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A COMPARATIVE ANALYSIS OF TCP/IP AND OSI NETWORK MODELS IN MODERN COMPUTER SYSTEMS

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ABSTRACT

This document covers both the OSI and TCP/IP models in detail since they are essential building blocks in science and network engineering. The analysis looks at how each model developed, how their designs were formed, what their different operation levels involve and the practical applications they each support for communication and data transfer. Although the OSI framework is studied as a basic reference and knowledge builder organised by seven layers, the TCP/IP framework is considered more practical and relevant, holding a key place in modern online networking due to four main layers. The document covers how data encapsulation achieves sending, organizing, steering and handling errors. It points out that layered abstraction is essential for fixing network problems more quickly and helping different devices work together. OSI model theory provides solid foundations, detailed analysis shows, whereas TCP/IP model delivers flexibility and is highly effective with networks that are both distributed and can handle a lot of data. Moreover, common network protocols such as HTTP, FTP, DNS, IP and TCP are examined to expose how protocol stacks are used in everyday network situations. The research details how systems handle various tasks associated with network communication and shows how these roles adjust to the growing needs of modern online services.

Keywords: TCP/IP, OSI, Networking

1. INTRODUCTION

Computer networks are groups of independent computers linked together using a common protocol. Network protocols are the lingua franca of the computer world. These protocols detail the bit-by-bit nature of computer-to-computer communication. It explains the norms and protocols that must be followed by all gadgets on a network. Packet switching is often used by protocols to transmit and receive data [1].

Protocols in a network provide the rules for how information is to be formatted and sent in messages and how devices are to find and connect with one another. For dependable and/or fast data transfer via networks, certain protocols include message acknowledgment and data compression. The protocols build upon one another.

By the time the Internet was created, layering was a tried-and-true method for developing compilers and operating systems [3]. As a result, the idea of layered protocols emerged, and they are currently the foundation of protocol design [4].Each layer exists to support the ones above it by delivering certain functions. To the layer above it, each successive layer is like a virtual machine. Data encapsulation, abstract data types, and information concealing are several names for the same idea in computer science and programming. The basic concept is to serve its consumers while concealing information about its internal state and the algorithms it employs.

In order for two data communication devices to exchange information with one another, a network protocol is required. Data transmission and reception is the foundation of every communication system. The following should be done to a large extent most of the time:

- Information interchange formats for digital bit strings.
- A lookup by address.
- The sending and receiving addresses in an electronic communication must have the same format.
- Internetworking-based routing.
- Networks that cannot guarantee fault-free operation need error detection.
- Timeouts and failed attempts to retrieve lost data.
- Management of sequence in the face of lost, delayed, or divergent lengthy strings of bits.
- Managing the flow of data when one party transmits at a higher rate than the other.
- If transmission is unidirectional, the direction of information flow must be considered.
- Connection-oriented communication acknowledgments for packet delivery success.

The networking protocol is put into action by connecting the protocol software modules to the OS framework [2]. Transmissions between systems seldom employ a solitary protocol. Instead, they use a collection of interoperating protocols, sometimes known as a protocol family or suite. IPX/SPX, AX.25, AppleTalk, and TCP/IP are only a few of the most well-known protocols.

Modern layouts include several layers of protocols. Layering is a design strategy that breaks down complex protocols into smaller, more manageable pieces, each of which is responsible for a discrete sub-task and only communicates with other layers in a few, well-defined ways [5]. The benefits of layered protocols include clearer specification of the techniques for transmitting information across levels as part of the protocol suite and isolation of modifications made inside a protocol layer from the other layers. Having them separated into their own functional levels makes it much easier to designate appropriate protocols for each layer's specific tasks. The five-layer Protocol Stack used by TCP/IP and the seven-layer OSI model are both examples of layered protocols. If you break the rules, it will be hard to talk to each other.

The diagram below depicts a five-layer network. Peers are the entries that make up the matching levels on separate computers. The peers may either be other processes or other hardware devices. There is no one-to-one correspondence between machines' layers n. Instead, information is sent from one layer to the next, all the way down to the bottom layer. Layer 1 at the bottom is the actual medium that allows for communication to take place.

In Figure 1, the dotted lines represent virtual communication whereas the solid lines represent physical communication [8]. Each set of neighboring layers has an interface between them. The interface specifies the set of basic operations and services provided by the underlying layer to the one above it. Determining uncluttered interfaces between layers is a crucial factor.

