A Project Report

On

Implementation of Blockchain on IoT based System

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APPROVAL SHEET

This is to certify that the project entitled

“Implementation of Blockchain on IoT based System”

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Declaration

We declare that this written submission for B.E. Declaration entitled "**Implementation of Blockchain on IoT based System**" represents our ideas in our own words and where others' ideas or words have been included. We have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any ideas / data / fact / source in our submission. We understand that any violation of the above will cause for disciplinary action by the institute and also evoke penal action from the sources which have thus not been properly cited or from whom paper permission has not been taken when needed.

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Abstract

A Blockchain is a distributed and decentralized ledger capable of maintaining an immutable log of transactions taking place in a network. Recently, this technology has gained significant interest in areas other than financial sectors, one of them being Internet of Things (IoT). Blockchain helps build a truly decentralized, tamperproof and secure environment for IoT systems. Internet of Things, an embedded technology helps enable breakthrough services by interconnection of physical and virtual things, intelligent interaction and Machine-to-Machine (M2M) communication between environments, objects and interoperable information technologies. But, IoT is challenged with unprecedented security issues. IoT applications can be attacked in many ways, often involving applications that first obtain access to an IoT application, then start monitoring, controlling and tampering the users' private data. The aim is to propose a Smart Laboratory System which will implement Blockchain as a security feature to prevent the above issues. The system will monitor the changes and store the usage and consumption patterns on a private blockchain network, produce analyzed reports as well as report abrupt changes.

Chapter 1

Introduction

1.1 Background

The Blockchain is undeniably an ingenious invention of a person (or group of people) known by the pseudonym, Satoshi Nakamoto. In 2008, Satoshi Nakamoto introduced the world to Bitcoin by releasing the paper, "Bitcoin: A Peer-to-Peer Electronic Cash System" that proposed to distribute electronic transactions rather than maintain dependency on centralized institutions for the exchange [1].

The term Internet of Things (IoT) was first coined by Kevin Ashton in 1999 in the context of supply chain management. IoT represents the ability of network devices to sense and collect data from the environment, and then share that data across the Internet where it can be processed and utilized for a wide range of applications like healthcare, utilities, home automation, transportation, defense and public safety, wearables or augmented reality.

1.2 Motivation

It is expected that IoT devices will rise up to 26 billion by the year 2020, which is 30 times the estimated number of devices deployed in 2009. As the number of IoT sensors is growing, it is increasingly important to find ways to maximize the value of the data generated by those sensors [2]. Such a huge growth at a fast pace involves greater risks for security, breach of privacy and increase in vulnerabilities. If the data on the IoT device is not encrypted then other individuals have access to it, which makes the data more vulnerable to surreptitious hijacking and theft. After Edward Snowden leaks, it has become difficult for IoT adopters to trust technological partners who, in general, give device access and control to certain authorities, allowing them to collect and analyze user data. Hence, privacy and anonymity should be the major concern of future IoT solutions.

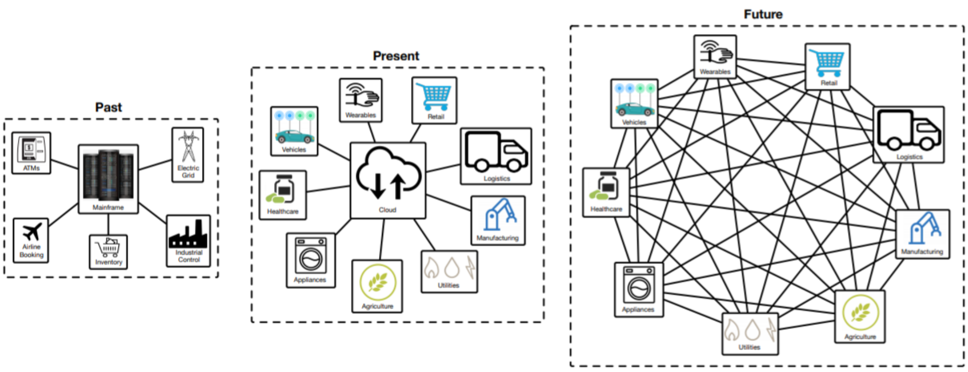


Figure 1.1: IoT Evolution

1.3 Aim and Objective

Applying Blockchain on an IoT based system can secure the users' private data by recording communication and controlling information as transactions in the distributed ledger. The Blockchain robustly prevents the intrusion with the extension of time-stamping and proper encapsulation. Any investigation could immediately verify this information from the distributed storage, thus the system would be difficult to hack.

Taking into account the above mentioned facts, we aim to propose a Blockchain based Smart Laboratory. In this system, the laboratory will be a private blockchain network. All the IoT devices in the laboratory will have a private distributed ledger. The IoT devices will execute transactions by using smart contracts in the local blockchain. A smart contract is a computerized transaction protocol that executes the terms of a contract. Under the blockchain context, smart contracts are stored scripts on the blockchain with unique addresses which could be triggered by addressing a transaction and executed automatically in an essential manner. New smart contracts could be designed to execute commands automatically based on users' usage history or other preferences.

1.4 Report Outline

Chapter 2 discusses the technologies used i.e. Blockchain and Internet of Things (IoT). Primarily, this section discusses the Blockchain technology, its first use case - Bitcoin, working of the Blockchain, its applications, Ethereum and Smart Contract. It also discusses the IoT technology, its architecture, applications, advantages, disadvantages and most importantly IoT Security. Lastly, this section studies some of the related works of the system.

Chapter 3 states the problem statement of the project. It describes the scope of the system and also the proposed system.

Chapter 4 discusses the requirements engineering of the project, which includes the software lifecycle model, requirements analysis - UML diagrams, cost analysis, system architecture - UI/UX and block diagram, hardware and software requirements of the project.

Chapter 5 discusses the implementation phase of the project which includes the information about the system, implementation of the Smart Laboratory, storing and retrieving IoT data on the Blockchain network. This section also includes the screenshots and sample code of the working system.

Chapter 2

Study Of Blockchain based IoT System

2.1 Blockchain and related work

2.1.1 Blockchain

Blockchain is a decentralized and distributed ledger that contains connected blocks of transactions for all members of the network. The major concept behind it is - tamper-proof storage of approved transactions. The Blockchain enables all parties involved to make the transactions in a trustless system i.e. they need not trust each other. In essence, it's a distributed database which maintains a continuously growing tamper-proof data structure of blocks which holds batches of individual transactions. The completed blocks are added in a linear and chronological order. Each block contains a timestamp and information link which points to a previous block.

2.1.2 Bitcoin: First use case of Blockchain

Bitcoin is a digital currency released as an open-source software in 2009. It is a decentralized cryptocurrency produced by all the participating nodes in the system at a defined rate. The chain of Bitcoins created over a period and linked to each other is called Blockchain. It can be used to search any past transaction that happened over the network between Bitcoin addresses. When a new block of transactions is created, it gets added to the Blockchain network. The new transaction records are continuously added to Bitcoin's public ledger and this process is called Bitcoin mining.

Secure Hash Algorithm-256 (SHA-256) which is a cryptographic hash function is used by Bitcoin. We can determine the integrity of a given data by comparing the execution output of SHA-256 algorithm called "hash" with an already known and expected hash value.

A hash algorithm converts a large amount of data into a fixed-length hash. And the same data will always produce the same hash but any slight modification in data will completely change the hash.

2.1.3 Working of Blockchain

Blockchain is a transaction database which contains information about all the transactions ever executed in the past and works on the Bitcoin protocol. It creates a digital ledger of transactions and allows all the participants on the network to edit the ledger in a secure way which is shared over a distributed network of the computers.

If a majority of the nodes agree in favor of a transaction, then it is approved and a new block gets added to the existing chain.

We can visualize Blockchain as a vertical stack having blocks kept on top of each other and the bottommost block acting as foundation of the stack. The individual blocks are linked to each other and each block refers to the previous block in the chain.

The individual blocks are identified by a hash which is generated using the Secure Hash Algorithm (SHA-256), a cryptographic hash algorithm on the header of the block. A block will have one parent but can have multiple children each referring to the same parent block hence contains the same hash in the previous block hash field. Every block contains hash of parent block in its own header and the sequence of hashes linking individual block with their parent block creates a big chain pointing to the first block called as the Genesis block [3].

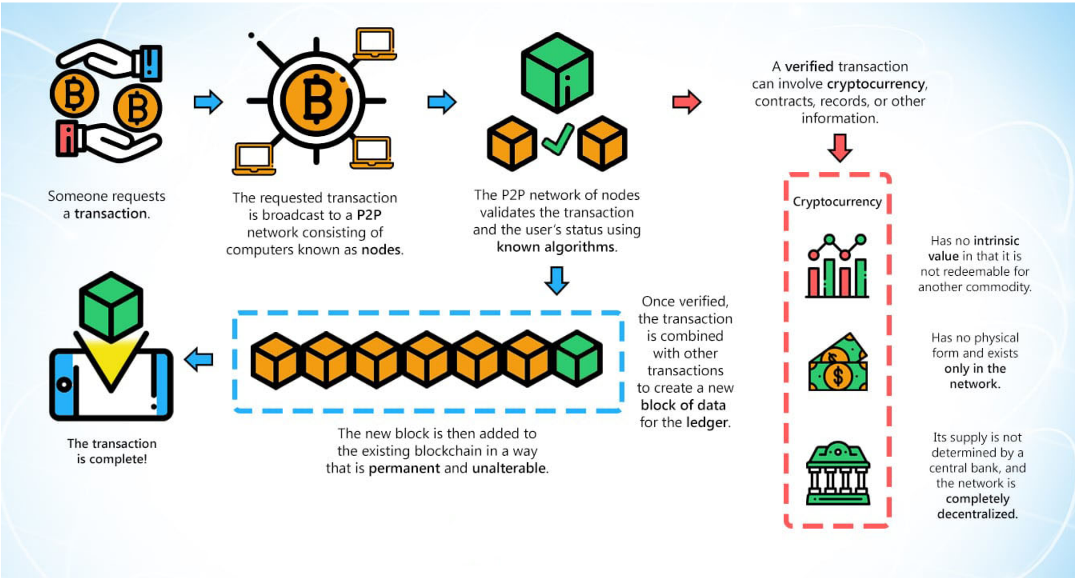


Figure 2.1: Working of Blockchain

2.1.4 Applications

1. Smart Contract

   Distributed ledgers enable the coding of simple contracts that will execute when specified conditions are met. At the technology's current level of development, smart contracts can be programmed to perform simple functions. For instance, a derivative could be paid out when a financial instrument meets a certain benchmark, with the use of blockchain technology and Bitcoin enabling the payout to be automated.

