Final Year Design Project
Final Report
[EEE 400C]

Project Title: Implementation of Li-Fi based home automation system.

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Chapter 1: Introduction

1.1 Introduction

We have reached that point in human civilization where we can set up our homes to take care of itself and us in the process, through a method known as “home automation”. Home automation is a process of automatization of a home which results in allowing us to control the electronic devices inside. It also provides home security and an emergency system to be activated when necessary. Home automation not only aims to lessen human efforts but also save time and energy. An automated home is also known as a "smart home".

Most common medium used for home automation nowadays are wireless mediums like Wi-Fi, Bluetooth and ZigBee. As amazing as they may be, they still possess certain limitations, of which the prominent one is security [1]. Since Wi-Fi is the most commonly used medium for smart homes, it is vulnerable in terms of security in the sense that it can face cyber hacking. One way around this is switching to Light Fidelity (Li-Fi) technology as the smart home communication medium. By using Li-Fi technology, the system is much secured because the light frequency cannot penetrate through walls and doors, and as a result, it cannot be hacked [2]. A Li-Fi based smart home can also be faster than a Wi-Fi based one, since Li-Fi uses light (photons) to communicate which is much faster than Radio waves that is used by Wi-Fi.

1.2 Objectives

Our objective is to build a smart home that will use Li-Fi as the communication medium and thus it will have a secured connection, free from the possibilities of cyber hacking. Our smart home will be able to control the home appliances that will be connected to the system and for this to happen it will be able to take commands from the user. Our smart home has various sensors that detects abnormalities inside the home such as presence of an intruder, gas leakage and notify the user using an alarm system. Moreover, it can also detect when the home temperature is too hot and turn on the cooling system. It can also detect whether there is daylight outside and if it’s dark, it can turn on required lights.

1.3 Specifications and requirements

Specifications	**Requirements**	**Components**
The system will connect using Li-Fi.	Li-Fi Transmitter and Receiver	LED, LDR
Can take decisions based on input from different sensors	Central Processing Unit	Arduino Uno, Arduino Nano

Can detect intruders, can detect gas leakage and notify the user. Can identify if someone appears in front of doorstep and initiate calling bell. Required lights can be turned on after dark. Fan is turned on when temperature exceeds 25°C.	Sensors, alarm system and outdoor lights.	LDR light sensor, PIR motion sensor, MQ9 gas sensors, Ultrasonic sonar sensor, LM35 temperature sensor, buzzer and LED bulbs.
Takes commands from the user that turn on appliances.	Signal controlling unit.	Keypad
Shows the current status of the appliances.	LCD Display	16x2 LCD display
4 Loads have been used for a single room.	Relay	4-Channel 5V DC relay module

1.4 Constraints

It is difficult to calibrate the gas sensor because the gas density in every household is not the same so we had to consider the house where we were installing as the house with the ideal environment. We also faced errors in our PIR motion sensor initially such as signaling even when there was no obstacle and also sending the signals longer than it should. We overcame this problem by modifying the potentiometer of the motion sensor depending on the situation. Then we were not getting the correct result in the LCD display because of its low brightness so we had to modify the resistance of the potentiometer to fix that. We also initially faced issue regarding data transmission from our transmitter side to the receiver side so we had to correct our Arduino code.

1.5 Applicable standards and codes

Since we will be designing a smart home, our project falls under the IEEE 1888.4-2016 Standard for Green Smart Home and Residential Quarter Control Network Protocol in which protocols are provided for measurement and control networks for home and residential quarters so that they can achieve green, smarter functions. Since our smart home system is Li-Fi based that uses LED light for data transmission, it is good for the environment since LED bulbs have great longevity and don’t require frequent replacements so they reduce trash accumulation. Moreover they also consume relatively low energy. So because of the stated reasons our project falls under IEEE 1888.4-2016.

Our project also falls under IEEE 802.15.7: Visible Light Communication that accommodates infrared and near-ultraviolet wavelengths, in addition to visible light, since it will be using Li-Fi as the communication medium.

1.6 Independent research and literature survey to validate the solution

Since our choice of Li-Fi as the communication medium for our smart home depend on getting around the limitations of Wi-Fi as the communication medium (as mentioned earlier), we have to look at more reasons for our choice. For instance, the radio frequency spectrum is regulated to avoid interference and pollution and also to ensure that it's used efficiently. However because of the increasing demand for broadband wireless data access, the RF spectrum which is already limited and most of which is licensed, is becoming congested [4]. On the contrary, the visible light spectrum is not yet licensed and most of it are yet to be used for communication. Moreover visible light can also provide a bandwidth of about (~ 400 THz to ~ 780 THz) which is thousand times wider than the conventional RF bandwidth (~ 3 kHz to ~ 300 GHz). This means Li-Fi has to offer a large amount of available unregulated spectrum which can help us decrease the congestion of the RF spectrum. Because of this Li-Fi can provide a better connection for the smart home.

Moreover, visible light cannot penetrate through opaque walls, so Li-Fi signals from adjacent rooms won't interfere with each other, which makes the Li-Fi connection of our smart home safe from cyber hacking. Also, Li-Fi, because it uses visible light, does not possess any health hazards, which would make the smart home safer health-wise. Furthermore, the transmitters and receivers can be made using simple devices and do not need frequency mixers or sophisticated algorithms for the correction of RF impairments such as phase noise and IQ imbalance. Other than this, Li-Fi can be implemented into existing lighting infrastructure with the addition of a few relatively simple and low-cost front-end components operating in baseband [4]. This means that our smart home can be built easily without much hassle.

All of the pros about Li-Fi as stated here, makes Li-Fi the better option to choose as the communication medium for our smart home.

1.7 Finding appropriate knowledge and skills and using them to develop the final prototype

Initially we only had DC loads in our project and no high loads. To overcome that we implemented a relay that allowed us to use high loads such as Table fans, household LED bulbs, LED tube lights. We also learned how to send multiple signals from our transmitter to our receiver since we need to control multiple appliances. We achieved this by first connecting all our sensors to the transmitter part, and then the transmitter sent data from each individual sensor.

Chapter 2: Project Design Approach

2.1 Introduction

A home automation system gives privileges to the users to control and monitor the home appliances through a remote mechanism. It implements the system as the integration of controllers, sensors, and actuators as a whole. At the same time, the invention of the microcontroller offers most of the intelligent building techniques of home automation. The network protocol mostly includes Gateways, Bluetooth, ZigBee, Wi-Fi, Li-Fi etc. **[3].** Again, the automation system of building, home, city, power line can be operated using any of the networking protocol.

2.2 Identify multiple design approach

In this project, we have chosen different networking protocols as the multiple solutions of this project to communicate wirelessly using the existing technologies. Here we developed 3 multiple designs for our smart home using Wi-Fi, Bluetooth, and Li-Fi to send data from transmitter module to the receiver module for our smart home.

2.3 Describe multiple design approach

The most important contribution of this project is to implement a low-cost and user-friendly smart home automation using existing modern technologies. To achieve the desire objectives of this project, we have developed our prototype using multiple ways and these are described below:

Design 1:

Wi-Fi: We use Wi-Fi for our smart home to send data from transmitter to receiver module. In this design ESP32 board is used. This board is used as the receiver module. On the other hand, our smart phones or computers are used as the transmitter part. The connection between transmitter and receiver part is connecter through an online server. The multiple devices of our home such as fans, lights, ac etc. are connected with the ESP32 using relay. To control these devices, the users should send command from their mobile or pc, then this command data will go to the server at first then this is forwarded to the ESP32 through internet. The receiver module ESP32 builds connection with internet with its built-in Wi-Fi. After receiving the data, the ESP32 will turn on/off the devices according to the command.

