Empowering IoT through Improving Technology

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Abstract
Best technology improves, saves, and protects our Universe. One of them is the Internet of Things (IoT) which is dynamic, intelligent, and ubiquitous. Academic and commercial organizations mostly prefer the Internet of Things for research. Day by day, IoT publicity is increasing. An intelligent network that concatenates all things (IP or non-IP based) to the Internet for information interchange and communication is the Internet of Things (IoT). This paper provides the IoT system with its applications, challenges, and open issues and discusses the state-of-the-art methods of the IoT system and its layered architecture. Sensors and actuators are combined in the IoT system for new services and products with highly efficient, low costs, and user friendly. The IoT is ordinarily composed of various advanced technologies like software, actuators, sensors, and electronics because of Micro-Electro-Mechanical Systems (MEMS) comprising electronic and mechanical components at the micron level.

Keywords
IoT, State-Of-The-Art Methods, MEMS, Actuators, Web of Things (WoT), Sensors, SigFox, Long-Range (LoRa), ZigBee, MQTT, Z-Wave, Wireless HART.

I. Introduction

In 1999, The Internet of Things (IoT) was introduced. To work in a smart or intelligible manner for things, the things are connected to the Internet. Billion/trillion/zillion nodes can be connected to the IoT that can sense and interact with information [2] over the internet. These interconnected nodes process, and generate the data which is stored, analyzed, and used for action, handling, making planning, and taking decisions intelligently [1].

IoT devices are programmed for taking action according to the conditions. These devices are appropriate for networking that interact with each other in the network and are connected to the Internet through communication networks for innovative, new services and applications. Various applications like home automation, agriculture monitoring system, smart health care, wearable, smart car, etc. are based on the communication networks like Wi-Fi, Bluetooth, SigFox, MEMS, Z-Wave, ZigBee, Long-Range (LoRa), Web of Things (WoT), Wireless HART, MQTT, etc. For connection among devices, devices to the internet, and applications we need appropriate user interfaces for proper use of IoT applications in real life.

II. IoT Challenges

Traditional IoT application is inefficient due [3] to interoperability [4], accessibility, maneuverability, trustworthiness, scalability, and handling. Low cost, less power consumption, small size, high security, and efficiency are required for a State-of-the-Art IoT system.

III. State-of-the-Art

Information explosion and availability of information in a variety of languages and formats create problems for their effective use. Information association and repackaging can solve these problems to a great degree. State-of-the-art reports, Trends Reports, Reviews, Advances, etc., are examples of information consolidation and repackaging which can overcome the barriers to the use of information.

IoT State-of-the-Art

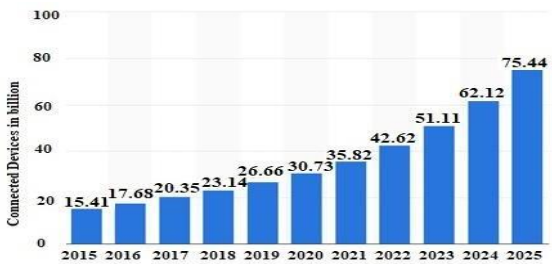
The IoT is a dynamic and global networked infrastructure that manages self-configuring objects in an extremely intelligent way. According to Ashton, "The Internet of Things has the potential to change the world, just as the Internet did. Maybe even more so". Later, it was officially presented by the International Telecommunication Union (ITU) in 2005. Many organizations and researchers defined and suggested the IoT. Guillemin and Friess

[5] have defined it as "The Internet of Things allows people and things to be connected from Anyplace, Anytime, with anything and anyone, ideally using any path/network and any service"

Sources: Perera *et al*. (2014), Razzaque *et al*. (2016)

Figure 1: The IoT can connect anything anywhere using any path

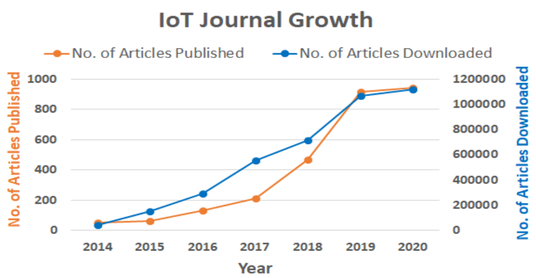
The IoT technology growing significantly [8]. There were a large number of objects/things connected to the Internet than people as shown in Figure 2. By 2025 it is predicted that; the number of Internet-connected devices reached or even exceed 75 billion which will add a huge amount of economy to the global economy by 2022 which involves installation costs, hardware, management services, software, and economic value from realized IoT efficiencies. The technical development has extended the knowledge of the IoT to comprise other technologies such as Wireless Sensor Networks (WSNs) and Cloud computing. It creates a market for IoT devices that enables companies to earn billions of dollars.



Source: https://www.researchgate.net/figure/

Figure 2: IoT connected devices/things from 2015 to 2025 (in billions)

One of the interesting topics for researchers is IoT. By Google, the IoT articles were published and downloaded almost 5 to 6 times from 2014 to 2020. Figure 3 shows the number of IoT articles published and downloaded per year from 2014 to 2020.



