A COMPARATIVE STUDY OF WIRELESS TECHNOLOGIES BASED ON HOME AUTOMATION BLUETOOTH LOW ENERGY, ZIGBEE, INSTEON AND ENOCEAN

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Abstract: **The home networking market is growing rapidly and wireless technologies play an important role in the most home networks. Wireless home automation networks comprise wireless embedded sensors and actuators that enable monitoring and control applications for home user comfort and efficient home management. 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 (like Bluetooth LE, INSTEON and Enocean) which give their best for controlling home devices. This thesis 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, cost and market adoption.* This thesis concludes with a statement of which technology will be the best and most cost effective solution to end user.**

Keywords: **Wireless Technology, Home Automation, Bluetooth LE, ZigBee, Insteon, Enocean.**

1. INTRODUCTION

Today the technological world's main focus is to automate every possible thing to take advantage in providing ease in life. In the most of the well developed countries home automation is very famous and well adopted because it has several many benefits like it saves electricity and provides security.

The concept of automation has existed for many years. It began with a student connecting two electric wires to the hands of an alarm clock in order to close a circuit of a battery and light bulb. Later, companies developed automated systems of their own to control alarms, sensors, actuators and video cameras and, in so doing, created the first automated buildings. At the beginning automated devices were independent or, sometime, grouped in small independent systems.

In today's life because of huge amount of standards available in the market choosing the best one is the biggest challenge. This thesis 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 disable 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.

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.

1.1 Motivation

Life is always changing; nowadays lifestyle is very different from 10 years ago. One of the reasons is the introduction of new technology in our lives.

Technology helps us to have a more comfortable life. Since ancient times technology has been influencing in our lifestyles. Achievements such as the invention of the wheel, hunting techniques or agriculture have made our life's more comfortable and easy.

Nowadays it is almost impossible to live without depending on any technology or skill, they are everywhere in different purposes and forms. The most common ones are result of aggregation of different techniques with technology having results like cars, phones, airplanes, fridges, microwaves, clothes and etc.

Someday we will become seniors too, it would be good if we can contribute to improve our aging lifestyle. Society has to concern about aging.

1.2 Problem Studied

Communication technology standard media to be deployed for home automation which can either be wired or non-wired. The followings areas are addressed in this study
- Identifying the challenges with choice of media and the requirements for the links
- Introduction and applications of home automation
- A propose home security system, features and requirements specifications
- Identifying available standard wireless technology of choice and evaluations in areas of reliability, range, adaptation and co-existence of links, as wells as cost
- External network and home security system
- How to interconnect the home network to external network

1.3 Home Automation

Home Automation is a very broad field and there exist a lot of different definitions of what exactly Home Automation is in the literature. What most of those definitions have in common is, that a Home Automation system should at least be able to control heating, ventilation, air conditioning (HVAC) and lighting. In addition to that, it should collect sensor data, for example the temperature, for further processing or displaying. Some systems also support multimedia, health care and security applications. A Home Automation system enables the user to conveniently control his home via a user interface. This user interface can be a terminal, a personal computer, a remote control or a mobile device. It is also possible that some processes of everyday life, for example the opening and closing of the window blinds, are automated. In most cases the system contains a central unit like a computer, a server or terminal to which all other units are connected. For communication between the individual parts of a Home Automation system a variety of different technologies is used, as there is not yet an established standard. Wireless as well as wired solutions are applied.

1.4 History of Home Automation

Home automation technology and Smart home appeared very much in science fiction of the 1920s. But no one knows the exact date of the invention of home automation. Based on human's smart technology improving process, the home automation system does not come by immediate invention. It comes step by step with only insignificant improvement. The previous step is almost same with the next step.

The first time people noticed the high technology in dwelling, they did some connection with home automation and it was 1960s. It was called wired homes at that time. It was built by some hobbyist. After that, the first official name of home automation appeared in 1984 by the American Association of House Builders. This development is the key to the modern smart homes.