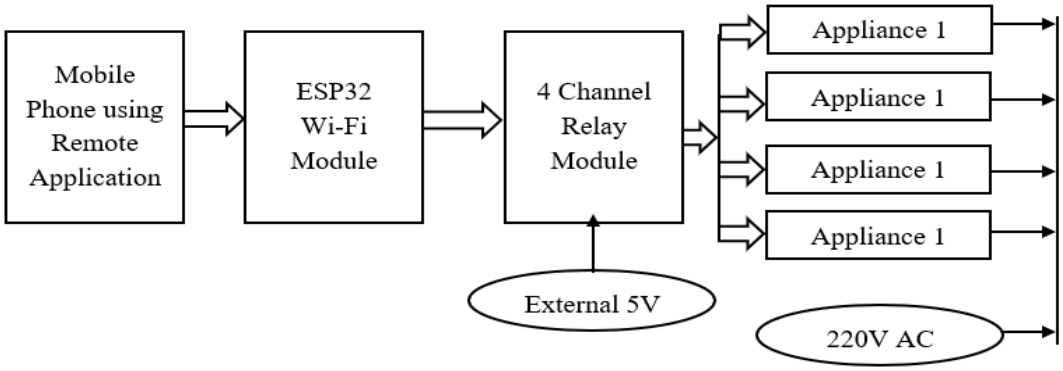


Figure: Smart Home [Wi-Fi]

Block Diagram:

Pros:
1.Convenience
2.Expandability
3.Connect Multiple Device

Cons:
1.Limited Distance to Cover
2.The number of devices that can be connected is limited
3.Interference
4.Obstacles
5.Connection Speed
6.Security and Privacy Issues
7.Wi-Fi Isn't Designed to Create Mesh Networks

Design 2:

Bluetooth: We design a prototype for smart home using Bluetooth for the data communication between transmitter and receiver part. In the receiver part, we connect a Bluetooth module HC-05 so that the Arduino can receive data wirelessly. A relay is also used between the Arduino and the home appliances such as fans, lights, ace etc. Smart phones are the transmitter part of this prototype. A dedicated mobile app is used in mobile smart phone and using this, we can send command to the Arduino uno to control our home appliances. Arduino receives the data transmitted from mobile phone with the help of Bluetooth module.

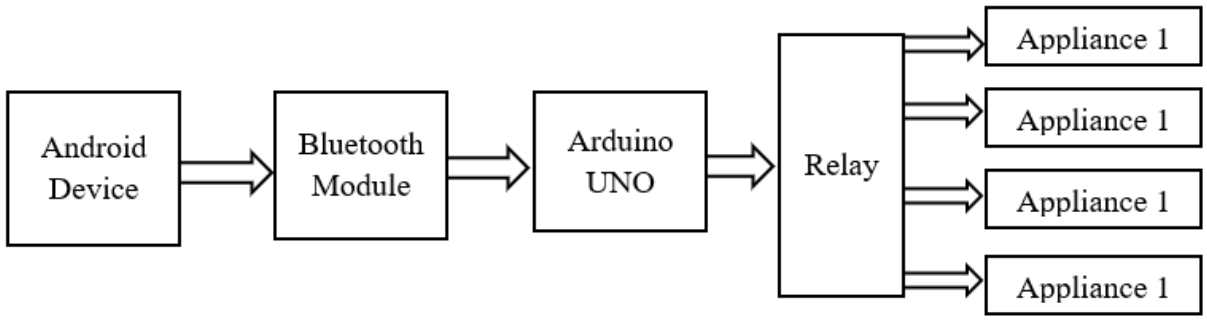


Figure: Smart Home [Bluetooth]

Pros:
1. Low Energy Consumption
2.Expandability
3.Connect Multiple Device

Cons:
1.Slow Transfer Rate
2. Distance Limitations
3. Interference
4.Battery Drain
5.Poor Security

Design 3:

Li-Fi: In the term of LiFi communication system, light is used as the communication media. In this system, we have used available led lights which are used in our home as the light sources. In the transmitter part, these led lights are used and in the receiver part LDR is used to receive signal. The receiver part and the transmitter part are connected to two different Arduino to process the signals. In the transmitter part, signals can be transmitted through mobile app or physical buttons. On the other hand, the LDR of the receiver part receives that signal and sends them to the Arduino for processing. After that the Arduino will turn on/off devices according to the signal via relay. In the same way, multiple devices can be controlled using the light.

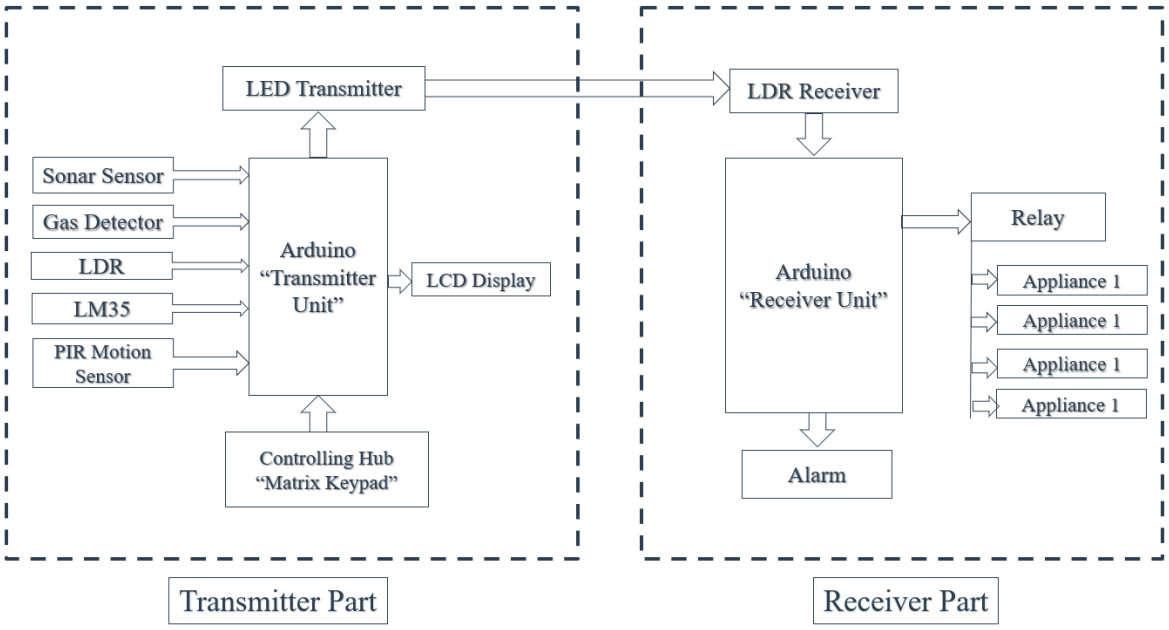


Figure: Smart Home [Li-Fi]

Pros:	**Cons:**
1. Availability. 2.Security. 3.Speed. 4.Efficient. 5.Less Complex. 6.System Reliability. 7.Low Cost.	1. Internet inaccessible without a light source. 2.Limited range of area for Li-Fi usage.

2.4 Analysis of multiple design approach

After deploying these three methods, we do some analysis in different perspectives such as safety, connectivity, data communication speed, usability, cost efficiency and so on. In the analysis, we notice significant differences. At the time of Bluetooth, anyone can find this network by searching from a long distance and connect his mobile with this network easily. In the same way, the hackers can easily hack Wi-Fi networks. But Li-fi cannot be accessed from outside the illuminated range of the LED lights.

