.
- **Resource sharing:** access to shared computing power, storage capacity, printers, and other devices.
- **Information access:** ability to search and retrieve data (from the Internet, etc.).
- **Cloud storage/services:** centralized and scalable storage accessible from anywhere.
- **Remote communication:** supports email, video conferencing, and other forms of online collaboration.
- **Scalability and flexibility:** easy to expand or modify as needs evolve.

Types of Computer Networks?

Types of Computer Networks

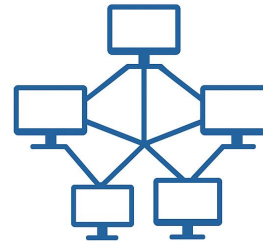
- **Client–Server Network**
(More Secure, distributed)

**Client–Server
Network**
(More Secure)

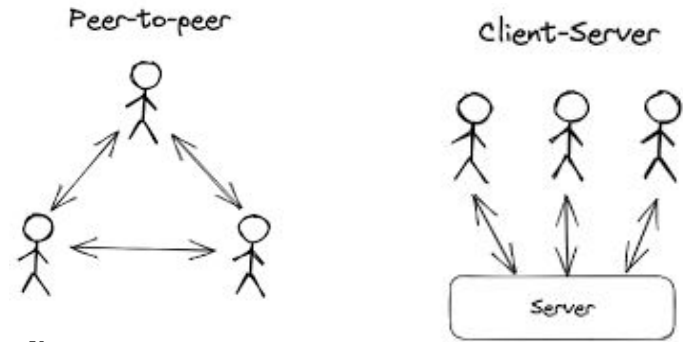


- **Peer-to-Peer (P2P) Network**
(Less Secure, decentralized)

**Peer-to-Peer
(P2P) Network**
(Less Secure)



Types of Computer Networks



- **Client–Server Network (More Secure, distributed)**
 - Centralized model where **clients** request services and **servers** provide them.
 - Offers **better security, centralized control**, and **easier management** of resources and user access.
 - Common in enterprises and organizations.
- **Peer-to-Peer (P2P) Network (Less Secure, decentralized)**
 - Decentralized model where **each device acts as both client and server**.
 - Easier to set up but **harder to secure and manage**.
 - Suitable for **small or temporary networks** (e.g., file sharing among a few devices).

Problem Statement

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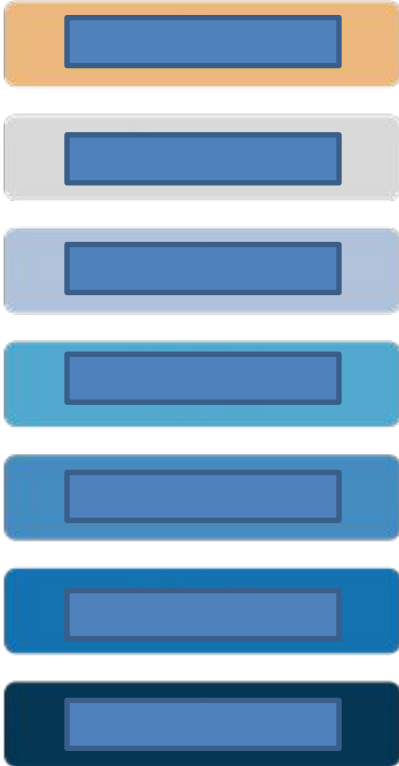
- To create a computer network and connect different machines/devices to it, it is essential to **consider the differences between these machines**.
- The machines to be connected to a network are often **built by different manufacturers and use different hardware and software/operating systems**.
- This diversity creates challenges in ensuring **interoperability, communication compatibility, and network reliability**.

Problem Statement

How can we make a network work properly so that all nodes can communicate with each other (regardless of their differences in hardware or software)?

Solution

OSI (Open System Interconnection) Model



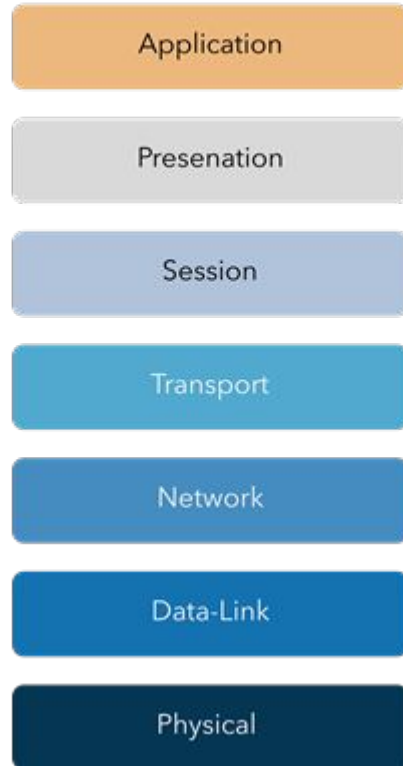
Each **layer** communicates only with:

