SMART-DIGITAL HOME

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ABSTRACT
This paper provides the comprehensive definition of Smart Digital Home giving a complete analysis of all the desired features and the various technologies that are available to automate the various home-appliances by setting up a network. The paper lists all of the prominent technologies/standards/protocols being used to implement such a system and explains the pros and cons of those technologies and describes why some technologies are superior to the others. The basic assembly of components for making prototype of smart home is also described. After covering all the features and the capabilities, this paper will come up with one of the most prominent and effective technology which can be widely used for the home automation due to its effectiveness and functionality.

KEYWORDS: *Home Automation System, Smart Digital Home, Protocols, Wireless Communication*

I. INTRODUCTION

Today is the era of Internet, in which all of the things can be done simply by the tap on the phone. With the smartest of the smartphones being available to each and every one in some form or the other, no part of the human life has remained unaffected from it. Thus, as a next addition to the revolution, what was supposed to be a luxury a few years back is now turning to be a need for the modern lifestyle. A Smart Home is one such quest in the emerging scenario.

What Does a Smart Home mean?

[1] defines Smart Environment as "A smart environment is a physical world that is richly and invisibly interwoven with sensors, actuators, displays, and computational elements, embedded seamlessly in the everyday objects of our lives, and connected through a continuous network". At the time where every next thing is getting smart, why not anticipate homes to be smart too.

A smart digital home thus can be defined as a home with all its electrical and electronic appliances connected to each other or through a common coordinator by means of a network. The network then facilitates the interaction between the devices and the execution of user-requests which can be as simple as glowing of an electric bulb or as complex as playing a song from the desktop hard-drive over the intelligent speakers. In simple terms, just like we have an IR remote to navigate through the various T.V channels, in a smart home, we can control the working of all the appliances by accessing a common network being used by all the devices of the house. This smart home network can be made even smarter by making use of various sensors and actuators that further imparts intelligence to the home-appliances. The Smart Digital Home concept opens a wide area for innovation and creativity for the developers to provide as much functionality with the maximum ease to the user. The early development of the idea maps back to 1970s when such a system was proposed and executed using the power lines (X10).

With the advancement in technology and the depreciating hardware costs for routers and gateways, today, a similar kind of functionality is being attempted to be delivered in a more sophisticated and modern fashion using various wireless protocols.

Agenda for this study

Although the development of a raw-prototype for the system is not that much of a cumbersome tasks, refining the system so as to actually meet the day to day needs and fulfil the commercial goals is a bit difficult to achieve. This paper, therefore, describes all the essential and desired features that can be considered to be of vital importance so as to make a product that meets the industry standards. Also, various different technologies available for implementation of the system, with each technology having its own boons and banes, can boggle anybody's mind while deciding which standards to choose. Therefore, the subsequent text in the paper, attempts to specify and elaborate various key characteristics of different technologies so as to facilitate the choice making process for implementation. The technology which defines and describes the futuristic smart-homes and emerges out to be having the good characteristics of all the prevailing technologies is also discussed.

II. DESIRED FEATURES

To identify a good wireless technology for house automation a list of requirements must be considered. These are:

2.1 reliability of the communication

Important functions such as window blind or even security installations are to be controlled via wireless signal. Hence it is essential that all messages will reach its destination and will be confirmed by the received device back to the transmitter. Not all wireless protocols comply with this requirement. So it is important that the technology which we are using for the smart home must adhere to the reliability factor.

2.2 security of communication

It must be guaranteed that an unauthorized third party cannot – on purpose or accidently – intercept or interfere the communication of the wireless system. Typically encoding technologies and handshake mechanisms ensures this. So the technology must have the certain mechanisms which ensure that the whole network must be secured from invaders and from any unauthorized access.

2.3 Low Radio Emission

Wireless technology for home automation is used on living rooms; hence issues like electromagnetic emission need to be taken into account i.e. we must take care of the health factor of the housemates living so technology should be that one which emit least possible radio waves and also work efficiently.

2.4 Ease Of Use

Home automation shall make the life of the user easier and not more complicated. If the usage of the technology and its operation is hard to understand and operate on then there is no meaning of using the technology because it will make life of user more complicated.

2.5 Reasonable Price

The technology which we are using should also be in the budget and must be of adequate price because if the technology is not price efficient, then also there is no means of using it.

2.6 Modularity And Future Proof Design

Home automation solutions are typically installed during the construction of new buildings or renovation and need to comply with typical product life cycles of home installation equipment. It is important to make sure, that the user can replace devices or extends their systems even after years as per the requirement and do not run into compatibility issues.