Source: IEEE IoT Journal – IEEE

Figure 3: Number of IoT Articles Published and Downloaded per year from 2014 to 2020

IV. Micro-Electro-Mechanical Systems (MEMS)

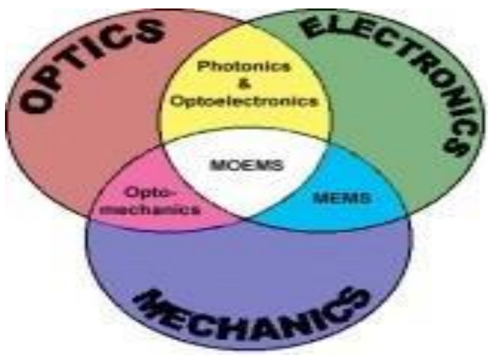
Components of MEMS

- ***Microelectronics:*** It is the brain that receives, processes, and makes decisions where data is coming from microsensors.
- ***Microsensors:*** Constantly gathers data from the environment which passes to microcontroller for processing that can monitor thermal, biological, mechanical, and chemical readings.
- ***Microactuators:*** These act as a trigger to activate an external device where microelectronics gives instructions to the microactuator.
- ***Microstructures:*** extremely small structures built on the surface of chips.

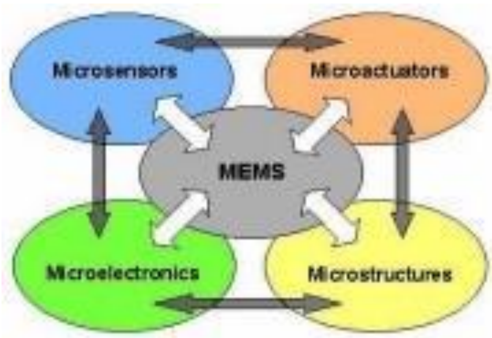
On the number of components in a chip, it is classified as SSI, MSI, LSI, VLSI, and VVLSI.

MEMS in the IoT

Micromechanical systems can be combined with microelectronics, wireless capabilities, or photonics to develop a new generation of Microsystems offering efficiency regarding space, accuracy, cost, precision, etc. Micromechanical systems (MEMS) technology can be used to fabricate application-specific devices. The associated micro packaging systems allow for the integration of devices or circuits, made with non-compatible technologies, in a System-on-Chip environment. Permanent, semi-permanent, or temporary interconnection of submodules in a System-on-Chip implementation is possible through MEMS technology. The interconnection of devices using MEMS technology is described with the help of a hearing instrument application and related micro packaging [Figure 4: A and B].



A



B

Figure 4: Schematic illustration of MEMS components

V. The ability of the IoT devices

The IoT devices can control, actuate and sense, the ability to limit power and energy, mobility, connection to the physical world, and irregular connectivity. Some provide privacy and security while some are unable to do so [9], and some are credible and fast. Any threats that affect functionality must be avoided by the IoT environments. Sensors sense while both actuators and sensors control, and for decision-making, both are fabricated on IC devices (microprocessors and microcontrollers). Sensors monitor some physical parameters and provide an appropriate output signal in the form of information which is the real representation of the parameter. The actuators are another form of transducer device. The electrical signal is taken by actuators as energy input and converted into [10] a mechanical physical motion that is useful to enrich the environments and control the physical objects in which they are located. The complicated control comprises the knowledge of the desired state, determines the present state, and moves toward the desired state in a system, elements. One or more sensors form a Control system to measure the state of a system and one or more actuators direct the system to the required state. Some IoT devices are vulnerable to external and internal attacks. Due to resource limitations like memory, battery power, and computational competence, it is not easy to implement and use dominant security.

VI. Electro-Optical Infrared Sensor in the IoT

Generally, a sensor detects variation in an environment and it is fruitless itself, but when it is connected to an electronic system, it can measure physical quantities that are converted into an electric signal [11]. The Internet of Things is the biggest network and one of the most vibrant and capable technological topics nowadays. There are about a billion or trillion connected devices. They are wearable, smartphones, and other devices, they use sensors that play a vital role in our everyday life and the Internet of Things. Sensors can monitor our home security, air quality [12], and health status, and are broadly used in the IIoT (Industrial Internet of Things) for monitoring. For sensing the environment, we use several ways such as chemical sensors, electrochemical, optical sensors, and electromechanical sensor plays the main role due to their quickness and accuracy. When photons are transformed into electrical signals, it is known as electro-optical (EO) sensing [Figure 5].

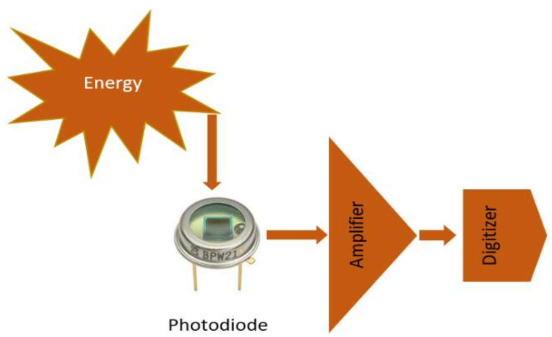


Figure 5: Conversion of optical to electrical energy then Amplification, Digitization, and Transmission

