6LoWPAN Based Smart Home Architecture For The Smart Future

by

Shah Muhammad Jannatul Hasan
16301056
Mohammad Ali
16301227
Taufiqul Islam Khan
16301189
Farzana Afrin
16301027

A thesis submitted to the Department of Computer Science and Engineering
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Department of Computer Science and Engineering
Brac University
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Declaration

It is hereby declared that

1. The thesis submitted is our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

Student's Full Name & Signature:

Shah Muhammad Jannatul Hasan 16301056	Mohammad Ali 16301227
Taufiqul Islam Khan 16301189	Farzana Afrin 16301027

Approval

The thesis titled "6LoWPAN Based Smart Home Architecture For The Smart Future " submitted by

1. Shah Muhammad Jannatul Hasan (16301056)
2. Mohammad Ali (16301227)
3. Taufiqul Islam Khan (16301189)
4. Farzana Afrin (16301027)

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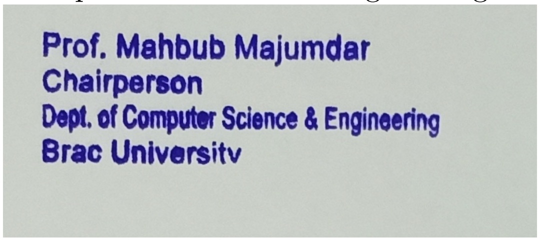
Supervisor:
(Member)

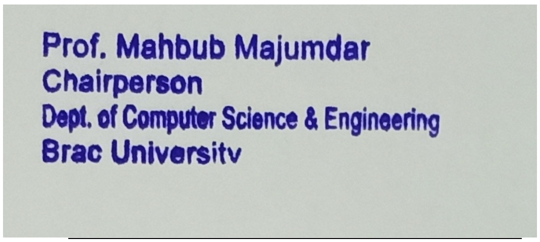


Md. Motaharul Islam,PhD
Professor
Department of Computer Science and Engineering
United International University

Program Coordinator:
(Member)

Md. Golam Rabiul Alam,PhD
Associate Professor
Department of Computer Science and Engineering
Brac University

Head of Department:
(Chair)



Mahbubul Alam Majumdar,PhD
Head of Department
Department of Computer Science and Engineering
Brac University

Abstract

6LoWPAN is an emerging area of research. It helps to extend network architecture for WSN which allows end-to-end connectivity between a 6LoWPAN node and any IP devices of the network. To make a low power consumption mesh network, 6LoWPAN is a promising solution on a simple embedded system. Target is to carry IPv6 packets efficiently within a small link layer frame IEEE 802.15.4. Currently the absence of IP address hinders the process of accessing sensors directly. In remedy, IP supporting devices are necessary. Here according to 6LoWPAN technology each sensor will have a unique IPv6 address that will be auto-configured. So, the user can easily access the sensors data directly from the Internet without any supporting device. In our home automation, we have implemented our proposal through simulator COOJA which is basically a simulator designed for wireless sensor network. It is a part of exceptionally versatile in performing various tasks and it works in framework Contiki. It has unlocked source where an integrated Internet Protocol Suite based on TCP/IP stack and multitasking takes only a few Kilobytes of RAM and ROM. A Contiki-based 6LoWPAN gateway is designed to interconnect 6LoWPAN nodes with the Internet IPv6. We have implemented our 6LoWPAN based network simulation in COOJA.We have found a better End to End communication, mobility, scalability and lower overhead which makes the system more convenient compare to other technology based home automation.

Keywords: 6LoWPAN, IPv6, IEEE 802.15.4, Embedded system, Contiki, Home automation(HA)

Dedication

We would like to dedicate this thesis to our loving parents and honorable teachers.

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Firstly, all praise to the Great Allah for whom our thesis have been completed without any major interruption.

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Chapter 1

Introduction

Fields like education, horticulture, ecological observing, brilliant metering and in numerous practice Wireless Sensor Networks (WSN) are assuming an inexorably significant job.[20] In this present era of modern world, a new configuration has come named as Internet of Things (IoT). Usually from the very beginning by this traditional version of concept, the smart objects interconnected with one another and share essential communication towards them. In that case the end user gets a remarkable assistance by connecting different kind of sensors through interface module e.g. Arduino, NodeMcu ESP8266. Thus people have the choice of making their own smart functionality for example smart home, smart agricultural system, smart product management system etc. All the matter can be applied with the help of supporting internet module because without them one will not be able to connect with the remote device from which they have control over the IoT system. Obviously, once WSN is incorporated into the Internet, the model will be completely unleashed for the part of the Internet of Things (IoT) [16]. That's why the interface module must work with the summation of internet module like GSM module, GPRS module, NodeMCU ESP8266 module etc. Those are very effective and advantageous but also a limitation arises which is user will only have the ability to access in a closed area or specific field. Here to shorten the puzzle we come up with the idea of a modernized technology called 6LoWPAN. 6LoWPAN is all-IP solution based on IPv6 over a low-power, lossy network. Here IPv6 is large address space which enables the integration of large numbers of devices to the IP network. The topologies include star, mesh and combination of star and mesh. So sensors get connected through internet. Besides, each sensor is connected to another one and make communication by passing data. Devices in the network typically work together to connect the physical environment to real world application. By this technology, the sensors will be able to generate its own IPv6 address. As a result, they might pass information over the internet. So user will be able to access the wireless sensors from anywhere. Consequently, the limitation of being on a fixed area will be over. Here this time we have focused on smart architecture for home automation. Our concept is to make a smart home automation system based on 6LoWPAN where sensors will be constructed along with home structure. As a result, user will be able to access them from anywhere by using mobile phone or any remote device. In such a way our attempt will help the modern world. Right now we face difficulties to arrange hardware components. That's why we move to implement software simulated model. Most devices are limited in energy and memory in the IoT and previously designed gateways are not convenient for the demand of lightweight gateways. Regarding that Swedish Institute of Computer Science has come out with the new lightweight embedded OS [27] that is built using in C language, Contiki. It requires only 10 KB of Random Access Memory and 30 KB of ROM. Some typical platforms like TI CC2530, STM32 etc. are supported on Contiki along with 6LoWPAN. A Contiki-based 6LoWPAN gateway is designed to interconnect 6LoWPAN nodes with IPv6 Internet. [3],[21] It does not, however, offer the implementation of the exact mechanism that is used in its experiment for the WAN interface. Here we have designed a 6LoWPAN based gateway in Contiki.

The main contributions of this paper are as follows:

- Establish a system by which the end users are allowed to send or collect data from the sensors node.
- The model has experienced a better lifetime comparing to other existing wireless medium e.g. Bluetooth, ZigBee etc.
- It has the ability to be connected with same or different kind of network.
- It has the best end to end communication facility which make the system more functional and beneficial for the user in compare to other models
- If any new sensors come across the implemented model for bring attached or if user wants to expand its network with more sensor or add new sensors with it, it has easy communication and connection.

1.1 Background

Today's world is the age of modernization and Science and technology. Nowadays things are becoming more digitized day by day. Seeing the surrounding places makes anyone understand how rapidly the world's environment is changing. In every sector whether it is small or big, announce the touch of modernity.

In that case people's homes are not like the previous one. It also gives the shine of freshness. Lately, the home condition has seen a fast presentation of system empowered computerized innovation. It has entered the modern and digitalized era for a long time. Mostly the common term people heard today is "home automation". IoT is the basic way to make that idea true. IoT is basically a technology that allows to control devices throughout the internet. And in home automation this IoT technology is being used in order to control home appliances, thus automating modern homes through the internet. From the very first,This technology proposes new and exciting opportunities to efficiently increase the connectivity of devices within the home.

A smart home is an application of ubiquitous computing or environment.As indicated by Rudolf the brilliant home idea is the joining of various administrations inside a home by utilizing a typical correspondence framework. It guarantees a monetary, secure and agreeable activity of the home and incorporates a high level of clever usefulness and adaptability.[21]

Another concept as per Sampath, A home which is sufficiently brilliant to help the occupants to live autonomously and easily with the assistance of innovation is named as a keen home. In a brilliant home, all the mechanical and advanced gadgets are interconnected to frame a system, which can speak with one another and with the client to make an intelligent space [31]. By taking into account the ideas, we can define the smart home as a global computing environment which is able to provide user context-aware automated services in the form of ambient intelligence.

Figure 1.1: General Home Automation

1.1.1 Home Automation In Past

At the earliest reference point home robotization began from a physical perspective with the development of automation things like-home apparatus. In the past nineteenth century, the ability to edify the room from a single switch profoundly changed the manner in which we lived by making it basic and decently safe to light huge locales for expanded periods around night time. After that the advancement of home TV during the 1950s and the later introduction of the infrared remote control which were useful for highlight control correspondence between contraptions. Furthermore, in 1901-1920: The invention of home appliances- like refrigerators, washing machines, dishwashers, irons, toasters and garments dryers. And also in 1966-1967: The invention of ECHO IV and Kitchen Computer. Those gadgets could enroll shopping records, control the home's temperature, and turn mechanical assemblies on and off. The "Kitchen Computer" was made for the present year. The bleeding edge came as the Internet, which made a general arrangement of PCs during the 1990s. After a short time, remote Internet as Wi-Fi transformed into an ordinary mechanical assembly in American homes. At last, in the 2000's: The mid 2,000's saw a further rising in splendid home development, including nearby tech, home frameworks organization, and various gadgets appearing accessible. A blend of short-run advances made by Zen-Sys in 2005, this remote innovation makes a work organize at the client's home and imparts signs at the 900 MHz range. The

Z-Wave innovation is equipped for associating an assortment of gadgets to control apparatuses, entryway bolts and even flood screens.

1.1.2 Present State of Home Automation

The Internet of Things (IoT),lately, has facilitated sensible contraption in this sector. Starting from coolers, to mechanical assemblies, to home security can be controlled with brilliant home advancement. Here gadgets are by and large remotely watched and controlled through the Internet, and are a basic stuff of the Internet of Things.

The current shrewd homes are increasingly about security and living. Contemporaneous examples for the most part join remote control, automated lights, robotized indoor controller change, booking machines, convenient/email/content alerts, and remote video perception. Right now, are the eyes and ears of the framework. There are sensors for a broad assortment of employments, for instance, estimating temperature, soddenness, light, liquid, and gas and perceiving improvement or disturbance.

The various technologies used in home automation- [38]

i. Bluetooth:

Bluetooth is a remote standard that has a spot with the PAN show family. It works in the 2.402 and 2.408 or 2.400 and 2.4835 GHz band,are used, in view of the Bluetooth variation utilized, which is partitioned into 79 sub channels with 1MHz, using FHSS. GFSK and furthermore PSK guidelines. TDD can endorse full duplex exchanges across it.

ii. Wi-Fi:

Wi-Fi, which belongs to the family of (W)LAN networks, is the most advantageous wireless technology nowadays. Contrasting with Bluetooth, the Wi-Fi run is separated into 13 midway covering sub channels (fourteenth open in Japan exactly) where each channel is including 22MHz band.

iii. ZigBee:

Radio recurrence (RF) concurrence standard is followed byZigBee . Here Each electronic gadget (i.e. Clothes washer, Television, Lamp and so on) is a ZigBee gadget which is in the framework. Only with a supervisor,networks of ZigBee can be entrenched.Consequent to right PAN parameters settings, different gadgets might agglutinate the system by erecting one of the topologies.

iv. X10:

Other home mechanization permutations are measured using X10. It might experience issues related to wiring partitions, arrange complexities, and line upheaval since it works with home's electrical link wiring . Because of more cutting-edge and increasingly versatile remote progressions,diversified pet trust for X10 development has come to a halt being old, luxated.

v. Z-Wave:

For remote home automation Z-Wave is adopted. Subservient territory of home automation is made benevolent by Z-Wave . Trade utilizations were baptized by its protracted framework firm quality.For homogeneity of setup and utilization as the home computerization industry permits, particularly handy for starting devotees, Z-Wave gadgets are meant

1.1.3 6LoWPAN Based Home Automation

Along with the research work, homes need to be more functionalized and should offer roughly all obligatory assistance, for instance, conveyance, therapeutic, toughness, expediency, amusement and security. With the stepping into the next generation, progressively more apparatus will undertake to tack on among themselves. Remarkably now the significant factor is that information ought to be conveyed among gadgets and people mentioning they are completely disconnected on manual info. End devices like mobile phones, laptops, computers should be enabled to excavate data unpreventably, later on use that data to modify the manner of the home environment. Such as, an astute thermostat should give the information or data of automatically gauged the temperature of a room which will help to adjust the central heating and cooling units according to necessity. With the advances in technology end devices of homes could be authorized, invigilatorized and secured by people. The smart home should be considered by the social insurance specialist organization as a viable method for giving remote social insurance administrations, particularly to the matured and debilitated who need customary medicinal services support.