- its **adjacent layers** (either above or below)
- the **corresponding layer** on another system

Questions

1. **Name these layers (OSI model layers)**
2. **Which one is Layer 1?**
3. **What do we call data at each layer?**

OSI (Open System Interconnection) Model



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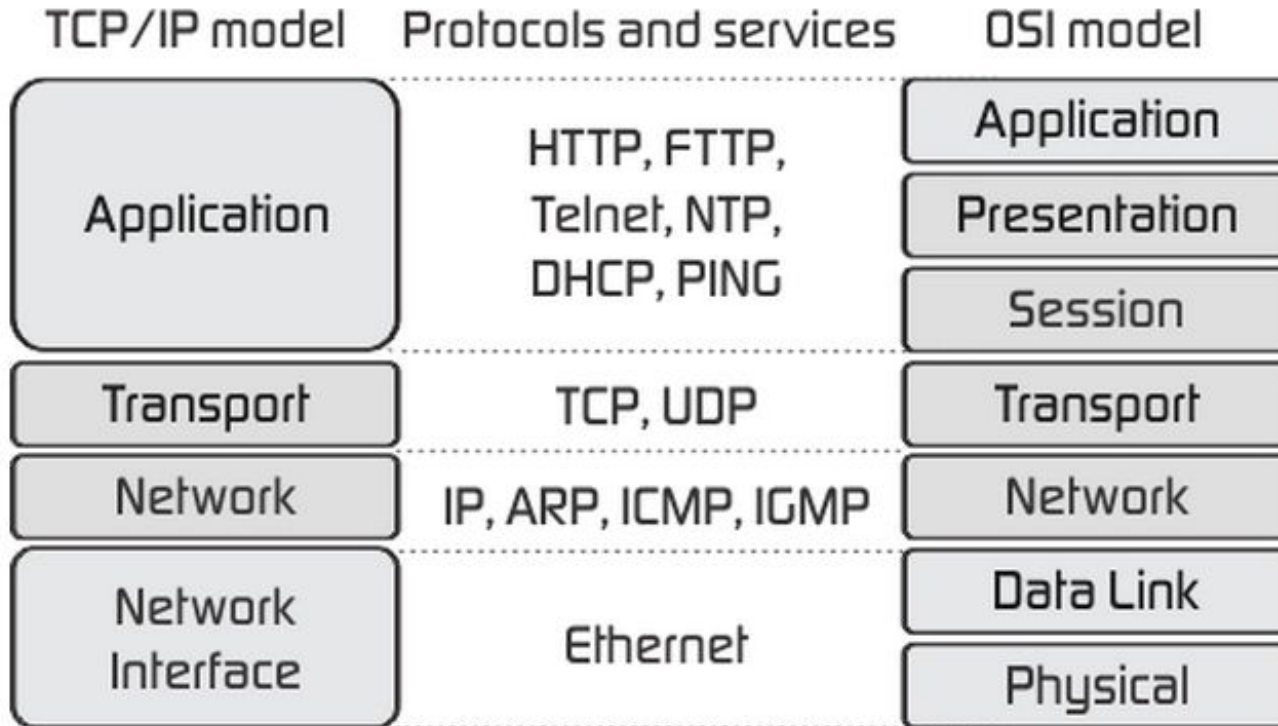
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OSI vs TCP/IP

OSI vs. TCP/IP



OSI Model Layers

OSI Model Layers—What Interests Us the Most?

In this course, we focus on the key networking concepts that are essential for **security engineering** and **system configuration**

- **Protocols:** such as the **TCP 3-way handshake**, which ensures reliable communication between hosts.
- **IP addressing:** including **address classes**, **ranges**, and **subnet masks**, fundamental for **firewall rules** and **network configuration**.
- **Services and Ports:** understanding which ports are used by different services is crucial for **monitoring**, **filtering**, and **defense**.

