OSI model

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OSI Model (Open Systems Interconnection Model) is a conceptual framework used to understand and standardize how data travels across a network

7 layers, each with specific roles.

Layer	Name	Function	Examples
7	**Application**	User interface, network services	HTTP, FTP, SMTP, DNS, Blynk
6	**Presentation**	Data translation, encryption, compression	SSL/TLS, JPEG, ASCII
5	**Session**	Establish/manage communication sessions	NetBIOS, RPC
4	**Transport**	End-to-end delivery, error recovery	TCP, UDP
3	**Network**	Routing and addressing (logical)	IP, ICMP, IPsec
2	**Data Link**	Physical addressing, error detection (frame level)	MAC, Ethernet, PPP
1	**Physical**	Raw bit transmission through physical medium	Cables, Wi-Fi, Bluetooth

Application Layer 7

The Application Layer is the topmost layer (Layer 7) of the OSI model. It provides theinterface between the user or application and the network

- Acts as a bridge between the user software (like browsers, email apps, or IoT apps) and the network.

- Initiates communication and receives data from the lower layers.

Function	Description
User Interface	Allows end-users to interact with the application (e.g., browser, app)
Network Services	Supports services like file transfer, email, web access
Data Formatting	Converts user data into a format that can be transmitted
Authentication & Authorization	Verifies user identity (e.g., login, API keys)
Data Integrity	Ensures the data received is correct and unmodified

- Does not perform the actual transmission; that is handled by lower layers.
- It is closest to the user.
- Only layer that directly interacts with user applications.
- Each protocol here is specific to an application's need.

Examples of Application Layer Protocols

- HTTP (Hypertext Transfer Protocol)
  - Used for: Accessing websites via browsers (Chrome, Firefox).
  - Example: Loading a webpage like `www.google.com`.
- HTTPS (Secure HTTP)
  - Used for: Secure web communication using SSL/TLS.
  - Example: Online banking, secure shopping.
- FTP (File Transfer Protocol)
  - Used for: Uploading or downloading files over a network.
  - Example: Transferring website files to a server.
- SMTP (Simple Mail Transfer Protocol)
  - Used for: Sending emails.

    - Example: Sending an email from Gmail to Yahoo.
- POP3 (Post Office Protocol v3)
    - Used for: Receiving emails by downloading them.
    - Example: Accessing your inbox in Outlook.
- IMAP (Internet Message Access Protocol)
    - Used for: Reading emails without downloading them.
    - Example: Gmail syncing emails across devices.
- DNS (Domain Name System)
    - Used for: Translating domain names into IP addresses.
    - Example: Resolving `www.facebook.com` to its IP.

Presentation Layer 6

The Presentation Layer is the 6th layer of the OSI model. It acts as a translator between the application layer and the lower layers by converting data formats, encrypting, and compressing data.

- Ensures that the data sent by the application layer of one system can be understood by the application layer of another.
- Responsible for formatting, encoding, encryption, and compression of data.

Function	Description
Translation	Converts data between different formats (e.g., EBCDIC to ASCII).
Encryption	Encrypts data before sending (for confidentiality).
Decryption	Decrypts data after receiving.
Compression	Reduces the size of data to improve speed.
Data Serialization	Converts data into a transmittable format (e.g., JSON, XML, protobuf).

Often integrated into application protocols or libraries (not usually separate in code).

- Also known as the syntax layer.
- Makes sure data structure and format are compatible between sender and receiver.

Real-World Examples – Presentation Layer

1. **Opening a JPEG or PNG image in a browser**
   - The presentation layer **decodes the image format** so it can be displayed.
2. **Watching a YouTube video (MP4 format)**
   - Video and audio data is **decompressed** before playback.
3. **Sending a secure message via WhatsApp or Gmail**
   - Data is **encrypted** before sending and **decrypted** on the receiver's side using SSL/TLS.
4. **Accessing an API that sends/receives JSON or XML**
   - Converts structured data like **JSON/XML into machine-readable format**.
5. **Opening a PDF or DOC file from an email**
   - Data is **translated** into readable document format.
6. **Data transfer between systems using different encoding formats (ASCII ↔ Unicode)**
   - Converts between character sets to maintain data compatibility.
7. **Compressing a file using ZIP before sending**
   - Data is **compressed** to reduce size and speed up transmission.