1.2 Problem Statement

Wireless Sensor Networks (WSNs) which is created on the basis of layer-2 standard IEEE802.15.4 is used in various applications like environmental monitoring, home and industrial automation, military, transport and so on.[33]There are home automation systems which can be controlled through smart phones and android based devices using Wi-Fi, which could get the job done.[38] But they seem inefficient in terms of power consumption and cost.[37] Thus 6LoWPAN has been proposed as it allows numerous good devices to attach to existing network in exactly a number of time and this property is owing to IPv6 support provided by IPv6 over Low-Power Wireless Personal space Networks (6LoWPAN).[32] This technology is based on IP version 6 and uses 128 bit which provides enough address to be accommodated by devices.[29]. 6LoWPAN is basically the latest IP version 6 based Low-power Wireless Personal Area Networks.[14] The Internet Protocol version 6 (IPv6) is expected to accommodate a large number of entities, predictably enough to connect billions of objects over the years to the Internet.[12] There have been numerous investigations on NEMO and gathering versatility.[29] To prop up consistent information transmission between MAC layer and system layer, a system adjustment layer between them is started by 6LoWPAN working gathering.[29] The adjustment layer is responsible for the fracture, reassembly of pieces, IPv6 header pressure, communicate headers and treatment of the work tending to [29].The Internet Protocol (IP) has been supporting Internet apps such as email, web, Internet telephony and video streaming for centuries. [12] In literature [40] a framework simulation has been proposed where It implements a simulator and traffic management system for the 6LoWPAN network, implementing a framework for building the best route and tracking the status of all available options to ensure the transmission of emergency information. In this proposed model they have chosen best route based on distance and stored the value as authentic node value in the table which they implemented using various algorithms like-knowledge free (also known as known as First Come First Served (FCFS)), knowledge based algo. [40]

By this study we found some basic challenges to build up a home automation system with the available source like- Bluetooth, ZigBee or other Wi-Fi module. Considering the existing home automation system, we found these areas which need to be improved:
i. Mobility: In the traditional home automation system, sensors are fixed in a particular position. For example, in an automated room with an existing system, the position of temperature sensor, motion detector, gas sensors are fixed in a certain position after installation. If anyone wants to re-organize the room, then it is very hard to change the sensor's existing position to a new position where it can get optimum values in the re-organized room. Mainly the wirings make the system immobile.

ii. Expanding System: In the traditional home automation system, it was implemented mostly based on the wired communication and in such a way where modification or shuffling the sensors commonly arises complexity. which ends up with the result of high overhead and incompetence of time. For example, if we want to add an extra motion detector to the system, then we have to build the interface first and then we have to change the controller device's program as well as server side program to attach this sensor with the system. This is not easy to implement.

iii. Connectivity: Traditionally our home automation system's main need was to be connected through unified interface. The sensors were connected but the system could not interact with different technologies or devices frequently without any prior modification. Besides this, the sensors of our current home automation systems cannot be accessible directly without any medium which has an IP address to communicate with the internet. We have to access each sensor of the network by accessing the ip supported device.

iv. Power Consumption: In existing home automation systems, it failed to maximize its lifetime. So here we need to replace its batteries after a certain time regularly and we cannot recharge the battery.

v. Data Rate: In traditional home automation we see high data rates. So it causes a difficulty of energy loss.

vi. Overhead of Application: Mostly, in a traditional system which uses Zigbee needs siding application. Because this system needs to send an ip packet to the border router which encapsulates sensors or nodes data and the ip address. As the receiver will need that to identify that it is for that node. When the data packet comes to the router, it will pack the encapsulated packet with IEEE 802.15.4 address. And finally it will be sent for the desired node. This several works increase the overhead of the system. Consequently, the system requires more time to finish its whole work and makes the home automation slow.

1.3 Research Challenges

6LoWPAN is a mostly modern technology in this world. It is a very latest strategy to implement a smart home, all-IP solution based on IPv6 over a low-power, lossy network. With the support of IPv6 it has a large address space by which a large number of devices can be integrated to the network.[17]6LoWPAN protocol enables home automation devices based on 802.15.4 wireless sensor network standards to be compatible with IPv6, while maintaining low power consumption and taking the nature of wireless networks into account. It has improved a lot that it has been able to grab the attention of other research groups e.g. ZigBee Alliance. They have announced the integration of IETF standards such as 6LoWPAN and RPL into its specifications in March 2013 [2]. But during our research work we faced some challenges which make the work complicated in some cases.
First of all, we attempt for hardware implementation. For that we tried to have 6LoWPAN supported sensors and modules. At first we tried to get waspmote. Waspmote is a module which has gateway(GW) and endnote connectivity. Where nodes mean integrated sensors that are used to gather the information and send to the GW. Here our target was to design a mesh network where the End Node should be with a 6LoWPAN radio, sensors and a battery. After that GW would take the information sent by the End Nodes and would send it to the tunneling IPv4 / IPv6 server by using the Ethernet IPv4 interface. Each GW Node equipped with a 6LoWPAN radio and an Ethernet interface and a battery. It was a very impressive way to develop the network but those products were unavailable in Bangladesh. Besides one most challenging part was limited time and budget shortage.[12] The components were expensive for us to buy and as they are found outside of the country it would take a lot of time to come to our hand. So unfortunately we haven't managed to develop the module. So, we had to shift to XBee (802.15.4 2.4GHz, SC2) to implement the system. Because it also supports 6LoWPAN. But due to unavailability we tried our implementation with XBee SC1. But unfortunately the experiment failed. Later we discovered that sc1 does not work on 6LoWPAN. It works with 802.15.4 but has no characteristics of 6LoWPAN.

Due to the unavailability of hardware components, shortage of time and budget we have shifted to software implementation. Studying about the network simulator, we found out some reliable simulators.

Along these options we use Contiki in this case. After selecting the simulator, we have seen that it has several mote options to implement a network. But from all of them only sky mote supports 6LoWPAN. So we go for further implementation with Contiki using sky mote.

Simulator	Characteristic	Advantage	Disadvantage
NS-2	Real time network simulator	Availability of protocol information	Need knowledge of scripting language
NS-3	Open environment for researchers	Latest simulator	Only IPV4 supported
OMNet++	Less power consumption	Realistic graphical user interface	Less compatible
Contiki	Real time	Portability and multitasking	Constraint resource

Table 1.1: Different Simulator

1.4 Research Objectives

As upgrading or rebuilding Home automation system is very difficult, it needs a stable, proven, and future-proof technology like 6LoWPAN. Besides it should be effective and always maximizing the benefits. Furthermore, if little modification is needed to the existing home environment, the addition should not hamper the existing system working and the overhead should be low. System configuration should be easy and time-efficient. Here All entities of the system should be connected and users will have accessibility not only inside the home but also when he/she is outside of the home. And finally, the system must be aware and protect its users from threats like unauthorized access, privacy invasion, or destruction.

Major objectives of the study are as follows:

- Implementation of a model in which the user can directly access any sensor node without any medium.
- Ensuring that each node can be accessed through internet
- Availability of connection over similar or different kind of protocol.
- If new devices come around the network, it should also be being connected to the network.
- Able to explore sensor nodes by the router's routing.

1.5 Organization of Research Paper

The remainder of the research paper is as follows:

In chapter 2 we have discussed previous research involving 6LoWPAN and Home Automation.

In chapter 3 we have explained the Experimental Setup, implementation and techniques used in the model and also explains our model.

In chapter 4 we have shown details evaluation, performance measure and result analysis of the models.

In chapter 5 we conclude the findings and future research.

Chapter 2

Related Works

Lightweight 6LoWPAN portal dependent on Contiki is structured and its plans of equipment and programming are depicted in [33]. A mind boggling test condition is displayed, in which the door's capacity of getting to the Internet is confirmed, and its exhibition about the normal system postponement and jitter are broken down. The exploratory outcomes show that the portal structured right now not just understands the interconnection between 6LoWPAN systems and Internet, yet additionally has great system flexibility and security. In our proposed home automation model, with in the ability of flexible connectivity we have the option of retrieving data of the nodes. By which user can take action on what is desired. For example, in real life scenarios, if someone unintentionally forgets to lock the door when he leaves, he will be able to know the information and take necessary steps.

In [38] authors were anxious about 6LoWPAN utilizing unslotted CSMA-CA IEEE 802.15.4 and analyzed two sending approaches depicted in RFC 6606 for 6LoWPAN directing, in particular "route-over" and "mesh-under". They expanded past work by assessing the two methodologies on an enormous testbed. Results were acquired for both low-noise and noisy channels. Their outcomes showed that, despite the fact that presentation is influenced by numerous components including transmission power, network topology and channel noise, the utilization of route-over sending for the most part brings about an increasingly adaptable and vigorous 6LoWPAN system. In our proposed system, we have demonstrated the model with mesh topology.

In [37] for assessing impact of Channel Check Rate on the location setup idleness and the correspondence cost author presented an experimental study. They noticed that for conserving energy ContikiMAC duty cycling protocol is utilized. Reduction in the frequency of node wakeup may increase the cost of communication and address configuration latency. In our case, as we simulated the model, there is no change in frequency so the cost of communication is not affected.

In [32] authors inspected and studied about two topologies based on reliabilities and latencies. The standard mesh network and single path configuration requires multiple parent motes and single parent mote of multi hopping for each sensor is required respectively and second one is trash in case of topologies. The unwavering quality of the standard setup is reliably 100.00percent during a test of 22 days, while as the reliabilities for the circle designs is 100.00perccent for a time of 4 days. The

Wireless HART arrange shows a dependability of 99.94percent, while 6LoWPAN system shows an unwavering quality of 99.84percent during a trial of 7 days.

In [29] the author worked with a long chain and implemented 6LoWPAN to help nodes of long chains to access the internet within wireless networks where IP address is allocated to the nodes. For avoiding collision in data in the transmission process and for betterment of system responsiveness they proposed a versatile routing protocol which is based on maximum routing radius (DMR). They got impressive results after that. In our proposed model, we have simulated using random and grid positions of multiple hopping in UDGM (Unit Disc Graph Medium): Distance Loss radio medium.

Mechanized devices of home were substantially connected by dint of an embedded board which was forged developed in a java deployed home automation system and pledge remote entrance to the system Integrating the Internet server with a personal computer(PC) .[31] This makes certain a reliable solution since java technology Comprises integrated network security functionality. On the other hand, as the IPv4 addresses are limited to develop WSN largely, we have proposed our home automation model using 6LoWPAN so that we can accommodate every single sensor node with a unique IP address.

The implementation of a telephone-based remote controller for home and office automation was unusual as all communications took place over a fixed telephone line as a substitute over the Internet. [2] Any telephone that supports Dual Tone Multiple Frequency(DTMF) could give access to the system. This system's drawbacks are threefold: graphical user interface is not equipped to users; users need to remember an access code; buttons, that is to press to operate connected devices, must be remembered. In our proposed system it is going to be controlled using smartphones and the internet, it will be privileged with mobility.

In [1] hand movements controlled novel networks were contemplated. Using a glove, the restrainer relays hand signals to the machine. The machine issue manifests the inexactness of hand expressions, alongside the likelihood of natural arm operativeness being misinterpreted as commands. Additionally, if repeated hand movements are needed, there lies jeopardy of user lethargy. As our proposed system is not designed to control using body gesture, there is no chance of user lethargy.

In [3] home automation system has been enforced using Bluetooth with the help of primary controller and Bluetooth sub-controllers along with dedicated Bluetooth module. Local Bluetooth sub-controller is connected with each of the domestic devices by wired connection and devices can communicate with their respective Bluetooth sun-controller through that wired connection. Sub-controllers transmit communication signals to the primary controller using wireless communication.It reduces the cost of wiring but the architecture is unable to mitigate the installation's intrusiveness completely by adding some circuited correspondences. In addition, splitting of a solitary Bluetooth module between particular gadgets often includes the downside of provoking a delay in entry. But in our proposed system we do not need any sub controller. Moreover, Bluetooth cannot be controlled using the internet so users cannot monitor devices from outside whereas our proposed system undeniably can overcome that.

In [9] a common gateway, that comes up with interoperability across networks, fast and versatile user interface and remote device access, has been used to deploy a home computerization scheme ground on ZigBee and merged with Wi-Fi network and internet. They focused on cost and complexity along with good security. Devices can be monitored and accessed by the user using any device with Java support and which is internet enabled. But, for the Wi-Fi investigator, the total delay of connection was greater than that of the ZigBee investigator. The Wi-Fi investigator and the ZigBee investigator had an unusual connection delay, which is 670 ms and 1337ms respectively. If ZigBee wants to bridge with other technologies like Wi-Fi, it needs an extra ZigBee gateway whereas, each 6loWPAN node can bridge with different technologies without any gateway with less complexity.

In [34] deployed a wireless home automation system where they focused on security and AES encryption was used for achieving security over the network. Notification will be sent to the user on noticing any interloper and will ring an alarm if necessary. As a server and controller, to control electronic devices and for providing security and validation to the user, Raspberry pi is used. Developing systems using Raspberry pi is complex and power consumption is comparatively high. On the contrary development of our proposed system is less complex and power consumption is low.

In [22] formulated an interface using Kinect V2 as a voice receiver and trained a computer system to recognize a series of voice commands that demonstrates voice control. Meanwhile using Arduino and light bulbs a circuit was evolved which imitated actual appliances Accuracy of their system was 95percent mentioning when noise is 53db and from user to Kinect distance is 4m. As we are using the internet in our proposed system so there is no limitation of distance in case of controlling devices.

In [10] implemented a system that provides the potentiality to open and close an electric door lock remotely and the execution was done by exploiting an embedded web server that is connected via IEEE 802.15.4 and IPv6 Low Power Network. Advantage of IPv6 over Common protocols for the local automation was analyzed and first data transmission evaluation within a 2.4 GHz band was Provided. On the other hand, our proposed system is a complete package for the entire home.

In [30] using IR remote, Bluetooth and GSM to use android apps to power AC devices a home automation system was introduced claiming that it is simple to do using the conventional transfer approach. Enlightening people about these technologies and making the system clearest and understanding to a common individual was the purpose. This program allows users to control devices through android application. To compare with our proposed model, we can see the use of android application to control Bluetooth devices make it distance limited and GSM module is also power hungry but our proposed model is not bound to distance limitation and power consumption is less.

In [26] proposed blended and interoperable home mechanization arrangements abusing the ideas of Edge Computing, Virtual IoT Devices (VID) and the Internet of Things (IoT). The Edge Computing stage is created and sent in a Raspberry Pi. An Android controlled cell phone is utilized as the customer gadget.

In [6] to give a progressively reasonable interface, a 3D virtual world is embraced as the User Interface (UI) for a home computerization framework. Also, a home server is utilized as a controller for home gadgets. As a data trade position between the virtual and this present reality, a control convention that works under an institutionalization procedure is presented. With the assistance of a 3D virtual world, a client can control and screen home gadgets by means of an easy to use interface that works both instinctively furthermore, sensibly anyplace and whenever with the help of the Internet.

