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IOT BASED SMART METERING SYSTEM IN SMART HOMES

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Master's Thesis

Supervisor

Asst. prof. Dr. Abdullahi Abdu IBRAHIM

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The thesis titled IOT BASED SMART METERING SYSTEM IN SMART HOMES prepared by MOHAMMED HAMID MOHAMMED and submitted on 09/08/2022 has been **accepted unanimously** for the degree of Master of Science in Electrical and Computer Engineering

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Mohammed Hamid

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ABSTRACT

IOT BASED SMART METERING SYSTEM IN SMART HOMES

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Even while new technologies are being developed to aid in the growth of humanity, their security systems still have weaknesses that might be exploited by those who want to steal or damage the data of others. An example of a typical security issue is the usage of passwords for devices that are either too easy to crack or too simple for users to remember. Botnets are a tactic used by malicious actors; they are networks of compromised devices that may be used to execute commands. Botnets are networks of hacked computing devices. As a direct result, issues about the security of the Internet of Things (IoT) must be addressed. According to, there might be as many as 26 billion Internet of Things (IoT) devices linked to the internet by the year 2020. Therefore, it is crucial to develop solutions for safeguarding the Internet of Things' security (IoT). In many network settings, intrusion detection systems serve as the first line of defense for network security. Several studies have been undertaken in this field of study, including [8] and [9], which use supervised machine learning to identify instances of hazardous behavior. [8] and [9] In these sorts of systems, the process of tagging databases demands a large investment of both computational and human resources. During the dataset preparation phase, also known as step 1, this technique's algorithm picks features based on the qualities of the data sets in order to organize them in decreasing order of their degree of similarity. This procedure is known as feature selection. DoS, R2L, U2R, and probing are among the four types of attacks that are included in the KDD CUP 99(KDD) dataset, which was created for testing IDS. There are 41 KDD features that are unique to every TCP connection. These characteristics may be categorized into three groups: traffic features, fundamental features, and content features. KDD has been used often in situations requiring intrusion detection data mining and machine learning investigations.

Keywords: KDD, IDS, CNN, DoS, SVM.

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ABBREVIATIONS

AI	:	Artificial Intelligence
FSK	:	Frequency Shift Keying
IoT	:	Internet of Things
PAN	:	Personal Area Network
OFDM	:	Orthogonal Frequency Division Multiplexing
TDMA	:	Time Division Multiple Access

1. INTRODUCTION

1.1 BACKGROUND

It is projected that the world of the Internet of Things will see unprecedented alterations. They are capable of communicating with one another on a far larger scale, exchanging information, and reacting and adapting to their surrounding environment. The Internet of Things (IoT) is commonly referred to as the third wave of the revolution in new information technologies, after the Internet's debut in the 1990s and Web 2.0's in the 2000s. Because IoT links common devices to the internet, this is the case. As a consequence of this revolution, it is much easier to create intelligent things. Home automation is merely one of several industries that the Internet of Things has substantially impacted (IoT). As a direct consequence of the emergence of new communication technologies and information processing solutions, our daily lives are in turmoil. To meet the requirements of today's intelligent living environment, housing must be able to accommodate new technologies that are aimed to simplify daily life, enhance the number of available alternatives, and achieve a higher degree. Internet connectivity, telecommuting, monitoring of consumption, information search, and many services and conveniences are included)

Figure 1.1: First internet message dispatched from UCLA

All these works propose that communication between computers must be done using packets and not circuits. Within the circuit-switched paradigm that is employed in telephone networks, users establish a dedicated connection with a fixed amount of bandwidth between source and destination during communication. This type of approach is efficient for voice telephone communications, where data is transmitted at a constant rate and the connection establishment time is, in general, less than the duration of the communication. However, the data traffic profile is different, it is no longer constant traffic, but burst. In this way, if the channel is allocated in a dedicated way, a great loss of efficiency will occur, since there may be periods where resources are allocated but not used. Another problem that can be addressed is that transmissions are often short-lived. Thus, the configuration for allocation of a circuit will have a large overhead. According to the packet switching paradigm, communication is not connection-oriented, and data transmitted on the network are separated into small units, which are chained to packets. Each packet contains the destination and origin address of the two entities that exchange information, and is routed independently through the network until it reaches its destination, without the need to reserve resources along its path.

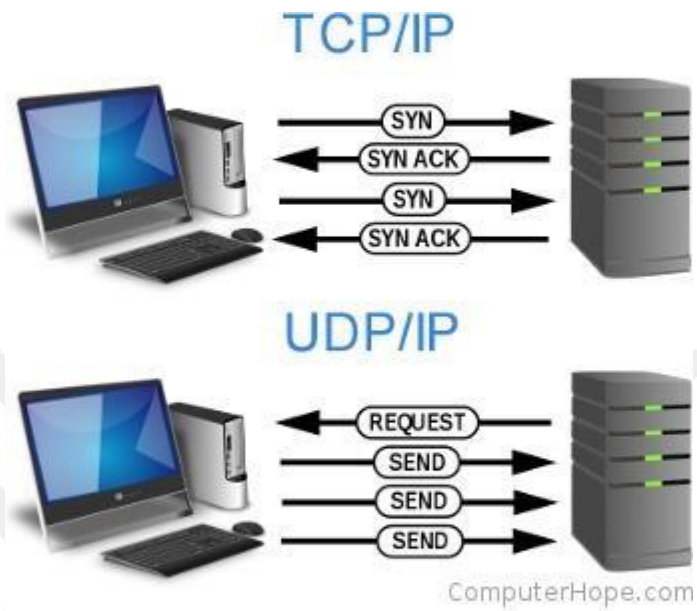

Figure 1.2: UDP/IP and TCP/IP protocols

In 1965, researchers examined whether or not computers using a time-sharing system could run programs and transmit data to other machines. These tests revealed that computers are capable of doing both tasks. In contrast, the circuit switching of the telephone network was completely unsuited for the discharge of this duty [6]. It has been shown that packet switch technology is an efficient form of computer communication. These concepts formed the basis for TCP/IP (Transmission Control Protocol/Internet Protocol), the very first protocol used for communication over the Internet. TCP/IP provided all of the capabilities required for "open architecture networks" to operate successfully. Internet Protocol (IP), which consists only of addressing and forwarding individual packets, and Transmission Management Protocol (TCP), which offers a number of functions including flow management and recovery of lost packets, were separated into two distinct protocols. IP is the only protocol that addresses and sends individual packets, while TCP provides all of these functions. This newly designed protocol enables applications that do not need TCP stability to have direct access to the core capabilities of the IP protocol. Previously, this protocol was known as the User Datagram Protocol, or UDP for short (UDP). As of December 31, 1985, the Internet was well-established as a mechanism of routine computer-to-computer communication and a resource for a vast community of researchers and developers.

1.2 PROBLEM STATEMENT

There are just a few apps that are now operating and have been widely disseminated, despite the fact that there are several companies working in this field. The most common commercial home automation solutions are automated lighting and thermostats; nevertheless, the ordinary consumer cannot afford a complete smart home system owing to the high cost and complexity of these systems. The most common commercial home automation items are automated lighting and thermostats. There are issues with the compatibility of the vast majority of these solutions with already-built homes. The availability of microcontrollers (AVR, PIC…) and low cost embedded systems like Arduino, BeagleBone, Raspberry PI, with their own Open Source platforms, has captured the attention of electronics inventors, experts, and small engineering firms. Automation. These tools are applied to create new concepts in this field by providing a large development space with very wide implementation possibilities and exceptional diversity, and possibly the appearance of a new type of these solutions which are call the home automation box in the market. With one goal, to guarantee comfort and improve the quality of life.

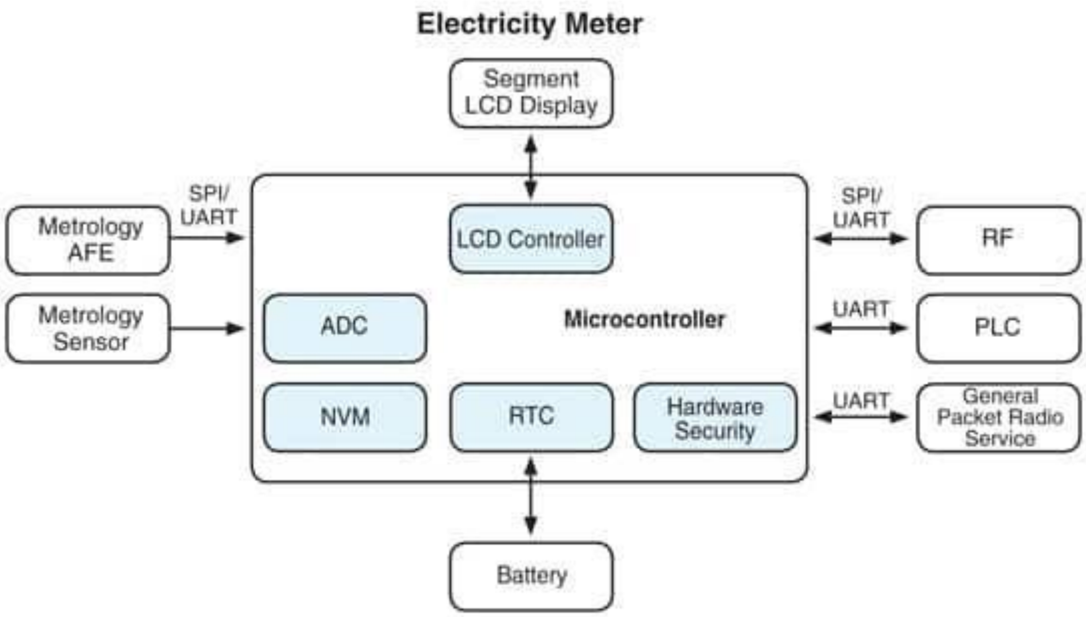

Figure 1.3: Schematic view of microcontroller in smart meters

1.3 AIMS AND OBJECTIVES

In this section, the general and specific objectives of the work are presented. Demonstrate the use of the Internet of Things and its communication technologies in the electricity sector in the area of smart energy metering. Apply the knowledge acquired to ongoing smart metering project, offering quality services to the consumer is a regulation and objective of energy utilities that seek new technologies to make their energy distribution networks more intelligent and connected. To implement an intelligent measurement and communication network, the concessionaire needs to look for new technologies that offer guarantees of reliability and durability, bringing financial return without unforeseen corrective maintenance costs.

To achieve the general objective, the following specific objectives are listed:

• Present the national interconnected energy distribution system;

• Understand the concept of Internet of Things, the characteristics and applicability aimed at the electricity sector;

• Deepen knowledge about communication technologies and their protocols that meet long-distance and battery life requirements;

• Investigate which communication technology has the best applicability in distribution concessionaires, taking into account various cost-benefit and regulatory factors;

• View the details of the technologies, with the purpose of consolidating the benefits of their adoption.

1.4 CONTRIBUTION

In this Master's thesis, we will propose an architecture and a design, of a smart house in the form of a low-cost home automation box, which takes a Raspberry Pi card as an intelligent element, and Arduino cards as control cards. communications and control, detailing the operation of the radio frequency layer of the system, the algorithms and protocols proposed, the technologies used, and explaining a little about the proposed circuits and the hardware used. The thesis is organized into 4 chapters, the first is the subject of a state of the art on the current technology of smart homes: commercial solution, and our open-source solution proposed as part of this project. The components of our solution will be detailed, in the second chapter the applications and modules based on ARDUINO technology, the third deals with the development and integration of an ARDUINO technology specific to the project, the fourth chapter is devoted to the design of the central body of our Smart Home project.

1.5 THESIS STRUCTURE

The thesis is structured as follows: Section 2 is where we review some of the previous work and implementation on smart grids. Section 3 is where we give a background about all the components. Section 4 is where we explain our model in details and implementation of that model in details, Section 5 is where we simulate our model and record the results obtained. Section 6 is where we conclude our work and put a future scope into perspective.

2. LITERATURE REVIEW

2.1 CHAPTER OVERVIEW

It is common practice to begin research with some type of literature review. However, even a comprehensive and objective review of the literature has little scientific significance. This is one of the reasons why systematic reviews are seen as so beneficial. A systematic review is a method for objectively describing and interpreting the findings of previous research. For example, systematic reviews must be conducted according to a predetermined search strategy.

