# Layered Architecture of Computer Networks

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## Outline

- Layered architecture
- Significance of layered architecture
- Reference Models
  - OSI reference model
  - TCP/IP



## Layered Architecture

### Computer Network Models

- A communication subsystem is a complex piece of Hardware and software
- Early attempts for implementing the software for such subsystems were based on a single, complex, unstructured program with many interacting components
- The resultant software was very difficult to test and modify
- To solve this ISO has developed a layered approach
- In a layered approach, the networking concept is divided into several layers, and each layer is assigned a particular task



## Layered Architecture

### Layered Architecture

- The main **aim of the layered architecture** is to **divide the design into small pieces**.
- **Each lower layer adds its services to the higher layer** to provide a full set of services to manage communications and run the applications.
- It **provides modularity** and clear interfaces, i.e., provides interaction between subsystems.
- It **ensures the independence between layers** by providing the services from lower to higher layer without defining how the services are implemented.
- **Any modification in a layer will not affect the other layers**.



## Layered Architecture

### Layered Architecture

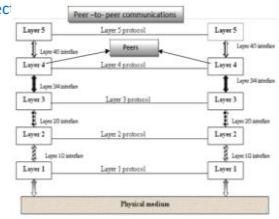
The basic elements of layered architecture are services, protocols, and interfaces

- **Service:** It is a set of actions that a layer provides to the higher layer
- **Protocol:** It defines a set of rules that a layer uses to exchange information with peer entity. These rules mainly concern about both the contents and order of the messages used
- **Interface:** It is a way through which the message is transferred from one layer to another layer
- In a layer n architecture, layer n on one machine will have a communication with the layer n on another machine and the rules used in a conversation are known as a layer n protocol



## Layered Architecture

### Layered Architec




Note: Every layer clubs together all procedures, protocols, and methods which it requires to execute its piece of task.

## Layered Architecture

Significance of Layered Architecture

**Modularity:**

- The community stack may be divided into layers so that every layer can be one after the other planned, carried out, and maintained.
- This modularity allows network setting up and simplifying improvements and updates.

**Interoperability:**

- The uniform compatibility of various suppliers' software programs and hardware components is made possible via standardised interfaces between layers.
- In circumstances with heterogeneous networks, interoperability is critical.



## Layered Architecture

Significance of Layered Architecture

**Troubleshooting and Debugging**

- Layered architecture makes it possible to isolate issues into particular layers
- Makes finding and fixing community issues simpler.

**Scalability**

- As networks develop in size and complexity, extra layers or protocols may be delivered to accommodate new requirements without disrupting existing functionalities.



## Layered Architecture

Significance of Layered Architecture

**Security**

The layered technique allows security features to be applied at a couple of degrees, protecting the community from various threats.

**Efficiency**

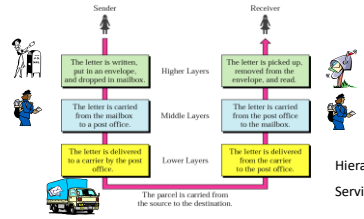
Each layer specializes in a selected factor to improve the performance.



## Layered Architecture

Layered Tasks

An example from the everyday life




Hierarchy?

Services



## Layered Architecture

Why layered communication?

- To reduce complexity of communication task by splitting it into several layered small tasks
- Functionality of the layers can be changed as long as the service provided to the layer above stays unchanged
  - makes easier maintenance & updating
- Each layer has its own task
- Each layer has its own protocol



## Reference Model

There are two reference models used to demonstrate the layered approach

- OSI reference model
- TCP/IP Protocol suite

## Reference Model

1. OSI reference model



## Reference Model

**OSI Reference Model**

- OSI stands for **Open Systems Interconnection**.
- It has been developed by **ISO – 'International Organization for Standardization'**, in the year **1984**.
- It is a **7 layer** architecture with each layer having specific functionality to perform.
- All these **7 layers** work collaboratively to transmit the data from one person to another across the globe.
- The term ***"open"*** denotes the ability to connect any two systems which conform to the reference model and associated standards.



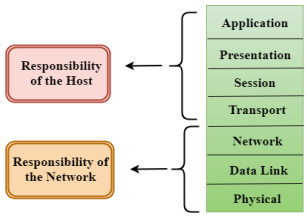
## Reference Model

**OSI Reference Model**




## Reference Model

**OSI Reference Model**






## Reference Model

**OSI Reference Model**

- The lower 4 layers (transport, network, data link and physical —Layers 4, 3, 2, and 1) are concerned with the flow of data from end to end through the network.
- The upper four layers of the OSI model (application, presentation and session—Layers 7, 6 and 5) are orientated more toward services to the applications.



