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A Blockchain Enabled IoT Infrastructure for Power Redistribution

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CERTIFICATE

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They have successfully and satisfactorily completed their **Project Exam** in all respects. We, certify that the work is comprehensive, complete and fit for evaluation.

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Abstract

With the working class of India increasing everyday, and their living standards improving, our country faces high surge in demand of power supply. One of the major challenge thus is to smartly distribute the energy in case of shortages or limited supplies. We can therefore think of a smart society where the the electic inverter smartly distributes the energy in case of outage of main power supply. Given the varying need of power supply each home may have, along with the power needs of the society as a whole (elevators, water pumps, lights) which maybe considered as of more priority, a smart network of power distribution need to be formed.

The solution this report discuss is to enable the appliances and billing meters with IoT. This will help the appliances to directly communicate with the smart grid for power requirements in case of failure or any other emergency. One major challenge that still exists is of smart billing, of individual homes and society as a whole. What if a resident is also able to request some power units in exchange of some power coins in real time?

Transactive energy is one of the key developments in the development of smart grids, as distributed energy resources, such as smart meters, move toward Internet-of-Things (IoT) devices that allow prosumers to trade energy directly amongst each other without the need for a centralised third party. Major utilities companies are planning a large-scale deployment and are looking into technical solutions because of the anticipated advantages in terms of cost-effectiveness. This study offers a blockchain-based smart contract infrastructure which allowes to ask for energy in exchange of power coins, one small step towards the big dream of transactive energy. Energy transactions are kept on the blockchain, which offers higher guarantees against manipulation because to its high replication level. Energy auctions are conducted in accordance with open guidelines implemented as smart contracts, making them public to all parties involved. By temporarily barring prosumers who are exposed from smart metres and updating their devices as soon as security fixes are made available, threats resulting from known smart metre vulnerabilities are reduced.

Table of Contents

List of Figures

List of Abbreviations

AMI	Advanced Metering Infrastructure
API	Application programming interface
BMS	Battery Monitoring System
DA	Distribution Automation
DEX	Decentralized Exchange
IDE	Integrated Development Environment
IIoT	Industrial Internet of Things
IoE	Internet of Everything
IoT	Internet of Things
IP	Internet Protocol
LAN	Local Area Network
M2M	Machine-to-Machine Communication
PaaS	Platform as a service
PAN	Personal Area Network
RFID	Radio Frequency Identification
SCADA	Supervisory Control and Data Acquisition
SIP	System in Package
SoC	System on Chip
WAN	Wide Area Network

Chapter 1
Introduction

1.1 Overview of Blockchain 1.0

A paper titled ”Bitcoin: A Peer-to-Peer Electronic Cash System” was published in 2008 by an individual or group writing under the name Satoshi Nakamoto. This study suggested a peer-to-peer electronic cash system that would allow internet payments to be made directly from one party to another without having to go through a banking institution. This concept was first realised in Bitcoin. The term ”cryptocurrency” now refers to all networks and mediums of exchange that utilise cryptography to protect transactions, as opposed to systems in which transactions are routed through a centralised trusted institution. Bitcoin was therefore the very first cryptocurrency, with its value fluctuating with the simple demand and supply cycle. Because the first paper's author wished to remain unknown, no one knows who Satoshi Nakamoto is today. A few months later, an open-source application was released that began with the Genesis block (the very first block) of 50 coins and implemented the new protocol (here protocol refers to the software which transfers the money between two parties in the system. It is also the one thing to whom the users trust in the system). Anyone can download and run this open-source programme to join the bitcoin peer-to-peer network Fig. 1.1. The popularity of the Bitcoin has never ceased to increase since then [10].

Bitcoin arranges transactions into a constrained-size structure called blocks, which all have the same timestamp. The network's nodes (any computer system with certain requirements of computational power can become a node and be a part of the network) [11]are in charge of connecting the blocks in chronological order, with each block holding the hash (cryptographic address) of the preceding block to form a ‘Blockchain’ (Fig. 1.2). As a result, the blockchain structure is able to keep a reliable and auditable record of all transactions.

This underlying Blockchain technology has drawn a lot of attention from academia and industry due to its potential application opportunities. Bitcoin, the first cryptocurrency, was named the best-performing currency in 2015 and the best-performing commodity in 2016, and has over 400,000 confirmed transactions per day as of January 2021 [12]. Simultaneously, the blockchain technology has been used in a variety of fields,including medical, economics, the Internet of Things, software engineering, and so on. The introduction of Turing-complete programming languages, which allow users to create ‘Smart Contracts‘ (more on this in later sections) that run on the blockchain, signals the beginning of the blockchain 2.0 era.

Traditional business processes have been severely disrupted by blockchains since apps

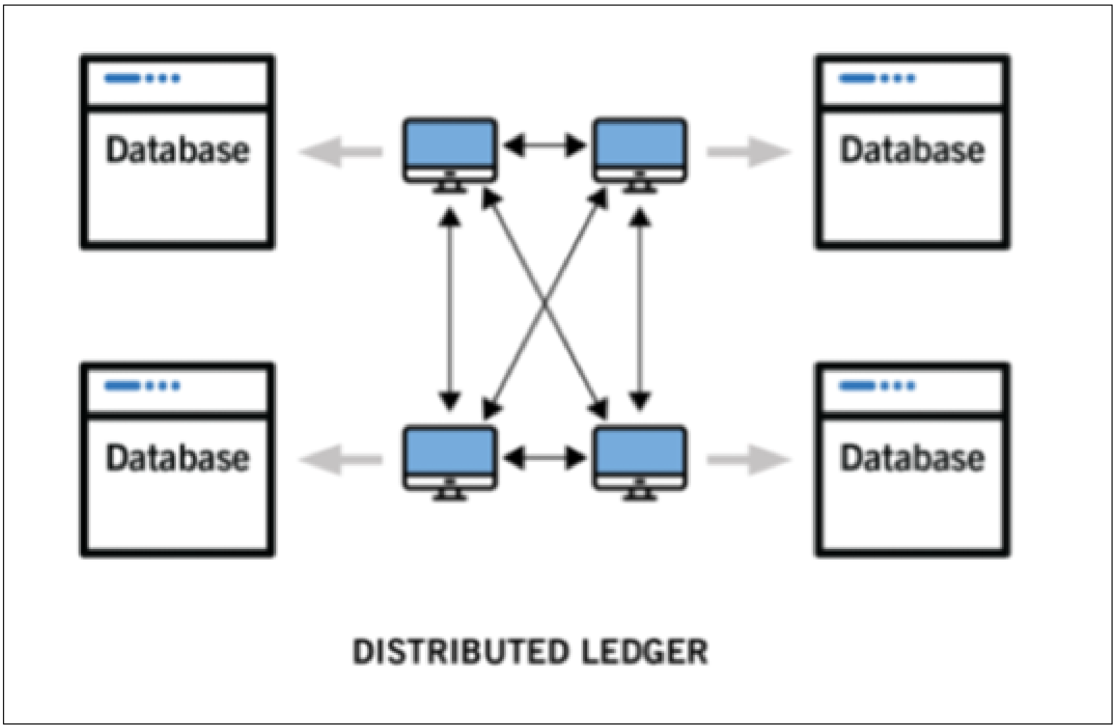

Figure 1.1: Distributed Ledger [1]

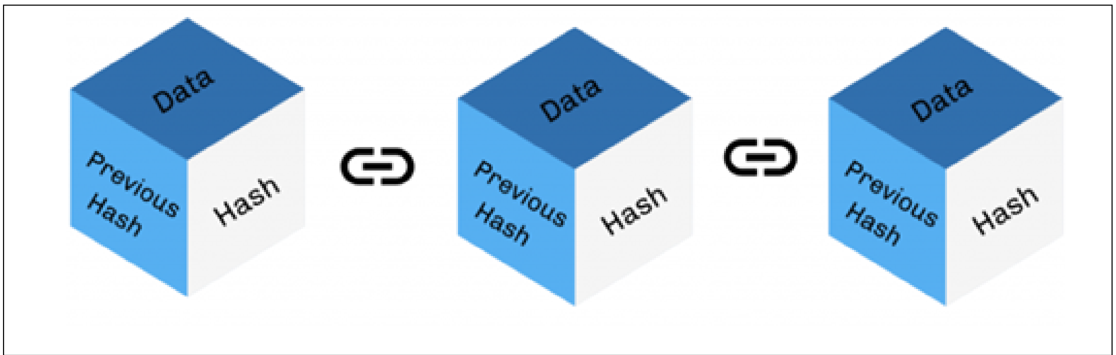

Figure 1.2: Basic Chain Structure [2]

and transactions that previously required centralised architectures or trusted third parties to authenticate them can now operate in a decentralised manner with the same level of assurance. Transparency, robustness, auditability, and security are all fundamental qualities of blockchain architecture and design. This is particularly advantageous in the banking sector, as banks can collaborate on the same blockchain and push their clients' transactions.

1.2 Advantages of Cryptocurrencies

Compared with traditional currency, cryptocurrency has the following characteristics and advantages [12] [13]:

1. Irreversible and traceable. Transfer and payment operations are irreversible usingcryptocurrency. Once the behaviour is completed, it is impossible to withdraw. Inaddition,all user behaviours are traceable, and these behaviours are permanently saved in the blockchain.
2. Decentralized and anonymous. There is no third-party organization involved inthe entire structure of cryptocurrency, nor does it have central management like banks. Inaddition, all user behaviours are anonymous. Hence, according to the transaction information,we cannot obtain the user's real identity.
3. Secure and permissionless. The security of the cryptocurrency is ensured by thepublic key cryptography and the blockchain consensus mechanism, which are hard to bebroken by the criminal. Moreover, there is no need to apply for any authority orpermissionto use cryptocurrency. Users can simply use the cryptocurrency through the relevant clients.
4. Fast and global. Transactions can be completed in only several minutes usingcryptocurrency. Since cryptocurrencies are mostly based on public chains, anyone in theworld can use them. Therefore, the user's geographical location has little impact on thetransaction speed.

1.2.1 Overview of Blockchain 2.0: Ethereum And Smart Contracts

Blockchain technology has progressed through two stages since the inception of the first blockchain system, Bitcoin: blockchain 1.0 and blockchain 2.0. The blockchain technology is mostly used for cryptocurrency at the blockchain 1.0 era. There are many different forms of cryptocurrencies, such as Litecoin, Dogecoin, and so on, in addition to Bitcoin. There are now over 9,749 different types of cryptocurrencies, with a total market valuation of over 2,525 billion US dollars [14].

Cryptocurrency's technology stack may be broken down into two layers: the base decentralised ledger layer and the protocol layer. Bitcoin Wallet, for example, is a cryptocurrency client that operates in the protocol layer to conduct transactions.

Ethereum is a public platform that goes beyond distributed computing. Rather than acting as a huge consensus database, the Ethereum network functions as a single giant consensus computing engine. Its computations are 'Turing-complete,' which means it can calculate anything that any other computer can, but at a far slower rate. The genesis block of Ethereum was released in July 2015, and the network is now one of the most popular platforms for permissionless smart contracts. Smart contracts allow developers to design a wide range of applications. A smart contract can be thought of as a simple DAPP (decentralized application). Ethereum is a typical system of blockchain 2.0. Each Ethereum node runs an EVM (Ethereum Virtual Machine) that executes smart contracts [12]. Besides Ethereum, several other blockchain systems also support smart contracts. In Ethereum, developers can use a variety of programming languages to develop smart contracts, such as Solidity (the recommended language), Serpent, and LLL. Since these languages are Turing-complete, smart contracts can achieve rich functions. Fig.1.3 shows the process of smart contracts' development, deployment and interaction.

1.3 Categories of Blockchain

PUBLIC BLOCKCHAINS: Permissionless or public blockchains are those in which anyone can join the network and act as a verifier without first acquiring permission to do so. Because anyone can join, uniqueincentive mechanisms are required to encourage verifiers to participate. It has thebenefit of being able to handle both anonymous and pseudo-anonymous actors.Permissionless blockchains include Bitcoin and Ethereum.
PRIVATE BLOCKCHAINS: The other option is the private or permissioned blockchain, which requires explicit permission from an authority to become a system verifier. Permissioned blockchains are designed with a specific purpose in mind, and can thus be made to work with existing applications (financial or otherwise) [11]
Scalability is one of the corebenefits of a permissioned blockchain. The data is saved on every computer in the network in a permissionless blockchain, and all nodes validate all transactions. Only a minimal number of pre-selected players are required to operate in a permissioned blockchain. Because of the smaller number of participants, it is much easier for a group of users to collaborate and alter the rules, or revert transactions and that is why only trusted parties should be given a permission to act as verifiers.Examples of permissioned blockchainsinclude Eris, Hyperledger, and Ripple [13].
A new category of blockchain, called **HYBRID BLOCKCHAIN**, is also being developed. It will have a mix of features of both public and private blockchains. It can be considered as an open ledger but with access to only a certain number of nodes [15].

1.4 Overview of Internet of Things

The Internet of Things (IoT) has its name in one of the most life changing technologies of the era. It's a network of interconnected, internet-connected objects that can gather and transmit data without the need for human interaction across a wireless network. It is an evolution from the internet of computers to the embedded physical systems called 'things' which acts like a simple computer with specific purpose. But how do some high-tech objects talking with each other can contribute our life? Is it safe to let these devices operate without human intervention? Let us discuss.
The possibilities for personal or professional development are limitless. A connected medical device, a biochip transponder (think livestock), a solar panel, a connected automobile with sensors that alert the driver to a variety of potential issues (fuel, tyre pressure, needed maintenance, and more), or any object equipped with sensors that has the ability to gather and transfer data over a network can all be considered a 'thing.' They help in various purposes like tracking packages, monitoring machines, measurements, etc. Depending on the type of this things, different ways of connecting them to IOT system are used.
They are capable of collecting this data mainly because of sensors and devices embedded in them. They collect data as per their purpose and type. Here multiple sensors can be a part of a single device. For example, various drones can have sensors to track their location, whether, height etc. And can communicate with other drones for a safe flight. The things can be connected to the cloud through Wi-Fi, Bluetooth or directly through internet. Every means of communication has its own procedures, advantages and trade-offs.

In home automation the devices which can controls switches and different appliances are used. In Cooling Systems, the data collected will the temperatures of various components of the machine at different time and their heating rates. All this data is sent to the associat-ed software in the cloudto perform various operations ranging from data analytics, machine learning, triggering APIs etc. as per the requirement.The APIs then triggering other applications and their output can trigger state change in the current device. For e.g., turn of the AC after the required temperature is hit, and turn it on again if required. Or to slow down a drone if the air space is already crowded and there are other drones in the locality. A general IoT platform can be seen in Figure 1.4 [16].
It's possible that the system may not be totally automated. The user has the ability to intervene and change the device's condition. So, here's where the interface comes in, allowing the user to engage with the system manually. A mobile application or direct switches on devices can be used as this interface.The apps and software designed for this interfacing may allow users to interact via touch, voice commands, hand gestures and a lot more.