2. Crowdfunding

   Blockchain makes the funding process safe, accessible from anywhere in the world, and completely transparent. Crowdfunding platforms that use Blockchain can help to maximize the success of a project. There are a couple of different ways that blockchain or Bitcoin crowdfunding is being used currently to help fund businesses; One of them is Initial Coin Offerings or ICOs.

3. Governance

   By making the results fully transparent and publicly accessible, distributed database technology could bring full transparency to elections or any other kind of poll taking. Blockchain enables organizational decision-making to happen on the network. In practice, this means company governance becomes fully transparent and verifiable when managing digital assets, equity or information.

4. File Storage

   Decentralizing file storage on the internet brings clear benefits. Distributing data throughout the network protects files from getting hacked or lost. An internet made up of completely decentralized websites has the potential to speed up file transfer and streaming times. Such an improvement is not only convenient, it's a necessary upgrade to the web's currently overloaded content delivery systems.

5. IoT

   The blockchain ledger provides security to the Internet of Things. With billions of devices linked together, cybersecurity experts worry how to make sure the distributed information stays secure. Then, there's the problem of how to organize and analyze this massive amount of data that's coming from these related devices. The blockchain ledger system ensures that information is only accepted and released to trusted parties. The ledger grants parties a management platform for analyzing the vast amounts of data [4].

2.1.5 Ethereum

Launched in 2015, Ethereum is an open-source, blockchain-based, decentralized software platform used for its own cryptocurrency, ether. It enables SmartContracts and Distributed Applications (DApps) to be built and run without any downtime, fraud, control, or interference from a third party.

Ethereum is not just a platform but also a programming language (Turing complete) running on a blockchain, helping developers to build and publish distributed applications.

The applications run on Ethereum are run on a platform-specific cryptographic token, ether. Ether is used by developers looking to develop and run applications inside Ethereum. Ether is used broadly for two purposes: it is traded as a digital currency exchange like other cryptocurrencies, and it is used inside Ethereum to run applications and even to monetize work.

Ethereum can be used to codify, decentralize, secure, and trade just about anything. One of the big projects around Ethereum is Microsoft's partnership with ConsenSys which offers Ethereum Blockchain as a Service (EBaaS) on Microsoft Azure so Enterprise clients and developers can have a single click cloud-based blockchain developer environment.

2.1.6 Smart Contract

Nick Szabo introduced this concept in 1994 and defned a smart contract as "a computerized transaction protocol that executes the terms of a contract" [5]. A smart contract is a self-executing contract with the terms of the agreement between buyer and seller being directly written into lines of code. The code and the agreements contained therein exist across a distributed, decentralized blockchain network. The code controls the execution, and transactions are trackable and irreversible.

Smart contracts permit trusted transactions and agreements to be carried out among various, anonymous parties without the need for a central authority or legal system.

Smart contracts are a helpful asset in IoT networks allowing for a high degree of coordination and authority [6]. Particularly, when it comes to managing transactions and interactions, smart contracts ensure proper cohesion. IoT is always built on the idea of being able to take the right amount of action at the right time. For example, suppose you want your house to be able to order a new light bulb when one burns out, you wouldn't want your house indiscriminately ordering crates of lightbulbs. Smart contracts are a great way to protect against this.

2.2 Internet of Things

2.2.1 Study of IoT

The IERC [7] (European Research Cluster on the Internet of Things) definition of IoT is as follows - "IoT is a dynamic global network framework with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network."

IoT is mainly an environment of a diversity of things having a wide presence, which through wireless and wired connections are able to interact with each other and cooperate with other things to create new applications and reach common designated goals.

2.2.2 Applications

The applications of IoT [7] are as follows:

1. Wearables
    - Smart bands
    - Wireless ECG monitor
    - Smart contact lens
    - Smart devices to help people quit smoking
2. Smart Healthcare
    - With the help of IoT, improved care for patients and providers can be facilitated.
3. Smart Clothing
    - Smart fabrics can communicate with smartphones to process biometric information such as heart rate, body temperature, breathing patterns, stress levels, hormone levels and movement of the body, with real time feedback.
4. Smart Buildings
    - IoT in architecture can help in accelerating development, adding intelligence across building operations, lower operational costs and consolidating workloads to build smarter offices, industries, residents, hotels, hospitals, etc.
5. Smart Energy
    - Economical electricity transmission
    - Immediate electricity restoration after power disruptions
    - Decreased operational and management costs

- Controlled demand

6. Smart Mobility and Transport

    - The transport with the help of internet-connected vehicles is effortless, hassle-free and safer. IoT provides cutting edge services relating to different modes of transport and enables users to be informed about the environment and make safer and smart decisions and thereby make optimum use of the transportation networks.

7. Smart Manufacturing

    - Digitized manufacturing systems

8. Smart Farming

    - Viable farming
    - Increased production with much lesser costs
    - Lesser environmental impact

2.2.3 Architecture

The architecture [8] of the Internet of Things is designed to stem a wide spectrum of data at any given point of time. It is an eminently decisive framework that can connect with any aspect of the smart device.

The base layer is the Sensing and Identification layer. Every device which senses the environment and uniquely identifies the sensed data belongs to this layer. The sensing level focuses on gathering information via the sensors. The sensors are small in size, inexpensive and are highly available because of which they can be embedded into mobile computation devices, wearables and autonomous machines. The environmental factors such as humidity, temperature, light, pressure and vibration can be captured with the help of the sensors.

The next layer is the Network Construction layer. This layer is responsible for operational handling of the IoT data. Routing of the information is done with the help of this layer. This can be anything like wireless LAN, wireless MAN, wireless wide-area network, wireless personal area network, Internet, etc. The sensed data is accumulated and then sent to the next layer by the network layer. By aggregating the data at the gateway, summarizing and analyzing, the network layer can curtail the volume of irrelevant data to be forwarded on.

The topmost layer is the Application layer - responsible for illustrating and interpreting the data. It reacts to its interpretation accordingly. We can think of an example wherein, if the temperature sensor in a smart home senses the temperature of the room to be increasing, then the air conditioner will be switched on promptly.

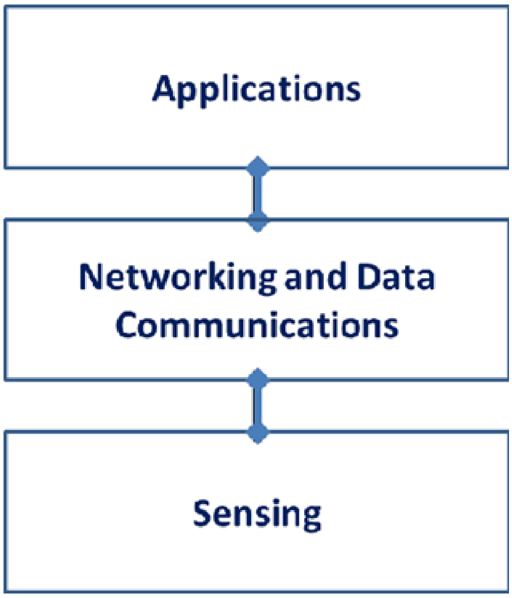


Figure 2.2: Three tier Architecture of IoT

2.2.4 Advantages

- **Communication** – Communication between physical devices is possible with the help of IoT and this leads to transparent systems which have better productivity and greater quality.
- **Automation and Control** – Without the intervention of humans, faster and timely output is achieved by automating machines which control vast amount of information.
- **Monitoring** – Smart sensors are used in monitoring different aspects of our daily life for assorted applications which successively saves time and money.
- **Better aspect of living** – Applications based on IoT are able to increase convenience, comfort and better administration in our daily life.
- **New business opportunities** – New business opportunities are created with the help of IoT technology; hence this increases monetary growth and new opportunities for jobs.
- **Better environment** – IoT helps in saving natural resources, trees and in creating a greener and sustainable planet.

2.2.5 Disadvantages

- **Compatibility** – As devices from different manufacturers would be interconnected in IoT, presently, there is no international standard of compatibility for the tagging and monitoring equipment.

- **Complexity** – IoT is a diverse and complex network. Any failure or bugs in the software or hardware will have serious consequences. Even power failure can cause a lot of inconvenience.

- **Privacy/Security** – IoT involves multiple devices and technologies and multiple companies would be monitoring it. Since a lot of data related to the context would be transmitted by the smart sensors, there is a high risk of losing private data.

- **Lesser employment of menial staff** – With the advent of technology, daily activities are getting automated by using IoT with less human intervention, which in turn causes fewer requirements of human resources. This causes unemployment issues in the society.

2.2.6 Security

Security [7] needs to be designed into IoT solutions from the concept phase and integrated at the hardware level, the firmware level, the software level and the service level. In IoT, it is important to drive security, privacy, data protection and trust across the whole IoT ecosystem. The evolution of connected devices as nodes to the IoT network brings limitless possibilities. All of the IoT applications need to be protected or they run the risk of undesirable outcomes such as:

- Improper or unsafe operation of IoT devices

- Theft of confidential data, private user information or application-related intellectual property

- Fraud and unauthorized access to payment processing channels

- Damage to companies' brand image and deterioration of the trust of their customers, prospects and partners.