## Reference Model

**OSI Reference Model**

## Reference Model

### OSI Reference Model

As the message travels from device A to device B, it may pass through many intermediate nodes. These intermediate nodes usually involve only the first three layers of the OSI model.

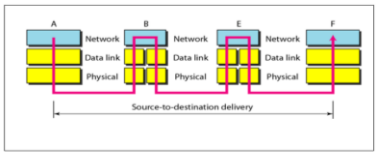



Fig: Data Transfer through Intermediate nodes



## Reference Model

### OSI Reference Model

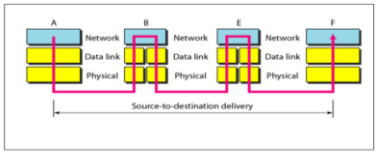



Fig: Data Transfer through Intermediate nodes

- The Data Link layer determines the next node where the message is supposed to be forwarded and the network layer determines the final recipient.



## Reference Model

### OSI Reference Model

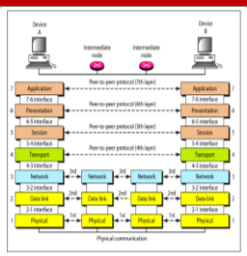
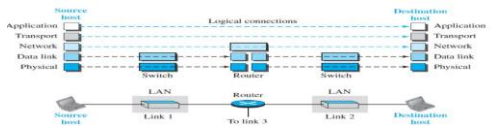


Fig: Communication & Interfaces in the OSI model



## Reference Model

### OSI Reference Model






## Reference Model

### OSI Reference Model

### Physical Layer

- It is the lowest layer of the OSI model.
- The physical layer is responsible for movements of individual **bits** from one node to another node.
- Transmission media is another hidden layer under the physical layer.
- It establishes, maintains and deactivates the physical connection.
- Two devices are connected by a transmission medium (cable or air).
- The transmission medium does not carry bits; **it carries electrical or optical signals.**

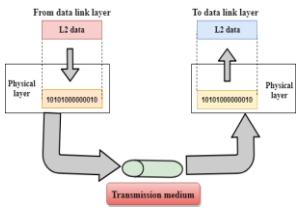


## Reference Model

### OSI Reference Model

### Physical Layer

- The physical layer
  - receives bits from the data-link layer
  - sends through the transmission media



## Reference Model

### OSI Reference Model

**Functions of a Physical layer**

- Line Configuration: It defines the way how two or more devices can be connected physically.
- Data Transmission: It defines the transmission mode whether it is simplex, half-duplex or full-duplex mode between the two devices on the network.
- Topology: It defines the way how network devices are arranged.
- Signals: It determines the type of signal used for transmitting the information.



## Reference Model

### OSI Reference Model

**Data-Link Layer**

- This layer is responsible for the error-free transfer of data frames.
- The data link layer transforms the physical layer, a raw transmission facility, to a reliable link and is responsible for node-to-node delivery.
- It makes the physical layer appear error-free to the upper layer (network layer).
- The data link layer packages data from the physical layer into groups **called frames**

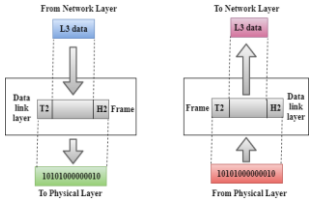


## Reference Model

### OSI Reference Model

**Data-Link Layer**

If frames are to be distributed to different systems on the network, the data link layer adds a header to the frame to define the physical address of the sender (source address) and/or receiver (destination address) of the frame.






## Reference Model

### OSI Reference Model

**Functions of the Data-link layer**

- **Framing**
  - Translates the physical's raw bit stream into packets known as Frames.
  - Adds the **header** and **trailer** to the frame
  - Header which is added to the frame contains the hardware destination and source address
- **Physical Addressing**
  - Adds a header to the frame that contains a destination address.
  - Frame is transmitted to the destination address mentioned in the header



## Reference Model

### OSI Reference Model

**Functions of the Data-link layer**

- **Flow Control**
  - Flow control is the main functionality of the Data-link layer
  - Technique through which the constant data rate is maintained on both the sides so that no data get corrupted
  - Ensures that the transmitting station such as a server with higher processing speed does not exceed the receiving station, with lower processing speed



## Reference Model

### OSI Reference Model

**Functions of the Data-link layer**

- **Error Control**
  - Achieved by adding a calculated value CRC (Cyclic Redundancy Check) that is placed to the Data link layer's trailer which is added to the message frame before it is sent to the physical layer.
  - If any error seems to occur, then the receiver sends the acknowledgment for the retransmission of the corrupted frames.

