

# **Design and Implementation of Wi-Fi based Smart Home Automation System**

*Thesis submitted in partial fulfillment of the requirements for the award of  
degree of*

**Master of Engineering  
in  
Computer Science and Engineering**

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**June 2018**

## CERTIFICATE

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I hereby certify that the work which is being presented in the thesis entitled, "*Design and Implementation of Wi-Fi based Smart Home Automation System*", in partial fulfillment of the requirements for the award of degree of Master of Engineering in *Computer Science and Engineering* submitted in Computer Science and Engineering Department of Thapar Institute of Engineering and Technology, Patiala, is an authentic record of my own work carried out under the supervision of *Dr. Avleen Kaur Malhi* and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.



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Shrey Sachdeva

## ABSTRACT

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With cities growing at fast pace with the blend of ever evolving technology, it appears everything will be connected to the internet in the coming days, with an estimated 11 billion devices already; excluding the smart phones and laptops. The aim of this research is to study the various technologies and build a smart home automation system with a low cost, which can be accepted readily. Its focus is to improve the standard of living of an average man. IoTis being used which is still in its evolving stage to build a smart home where all the electrical devices are connected to the internet and can be accessed through a mobile phone. In building such architecture, various technologies need to be studied which are being used like Bluetooth, Zigbee, Wi-Fi to do a comparative study for knowing the best technology and which protocol will be good to implement such a system. In current work,nodeMCU(microcontroller) is used which is based on open source technology and uses Lua script for coding and assigns an ip address to the microcontroller which signals to the relays for turning on and off the device based on the user input. It uses HTTP protocol for sending the requests. The response is real time and can be applied with low installation costs. Bandwidth requirement is low for the microcontroller. Thus, it provides a wifi based low cost and reliable solution which can be readily accepted by users for its deployment and maintenance.

**Index terms:** Internet of Things, Home Automation System, Real time response, Wifi based solution

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# CHAPTER 1

## Introduction

In 2004 there were 6.8 billion people and 600 million devices connected to internet, which are expected to grow to 8 billion people and 15 billion devices by year 2020. Even though the exact number is not known at the current time but it is expected to have a major impact on our lives and the society combined. Internet of Things provides us with a new communication paradigm for connectivity between networks of devices for performing communication with their surroundings. It surely consists as a next step towards the digitization of our economy and society. Hence, it can be seen as a distributed network of connected devices using standard communication protocols, which can act with their environment or talk to other machines or computers. It provides easy access and connectivity with uniquely addressable devices like home appliances, security cameras, sensors, etc. So, it will have a high impact on everyday lives of people and behavior of potential users.

### 1.1 Internet of Things (IOT)

Internet of Things provides us with a new communication paradigm, through which all the devices will be connected to the internet forming an inter-connected network of devices which will be able to talk to themselves and their respective surroundings. It surely consists as a next step towards the digitization of our economy and society. Hence, it can be seen as a distributed network of connected devices using standard communication protocols, which can act with their environment or talk to other machines or computers.

Such a heterogeneous field of application makes it difficult to build a standard architecture due to its wide range of application and its complexity. The advances in the field are hampered due to lack of clear and widely accepted business model. The issue remains how to provide inter connectivity and high functionality, preserving the security, privacy and storage technologies, because if devices from different vendors don't use the same standards the inter-operability remains a major concern, with more gateways required to make a platform independent standard. The issue remains to be seen how the standards are chosen without limiting or reducing the functional requirements of various fields.

The market and technological aspects have a great influence over an evolution of an innovative technology, basically to keep in mind as to which users it is going to serve best.

But where market and technology are new or poorly understood, the product or system is called ‘complex’.Complex systems generally consist of other complex components or sub systems. The solution can be provided to the customer as a bundled solution with its components and an interface which is provided by the manufacturer. But such a system cannot generally be optimized as per customer needs. Configuration brings together the hardware components, software, sensors, standards, services and user practices that makes it highly dependent on the context of application like a water sprinkler IoT based solution, which is limited to the outdoor lawns. The connections in complex systems can be depicted in Fig.1.1. The complex systems can be well explained in Fig. 1.2 with various domains covered and their functionalities.



**Fig. 1.1 Many connections in a complex system**

Components use existing technologies at component level. But at an architectural level they need to be combined to provide the interoperability. And to understand such systems we need to have the knowledge of following levels:

### **1.1.1 Component Level**

Many sub systems work together to form the complex system. It includes the study of various sub systems at their smaller units of which they are made of;for example, in this work the various components are nodeMCU and its properties like what programming language it uses and how much voltage is required to operate it in an efficient way i.e., the underlying technologies and power requirements of the individual components.

### 1.1.2 Architectural Level

All the sub systems make the application. Knowledge at architecture level means how these various sub systems are integrated together and deliver the service. This requires the study of the technologies that integrate the various modules and their interdependencies. So if one system fails we know what to do to correct it and get the service back up running as quickly as possible.

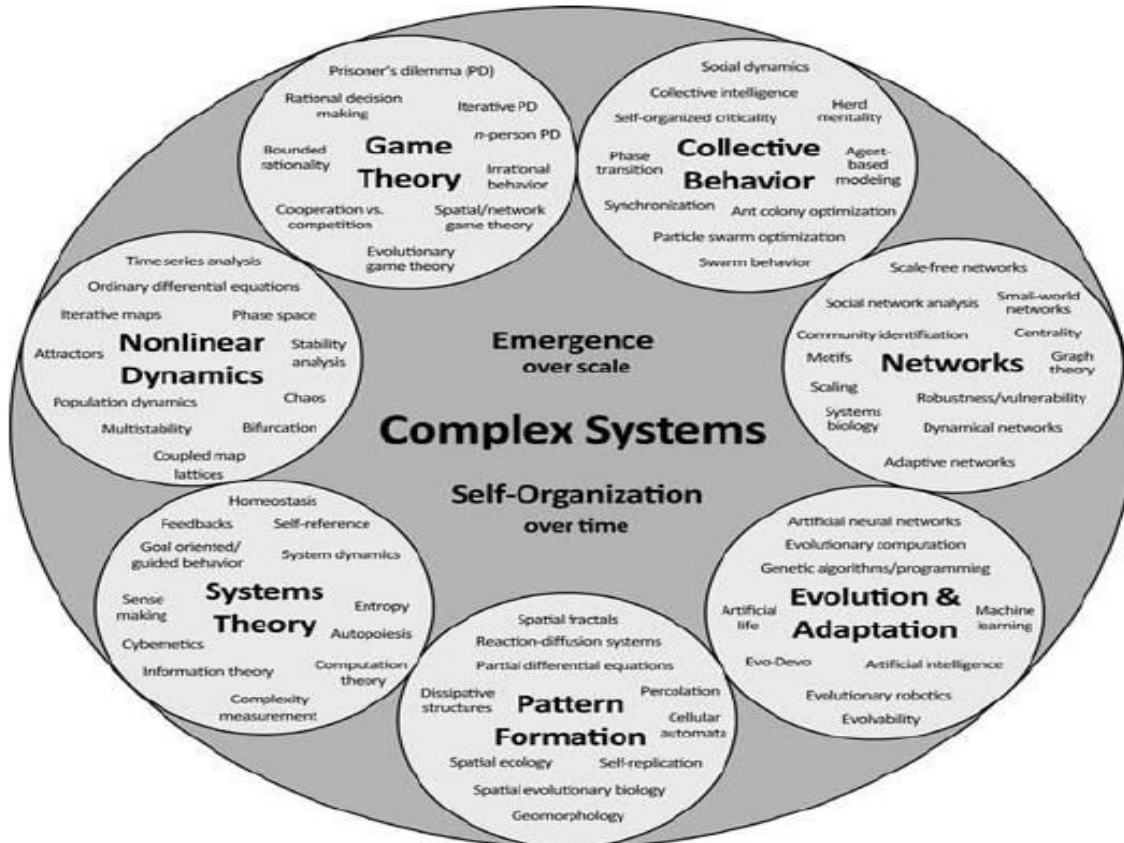


Fig. 1.2 Overview of a modern complex system [22]

## 1.2 Home Automation

The term Home automation refers to building smart home, where devices are automated like lighting, climate, entertainment systems and security systems. When they are connected with the internet they can be accessed from anywhere if we have a working internet connection. This depends on the architecture of the home automation and the interface which is provided by the manufacturer. A home automation system connects to a common connection point for all the devices, a central hub. The interface is generally built on a web based application, or a mobile application or a computer application. It provides the ease of use and a better standard of living to the end user. Fig. 1.3 explains the general network for home automation systems. It gives you better controlling power by controlling the individual elements of the house like:

**Light Control:** A light can be controlled from anywhere in the house because of the availability of internet. Lights can also be controlled through a response by remote control or a smart phone. It can automatically detect when the people are in a poorly illuminated room through luminance sensors and presence sensors.

**Remote Control:** The technology that has been used for remotely controlling devices like TV, heating, ventilation, etc., is infrared technology. The limitation is Line of Sight and short distance which makes the use of technology very limited.

**Smart Energy:** So many household equipments can be controlled automatically like HVAC, windows, central heating systems based on sensors data which can save a lot of energy who monitor variables like humidity, temperature, light. Therefore a lot of energy can be saved, smart meters can be applied to check the utility peaks and power companies can use WHANs to monitor and control the supply of energy.