OSI Model Layers

1. Physical Layer

1. Physical Layer

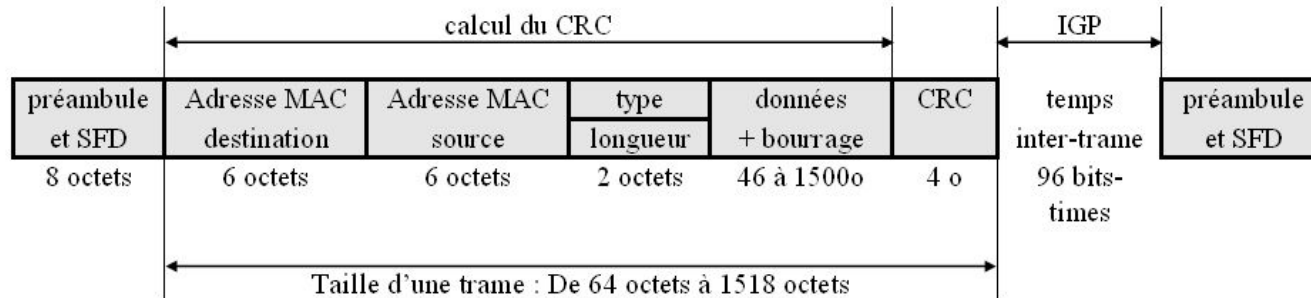
- The lowest (first) layer of the OSI model.
- Responsible for transmitting data **bits** from the sender to the receiver.
- The information traveling through the transmission medium can be **discrete** (e.g., text, image) or **continuous** (e.g., sound).
- To transmit a continuous signal (also called an analog signal), it must undergo three phases known as signal normalization:
 - **Sampling phase:** divides the signal into regular time intervals.
 - **Quantization phase:** establishes a correspondence between certain values (called quantization levels) and the amplitude of a sample.
 - **Encoding phase:** enables the transmission of binary data.
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- Discrete information requires only the encoding phase.

OSI Model Layers

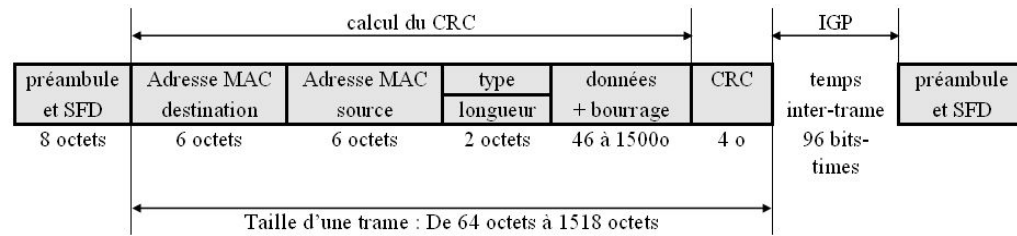
2. Data link Layer

2. Data Link Layer

- The second layer of the OSI model manages the **physical addresses** of machines (**MAC addresses**).
- In addition, it is responsible for error detection, correction, and retransmission.
- At this layer, the transmitted data are called **frames**.



2. Data Link Layer



- The different fields of a frame and their meanings are as follows:
 - **Destination MAC address:** MAC address of the destination machine.
 - **Source MAC address:** MAC address of the source machine (the one sending the frame).
 - **Data:** information coming from Layer 3, in the case of Ethernet.
 - **Padding (PAD):** padding bytes inserted if the length of the data is insufficient (less than 46 bytes).
 - **CRC (FCS):** field used for error checking.
 - Cyclic Redundancy Check and Frame Check Sequence
- **MAC Address**
Its length is 6 bytes, represented in hexadecimal.