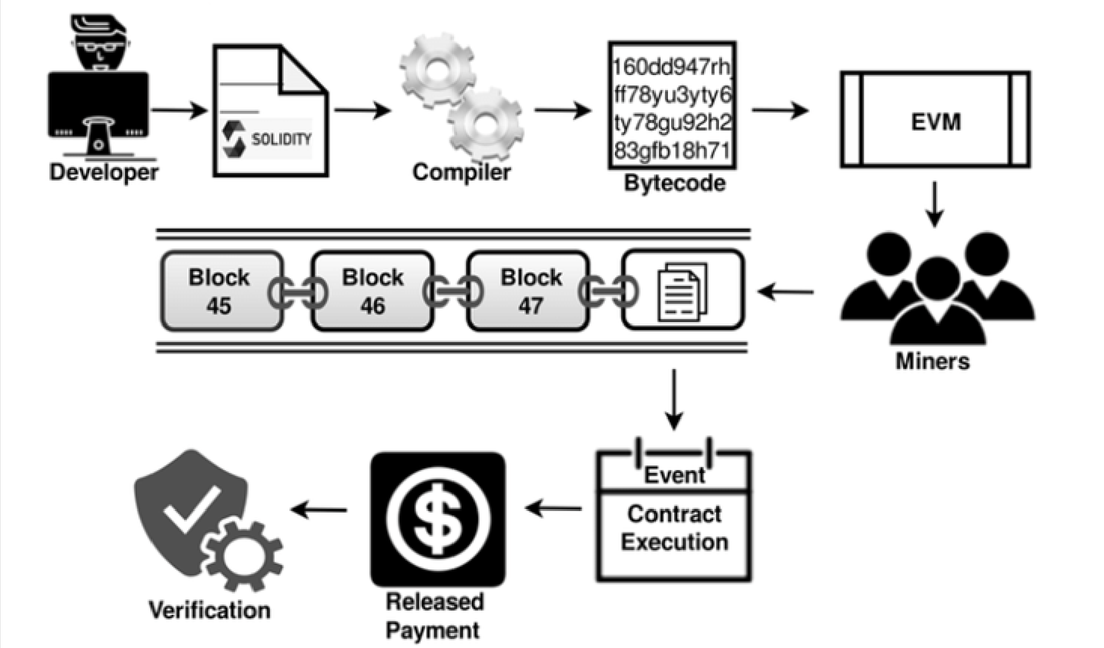

Figure 1.3: Illustrating an IoT platform [3]

Organisations, businesses and corporates are currently inspired by IoT and the potential for increased revenue, lower operational costs, and improved efficiencies. Regulatory compliance is also a driving force for businesses. IoT device installations give the data and insights required to optimise workflows, visualise usage patterns, automate operations, meet compliance needs, and compete more effectively in a changing business environment, regardless of the reasons. Businesses who can take use of the data created by the Internet of Things will thrive in the future. They will gain a huge competitive edge as a result of this [16]. Avery amount of money and resources are being spent in the RD of this technology as more and more people get to know about the use cases.

1.5 Overview of Blockchain-Iot System

But why is IoT such a big deal? It has been around for more than decade now, but still we can't see it around very often. Even keeping the high costs aside, they are not much visible even in big corporates. Some of the main reasons behind this are [17]:

1. Privacy: Imagine if the data of an IoT enabled device in your home gets leaked. It may have very private information like the pictures of your house, recordings of your conversations, fingerprints and many more depending on the kind of device. We can't afford to compromise this kind of data.Recently Amazon launched an inside home drone, but was harshly criticised as it can put the customer's personal data in jeopardy. Even if the data only remains to Amazon, we will never be comfortable to share the data to a third party as we will never know the intentions.

2. Security: Other than personal privacy, life and economic security may also be at risk in case of IoT enabled temperature management systems, smart locks etc. where the costs of even a small malfunctioning is high. Risking matters of national security, military drones or nuclear equipment are out of question.

3. Centralised Architecture: Today, the IoT devices work on a 'Centralised architecture', meaning that the devices are connected to a central network owner. That owner stores and manages the data and the code. These are mostly cloud-based storage facilities like Google Cloud, Amazon Web Services, Microsoft Azure etc. If a consumer buys three Google smart devices, two Samsung smart devices, and one Apple smart devices, without shared standards, these devices cannot communicate with each other.

4. Bad Incentives: Consumers have demonstrated little enthusiasm in switching to smart gadgets because the benefits do not outweigh the expenditures, to put it bluntly (i.e. low ROI). The effort to distribute and install these gadgets in the actual world has not been done by businesses (high costs, unclear ROI).

The solution is a highly secure, 'Decentralised architecture' that everyone trusts. A database that is capable of self-sustaining, executing codes and triggering state changes, without any doubt on reliability. A database where data is stored in the form of hashes so that no one knows the true identity of the user and is never exposed to a third party without the permission of the one who generated data and gave the commands. Blockchain provides with exactly the same. With the inception of Smart Contracts, Blockchain 2.0, Blockchain 3.0, it has provided with exactly what IoT devices needed [17]. The new evolved blockchains are capable of triggering events and running self-sustaining code very efficiently and require little to no intervention from humans and still can be trusted because of highly secure and decentralised system. Blockchain, in future, can act as a global truth that just everyone believes in.
An intensive amount of research is being carried on both of these technologies and how they can both work together. IBM is leading the way with its various projects and initiatives. They introduced the first implementation of IoT in Blockchain using Ethereum. We will study more on Ethereum in the later section of this report. They have also developed highly efficient frameworks for the smart integration of blockchain with micro controllers, sensors and small devices. Various other architectures are also in the making. A whole separate blockchain "Helium" also came into picture, specially designed for IoT architectures. The availability of Permissioned and Hybrid Blockchains, in which data can be accessed by only a specific group of people or we can say computer nodes, is also being leveraged. We will study more on these concepts in later sections. [12]

1.6 Smart Grids

Smart grid (SG), an evolving concept in the modern power infrastructure, enables the two-way flow of electricity and data between the peers within the electricity system networks (ESN) and its clusters. The self-healing capabilities of SG allow the peers to become active partakers in ESN. In general, the SG is intended to replace the fossil fuel-rich conventional grid with the distributed energy resources (DER) and pools numerous existing and emerging know-hows like information and digital communications technologies together to manage countless operations. With this, the SG will able to "detect, react, and pro-act" to changes in usage and address multiple issues, thereby ensuring timely grid operations.
However, the "detect, react, and pro-act" features in DER-based SG can only be accomplished at the fullest level with the use of technologies like Artificial Intelligence (AI), the Internet of Things (IoT), and the Blockchain. The techniques associated with AI include fuzzy logic, knowledge-based systems, and neural networks. They have brought advances in controlling DER-based SG. The IoT and Blockchain have also enabled various services like data sensing, data storage, secured, transparent, and traceable digital transactions among ESN peers and its clusters. These promising technologies have gone through fast technological evolution in the past decade, and their applications have increased rapidly in ESN. Hence, this study discusses the SG and applications of AI, IoT, and Blockchain.
First, a comprehensive survey of the DER, power electronics components and their control, electric vehicles (EVs) as load components, and communication and cybersecurity issues are carried out. Second, the role played by AI-based analytics, IoT components along with energy internet architecture, and the Blockchain assistance in improving SG services are thoroughly discussed. This study revealed that AI, IoT, and Blockchain provide automated services to peers by monitoring real-time information about the ESN, thereby enhancing reliability, availability, resilience, stability, security, and sustainability.
SG is a collection of technology and services that make up an intelligent digital electric grid. The technologies and services utilised in SG differ depending on the load type provided and ESN type (such as residential, commercial, and industrial), and they are clearly displayed in Figure 1.4.

1.7 Motivation

As energy production and distribution have evolved, the concern was how to make appliances and grids smart enough to not waste energy with minimal human intervention. This is where we imagine integrating it with Internet of Things, another revolutionary

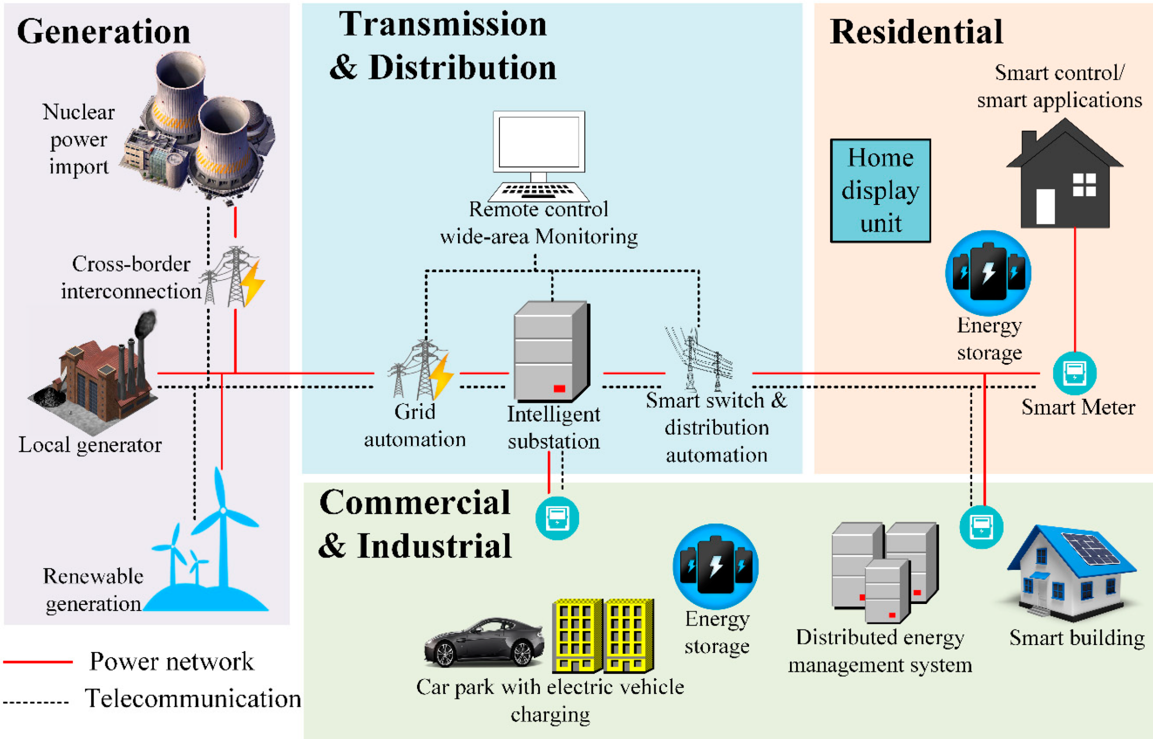

Figure 1.4: Smart grid services conceptual representation highlights [4]

technology that can make everyday objects "smart" and "able to think and communicate." It expanded internet use beyond PCs.
Another proposal was to link money with technology to eliminate the need for humans to read metres and bill. Cryptocurrencies, as "coded currency," seem like the greatest option. Residents can use "power coins" to buy power units instantly, pre-paid, and without human intervention. Ethereum revealed blockchain's potential beyond currency.
Blockchain and IoT could revolutionise this decade. As engineers, we can't miss these technologies' fundamental changes to technology.

1.8 Objective

The objective of the report is to explore the potential of using blockchain, IoT, and Arduino technology in developing a smart grid system, understand the current state of smart grid technology and identify the key challenges facing the industry. We aim to discuss and develop efficient models integrating blockchain and IoT for the making of a reliable smart grid. Our key objectives are is to also

- Focus on the benefits such as increased security, transparency, and the availability of transactive energy via power coins, that are gained by using blockchain in our model.

- Smart distribution of power when there is a shortage of it, on the basis of defined priority.
- Give power to a customer when asked for in exchange of ether coins (power coins in real life implementation)

1.9 Organisation of the report

Until now we had the introduction of both IoT and Blockchain, justifying the hype around them and why we are thinking of developing a system of both of them working together. The report will further proceed as follows:

CHAPTER 2: LITERATURE SURVEY

The chapter discusses various models that integrate the above technologies in effective ways. The study involves Distributed Energy Resources and the Application of AI, IoT, and Blockchain in Smart Grids, Blockchain Based Metering and Billing System Proposal with Privacy Protection for the Electric Network, Integration of IoT with Smart Grid and some other models worth having a look. [18]

CHAPTER 3: SYSTEM DESCRIPTION AND MODEL

This chapter discusses our model for the integration of the above technologies and the technicalities we have explored. It involves the flow charts of the system and the components required for its implementation. We have also described the working of the model and its whole implementation.

CHAPTER 4: CONCLUSION AND FUTURE SCOPE

The chapter summarises our entire work, including the implementation of model on hardware and software. We have even discussed future possibilities about how to upscale and improve the system.

Chapter 2
Literature Review

2.1 Distributed Energy Resources and Smart Grids

To promote peer engagement in automated transactions is one of SG's key goals. Data and decision-driven by data are required for the construction of an automated distributed energy distribution network. Given that they offer a two-way flow of electricity and the related data, SG offers such data-driven decisions. Due to the intermittent nature of RE and the inclusion of ESS, the SG's intelligence will permit the time-shifting of energy demand .Overall, using SG, the CEG services will be replaced with advanced automation services, control methods, sensors, computer servers for energy transaction record-keeping, power asset management platforms, and many other new and emerging technologies, all of which are anticipated to operate in concert to improve the operation of the power grid for better functionality. To create, deliver, and use energy as reliably and effectively as possible, SG's components will react intelligently and digitally to grid circumstances based on energy demand, supply, and fault occurrences on the system [19].

Additionally, it becomes crucial to guarantee the computational and energy efficiency of the SG operations as it goes through digitization. Computational tools are advised for managing such digital processes. Perhaps one of the most important techniques for gauging the commercial performance of an SG service is rapid computing methodologies. Artificial intelligence (AI) Internet of Things (IoT) , Big Data analytics , machine learning , deep learning , cloud computing , and Blockchain (BC) are just a few examples of the many computational and digital tools that are available today [19]. To design systems that are both energy-efficient and sustainable, these technologies have been cleverly integrated into a variety of applications in networking, manufacturing, building management, transportation, and shipping. We think that these technologies, particularly in the SG operations, can be used in the energy sector.