People at that time understood that a smart home is not owing to how well it is built, to how effectively it uses space, not due to how it is environmentally friendly. It is only because of how interactive technologies that it contains. Those are still useful rules for home automation technology today

In the 1960s, there were not so much interactive technologies. Even though Stanford University researched a lot of this kind of technology, they didn't become so successful. They concluded some principal reason for not succeeding is scientific research.

> a) Lacking of motivation to increase productivity in domestic work
>
> b) Less involvement of users of the technology in the design process
>
> c) The view held by product designers that domestic technology is unexciting
>
> d) A continued focus on stand-alone appliances in the design of new technology

For marketing and technical purposes, those four factors mentioned above have become smart home industry's chance and challenge nowadays.

2. WIRELESS HOME AUTOMATION TECHNOLOGIES: AN OVERVIEW

This section introduces the Zigbee (over IEEE 802.15.4), Bluetooth LE, Insteon and Enocean (over ISO/IEC 14543-3-310) which is optimized 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 four standards.

2.1 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 250kbits/s which operates in 868 MHz, 915 MHz and 2.4GHz.

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 Quadrate 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 RFD's. Throughput increases less linearly in point to point link and reduce by factor 2 in presence of routers. Its delay can be high with small packet length.

2.2 Bluetooth Low Energy

Bluetooth Low Energy (BLE) is a new feature of Bluetooth4.0 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.

2.3 Insteon

This standard is created by smart labs and promoted be Insteon alliance. It enable 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 multi hop 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 multi hop communication possible. Advantage of simulcast is that data can be reached through an alternative path when an intermediate device is unavailable.

2.4 Enocean

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. Enocean trans-receivers use novel RF oscillator that can be switched on and off in less than $1\mu s$. 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.

Table: 1 Overall Comparison of Wireless Technology

Characteristics	Bluetooth LE	ZigBee	Insteon	Enocean
Frequency Band	2.4 G Hz	868/915 MHz, 2.4 G Hz	904 MHz	868MHz
Radio Technique	GFSK	O-QPSK BPSK	FSK	ASK
Spread Spectrum	FHSS	DSSS	No	No
Bandwidth	720Kbps	20kb/s,40kb/s 250kb/s	38.4kb/s	20kbit/s
Latency(indoor range)	10m	100m	50m	30m
Security	128- bit AES	128-bit AES	Rolling code Encryption	Basic Encryption
Cost	Good	Good	Good	Excellent
Market Adoption	Yes	Yes	Yes	NO

3. CONCLUSION

Wireless technologies available for deployments in home environments are: Bluetooth LE, Zigbee, Insteon and Enocean. From table-1, after careful evaluations of the above mentioned standard, Bluetooth LE and ZigBee could be described as open multi-vendor, stable and mature wireless technologies standard for home automation. It also satisfies conditions for the range of coverage for homes. Evaluation of Bluetooth LE and Zigbee in terms of cost, the operational cost and deployment cost, Bluetooth LE and ZigBee have comparative advantage compared to Insteon and Enocean. Conditions like data rate, security schemes, co-existence with other wireless technologies sharing the same bandwidth, was met by the two standards-Bluetooth LE and ZigBee. All are proven to be robust, good security schemes with support for in built for encryption standard with authentication schemes. All establish connection quickly, are scalable and support a number of sensory nodes for home security application.

INSTEON cannot perform the functions of a high-speed data network (like Home theater, audio/video and video surveillances, it can integrate with your data network to provide the complete smart home experience. The Enocean is not good in market level. The Bluetooth low energy is new one for market. ZigBee is a competing low energy communication system, which was introduced in 2004. It has already gained a strong foothold in the market. I concluded that Zigbee technology is an ideal choice for home automation putting in considerations the home Security system would be built from the very scratch, with no existing infrastructure to deploy on. Zigbee technology provides low-power wireless sense and control of appliances. It get rids of connecting cables and power cables, the sensory nodes could be operated with a battery and with a longer battery life. And in the nearest future the zigbee nodes will be able to harvest energy from the environment.

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