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COMPARISON BETWEEN ZIGBEE AND Z-WAVE TECHNOLOGIES

salih saad garash
Department of electrical and computer
Libyan academy
Tripoli, Libya
Email: salih.garash@academy.edu.ly

Abstract— The market for the Internet of Things (IoT) is continuing to grow and become more commonplace for consumers and engineers alike ,Home automation systems represent the front-end of smart grids, There are many home automation technologies available in the market. Two popular IoT technologies are ZigBee and Z-Wave. Users of smart homes are facing challenges of selecting the best technology, both are great wireless solutions for home automation, smart energy, telecommunications, health care, remote control. In this paper, after overview of the on networks topologies ,Protocol Stack , Applications , of ZigBee, Z-Wave technologies ,we attempt to make a comparison of them about Speed and Compatibility, Connectivity ,Data rate , power consumption ,Frequency Range ,Cost . The results of this study the users can make the appropriate choice of technology to use in home automation systems.

Keywords- home automation, ZigBee ; Z-Wave; IoT

I. INTRODUCTION

Home automation industry has drawn considerable attention of the researchers ,The main idea is to automatically control and monitor electrical and electronic home appliances Revenue in the Smart Home market is projected to reach US$115.70bn in 2022, the number of active households is expected to amount to 573.7m users by 2026 [1] . The vision of the Internet of Things (IoT) is to build a smart environ-mint by using objects (wireless sensor, RFID, smart phone, wearable's ...), which have the ability to collect information from the environment in which they are deployed, store it, process it, and transmit it using an Internet gateway for decision making [2].

In smart homes, automation systems are used to monitor and control the energy usage of electrical appliances and equipment [3], there are many other devices that can be connected to the home automation systems such as temperature sensors motion sensors. A typical home automation system (WHAS) consists of battery operated low power wireless sensors and actuators attached with the home appliances. These sensors and actuators are connected to a backbone wireless network, smart home market is growing rapidly with the entry of more players in consumer electronics such as Samsung and LG, These companies have announced products and services that could rapidly grow the smart home industry, In wireless-based home automation system, different types of technologies and each technology having its own advantages and disadvantages. When it comes to home automation systems, ZigBee, Z-Wave, Wi-Fi, and Bluetooth are the current technologies we use for communication [4].

The of this paper is organized as follows, the next section show ZigBee Technologies ,Section 3 explains Z-Wave Technologies, Section 4 include Comparison Between ZIGBEE and Z-Wave Technologies ,Section 5 contains a Advantages and disadvantages of the two technologies, Finally, this paper is concluded with section 6.

II. THE ZIGBEE TECHNOLOGY

ZigBee alliance is responsible for ZigBee standard and IEEE is for IEEE802.15.4. ZigBee (software) defines the network, application security application layers, ZigBee (hardware) defines the physical and media access control layers for LR-WPAN [5]. ZigBee has three radio bands that operate in 868MHz, 915MHz, and 2.4GHz with low-power consumption and range of 300 meters. It can accommodate up to 6000 devices..

A. ZIGBEE STANDARD

ZigBee devices are a combination of ZigBee logical and physical device types .ZigBee device are the combination of application such as sensors , and ZigBee physical device types (FFD , RFD) [6] .

1. ZigBee physical device types

Full Function Devices (FFD) , can perform all available operations within the standard, as routing mechanism, sensing tasks and coordination task. Reduced Function Devices RFDs do not route packets, these are end devices only doing limited tasks like monitoring lighting.

2. ZigBee logical device types

There are 3 ZigBee logical devices – Coordinators, Routers and End Devices. (FBSS).

- *Coordinator* There is exactly one coordinator in each network. It is root of the network tree and might bridge to other networks, It is responsible for initiating the network and selecting the network parameters such as

unique network identifier and radio frequency channel, setting other operational parameters.

- *Routers* It is root of the network tree and might bridge to other networks, It is responsible for initiating the network and selecting the network parameters such as radio frequency channel and unique network identifier, setting other operational parameters.
- *End Devices*: They can collect various information from sensors and switches. The end devices depend on a coordinator or router to send the data and it cannot relay data from other devices, each of these devices has 240 end nodes. The same ratio.

3. *Access Modes:*

Two ways of multi-access in ZigBee protocol, are Non-beacon and Beacon, in beacon nodes can only transmit in predetermined time slots. In Non-beacon enabled network, every node in the network can send the data when the channel is free. All devices should be synchronized for this process. This will be achieved by sending beacon signal. The coordinator is responsible to transmit beacon signals to synchronize the devices attached to it [7].

