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A Study of Link Layer Protocols in IOT

Mani Pareek
M.Tech (Computer Science)
Department of Computer Science
Banasthali Vidyapith
Tonk, India

Sushil Buriya
Assistant Professor
Department of Computer Science
Banasthali Vidyapith
Tonk, India

***Abstract*—** Internet of Thing is a new paradigm of current world. The Internet of Things is represent as a model in which physical objects (things) fitted with sensors, actuators and network connectivity which enable these objects to communicate each other. Communication plays central role to the Internet of things. Networking technologies used in communication between IoT devices and other devices as well as with applications and services that are running in the cloud. To ensure the security and reliability of communication between heterogeneous devices Internet based on standardized protocols. These standard protocols gives the rules and formats that devices use for establishment and management of networks as well as for transmission of data across those networks This paper presents an overview of IoT connectivity. This paper surveys protocol stack architecture for Internet of Things and focus on link layer technologies used in communication of smart objects.

Keywords*— IoT; Communication; Data link layer; protocol stack; PAN; LAN; WAN.*

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I. INTRODUCTION

Internet of Things is a world of pervasive connectivity where huge amount of appliances will be connected to the Internet. IoT term can be defined as an agglomeration of different physical things, sensors, actuators and various technologies. Embedded systems are already playing important role in the development of the IoT. These embedded sensors, actuators, transceivers and processors provide intelligence and interconnection to IoT devices. Any kind of conceivable object can use as smart object of IoT network which provide embedded computing and networking capabilities. In current scenario of research, industrial and commercial IoT is most popular topic. Different kind of applications of IoT is used which affect human life in unbelievable way. Now days IoT is used in commercial sector as smart homes and wearable smart devices. In industrial area most popular application is the machine to machine communication to enable directly communication between devices without human intervention. Other applications of IoT such as: Smart cities, waste management, smart environmental and agriculture, energy conservation, social life and entertainment, smart water system etc. [1]. IoT is playing major role to change the world in which we live and it become digital world.

Broadly there are four main components of IoT system [2]:

-The things (devices): Devices are the essential part of IoT system which provides sensing through sensor devices, actuation by actuators, control and monitoring activities by processors and transceivers. For instance, various types of IoT devices are wearable sensors, home automation devices, smart watches, LED lights, virtual reality IoT devices, Automobiles and industrial machines etc.

-The local network: local network is reliable for connecting other smart things, network devices and servers. This can include a gateway which works to translate proprietary communication protocol to internet protocols. Networks are like wireless, 4G, LAN, Bluetooth, LoRa, RFID, and NFC.

-The Internet: It stores, evaluate and process vast amount of data that comes from local networks.

-Back-End Services: It includes enterprise data systems, PCs, and mobile devices.

An IoT system works as follow: Sensors sensed data from physical environment. Then this data has to be stored, analyzed and processed wisely to acquire useful inference from it at edge of network or in a remote server. Communication protocols are used to communicate data between IoT devices and gateway devices or remote servers. After preparing the received data some action infer to modify physical world through actuators [1].

In this paper we focus on communication function block of IoT systems. The communication segment performs the communication between devices to devices, and devices to remote servers. Different IoT communication protocols involve in different layers of protocol stack. Table 1 explain communication protocol stack of IoT at different layers. This stack of technologies contain at bottom of the stack such as IEEE 802.15.4e, relating to physically connecting devices, at network layer encapsulation protocol such as 6loWPAN, relating to logical device addressing and RPL protocol used for routing of network traffic. Technologies further at the top of the stack message queuing technologies that are used by applications and services. The objective of this paper is to survey of link layer communication technologies on the basis of network type. The paper organized as follow. Section III of this paper discusses the related work. Section IV discusses communication in IoT systems. Section V discusses various link layer technologies and networks. Finally section V concludes this paper.

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II. Related Work

This section provides the related work of the survey at data link layer of IoT and comparative review of different link layer technologies. Mohammadi and Alehdheri [4] presented paper "Internet of Things: A Survey on Enabling Technologies, Protocols and Applications". This paper covers relevant protocols and application issues.

