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Electrical and Computer Engineering

INTERNET OF THINGS BASED ZIGBEE SNIFFER FOR SMART AND SECURE HOME

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INTERNET OF THINGS BASED ZIGBEE SNIFFER FOR SMART AND SECURE HOME

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Farah Shakir Mahmood ALbayati

DEDICATION

I devote and pledge this research work to my supervisor who is salient for guiding me through whole research work as well as my family for always assisting me in my hard time.

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First and foremost, I would like to thank my supervisor Prof. Dr. Galip CANSEVER for guiding and helping me along the way in writing this thesis. Discussing my progress, problems, and ideas with my supervisor Prof. Dr. Galip CANSEVER a couple of times every week helped me tremendously in understanding the logic behind the research. It made me better realize the technical need for this research work.

ABSTRACT

INTERNET OF THINGS BASED ZIGBEE SNIFFER FOR SMART AND SECURE HOME

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This thesis aims to resolve the Internet of Things (IoT) based ZigBee sniffer for smart home and determine the usage of energy or power with high spectrum allocation in future ZigBee Protocol with the help of clustering in IoT with data mining. The research work starts presenting an overview of the broadband network energy sector and the challenges that face it. It is observed a change in the energy policies promoting energy efficiency, encouraging an active role of the consumer, instructing them about the importance of consumer behavior, and protecting consumer rights. Electricity is gaining room as an energy source. Its share will keep constantly increasing in the following decades. ZigBee Protocol and smart meters' deployment will benefit both the utility and the consumer in the near future. New services and new businesses appear in this environment, focusing on the energy management field and tools. They require specialization in fields such as computer science, software development, and data science. This research has segmented the ZigBee Protocol according to the similarities of their electrical load profiles, using the proportion of energy usage per hour (%) as a common framework. This energy consumption segmentation aims to provide personalized recommendations to each group to reduce their energy consumption and the associated costs, fostering energy efficiency measures and improving consumer engagement. The desired segmentation is obtained by an iterative process, based on computational

clusters calculation (using a Python programming language) and finalized by a post-clustering analysis applying visualization and statistical data mining technique to detect the energy consumption and reallocate them to a more appropriate group. The K-Means clustering technique was tested and compared, giving the best prediction of accuracy 98.46% for all energy load profiles with a high spectrum of 100GHz. The solution from the K-Means clustering is the one that better adapts to the segmentation sought, which is used as the base of the post-clustering stage to obtain the final energy consumption segmentation. Most of these methodologies use the absolute values in 100 kWh, focusing on identifying the users with higher energy savings potential. The energy consumption segmentation of the electricity consumers provides knowledge and a better understanding of the consumer. In this particular case, it allows to personalize energy savings recommendations according to the ZigBee protocol-specific characteristics, improving the consumer experience by providing adequate advice at the appropriate time, facts that increase the effectiveness of the energy efficiency advice' service future ZigBee protocol.

Keywords: Internet of Things (IoT), K-Means Clustering, Energy Consumption, Smart, Zigbee protocol.

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LIST OF ABBREVIATIONS

AMI	:	Advance Machine Infrastructure
API	:	Application Programming Interface
DER	:	Distributed Energy Resource
EU	:	European Union
G2V	:	Grid to Vehicle
GPRS	:	General Packet Radio Service
IEA	:	International Energy Agency
kWh	:	Kilowatt Hours
Mtoe	:	Millions of Tons of Oil Equivalent
IoT	:	Internet of Things
TCP	:	Transmission Control Protocol
WAN	:	Wide Area Network
RDBMS	:	Relational Database Management Systems

1. INTRODUCTION

1.1 OVERVIEW

The Internet of Things can be defined as the network of physical devices embedded with electronics, software, sensors, actuators, and connectivity, enabling them to exchange data with each other and the internet using their unique identifiers as mentioned in [1]. Such an infrastructure allows the development of applications and services that facilitate the lives of citizens and workers around the world and bring us closer to the convergence of the physical and digital worlds. Some successful examples include Nest and Ecobee for smart-heating, Phillips Hue for smart-lighting. Smart things as a provider for multiple smart-home solutions, researchers in [2] worked for personal fitness trackers and personal assistants like Alexa from Amazon or Siri from Apple. These applications have provided us with smart-grids, smart homes, intelligent transportation, or smart cities.

Figure 1.1: A smart ZigBee used with several popular firms [2].

Despite the massive growth of IoT applications, the usefulness of the data originating from these systems is still to be validated and proved, as mentioned in [3]. The volume of data generated from a single sensor device installed in a house or a wearable device can be overwhelming for the device itself. In most cases, it needs to be offloaded to a data-processing application from which users can access it and connect it to a more meaningful use [4]. The rate of such devices integrated into our everyday lives causes offloading information in the cloud. Therefore, It creates vast volumes of data, as mentioned in [5]. Such data need to be communicated, processed, and stored in real-time while accessing it in its raw format tends to be useless when compared with the knowledge it can generate (e.g., information about a person's lifestyle and diet compared with their daily step count and trips as latitude-longitude coordinates) as mentioned in [6]. As a result, the need for a holistic solution on managing the data generated is still an open subject for research in both academic and enterprise scopes. Similarly, multiple interfaces for communicating and representing such data formats have been used, with none getting a clear step ahead of the others in the path for a global standard, if and when this will be possible.

Figure 1.2: Controlling the smart home feature with a touch of IoT [6].

Another essential characteristic of the IoT domain is the massive diversity of communication mediums, protocols, data representation, and exchange formats. Figure 1.2 showcases how IoT devices communicate the collected data with cloud services using multiple technologies and protocols for local-only or local-to-cloud communications, as mentioned in [7]. Each protocol offers different capabilities in terms of throughput, communication range, or power consumption, based on the needs for the application use case. For example, communication protocols with a limited range like Zigbee, Bluetooth LE, or Wi-Fi communicate data between wearables or smart-home devices and local gateways, as mentioned in [8]. Zigbee and Bluetooth LE are better suited for devices that operate on batteries and exchange limited amounts of data (e.g., wearable fitness trackers or beacons). However, Wi-Fi is more suited for devices that need real-time communication and can exchange larger chunks of information like smart plugs or cameras. Such devices are mostly connected to wall outlets as Wi-Fi needs significantly more power, and batteries are not feasible long-term.

On the other hand, to communicate information with the internet, gateways or smart devices use technologies like DSL lines, LTE or LoRa, and Sigfox, as mentioned in [9]. DSL and LTE offer a higher throughput when compared to LoRa and Sigfox but have a higher installation and operational cost as they require on-premises infrastructures, maintenance, and recurring costs either as monthly or pay-as-you-go data plans as mentioned in [10]. Lora and Sigfox are simpler solutions, with no installations on the user's premises, other than the device itself, and minimal (i.e., a yearly subscription for Sigfox) or no costs (LoRa) but offer significantly reduced throughput. They use the characteristics of the communication module to define the sampling rate that can be achieved by the sensing modules of the device, as mentioned in [11]. A general rule followed in most available applications or devices is that devices try to sample and transmit data as fast as possible while maintaining decent battery life. This is done to ensure that the phenomena monitored are well observed and no desired events are missed due to devices sleeping to conserve power, as mentioned in [12]. This behavior leads to an ever-increasing load of data that needs to be processed to extract useful information and conclusions.

The fragmentation in the IoT domain presents the main challenge of integration and interoperability to achieve the desired result of a unified virtual environment. For instance, a data analytics solution needs to ingest data streams from multiple sources presented above. Mixing different hardware and technologies makes this much more complex to make every device or system "talk to" and "understand" each other. Finally, all the cyber-security and cyber-privacy issues for wireless communication and the control and operation are connected assets, as mentioned in [13].

From the user's or customer's perspective, it is a costly and time-consuming experience to become familiar with and maintain multiple solutions from different vendors and integrate them all in a single system, as mentioned in [14]. Industry standards are being developed (i.e., as wireless protocols) and continue to evolve through open-source frameworks that encourage collaborations among solution developers, but global acceptance is hard to achieve due to contradicting interests from the involved partners.

