RESEARCH AND DEVELOPMENT DOCUMENT

**ON**

**Working and Functionality of TCP/IP Model**

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By

**Anirudh Sharma**

**(CT\_CSI\_CI\_66)**

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Celebal Summer Internship on Cloud Infra & Security

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Transmission Control Protocol (TCP) and Internet Protocol Model (IP)

The TCP/IP model (Transmission Control Protocol/Internet Protocol) is a four-layer networking framework that enables reliable communication between devices over interconnected networks. It provides a standardized set of protocols for transmitting data across interconnected networks, ensuring efficient and error-free delivery. Each layer has specific functions that help manage different aspects of network communication, making it essential for understanding and working with modern networks.

**Role of TCP/IP**

TCP/IP enables interoperability between diverse systems over various network types (e.g., copper, wireless). It ensures seamless communication across LAN and the internet. Without TCP/IP, large-scale global networking would not be possible.

The main condition of this process is to make data reliable and accurate so that the receiver will receive the same information which is sent by the sender. To ensure that, each message reaches its destination accurately, the TCP/IP model divides its data into packets and combines them at the other end, which helps in maintaining the accuracy of the data while transferring from one end to another end.

**Layers of TCP/IP Model**

* Application Layer
* Transport Layer (TCP/UDP)
* Network/Internet Layer (IP)
* Network Access Layer

**1.Application Layer**

The Application Layer is the closest to the end user and is where applications and user interfaces reside. It serves as the bridge between user programs and the lower layers responsible for data transmission.

* Function: Provides services and interfaces for end-user applications to access network resources.
* Key responsibilities:
  + Supports application protocols like HTTP, FTP, SMTP, DNS, etc.
  + Enables communication between software applications across networks.
  + Handles data formatting, encryption, and session management.

**2. Transport Layer**

This layer ensures data is delivered reliably and in the correct order between devices. The two main protocols in this layer are TCP (Transmission Control Protocol) and UDP (User Datagram Protocol).

* Function: Ensures reliable or unreliable delivery of data between hosts.
* Key responsibilities:
  + TCP (Transmission Control Protocol): Provides reliable, connection-oriented delivery with error checking, retransmission, and flow control.
  + UDP (User Datagram Protocol): Provides faster, connectionless transmission without guarantees.
  + Manages flow control and segmentation/reassembly of data.

**3. Internet Layer**

It handles the routing of data packets across networks. It uses the Internet Protocol (IP) to assign unique IP addresses to devices and decide the most efficient path for data to reach its destination.

* Function: Determines the best path for data to travel across networks.
* Key responsibilities:
  + IP (Internet Protocol): Provides addressing and routing.
  + Handles packet forwarding, fragmentation, and logical addressing (IP addresses).
  + Involves protocols like IP, ICMP (for diagnostics), and ARP (for address resolution).

**4. Network Access Layer**

This layer is the lowest layer in the model and responsible for the physical connection between devices within the same network segment.

* Function: Manages the physical transmission of data over the network hardware.
* Key responsibilities:
  + Handles how data is physically sent over cables, Wi-Fi, etc.
  + Manages MAC addressing, framing, and error detection at the physical link.
  + Includes Ethernet, Wi-Fi, and other data link technologies.

**Working of TCP/IP Model**

**When Sending Data (From Sender to Receiver)**

* **Application Layer**
  + A user sends data through an application (e.g., opening a website via a browser).
  + The application prepares data for transmission (e.g., using HTTP, FMTP etc.)
* **Transport Layer (TCP/UDP)**
  + TCP breaks data into small segments, adds a header (with sequence numbers, source/destination ports).
  + Ensures reliable delivery (TCP) or fast, connectionless delivery (UDP).
* **Internet Layer (IP)**
  + Adds IP addresses to each packet (source and destination).
  + Determines the route the packet should take to reach the destination.
* **Link Layer (Network Access Layer)**
  + Converts packets into frames, adds MAC (physical) addresses.
  + Sends data as binary bits (0s and 1s) over the physical medium (e.g., Ethernet, Wi-Fi).

**When Receiving Data (At the Destination)**

* **Link Layer**
  + Receives bits and reconstructs frames.
  + Passes frames up to the Internet layer.
* **Internet Layer**
  + Reads the IP address to confirm it's the correct recipient.
  + Removes the IP header and sends the data to the Transport layer.
* **Transport Layer**
  + Reassembles TCP segments in the correct order.
  + Verifies data integrity using acknowledgments and checksums.
* **Application Layer**
  + The data is delivered to the appropriate application (e.g., browser displays a web page).

**TCP/IP over OSI Model**

* **Simpler Structure:** TCP/IP has only 4 layers, compared to 7 in OSI, making it easier to implement and understand in real systems.
* **Protocol-Driven Design:** TCP/IP was designed based on working protocols, while the OSI model is more of a theoretical framework.
* **Flexibility and Robustness**: TCP/IP adapts well to different hardware and networks and includes error handling, routing, and congestion control.
* **Open Standard:** TCP/IP is open, free to use, and not controlled by any single organization, helping it gains universal acceptance.
* **Actual Use vs Conceptual Model:** The OSI model is great for education and design principles, but TCP/IP is the one used in real-world networking.

**Advantages of TCP/IP Model**

* Interoperability: The TCP/IP model allows different types of computers and networks to communicate with each other, promoting compatibility and cooperation among diverse systems.
* Scalability: TCP/IP is highly scalable, making it suitable for both small and large networks, from local area networks (LANs) to wide area networks (WANs) like the internet.
* Standardization: It is based on open standards and protocols, ensuring that different devices and software can work together without compatibility issues.
* Flexibility: The model supports various routing protocols, data types, and communication methods, making it adaptable to different networking needs.
* Reliability: TCP/IP includes error-checking and retransmission features that ensure reliable data transfer, even over long distances and through various network conditions.

**Disadvantages of TCP/IP Model**

* Security Concerns: TCP/IP was not originally designed with security in mind. While there are now many security protocols available (such as SSL/TLS), they have been added on top of the basic TCP/IP model, which can lead to vulnerabilities.
* Inefficiency for Small Networks: For very small networks, the overhead and complexity of the TCP/IP model may be unnecessary and inefficient compared to simpler networking protocols.
* Limited by Address Space: Although IPv6 addresses this issue, the older IPv4 system has a limited address space, which can lead to issues with address exhaustion in larger networks.
* Data Overhead: TCP the transport protocol, includes a significant amount of overhead to ensure reliable transmission. This can reduce efficiency, especially for small data packets or in networks where speed is crucial.

**References**

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