Secondly, we observe the speed of these three networks. Since we have no modern tools to measure the speed accurately, we do research on these three network's speeds and learnt from literature review that Li-Fi is faster than Wi-Fi and the speed of the Bluetooth is the lowest. Thus, we observe some things in the test that Wi-Fi and Bluetooth take a little bit time to transmit the commands. After that, if we consider the connectivity, we can see that the connectivity between Li-Fi transmitter and Li-Fi receiver module is more convenient than the other two networks. However, Li-Fi can be built with the existing technologies and using the available components which cost very low. That means the manufacturing cost is very low that the Li-Fi and Bluetooth.

2.5 Conclusion

After conducting the literature survey, we found the three ways to communicate between the transmitter and receiver part of a smart home system. The three communications are Bluetooth, Wi-Fi and Li-FI. After that, we analyze the three-communication channel advantage and disadvantages for making the smart home design.

Chapter 3: Use of Modern Engineering and IT Tool.

3.1Introduction

It is essential for an engineer to possess ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. Modern engineering and IT tools empower engineers to explore more design alternatives, which increases the likelihood that better designs will be found, and eliminates some of the non-value add activities from the design cycle. To validate our project, we physically prototyped our design and conducted the design test. By testing practically, we verified and validated our product performance before moving to physical prototyping and testing

3.2 Select appropriate engineering and IT tools

Initially we have selected these tools for our project based on what we thought we needed: Tinker-Cad and Arduino IDE (for coding). For hardware part we chose Arduino Uno, Arduino nano, Multimeter, Soldering iron., LCD display, cardboard, glue gun.Our reasons for choosing the hardware tools include: to make the microcontroller more convenient to prototype with and to program the chip (using Microcontroller development board), to make the central processing unit (using Arduino Uno), to measure voltages and current (with a multimeter), soldering the wires (with the soldering iron), developing the model of a house (using cardboard), to join the cardboard pieces (glue gun).

3.2 Use of modern engineering and IT tools

To develop the final design of our project, these are the tools we have used:

Software:

- Arduino IDE for code writing and developing

Hardware:

- Arduino Uno for the central processing unit
- Multimeter to measure voltages and currents
- Soldering iron to solder the wires
- Cardboard pieces to make the model of a house
- Glue gun for joining the cardboard pieces.

Chapter 4: Optimization of Multiple Design and Finding the Optimal Solution.

4.1 Introduction

Communication system is classified into two, wired communication and wireless communication. Wireless communications is the fastest growing field of the communication technology. Radio technology was improved rapidly to enable transmission over large distances with high quality, low power and smaller, devices, thereby enabling television, and wireless networks. A digital radio can transmit a continuous bit stream or it can form into packets **[5].** Cellular network systems have experienced exponential growth and there are currently around 1.4 billion users worldwide. Ultra-wideband radios are extremely wideband radios with very high potential data rates. Paging systems transmits a short paging message simultaneously from many base stations or satellites at very high power **[6].** Bluetooth provide short range connection capability between wireless devices along with networking capabilities. The Bluetooth standard is based on a tiny microchip with a radio transceiver that is embedded into digital device **[7].**

4.2 Optimization of multiple design approach

After observing the proposed multiple designs of the smart home automation system, it can be said that LiFi network will be the optimal solution in the perspective of cost, efficiency, usability, manufacturability, impact, sustainability, maintainability etc. The equipment required by Li-Fi are already present, as light is common source of illumination which reduces the cost of implementation. The transmission of data through illumination can be obtained by taking fiber out of fiber optics and transmitting data through a LED.

4.3 Identify optimal design approach

As stated on the literature section, since Li-Fi does not require additional hardware, then the electricity consumption theoretically lower than Wi-Fi. That is why Li-Fi can be assumed as a “greener” technology compared to Wi-Fi. Transmitting data from transmitter to receiver, there are two optimal ways. The first one is using visible light and another is using invisible lights. In both part, binary signal is transmitted from the transmitter and that signal is captured by the receiver. At first these signals are decoded to control different appliances such as light, fac, ac etc. There is a dedicated controlling hub in the transmitter part and there are some buttons as well as connected some sensors. When these buttons are pressed, then it generates various signals. These signals are

captured and decoded in the Arduino of the transmitter part and then passed the signals to the receiver unit using led. Some sensors are used to extend the features of this LiFi based smart home automation system.

4.4 Performance evaluation of developed solution

In this project our main target is to build smart home automation system and use LiFi as the data communication medium. After building the project, we evaluate all the features in different perspectives to obtain the objectives.

Our main objective was to pass data using lights. Here, data passing is possible using visible light. We observe that our desired data can pass using the lights as well as control the home appliances. However, this method increases the security level because no one can access the network from the outside of the illuminated area. Thus, if we create a barrier between the transmitter and receiver, then data cannot be received in the receiver module. So, it can be said that another goal which is to improve the security is obtained properly. After that while testing the connectivity issue, we observed that transmitter is connected with the receiver instantly. If we consider the manufacturing cost, it is observed that all the materials cost very low and this system is developed at a very low cost. Thus, after evaluating the design, it is clear that the objectives of this project are fulfilled.

4.5 Conclusion

Based on the technical comparation, PPR (Performance per Price Ratio), and their effects on environment, Li-Fi technology has its advantage in all discussed aspects against Wi-Fi technology. Li-Fi technology has better speed with lower electricity usage and more environmental-friendly.

Chapter 5: Completion of Final Design and Validation.

5.1 Introduction

The prototype of the proposed smart home is designed using Li-Fi as the communication medium between linked gadgets. After doing a lot of researches and analysis, we find out that LiFi is the optimal solution. The reason we chose Li-Fi is that, in theory, it surpasses existing RF technologies in terms of speed and security, since not only are light waves faster than radio waves, but they will also be restricted to a certain region using non-transparent barriers, making it safer.

5.2 Completion of final design

The smart home has two rooms, one kitchen, one bathroom, one veranda. There is a ventilator in the kitchen. For the design and implementation of Li-Fi based home automation system, it uses general led lights along with Arduino and some other sensors such as LDR, sonar sensor, pir motion sensor, gas sensor, temperature sensor. As well as, this smart home automation system can be controlled remotely using visible lights. In our project, we build main two part and they are: transmitter module and receiver module. Transmitter module and receiver module are connected via LiFi as a medium of communication.

In the transmitter module there is a controlling hub to send commands to control the home appliances. An Arduino is used in the transmitter part to process the signal. From this part, data will be passed using led lights.

Figure: Transmitter module of LiFi system.

On the other hand, another Arduino is used in the receiver part. A LDR is used in the receiver part to receive the data transmitted from the transmitter part.

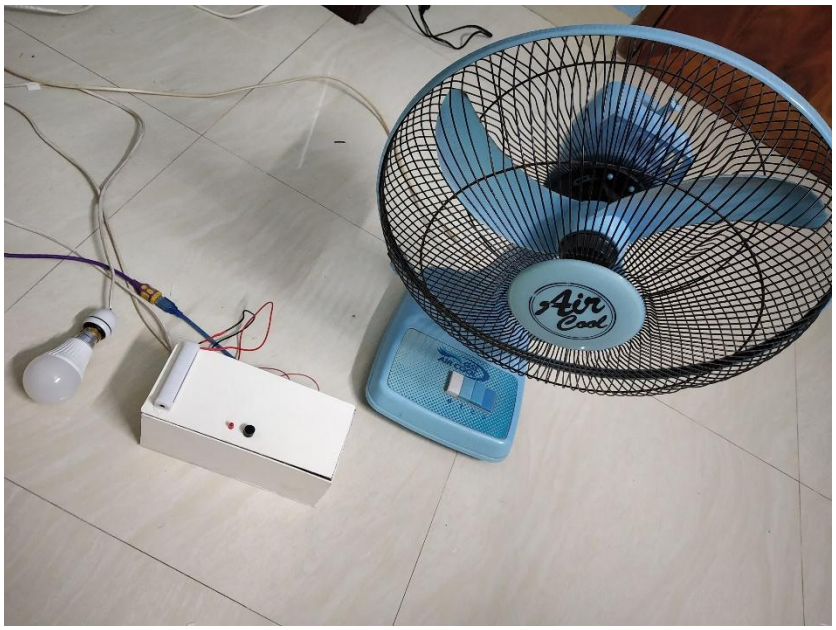


Figure: Receiver module of LiFi system.

