Hamad M. Alfouzan. International Journal of Engineering Research and Applications
www.ijera.com
ISSN: 2248-9622, Vol. 13, Issue 2, February 2023, pp. 18-23

RESEARCH ARTICLE OPEN ACCESS

Communication of Smart Homes Automation Systems

Hamad M. Alfouzan
Corresponding Author: Hamad M. Alfouzan
Public Authority of Applied Education And Training

Date of Submission: 01-02-2023 Date of acceptance: 11-02-2023

In this era communications have reached new peaks thanks to the advancements in electronic components and software development. The convergence of the World Wide Web of Internet with the world of GSM-Global System of Mobile Communication Network, created the biggest world wide network so far. And with the introduction of 5G Mobile Networks communications have heightened again even higher to include but not limited to new areas in Artificial Intelligence, Robotics, Autonomous Vehicles, and other means of smart automations such as Smart Homes and buildings.

Such technologies are possible because of the advancement of communications, not only on the level of human to human but also inter-devices (eg. Cars) or externally between electronic devices and controllers throughout multiple communicating components (eg. IOT - Internet Of Things devices). Moreover, communications can span over several mediums such as wired, optical, and or wireless mediums. In order for such systems to communicate properly they must speak the same language within each communication stream, thus communication protocols have been developed spanning over the 7 layers OSI model[1].

Communication mediums:

Communication mediums are divided into two groups, wired, and wireless.

Wired Communication Mediums:

Wired communication mediums are physically connected devices usually using copper wiring, most commonly used is twisted pairs or coaxial cables, such devices connect together directly or through centralised hub or switch. A common example of a wired communication medium is LAN (Local Area Network), LANs use Ethernet connections to connect different NICs (Network Interface Card). Ethernet is maintained by the Institute of Electrical and Electronic Engineers IEEE. Cables in Ethernet networks usually consist of 4 twisted copper wire pairs in a single sleeve, each wires are colour coded. Currently Only two pairs are used for communicating in such cable, one pair used for TX (transmitting) and the other is for RX (receiving) data. Each twisted pair of the pairs in the same sleeve is twisted in a different number of twists to reduce parallel insulated surfaces between conducers which might create a capacitance effect in high frequencies, thus will increase what is defined as unwanted cross communication in high frequencies which are used to increase bandwidth and data transfer rate throughput. Ethernet is more like the universal connecting connector in which the internet is interconnected with in LANs.
WAN (Wide Area Network) is the connection of multiple LANs together such as the Internet or WWW (World Wide Web).

TP (Twisted copper wire Pair) is used also as a smart home communication networks like KNX. KNX is a consortium of over 300 companies that make communication between KNX certified smart home devices possible. The wired part of KNX uses a single twisted pair of wires that utilises a 9600 bps communication speed in which only one device can use the network at once.

Power Line is another smart home communication protocol that is used by some smart home standards like KNX to send and receive control communication telegrams over local power lines.

Optical Fibers (Optical Fiber Cables): are made of glass fibres used for long distances, and clear plastic for local short distances. Fiber optical cables are capable of much higher data transfer rates than copper and wireless, hence such systems are generally used as a backbones in communication systems, moreover they are resistant to many destructive elements during times of wars.

Wireless communication mediums:

Wireless communications depends on electromagnetic waves and its electromagnetic properties whether transferring energy between antennas in air or empty space, or receiving such electromagnetic frequency by antennas. Electromagnetic waves include frequencies of visible optical properties of light. Most common used wireless communications medium is WiFi, WiFi wireless devices such as routers and access point, and other end user devices, eg. Mobile phones and laptops. They use different frequencies that can vary the transfer rate as well as speed and latency depending on its surrounding environments and mediums.

Another commonly used wireless system is GSM (Global System of Mobile Communications). GSM communication is divided by content into three main categories Voice, Short Messaging Service SMS, and data (Internet) which have been tremendously evolving in GSM generations 3G, 4G, 5G.
A GSM network is consist of a wireless network and a switching network that connects to other Mobiles and other external networks.

RF (Radio Frequency) is used as a wireless medium in standards like WiFi and KNX-RF to send and receive communication control telegrams throughout a smart building.

IR (Infra Red Radio Frequency) is most common optical medium, mostly used in remote controls and some times as transmission communication devices.

Bluetooth is another short range wireless communication system that is commonly used for wireless accessories connection to Mobile and other devices.

There are other wireless networks systems more specifically used for transmission lines between communications operator equipment such as long range microwave and infrared point to point communication systems.

LoRa are low power long range devices mostly commonly used in sensors and weather stations energised by batteries, it uses very limited energy and can provide a long range reach according to the frequency used, they are most commonly used in weather sensors.