2.1.1 Application of Internet-of-Things and Energy Internet in Smart Grids

Two further areas where their contributions to SG are fairly significant are IoT and the Energy Internet (EI) . These two ideas are cutting-edge communication concepts. The literature describes the most significant effects on the power market, home appliances, waste management, and smart cities (SC). The "data gathering, transmission, and processing" networks of SG are receiving the IoT gateways. For instance, an IoT gateway

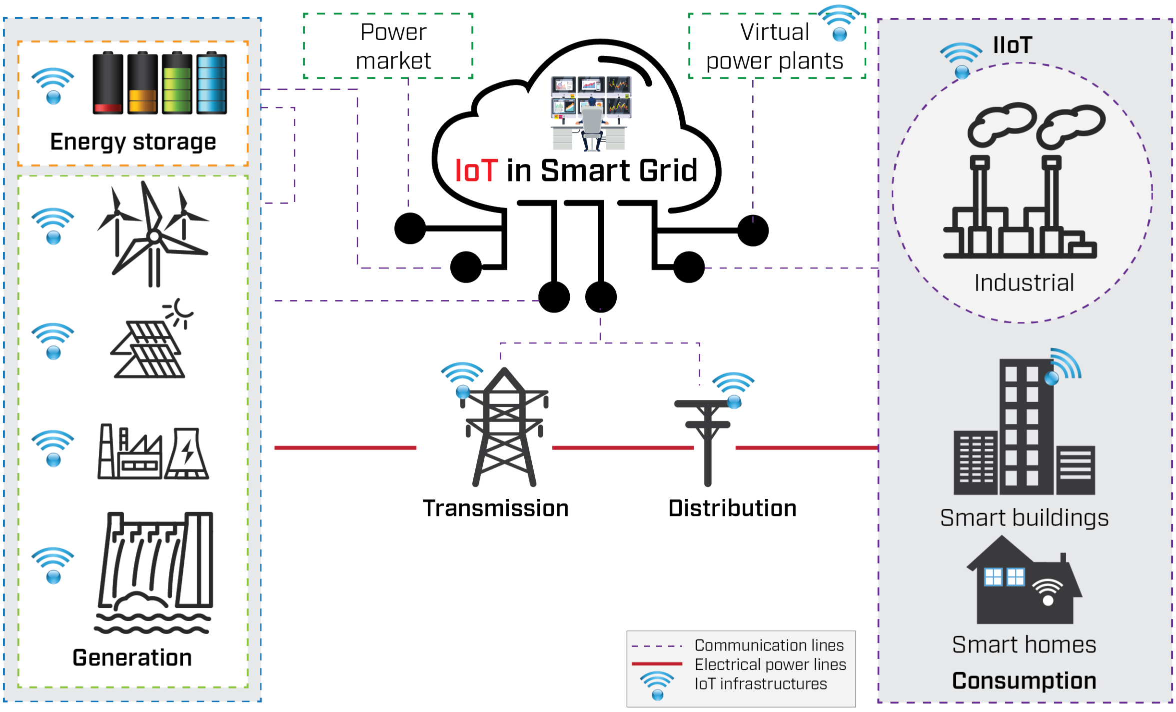

Figure 2.1: IoT Layout in Smart Grid [5]

device enables bidirectional communication (i.e., device-to-gateway and gateway-to-cloud) and data routing over the IoT network . Continuous connectivity and communication, which give equipped devices these capabilities, is one of SG's essential components. The Neighbour Area Network (NAN), Home Area Network (HAN), Wide Area Network (WAN), and Field Area Network (FAN), which are in charge of the roles-based data transfer between utility data centres, substations, and smart metres inside and outside of the ESN, are presented by Kabalci et al. in Reference .

IoT Components in the Context of Smart Grids

Information and operational data are the two types of data that are communicated and transmitted from the SG. Meter readings, utility bills, power rates, marking and pattern data, and consumers' geographical location are all included in the database. The operational information contains the current and voltage levels, condenser banks, fault locations, and energy storage values of a network in real time. The many intelligent devices listed below are made up of SGs by the central and peripheral technologies.

Advanced Sensing and Measurement

Smart metering, which collects information on electricity costs and usage for consumers and utilities, including the period of time and amount of electricity consumed, is a component of SG. This evaluates grid integrity, system safety, and enhanced protective relays .

Automatic Monitoring and Control

In order to help device operators and users recognise and optimise power system modules, actions, and output, SG provides real-time tracking and display of energy system device states and efficiency through linkages and over sizable geographic areas .

Renewable Resources Forecasting

An accurate forecast is required due to the constraints posed by the intermittent nature of renewable energy sources, especially wind and solar. Advanced accurate wind and solar energy availability forecasts can mitigate detrimental effects on the grid's necessary spinning reserves [149].The forecast would bring about a dynamic nature in all power system levels while balancing variable generation by keeping the grid stable .

Information and Communication Technology

All significant power system operational facilities (generating, transmission, and primary distribution substation) are currently connected to the system control centre, which is a component of a traditional power system . However, because this communication is extended beyond distribution networks and provides fast two-way communication flows, the SG becomes dynamically interactive and allows for the exchange of real-time information.

Distribution Automation

Distribution automation (DA) is an automated control approach that improves the performance of energy distribution networks to make the grid more dependable and effective. DA is a crucial element of SG. Incorporating renewable variability, power ramping, and bidirectional power flows into the distribution topology is beneficial . A distribution circuit's many points can sense and monitor voltage and power factors thanks to DA. It initiates automatic control of voltage regulating devices when it detects a divergence from the predicted range . This enables the regulation of voltage to the pre-set value and the injection of reactive power. When a problem or outage occurs, operators, even those in remote locations, can quickly and precisely identify and locate the incident's real-time incidence using DA. As a result, consumers won't need to report problems to the distribution firm, and time will not be wasted on manual fault tracing.

2.2 Blockchain Based Metering and Billing System Proposal

An unchangeable distributed ledger can be used by blockchain technology to keep transactions. The blockchain network's users can conduct transactions without having to have faith in one another or a third party. Cryptographic algorithms can ensure the privacy of personal data. The blockchain system's decentralized architecture will protect the network from cyber threats. IoT devices can be adapted to automatically measure energy use and function with the blockchain network. A solution that is affordable, scalable, safe, and energy-efficient can be created [20].

Blockchain technology aids in maintaining a private, transparent, and secure list of records where the data blocks are connected via cryptographic methods. The ledger is the name of the utilized registry. Ledger is stored on a number of devices that are interconnected through a P2P network. Blockchain technology offers a decentralized system that makes use of distributed devices. Consensus protocols are used to ensure system co-decision without creating an authority. Anyone can join this network without needing authorization or a recommendation. The trust in the validator is minimal since anyone can become a node. To give the system enough security, the number of nodes must be increased. Due to the prize mechanism of adding blocks in these networks, PoW-style high energy consumption consensus procedures are required for fair node selection. As all network users have access to all transaction data, transparency is provided. This kind is unsuitable for the majority of enterprise applications since no portion of the data can be made private. Privacy concerns relating to Bitcoin are examined. The requirements for enterprise applications and privacy protections, however, differ.

IoT (Internet of Things) devices are miniature computers that collect data using a range of sensors. For the most part, these gadgets connect to other gadgets via wireless connections. Because of their limited processing and memory capacities, they are economically priced. Gas, water, and electricity meters started to change into more sophisticated IoT models. Smart meters with internet of things connections can be configured to communicate data almost quickly [20]. Users of the system will be able to effectively monitor the distribution network thanks to this.

2.2.1 Distribution System

The suggested method utilises a decentralised system to address the cost, privacy, and security issues associated with measuring and billing system. The certificate authority is CA. There are four main actors in this system:

- Users: People who want to receive service from distributors.

- Distributors: Energy distribution companies.
- Smart Meter (IoT) Devices: Device with internet connection for sending energy consumption measurements.
- Public Authority (PA): This can be any governmental institution which wants to get the current view of the system, such as the current load of the electricity grid in a neighborhood, district or a city.

2.2.2 The user application process is divided into four stages:

- **Account Creation:** The user sets up a local account on a smart mobile device by installing the system's user interface application. Through the interface, users provide the personal information needed for the service. During this procedure, the application creates a session key, uses it to encrypt the user's personal data, and stores the encrypted data in the smart meter.
- **Subscription Start:** The user sends a subscription request to the distributor. Once the distributor has approved the request, the subscription phase starts. The session key is encrypted with the public key of the distributor and sent encrypted to the distributor. The distributor gets the session key which will be used during the subscription.The user uses the mobile application to pair the account with an IoT device to receive the service. Encrypted personal data is copied to the IoT device during this pairing. The IoT device informs the blockchain network and sending measurements to the blockchain network starts afterward.
- **Subscription:** At predetermined intervals that are set by the distributor, IoT devices report measurements to the blockchain network. These metrics are encrypted with the session key and stored in the blockchain. These measurements are only visible to the distributor and the public authority in the channel. The subscriber has access to his or her own consumption data and can view the required payment amount. Only a Subscription ID that the distributor sets is stored in the blockchain as personal information. A request is created in the system if the distributor or the public body needs to access the subscriber's personal data for administrative purposes.The blockchain also stores the request and its justification. The smart contract permits access to the data kept on the user's IoT device if the requester has the user's session key.Regularly sending measurement data to the blockchain system may also jeopardize the subscribers' privacy [20].

  There are solutions to this issue, however this work will be done in the future.When the subscription expires, the session key is still in effect. Personal data is encrypted using a new session key that is produced if the subscription is canceled by the user or expires. This ensures the privacy of the personal data. The former distributor will still have access to measurements encrypted with the prior session key, but not to the user's personal information. After quitting one distributor, the user can sign up with any other one to resume service [21].

2.3 Integration of Iot With Smart Grid

2.3.1 AMR with high reliability based on IoT

Characteristics like dynamic, intelligence, and integrativeness can offer technical support for the dev elopment of smart grids. The following are the primary IoT application scenarios for the smart grid: AMR with high reliability based on IoT : Smart grid heavily relies on automatic metre reading systems. It is a system in charge of intelligently gathering, processing, and real-time monitoring power consumption data. IoT enables automatic collection, aberrant measuring, monitoring of the quality of the electricity, and analysis of consumption patterns. The system also makes it possible for features like information release, distributed energy monitoring, and information sharing across smart power equipment. In the past, data on power usage was manually gathered throughout time on the spot, which made it insufficient in terms of timeliness, accuracy, and applicability [22].

The remote metre reading system, which integrates WSN, power line communications (PLC), and optical PLC (OPLC), gathers electricity data and other useful real-time information with high reliability through private power line communication networks and public communication networks, and thus achieves power consumption statistics, analysis, and state of use via advanced communication technologies, computing technologies, and electric energy metering technologies. The value of such a system is found in its real-time, accuracy, and efficiency in terms of statistics and monitoring of electrical quality. The stability and accuracy of the conventional AMR system would be significantly improved by the suggested system.Thissystem also has perks that people can take advantage of. According to the facts and analysis of power usage as well as the applied price ladder, they can modify their behaviour when using electricity to save money.

2.3.2 Smart home based on IoT

As the central component of the smart grid, the smart home is a significant tool for enabling real-time communication between users and the grid, expanding the functionality of the grid's integrated services, satisfying the desire for interactive marketing, and raising service standards. The adoption of smart home services increases everyday power consumption. Residents can, for instance, turn on their chargers and washing machines late at night when the cost of electricity is substantially lower. In order to enjoy the air conditioning and a hot red bath without having to wait, they can turn on electric water heaters and air conditioners remotely before arriving home by calling or sending a text message. Additionally, they have the ability to check on the state of their homes whenever they are away from them and to call the police in the event of a hacking. The peak residential load can be shifted, which will minimise the demand for transmission and distribution capacity and the investment in the power system. While this is going on, selling the shifted residential peak load to commercial and industrial customers aids in raising revenue for grid firms without raising generation capacity.

IoT can be used for a number of smart grid applications.It can be used in the general home sensor LAN protocol of the smart home service system, which offers user interaction, information services, smart appliance control, multi-meter reading, information gathering on power consumption (including electricity, gas, water, heat, etc.), home sensitive load monitoring and control, access to renewable energy, and more. It can also be used to provide an universal platform on which studies on wireless sensors, PLCs, power line composite cables, and next-generation broadband wireless networking technology can be done [22]. In the long run, IoT applications would hasten the growth of digital, information cities, and AMR, analysis, and expert decision systems. Consequently, we will achieve our objectives of conserving energy and efficiently utilising a variety of resources.

2.3.3 The online visual monitor platform of smart grid transmission line

Pictures and speech information, which are not real-time, have traditionally been used to ease the site operation of high voltage line construction. The comprehensive visualisation application used in high voltage line construction can monitor the transmission line and find, diagnose, and remove fault and concealed problems thanks to the integration of visualisation, wireless broadband, and satellite communication technologies. High voltage line live video and crucial data can be sent back by video monitoring and environmental data collection at key locations or along the entire transmission line. Additionally, the visualisation of real-time monitoring of the swinging, ice, bird hazard, and human-caused disaster can promote the safe operation of transmission lines. The power line broadband wireless network is a complement to the ground fibre optic network, which serves as the foundation for the video monitor bearer network. The video monitor system is now frequently used in converters and substations, and it aims to move towards a digital platform and the integration of several technologies and systems.

Chapter 3
System Description and Model

3.1 Work Flow

Given a lot of various components involved in the solution we are trying to implement, an attempt has been made to display the working of our system and its components with the help of a flow chart for easy understanding.

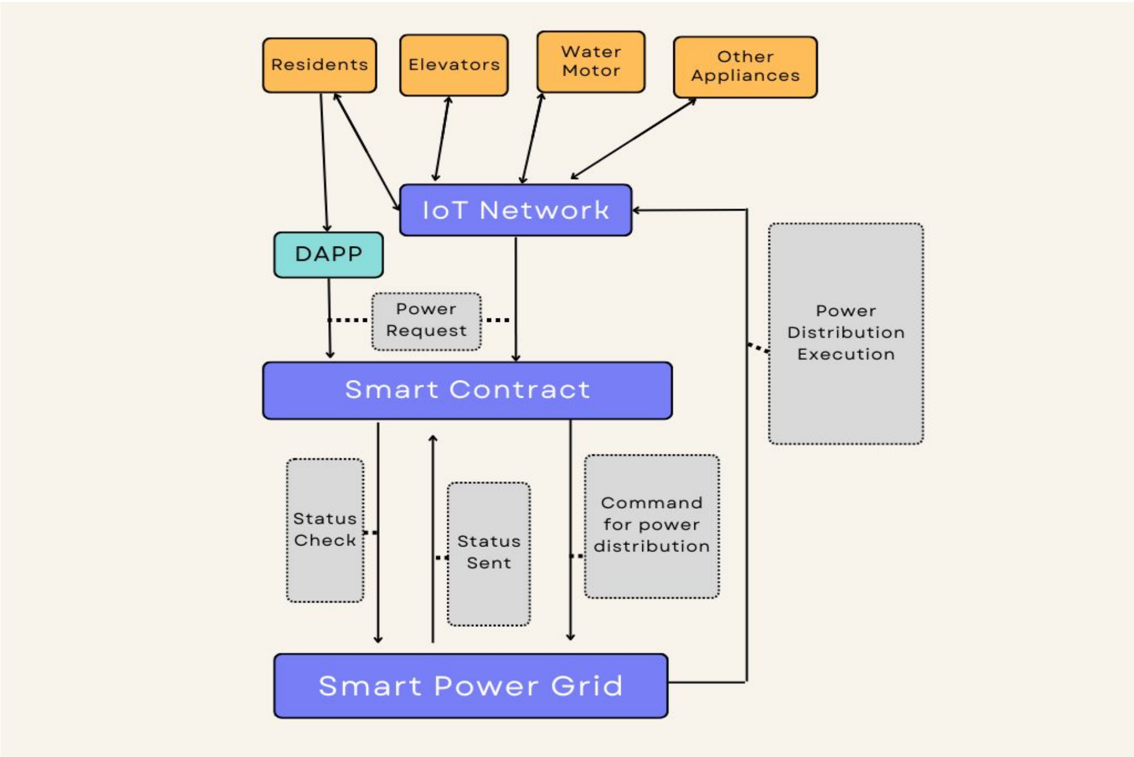

Figure 3.1: Work Flow of proposed model

This flowchart shows the system description of our model. All the components and pathways are labeled and are easy to understand. One can start from the appliances section which will be interconnected and are a part of the IoT network, whose rules and algorithm will be defined in the smart contract. The Smart Power Grid will be responsible for final implementation of power distribution.