Tara Salman [5] provides a review paper which includes different standards of communication, routing, management protocol, security protocol, and network and session layer of the networking standard.

JP Vasseur et al. [6] presented a survey paper for low power wired and wireless link layer technologies for IP smart objects to provide a technical review. These are: IEEE 802.15.4, IEEE 802.15.4e, Low Power Wi-Fi, PLC and Homeplug green PHY.

H. Kaur et al.[7] compare six Wireless Technologies Zigbee, Bluetooth LE, EnOcean, Wavenis, Insteon and UWB on the basis of different matrices are frequency band, range, maximum node count, cost and security.

Azamuddin Bin Ab Rahman [8] present a paper to Compare Data Link Protocols of IoT. They include ZigBee, Bluetooth LE, Z Wave, NFC, HomePlug GP and Wi-Fi six protocols standard using matrices such as Radio Channel, Coexistence Mechanism, Security, Power Consumption. This paper tried to cover all exist data link layer technologies and subareas of network types.

III. Communication and Connectivity

IoT applications have many heterogeneous smart hardware devices which are properly arranged in network and accessible by communication. IoT smart objects use basic communication models- 1) Device to Device 2) Device to cloud 3) Device to gateway 4) Back end sharing. Data link layer connect two sensor devices or the sensor device and the gateway device (that connects a set of sensor device to the Internet). Various link layer technologies used to implement them. IoT devices are deployed in different ways- in houses, buildings, factories, campuses, cities, and even clothing and body parts. Selection of communication technology as requirement to communicate the smart object is crucial consideration.

Sensors transmit sensed information to the networks through network devices gateways, hubs, bridges and routers. In networks, network protocols set of rules to set up the connectivity are used. These network protocols are used to identify the devices in the network and then enable communication among them via technology. Network protocols are of two types- proprietary and open protocols. IP protocol is an open protocol and Z-Wave is a proprietary protocols. Wi-Fi router is a networking device used to connect devices like laptops, smart phones, tablets and other devices to the Wi-Fi network. We can classify these link layer connectivity technologies on the basis of network type in which they can used. There are network types:

Layers	TCP/IP Protocol suite	IoT Protocol Suite
Application layer	HTTP, FTP, SMTP, DNS,RIP, SNMP	MQTT, SMQTT, CORE, DDS, AMQP, XMPP,COAP....
Transport layer	TCP, UDP	UDP
Network layer	IGMP, ICMP, ARP, IP (IPv4), IPv6 ND, MLD, ICMPv6	6LoWPAN, 6TISCH, 6Lo, Thread, RPL,CORPL, CARP.....
Physical and Data link layer	Ethernet, Optical Fiber, 802.11 wireless LAN, Frame Relay, ATM	IEEE 802.15.4 PHY/Physical Radio, PLC, NFC & RFID, Bluetooth Low Energy, Z-wave, Zigbee Smart, DECT/ULE, 3G/LTE, Weightless ,Homeplug GP, 802.11ah, 802.15.4e, G.9959, WirelessHART, DASH7,ANT+,LTE-A, LoRaWAN....

Table 1: protocol stack [3],[4]

1. Personal Area Network (PAN)
2. Local Area Network (LAN)
3. Metropolitan/Neighborhood Area Network (MAN/NAN)
4. Wide Area Network (WAN)

Mainly PAN, LAN, WAN use to connect IoT devices. Mostly all IoT devices within short range area such as body area or a room area these devices use PAN network with combination of Smartphone. Smartphone will use as gateway to the WAN (Internet).

LAN networks used to connect IoT devices within houses or company to find their ways to the Internet. To connect the IoT devices to WAN network need to get that WAN, this WAN set up by connecting the various LANs through routers and that is the challenge for a range of IoT devices. To understand connectivity of IoT devices wireless networks can further classified.