## Reference Model

### OSI Reference Model

**Functions of the Data-link layer**

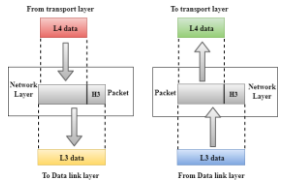
- **Access Control:** When two or more devices are connected to the same communication channel, then the data link layer protocols are used to determine which device has control over the link at a given time.



## Reference Model

### OSI Reference Model

**Network Layer**






## Reference Model

### OSI Reference Model

**Network Layer**

- It is in layer 3 that manages device addressing, tracks the location of devices on the network.
- Provides details that enable data to be routed between devices in an environment using
  - multiple networks
  - sub-networks
  - both
- The network layer is responsible for creating a connection between the source computer and the destination computer The communication at the network layer is **host to host**



## Reference Model

### OSI Reference Model

**Network Layer**

- The network layer also has some auxiliary protocols that help IP in its delivery and routing tasks
- The Internet Control Message Protocol (ICMP)helps IP to report some problems when routing a packet
- The Internet Group Management Protocol (IGMP) is another protocol that helps IP in multitasking
- The Dynamic Host Configuration Protocol (DHCP) helps IP to get the network layer address for a host



## Reference Model

### OSI Reference Model

**Network Layer**

- Responsible for addressing messages and data so they are sent to the correct destination, and for translating logical addresses and names into physical addresses.
- Since there can be **several routers from the source to the destination**, the routers in the path are responsible for **choosing the best route for each packet**
- **Networking components** that operate at the network layer include **routers and their software**.
- Network layer in the Internet includes the main protocol, Internet Protocol (IP), that defines the format of the packet, called a **datagram** at the network layer.



## Reference Model

### OSI Reference Model

**Functions of Network Layer:**

- Internetworking
  - An internetworking is the main responsibility of the network layer
  - It provides a logical connection between different devices
- Addressing
  - A Network layer adds the source and destination address to the header of the frame
  - Addressing is used to identify the device on the internet.

## Reference Model

### OSI Reference Model

**Functions of Network Layer:**

- **Routing**
  - Routing is the major component of the network layer
  - It determines the best optimal path out of the multiple paths from source to the destination
- **Packetizing**
  - A Network Layer receives the packets from the upper layer and converts them into packets. This process is known as **Packetizing.**
  - It is achieved by Internet Protocol (IP).



## Reference Model

### OSI Reference Model

**Transport Layer**

- The Transport layer is in Layer 4 ensures that messages are transmitted in the order in which they are sent and there is no duplication of data
- The transport layer controls and ensures the end-to-end integrity of the data message propagated through the network between two devices
- Provides reliable and transparent transfer of data between two endpoints
- The main responsibility of the transport layer is to transfer the data completely



## Reference Model

### OSI Reference Model

**Transport Layer (Steps followed)**

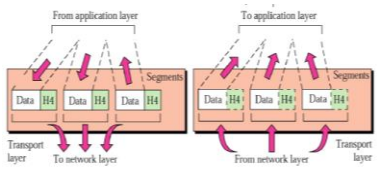
1. The transport layer at the source host gets the message from the application layer
2. Encapsulates the data in the transport layer (called a **segment** or a **user datagram** in different protocols)
3. Sends it through the logical connection, to the network layer



## Reference Model

### OSI Reference Model

**Transport Layer**






## Reference Model

### OSI Reference Model

**Transport Layer**

The two protocols used in this layer are

- Transmission Control Protocol (TCP)
- User Datagram Protocol (UDP)



## Reference Model

### OSI Reference Model

**Transport Layer**

- **Transmission Control Protocol**
  - It is a standard protocol that allows the systems to communicate over the internet.
  - It establishes and maintains a connection between hosts.
  - When data is sent over the TCP connection, then the TCP protocol divides the data into smaller units known as **segments.**
  - Each segment travels over the internet using multiple routes, and they arrive in different orders at the destination.
  - The transmission control protocol reorders the packets in the correct order at the receiving end.

## Reference Model

### OSI Reference Model

**Transport Layer**

- **User Datagram Protocol**
  - User Datagram Protocol is a transport layer protocol.
  - It is an unreliable transport protocol as in this case receiver does not send any acknowledgment when the packet is received
  - Sender does not wait for any acknowledgement
  - This makes a protocol unreliable.



