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IoT AND ITS CONNECTIVITY CHALLENGES IN SMART HOME

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Abstract – *The Internet of Things (IoT) has become an emerging concept in the area of communication and automation technology. The keen application of IoT can be observed in "Home Automation", where a simple home is transformed to 'Smart Home' by this technology. The Smart home connects most of the digital devices together and helps to communicate with the help of Internet network. Only the trouble is that each digital device follows a different protocol for communication and also may vary based on manufacturer. The primary aim of this report is to furnish an overview of Internet of Things, connectivity standards and some difficulties/challenges faced in the smart home network.*

Key Words: IoT, Challenges, Smart Home, Automation

1. INTRODUCTION

IoT represents a network of interconnected devices which communicates with each device and performs tasks as expected by the user. IoT is may be also set as the "interconnection of sensing and actuating devices, providing the power to share data across programs through a unified framework, producing a common operating picture for enabling advanced applications" [1]. Thus IoT aims to improve one's comfort and control strategies, by empowering collaboration among smart devices. The IoT is a technical revolution that represents the future of computing and communications, and its evolution depends on vital technical innovation in a number of important subjects, from wireless sensors to nanotechnology. They are starting to go after each object for identifying, automating, monitoring and controlling [2].

IoT is coined from two words, "Internet" and "Things". The Internet is a worldwide network which follows TCP/IP protocols to assist all the applications in the macrocosm. It is a mesh of networks that consists of millions of individual, public, academic, commercial enterprise, and government networks, of local to global scope, that are joined by a spacious array of electronic, wireless and optical networking technologies [3]. More than 190 countries are linked into exchanges of data, news and thoughts. According to Internet World Statistics, as of June 30, 2016 there was an estimated 3,631,124,813 Internet users worldwide, of which the increase rate was nearly 905.9% in the year 2000 – 2016. (Accessed data dated on 23/10/2016: from www.internetworldstats.com). This signifies that 49.5% of the world's population are using the internet. And the word "Things" implies the everyday objects include not only electronic devices and technologically advanced products like gadgets and equipment, but may also include food, clothing, furniture, home, material, parts, commerce, culture and comfort [4]. So, the "Things" are real objects in this physical or material world. By the introduction of IoTs, the field of home automation has grown at a rapid rate and many researches and developments has become popular. The gimmicks are being controlled by IoT concept for the amelioration of human life and to increase comfort, privacy and protection. To get it more intelligent, many researches and developments are performed in the arena of 'Home Automation'. Recent inquiries have also adapted wireless technologies to connect from remote offices to improve the intelligence of the home automation system. The internet helps us to bring in with immediate solutions for many problems and also capable to connect from any of the remote places which contributes to overall cost reduction and energy consumption [5].

For the effective implementation of IoT in home automation one of the major parts is communication technology or called as Connectivity. Some connectivity medium are Bluetooth, Wi-Max and Wireless LAN (Wi-Fi), ZigBee, and Global System for mobile communication (GSM) [6]. Even though in that respect are many advancements in communication technologies, there are some disadvantages which affects the operation. The main connectivity issues can be narrowed down to standards and challenges. The connectivity standards are considered the backbone of IoT as the choice of standards has an untoward impression on execution. The standards usually employed in IoT are Wi-Fi, ZigBee, Z-Wave, Bluetooth LE, Thread, etc., Some challenge factors in IoT communications are Interoperability, Self-Management, Maintainability, Signalling, Bandwidth and Power Consumption [7]. Depending on connectivity, cloud based IoT concepts is advantageous while considering energy dissipation and a hardware effort.

This report is coordinated as follows: Section 2 delineates the standard protocol used in the smart home network. Section 3 discusses the connectivity challenges and the protocols.

2. CONNECTIVITY STANDARDS

The wireless technology is growing in a rapid rate which gives the users to opt their connectivity standard by considering various characteristics of the standards. There are some 14 standards which are utilizing the connectivity standard for the IoT generally known as enabling technologies. RFID and near-field communication, Li-Fi, Optical tags and quick response codes, Bluetooth low energy, Low energy wireless IP networks, ZigBee, Z-Wave, Thread, LTE-Advanced, WiFi-Direct, HaLow, HomePlug, Ethernet, MoCA are some of the commonly used enabling technologies.

The Table 1 shows the characteristics of several standards used along with IoT in the home network. The highlighted standard are those which can be applied effectively in home automation [4, 7].