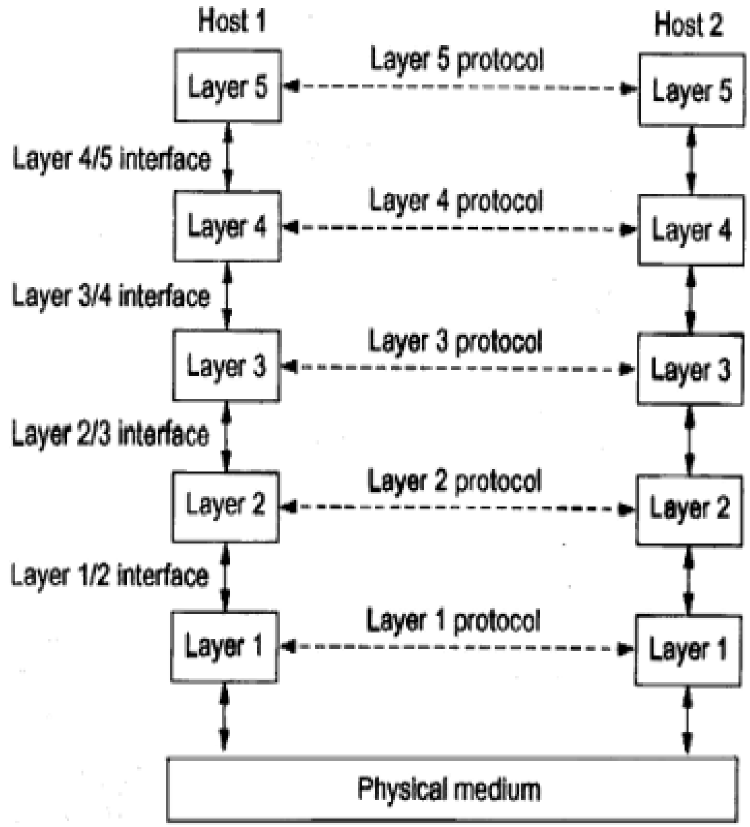

Figure 1: Layers, Protocols and Interfaces [7]

Each layer has to carry out a small set of well-defined tasks to keep the data footprint to a minimum. Since the new implementation provides the same set of services to the upstairs neighbor as the previous version, it is easier to replace one layer with a totally different implementation.

We refer to the framework of a network as its architecture. Since the implementation and interface specifications are internal to the machines, they cannot be considered part of the architecture. A protocol stack is a hierarchical set of protocols utilized by a given system. The OSI reference model and the TCP/IP reference model are two widely used frameworks for designing networks. The OSI reference model is briefly explained in Section 2. In Chapter 3, we learn what the TCP/IP reference model is. There will be a comparison of the two models in Section 4, followed by a summary and final thoughts in Section 5.

2. OSI REFERENCE MODEL

In 1984, ISO (the International Organization for Standardization) presented the Open System Interconnection Model. The approach provides a seven-layer summary of complex network phenomena and instances. By dividing a communication system into abstraction layers, its inner workings may be defined and standardized. The seven logical levels of the paradigm are used to organize the various communication functions. Each layer is both a provider and a recipient of services from the layers above and below it. The seven-layer structure is based on the following principles:

- Each layer need to serve a specific purpose.
- When a new level of abstraction is required, a layer should be added.
- International protocols should be defined by the roles that each layer plays.
- Information leakage between layers should be kept to a minimum at their borders.

- There should be a sufficient number of levels so that unrelated tasks aren't lumped together where they won't be useful [9], but not so many that the design becomes unmanageable.

This paradigm was created to reduce the learning curve for working with networks and to make troubleshooting networks less complicated [10]. Figure 2 below describes the OSI model's layers:

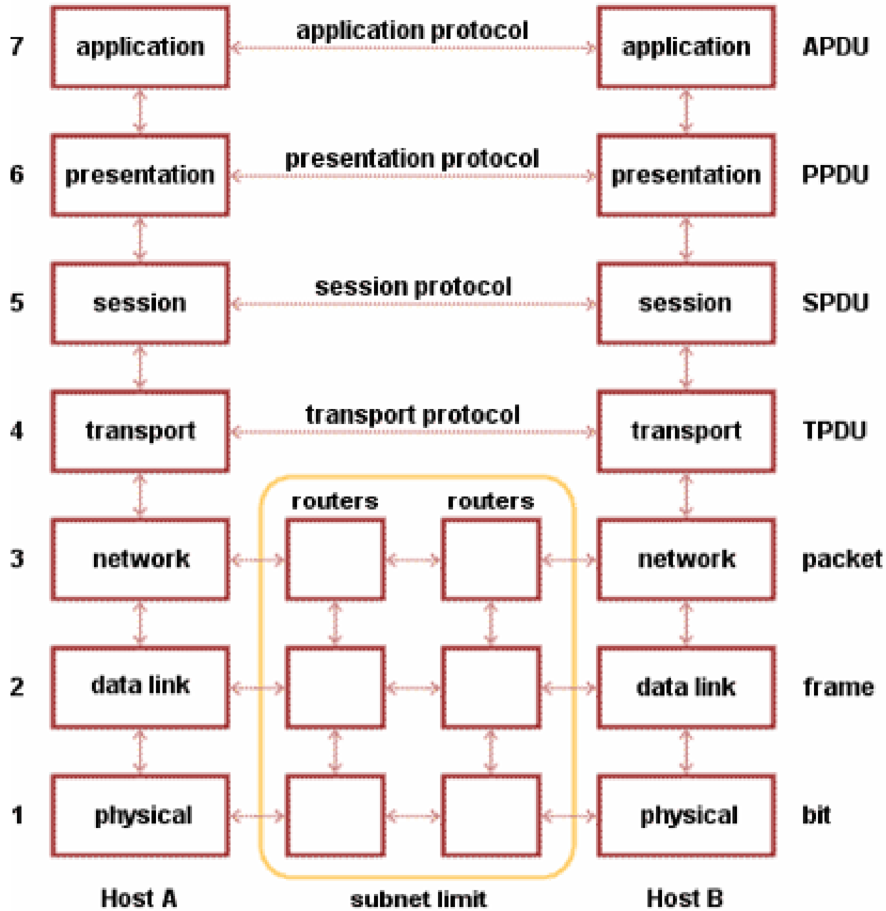

Figure 2: OSI Reference Model

The Physical Layer

The Physical Layer is the OSI Model's lowest level. It deals with the actual network's features, such the cables utilized, the connections, the maximum length of the wires, and so on [11]. The physical layer is in charge of sending unencoded data via the network. The data connection's electrical and physical requirements are laid forth. The connection between a gadget and its physical transmission medium (such as a wire or a fiber optic cable) is also discussed. The design challenges must ensure that when one side transmits a 1, the other side also receives a 1, and not a 0.

The Electrical Characteristics of the Signals Used in Data Transmission Over Cables are also defined by the Physical Layer. These signals have no significance beyond the binary values 0 and 1 as defined by the Physical Layer. The bits sent at the Physical Layer need to have meanings assigned to them at higher OSI model layers.

The Data Link Layer

At the Data Link Layer, the bottommost stratum of a network, bits are bestowed with significance before being transmitted. Data-link protocols handle concerns such as the utmost packet magnitude, how to authenticate that only one node at a given moment is transmitting data across the network, and how to avert numerous nodes from transmitting data simultaneously.

The information connection stratum's main duty is to hide any transmission issues from the network stratum, rendering a basic transmission capability appear flawless. Mistakes in the tangible stratum may be identified and conceivably reestablished to offer a steady linkage between two directly connected nodes.

The Media Access Control (MAC) stratum and the Logical Link Control (LLC) stratum are two sub-strata of the data link stratum. Entry to network information and permission to transmit it are regulated by the MAC sub layer. Frame synchronization, stream regulation, and error verification are all overseen by the LLC layer.

The task is accomplished by sequentially transmitting data frames that were previously fragmented by the sender. If the service is reliable, the receiving end will verify successful delivery of each frame with an acknowledgment frame of its own. PPP, FDDI, ATM, IEEE 802.5/802.2, and IEEE 802.3/802.2 are all examples of Layer 2 Data Links.

3. HDLC AND FRAME RELAY.

The Network Layer

Communications transmitted across a network are conveyed through the Network Layer. It controls the operation of the subnet. The Network Layer is accountable for logical addressing, amidst other things. MAC addresses are tangible addresses that are assigned to each network device when it is initially formed. To gain entry to a contraption on a network, it must be allocated a rational location. IP and IPX are the network strata accountable for this. MAC addresses are obtained from logical addresses through the Network Layer protocol.