Session Layer 5

The Session Layer is the 5th layer in the OSI model. It is responsible for establishing, managing, and terminating sessions between two communicating devices or applications.

- Creates a "session" (or conversation) between two systems.
- Manages the start, ongoing communication, and end of a connection.
- Ensures synchronized and organized data exchange between systems.

Function	Description
Session Establishment	Sets up a communication link between devices (like login handshake).
Session Maintenance	Maintains the connection; handles dialog control (who talks when).
Session Termination	Gracefully ends a session when communication is done.
Synchronization	Inserts checkpoints (sync points) for large data transfers.
Dialog Control	Manages full-duplex or half-duplex communication.

- Ensures that **long or complex conversations** (like file transfer or streaming) remain **coherent and synchronized**.
- Allows **resuming from failure points** if interruptions happen.

Real-World Examples – Session Layer

1. Logging into a remote Linux server using SSH
    - A session is established between client and server after authentication.
2. Video call on Zoom, Google Meet, or Microsoft Teams
    - A session maintains the audio/video stream during the call duration.
3. Playing an online multiplayer game (e.g., PUBG, Free Fire)
    - A session keeps track of player states and ensures synchronized interaction.
4. WhatsApp Web or Telegram Web
    - A session is created between your browser and your phone to sync messages.
5. Downloading a large file with resume support (e.g., using IDM or wget)

- The session remembers where it left off and resumes from that checkpoint.

6. Using Remote Desktop (RDP or VNC)
    - A session controls the interaction between the local and remote machines.

Transport Layer 4

The Transport Layer is the 4th layer of the OSI model. It is responsible for end-to-end communication between two devices — making sure data is delivered completely, reliably, and in order

- Ensures reliable or unreliable delivery of data between host systems.
- Breaks data into segments, handles error checking, flow control, and retransmission.

Function	Description
Segmentation	Splits large messages into smaller pieces (segments).
Reassembly	Rejoins received segments into complete messages.
Error Detection	Verifies data integrity using checksums.
Reliable Delivery	Ensures data reaches the destination (TCP).
Flow Control	Prevents sender from overwhelming receiver.
Connection Control	Establishes and terminates communication sessions.
Port Addressing	Uses port numbers to direct data to specific applications (e.g., port 80).

TCP	Connection-oriented	Reliable, ordered delivery (e.g., web pages, emails)
UDP	Connectionless	Fast, no guarantees (e.g., video streaming, gaming)

- TCP is reliable but slower (e.g., email, web browsing).

- UDP is faster but unreliable (e.g., video/audio streaming).
- Provides process-to-process communication using ports.

Real-World Examples

- Opening a website in a browser (e.g., www.google.com)
  - Uses TCP to reliably deliver web page data over HTTP.
- Streaming a YouTube video or music
  - Uses UDP for fast transmission, tolerates occasional data loss.
- Sending a WhatsApp or Telegram message
  - Uses TCP (reliable delivery) or a combination of UDP for faster typing indicators.
- Online multiplayer gaming (e.g., PUBG, Free Fire)
  - Uses UDP to minimize delay (lag), accepts some data loss.
- Sending an email via Gmail or Outlook
  - Uses TCP through SMTP/IMAP for guaranteed delivery.
- IoT Sensor sending data to the cloud (e.g., ESP32 to ThingsBoard)
  - Uses MQTT over TCP for reliable message delivery. Some cases use UDP for faster telemetry.
- Video conferencing (e.g., Zoom, Google Meet)
  - **Uses UDP for real-time audio/video data, reducing delay.**

Data Link Layer 2

The Data Link Layer is the 2nd layer of the OSI model. It is responsible for node-to-node delivery — transferring data between directly connected devices on the same network.

