A Review of Connectivity Challenges in IoT-Smart Home

S.Sujin Issac Samuel
Department of Computing,
Middle East College,
Muscat, Sultanate of Oman
sujin@mec.edu.om

Abstract— **The Internet of Things with its enormous growth widens its applications to the living environment of the people by changing a home to smart home. Smart home is a connected home that connects all type of digital devices to communicate each other through the internet. These devices form a home area network where communications are enabled by different protocols. As these devices are designed by different companies with different standards and technologies there is a problem exists in their connectivity. This paper aims at describing the wireless standards used in home network and how these protocols face the connectivity challenges in the smart home network.**

Keywords—Smart Home Network; IoT; Wi-Fi; Bluetooth Low Energy; ZigBee; Z-Wave; Thread.

I. INTRODUCTION

A home that provides intelligent living environment for daily convenient life is a smart home. In smart homes all the household digital devices are connected to the internet to monitor, manage, control, and automate every piece of electronics in the home. Nowadays, Internet of Things (IoT) means advanced connectivity of anything such as devices, systems, and provide access to the users at any time in anyplace [2]. The connected devices in the smart home form a home network that deals with various devices, digital appliances and handles different kind of network devices. There are many communication schemes and interfaces are used within a home network and these connections should enable smooth communication among the devices without interference with other wireless networks.

M2M architecture is almost similar to IoT. Including various range network protocol and platform. While M2M growth projections are high, the related smart home network has been unable to keep pace with the complex requirements. In addition, the current M2M market is highly fragmented and standardization levels are low. There are a number of diverse players that need to collaborate to arrive at a specific solution. Whether it's the end equipment, the connectivity piece, the middleware, or the back-end systems – there are multitude of options available for any M2M[6]. Connectivity is the backbone of IoT that is established by communication standards variety of wireless network protocols are being used 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. As the home network builds with products from different vendors and connected with different protocols, certain challenges have to be faced in connectivity within the smart home. Each appliance in a home connects to the control system or internet in its own unique way. Depend on connectivity, cloud based IoT concepts are advantageous when consider energy dissipation and a hardware efforts.

This paper is organized as follows: Section 2 describes the standard protocols used in smart home network. Section 3 discusses the connectivity challenges and the protocols. Section 4 gives the typical infrastructure for the smart home network.

II. CONNECTIVITY STANDARDS

Smart home systems can be challenging with evolving wireless connectivity standards that are relevant for smart home applications. Table 1 shows the characteristics of different wireless standards that can be applied in home network.

Wi-Fi*:*

WiFi enables communication between electronic devices such as smartphones, tablets etc. 802.11ah is the recently developed IEEE WiFi standard. It operates in 2.4 and 5 GHz and that reduce the complexity of implementation. 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 provide longer range and easier connectivity that find attractive for IoT applications. Variety of wireless network protocols are being

978-1-4673-9584-7/16/$31.00

used 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.

***ZigBee**:*

ZigBee is a low power wireless mesh technology. It uses digital radios based on IEEE 802.15.4 standard for Personal Area Network with a focus on monitoring, control and sensor 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 systems to security monitors and smoke detectors.

***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 includes home theater, automate window treatments, pool and spa control and automated meter readings.

***Bluetooth LE**:*

Bluetooth LE (IEEE 802.15.1) is a standard intended to be a secured and a cheap way of connecting and transferring data among supported devices. Bluetooth LE has the frequency radio bands from 2.4 to 2.485 GHz. It significantly reduces the power consumption of Bluetooth devices and enables long term operation using coin cell batteries. Bluetooth offers an infrastructure of direct connection from smartphones and tablets, allowing users to control home appliances from their mobile devices.

***Thread**:*

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

TABLE I. CHARACTERISTICS OF HOME NETWORK WIRELESS STANDARDS

Wireless Protocol / Characteristics	ZigBee	WiFi	Thread	Z-Wave	Bluetooth LE
IEEE Standard	802.15.4	802.11	802.15.4	N/A	802.15.1
Frequency band	2.4 GHz	2.4 GHz, 5 GHz	2.4 GHz	900 MHz	2.4 GHz
Nominal range	100 m	150 m	30m	30m	10 m
Peak current consumption	30 mA	116 mA	12.3 mA	17 mA	12.5 mA
Power consumption per bit	185.9 µW/bit	0.00525 µW/bit	11.7 µW/bit	0.71 µW/bit	0.153 µW/bit
Data Rate	250 Kbps	1Gbps	250 kbps	100 Kbps	1 Mbps
Network topology	Star, Cluster, Mesh	Star, Mesh	Mesh	mesh	Star-Bus
Number of nodes per network	65000	250/access point	300	232	one-to-many

