

# Different Technologies Used in Home Automation - A Review and Comparison

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**Abstract**— "Home Automation" industry is growing rapidly. Home Automation is a way to have things around your home happen automatically. The first thing that comes to mind when folks think of home automation are robots, flashing lights, complicated electronics and a general feeling that their home is less of a warm home and more of a cold science experiment. Home automation systems must comply with the household standards and convenience of usage. The term 'Home Automation' today applies to the next level of automating home electronics. The home automation system is intended to control all lights and electrical appliances in a home or office using voice commands. This Paper attempts to study technologies which are used for Home Automation. In brief, concern of this Paper is to cover the detail Technical aspects of the Home Automation Technology.

**Keywords**— Automation; Technology; Reliable; Tasks

## I. INTRODUCTION

Home Automation is a concept that has been developing reasonably slowly when you compare it to how other technology such as televisions have progressed. Home Automation is also referred as Domotics. As Home Media devices become cheaper, Home Automation is a technology that more people will be looking into to install in their house. There are many definitions of home automation available in the literature. [1] describes home automation as the introduction of technology within the home to enhance the quality of life of its occupants, through the provision of different services such as telehealth, multimedia entertainment and energy conservation.

Home automation is one of the major growing industries that can change the way people live. Some of these home automation systems target those seeking luxury and sophisticated home automation platforms; others target those with special needs like the elderly and the disabled. There are many Home Automation technologies are available but there are no standard practices among designers, installers and contractors to realize the systems which has lowered the quality. The past research has concentrated mostly on the end users, especially on the elderly and disabled users who benefit from automation the most. It is important to study the actual process of developing the home automation systems so that the operations can be improved and updated where needed.

## II. TASKS OF HOME AUTOMATION

### A. HVAC

Heating, Ventilation and Air Conditioning (HVAC) solutions include temperature and humidity control. This is generally one of the most important aspects to a homeowner. An Internet-controlled thermostat, for example, can both save money and help the environment, by allowing the homeowner to control the building's heating and air conditioning systems remotely [27].

### B. Lighting

Lighting control systems can be used to control household electric lights in a variety of ways: [27].

- Extinguish all the lights of the house
- Replace manual switching with Automation of on and off signals for any or all lights
- Regulation of electric illumination levels according to the level of ambient light available
- Change the ambient color of lighting via control of LEDs or electronic dimmers

### C. Natural Lighting

Natural lighting control involves controlling window shades, LCD shades, draperies and awnings. Recent advances include use of RF technology to avoid wiring to switches and integration with third party home automation systems for centralized control.

### D. Audio

This category includes audio switching and distribution. Audio switching determines the selection of an audio source. Audio distribution allows an audio source to be heard in one or more rooms. This feature is often referred to as 'multi-zone' audio [27].

### E. Video

This includes video switching and distribution, allowing a video source to be viewed on multiple TVs. This feature is often referred to as 'multi-zone' video. Integration of the intercom to the telephone or of the video door entry system to the television set, allowing the residents to view the door camera automatically.

### F. Security

With Home Automation, the consumer can select and watch cameras live from an Internet source to their home or business. Security cameras can be controlled, allowing the

user to observe activity around a house or business right from a Monitor or touch panel. Security systems can include motion sensors that will detect any kind of unauthorized movement and notify the user through the security system or via cell phone [27].

### G. Intercoms

An intercom system allows communication via a microphone and speakers between multiple rooms.

- Ubiquity in the external control as much as internal, remote control from the Internet, PC, wireless controls (e.g. PDA with Wi-Fi), electrical equipment.
- Transmission of alarms.
- Intercommunications.

### III. HOME AUTOMATION TECHNOLOGIES - AN OVERVIEW

Home automation can offer benefits on many fields that a home requires. It can offer security, energy efficiency, automation, remote control, remote access to information of home, is environmental friendly and generally anything that can be achieved by the current technology. This is because the garden will get automatically watered, the geyser will always have hot water from the solar energy, and the lights will be opened only when someone is in the room and so on. This means the owner will have to take less actions which equals to more free time. Furthermore, the home has fewer bills, the owners of the home are more relaxed and become less tired by trivial actions and finally, all this can mean in the end fewer bills. As a result, the home automation is needed to make our lives easier, better, healthier, relaxed and finally, happier.