The Network layer is additionally accountable for routing, or ascertaining the optimal way across the network. A computer on one network utilizes routing when it desires to transfer a packet to another computer on a distinct network. A router functions at the Network Layer and is accountable for transmitting the packet to its ultimate endpoint. Routers' capacity to connect diverse Layer-2 protocols is a crucial capability. A router, for example, can connect the divide between two networks functioning on different collections of low-level protocols, like an Ethernet-based local area network and a TCP/IP-based wide area network [12].

The Transport Layer

The Transportation Stratum is the bottommost tier of a network's structure where information can be transmitted from one device to another. End-to-end mistake retrieval and stream regulation are managed by this stratum, which additionally enables data conveyance between hosts. It ensures the complete transfer of information. It additionally determines the type of assistance the session layer, and thus the users of the network, will receive.

The transportation stratum is accountable for the dependable and punctual conveyance of information without any distortion, replication, or misplacement. It liberates the higher stratum protocols from fretting about data interchange with their counterparts. The abilities of the underlying network layer determine the ideal magnitude and intricacy of a transport protocol. A proficient network stratum with virtual pathway assistance may be achieved with merely a handful of strata of conveyance. The transportation protocol should possess resilient error identification and restoration capabilities if the network layer is unreliable and/or exclusively sustains datagrams.

Frequently, the Transport Layer protocol will disassemble a message into smaller packets so that it can be transmitted more rapidly and efficiently across the network. When a message is received, the Transport Layer protocol assembles all the fragments to guarantee that no data is misplaced during transportation.

The Session Layer

Sessions are established between nodes in a network at the Session Layer. Before any data is transmitted over a network, a session must initially be established. The session stratum is accountable for establishing and upholding these connections. Interactions among applications are established, upheld, and disposed of by this stratum. Discussions, interactions, and talks between apps are initiated, coordinated, and closed via the session layer. It's focused on synchronizing meetings and connections.

The Presentation Layer

When the demonstration service provides an extensive correlation between application-level entity syntax and semantics, the Display Layer establishes a setting in which the application-level entities can employ their favored syntax and semantics. If a mapping is discovered, information entities from the presentation service are enveloped in information entities from the session protocol and transported further down the protocol stack [13]. This stratum, frequently discovered in an operating system, interprets amidst diverse exhibition arrangements for information as it voyages in both directions [14]. By converting from application to network format, and vice versa, this layer enables applications to operate autonomously of alterations in data portrayal (such as encoding). Information is converted by the display layer so that it can be utilized by the application layer. This stratum readies information for conveyance across a network by arranging and ciphering it, rendering it universally employable. The grammatical stratum is an alternative term for this.

The Application Layer

The OSI application stratum is the most directly user-facing stratum, enabling for two-way communication between the user and the program. This stratum communicates with applications that utilize a networking component. Numerous user-solicited protocols can be discovered on the application stratum. The functioning of applications and end users are aided by this layer.

Collaborators in communication are established, excellence of service is evaluated, user verification and confidentiality are considered, and data grammatical limitations are acknowledged. At this stage, everything is customized to a specific software. Hyper Text Transfer Protocol (HTTP) is one frequently utilized application protocol since it serves as the basis of the World Wide Web. A browser solicits a webpage by transmitting the server the desired page's title via the Hypertext Transfer Protocol (HTTP). The page is subsequently delivered by the server. File exchanging, electronic mail, and network message boards all utilize diverse application protocols. The application stratum is the sole site of protocols such as Telnet and FTP. This stratum is accountable for layered application frameworks [15].

TCP/IP Model

Transmission Management Protocol/Online Protocol is abbreviated as "TCP/IP." It establishes the guidelines for how computers and other electronic devices should interact with each other through the Internet. TCP is the protocol in control of dividing data into packets before transmitting them over a network and assembling them after they have reached their target. Inter-machine conversation is managed via IP. It manages online packet addressing, transmission, and reception. Transmission Management Protocol (TCP) guarantees the accurate transmission of data packets between applications on diverse computers through a network (like the Internet). The transportation stratum is where it might be discovered.