1.2 MOTIVATION

To better understand the collection mechanisms of data from more distributed and uncontrolled IoT installations, we also developed a solution that can collect data using smartphones in smart cities carried by volunteers in the context of crowd-sourcing campaigns. This method is used to augment smart-city installations with mobile and inexpensive infrastructures using the power of volunteer’s local activist groups, as mentioned in [15]. Such solutions can be deployed with minimal cost by the city officials as a new service that can provide them with essential insights for the local conditions, environmental, social, or other. This smartphone application was used in more than ten experimentation campaigns in cities around Europe by more than 50 users over the past two years, as mentioned in [16].

We also present a framework for characterizing the data from all the above inputs using Machine Learning in real-time by taking advantage of the streaming data mechanism developed in the data processing engine described above. This framework analyzed real-world data from smart-city IoT infrastructures and the data originating from smaller-scale IoT installations. The data generated in the context of the IoT do not follow the typical characteristics of data processing technologies and methodologies used in past computer science use cases as their volume usually exceeds the size a single machine can process in real-time. The first attempts to harness such data were made using big data technologies like Hadoop [17].

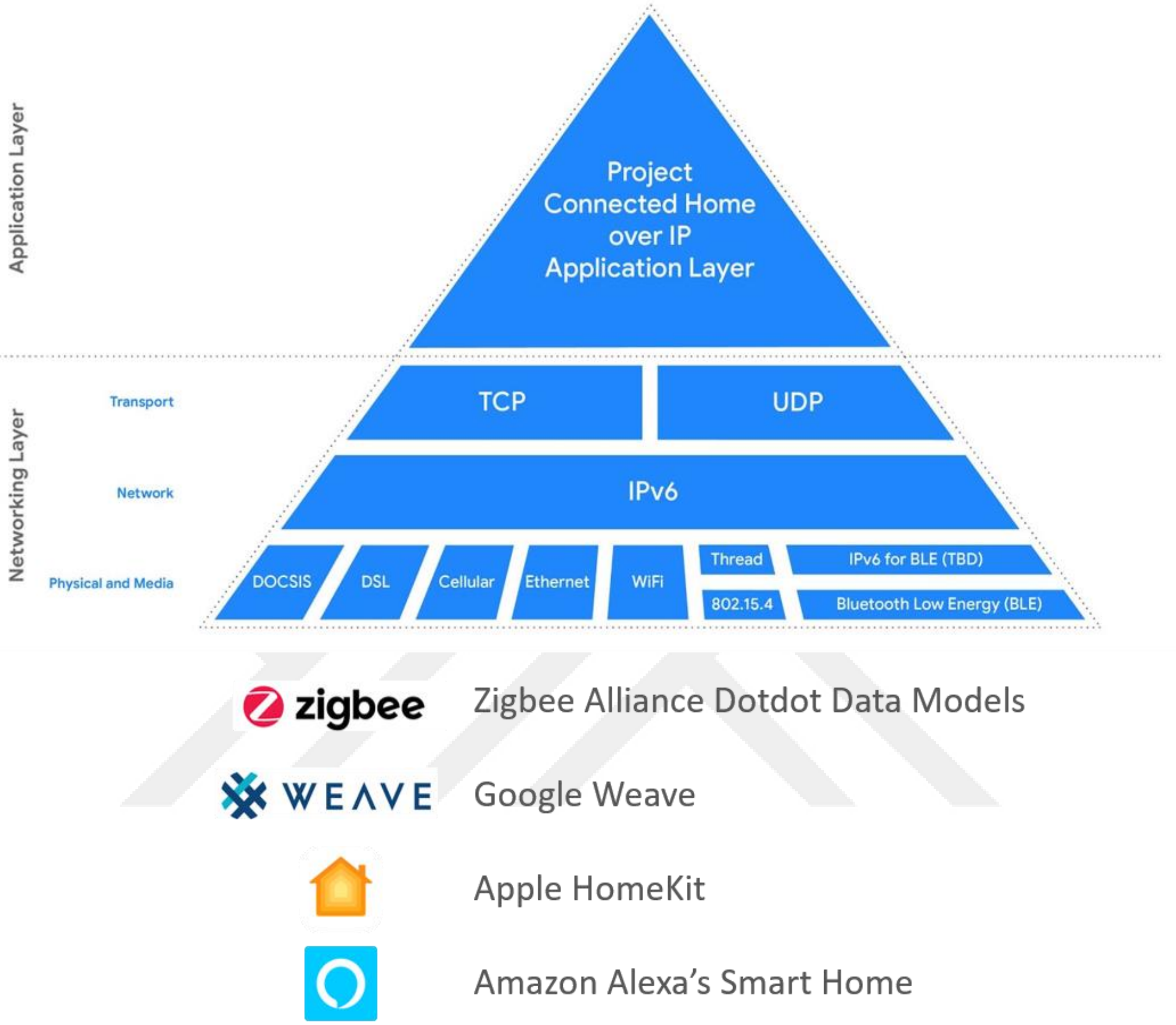

Figure 1.3: Technology pyramid for major solution providers [18].

Such systems use a set of processes that can be run in rounds one after the other, reduce the actual volume of data available to small and usable information, and overcome the original problems encountered in IoT systems. However, they lack a viable solution in IoT's most recent use cases, where the actual data are not a priori available to the system that will process them. Such data are called streaming and are becoming a more typical example of how the information from IoT installations will arrive at the processing system [18].

For managing large data streams produced by the Internet of Things for smart home, several research prototype implementations and some more commercially oriented solutions have been presented, as mentioned in [19]. An extensive set of requirements, like publishing/subscribing to data streams, interfacing with various technologies, and performing real-time analysis, make it crucial to build systems extending many classical RDBMS systems. One of the first available options in this area is a security monitoring system, as mentioned in [20]. It is a secure, scalable platform connecting devices and products with applications to provide real-time control and data storage. Other enterprises that offer computing services, like Amazon and Microsoft, also offer solutions for IoT-ZigBee data processing with AWS IoT and Azure IoT Suite, as mentioned in [21]. Both systems focus on helping device manufacturers collect and send data to the cloud while making it easy to load and analyze.

At the core of all similar solutions lies the concept of message exchanges typically using a central service that plays a security generation. In the general case, a security generation maintains a list of available topics on which client applications can publish updates while other applications can subscribe for updates, as mentioned in [22]. This design concept allows the development of asynchronous system designs that can be developed independently without restriction on the hardware or software used.

1.3 PROBLEM STATEMENT

In order to provide such a holistic solution, it is essential to be able to integrate the data generated by all of these smart homes in a common base. We need to be able to process them, view them and operate on them using a standard methodology and also be able to gain common knowledge with security monitoring. This is the most critical step towards unifying the information from a fragmented ecosystem that significantly reduces next-level applications and services development efforts. In this dissertation, we study the possible solutions to the problems above in an environment filled with IoT-ZigBee devices. We focus our work on the following research problems:

a. The representation of the IoT-ZigBee environment and its metadata and semantics in a suitable representation format can handle the complex relationships generated in such a densely populated environment.

b. We focus on efficiently collecting and processing streaming IoT-ZigBee data in real-time with minimum processing time and latency.

c. We use a modular system that can be extended to support additional data types and devices with limited interventions.

d. They are focusing on the extraction of knowledge from the collected and processed IoT-ZigBee data. Raw data are of limited value to end-users in most cases. The real value lies in the conclusions that can be extracted from them.

Once we have achieved all objectives, we will be able to analyze IoT-ZigBee data in real-time for smart home with security generation offering the outcomes of our work to researchers that can then build upon our work and generate a brilliant and connected environment.

