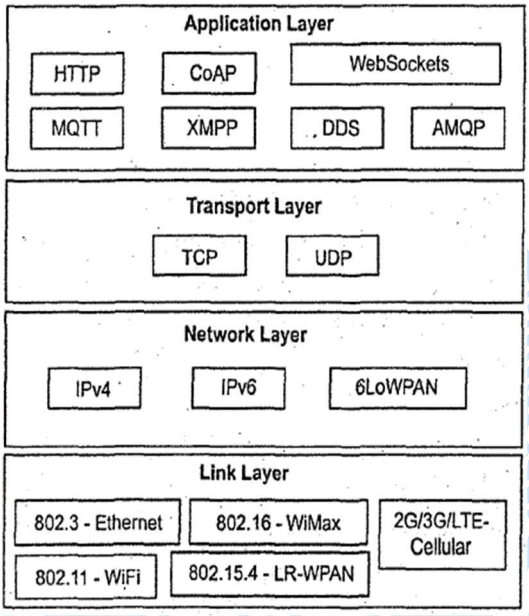
IoT Layers



(1) Link Layer

- Data link layer protocols determine that how the data is physically sent over the network's physical layer or medium such as copper wire, coaxial cable or a radio wave.
- Using link layer protocols, hosts on the same link exchange data packets over the link layer. Some of the link layer protocols which is relevant to the context of loT are as follows:

(i) 802.3 Ethernet:

- IEEE 802.3 is a collection of wired Ethernet standards for the link layer.
- IEEE 802.3 is the standard for 10BASE5 Ethernet that uses coaxial cable as a shared medium.
- IEEE 802.3.i is the standard for 10BASE-T Ethernet over copper twisted-pair connections.
- IEEE 802.3.j is the standard for 10BASE-F Ethernet over fiber optic connections.
- IEEE 802.3a.e is tire standard for 10 Gbit/s Ethernet over fiber.

  " All the above standards provide data rate from l0Mb/s to 40 Gb/s and even higher.

(ii) **IEEE 802.11: Wi-Fi**

- **IEEE 802.**11 is a collection of Wireless Local Area Network (WLAN) communication standards.
- **802.11** a operates in the 5 GHz band.
- 802.11 b and 802.11 g operates in the 2.4 GHz band.
- **802.11n** operates in the 2.4/5 GHz bands.
- **802.1 lad** operates in the 60 GHz band.

- These standards provide data rates from 1 Mb/s to 6.75 Gb/s.

(iii) IEEE 802.16: WiMax

- IEEE 802.16 is a collection of Wireless broadband communication standards that provide the data rates from 1.5 Mb/s to 1Gb/s.
- The recent update (802.16m) provides data rates of 100 Mbit/s for a motile station and 1 Gbit/s for a fixed stations.

(iv) IEEE 802.15.4: LR-WPAN

- **IEEE 802.15.4** is a collection of standards for Low-Rate Wireless Personal Area Networks (LR-WPAN) which provides the data rates from 40Kb/s to 250 Kb/s. These standards form the basis of specifications for higher level communication protocols such as ZigBee.
- These standards provide low-cost and low-speed communication for the power constrained devices.

(v) 2G/3G/4G: Mobile Communication

- The second generation (2G) includes GSM and CDMA, third generation (3G1 includes UMTS and CDMA 2000 and the fourth generation (4G) includes LTE.

- loT devices based on these standards can communicate over cellular networks with the data rates of 9.6 Kb/s for 2G upto 100 Mb/s for 4G.

(2) Network Layer (or) Internet Layer

- The network layer is responsible for sending of IP datagrams (packets) from the source network to the destination network This layer performs the hod addressing and packet routing.
- The datagrams contains a source and destination address that are used to route them from the source to the destination across the multiple networks.

(I) Internet Protocol version 4 (IPv4)

- IPv4 is an internet protocol that is used to identify the devices on a network using a hierarchical addressing scheme.
- It uses 32- bit address scheme that allows total of 232 or 4,294,967,296 addresses. If more and more devices got connected to the Internet then, we can use IPv6.

(ii) Internet Protocol version 6 (IPv6)

- It is the newest versions of internet protocol and successor to IPv4. IPv6 uses 128-bit address schemes that allows total of 2128 or 3.4 x 1038 addresses.