Photodiodes are the simple electro-optical devices that sense a break in a beam of IR (infrared) light that is used in a garage and elevator doors to force closing on a person or in a water outlet to sense the presence of a hand. The EO (electro-optical) sensors operate in the IR wavelength that is suitable for the [13] process temperature, for instance, SWIR (Short Wave Infrared) for semiconductor growth and processing, NIR (Near Infrared) for steel manufacturing processes, and MWIR (Mid Wave Infrared) for monitoring cement temperature. When sensors work in the 350–700 nm (visible range) then they are applicable in IoT devices, the real influence of EO sensors for IoT is in the >750 nm (IR range). Incoming photon energy from light is converted into electrical energy or the modulation of electrical energy by photodiode [Figure 5]. The electrical energy is then transmitted after amplification and digitization. The photodetectors have diverse broad spectral wavelength ranges, from 10-400 nm (ultraviolet), 400-750 nm (visible), 0.01-10 nm (X- ray), and 750 nm-100's μm (IR) to millimeter waves. The appropriate wavelength range of interest [14] plays a role in IoT. Spectral response wavelength ranges delivered many groups in IR photodetector. Photon detectors and thermal detectors are two IR detectors. Photon detectors worked on the absorption of photons by the semiconductor materials because of IR illumination, which creates electron-hole pairs with the output signal being either photocurrent or photovoltage. Thermal IR detectors are built on the temperature increment of IR materials from absorption of IR illumination, which is the reason for the transformation of certain material characteristics like thermoelectric effect, resistance transforms effect, or pyro-electric effect.

VII. Piezo resistivity in IoT

The piezoresistive sensor is used in several applications relating to **mechanical stress measurement**. The automotive industry employs them as vacuum and pressure sensors or to indicate oil and gas levels. They are used in the medical field devices like blood pressure measurement equipment.

Piezoresistive method

A piezoelectric crystal is a device that converts pressure energy into electrical energy [Figure 6].

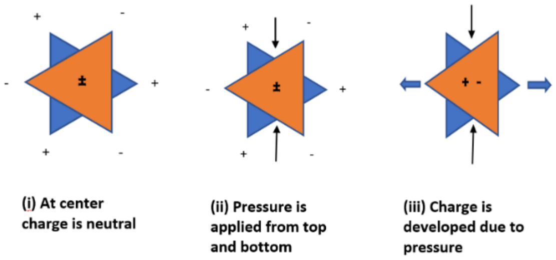


Figure 6: Piezoresistive method

VIII. The Domain View of the IoT with Controller & Sensor

The IoT solutions fashioned a requirement for the coming generation of sensors and are equipped with features to solve the current automation challenges [15]. Sensors, equipment, and real-time analysis [16] are being used by State-of-the-Art IIoT technologies for improving efficiency through successive digitization.

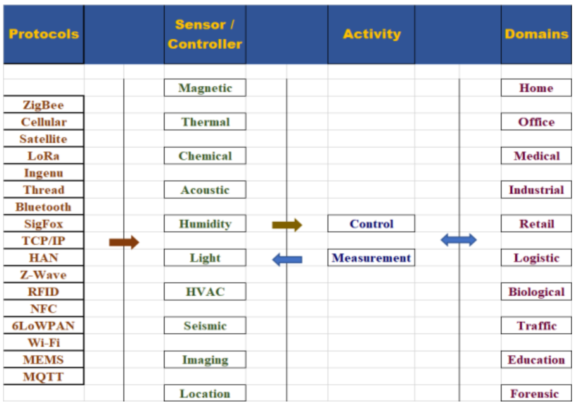


Figure 7: The Domain View of the IoT with Controller & Sensor

The IIoT (Industrial Internet of Things) takes processes that are conservatively handled on the factory base by machines and people then moves them to the cloud where they can be handled independently and remotely [16]. For industrial IoT setup data are the core, and the role of sensors is compulsory for making the entire environment smarter figure 7 shows the domain view of the Internet of Things with sensor & controller. The physical technologies that certain that the sensors are low on cost, more actual, power demand, and of reduced size. A very low power requirement in industrial IoT applications when sensors are far from the control center. Currently, they can collect the spread data and enable the industries to work with better efficiency [Figure 7].

IX. Network Technologies in IoT

Due to the heterogeneity, the IoT is a group of different components like people, software, and, systems connected over the Internet Technology. The communication network is an important component which is IoT wireless technology, [17] and it is the gateway between a software platform and an IoT device. To connect billions of devices to the Internet, extra Internet addresses were required than were present from the IPv4 protocol. Different strengths for different applications require various types of networks. Receiving and broadcasting are the capabilities of radio waves for transmitting data or signals that need the IoT wireless technology in its simplest form. Power consumption and data transfer rates are two key considerations when selecting a network technology for the application. This technology such as LTE, LTE-A (4G), and 5G is right for IoT applications. Further, Table 1 shows the comparison of IoT communication protocols and Table 2 shows the comparison of common IoT protocols that are discussed in this paper.