In [18] home robotization structure planned for diminishing usage of electricity normally uses different sensors arranged in different zones of the house that talk with a method unit to control the lights, HVAC system, consumer equipment, etc., so the strategy unit turns these systems on exactly when needed. Additionally, other automated assignments may consolidate setting the HVAC to an essentialness saving setting while the house is relinquished, and restoring the common setting when an occupant is going to return. To improve current home computerization structures, it is prescribed that by considering the direct of the occupants inside a house, the power eaten up normally will be generally diminished. Such a power decline could be practiced by both the sensors that screen the developments of the tenants inside a house and the flexible control structure that rapidly adjusts itself to the best level to also lessen power usage reliant on different exercises, inclinations and lifestyle of the tenants. In our proposed system we do not need extra sensor for power consumption as 6LoWPAN itself is feasible for low power consumption, as a result extra device is not needed.

In [25] proposes a Customer Server administration and gadget cordial methodology for Home robotization. An ordinary home computerization work process comprises 4 stages. Recognizing the client's estate by encountering, affirming the occasions to a evaporated substance, brought together ingredient investigations and triggers the work process, the work proceeding will assassinate and reinvigorate the client by any perceptive channels or even exercise over a home gadget (impelling). The state of being of the gadget can likewise be modified depending on the client demand. Home computerization can be made effective by including security factors by alarming clients about an obscure individual in the house. This IoT venture executes a customer Server based home robotization with gatecrasher caution to the client cell phone. The client can likewise recover the picture of the individual entered into the home.In our proposed system there is no such stages, users can directly access and command devices from anywhere if there is internet.

In [28] proposed a Voice Controlled Home Automation Systems (VCHAS) which is based on ZigBee and Wi-Fi arrange are bound together through a common home gateway for taking care of automated, hard coded programming issues that are available in the vast majority of the robotization framework which are neither client characterized nor restrictive control. The combinatory offers organize interoperability, a basic and supple UI, and far off access to the framework.

In [24] build up a versatile characterization conspire (ACS) to arrange power source sort of home robotization sensors in savvy home, and further propose dynamic appropriated vitality the executive's calculation (DDEM) to modify vitality conveyance for setting up canny home computerization the board framework. At long last, the proposed plan can successfully drag out the activity life of home sensor networks. In our proposed model we have designed an automation system for the entire home whereas here, they proposed an algorithm which focuses on recognizing power sources only.

In [19], focusing on flexibility, wireless innovation correspondence and cost of establishment, an IP-based half and half engineering of home robotization is introduced which can bolster adaptable mixes of Cloud-Based mode and Standalone mode through and through as their perspective, neither the unadulterated Cloud-Based nor the Stand-Alone design is adequate. Fundamental prototyping dependent on the 6LoWPAN and trial assessment of exhibitions have demonstrated the specialized plausibility just as future headings of progress. They thought of trial use of 6LoWPAN and also combination of cloud-based and standalone technology can create hassle, on the contrary in our proposed model we have used 6LoWPAN and there is no hassle neither in building nor in maintaining.

All the above systems represent home automation using various devices, protocols and technologies. Our system is different from the existing systems. We have implemented IVv6 based 6LoWPAN technology that can be accessed from any platform that is connected with the internet. because IPv6 device numbers would not matter, all the devices that are in the system can communicate among them.

Chapter 3

Methodology

The proposed system has solved the issue of transferring data from sensor to device. Considering the software solution, Contiki has been used. The main focuses of the problem which has been solved are: 1) How to intercommunicate between the nodes that follow IEEE 802.15.4 protocol to the same type of nodes in the networks of 6LoWPAN . 2) How to comprehend those intercommunications of datagrams of IPv6 . 3) How to empower the GW to approach the Internet and resend acknowledged datagrams of IPv6 . To do so the program has been implemented based on Contiki. IEEE802.15.4 Module has been programmed and assembled by designs of GW's equipment.As the 6LoWPAN convention has been executed in Contiki, the program makes it conceivable that the GW can broadcast with other IEEE 802.15.4 hubs in the 6LoWPAN systems, and empowers the transmission of IPv6 datagrams among them. In the meantime, when gateway receives any IPv6 datagram through component, the goal arrange address of the datagram is dissected [35]. If the destination is for this 6LoWPAN network, the datagram is handled in consonance with the routing covenant of 6LoWPAN. Now focusing on router mote, it would be loaded after the router node placing is done on simulation software. To help fundamental equipment drivers, TCP/IP conventions, a particular record framework ought to be aggregated and introduced. Thirdly, the assortment of the tunslip6 Contiki file. At that point the gathered program is stacked into the Micro Control Unit Module. The guidance of tunslip6 will be executed. Accompanying that, 'tun' is added to the gateway ,that is a pragmatic network accessory ,where TSF_PREFIX labeled network address likewise. So, the IPv6 datagram spreaded from the IEEE 802.15.4Module to the Micro Control Unit Module by SLIP, is processed by the virtual network device 'tun'. Then the IPv6 datagrams acknowledged from the Internet can be dispatched to the complementary 6LoWPAN network. After that, the router gets an ipv6 public address and the router node can now supervise the Ethernet Module for approaching the internet. As a result, it has been enabled for communication with the Modules. Now the gateway are capable of accessing the IPv6 network.

3.1 Proposed System With Architecture

Fig.3.1 represents the architecture of the proposed system. The following subsections describe the whole process of our proposed architecture.

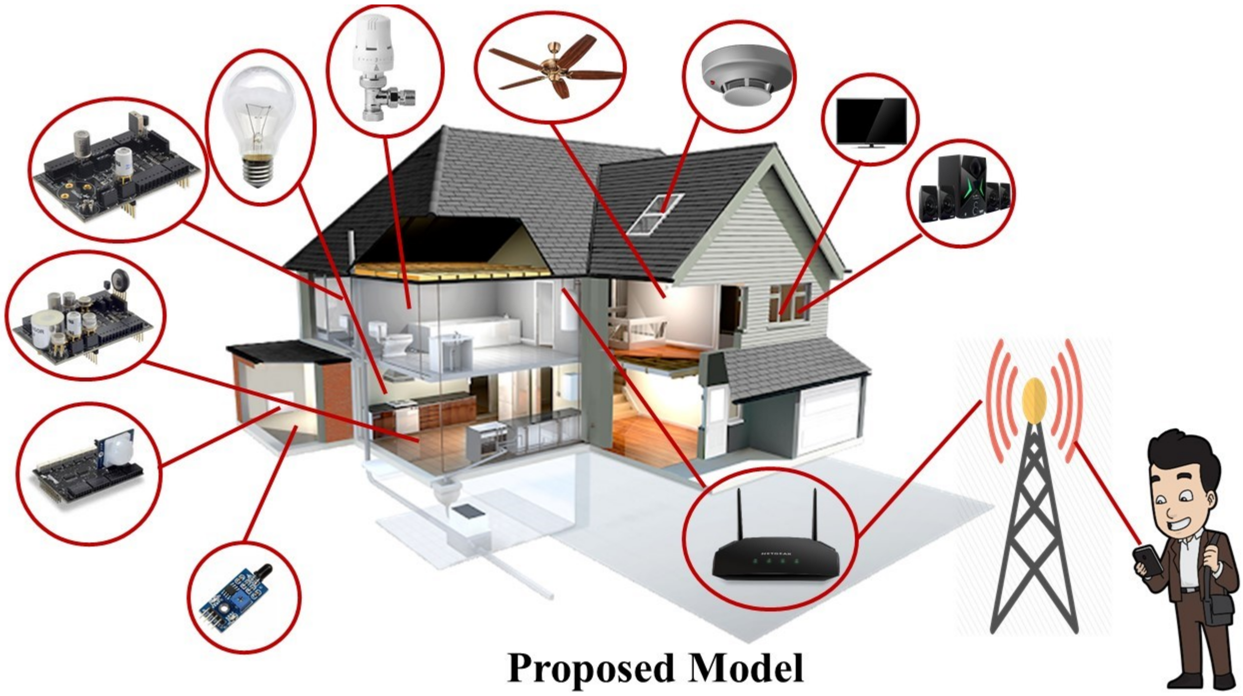

Figure 3.1: Prpoposed Home Automation System

3.2 Experimental Setup

3.2.1 Components

The proposed system solve the issue of transferring data from sensor to device. Considering the software solution, Cooja is going to be used. Cooja is a simulation tool which runs in the Contiki operating system. In the contiki different notes are present in which sky mote is ipv6 supported. So sky mote used to create different nodes of implementation.

3.2.2 Procedure of our Proposed system

The main focuses of the problem are: 1) How to articulate between the nodes that follow IEEE 802.15.4 protocol to the same type of nodes in the networks of 6LoW-PAN . 2) How to comprehend those articulations of datagrams of IPv6 . 3) How to empower the GW to approach the Internet and resend acknowledged datagrams of IPv6

i. To implement the intercommunication between nodes to nodes the program has been implemented based on Contiki. IEEE802.15.4 Module and it must be assembled in consonance with the composition of gateway's hardware. Since 6LoWPAN protocol has been deployed in Contiki, the program makes it conceivable that the GW can communicate with other nodes that follow IEEE 802.15.4 protocol in the 6LoWPAN networks, and facilitates the transference of IPv6 datagrams among them.

ii. While the packets start to be transmitted via nodes meanwhile the GW obtains any IPv6 datagram through Module, datagram's landing-place network address is scrutinized[35].The datagram is handled in consonance with the routing protocol of 6LoWPAN only finding that the destination is for that 6LoWPAN network. Now focusing on the router mote, it will be loaded after the router node placing is done on simulation software. To support crucial housewares coachman, TCP/IP protocols, a specific file system should be compiled and installed.

iii. The assortment of the tunslip6 Contiki file. At that point the gathered program is stacked into the Micro Control Unit Module. The guidance of tunslip6 will be executed. Accompanying that, 'tun' is added to the gateway ,that is a pragmatic network accessory ,where TSF_PREFIX labeled network address likewise. So, the IPv6 datagram spreaded from the IEEE 802.15.4Module to the Micro Control Unit Module by SLIP, is processed by the virtual network device 'tun'. Then the IPv6 datagrams acknowledged from the Internet can be dispatched to the complementary 6LoWPAN network. After that, the router gets an ipv6 public address and the router node can now supervise the Ethernet Module for approaching the internet. As a result, it will be enabled for communication with the Modules. Now the gateway will be capable of accessing the IPv6 network

3.3 Implementation Details

The prototype model is executed with the help of COOJA simulation software. First of all, we have installed ContikiOS on Oracle VM Virtual Box to install COOJA on a 32bit based Linux operating system. From the virtual machine (VM) at first we have tested router-server connection over IEEE802.15.4 and IPv6. Secondly, the Router-Server-Sensor and sensor to sensor network has been tested. Here, the router establishes the communication between servers and the Internet. The router is connected on the internet through a public IPv6 address and server socket port. Server receives the data from Sensor nodes. The sensor nodes are actually the end devices which only send data to its neighbor sensors and servers. On the simulator, the background grid is 10m. Each node has TX range (Green colored) of 50m and INT range (Ash colored) of 100m where TX range refers that the transmitted packet can be received easily by any node which are inside of the range while INT range is the range where the transmission of packets can be heard but cannot receive the transmitted packet.

To run our first simulation (figure:3.2) after pressing the start button(In below figure) the simulation started.