Smart homes are homes technologically advanced than other homes that get benefit of the current existing technology in order to achieve the wanted home automation. The wanted home automation may vary from owner to owner of a smart home. The need for home automation becomes more obvious when people become familiar with the new trends of technology. The people slowly develop more expectations from technology and realize how much they could benefit from it. Then, home automation takes place.

Home Automation System has the following properties :

- **Adapted to New Technologies:** Using Wireless communications instead of wired ones.
- **Reliability:** A trustable system.
- **Expandable:** You can add and remove modules of the HAS to adapt it to your needs.
- **Low Cost:** Chosen Wireless Devices are cheap and for the main system we only need an old computer.
- **Energy Efficient:** Wireless Autonomous devices have limited battery life which is why battery management is very important to enhance the battery lifetime.

The General Home Automation Schema is as shown in Fig.1.

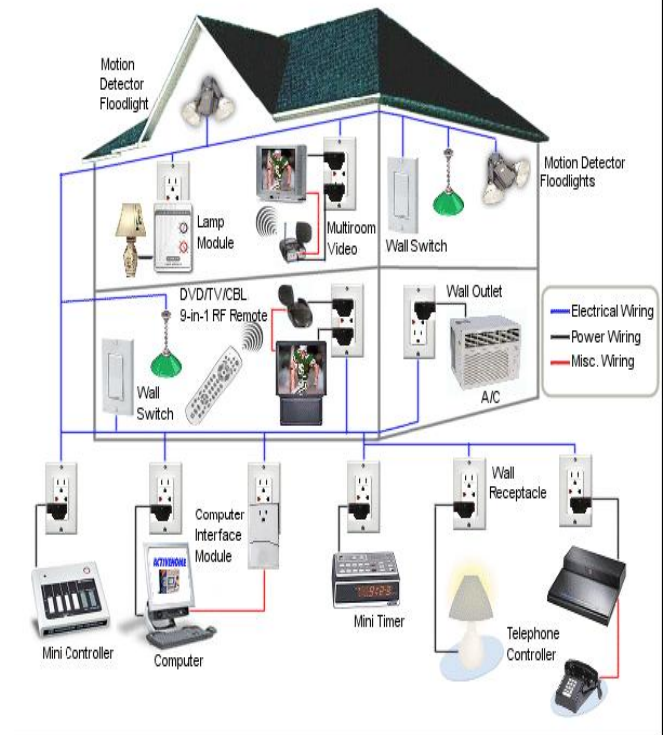


Fig.1.General Home Automation Schema

The different technologies used in Home Automation are :

- 1) Bluetooth
- 2) Wi-Fi
- 3) Certified Wireless USB
- 4) ZigBee
- 5) X10
- 6) UPB
- 7) INSTEON
- 8) Z-Wave

#### A. Bluetooth

Bluetooth is a wireless standard that belongs to the PAN protocol family. It operates in the 2.4 GHz band divided into 79 sub channels with 1MHz spacing, employing FHSS [5] [6]. GFSK and/or PSK modulations are used, depending on the Bluetooth version used. Full duplex transfers are realized via TDD. It is defined by the IEEE 802.15.1 standard and extended by the Bluetooth Special Interest Group [7].

#### • Hardware Dimensions

The smallest Bluetooth devices currently available on the market are utilizing the v2.1 EDR chips manufactured by CSR in the Blue Core series [8]. The dimensions of these chips in the WLCSP are no larger than 4x4mm (0.17x0.17in), thus they can be easily integrated e.g. into USB-A type connectors [9].

- *Memory Requirements*

A disadvantage of Bluetooth usage in small medical devices is the fact that a full Bluetooth stack is too large for embedded applications [10]. Because of that, most simple applications only include a fraction of the stack in their firmware [11]. Full stack is then implemented in a device with more computational power (and usually acts as a host),

As for hardware in numbers, the latest BlueCore series chips (BlueCore6) are equipped with 6MB of ROM and 48kB of RAM (parts of the ROM are used not only for Bluetooth stack, but for audio and other libraries as well).