2.1 Wi-Fi:

WiFi enables communication between electronic devices such as smartphones, tablets, etc. 802.11ah has been the recently developed IEEE WiFi standard. It works in 2.4 and 5 GHz and that cut down the complexity of execution. The established WiFi standard 802.11 is only effective at the nearest access point and couldn't provide service to the users with large homes. But IEEE 802.11ah overcomes this as an ultra-low power version of the standards which offer longer range and easier connectivity that find attractive for IoT applications. Variation of wireless network protocols are being applied in smart home applications, like IEEE 802.11 (Wi-Fi), Bluetooth LE (Low Energy), cellular, ZigBee (a low-power wireless technology), Z-Wave and Thread.

2.2 ZigBee:

ZigBee is a low power wireless network technology. It uses digital radios based on IEEE 802.15.4 standard for Personal Area Network with a focus on monitoring, control and detector applications. It mainly operates in 2.4 GHz ISM band. The ZigBee Alliance is pushing the standard for home based devices, from temperature and lighting arrangements with security monitors and smoke sensors.

2.3 Z-Wave:

It is a low-power wireless communication protocol for home automation specifically to remote control application in residential and light commercial environments. It appears in broad range of consumer products all over the world. These include home theatre, automated window treatments, pool and spa control and automated meter readings.

2.4 Bluetooth LE:

Bluetooth LE (IEEE 802.15.1) is a standard intended to be a secured and a tawdry means of connecting and transmitting data between supported devices. Bluetooth LE has the frequency radio bands from 2.4 to 2.485 GHz. It importantly reduces the power consumption of Bluetooth devices and enables long term operation using coin cell batteries. Bluetooth offers an infrastructure of the direct connection from smartphones and tablets, leaving users to control household appliances from their mobile devices.

2.5 Thread:

It is a new IP based wireless mesh standard for the smart phone. This protocol supports IPv6 using 6LoWPAN. The thread is built on 802.15.4 physical layer.

3. CONNECTIVITY CHALLENGES IN SMART HOME NETWORK

3.1 Interoperability

Interoperability is a prime concern because consumers must have easy-to-connect and easy-to-use devices that simply work together. In a smart home network devices and systems comes from different vendors with different network interfaces, but nevertheless need to read to achieve join execution of projects. Interoperability is defined as the ability of systems, applications, and services to work together reliably in predictable style. It is the power of two or more systems exchange information and utilize the information that has been exchanged [8]. The immense success of WiFi is largely due to the remarkable interoperability program run by WiFi alliance. ZigBee 3.0 will permit a wider range of devices to seamlessly interoperate irrespective to their functional areas compare to its first version that went bad to attain interoperate. A blended solution that will enable ZigBee products to use the Thread protocol and a authentication course of study to ensure interoperability is the outcome of a partnership that the two groups announced in April 2015. It is also the latest step in consolidating a widely fragmented environment that includes myriad standards efforts around the Internet of things (IoT). WiFi alliance has one of the most trusted certificate regimes in the world with tens of thousands of certified devices that have demonstrated interoperability. The comprehensive certification programs defined by the Bluetooth SIG cover the full protocol stack as well as the application profile helping Bluetooth to achieve excellent interoperability in the market [9]. ZigBee and thread share basic physical specifications that would produce some level of interoperability between two standards, whereas a Z - wave technology on the market delivers application level interoperability.

3.2 Self-Management and Maintainability

Intelligent devices can monitor their own operating health and notify the users about the potential issues before they shut down. Several sensor network applications are operated without infrastructure support or the ability for maintenance and fixing. To operate and cooperate with other devices, to adapt to failures, changes in the environment, it is a principal requirement of the sensor nodes to be self-managed, which is intended to be entirely independent of human interference. The installation and deployment of Z-

Wave is simple with automatic address assignment for the ease of network management. Its anti-interference property is excellent with the support of random back-off algorithm, two-way acknowledgement and collision-avoidance. ZigBee has robust and self-formed mesh networking that allows for reliable data transfer. It is too flexible in networking with multiple topologies [10].

Maintainability is an essential requirement in a network that reflects how reliable and durable the smart home network is. Changes happen everywhere, including the home environment with, failing nodes tired batteries, and new tasks. So the subsystems in the smart home network have to supervise their own effectiveness and status in order to change operational parameters or to choose different services, such as offering lower quality with limited energy resources. The smart home network must be designed with the goal of easy maintenance that repairs the various devices and communication components quickly and cost-effectively [11].