2.2 LITERATURE REVIEW

Diverse companies and alliances are developing Internet of Things (IoT) frameworks and platforms to improve the connectivity of devices and objects to cloud storage and other network services. These frameworks and platforms allow multiple devices to communicate with one another and offer a substantial amount of analytical power. [11]. Using particular frameworks, IoT data from numerous applications can be accessed. These frameworks also offer additional services, including authentication and security. This survey investigates commercial frameworks, open source frameworks, and frameworks proposed by researchers. Some businesses rely on commercial frameworks, but solutions of this nature are considered proprietary. Components and technologies are made available to address a specific issue.

Maven Systems [39] is able to collect data from smart meters connected to GSM networks utilizing a wireless connectivity module known as WiArt. This information is currently being transmitted via GPRS to the data concentrator. They are capable of generating a variety of management reports and storing collected data in the cloud. ISM bands are used by Maven systems in order to communicate over a mesh topology.

Kevin Laubhan and his coworkers [17] devised a framework for transmitting sensor data to the cloud with minimal power consumption. A low-power microcontroller is responsible for collecting sensor data in the node architecture, and the regional hub is responsible for collecting data from that node. By utilizing a cloud-based architecture, data processing can be performed in a more efficient and straightforward manner. To maximize the coverage area while minimizing the amount of energy consumed, the algorithms for node deployment and scheduling must be enhanced.

An Internet of Things (IoT) framework for a smart water meter reading system was proposed by Neeharika Cherukutota et al. [10]. In order to connect water meters to the cloud, they have utilized a Mediatek cloud sandbox in conjunction with RESTful web services.

According to Enrique Carrillo and colleagues, the provision of computational power from cloud services can enable the development of a framework for intelligent systems. The proposed framework utilizes the integrated development environment provided by Arduino for the management and monitoring of the network. The Raspberry PI serves as the primary gateway controller for all Arduino projects, while Microsoft Azure's cloud services provide the computational power. Mohammed ShahanasK. and Dr.BagavathiSivakumar P. [25] propose a framework for an intelligent water management system, situating their work in the context of smart city initiatives in India.

They have made an effort to identify a cost-effective and cloud-based solution for the transmission and management of data. In Sanchez, Tomas, and others' work [24], they implemented an Adhoc network with clustering of objects and proposed a framework for increasing the network's lifetime in data collection.

Lloret, Jaime, and their colleagues [18] also suggested the use of a three-layered communication architecture. According to the authors, the lack of standardization in communication protocols renders proprietary meter communication solutions inapplicable to all types of smart meters. These solutions are intended to communicate with particular smart meter types. The smart grid is one of the Internet of Things applications considered to be of the utmost significance. Sensors and actuators are used to connect real-world consumer goods to the internet and give them the ability to communicate with one another [26].

Regarding the sphere of wireless communications, the Internet of Things (IoT) is shifting towards a hybrid paradigm (IoT). In recent decades, tremendous progress has been achieved in several domains as a result of the "anytime, anywhere, any medium" mentality that guides the evolution of communication technology. As a result, the ratio of radioactive particles to humans in this scenario is approaching parity [27]. There are three separate notions to examine inside the Internet of Things: things-oriented, internet-oriented, and semantics-oriented. [28] Things Oriented [29] may refer to tags, sensors, actuators, RFID, and NFC, among other things.

Internet Protocol version 6, Internet Protocol version 6 for Smart Things, and the Internet of Things (IoT) are all Internet-compatible protocols. Semantically oriented approaches may uncover difficulties with tags and sensors at an early point in the application development process.

Semantically, the Internet of Objects is best described as "things with identities and interconnections functioning in smart cities using intelligent interfaces to establish communication within social, environmental, and user contexts."

The WSN platform that M.T. Lazarescu and his colleagues [33] developed has the potential to be used to monitor Internet of Things-connected applications over a long length of time.

For this application, you will want a good service quality, sensors, rapid deployment, a long lifetime, and minimal maintenance costs. The notion of platform reuse with little effort is considered from the beginning of the requirements phase until the end of the design phase while creating a variety of linked monitoring applications.

Yashiro et al. [34] proposed that the uID-CoAP architecture would allow Internet of Things services to be hosted on common embedded devices such as home appliances. A software framework for embedded appliance nodes may be used to develop RESTful services. This framework combines the architectures of the restricted application protocol (CoAP) and the ubiquitous ID (uID). These traits would make it hard for a sensor node to compete. The framework was created with embedded hardware explicitly in mind. V.

When Trifa and his colleagues introduced the Lean Transport Protocol (LTP) for the first time, they referred to it by its acronym, LTP, which stood for "Lean Transport Protocol." Using this protocol, Web Service messages may be transmitted transparently across a broad variety of resource-constrained devices, servers, and PC-class PCs. Because the protocol is open and standardized, this is achievable. There is a need for a [bibliography]. LTP has the potential to be used in the communication process between Internet of Things-connected devices. Utilizing real measurements, it is proven that the capability has been enhanced.

In an effort to enhance their general reliability, flexibility, and security, as well as their overall efficacy, enormous electrical systems are progressively being interconnected with electronic and information technology. By coordinating system load balancing and utilizing demand-response mechanisms with time-based pricing information to homes, smart grid technology is possible to cut peak energy use. This is feasible due to its capacity to give pricing information depending on time. Advanced Metering Infrastructure (AMI), which is used by utilities to control dynamic rates on residential premises, should be included in a smart home. Obviously, a smart grid would include energy-efficient household appliances, different renewable energy sources, and automotive plug-ins (see figure 37). (System for Energy Management in the Home)

[38] Using their mathematical model, Bozchalui et al. [38] evaluated in real time the most crucial components of home energy consumption, including energy consumption, energy storage, and energy generation. Throughout this endeavor, models of popular home appliances such as refrigerators, washers and dryers, stoves, hot tubs, and pool pumps have been created. In addition, mathematical models for lighting, heating, and cooling systems are created.

Manages the loads in the home in line with the established priorities and ensures that the overall amount of energy consumed by the family does not exceed the predetermined limits. [39] In accordance with the results of Manisa et al., a simulation software was developed to illustrate the applicability of an algorithm by illustrating how it may be used to implement demand response at the appliance level and for residential users. This was performed to demonstrate how the method may be implemented. The HEM algorithm considers both the importance of the load and the consumer's degree of satisfaction.

Dae-Man and his coworkers have proposed [40] the development of a new routing protocol named DMPR (Disjoint Multi Path Routing Protocol).

Nils et al. [41] are investigating the efficacy of home automation systems in interior areas using wireless network connections. The comparison serves as a foundation for determining which wireless technologies are the most effective for usage in European interior environments.

The Grid-connected micro-grid (CMG) energy management program (Yujiao et al.[42]) addressed a variety of issues, including energy purchase and self-scheduling problems, to minimize energy costs by forecasting loads, prices, and renewable generation using genetic algorithm and pattern search methods, expectation model, and Monte Carlo methods to solve uncertainty problems. This was completed in an effort to save energy expenditures. connected microgrid energy management system for usage with electric cars and renewable energy sources (Y)

As part of their work on the DC microgrid, Chen and his colleagues [43] developed an energy management system that they were able to implement. [Bibliography required] LabVIEW is utilized to design the system, while MATLAB is used for modeling, analysis, and control. MATLAB is a graphical environment for programming. Zigbee and Rs 485 are two wireless communication protocols that might be used to regulate the DC microgrid.

Using the smart gateway [44] as a case study, it is feasible to improve the reliability of the power supply and provide better service to houses. Simultaneously, it is conceivable to reduce consumption and meet the demands of the average American home at a cheap cost and with high efficiency. [44] Daniel Wang and his coworkers [45] Individually and collectively, Tischer's colleagues [45] contributed to his success. The capacity of the smart grid to monitor and regulate its resource utilization is advantageous for both consumers and utility companies. Load management relies heavily on dynamic pricing for utility providers with time-varying rate structures.

Customers must regulate their appliances in line with the time-of-use rates for which they are being charged. Utilizing an energy management system to move the load to off-peak hours and decreasing the quantity of power consumed are, respectively, the two most effective methods for minimizing the monthly cost of a household's electricity bill. F.

LabVIEW is used by the energy management system developed by Baig et al. in order to give clients with a full energy profile that includes voltage, current, and power. Using zigbee technology, customers may remotely monitor and manage their home appliances.

Zaker, N., et al. [48] provide a Fi-WSN gateway that enables FTTX customers to prioritize the quality of service (QoS) of their data and achieve reduced latency for high-priority packets at predetermined levels. It may also be able to achieve the low latency levels needed by FTTX users with this gateway.

Using a public mobile network, the hardware and software approaches developed by Al-Ali et al. [49] enabled bidirectional communication with home appliances. This was done because there was a need to monitor and control the local power use.

3. MATERIALS AND METHODS

3.1 HISTORICAL OVERVIEW

Not until the early 1980s did the first applications for home automation emerge, and it was not until the late 1990s that they became mainstream. They were created as a direct result of the miniaturization of several computer and electrical components. The phrase "home automation" refers to the technique whereby home equipment may now operate more efficiently while using less energy. These advancements in electronic components have enabled this.

• Despite being on the market for over twenty years, the home automation sector continues to provide fresh ideas to consumers. Before the early 2000s, home automation was primarily a niche market. A number of academic and industrial institutions are currently developing the concept of a "smart home" in an effort to bring new technologies to life and attract more consumers. There is currently not the slightest amount of uncertainty regarding the future of home automation. Home automation is gaining popularity among those who desire a higher level of control over the various components of their homes. One of the aims of specialists that specialize in home automation is to make this notion as useful as possible for day-to-day activities. Since 2008, scholars and industry experts have debated whether or not robots, for instance, may be used routinely.

Again, the options are practically unlimited and are mostly constrained by the current state of development of the applicable technology.

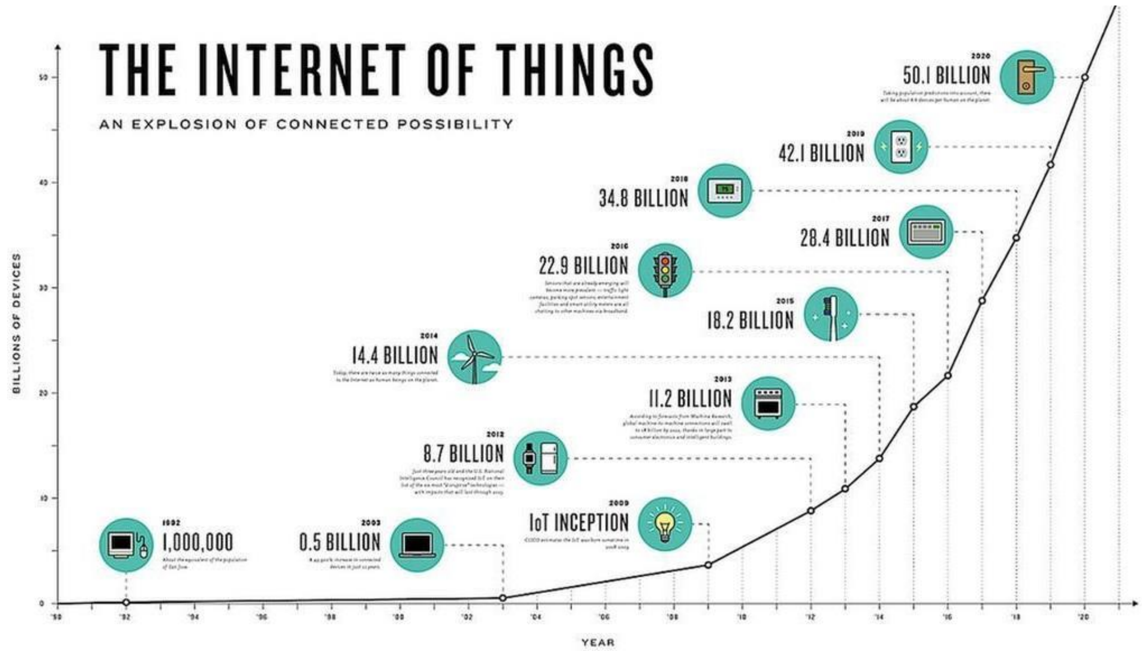

Figure 3.1: Timeline of IOT history

3.2 DISTRIBUTED ENERGY

The distribution of electric energy is the final step of the electric power system, after the generation and transmission of energy and consists of the delivery of energy to consumers. In order for energy distribution to occur efficiently with the least possible number of losses, several energy transformation and control systems are necessary. Substations interconnect the energy transmission system to the distribution system, lowering the electrical voltage in order to allow the use of electrical transformers that make it possible for consumers to use electrical energy the consists of four subsystems: The bulk of the northeastern and midwestern regions, as well as a substantial chunk of the northeastern regions. Using the transmission grid, energy may be transported across various subsystems, allowing for synergistic effects and the opportunity to study the hydrological regimes of basins with distinct characteristics. Combining the resources utilized for generating and transmission enables efficient and cost-effective delivery of dependable service to the market. The bulk of the SG's installed generating capacity consists of hydroelectric units, which are dispersed throughout sixteen distinct hydrographic basins in various parts of the nation. In recent years, the installation of wind farms, mainly in the Northeast and South regions, has shown strong growth, increasing the importance of this generation for serving the market. Transmission systems integrate the different sources of energy production and make it possible to supply the consumer market.