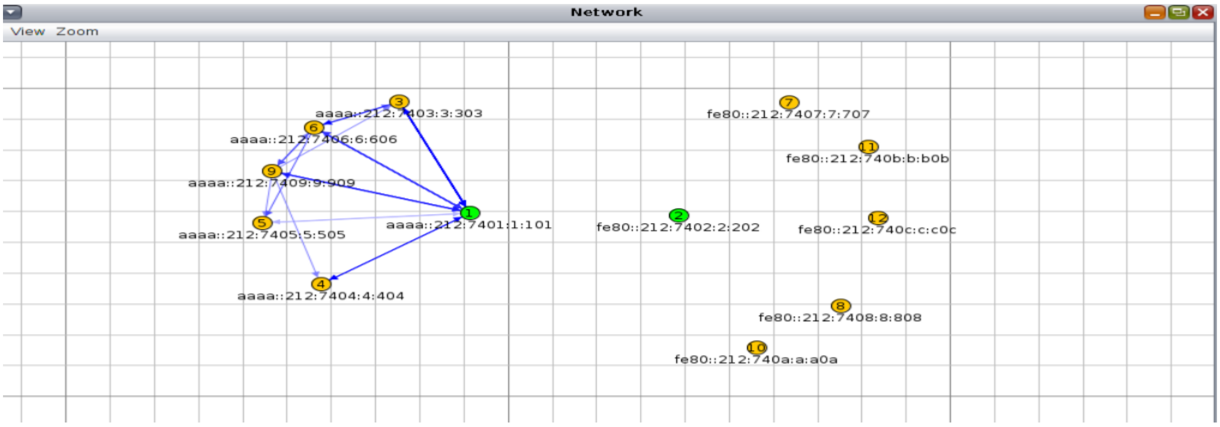

Figure 3.2: Router-Sensor connection simulation

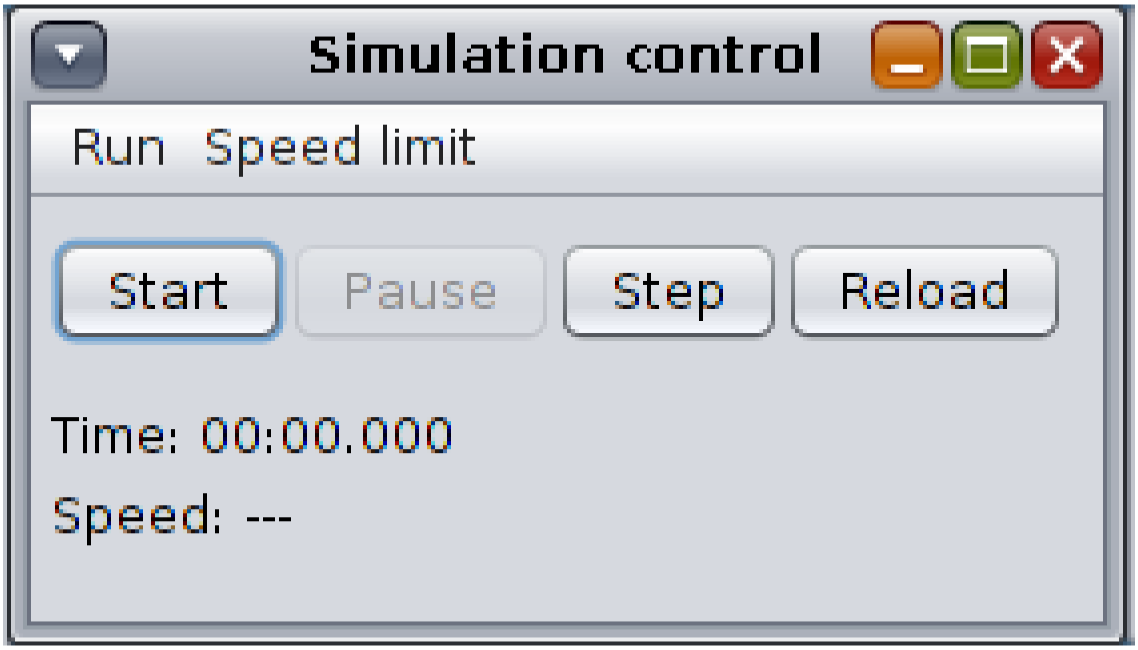

Figure 3.3: Simulation control

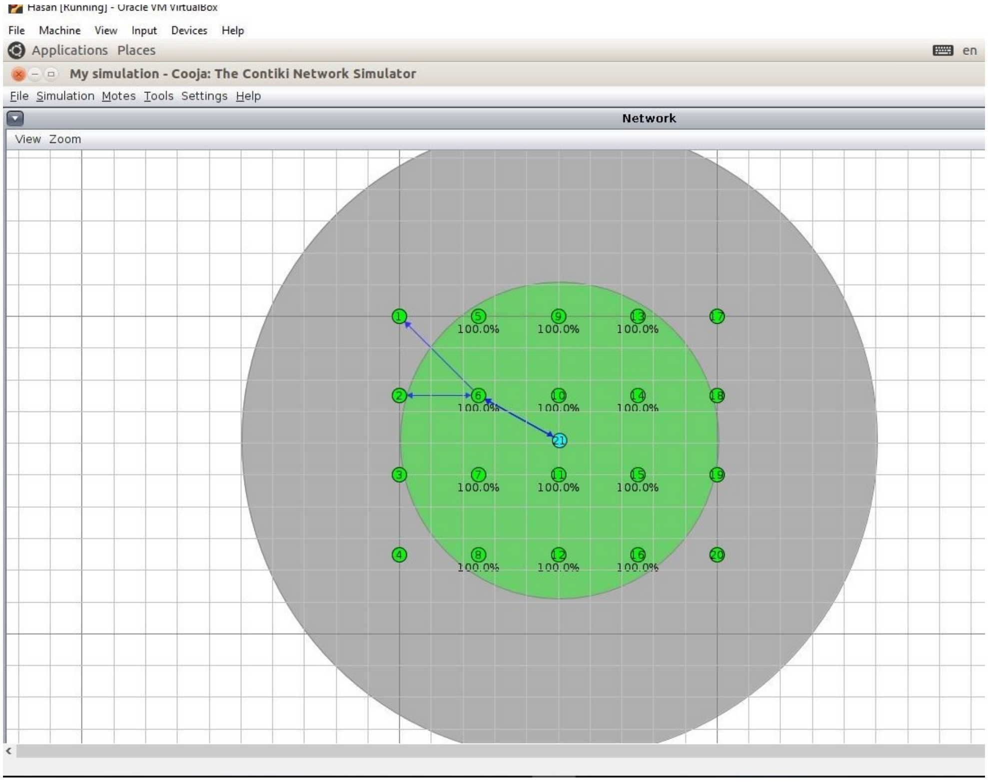

Figure 3.4: Router-Sensor connection simulation (Grid)

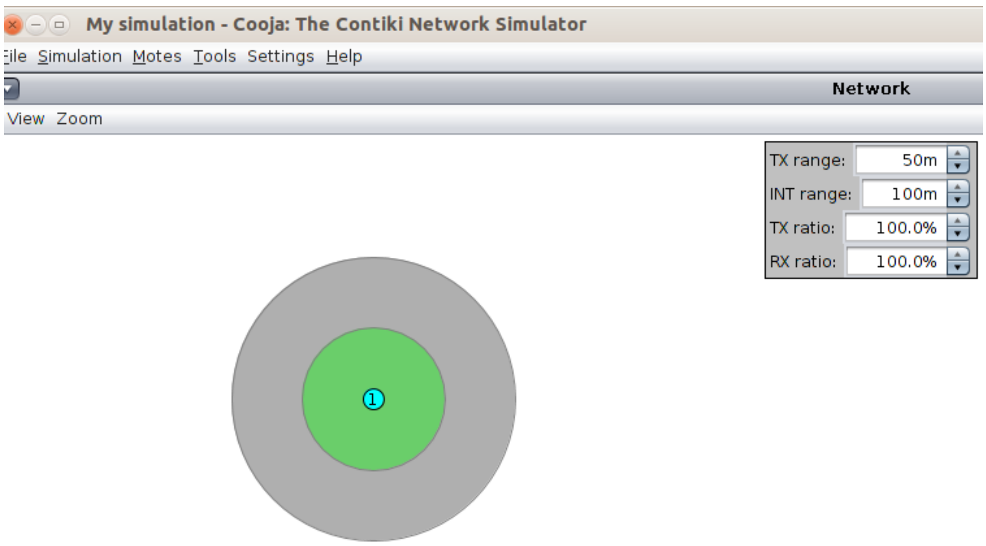

Figure 3.5: Tx range and INT range

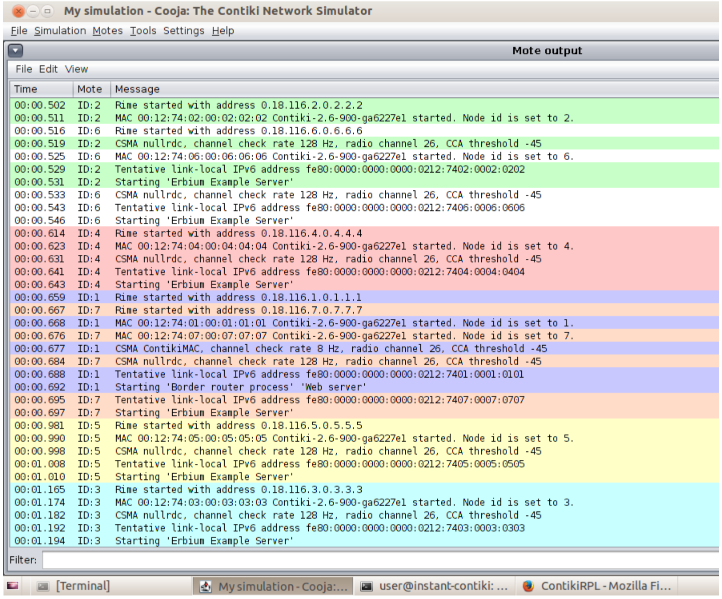

Figure 3.6: Mote output

After starting the simulation each node follows some steps to get connected with each other. (From Figure: 3.6) At the first step, a set of custom lightweight networking protocol rime stack starts. When one node comes to the stack it automatically gets an abstract address and when the next node comes then they automatically get connected by following other steps. On the second step, the node gets a mac address and assigned with a node id. After that, the radio channel, channel band and CCA threshold value has been set. The values are the same for all nodes of the network. Next, the node is assigned with a tentative IPv6 address and at last the node starts transmitting or receiving data.

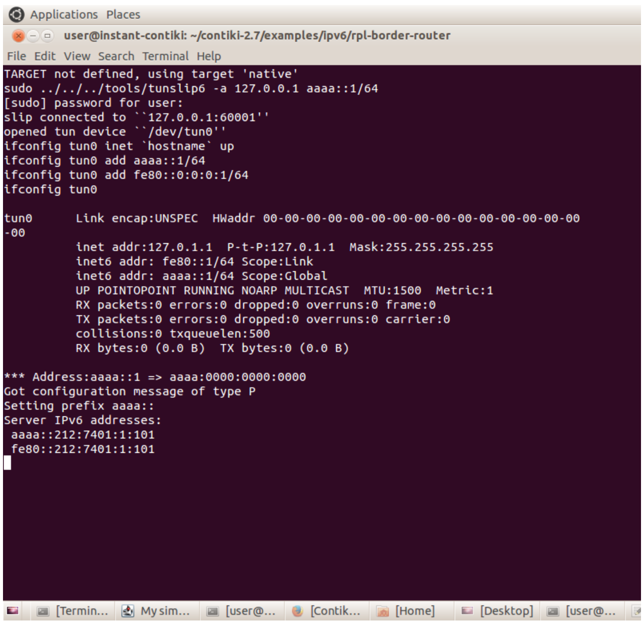

Figure 3.7: Command line for starting connection between Router and Internet

After entering the command "usr/home/contiki-2.7/ipv6/rpl-border-router make connect-router-cooja" ip configuration of the router has been done. And now it can be accessed from the internet where we can see the router's neighbors and routes. So, we put the ipv6 address of the router on a webpage and it shows us the neighbors and routes of that router (fig: 3.8).

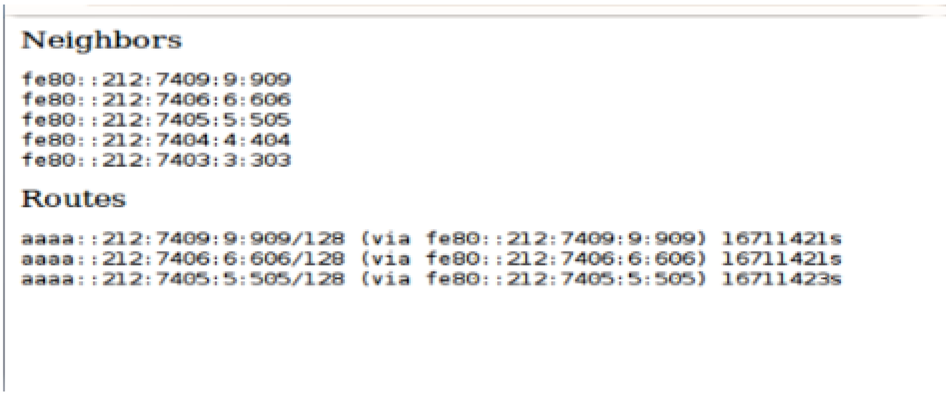

Figure 3.8: Accessing data of Router

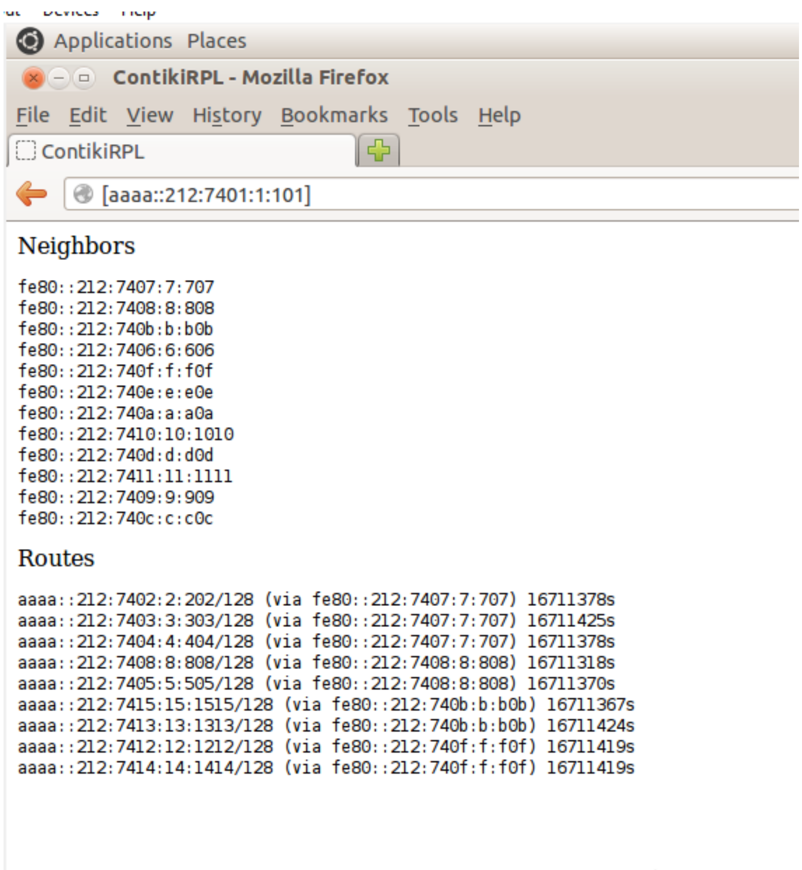

Figure 3.9: Accessing data of Router (Grid)

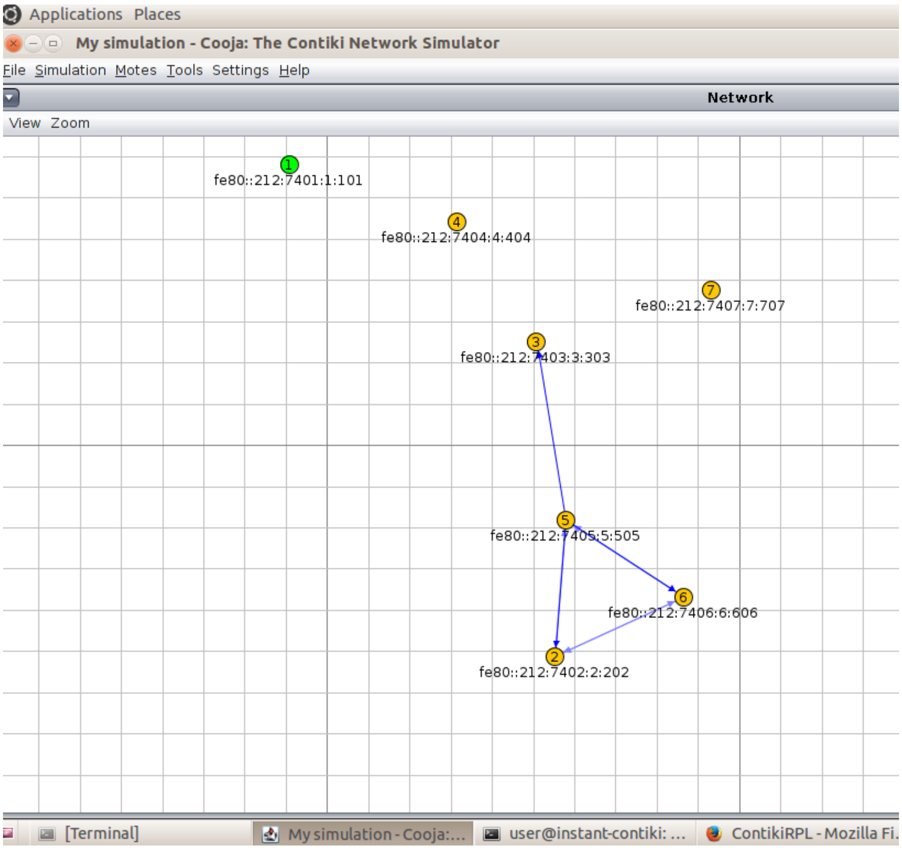

Figure 3.10: Sensors are transferring packets

After establishing the connection, sensors can communicate with each other by sending data packets by following IEEE802.15.4 6LowPAN protocol. Fig:3.11 is showing the transmitted data packet history and the protocol which it followed.Through this process the router can recognize every nodes and collect the data for the end devices.