1.4 RESEARCH CONTRIBUTIONS

Based on the problem set in Section1.3 in this dissertation, we contribute to data analytics for the Internet of Things in smart home environments and the post-processing analysis of the IoT-ZigBee data to better understand the physical surroundings with the help of solar system monitoring. We propose new and extensible methods to store the information of IoT-ZigBee installations, and our findings allow for fast lookups across the whole set of IoT-ZigBee devices in the network. Processing the data generated in real-time becomes a more streamlined workflow, using a standardized methodology that allows for changing the data analysis from a single point. Data generated can be easily stored and retrieved from a specifically designed, reliable, and efficient storage engine. Using the original and calculated data in a feedback loop also allows us to build additional processing and analysis layers that generate more data and information resulting in more accurate outcomes.

a. The first goal was to build a base set of infrastructures to digitally transform the physical world for smart and secure homes using ZigBee technology. We wanted to understand where and how it interacts with its environment and what it observes in real-time. Our work towards this direction was twofold: The results of our work can be categorized in the following points:

b. We have developed a graph-based schema to represent IoT-ZigBee installations together with their semantics and meta information. The schema is not based on the traditional relational databases but builds on the ideas of graph theory and utilizes a new database model, a graph database. Each entity that participates in fundamental world interactions or can be observed by the IoT-ZigBee device is represented as a graph node, while the interactions themselves are the graph's vertices.

c. We, therefore, build a web of entities and relations that are easy to visualize and traverse to find answers to various queries that may arise inside a smart environment. Such queries can look for the causes of events observed (e.g., what caused the rise of luminosity in the room), the available information for an area (e.g., what information is sensed for the building), or even the social interactions and connections of individuals (e.g., which people use the same appliances).

d. For the analysis of the data, we provide a template implementation for setting up a system that can receive, process, and analyze an unbounded number of input data streams with no impact on its operation using ZigBee with a data mining-based K-Means algorithm. Such data streams can originate from sources that range from single smartphones to city-wide sensor installations.

e. This processing engine can identify the data from each sensing device, routing them to the appropriate processor without any prior per-device configuration. The system can also handle data streams that provide unbalanced volumes of information with no performance drops. The calculation methodology is easily customized and extended based on the data types and the calculations required in every environment deployed to ZigBee.

f. The database and processing engine are used to support a publicly available system that supports over 300 users and consumes data from more than IoT-ZigBee installations with almost 5000 sensing points. Based on our evaluation, the database model can easily respond to all queries in real-time, even in cases where the database ranges to tens or hundreds of thousands of entities.

g. We also extensively evaluated the processing engine in real-world conditions for more than three months, achieving sub-millisecond processing times per measurement. We stressed our system with data volumes that exceed the data collection rates of our real-world installation to prove that it is future-proof and scalable.

1.5 THESIS OUTLINE

The first chapter presents background, motivation, research question, methodology, and outline. The smart home based on IOT network and IoT network challenges are presented with a specific emphasis in the introduction of the dissertation with dependencies of the problem statement and research contribution. The chapter ends with a description of the characteristics of an organization of the thesis.

The second chapter describes the literature review on smart home and the internet of things. It starts with a small historical note, a definition of the commercially available types of available solutions and ending with a description of the major drawbacks of not classifying the normal IoT-ZigBee network for smart homes and the definition of security system for real-time monitoring on a large-scale environment.

The third chapter presents the smart home IoT-ZigBee system with the methodology background. The concept of ZigBee technology with networking concepts is presented, followed by the methodology for smart home with security monitoring techniques, a characterization of the internet of things-based network, and the method for classification and reducing cost of security monitoring system with the internet of things by providing the cost analysis, the purpose of this chapter, go through a sensitivity analysis and are presented and discussed.

The fourth chapter in terms of structure is very similar to the third chapter, but for the result of dissertation with an aspect of this work, that is the IoT-ZigBee based smart home with security monitoring system using time-related features on the internet of things-based system. A typical framework outline is followed: first, the concept of IoT-ZigBee-based smart home results is described, then the objective and scope of the analysis are being found, followed by data collection for smart home using the internet of things.

The fifth section furnishes the conversation of the outcomes with an investigation and their particular conversation dependent on the impediments and examination with other existing frameworks on keen home with the internet of things with security observing framework.

The 6th part gives the principal determinations of this thesis and outlines the primary discoveries, the outcomes these outcomes have in arrangement making, trailed by the fundamental limits of this examination, and closures with leads for future work.

This thesis work is motivated by overcoming the challenges and difficulties that smart homes face with the help of IoT techniques in real-time with their structure and the environmental hostility surrounding them by creating a better environmental solution. This solution will avoid the shortcomings of the traditional smart home controlling operations. For the sake of explaining the motivation of this thesis work, a detailed review of all these difficulties and constraints is discussed in depth in the sections below; furthermore, a comprehensive review of solar monitoring systems and their advantages that this thesis work aims to overcome.

2. RELATED WORK

2.1 LITERATURE REVIEW

As we are now rapidly approaching 2030, it is as important as ever to address the skills that will enable all citizens to make informed and well-thought choices, as mentioned in [23]. Another ubiquitous fact should also come to mind: we cannot manage what we cannot measure. It is necessary to monitor the impact of our current behavior or the effect of potential behavioral changes to have a clearer picture concerning, e.g., our everyday smart and secure home. Furthermore, as part of the broader issue of science, it is an essential component of the EU cultural heritage. EU considers environmental education one of the most prominent instruments to influence human behavior towards more environmentally sustainable patterns [24]. Hence, associating environmental education and game-based learning will lead to students taking over a leading role in the educational process, setting questions, investigating the possible answers, and looking for alternative explanations to develop a fitting model.

Several software products for monitoring sensor data exist to capture proprietary data formats or protocols and visualize them. While such systems provide end-users and developers with powerful tools and front ends, we believe they should also be paired with multiple approaches, offering multiple possibilities to interact with the system. Regarding visualization, discusses the most common approaches concerning feedback design in eco-conscious work for the past decade, from the perspective of both ICT and psychology, providing insights into their strengths and weaknesses. The researcher in [25] presented an example of a typical engineering-focused approach that utilizes several skeuomorphic metaphors to enable smartphone smart home feedback creation. Examples of large-scale smart metering deployments used IoT portals (for electricity and water) and other visualization tools to support the system and engage end-users to participate. Their findings support the notion that using multiple approaches concerning visualization and feedback serves such purposes well. We have followed a similar line of thought while implementing our user interfaces and will continue to evolve our approach in future system revisions.

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There are vulnerabilities besides all the benefits and positive characteristics that the wireless medium has brought to IoT. There are different forms of traffic anomalies and attacks. The most common security threats are intruders, which is generally referred, as hacker or cracker and the other is a virus as mentioned in [26]. However, the pattern changes when data change; this is where the Intrusion detection techniques come into play in the context of the internet, specifically in the context of the Internet of Things.

Logical controls are used as software shields to ensure the system and data are only accessible to authorized entities such as individuals and processes. Intrusion detection and prevention systems, passwords, access control, etc., include logical controls as mentioned in [27]. Two types of the intrusion detection system are there. They are Anomaly-based detection and Signature-based detection. Anomaly-based detection methods detect unknown attacks by observing the whole system and its entities, such as traffic, objects, etc. Anything other than normal behavior is identified as a potential smart home. Conversely, signature-based detection methods are powerful to detect specific patterns of the smart home that are known by investigating network data or traffic, as mentioned in [28].

After researching specific use cases, data characteristics, and system needs, such a diversity of characteristics has confirmed that no unique method would provide efficient and accurate intrusion detection for every dataset under the analysis as mentioned in [29]. Flaws in software are frequently found because IoT devices cannot be patched or fixed, as mentioned in [30]. Ransomware and Malware rely on encryption to lock out users' devices entirely and steal the user's data. Privacy remains among the most significant issues of IoT as data is being transmitted, stored, processed, and harassed by large companies, as mentioned in [31]. This same data is then being sold to various other companies, violating our privacy and data security rights. Home Invasion is one of the scariest threats that IoT can possess as most of the homes and offices rely on automatic processes that lead to the use of IoT devices in these places. The IP address of these devices is exposed to hackers who can use them to pinpoint the location and gain access to our data just to sell them to underground sites, which are the hives of criminal activities, as mentioned in [32].