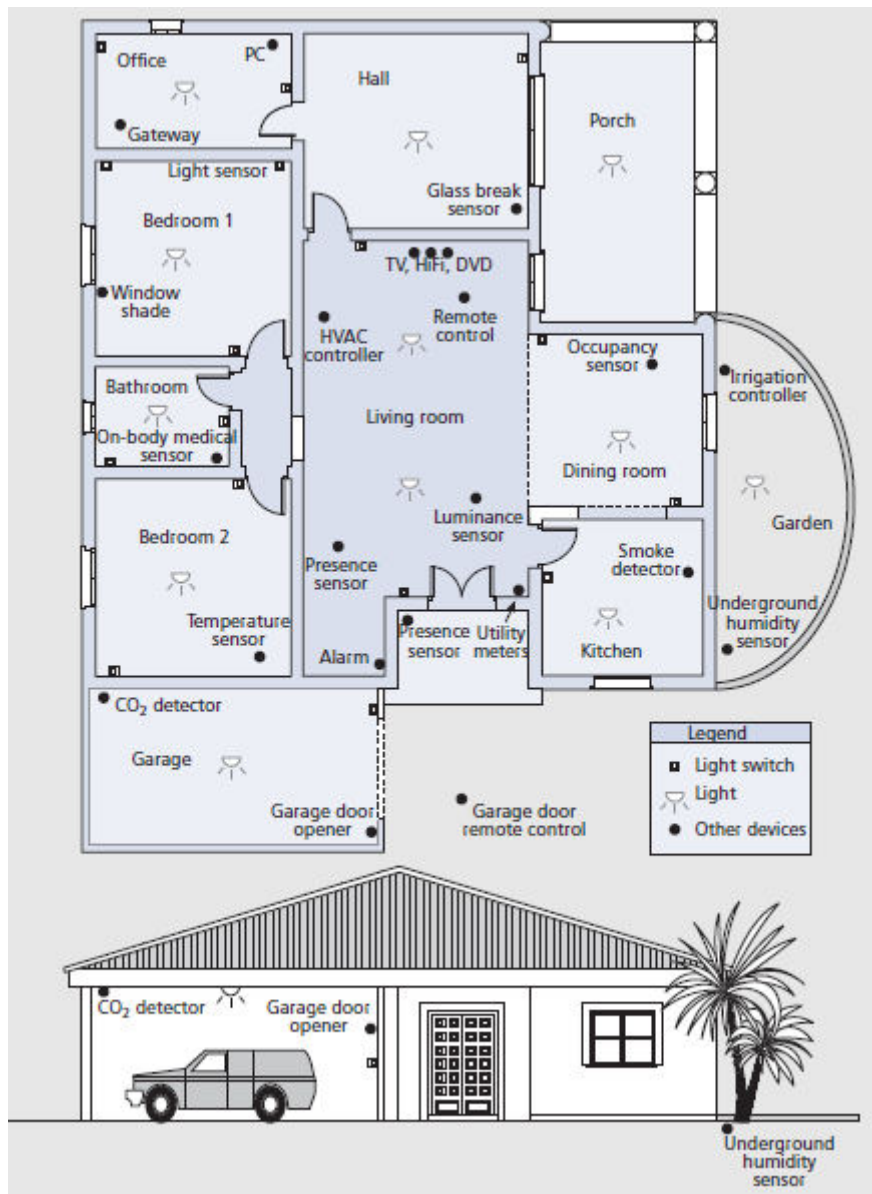
**Remote Care:** It can take care of elderly patients by remotely sending sensitive data like heart rate, blood pressure, sugar levels through sensors. In case of emergency alarms can be activated or a signal can be sent to the supervisor.

**Security and Safety:** Again sensors play an important role for security systems, like gas leak detectors, motion detectors, smoke detectors to take appropriate actions in case of a situation arises for example fire alarms can be detected in case of smoke is detected by sensors.

Figure 1.3 represents the overall network generated by home automation system by taking an example of wireless home automation network.

#### **Requirements of wireless home automation systems**

- There is high potential of node density, which can be in the range of hundreds.
- Home has a multipath environment which means there are multiple reflective surfaces like walls, floors etc.
- Residential scenarios might interfere with the bands that are already present at frequency levels like Bluetooth, Wi-Fi etc.
- There needs to be a multiple hop protocol so that end to end communication is possible between various nodes.
- Delay is not a major issue for some monitoring systems but WHANs need to be careful of real time data response, so that immediate action can be taken.
- WHANs should have internet connectivity so that they can be monitored remotely.



**Fig. 1.3 A typical example of wireless home automation systems**

### 1.3 Technological Standardization

Technical standards are established norms or requirements applied to technical systems. ‘A standard can be defined broadly as the consensus of different agents to do certain key activities according to agreed-upon rules, and a technology standard can be viewed as ‘a set of specifications to which all elements of products, processes, formats, or procedures under its jurisdiction must conform’. This works on a supply demands basis, on supply side, it defines a set of technological standards and functional requirements for a specific type of product. On a demand basis it shows the acceptance from consumers, so both combined brings a uniform and balance product between the technological feasibility and the corresponding acceptance of the product by the end user, which include the political, social and economic institutions. A de facto standard is a product which is highly accepted by the

consumers that it becomes a standard of its own. In most cases, many firms working on the same area make a consortium of their own to bring about the standardization of a technology through their own processes and knowledge sharing.

### **1.3.1 End User**

Systems that are still under development and the technology in its infancy, lack a stable system identity. Local practical knowledge is the most important asset in such a situation, to create a product that meets the end user requirements. Therefore IoT requires the knowledge of generic technology base and local practical knowledge. It has to be technologically and economically feasible, to provide a meaningful application. End users are really important because they can provide the local practical knowledge as to what their expectations are from the product, which can then be used as a feedback to help improve the technology further, for its successful adaptation on a large scale.

## **1.4 Internet of Things: Standards**

This section will cover the main technologies that are being used in industries to enable the IoT paradigm shift. It contains technical information about the open standards that are currently being used.

### **1.4.1 IEEE 802**

It started in 1985, when the United States Federal Communications Commission opened the frequencies 900 MHz, 2.4 GHz, and 5.8 GHz which were to be used without a license. These bands of frequencies were already used in the household appliances such as microwaves, but were thought of useless to have a practical application in communications. Later, WLAN (Wireless Local Area Network) emerged, since the technology was proprietary, hence wireless devices from one manufacturer didn't work with the technology from another one. But, in 1988, the NCR Corporation needed a WLAN standard to use in the wireless cash registers and requested the Institute of Electrical and Electronic Engineers (IEEE) to assist. The IEEE made a working team and named it IEEE 802 [23]. IEEE 802 is a group of IEEE standards that deals with local area networks (LANs). The services and protocols specified in IEEE 802 goes down to the physical and data link layers of the seven-layer OSI networking reference model. From here, several standards have been created that now form the basis of many local area networks. This gave rise in 1997 to standard IEEE 802.11, which refers to a set of standards developed for the wireless local area networks (WLAN). Another example is IEEE 802.15, which refers to the working team who specifies Wireless Personal Area Network (WPAN) standards. Within this working group, several task groups exist. Each task

groups deals with a certain subject of study from which a standard can be derived. For example, the IEEE 802.15.1 project has derived a Wireless Personal Area Network (WPAN) standard which is based on Bluetooth, IEEE 802.15.3 a standard concerning high-rate WPANs and IEEE 802.15.4 deals with low-rate WPANs. This last standard forms the basis of several protocols within the field of IoT. The IEEE is now one of the leading standard-setting organizations in the world and consists mainly of engineers.

#### 1.4.2 Wi-Fi

Based on a star-shaped topology, access point (AP) is used as Internet gateway for the Wi-Fi networks. Wi-Fi is laid upon the IEEE 802.11 standard and was made as a replacement for the widely used, cable-based IEEE 802.3 Ethernet standard. Currently, the IEEE 802.11 standard has many applications like in homes and is used in many businesses, which gives a significant throughput in the wide range of hundreds of megabit per second. This capacity is fine for file transfers, but it is too much for IoT devices as they generally require low bandwidth on an average.

Wi-Fi Households – Penetration of Total Households: 17 Selected Countries in 2011

Wi-Fi Household Penetration %	2011
South Korea	80.3%
United Kingdom	73.3%
Germany	71.7%
France	71.6%
Japan	68.4%
Canada	67.8%
Italy	61.8%
USA	61.0%
Spain	57.1%
Australia	53.8%
Czech Republic	31.6%
Mexico	31.5%
Poland	28.0%
Russia	22.9%
China	21.8%
Brazil	20.4%
India	2.5%

**Fig. 1.4 Wi-Fi Penetrations across the Globe**

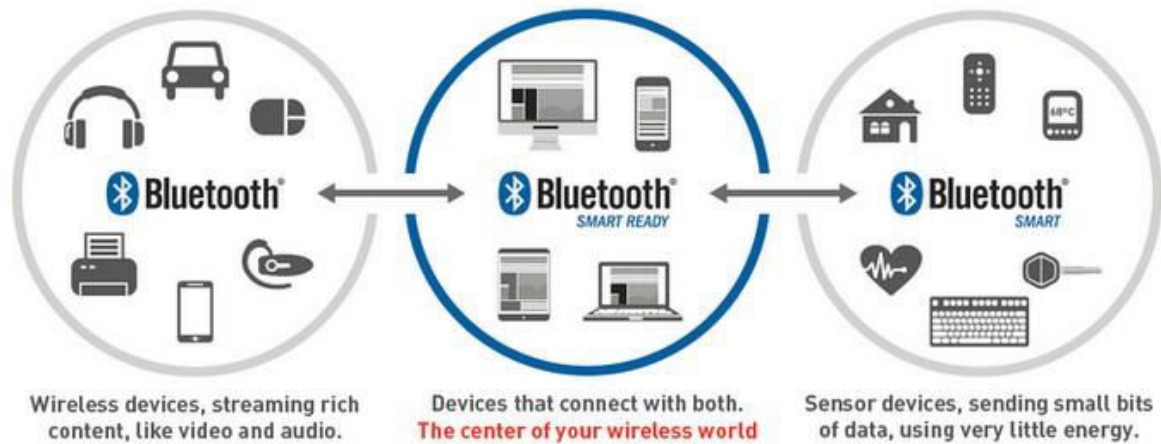
Moreover, the high power consumption required for achieving high data rates and good coverage in buildings makes Wi-Fi not often suitable for battery-operated devices. Although the Wi-Fi technology mainly defines the data link layer of a LAN, it is also integrated into the TCP/IP stack. Using Wi-Fi therefore implies that TCP/IP is used for Internet connectivity. Until recently, it was quite expensive to provide Wi-Fi connectivity to devices with low processing performance (e.g. thermostats or household appliances) due to the size and

complexity of the Wi-Fi and TCP/IP software. However, new devices and software often include the Wi-Fi and TCP/IP support. Fig. 1.4 explains the wifi penetration rate across the globe. A WLAN is generally password protected, it can also be open, this case any user can connect to the network if it is in the network's range. Wi-Fi is being used in many places such as home, offices and even at public locations via hotspot. Some business often do it to attract customers like Airports, hospitals, and restaurants which provide it through Wi-Fi hotspots, its range lies between 100 to 300 meters.

### **1.4.3 Bluetooth**

Bluetooth technology was invented in 1994 by Ericsson as a standard to form the basis of wireless communication between devices like computers and phones. Bluetooth is an open wireless standard to exchange the data for shorter distances, among disparate devices is also used for building personal area networks (PANs). Bluetooth has an average range of approximately 10 meters. Bluetooth exists in many products and it is more useful in a situation where devices are close to each other and there is a bandwidth constraint. A computer that doesn't have an embedded Bluetooth chip can use a Bluetooth adapter that enables the PC to help communicate with other Bluetooth devices, which makes the technology potential accessible to all users. Bluetooth is a PAN (Personal Area Network) technology it can support a bandwidth up to 2Mbps. Bluetooth is generally used in a point to point communication or in a star shaped topology. The thing that made Bluetooth famous was the wireless use of phone calls and car stereos. Thereafter as the technology grew it found its application in health and other fitness devices and music high-fidelity application.