Numerous educational institutions and governmental establishments were interconnected via rented phone lines and the APPARNET, a research network supported by the Department of Defense (DoD). A fresh reference framework was formulated because existing protocols encountered challenges when interacting with recently introduced satellite and wireless networks. The main goal was to guarantee the seamless functioning of interconnected networks. The TCP/IP Model is the title that ultimately adhered for this specific structure.

The continuation of ongoing discussions was another crucial requirement [16] for the network design. What this implies is that the Department of Defense required links to endure as long as the source and destination apparatus were operational, even if any of the devices or communication lines in between abruptly ceased functioning. Various applications, ranging from document exchange to voice over IP in live time, require a versatile layout. IP and TCP rely on each other immensely. IP designates where data packets should go while TCP guarantees their secure transmission.

TCP/IP functions on two separate tiers. Transmission Management Protocol, an upper stratum, is accountable for dismantling a communication or document into smaller fragments for conveyance across the World Wide Web and subsequently reconstructing them into the initial communication upon reception. Internet Protocol, a subordinate stratum protocol, is accountable for guaranteeing that packets are dispatched to the accurate destinations. This location is utilized by each gateway machine in the network to ascertain where the message ought to be dispatched. A few of the communication packets might follow an alternative route, but they will all be reconstructed at the ultimate endpoint [17].

The seven tiers of the Open Systems Interconnection (OSI) framework correspond to one or more of the model's strata. Figure 3 displays the model's stratification configuration.

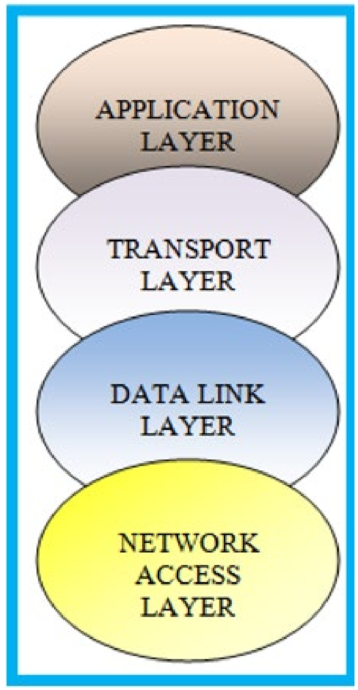

Figure 3: TCP/IP Model [18].

The Network Access Layer

In the TCP/IP paradigm, the uppermost tier is the Network Access tier. How bits are electrically or visually signaled by hardware devices that interface directly with a network media like coaxial cable, optical fiber, or twisted pair copper wire is explained in the Network Access Layer [19]. This stratum manages the transfer and receipt of TCP/IP packets across the network medium. TCP/IP was engineered to operate with any frame structure and medium, irrespective of the manner in which the network is accessed. TCP/IP enables the interlinking of numerous diverse network structures. Local Region Network (LAN) technologies like Ethernet and Token Circle, and Broad Area Network (WAN) technologies like X.25 and Frame Relay are instances of these. TCP/IP's ability to be adjusted to novel network technologies such as Asynchronous Transfer Mode (ATM) is primarily attributed to its autonomy from any specific network technology.

The OSI model's Data Link and Physical strata are merged into a solitary entity known as the Network Interface stratum. It is crucial to bear in mind that the Internet layer does not utilize any ordering or acknowledgment services that might be accessible at the Data-Link layer. It is thought that the Network Interface layer is undependable, and it is the duty of the Transport layer to offer dependable communications by establishing sessions and appropriately ordering and acknowledging packets.

Internet Layer

The Internet Layer is the middle layer of the TCP/IP architecture. Between the underlying Network Access Layer and the higher-level Transport Layer is where you'll find the Internet. The Internet Protocol layer encapsulates data into packets called IP data grams, which are then sent from host to host and network to network using the data's source and destination addresses. IP datagrams are also routed via the Internet layer.

A layer of connectionless internetwork is essential to the operation of a packet switching network. The Internet layer is the highest level. Its purpose is to let hosts send packets into any network and have those packets reach their destination without any intervention from the sending network. Data packets arriving at their destination may not be in the same sequence as they were transmitted. The upper layers are responsible for rearranging the packets such that the Application layer of the network can receive them and process them appropriately [20].

Packet transmission over various networks falls under this layer's purview. In order to do any kind of internetworking, data must be sent from one network to another. The term for this procedure is "routing" [21].