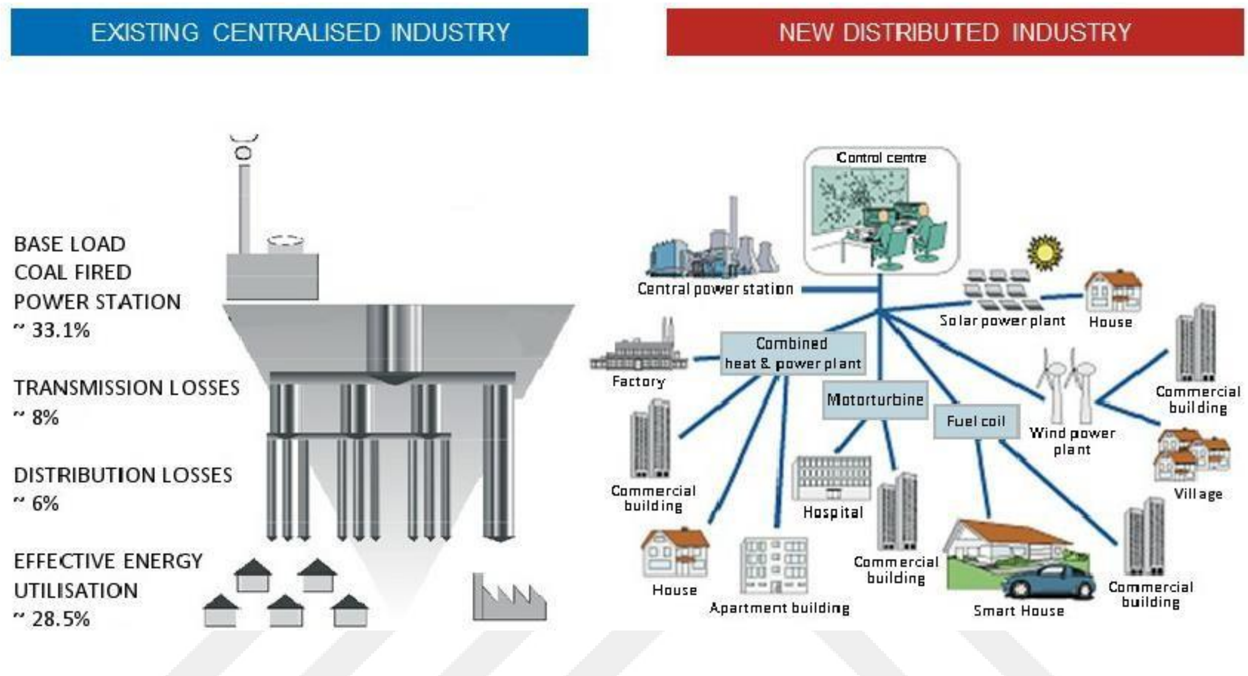

Figure 3.2: Evolution of distributed energy generation

3.3 INTERNET OF THINGS

To assist in the understanding of this work, the concepts about the Internet of Things will be presented here, which also includes communication technologies and the main protocols in addition to some basic examples of applicability.

3.3.1 IOT Concept

The Internet of Things (IoT) is a global infrastructure that enables advanced services through the interconnection between things (physical and virtual) allowing the capture, analysis and manipulation of data autonomously and intelligently, through several technologies, being able to react to events initiated by the data obtained between these “things” and the environment in which they are inserted, based on information and communication technologies. The term Internet of Things was first mentioned by Kevin Ashton, one of the founders of MIT's Auto-ID center, in 1999. On that occasion, the author reflected on the possibility of computers having knowledge of everything that was possible to know about the environment around it without needing the help and intervention of users Objects that are part of the Internet of Things have the following requirements:

• Shape: Possessing a physical object;

• Identification: Possess a name and address on the internet;

• Communication: Ability to send and receive information with other devices;

• Interaction: Transfer information to other network objects;

• Intelligence: Process even the basic information collected;

• Sensing: Collecting information from the environment where it is installed and operating.

Thus, objects or intelligent things become active participants in business, information exchange and social processes. These smart objects are characterized by the ability to interact and communicate with each other through the exchange of data or information captured through electronic sensors that convert analog signals from the environment into digital signals. Through the combination of several technologies, the Internet of Things has increasingly shortened the distance of monitoring and managing processes in recent years, enabling billions of devices to be connected. According to [44] a leading research and consulting company, the number of connected “things” that will be in use in 2017 is expected to reach 8.4 billion. This is equivalent to 31% more compared to 2016. The estimate is that this number will reach 20.4 billion things connected in 2020.

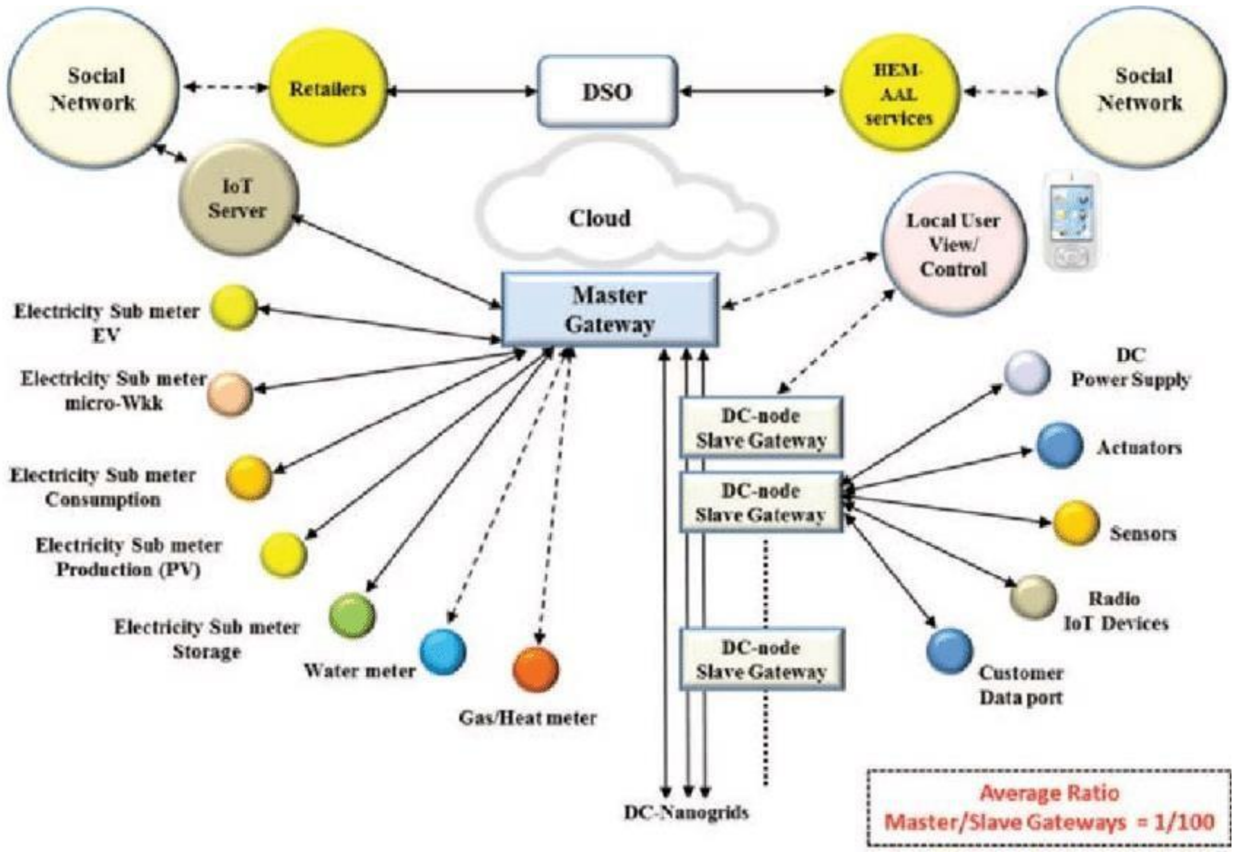

Figure 3.3: IOT concept for smart home communications

3.3.2 Applications of IoT in the Electric Sector

There are several applications for the Internet of Things and in the electric sector it is possible to demonstrate the applicability in several areas with financial objectives and consumer loyalty with the company. Below are some examples of applications:

• Electric vehicles and the growing need for fast charging stations;

• Monitoring and management of energy distribution network assets;

• Reduction of energy waste through real-time control of losses;

• Communication between equipment and field teams;

• Smart networks with system re-establishment for service continuity;

• Smart meters that allow you to monitor energy consumption. Based on the examples above, the following chapters detail the Internet of Things in Smart Meters and the technology used for communication.

3.3.3 Smart Metering

The Smart Meter is the identification and measurement of consumer energy consumption and the transmission of data to the utility. It can also provide in real time, in addition to consumption, quality values in the supply and allow the control of appliances and devices in the consumer's electrical installations. With the adoption of smart meters, the utility can remotely control the use of energy by cutting and reconnecting the supply without having to go in person to the consumer unit. The charge for the energy used can be monitored in real time by the consumer, who can thus change their consumption habits to reduce the final amount of the bill. For the adoption of an intelligent energy metering system by the energy distributor, the replacement of electromechanical meters is necessary. quality and billing information. Regarding the characteristics of the technology, each meter connected to the communication network has its own IP address and sends the tax page every 15 minutes and sends the mass memory 4 times a day. Smart Meters are key elements for the adoption of smart grids by utilities, being directly linked with the advanced metering infrastructure or Advanced Meter Infrastructure (AMI). For smart meters to transmit and receive information, it is necessary to implement technologies that allow instant data communication with reliability and security. In the following items of this monograph, the intention is to highlight the technologies and protocols related to the Smart Meter project being implemented

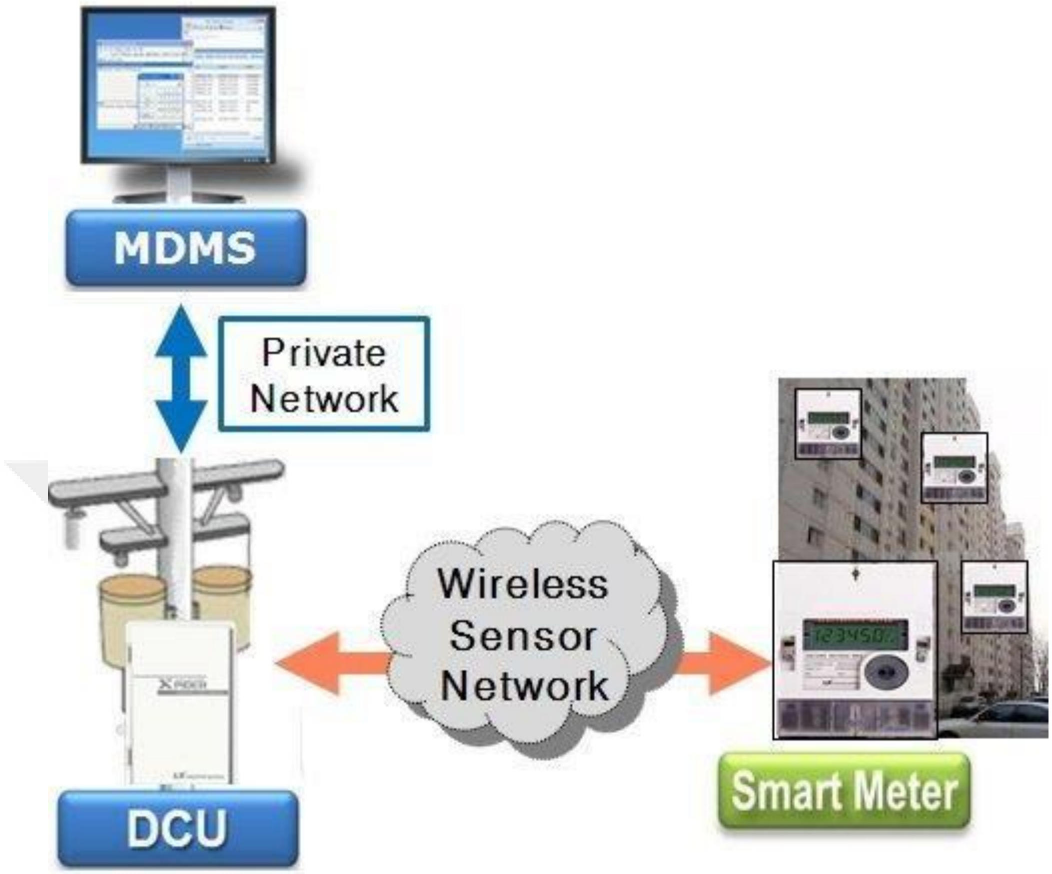

Figure 3.4: Advanced Meter Infrastructure (AMI)