Example: 00:1B:44:11:3A:B7

OSI Model Layers

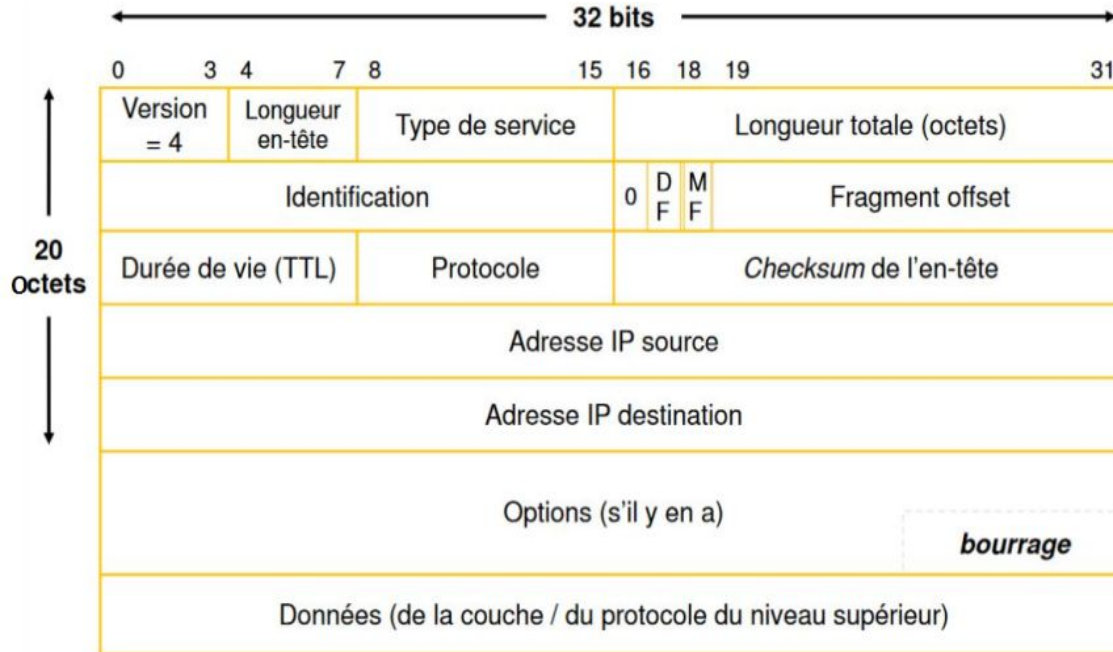
3. Network Layer

3. Network Layer

- The third layer of the OSI model.
- Responsible for determining how packets are routed from point A to point B.
- The information transmitted at this stage is called a **packet**, and the addresses used are called **logical addresses (IP addresses)**.

3. Network Layer

- The different fields of a frame and their meanings?



3. Network Layer

- An **IP address** is unique within a computer network and has a length of **4 bytes (32 bits)**.

Example: **XXX.XXX.XXX.XXX**, where each X is a digit.

- Each part of the IP address ranges from 0 to 255.
Thus, **192.168.14.10** or **122.32.1.0** are examples of **IPv4 addresses**. The Net 1995
- An IP address consists of two parts:
 - one identifying the network (called **netID**) and
 - the other identifying the host (called **hostID**).



3. Network Layer

IP Address Classification

- There are mainly two classes of IP addresses
 - **Private IP addresses** are used only within a local network (LAN) and cannot be routed on the Internet. Below are the private IP address ranges:
 - **10.0.0.0/8**, i.e., from **10.0.0.0** to **10.255.255.255**
 - **172.16.0.0/12**, i.e., from **172.16.0.0** to **172.31.255.255**
 - **192.168.0.0/16**, i.e., from **192.168.0.0** to **192.168.255.255**
 - **Public IP addresses** are routable on the Internet and are assigned, for example, by an Internet Service Provider (ISP).

3. Network Layer

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3. Network Layer

The hotel's
free WiFi is
really fast

Your IP
address
starts with
172.16.42.x



3. Network Layer

Specific IP Addresses

- **Subnet Mask (Netmask)**

- The subnet mask is used to separate the network portion from the host portion of an IP address.
- It allows checking whether two machines belong to the same network or not.
- If they do not, a router must be used to route information from one network to another.

Example

- 192.168.30.0 : 255.255.255.0 → network 192.168.30.0/24
- 192.168.65.0 : 255.255.255.0 → network 192.168.65.0/24

3. Network Layer

Specific IP Addresses

- **Loopback Address**

This is a self-referencing address used for testing, e.g., **127.0.0.1**.

- **Broadcast Address**

In this case, all the bits in the host portion are set to 1. **Example: 192.168.65.255**

- **Network Address**

All the bits in the host portion are set to 0. **Example: 192.168.65.0**

- **0.0.0.0**: When all bits of the IP address are set to 0, it indicates the **default route** or is used by a machine during boot to discover its own IP address.
- **255.255.255.255**: When all bits of the IP address are set to 1, it represents **all hosts on the local network** (broadcast on the local network).

OSI Model Layers

4. Transport Layer

4. Transport Layer

- The fourth layer of the OSI model, its main role is to ensure **logical communication between applications**.
- It is also responsible for the **fragmentation** of data from the upper layers (called SDU, Service Data Units) into several smaller units called PDU (Protocol Data Units), which are then sent to the network layer.
- Once these PDUs are received by the destination, the transport layer reads their headers and **reassembles** them into a single data unit.