Table 1: Comparison between IoT communication protocols

Characteristics	ZigBee	LPWA	LoRa	Ingenu	Thread	Bluetooth	SigFox	Z-Wave	RFID	NFC	6LoWPAN	Wi-Fi	MQTT
Standard	IEEE 802.15.4	Cellular and non-cellular	LoRaWAN	3GPP	IEEE 802.15.4 IPv6 based	IEEE 802.15.1	Sigfox	Z-Wave Alliance	ISO-11784, ISO- 11785	ISO/IEC 18000-3	IEEE 802.15.4	IEEE 802.11n	ISO/IEC 20922
Network type	WPAN	WPAN	WPAN	Machine Network		WPAN	First LPWAN	WPAN		P2P Network	WPAN	Wireless Technology	Lightweight message protocol
Layer		Physical	Physical, Transport, Application		Network	Link	All PHY, MAC, Frame, Application	PHY, MAC, Transport, Application	Physical, Communication, Application	Physical, Data Link, Application	Network	Link	Application
Modulation	Direct Sequence Spread Spectrum (DSSS) and OQPSK	Packet level index modulation	Chirp Spread Spectrum	Direct Sequence Spread Spectrum (DSSS)		Frequency-hopping Spread Spectrum	Binary Phase-Shift Keying (BPSK)	Frequency-Shift Keyed modulation (FSK)	backscattering modulation-Near and Far-Field Coupling and Digital modulation-ASK, FSK, PSK	NRZ-L, Manchester, Modified Miller, ASK, etc.	Chirp Spread Spectrum at 2.4 GHz and Ultra Wide-Band *at 3.1–10.6 GHz*	Complementary Coded Keying (CCK)	
Frequency Band	2.4 GHz	868 MHz or 902 MHz bands	Unlicensed 1 GHz	2.4 GHz (ISM)		2.4 GHz (ISM)	900 MHz	900 MHz	2.38-MHz Radiowave	13.56 MHz (ISM)	2.4 GHz	2.4 GHz and 5 GHz bands	
Range	Short Range 10-100 m	A few kilometers in urban areas to over 10 km in rural settings	Long Range up to 15 km	over a 30 mile		Short Range 15-30 m	Up to 50 km	Short Range 30-100 m	3 to 30 MHz	Short Range Up to 200 m	Short Range 10-100 m	50 meters to 100 meters	
Data Rate	250 kbps	3 Kbps to 375 Kbps	0.3 kbps to 50 kbps	Hundreds of Thousands of bps		1 Mbps	10-1000bps	100 kbps	480 kb/s	100-420 kbps	250 kbps	600 Mbps maximum Commonly 150-200 Mbps	Up to 256 Mbps
Power	30 mA Low power	Battery Efficient	Low power (milliwatts (mW))		Low power	30 mA Low power Ultra-Low Power	Minimum Power	2.5 mA Low power		50 mA Low power	Very Low power consumption		
Topology	Star, Mesh, Cluster Tree	Simple Star, Mesh	Star	Star, Cluster Tree	Mesh	Star, Bus		Mesh		P2P Network	Star, Mesh		Ring
Security	128-bit AES	SIM Policy, VPN + APN	AES	256-bit encryption and two-way authentication	AES	AES	Shielded from the internet by a very strict firewall	AES	Stronger encryption or Passwords	RSA and AES	AES		Transport Layer Security (MQTT-TLS)
Cost	Low	Low	Low			Low			Based on volume, the amount of memory on the tag and the packaging of the tag				
Applications	Home control and Monitoring	Smart meters, Smart city, Track and trace, Smart agriculture, Smart building applications.	Intensive Indoor Coverage	Smart meter and Oil and Gas applications	Home Automation	Wireless Headsets and Audio Applications	Home and consumer goods, Transportation, Smart meter, Retail	Home Control and Monitoring	Ticketing, Payment, and Data transfer applications	Contactless Payment	Monitor and control via internet	Commonly used in Homes and various business	Healthcare, Agriculture', Logistics, Disaster Management, and Smart city Services, Facebook Messenger for online chat

Table 2: Comparison among common IoT communication protocols

Characteristics	ZigBee	Bluetooth	Z-Wave	NFC	6LoWPAN
Standard	IEEE 802.15.4	IEEE 802.15.1	Z-Wave	ISO/IEC 18000-3	IEEE 802.15.4
Network type	WPAN	WPAN	WPAN	P2P Network	WPAN
Frequency Band	2.4 GHz	2.4 GHz	900 MHz	13.56MHz	2.4 GHz
Range	Short Range 10-100 m	Short Range 15-30 m	Short Range 30 - 100 m	Short Range Up to 200 m	Short Range 10-100 m
Data Rate	250 kbps	1Mbps	100kbps	100 – 420kbps	250 kbps
Power	30 mA Low power	30 mA Low Power	2.5 mA Low power	50 mA low power	Very low power consumption
Supported Topology	Star, Mesh Network	Star and Bus Network	Mesh Network	P2P Network	Star Mesh Network
Security	AES	AES	AES	RSA and AES	AES
Common applications	Home control and monitoring	Wireless headsets and audio applications	Home control and monitoring	Payment and access	Monitor and control via internet

A. ZigBee

IEEE 802.15.4 standard-based ZigBee is used for WPANs (wireless personal area networks) communication. It is a robust, mesh-capable, self-healing, secure protocol. It can work on thousands of nodes in large areas. Its enabled devices, are power-efficient and enable cost wireless networking over large distances through mesh networks. In ZigBee system architecture, ZR (ZigBee Router), ZC (ZigBee Coordinator), and ZED (ZigBee End Device) are 3 device types in which only one coordinator is available in the network. The coordinator establishes the network, selects the network topology, and administers configuration information. It acts as the gateway in and out of the network, hence the power to be on and execute at all times. ZigBee routers move data and broadcast information through the network and they can function as a sensor node.