The command which we want to transmit, is processed by the Arduino of the transmitter part and then it is transmitted using led. When it is received by the LDR of the receiver part, it is again processed by another Arduino and give the signal to the relay to turn on and off our desired appliances. All the home appliances are connected with the receiver and relay is used for controlling AC home appliances. However, some sensors are used to extend the features of the home automation system and they all are connected with the transmitter part. Using these sensors, the home appliances will be automated. The sensors collect data of the home's environment and weather and then it send them to the receiver part to turn on or off the appliances.

To control ac loads, a relay module is used. It is well known for controlling a high-powered circuit by a low power signal. Usually, a DC signal is used for controlling the circuit which is driven by high voltage such as controlling AC home appliances through DC signals from microcontrollers**.** The relay board is used for controlling high voltage AC, fan washing machine. We connected to light, Fan/AC, outdoor lights through the relay module.

LM35 temperature sensor. LM35 sensors are generally used for sensing the temperature and humidity of an area. It works for triggering related devices with a relay module. LM35 is one of the most popular and low-cost temperature sensors. LM35 is another one. But its cost is high and it's not available. We measured the temperature and humidity through this sensor. It is connected to the microcontroller board.

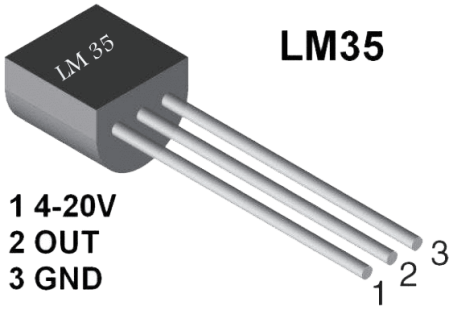


Figure: LM35 Temperature Sensor

We have used PIR motion sensor (HC-SR 505) to detect the intruders. It is a passive infrared (PIR) sensor is an electronic sensor that measures infrared (IR) light radiating from objects in its field of view**.** PIR sensors are commonly used in security alarms and automatic lighting applications. In this study, we used the imaging motion sensor. It detects the presence of a person at the door. We can monitor the presence of any intruder through the motion detector from a remote place.

Figure: PIR Motion Sensor

MQ2 gas sensor is used in this project to detect the gas leakage. It is an electronic sensor used for sensing the concentration of gases in the air such as LPG, propane, methane, hydrogen, alcohol, smoke, and carbon monoxide. MQ2 gas sensor is also known as chemical-resistor. It contains a sensing material whose resistance changes when it comes in contact with the gas. It can detect gases in the concentration of range 200 to 10,000 ppm. There are different types of gas sensors such as MQ4, MQ5, MQ7 etc. Especially, we used the gas sensor MQ2 in the kitchen of the smart home.

Figure: MQ2 Gas Sensor

However, there're some features and used some sensors such as ldr, sonar sensor as well as lcd monitor. LDR sensors are used to detect the day lights. When the sun sets, it is detected by this ldr and then it gives signal to turn on the garden lights or the outdoor lights. On the other hand, sonar sensor is also used to detect the distance of any person from the main door. When someone is so close to the main door, then the calling bell is turned on as well as when any car

comes in front of the garage, then the garage door will be turned on automatically. So, these are the extra features of the smart home automation system.

5.3 Evaluate the solution to meet desired need

After completing the final design and developed the final system prototype, we evaluate the whole system's results. The main communication system of our project is LiFi and our data will be transmitted from the transmitter part to the receiver part using the normal led light. At first, we checked the data communication system and our target is to transmit multiple signal from the transmitter part to the receiver part since we need to control multiple home appliances. After developing the system, we noticed that multiple signals can be transmitted and using these signals multiple devices can also be controlled.

Secondly, we need to automate turn on/off system of the home appliances. To do that, some extra sensors are used in this project such as LM35, PIR motion sensor, Sonar sensor, Gas sensor. These sensors are connected with the transmitter sensor and helps to automate the appliances of receiver unit. We noticed that all the sensors are working properly such as the LM35 can measure the temperature properly. This sensor can measure between −55°C to 150°C. In our case, when the room temperature is above 25°C then it will be detected by this sensor and this sensor will send a specific signal to the receiver unit to turn on the fan. We observed that the sensor measures the temperature accurately and send the proper signal. In the same way, the PIR motion is used to detect the intruders. In our system we noticed that this sensor is giving signal when any intruders is detected within 10 meters. Then there is a sensor which is used to detect gas leakage. In this project, sonar sensor's detection range is up to 21meters and when something is detected within this range then our receiver part receives a specific signal from the transmitter part. At last, we evaluate the outputs of the gas sensors. The gas sensor can detect the gas leakage properly and the gas sensor will give warning when the gas density of the room is increasing and when the percentage of gas is above 20% then it will give warning to be alert. So it can be said that all the sensors can measure the accurate data and then according to the data these sensors will send specific signals and these signals are transmitted using the lights.

Another target is to make the communication system between the transmitter and receiver more secured. Since we are using light to pass data so none can access the network from outside of the room as well as outside of the illuminated area because light cannot penetrate walls. Thus, if we create a barrier between the transmitter and receiver, then data cannot be received in the receiver module. So, it can be said that another goal which is to improve the security is obtained properly. After that while testing the connectivity issue, we observed that transmitter is connected with the receiver instantly. If we consider the manufacturing cost, it is observed that all the materials cost very low and this system is developed at a very low cost. Thus, after evaluating the design, it is clear that the objectives of this project are fulfilled.

5.4 Conclusion

In sum, the goal of LiFi is to reduce excessive power utilization. LiFi requires no more infrastructure other than standard LED lights from the home. LED lights last 25 times longer than incandescent bulbs and consume at least 75% less energy. Light bulbs have two purposes when it comes to LiFi. The first is to light up a room. The second is to provide electricity for a wireless connection. Users can cut both their energy use and energy expenses by combining energy sources into a single item.

Chapter 6: Impact Analysis and Project Sustainability.

6.1 Introduction

Engineering solutions will always have some impacts, whether positive or negative, in terms of societal, health, safety, legal and cultural context. Engineers have to give proper attention to the safety and cost of their products, two aspects that impact all users of engineering products and therefore society as a whole. On top of that engineers also have to assess the impacts their solutions have on the environment and whether they are sustainable or not. Below we have mentioned the impacts of our project and also described how much sustainable it actually is.

6.2 Impact Analysis

Since Li-Fi based home automation can be a practical alternative to Wi-Fi based home automation (which is presently the commercially available system), it can remove the negative health impacts that is caused by Wi-Fi due to it being a RF based technology. Li-Fi sends data through light waves on the electromagnetic spectrum. So, it is completely free from harmful radiofrequency radiation. For instance, intense exposure to radio waves can change brain waves and behavior, can induce insomnia, affect cell growth and normal fetal development, reduce brain functionality and also several potential dangers like fertility problems and cardiac arrests. **[5]** Fortunately, the electromagnetic waves of the light signal are inherently safe from these aforementioned issues, and so implementing Li-Fi based smart homes can help us avoid these issues.