3.4 COMMUNICATION PROTOCOLS

Communication protocols are sets of mandatory rules and standards that every object or equipment must follow for the correct transfer, reception and interpretation of data in an IoT network. Without these protocols, communication would become chaotic and inefficient. For the proper functioning of communication in the IoT network, the existing standardized protocols are used, such as the IP protocol, which provides communication with the Internet and has well-defined rules to connect thousands of equipment, and the specific protocols that are used for communication. between objects and with hubs. There are several current protocols used in the Internet of Things and the main ones are mentioned below, with emphasis on the normative standard, practical applicability and frequency of operation. On the Internet, in order for objects to communicate correctly, there is a set of protocols that are required. Among these, the IP protocol is one of the main ones and is responsible for assigning an address to these devices.

3.4.1 Internet Protocols: IPv4 and IPv6

Currently, the most used version of the IP protocol is version 4, however, due to the scarcity of new addresses, a new version of the protocol, version 6, was created. 1990s, almost 20 years after its emergence, the IPO IPv4 protocol is based on a pool of addresses encoded in 32 bits, which makes four billion addresses available for devices to be directly connected to the internet IPv4 addresses are of the form 179.96.35.170 and use 4 8-bit words or octets, resulting in 2 to the 32-bit. This generates 4,294,967,296 possible IP addresses. The IANA, the central body for allocating IP numbers for the Internet, no longer has a stock of IPv4 addresses. When version 4 of the IP protocol was developed, a network with billions of connected devices was not imagined, nor the problems of security or transport of so many types of data and services through the networks. IPv4 is not scalable enough to meet the demand for Internet of Things addressing. IPv6 replaces IPv4, being “a more effective approach to address the shortage of IPv4 addresses”

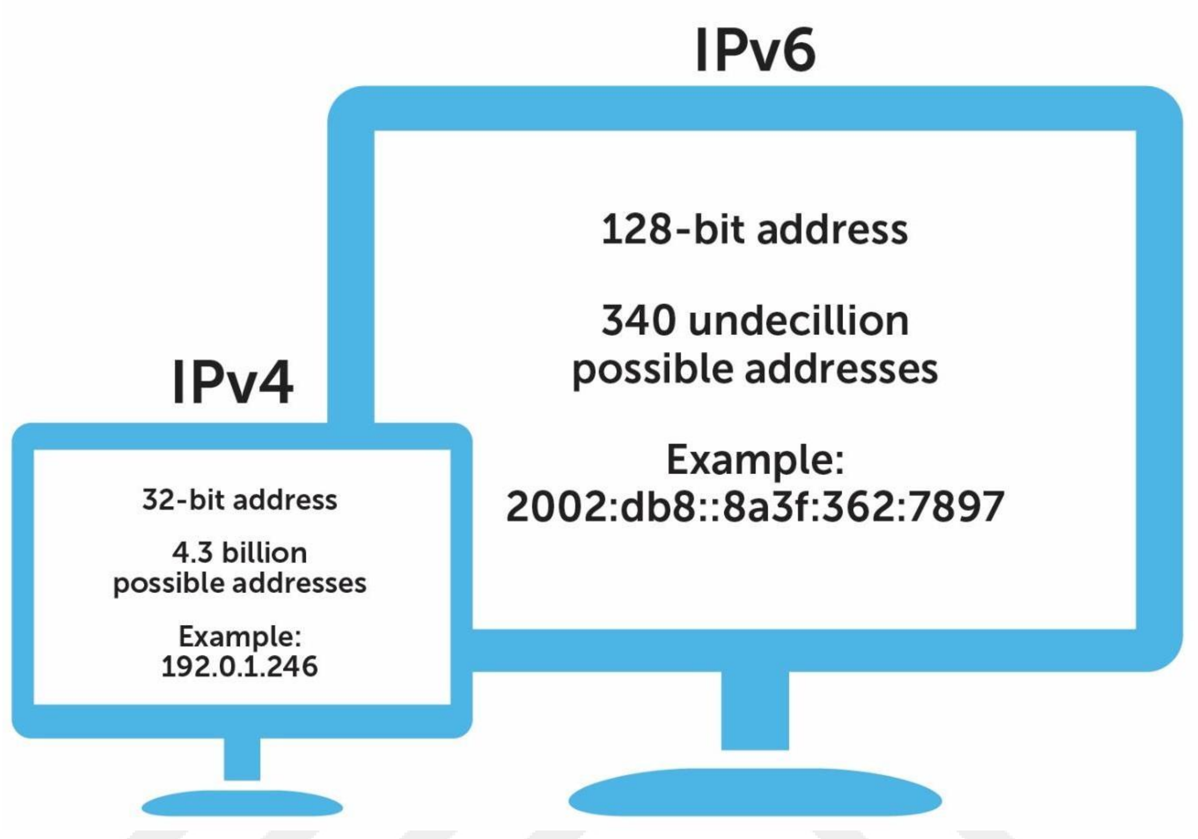

Figure 3.5: stock of IPv4 and IPv6 addresses

Therefore, it is necessary to migrate from IPv4 to IPv6, in order not to have a gross rupture between the technologies, since the intention of those responsible for the internet is to implement IPv6 and make it work together with IPv4 until everything can be migrated to the IPv6. In the world there are public and private organizations working on transition mechanisms that allow the interoperability of IPv4 and IPv6 networks. These mechanisms specify ways of tunnelling, routing and support for the two versions of IP protocols that are initially incompatible. With IoT, you basically have an IP address for each connected device or object. IPv6 arrives with addresses encoded in 128 bits, roughly 67 trillion addresses per square millimeter of the planet.

However, half of them is reserved for local addressing on the same network, and therefore, there are possible networks, enough to serve the internet in an imaginable future. Among the advantages of IPv6 we can mention:

• Large address space, global standard and Scalability;

• Simplified header format for packet delivery optimization;

• Hierarchical network architecture for efficient routing;

• Support for current routing protocols;

• Self-configuration services;

• Native implementation of IPSec;

• Growth in the number of multicast addresses;

• Implementations for quality of service;

• The availability of an almost unlimited number of IP addresses is one of the biggest benefits of the implementation. So IPv6 is the only possible technology to connect “billions to the internet” and build the Internet of Things.

3.5 WIRELESS COMMUNICATION NETWORKS

There are currently more than 60 formats of wireless communication protocols available for use in the Internet of Things, and this diversity grows every day. The big challenge is to carefully analyze each technology to determine the best cost benefit as well as meet all project requirements. The Institute of Electrical and Electronics Engineers (IEEE) recommendations, particularly the IEEE 802.11 series recommendations, are the best-known examples for wireless network standards and allow us to consider the existence of 5 large groups, compared in Figure 6. They are:

1.Wireless Personal Area Network (WPAN): Where are the short-range wireless technologies (between 10 and 100 meters). It is a standard for local area networks, defined by IEEE 802.15, for addressing wireless networks using portable or mobile devices;

2.Wireless Local Area Network (WLAN): Where are the wireless technologies intended for the interconnection of local networks with a range between 100 and 300 meters. This is a standard implemented as an extension or alternative to networks with conventional cabling (metallic pair or optical fiber);

3.Wireless Metropolitan Area Network (WMAN): These are technologies that deal with broadband accesses with transmission rates from 200Kbps to 1Mbps and are used for the last mile for networks in metropolitan areas, with a range of around 5km;

4.Wireless Wide Area Network (WWAN): Technologies aimed at long-distance networks in telecommunications, serving voice services and some data services; 5.Low Power Wide Area Network (LPWAN): These technologies combine low consumption with long range (around 15km).

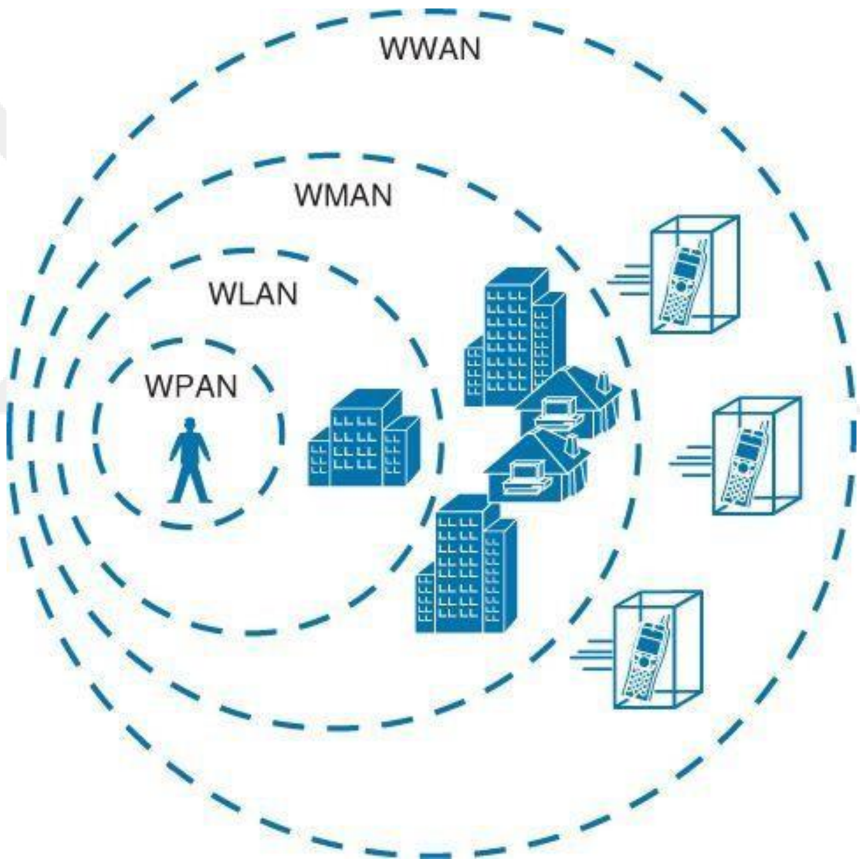

Figure 3.6: Wireless Communication Networks for Smart Homes

3.5.1 802.X Standards

Due to the need for standardization among wireless devices, the IEEE has established some technological standards aiming at transparency in the wireless communication of devices from different manufacturers.

3.5.2 IEEE 802.15.4

Standard IEEE 802.15.4 is a standard for low-speed WPANs. They are characterized by serving low-cost devices, communicating over short distances, generally powered by batteries and with severe restrictions on available processing and memory. The complexity of IEEE 802.15.4 is considered low compared to other similar standards such as Bluetooth. It uses three possible frequency bands: 868Mhz, 915Mhz and 2.4Ghz, adapting to the standards of most countries. The radio range is usually between 10 and 100m, but there may be devices with longer ranges (MOREIRAS, 2013).