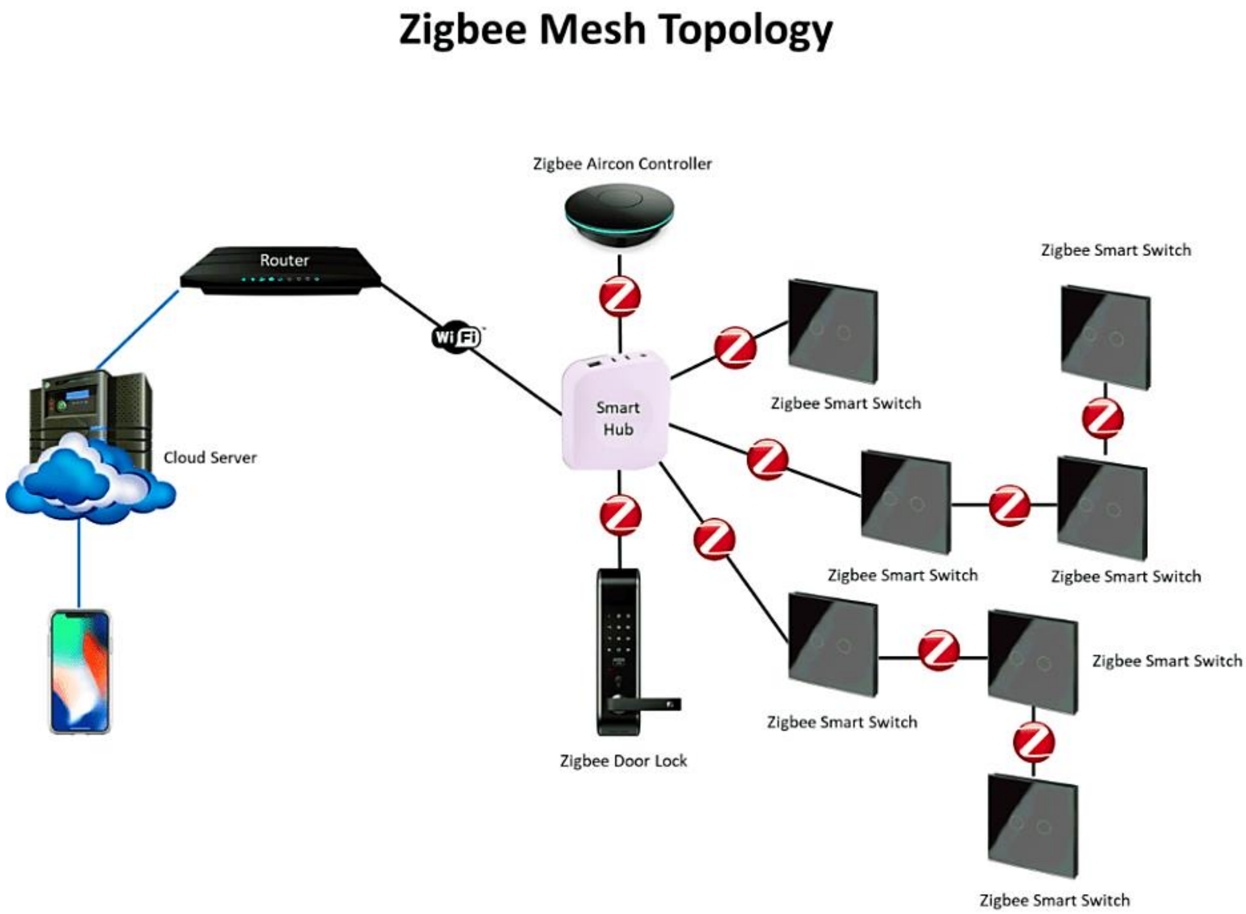

Figure 2.1: An advance home automation system schema developed for home [32].

In order to interact with an IoT installation, an appropriate representation for it in the digital world is required. Each installation comprises multiple elements that produce, consume or transfer data. Every element in this ecosystem potentially has multiple relations with other ones creating a complex schema that can be hard to understand or visualize as the scale of the installation increases, as mentioned in [33]. To overcome this problem and simplify our interaction with this digital image representation, formats more appropriate than the traditional relational databases need to be applied. At the same time, these formats need to be easy to understand and be used by non-tech-savvy users like artists or activists in their work with this now accessible, living part of our environment. Researchers in [34] focus on a simple case of a building populated with IoT devices for monitoring and limited actuation use cases to extract information about all the involved entities and their possible interactions. This information will help us define a representation schema that best fits our requirements and is suitable for a high-performance computation system.

An intelligent home system should provide smarter mechanisms than just turning devices ON or OFF or just reading sensor values. In order to achieve the desirable intelligence, our system provides a Complex Actions Management System that allows the creation of flows of execution according to specific conditions, such as device components' states. The system consists of preconditions (events) defined by users and actions triggered when the events occur. An example of how this system could work is: when the home temperature is 26ºC, turn on the air conditioner. It could also be more complex, such as when the outdoor light sensor detects a lack of sunlight and a person in a specific room, it will automatically close the electric window blinds and turn on ambient lighting. Although we did not implement this feature in our system, it could be implemented using descriptive language to describe complex actions. A polling system will check periodically if the properties' values match with any conditions defined and, if they do, the system will execute the corresponding actions.

2.2 BENEFITS OF INTERNET-OF-THINGS

In 2019 the number of Internet of Things (IoT) connected devices was 19.71 billion worldwide. By the end of 2020, it will hit 26.66 billion, as mentioned in [35]. In 2025, the number of devices connected to the internet will be 75.44 billion, causing the number to rise five times in a decade. These smart devices connected to the internet can generate data on their own based on behavior or expected result and share it over the internet. This is what constitutes the concept of the Internet of Things (IoT). IoT is a massive group of sensors or actuators connected over wired or wireless networks in the ZigBee network.

Regarding the devices allowed, the requirements are minimal since the system management is done on a higher level, requiring that devices only manage their components and connect to a Wi-Fi network. Our system also offers a feature that allows gateways to connect with simpler devices that cannot connect to a Wi-Fi network. Because the system architecture was designed to be highly scalable, there is no limit regarding the quantity of devices that users can connect. It is designed according to a service-oriented architecture with RESTful web services, independent of each other, with an MQTT broker for internal communication that allows lightweight and simple messages between devices. An auxiliary database also stores all the system information, such as connected devices, components, status, the house's structure (rooms), registered users, allowed user roles, and permissions, as mentioned in [36].

We noticed a small delay in the messages' delivery during our evaluation related to the message propagation time over the network and the number of components involved. However, this duration is short, and the more complex action (when a user changes a property value) takes 1.5 seconds on average to be processed by the system upon receipt, which is reasonable considering the constrained resources of IoT devices.

The architecture of our system includes a mechanism for managing users and their permissions. We proposed a solution. However, this mechanism was not implemented and tested in our project, so we cannot demonstrate a concrete evaluation regarding our solution's effectiveness and good functioning.

Our system provides security-related external accesses, requiring customers to use secure communications protocols, HTTPS, and authentication with digital certificates. These security mechanisms are simple to be used by customers, however, although this functionality is contemplated in the architecture of our solution, we have not been able to implement and test it properly, so we have not been able to prove that it is adequate to provide the desired security as mentioned in [37].

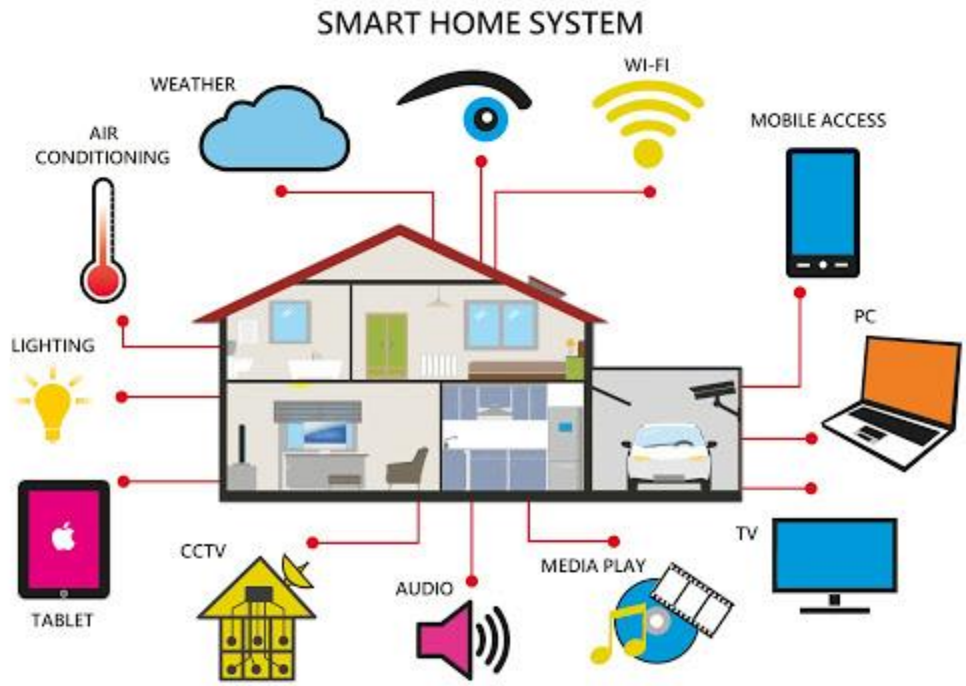

Figure 2.2: A model of intelligent home transformation with smart power [37].