III. CONNECTIVITY CHALLENGES IN SMART HOME NETWORK

A. 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 still need to interoperate to achieve join execution of tasks. Interoperability is defined as the ability of systems, applications, and services to work together reliably in predictable fashion. It is the ability of two or more systems exchange information and use the information that has been exchanged [8]. Huge success of WiFi is largely due to the remarkable interoperability program run by WiFi alliance. ZigBee 3.0 will allow a wider range of devices to seamlessly interoperate irrespective to their functional areas compare to its first version that failed to attain interoperate. A combined solution that will enable ZigBee products to use the Thread protocol and a certification program to ensure interoperability is the result 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 proven interoperability. The comprehensive certification programs defined by the bluetooth SIG cover the entire protocol stack as well as the application profile helping bluetooth to achieve excellent interoperability in the market [4]. Zigbee and thread share basic physical specifications that would create some degree of interoperability between two standards whereas Z-wave technology on the market delivers application level interoperability.

B. Self-Management

Intelligent devices can monitor their own operating health and notify the users about the potential issues before they shutdown. Several sensor network applications are operated without infrastructure support or the ability for maintenance and repair. To operate and collaborate with other devices, to adapt to failures, changes in the environment, it is a main requirement of the sensor nodes to be self-managed, which is meant to be completely independent of human intervention.

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 also flexible in networking with multiple topologies [7].

C. Maintainability

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 smart home network have to monitor their own strength and status in order to change operational parameters or to choose different services, such as providing 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 [1].

D. 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 smart home network may be communicate to a server to collect data, or the server talks to the devices, or say those devices are communicating with each other. The key point is, data needs to get from point A to point B quickly and reliably. You need to be 100% sure that stream of data is going to arrive at its destination every time [1] [5]. 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 makes 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 interfere with a Wi-Fi network. The protocol thread uses radio communication in 2.4 GHz band that might interfere with Wi-Fi signals. 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.

E. Bandwidth

Bandwidth consumption is another challenge for IoT connectivity. Managing bandwidth in home network also become crucial. With the increasing number of personal and home devices, huge amount of data has been created, and as a result bandwidth requirement is common in modern homes. Video stream in particular has become the application that requires the highest amount of bandwidth. It creates a huge server issue that needs a large scale server for handling all this data. Therefore a lightweight network can seamlessly transfer data between devices and servers. 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)

F. 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 sends signals and data round the clock between one another toll on power and CPU consumption. An efficient IoT network need 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 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 Wi-Fi but the data transfer rate is slow compared with Wi-Fi. 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.

IV. INFRASTRUCTURE

Looking at the existing connection schemes in a smart home, Wi-Fi plays an important role and largely driven by PCs and handheld devices. Traditionally Wi-Fi has high data rate and consumes more power. Recently there has been a push towards a new standard IEEE 802.11ah for IoT applications that offers longer range at lower data rate and power. Another option offered for the connected devices by ZigBee. Variety of products like smart meters, thermostats, light bulbs, electric vehicle charging stations uses ZigBee. Coming to mesh connectivity and network authentication another wireless protocol Thread plays an important role.

The primary design consideration pertained to connectivity is to choose networking and routing protocols that offers scalable, versatile and management solution. Evaluating the networking and routing parameters is hard in physical network. So software simulator can be used to obtain the required data. To access web based services CoAP (Constrained Application Protocol) is used to provide reliable and flexible way to remotely obtained sensor and network data [3].

Bandwidth delivered to a home or business is useless unless it can be distributed to user devices. Distributing bandwidth and managing connected devices is the job of a home network, and home networking technologies continue to improve, becoming faster, more reliable and more energy efficient with each succeeding generation [9].