3.5.3 802.15.4g Standard

IEEE amended this standard in 2012 to add IEEE 802.15 4g to better support the Smart Metering Utility Networks (SUNs) specific communication needs (IEEE802.15.4, 2011). (IEEE802.15.4g, 2012). SUNs play a significant role in the development of smart grids because they enable multiple applications to run on shared network resources, provide two-way communications between the measurement and control devices of a utility system, and cover vast regions containing a significant number of devices located outside the utility system. IEEE 802.15.4g for WPAN (Wireless Personal Area Networks) is intended to achieve data transmission speeds of 2.4 kilobits per second to 800 kilobits per second and to operate in several frequency bands ranging from 450 megahertz to 2 gigahertz. According to the IEEE article, the change was made to develop a worldwide standard for the regulation of large-scale industrial applications such as the power grid.

Table 3.1: parameters of IEEE standards for IOT

Frequency band identifier	Frequency (MHz)	Designation
0	169.400–169.475 (Europe)	169 MHz band
1	450–470 (US FCC Part 22/90)	450 MHz band
2	470–510 (China)	470 MHz band
3	779–787 (China)	780 MHz band
4	863–870 (Europe)	863 MHz band
5	896–901 (US FCC Part 90)	896 MHz band
6	901–902 (US FCC Part 24)	901 MHz band
7	902–928 (US)	915 MHz band
8	917–923.5 (Korea)	917 MHz band
9	920–928 (Japan)	920 MHz band
10	928–960 (US, non-contiguous)	928 MHz band
11	950–958 (Japan)	950 MHz band
12	1427–1518 (US and Canada, non-contiguous)	1427 MHz band
13	2400–2483.5	2450 MHz band

3.6 INTERNET PROTOCOLS FOR IOT

For the viability of communication between Internet of Things devices, it was necessary to implement a new protocol that allowed solving IPv6 packet header compression issues, keeping only the fields necessary for the use of the IEEE 802.15.4 standard, which limits the packets to 128 bytes. To solve this problem, the IETF created the 6LoWPAN (KUSHALNAGAR; MONTENEGRO; SCHUMACHER, 2007).

3.6.1 6LowPAN - Low Power Wireless Personal Area Networks

Low Power Wireless Personal Network is an acronym for IPv6 Low-power Wireless Personal Area Network, which is an Internet Protocol (IP) protocol. Another name for this protocol is 6LowPan. Figure 7 illustrates the 6LowPAN protocol. This protocol specifies the encapsulation of data packets, together with their respective headers and compression settings. The IPv6 stack was a crucial first step in the process of enabling the Internet of Things. A working group of the IETF named 6LoWPAN has developed specifications for adapting IPv6 protocol packets to the environment of low-power personal networks, such as those defined by the IEEE 802.15.4 standard and also known as sensor networks. Since IP is not required for communication, existing IP networks may be leveraged with 6LoWPAN without the requirement for proxies or content translators.

3.7 AUTOMATION IN SMART HOMES

Few individuals really know what home automation includes, despite the fact that everyone mentions it. To be persuaded, you need just peruse the catalogs of the several manufacturers of the goods. There are several dictionary entries with multiple meanings that have the same sound. The 1995 version of the Hachette dictionary has the following definition of "home automation": "Computing applied to all security systems and the management of household duties intended to facilitate everyday life." It will be a tremendous undertaking! When it comes to home automation, where does the consumption of electricity end and where does it begin? In the past, a single electrician might complete the electrical installation for a whole building, but this is seldom the case nowadays. All home appliances are interconnected, necessitating a wide range of technical abilities, such as electronics, automation, security, thermal, and energy management. This equipment is interconnected using wireless or cable connections that have been carefully designed. It is possible to link the power plant to a computer network using IP over Ethernet or a telephone modem on a home switched network in order to handle all of this equipment. These choices are both accessible. As a result, the term "home automation" is a contraction of the terms "house" (which is derived from the Latin word "domus") and "automatic," which alludes to the technological sector that deals with home automation. The technique entails establishing networks between various home stereos, home automation systems, and household appliances such as refrigerators. As a consequence, it combines a vast array of services that may be used in the process of integrating contemporary technology into the home.

Figure 3.7: Automation in smart homes

3.7.1. Definition of the Smart Home:

Since the words "Smart Home" and "Home Automation" are often used interchangeably, there is a danger of misunderstanding. In recent years, home automation has been overtaken by the notion of a "intelligent house," which refers to a way of building that includes the Internet of Things and advances in ubiquitous computing, also known as ambient computing. This building technique has replaced conventional home automation. The smart home of the 2010s is expected to prioritize the user experience, a break from the prevalent tech-savvy approach of home automation in the 1990s. In addition to the predominance of the computer component. Control and command must be centralized if the system is to possess intelligence. Unlike a traditional electrical layout, the control and power circuits in this system function separately. Now, it is feasible to create a link between the command receivers and the control devices, which are often located in different regions of the system. They debuted in 2009 and are now available from a number of vendors. In order to keep costs to a low, home automation boxes use the internet and wireless technologies as opposed to more typical wired options. Even if a user is not a member of the affiliated organization, they are available to anybody who wants to utilize them. To manage them, either a desktop computer or a mobile device may be utilized. Installation may be completed in a few minutes by almost anybody, regardless of their level of skill.

3.7.2 Ambient Intelligence

As a result of technological advancements and the capacity of sensors to connect with one another, the computer no longer focuses just on the user, but also takes into consideration the surrounding environment. The surroundings of a person may include their home, a moving vehicle, or their place of work. Weiser created the term "ubiquitous computing" in 1988 at the PARC Xerox Research Center to describe a kind of human-computer interaction that incorporates everyday activities into the processing of information [31]. The goal of ubiquitous computing has been achieved by the use of a large number of low-cost, long-lasting, network-connected devices that can be deployed in places where people conduct their daily activities. IBM used the term "pervasive computing" to characterize this burgeoning area of technology after creating it. In the relevant study, the phrases "ambient intelligence" and "ambient intelligence" are often used interchangeably.

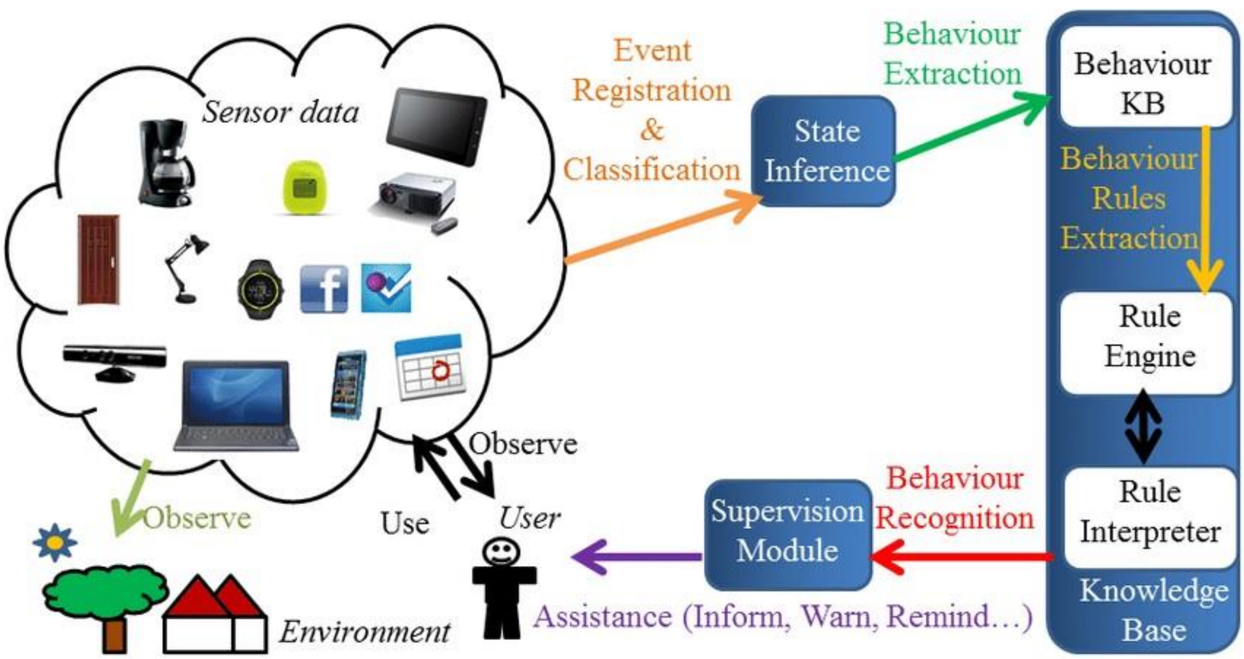

Figure 3.8: Ambient intelligence in smart homes

Both of these expressions have a number of similarities. Augusto J. C [32] argues that the idea of ambient intelligence has a greater scope than the mere availability of resources and that it necessitates the application of artificial intelligence in order to fulfill its aim, which is to exhibit a prudent and proactive disposition. This claim is founded on the fact that the idea of ambient intelligence has a greater scope than basic resource availability. We believe that this is more relevant. In contrast to the other two notions, "ambient intelligence" requires contributions from experts in domains such as "machine learning," "multi-agent systems," and "robotics." Objects have the capacity to communicate: Through machine-to-machine (M2M) communication, machines may interact with one another or with a central server without requiring human intervention (also known as Machine-to-Machine). This is a relatively new sector that is seeing tremendous growth as a consequence of strong technological and economic improvements. The rate of growth will vary from industry to industry. Nonetheless, there have been a number of hopeful advancements in the domains of health and safety... Also evident at the level of home automation is the proliferation of these networked devices. Objects like as water heaters, home appliances, and so on now have the capability to speak with one another. Even while their essential characteristics have stayed the same, this "interconnection" has improved the capacity of our domestic appliances by a factor of 10. In contrast, there is an abundance of newly created specialty products.

4. ROPOSED METHOD

Initially, only a small number of wealthy persons had access to electricity. These persons were mostly wealthy. As technical improvements were made, it became less difficult to accommodate the needs of the global populace. Researchers from the past had a significant contribution in the evolution of the electricity meter. In the early 1870s, telegraphs and arc lights were the only technologies in widespread use. The creation of the electric light by Thomas Edison in 1879 made it feasible for the general public to enter the market for electrical energy. Oliver B. introduced the world to Shallenberger's alternating current ampere-hour meter in 1888. The further advancement of metering technology will significantly enhance the quality of life for a huge number of people [33].

4.1 STANDARD METERS

The word "electricity meter" refers to an electrical device that measures energy and displays the data. Since the second part of the nineteenth century [28], traditional meters have been used. Both the generation and distribution of energy are computerized processes that include the exchange of data between numerous pieces of electronic equipment. Discs of aluminum are often used by conventional energy meters to monitor power usage [28]. Even though modern power meters are automated, they nevertheless have a few flaws.

Figure 4.1: depicts a conventional electricity meter with one phase and two wires

Listed below are some of the limitations connected with the basic electricity meter:

- Due to the fact that clients are expected to budget for their monthly power expenses in advance, electricity meters are infamously incorrect.
- Due to the mechanical framework that supports the measuring process, these instruments are also referred to as electromechanical meters.
- A substantial number of inspectors are needed to collect readings from meters.
- Payment processing, which is time-consuming and costly

- Why It is not feasible to create new hourly rates that are consistent with existing meters in order to attract new customers.
- The development of software for meters and the networks that support them requires considerable time and effort.

As a consequence of the installation of traditional meters, a chasm is formed between the user and the distributor, in addition to the constraints already outlined. Each meter type is unique from the others. Even if energy meters were erected in a timely manner, there is no way to alter power use data since no mechanism exists to do so. Here is a list of the most prevalent kinds of electricity meters:

Table 4.1: Other types of electricity meters

Different Types	Outline
Electrolytic Meter	The whole current passes through the electrolyte. The major drawback is mechanical considerations and adoption by limited localities.
Commutator Meter	Brush-shifting device is used to vary the current load and commutator's of small diameter facilitates in insulation attention. The major drawbacks are inadequate load characteristics, maintenance cost and lack of proper insulation.
Mercury Motor Meter	There is a satisfactory performance with the introduction of this meter. The adoption of rotor made a prominent role in supplying the calibration. The momentary short circuit is reduced or even prevented.
D.C Watt Hour Meter	This meter model is developed for heavy current circuits where the temperature coefficient is high. For indication of demand purposes a separate time switch is used. Also, it is a clock-type meter in which voltage variations is less with the reduced shunt loss.
Single Phase Induction Meter	Magnetic conditions are better improved to control the energy consumption and a considerable improvement in performance is also done. Meter inspection is easily assessed as the construction of this model has accessibility of simplifying assembly.
Poly-Phase Watt Hour Meter	Lagging power factors in the meter reflects the characteristics of the current transformer. Attempts for improving high degree of accuracy have been built to avoid troublesome corrections. Interaction effects, calibration and increase in the effects of shunt loss are the greatest drawback of this model.