2.3 ZIGBEE SUPPORT IN INTELLIGENT HOME AUTOMATION

2.3.1 Advantages of ZigBee

ZigBee provides several day-to-day advantages not only for the consumer sector but for the business sector, as well, as mentioned in [38]. This technology allows us to view real-time information that was not available before. Business can improve their production efficiency by reducing material waste and unforeseen downtime. Since Artificial Intelligence is used, it saves considerable human effort and time. Sensors can be used to build infrastructure, detect damage to infrastructure. Automated traffic control can help reduce road congestion, and gadgets or sensors can be implemented outside to recognize the change in the environment and warn us of any impending natural calamity

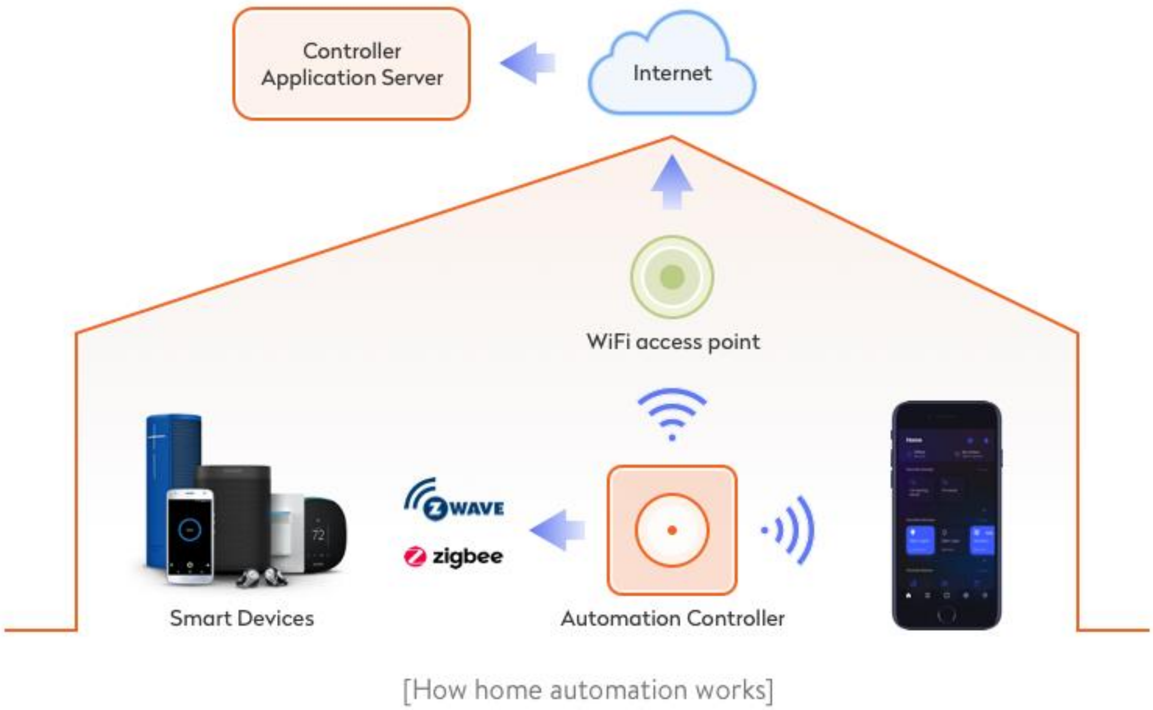

Figure 2.3: The ZigBee support with the automation controller [38]

ZigBee makes our homes, offices, and vehicles smarter, more measurable, and this, in turn, makes our life more pleasing. Smart speakers like Amazon's Echo or Google home make it very easy to set timers, get information on the go, or be it to play music. We can remotely monitor our home from other places through a home security system and see what is happening inside and outside or talk to visitors. Smart lighting systems can reduce unnecessary smart and secure home as it stays off if there is no one in the house or smart air conditioners will turn on when it knows you are on your way to your home.

2.3.2 Disadvantages of ZigBee

Security in ZigBee is a double-edged sword. Now that we have a system of interconnected devices on a network, it makes the system somewhat secure and efficient, as mentioned in [39]. However, connected devices generate a colossal amount of data and constantly exchange between devices, generating lots of internet traffic. These data can make the devices useful, but this easily accessible nature of the internet brings up both security and privacy issues. These issues arise for many reasons. Flaws in software are frequently found because ZigBee devices cannot be patched or fixed, as mentioned in [40]. Ransomware and Malware rely on encryption to lock out users' devices entirely and steal the user's data. Privacy remains among the most significant issues of ZigBee as data is being transmitted, stored and processed, and being harassed by large companies. This same data is then being sold to various other companies, violating our privacy and data security rights. Home Invasion is one of the scariest threats that ZigBee can possess as most of the homes and offices rely on automatic processes that lead to the use of ZigBee devices in these places. The IP address of these devices is exposed to hackers who can use them to pinpoint the location and gain access to our data just to sell them to underground sites, which are the hives of criminal activities.

2.3.3 ZigBee-Growth in Smart-Home

Internet of things disconnection happens in smart homes due to many reasons. It could be because of the high growth of ZigBee in the world. Other reasons could be the movement of nodes, which could be a random walk to single or both nodes of each link, or periodic due to satellites and planets' movements on orbits. It is good to mention also that some cut-offs occur due to the node's periodic power saving, like low power nodes in ZigBee networks as given in [41].

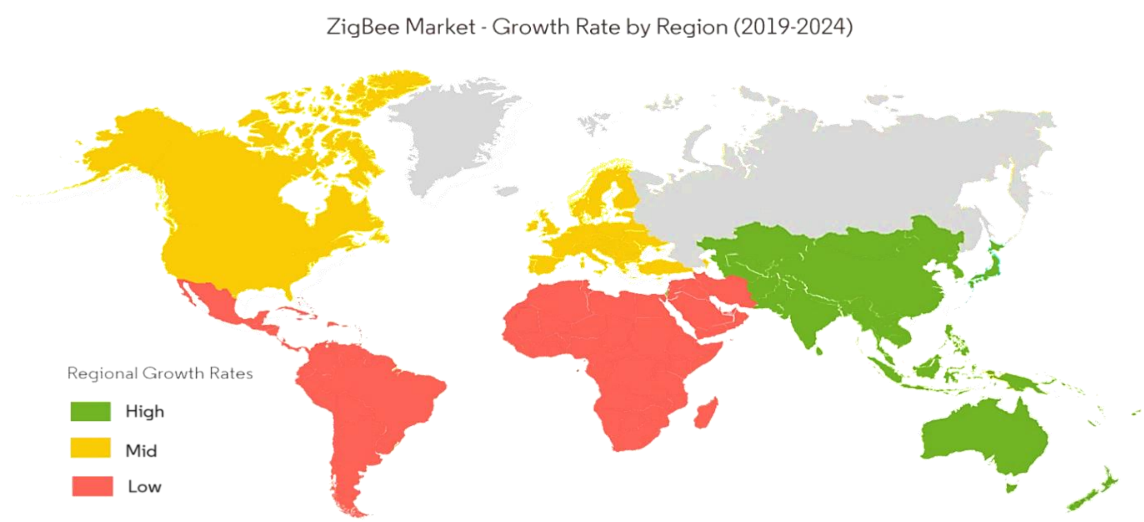

Figure 2.4: Interest over time according to ZigBee predicted growth [41].

2.3.4 Unexpected Lengthened Queuing in ZigBee Networks

In conventional ZigBee networks, queueing delays could be parts of seconds to seconds in extreme cases. However, due to the abnormal circumstances of smart home queueing, delays could reach days, if not hours. What contributes to those longer queueing delays is the nature of smart homes, where many copies are traversing among the nodes, not to mention the retransmission that occurs when data cannot reach their destinations. Home Automation is similar to Samsung SmartThings but is developed by Belkin Company. It provides an entire smart home system with out-of-the-box smart devices and applications (mobile and web-based) to control and manage the smart home system. Its architecture is slightly different from Samsung SmartThings because the devices are managed directly from the applications, without an intermediary hub, since they are Wi-Fi enabled. The system uses the Wi-Fi router to create a smart home network. Adding a hub, such as a Raspberry Pi, is necessary to control from outside the home. Similar to Samsung SmartThings, the Belkin WeMo Home Automation system does not provide flexibility to add custom-made devices without adding a WeMo product (WEMO Maker) to connect with all other devices, even if the users create devices that communicate through Wi-Fi, as mentioned in [42].