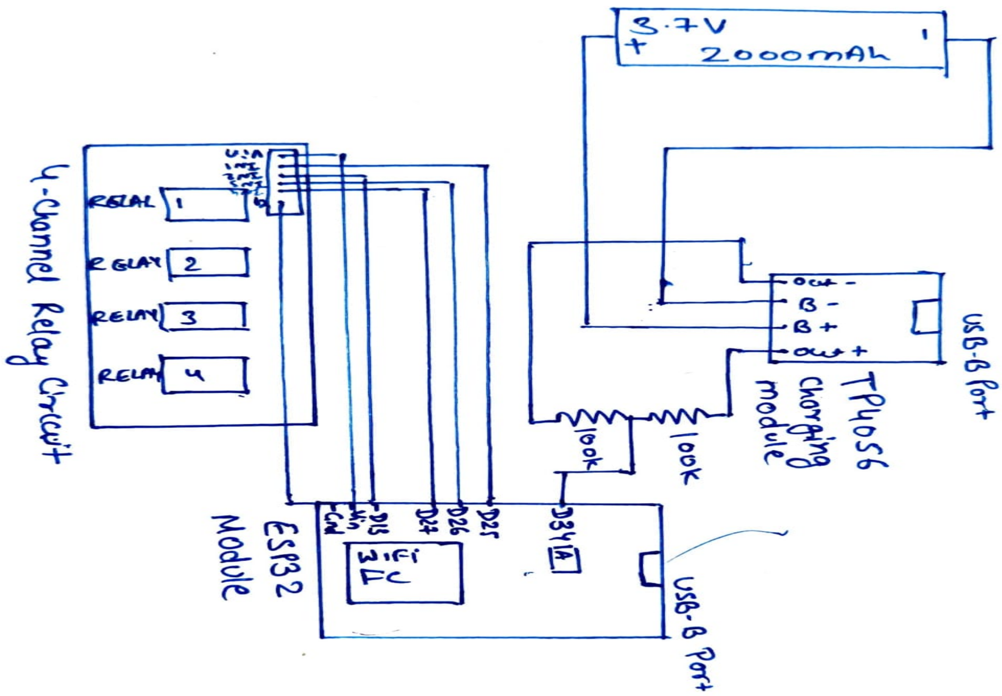

Figure 3.2: Circuit Diagram

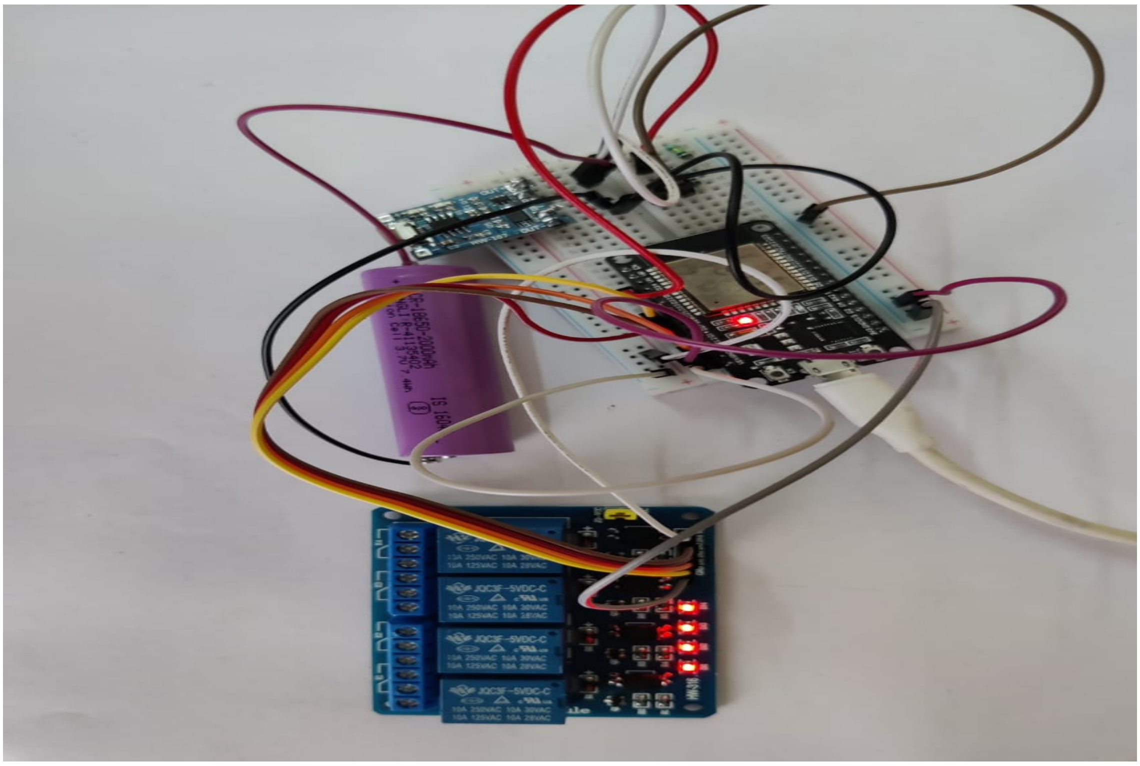

Figure 3.3: Circuit Diagram Implementation

3.2 Tools

3.2.1 Ethereum and Smart Contracts

As of now we have discussed the working of a basic blockchain system. Bitcoin is hardly anything more than that. Now we will discuss what Ethereum has to offer more and how it enables the use of 'Smart Contracts'. The basic structure of Ethereum network remains the same, with a few add-ons.

Transactions AND Messages

All transactions contain the following components, regardless of their type: we won't be discussing each of them in detail here. Ethereum is a transaction-based state machine, as we mentioned earlier. To put it another way, transactions between various accounts are what move Ethereum's global state from one state to the next. A transaction is a cryptographically signed piece of instruction generated by an externally owned account, serialised, and then posted to the blockchain in the most basic meaning [23]. Message calls and contract creations are the two forms of transactions (i.e., transactions that create new Ethereum contracts).
Transactions, both message calls and contract-creating transactions, are always initiated by externally owned accounts and published to the blockchain, as we learnt in the "Accounts" section. Another way to look at it is that transactions are what connect the outside world to Ethereum's internal state.

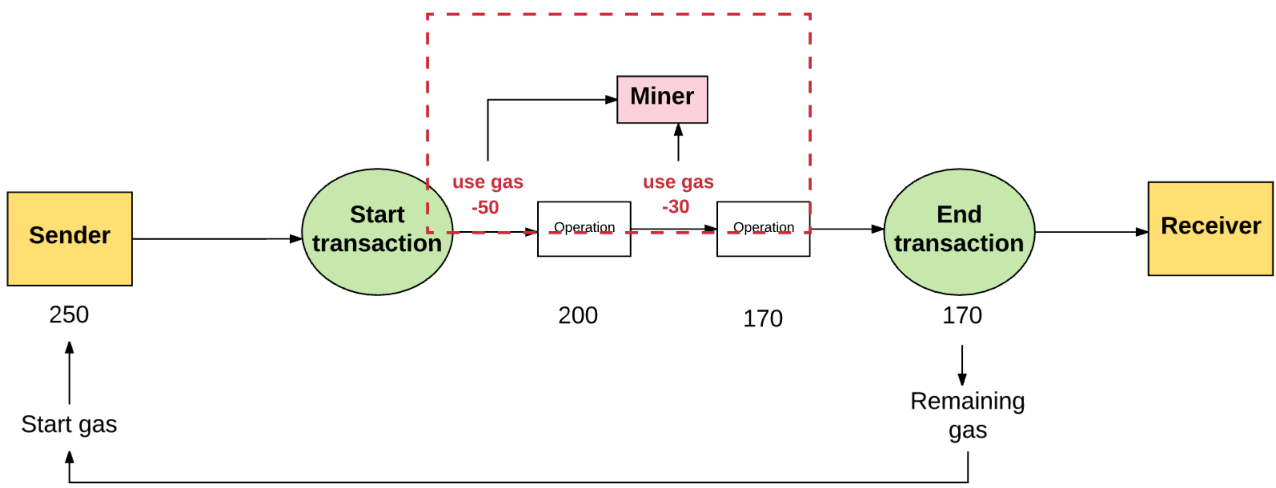

Figure 3.4: Flow of Transactions

This isn't to say that contracts can't communicate with one another. Contracts that are part of Ethereum's global scope can communicate with other contracts in the same scope. This is accomplished by sending "messages" or "internal transactions" to other contracts. Messages or internal transactions are similar to transactions, with the exception that they are not generated by accounts that are not controlled by the company. Contracts, on the other hand, generate them. They are non-serialized virtual objects that only exist in the Ethereum execution environment, unlike transactions. When one contract sends an internal transaction to another contract, the associated code that exists on the recipient contract account is executed.
One important thing to note is that internal transactions or messages don't contain a gasLimit. This is because the gas limit is determined by the external creator of the original transaction (i.e. some externally owned account). The gas limit that the externally owned account sets must be high enough to carry out the transaction, including any sub-executions that occur as a result of that transaction, such as contract-to-contract messages. If, in the chain of transactions and messages, a particular message execution runs out of gas, then that message's execution will revert, along with any subsequent messages triggered by the execution. However, the parent execution does not need to revert [18].
Now we have learnt how the data in Ethereum networks talk with each other in a highly secured, transparent, decentralised way. It makes it perfect solution for all the problems IoT had to face.

Implementation of the smart contract :

```
    // SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;

contract Sample {
    uint data;

    function set(uint d) public{
        data = d;
    }

    function get() public  view returns(uint retVal) {
        return data;
    }
}
```

3.2.2 ARDUINO IDE

Arduino IDE (Integrated Development Environment) is an open-source software used for writing and uploading code to the Arduino board. It provides a platform for creating and testing programs for microcontrollers such as the Arduino Uno, Arduino Mega, and others.
The Arduino IDE is available for download on various operating systems such as Windows, Mac OS, and Linux. It uses a simplified version of the C++ programming language, making it easier for beginners to learn and use.
The IDE includes a code editor, a compiler, and a uploader. The code editor provides features such as syntax highlighting, auto-completion, and error highlighting. The compiler translates the code into machine language that can be understood by the microcontroller, and the uploader transfers the compiled code to the board for execution.
Overall, the Arduino IDE is a powerful tool for creating and testing programs for microcontrollers and is widely used by hobbyists, students, and professionals alike [6].

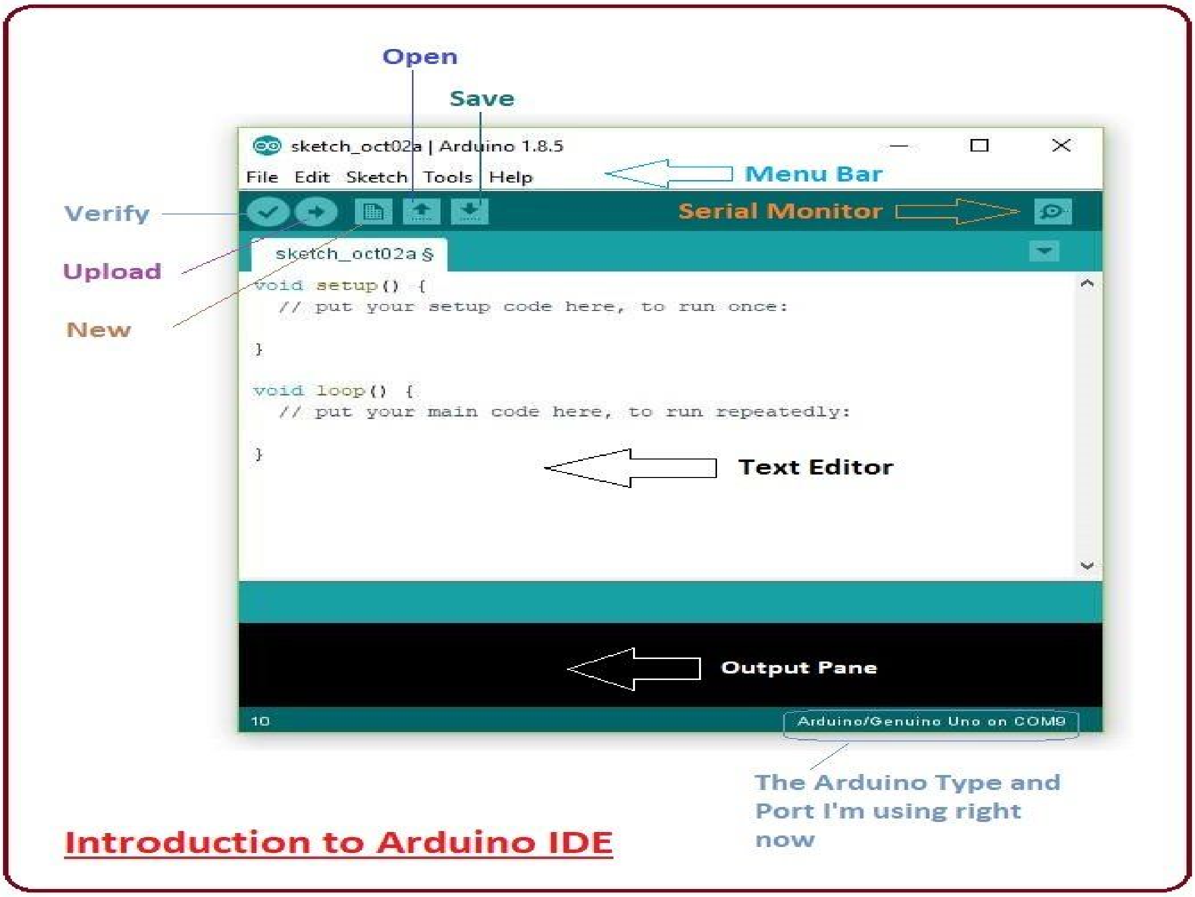

Figure 3.5: Arduino [6]

RELAY

Relay is the high voltage, three-terminal device (NC, C, and NO) that connects to control. Additionally, the relay has three low voltage (ground, Vcc, and signal) pins that link to the Arduino. Relay is an internal electromagnet-connected 120–240 switch. Relay contacts open or close when electromagnet charges up in response to a HIGH signal received at the signal pin.