4.2 SMART GRIDS

Current power grid is referred to as the "Smart System." The wide range of electrical products found in modern homes contributes to the instability of the electrical networks that supply these dwellings. In line with the expansion of the global population, the vulnerability of the world's power infrastructure is growing. Population expansion correlates with a corresponding rise in the grid's load. The capacity to remotely manage and enhance the reliability of the grid, assess consumptions in a communication that is supported by providing data (in real-time) to customers and suppliers, and vice versa, is one of the capabilities referred to by the term "Smart Grid." Automated sensors are used by smart grids. Using these sensors, utility firms may monitor power outages and prevent power lines from overheating by communicating the data they have seen. It takes use of its inherent potential for self-healing. The notion of a smart grid spawned the idea of a smart meter, which in turn led to the creation of a smart grid. It is projected that this company's installations will reduce carbon emissions by 5 percent annually by 2030; hence, this may have a significant influence on the environment. Smart Grids have been proposed for a number of nations in order to ensure the long-term viability of grid infrastructure and to allow the creation of additional grids.

4.2.1 Smart Meters

The kilowatt-hour-based "Smart Meter" is an energy meter that was designed to minimize its environmental effect (Kilowatt - hours). Customers who wish to save money on their monthly electricity costs may instantly profit from using this equipment. One of their roles as part of the Advanced Meter Infrastructure division is to guarantee that the energy provider gets automated readings from the meters. An image of a smart meter is seen below. Due to its capabilities, the Smart Meter will be able to deliver totally accurate meter readings. They measure the amount of food and fluids they eat less often, such as every hour. This kind of meter has tamper detection, remote connection and detachment, nonvolatile data storage, and bidirectional communication capabilities. They use the Internet to transfer the collected data to the central meter. This central meter is responsible for Smart Meter monitoring. The use of smart meters improves operational administration and control of the grid [6]. The following are a some of the advantages associated with the use of smart meters:

- The benefits-to-costs ratio
- Both utility users and utility companies save time when transferring meter readings to energy suppliers due to the time savings.
- It is possible to pay your power bill online.
- Using intimidation, it may be feasible to dramatically reduce power use during periods of peak demand.
- When appliances are not in use, they may be configured to automatically shut down [39].

The Smart Meter can monitor and record each and every unit of energy used by a residence. Readings from meters let energy providers to have a better knowledge of their customers' habits, which in turn allows customers to make modifications to their general energy use patterns. Last but not least, the amount of information provided by smart meters will be used in the construction of future citizens.

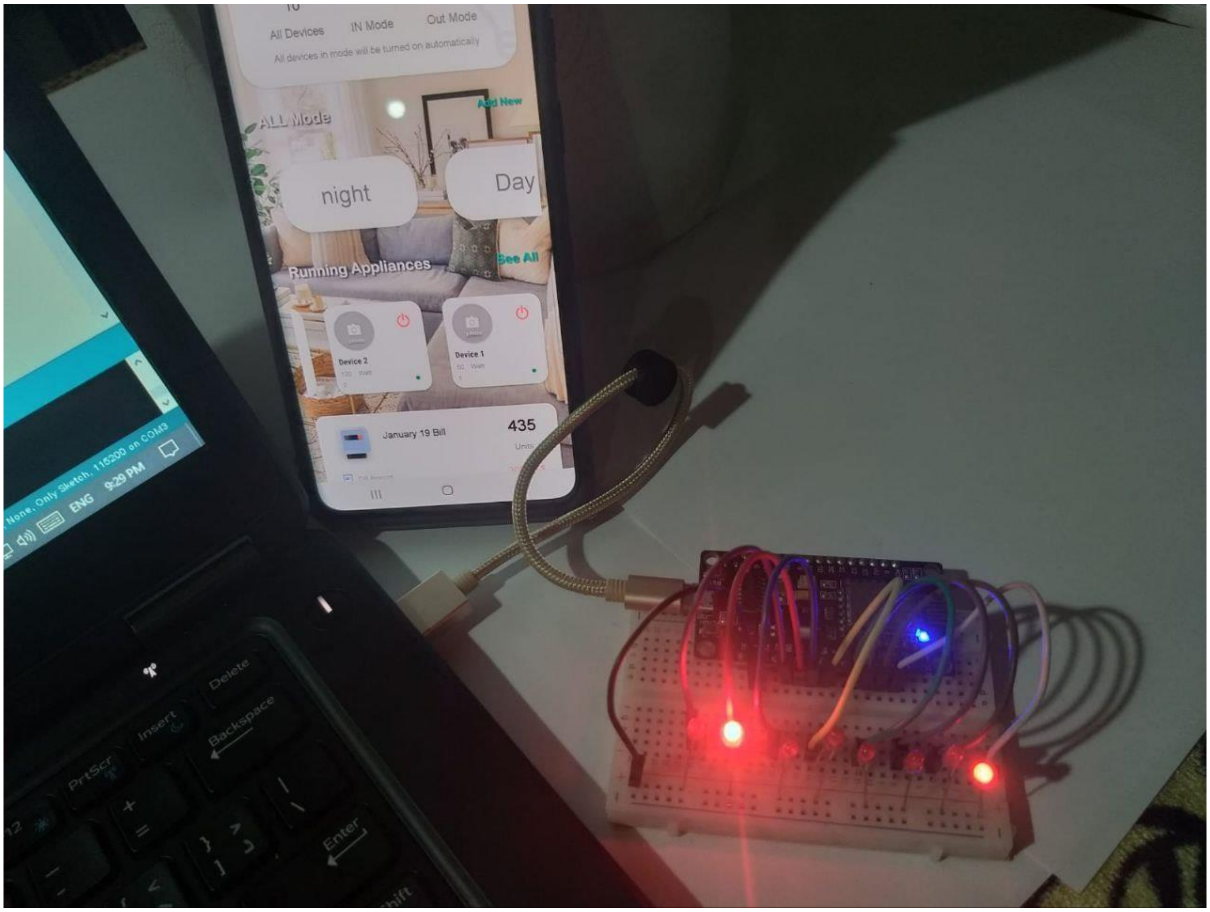

Figure 4.2: Image of the proposed smart meter

This gadget has a power usage of 4.4 Watts per hour. The word "electricity consumption" refers to the entire quantity of energy utilized inside a single dwelling. Utilization is of the highest significance in terms of energy accessibility. People must be aware of the need of energy conservation in order to conserve it for future generations. Because energy is required for even the most fundamental tasks, energy patterns have evolved throughout history. This variation in consumption patterns may be attributable to weather fluctuations or reckless energy usage by humans. Some folks, for instance, do not turn off the lights or the television when they are not using them. They might have a more significant effect on the user in the long run. As a consequence of the huge amount of energy supplied by energy suppliers, the great majority of individuals are unaware of the need of energy conservation. Utilities are beginning to diminish the significance of use in their operations. Customers must be made aware of the negative consequences of their existing consumption levels, and utility firms must play a crucial role in the development of smart meter technology.

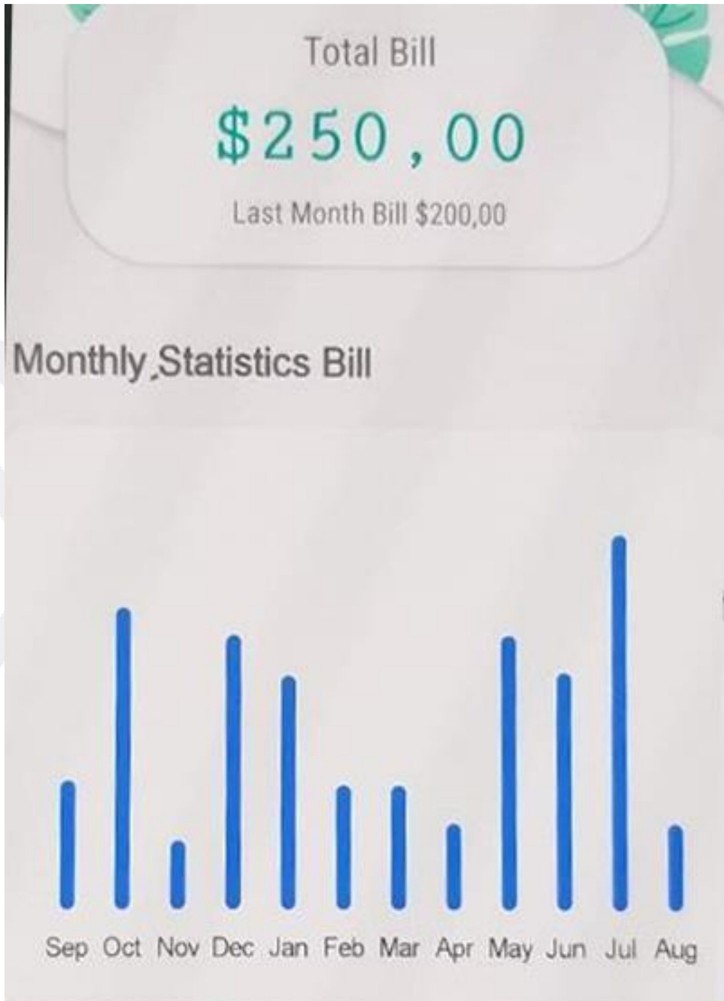

Figure 4.3: Monthly statistics of the proposed system

Consumer behavior refers to the habits and choices that consumers make about the usage of household equipment. Consumption by consumers is indicative of how often and for how long customers use equipment, and because this is the case, it follows that the cost is directly proportionate to the frequency and duration of usage. It is crucial that energy providers adhere to the criteria established by their customers. In actuality, the majority of customers rely on the next monthly payment they are required to make. The great majority of people are ignorant of which of their home appliances uses the most energy, much alone how to limit this consumption effectively.

The client's behavior is significantly affected by these factors. The only way to get a more comprehensive understanding of human behavior is to investigate how people use their energy. When using their equipment, customers must be persuaded in a style that demonstrates consideration. Figure 4.3 is an example of a Smart Meter being used to measure household appliances. This specific Smart Meter was put in the home. The graph above depicts the data collected by a Smart Meter on the daily energy consumption of a residence's appliances. Installing a Smart Meter outside the home and monitoring its hourly power use statistics might help homeowners reduce their energy costs. Even a modest house has the potential to be transformed to a smart home by using these measuring capabilities.

Concerns regarding the economic climate:

In the sphere of communications, the worth of a pleased customer is evaluated by the client's level of confidence in the provider's services. In [2,] the author discusses how people will utilize smart metering and the services it will offer, including real-time monitoring of electricity consumption, the ability to see the effects of turning on and off appliances, an estimate of the upcoming bill, and direct communication with the grid operator. Smart meters will be put in all American homes and businesses. The article presents forecasts on consumption patterns during nights and weekends. In order to encourage individuals to become more energy conscious, a survey is being run across many nations and family types, and user input is being collected. In an attempt to encourage ecologically responsible power use, a study has been done on the sociotechnical effects of placing smart meters in homes and businesses. There is a presentation of research questions, and responses to those questions are provided.

1) Is it possible to lower energy use while simultaneously influencing behavior via the use of feedback?

How should one precisely convey feedback when the time comes to do so?