- *Bandwidth and Range*

Both bandwidth and ranges have been extended along with the popularization of Bluetooth [12]. The latest IEEE 802.15.1- 2005 specification defines Bluetooth 1.2. Bluetooth 2.0/2.1 is developed under Bluetooth SIG only. The EDR technology allows higher speeds by using PSK modulation for parts of the transmission instead of GFSK and also uses different packet structure.

- *Power Consumption*

Power consumption has become an important concern of end device manufacturers recently. Bluetooth SIG responded by enhancing the feature set of new Bluetooth versions. The power consumption can be primarily lowered by adjusting network scanning and transmission parameters, which, however, sacrifices bandwidth and prolongs the link initialization [11]. An average Bluetooth chip usually drains about 50mW for both receive and transmit modes. In sleep mode (or equivalent mode, e.g. Parked state), some of the chips (e.g. CSR's BlueCore) can lower the consumption below 1mW.

- *Network Features*

In basic mode, Bluetooth creates a temporary device link in a process called 'pairing' – a process of establishing point-to-point ad-hoc connection between two devices. So called 'piconet' is a network created on a temporary basis (although usually the intention is to create a permanent network) and is an extension to the point-to-point topology. Fig.2 shows the piconet and scatternet of Bluetooth. It forms a 'star' master-slave topology. To create a piconet, in the process of device pairing one device has to be elected as the network master, while other devices join the network as slaves. Master defines the physical layer parameters of the network. The maximum number of active devices in piconet is limited by the structure of Bluetooth's MAC layer to 7 slaves and one master.

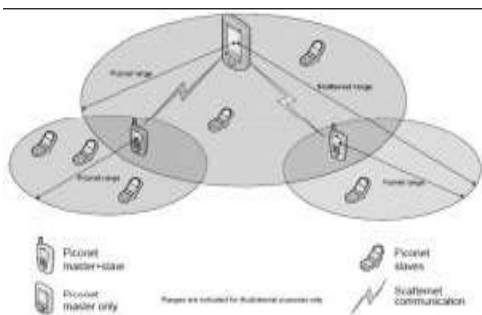


Fig.2. Bluetooth's piconet and scatternet

- *Security and Reliability*

Bluetooth offers an authentication method using 128bit key [13]. Bluetooth is more resistant to eavesdropping than other technologies, because in difference to e.g. Wi-Fi or ZigBee, the modulation it uses on the physical layer is FHSS and not DSSS, which means we need to follow the frequency hopping in order to continue receiving data [14]. Reliability is a rarely discussed attribute of Bluetooth. The technology used on physical layer makes Bluetooth slightly more likely to suffer from interferences and intentional jamming. The scatternet is also not a topology that can guarantee reliable multi-hop data transfers. Moreover, the spontaneous nature of all connections is not an attribute that benefits the reliability.

- *Costs*

There are several manufacturers of Bluetooth chips available on the market. Broadcom offers the BCM2046 SoC, however, at unknown price and probably only for wholesale. Texas Instruments' portfolio contains a number of Bluetooth chips (e.g. the BlueLink series). All of them are available to 'high-volume wireless OEMs and ODMs' only. The same situation repeats with Infineon. They also offer more information about their solutions than other manufacturers. Their BlueCore4 SoC and BlueCore5 SoC (Bluetooth transceivers without ROM/Flash) cost from \$3 to about \$10 / unit, depending on the range of included multimedia.

### B. Wi-Fi

Wi-Fi is probably the most exploited wireless technology nowadays. It belongs to the family of (W) LAN networks, but with latest amendments it could also be belonging to the (W) MAN family. It is built on the IEEE 802.11 standard, which first version was announced in 1997 and first successful commercial standard (the 802.11b and 802.11a) was adopted in 1999.

The physical layer defines the operation frequency to 2.4GHz (802.11b/g/n) and 5GHz (802.11a/n) employing DSSS (802.11b) or OFDM (for higher speeds in 802.11a/g). In difference to Bluetooth, the Wi-Fi spectrum is divided into only 13 partly overlaying sub channels (14th available in Japan only), each occupying the band of 22MHz. At an instant moment, the 802.11a/b/g versions are always occupying only a single channel [15].