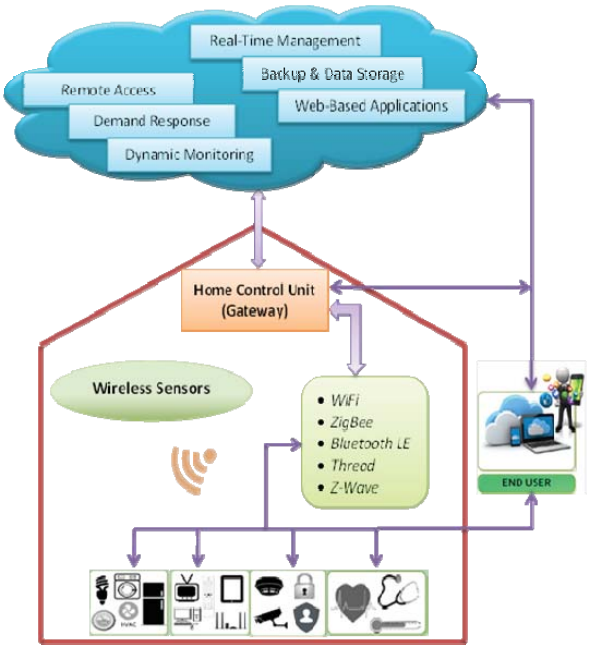

Fig.1. Smart home devices accessed through wireless standards.

The system consists of several smart nodes in a home area network incorporated with several sensors. The sensors like light, solar, temperature and humidity are connected depending on the technology and hardware used. The sensor nodes are connected to a gateway device or Home Control Unit (HCU) using any of the wireless standards. The gateway device basically acts as a bridge for sending data from wireless sensor network to Internet. Web based system or mobile application can be used to read nodes and sensor data from the internal database and display to the users. Fig. 1 describes the typical global network framework that provides access to the smart home devices.

V. 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 infrastructure that supports interoperability with multiple wireless protocols will become a solution for a smart functioning of a smart home in the near future.

References

[1] Mendes, T. D., Godina, R., Rodrigues, E. M., Matias, J. C., & Catalão, J. P., "Smart home communication technologies and applications: Wireless protocol assessment for home area network resources", Energies, 8(7), 7279-7311, 2015.

[2] Cho, Ji Yeon, Hye Sun Lee, and Bong Gyou Lee, "Connectivity Issues on IoT Business-The Korean Case of Smart Home Network." The Second International Conference on Electrical, Electronics, Computer Engineering and their Applications (EECEA2015), 2015.

[3] Joshi, Manveer, and Bikrampal Kaur. "Web Integrated Smart Home Infrastructure Using Internet of Things", International Journal of Engineering Research and General Science Volume 3, Issue 6, 2015.

[4] Reiter, Gil. "Wireless connectivity for the Internet of Things." Europe 433, 868MHz, 2014.

[5] Todd Greene, 5 Challenges of Internet of Things Connectivity, 2014, unpublished.

[6] Sukriti Jalali, Shalini Arora, Technology Review and Trends in M2M Communication, White Paper, Tata Cosultancy Services, 2012.

[7] Cheng, Jin, and Thomas Kunz. "A survey on smart home networking."Carleton University, Systems and Computer Engineering, Technical Report, SCE-09-10, 2009.

[8] Perumal, T., Ramli, A. R., Leong, C. Y., Mansor, S., & Samsudin, K., Interoperability for smart home environment using web services. International Journal of Smart Home, 2(4), 1-16, 2008.

[9] Masha Zager, Connected Homes Will Need More Bandwidth, Broadband Communities, 2013, unpublished.

[10] Bhide, Vishwajeet H. "A Survey on the Smart Homes using Internet of Things (IoT).", International Journal of Advance Research in Computer Science and Management Studies, Volume 2, Issue 12, 2014.

[11] White paper, Overcoming Challenges of Connecting Intelligent Nodes to the Internet of Things, Silicon Laboratories, Inc., 2012

[12] Zachariah, T., Klugman, N., Campbell, B., Adkins, J., Jackson, N., & Dutta, P.,. The Internet of Things Has a Gateway Problem. In Proceedings of the 16th International Workshop on Mobile Computing Systems and Applications (pp. 27-32). ACM., 2015.

[13] Yong-Geun Hong, Internet based IoT connectivity Technologies, ETRI Protocol Engineering Center, 2015, unpublished.

[14] Gong, Qingchao, Guangming Li, and Yong Pang. "Design and Implementation of Smart Home System Based on ZigBee Technology." International Journal of Smart Home 8.6, 2014.