B. ZIGBEE PROTOCOLS STACK

. ZigBee builds on IEEE standard 802.15.4 which defines the physical and media access control (MAC) layers. Protocol architecture is based on Open system interconnection (OSI). ZigBee alliance defines the application layer and network layer. Fig.1 shows protocol stack of ZigBee system.

FIGURE 1. ZIGBEE PROTOCOL STACK

- **Physical Layer**: The physical layer of the IEEE802.15.4 standard is the closest layer to the hardware, which control and communicate with the radio transceiver directly. It handles all tasks involving the access to the ZigBee hardware, including initialization of the hardware, channel selection, link quality estimation, energy detection measurement and clear channel assessment to assist the channel selection. Three frequency bands Supports, 2.45GHz band which using 16 channels, 915MHz band which using 10 channels and 868MHz band using 1 channel.
- MAC Layer: This layer provides interface between physical layer and network layer, The Mac layer is responsible for the generation of a beacon if the device transmitting signal is a ZigBee coordinator. ZigBee devices can interact with each other regardless of manufacturer (even if the message is encrypted).
- Network Layer: This layer is responsible for taking up tasks such as setting up a network ,routing, configuring different devices in the same network. End-to-end device connection ,this layer Provides network wide security.
- Application Layer: It is the topmost layer in the protocol suite, ZigBee specification separates the APL layer into three different sub-layers, ZigBee device objects, Application support sub layer, and Application Framework.

1. ZigBee Device object: this layer is it provides service discovery, security, and binding [8] .
2. Application support sub layer: helps this sub layer in decoding the frames from a node and managing the cryptographic keys that are used to encrypt and decrypt the data at the nodes.
3. Application objects (APO): helps in controlling and maintaining all the protocols that are necessary to run a ZigBee device.

C. ZIGBEE topologies

There are following topologies:

- Star Topology: Star topology consists of one coordinator and any number of end devices. In star topology a master slave network model is adopted where master is the ZigBee coordinator which is FFD and slave will be either FFD or RFD. Devices can only communicate with the coordinator-transmitter.
- Mesh Topology: In mesh topology, each node can communicate any other node within its range. Mesh topology is complex to maintain and beaconing is not allowed here. But it is more robust and tolerance to fault.
- Cluster Tree Topology:. The difference is that other nodes can communicate with each other. The advantage is the possible geographical expansion of network. Cluster tree topology is similar to the star topology, and Fig.2 shows ZigBee Topology..

protocol supports automatic topology discovery and healing to detect new network location and routes and optimize the routing tables [9].

- Application layer this layer is responsible for parsing the frame payload and decoding the Z-Wave commands and supplied parameters, takes care of control of payloads in the frames received or to be transmitted. If the node was a Z-Wave controller device the decoded command and associated parameters will be forwarded to the controller software running on the home control computer or appliance.

Figure 2: ZigBee Topology

III. Z-WAVE TECHNOLOGY

Z-Wave is a proprietary wireless communications protocol designed for home automation ,It uses simple, reliable, low-power radio waves that easily travel through walls, floors and cabinets, such as lighting, home access control, entertainment systems and household appliances.

A. Z-Wave protocol stack

The z-wave protocol layers main function is to communicate very short messages of few bytes long from a control unit to one or more z-wave nodes, as fig-3 shown, z-wave protocol stack consists of 5 layers (PHY layer, MAC layer, Transport layer, network layer and application layer), and Following are the major functions of these protocol layers:

- Physical layer takes care of modulation and RF channel assignment as well preamble addition at the transmitter and synchronization at the receiver using preamble. It also takes care of RF channel allocation as desired. The input for configuring the z-wave PHY is data rate (9.6 or 40 or 100 Kbps).
- MAC layer takes care of Node ID and Home ID, controls the medium between nodes based on collision avoidance and back off algorithms.
- Transport layer takes care of transmission and reception of frames, takes care of retransmission, ACK frame transmission and insertion of checksum. Transport layer relies on a frame checksum value to detect and discard erroneous frames. is mainly responsible for retransmission, packet acknowledgment, waking up low power network nodes (Beaming) and packet origin authentication,
- Network layer takes care of frame routing, topology scan and routing table up, In order to determine the best route to a destination node, each device in the Z-Wave network maintains a network topology that indicates all other devices in proximity. The Z-Wave

As fig-3 z-wave protocol stack

B. Z-Wave Topology

A network topology defines the way various components communicate with each other within an IoT network, Topologies can vary greatly in security complexity, cost, and power consumption.