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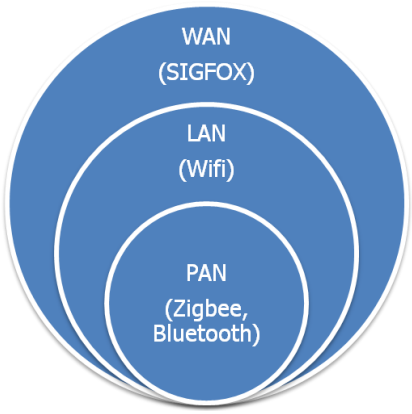

Fig.1. Network classification

A. WPANS

802.15 Wireless Personal Area Network used in short range communication of intelligent IoT objects which are few meters (typically 1m to 100m) far from a person like tablets, smart phones, body monitors etc. WPAN can be used for intrapersonal communication(Communication among the personal devices) and can be used for connecting personal device to Internet [10].

Bluetooth: Bluetooth is an 802.15.1 based short range WPAN technology initially developed by Ericsson for portable personal devices. Bluetooth has four versions. Bluetooth Low Energy (BLE) is the fourth version as alternative to the "power management" widely used for in-vehicle networking.

Ultra Wide Band: A radio technology UWB used in short distances WPAN to achieve high data rate. This technology provides suitable audio and video delivery in home environment through wide bandwidth up-to 480 Mbps [8].

LR-WPANs: 802.15.4 standard describes high level communication protocols for low-rate wireless personal area network such as 6lowpan, Zigbee. These standards provide extremely low cost and low- rate communication to reasonable battery powered devices.

Zigbee: Zigbee technology based on 802.15.4 standard. It provides low data rate and power consumption, reliability and short range connectivity. Zigbee mostly used in health care, home/building automation, telecommunication, remote monitoring, energy harvesting, interactive toys etc.

WirelessHART: HART protocol (highway addressable remote transducer) based wireless sensor networking technology operate in the 2.4 GHz ISM band using IEEE802.15.4 standard radios [10]. It provides cost effective automation, self organizing and self healing mesh architecture.

Thread: Thread protocol is an IPv6-based mesh networking. This protocol used to connect objects around home and building to the internet and to the cloud. Thread runs on low-power IEEE802.15.4 chipsets.

6lowpan: 6lowpan run IPv6 over 802.15.4 network. It takes care of basic encapsulation, header compression and efficient representation of data packets.

ISA100.11a: International Society of Automation developed standard to address wireless technologies in the areas of plants, environments in which the wireless technology deployed, technology and life cycle for wireless equipment and system and in application of wireless technologies. This also includes addressing of low-energy consumption devices, wireless infrastructure, interoperability, coexistence and robustness of ISA100 devices.

MiWi: MiWi is low cost embedded wireless connectivity protocol runs on the IEEE802.15.4 RF Physical layer. This protocol used in applications such as home networks, alarm sensors, HVAC systems etc.

EnOcean: EnOcean is a standard which recently rectified and published in 2012. This standard mostly used for energy harvesting with extremely ultra- low power. It was effectively used for building automation, smart homes, industrial automation, logistics and transportation.

WBAN: PANs can be used to support wireless body area network 802.15.6.

The WBAN technologies in the healthcare industry provides very low-power consumption, very low transmission power, and high quality of service (QoS) and reliability.

NFC and RFID: Near field communication is a wireless communication technology which operates in few centimeters. It enables interaction between two NFC devices (probably mobile devices) in very short range. It is based on RFID technology. RFID is the radio frequency identification technology used to uniquely identify the connected objects. RFID has two parts: readers and tags. Tag used to identify each object and reader used to broadcast signal that nearby active tag reply its using unique key [2].

IrDA: Infrared Data Association develops IrDA which is wireless infrared communication technology. It uses Infrared light as communication medium and gives complete set of protocols for wireless infrared communication.

ANT+ and NIKE+: these are two proprietary systems. A wireless sensor network technology ANT+ can be used in manufacturing of bikes. NIKE and APPLE develop NIKE+ to build products that allow user to monitor the activities while exercising.