2.7 Interoperability

Home automation functions such as heating, lighting or window control are implemented with products of different vendors with expertise in their respective area. It is not acceptable to be forced to stick with one vendor and buy - as an example - heating technology from a vendor with core competence in lighting just to enable interoperability. Each installed wireless technology has to be

used independent from several manufacturers. So, the technology used must be able to interwork with different vendors' equipment and work efficiently.

2.8 Investment Protection

It is important to make sure that installed Controller or Modules can be easily replaced in the future. Consider having installed a system that has some components fail after 5 years, and at the same time, the company which installed it became bankrupt. The home owner would be left with no choice but to completely revamp the entire electrical system in the residence which would cost more in time, labor, and equipment that what was originally paid for the automation system. Having a system that is standardized means that any other company can support it or replace certain parts with different products, maybe from different vendors, in order to ensure continued operation.

2.9 Features And capabilities

It is important that automation technologies go beyond just controlling individual modules and have the capability to integrate with other systems most typically entertainment since that is an area of high usage of any home owner. Example: Easy Integration with Multi-room Music Systems, Multi-room multimedia distribution systems (Movies, Videos, Pictures, Music)...etc.

2.10 Low Interference With Other Signal Frequencies

It is also important that the technologies implemented for smart home automation should not interfere with other wireless networks that are expected to be present in a house such as Wi-Fi etc.

III. BASIC ASSEMBLY OF COMPONENTS

Depending on the various solutions that can be used to automate a home, several different kinds of devices may be used, but the basic assembly of devices remains the same {for most of the systems/technologies}. The main devices required in the system are:

3.1 Signal Transmitter

A transmitter is a device that is used to send a signal to the other device. The encoded message is sent from one end to the other using the transmitter. The user sends the various commands to the system using this transmitter.
There can be various different types of transmitters depending upon the network/technology used. For example, a Television remote-control is an IR-transmitter (For IR based system [2]). Various different types of transmitters include Cell Phone, A computer port (USB, serial port or WLAN), customized remote controls etc. The acknowledgment for successful execution of the operation is also received at the transmitter thus it should also have the capabilities to process that signal in order to make the system reliable.

3.2 Communication Technology

It refers the set of protocols and standards to be followed in order to transmit and process the signal between the various devices. It is the primary factor that actually shapes the type of smart home to be delivered. There are a lot of technologies being used for this propose which are later discussed in this paper. Each technology has its own set of advantages and disadvantages. Each technology imparts certain special characteristics to the system such as enhanced security etc. Thus, it is very crucial to choose the transmission technology for the system.

3.3 Receiver And Decoder

This device is installed with the devices we are going to operate on. The signals sent by the user are received and decoded at the receiver. The receiver than forwards the signal to the micro-controller it is attached to for deciding the further course of actions. The choice of this receiver also depends on the transmission technology chosen for establishing the connection.
For enhanced reliability, receivers are sometimes required to send a small feedback/acknowledgement packet back to the user-transmitter so as to acknowledge the successful execution of the request or command.

3.4 Microcontroller/PIC

After having established a secure and effective communication between the user and the device, the next concern becomes the execution of tasks and deciding the appropriate actions to be taken as per the request signal received. All this decision making and request-to-action mapping is coded in a microcontroller chip which is sometimes referred to as the logic card of the system. The input pins of the micro-controller are connected to the signal-receiver and the output pins to the device (with a relay in between) so that the request from the user reaches the micro-controller for processing and then after processing, the micro-controller sets the appropriate pin(s) high depending on the switching logic coded in it.

Figure 3.4.1: A Microcontroller (Image source [3])

3.5 Relay

While all the devices used in establishing the communication and sending and receiving the signals are "Low-power devices", the devices for which these signals are required to operate upon in the end are not one of them i.e. a transmitter-remote, receiver and micro-controllers are low power devices that operate on very less voltage but the light bulb (say) that the user requests to glow do not understands this low power signals. Thus, in order to fill the gap, a 5 V relay is used between the micro-controller and the end device so as to establish a successful communication between the two.

Figure 3.5.1: A Relay (Image source [4])

3.6 Gateways

Gateways are the devices that are used to connect two dissimilar networks. Gateways are used in Home Automation because sometimes for wider interoperability, different kinds of networks are used for different devices thus; a gateway helps establishing communication and acts as an interface between those dissimilar networks.

3.7 Other Requirements

Components that are to be operated on (such as light bulbs etc.) are powered externally and should not extract power from the system other than establishing communication.
Also, the interface for the system can be made more and more User-friendly and advanced using JAVA, ASP.NET etc.
Various different sensors such as photo-sensors, temperature-sensors can also be used in the system for enhanced automation. The logic for these sensors is also coded in the same micro-controller.

IV. DESCRIPTION OF VARIOUS TECHNOLOGIES/PROTOCOL STANDARDS

The following are the technologies along with their some of the distinguishing features that make them well suited and most appropriate for the working of a smart home.