- Converts raw bits (from the Physical Layer) into **structured frames**.

- Ensures **error-free communication** between devices on the same local network.
- Uses **MAC addresses** to identify devices at the hardware level.

Function	Description
Framing	Encapsulates packets from the Network Layer into frames.
MAC Addressing	Uses unique MAC addresses for device identification.
Error Detection	Detects (but doesn't always correct) errors in transmitted frames.
Flow Control	Manages the rate of data flow to prevent overflow at receiver end.
Access Control	Controls which device can use the channel (e.g., CSMA/CD in Ethernet).

- LLC (Logical Link Control):
  - Handles error checking, flow control, and multiplexing.
- MAC (Media Access Control):
  - Deals with access to physical hardware, addressing (MAC), and collision handling.

MAC Address 48-bit unique ID for every network device (e.g., 00:1A:2B:3C:4D:5E)
Frame A structured data unit used for transmission at Layer 2

Real-World Examples – Data Link Layer

1. Two laptops connected to the same Wi-Fi network
   - Uses MAC addresses to send frames between devices.
2. A switch forwarding data to the correct device
   - Switch checks the destination MAC address and sends the frame to the correct port.
3. Ethernet cable communication between a PC and router
   - Data is sent as Ethernet frames over the cable.
4. Wi-Fi network using IEEE 802.11 standard

- Data is framed and sent over the air using wireless protocols at Layer 2.

5. MAC address filtering on a Wi-Fi router
    - Only devices with approved MAC addresses are allowed to connect.
6. Network collision handling in old Ethernet hubs (CSMA/CD)
    - If two devices transmit at once, collision is detected, and they resend.

Physical Layer

The Physical Layer is the 1st and lowest layer of the OSI model. It is responsible for the

physical transmission of raw bits (0s and 1s) over a communication medium.

- Transmits **raw binary data (bits)** as electrical, optical, or radio signals.
- Defines the **hardware and media** used for the actual data transmission.

Function	Description
Bit Transmission	Sends and receives individual bits (0s and 1s).
Physical Connections	Defines hardware components (cables, connectors, NICs, etc.).
Signal Encoding	Converts bits into signals (electrical, optical, or wireless).
Modulation/Demodulation	Converts digital to analog signals and vice versa (used in wireless/modems).
Data Rate Control	Determines transmission speed (baud rate or bit rate).
Transmission Mode	Defines direction of communication: simplex, half-duplex, full-duplex.
Topology & Media Type	Defines physical layout and media (e.g., bus, ring, star; coax, fiber).

- Deals only with hardware and physical transmission.
- Understands only 0s and 1s — no frames, packets, or IPs.
- Provides the foundation for all higher OSI layers.
- Defines cables, voltages, frequencies, connectors, etc.

Real-World Examples – Physical Layer

1. Ethernet cable connecting a PC to a router
    - Transmits data as electrical signals over twisted pair cable.
2. Wi-Fi communication between phone and router
    - Sends radio waves representing 0s and 1s through the air.
3. Bluetooth headset receiving music from mobile
    - Uses short-range wireless signals to carry audio data.
4. Fiber optic cable providing internet to your home
    - Transmits data using light pulses over glass fibers.
5. STM32 microcontroller sending data over UART
    - Sends and receives serial bits as voltage pulses (TX/RX).
6. USB pen drive transferring data to a laptop

    Transfers bits over USB electrical lines.

Real-Life Example: Sending a WhatsApp Message

Layer	Action
Application	You type a message and hit "send"
Presentation	The message is encoded/encrypted if needed
Session	A session is created between your phone and WhatsApp server
Transport	Message is broken into segments (TCP or UDP)
Network	Segments get an IP address to find the destination
Data Link	Converts to frames and assigns MAC addresses
Physical	Transmits bits through Wi-Fi or mobile data