2.4 A SMART HOME IN A BOX

The smart home in a box project aims to design and create a smart home kit that is ready to work" out of the box." This means the users just have to purchase these kits and, with minimal effort, can install and use all of the smart home components. The main advantage of these kits is that anyone without technical knowledge can create and install a smart home system. The system components are extendable, allowing the users to buy and add more components after getting this kit, as mentioned in [43].

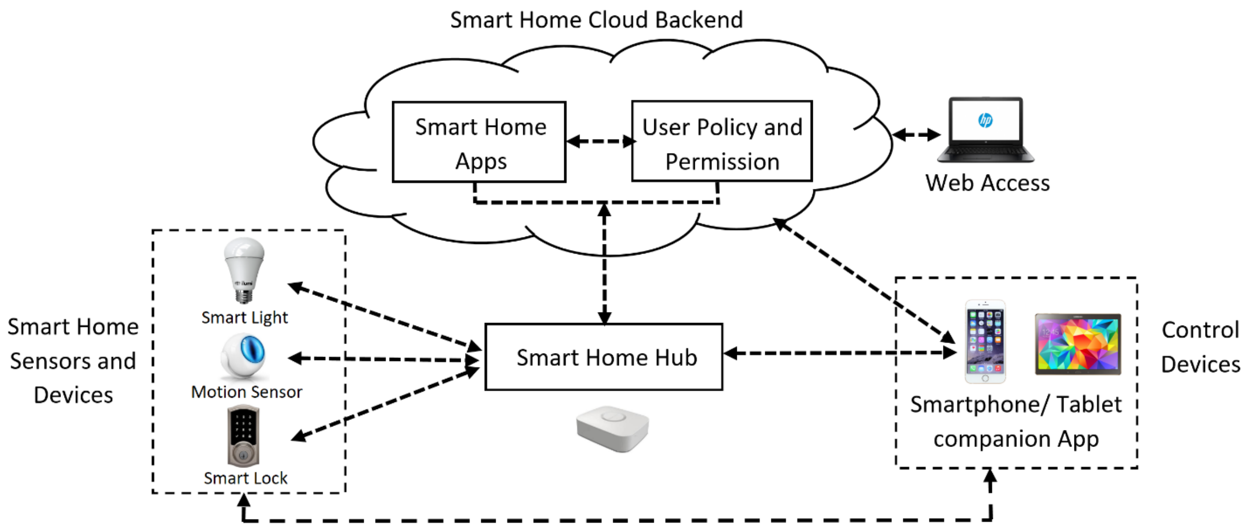

Figure 2.5: Smart Home System Architecture [43].

The architecture of this project is illustrated in Figure 2.5. The physical layer uses a ZigBee wireless mesh which communicates directly with the hardware components. It is a good choice because ZigBee is a low-cost wireless technology with low energy requirements, as referred to in [44]. The middleware layer works in a publisher/subscriber paradigm, where the manager adds named broadcast channels that allow other components to publish and receive messages. All the components of this system communicate with the publish/subscribe manager through a customized ZigBee bridge. The main goal of this project was to create a product that allows any customer to create and deploy a smart home system with minimal effort, but it lacks in some critical issues. It does not offer a user interface, and it does not allow to control the home appliances remotely.

2.5 INTELLIGENT HOME SYSTEM

The Intelligent Home System is an academic project that provides a generic approach to home automation, independent of any technology. The specification is based on a standard language, XML, to describe the system, supporting inter-operation with different technologies as mentioned in [45]

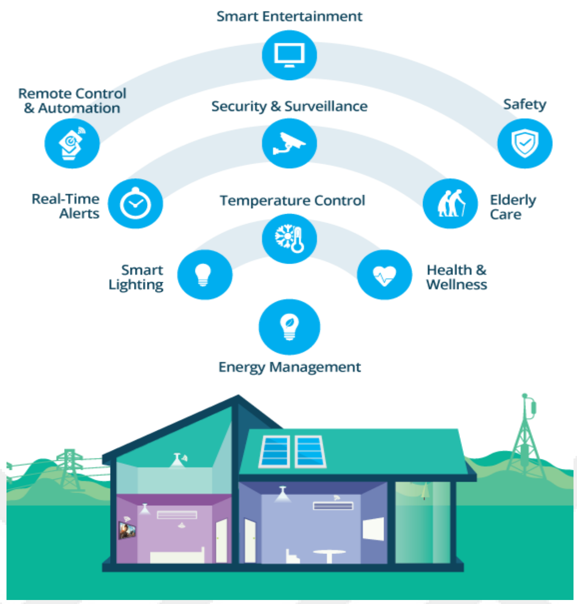

Figure 2.6: The specification and parameters of smart home with components [45].

This system offers an easy and extendable way to create and define scalable and flexible automation projects with a distributed architecture. The authors have proposed a multi-level architecture, illustrated in Figure 2.6. The *High-Level* components, Supervision Modules (SM), are PCs or Raspberry-Pi-like boards and perform supervision tasks, interface with users and offer remote access through an internet access point. The *Low-Level* components consist of Control Modules (CM), which are simple development boards plus interface electronics or power electronics to interconnect with physical devices - sensors and actuators and, optionally, a Router module(R) to allow to interconnect different *low-level* network segments.

In the smart system, a device is an abstract entity characterized by a set of *properties* where three standard operations over them are available:

a. **GET**: Read a property value.

b. **SET**: Modify a property value.

c. **NOTIFY**: Each device can be configured autonomously, notify its supervisor when property value changes, sending the new valuable information.

In another project [46], researchers follow the same *Device Concept* to allow a generic approach and develop a system that can work with all types of sensors/actuators. The communication is established according to the SMS (Short Message Service) protocol. It is a suitable communication protocol when users are in remote locations without internet access. A GSM modem is connected to the home automation server, translating the commands received via SMS to home automation commands. There is also an internet server to receive internet commands (from a webpage). All of these commands are managed by the Main Control Program, which is connected to a database and is responsible for managing the home automation system and exchanging commands with the IoT module, which translates the serial commands to IoT commands to communicate with the home appliances. This project illustrates a different way to control a smart home, using ZigBee, Internet, and Speech, and we will take advantage of some concepts explored here, such as the Home Server component that supports different communication protocols and acts as a Gateway to the internal home automation protocol.

2.6 CHARACTERISTICS OF INTELLIGENT HOME

A home is considered smart when the user assembles a collection of smart devices under one roof and enables them to connect to a network and communicate. Home automation is also used because the smart devices work together to automate tasks and home operations. Smart homes offer users the ability to control everything in their home, as well as the ability to automate most household chores. There are various levels of "smartification" for smart homes, from adopting essential communications to task automation. The researcher in [47] defines three steps towards home automation: adoption of essential communications, simple commands over the home, automating basic functions, tracking, and taking action, prompting activities, and automating tasks. This study summarizes these steps into four steps to make a home Smart.

Automation of Basic Functions: The first step towards the smartification of a home is to automate essential functions, giving way to automatic controls such as room temperature, activating or deactivating the alarm system, running sprinkler system based on a specific program, etc. The second step towards home automation is to adopt sensor technology to track their behavior to determine their activity, sleep, or health status [48]. This step converts the home into a giant monitoring system. At this point, the home starts generating a large amount of data handled by programmed algorithms or essential artificial intelligence to make decisions based on the users' behavior.

Prompting Activities in Smart Homes: The next step for a smart home that monitors its users is activities suggestions. Behind activity suggestion, there must be relevant data processing happening to the data collected from the users. The home's big data algorithms can predict user behaviors or future information needs based on this data. Smart homes can remind activities to their uses based on the collected data from the users. At this point, homes stop being reactionary and predictive; thus, they can be considered "Smart."