2.3 Related Works

A few systems have been studied that apply the same technologies as proposed.

Reference [9] shows a Smart Laboratory implementation which is built across IoT and Mobile communication technologies to supervise the overall activities of the laboratory including power consumption and application of devices, sensing environmental parameters, thereby providing a smart environment with balanced energy consumption and comfort. The system monitors the consumption pattern of the devices and uploads it to their server and establishes remote control of appliances from anywhere, thus reducing power wastage.

Reference [10] shows a Smart Laboratory implementation for management of subsystems of a university, including lighting conditions, air conditioning, heating, audio/video, controlling switches and security. It highlights the benefits for university and the students using the smart laboratory.

Reference [11] shows a Secure and Smart Laboratory implementation with Wireless Sensor Network (WSN). The system is implemented using an Ambient lighting module. It uses Passive Infrared Sensor (PIR) and Environment Sensor (ES) for security. The difficulty faced by the system is, WSN has limited computation, lack of communication resources, reduced power, shortage of storage, prone to attacks and lower bandwidth to communicate.

Reference [2] applies Sensing-as-a-Service (S^2aaS) business model combined with Blockchain. This paper proposes the creation of an Ethereum blockchain decentralized application (DApp) enabling users to easily buy and sell IoT sensor data, by using a custom token as the payment currency. This application is a platform for sharing (buying and selling) measurements of IoT weather sensors and operates on the Ethereum blockchain, acting as a marketplace for IoT sensor data.

Chapter 3

Proposed System

3.1 Problem Statement

We want to minimise the number of potential risks for security of the users' data and decrease the vulnerabilities in the automation system to maintain privacy and anonymity. We also want to minimise the power consumption of the laboratory.

3.2 Scope

The project involves setting up an environment for the laboratory which will control lights and fans based on environmental parameters and also according to the college schedule. The laboratory will be a private blockchain network. All the IoT devices in the laboratory will have a private distributed ledger. The IoT devices execute transactions by using smart contracts in the local blockchain.

3.3 Proposed System

We propose to implement Blockchain technology on an IoT based system. The proposed system will consist of an IoT network set up in the college laboratory. The laboratory will be a private Blockchain network where all the IoT devices will act as nodes on the Blockchain and maintain a private distributed ledger. Every action taken by the system will be recorded as a transaction on the Blockchain using a Smart Contract.

The Blockchain technology will prove as a security feature to the already risk associated IoT network. With its help, the users' private and sensitive data will be secured and it will be ensured that no tampering can be done.

The system will sense its environment i.e. the laboratory for motion, temperature, humidity and luminosity values. On comparing these values with the thresholds, actions would be taken accordingly. Then, these sensor values as well as actions will be recorded on the Blockchain network.

Chapter 4

Design Of the System

4.1 Requirement Engineering

4.1.1 Requirement Elicitation

- **Quality requirements for Smart Laboratory System**

  1. The system should accurately define if motion is detected in the laboratory. [Performance requirement]
  2. The system should sense proper values of temperature, humidity and luminosity of the laboratory. [Performance requirement]
  3. Appropriate response/action should be taken based on the sensor values. [Performance requirement]
  4. There should be no hardware failures. [Reliability requirement]
  5. There should be no tampering of the sensor and response values. [Security requirement]

- **Constraints**

  1. The system must always be connected to the Internet during the functioning of the laboratory.
  2. The system should have constant power supply during the functioning of the laboratory.

4.1.2 Software lifecycle model

The Software lifecycle model used is V (Validation and Verification) model. Being an IoT based project, every stage of development is followed by a testing stage. The next phase starts only after completion of the previous phase i.e. for each development activity, there is a testing activity corresponding to it.

- **Validation**

  - **Requirement Gathering and Planning**

    The hardware requirements of our project contains - a Microcontroller (Raspberry Pi v3B), a PIR Sensor Module, a Temperature and Humidity sensor (DHT11), a Luminosity sensor (TSL2561), 8-channel Relay module, an LED bulb, a DC fan.

    The software requirements of our project contains - Python, Ethereum, Geth, Apache Web Server.

  - **Design**

    This phase contains the system design and the complete hardware and software setup for developing the system. For the design phase, first we design the model for the Smart Laboratory system, in which all the sensors would communicate with the microcontroller. On comparing these sensor values with the thresholds, the microcontroller would then take the required actions. Then, these recordings i.e. the sensor values along with the actions taken would be stored on the private Ethereum Blockchain network.

  - **Coding**

    The actual coding of the system modules designed in the design phase is taken up in the Coding phase. In this phase, we build the model for the Smart Laboratory system according to the system design discussed above. Using Python, the sensor values are transmitted to the microcontroller i.e. Raspberry Pi v3B. It then compares these values with the thresholds and takes actions accordingly i.e. switching on/off of the light/fan. Then, all these values are pushed and recorded on the private Ethereum Blockchain network as transactions with the help of Smart Contract, using Python and Solidity programming languages.

- **Verification**

  - **Unit Testing**

    Here, we begin by testing the sensors one by one to check if they are functioning properly.

  - **Integration Testing**

    Here, we test if the sensors are working properly in cohesion.

  - **System Testing**

    Here, we test the system as a whole. We test if the Blockchain and the IoT System are properly synced and functioning in coordination.

4.1.3 Requirement Analysis

4.1.3.1 UML diagrams

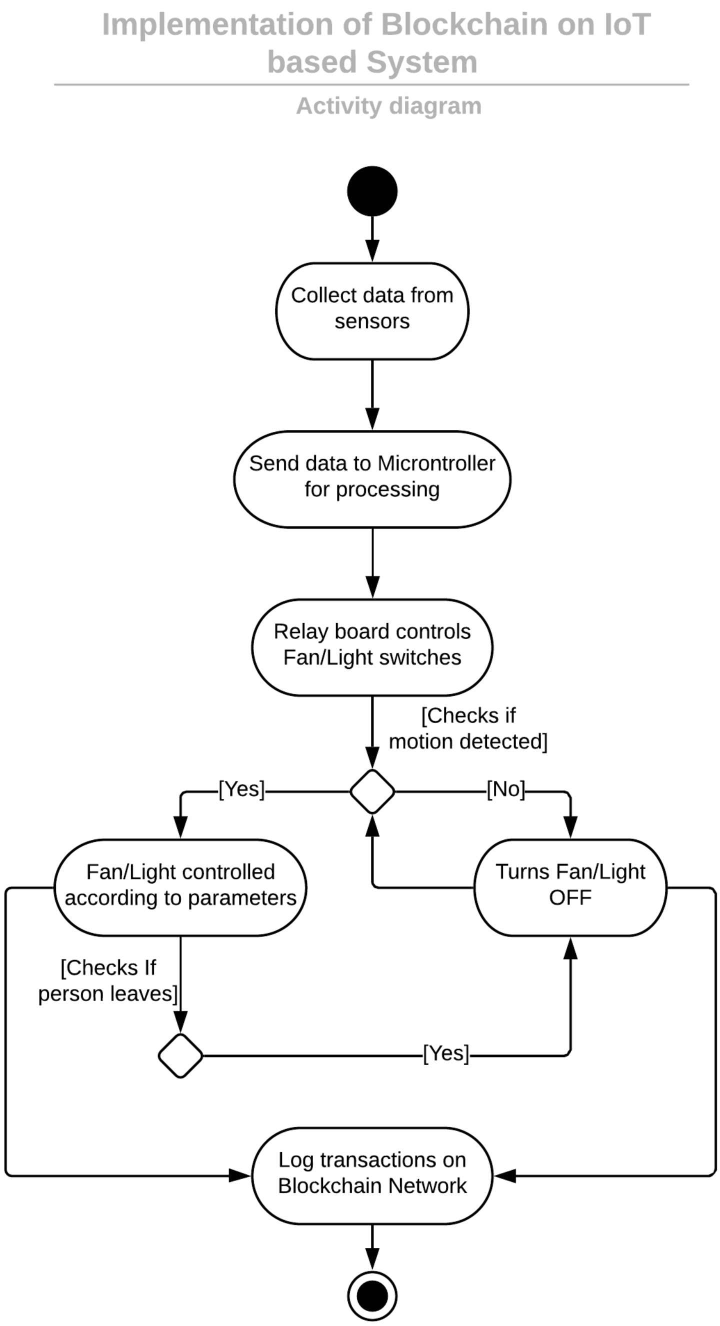


Figure 4.1: Activity Diagram

The first task is to collect data from the sensors (DHT11, PIR Sensor Module, TSL2561) and send it to the microcontroller (Raspberry Pi v3B) for processing. Based on the detection of motion, the lights and fans are controlled.

If the temperature value is beyond a certain threshold value, the fans will be switched on, else switched off. Similarly, if the luminosity of the environment is beyond a certain threshold value, the lights will be switched off or else switched on.

All the above transactions i.e. the controlling of appliances are logged on the Blockchain network.