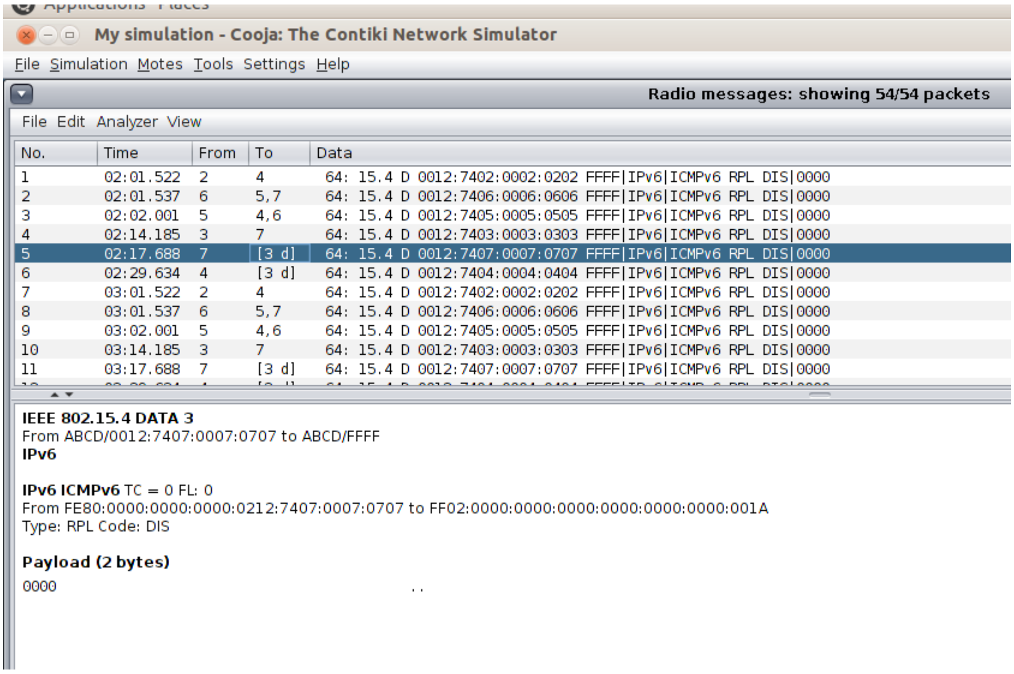

Figure 3.11: Packet history

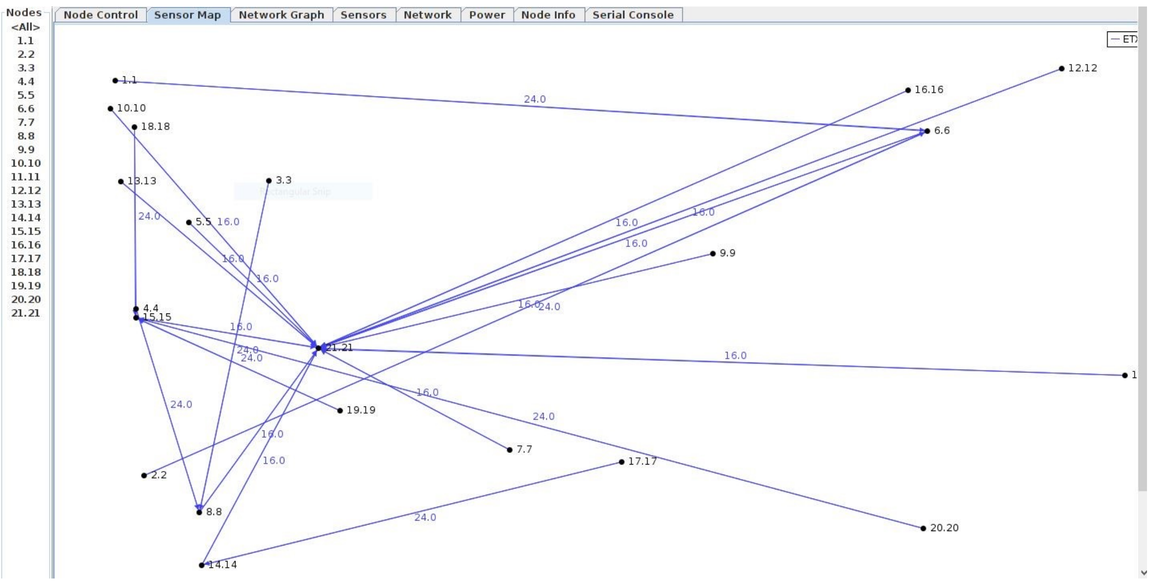

Figure 3.12: Sensor to Sensor network map (Grid)

After setting all the connections, we try to see the data collection network of node 21. For fig:3.12 all the nodes were discoverable by node 21. So the figure shows that all the nodes are directly connected to node 21 or they are connected by hops. We have tested the same sensor -sensor network again but with keeping node 5 out of the tx range of node 4 and we have checked the sensor map again whether it can communicate with it or not. As a result, we can see that node 5 is connected with node 4 through node 1 as it is only one node which is placed The COOJA timeline shows the timeline of each node at the time of simulation. The blue color remarks one node is transmitting data. The green shows which nodes are receiving data and the red one shows which one is interfered by a transmission. The gray color says where the nodes are on.

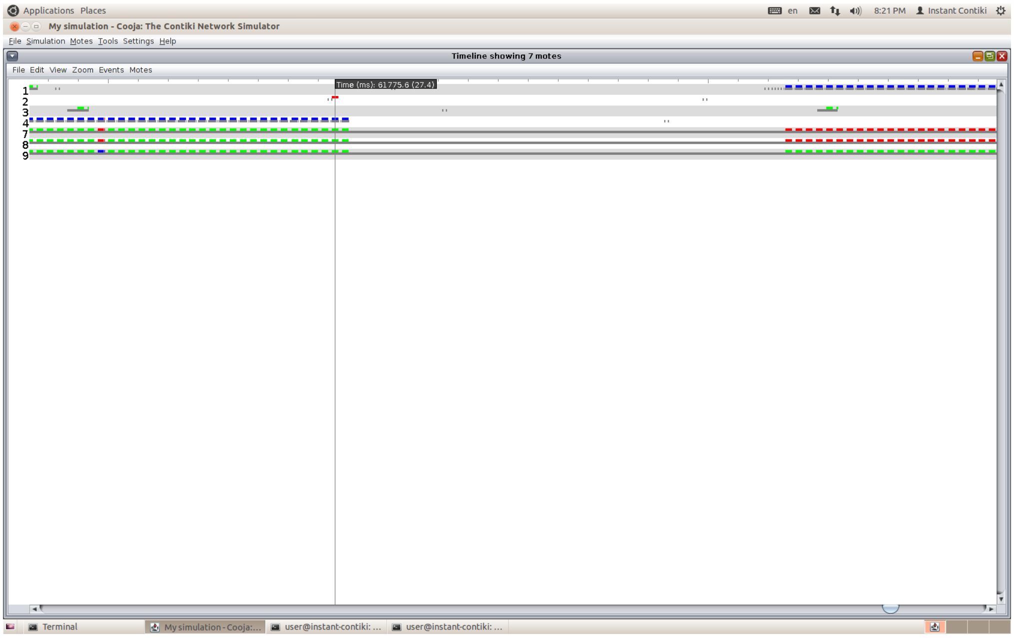

Figure 3.13: Timelines of mote states at time 61775.6ms

Chapter 4

Experimental Results

4.1 Comparative Study

Here we have shown a comparative discussion between 6LoWPAN [36], Bluetooth and ZigBee regarding the concept of radio frequency, data rate, range, topology, certification, supported internet protocol, data packet, peak current consumption, real life application and supporting devices. According to the analysis, ZigBee and

Technology	Proposed 6LoWPAN architecture	Existing Bluetooth architecture [15]	Existing ZigBee architecture [36] [15]
Supported Radio frequency	668MHz,915MHz,2.4GHz	2.4GHz	2.4GHz
Data rate	250kbps	1Mbps	20kbps to 250 kbps
Distance	10 - 200 meters	8 to 100 meters	10-75 meters
Topology	Star or Mesh	Star or Bus	Star ,Tree, Mesh
Certification	IETF/open source	Bluetooth SIG	Zigbee Alliance
IPv6 support	Yes	No	Yes
Packet Size	127 octets	Up to 251 bytes	128 bytes
Peak current consumption	Tx:12-25mA,Rx:20-35mA	Tx: 15 - 30mA, Rx: 15 - 30mA	Tx:20-30mA,Rx:20-35mA
Main application	Monitoring and control	Data and voice transmission	Monitoring and control
Support device for Internet	Router		Zigbee gateway

Table 4.1: Comparison of 6LoWPAN, Bluetooth and Zigbee

6LoWPAN perform much better rather than Bluetooth in terms of monitoring and controlling home nodes because Bluetooth modules can not have access over the internet. So it has the ability only to retrieve data. Now in between ZigBee and 6LoWPAN network, 6LoWPAN shows better results on end-to-end delays with authenticity. [13]

4.2 Result Analysis

Here in our model (considering the grid structure) we take light sensors as a test case for all nodes. The Fig:4.1 and Fig:4.2 show the incorporated mode of light view. Here the graph represents that sensors periodically send requests to the udp servers and at a time we get the value at which time the light was active. and by the sink node we can assume that what values it retrieved from the nodes. Here we maintain 1 hop distance when we set the nodes to make the model more efficient. Besides we maintain Max retransmit factor 0, Max transmit wait 93000, Ack timeout 2000, Ack random factor 1.5. Here we are showing two different Light source models of our simulation.