B. LPWA (Low-Power Wide-Area) Networks

LPWA (Low-Power Wide-Area) Networks are the response to the need for battery-efficient, pervasive, out-of-the-box connectivity, and are professionally managed to unlock massive value for 10 to 100 billion devices.

C. LoRa (Long-Range)

Long Range (LoRa) approaches an attractive mix of low power consumption, long-range, intensive indoor coverage, and secure data transmission shown in figure 8. It uses spread spectrum technology so that impending transmitters are less likely to tamper with each other and operates in the unlicensed 1GHz frequency range that increasing the dimensions of each gateway. Spread spectrum communications also deliberate a coding gain over narrowband communications [3]. This outcome is a powerful communications link, which can support a huge range of communications. It can support a range of up to 15km with the Data rates ranging from 0.3 kbps to 50 kbps.

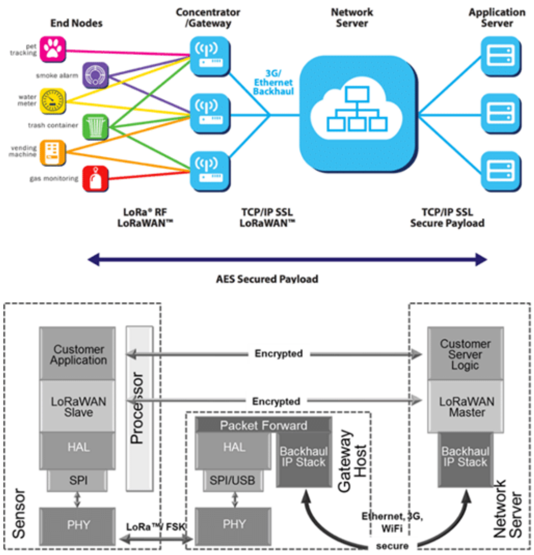


Figure 8: The LoRa Network and LoRa WAN Security Architecture

D. Ingenu

The Ingenu IoT wireless technology focused on oil and gas and smart meters applications. It includes urban and agricultural environments [6] by expanding into other IoT wireless applications. Its solution uses Random Phase Multiple Access technologies and it enables data rates in the 100 of 1000 bits per second. It works on the 2.4 GHz unlicensed and universal frequency band that proposes huge bandwidth, greater pliability, and a decrease in the eventuality of interference. It also uses the Viterbi algorithm for channel coding to assure data delivery with a high quality of service. It is inflexibly synchronized for supporting low delay applications and uses encryption of 256-bit and two-way authentication to deliberate enterprise-level security. It could be one of the best IoT wireless technologies to deal with a difficult situation.

E. Thread

The main use of a Thread IoT wireless technology is within the home to connect and control products. It makes a modest bridge between the Internet and a Thread mesh network for easy use with an IoT system. It permits, home automation devices to communicate through, radio frequencies, power lines [7], or a combination of both. It is an IEEE802.15.4 link-layer IPv6-based protocol.

How to send data within the network is clarified by the Thread, but not how to interpret it because it is not an application layer protocol. Thread supports IP-based application layers. Google and Nest compelled the Thread and are used in house automation.

F. Bluetooth

Bluetooth wireless technology is capable to transfer data in personal area networks for short distances that is introduced in 1999. BLTE (Bluetooth Low Energy) is a new addition to Bluetooth technology that reduces the power to approximately half the power of a traditional Bluetooth device. 0.6 to 1.2 milliseconds [18] scanning time is required for BLTE devices to detect other devices. It is integrated into mobile devices, smartphones, and many other personal.

G. SigFox

SigFox uses binary phase-shift keying which is a standard radio transmission procedure, and it takes a very less portion of the spectrum and transforms the phase of the carrier radio wave to encode the data which is an ultra-narrowband technology. Sophisticated signal processing and low data rate transmission keep away from network interference and guarantee the integrity of the transmitted data are the beauty of the Sigfox in figure 9. Sigfox wireless technology permits bidirectional communication but always commences by the device. It is emphatic for communications from endpoints to base stations (uploads). However, it is not emphatic for communications from base stations to endpoints (downloads Sigfox consumes a fraction (1%) of the power used via cellular communication). Sigfox would be perfect for one-way systems, including environmental sensors, basic alarm systems, and agricultural and simple metering as well as this technology is fit for any application that needs to send trivial, unfamiliar bursts of data.

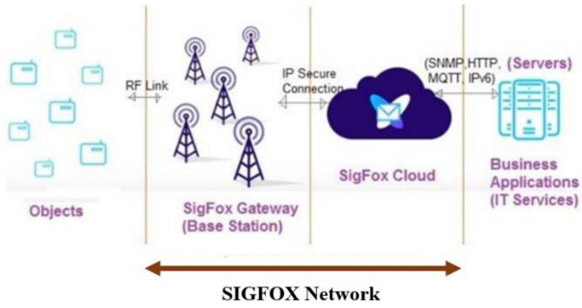


Figure 9: The SigFox Network Architecture

H. Z-Wave

Low-power IoT wireless technology is a Z-Wave that is designed for home automation. It is developed by Zen-Sys and later acquired by Sigma Designs. It proposed low-latency communication with data rates up to 100kbit/s [19] and authentic. In a smart home application, after receiving a command on a user's smartphone or computer, or tablet, it routes the command to its destination device across networks of up to 232 devices including the hub shown in figure 10.