4.1 POWER LINES

It is the earliest and most popular wired technology which uses 230 V mains lines for the process communication i.e. signalling and control operations. It is based on the X10 protocol which is used in home automation for the communication between the electronic devices. In this the power lines are used for the transmission of the digital data between the X10 products. The data is sent from the controller to the controlled devices and it consists of address where to send and the command i.e. which action to be performed. There can be any kind of command i.e. from simple temperature reading to the on and off of the light etc. The packets which are transmitted using X10 protocol consists of 4 bit house code followed by 4 bit unit code and then 4 bit command code. In this network during the time of installation itself, every controlled device is configured to response to any of the possible 256 possible addresses. Its operation is very simple.
The user just has to just use the dial buttons on the transmitter side and the signal is sent to the receiver side performing the operation.
But a lot of problems faced with this technology are making this technology less popular nowadays. The first and most prominent drawback is its structure i.e. the wired one which not only results in the geographical constraints but also result in the problems like attenuation, noise and other phenomenon. Moreover the biggest problem faced with this is the lack of reliability and the security. There is conformation form the receiver part and that the operation is performed successfully or not i.e. it is unreliable. Moreover, if any unauthorized person is able to tap the power line so he/she can easily send different commands and signals and thus questioning the security feature of this protocol. Also, the features and functionality it provides are of very limited domain and are restricted only to on-off, dimming lights etc.

4.2 KNX

It is a network communication protocol which is used for home control automation. It can use several communication media e.g. twisted pair wiring, power line networking, radio transmission etc.
Using a microcontroller of 8-bit with a PC depending on the needs of a network, a KNX device network can be used efficiently and effectively.

There are three categories of the KNX device which are as follows:-

- **A mode or Automatic modes**- These types of devices have ability to configure them automatically and moreover end users can themselves install them
- **E mode or Easy mode**- For the installation of these types of devices, a basic training is required
- **S mode or System mode**- they need to be programmed properly and also installed by the technicians

KNX also finds a wide range of areas where this technology can be effectively used due to its following advantages:-

- It is a universally accepted standard so it is an international standard.
- It can be used with the several different media and technology resulting in the interoperability and internetworking.
- It is independent of any technology and software as an 8-bti microcontroller can be used for the intelligent operation.
- It can be widely implemented for the wide range of applications in the home control, building control and other automation systems

4.3 Z-Wave

One of the most advanced and used protocol for the home automation systems now-a-days is z wave protocol. It is a low bandwidth reliable wireless communication protocol which is mainly used to communicate the short messages in a reliable manner. It uses a low power RF radio embedded in the home electronics system e.g. lighting system, entertainment system etc. to control the various actions to be performed. In the Z-Wave network each device is assigned a unique identification number known as Node ID which is of 1 byte and each complete network is recognized by its Network ID.

The complete Z-Wave network consists of nodes which can be classified as "master" node and "slave" node. All the controlling nodes which give commands for the particular action to be performed to the other nodes are termed as master nodes and commonly called "Controllers". And the nodes to which commands are given are called slave nodes.

4.4 Zigbee

ZigBee is an open wireless network communication protocol based on the IEEE specification IEEE 802.15.4, which enables the Controller to communicate with its Modules via Radio Frequency. ZigBee is used in applications that require a low data rate, long battery life, and secure networking.

Even after being low-powered, ZigBee devices can send data over longer distances by routing them through the intermediate devices thereby creating a mesh network. ZigBee has a defined rate of 250 Kbit/s, best suited for periodic or intermittent data or a single signal transmission from a sensor or input device.

ZigBee networks are secured by 128 bit symmetric encryption keys. In home automation applications, transmission distances range from 10 to 100 meters line-of-sight, depending on power output and environmental characteristics. A complete ZigBee solution is described in [6]

ZigBee devices/nodes can be classified into three types based on functionality:

- ***ZigBee Coordinator (ZC)***: The most capable device, the Coordinator forms the root of the network tree and might bridge to other networks.
- ***ZigBee Router (ZR):*** As well as running an application function, a Router can act as an intermediate router, passing on data from other devices.
- ***ZigBee End Device (ZED)*****:** Contains just enough functionality to talk to the parent node (either the Coordinator or a Router); it cannot relay data from other devices. This relationship allows the node to be asleep a significant amount of the time thereby giving long battery life.

4.5 Bluetooth

Bluetooth is a wireless technology standard for exchanging data over short distances (using short-wavelength radio transmissions in the ISM band from 2400–2480 MHz) from fixed and mobile devices, creating personal area networks (PANs) with high levels of security.

It can connect several devices, overcoming problems of synchronization. The transmitted data is divided into packets and each packet is transmitted on one of the 79 designated Bluetooth channels [7]. Each channel has a bandwidth of 1 MHz thus it can be used in places where data-intensive communication is to be established such as sending a command to print a page to the printer.