4. Transport Layer

The main services provided by the transport layer include

- **Connection-oriented communication (TCP):** ensures that a logical connection is established before data transmission.
- **Order of delivery:** the transport layer manages sequencing and ensures that data is received in the same order as it was sent (using sequence numbers).
- **Reliability:** ensures that the receiver has successfully received all segments; missing or corrupted segments are retransmitted (TCP).
- **Multiplexing/Demultiplexing:** allows multiple applications to send and receive data simultaneously over the same network connection.

4. Transport Layer

Port Number

- The port number in the transport layer is used to **identify an application**.
- It is a 16-bit integer (2 bytes) and can have a value ranging from **0 to 65,535**.
- Each type of application is associated with a specific port number.

There are three categories of ports:

- **Well-known ports (0–1023)**: reserved for common and standardized services (e.g., web, file sharing, email, etc.).
- **Registered ports (1024–49151)**: assigned for use by proprietary or user applications.
- **Dynamic or private ports (49152–65535)**: available for temporary or custom use by applications.

4. Transport Layer

TCP and UDP Protocols

- The transport layer uses two essential protocols: **TCP** and **UDP**.
- **UDP (User Datagram Protocol)**
 - UDP is a **connectionless transport protocol** that does not guarantee that data will reach its destination.
 - It does **not provide retransmission mechanisms** in case of packet loss, making it faster but less reliable.
- **TCP (Transmission Control Protocol)**
 - TCP is a **connection-oriented transport protocol** that enables **two-way communication** between two endpoints using the **3-Way Handshake** procedure.
 - It is a **reliable protocol**, meaning it ensures that all transmitted data successfully reach their destination.
 - If transmission errors occur, TCP automatically **retransmits lost data**.

4. Transport Layer

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OSI Model Layers

5. Session Layer

5. Session Layer

The session layer allows users on different machines to **establish sessions**.

A session provides various services, including

- **Dialog management:** keeps track of whose turn it is to transmit.
- **Token management:** prevents two participants from attempting the same critical operation simultaneously.
- **Synchronization:** manages **recovery points** so that long transmissions can resume from where they stopped after an interruption.

OSI Model Layers

6. Presentation Layer

6. Presentation Layer

- Unlike the lower layers, which mainly deal with the transmission of bits, the presentation layer focuses on the **syntax and semantics** of the transmitted information.
- To enable communication between computers using **different data representations**, the exchanged data structures must be defined in an **abstract way** and linked to a **standard encoding system** used during transmission.
- This layer is responsible for **managing these data structures** and allows the **definition and exchange of higher-level structures** (for example, banking records).