## Reference Model

### OSI Reference Model

**Functions of Transport Layer**

- **Service-point addressing**
  - Computers run several programs simultaneously due to this reason, the transmission of data from source to the destination not only from one computer to another computer but also from one process to another process.
  - The transport layer adds the header that contains the address known as a **service-point address or port address**.
  - The responsibility of the network layer is to transmit the data from one computer to another computer and the responsibility of the **transport layer is to transmit the message to the correct process**.



## Reference Model

### OSI Reference Model

**Functions of Transport Layer**

- **Segmentation and reassembly**
  - When the transport layer receives the message from the upper layer, it divides the message into multiple segments, and each segment is assigned with a sequence number that uniquely identifies each segment.
  - When the message has arrived at the destination, then the transport layer reassembles the message based on their sequence numbers.



## Reference Model

### OSI Reference Model

**Functions of Transport Layer**

- **Connection control**
  - Transport layer provides two services Connection-oriented service and connectionless service.
  - A connectionless service treats each segment as an individual packet, and they all travel in different routes to reach the destination.
  - A connection-oriented service makes a connection with the transport layer at the destination machine before delivering the packets.
  - In connection-oriented service, all packets travel in the single route.



## Reference Model

### OSI Reference Model

**Functions of Transport Layer**

- **Flow control**
  - The transport layer is also responsible for flow control but it is performed end-to-end rather than across a single link.
- **Error control**
  - The transport layer is also responsible for Error control.
  - Error control is performed end-to-end rather than across a single link.
  - The sender transport layer ensures that the message reaches the destination without any error.



## Reference Model

### OSI Reference Model

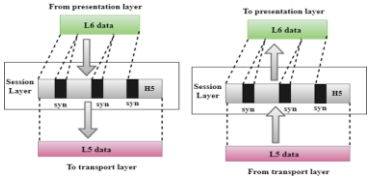
**Session Layer**

- It defines how to start, control and end conversations (called sessions) between applications.
- The Session layer is used to establish, maintain and synchronizes the interaction between communicating devices.
- Session responsibilities include network log-on and log-off procedures and user authentication.
- Session layer characteristics include virtual connections between applications or entities

## Reference Model

### OSI Reference Model

**Session Layer**






## Reference Model

### OSI Reference Model

**Functions of Session layer**

- **Dialog control:** it allows the communication between two processes which can be either half-duplex or full-duplex.
- **Synchronization:** Session layer adds some checkpoints when transmitting the data in a sequence.
- If some error occurs in the middle of the transmission of data, then the transmission will take place again from the checkpoint.
- This process is known as Synchronization and recovery.



## Reference Model

### OSI Reference Model

**Presentation Layer**

- Responsible for translation, compression, and encryption.
- The presentation layer at sending side receives the data from the application layer adds header which contains information related to encryption and compression and sends it to the session layer.



## Reference Model

### OSI Reference Model

**Presentation Layer**

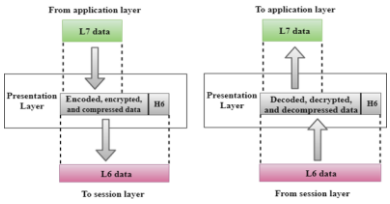
- At the receiving side, the presentation layer receives data from the session layer decompresses and decrypts the data as required and translates it back as per the encoding scheme used at the receiver.
- Presentation functions include
  - data file formatting
  - encoding
  - encryption and decryption of data messages
  - dialogue procedures
  - data compression algorithms
  - synchronization
  - interruption, and termination.



## Reference Model

### OSI Reference Model

**Presentation Layer**






## Reference Model

### OSI Reference Model

**Functions of Presentation layer:**

- **Translation**
  - The processes in two systems exchange the information in the form of character strings, numbers and so on.
  - Different computers use different encoding methods, the presentation layer handles the interoperability between the different encoding methods.
  - It converts the data from sender-dependent format into a common format and changes the common format into receiver-dependent format at the receiving end.

## Reference Model

### OSI Reference Model

**Functions of Presentation layer:**

- **Encryption**
  - Encryption is needed to maintain privacy.
  - Encryption is a process of converting the sender-transmitted information into another form and sends the resulting message over the network.
- **Compression**
  - Data compression is a process of compressing the data, i.e., it reduces the number of bits to be transmitted.
  - Data compression is very important in multimedia such as text, audio, video.



## Reference Model

### OSI Reference Model

**Application Layer**

- Responsible for providing services to the user.
- An application layer serves as a window for users and application processes to access network service.
- It handles issues such as network transparency, resource allocation, etc.
- An application layer is not an application, but it performs the application layer functions.
- This layer provides the network services to the end-users.