Automation of Tasks: Automating significant tasks in the home, such as reorder medications, prepare grocery lists, or run the vacuum cleaner, can save plenty of time. Smart homes learn and adapt so that they can schedule household tasks on their own. The automation of tasks considers the data gathered through sensors and the analysis performed on such data [49]

2.7 USAGE OF IOT AROUND THE WORLD

We can use the context of the internet of things anytime and anywhere as early as desired. It could be a way ahead of time to receive any data bundle for usage in the world. The cities count with an international population demographics and play an essential role within the global economy. It belongs to the group of megacities with a population of 22.5 million by 2022. The scenario could be either good or bad depending on whether megacities are considered positive or negative for the agenda on sustainable development. By attempting to correlate "countries with the highest number of megacities" with the "World Environmental Performance Index," it can be inferred that there is no correlation between countries with a high percentage of the population living in megacities and environmental sustainability as mentioned in [50]. All the countries with megacities by 2022. China, India, and Japan have six, five, and three megacities, respectively. Their environmental index does not change accordingly with their number of megacities or either with the percentage of the population in megacities.

In conventional IoT networks, queueing delays could be parts of seconds to seconds in extreme cases. However, due to the abnormal circumstances of smart home queueing, delays could reach days, if not hours. What contributes to those longer queueing delays is the nature of smart homes, where many copies are traversing among the nodes, not to mention the retransmission that occurs when data cannot reach their destinations. Home Automation is similar to Samsung SmartThings but is developed by Belkin Company. It provides an entire smart home system with out-of-the-box smart devices and applications (mobile and web-based) to control and manage the smart home system. Its architecture is slightly different from Samsung SmartThings because the devices are managed directly from the applications, without an intermediary hub, since they are Wi-Fi enabled. The system uses the Wi-Fi router to create a smart home network. Adding a hub, such as a Raspberry Pi, in the ZigBee network is necessary to control from outside the home. Similar to Samsung SmartThings, the Belkin WeMo Home Automation system does not provide flexibility to add custom-made devices without adding a WeMo product (WEMO Maker) to connect with all other devices, even if the users create devices that communicate through Wi-Fi, as mentioned in [51].

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Home Server component that supports different communication protocols and acts as a Gateway to the internal home automation protocol [52].

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This step converts the home into a giant monitoring system. At this point, the home starts generating a large amount of data handled by programmed algorithms or essential artificial intelligence to make decisions based on the users' behavior. The next step for a smart home that is already monitoring its users is activities suggestions. Smart homes can remind activities to their uses based on the collected data from the users. At this point, homes stop being reactionary and predictive; thus, they can be considered "Smart." Behind activity suggestion, there must be relevant data processing happening to the data collected from the users. The home's big data algorithms can predict user behaviors or future information needs based on this data. Automating significant home tasks, such as reordering medications, preparing grocery lists, or running the vacuum cleaner, can save plenty of time. Smart homes learn and adapt to schedule household tasks independently, as mentioned in [53]. The automation of tasks considers the data gathered through sensors and the analysis performed on such data

3. METHODOLOGY

The research is organized in various sections starting with a description and the philosophy of the research from which the electricity consumption data and house information is taken and used as input for the study; a remark is made in how consumer behavior can contribute to foster energy efficiency; then the objectives and goals are defined.

Moving to the more technical part, cleaning the raw data is explained to have the processed data start the analysis sought. First, data exploration and visualization were carried out to extract the first outcomes from the consumer's load profiles.

The core of this research focuses on the smart home network segmentation according to their electrical load profiles; various clustering methods are used and compared to find adequate consumer segmentation. Then, the house features and household characteristics are considered to find any relation between customer segments and their house properties.

The data generated has increased this last decade exponentially. This data could contain valuable information, but it needs to be explored. The electricity market is also living a data boom. For instance, the electricity meter reading has moved from one read every month to host smart meters able to read electricity consumption every smart home network; this implies that each consumer will have around 100 measurements per year.

Store and manage this data are already a challenge itself. That is the reason why smart home networks and computer science have increased their presence in the energy sector; but also the possibility to add value to this massive amounts of data by applying data mining and analytics to extract hidden information or at least be able to separate the useful one to the less interesting. Big data analytic tools are essential to add value to all this data, specifically in the energy sector, could add value in terms of energy balance, energy efficiency, or energy prediction; that could be profitable for both the consumer and the utility.

Consumer behavior and demand response can significantly foster energy efficiency in the residential sector, pushing a behavioral change to boost energy savings. By analyzing different types of data, such as consumers' load profiles, households' properties, and householder's characteristics; some patterns could be found, and knowledge could be discovered in order to guide the end-consumer not only how to reduce its smart and secure home but also when is the best time to do so.

Specialized software programs and programming languages are used to analyze large data sets; for instance: customer segmentation by clustering them by load profiles similarities, finding the correlation between electricity consumption and temperature, performing consumption data exploration and visualization or consumption prediction; among many others.

In the current research data analysis, the "Python" programming language is used, "Python" is free, open-source software that can be used for both experts and beginners who have the first contact with the programming languages as many online-online help material and tutorials are available, which facilitates the learning.

3.1 DATA ANALYSIS FOR SMART AND SECURE HOME

The main objective is to discover knowledge from the electricity consumption data measured in residential smart home networks, in concordance with the idea to provide personalized energy efficiency recommendations to the consumers. We aim to establish a methodology to automatically classify any new user into a load pattern group by looking at the household and house characteristics.

This process consists of three phases described below and graphically shown in Figure 3.1:

Phase 1: The current users are clustered/segmented into different groups according to their electrical load profile similarity from the existing data. Similar load profiles mean that the consumer behavior and habits are almost identical.

Phase 2: Once the users are placed in one cluster or another, further analysis is carried out to find the more likely properties related to the house and household of each group.

Phase 3: Classify any new user to one of the existing segments by looking at the household properties and the house characteristics.

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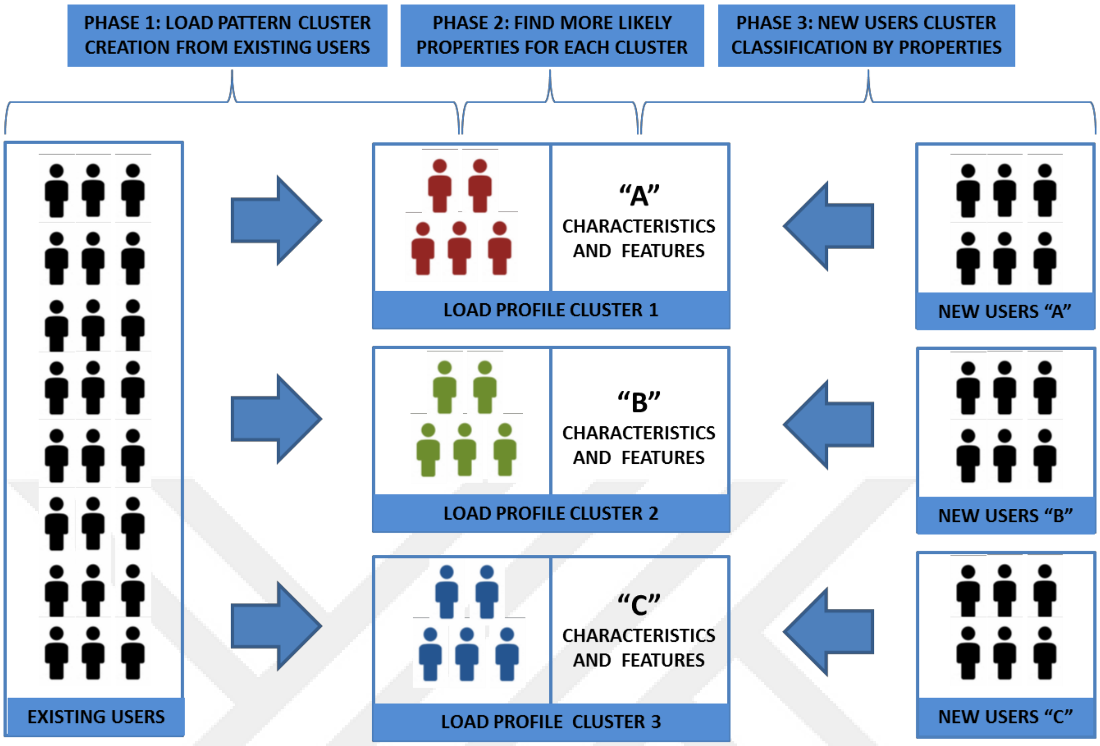

Figure 3.1: Diagram that describes the phases of the methodology applied in this study.