Z-Wave: This is an ecosystem which provides wireless connectivity via Remote Control in smart homes. This technology uses radio waves which can easily cross the walls and cabinets. Wavenis: A long range and ultra low power wireless technology used in applications of (m2m) machine to machine communication developed by Chronis. These Wavenis devices are used in smart grid applications, remote telemetry, automatic meter reading, advanced metering infrastructure.

Insteon: This is a wireless connectivity standard which enable low cost network using mesh topology with and power line links and radio frequency. Insteon devices can connect through point to point link and communicate via multihop approach.

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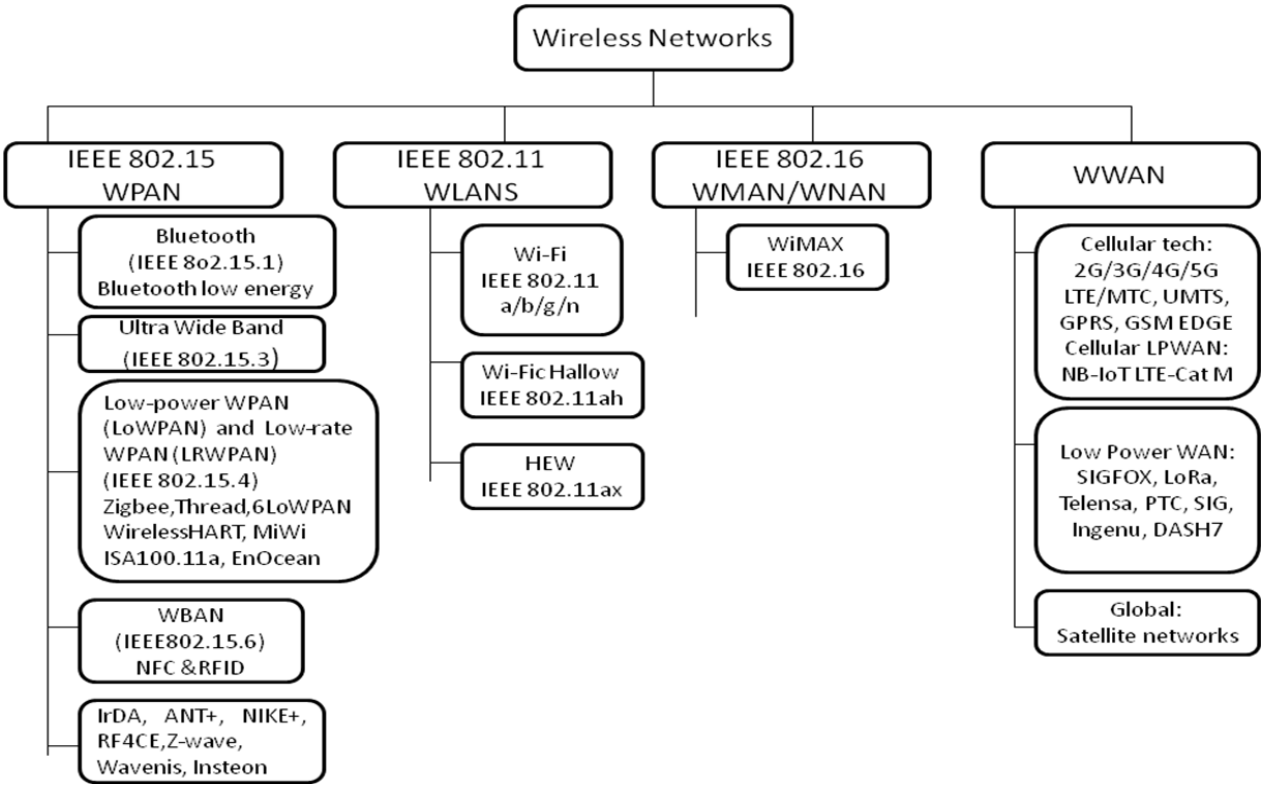

Fig.2. Communication technologies

B. WLANs

IEEE 802.11expands 802 network standards for the wireless channel provide the operations of wlan used for connectivity of short range (50m to 150 m) smart IoT devices. WLANs use ISM radio bands for communication.