- *Hardware Dimensions*

The average size of a Wi-Fi RoC (usually means Wi-Fi + Radio-MCU + Caches) is about 8x8mm. Most of the modern chips that are being introduced now are even smaller, some of them, mostly coming in the TFBGA packaging, have the size of 5x3 mm (0.2x0x12 in). The disadvantage of Wi-Fi is its requirement of external memories and processors, which in the end means that general Wi-Fi device is much larger (scope of centimeters) than all of the other devices mentioned in this Research paper.

- *Memory Requirements*

Wi-Fi is, compared to Bluetooth, WUSB and ZigBee, the most memory and computing-power demanding. Modern chips contain 400MHz RISC processors with 64KB-128KB caches, and are using external RAM and ROM in the sizes of MB. Common Wi-Fi USB dongles do not contain the Wi-Fi stack in their firmware.



- *Bandwidth and Range*

The theoretical maximum for Wi-Fi range is in the units of kilometers (miles). There are working installations on the distance of above 2 km (1.2 mile) in the 5GHz band and above 1 km (0,6 miles) using a standard hardware. Standard ranges achieved by stock antennas and standard output power are 100 m (300 feet) for outdoor (line-of-sight) range, and about 10 m (30 feet) for indoor use.

- *Power Consumption*

The main purpose of Wi-Fi is to deliver enhanced data rate. The power consumption issue is in this technology not significant, and there is no main intention in the development to try to lower it. There were some attempts to create low power Wi-Fi devices, but the results are not as persuasive as e.g. Bluetooth or ZigBee can be. Broadcom has developed a chip that drains 270 mW in full speed, and calls it low power. Gainspan has developed another chip, GS1010, which is truly SoC, with radio, MCU, RAM and Flash integrated in single chip, thus lowering the final power needed. They claim that single AA battery will last years in their product [17]. In numbers, an average full speed power consumption of an 802.11g device ranges from 400mW up to 1W.

- *Network Features*

Wi-Fi defines two types of networks – ad-hoc and infrastructure. In ad-hoc network, there is no master device, all devices have equal roles and all of the connections made are peer-to-peer. These are mostly used for temporary purposes. Infrastructure is a network with one (or more) master devices. These devices define the parameters of the network. Devices that join the masters and are not providing connection to the network to other devices are called slaves.

The topologies possible to form using Wi-Fi are star or tree (using multiple AP). There are also proprietary mesh network applications being developed, with the aim on metropolitan networks.

- *Security and Reliability*

Wi-Fi is well known for its former weak WEP encryption. In last few years, as its popularity grew up, new security algorithms were applied in Wi-Fi. Nowadays, the security standard is defined by 802.11i. WPA2 supplies most features defined by that standard (using AES for enciphering) and together with authentication protocols (various forms of Extensible Authentication Protocol (EAP)) it is at least for now considered secure.

- *Costs*

It is difficult to obtain prices for single chips for Wi-Fi, as most of the SoCs / RoCs are currently under development, and the others are not for sale separately and wholesale prices are kept as confidential. The total price of the wireless card is far below 100\$. So, for a single chip, the price could be approximately ten of dollars.

### C. Certified Wireless USB

This is the only technology that, at the moment, is not based on an actively maintained IEEE standard. Thus, there is a lot more competition in this field – various companies are using the name "Wireless USB" for their products, which are, however, not compatible with other company's "Wireless

USB" [16]. Due to this confusion in terminology, the largest group of industries concerned in Wireless USB development decided to call their solution "Certified Wireless USB". It is officially supported by the authors of USB – the USB Implementers Forum, and names such as Microsoft, Samsung, HP, Intel, NEC, Nokia, LSI and NXP figure among companies supporting and contributing to its development.

- *Hardware Dimensions*

Alereon is the main manufacturer of UWB chipsets. The company maintains a 3rd generation of Certified Wireless USB compliant chips; one of the current chips (the AL5300) can be used worldwide (bands 1, 3, 4 and 6), others only in USA (band 1 only). There is no official information on the dimensions of the chips, but according to original scale images, they come in both TFBGA and WLCSP package in the sizes of about 5x5 mm (0.2x0.2 in). Artimi delivers another SoC to the market, which, however, needs an external WiMedia compliant chip to function. It comes in 10x10 mm (0.4x0.4 in) LFBGA package [18].