Moreover, a Li-Fi based home automation system can benefit everyone, who are willing to use it since a Li-Fi connection doesn’t require too many components unlike a Wi-Fi connection. Li-Fi only requires a few pieces of equipment that aren't overly expensive and can be purchased by the general public which are an LED lightbulb, a solar cell, and a laptop to act as a receiver. Furthermore, it also consumes less power compared to other communication systems, since not many components are required to maintain the connection. Plus, LEDs can serve as an illumination source while providing a Li-Fi connection making Li-Fi-based smart homes a more energy-efficient choice. Other than these, LED lights are safe to use since they don’t contain toxic elements and chemicals.

6.2 Sustainability

The advantages of a Li-Fi based smart home are not only in terms of security and speed. It is estimated that in the near future we will be able to transmit data through solar energy, which will

facilitate access to people without internet and with limited electricity resources. The operation of the Li-Fi technology will save costs as in homes and, above all, workplaces, it could do without electronic devices such as routers, modems, signal repeaters, wave amplifiers and antennas. These devices, which are currently connected to the power grid 24 hours a day, 7 days a week, would stop consuming electricity and its function it would be replaced by a LED bulb, which in most cases is already on during work time, so would not mean an extra cost. So, we can see that using Li-Fi as our medium will cut down on electricity consumption.

Other ways that Li-Fi technology can save electricity is that every light bulb can be used like a Wi-Fi hotspot to transmit wireless data. This means that if Li-Fi based smart homes were to be implemented on a large scale it means less amount of electricity will be required to sustain such smart homes. Moreover, with Li-Fi, light bulbs have two roles. The first, to illuminate a space. The second, to power a wireless connection. By consolidating energy sources into one item, users can reduce both their energy consumption and energy costs.

Other than helping with energy consumption, implementing a Li-Fi based smart home can help with trash accumulation since the LED bulbs to be used last up to six times longer than other types of lights which reduces the requirement for frequent replacements.

6.4 Conclusion

To sum it all up, our smart home will have positive impacts in terms of health since it eliminates the harmful effects of RF technology and also because LED bulbs are non-toxic which are used for the Li-Fi connection in our smart home. Furthermore, our smart home is both cost efficient and energy efficient because of not needing too many components and ultimately consuming relatively low energy. Our solution is also sustainable since in many ways it helps to reduce power consumption and also reduce trash accumulation since LED bulbs have great longevity.

Chapter 7: Engineering Project Management

7.1 Introduction

Project management is the practice of initiating, planning, executing, controlling, and closing the work of a team to achieve specific goals and meet specific success criteria at the specified time. Regarding that our project is temporary in that it has a defined beginning and end in time, and therefore defined scope and resources.

7.2 Define, plan, and manage engineering project

our project had started with routine operation, but a specific set of operations designed to accomplish a singular goal. Our projects started formally in Spring 2021. As we decided to build a smart home with Li-Fi technology, therefore the works each step was maintained within the given timeline. We initially made a Gantt chart to work according to with timeline. The Gantt chart puts us on notice that the project is being launched and that it has management's acknowledgment and commitment. We made the Gantt chart to perform our project Plans must be flexible, and provisions should be provided to update them as needed throughout the project.

7.3 Evaluate project progress:

Project Planning Steps:

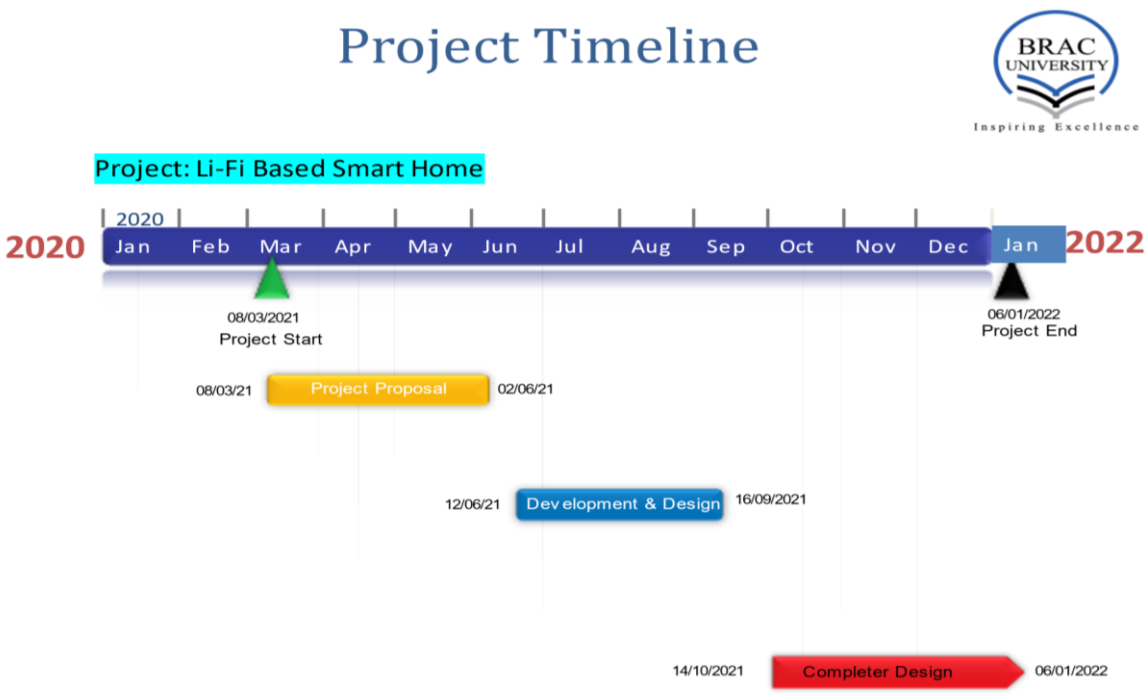
- Objectives: Project objectives are the basis for all project planning. Our project objectives are clearly stated, specific, measurable, and achievable. All the group members were agreed to start with Li-Fi based smart home project. As we have to do a complex engineering project, our project meets all the requirements.

- Project content and context: The project builds on new experiences because there are not many resources available on the Internet. Furthermore, it states here an existing thing utilized.

- Statement of work/Specification: We design and build the project prototype to keep in mind stakeholder requirements. For large projects, it will be a formal part of the contract. The stakeholder requirements specify the reason for establishing the project, the desired results, and the performance, budget, and schedule goals. It also includes specific acceptance criteria, as well as a management section that discusses peer relationships, project organization and personnel reporting, contingencies, and communications.

- Establish project Timeline: Our Project started in spring 2021 and the end dates of the project fall2021 January 06/01/12. Milestones are designated points in time by which certain specific project tasks/accomplishments are to be completed. The set of milestones

forms a group of waypoints that provide a basis for status assessment, management reviews, and replanning the project.



Risk Management and Contingency Planning

1. Connections go wrong or are not soldered properly. To resolve this error and ensure long-term reliability, simply reheat the joint and apply more solder until the joint is strong.

2. Components may be damaged. As it is stated before that everything in this project is controlled by using a microcontroller called Arduino UNO. In this microcontroller, ATMega328 is used. It is a common scenario that, the microcontroller doesn't run properly according to the command. It is caused when the microcontroller is damaged. As a result, expected outcomes cannot gain. Generally, this is solved by replacing the microprocessor, ATMega328.

3. Phone's Application might not be worked properly because of the Bluetooth module connection. In this case, we will change the Bluetooth module.

4. Distance between the transmitter and receiver is large. During this case, it will be difficult to get a good response. So, for the best response, we have to make sure that the line of sight between the receiver and the transmitter is not blocked by furniture, walls, and other objects.