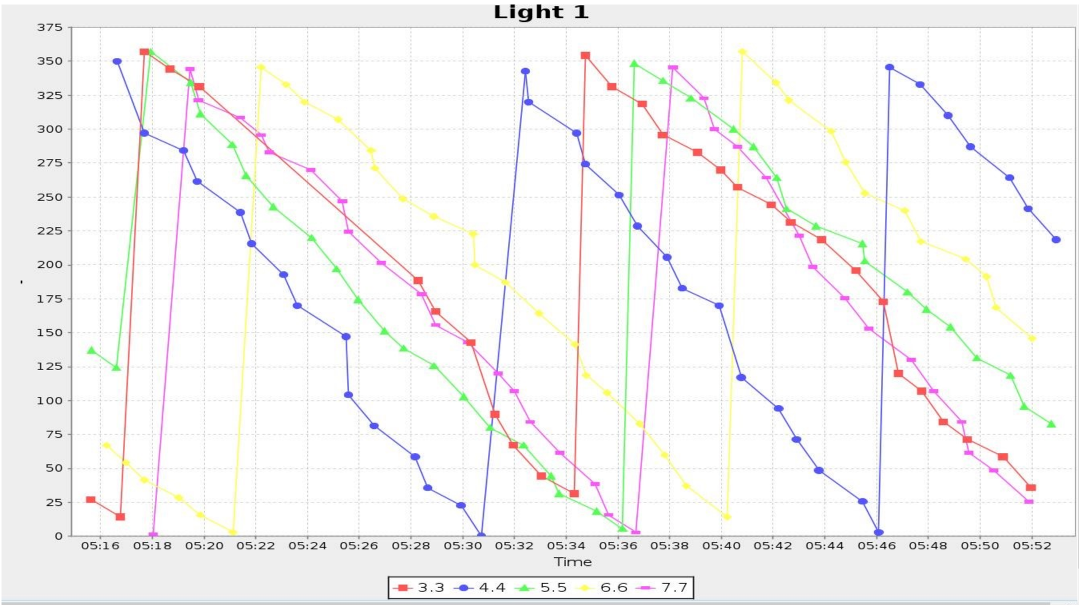

Figure 4.1: One Light View

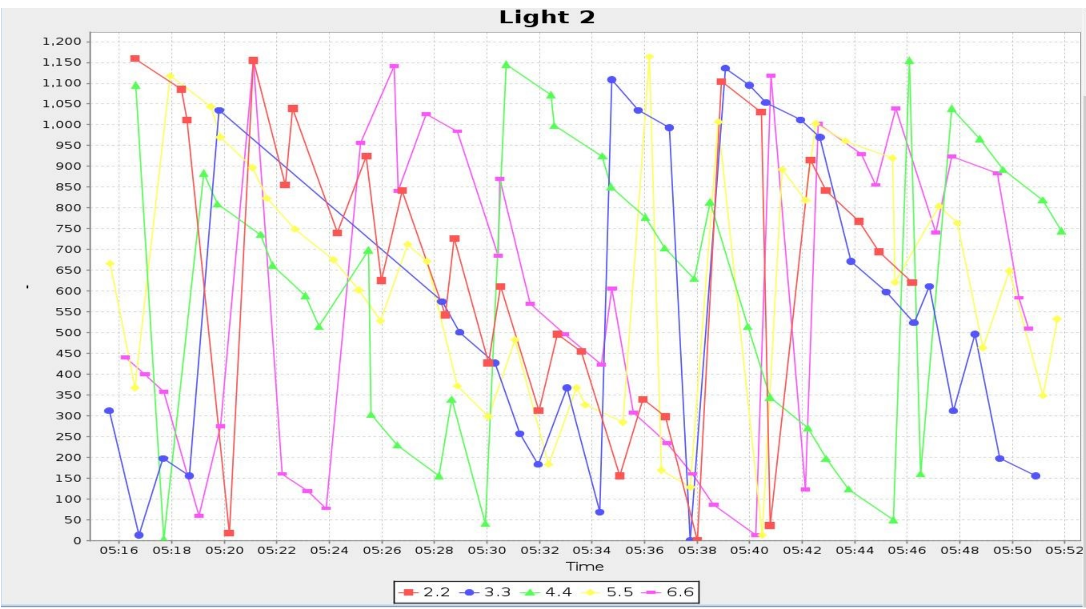

Figure 4.2: Second Light View

Here Fig 4.2 shows the basic power calculation of our home automation model. As we mentioned earlier in our simulation process, we take 20 sensor nodes where 12 nodes are directly connected with the router and 8 have no direct connect but they can communicate through other nodes. In the figure. We see that every sensor node power consumption has four partitions where the yellow part shows the power consumption of Radio Transmission. It normally produces because of alternative current of radio frequency which may be applied in its antenna. Secondly, the green part shows the power consumption of Radio Listening, the blue part shows the power consumption of CPU and the red part shows the power consumption of LPM.

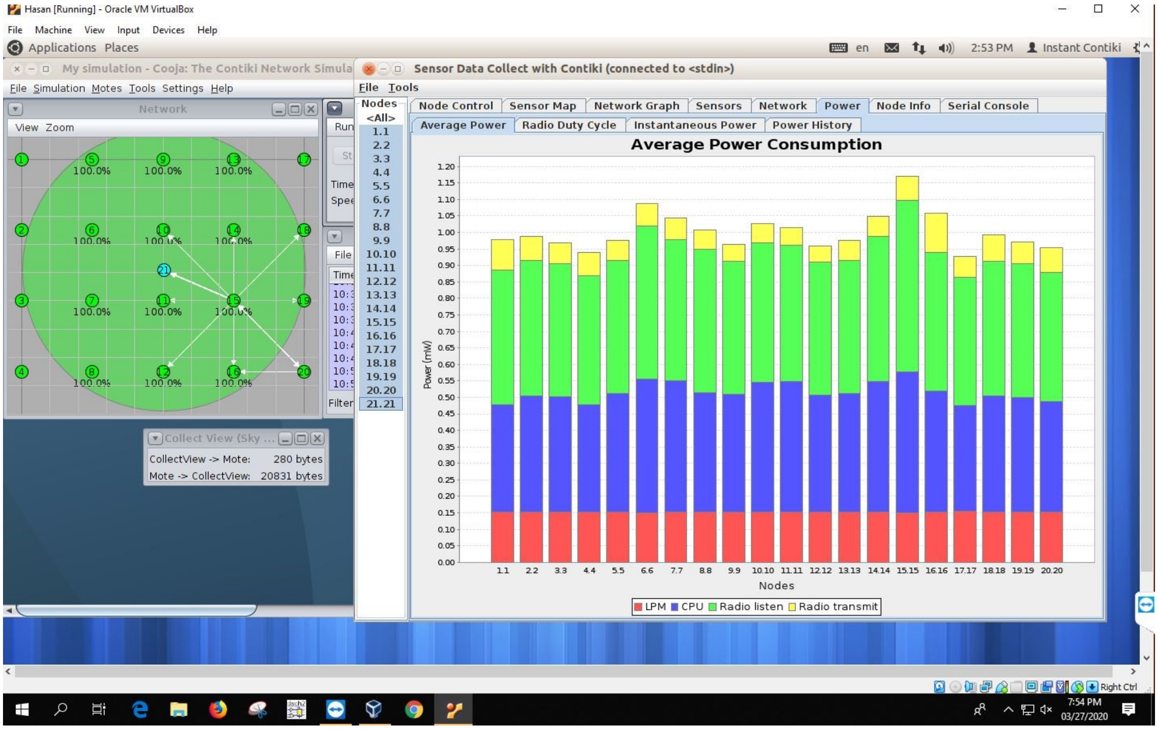

Figure 4.3: Average power consumption

In Fig 4.4 shows the battery state corresponds to its sleeping and active mood time. From the figure we see that the battery sate starts from voltage 0.30 volt and when the sensors node is in active session the battery lose its power and after a time period when the sensors node in sleep mood the battery start to charge and contain the voltage upto 0.30 volt. So we can see that the battery is losing its voltage when the sensors node is in active mode and charging when it is in a sleeping mood. Therefore, there is no need to change the battery after a time period because it can harvest the power from the environment.

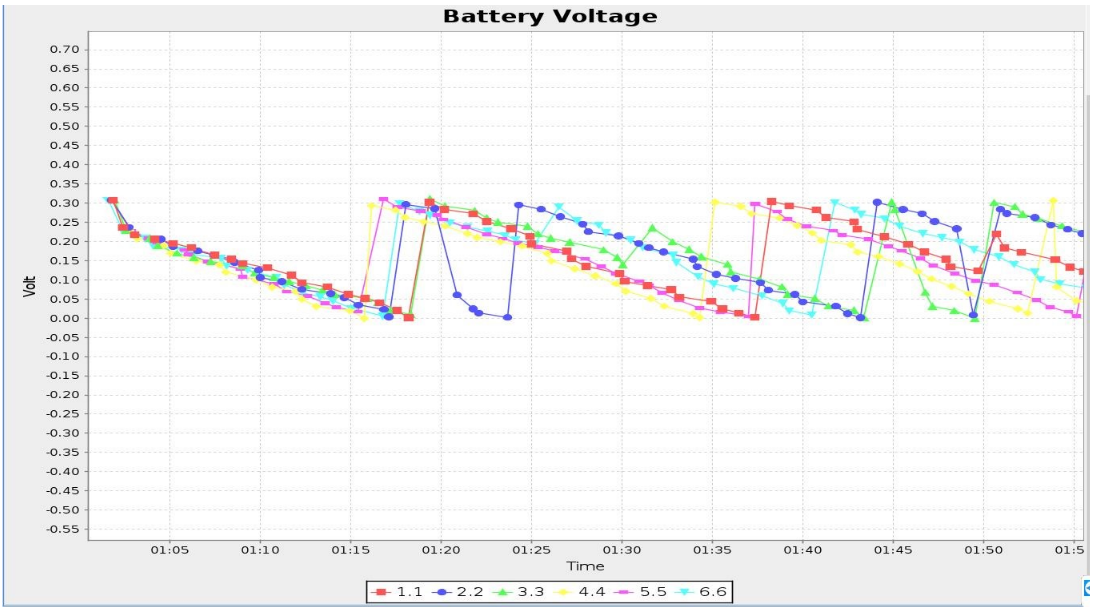

Figure 4.4: Battery voltage

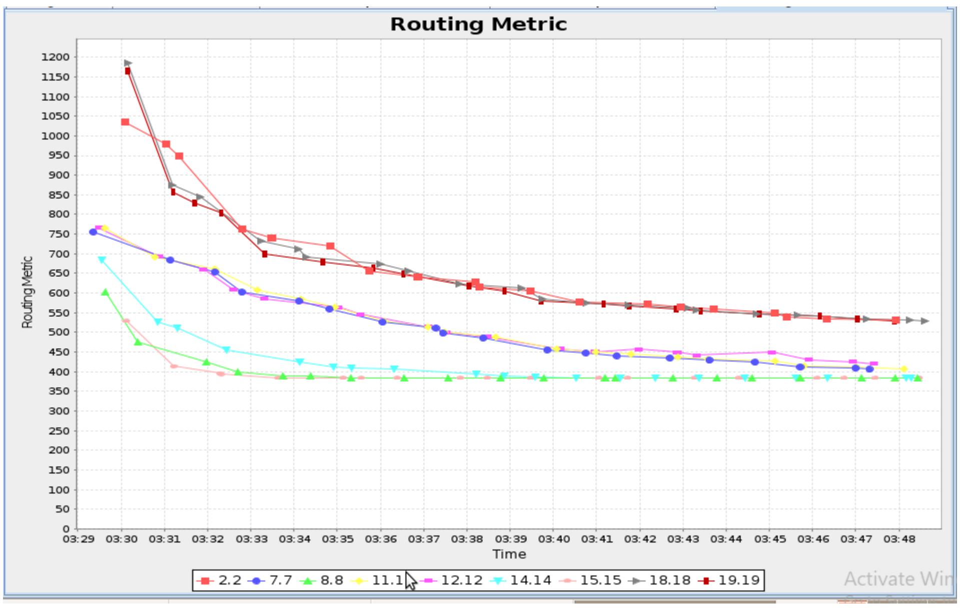

Figure 4.5: Routing metrics

Fig 4.5 shows the routing metrics of sensor nodes. In the COOJA simulator, the routing metrics are calculated by ETX [23]. ETX means Expected Transmission Count. It measures the expected number of data transmission from source node to destination node. Whenever any source node sends a data packet, the destination node sends an acknowledgment that it receives the packet. Otherwise it represents packet loss. If we consider that df is the forward ratio and dr is the reverse ratio then the formula of ETX will be ETX=1/df*dr[11].

In Fig 4.6 the ETX rate is decreasing with respect to time. The ETX rate will only decrease if the value of dr and df will increase because they are inversely proportional with ETX. So it is good to see the decreasing value of ETX.