Relay's primary characteristics are its 10A switching capacity despite its compact size and design for placement on high-density PC boards.

Relay receives an instruction from the cloud and sends it to the Arduino microcontroller for processing [24].

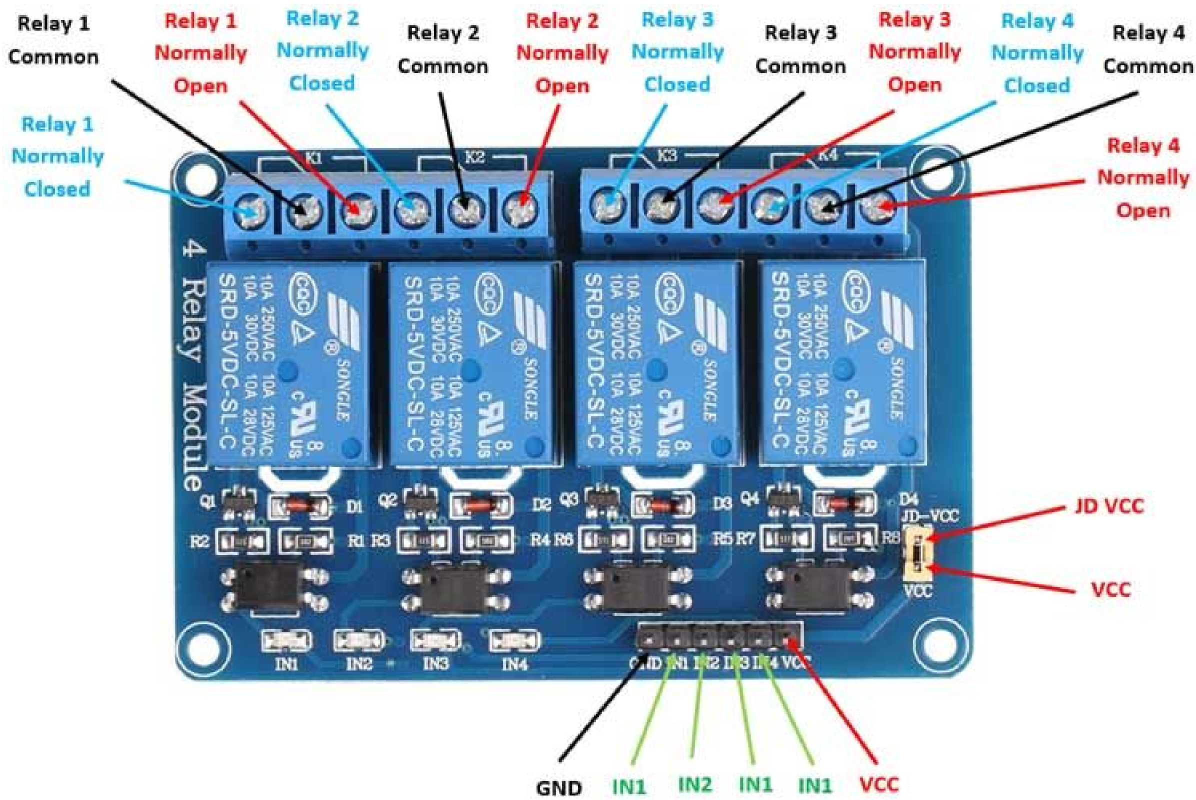

Figure 3.6: Relay [6]

POWER METER

The tool used to gauge how much electricity is used in home and large-scale industries is called a power meter.

Electric meters located at customers' locations are used by electrical companies for billing purposes. Relays built into meters allow for load shedding in response to demand during times of high load. The load power consumption is tracked, and data is relayed to Arduino [25].

3.2.3 IoT Based Battery Monitoring System using ESP32

As it powers the entire system, the battery is, as we all know, the most crucial part of any device. Therefore, it's crucial to keep an eye on the battery's voltage level because improper or excessive charging or discharging can harm the battery or cause a system failure. Battery Management System (BMS) is a separate system that is present in the majority of electrical and electronic equipment. The BMS keeps track of all the battery's characteristics, including its voltage, current, temperature, and auto-off system. This guarantees the handling of lithium-ion or lithium polymer batteries in a safe and proper manner [7]. Earlier BMS only kept track of the battery's health and alerted the user via a battery indicator. But because of the Internet of Things, we can now instantly alert people from a distance. On their smartphone or computer dashboards, they can check the battery level from anywhere in the world. Wemos D1 Mini with an ESP32 chip will be used in this IoT-based battery monitoring system to transmit data about the battery's status to ThingSpeak's cloud. In both charging and draining scenarios, the Thingspeak will show the battery voltage in addition to the battery percentage.
Components Required are :
1) NodeMCU ESP32 or Wemos D1 Mini Board.
2) TP4056 Battery Charging Module
3) Resistor 100K
4) Micro-USB Cable
5) 3.7V Li-ion Battery [7]

Lithium-Ion Batteries

Figure 3.7: Lithium Ion Battery [7]

During discharge and recharging, lithium ions in this battery flow from the negative electrode through an electrolyte to the positive electrode. The positive electrode in lithium-ion batteries is made of an intercalated lithium compound, while the negative electrode is commonly made of graphite. The batteries are minimal self-discharge, have no memory effect, and have a high energy density.

Nominal, Maximum Cut-off Voltage

A simple battery management system circuit is added to some batteries to provide over-voltage protection, balanced charging, short-circuit protection, etc.

The nominal voltage of the majority of lithium-ion batteries is 3.7V. Maximum voltage for a fully charged battery is 4.20.5. The cut-off voltage is 3V and varies based on the battery type and usage, as can be seen in the manufacturer's data-sheet. My battery's cut-off voltage for discharge is 2.8V. Batteries with a 2.5V cut-off voltage are also available.

Circuit and Schematic Designing

A schematic diagram is a fundamental two-dimensional circuit representation showing thefunctionality and connectivity between different electrical components. We'll create a mechanism to keep an eye on the battery voltage as well as the charging and discharging processes. We use the Wemos D1 Mini microcontroller, which features an ESP32 wifi chip. Alternatively, you can utilise the NodeMCU ESP32 Board. This WiFi chip can join a WiFi network and frequently upload data to a server [7].

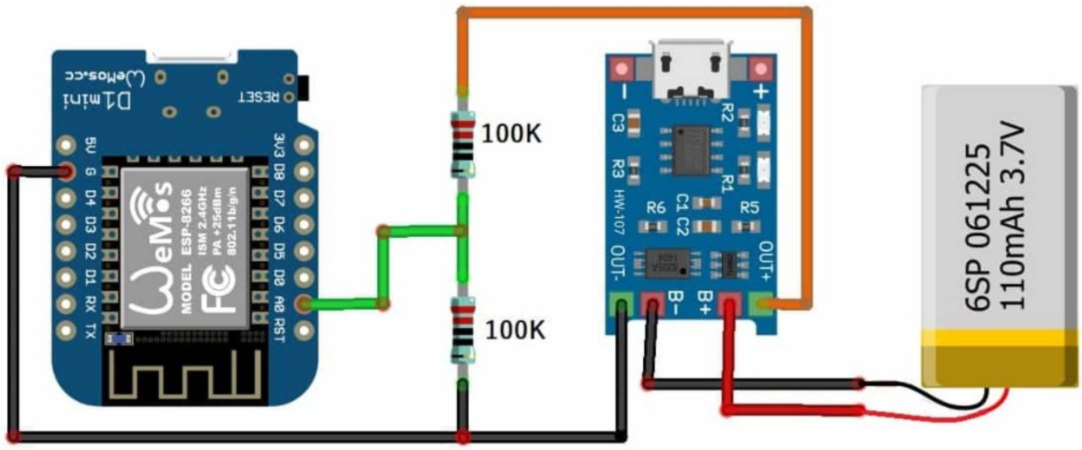

Figure 3.8: Circuit Design [7]

The TP4056 module can be used to charge the battery because it is most appropriate for battery management applications. TP4056 can also be substituted with the

MCP73831 IC. Only 3.3V can be used as the input analogue voltage for the ESP32 chip. However, the battery voltage can reach 4.2V. Therefore, to reduce the input voltage, we must create a voltage divider network.

Voltage Divider Network Calculations

Voltage Divider circuits are used to produce different voltage levels from a common voltage source but the current is the same for all components in a series cicruit. Because the ”Volt,” the voltage unit, measures the magnitude of the potential difference between two places, voltage dividers are sometimes referred to as potential dividers. A voltage or potential divider is a straightforward passive circuit that makes use of the voltage drop that occurs when components are linked in series. The battery has a 4.2V maximum voltage and a 2.8V cutoff voltage. The ESP32 Analogue Pin can readily support any voltage lower than 3.3V.

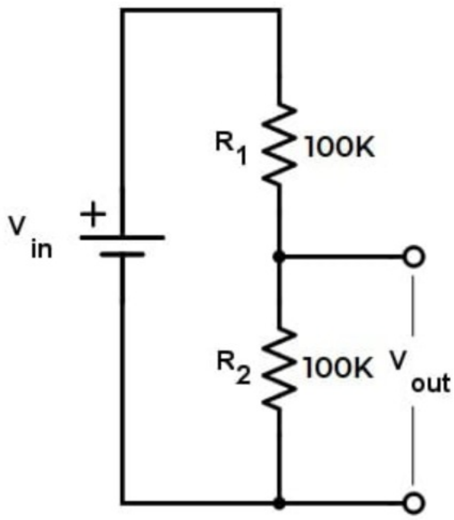

Figure 3.9: Voltage Divider [7]

First, we need to lower the voltage level. There are two 100K resistors and a 4.2V supply voltage. This will result in a 2.1V output. The same voltage divider network is also used to achieve the minimal voltage, which is 2.8V as a cutoff value and steps down to 1.4V. As a result, the ESP32 Analogue Pin supports both the upper and lower voltage. The project is assembled in its entirety here. The circuit diagram’s connection is the same as this one. You can use a lithium-ion battery of any capacity for testing. For instance, I am utilizing a battery having a 1950mAh capacity [7].

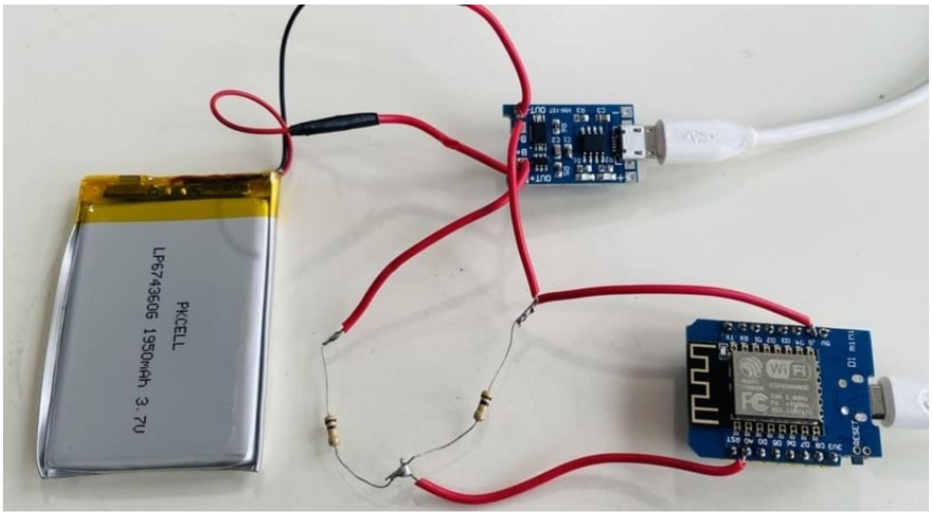

Figure 3.10: Battery Monitoring System [7]

3.2.4 The Internet of Things with ESP32

The ESP32 system on a chip (SoC) series was developed by Espressif Systems and features dual-mode Bluetooth and Wi-Fi functionality! The chips ESP32-D0WDQ6 (and ESP32-D0WD), ESP32-D2WD, ESP32-S0WD, and the system in package (SiP) ESP32-PICO-D4 are all members of the ESP32 family. A dual-core or single-core Tensilica Xtensa LX6 CPU with a clock frequency of up to 240 MHz powers the device. With integrated antenna switches, RF baluns, power amplifiers, low-noise receive amplifiers, filters, and power management modules, ESP32 is highly integrated. ESP32, a microcontroller designed for mobile devices, wearable electronics, and Internet of Things applications, consumes extremely little power with features like fine resolution clock gating, numerous power modes, and dynamic power scaling . The ESP32 supports three types of I/O modes with each GPIO Pin: Digital, Analog and Internal Sensors [26]
Analog: Used to send/receive analog data using the following functions:
* examples based on Arduino IDE
analogRead();
analogWrite();
Digital: Used to send/receive digital data using the following functions:
* examples based on Arduino IDE
digitalRead();
digitalWrite();
Internal Sensors: This mode allows us to fetch internal sensor data from the ESP32 itself. The three sensors available are as follows:
Internal Temperature Sensor
Hall Effect Sensor

Touch Sensor
These sensors can be accessed by the following functions:
* examples based on Arduino IDE
temprature_sens_rad()
hallRead()
touchRead()