5. The other conceivable danger is if the LED is broken. Broken LED lights may emit arsenic vapor. However, only a small amount of arsenic concentration was found during testing of recently produced LED lights and the vapor itself is non-lethal. To solve this, we will supplant the wrecked LED for certain new LEDs.

6. The other adverse consequence of Li-Fi is the LED light. LED lights tend to produce blue lights, which are the most damaging light to human eyes as shown in Figure (Ticleanu & Little fair, 2015). Fortunately, blue lights can only reach the retina if the sources (in this case the LED light bulbs) are directly viewed. That's why the LEDs should be placed in a place from where the blue lights cannot reach the retina of human eyes.

Risk Event	**Response**	**Contingency Plan**	**Who is responsible?**
Phone's Application Problem	Recheck the application/Check the Bluetooth connection	Replace the Bluetooth Module/Reset the phone application	Tareq
Transmitter and Receiver Set Up malfunction	Recheck the wire connection/Recheck the LED and LDR	Check wire properly/Replace LDR and LED	Refat
Connection or Soldering Problem	Check whether any short-circuited issues	Re-solder Properly	Faiyaz
Microcontroller Problem	Recheck the ATMega328	Replace the ATMega328	Refat

Establish detailed schedules

Tasks	Start Date	Duration	End Date
EEE 400C: 16 September 21- 9 January 22			
Implementing the selected design	16-Sep-21	30	16-Oct-21
Perform testing and evaluate the result	17-Oct-21	30	17-Nov-21
Report Writing	18-Nov-21	50	6-Jan-22
Final demonstration	6-Jan-22	1	6-Jan-22

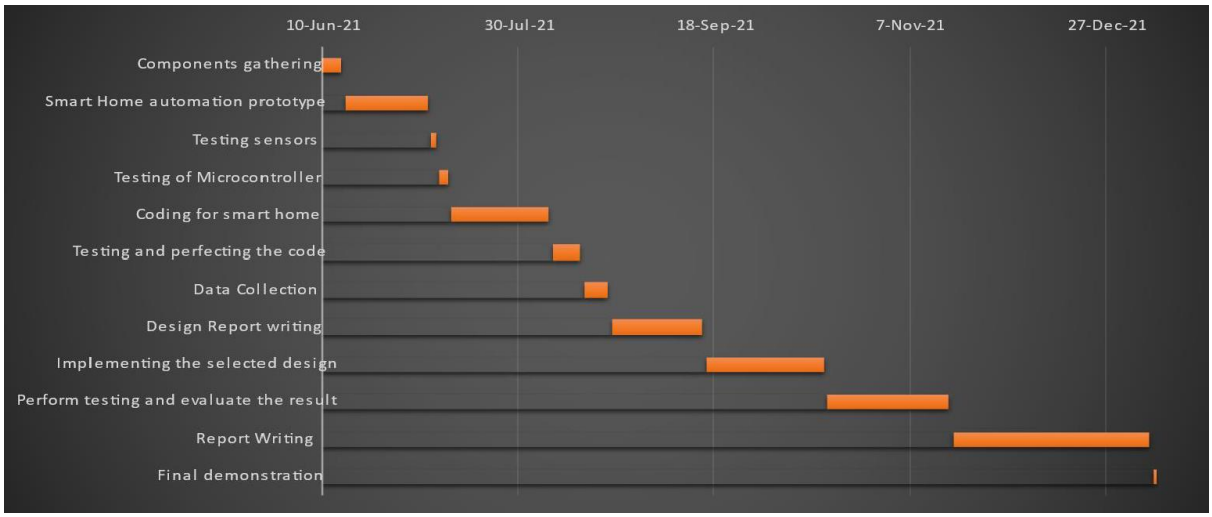


Figure: Gantt Chart for the project

Establish detailed budgets:

Name	Quantities	Tentative Cost Per Product (in Taka)	Total
Arduino Uno R3	2	480	960
Arduino Nano	1	400	400
5V 4 Channel Relay Module	1	205	205
LED ultra bright White 5mm	10	2.4	24
Breadboard	2	75	150
Male To Female Jumper Wire	20	2	40

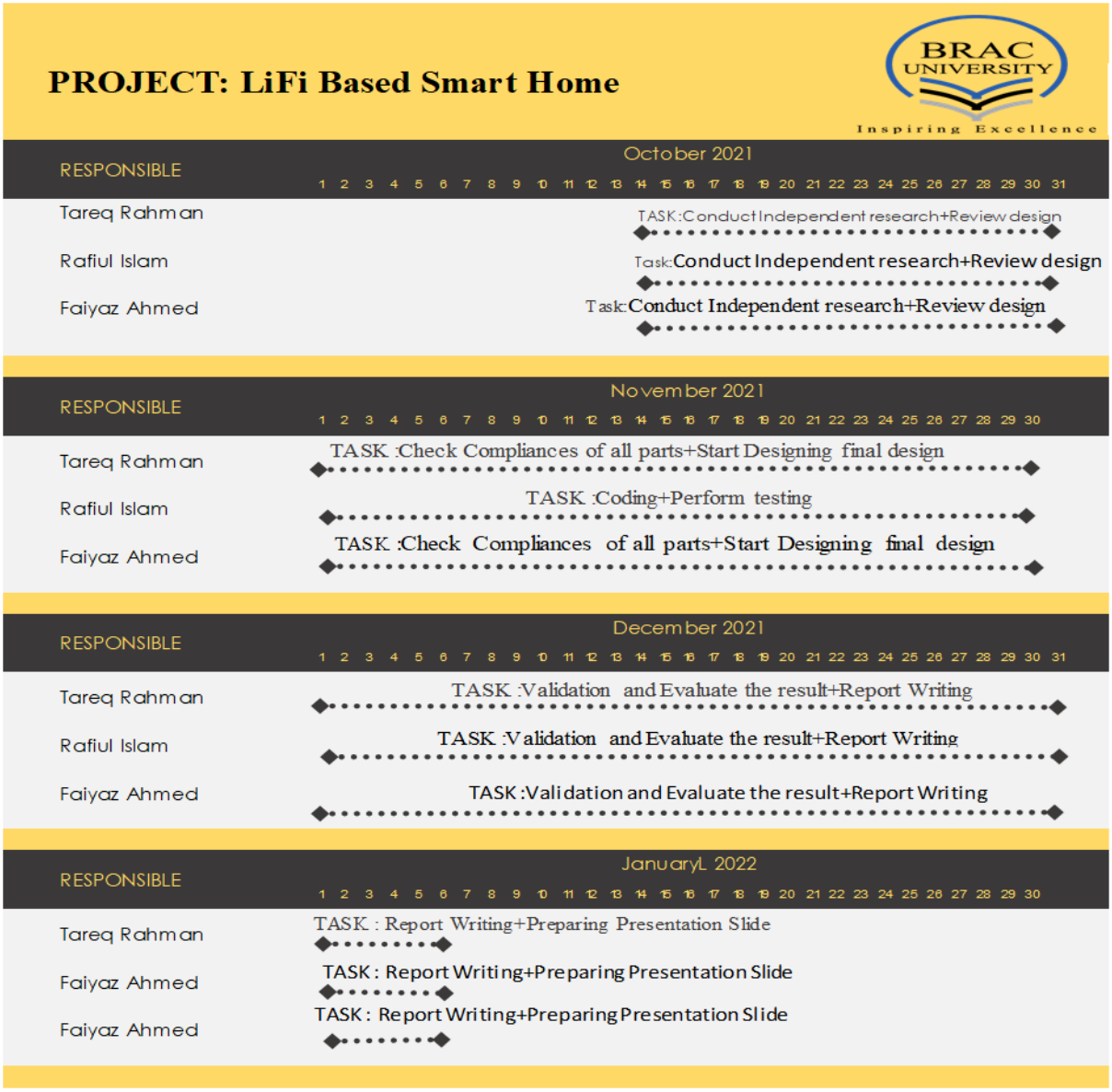
Female to female Jumper	20	2	40
Male to male jumper	20	2	40
Glue Gun	1	238	238
Glue Gun Stick	5	16	80
Soldering Iron 60W	1	340	340
0.3mm Tin Lead Soldering Wire Reel	1	73	73
Soldering Paste (150g)	1	58	58
LDR Medium 10mm	1	23	23
LDR Sensor Module	1	80	80
Bluetooth Module HC05	1	260	260
Fan DC12V 30mm	1	120	120
LM35	1	78	78
MQ6 Smoke Sensor	1	175	175
Security PIR Motion Sensor	1	530	530
LCD 16X2 With 12C Module	1	300	300
Stationary Component		313	313
IR Receiver Sensor	2	29	58
Matrix Keypad (4×4)	1	80	80