Wi-Fi: Wi-Fi uses radio waves for wireless communication. This technology supports IEEE 802.11a/b/g/n standards operates on different frequency bands. The IEEE 802.11a uses the 5.4GHz frequency band, 2.4GHz band used by 802.11b/g and 802.11n uses both 2.4GHz and 5GHz band by MIMO mechanism.

Low-power Wi-Fi: This technology consumes minimum power than conventional Wi-Fi. It optimized power consumption of sensor applications and beneficial for IEEE 802.11 standard in such areas security (802.11i), meshing (802.11s) and QOS (802.11e).

Wi-Fic Hallow: This technology is suitable for short range and low power concerned IoT devices. This is based on IEEE802.11ah and operates on less than 1 GHz (900 MHz) frequency band.

HEW: High Efficiency Wireless based on IEEE802.11ax is more suitable for IoT systems. This technology increase data rates in high density WLANs. HEW uses MIMO-OFDM which enables it to subdivide signals and increase capabilities four times.

C. WMANs

Wireless metropolitan area network based on IEEE802.16. Applications of this network include smart cities.

WiMAX: Worldwide Interoperability for Microwave Access formed in June 2001. It provides interoperability and conformance of the IEEE802.16 standard. This technology delivers wireless broadband access and delivers 100 Mbps data speed. WiMAX 2 is the latest technology provides 1Gbps speed.

D. WWANs

Wireless Wide Area Network communication is important aspect of IoT system. This covers wide geographical area to connect IoT devices. It includes lp-wan for overlong range and low power connectivity of devices.

LTE and LTE-A: Long term evolution and LTE-Advanced, WWAN technologies developed by 3GPP standard in 2008.LTE provides data speed up-to 300Mbps and LTE-A provide data speed up-to 1Gbps.

UMTS: UMTS tends for Universal Mobile Telecommunications System. A 3G mobile cellular technology UMTS used to delivering voice and IP data packet in network. UMTS build on Global Systems for Mobile Communication (GSM) systems developed by 3GPP.

EDGE: Enhanced Data Rates for Global Evolution is the intensification of existing GSM technology. It provides high

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bit rates up to 384 kbps in both circuit and packet switching for data applications.

standard and LoRa Alliances. This standard protocol used by IoT devices that need to transmit low data rate over a long range in minimum power consumption for maximizing battery lifetime.

SIGFOX: A LPWAN technology used for IoT device connectivity. Sigfox connect remote devices through ultra narrow band binary shift keying with 100mbps maximum data rate.

LoRaWAN: Lora technology used in high range and minimum data rate applications. It uses star topology and deliver maximum data rate of 50kbps.

On-Ramp (Ingenu): This is a proprietary technology powered by RPMA (Random Phase Multiple Access). It is based on star topology and gives 20kbps max data rate.

LTE-M: This is a cellular technology deployed for LPWAN IoT devices. It requires narrow bandwidth in compare to other LTE services. Long term evolution provides 1mbps data speed with maximum battery lifetime of devices.

NB-IoT: Narrow band IoT is a LPWAN technology initiative by 3GPP. This technology addresses the low data rate, battery powered devices that need to connect to mobile networks. It delivers 200kbps maximum data rate.

DASH 7: DASH7 is a wireless communication protocol operates in ISM band for active RFID. This is a long range LPWAN technology. It covers 10 m to 10 km dynamically adjustable range with 28kbps to 200kbps data rate.

Satellite systems: Satellite communications is a LOS (Line of Sight) one-way or two-way RF transmission system that is includes uplinks (transmitting station), a satellite system work as a signal regeneration node, and one or more downlink (receiving stations). Satellite communication used in commercial, TV/media, government, and military communication such kind of applications.

IV. Conclusion

This paper only gives an overview of link layer protocols of IoT paradigm on the basis of network types, but does not conclude which one is better. These wireless protocols suitable for different applications by consider factors like power consumption, cost, data rate, security etc. This paper contributes in understanding of connectivity of IoT devices.

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