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Comparative study of wireless home's automation: a case study of Zigbee, Bluetooth, Enocean, Wavenis, Insteon and UWB.

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ABSTRACT
Choosing the best standard for controlling devices at home without any change in infrastructure is one of the major challenges of home automation. The promising home automation in the past was Zigbee but nowadays, there some other standards which are the best for controlling home devices. It is in view of this that the paper presents general over view of different wireless communication standards so that the researcher will be able to make comparison in terms of their main features using various metric such as range, frequency band, maximum node count, security and as well as expenses.

Keywords: Bluetooth LE, Zigbee, Insteon, Wavenis, UWB, Enocean

I. INTRODUCTION

Technological advancement has been making things easy especially at home and in the office. Home automation is a globally accepted way of doing things at home; it helps to make an individual performs a number of tasks conveniently without walking up and down in the house. This type of engineering technology saves time and it is very economical. It is a telecommunication system that enables one to view and control home's electronics appliances from every cover in the house, using a computer and smartphones. This is an automated way of controlling home's electronics at anywhere in the house. This electronics device if connected properly will make someone in his house view visitors at the door with camera and prevent them or allow them to come inside the house with a smart door lock. This gadget can help individual dim lights whenever it is sunny and it can also help in brightening the light whenever it is cloudy. The gadgets can be fitted in the house and they are easy to operate and maintain. The system has gone a long way in wiping out traditional way of controlling electronics at home. Home automation is important because it enables aged and disabled people to have total control over their home. Gomez and Paradells (2010) opined that smart homes provide better quality of life involves comfort, security, safety, healthcare, energy conservation, and entertainment.

Wireless engineering for home automation involve a number of devices which are not necessarily be battery powered but with low power radio frequency. Radio frequency has an advantage over infrared that any new devices can easily be added or removed from network. A large number of electronic devices are put together to form a network and every appliance performs its own work without any interference. After the formation of a network, manual events, timed events and triggered events are put in place for effective functioning of the network. It is very important to note that all the devices are put and collected to a common network which serves as a central regulation and control unit for all of them.

Control systems are divided into three and these are:

1. Centralized control system. This is a type of system in which every device is connected by a central control unit and more so, the problem of this system is if central controller is faulty it will affect all the systems
2. Individually control system: as the name implies, individually control system has only one appliance is controlled. A very good example is the remote control unit.

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3. Distributed control unit: in this type of system, controller points are not in a central position and the points are districted throughout the network and they are controlled by one or more controllers.

The rate at which individuals make use of mobile internet devices in increasing on a daily basic and this is because the data is accessible at any time irrespective of the areas. The data can also be accessible in the villages on like before. WSN are not used athome because of its disadvantages, trade-off between cost and performance is somehow difficult to implemented. These days, the proliferation of WSN has created consumer demand and it is being used at homes for the management of energy.

Wireless home automation engineering: an overview

Zigbee (over IEEE 802.15.4), UWB (over IEEE 802.15.3) is introduced under this sub-section, also, Bluetooth LE, Wavenis, Insteon and Enocean (over ISO/IEC 1453-3-310) which is optimized for wireless solution with ultra-low power and energy harvesting. IEEE defines only two layers PHY(Physical layer) and MAC(Media Access Control layer) in its standards are equally introduced under this section.

The objective of this research is to make a comparison between six wireless standards (Zigbee, Bluetooth, Enocean, Wavenis, Insteon and UWB).

Table 1: Summary of features of Zigbee, Bluetooth LE, Wavenis,Insteon, Enoean and UWB

S/N	Features	Zigbee	Bluetooth LE	Wavenis	Insteon	Enocean	UWB
1	Data Rate	40kb/s, 60kb/s, 270kb/s	720bk/s	5..2kb/s 100kb/s	40.2kb/s	140kb/s	100mb/s
2	Frequency band	767/825MHz, 3.5 GHz	3.5GHz	60KHz	806MHz	789MHz	4.2-11.7GHz
3	Modulation Technique	BPSK, O-QPSK	GFSK	GFSK	FSK	ASK	BPSK GPSK
4	Spread Spectrum	DSSS	FHSS	FHSS	NO	NO	DS-UWB MB-OFDM
5	Indoor Range	120m	30m	1200m	70m	50m	500m
6	Security	130-bt AES	EO Stream cipher	130-bt AES	Rolling Code Encryption	Basic	AES
7	Cost	Good	-	Good	Good	Very Good	-
8	Risk of Data collusion	Average	High	Low	Average	Very Low	-
9	Max Node Count	➢ 6800	8	-	300-400	234	8
10	Energy needed	Medium	High	Medium	Medium	Very low	high
11	Market acceptance	Yes	Yes	No	No	Yes	Yes