HC SR04 Ultrasonic Sensor	1	98	98
HC SR501 PIR Sensor Module	1	88	88
Gas Sensor (MQ-9)	1	180	180
Arduino Nano R3 with Cable	1	366	366
Buzzer	1	10	10
Ribbon Cable-10 wire(1 ft.)	3	22	66
5mm Heat Tubing	7	2	14
SG90 9G Micro Servo motor	1	150	150
Breadboard Big	1	75	75
Total			**5478**

Source: https://www.allmartbd.com/

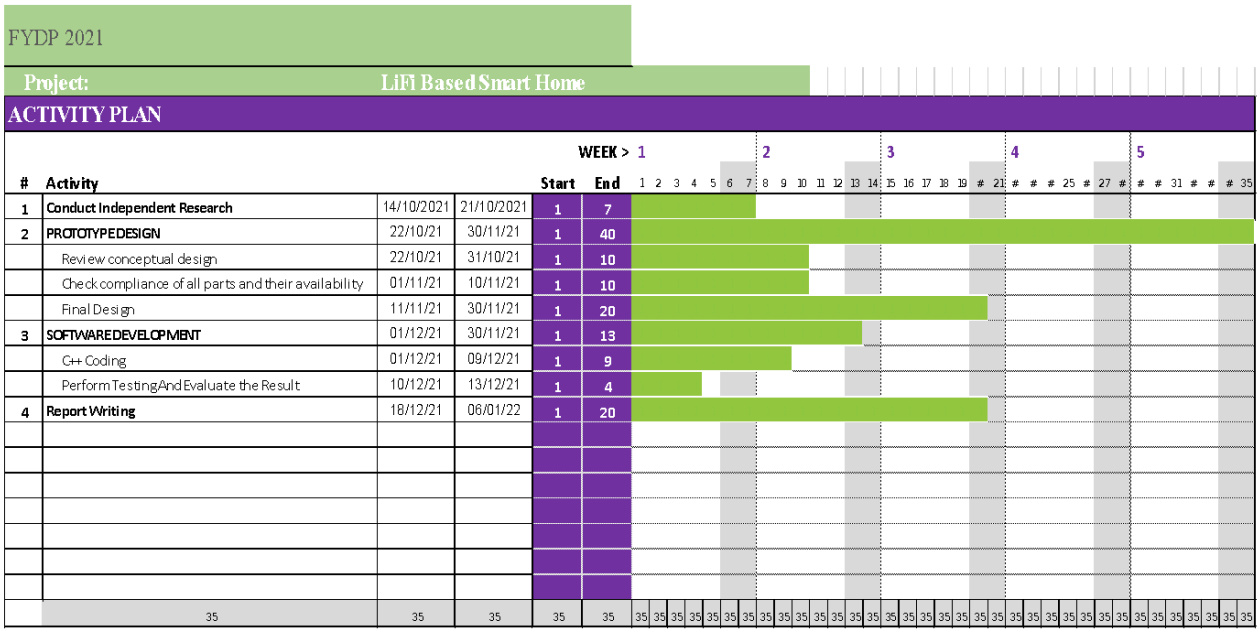
Define responsibilities

All the group members individually involved in the project design and delivery. Furthermore, we divided the tasks and assigned to each member. This section reveals who is responsible for decision-making and the project.



Replan as required

We have to replanned our Gantt chart after getting the new guild line for the project report.



FYDP 2021

Project: LiFi Based Smart Home

ACTIVITY PLAN

#	Activity			Start	End
1	Conduct Independent Research	14/10/2021	21/10/2021	1	7
2	PROTOTYPE DESIGN	22/10/21	30/11/21	1	40
	Review conceptual design	22/10/21	31/10/21	1	10
	Check compliance of all parts and their availability	01/11/21	10/11/21	1	10
	Final Design	11/11/21	30/11/21	1	20
3	SOFTWARE DEVELOPMENT	01/12/21	30/11/21	1	13
	G++ Coding	01/12/21	09/12/21	1	9
	Perform Testing And Evaluate the Result	10/12/21	13/12/21	1	4
4	Report Writing	18/12/21	06/01/22	1	20

Record keeping **:**

We have to keep record everything regarding to our project from the beginnings. All members are responsible for managing all the documents of the project and record keeping. Therefore, We have maintained Logbook to keep record on our working details.

Communication Strategy

Successful project management depends on successful communication. We have communicated with ourselves to share our knowledge. Besides, we have communicated with our respected ATC through mail and zoom meeting. Furthermore, we communicate with the stakeholders in-person to know their requirements for making Li-Fi-based smart homes.

7.4 Conclusion:

Project management helps us to write detail what tasks were accomplished, who was involved in completing the tasks, and when tasks started and finished. Several tools were used to manage the project and communicate timing and status, including task diaries, Logbook, and Gantt charts. Finally, we set up the controlling tools we want to use and define our project communications, reporting, and documentation

Chapter 8: Economical Analysis.

8.1 Introduction

Engineers frequently have to come up with a minimum-cost solution. We come up with a minimum-cost solution of Li-Fi-based smart home implementation where we have two or more cost components that are affected differently by the same design element. That is, for a single design variable, some costs increase while others decrease. we have identified which cost component we need to control to obtain the minimum cost solution to build our design.

8.2 Economic analysis

As we are using existing technology in our project. Therefore, the infrastructure cost is very less compared to other home automation systems because we are using our existing light to communicate with appliances and the infrastructure is already present in our home. Here, we don't need any additional things for light. Since Li-Fi-based home automation can be a practical alternative to Wi-Fi-based home automation (which is presently the commercially available system), it can remove the negative health impacts that are caused by Wi-Fi due to it being an RF-based technology. Li-Fi sends data through light waves on the electromagnetic spectrum. So, it is completely free from harmful radiofrequency radiation. For instance, intense exposure to radio waves can change brain waves and behavior, can induce insomnia, affect cell growth and normal fetal development, reduce brain functionality, and also several potential dangers like fertility problems and cardiac arrests. Fortunately, the electromagnetic waves of the light signal are inherently safe from these aforementioned issues, and so implementing Li-Fi based smart homes can help us to become a more economical project for all people including elder age people.