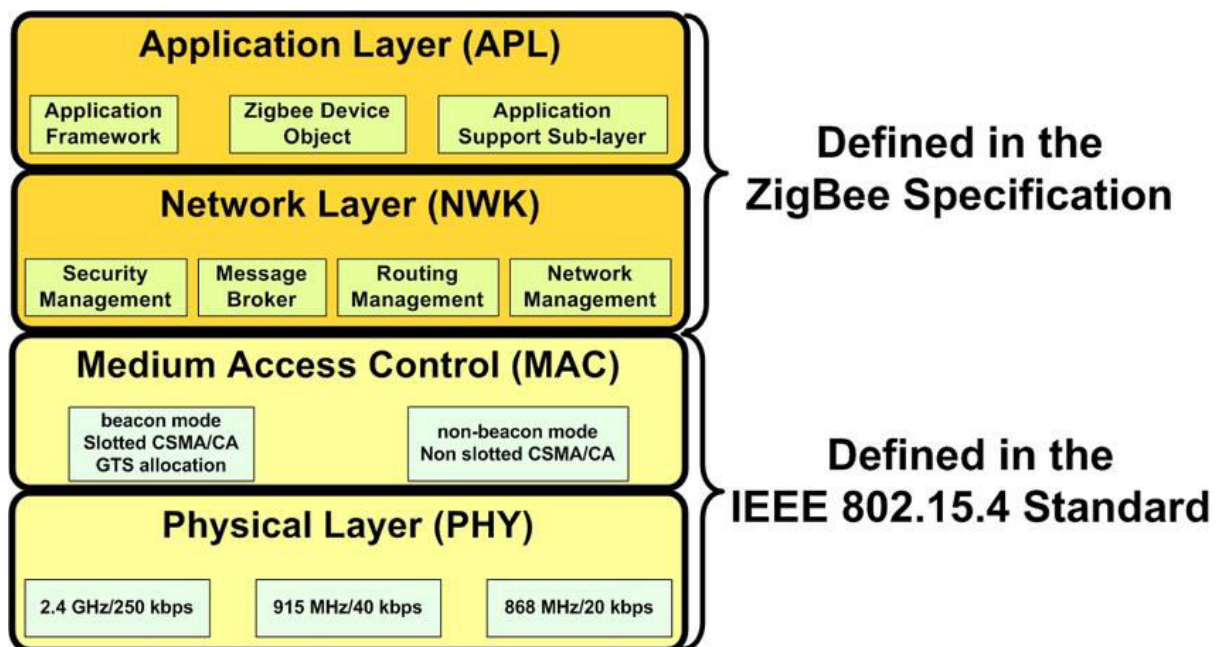
Bluetooth Low-Energy (BLE) (also called Bluetooth Smart), published in 2006, was designed to offer significantly reduced power consumption. The less power consuming Bluetooth technology is fit for devices that run on low power consumption for longer durations on sources like coin cell batteries. The flexible part is the availability of native support on every major Operating System, which can be used for mobile development or cloud support. BLE is not designed for high size file transfers but for transfer of chunks of data. Because of its widespread use it has found use in many areas especially in personal device context. Fig. 1.5 depicts the general scenario of Bluetooth system.



**Fig. 1.5 Bluetooth System**

### 1.4.4 ZigBee

Conceived as a mesh network, ZigBee [24] is a specification based on IEEE 802.15.4 that can reach a data throughput of up to 250kbps (although data rates tend to be much lower in practical applications). The name ZigBee has been derived from the fact that it is a mesh network: ZigBee is named after the bees when because of their waggle dance when they return from the field, to indicate to their hive the type of food, distance and direction of food source. The standard defines the protocol layers above the 802.15.4 data link layer and provides several application profiles.



**Fig.1.6 ZigBee Architecture [24]**

ZigBee has been used in many applications but has mainly taken attention in home automation applications where the distance is of a few 100 meters. Although an IP

specification (i.e. the process by which the data is transferred between two computers) exists for the ZigBee standard, it is detached from the common profiles of the main application areas and has not reached widespread adoption yet. Application level network is required by Zigbee for cloud connectivity. This gateway is a part of the network and contains TCP/IP stack and connects to the internet or Ethernet by which it provides internet connectivity. Implemented as a node, the gateway is part of the ZigBee network while it simultaneously executes the TCP/IP stack via Ethernet or Wi-Fi. The ZigBee architecture is depicted in Fig. 1.6.

### 1.4.5 6LoWPAN

6LoWPAN [25] is an open specification defined in RFC6282 by the Internet Engineering Task Force (IETF). It combines the latest IP protocol IPv6 and Low-power Wireless Personal Area Network, More than an IoT protocol like the other technology like Bluetooth or Zigbee, it is a mesh network protocol that lays between the 802.15.4 link layer and the TCP/IP stack (as shown in Fig. 1.7). It is meant for devices with low power consumption and low processing requirements and provides IoT connectivity even for very small devices. It aims at providing IP address assigning to even the less significant devices. The key feature is introduction of IPv6 format of addressing which has helped the IoT. IPv6 (the most recent version of the Internet Protocol) is the next step of IPv4 protocol which will assign almost  $5 \times 10^{25}$  addresses to each person in the world. This will allow for all the embedded systems to have their own IP address, which consequently enables the devices to be connected to the Internet.



**Fig. 1.7 6LoWPAN layer stack[25]**

## 1.5 Objectives

The main objectives of thesis can be summarized as:

1. To study, explore and analyse already existing methods for home automation and overcome the limitations of that existing methods with new approach.
2. To provide a low cost and efficient solution for home automation.
3. To test and validate the proposed solution by implementing it using various hardware devices.

## **1.6 Importance**

This research aims at understanding the evolution of IoT and the protocols that work best with it. As such no design exists to this fairly new and evolving technology, as it has to maintain openness to a wide variety of devices and applications. Innovation has to be from the parts of open standards, which will help interoperability without compromising the functional requirements of the underlying technology in its infant stage. We intend to study the open standards that are available so as to implement an IoT application, which can be readily used by all. There are many challenges that need to be confronted in order to bring out the best possible solution, for instance

- Ownership of data created
- Security concerns of data related to devices and their usage
- Inter-operability of heterogeneous devices.

This research gives insight on open standards, and protocols that can be used to implement the solution for the above stated problems.

## **1.7 Structure of Thesis**

The thesis is grouped into 6 chapters including literature review, problem statement, methodology, experimental results, summary, conclusion and future scope followed by references.

Chapter 1 provides the subject area in which thesis work has been done and also provides the objectives of the thesis.

Chapter 2 provides the literature survey of all the different methodologies for home automation processes that have been used so far.

Chapter 3 discusses about the problem statement and gap analysis.

Chapter 4 provides the methodology that how the problem has been solved which includes detailed design and implementation of home automation process.

Chapter 5 includes the results analysis and discussions.

Chapter 6 presents conclusion and future scope which discusses what further can be done in this research area.

## CHAPTER TWO

### Literature Review

In recent times, the environment at home has seen a fast expansion of network enabled digital technology. This gives us the exciting opportunity to give us the increased connectivity of many devices over the home network which can be used to provide a good home automation purpose. With the advent of internet, it gives us the non-channeled potential to expand it to various towns.

#### 2.1 Home automation Solutions

There are different solutions available for home automation process based on the various technologies used. The various solutions proposed so far based on differing technologies have been discussed in this section.

##### 2.1.1 ZigBee based

ZigBee has been used for many home automation environments over the years; it provides low cost, reduced complexity. Hence it doesn't include complex and expensive components. The system is flexible enough and scalable to add or remove devices based on the user requirement with minimum effort. It allows the user to control and monitor various devices in the home through many means, which includes Zigbee based remote control, or from any Wi-Fi enabled device. A home gateway can be used to provide the facility to connect to the devices over many networks, with a working internet connection from anywhere. The Zigbee coordinator plays the main role of creating and maintains the network. Every device is a Zigbee device managed by the coordinator. *Gill et al.* [1] The coordinator plays the role of intermediate station; every request goes through the coordinator to the individual devices. Because Zigbee is wireless it helps reduces the installation complexity of devices. The Zigbee standard provides the bandwidth of 250kbps; it is feasible for home automation devices as most of the devices operate on 40kbps.

This approach deals with the major issues why consumers have not yet picked these technologies; they are the expense and the architecture design of the system that needs to be implemented, the ease of system installation, the gap between the interoperability of different devices in home environments, inflexibility of the user interface and the security and safety of the system that needs to be implemented.

### **2.1.2 Bluetooth based**

Over the years the wireless technology has become more popular; it gives them the relief from managing cables which is often sometimes a headache especially if you are dealing with servers. Home automation is a major application of this well-established Bluetooth technology. It works with the distance of 10m to 100m. There are a few things that need consideration before designing a system, it needs to be scalable, and the interface should be user friendly. Most importantly it should be fast enough to render the need for a wireless system. The system is made up of two hardware elements: the cell phone and the arduino Bluetooth board which gives the inbuilt functionality of Bluetooth support. *Piyare et al.* [6] It is a 8 bit microcontroller board based on ATmega168 with 23 digital input output pins and 16KB flash memory. Cell phone uses packets to send commands to the arduino Bluetooth microcontroller which enables the pins, which are further connected to relays and to electrical devices. It also uses a feedback circuit to check the current when it sends the signal to the lamp, and corresponds with the voltage on the board whether the device is actually on or off, which gives the reliability to the architecture. The security is also enabled because the cell phone and arduino Bluetooth board are paired using keys, so it makes the overall system secure.

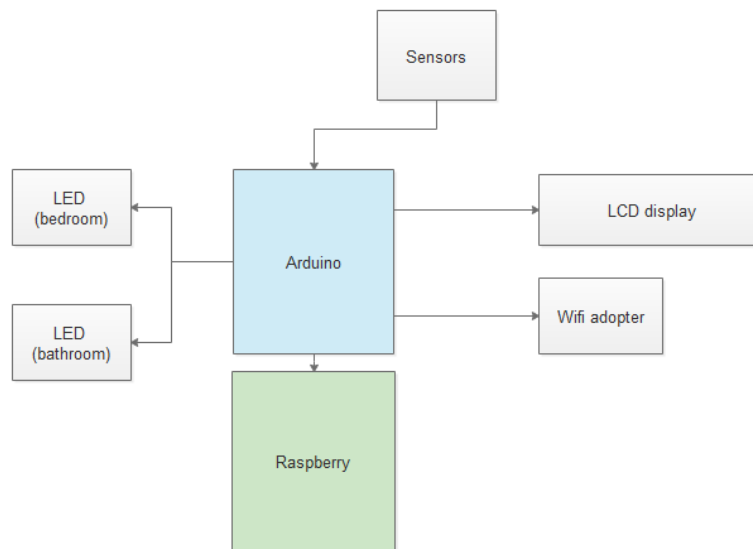
### **2.1.3 Wi-Fi based**

The Wi-Fi technology has been widely used to make architectures wireless, it is widely accepted and often integrated with Zigbee, arduino and nodeMCU because the spread of smart phones has seen an exponential increase in its usage. And it is a common technology available to everyone on the touch of their hands. It reduces cost as no cabling is required. The devices can be installed anywhere because the system is wireless where cables might not even reach. In contrast, to wired installations scaling the system is much easier as no more cable is required the commands can be sent over the phone. The system comprises of three main components the hardware, the server and the software which provides the user interface for end user interaction to the system. *Rathnayaka et al.* [10]

The software package for the system is a web based application that runs on a web server such as apache. It is responsible for setup, maintaining and keeping the whole application alive. There are a few setbacks if the server goes down the whole system will go down. So, special care is given to power backup. The software is connected to arduino through relays to the electrical devices. Security is maintained by giving the consumer a username and password to login into the server software application.