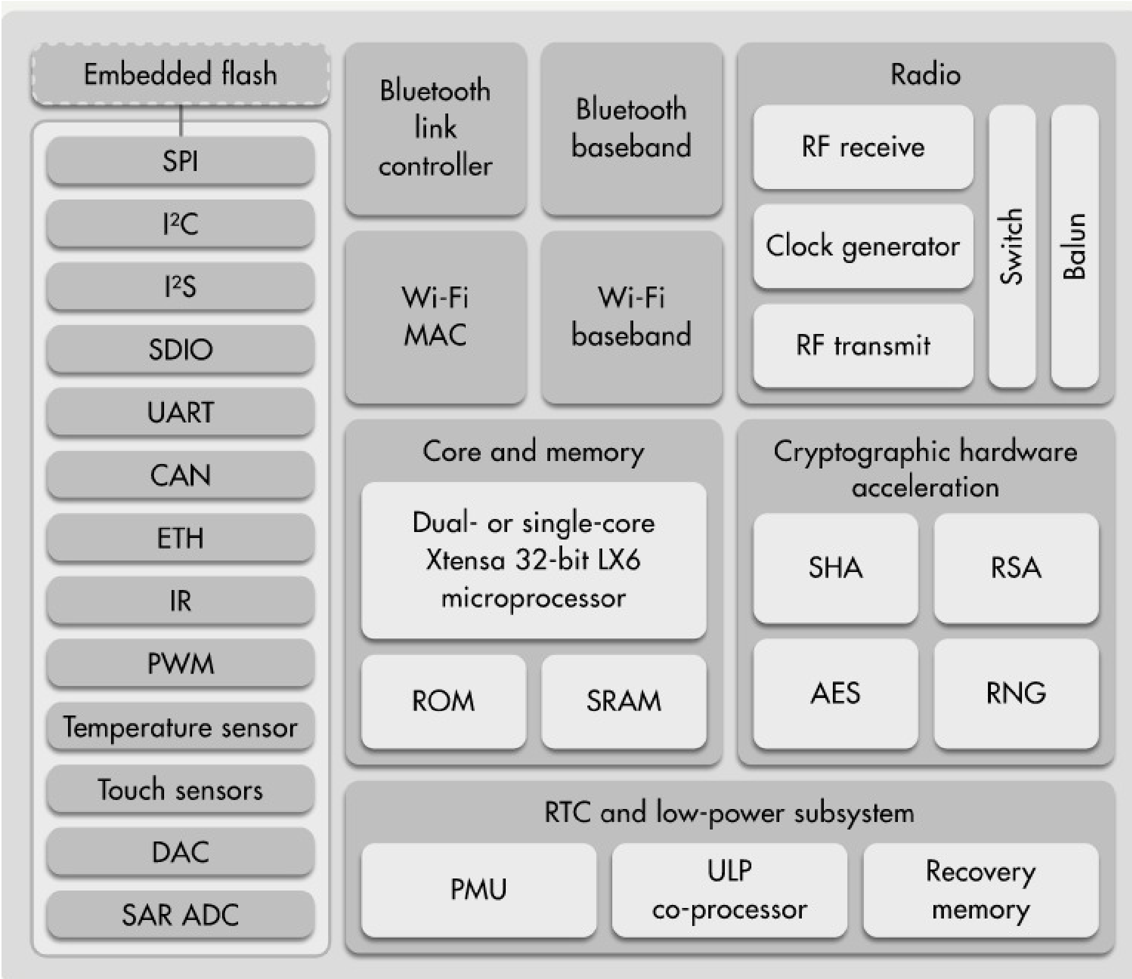

Figure 3.11: Esp32 Function Block Diagram [8]

3.2.5 TP4056

For single cell lithium-ion batteries, the TP4056 is a complete constant-current/constant-voltage linear charger. The TP4056 is unique due to its SOP packaging and few external components. Excellent for applications that require portability. The TP4056 can also be used with a wall adapter and a USB. Due to the internal PMOSFET architecture's ability to prevent negative Charge Current Circuit, no blocking diode is necessary. In situations of high power operation or high ambient temperature, thermal feedback controls the charge current to restrict the die temperature. The charge voltage is fixed at 4.2V, and a single resistor can be used to externally programme the charge current. When the charge current reaches 1/10th of the programmed value after the ultimate float voltage is reached, the TP4056 automatically stops the charge cycle. TP4056 Other features include two status pins to indicate charge termination and the presence of input voltage, under voltage lockout, automated recharge, and current monitor [9].

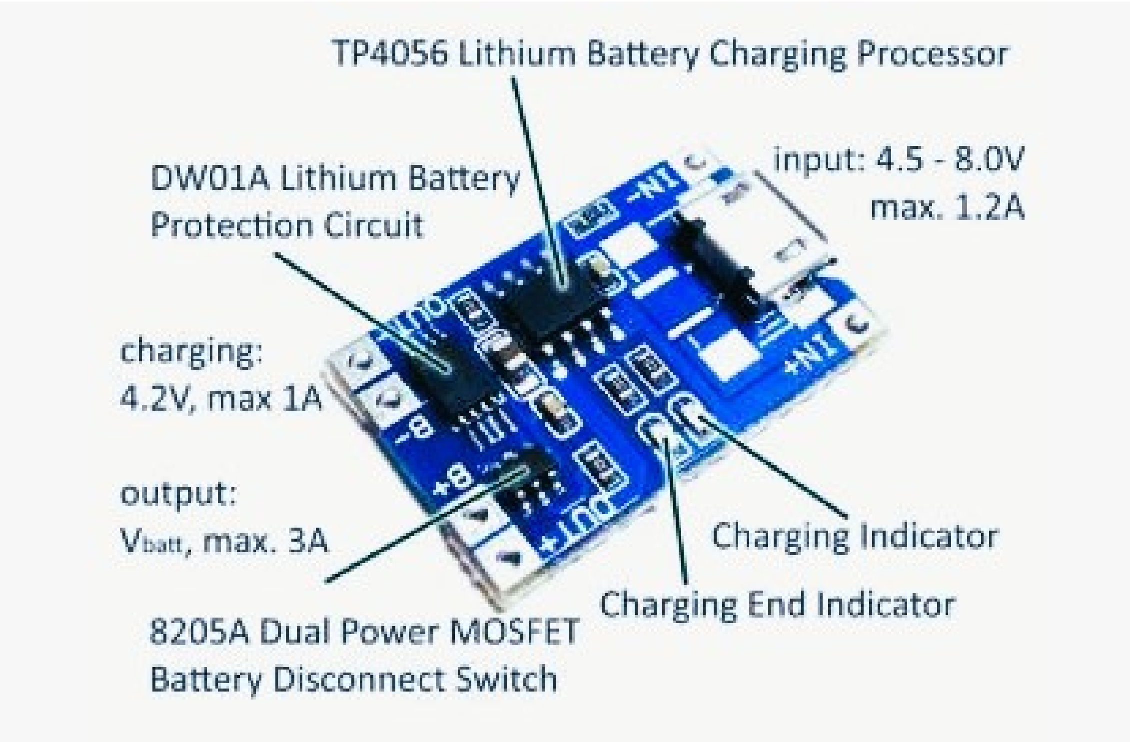

Figure 3.12: TP4056 [9]

3.2.6 Blynk - IoT Platform

Blynk is a low-code IoT software platform for managing thousands of users and deployed products, connecting devices to the cloud, and creating mobile apps to remotely control and monitor them. It's a PaaS (Platform-as-a-Service) that enables companies and individuals to proceed smoothly from a connected product prototype through its commercial launch and future expansion. Native mobile apps are a part of every Blynk plan, in addition to the usual IoT infrastructure. Customers can connect any device to the Internet and utilize a variety of software solutions to perform business initiatives thanks to the support for over 400 hardware models. A project can also be shared with friends or even clients so that they can access the linked devices but cannot edit the project itself. Consider creating a smartphone app that allows users to adjust the temperature, window coverings, and lighting from their device. Other family members can utilize the feature by being given access to the project [27].

3.2.7 MetaMask

Users can use MetaMask to store and manage account keys, broadcast transactions, send and receive Ethereum-based coins and tokens, and securely connect to decentralised applications using a suitable web browser or the built-in browser of the mobile app. Websites or other decentralized applications can connect, authenticate, and/or integrate other smart contract functionality with a user's MetaMask wallet (and any other similar blockchain wallet browser extensions) using JavaScript code, which enables the website to send action prompts, signature requests, or transaction requests to the user via MetaMask as an intermediary. The software features an integrated tool for trading Ethereum tokens by aggregating the best exchange rates from multiple decentralized exchanges (DEXs). This function, known as MetaMask Swaps, levies a 0.875 percent service fee on each transaction amount [28].

3.3 Working

3.3.1 React.js and Node.js

We use both ReactJS and NodeJS in our application. Both are JavaScript-based technologies. However, the applications of NodeJS and ReactJS are vastly different. NodeJS is a JavaScript framework that is primarily used for working with our application's backend or constructing the backend using JavaScript, whereas ReactJS is a JavaScript frontend library. It is mostly used to create the user interface, or frontend, of our program. Despite the fact that they are used for different objectives, each of these technologies makes our application faster and easier to use.

3.3.2 Sepolia Testnet

Sepolia was a proof-of-authority testnet built and maintained by Ethereum core developers in October 2021. Testnets are blockchains that are intended to imitate the operation of a'mainnet' but reside on a separate ledger. These testnets allow developers to test their applications and smart contracts in a risk-free environment before putting them to Ethereum's mainnet. Sepolia was built to simulate difficult network conditions and offers lower block times, allowing developers to receive transaction confirmation and feedback faster. In comparison to other testnets such as Goerli, Sepolia's total amount of testnet tokens is unbounded, which means that developers utilising Sepolia are less likely to suffer testnet token scarcity.

3.3.3 Integration of Arduino Ide and Blynk App

In the start we import various libraries to connect and provide Blynk Application authorisation from Arduino Ide.

```
// Template ID, Device Name and Auth Token are provided by the Blynk.Cloud
// See the Device Info tab, or Template settings
#define BLYNK_TEMPLATE_ID "TMPL3gxTB0FDv"
#define BLYNK_TEMPLATE_NAME "FInalYearProject"
#define BLYNK_AUTH_TOKEN "v6UdRkeoyZZT2uAbSjgikHer5ZICA7mW"

// Comment this out to disable prints and save space
#define BLYNK_PRINT Serial

#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
```

Figure 3.13: Code-i

Then after that we connect our Wi-fi to our system.

```
// Your WiFi credentials.
// Set password to "" for open networks.
char ssid[] = "Vivek";
char pass[] = "123Vivek";
```

Figure 3.14: Code-ii

After connection of Wi-fi we assign our ports a unique identity by assigning them a number.

```
BlynkTimer timer;

BLYNK_WRITE(V0)
{
  int pinValue=param.asInt();
  digitalWrite(25,pinValue);
  }
BLYNK_WRITE(V1)
{
  int pinValue=param.asInt();
  digitalWrite(13,pinValue);
  }
  BLYNK_WRITE(V2)
{
  int pinValue=param.asInt();
  digitalWrite(26,pinValue);
  }
  BLYNK_WRITE(V3)
{
  int pinValue=param.asInt();
  digitalWrite(27,pinValue);
}
```

Figure 3.15: Code-iii

And we control our output by running the code :

```
void setup()
{


  pinMode(25,OUTPUT);
   pinMode(13,OUTPUT);
    pinMode(26,OUTPUT);
     pinMode(27,OUTPUT);

  // Debug console
  Serial.begin(115200);

  Blynk.begin(auth, ssid, pass);

}

void loop()
{
  Blynk.run();
}
```

Figure 3.16: Code-iv

By using these the port numbers 25 , 13, 27, 26 are used to control the output of the system.

3.3.4 Working on Blynk IoT platform

In this platform all the information of ESP32 is uploaded on cloud server of Blynk platform through which we connect the system.

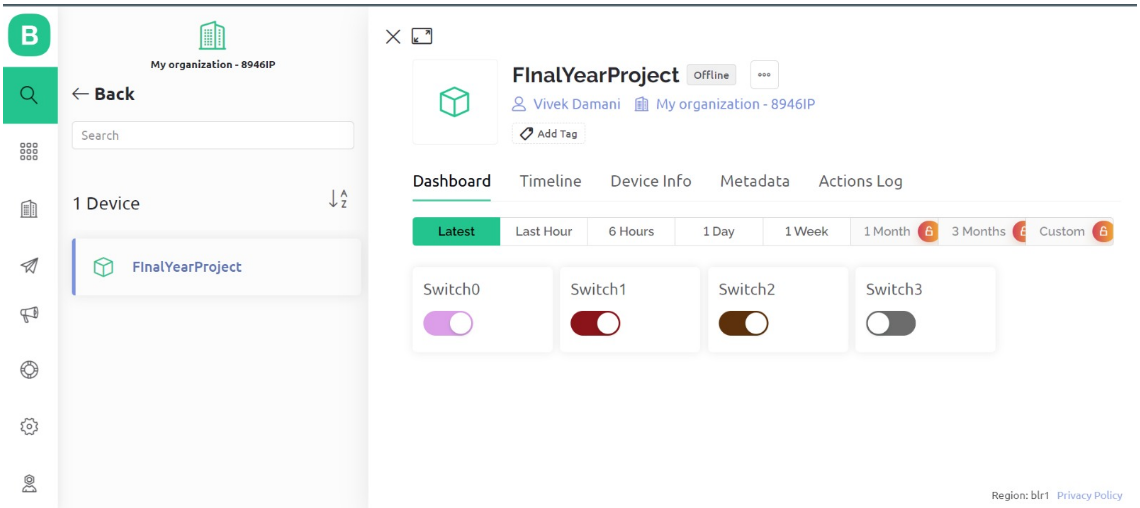

Figure 3.17: Blynk Dashboard

Blynk app provides the external API's that further gets connected to the blockchain.

Figure 3.18: Device Information

3.3.5 Algorithm for Power distribution based on Priority/Battery Level

In this algorithm we take the priority of each device and then according to the power level of the battery we turn off the devices with least priority.
As here we have taken 4 devices and have done that when the battery percentage is less than 75 percentage we turn off the device with the least priority. After that when the battery percentage is less than 50 percentage the device with the third least priority is switched off. Similarly when the battery is less than 25 percent next device is turned off until the battery runs out of power.

```
    function sleep(ms) {
    return new Promise(resolve => setTimeout(resolve, ms));
}

async function runPriority(priority_1, priority_2,
priority_3 , priority_4){

    P = 100 // initial_power_of_battery ;
    P_cur = 100 // current_power_of_battery;

    W=4; // power_consumed_when_active_all_4 (per sec)
    X=3; // power_consumed_when_active_all_3 (per sec)
    Y=2; // power_consumed_when_active_all_2 (per sec)
    Z=1; // power_consumed_when_active_all_1 (per sec)
    cur=4;

    for(let time=0;P_cur>0;time++){

        if(cur==4){
            P_cur=P_cur-W;
            if(P_cur<=3*P/4){
                switch_off(priority_4);
                cur=3;
            }
            //console.log(4);
        }
        else if(cur==3){
            P_cur=P_cur-X;
            if(P_cur<=P/2){
```

```
                switch_off(priority_3);
                cur=2;
            }
            //console.log(3);
        }
        else if(cur==2){
            P_cur=P_cur-Y;
            if(P_cur<=P/4){
                switch_off(priority_2);
                cur=1;
            }
            //console.log(2);
        }
        else if(cur==1){
            P_cur=P_cur-Z;
            if(P_cur<=0){
                switch_off(priority_1);
                cur=0;
        }
        //console.log(1);
        }

        if(cur<=0) break;
        //console.log(P_cur);
        await sleep(1000);
    }
}

runPriority();
```

3.3.6 Web App with Priority based Model

In this section we discuss the implementation of the previous code on Esp32 and Relay by making an interface through WebApp to control the power distribution according to the battery percentage and priority. Figure 3.23 displays the interface that shows the current battery level along with the status of the current appliances and their priority order. As displayed by the app, its physical world display is represented by figure 3.22, which shows our esp32 module and power relay in action. The four LEDs on the power relay represents the four appliances we are setting the priority order for.