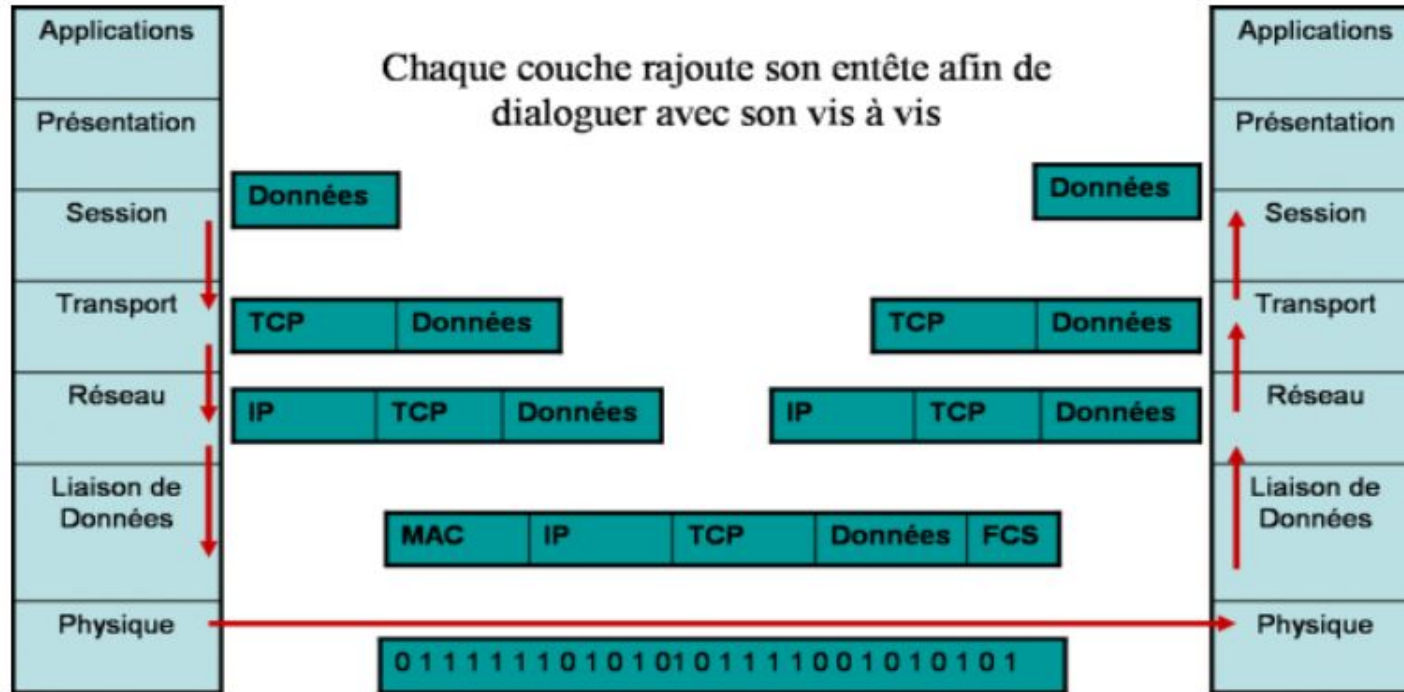
OSI Model Layers

7. Application Layer

7. Application Layer

- The application layer contains a variety of **protocols useful to end users**.
- **HTTP (HyperText Transfer Protocol)**, which forms the foundation of the **World Wide Web**, is one of the most widely used application protocols.
- When a browser needs to display a web page, it sends the page name to the server using the **HTTP/HTTPS** protocol.
- The server then responds by sending back the requested web page.
- Other application protocols are used for **file transfer, email communication**, and various other services.

Principle of Encapsulation / De-encapsulation



Quizz Time

Quiz 1 - IP Addressing

What is the main purpose of a subnet mask?

- A. To identify the network and host portions of an IP address
- B. To encrypt IP packets
- C. To assign MAC addresses
- D. To route data between networks

Quiz 2 - TCP Protocol

What are the three steps of the TCP three-way handshake?

- A. SYN → ACK → SYN-ACK
- B. SYN → SYN-ACK → ACK
- C. ACK → SYN → FIN
- D. FIN → ACK → SYN

Quiz 3 - OSI Model: Data Units

Each layer of the OSI model uses a specific type of data unit (PDU).

Match each data unit to the correct OSI layer.

Option

Layers

A.

B.

C. Packet

D.

Layer 1

F. Data

Layer

Layer

Layer

Layer

5 Bit

4 Frame

3

2 Session

Datagram

Quiz 4 – IP Addressing

Which of the following is a *private IP address*?

- A. 8.8.8.8
- B. 172.16.5.10
- C. 200.10.5.6
- D. 150.20.0.2

Quiz 5 – Common ports

Match the following **ports** with the correct **services**.

- 21 → ? NAS SAN OWASP
- 22 → ?
- 23 → ?
- 25 → ?
- 80 → ?
- 443 → ?
- 53 → ?
- 3389 → ?

Quiz 6 – Subnetting Concept

How many hosts can a /24 network support?

- A. 254
- B. 256
- C. 512
- D. 128

Quiz 7 – Protocols in Security

What is the purpose of **ARP** (Address Resolution Protocol)?

- A. Converts IP addresses to MAC addresses
- B. Converts MAC addresses to IP addresses
- C. Routes packets between networks
- D. Encrypts data packets

Quiz 8 – Protocols & Security Risks

Some network protocols are inherently insecure if used without encryption.
Match the following **protocols** to their **secure or insecure equivalents**.

Insecure Protocol	Secure Alternative
FTP	?
Telnet	?
HTTP	?
POP3	?
LDAP	?

Quiz 9 – IP Addressing and Subnetting

For each of the following networks:

- 172.16.0.0/16
- 192.168.20.3/24
- 192.168.67.34/19

Indicate the following:

- subnet mask
- network address
- first usable host address
- last usable host address
- broadcast address



Q & A

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<https://github.com/amine-merzoug>