### 2.1.4 Others

There are other technologies as well which have been used in order to reduce the consumption of energy and provide with a better connectivity and solution. Raspberry Pi, but it is more complex than arduino because it can run a whole operating system like Linux which can be hard to manage sometimes for a beginner. *Jain et al.* [14] but it can run multiple programs and has two USB ports. It is the heart of the system because it does all the processing that is required by the architecture, arduino works as a slave (shown in Fig. 2.1). The arduino receives signal from sensors and turn on or off the devices based on the data.



**Fig. 2.1 Overview of Architecture [14]**

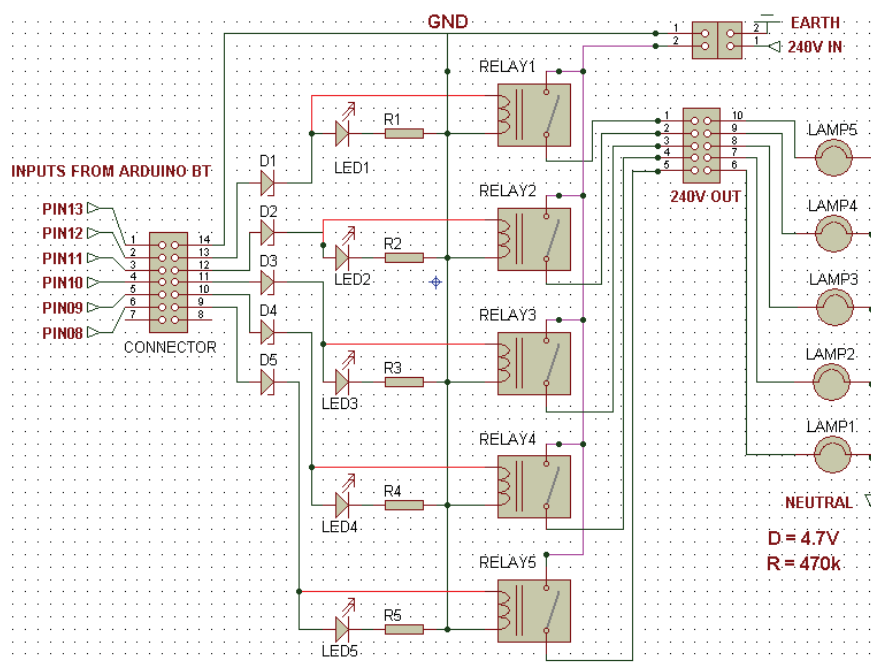
The system is a little complex as compared to other implementations of home automation but it provides better functionality and a good user interface as it has more processing power and a server can be built upon the Raspberry Pi, we don't require expensive hardware as it is available at low prices. Another approach for home automation has been used by using GSM Global System for Mobile Communication. PIC16F887 microcontroller is integrated with GSM and provides the smart house system with the baud rate of 9600 bps.

We have focused on various technologies like Zigbee, Bluetooth and Wi-Fi through design and implementation of flexible home automation architecture. A Zigbee based home automation and Wi-Fi network are connected to each other over a common gateway. The purpose of gateway is to provide a simple and flexible interface and network interoperability. There are solutions which apply java based embedded systems to achieve the same effect, the design is based on embedded system board which is connected to the PC to give the solution. Technologies used are JavaServer Pages, Java Beans, and interactive C. The home appliances can be managed locally or globally via web browser using the World

Wide Web. Since technology is a never ending process, so to design a product which can improve the lives of the people with its low cost value, using the existing technologies is a huge contribution to society. One approach is used based on the design of arduino BT module with electrical devices connected with the help of relays (shown in Fig. 2.3). The communication is wireless between the arduino and the cell phone (shown in Fig. 2.2).



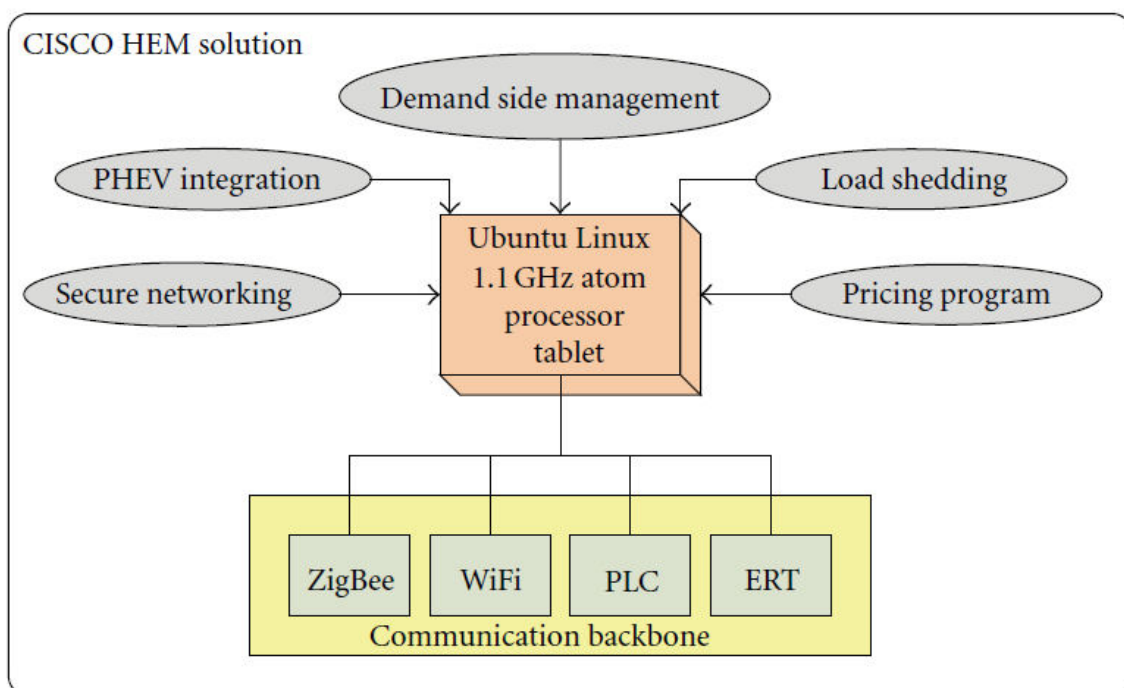
**Fig. 2.2 Overview of Architecture[6]**



**Fig. 2.3 Home Energy Management and Home Area Networks**

Home area Networks are extension of smart grid just like Local Area Network, but inside a home. They consist of devices that are capable of sending the signal to Home Energy management applications, which improve power consumption, which means the efficient use of home appliances example, the water heater is switched off automatically if not required. It is important because it gives time scheduling and predictive scheduling to save resources in terms of time and energy which are always scarce. With predictive scheduling the user

doesn't need to always turn it on, which makes the living easier for the consumer. The security and motion detectors can be implemented to alert the local police in case of theft or intrusion *Gill et al.* [1]. As climate change has become a real concern it is more important now, more than ever to pay attention to energy conservation in homes and businesses. It creates the idea of green home, which is energy efficient and low carbon emitting. HEMs provide a good way to monitor the day to day energy consumption and cut down on CO2 emissions wherever there is a scope to do so. As a consequence the bills can be reduced for electricity, consider it over a major period of time it is surely an investment. *System for Home Automation Using IoT*[20].



**Fig. 2.4 Example of available systems**

Though such solutions already exist (depicted in Fig. 2.4), it's a matter of providing it at an affordable cost so the mass public can consume and apply it. As the smart grid is making its way to a number of households and businesses, smart phones controlled devices will become important. Though there are many technologies available for such an application like Zwave, Bluetooth, Wi-Fi, Zigbee, but there is not a clear winner. So, it is upto the designer of the application to choose whichever technology fits the best to the current environment and architecture, while addressing the problem of interoperability with other HAM networks. This gives an insight to what the future holds and this thesis work has been a step forward in that direction.

The Internet Of Things is means of providing connectivity to everyday objects like TV, fridge, lights etc, so they can talk to each other and provide convenience to the user, and to enable new forms og communication between things and the consumer. There are two types of home automation systems one is locally controlled and the other is globally controlled. Locally controlled are concentrated towards an in built home sensors and monitors which can be controlled within the home, but on the other hand due to the increase in technology now the homes can be controlled from anywhere with the use of internet. The cloud storage can also be used to connect to the various devices from anywhere. There are few considerations that should be kept in mind while designing a home automation system, it should provide a user friendly interface on the host side, the overall system should be flexible enough to use the technology efficiently. It should also be cost efficient so that it it can be accepted on a mass scale.

## 2.2 Comparative Analysis

The various technologies which have been used so far for home automation process have been discussed in section 2.1 and now table 2.1 gives the comparative analysis of all the techniques which have been used so far for the design of home automation processes.

**Table 2.1 Comparative study of the existing home automation processes.**

Paper Name	Year	Technology	Contribution
Gill et al. [1]	Zigbee	2009	Low power consumption
Gomez et al. [2]	Zigbee	2010	More Robust architecture
Yang et al. [3]	Zigbee	2009	Application is easy
Han et al. [4]	Zigbee	2010	Good scalability
Sriskanthan et al. [5]	Bluetooth	2002	Commonly available technology used
Piyare et al. [6]	Bluetooth	2011	Low cost solution
Lee et al. [7]	Bluetooth	2003	Intergrated with many devices

Shepherd et al. [8]	Bluetooth	2001	Security features are good.
Ahmed et al. [9]	Wi-Fi	2012	Commonly available Technology.
Rathnayaka et al. [10]	Wi-Fi	2011	Simple Design of system
Wilson et al. [11]	Wi-Fi	2013	Additional Security features.
Domínguez et al. [12]	Wi-Fi	2012	Easy installation of system.
Teymourzadeh et al. [13]	GSM	2013	Use of Telecommunication
Jain et al. [14]	Raspberry Pi	2014	Run multiple programs.
Vujović et al. [15]	Raspberry Pi	2015	Full operating system functionality
Al-Ali et al. [16]	Java, JSP	2004	Platform independent solution
Pyare et al. [17]	Bluetooth	2011	Commonly Available Solution
Gill et al. [18]	Zigbee	2009	Low bandwidth, low power consumption
Al ali et al. [19]	JSP, Java Beans, Inteactive C	2004	Web based solution, platform independent.
Bhide et al. [20]	ZigBee	2015	With less human interaction
Teymourzadehet al.[21]	SMS, GSM	2013	Telecommunication solution

The state-of-the-art solutions are compared to study their major contributions and a new low cost home automation system has been proposed to overcome the difficulties incurred in the

already existing approaches. The new system proposed is also user friendly which the wifi technology for managing the automation process. The home automation is controlled by using the mobile app installed on the user mobile phone.