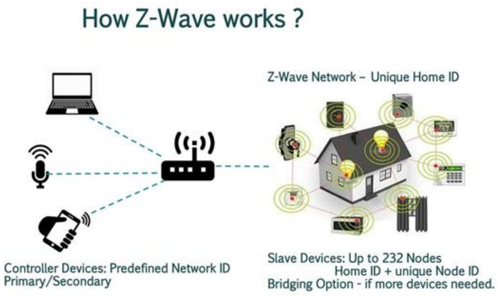


Figure 10: Z-Wave Network

I. RFID

People or objects are recognized by RFID (Radio Frequency Identification) technology using radio waves. A device of this RFID reads the information present in a tag (wireless device) from a distance without any physical contact or a line of sight. Information is electronically stored in the tags [30. In passive tags, energy is collected from a nearby RFID reader's cross-examines radio waves while the active tags have a local power source and can operate within 100 meters of the RFID reader.

X. WoT (Web of Things)

Multiple applications are installed on phone to communicate with multiple different devices. It means that there is not a single application that solves this problem in IoT. Things could easily exchange data with each other without compromising data means. Web protocols like HTTP were introduced to the Internet which is a universal way to describe other media elements, text, and images so that machines could understand each.

In the evolution, the next stage that connects everything in the universe and gives it existence on the WWW (World Wide Web) is the Web of Things (WoT) [20]. The following WoT Architecture is a way to structure the galaxy of Web protocols and tools into a beneficial framework for connecting any device or object to the Web. The following WoT architecture stack consists of a flexible server that adds extra functionality.

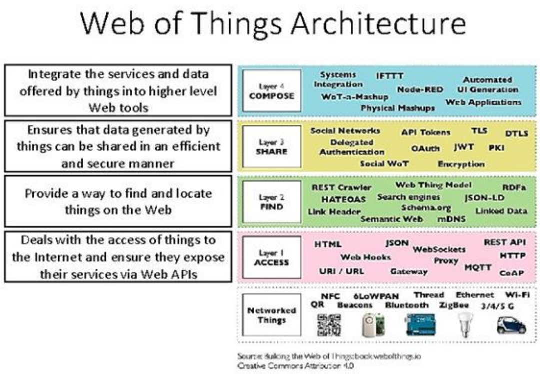


Figure 11: WoT Architecture

Layer 1 (Accessibility)

This layer converts any Thing into a Web Thing that can be communicated using HTTP requests of HTTP protocol equivalent to any other resource on the Web [21]. That is, a Web Thing is a REST API that permits communication with something in the universe.

Layer 2 (Findability)

HTTP clients can easily use the Thing and this Thing is findable and used by other WoT applications as well as other HTTP clients automatically.

Layer 3 (Sharing)

The IoT will only blossom if Things have a way to share data across services securely i.e., this layer is accountable for how the data generated by Things can be shared efficiently and secure manner over the web.

Layer 4 (Composition)

Integration of data and services from Things which has ubiquitous and heterogeneous properties into an enormous environment of web tools like mashup platforms and analytics software.

XI. IoT Protocols and Standards

IoT is a large environment of connected devices and growing over the globe. At present, a large number of objects around us is enabled us to collect, process, and send data to other servers, objects, or applications. IoT technologies have been enabled by the intense evolution of micro-computing, mini hardware manufacturing, the mobile Internet, and M2M (machine- to- machine) communication. Physical objects talk to each other due to the hidden language consisting of IoT standards and protocols. The general protocols used for smartphones, tablets, or personal computers are not suitable [22] for specific requirements like the range, bandwidth, and power consumption of IoT-based solutions. The three-level architecture of an IoT system is devices, gateways, and data systems [Figure 12]. The data moves among these levels.

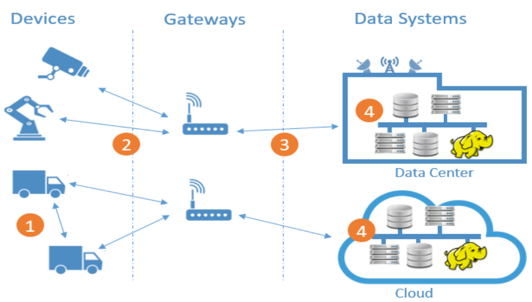


Figure 12: IoT Architecture (Three-Level)

1. Data Link Layer Protocols in IoT

The data link layer protocol standards figure 13:

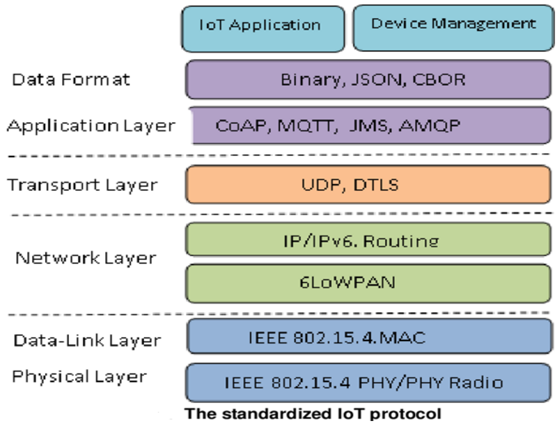


Figure 13: Standard of IoT Protocol

IEEE 802.15.4e

At the MAC sub-layer, the IEEE 802.15.4 is used as the IoT standard. MAC defines a frame format in which headers include the destination and source addresses, and connection with each other. In conventional networks, the frame formats are not appropriate for low- power multi-hop networking in IoT because of overhead. To meet IoT communications necessities [23], low cost, and to enable high credibility, it uses time synchronization and channel hopping. The standard is unable to define how the scheduling is done, and it needs to be built carefully so that it manages mobility. A new device should pay attention to advertisement commands, and upon receiving at least one such command, it can send a join request to the advertising device.

