

A Comparative Study of Wireless Technologies: Zigbee, Bluetooth LE, EnOcean, Wavenis, Insteon and UWB

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Abstract-The major design challenge of home automation is to choose best standard for controlling devices in existing home environments without any changes in infrastructure. In recent years Zigbee was the promising technology for home automation. But, nowadays there are some other standards which give their best for controlling home devices. This paper presents an overview of different wireless communication standards by comparing their main features in terms of various metrics such as range, frequency band, maximum node count, security, and cost.

Keywords: Wireless technologies, Bluetooth LE, Zigbee, EnOcean, Insteon, Wavenis, UWB.

Introduction

In today's life because of huge amount of standards available in the market choosing the best one is the biggest challenge. This paper reviews some standards. A smart home provides a better quality of life as compared to traditional homes by introducing automated appliance control and assistive services. Home automation plays a vital role for elderly and disabled persons to remain at home. The symptoms of disabled persons include chronic diseases include cancer, diabetes, mental impairment, birth defects, malnutrition and HIV/AIDS. It is not possible to take care of all these patients in hospitals or nursing homes for uncertain period of time. Its solution is to provide healthcare services and assistive technologies in their own homes. Smart homes provide a better quality of life that involves comfort, security, safety, healthcare, energy conservation, entertainment. [1], [2]

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Wireless technologies for home automation include several types of embedded devices which may be battery

powered and battery less with low power radio frequency (RF). Radio frequency having a biggest advantage over infrared (IR) that new devices can easily be added or removed from the network. Individual devices forming a network and all are working together in harmony. After forming a network there are certain events that takes place like manual events, timed events and triggered events. All devices are connected to common network and controlled by a central regulation and control unit. There are three types of controls systems such as:

-Individually control system: Only one appliance or function is controlled in these systems. For example a remote control unit.

-Distributed control systems: Controller elements are not in central location in these systems, they are distributed throughout the network and controlled by one or more controllers.

-Centralized control systems: In these systems all devices are controlled by a central control unit. The major drawback of these systems is that if central controller fails the whole system fails.

Mobile internet devices have been becoming increasingly essential for consumers because all their data should be accessible at anytime from anywhere. WSN are not effectively implemented in homes because of trade-off between cost and performance. Nowadays, the proliferation of WSN has created consumer demand and gradually being used in homes for energy management services.

The paper organized as follows. Section II of this paper explains the features of Zigbee, Bluetooth LE, Wavenis, Insteon, EnOcean and UWB. Section III describes the comparison of these standards by investigating several parameter such as data rate, modulation technique, cost, collision avoidance, energy needed, security, spread spectrum, packet delay, signal to noise ratio. Finally Section IV concludes this paper.

Wireless Home automation
Technologies: An Overview

This section introduces the Zigbee (over IEEE 802.15.4), UWB (over IEEE 802.15.3), Bluetooth LE, Wavenis, Insteon and EnOcean (over ISO/IEC 14543-3-310) which is optimised for wireless solutions with ultra-low power and energy harvesting. IEEE defines only two layers PHY and MAC in its standards. An overview presented in this paper is widely available in literature. The main ambition of this paper is not to carry out research on all wireless standards, but to present a comparison of only six standards.

ZIGBEE

Zigbee is IEEE 802.15.4 standard based technology for low data rate, low power consumption, reliability and short range applications. Zigbee has become a primary solution in several applications such as remote monitoring, health care, home automation, telecommunication, building automation, interactive toys, energy management and efficiency. Zigbee is a complete open global standard gained ratification by Institute of Electrical and Electronics Engineer (IEEE) in 2003. It is based on the earliest version of IEEE 802.15.4 with varying data rates 20 to 250kb/s which operates in 868 MHz, 915 MHz and 2.4GHz. [1], [2] It is created by Zigbee Alliance which is supported by number of companies such as Chipcon, Ember, and Free scale, Honeywell, Mitsubishi, Motorola, Philips and Samsung. It uses direct sequence spread spectrum to transmit the data by using Binary Phase Shift Key (BPSK) and Orthogonal Quadrature Phase Shift Key (O-QPSK) modulation techniques. Reasons for using Zigbee over proprietary protocols:

- Its encryption techniques provide more security.
- Provides long battery lifetime due to low duty cycle.
- It supports large number of nodes up-to 65000 in a network.
- Easy to deploy
- Its cost is low and used globally.