4.1.3.2 Cost Analysis

Sr No.	Component	Cost (in INR)
1	Raspberry Pi version 3 B	3175
2	DHT11	120
3	TSL2561	175
4	PIR Sensor Module	80
5	8 Channel Relay Board	350
6	Breadboard	60
7	LED Bulb	100
8	DC Fan	150
9	Other Electrical Components	100
	Total	4310

Table 4.1: Cost Analysis

4.1.3.3 Hardware and software requirement

1. Microcontroller
   (a) Raspberry Pi version 3 B
2. Sensors
   (a) Luminosity Sensor TSL2561
   (b) Temperature and Humidity Sensor DHT11
   (c) Passive Infrared Sensor (PIR) Motion Detector Sensor module
3. 8 channel Relay board
4. Appliances
   (a) LED Light bulb
   (b) DC Fan
5. Jumper cables
6. Resistors

7. Breadboard
8. Raspbian Operating System
9. Python 2.x / Python 3.x
10. Apache Web Server 2.x
11. PHP version 7.x / HTML5 / CSS
12. Common Gateway Interface (CGI)
13. Ethereum - Geth 1.8.23
14. Ethereum Wallet 0.9.0
15. Truffle 5.1.17
16. Solidity 0.5.1
17. web3.py 5.4.0

4.2 System architecture

4.2.1 UI/UX diagram

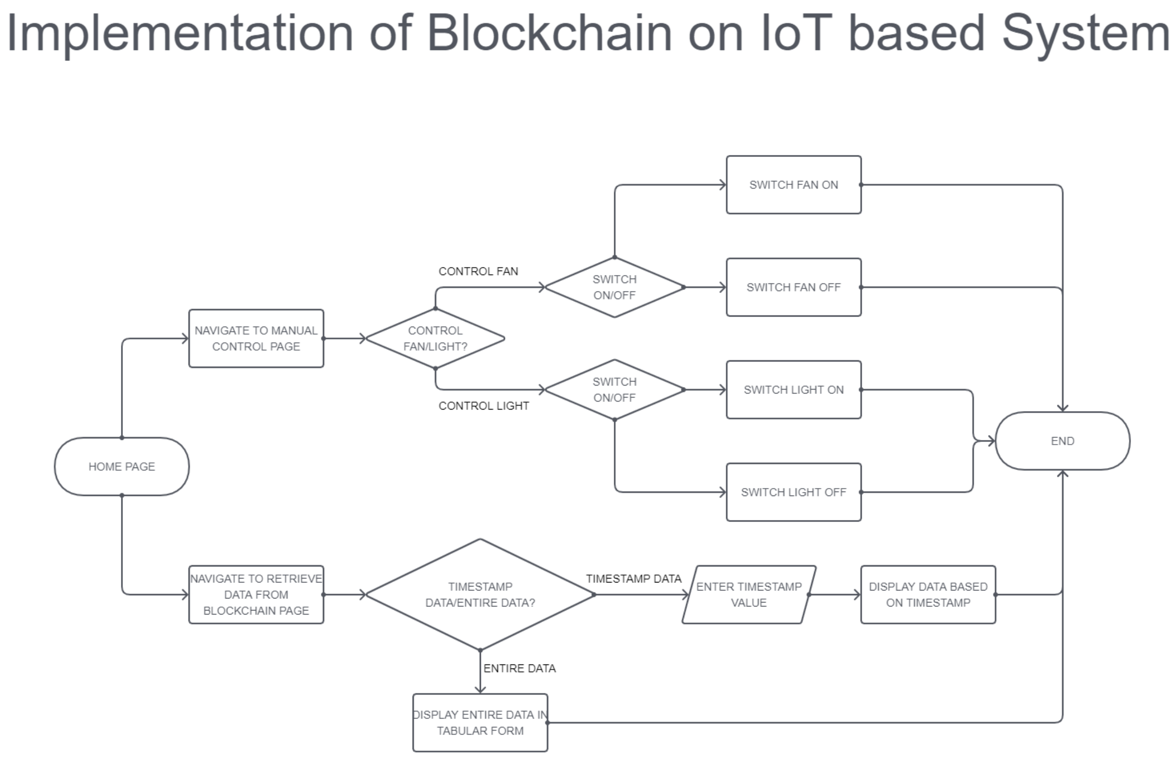


Figure 4.2: UI/UX Diagram

4.2.2 Block diagram

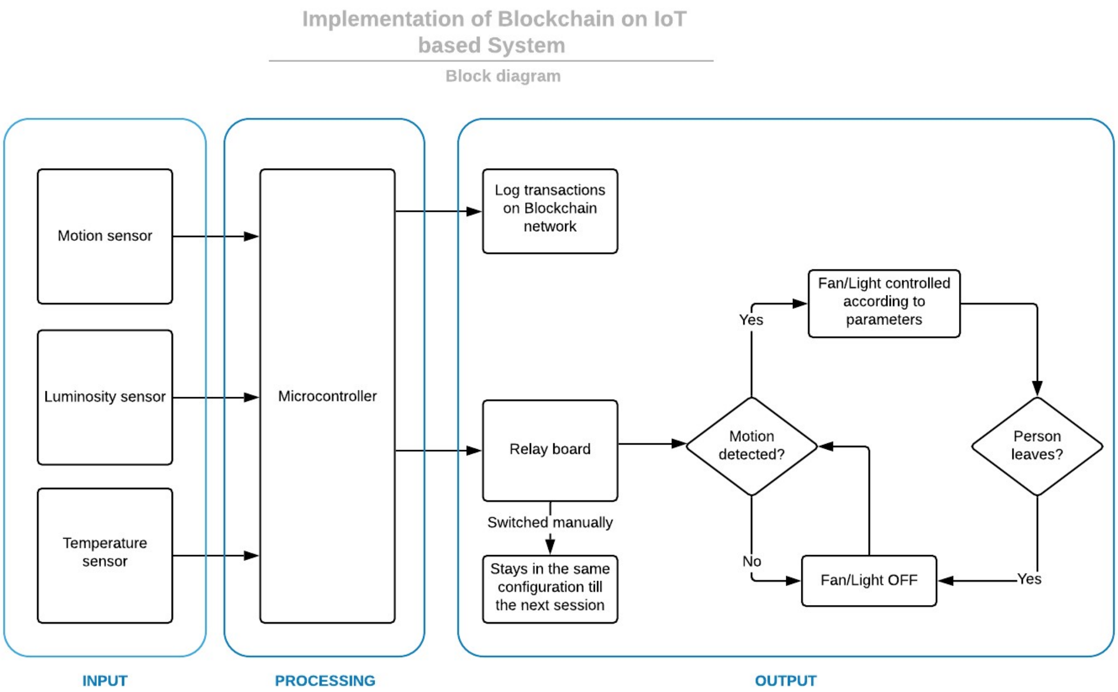


Figure 4.3: Block Diagram

The data from the environment will be sensed with the help of motion sensor (PIR Sensor Module), luminosity sensor (TSL2561), temperature and humidity sensor (DHT11). This data from the sensors will then be transmitted to the microcontroller - Raspberry Pi version 3B. The microcontroller processes the data. Based on processing, following decisions are made:

- Logging transactions on the Blockchain network
- Controlling Lights/Fans
  - Switching is done with the help of Relay board

Chapter 5

Result and Discussion

5.1 Implementation

5.1.1 Information about the System

We used the PIR motion sensor, Temperature and Humidity sensor (DHT11) and Luminosity sensor (TSL2561) to sense the environment - in this case, college laboratory.

When a warm body like a human or animal passes by, a **PIR motion sensor** first intercepts one half of the PIR sensor, which causes a positive differential change between the two halves. When the warm body leaves the sensing area, the reverse happens, whereby the sensor generates a negative differential change. These change pulses are what is detected.

DHT11 temperature and humidity sensor consists of a capacitive humidity sensing element and a thermistor for sensing temperature. The humidity sensing capacitor has two electrodes with a moisture holding substrate as a dielectric between them. Change in the capacitance value occurs with the change in humidity levels. The IC measures, processes this changed resistance values and changes them into digital form. For measuring temperature this sensor uses a Negative Temperature coefficient thermistor, which causes a decrease in its resistance value with increase in temperature.

The **TSL2561 luminosity sensor** is an advanced digital light sensor, ideal for use in a wide range of light situations. This sensor is precise, allowing for exact Lux calculations and can be configured for different gain/timing ranges to detect light ranges from up to 0.1 - 40,000+ Lux on the fly. This sensor contains both infrared and full spectrum diodes. That means it can separately measure infrared, full-spectrum or human-visible light. The sensor has a digital (i2c) interface. We can select one of three addresses so we can have up to three sensors on one board - each with a different i2c address. The built in ADC (Analog to Digital Converter) means we can use this with any microcontroller, even if it doesn't have analog inputs.

Solidity is a contract-oriented, high-level language for implementing smart contracts. It was influenced by C++, Python and JavaScript and is designed to target the Ethereum Virtual Machine (EVM). It is statically typed, supports inheritance, libraries and complex user-defined types among other features.

Web3 is a collection of libraries which allow you to interact with a local or remote ethereum node, using a HTTP or IPC connection. Web3 enables you to fulfill the responsibility of developing clients that interact with the

Ethereum Blockchain. It allows you to perform actions like send Ether from one account to another, read and write data from smart contracts and create smart contracts.

5.1.2 Implementation of Smart Laboratory

The Smart Laboratory system will sense the motion in the environment using the PIR sensor. When the motion is detected, the temperature, humidity and light intensity from the environment will be sensed using the DHT11 temperature and humidity sensor and TSL2561 luminosity sensor. If the value of the temperature is beyond a certain threshold, then the fans of the laboratory will be switched on for a certain time interval, else remain off. Similarly, if the luminosity value is below a certain threshold, then the tube lights in the laboratory will be switched on for a certain time interval, else remain off.

When no motion is detected, then lights and fans of the laboratory will remain switched off until motion is detected again. The data from the sensors will be sent to the microcontroller, Raspberry Pi version 3B. The processing will be done by the microcontroller and appropriate actions will be taken i.e., controlling tube lights and fans.