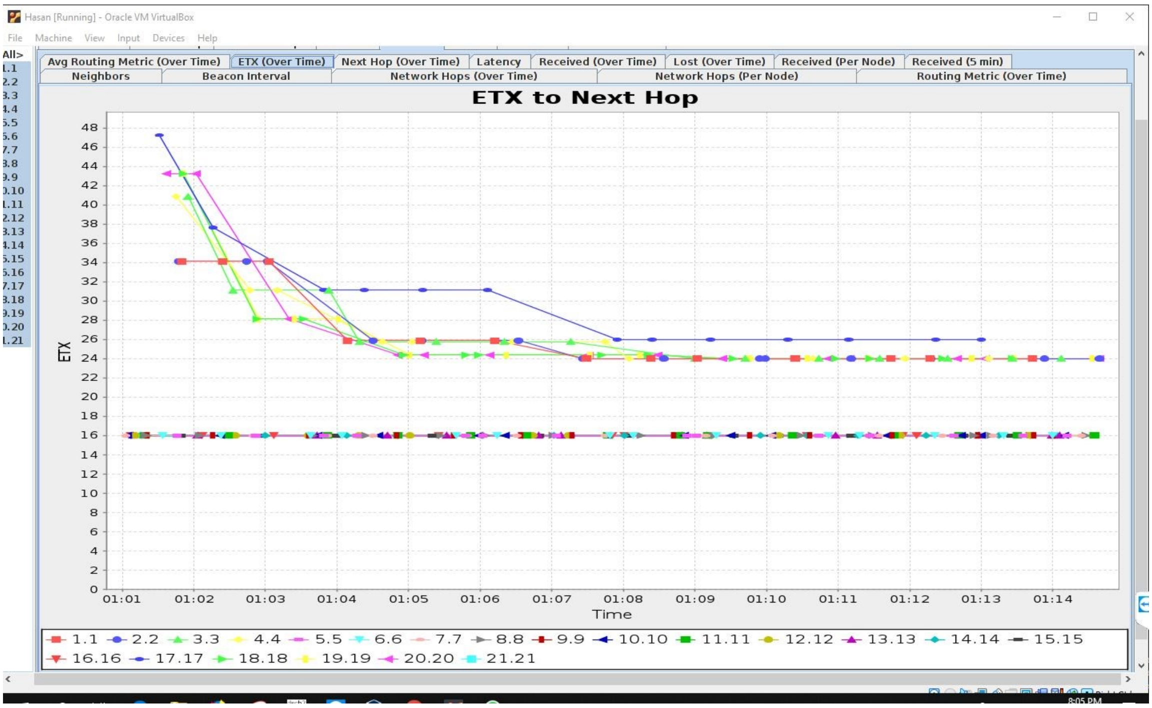

Figure 4.6: ETX to next hop

Fig 4.7 shows The average routing metric of the simulation

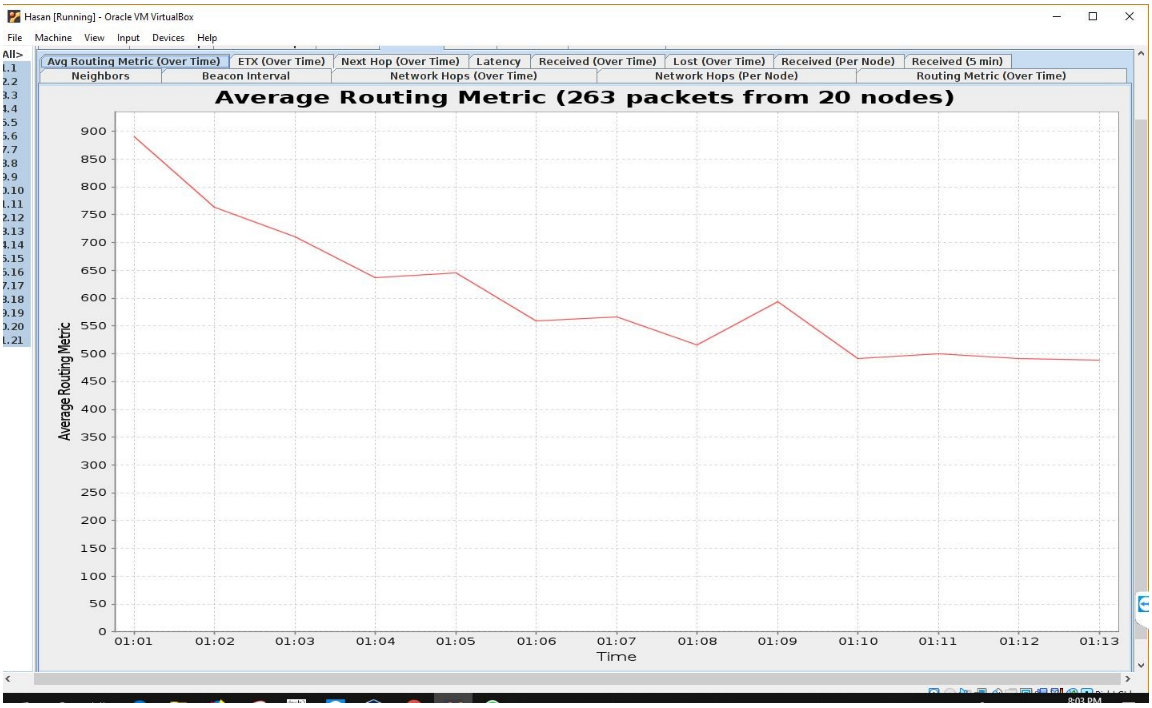

Figure 4.7: Average Routing Metric

Fig 4.8 represents Sensor nodes information about the power consumption, Duty cycle and packet transmission time. Whereas the node's average power consumption is 0.920 mw. In case of duty cycle it shows two different values e.g. Listen and Transmit duty cycle. Listen duty cycle means the period of time where the nodes receive data and transmit duty cycle means the time period of transmitting data. In this simulation it is found that the average transmit duty cycle is 0.044 and average listen duty cycle is 0.653. Besides it shows the packet transmission time between sensor nodes. We found min inter-packet transmission time is 0.08s (on average) and maximum inter-packet transmission time is 110s (on average)

Node	Power	Listen Duty Cycle	Transmit Duty Cycle	Avg Inter-packet Time	Min Inter-packet Time	Max Inter-packet Time
1.1	0.888	0.644	0.060	0 min, 58 sec	0 min, 06 sec	1 min, 56 sec
2.2	0.904	0.642	0.053	0 min, 58 sec	0 min, 05 sec	1 min, 49 sec
3.3	0.905	0.643	0.053	0 min, 58 sec	0 min, 10 sec	1 min, 52 sec
4.4	0.881	0.641	0.052	0 min, 58 sec	0 min, 12 sec	1 min, 50 sec
5.5	0.901	0.639	0.032	0 min, 58 sec	0 min, 05 sec	1 min, 49 sec
6.6	0.987	0.697	0.050	0 min, 58 sec	0 min, 10 sec	1 min, 46 sec
7.7	0.936	0.644	0.030	1 min, 00 sec	0 min, 10 sec	1 min, 56 sec
8.8	0.957	0.695	0.054	0 min, 59 sec	0 min, 05 sec	1 min, 52 sec
9.9	0.895	0.635	0.027	0 min, 58 sec	0 min, 07 sec	1 min, 54 sec
10.10	0.933	0.645	0.026	0 min, 59 sec	0 min, 08 sec	1 min, 47 sec
11.11	0.935	0.644	0.028	0 min, 58 sec	0 min, 10 sec	1 min, 55 sec
12.12	0.902	0.651	0.027	0 min, 59 sec	0 min, 12 sec	1 min, 56 sec
13.13	0.894	0.633	0.028	0 min, 59 sec	0 min, 07 sec	1 min, 51 sec
14.14	0.962	0.674	0.040	0 min, 59 sec	0 min, 07 sec	1 min, 55 sec
15.15	1.032	0.742	0.067	0 min, 58 sec	0 min, 02 sec	1 min, 46 sec
16.16	0.909	0.634	0.051	0 min, 59 sec	0 min, 05 sec	1 min, 44 sec
17.17	0.883	0.638	0.056	0 min, 58 sec	0 min, 08 sec	1 min, 53 sec
18.18	0.905	0.646	0.051	0 min, 58 sec	0 min, 11 sec	1 min, 47 sec
19.19	0.904	0.644	0.050	0 min, 58 sec	0 min, 10 sec	1 min, 41 sec
20.20	0.890	0.634	0.053	0 min, 59 sec	0 min, 15 sec	1 min, 58 sec
21.21	0.000	0.000	0.000			
Avg	**0.920**	**0.653**	**0.044**	**0 min, 59 sec**	**0 min, 08 sec**	**1 min, 50 sec**

Figure 4.8: Some basic data from Simulation (of 1hr)

4.3 Coordination of IEEE802.15.4 and 802.11g

There are many similarities between IEEE 802.11b/g and IEEE 802.15.4 but a few differences exist which mainly have impact on the performance of IEEE 802.15.4. CSMA/CA mechanism contains the key difference between them IEEE 802.15.4 cannot sense channel during back off period like IEEE 802.11 but only at the time of Clear Channel assessment(CCA) period. Additionally, the contention window of IEEE 502.11b/g remains unchanged when it determines a busy channel but in IEEE 802.15.4 the contention window is doubled when the channel is found busy whereas the contention window is doubled in IEEE 802.11b/g only when ACK is not acquired. Worst Case scenario can be observed if two IEEE 802.11b/g send each other video streams or large files. An IEEE 802.15.4 packet can be effectively receiving under IEEE 802.11b/g impedance if both of the accompanying two circumstances are satisfied:

1)At the point when the IEEE 802.15.4 parcel covers an IEEE802.11 bundle, the in-band obstruction power from the IEEE 802.11 parcel is significantly lower than the valuable sign force from the IEEE 802.15.4 bundle at an IEEE 802.15.4 collector. As indicated by the specification [7], if IEEE 802.11b/g obstruction is powerless enough so that the in-band signal-to-impedance proportion (SI R) is bigger than 5-6 dB, an IEEE 802.15.4 bundle could be effectively gotten with a likelihood of 99%.

2)Tidal denotes the transfer time of an IEEE 802.15.4 packet between two successive IEEE 802.11b / g packets such that the IEEE 80 2.15.4 packet does not overlap an IEEE02.11 packet. Although in the home environment homogeneous and heterogeneous networks might exist side by side but since Bluetooth, ZigBee, Wi-Fi, and 6LoWPAN all use the 2.4 Ghz band, the number of problems are increasing in case of intervention between these networks. Potential intervention issues were explored in 6LoWPAN over IEEE 802.15.4. [4] given significant analysis of the coexistence concerns for ZigBee, Bluetooth, Wi-Fi and microwaves. In [5] concentrated on quantifying possible conflict amidst IEEE 802.15.4 and IEEE 802.11 g by analyzing the effect of coexisting in a specific area on the transmission efficiency of Wi-Fi and ZigBee devices. IEEE 802.15.4 interference has been found to have an insignificant impact on the Wi-Fi performance. Wi-Fi's impact on 802.15.4 throughput is a decrease of 10 per cent. It can be inferred that IEEE 802.15.4's use of the illegitimate component of the wireless appearance creates intervention issues. Yet IEEE 802.15.4 and Wi-Fi will coexist with less issues with interference.

4.4 Performance Evaluation

Research finds the following benefits comparing to the existing home automation systems:

- In our proposed system the main advantage is the sensors are wirelessly connected with each other. Therefore, we can move the sensors according to our needs and also add sensors according to our needs. Therefore, we can rearrange the sensors (temperature sensor, pressure sensor, motion sensor etc.) according to our need without any hassle. Thus the system finds a better movable option. Besides, 6LoWPAN allows the system to be connected with each other with the bridging of different technologies as well as devices with minimal changes. Therefore, they can be able to control or communicate easily. It makes the system similar to plug-and-play. In our proposed model, the sensors of the system will have individual IP addresses and that is why one will be able to access the sensors without any extra supporting device as well as any sensor will be accessed directly to transfer or receive data. In the proposed model we use 6LoWPAN internet protocol which establishes a connection to our sensor with End devices (e.g. mobile and laptop or tab). First of all, IP addresses are generated for the sensors and then it creates help to connect with the mobile, laptop or tap. For wireless connection an inter media gateway IG connects the end devices to the sensor nodes. So, the end devices when requested for connection to the IG. The IG authenticates the end devices. On the other hand, the sensor nodes SN authenticate with the IG. Then through this process the end devices connect with the sensor node SN. So When we move or add our sensor according to our need it recreate it connection to the end devices and for that The mobility and the scalability cost of sensor is Cwsn are derived below

$$C_{wsn} = N(2(C_{EN \cdot IG} + C_{IG \cdot 0IG} + C_{IG \cdot SN}) + 3 \times a_{IG} + a_{0IG} + a_{sN}) \quad (4.1)$$

Here,
C_{wsn}= *The total mobility cost for our proposed model*
$C_{EN.IG}$= *The cost of authentication for end devices*
$C_{IG.OIG}$ = *The cost of sending acknowledgement to the end devices and sensor node*
$C_{IG.SN}$ = *The cost of authentication for sensor nodes*
a_{IG}= *Number of IG request*
a_{OIG}= *Number of IG acknowledgement*
a_{SN} = *Number of SN request*
N= Number of end devices request

When we establish a wire connection of the sensor and get the sensor data from end devices we have the connection of sensor node to router and the router connect with the internet. So when we move our sensor we have to consider the sensor node connection cost CSN, the router connection cost CRG, the internet connection cost CGIG So the total connection cost is

$$C_{wrd} = M \times C_{SN} + N \times C_{GIG} + P \times C_{RG} \tag{4.2}$$

Where,
M = is total number of sensor node
N= total number of internet connection

P= total number of router connection
So now we defined the C_{SN}, C_{RG} and C_{GIG} value

$$C_{SN} = 2\times(C_{EN\cdot IG}+C_{IG.RG}+C_{RG.GIG}+C_{GIG.SN})+2(a_{FA}+a_{RG}+a_{GIG})+a_{SN} \tag{4.3}$$

$$C_{GIG} = 2 \times (C_{EN\cdot IG} + C_{IG.RG} + C_{RG.GIG}) + 2(a_{IG} + a_{RG}) + a_{GIG} \tag{4.4}$$

$$C_{RG} = 2 \times (C_{EN\cdot IG} + C_{IG.RG}) + 2(a_{FA} + a_{RG}) \tag{4.5}$$

Here,
$C_{EN.IG}$ = *The cost of authentication for end devices*
$C_{IG.RG}$ = *The cost of authentication for router*
$C_{RG.GIG}$ = *The cost of router to internet connection*
$C_{GIG.SN}$ = *The cost of sensor node to internet connection*
a_{IG} = *Number of IG request*
a_{RG} = *Number of RG request*
a_{SN} = *Number of SN request*
a_{GIG} = *Number of GIG request*

Here we see that when we establish the wireless connection like our proposed model, we need not to consider the extra connection cost of CRG and C_{GIG} where this cost is extra for every time when we move any sensor and add any sensor. whereas for wired sensor connection the system will add these two extra cost values of C_{RG} and C_{GIG}. Therefore, we can say that our proposed model has lower mobility and scalability cost then wired based home automation.

- In terms of expanding the system, 6LoWPAN comes with the solution as low overhead and efficiency of time. Basically, 6LoWPAN sensor nodes communicate wirelessly throughout the system which eliminate the difficulties of wired connection. As a result, adding new sensors or modifying existing systems make them less complex compared to old home automation models. Besides, because of its wireless sensor network, it makes the system efficient. To solve the above issue of adding an extra motion detector, in our proposed system we just need a 6LowPAN supported motion detector and place it in the room. The controller will automatically connect with it wirelessly.

$$Overhead = \frac{1}{Throughput(bit/s)} \tag{4.6}$$

From Fig we can check the overhead differences

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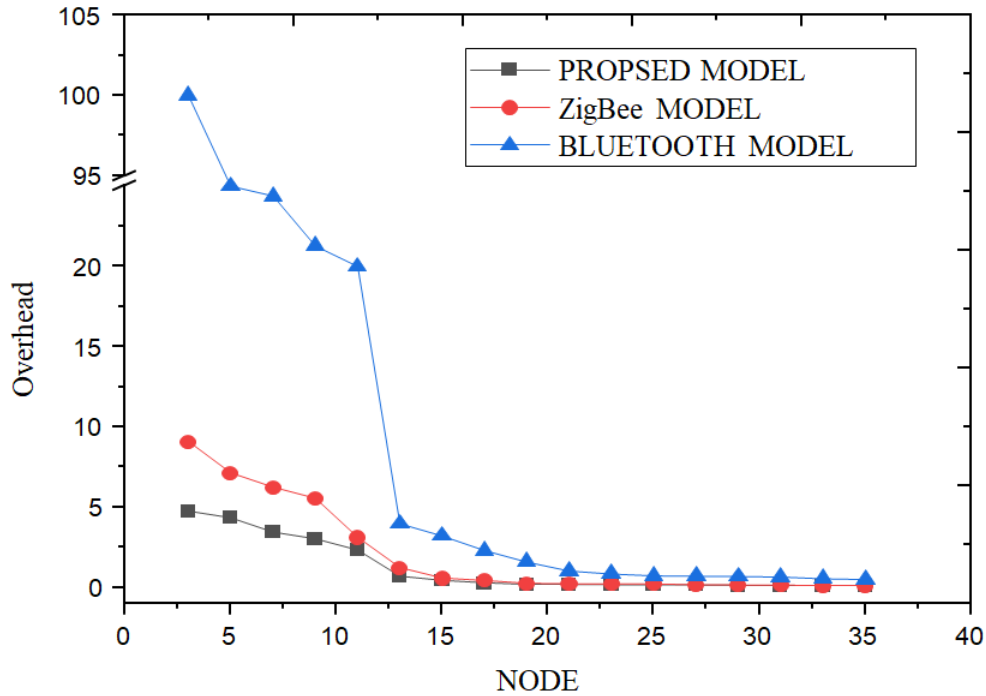