## CHAPTER 3

### Problem Statement

#### 3.1 Problem Definition

Home automation has been available from over three decades, but has faced many challenges in adoption due to the high cost incurred in implementing these systems as well as they also lack flexibility in the interoperability of products due to wide range of products available in market. The technology is not user friendly that everyone cannot use it which also hampers the growth of home automation systems. The various elements of home automation systems use different standards and protocols, so interoperability among these varying standards in an important aspect which should be taken care of. The various systems should be able to communicate with each other irrespective of their underlying protocols and standards and with less cost incurred. Therefore, the main objective is to provide low cost and efficient solution to these problems and to make the system scalable which can integrate more devices without affecting the overall efficiency of the system.

#### 3.2 Gap Analysis

- This is more of an exploratory area by which we can find the best possible solution to the underlying problem of uniformity in absence of standard protocols.
- This research deals with what protocols will suit best for an affordable and efficient architecture with its software domains and uniquely addressable schemes for each device.
- Due to the vastness of the devices which can be connected to the internet, devices must be able to address the different protocols to solve interoperability problem.

## CHAPTER 4

### METHODOLOGY

The customers which are the lead users have been kept in mind, to design the framework and the ease of implementation and maintenance has also been taken into account, to provide a simple solution.

#### 4.1. Architecture design

This research follows exploratory characteristics, as Internet of Things is fairly new and evolving technology. Few of the technologies have been studied and then carefully chosen to be implemented, so that it gives the researcher a significant insight as to which technology is best suited for the specific application of home automation. Most important thing that remains in IoT is using the existing technologies to provide an efficient solution, the main backbone of most of the communication model still remains the OSI (Open Systems Interconnection) model, and it breaks the whole model into modular parts and gives a better understanding of how the things actually work.

The OSI model (shown in Fig. 4.1) has seven layers associated to it which are further discussed, with each layer having its specific purpose and designed to give a modular implementation, so it is easy to understand and change a specific part if something is wrong or some modification is required we only need to change one layer, because the dependency is very low and functionality is totally different for each layer.

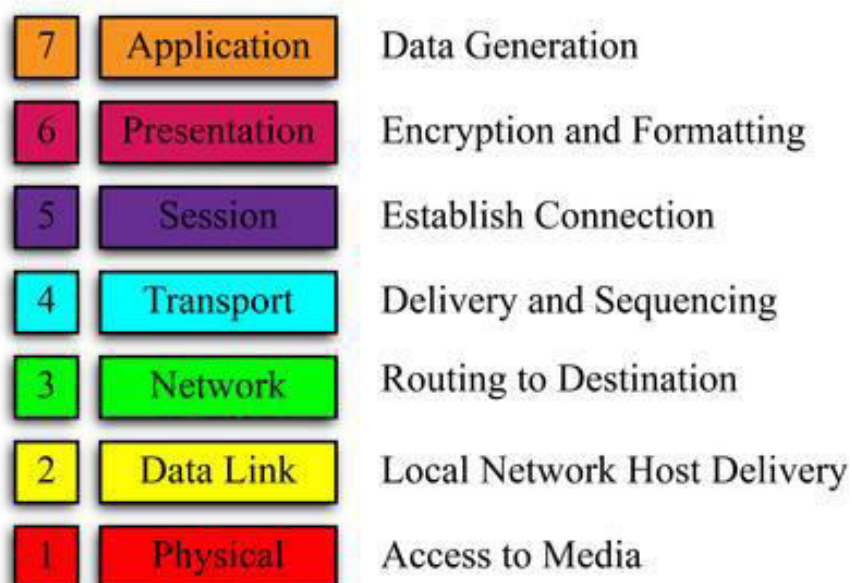


Fig. 4.1 The OSI layers

1. **Physical layer:** It is responsible for transfer of individual bits over the network, it sends data in form of simple logic which is binary bits 0 or 1. It is also responsible for keeping the checks of start flag and end flag.
2. **Data link layer:** It is the intermediate layer between physical layer and network layer which takes the data from physical layer and adds the checksum to see if there is some error while transferring the data. It contains further MAC (Medium Access Control) where it is defined how the medium of communication will be accessed by various machines among themselves over the same network.
3. **Network layer:** It gives switching as well as routing capabilities with different routing schemas ARP (Address Resolution Protocol) and RARP (Reverse Address Resolution Protocol). Works on the IP (Internet Protocol) which is the basis of addressing scheme over the internet with two IPv4 and Ipv6 versions for carrying IP packets.
4. **Transport layer:** This layer maintains the flow control and error checking of data. TCP (Transmission Control Protocol) is responsible for the reliability of transfer of data.
5. **Session layer:** It establishes and keeps the record of connections between various applications over the two machines.
6. **Presentation layer:** This layer's main function is to convert the application data into the network format data, so it can be processed accordingly and sent forward to other layers for its transmission.
7. **Application layer:** The main function of this layer is to represent the data in a standard format so that it is easily readable by applications on both ends, and provides better understanding due to uniformity. Like FTP (File Transfer Protocol) or HTTP (Hypertext Transfer Protocol), it can be customized by individual developers as per the application's requirements on the port number.

## 4.2 Hardware Used

This section covers the hardware used for the implementation of home automation system.

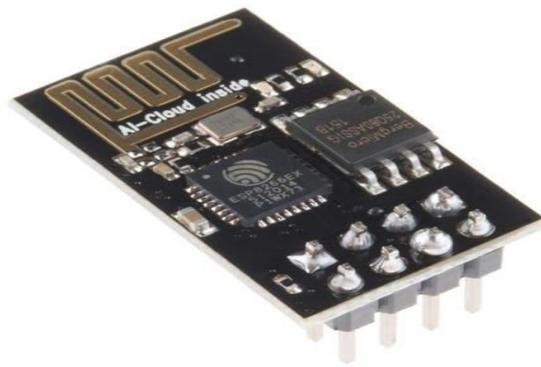
### 4.2.1 NodeMCU

The typical example of NodeMCU [28] can be shown in Fig. 4.3. It is an open source IoT device, which works on Wi-Fi system on Chip, and uses Lua scripting language [26]. It was created after the ESP8266 (shown in Fig. 4.2) [27] module was rolled out in the market; it offers more GPIO Pins General Input Output Pins. With its low cost it has gained attention of

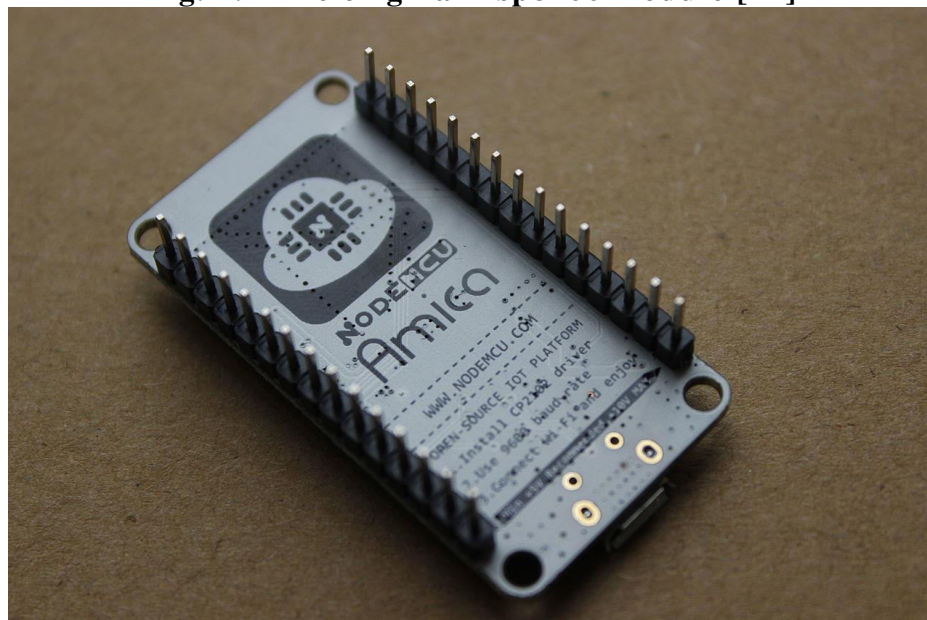
many people, especially when you are looking for a low cost system, which can provide efficient results and also makes it economically feasible. The details about Esp8266 are shown in table 4.1

**Table 4.1 Esp8266 details**

Type	Single Board Microcontroller
Developer	ESP8266 Open source Community
Memory	128 KB
Storage	4MB
OS	XTOS



**Fig. 4.2 The original Esp8266 module [27]**



**Fig. 4.3 NodeMCU [28]**

The Wi-Fi library of Esp8266 has been made upon the Esp8266 SDK, with the naming conventions of arduino Wi-Fi library. Over time the features for esp8266 outgrew those of Arduino Wi-Fi library and required a separate documentation, on what was new and extra. Stations are known as devices that connect to a Wi-Fi network. They all connect to a single node which is known as an Access Point (AP), which is the central part of the network. Access point is integrated to a router that provides internet connectivity to the Wi-Fi network. It also has the ability to work in a Soft-Access Point mode which means it can create an access point and other stations can connect to it, which will work as a central node of the Wi-Fi network (as shown in Fig. 4.4). Thus it can form a mesh network because it has the ability to work both in station and Access Point mode.