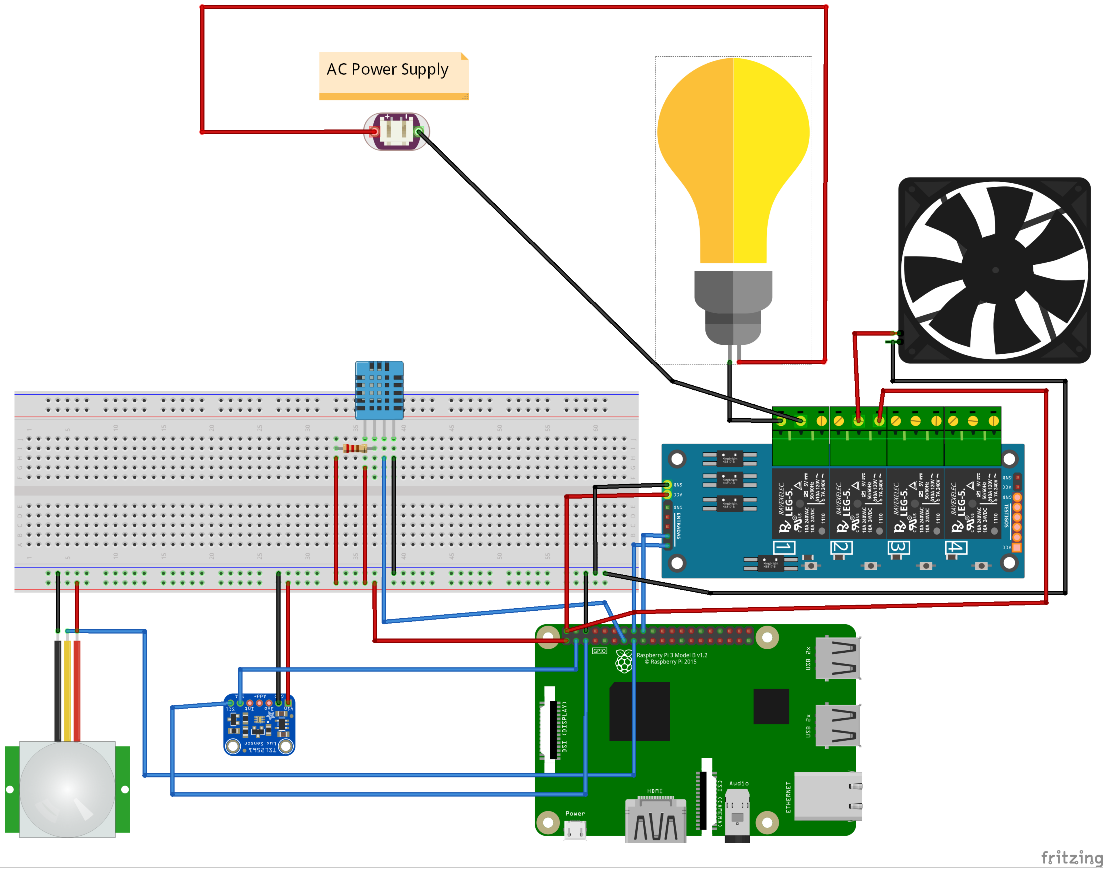


Figure 5.1: Circuit Diagram of the System

5.1.3 Storing the values on the Blockchain Network

The data from the sensors and the appropriate actions taken are stored on the private Ethereum Blockchain network as a transaction with the help of Smart Contract. The smart contract is written in Solidity, which is an object-oriented programming language. Each transaction stored on the network comprises of -

1. Timestamp value when the values were recorded
2. Motion sensor ID
3. Motion sensor value
4. Temperature and Humidity sensor ID
5. Temperature value
6. Humidity value
7. Luminosity sensor ID
8. Luminosity sensor value
9. Action taken for light
10. Action taken for fan

5.1.4 Retrieving values from the Blockchain Network

The values or the data stored on the Blockchain network in the form of transactions will be retrieved with the help of the smart contract. We are able to interact with the smart contract with the help of Web3 (in python) which allows us to interact with any local/remote Ethereum node.

We can fetch all the transactions stored on the Blockchain network at a time, or a single transaction for a given date and time specified by the user.

5.2 Screenshots of the System

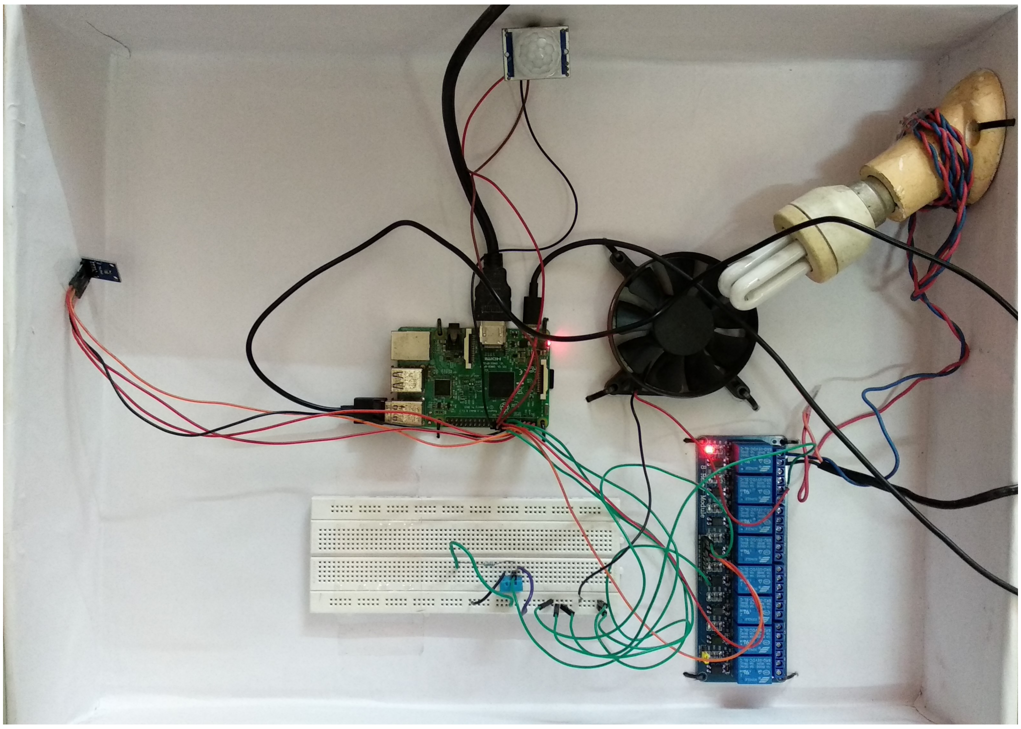


Figure 5.2: Model of the IoT System

Figure 5.2 depicts the model of the IoT System. It comprises of the sensors and Relay board connected to the Microcontroller. The appliances (i.e. Light and Fan) are connected to the Relay board.

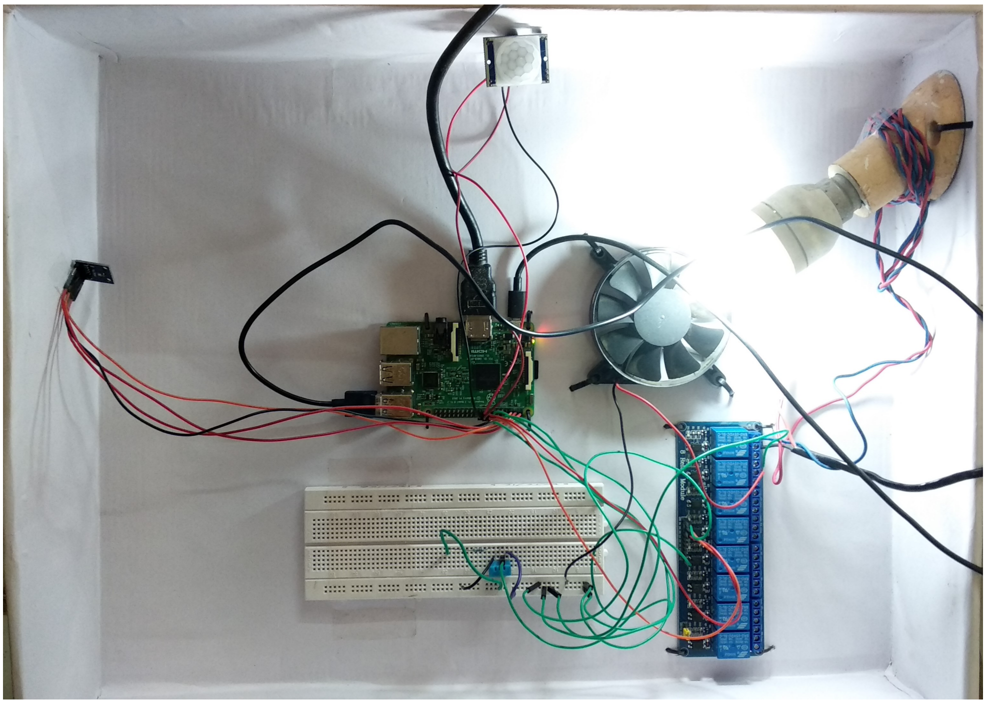


Figure 5.3: System with Light ON

Figure 5.3 shows the light bulb being turned on when the PIR sensor detects motion and the value sensed by the Luminosity sensor goes below the threshold value.