Note the following:
BPSK means Binary Phase Shift Keying
O-QPSK: Orthogonal Quadrature Phase-Shift Keying
GFSK means Gaussian Frequency-Shift Keying
QPSK means Quadrature Phase-Shift Keying

The table above shows the main features of all the six standards (Zigbee, Bluetooth LE, Wavenis, Insteon, UWB and Enocean). Enocean and Zigbee are based on 802.15.4 IEEE standard and UWB is bases on the same 802.15.3 IEEE standard. Comparing these with other telecommunication UWB has one unique feature

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which is that its signal can pass through doors and any obstacles. The six protocols have authentication mechanisms in which Zigbee, Wavenis as well as UWB use advanced encryption method while Bluetooth LE uses EO stream cipher and Enocean uses rolling code encryption and only Insteon among the all uses basic encryption technique.The maximum node count of Zigbee is > 680, for building a cell in Bluetooth LE and UWB, maximum node count is 8 while Enocean 300-400 and for Insteon 234. The Gaussian frequency shift (GFSK) technique is used by Bluetooth LE and Wavenis while Binary Phase Shift Key (BPSK) and Orthogonal Quadrature Phase Shift Key (OQPSK) is used by Zigbee and UWB. Also, Enocean uses Amplitude Shift Key (ASK) modulation technique and Insteon use Frequency Shift Key (FSK). Insteon is the only system that supports both communication Radio Frequency (RF) and power-line which provides more reliability. The issue is that all Insteon devices are secured and security conscious because they have their unique identity that provide enough security and nobody can control someone home without the owner's permission.

Wavenis

Wavenis is a wireless technology created by Coronis in the year 2000. It is developed for ultra low power and long range Wireless Sensor Networks(WSNs). It has become popular due to promotion by Wavenis Open Standard Alliance.Wavenis technology was designed and developed by wireless experts to meet the needs of the utility industry as well as to provide a wireless standard for a variety of other sensor-related fields with similar cost-performance requirements. This includes home comfort, alarms, home healthcare, centralized building management, access control, cold-chain monitoring, plus long-range UHFRFID applications for identifying, tracking, and locating people and objects. Robust 2-way communications give Wavenis customers a unique way to create applications that meet their exact expectations in all these areas.Engineered to support wireless applications with extreme power limitations, yet still requiring connections over longer distances than is possible with other protocols, Wavenis OEM solutions can satisfy any engineer's need to balance development cost with fast time-to-market and product customization. Low footprint and low power requirements also mean a lower BOM for your end products.

Insteon

Insteon was a proprietary home automation (domotics) system that enabled light switches, lights, thermostats, leak sensors, remote controls, motion sensors, and other electrically powered devices to interoperate through power lines, radio frequency (RF) communications, or both. Insteon runs off radio frequency communications and power lines. Using a dual mesh network, it transmits and receives messages allowing your devices to connect to the internet. Compared to others, Insteon technology travels farther and has no interruptions contributing to the dual-band powerline. Trichakis, Christins, Rigakis&Antonidakis (2014) the Home Control Assistant is a software program that runs on any computer that uses the Windows XP, Vista or Win7 operating system. It works with automation interfaces to control lights and appliances in your home using X10, Insteon, UPB, Wireless and IR technology. Insteon works with the Google Assistant on voice-activated speakers, eligible Android phones, TVs and more. Insteon Hub sets the bar for easy-to-use home automation; control and monitor your home from your smartphone or tablet, create schedules and multi-device scenes, configure alerts from sensors and more.InsteonTrademark, (2015) Insteon was an Irvine, CA-based developer of home automation (aka domotics) hardware and software. The technology, also called Insteon allows light switches, lights, thermostats, motion sensors, and other electrical devices to interoperate through power lines, radio frequency (RF) communications, or both.Joe (2014) opined that the company produced over 200 products featuring the engineering technology.

UWB

Like Bluetooth and Wi-Fi, ultra-wideband (UWB) is a short-range, wireless communication protocol that operates through radio waves. But unlike its counterparts, it operates at very high frequencies — a broad spectrum of GHz frequencies — and can be used to capture highly accurate spatial and directional data.Ultra-wideband characteristics are well-suited to short-range applications, such as PC peripherals, wireless monitors, camcorders, wireless printing, and file transfers to portable media players. UWB was proposed for use in personal area networks, and appeared in the IEEE 802.15. Ultra-wideband (also known as UWB, ultra-wide band and ultraband) is a short-range wireless communication protocol. It uses radio waves to enable devices to talk to each other. Sounds familiar? Yes, it is similar to Bluetooth but more precise, reliable and effective. Hence, a UWB device signal cannot interfere with other narrower band device signals and because of this reason a UWB device can co-exist with other wireless devices. At present, UWB is the only

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commercially available wireless technology that delivers highly accurate and highly precise location and fine ranging measurements while also supporting high-level security to protect access credentials and data communications.UWB-enabled device like a smartphone, smartwatch, smart key or tile is near another UWB device, the devices start "ranging (Stone, 2021)." Ranging refers to calculating the time of flight (ToF) between devices: the roundtrip time of challenge/response packets.Using larger channel bandwidth (500MHz) with short pulses (two nanoseconds each), UWB achieves greater accuracy. The UWB positioning process instantaneously tracks the device's movements in real-time. In doing so, UWB-enabled devices can understand both motion and relative position (Honkanen, Lappetelainen&Kivekas, 2014).