Wireless Highway Addressable Remote Transducer (Wireless HART)

The Wireless HART protocol is a data link layer protocol that works at the top of IEEE 802.15.4 PHY and adopts TDMA in its MAC. It is vendor-independent and an open standard. So, it is a globally supported protocol in the process industry, with many HART-based products available from numerous vendors. It is secure and authentic [24] MAC protocol and uses innovative encryption to encrypt the messages and calculate the integrity for trustworthiness. It consists of a network manager, a gateway, and a security manager to connect the wireless network to the wired networks, and wireless devices as field devices, routers, access points, and adapters shown in figure 14. The standard proposed end- to- end, per- hop, or peer- to- peer security mechanisms, enforce security from sources to destinations, in end- to- end security mechanisms, while per- hop mechanisms secure it to next-hop only.

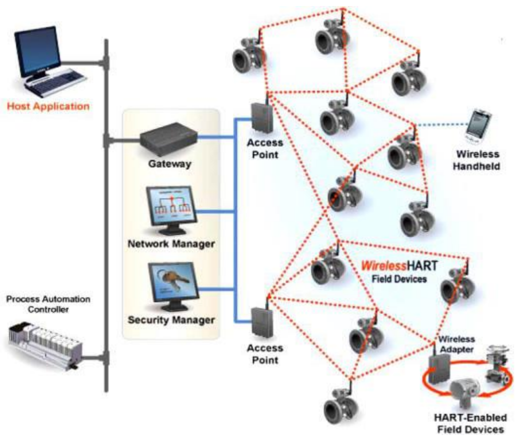


Figure 14: The Wireless Highway Addressable Remote Transducer Architecture

IEEE 802.11ah

A light version of the IEEE 802.11 wireless medium access norm is the IEEE 802.11ah and is designed to meet IoT requirements with minimum overhead. They have been widely adopted and used for all digital devices, like tablets, laptops, digital televisions (TVs) [25], and mobiles. However, the actual Wi- Fi standards are not suitable for IoT applications due to power consumption and their frame overhead. Subsequently, IEEE 802.11 working group introduced the 802.11ah task group to develop a norm that supports power-friendly communication, the lowest level overhead appropriate for sensors. 802.11ah is designed for low- power sensors and, consequently, permits a longer sleep period and waking up occasionally to exchange data only.

HomePlug

HomePlug Power line Alliance developed the HomePlug Green PHY which is a MAC protocol that is used in home automation applications. Both MAC and PHY layers use HomePlug. HomePlug AV (audiovisual), HomePlug AV2, and HomePlug GP [26] are the three editions of HomePlug. First (HomePlug AV) is the basic power line communication protocol that uses TDMA and CSMA, and CA as MAC layer protocol endorsement adaptive bit loading which permits it to transform its rate depending on the noise level. HomePlug AV uses OFDM (Orthogonal Frequency Division Multiplexing). HomePlug GP is deliberate for the Internet of Things generally. It is used for smart grid applications and home automation. Its design objective of it is to reduce power consumption and the expenditure of HomePlug AV with trustworthiness, interoperability, and coverage. Its power save mode permits nodes to sleep much more than HomePlug.

2. Network Layer Protocols in the Internet of Things (IoT)

This section discusses routing standard and non-standard protocols for IoT applications.

RPL

A distance-vector protocol that can authorize a variety of data link protocols is RPL (The Routing Protocol for Low Power and Lossy Networks) [27].

CARP

A distributed routing protocol developed for underwater communication is CARP (Channel-Aware Routing Protocol). IoT uses it due to its lightweight packets.

6LoWPAN

6LoWPAN (Low power Wireless Personal Area Network) is a protocol over IPv6 standards to be used in low-power wireless networks with IEEE 802.15.4. The IETF 6LoWPAN working group maintains it. The motivation for introducing 6LoWPAN is that the current IPv6 is too bulky for WSN. The IPv6 header is compressed to only a few bytes by introducing an adaptation layer that resides between the network and MAC/PHY layer while retaining the main IPv6 functionality in 6LoWPAN. The adaptation layer provides fragmentation and reassembly of The transmission of 1280 bytes IPv6 Maximum Transmission Unit (MTU) over IEEE 802.15.4. The detailed specification of this protocol is described in the IETF standard RFC4944. In House and Building automation, Mesh topology, Low bandwidth, variable-length addresses, scalability networks, low cost, Low power consumption, mobility, unfaithfulness, and prolonged sleep time are required that are supported by 6LoWPAN.

3. Session Layer Protocols in the Internet of Things (IoT)

This section is about the standards and protocols related to the IoT for message passing at the session layer proposed by different standardization organizations.

MQTT

In 1999 IBM proposed MQTT (Message Queue Telemetry Transport) as a messaging protocol. It is well-suited for low memory, low power, cheap, and small devices [29]. Initially, it was built for far-away tracking and monitoring sensor nodes in the Internet of Things. Publishers, subscribers, and a broker are the three main components of MQTT as shown in figures 15 A and 15 B.