The Internet layer is not only neutral with regards to transport layer data formats, but it also does not make any distinctions between the functions performed by the different transport layer protocols. Information for many uppers may be sent through IP. Internet Control Message Protocol (ICMP) and Internet Group Management Protocol (IGMP) are examples of such protocols, and they are both designated by the numbers 1 and 2, respectively. Some of the most important protocols implemented at the Internet layer include the Internet Control Message Protocol (ICMP), the Address Resolution Protocol (ARP), the Reverse Address Resolution Protocol (RARP), and the Internet Group Management Protocol (IGMP).

Transport Layer

Data packets may be sent from one end of the network to the other thanks to the Transport Layer. End-to-end (host-to-host) communication is the focus of the Transport Layer. Transmission Control Protocol (TCP) is an Internet Protocol (IP) layer protocol that ensures the secure, connection-oriented transfer of data between two computers' endpoints (sockets). The User Datagram Protocol allows for the unreliable, connectionless transfer of data between two Internet Protocol endpoints (sockets) on different systems. When sending data, the Transport Layer passes it on to the Internet Layer, and when receiving data, it passes it on to the application layer [22]. The transport layer controls the flow of data during a communication session between hosts and specifies the quality of service and connection status being utilized.

Application Layer

The TCP/IP Application Layer specifies the protocols used by applications running on a host computer to communicate with network services provided by the Transport Layer.

The user's communication interface is provided by this layer. The browser, email client, or file transfer client are all examples of such software. Here is where you'll find your web browser, telnet client, FTP client, email client, and so on. Any program that runs on top of TCP or UDP utilizes two IP addresses and two corresponding virtual network sockets. Data is sent to and received from the transport layer by the application layer.

For the TCP/IP protocol suite, this is the highest level. Applications and processes that rely on transport layer protocols to transmit data to their final destinations are part of this layer. Options for protocols to use at each tier allow it to perform its specified function. Therefore, apps may connect with the second tier, the transport layer, through a variety of protocols available at the application layer. Domain Name System (DNS), Hypertext Transfer Protocol (HTTP), Telnet, Secure Shell (SSH), File Transfer Protocol (FTP), Trivial File Transfer Protocol (TFTP), Simple Mail Transfer Protocol (SMTP), Dynamic Host Configuration Protocol (DHCP), X Window System (X Windows), Remote Desktop Protocol (RDP), etc. are all examples of protocols found in the application layer [23].

Comparison between OSI and TCP/IPModels

Email, the World Wide Web, File Transfer Protocol, etc. all utilize Transmission Control Protocol to communicate across the Internet. The Defense Advanced Research Projects Agency (DARPA) created TCP/IP so that different devices may communicate over a single network (the Internet). The primary goal of the protocol's development was to provide a reliable, self-repairing phone line breakdown on the battlefield. Open Systems Interconnection, on the other hand, was created by ISO (the International Organization for Standardization). The seven-layer model and a selection of protocols [24] make up the two main parts of this paradigm.

Table 1: OSI and TCP/IP Model [25].

OSI Reference Model	TCP/IP
Application Layer	Application Layer
Presentation Layer	
Session Layer	
Transport Layer	Transport Layer
Network Layer	Internet Layer
Data Link Layer	Link Layer
Physical Layer	

Although the TCP/IP Model merely consists of four tiers, the OSI Model encompasses a total of seven tiers. This is due to the fact that, beyond the Transport Layer, TCP/IP anticipates programs to manage everything themselves. It's significant to mention that the TCP/IP Model combines the Physical and Data Link Layers of the OSI into a solitary Network Access Layer [26]. Figure 4 illustrates the main disparities between the OSI and TCP/IP architectures.

The Unlocked Systems Interconnection (OSI) blueprint was formulated by the International Organization for Standardization (ISO) as a "benchmark model" to delineate the appropriate partition of work and interaction amidst the numerous software and hardware constituents that constitute a network communication. From the PHY interface at Stratum 1 (also recognized as the corporeal stratum) to the application stratum at Stratum 7, it constructs a seven-stratum stack of operational components.

A few of the utmost significant protocols that constitute the Internet are the Transmission Control Protocol (TCP) and the Internet Protocol (IP). Internet Protocol (IP) designates the methods by which computers can interchange information across a network of routed and interconnected networks. TCP delineates how applications can establish secure channels of communication in such a framework. TCP specifies how to maintain a communication over the network without data distortion or depletion, whereas Internet Protocol specifies how addresses and packets are directed.