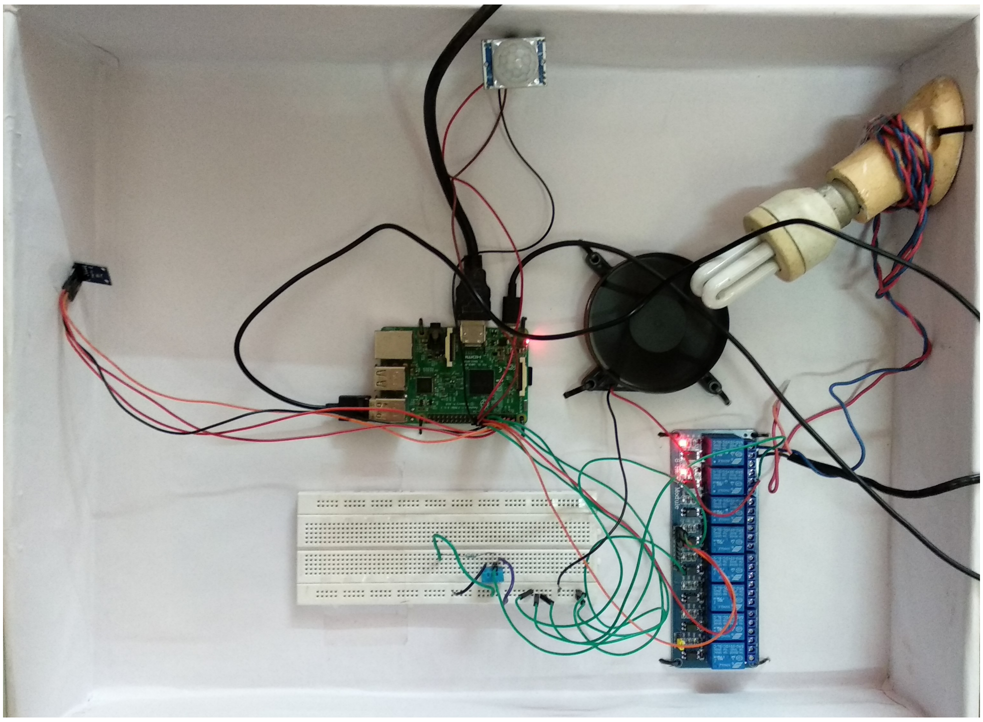


Figure 5.4: System with Fan ON

Figure 5.4 shows the fan being turned on when the PIR sensor detects motion and the value sensed by the Temperature and Humidity sensor goes beyond the threshold value.

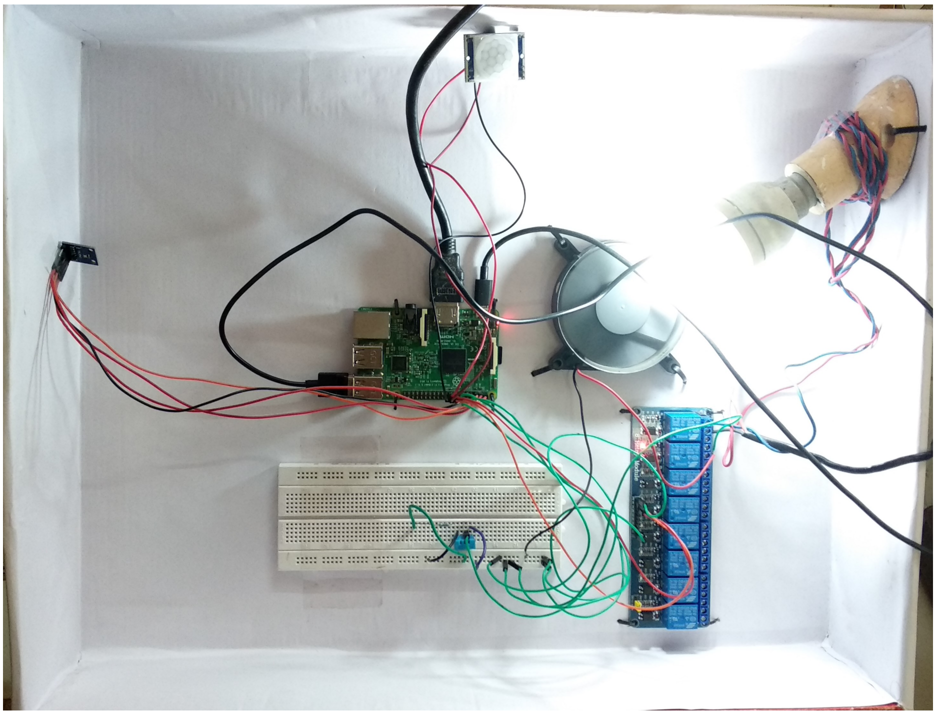


Figure 5.5: System with Light and Fan ON

Figure 5.5 shows the light bulb and fan being turned on when the PIR sensor detects motion and the value sensed by the Luminosity sensor goes below the threshold value and the value sensed by the Temperature and Humidity sensor goes beyond the threshold value respectively.

```
pi@raspberrypi:~/Desktop/Model $ python3 Final_Model.py
Web3 connection:  True
PIR Value:  0
Temperature DHT11:  27.0
Humidity DHT11:  87.0
Lux Value:  0
Lamp action:  0
Fan action:  0
-------------------------
PIR Value:  0
Temperature DHT11:  28.0
Humidity DHT11:  88.0
Lux Value:  63
Lamp action:  0
Fan action:  0
-------------------------
PIR Value:  1
Temperature DHT11:  28.0
Humidity DHT11:  88.0
Lux Value:  54
Lamp action:  1
Fan action:  0
-------------------------
PIR Value:  0
Temperature DHT11:  28.0
Humidity DHT11:  88.0
Lux Value:  106
Lamp action:  0
Fan action:  0
-------------------------
PIR Value:  1
Temperature DHT11:  28.0
Humidity DHT11:  88.0
Lux Value:  63
Lamp action:  1
Fan action:  0
-------------------------
```

Figure 5.6: Output from the IoT System

Figure 5.6 shows the sensor values from the IoT system as well as the actions taken by it i.e. switching ON/OFF of the light bulb and fan.

Figure 5.7: Starting the miner

Figure 5.7 shows the Geth server of the miner being up-and-ready to accept connections from local/remote nodes and miners.

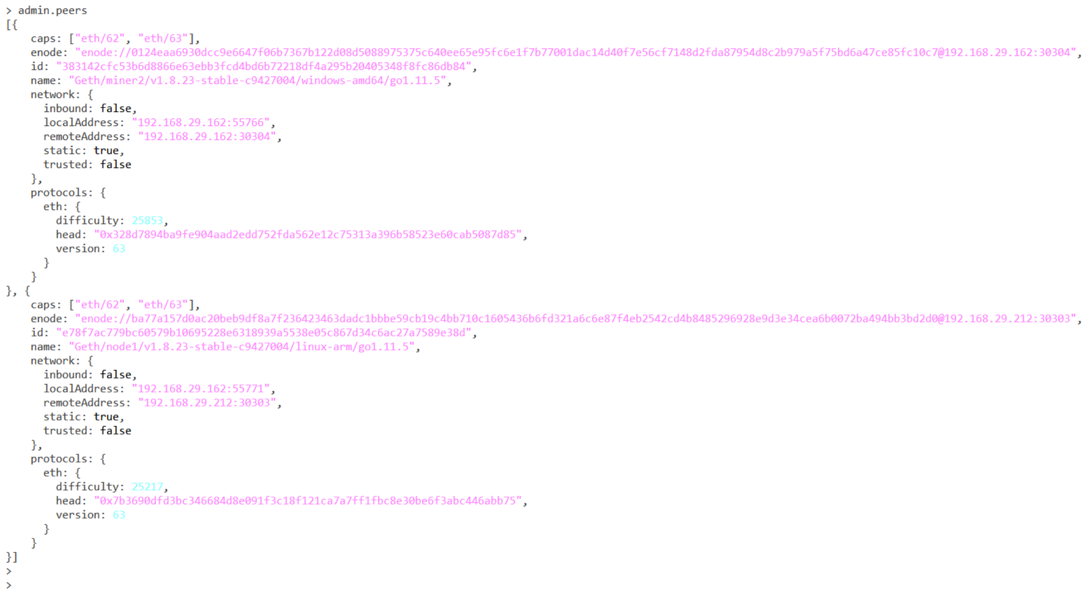


Figure 5.8: Geth console of the Miner

Figure 5.8 shows that the miner is paired with the node and other miners identified by their IP addresses and Port numbers. This shows that the Node and the Miners are now connected with each other.

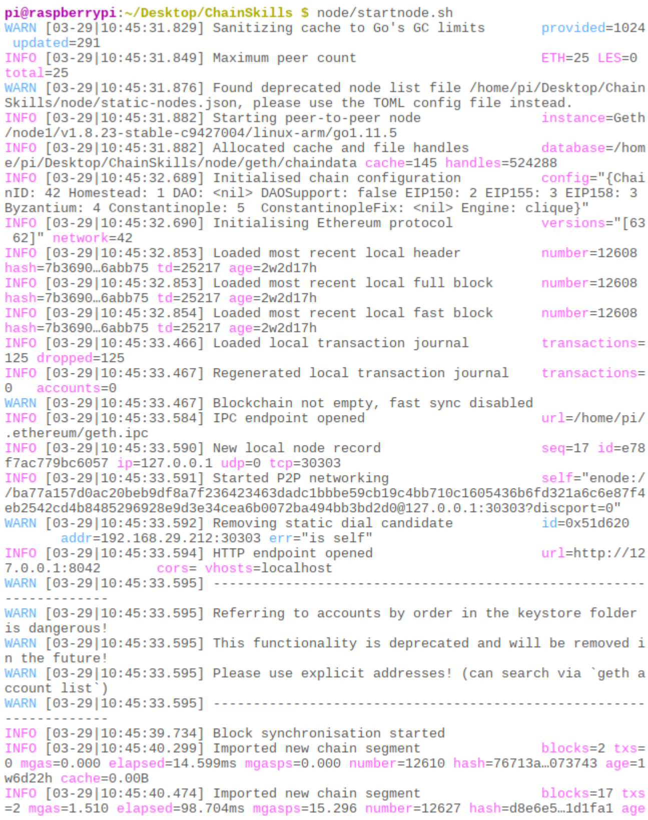


Figure 5.9: Starting the Node

Figure 5.9 shows that the node i.e. Raspberry Pi gets connected with the Geth server.

```
pi@raspberrypi:~ $ geth attach
WARN [03-29|10:58:21.029] Sanitizing cache to Go's GC limits       provided=1024
 updated=291
Welcome to the Geth JavaScript console!

instance: Geth/node1/v1.8.23-stable-c9427004/linux-arm/go1.11.5
coinbase: 0x035b4cb072c97995e07f1f045ab85d8b3fb90730
at block: 13176 (Sun, 29 Mar 2020 10:58:21 IST)
 datadir: /home/pi/Desktop/ChainSkills/node
 modules: admin:1.0 clique:1.0 debug:1.0 eth:1.0 miner:1.0 net:1.0 personal:1.0
rpc:1.0 txpool:1.0 web3:1.0

> admin.peers
[{
    caps: ["eth/62", "eth/63"],
    enode: "enode://81f79fb3ad84032e118e1a2dfaf1ddfe60066c1d7abfa34413c769c04c9a
404f92ed7c643289a745069faef71a5075524559f5eebd3178fe62b712e5129f891d@192.168.29.
162:55771",
    id: "7b6ec4798f6410d73662a317df02c99826f1f63112cf6725ece69f58655bcee2",
    name: "Geth/miner1/v1.8.23-stable-c9427004/windows-amd64/go1.11.5",
    network: {
      inbound: true,
      localAddress: "192.168.29.212:30303",
      remoteAddress: "192.168.29.162:55771",
      static: false,
      trusted: false
    },
    protocols: {
      eth: {
        difficulty: 26355,
        head: "0xc39b99c3ed03e3f137e9ac9c5fb268b4650162bc9ed832e924105d2e5b2d548
4",
        version: 63
      }
    }
}]
>
> 
```

Figure 5.10: Geth console of Node

Figure 5.10 shows that the node is paired with the miners identified by their IP addresses and Port numbers. This shows that the Node and the Miners are now connected with each other.