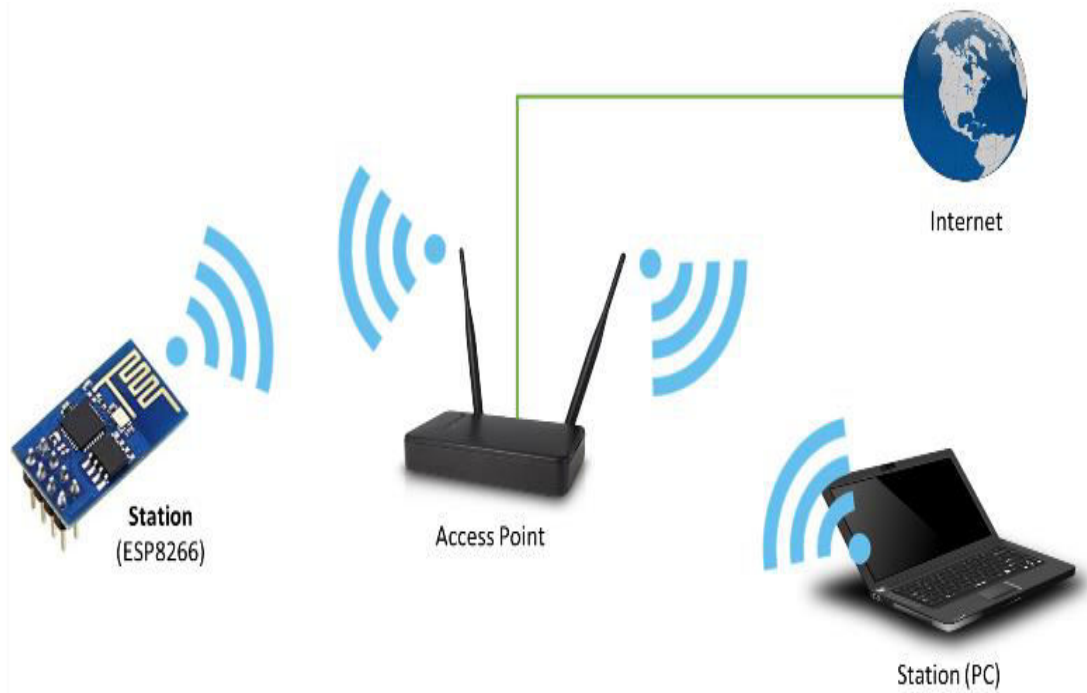


**Fig.4.4 ESP8266 in station + soft access point mode**

<b>B</b> BufferDataSource BufferedStreamDataSource	<b>E</b> ESP8266WiFiAPClass ESP8266WiFiClass ESP8266WiFiGenericClass ESP8266WiFiMulti ESP8266WiFiScanClass ESP8266WiFiSTAClass	<b>S</b> SList SSLContext	WiFiClient WiFiClientSecure WiFiEventHandlerOpaque WiFiEventModeChange WiFiEventSoftAPModeProbeRequestReceived WiFiEventSoftAPModeStationConnected WiFiEventSoftAPModeStationDisconnected WiFiEventStationModeAuthModeChanged WiFiEventStationModeConnected	WiFiEventStationModeDisconnected WiFiEventStationModeGotIP WiFiServer WiFiUDP
<b>C</b> ClientContext	<b>P</b> ProgmemStream	<b>U</b> UdpContext	<b>W</b> WifiAPList_t	
<b>D</b> DataSource				

**Fig 4.5 Classes in the ESP8266 Wi-Fi library**

The classes in Esp8266 are shown in Fig. 4.5. Station class contains several features to manage the connection in case the Wi-Fi connection is lost (Fig. 4.6). It automatically connects to the last access point that was available, as soon as it is up again. The same happens on module Reboot. This becomes possible because it saves credentials in the flash memory which is non-volatile.

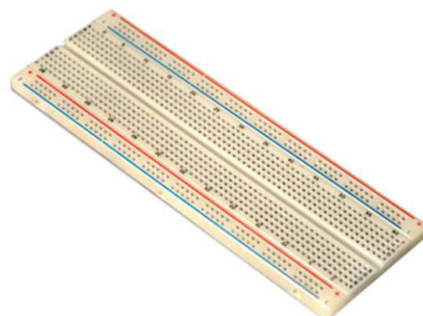


**Fig 4.6 ESP8266 Working in Station mode**

An access point gives a connection for other stations to connect to it. Esp8266 also provides the same functionality but it doesn't have interface to connect to a wired medium, this type of mode operation is known as soft access point. The maximum numbers of stations that can be connected to esp8266 are five.

#### **4.2.2 Breadboard**

Solder fewer breadboards (Fig. 4.7) [29] used for making a circuit using jumper wires and other components which easily fit on it and helps in providing an easy implementation. Its size is 5.5 cm x 17 cm x 1cm.



**Fig 4.7 A typical Breadboard [29]**

#### **4.2.3 MB102 Power Supply**

This MB102 power supply board (Fig 4.8) [30] is designed to plug into a breadboard panel with 2 power distribution strips. The module can be powered by a USB port or an external power supply 7-12V. The module has two independent power lines, which can be set to output voltage of 5V or 3.3V, or completely remove power from the line. The module has ON / OFF switch to turn on and off module. It comes with reverse polarity and short circuit protections, which greatly helps during building and testing circuits on the breadboard.

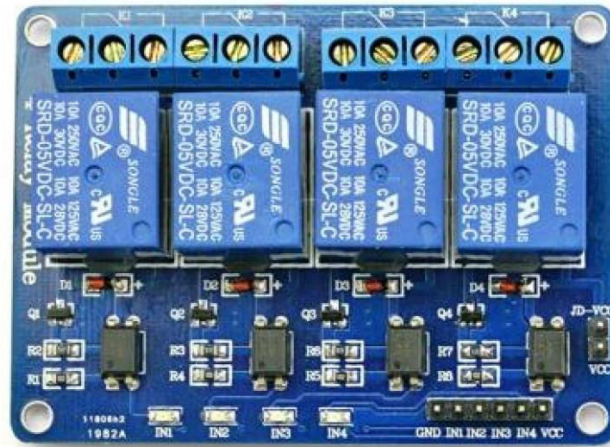


**Fig. 4.8 MB102 power supply module**

#### **4.3.4 4 Channel Relay**

A 4 channel relay (Fig. 4.9) [31] details include:

- 4-channel relay output module, relay output contact is maximum 250A 10A
- Effective VCC, GND power input, can relay a separate power supply relay power input of JD-VCC.
- Input IN1, IN2, IN3, IN4 signal line active low
- 5V 4-Channel relay board controlled directly by micro-controller (Arduino, 8051, AVR, PIC, DSP, ARM, ARM, MSP430, TTL logic) need 50-60mA driver current.
- High-current, AC250V 10A, DC30V 10A.



**Fig 4.9 4 Channel Relay**

### 4.2.5 Jumper Wires

Jumper wires (Fig. 4.10) [32] are used to make connections on the breadboard with different components so that they work together.



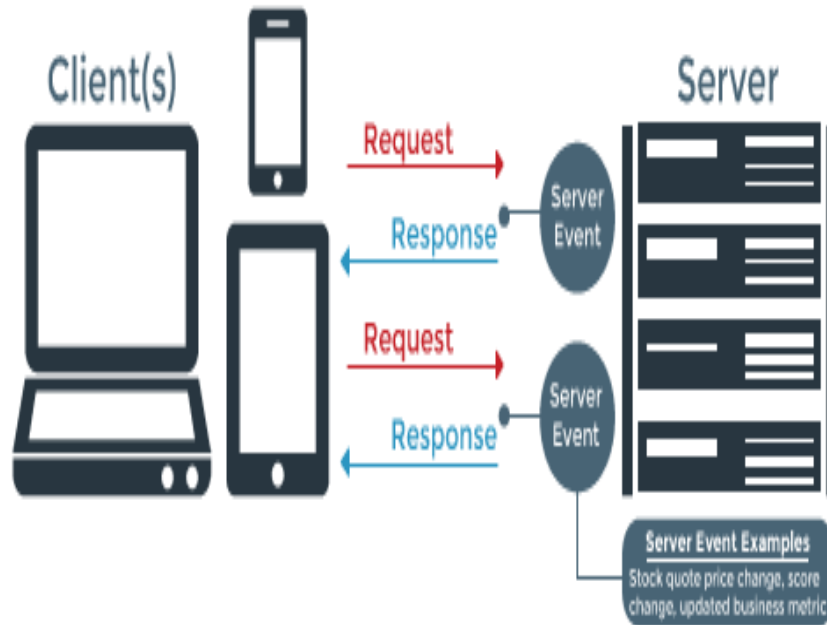
**Fig 4.10 Jumper Cables**

### 4.3 Protocols Used

Protocol is a set of rules that a process is supposed to follow to give uniform results, without ambiguity of any type. In computer world, they can be implemented using hardware or software or both. All the communication protocols have a set of rules for proper message transfer and the received data is checked in how the communication is going, it needs to have rules in the correct context of the application and it should also describe the context. Here we intend to study two protocols, HTTP and MQTT which have been used in our design.

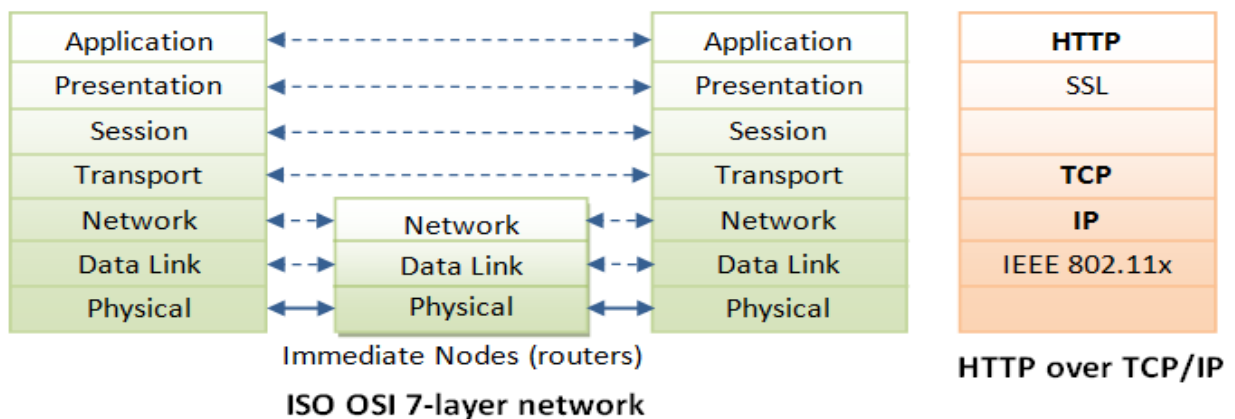
### 4.3.1 HTTP Protocol

It is an asymmetric client-server request response protocol. A client that supports HTTP (Fig. 4.11) [33] sends a request to the server. Server replies with a response message in return. It is a pull protocol; the HTTP client requests the information and it is pushed by the server on getting the request with a proper response.



**Fig 4.11 Multiple clients making request to http server**

It is a stateless protocol, it doesn't keep track of things that have been sent, whether they were received or not. HTTP can send any type of data, so it make it flexible to send any type of data to the client, a client can request any kind of data which makes this protocol data independent.