8.3 Cost-benefit analysis

Cost-Benefit Analysis is a critical step in any project planning process. It can offer short-term and long-term views of the proposed project including the impacts surrounding communities from the project. Cost-Benefit Analysis is one of the most critical analyses for stakeholders because it gives a comprehensive understanding of why money should be allocated and spent on those projects. A li-Fi-based home automation system can benefit everyone, who is willing to use it since a Li-Fi connection doesn't require too many components, unlike a Wi-Fi connection. Li-Fi only requires a few pieces of equipment that aren't overly expensive and can be purchased by the general public which is an LED lightbulb, a solar cell, and a laptop to act as a receiver. Furthermore, it also consumes less power compared to other communication systems, since not many components are required to maintain the connection. Plus, LEDs can serve as an illumination source while providing a Li-Fi connection making Li-Fi-based smart homes a more energy-efficient choice.

8.4 Evaluate economic and financial aspects

Financial and economic analyses have similar features. Both estimate the net benefits of a project investment based on the difference between the with-project and the without-project situations.

However, the financial analyses of our project compare benefits and costs to the enterprise, while the economic analyses compare the benefits and costs to the whole economy Considering the financial analysis our project cost 5478tk which uses market price to check the balance of investment and the sustainability of the project. Economic analysis uses economic price that is converted from the market price by excluding tax, profit, subsidy, etc. Yet, we didn't commercially sell the system in the market but hopefully, we introduce our Li-Fi-based smart home system soon in the market.

8.5 Conclusion

We have developed a design that is feasible for people which will consume less power. Less power consumption means less money and will be economically benefitted. Besides, our system construction infrastructure is not very expensive because the light is the communication channel for our smart home. Therefore, it takes less time to finish a task and make our work simple.

Chapter 9: Ethics and Professional Responsibilities

9.1 Introduction

We are determined to conduct all processes ethically, beginning with the research and concluding with the implementation. As electrical engineering students, we must consider the ethics of our study and work because our current and future work may have an impact on communities, societies, or even all human beings.

9.2 Identify ethical issues and professional responsibility

Public trust in engineering requires that the profession considers its impacts on human safety. There is widespread consensus in the codes of ethics of engineering professional societies worldwide that engineering has a primary duty to protect public safety, health, and welfare
We have conducted our project while ensuring public safety and health. We have tried our best to avoid engineering-related failures and problems that may result in an injury, by using good quality components and materials. Not only that, but we also try to demonstrate our project within safe limits (by controlling various factors such as time, voltage, etc.) to minimize the chances of accidents. Our project revolves mostly around light and LED, so for the most part it doesn't pose any health hazards to the demonstrators and inspectors. Still, there can be minor inconveniences such as blue light radiation from LED which can be straining for the eyes, so we will try to use those LEDs that emit less blue light. Other health risks can come from broken LEDs since they emit arsenic vapor. However, this is not something to worry about since recently produced LEDs contain very little arsenic and it is highly unlikely to break LEDs if the experiment is conducted with seriousness and care. Besides, we have identified the professional responsibilities in our project such as not using the cheap product, applying the standard code related to our project, maintaining the stakeholder requirement, satisfaction of the user in terms of convenience, accuracy, cost, user friendly.

9.3 Apply ethical issues and professional responsibility

Our project does not pose any risk to the environment as it is an indoor-based project, where the prototype will be installed and tested inside buildings and rooms, and also if the commercial versions become available in the future, those will be designed to function inside homes. Furthermore, all resources and data used for our project have been treated as confidential and all the study and work has been done by us voluntarily. In each step of the project, data was carefully recorded and examined. We also focused on minimizing human and animal harm as much as possible and maximizing benefits. We didn't breach anyone's privacy for doing this project. Finally, we acknowledged the literature review and work of others.

Professional responsibility:

- Maintain logbook and supervise with ATC
- Perform electrical developments executing quality, operation, and safety enhancements.

- Conduct design of electrical engineering, parameters, and review.
- Ensure to make decisions related to electrical engineering principles applied to operation problems and requirements proposed.
- Prepare reports and study existing technical information clearly and precisely to attain stakeholders' requirements.

9.4 Conclusion

An individual member with integrity adheres to treating our work confidential. Firstly, we find out the ethical issues and professional responsibilities and work accordingly by applying and mitigating the issues in our project considering as a professional engineer. As a guide to professional behavior, codes serve as a benchmark that all members of a profession can use to judge whether our project work is ethically and professionally worked out or not. Professionalism is therefore a privilege and is accompanied by both responsibilities and benefits.

Chapter 10: Conclusion and Future Work.

10.1 Project summary/Conclusion

We had an interest on smart homes and Li-Fi technology so we wanted to work on smart homes that use Li-Fi as the communication medium. We started on February 2021, when we identified the problems with modern smart homes and proposed our solution. We conducted independent research by studying many articles relating to smart homes and Li-Fi technology to get the necessary information to get our project approved. Then we made our project plan that included an estimated timeline to design and complete the project. We started working on our project according to our plan on June 2021. We also had to find multiple solutions to our problem and choose the optimum one and then design the optimum solution. Afterwards, we started on completion of the design of our prototype and by early January 2022 we have finished building our prototype. Despite working for over a year on our project by studying numerous articles, modifying the project several times and giving many presentations on our progress, we're satisfied that we have been able to finally complete what we have initially planned.

10.2 Future work

Li-Fi based smart home is still a relatively new concept since Li-Fi itself has been introduced recently in 2011 and there are not many resources available regarding smart homes that implement Li-Fi. Therefore, we completed this project in the best way we could with what we have. Still, as impressive as it may be, we feel in the future we may be able to improve it more. We want to add some more features to the project like adding more sensors so that it can control a greater range of appliances. We also want to incorporate mobile phone app control system in our smart home so that users can have access to the smart home using their mobile phone. We would also like to add solar panels to acts as power sources for our appliances. And finally we also hope we can build a commercial version of this project so that people can use it in their homes.

Chapter 11: Identification of Complex Engineering Problems and Activities

Attributes of Complex Engineering Problems (EP)

	Attributes	Put tick (√) as appropriate
P1	Depth of knowledge required	**(√)**
P2	Range of conflicting requirements	**(√)**
P3	Depth of analysis required	**(√)**
P4	Familiarity of issues	
P5	Extent of applicable codes	**(√)**
P6	Extent of stakeholder involvement and needs	**(√)**
P7	Interdependence	**(√)**

Note: Project must have P1, and some or all from P2-P7

Attributes of Complex Engineering Activities (EA)

	Attributes	Put tick (√) as appropriate
A1	Range of resource	**(√)**
A2	Level of interaction	
A3	Innovation	**(√)**
A4	Consequences for society and the environment	**(√)**
A5	Familiarity	**(√)**

Note: Project must have some or all of the characteristics from attributes A1 to A5

P1. Requires knowledge of objectives, specifications, and requirements for designing the system, use of engineering tools, and engagement in the research literature. We also needed the Li-Fi data transmission knowledge of how it works with the sensor on the microcontroller transmitter unit part also the design knowledge required. Furthermore, considers safety and health issues in design.

P2. Requirements are conflicting. All facilities are desired, but the system should be user-friendly and low-cost budget.

P3. No unique way to design. Depth of analysis is needed to select a specific solution from many alternatives also Numerous coding can be adopted. Choice of the selected coding requires in-detail analysis

P4. We had to understand the microcontroller work principle. Besides, the wiring connection.

P5. As we didn't find the Li-Fi based smart home system therefore we design a system to meet the requirements subject to the constraints

P6. Develops a final design that satisfies all specifications and requirements according to stakeholders' needs.

P7. The project involves several interdependent sub-systems (components), such as sensor system, Li-Fi data communication system, Load.

A1: The design involves resources, such as money, information, and technology.

A3: We addressed that sustainability and reducing costs require innovative use of engineering principles and knowledge.

A4: Our design will have an impact on society and the environment in terms of sustainability.

A5: The project deals with a new, unfamiliar area such as not many resources online.

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