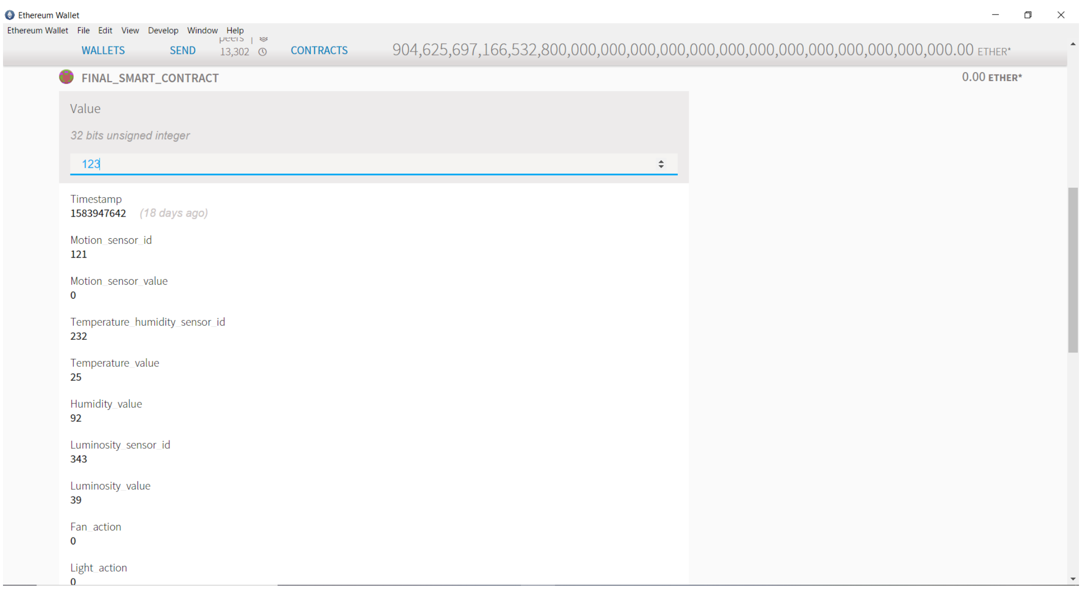


Figure 5.11: Ethereum Wallet showing the Smart Contract values

Figure 5.11 shows the values being stored on the Blockchain network with the help of Smart Contract.

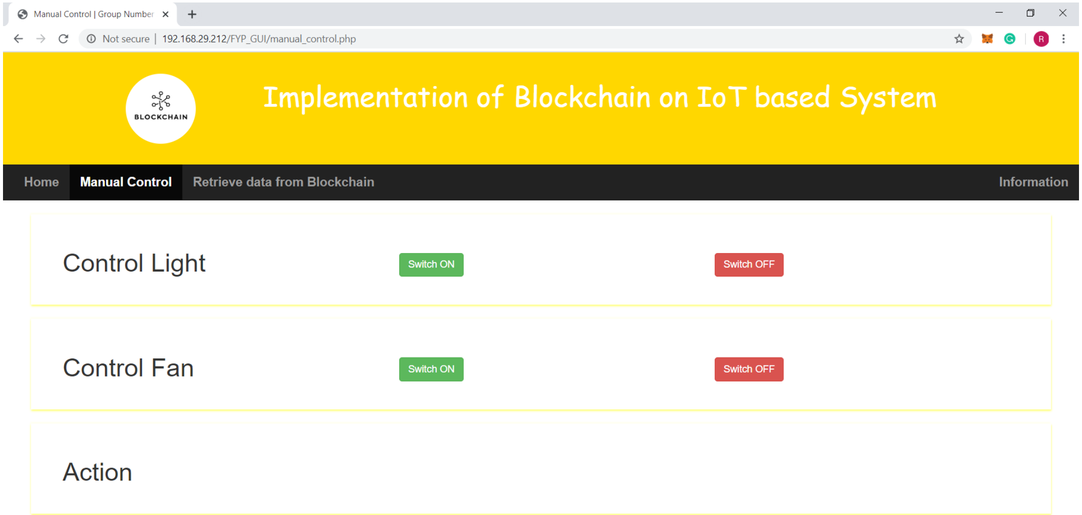


Figure 5.12: GUI - Manual Control

The appliances (i.e. light bulb and fan) can be controlled manually as shown in the figure 5.12 above.

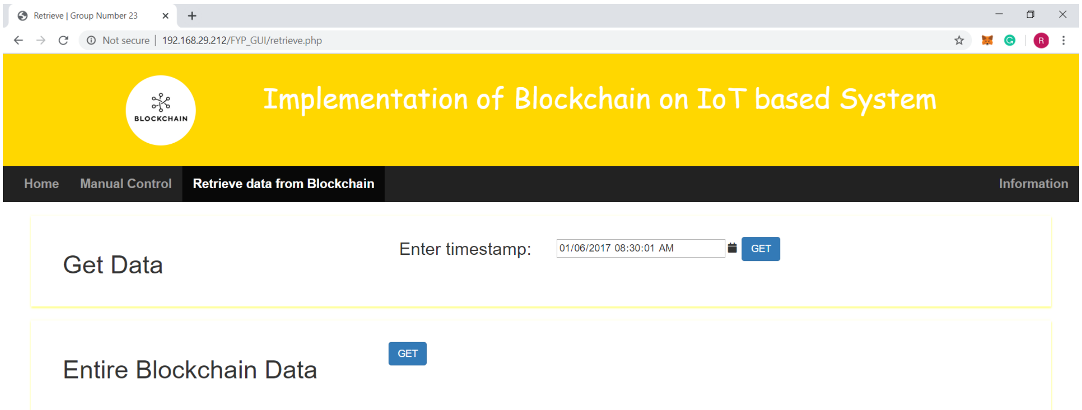


Figure 5.13: GUI - Retrieve Data from Blockchain

The values stored on the Blockchain network can be retrieved using the GUI as shown in the figure 5.13 above.

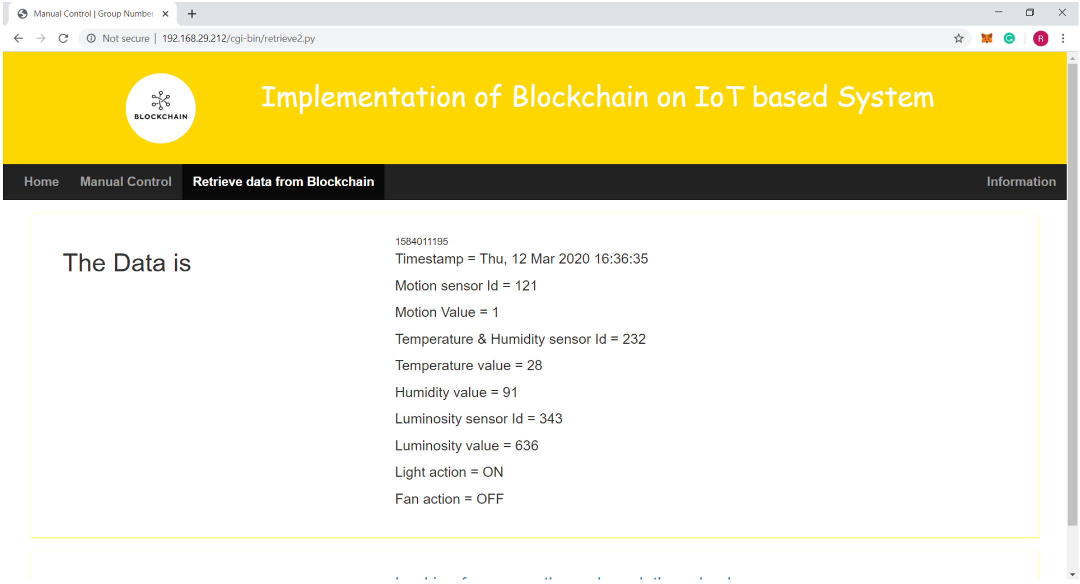
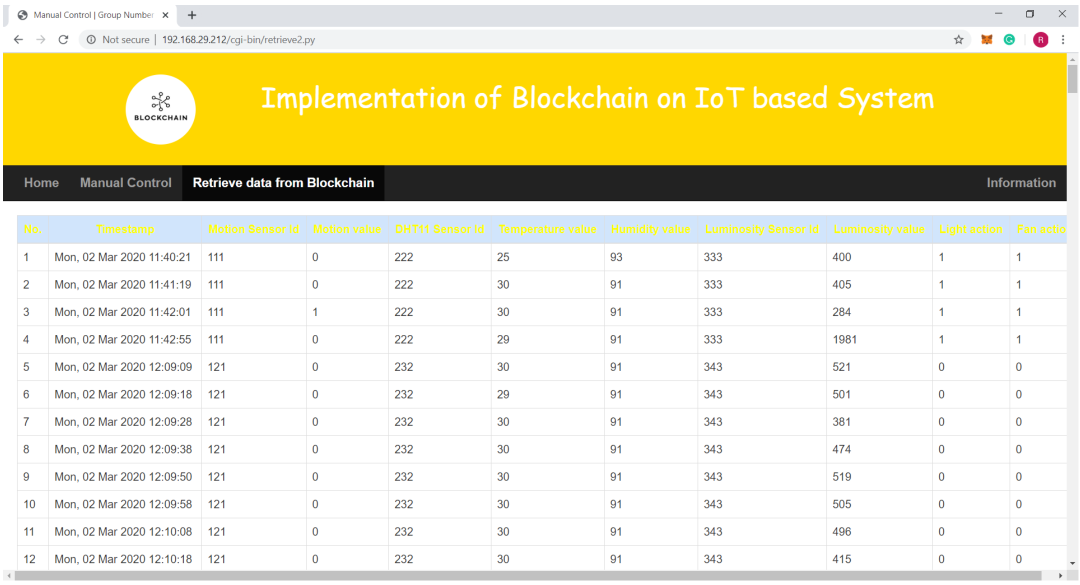