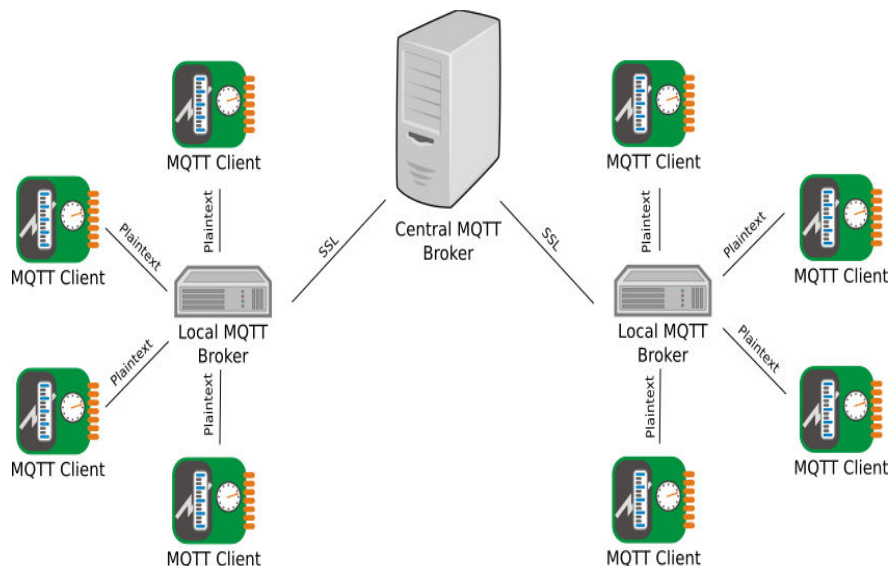


**Fig 4.12 Communication between several protocols**

HTTP works as an application layer protocol which is application dependent, Telnet and SMTP are some other example of the category. It provides a common interface between machines to be able to communicate to each other.

#### 4.3.2 MQTT Protocol

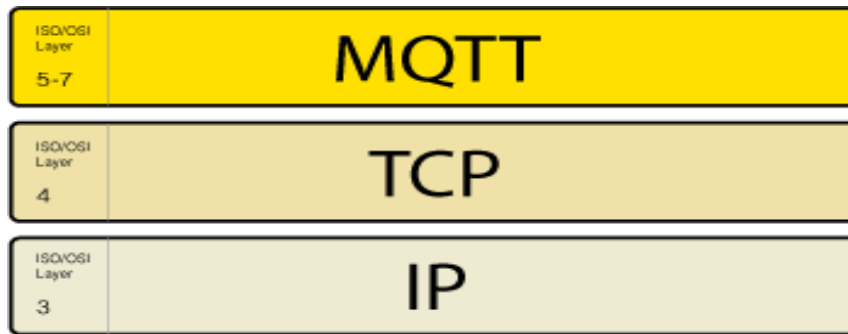
MQTT (Message Queuing Telemetry Transport) protocol (Fig. 4.13) [34] is a lightweight protocol where there is a constraint on resources to pass the telemetry information. This protocol enables the IoT enabled devices to send the information or publish it on a topic through a MQTT broker which acts as a server. Then the broker will pass the information to other nodes on the network which have previously subscribed to that respective topic. This protocol suits best in a situation where there is latency in the network or the connection is unreliable. It maintains the state, in case the message gets broken due to some reason it will again send the message to device via MQTT broker when it becomes online again.



**Fig 4.13 MQTT Architecture [34]**

A MQTT session is grouped into four stages, connect, authorize, communicate, terminate. The client always tries to make a connection which is of the TCP/IP connection to the broker. If the broker identifies the client it might reuse the old session and append the connectivity of the device. 1883 and 8883 are usually the standard ports for unencrypted and encrypted communication. During the SSL handshake, client tries to authenticate the server with its certificate. The client can also possess the capability of providing the certificate so that the server can authenticate the client. It was not intended to be part of the MQTT specification but over the time has become a general trend to do so. It enables to provide a secure communication between the client and the server so the data can't be interpreted by man in

the middle attack or any other hacking attempt. The MQTT protocol stack can be shown in Fig. 4.14.



**Fig 4.14 MQTT Protocol stack [34]**

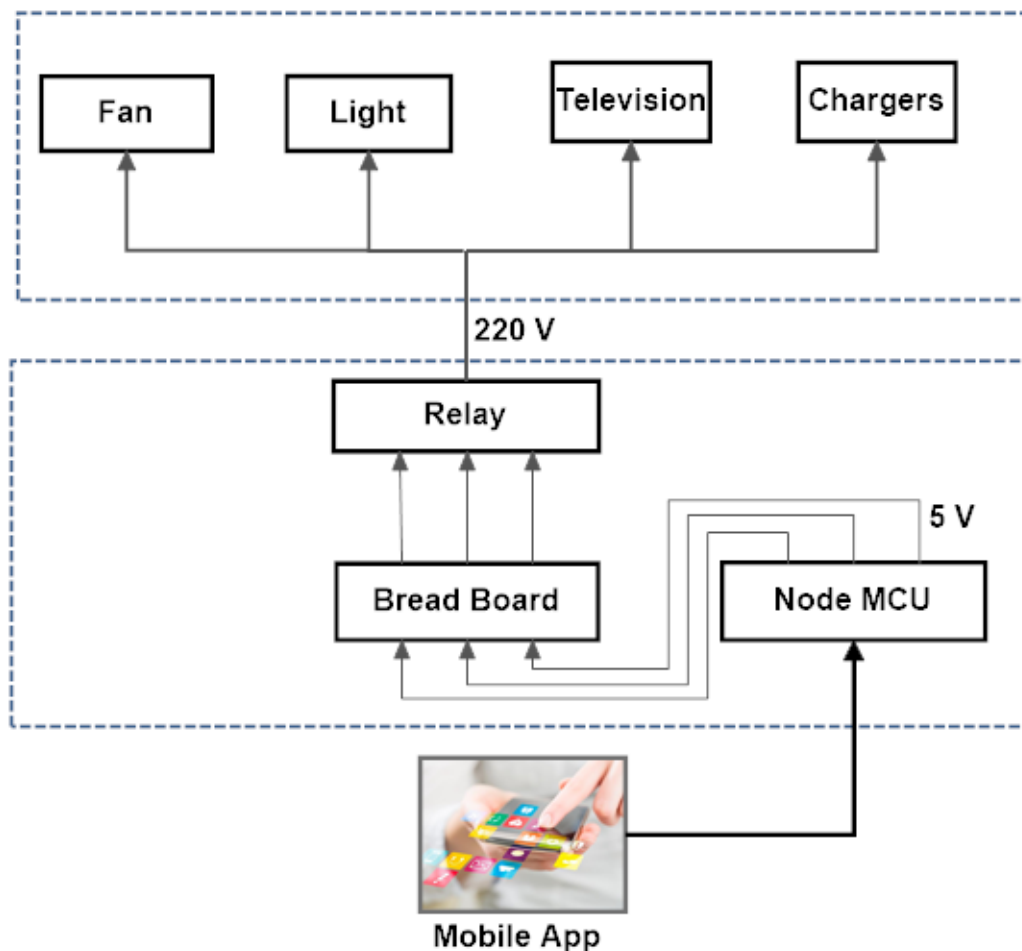
Because this protocol is generally used in resource constraint environments, doing the SSL might not be needed in some specific application, in that case the client and server send CONNECT/CONNACK packets. Brokers who are in internet can accept connection from any client in such a case, username and password are generally blank. It is a lightweight protocol because all of its packets contains code fingerprint. Every packet consists of a fixed header -- 2 bytes , a message payload that has a limit of 256 MB of information and a quality of service (QoS) level. The difference between HTTP and MQTT protocols are given in Table 4.2.

**Table 4.2 Difference between HTTP and MQTT**

	HTTP	MQTT
<b>Messaging Pattern</b>	Request-Response	Publish-Subscribe
<b>Server Updates</b>	Poll	Push
<b>Websocket support</b>	Yes	No
<b>Compact Libraries (&lt;1MB)</b>	Yes	Yes
<b>Binary Payloads</b>	No	Yes

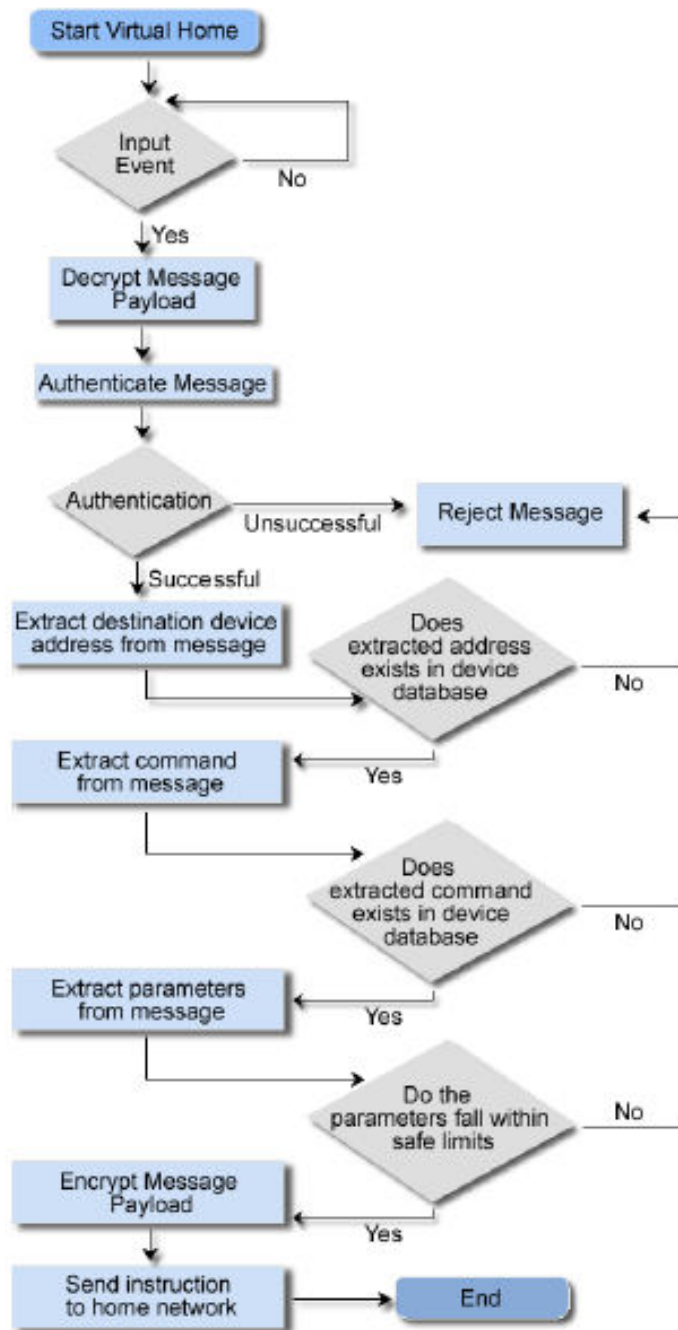
#### 4.4 Implementation

The overall flow diagram of the proposed system is depicted in the Fig. 4.15. As depicted, Wi-Fi based home automation is used for controlling electrical devices. An android app has been used to communicate with the module (nodeMCU); which works as an interface for the user to control various devices. The app sends a request to the nodeMCU which acts as a server, which is on the home automation network (Wi-Fi). It stops unauthorized users to connect to the network as the access to the Wi-Fi is already encrypted with a password. It works on the client server architecture. The smart phone makes the request to the server over the Wi-Fi network to turn the home appliances on and off. The Microcontroller works as a server to process the request and turns the pin which gives the signal to the relay to switch and make the connection. The power module MB105 takes a 12V DC input to provide power to both relay and the microcontroller. The output pins of the microcontroller are connected to the relay which changes to high and low according to the user input, which turns the devices on and off.