(iii) IPv6 over Low Power Wireless Personal Area Networks (6 LoWPAN)

- This standard supports low power devices which have limited processing capability. It operates in the 2.4 GHz frequency range and provides the data transfer rates of 250 Kb/s.
- 6L0WPAN works with the 802.15.4 link layer protocol and defines compression mechanisms for IPv6 datagrams over IEEE §02.15.4 based networks.

(3) Transport Layer

- The transport layer protocol provides end-to-end message transfer capability independent of the underlying network. The message transfer capability can be set up on connections, either using handshake such as TCP or without handshakes / acknowledgements such as UDP.
- The functions of the transport layer are,
  - Error control,

- Segmentation,
- Flow control, and
- Congestion control.

(i) Transmission Control Protocol (TCP):

- TCP is the most widely used transport layer protocol that is used by the web browsers along with HTTP, email programs (SMTP application layer protocol) and file transfer (FTP).
- TCP is a connection oriented and stateful protocol. When IP protocol deals with sending the packets, TCP ensures reliable transmissions of packets in an order. TCP also provide error detection capability so that the duplicate packets can be discarded and lost packets are retransmitted.
- The flow control capability of TCP ensures that rate at which the sender sends the data is not too high for the receiver to process. The congestion control capability of TCP helps in avoiding network congestion.

(ii) User Datagram Protocol (UDP)

- UDP is a connectionless protocol, it is useful for time-sensitive applications that have very small data units to

exchange and do not Want the overhead of connection setup.

- UDP does not provide guaranteed delivery, ordering of messages and duplicate elimination. UDP is described in RFC 768.

(4) Application Layer

- Application layer protocol defines how the applications interface with the lower layer protocols to send the data over the network.
- The application data are typically in files which is encoded by the application layer protocol and encapsulated in the transport layer protocol which provides connection or transaction oriented communication over the network.
- Application layer protocols enable process-to-process connection using ports. The ports numbers are used for application addressing.

  Example: Port 80 for HTTP and Port 22 for SSH.

(i) Hypertext Transfer Protocol (HTTP)

- HTTP is an application layer protocol that forms the foundation of World Wide Web (WWW).This protocol

follows a request-response model where a client sends request to the server using the HTTP commands.

- An HTTP client can be a browser or an application running on the client. Example: An application running on an loT device.
- HTTP protocol uses Universal Resource Identifiers (URIs) to identify HTTP resources. HTTP is described in RFC 2616.

(ii) Constrained Application Protocol (CoAP)

- CoAP is an application layer protocol for Machine-to-Machine (M2M) applications. It is a web transfer protocol and uses a request-response model and runs on top of UDP.
- CoAP uses a client-server architecture where clients communicate with servers using connectionless datagrams.

(iii) WebSocket:

- Websocket protocol allows full duplex communication over single socket connections for sending messages between client and server.

- Websocket is based on TCP and allows streams of messages to be sent back and forth between the client and server while keeping the TCP connection open. The client can be a browser, a mobile application and an loT device. WebSocket is described in RFC 6455.

(iv) Message Queue Telemetry Transport (MQTT)

- MQTT is a light-weight messaging protocol based on the publish -subscribe model. It uses a client - server architecture where the client (such as an loT device) connect to the server (also called the MQTT Broker) and publishes messages to topics on the server.
- The broker forwards the messages to the clients subscribed to topics. MQ'I T specifications are available on IBM developer works.

(v) Extensible Messaging and Presence Protocol (XMPP)

- XMPP is a protocol for real-time communication and streaming XML data between network entities. XMPP supports wide range of applications including messaging, presence, data syndication, gaming, multi-party chat and voice I voice calls.

- XMPP is a decentralized protocol and uses client-server architecture. It supports both client-to-server and server-to-server communication paths. XMPP allows real-time communication between loT devices.

(vi) Data Distribution Service (DDS)

- DDS is a data- centric middleware standard for device-to-device (or) machine - to- machine communication.
- DDS uses a publish-subscribe model where publishers (e.g. devices that generate data) create topics to which subscribers (e.g., devices that want to consume data) can subscribe.
- Publisher is an object responsible for data distribution and the subscriber is responsible for receiving published data. DDS provides Quality of Service (QoS) control, and configurable reliability.

(vii) Advanced Message Queuing Protocol (AMQP)

- AMQP is an open application layer protocol for business messaging. AMQP supports both point-to-point and publisher/subscriber models, routing and queuing.
- AMQP brokers receive the messages from publishers and route them occur connections to consumer. Publishers publish the messages to exchange which 1 then distribute message copies to queues.