Z-Wave Network Topology Basic Principles

The following is a summary of the basic Network topology principles established by ITU-T G.9959 [10], Groups of nodes are divided into domains:

- The division of physical nodes into domains is logical. Domains may fully or partially overlap each other's radio frequency ranges
- The Z-Wave Network Layer supports up to 232 domains.
- Each domain is identified by a unique Home ID.
- Management of different domains in the same physical media is handled by individual domain masters.

The domain is a set of nodes connected to the same medium:

- One node in the domain operates as a domain master, known as the Primary Controller.
- Each domain may contain up to 232 nodes (including the domain master).
- Each node in the domain is identified by a Node ID that is unique within the actual domain.
- Nodes of the same domain can communicate with each other either directly or via other nodes in the same domain.

Z-Wave Mesh topology

Mesh topology is widely employed to extend the coverage of short-range wireless technologies such as ZigBee, Z-Wave, and Wireless HART. Most mesh networks have a self-healing capability as data can be re-routed using another path if one repeater node fails, thereby enhancing robustness. A sensor node, serves as both an endpoint that captures and transmits their own data as well as a repeater that relays data from other nodes. In a partial mesh network, only selected nodes have the repeater/relaying function and are connected with more than one other node, while in a full mesh network, all nodes are homogeneous and fully interconnected to each other. The figure 4 shows the Z-Wave Network Topology.

The figure 4 Z-Wave Network Topology

Z-Wave Applications

Z-wave is currently supported by over 200 technology vendors worldwide and it is becoming increasingly popular It is a low-frequency, reliable, and easy-to-use technique to manage and operate your household equipment without needing you to be physically present. Some common applications of Z-wave technology include:

- Lighting - Using Z-Wave technology with the home electronics such as lighting, security lights, etc. these appliances can be controlled and monitored via remote control.
- Air Conditioners/Heaters - With Z-Wave enabled thermostats, air conditioners can be operated remotely to lower or raise temperatures, switch off and on the appliance, and various other controls.
- Home Security Systems Z-Wave is very useful also when it comes to managing home security. For example, with a Z-Wave enabled door, you can open or close the doors or the main gate to your house. A Z-Wave enabled garage door can trigger lights and a webcam, which would allow the users to monitor their home from another place. You can also activate and deactivate a home security system via remote control.
- Home Entertainment Z-wave technology is great for home audio and video applications, too. You can do lot of things with Z-Wave enabled entertainment electronics such as playing a DVD, stopping it, etc. You can also turn on radio, change the frequency, and more

IV. ADVANTAGES AND DISADVANTAGES OF ZIGBEE AND Z-WAVE TECHNOLOGIES

This show section the advantages and disadvantages of the two technologies OF ZIGBEE and Z-WAVE.

A. ZIGBEE technology

ZigBee technology is used by applications that require a low rate of data, and hence the technology needs long battery life and safe networking, table shows following the Comparison between advantages and disadvantages of ZigBee Technology.

TABLE 1 ADVANTAGES AND DISADVANTAGES ZIGBEE TECHNOLOGY

Advantages	Disadvantages
The ZigBee technology has high node support. It can support thousands of nodes under a single network.	Since the technology used in ZigBee is of low bit rate, the transmission rate of this technology is also low.
This technology is apt for devices with low power since its bandwidth requirements are low.	ZigBee has many security threats like stealing of nodes, loss of services provided by the network, theft of data, etc. It also has compatibility issues.
The ZigBee technology has a flexible structure. It has an easy installation process and also has long battery life.	Implementing a ZigBee technology is quite expensive as the size and range of the network affect the cost.
Since this technology is a mesh network, its transmission range can be expanded by connecting nodes to the network, which acts as repeaters.	The ZigBee technology can get altered by the Z-Wave wireless communication since the latter provides better stability and range.
Zigbee technology is easy to control and monitor with the help of a remote. There is no existence of a central controller.	This technology is very prone to network interferences because it uses the 2.4 GHz band, which is also used by other wireless devices.

B. Z-Wave technology

The main objective of a smart or home is to make your living simpler and more pleasant, and to increase your security and comfort. Z-Wave It meets all the requisites for creating the ideal smart home and smart living, following are the most important technical features Z-Wave:

- **Simple installation:** Installation of most Z-Wave devices is as simple as replacing a light bulb - just about anyone can do it, To start using an electronic Z-Wave device such as a light switch just switch it on, add it to the Z-Wave network. Z-Wave is a wireless

technology, so its installation doesn't require any additional cabling.