Zigbee supports three different kinds of nodes router, coordinator and end device. First two nodes router and coordinator are referred to as Fully Function Device (FFD), whereas end device is referred to as Reduced Function Device (RFD) For throughput reduce signal strength indicator (RSSI) is measured in the presence of point to point link, routers and in the presence of two RFDs. Throughput increases less linearly in point to point link and reduced by factor 2 in presence of routers. Its delay can be high with small packet length. [6, 8, 10-12]

BLUETOOTH LE

Bluetooth Low Energy (BLE) is a new feature of Bluetooth 4.0 specification with low power, low latency for exchanging data over short distances. As Bluetooth, Bluetooth LE is also driven by Bluetooth Special Interest Group. BLE made market adoption in 2007 when merged with Nokia Wibree group. Bluetooth LE uses Gaussian frequency shift key modulation technique to transmit the data over short distances. In 802.15.4 direct sequence spread spectrum is utilized which is more complex as compared to frequency hopping spread spectrum(FHSS) in BLE. FHSS is used to

mitigate the interference and it operates in 2.4 GHz ISM frequency band. The whole frequency band is bifurcate into 40 channels and these channels are apart by 2MHz. Further these 40 channels are divided into separate 37 channels which are serves as data channels and out of these 40 channels 3 of them are used for connection setup. When request is send to set up the connection same channel is used to initiate the connection and same data channels are used for communication when device is discovered. [2], [6]

Bluetooth LE devices may operate in different mode:

- Advertising Mode: In this mode BLE device regularly transmits the data and may response with additional information.
- Scanning Mode: In Scanner Mode BLE device listen to advertising information sent by the other devices and requests for extra information
- Master Mode
- Slave Mode

ENOCLEAN

This standard is recently rectified and published in March 2012. In Europe it operates on 868MHz frequency by using Amplitude Shift Key (ASK), whereas in North America it operates on 315 MHz frequency. EnOcean protocol stack composed of four main layers: physical layer, data link layer and network layer. On physical layer secured data is transmitted by using ASK on either 315MHz or 868mMHz with data rate 125kb/s. The main goal of EnOcean is energy harvesting with extremely ultra-low power.

The main advantage of this standard it is easy to install no wires are required and time is saved. EnOcean was effectively used for building automation but it also applied to many other areas like smart homes, logistics, industry and transportation. EnOcean devices are battery less but also offer superior performance to operate maintenance-free. Up to 30m radio signals are transmitted from sensors or switches. When multiple signals are transmitted over the network there is a risk of collision\on but EnOcean mitigate both effects collision and interference. [3], [4]

EnOcean trans-receivers use novel RF oscillator that can be switched on and off in less than 1 μs . It is solar driven system which uses solar panels through which it can work for many days in darkness. Its indoor range is 30m and outdoor range is 300n but its range can also be exceeded by using repeaters. [5]

WAVENIS

Wavenis is a wireless technology developed by chronis system with ultra-low power consumption and long range wireless technology for machine to machine (M2M) applications It is promoted by the Wavenis Open Standard Alliance. In smart grid Wavenis devices are used for many applications such as remote telemetry, advanced metering infrastructure (AMI), automatic metric reading (AMR), utility monitor metering. Its ISM bands operate at 433MHz in China, 868MHZ in Europe and 915 MHz US. It uses frequency hopped spread spectrum method to transmit radio