Using a variety of energy-saving gadgets, [3] offers scientific advice on how to minimize energy use in the home. As part of a Smart Metering Privacy Model, the level of privacy given by a smart meter may be examined with or without the participation of third parties. The Smart Metering method provides a number of benefits, including decreased metering costs, higher energy efficiency, and a greater ability to identify fraudulent activities more quickly [7]. There, the results of a survey conducted on a sample of residences and contained in the publication [9] are provided. It has been mapped how customers feel about different home appliances. TAM, or the Theoretical Appliance Model, is presented as a theoretical framework for comprehending how smart home appliances are perceived. Perceived value, perceived ease of use, attitude and intent to use, as well as safety, control, and comfort are tallied. Concerns with the current state of technology include the following: There are a variety of methods for connecting the meter to the various appliances in your home. Multiple channels, including a dedicated line, wireless connection, web-based communication, and power lines, allow home appliances to communicate [1]. Creating a link between the meter and the data center helps maintain the security of the protected environment. When a device is linked to a Smart Meter, it is feasible to determine the amount of energy it uses when it is turned on and off, plugged in and disconnected [5]. The Smart Metering technology used by [8] involves the installation of one or more Smart Meters and the transfer of consumer data. In addition to the prospect of a decrease in carbon emissions, smart meters may deliver safer, more secure, and more cheap electricity to consumers. The Smart Energy Management System was designed in [13] to regulate transmission capacity and tariff generation for aggregated demand circumstances including Smart Appliances. Peak, off-peak, and mid-peak energy costs, quantities utilized, and total expenditures are tallied on a single worksheet. A graphical depiction of each appliance's energy usage is displayed. The article [14] explores the commercial viability of the smart meter from both the consumer and corporate perspectives. The properties of smart meters and their advantages over mechanical meters are described below. The authors of the research piece are eager to discover the study's hypotheses on the topics that will be explored. A more energy-efficient society demands more consumer knowledge of their energy use. As a consequence, a variety of various feedbacks to save energy and increase energy efficiency are presented as a result of this work. In [38], the Smart Meters of Hungary are described in further detail. In addition to activities based on tariffs and the ability to be remotely controlled, the meter also has two-way communication capabilities. There are many methods for connecting the meters, including Zigbee, Wimax, and Home Area Network (HAN). It has been recommended that a comprehensive energy management system be implemented. Cases: In [10], a web-based real-time reporting system is used to study the consumption habits of two British families and a workplace. It is explained what smart meters are, their advantages, and how they may be used to monitor energy use. The experimental setting for the study comprised of one dwelling from each of three distinct types. The experimental setup contains some of the previously disclosed hardware and software. In a 24-hour cycle, the graphs are studied online for weekdays and Sundays, both before and after the modification to the appliance. The scope of the investigation includes printing using a laser printer, heating water, and activating the central heating system. It is very recommended that appliances with a high burn rate get fast response. It was successful in reaching its goal of changing consumer behavior by directing attention to possible areas where savings may be made. In [36], a comprehensive examination of home meter data gathered every 15 minutes from fifty distinct households was performed. This resulted in the creation of several applications, including the identification of demand response potentials, anomalous load patterns, and the detection of defects. The article [11] discusses the usage of a Supervisory Control and Data Acquisition System (SCADA) to handle data from smart meters, billing information, and meteorological data. Researchers at the Pacific Northwest National Laboratory used the findings. During the month of April, the load profiles of two households are shown, one with the highest and the other with the lowest 15-minute energy consumption. It is simple to comprehend how temperature affects a home's energy use. [15] describes both the functioning of a Smart Metering development system for the Korean residential setting and the monitoring processes for the systems of other nations. As part of the pilot test, 77 different families in two cities use the device. These families hail from around the nation. The subject of the research is the In-Home Display, a crucial component of Korea's Smart Metering system. Smart Grid, Smart Metering, and Advanced Meter Infrastructure have all been the subject of debate. According to the study, those who live in the smaller homes are more sensitive to price increases. Before and after the implementation of In-Home Display, the daily patterns of power usage in two cities are compared. The average daily electricity consumption is affected by temperature.

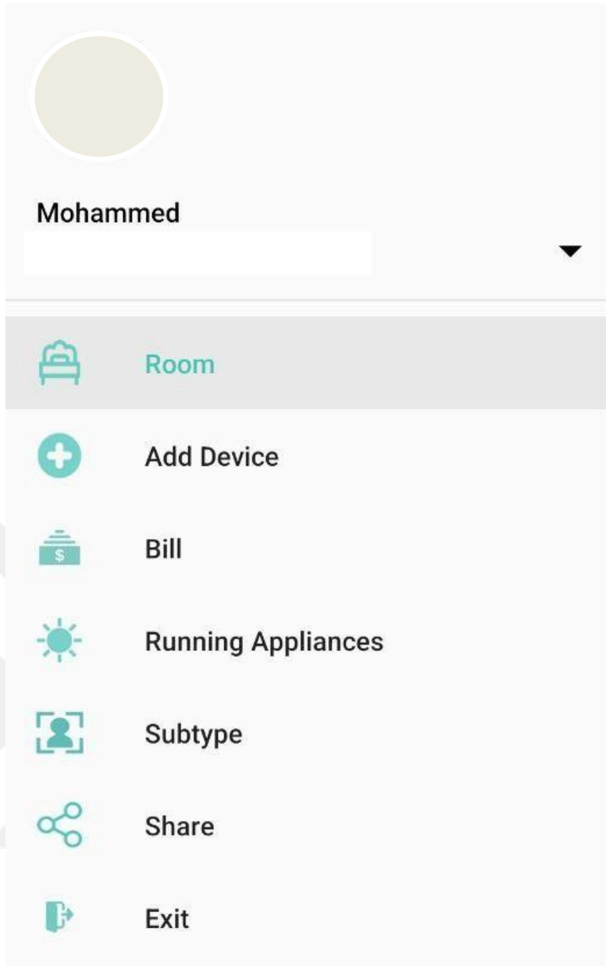

Figure 4.4: UI of the proposed HEMS

Utilizing the Home Energy Management System, it is possible to predict expenditures in [12]. According to the findings of the research, it is feasible that the experiment will result in a 22,2 percent reduction in the daily cost of electricity. Numerous pricing models have been described in depth, including real-time pricing, day-ahead pricing, time-of-use pricing, and critical peak pricing. XML is used to develop the client interface data model for energy usage. In addition, there is a comparison of actual and predicted expenses, as well as the peak hours of energy use (i.e., peak hours). The Home Energy Management System (HEMS) test bed is intended to enable the testing of different home energy management systems. The simulation model indicates that it is feasible to establish flat rates by generating the load profiles of individual homes (see [21]). This article investigates the effect of variable rates and energy-efficient household equipment on the monthly electricity cost of a family. The cost savings estimates for utilities and other costs are derived from field experiments. Users might save money by reusing the functions of different items of domestic equipment. The load curves for working days, Saturdays, and Sundays are provided here. A side-by-side comparison is made between the load curves for flat rates and time-based tariffs. This study's findings provide light on how hypothetical pricing changes can influence consumers' purchase choices. As described in [22], an ARIMA model that accounts for the likelihood of forecasting mistakes may be used to predict the short-term price of energy. Using data from the California electricity market as historical input, the ARIMA model is used to examine daily average prices. Here are graphical depictions of both single and double error predicting curves. In order to make a price estimate for the state of California, statistical metrics such as the mean, variance, Mean Square Error, and Maximum Absolute Error are provided after two error corrections. Utilizing the European Energy Exchange's data, [26] was able to anticipate the spot price of power. It was determined that modeling the experiment yielded the most accurate findings. The maximum and average absolute percentage errors produced by the model were rounded based on the data. This study considers information from the Spanish and Californian marketplaces [27]. To assess the differences between the two markets, the ARIMA model was used. Using time series analysis, the prediction powers of the model are shown. The projections for the Spanish market take five hours, but the forecasts for the Californian market take just two. The approach used by the Provincial Electricity Authority of Thailand to project monthly energy data deconstructs trend cycles and seasonal trends. You may find this information in the report. In time series forecasting, the decomposition approach is used; the accuracy of fitting is assessed using correlation coefficients and mean absolute percentage errors [36].

4.3 RESULTS

It is a case study in which data analysis is conducted using a specific research approach. We took a number of processes while conducting the case study we used for this study. The necessary activities are as follows:

In the early phase of our research, a regional energy supplier who requested anonymity supplied us with information from smart meters. This data has been forwarded to our management.

The supervisor of our team shares this information with us so that we may independently study and evaluate it. Since the information acquired by smart meters is given by a utility company, it may be depended upon.

There were Microsoft Excel spreadsheets included with the material that was sent to me.

Excel files a and b provide the pricing on the sheet, we compared the prices in SE4, which stands for the fourth district. Due to the fact that the hourly rates for each day are varied, there are a total of 24 distinct pricing for each day.

On the second page, you can get the use data for sixteen distinct Smart Meters. The spreadsheet provides daily and per-household information. This page's data spans the time period from March 30 and April 1, inclusive. We added the current day's hours from 1:00 a.m. to 23:00 p.m. and the following day's times from 0:00 a.m. to 24:00 p.m. on the sheet. Excel spreadsheets are utilized to preserve the integrity of this information. Because data skips have such a significant influence on the outcomes, it is crucial to keep a close eye on the situation when restructuring the sheets. To protect the privacy and anonymity of the homeowners, each of the 16 dwellings has been issued a unique number between 1 and 16

In order to comprehend the real data from the smart meter, a fresh Excel sheet must be created. It has been organized on a sheet from 1:00 a.m. to 24:00 a.m. in terms of time, price, energy consumption, and cost, as well as the lag 1 autocorrelations and correlations of each variable. This was accomplished with regard to time, cost, energy use, and expense.

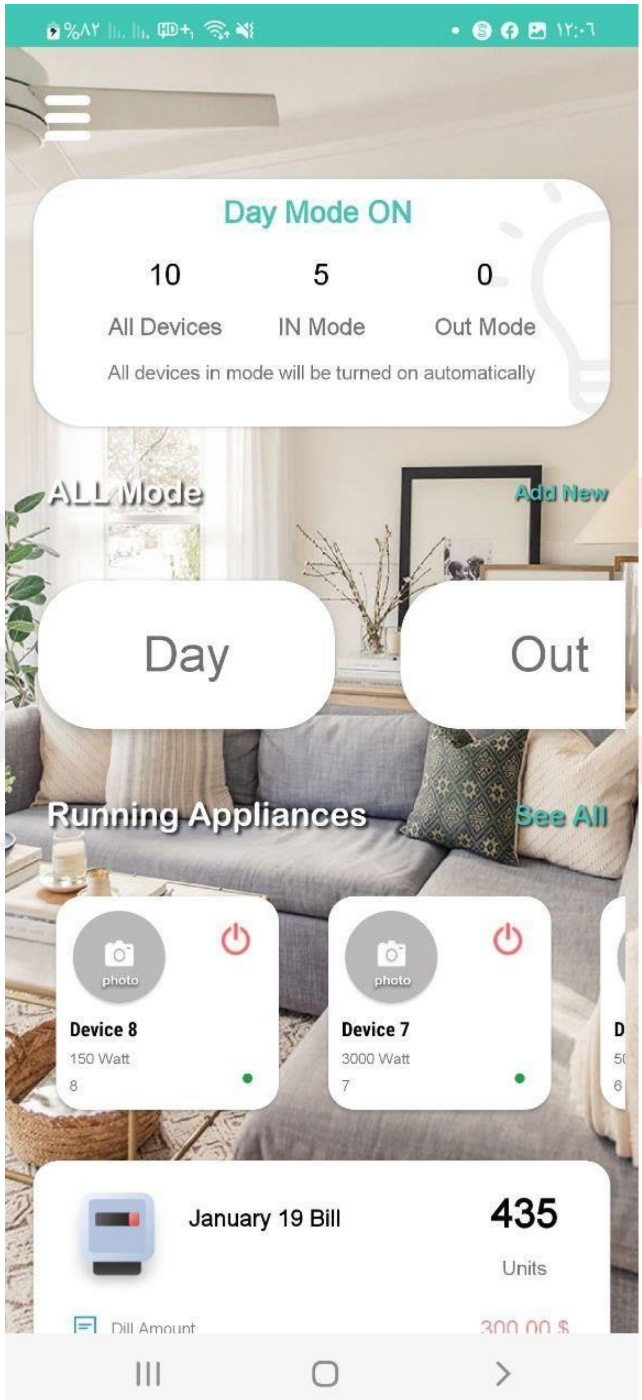

Figure 4.5: Device calculations on 24hrs bases

Graphs demonstrating time vs. consumption (kWh), price, cost, and cumulative cost are generated with research-derived data. On the x-axis and y-axis, respectively, graphs illustrating time consumption, price, time cost, and time cumulative cost are shown.