In order to specify specification of communication interconnections and in order ease the development of such systems and isolate complexities according to functionality the OSI Model was developed: OSI - Open System Interconnection Reference Model, simply referred to as OSI. Was designed to simplify complexity and isolate communications functionality between layers to guides vendors and developers in creating end to end communications ensuring the interoperation between all layers in all communication devices.

Communication protocols:

In order to have any two devices communicate, they must speak the same language. Thus comes the part of communication protocols. Protocols are the communication specifications and rules that makes communication devices communicate and relay data. In smart homes some of the major protocols are:

KNX : KNX is a communication protocol developed by KNX which is based on EIB (European Installation Standard). It depends on a Telegram message that can travel between devices on a smart building KNX network. It is widely used in home and building automation. It is standardised into EN 50090, ISO/IEC 14543, OSI based network communication protocol administered by KNX Association.
KNX defines several physical communication media: Twisted pair wiring, Powerline networking, Radio Frequency KNX-RF, Infrared, and Ethernet KNXnet/IP.[2]

Infrared: there are many infrared protocols used by light of sight devices such as Televisions, Radios, Stereo systems, and other electronic devices that require remote access. Since Infrared can be blocked by any object in the way, it can only be used in line of sight.

WiFi: WiFi is the most commonly used wireless protocol. It went into several improvements over the years into lately WiFi 6 which introduces unimaginable speeds theoretically up to 9.5Gbps, in addition to better devices battery life as well as improved security[3].

Zigbee is a low data transfer, low power consumption, and low cost, wireless networking protocol designed for automation and applications of remote control. It started with IEEE 802.15.4 committee working on a low data rate standard. Then the ZigBee Alliance and the IEEE decided to join forces and decided that the commercial name for this technology becomes ZigBee. The design (Appendix 1) aimed for equipment in need oflong

battery life such as several months to several years, while not requiringhigh data transfer rates. The wireless range of Zigbee devices is expected to be less than 75 meters depending on the RF environment. With the possibility to communicate as a mesh network, meaning some Zigbee devices can relay other devices communications.[4]

Z-Wave is a two-way communication protocol that utilise mesh networking and message acknowledgment. It is primarily used in smart home networks. It offers low cost wireless connectivity, lower-power consumption to Wi-Fi and it provides a longer range than Bluetooth as an alternative. A Z-wave network consist of (IoT - Internet of Things) devices and a primary controller which is the only device that connects to the internet. Signals can travel through up to 232 devices including the hub. Communication between devices can span from approximately 30 to 100 meters, but it is common best practice to place Z-wave devices 15 meters or less away to maximise signal strength. Moreover it is possible to use Z-Wave repeaters that use direct line electricity to strengthen signals to a maximum of 4 hops with an estimated range of approximately 200 meters. Some Z-Wave devices are power optimised in a way that it can last up to 10 years on a single battery. Z-Wave certified devices are backward compatible. [5]

UPB (Universal Powerline Bus) is a protocol proprietary to Powerline Control systems. It is designed to communicate home automation devices over household electrical wiring via plus-position digital modulated signals directly without any need for a central controller. It can host up to 250 devices per house and per transformer. [6]

Insteon company based in Irvine, California, USA have developed Insteon a smart home protocol that allows smart home devices to communicate using RF (Radio Frequency), Powerlines, or both. Insteon requires a hub which requires an internet connection. Insteon communicate using standard and extended messages. [7]

HomeKit is part of Apple eco system, it is a framework that enables Apple applications throughout different apple products to control and coordinate accessories from multiple vendors to create a coherent user focused interface for home automation. [8]

DotDot is a new standardisation effort towards a single language that handles the connectivity attributes for IoT devices, it is an open, common protocol developed by Zigbee running on Thread's IP-Based protocol platform. [9]

Amazon Sidewalk uses uses a device called Sidewalk Bridge as a low-bandwidth shared network to communicate with Sidewalk-enabled devices supporting a range of experiences from finding objects to smart security systems and lighting control, as well as diagnostics of appliances and tools to enhance the home automation experience. [10]

Thread is a low power consumption low latency wireless mesh network open protocol. It solves complexities of IoT devices like interoperability, long range, security, energy consumption and reliability of such devices. It has no single point of failure and it has the ability of self healing. [11]

Matter is formally called CHIP (Connected Home over IP) it is an open source interoperability standard. It promises to enable different devices and ecosystems to work together seamlessly. Device manufacturers have to comply with Matter standards to ensure devices interoperability. Theoretically since Matter does not provide an app or assistant, it can use any supporting device with any voice assistance or platform of your choice like Apple Homekit, Amazon Alexa, Google Assistant. Matter protocol runs on IP and or Thread network layers it uses Bluetooth low energy to connect directly to BTLE enabled smart devices for setting up. [12]