- **Low Interferences** advantage of Z-Wave is that it does not suffer from major radio interference issues and physical obstructions because it operates around the 900 MHz band of the electromagnetic spectrum compared to the 2.4 GHz band used by Wi-Fi 2.4 GHz, Bluetooth, and ZigBee.
    - **Cost:** advantage of Z-Wave in comparison to traditional smart home solutions is its affordability because the installation does not require a specialist contractor or construction work, and you can choose to expand your system at any time, Z-Wave home automation solutions are suitable and available for everyone.
    - **Energy efficiency**: The ability to save power is very important. Some Z-Wave devices, such as temperature and motion sensors or thermostats, are battery powered. Energy efficiency is thus paramount. Z-Wave devices are optimized for energy efficiency with a typical battery life of one year and more.
    - **Interoperability and availability of devices:** All Z-Wave devices are fully interoperable. That means you are not tied to a single manufacturer when implementing a home automation solution. So your investment is better protected compared to using a proprietary solution from a single manufacturer.

DISADVANTAGES OF Z-WAVE

Following are the disadvantages of Z-wave:

- The coverage is limited and hence requires more z-wave devices to cover larger region
- Limited Number of Nodes only supports up to 232 nodes
- It supports only tree topology structure , which has specific disadvantages to include difficulty in configuration
- Implementation Cost: A system based on Z-Wave is relatively inexpensive to deploy because there is a wide selection of affordable devices in the market
- Security Issues : This is due to the fact that z-wave works on RF (Radio Frequency) and it is wireless in nature which can be accessed from anywhere
- Z-wave is supports less data communication speed up to 100 kbps which is less compare to ZigBee [11].

V. COMPARISON BETWEEN ZIGBEE AND Z-WAVE TECHNOLOGIES

Both Z-Wave and ZigBee are wireless technology used to connect smart home devices to each other and the internet, In this section, i will show the main differences between the two techniques:

A. Frequencies

Both types use different radio frequencies. ZigBee uses a frequency of 2.4 GHz or 915 MHz while Zwave uses a lower frequency, Therefore, a ZigBee device cannot interact with a Z Wave network and vice-versa.

B. Speed

ZigBee is faster than Z-Wave. ZigBee transmits data at 250 kbps compared transmission rate of 100 kbps for Z-Wave's. ZigBee is faster, hands down, when it uses its 2.4 GHz frequency. The problem is, you sacrifice power consumption for speed.

C. Compatibility

ZigBee and Z-Wave are not compatible since they use different frequencies, Z-Wave devices all work together, while there are some versions of ZigBee that don't work with each other. Table 2 network simulation parameters

D. Connectivity

A Z-Wave can support up to 232 smart devices connected at once, but it's limited to only four hops for information to get from one compatible device to another. ZigBee supports more than 65000 devices and supports an unlimited number of hops. Table 4 show comparison between ZIGBEE and Z-WAVE

TABLE 2 COMPARISON BETWEEN ZIGBEE AND Z-WAVE TECHNOLOGIES

basic	ZigBee	z-wave
Released (Year)	2004	2001
Inventor	ZigBee Alliance	ZenSys Corp.
Primary Markets	Industrial Automation, Research, Home Automation, Telecommunications, Healthcare	Home Automation
Data rate	250 Kbit/s	40 Kbit/s
power consumption	40 MA	2.5 MA
range	10/20 M	30/65 M
Frequency Range	2.4 GHZ	900 MHZ
Encryption	128-bit AES	128-bit AES

Max Nodes Connected	65,536	232
Modulation	Quadrature phase-shift keying (OQPSK)	Gaussian frequency shift keying (GFSK)
Network Topology	Mesh, Cluster ,star	Mesh
Cost	Low	High
Interoperability	Same manufacturer	Different manufacturers
Battery Life	Up to 7 years	12-14 months
Number of hops allowed	30	4

IV. CONCLUSION

In this paper, a comparison of popular home automation technologies is presented, are ZigBee and Z-Wave technologies. Both smart home device control protocols have certain advantages and disadvantages, the user's selection of suitable wireless technology for home automation is dependent on the requirements of your selected application. Z-Wave is the best choice if the criteria of interest is energy saving, or the user is interested in using different devices from different manufacturers, ZigBee preferred technology by many, mainly because of the fact that it is an open standard. In addition, ZigBee offers high data security and reliability, and strong data encryption capabilities. ZigBee allows for over 65,000 devices while Z-Wave only permits 232 nodes, But, the major disadvantage is its noncompliance by different manufacturers.

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