**Fig. 4.15** The overall flow diagram of the proposed system

The solution is low cost and efficient as it does not require much processing power, or any such complex algorithms which can turn it as slow. The network thread is given the highest priority in the application so that the input output operations are not affected and the response and request to the server are the quickly made.

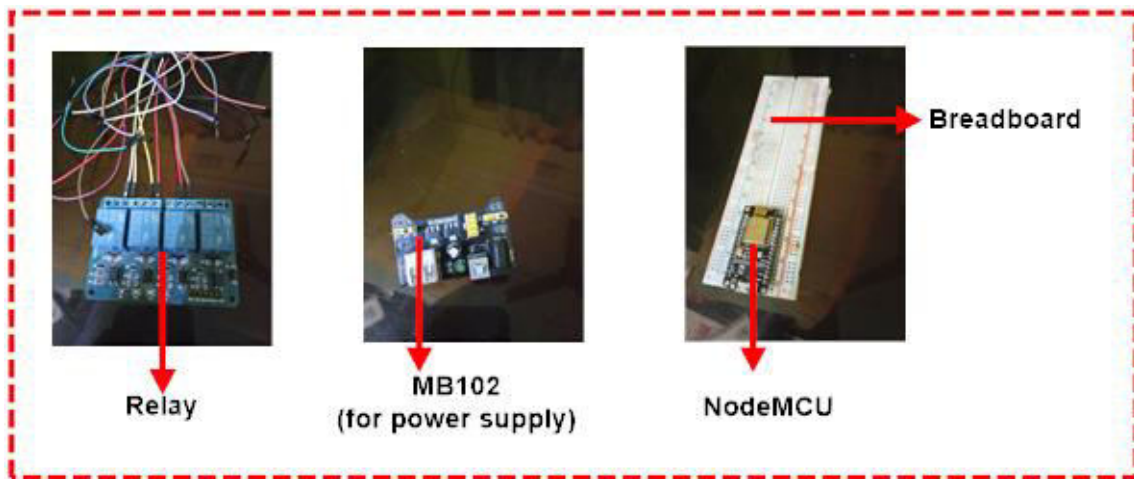


**Fig. 4.16 Home automation flowchart[2]**

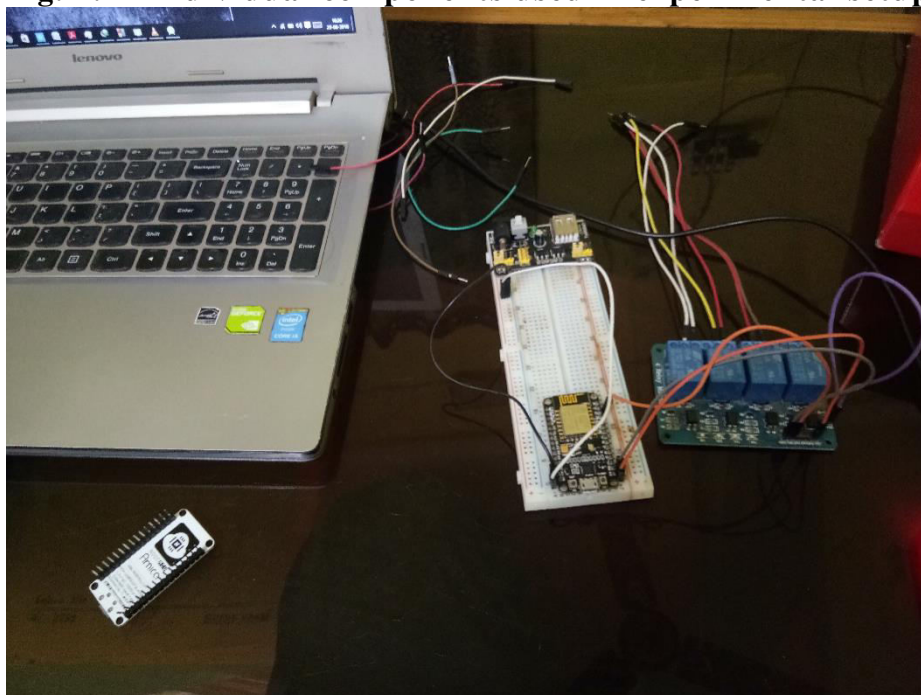
#### 4.4.1 Architecture

Our aim is to provide home automation with reliable and economically feasible solution which is best suited for Indian middle class. So to achieve this, we researched a lot on state-

of-the-art techniques about the architecture and the hardware components as well as related technologies which have been mentioned earlier. This section aims at explaining how the things were integrated and an overall solution was presented to tackle the problem. We started with the analysis of current standards that are present in the market, after finding the appropriate hardware we found out what technologies we need to use and defined the architecture of the product from a bottom-up approach. The flowchart of home automation system is shown in figure 4.16.



**Fig. 4.17 Individual components used in experimental setup**



**Fig. 4.18 System Implementation**

We created a server on NodeMCU which handles the requests from a client and turns the GPIOs General Input Output to high or low as required, which is further connected to relay

which in turn channels the output current of 220V to the electrical devices turning them on and off. We tried with different protocols to get most efficient results in terms of network congestion and delays in the network; we tried with HTTP protocol and MQTT protocol. Architecture of the proposed home automation system has been made of server software and microcontroller (NodeMCU) which runs on LUA script and turns it into a server. It can be accessed on the same private network or on the internet if we know the public-id. The software which is running on the server is responsible for the setup, running and maintenance of the whole system. The components which have been used in the system implementation are shown in Fig. 4.17. The overall implemented system can be shown in Fig. 4.18.

## CHAPTER 5

### RESULT ANALYSIS

In this section, we evaluated the wireless technologies based on different parameters and choose an appropriate technology as per our usage. The various wireless technologies can be compared in Table 5.1 depicting that Wi-Fi is best suited for implementation of home automation systems depending on the various parameters being discussed in table.

**Table 5.1 Comparison of Wireless Technologies**

	<b>Zigbee</b>	<b>Bluetooth</b>	<b>Wi-Fi</b>
<b>Standard</b>	<b>IEEE 802.15.4</b>	<b>IEEE 802.15.1</b>	<b>IEEE 802.11 a,b,g</b>
<b>Industry Organization</b>	Zigbee Alliance	Bluetooth SIG	Wi-Fi Alliance
<b>Topology</b>	Star, Mesh, Tree	Star	Star
<b>RF Frequency</b>	868/915 MHz 2.4 GHz	2.4 GHz	2.4, 5.8 GHz
<b>Data Rate</b>	250 kbps	723 kbps	11 to 105 Mbps
<b>Range</b>	10-300 m	10 m	10-100 m
<b>Power</b>	Very Low	Low	High
<b>Battery</b>	Alkaline.	Rechargeable.	Rechargeable.
<b>Operation</b>	Months to Years	Days to weeks	Hours
<b>Nodes</b>	65,000	8	32

Reliable delivery of message is of utmost importance in such systems because if wrong information is provided in the messages it may lead to inaccuracy. Detecting and correcting the error is necessary for correction of corrupted data in unpredictable communication channels. CRC cyclic redundancy check is used by Zigbee, Wi-Fi, Bluetooth for this issue to

validate the packets. Some bits are appended to check the accuracy of the packets received. Table 5.2 details the various parameter values such as data rate, frequency, sensitivity, transmitter power and link budget for various technologies.

**Table 5.2 Comparison of Wireless technologies**

<b>Technology</b>	<b>Data Rate</b>	<b>Frequency</b>	<b>Sensitivity</b>	<b>Transmitter Power</b>	<b>Link Budget</b>
<b>Wavenis</b>	19 Kbps	900 MHz	-107 dBm	14 dBm	121 dB
<b>Zigbee</b>	250 Kbps	2400 MHz	-98 dBm	8 dBm	106 dB
<b>Bluetooth</b>	1 Mbps	2400 MHz	-85 dBm	7 dBm	92 dB
<b>Z-Wave</b>	40 Kbps	900 MHz	-101 dBm	Upto 0 dBm	101 dB
<b>DECT</b>	1 Mbps	1900 MHz	-98 dBm	25 dBm	123 dB

The various network technologies have also been compared in table 5.3 indicating that how wireless technologies can be best suited for home automation systems with Wi-Fi having the maximum speed per channel and appropriate range for implementation of such systems with adoption rate also extremely high. Therefore depending on these parameters, wifi based home automation system has been designed in the current work giving the most effective results with minimum delay.

**Table 5.3 Comparison of Network Technologies for WHANs**

<b>Connectivity</b>	<b>Technology</b>	<b>Max speed per channel</b>	<b>Range (m)</b>	<b>Adoption Rate</b>
<b>Wired</b>	1. Homeplug	1. 14-200 Mbps	300	Medium
	2. Ethernet	2. 100-1000 Mbps	100	Extremely High
	3. X10	3. 50-60 Kbps	300	Medium
	4. Insteon	4. 1.2 Kbps	3000	Medium
	5. ITU G.hn	5. upto 1 Gbps	-----	Not Widely
<b>Wireless</b>	1. Zwave	1. 40 kbps	30	Widely
	2. Wi-Fi	2. 11-300 Mbps	100	Extremely High
	3. One-Net	3. 38-230 Kbps	500	Not Widely
	4. 6LoWPAN	4. 250 kbps	10-75	Medium
	5. Zigbee	5. 250 kbps	10-75	Widely
	6. EnOcean	6. 120 kbps	30	Not Widely

All the technologies use a fixed amount of data for error checking and controlling known as checksum. Bluetooth, Zigbee and 6LoWPAN use 16 bit checksum. To check if the data was not modified or damaged while transmitting, it is checked by the receiver if checksum matches with a slight range of probabilities. In case the checksum is matched, an acknowledgement is sent otherwise the whole packet is dropped. EnOcean doesn't have any means to check data in the error so it is deployed in places where the environment is not noisy, thus having less probability of error.

## CHAPTER 6

### Conclusion and Future Work

#### 6.1 Conclusion

The most important goal is to provide a cost efficient and viable solution to the end user which enhances the overall standard of living and which is also energy efficient. After carefully examining the various technologies and comparing on different parameters, Wi-Fi suits best to the current application scenario with http protocol. In this work we studied about various wireless technologies and concluded that Wi-Fi suits best for such an application where devices can be controlled all over the internet. A home automation system is being designed based on wifi technology where the problem of interoperability has been solved and reliable solution has been proposed. The reliability of the proposed system has been tested by comparing it with the other technologies concluding that wifi is best suited for designing home automation based networks.

Hence we can conclude that the home automation objectives have been met, which are economically feasible.

#### 6.2 Future Work

The major concern for such an application is security, which is aimed to be done to further improve the implementation for general public. It has the potential to change the lives of people by improving the standard of living. For a more widely accepted and threat prone product, we will use more secure algorithms and protocols such as https.

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