Figure 4.9: Overhead of different nodes

- 6LoWPAN home automation node has additives to the battery energy. It can escalate the lifetime and thoroughly run for a maximum chunk of time.Therefore periodical replacement of its batteries is not necessary.. Be that as it may, all out force yield required from vitality gathering relies to a great extent upon vitality utilization of the 6LoWPAN Home Automation System and the sensor utilized

$$I_{avg} = \sum_{i=1}^{n}(\frac{T_i}{P_i} \times I_i) + (1 - \sum_{i=1}^{n}(\frac{T_i}{P_i})) \times I_{sleep} \tag{4.7}$$

Here in equation represents the average current consumption I_{avg} whereas Ti represents value of time interval on which the device consumes the current, Pi give the total time period, Ii is the consumed average current over Ti time and I_{Sleep} is the current consumption when the device is in sleep mode. We have considered TI CC2538[39] as 6LoWPAN node, TI CC2520 [8] as Zigbee node and TI LMX9830 as Bluetooth node. From equation (4.6) calculated ZigBee I_{avg} value is 2.03mA and for 6LoWPAN the I_{avg} value is 1.49mA and for the Bluetooth case 7.06 mA. Now to calculate the lifecycle of these three different technology-based nodes we can consider the nominal battery voltage is 2850 mAh.

$$LifeTime(h) = \frac{BatteryCapacity(mAh)}{AverageCurrent(mA)} \tag{4.8}$$

Computing the lifetime Bluetooth based model gets 16.82days h and ZigBee based systems get 58.50days whereas 6LoWPAN based systems get 79.70 days. So, it is seen that from these three models our proposed 6LoWPAN model provides the highest life time.

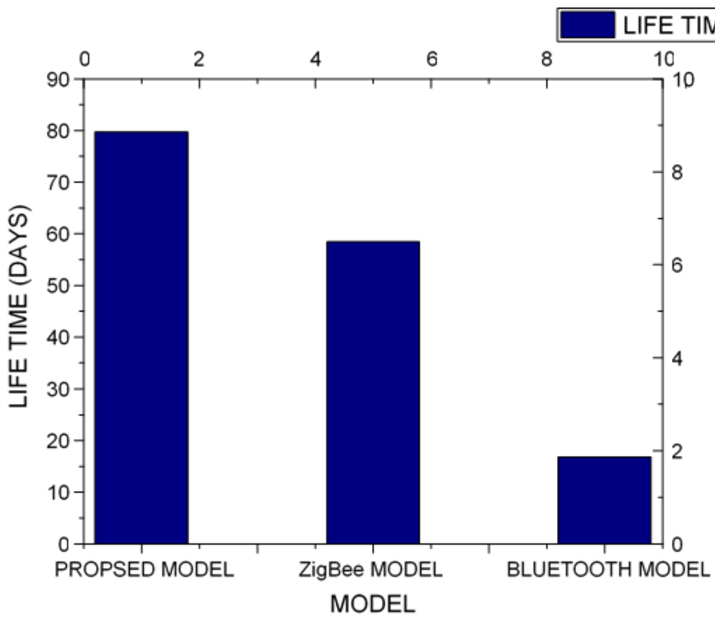

Figure 4.10: Lifetime measure

- Compared to the traditional Home automation model 6LoWPAN adopts a different approach to the other low power wireless sensor network solutions.

The overall system aims at providing wireless internet connectivity at low data rates. Here the IP networking target for low-power radio communication and applications need wireless internet connectivity at lower data rates for devices with very limited form factor. The header compression mechanisms standardized in RFC6282 can be used to provide header compression of IPv6 packets over such networks. In case of overhead calculation, we found that 6LoWPAN makes the border router less complex. Because here it works with the combination of IEEE 802.11 with IEEE 802.15.4 networks. This enables the nodes to use an IP packet. The network reliably does the work. So, node to end device connectivity becomes faster because of low overhead. In case of The IP routing over 6LoWPAN links, does not necessarily require additional header information. Layer. This reduces the overload of packets and allows more room for the payload data. Moreover, the size of the typical code of a pile with all the functions is 90KB for ZigBee and only 30 KB for 6LoWPAN.We can measure the overhead by throughput. We know that if the throughput is high there will be low overhead. The throughput equation for 6LoWPAN, Bluetooth and ZigBee is

$$Throughput = \frac{P_{sccess} \times L_{pacate}}{T_{tx}} \tag{4.9}$$

Here in the equation $\mathrm{P_{success}}$ represents the total number of packets successfully received at the destination node. $\mathrm{L_{packets}}$ is the length (in bits) of packets for each node. And $\mathrm{T_{tx}}$ shows the total simulation time. Our simulation time is $\mathrm{T_{tx}}$ =3600s

So here we can see that the proposed model has a higher throughput than ZigBee and Bluetooth based home automation. So, we know that when throughput increase the overhead percentage will decrease

- Moreover, another significant parameter to evaluate our proposed model with others would be End-to-End delay measurement for different numbers of nodes. Here End-to-End delay indicates the required time for a packet to travel from source node to destination node. To evaluate the proposed model, we should consider here a mathematical formula. And the end-to-end delay equation is,

$$Delay(X) = T_{BO} \times P_c(N) + T_{Fram(}X) + T_{TA} + T_{ACK} + T_{IFS}(X) \tag{4.10}$$

Where,

$$T_{BO} = Slottime \times R \times P_c(N) \tag{4.11}$$

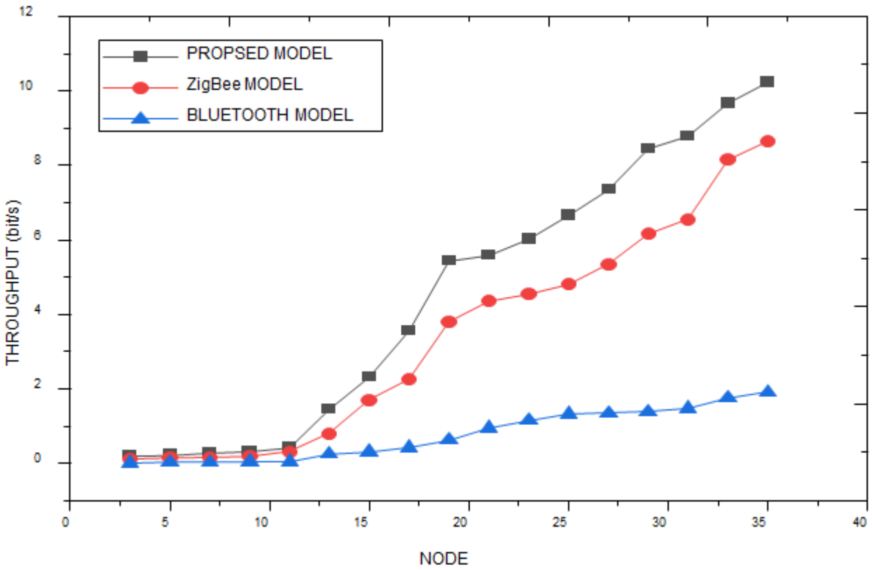

Figure 4.11: Throughput of nodes

$$T_{Fram(}X) = \frac{8(L + L_{MAC.HTR} + L_{ADRESS} + L_{NW.HTR} + L_{ML.HDR} + L_{MAC.FTR} + X}{R_{data}} \tag{4.12}$$

$$T_{ACK} = \frac{8(L + L_{MACHTR} + L_{MAC.FTR} + L_{NW.HDR} + L_{ML.HDR})}{R_{data}} \tag{4.13}$$

$\mathrm{T_{IFS}(X) = AIFSN[AC]} \times Slottime + RxRFDelay + RxPLCPDelay + MacProccessingDela + RxTxTurarroundTime$ (4.13)

Here,
$P_c(\ N\ )$ =*The probability of collision between two stations*
$T_{Frame}\ (X)$= *the time required to transmit a frame of 'X' bytes*
T_{BO} = *back off time to wait in case of collision*
T_{ACK} = *the time to receive an acknowledgement*
which is the time taken to receive only header part of acknowledgement
L_{PHY} = *Length of the PHY header in bytes*
L_{MAC_HDR} = *Length of the MAC header in bytes*

$L_{MAC.FTR}$ = *Length of the MAC footer in bytes*
$L_{ADDRESS}$ = *length of address fields in bytes*
L_{NW_HDR} = *Length of the NWK layer Header*
L_{ML_HDR} = *Length of the Adaptation layer Header*
X = *Length of data*
R_{data}= *Raw data rate*
RxRFDelay = the time needed by the PMD layer to deliver a symbol to the PLCP layer.
RxPLCPDelay = is the time needed by the PLCP layer to deliver a bit to the MAC layer

By equation number (4.10) we get the mean end-to-end delay for our proposed model is 114.9 ms and the ZigBee based model end-to-end delay is 627.9ms. From the value we see that our proposed model has 31percent smaller delay than ZigBee based model. As a result, our proposed model has better End to End communication compare to ZigBee.

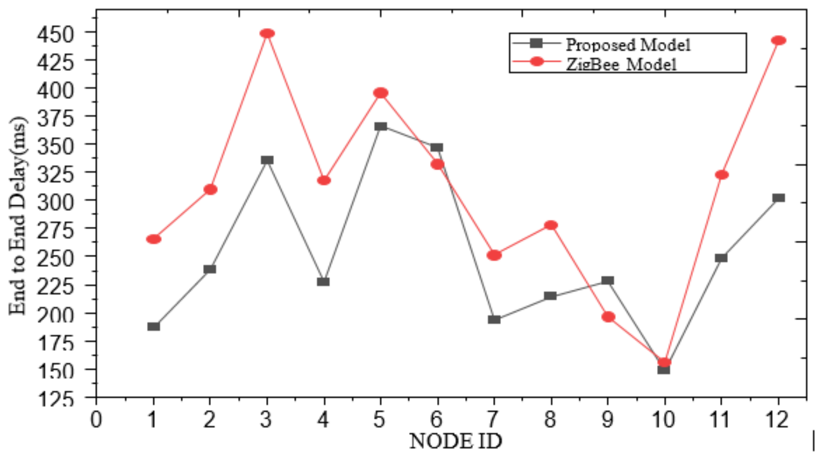

Figure 4.12: End to End Delay

Here in Fig 4.12 we see that the End-to-End delay for different node id is different cause ,in our delay equation (4.10) we see that the delay depends on T_{Frame} and T_{ACK} . Where T_{Frame} and T_{ACK} depend on the length of packet . Here every node id do not transfer same length of packet for every time. So their T_{Frame} and T_{ACK} are different. Therefore we get End-to-End delay graph is like the Fig 4.12 . Here we also see that the delay of our proposed model is lower than the ZigBee model as we showed in Fig 4.9 that the overhead of our proposed model is lower than the ZigBee model so the T_{Frame} and T_{ACK} is smaller for our proposed model than ZigBee model.

Parameter	Traditional Home Automation	Proposed model
Mobility	As the sensors are connected through wire, the systems have less mobility.	As the sensors are connected wirelessly with each other it is easy to reorganize them.
Scalability	In terms of expanding sensors or devices the current systems are hardly scalable.	2This system has emerging ability to expanding the network
Supporting Device	Need internet module like GSM module, GPRS module, NodeMCU ESP8266 module etc.	Having in built Internet protocol which support IPv6
Direct Communication with sensors	No ability to inter-communication between sensors. Firstly, sensors connect with supporting devices and then communicate with the end user.	Because of the ability to generate own IPv6 address at the starting of the communication, each sensor can easily connect with internet and send data to end user
Complexity	Becomes high whenever any extra sensor needs to add in the system. Because supporting devices need to be configured to connect with the sensors.	In terms of adding new nodes in the network complexity is very low. Because 6LoWPAN nodes can route data to other nodes.
Power consumption	In terms of power consumption ZigBee needs 1mw power to run the sensor which was previously considered a very low power consumption model.	Here it requires only 0.920mw power to run the sensor. So, it shows better performance rather than others.
Battery life time	In Traditional home automation there needs to replace the battery after a period of time. Because there is no such a way to recharge the battery by harvesting energy	Solar energy harvesting can power a 6LoWPAN home automation node for an infinite amount of lifetime. So, there is no need to replace the battery after a time period. It is shown in Fig 4.5

Table 4.2: Comparison between traditional Home Automation and proposed model

Chapter 5

Conclusion

In this present era of technology it has been really easy for us to manage our comfort via the maximum use of technology but it somehow remains unsorted because of their different drawbacks in different cases.Here to shorten the puzzle we come up with the idea of a modernized technology called 6LoWPAN that has tremendous area leeway which empowers the amalgamation of huge quantities of gadgets to the IP network. Gadgets in the system commonly cooperate to interface the physical condition to true application.We have presented our work to develop a well founded arrangement that can dominate home automation devices using 6LoWPAN technology. Our proposed system facilitates users with the advantage of checking status of gadgets and controlling remotely by virtue of internet .We have compared our proposed model with existing technology in basis of mobility,scalability,Power consumption and other important aspects which shows that our proposed model is better than existing ones considering those factors.Further the use of 6LoWPAN communication technology helps lower the expense of the system and the easier communication to the End-to-end paradigm communication. Before our final implementation we implement the simulated prototype. And Our future task will be implementing this simulated one into hardware setup where actual data will be transmitted by sensors and receive by end devices.

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