Another communication protocol is MQTT is based on Client / Server and Publish/Subscribe of messages a transport protocol. Some of its characteristics is that the protocol is light, it is open-source, fairly simple, and it is made to be easily implemented. Such characteristics make it a good choice for communicating Machines to Machines (M2M) as well as the Internet of Things (IoT) solutions where smaller software is necessary and/or network bandwidth is scarce.
The design of the protocol is set to run over TCP/IP, or over other network protocols whichhave lossless, ordered, two way connections. Some of its capabilities include:
• The use of Publish/ Subscribe messaging that can be used as a one-to-many message distribution and be decoupled of its application.
• A transport messaging that is compatible to the content of the payload.
• Includes three "qualities of service"type of message delivery:
- "At most once", a one time message to be delivered by best effort of the system environment and not to be repeated. Where message

loss is acceptable. Such level can be used, with ambient sensor data where individual signal would be published soon after.

- "At least once", to ensure message deliverymessage is sent at least once and duplicate messages can occur.
- "Exactly once", Only send one messages where arrival is assured to arrive once and exactly. Such level is suitable, for example, Invoicing systems in which duplicates or message loss can lead to incorrect charges to be applied.
- Optimise network traffic due to its small foot print..
- An abnormal disconnect mechanism to notify interested parties when a disconnection occurs.[13]

In conclusion there is a race for home / building automation protocols that manufacturers / technology giants are competing in, there are many differentiation evaluation factors in determining the leader such as quality of service, interoperability between other devices and platforms, integration into common home automation platforms, ease of use and installation as well as setting up, in addition to other decisive factors. In order to simplify comparison I created the following table to show the major differences:

Feature	KNX-TP	KNX-PL	KNX-RF	KNX-IP	MQTT	ZigBee	Z-Wave	UPB	Thread	Matter
Communication Method	Telegram Message				Message Queue	Stack Architecture layers	Command Class	PPM	Message Queue	Stack Architecture layers
Message construction Fields	Control, Address, Data, Checksum	Training Sequence, 2 Preamble, KNX-TP frame, system ID	Sync, Data Block 1, checksum, Data block 2, checksum, data block … , checksum	Header, Protocol Version, Service type Identifier, Total Length, KNXnet / IP-Body	Control, Address, Data, Checksum.	Appendix 1	Can contain up to 255 commands with future extension to over 4000	Pulse Position Modulation	6LoWPAN, LLF	Application, Thread, Bluetooth LE
Communication Medium	TP Bus	PL Bus	Wireless RF	IP Couplers	TCP/IP	Wireless 2.4 GHz, 900MHz, 868MHz.	Wireless 868 MHz to 922 MHz	50Hz, 60Hz	Wireless 2.4GHz	Wireless 2.4 GHz, 900MHz, 868MHz.
Network Topology	Bus				Star	Point to Point, Point to multipoint, and Mesh	Mesh	Bus	Mesh	Star
Connection Type	Device to Device				Device to Broker	Device to Device	Device to Device	Device to Device	Device to Device	Device to Device
Connection period	Only one Device can transmit on Bus at a time, All other devices listen.				Connected until Device request disconnect	Instant Execute Acknowledge	Instant Execute Acknowledge	Instant Execute Acknowledge	Instant Execute Acknowledge	Instant Execute Acknowledge
Data rate	9600 bit/s	1200 bit/s	Depend on Frequency	Depend on Network	Depend on Network	250kbps	9.6 kbps, 40 kbps, 100kbps	240 bps	250 kbps	250 kbps
Authentication	✖ □				✔ □	✖ □	✔ □	✖ □	✔ □	✔ □
Access Control	CSMA/CA - Carrier Sense Multiple Access / Collision Avoidance				✔ □	CSMA-CA	✔ □	✖ □	CSMA	CSMA