Figure 5.14: GUI - Get Timestamp Data

A single record from the Blockchain network can be retrieved by specifying the timestamp as shown in the figure 5.14 above.



No.	Timestamp	Motion Sensor Id	Motion value	DHT11 Sensor Id	Temperature value	Humidity value	Luminosity Sensor Id	Luminosity value	Light action	Fan actio
1	Mon, 02 Mar 2020 11:40:21	111	0	222	25	93	333	400	1	1
2	Mon, 02 Mar 2020 11:41:19	111	0	222	30	91	333	405	1	1
3	Mon, 02 Mar 2020 11:42:01	111	1	222	30	91	333	284	1	1
4	Mon, 02 Mar 2020 11:42:55	111	0	222	29	91	333	1981	1	1
5	Mon, 02 Mar 2020 12:09:09	121	0	232	30	91	343	521	0	0
6	Mon, 02 Mar 2020 12:09:18	121	0	232	29	91	343	501	0	0
7	Mon, 02 Mar 2020 12:09:28	121	0	232	30	91	343	381	0	0
8	Mon, 02 Mar 2020 12:09:38	121	0	232	30	91	343	474	0	0
9	Mon, 02 Mar 2020 12:09:50	121	0	232	30	91	343	519	0	0
10	Mon, 02 Mar 2020 12:09:58	121	0	232	30	91	343	505	0	0
11	Mon, 02 Mar 2020 12:10:08	121	0	232	30	91	343	496	0	0
12	Mon, 02 Mar 2020 12:10:18	121	0	232	30	91	343	415	0	0

Figure 5.15: GUI - Entire Blockchain Data

The entire data stored on the Blockchain network can be retrieved as shown in the figure 5.15 above.

5.3 Sample Code

Algorithm 1: To decide action for Light and Fan

```
Result: Action for Light and Fan
motion_val ← get_motion_sensor_value()
temperature_val ← get_temperature_sensor_value()
lux_val ← get_luminosity_sensor_value()
light_threshold ← 1000
temp_threshold ← 28
while True do
    if motion_val = 1 then
        if temp_val ≤ temp_threshold then
            fan_OFF()
            fan_action ← 0
        else
            fan_ON()
            fan_action ← 1
        end
        if lux_val ≤ light_threshold then
            light_ON()
            light_action ← 1
        else
            light_OFF()
            light_action ← 0
        end
    else
        light_OFF()
        light_action ← 0
        fan_OFF()
        fan_action ← 0
    end
end
```

Algorithm 2: To retrieve IoT data from Blockchain network

```
Result: IoT data from Blockchain network
if timestamp ← enter_timestamp() then
    while next_value != NULL do
        if timestamp = current_value_timestamp then
            print(timestamp)
            print(motion_sensor_id)
            print(motion_sensor_value)
            print(temperature_humidity_sensor_id)
            print(temperature_sensor_value)
            print(humidity_sensor_value)
            print(luminosity_sensor_id)
            print(luminosity_sensor_value)
            print(light_action)
            print(fan_action)
        end
    end
end
if get_enitre_blockchain_data then
    while next_value != NULL do
        print(timestamp)
        print(motion_sensor_id)
        print(motion_sensor_value)
        print(temperature_humidity_sensor_id)
        print(temperature_sensor_value)
        print(humidity_sensor_value)
        print(luminosity_sensor_id)
        print(luminosity_sensor_value)
        print(light_action)
        print(fan_action)
    end
end
```

5.4 Testing

5.4.1 Unit Testing

In Unit Testing, we begin by testing the sensors one by one to check if they are functioning properly. We test if the DHT11 sensor is providing correct values of temperature and humidity. We test if the PIR Sensor Module is detecting motion accurately. Also, we test if the TSL2561 sensor is providing correct values of luminosity. We also test if the light and fan are working properly.

5.4.2 Integration Testing

In Integration Testing, we test if the sensors are working properly in cohesion. If any motion is detected by the PIR sensor, then the DHT11 sensor should sense the temperature and humidity values, and the TSL2561 sensor should sense the luminosity value. We also test whether the light and fan are controlled properly based on the comparison between the sensor values and the thresholds.

5.4.3 System Testing

In System Testing, we test the system as a whole. We test whether the values obtained from the sensors along with the actions taken are getting recorded properly on the Blockchain network for the exact timestamp when the IoT data was recorded. We also test whether we are able to retrieve the entire data recorded on the Blockchain network or based on a specific timestamp value.

Chapter 6

Conclusion & Future Scope

In this report, the IoT based system, i.e. the Smart Laboratory extends home automation technology to college laboratories which allow controlling the appliances. It thereby reduces the amount of power consumed throughout the day and helps in managing energy efficiently. Also, the automation of the laboratory leads to improved organization and reduces staff involvement in simple administration tasks.

Since the security and privacy of the IoT data as well as the vulnerability of the IoT system is a huge concern, we implement Blockchain technology as a solution. The IoT data is stored and recorded on a private Ethereum blockchain network as transactions with the help of a Smart Contract using the Proof-of-Authority consensus mechanism. The immutability and trustlessness of the Blockchain network ensure tamperproof storage of the IoT data. The data can also be retrieved by interacting with the Ethereum Blockchain network with the help of the Smart Contract using Web3 technology.

From this project, we got to learn two of the latest technologies i.e. Internet of Things (IoT) and Blockchain. By integrating both of them, we suggest Blockchain as a solution to insecure and vulnerable IoT ecosystems. Blockchain offers a scalable and decentralized environment to IoT devices, platforms, and applications.

By implementing the Smart Laboratory system, we were able to reduce the power consumed throughout the day and manage energy efficiently. Moreover, by implementing Blockchain on the IoT based system, the privacy and security of the IoT data are maintained.

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Appendix A : Timeline Chart

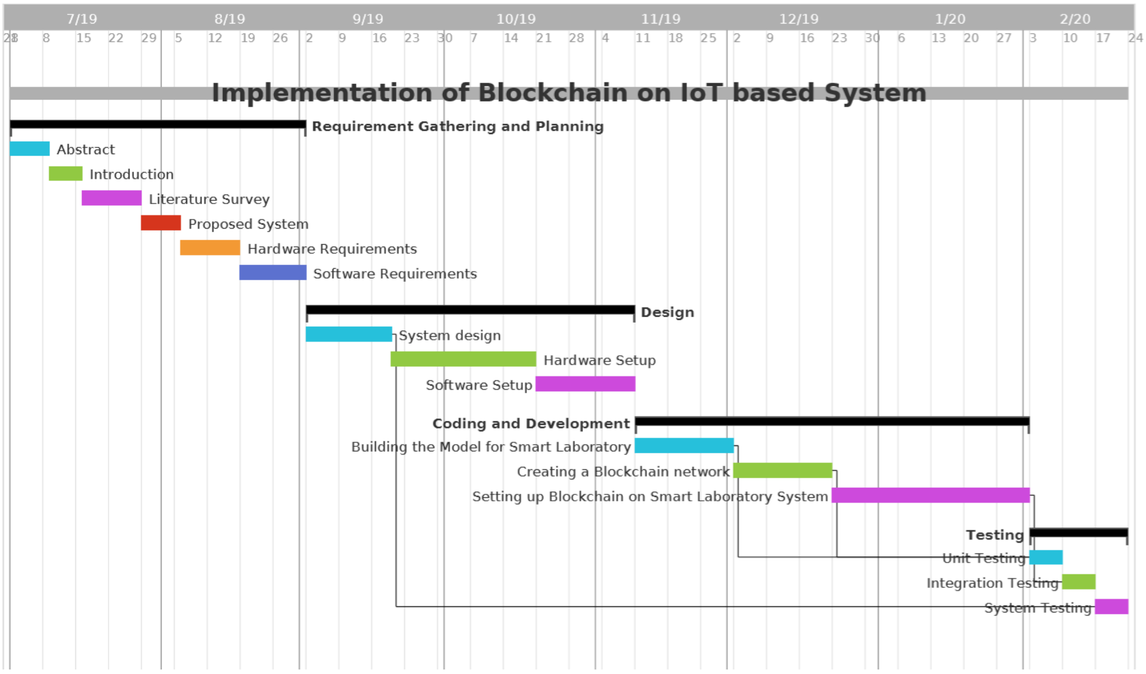

Figure 6.1: Timeline Chart

Appendix B : Publication Details

Amruta N. Banagar , Rajshankar Khattar, 2020, IoT based Smart Laboratory System, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) Volume 09, Issue 01 (January 2020),