Bluetooth LE

Bluetooth Low Energy (Bluetooth LE, colloquially BLE, formerly marketed as Bluetooth Smart (bluetooth.com, 2017). This is a wireless personal area networktechnology designed and marketed by the Bluetooth Special Interest Group (Bluetooth SIG)aimed at novel applications in the healthcare, fitness beacons,[1] security, and home entertainment industries (Gomez,Oller&Paradell, 2012).Bluetooth Low Energy is a power-conserving variant of Bluetooth personal area network (PAN) technology, designed for use by Internet-connected machines and appliances. Also marketed as Bluetooth Smart, Bluetooth LE was introduced in the Bluetooth 4.0 specification as an alternative to Bluetooth Classic.BLE devices are discovered through the broadcasting of advertising packets over 3 separate frequencies to reduce interference. A BLE device sends out a repetitive packet of information over one of three channels with random delays of up to 10 milliseconds.The Bluetooth SIG renamed the low-power wireless technology 'Bluetooth Low Energy' (Bluetooth LE). In 2010, the Bluetooth 4.0 specification included both classic Bluetooth and Bluetooth LE.Similar to Bluetooth, Bluetooth LE operates in the 2.4 GHz band. The hidden difference is that Bluetooth Low Energy remains in sleep mode unless a connection initiates. The actual connection times only last a few milliseconds, unlike Bluetooth, which connects for a few seconds or a few hours at a time.

Enoclean

This is the type of standard unit, is operated on 868MHz frequency in Europe and it uses Amplitude Shift Key (ASK), but in America, it operates on 315 MHz frequency. The layers of this electronic device are physical layer, data link layer and network layer. In physical layer, data is transmitted by using ASK on either 315MHz or MHz with data rate of 12. Enocean is energy harvesting with ultra-low power. The installation of Enoclean is easy and more economical. This is because it requires no wire and also the time needed for its installation is limited. It is used for building automation but it applied to a number of areas like smart homes, transportation e.t.c. Enoclean do not make use of batteries but it is very powerful. More than 30m radio signals are transmitted from sensors or switches. Ploennings, Ryssel and Kabitzsch (2010) multiple signals are transmitted over the network and there is a risk of collision but with the presence of Enoclean, the effect of collision and interference is minimized.

Zigbee

Lee, Wei and Shen (2014) Zigbee is a wireless device developed as an open global standard to address the unique needs of low-cost, low-power wireless IoT networks. The Zigbee standard operates on the IEEE 802.15. 4 physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.Its low power consumption limits transmission distances to 10–100 meters line-of-sightdepending on power output and environmental characteristics (Gislason, 2013).Zigbee is a standards-based wireless technology developed to enable low-cost, low-power wireless machine-to-machine (M2M) and internet of things (IoT) networks. Zigbee is for low-data rate, low-power applications and is an open standard.Zigbee network is more reliable as compared to Wi-Fi network. WiFi network is less reliable as compared to Zigbee network. It requires low bandwidth but greater than Bluetooth's bandwidth most of time. It requires high bandwidth.Zigbee is designed to carry small amounts of data over a short distance while consuming very little power. As opposed to WiFi, which uses a star network, Zigbee uses a mesh networking standard, meaning each node in the network is connected to each other.The frequency ranges supported in Bluetooth vary from 2.4 GHz to 2.483 GHz. It covers less distance than Zigbee. In bluetooth, GFSK modulation technique is used.ZigBee is targeted at radio-frequency (RF) applications which require a low data rate, long battery life, and secure networking. For any system being used in home automation, the main goal is to reduce human effort by operating various appliances remotely.

Paul (2020) outlines devices that work with Zigbee as follows:

- Philips Hue.
- Samsung SmartThings.
- Amazon Echo.
- Hive Active Heating and accessories.
- Honeywell thermostats.
- Ikea Tradfri.
- Innr.
- BelkinWeMo Link

II. CONCLUSION

The paper provides an overview of six wireless standards and they are Zigbee, Insteon,UWB,Enocean, Wavenis and Bluetooth LE. The overview on the superiority of all the six standards were not established because the suitability of wireless standards is greatly influenced by practical applications like some standards decrease energy cost at home while others provide the security. More so, for high rate applications UWB will be better solution whereas Blutooth LE and Zigbee are suitable for low data rate applications which are more economical to be used at home.

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