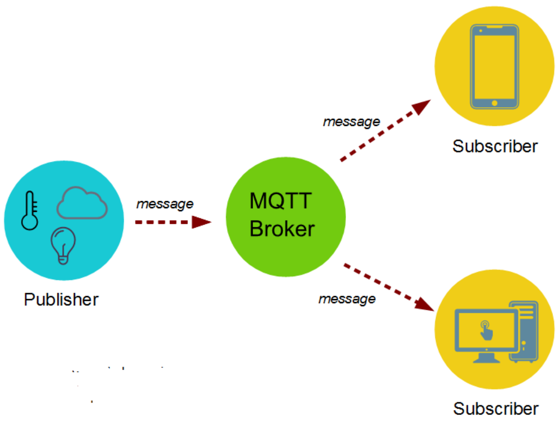


Figure 15 A: Standard MQTT Architecture

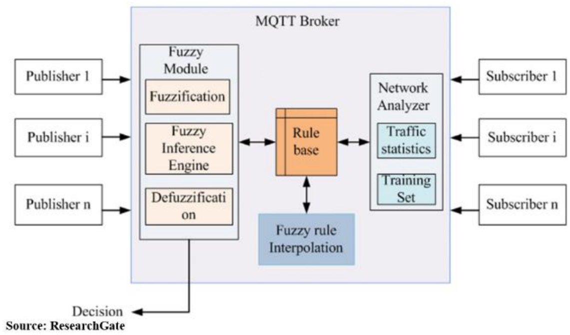


Figure 15 B: Proposed MQTT Architecture

AMQP

AMQP (Advanced Message Queuing Protocol) is a session layer protocol that was developed for the financial industry. It executes over TCP and provides a publish-subscribe architecture that is the same as that of MQTT. The two main components of a broker are swapping [30] and queues. It is best for end-to-end uses for selecting IoT use cases.

XMPP

For chatting and message exchange applications, XMPP (Extensible Messaging and Presence Protocol) messaging protocol was developed that is well known and has proven to be highly dexterous over the Internet. It has been reused in IoT applications and a protocol for SDN. The same standard is reused due to its use of XML (Extensible Markup Language).

4. Other Protocols in the IoT

This section is related to the other protocols in IoT.

REST

HTTP methods say that no client library is needed on the client-side, these features are used by the RESTful communications, useful for a much-uncomplicated sensor and device that only need one-way communication. Therefore, gaining RESTful POSTs can gain data from that sensor any service that can. Denial of getting any behavior of a messaging protocol [31] is compromised. If the server is unattainable or backlogged, data from the sensor will be missed, while the sensor application handles buffering and retries in the application code.

Sigfox

For the M2M applications, Sigfox was proposed and designed that can only send data at a low level. It is one of the best technologies which accepts the attributes of both WiFi and Cellular. Due to Ultra Narrow Band (UNB), Sigfox can grip speeds of 10 to 1000 bits per second for relocating low data. It works on 50 microwatts of power [50].

CoAP

Constrained Application Protocol (CoAP) is a protocol that uses low-power for computing devices on the Internet of Things and REST of HTTP methods, adds finite QoS (Quality of Service), and relies upon UDP only, [32] not TCP. At the beginning of IoT, it was developed for constrained device connectivity. MQTT standard is equivalent to constrained devices with the broader feature.

EnOcean

An innovative turn is EnOcean which is a wireless energy harvesting and sensing platform. It is perfect for designing devices whose response is based on alterations in lighting, temperature, and other patchy circumstance. Many applications are based on this IoT protocol in home automation, transportation, logistics, and industrial automation. Radio communication in IEEE 802.15.4 standard can be controlled by the EnOcean wireless energy harvesting technology [33]. This total suite enables several wireless applications, which work without wires and batteries. This platform is capable of handling the incorporation barriers very low. This empowers integration processes trouble-free, without the requirement for exhaustive knowledge of battery-less technology.

DDS

DDS (Data Distribution Service) was developed for connecting devices to other devices with minimum overhead. Its implementations have a direct D2D (Device-to-Device) data bus [28]. It can run over TCP, UDP, other proprietary networks, and shared memory. That depends on the transport layer for faithfulness.

XII. Conclusion

The Internet of Things (IoT) is still fast-growing, and industry required incidence. The components of the Internet of Things have various complexity from simple recognition tags to complex M2M (Machine-to-Machine) communication. Things are enriched day by day with communication and computing powers capable of superseding human scanning and reproducing senses in the virtual world. The IoT empowers a smarter bridging of human spheres, physical, and digital by together these capacities in a secure manner in a networked environment. This is true not only for the connected devices but also for the hardware, software, middleware, connectivity and communication protocols, and so much more to create IoT solutions. Further, it is also about many technologies and processes like Fog Computing, Cloud Computing, IoT gateways, Big Data, Analytics, IoT platform software, etc. This paper proposes IoT technologies with new taxonomy including MEMS and highlights some of the most important protocols and standards, a piezoresistive sensor, an electro-optical infrared sensor, and many more like these in the Web of Things (WoT), the Internet of Things, IoT challenges, so that, the IoT system becomes the State-Of-The-Art IoT system that will be developed and impact human life in incredible ways in future.

XIII. *References*

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