- *Memory Requirements*

For the host adaptors, it is assumed that a computer or other powerful computational device is present that will manage all the required calculations. For the device adaptors, the computational power correlates with the required speed of the device. Most of the manufacturers use RISC processors with tens of MHz and under 100kB of RAM and ROM [19].

- *Bandwidth and Range*

As was already mentioned in the introduction, Wireless USB is supposed to replace the current wired USB, thus it offers the 480 Mbit/s maximum data. But, due to the design of physical layer, this speed can be achieved only at short (3 m (10 feet)), line-of-sight distances. For longer distances it drops rapidly, to about 110 Mbit/s at 10 m (33 feet) and even less at longer distances. The maximum range for reliable transfers is not far behind 10 m [20].

- *Power Consumption*

The general power consumption of Wireless USB can be defined as lower than Wi-Fi but higher than Bluetooth. All the chip manufacturers I found were boasting with low power. Wireless USB solutions, but only one gives exact numbers: Artimi's draining 100mW under certain circumstances when online. A-150 can run The Wireless USB devices are also able to sleep, lowering the consumption to under 5mW.

- *Network Features*

Only a simple peer-to-peer star topology network is offered by Certified Wireless USB. The central device is the "host adapter" which provides connection for „device adapters“. The maximum number of device adapters for single host adapter is 127. They are sharing the common bandwidth through a TDMA.

- *Security and Reliability*

There are several uses of encryption / authentication methods in WUSB. The standard method is AES-128 Counter with CBC-MAC. It also specifies a public key encryption, but for authentication purposes only. It has to be as strong as the CBC-MAC, so it uses RSA cipher with 3072

bit keys for encryption and SHA-256 for hashing [16]. The security architecture is also capable of wired connection detection as a form of encryption, allowing leaving out additional cryptography. Wired connections can be also used for secure initial CCM Connection Key distribution. Most of the reliability considerations were already mentioned, in general transfers within the 10 m (33 feet) range can be considered reliable, although, there is a large influence on the reliability with the presence of other wireless technologies.

- *Costs*

The cost of single chip is not publicly available from any of the above-mentioned manufacturers. Nevertheless, it should not be much higher than 10\$, as the technology claims to be low-cost and also because it is trying to compete Bluetooth, which chips cost about 10\$.

#### D. ZigBee

ZigBee is a radio frequency (RF) communications standard based on IEEE 802.15.4. Figure 3 depicts the general architecture of a ZigBee based home automation network. The ZigBee coordinator is responsible for creating and maintaining the network. Each electronic device (i.e. Washing Machine, Television, Lamp etc) in the system is a ZigBee device managed by the coordinator. All communication between devices propagates through the coordinator to the destination device. The wireless nature of ZigBee helps overcome the intrusive installation problem with the existing home automation systems identified earlier[1].

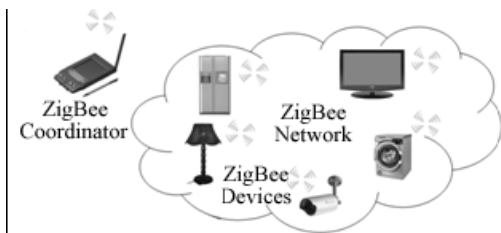


Fig. 3. ZigBee Home Automation Architecture.

- *Hardware dimension*

The dimensions of both ZigBee SoCs and ZigBee transceivers are approximately the same, ranging from 4x4 mm (0.15x0.15 in) to about 7x7 mm (0.27x0.27 in), mostly in QFN packages. Additionally, because of a low number of external components, the final product can reach similar sizes to Bluetooth, as the only larger external part required is an antenna.

- *Memory Requirements*

When compared to other technologies, memory requirements of ZigBee are the least demanding. The total required memory is based on the particular ZigBee stack you want to use [21]. But, in global terms, 100kB of ROM and units of kilobytes of RAM should be sufficient for most of the stacks. Also the computational power is reasonable – usually RISC MCUs at frequency below 30 MHz are used.