## Reference Model

### OSI Reference Model

**Application Layer**

- Communication at the application layer is between two *processes*
- To communicate, a process sends a request to the other process and receives a response
- Process to process communication is the duty of the application layer

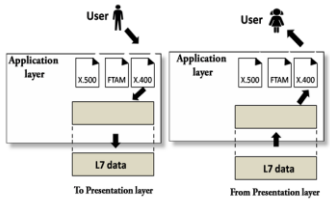


## Reference Model

### OSI Reference Model

**Application Layer**

- **X. 400** (Electronic Mail Protocol)
- **X. 500** (Directory Server Protocol)






## Reference Model

### OSI Reference Model

**Functions of Application layer:**

- **File transfer, access, and management (FTAM):** An application layer allows a user to access the files in a remote computer, to retrieve the files from a computer and to manage the files in a remote computer.
- **Mail services:** An application layer provides the facility for email forwarding and storage.
- **Directory services:** An application provides the distributed database sources and is used to provide that global information about various objects.



## Reference Model

**2. TCP/IP Protocol Suite**

## Reference Model

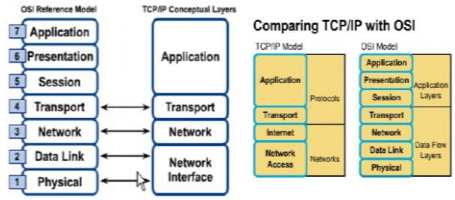
### TCP/IP Protocol Suite

- The U.S. Department of Defense (*DoD*) created the TCP/IP reference model because it wanted a network that could survive any conditions, even a nuclear war.
- Transmission Control Protocol/Internet Protocol (TCP/IP) model is a set of communication protocols that allow communication across multiple diverse networks.
- TCP/IP is a hierarchical protocol comprised of either three or four layers.
- The three-layer version of TCP/IP contains the network, transport and application layers.
- Four layer versions specify the host to network layer.



## Reference Model

### TCP/IP Protocol Suite






## Reference Model

### TCP/IP Protocol Suite

- The designers of TCP/IP felt that the higher-level protocols should include the *session* and *presentation* layer details.
- They simply created an **application** layer that handles high-level protocols, ***issues of representation, encoding, and dialog control***.
- The TCP/IP combines all application-related issues into one layer, and assures this data is properly packaged for the next layer.
- The TCP/IP **transport layer** deals with the quality-of-service issues of ***reliability, flow control, and error correction***.



## Reference Model

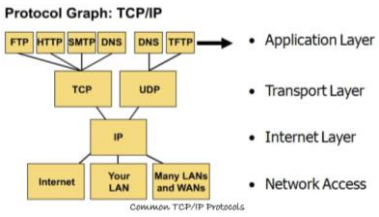
### TCP/IP Protocol Suite

- One of its protocols, the **transmission control protocol (TCP)**, provides excellent and flexible ways to create reliable, well-flowing, low-error network communications.
- TCP is a *connection-oriented protocol*.
- The other protocol is **User Datagram Protocol (UDP)** which is a connection less protocol.



## Reference Model

### TCP/IP Protocol Suite





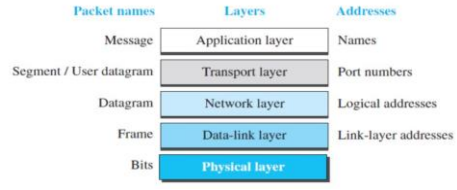

## Reference Model

### TCP/IP Protocol Suite

- The purpose of the ***Internet layer*** is to send source packets from any network on the internetwork and have them arrive at the destination independent of the path and networks they took to get there.
- The specific protocol that governs this layer is called the **Internet protocol** (IP).
- *Best path determination* and *packet switching* occur at this layer.
- The **network access layer** also called the ***host-to-network*** layer is concerned with all of the issues of physically delivering data packets using frames or cells.

## Reference Model

### TCP/IP Protocol Suite




Addressing in TCP/IP Protocol Suite



## Reference Model

### TCP/IP Protocol Suite

**Differences between OSI and TCP/IP**

- TCP/IP combines the presentation and session layer issues into its application layer
- TCP/IP combines the OSI data link and physical layers into one layer
- TCP/IP appears simpler because it has fewer layers
- TCP/IP protocols are the standards around which the Internet developed, so the TCP/IP model gains credibility just because of its protocols. In contrast, typically networks aren't built on the OSI protocol, even though the OSI model is used as a guide.



## Thank you!