Table 1

Summary of Features of Zigbee, Bluetooth LE, Wavenis, Insteon, EnOcean, UWB

	Zigbee	Bluetooth LE	Wavenis	Insteon	EnOcean	UWB
Data Rate	20kb/s 40kb/s 250kb/s	720kb/s	4.8kb/s 100kb/s	38.4kb/s	120kbit/s	110mbits/s
Frequency band	868/915 M Hz, 2.4 G Hz	2.4 G Hz	50 K Hz	904 M Hz	868 M Hz	3.1-10.6 G Hz
Modulation Technique	BPSK, O-QPSK	GFSK	GFSK	FSK	ASK	BPSK QPSK
Spread Spectrum	.DSSS	FHSS	FHSS	No	no	DS-UWB MB-OFDM
Indoor Range	100m	10 m	1000 m	50 m	30 m	300 m
Security	128- bit AES	E0 Stream cipher	128-bit AES	Rolling code Encryption	Basic	AES
Cost	Good	-	Good	Good	Excellent	-
Risk of data collision	Medium	High	Low	Medium	Very low	-
Max node count	>6500	8	-	200-300	2 ³²	8
Energy needed	Medium	High	Medium	Medium	Extremely low	High
Market Adoption	YES	YES	NO	NO	YES	YES

Signals and its frequency bands are licence free in most parts of the world. Synchronous and Asynchronous operations are depending upon network size and applications and support a variety of mesh networks from simple point to point connections to advanced tree structure with multiple repeaters. [1]

INSTEON

This standard is created by smart labs and promoted by Insteon alliance. It enables simple low cost, to be networked together using mesh topology with both radio frequency and power line links. Devices are connected to each other by a point to point link, means each device can transmit, receive or repeat message by simultaneously casting them into small time slots synchronized to the power line zero crossing. Devices which are placed in an irregular fashion communicate with each other by multihop approach, which is performed using a time slot synchronization scheme.

Maximum four hops are given to each message. Rolling code encryption is used for providing security to data to transmit at the data rate 38.4 kb/s. At a time hundreds of thousands of devices can activate by receiving a single signal from an Insteon. Insteon devices use simulcast instead of routing, which avoids the need to store state for making multihop communication possible. [1]. Advantage of simulcast is that data can be reached through an alternative path whenever an intermediate device is unavailable. [7]

UWB

Ultra wide band is a radio technology used for high data rate communication over short distances. Its unique feature is that its bandwidth is up-to 480Mbps which is suitable for audio and video delivery in home environment. UWB uses direct sequence ultra wide band (DS-UWB) and multiband orthogonal frequency division multiplexing (MB-OFDM) spread spectrum method to transmit information at specific

Time intervals and occupying large bandwidth whereas conventional radio transmits information systems transmit information by varying power level and frequency [6]. UWB has some characteristics which makes it more attractive such as:

- Low complexity and low cost.
- Resistant to severe multipath and jamming.
- Having a noise-like signal spectrum.
- Having a very good time domain resolution for location and tracking applications

Comparative study

Table I shows the main features of Zigbee, Insteon, UWB, Bluetooth LE, wavenis and Enocean. Zigbee is based on 802.15.4 IEEE standard whereas UWB is based on 802.15.3 IEEE standard. As compared to other technologies UWB has one of its unique features is that its signal is pass though through doors and obstacles. All these six protocols have authentication mechanisms in which Zigbee, wavenis and UWB uses advanced encryption method whereas Bluetooth LE uses E0 stream cipher and Enocean uses rolling code encryption. Only Insteon uses the basic encryption technique.

Maximum node count for Zigbee is >6500, for building a cell in Bluetooth LE and UWB maximum node count is 8 whereas for Enocean 200-300 and for Insteon it is 232. Gaussian frequency shift key (GFSK) technique is used by Bluetooth LE and Wavenis whereas binary phase shift key (BPSK) and orthogonal Quadrature phase shift key (O-QPSK) is used by Zigbee and UWB whereas Enocean use Amplitude Shift Key (ASK) modulation technique and Insteon use Frequency Shift Key (FSK).

As compared to other technologies Insteon is the only technology that supports both types of communication Radio frequency (RF) and power-line which provides more reliability. All Insteon devices having their own unique id which provides more security no-one can control your home without you.

Conclusion

This paper only gives a broad overview of Zigbee, Insteon, Enocean, UWB, Wavenis and Bluetooth LE but does not give any conclusion which one is superior standard because the suitability of wireless standards is greatly influenced by practical applications like some standards decreases energy cost in your homes whereas other provides the security. For high data rate applications UWB would be better solution whereas Bluetooth LE and Zigbee are suitable for low data



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rate applications. There are some other points that can be considered for comparison of these standards such as: Duty cycle and Transmission power.

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