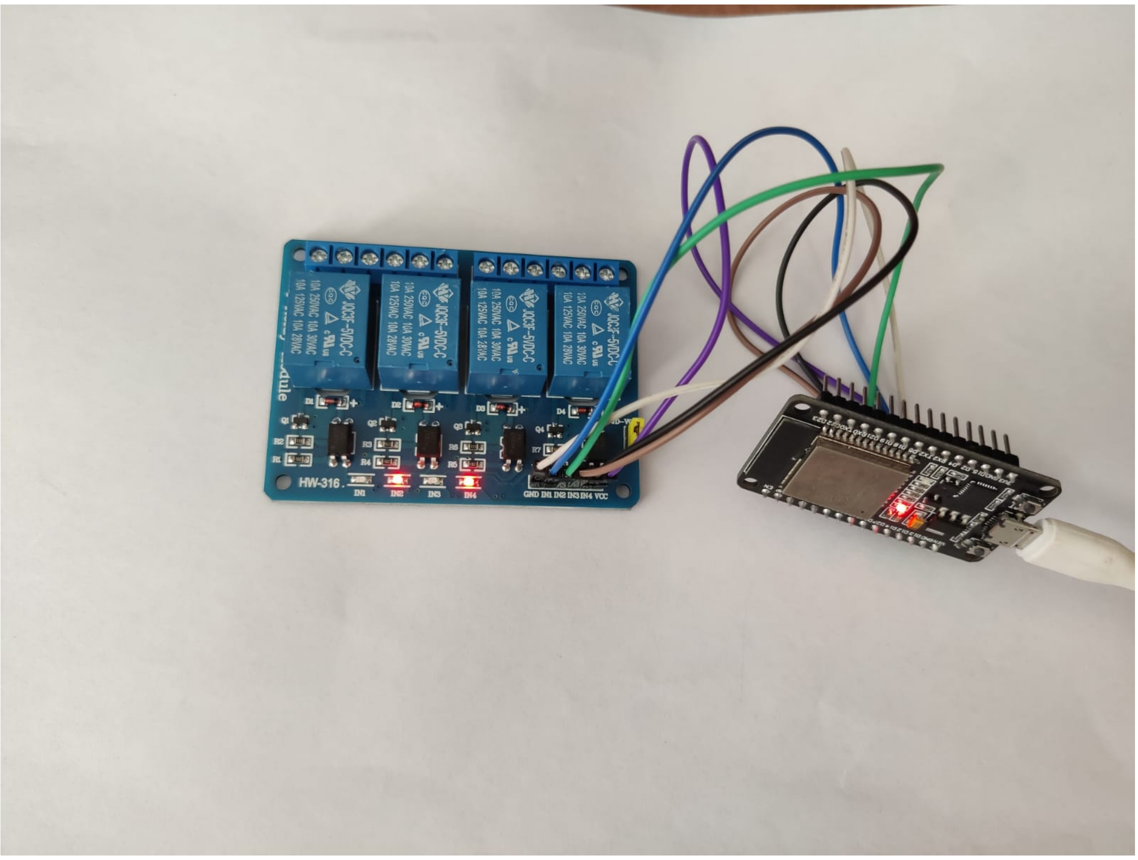

Figure 3.19: Hardware Implementation on Esp32 and Relay.

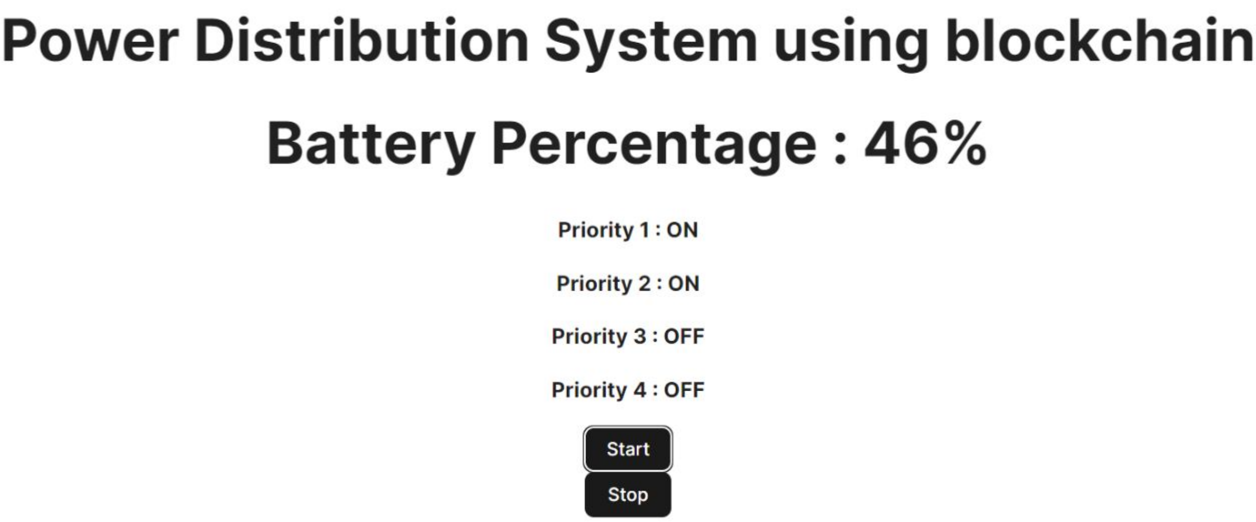

Figure 3.20: WebApp Control.

The following figure 3.24 shows the interface to update the priority order, as maybe required by the society's authorities. As a matter of security, the update of the priority order will require the designated authority to make a transaction via metamask, that will prompted once they hit the sumbit button, allowing only the designated authority to make the transaction and not anyone else. We will discuss more about these state change of smart contract and transaction via metamask in the further section.

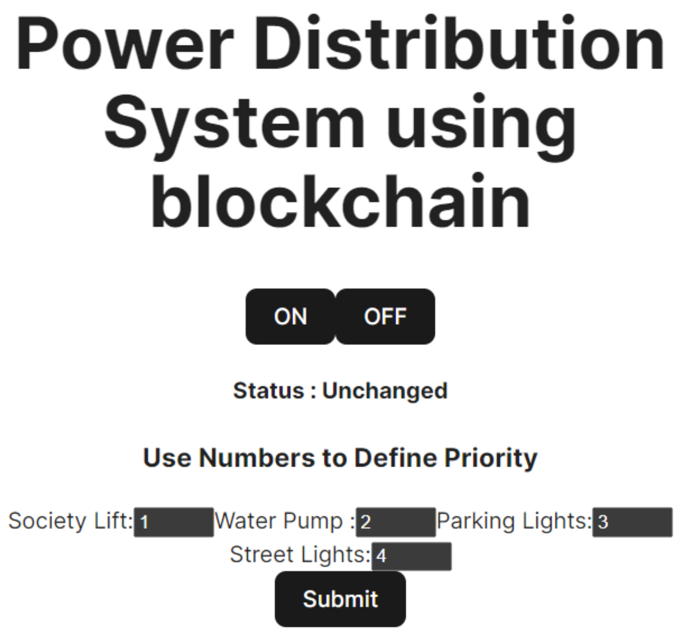

Figure 3.21: Setting the priority order

3.3.7 Web App with User's Requirement based Model:

In the interface as shown in figure 3.25, the user who needs power will be asking for it by entering its switch number (in real life, it may represent its house number etc.) and will hit submit button. As this this will prompt the user to send the coins required to complete the transaction via Metamask, as shown in the figure 3.26. On successful completion of the transaction, the user will be provided with the power output, as represented by the respective bulb number in our hardware circuitry.

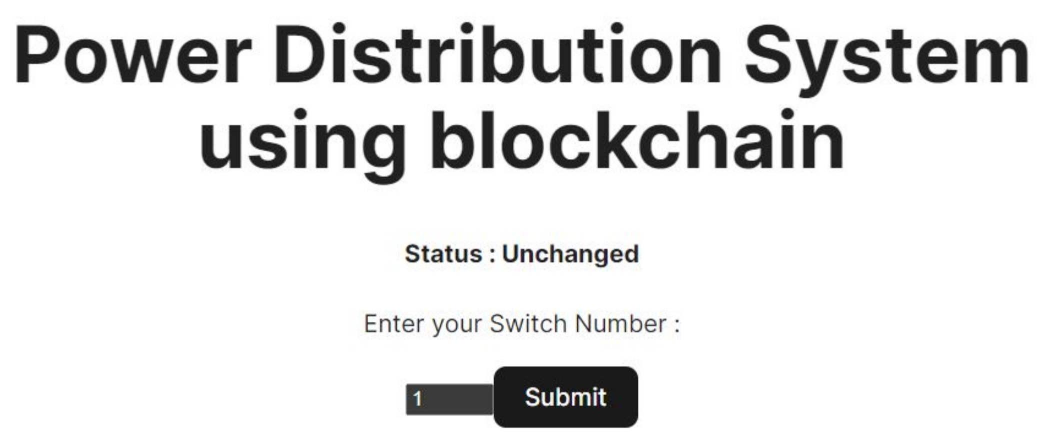

Figure 3.22: WebApp interface for user's power requirement

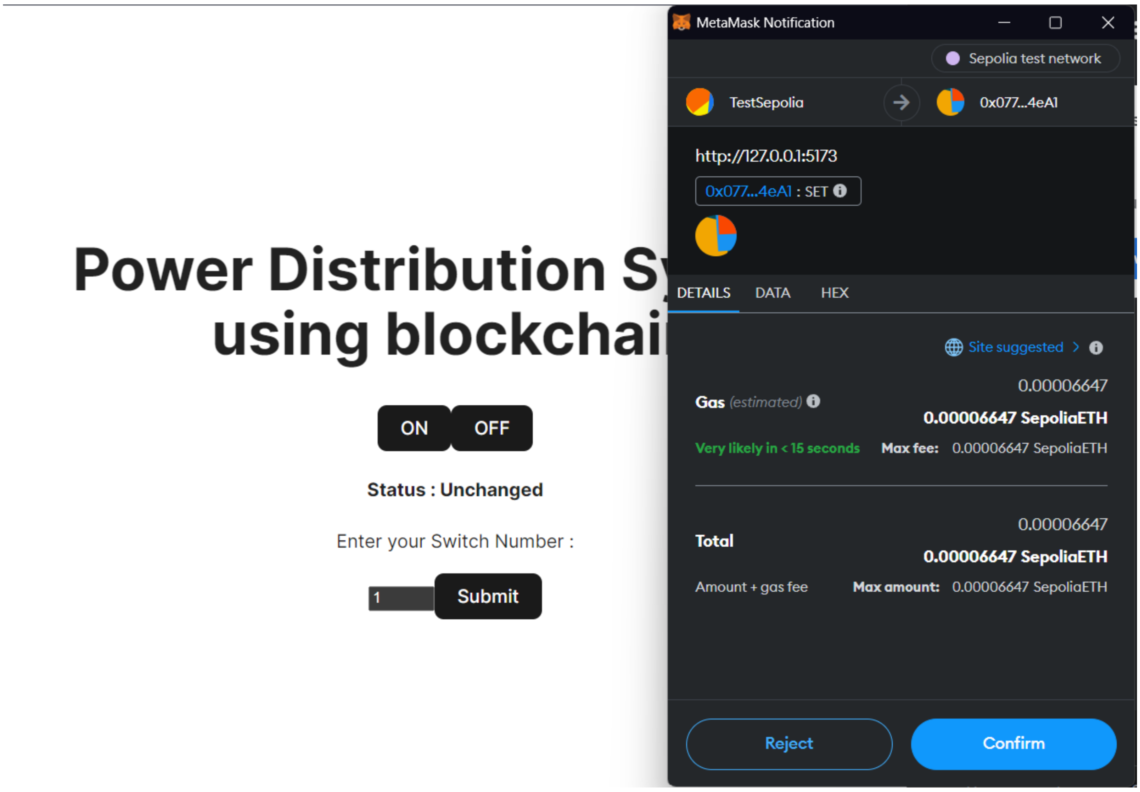

Figure 3.23: Metamask's prompt for transaction

As all the transactions are done on blockchain, they must be visible somewhere even in encrypted form. Sepolia Etherscan is the appropriate platform, providing the data of all the transactions that happened on the network in an encrypted form, providing us with both security and transparency. A window of sepolia.etherscan.io , showing all the transactions made in our smart contract can be seen in figure 3.27.

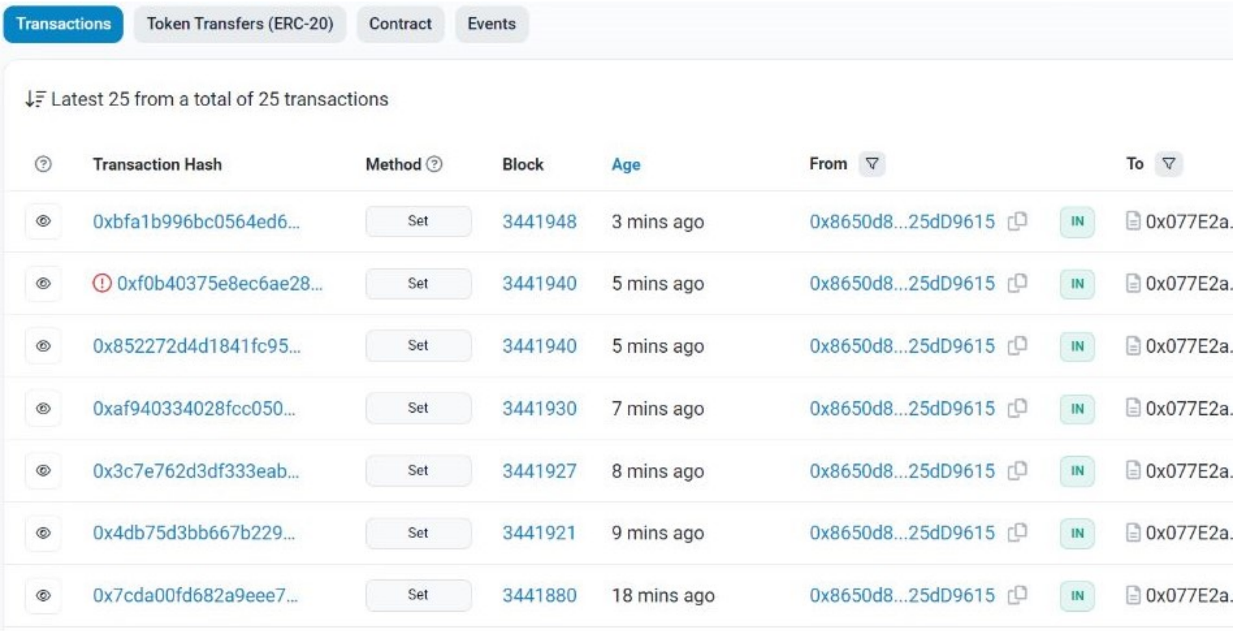

Figure 3.24: Etherscan window

3.3.8 Battery Monitoring System

In Blynk IoT App we see the visual graphs of Battery Voltage and Battery Percentage.