- *Bandwidth and Range*

ZigBee belongs to the low-speed WPAN network family, thus its bandwidth is limited. The maximum data rate is 250kb/s at every physical layers defined in the latest 802.15.4 standard [17]. The standard range for indoor application is about 30 m (100 feet) for indoor applications and about 100 m (300 feet) for outdoor use. The range can be also extended by using higher power, whip / external antennas, and clearing the Fresnel zone. In numbers, typical ZigBee radio uses from 30 to 50 mW for receive and about one quarter more for transmit. The sleep power is about (but mostly lower than) 0,001 mW.

- *Power down and wake up cycles*

As most of the devices in the network are sleeping endpoints, the duration of a power down and wake up cycle is important factor that influences the length of battery life. Speaking about the SoCs or modules, the time required for them to wake up is mostly dependent on the software (firmware) used. E.g. a radio running only the 802.15.4 compliant software does not need to undergo the initialization process of a ZigBee stack, which can in case of very low duty cycle save valuable milliseconds [22]. This fact should be considered when deciding between ZigBee and proprietary 802.15.4 application [23]. The power down is not a computationally difficult task. Generally, the end devices can be turned down instantly at any time. Nevertheless, a timeout is usually implemented for applications that use duplex transfers [24].

- *Network Features*

ZigBee networks can be established by a coordinator only [25]. Upon correct PAN parameters settings, other devices may join the network, forming one of the following topologies [26].

#### E. X10

X10 has long been the standard by which other home automation technologies are measured. X10 works via home's power line wiring and may experience problems related to wiring distances, phase differences, and line noise. Many enthusiasts believe X10 technology has become obsolete, replaced by the newer and more versatile wireless technologies. If you're new to home automation it's probably a good idea to start with some other technology, because X10 devices can be more difficult to configure and performance is sometimes erratic.

#### F. UPB

Universal Powerline Bus (UPB) is similar to X10, using the home's built in wiring to transmit home automation control signals. Developed to overcome many of the shortcoming that X10 experiences, UPB is a superior powerline technology to X10. UPB is not X10 compatible. If you have X10 compatible products and you want your UPB and X10 compatible products to work together you will need a controller that talks to both.

#### G. INSTEON

Designed to bridge wireless home automation to powerline automation, INSTEON devices communicate over both power lines and via wireless. INSTEON is also X10 compatible, thereby adding wireless capability to an existing

X10 network. Finally, INSTEON technology supports even home automation novices: even non-technical individuals can set up and add devices to the network.

#### H. Z-Wave

The original wireless home automation technology, Z-Wave set standards for wireless home automation. Z-Wave extended the usable range of home automation by making all devices double as repeaters. Its increased network reliability also enabled commercial applications. Z-Wave devices are designed for ease of setup and use, and come about as close to turnkey as the home automation industry allows, especially helpful for beginning enthusiasts.

### IV. TECHNOLOGIES COMPARISON

The comparison table for different technologies is as shown in Table.1.

Table.1.Home Automation Technologies Comparison

	ZigBee	802.11 (Wi-Fi)	Bluetooth	UWB (Ultra Wide Band)	Wireless USB	IR Wireless
<b>Data Rate</b>	20, 40, and 250 Kbits/s	11 & 54 Mbits/sec	1 Mbits/s	100-500 Mbits/s	62.5 Kbits/s	20-40 Kbits/s 115 Kbits/s 4 & 16 Mbits/s
<b>Range</b>	10-100 meters	50-100 meters	10 meters	<10 meters	10 meters	<10 meters (line of sight)
<b>Networking Topology</b>	Ad-hoc, peer to peer, star, or mesh	Point to hub	Ad-hoc, very small networks	Point to point	Point to point	Point to point
<b>Operating Frequency</b>	868 MHz (Europe) 900-928 MHz (NA), 2.4 GHz (worldwide)	2.4 and 5 GHz	2.4 GHz	3.1-10.6 GHz	2.4 GHz	800-900 nm
<b>Complexity (Device and application impact)</b>	Low	High	High	Medium	Low	Low
<b>Power Consumption (Battery option and life)</b>	Very low (low power is a design goal)	High	Medium	Low	Low	Low
<b>Security</b>	128 AES plus application layer security		64 and 128 bit encryption			

### V. CONCLUSION

This paper covers the review of different Technologies which strongly support the Home Automation systems in Reliable way.

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