TCP/IP is a protocol suite that evolved from studies conducted by the United States Department of Defense and is built on a flexible rather than rigid layered architecture. The Hypertext Transfer Protocol (HTTP), which is the foundation of the World Wide Web, and the Simple Mail Transfer Protocol (SMTP), which is the backbone of email, are both constructed on top of TCP. The User Datagram Protocol (UDP), a companion to TCP, forgoes the stability assurances made by TCP in favor of a more rapid data transfer rate. TCP/IP was created before the OSI model and was meant to address a particular set of issues; it was not intended to serve as a universal representation of network communications. The OSI model and TCP/IP are related and different in [27] ways :

- Several features of Layer 5 (session) are performed by TCP, which corresponds to OSI Layer 4 (transport) and the network layer.
- While OSI specifies a number of standardized functions at higher levels than Layer 5, where a network session occurs, TCP/IP makes no such assumptions.
- Whereas OSI prescribes two connection layers below IP, TCP/IP makes no such requirements.

In cases when the program requires functionality that is not provided by TCP/IP, the application must provide it. Because of the abstract nature of the interfaces between the layers in the OSI model, it is presumed that applications would never implement any functionality that properly belongs in any designated layer. The TCP/IP model and the OSI paradigm are quite similar in how they function. But there are nuances between them that are worth noting. The primary distinction is the thickness of the layers. TCP/IP has a four-layer architecture, whereas OSI has seven. Differences between the OSI Model and the TCP/IP Model [29]

- Layer functionality is provided by OSI, and all of the layers' roles are defined by OSI.
- In the OSI model, packet delivery is ensured by the transport layer.
- A horizontal strategy is used.
- There is an independent layer for the visuals.
- This is only a template for basic situations.
- Both connection-oriented and connection-less services may be accessed via the network layer of this approach.
- The OSI model struggles to accommodate all of the many protocols.
- In this architecture, protocols are concealed and may be updated quickly when new technologies become available.
- Services, interfaces, and protocols are all defined carefully, and their differences are highlighted.
- Differences between the TCP/IP and OSI models are as follows [29]:
- When compared to other levels, the TCP/IP paradigm is rigid since it relies so heavily on protocols.
- Packet delivery is not guaranteed by the transport layer.
- It takes a top-down method.
- There is no presentation layer that can be toggled on or off.
- There is no other context in which this paradigm may be useful.

- Connectionless services are provided by the network layer in this architecture.
- It's not simple to switch out the protocol in TCP/IP.
- TCP/IP's services, interfaces, and protocols are not neatly compartmentalized.

Table 2 below illustrates the comparative summary:

Table 2: Differences between OSI and TCP/IP Model [28].

TCP/IP	OSI
Implementation of OSI model	Reference model
Model around which Internet is Developed	This is a theoretical model
Has only 4 layers	Has 7 layers
Considered more reliable	Considered a reference tool
Protocols are not strictly defined	Stricter boundaries for the protocols
Horizontal approach	Vertical approach
Combines the session and presentation layer in theapplication layer	Has separate session andpresentation layer
Protocols were developed first and then the model wasdeveloped	Model was developed before the development of protocols
Supports only connectionless communication in the networklayer	Supports connectionless and connection-oriented communication in the networklayer
Protocol dependent standard	Protocol independent standard

4. CONCLUSION

In this work, I look into the distinctions between TCP/IP and the OSI models. USC provides a visual model of how information packets move through a network. The Department of Defence (DoD) designed the TCP/IP system to secure important military data and to keep its communication open in conflict situations. The good performance and effectiveness of a TCP/IP network are influenced by proper implementation according to industry standards. Unlike other standards, the TCP/IP approach is more flexible, leaving the door open for implementers to use their own ideas. Since TCP/IP is designed in modules, systems can leverage unique operating system features, boost efficiency and still be compatible with other operating systems. A mix of connection-based and decentralised transport ideas are both included in TCP/IP and OSI models. Alternatively, the part that makes the Internet works calls the two categories "linkages" and "information packets." Unlike the classic OSI, the "precise" framework uses connection-oriented and connection-dependent for the first model and connectionless-oriented for the second. TCP/IP has existed for a longer time and is better established than UDP. Even so, many other data transmission protocols include and rely on the OSI model. It will continue to be regarded as the model for which all other communication software is tested.

CONFLICT OF INTERESTS

None.

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None.

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