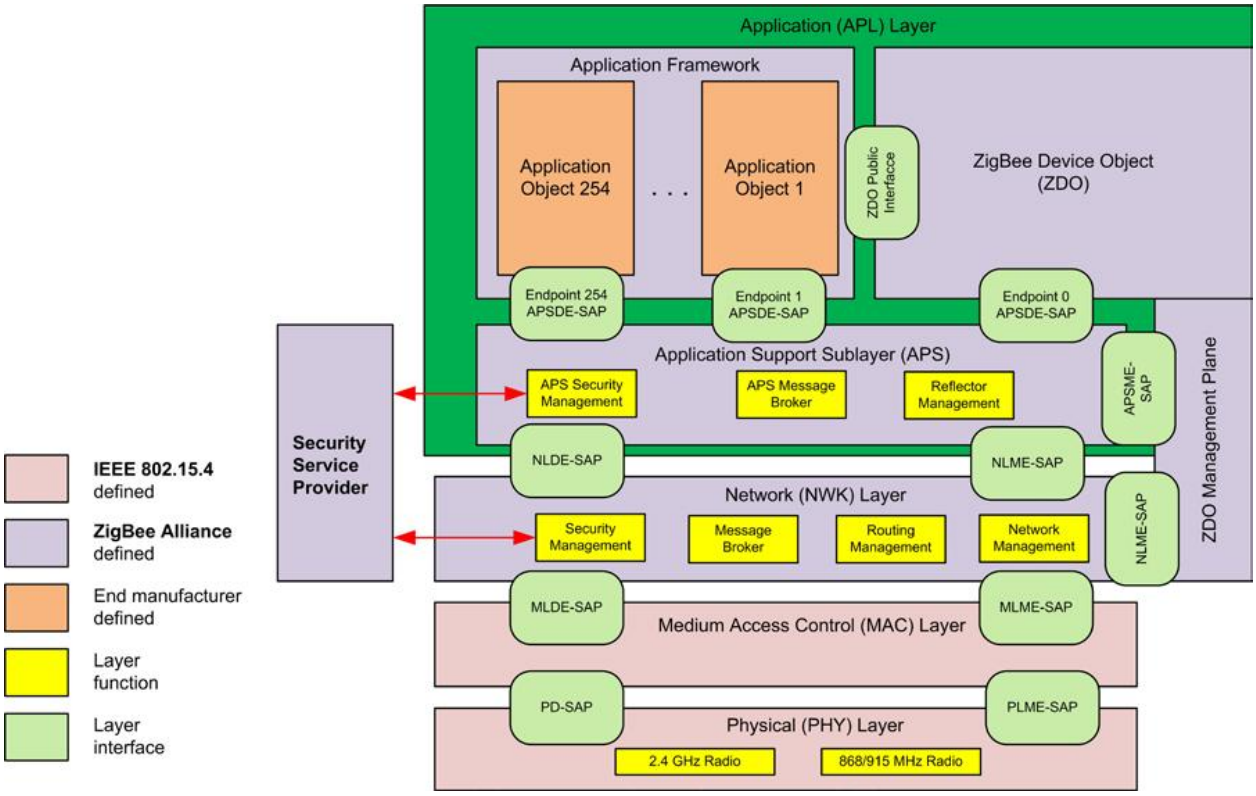
Feature	KNX-TP	KNX-PL	KNX-RF	KNX-IP	MQTT	ZigBee	Z-Wave	UPB	Thread	Matter
QoS	✖				✔	✔	✖	✖	✔	✔
Last Will Message	✖				✔	✖	✖	✖	✖	✖
Retain Message	✖				✔	✖	✖	✖	✖	✖
Duplicate Message	✖				✔	✖	✖	✖	✖	✖
Session	✖				✔	✖	✖	✖	✖	✖

Table Key: TP (Twisted Pair Cable), PL (Power Line), RF (Radio Frequency), IP (Internet Protocol)

A notable emerging and relatively new protocol that might have a promising future is Matter. Devices bearing Matter logo are expected to be compatible with many Matter devices / platforms that start installation using bluetooth then completing installation over WiFi seamlessly. Making it easy for consumers to bypass complexity when installing Home automation. Moreover It has the ability to be added into multiple home automation platforms at the same time independently of each other such as Amazon Alexa, Apple Homekit, and Google Assistant, thus making Matter smart devices accessible from multiple home automation platforms independently.

Appendix:

1. Outline of the ZigBee Stack Architecture



References:

[1]. https://en.wikipedia.org/wiki/OSI_model
[2]. https://www.knx.org/wAssets/docs/downloads/Marketing/Flyers/KNX-Basics/KNX-Basics_en.pdf
[3]. https://www.theverge.com/2019/2/21/18232026/wi-fi-6-speed-explained-router-wifi-how-does-work
[4]. https://pages.cs.wisc.edu/~suman/courses/707/papers/zigbee.pdf
[5]. https://www.techtarget.com/iotagenda/definition/Z-Wave
[6]. https://en.wikipedia.org/wiki/Universal_powerline_bus
[7]. https://www.rfwireless-world.com/Terminology/Insteon-RF-and-Powerline-Protocol-basics.html
[8]. https://developer.apple.com/apple-home/
[9]. https://www.nordicsemi.com/News/2018/11/Joining-the-Dots-with-Thread-and-Zigbee
[10]. https://www.amazon.com/Amazon-Sidewalk/b?ie=UTF8&node=21328123011
[11]. https://www.threadgroup.org/What-is-Thread/Thread-Benefits
[12]. https://www.silabs.com/documents/public/user-guides/ug103-11-fundamentals-thread.pdf
[13]. https://www.hivemq.com/mqtt-essentials/