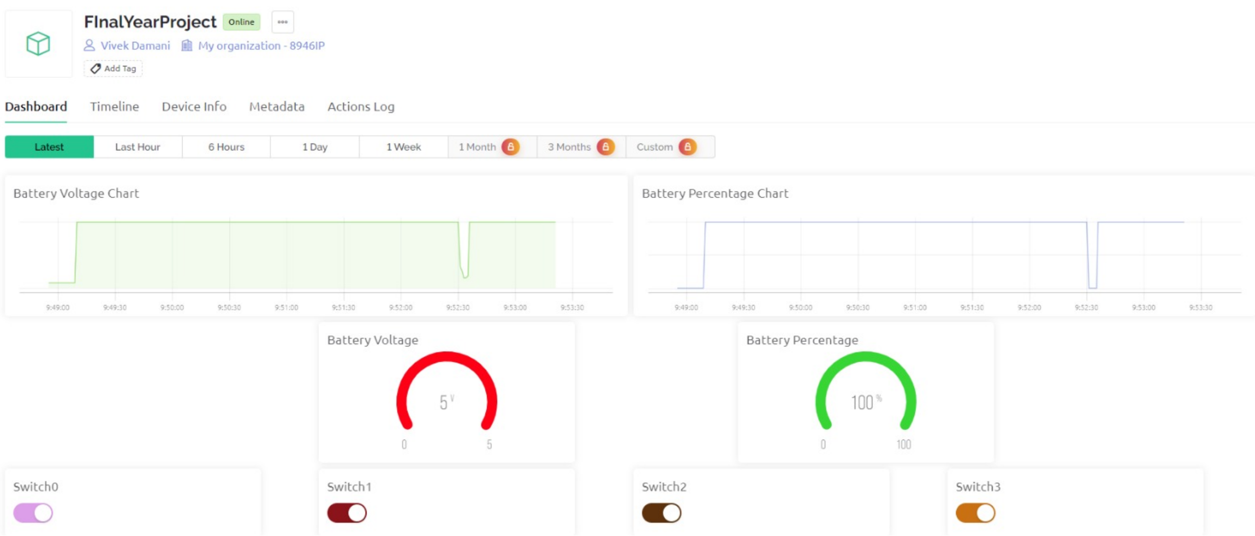

Figure 3.25: Battery Monitoring System

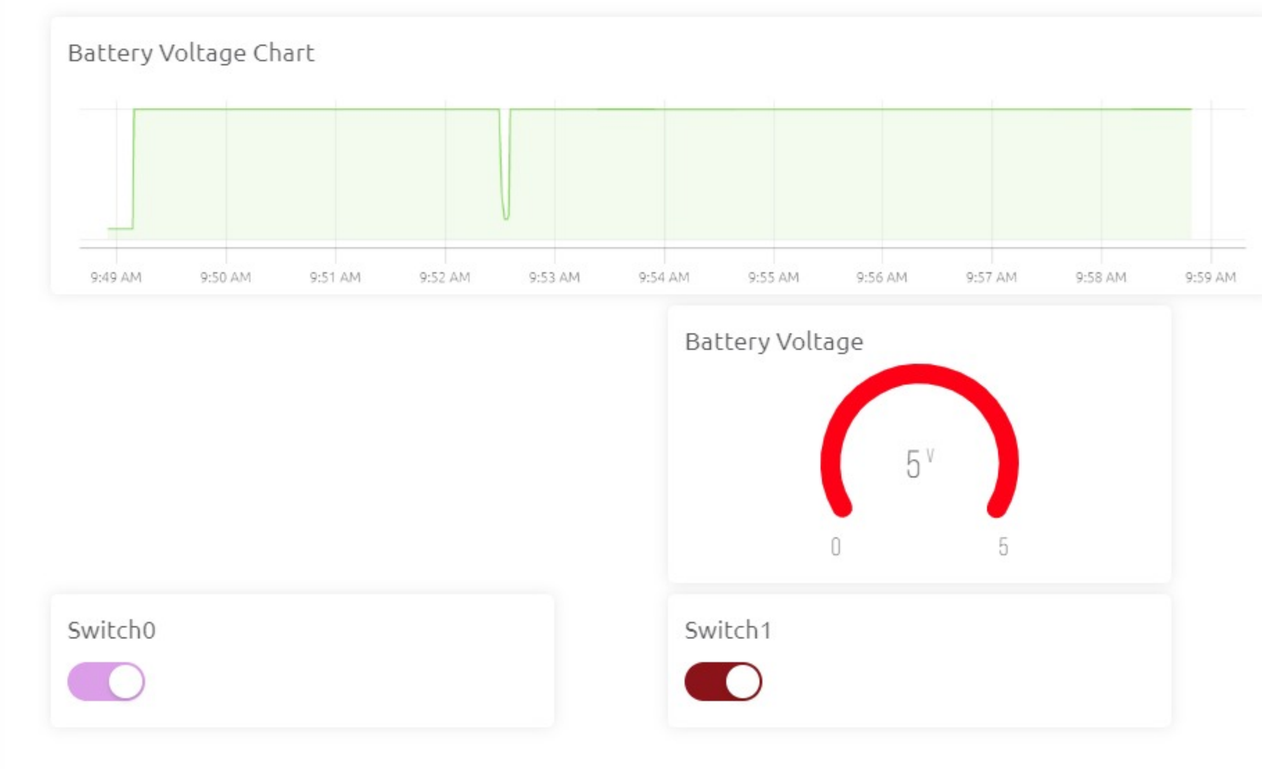

Figure 3.26: Battery Voltage Chart

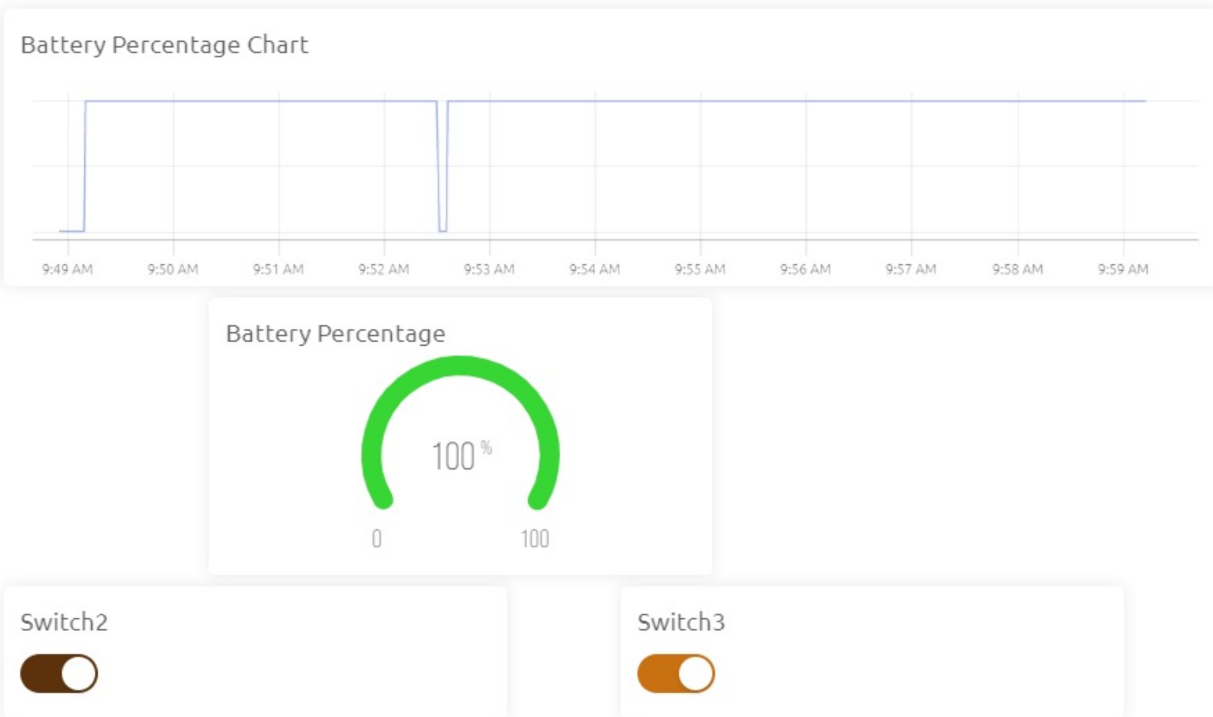

Figure 3.27: Battery Percentage Chart

In this code we read the values from sensor and ca-liberate the voltage. After that we add conditions on the battery percentage for the desired output.

```
  sensorValue = analogRead(analogInPin);
voltage = (((sensorValue * 3.3) / 1024) * 2 + calibration);
//multiply by 2 as voltage divider network is 100K resistor each

bat_percentage = mapfloat(voltage, 2.8, 4.2, 0, 100);
//2.8V as Battery Cut off Voltage & 4.2V as Maximum Voltage

if (bat_percentage >= 100)
{
  bat_percentage = 100;
}
if (bat_percentage <= 0)
{
  bat_percentage = 1;
}

    //send data to blynk

  Blynk.virtualWrite(V4, bat_percentage);
  // for battery percentage

  Blynk.virtualWrite(V5, voltage); // for battery Voltage
```

Chapter 4
Conclusion and Future Scope

The research provided us with a very excellent grasp of both the Internet of Things (IoT) and Blockchain, as well as how we may proceed to create a model that is based on these technologies. The first chapter of the paper provided an overview of both of these emerging technologies, including an introduction to Blockchain and an explanation of the Internet of Things (IoT), as well as the rationale for why combining the two would be a smart idea. In the following chapter, numerous models were discussed that demonstrated how these technologies may effectively distribute power, with the primary emphasis being placed on a residential society level. The third chapter focused more on the practical aspects of putting the final model that was offered into action. We implemented power distribution system by two methods one through power distribution based on prioritizing the defined appliances and distributing according to the power remaining in the battery, and keeping a track on how battery level is gradually decreasing. The second model focused more on a commercial level, when a user or industry can ask for power in exchange of power coins.

Our power distribution system was created on a very modest scale. The battery's power level and appliances' priorities were added manually, and even the power depletion function was done as a linear process. As a result, we can automate the prioritisation of devices as well as the battery power check. For power loss, we can also include the actual exponential function. These simplifications allowed us to show a working model for our objectives, however, there are many unrecognised issues that may arise while scaling this project. It maybe hard to accurately measure the battery power levels in case of large societies having multiple set of inverter batteries. Setting of priorities may also be a hard task, and exact power consumption rates of all the appliances may also be hard to determine. Keeping everything connected on a single network and then distributing such large amounts of power may not be such an easy task in case of smart grid. But with some more research and investigation in this area, the model can definitely be scaled and will offers a substantial contribution in the field of smart power distribution.

References

[1] "Distributed ledger." [Online]. Available: https://www.mondaq.com/unitedstates/fin-tech/1101184/an-overview-of-blockchain-in-supply-chain-what39s-the-url

[2] "Basic chain structure," 2023. [Online]. Available: https://www.salesforceben.com/salesforce-blockchain-for-dummies/

[3] "Illustrating an iot platform." [Online]. Available: https://www.researchgate.net/figure/Total-cycle-of-smart-contract-execution-over-Ethereum-blockchain_fig2_338926064

[4] "Smart grid services conceptual representation highlights," 2023. [Online]. Available: https://www.researchgate.net/figure/Digital-Business-Ecosystem-Example_fig3_339552585

[5] "Iot layout in smart grid," 2023. [Online]. Available: https://www.mdpi.com/2079-9292/8/9/972

[6] 2023. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/8728311

[7] "Battery monitoring system." [Online]. Available: https://how2electronics.com/iot-based-battery-status-monitoring-system-using-esp8266/

[8] "Esp block diagram," 2023. [Online]. Available: http://esp32.net/

[9] "Tp4056," 2023. [Online]. Available: https://dlnmh9ip6v2uc.cloudfront.net/datasheets/Prototyping/TP4056.pdf

[10] F. . L. LLP, "An overview of blockchain in supply chain: What's the url? accessed," 2021. [Online]. Available: https://www.jdsu-pra.com/legalnews/an-overview-of-blockchain-in-supply-3023363/

[11] X. Li, P. Jiang, T. Chen, X. Luo, and Q. Wen, "A survey on the security of blockchain systems," *arXiv preprint arXiv:1802.06993*, Feb 2018.

[12] ——, "A survey on the security of blockchain systems," *Future Generation Computer Systems*, 2020. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0167739X17318332

[13] A. Rosic, "What is cryptocurrency: Everything you need to know. blockgeeks," 2023. [Online]. Available: https://blockgeeks.com/guides/what-is-cryptocur-rency/

[14] CoinGecko, “Cryptocurrency global chart,” 2023. [Online]. Available: https://www.coingecko.com/en/global_charts

[15] S. Sayeed, H. Marco-Gisbert, and T. Caira, “Smart contract: Attacks and protections,” *IEEE Access*, vol. 8, pp. 24 416–24 427, Jan 2020.

[16] J. Lee, “How to choose the right iot platform: The ultimate checklist,” 2018.

[17] P. Kasireddy, “Will helium make iot a reality?” 2023. [Online]. Available: https://www.preethikasireddy.com/post/will-helium-finally-make-iot-a-reality

[18] R. de Best, “Daily bitcoin (btc) transactions worldwide as of septem-ber 13, 2021,” 2021. [Online]. Available: https://www.sta-tista.com/statistics/730806/daily-number-of-bitcoin-transactions

[19] N. Manoj Kumar, A. Chand, M. Malvoni, K. Prasad, K. Mamun, F. Islam, and S. Chopra, “Distributed energy resources and the application of ai, iot, and blockchain in smart grids,” *Energies*, vol. 13, p. 5739, 11 2020.

[20] A. Gür, Öksüzer, and E. Karaarslan, “Blockchain based metering and billing system proposal with privacy protection for the electric network,” in *2019 7th International Istanbul Smart Grids and Cities Congress and Fair (ICSG)*, 2019, pp. 204–208.

[21] T. Alladi, V. Chamola, J. J. P. C. Rodrigues, and S. A. Kozlov, “Blockchain in smart grids: A review on different use cases,” *Sensors*, vol. 19, no. 22, 2019. [Online]. Available: https://www.mdpi.com/1424-8220/19/22/4862

[22] A. Cornel Cristian, T. Gabriel, M. Călin-Arhip, and A. Zamfirescu, “Smart grid integration of iot,” in *2019 54th International Universities Power Engineering Conference (UPEC)*, 2019, pp. 1–5.

[23] P. Kasireddy, “How does ethereum work anyway?” 2017. [Online]. Available: https://www.preethikasireddy.com/post/how-does-ethereum-work-anyway

[24] “Relay,” 2023. [Online]. Available: https://www.electronicshub.org/what-is-relay-and-how-it-works/

[25] “Power meter.” [Online]. Available: https://www.hbm.com/en/9206/what-is-a-power-meter/

[26] “Esp working,” 2023. [Online]. Available: https://catalog.us-east-1.prod.workshops.aws/workshops/5b127b2f-f879-48b9-9dd0-35aff98c7bbc/en-US/module1/esp32

[27] “About blynk app,” 2023. [Online]. Available: https://www.g2.com/products/blynk-iot-platform/reviews

[28] “Metamask.” [Online]. Available: https://www.investopedia.com/metamask-cryptocurrency-wallet-review-5235562