3.3 Signaling

In a connected IoT network of devices, reliability of bidirectional signaling is vital for collecting and routing data between devices and here the IoT data streams plays the role. All the devices in the smart home network may communicate to a server to collect data, or the server talks to the devices, or say those devices are communicating with each other. The central point is, data needs to get from point A to point B quickly and dependably. You need to be 100% sure that stream of data is proceeding to arrive at its goal every time [7, 11]. When considering the Wi-Fi standard it has signal loss, whereas ZigBee and z-wave has no signal loss because of their low bandwidth that causes these two standards great for devices which needs only data connections to on or off. Z-wave uses a low frequency radio band 908.4 MHz (US) and its devices will not interpose with a Wi-Fi mesh. The protocol thread uses radio communication in 2.4 GHz band that might interfere with WiFi signals. The thread doesn't have a hub, and because it's a fully distributed mesh network, with no single point of failure, it means that we get additional reliability and range in our home.

3.4 Bandwidth

Bandwidth consumption is another challenge for IoT connectivity. Managing bandwidth in home network also become crucial. With the increasing number of personal and household devices, huge amount of data has been created, and as a result bandwidth requirement is common in modern houses. Video stream in particular has become the application that demands the highest measure of bandwidth. It produces a huge server issue that requires a large scale server for handling all this data. So a lightweight network can seamlessly transport information between devices and hosts. Wi-Fi is a high bandwidth network that is power intensive whereas Bluetooth LE has higher data bandwidth than ZigBee and Z-Wave (lower than Wi-Fi).

3.5 Power consumption

The devices connected in IoT smart home can determine the best time to operate which in turn provide higher efficiency in power consumption. Thousands of IoT devices connected in the smart home send signals and data round the clock between one another toll on power and CPU use. An efficient IoT network needs minimal battery drain and low power consumption in such communication. Power consumption is high in Standard Wi-Fi. Bluetooth Low Energy is better in power consumption, but has a limitation in signal range and the number of devices. ZigBee based networks generally consume 25% of the power of Wi-Fi networks and Z-wave has limited power consumption than WiFi, but the data transport rate is sluggish compared with Wi-Fi. The thread is designed to be battery friendly and requires very little energy to operate. Devices efficiently communicate to deliver a great user experience, yet still run for years on the smallest of batteries.

4. CONCLUSION

The smart home networks are currently influencing the people for a quality life style. Soon IoT will connect even the simplest devices in the home to the internet. This paper summarizes the available standards in the market which are the building blocks of the home network and innovation. Also the challenges in the smart home network are addressed based on its connectivity. For low power needs ZigBee modules are used and for higher bandwidth applications Wi-Fi is dominant. Hence the degree of standardization between the protocols is low in a smart home network. A standard base that supports interoperability with multiple wireless protocols will become a solution for a smart functioning of a smart house in the close future.

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Table -1: Characteristics of Various Wireless Protocol

S.No	Wireless Protocol	Characteristics							
		IEEE Standard	Frequency band	Nominal range	Peak current consumption	Power consumption/bit	Data Rate	Network topology	Number of nodes/network
1	RFID and near-field communication	802.15.4f	2.4 GHz, 5 GHz	2m	Low power	Low	640 kbps	Hybrid	one-to-many
2	Li-Fi	802.15.7r1	2.4 GHz	32m	Lower Power Level	Low	1 Gbps	Hybrid	Point to point
3	**Bluetooth low energy**	802.15.1	2.4 GHz	10 m	12.5 mA	0.153 µW/bit	1 Mbps	Star-Bus	one-to-many
4	**ZigBee**	802.15.4	2.4 GHz	100 m	30 mA	185.9 µW/bit	250 Kbps	Star, Cluster, Mesh	65000
5	**Z-Wave**	N/A	900 MHz	30m	17 mA	0.71 µW/bit	100 Kbps	Mesh	232
6	**Thread**	802.15.4	2.4 GHz	30m	12.3 mA	11.7 µW/bit	250 kbps	Mesh	300
7	LTE-Advanced	802.16	1850 MHz to 3800 MHz	Miles	High	N/A	1000 Mbps	High	Higher
8	**WiFi**	802.11	2.4 GHz, 5 GHz	150 m	116 mA	0.00525 µW/bit	1Gbps	Star, Mesh	250/access point
9	HaLow	802.11ah	900-MHz	>Wifi	Low power	N/A	1Gbps	N/A	N/A
10	HomePlug	1905.1	86.13MHz	30m	Low Power	N/A	85Mbps	N/A	N/A
11	Ethernet	802.3	N/A	>100m	Low Power	N/A	2.94Mbps	Most of the Topology	N/A

TABLE 1: Characteristics of various Wireless Protocols
*The highlighted are most commonly used connectivity standard