The advantage of using Bluetooth in home automation is that almost all the smartphones have built in Bluetooth feature in them and thus, it becomes easier to connect to various devices using the smartphone. A complete android app based is described in [8]. Also, Bluetooth supports a high level of interoperability.

A master Bluetooth device can communicate with a maximum of seven devices in a piconet.

4.6 GSM

GSM refers to Global System for Mobile Communication and is the most widely used technology in the operation of mobile phones. The same technology can be used to automate a home by installing a GSM Module (Modem) at the device to be controlled.

The Module will have a SIM inserted in it and the user can remotely trigger the device by either calling or sending an SMS at the number attached with the device depending on the configuration of the micro-controller.

Using this technology, as described in [4], a low cost, secure, ubiquitously accessible, auto-configurable, remotely controlled solution for automation of homes can be achieved. The basic level of home appliance control and remote monitoring has been implemented. The system is extensible and more levels can be further developed using automatic motion/glass breaking detectors so the solution can be integrated with these and other detection systems. In case of remote monitoring other appliances can also be monitored such that if the level of temperature rises above certain level then it should

generate SMS or sensors can also be applied that can detect gas, smoke or fire in case of emergency the system will automatically generate SMS.
But the solution is not a long term solution for regular usage as it will gradually turn out to be a tedious task to send an SMS and bear the charges for just glowing of a bulb.

4.7 EnOcean

It is a wireless technology which is based on the concept of the energy harvesting and is used primarily in automation industry, transportation and in smart home concept as well. In this technology, we use the sensor network that derives the energy from the external sources of the energy e.g. Wind energy, solar energy, thermal energy and then store it and then these are converted into the electrical energy form with the help of electromagnetic, solar energy converters.
The modules based on this technology use these converters with the ultra-low power electronics and the combination of both enables the wireless communication between the wireless sensors, controllers, gateways etc. The various forms of energy which can be used from the environment are like difference in the temperature due to indoor lights, humidity difference, CO_2 emission sensors etc.
The products based on this technology **perform without batteries** and radio signals from the sensors have range of about 300 meters in open. The packet size is relatively small (14 byte long) with the transmitting speed of 125kbit/sec. And the good thing is that it emits the energy only for the respective 1's in the binary format which results in the less power consumption thereby reducing the energy requirements to Nano-watts.
The technology basically the combination of three technologies:

- Energy harvesting – In this the wireless sensors use motion controller, thermo convertors etc.
- Energy management – It ensures that we can work with the tinniest amount of energy.
- Software Components – It enables the integration of the components in a user friendly and operable environment.

V. COMPARISON OF VARIOUS TECHNOLOGIES

Having a lot of options to choose from, it becomes a crucial task to decide which technology can be considered ideal for which scenario as each has its own characteristics associated with it. Thus, to the following table compares various technologies discussed above in terms of various desirable features and characteristics (based on [5]) shown by them:
Based on Reliability, security of connection and the interoperability between devices:

Table 1. Comparison of Various Technologies (I)

	Reliability	**Security**	**Interoperability**
Power Lines	Questionable	Questionable	High
KNX	High	High	Medium
EnOcean	Low	High	High
ZigBee	High	Low	Low
Z-Wave	High	High	High
Bluetooth	High	High	Medium
GSM	Low	Questionable	Low

Based on Cost of installation, maintenance & working, radio emissions, simplicity and investment:

Table 2. Comparison of Various Technologies (II)

	Price	Radio-emissions	Simplicity	Investment Protection
Power Lines	Low	Low	Low	High
KNX	High	Medium	Medium	Moderate
EnOcean	High	Low	Medium	High
ZigBee	High	Medium	Medium	High
Z-Wave	High	Medium	Low	High
Bluetooth	Low	High	Medium	High
GSM	High	Medium/High	High	Medium

VI. CONCLUSION

From the detailed study of the technologies mentioned in this paper, it can be clearly concluded that each of the various technologies or protocol standards have their own pros and cons. While some are suited for one purpose, others are quite useful for others. So, after going through all the capabilities and features it comes to our sight that Z-Wave technology is the most advanced, efficient and fulfills the needs on the ground of security and reliability which are the most desired features for the successful implementation of the home automation network.

VII. FUTURE USE

With the on-going advancements in the technology industry where more emphasis is given to the environment friendly and sustainable products and technologies, EnOcean comes out as the need of the future as it works on the concept of energy harvesting and energy management. So, seeing the future eco-friendly perspectives this technology is well suited for the home automation industry [10]. Moreover, if the controllers and sensors are embedded in the daily usage appliances e.g. mobile phones etc. then it can be more handy and user friendly as well.

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