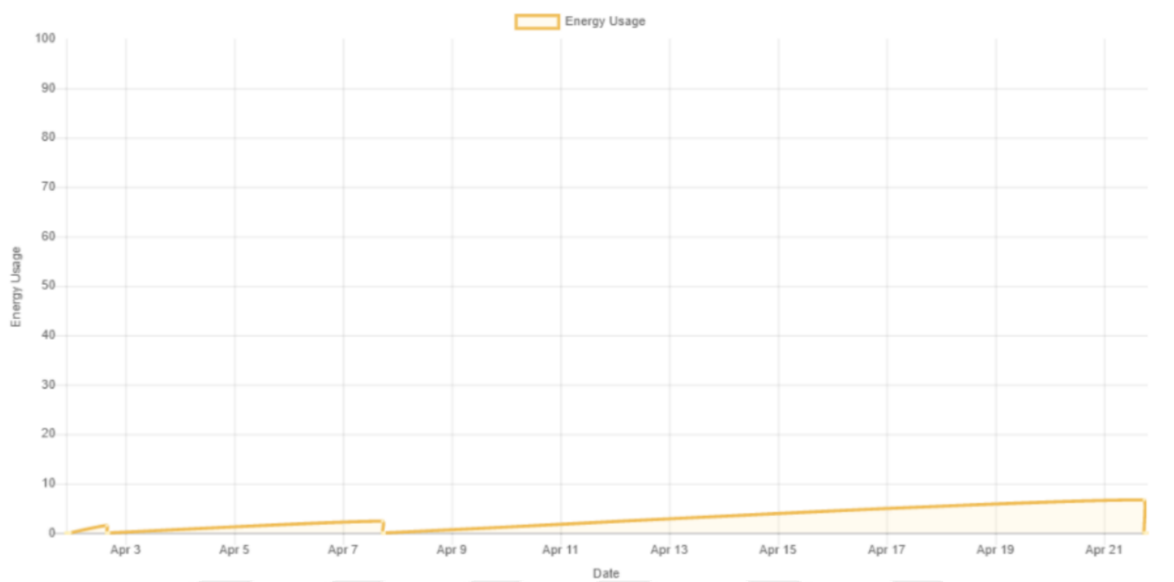

Figure 4.6: time range of energy consumption

Correlation is one of the most essential statistical measures for examining the connection between two variables. It is possible for the value to go from +1 to -1. There are two unique kinds available. It is said that the correlation between two variables is positive when one variable drops and the other one rises. When this happens, the connection between them is said to be moving in the same direction. In terms of statistics, the number +1 [29] denotes the highest possible positive correlation.

When one variable decreases, the other variable increases, and when one variable increases, the other variable decreases, we get what is known as a negative correlation between the two variables in issue. A negative correlation in statistical analysis may have a maximum value of -1. In addition, correlations between price and cost, consumption and cost, as well as averages, standard deviations, and coefficients of variation are calculated.

February 28, 2019 23:56:34	798.00000000	BDT667.00
February 16, 2019 00:00:00	60.00000000	BDT72.00
February 15, 2019 00:00:00	42.00000000	BDT8.00
February 14, 2019 00:00:00	40.00000000	BDT32.00
February 13, 2019 00:00:00	32.00000000	BDT4.00
February 12, 2019 00:00:00	31.00000000	BDT24.00
February 11, 2019 00:00:00	25.00000000	BDT20.00
February 10, 2019 00:00:00	20.00000000	BDT8.00
February 9, 2019 00:00:00	18.00000000	BDT4.00
February 8, 2019 00:00:00	17.00000000	BDT4.00
February 7, 2019 00:00:00	16.00000000	BDT12.00
February 6, 2019 00:00:00	13.00000000	BDT12.00
February 5, 2019 00:00:00	10.00000000	BDT8.00
February 4, 2019 00:00:00	8.00000000	BDT8.00
February 3, 2019 00:00:00	6.00000000	BDT8.00
February 2, 2019 00:00:00	4.00000000	BDT8.00
February 1, 2019 00:00:00	2.00000000	BDT8.00

Figure 4.7: Usage timetable

This process is performed everyday for the whole month for each individual family. This trend is seen in each of the sixteen distinct families.

To complete the analysis, an additional classified sheet is required. As a result of the investigation's success, we gave those sheets a moniker that related to the home represented by the number 1. This determined sheet was used to compute the actual cumulative cost, the average cumulative cost, and the difference between the average cumulative cost and the actual cumulative cost.

Since it is predicted that a positive correlation between price and consumption would lead to an increase in the cumulative cost, the correlation between price and consumption is explored. By comparing the hourly rate to the average cost of the service being rendered, this indicates the circumstances in which customers are placed in a disadvantageous or advantageous position. Both the connection and the difference are shown on separate plots. The first graph illustrates the number of days on the x axis and the connection between price and consumption on the y axis, while the second graph depicts the actual cumulative cost vs the average price and the number of days as difference graphs.

The presentation program Microsoft PowerPoint separates the most costly conceivable price, the peak power consumption, and the overall cost across three pages for your convenience and better understanding. In Excel files, correlation and difference graphs were created as a consequence of the integration of data from 16 separate households. Examining the link between consumption and cost is one of the greatest methods to analyze the customer's benefit from hourly charging. Cross-correlation. It is a way for keeping track of the relationships between items. Increases or declines in price and consumption go hand in hand by 10 percent. Consumption will always decrease in reaction to a price increase, and the opposite is also true.

When both of these criteria are present, there is a positive relationship between cheap price and high consumption.

When there is a negative correlation between the two, it is probable that low prices will accompany low prices.

The reader will have an easier and more efficient time interpreting the data as a result of the correlations established in this study.

Using Excel files containing power use data collected from an energy supplier, a thorough investigation was conducted. The calculations are made using an Excel spreadsheet that takes into account a range of elements, such as cost and time. Price-cost and price-consumption autocorrelations are computed, together with the means, standard deviations, and coefficients of variation for each of these variables. To make things as simple as possible for you, we have offered the aforementioned concerns in a table. All sixteen households' consumption, prices, expenses, and cumulative costs are collated and graphed. The following details must be provided for each parameter:

Power is the quantity of energy used in a certain length of time. Power is measured in kilowatt-hours and then divided by time.

The cost is determined by adding the purchase price to the total amount of energy used. We use the numerous monetary denominations as a unit of measurement. Since p is the cost per KWh given in monetary units and e is the amount of energy utilized in KWh, we may conclude that c = p. Following a thorough examination of the data, the following visualizations have been created. As they add to the overall persuasiveness of the information, the chosen images will be included in the final report.

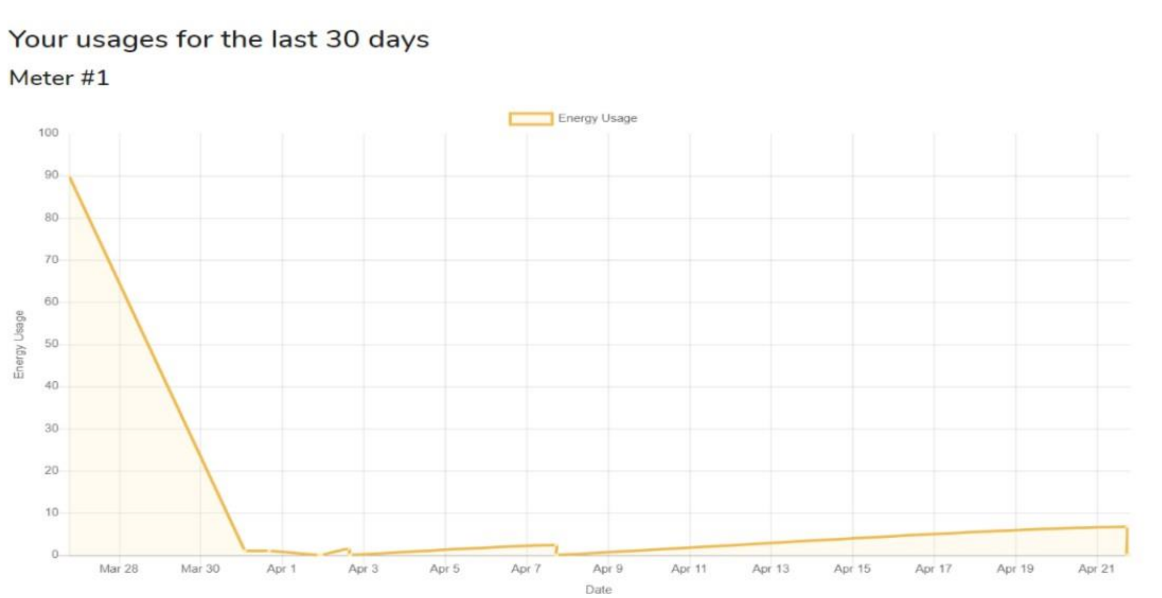

Figure 4.8: Final report of the energy usage

In terms of their energy use, the families shown in the following graphs consume 24 hours' worth of kilowatt-hours every day.

The y-axis of the graph that follows shows price, while the x-axis represents time (24 hours). This graph compares the expenses and prices of different households.

The following graphs depict the cumulative cost over time for numerous families, with the y-axis representing cumulative cost and the x-axis representing time (24 hours). This is shown by the three graphs below, which depict consumption, price-cost, and cumulative cost for a family on a given day. It is the initial step in analyzing multiple graphs in order to use them as references in the future.

5. CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

In the course of working on this thesis, I gathered, analyzed, and interpreted data regarding consumption, and I also graphed the daily activities of a number of different households. We proposed that they alter their subjected patterns by utilizing the many different methods of forecasting that are outlined in this thesis.

The models and research presented in this study have the potential to convince users to alter their patterns of consumption and to make better use of the funds that are available to them. In this section, the findings that were obtained from the investigation into the research questions are presented. Their individual names are given in the following list:

RQ1: How can the real-time power consumption of applications used in the home be measured and analyzed? Which different approaches are available? A review of the relevant literature indicates that smart meters can be utilized to accurately measure the amount of electricity that is consumed. [Citation needed] [Citation needed] When conducting data analysis, Excel spreadsheets are used to perform calculations such as correlation, autocorrelation, and standard deviation. The process of hourly billing and the capacity to make cost reductions both make use of cross correlation in various ways. An uncomplicated examination of the structure, accompanied by an original statistical presentation, has the potential to put the reader in the limelight by drawing attention to them.

In order to provide an answer to RQ2, how can we model both the energy consumption of individual households as well as the consumption of the entire population of households as a whole? The discussion of the ARIMA model in the results section has led us to the conclusion that the ARIMA (2, 0, 1) (2, 1, 0)12 model is a contented goodness-of-fit modeling model. This conclusion can be drawn because of the following: Helpful for forming educated hypotheses regarding the manner in which future price fluctuations will take place. It is helpful to have a look at the forecast for the next twenty-four hours in order to get an idea of what the next day will be like. The reorganization of market competition can be carried out in a variety of different ways according to this model. The utilization of accurate forecasting models can improve the ability of the utility as well as the customer to play a role in leveling out consumption, which will in turn have an effect on the price of electricity.

we have a number of different home appliances, if there is anything that can be done to lessen the amount of electricity that all of these devices consume on a daily basis? It is possible to bring the consumption curve down, which will result in savings in costs. In the section on the results, there is an analysis of the flattening technique that states it is possible to encourage consumers to consume more by incorporating beneficiary modifications and adjusting the timing of when consumers consume. This recently developed method is essential for both purchasers and vendors, as rivals can now formulate negotiation strategies based on the graphs that were flattened earlier in the process. This opens up more opportunities for everyone involved. In conclusion, we would like to state that it is the responsibility of each individual to contribute to the preservation and protection of the energy resources of the nation. As a direct consequence of this, the findings that were presented in this paper will be stored away for use in the future.

5.2 FUTURE SCOPE

Three types of predictive models are Artificial Neural Networks, Generalized Autoregressive Conditional Heteroscedastic models, and Autoregressive Moving Averages with Exogenous Inputs. The ability of these models to model volatility distributions, determine complex nonlinear relationships between dependent and independent variables, and improve future forecasts by utilizing past forecast errors distinguishes them from other models. This study could be expanded to include the evolution of additional real-time data from gas and water meters, most likely by employing a more sophisticated flattening method. In addition, the evolution of these data could be incorporated into this study.

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