Also, the household and householder's characteristics were analyzed to find the most common attributes for the whole set of consumers and inside each group, looking for any pattern or relation when crosschecking load profiles groups and house characteristics. Likewise, additional actions were done to explore and visualize data to be incorporated into the newsletter or monthly reports sent to the users periodically. Moreover, in parallel to provide the municipality the starting point for deeper data analysis that is currently willing to perform

3.2 DATASET DESCRIPTION

A dataset is composed of rows and columns, where, usually, each row represents an observation and each column a different variable. The dataset is named "*Smart Home Dataset with weather Information*," freely available on KAGGLE. This data can be qualitative (categorical) such as gender, country, city, or quantitative (numeric) such as electricity consumption, height, price, distance. Again, and as said before, depending on the type of data, the approach used to the analysis may vary because it is not treated the same way numeric and categorical data. The size of this dataset is relatively manageable due to mainly three facts. The dataset can be downloaded from the link: https://www.kaggle.com/taranvee/smart-home-dataset-with-weather-information.

a. The number of sub-meters installed is a small amount accounting for different sub-smart home networks.

b. The measurements period is, in most cases, around year length

c. The data was aggregated hourly, which reduced the final number of observations, and therefore, the dataset's size consisted of 124.89 MB.

d. Electricity consumption data for smart home networks with weather information.

e. Households and householder’s information based on smart home network usage.

3.3 COMMUNICATION VIA SMART HOME NETWORK

Communication via smart home network solves many problems that directly affect the data quality, as if the smart home network is switched on, communication can be established, interrupting the sending and reception of data. Then, the data for this period is represented by zeros as it was no consumption, thus altering the dataset values, which need to be eliminated to perform accurate data analysis.

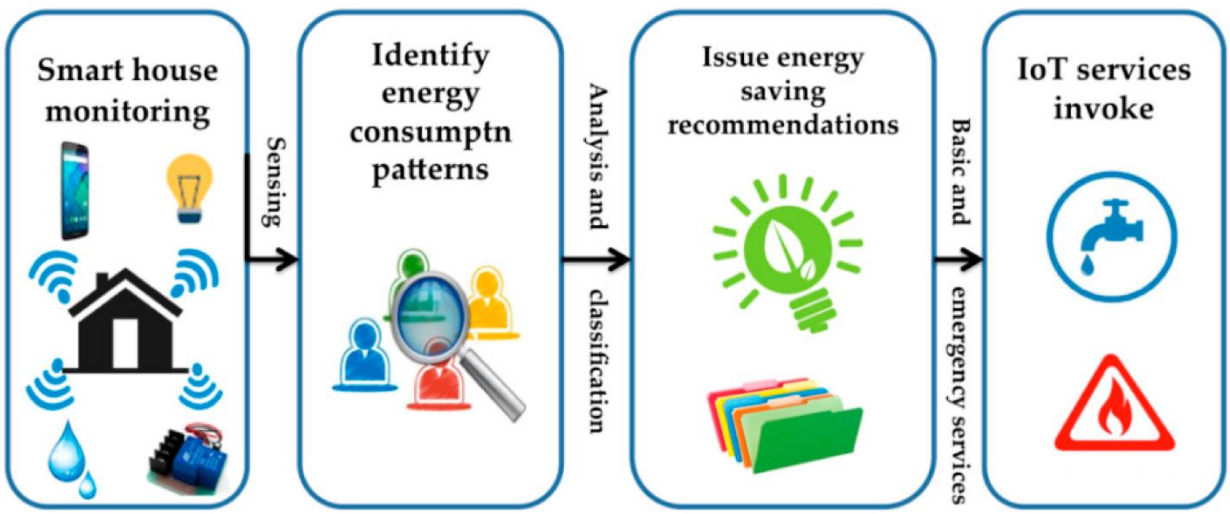

Figure 3.2: Diagram that describes the different platform with data transfer rate.

From the database server, the software as a Service (SaaS) company, in this case, access the data stored and proceed to upload it into the web-app platform for the visualization of each user. Finally, the data used for the current analysis were obtained through an Application Programming Interface (API) configured by this research in order to:

a. First, aggregate all the data hourly. The sub-metering equipment can measure the consumption in high-resolution frequencies, each 5-15 minutes according to the device. For the aim of this study, the hourly aggregation is enough and a good starting point if a further deeper study is sought in the future.

b. Second, all the household consumption data are in the same file. The fact that facilitates the analysis procedure as reading one file is enough to analyze the data.

Hence, by using the "python programming" that permits access to the database server, a ".csv" file is downloaded. This file is the input data regarding electrical consumption that will be used for the data analysis. This data is considered time series numerical as it records the electrical consumption and time of it.

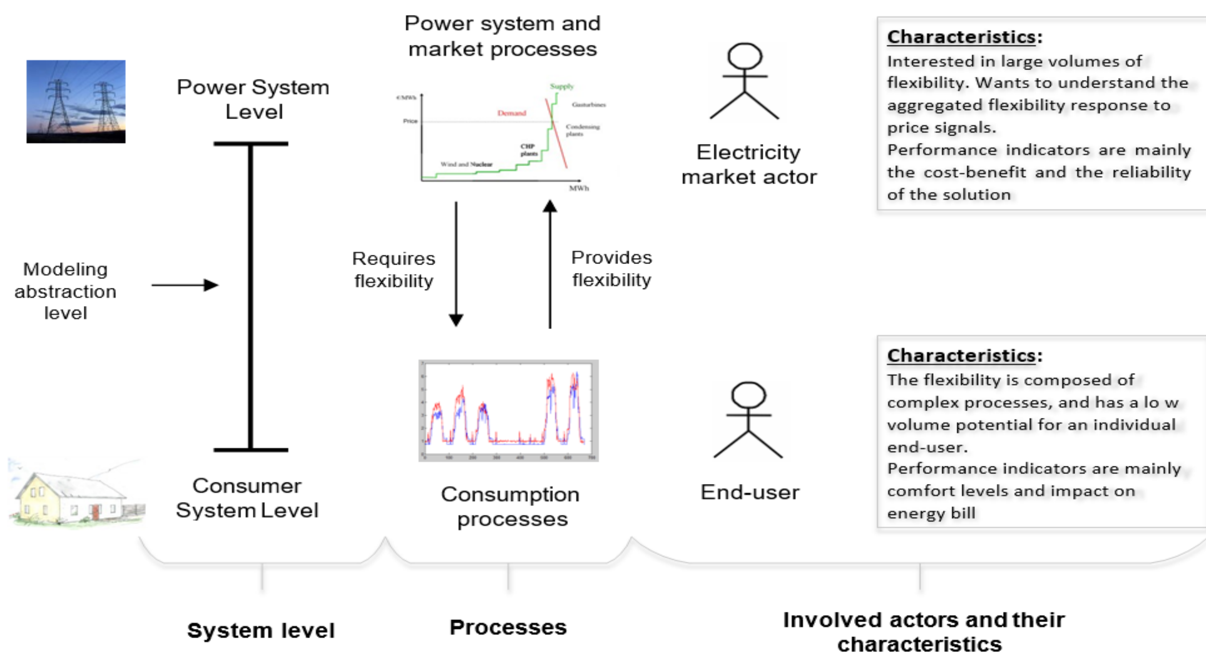

Figure 3.3: Diagram that describes the functions of power system .

Hence, by using the "python programming" that permits access to the database server, a ".csv" file is downloaded. This file is the input data regarding electrical consumption that will be used for the

data analysis. This data is considered time series numerical as it records the electrical consumption and time of it.

The “.csv” files have the characteristic that is easy to read by software prepared to conduct data analysis, for instance, "MS Excel," "Python" among others. "Python" is the programming language used to carry out the current analysis

3.4 SMART AND SECURE HOME IMPUTATION & CORRELATION

The data regarding the electricity consumption is the main one used in the later analysis; it is numerical data as its records the measurements of electrical consumption for every household participating in the research. The following Figure 3.4 summarizes graphically how the electrical consumption data used for the analysis is obtained

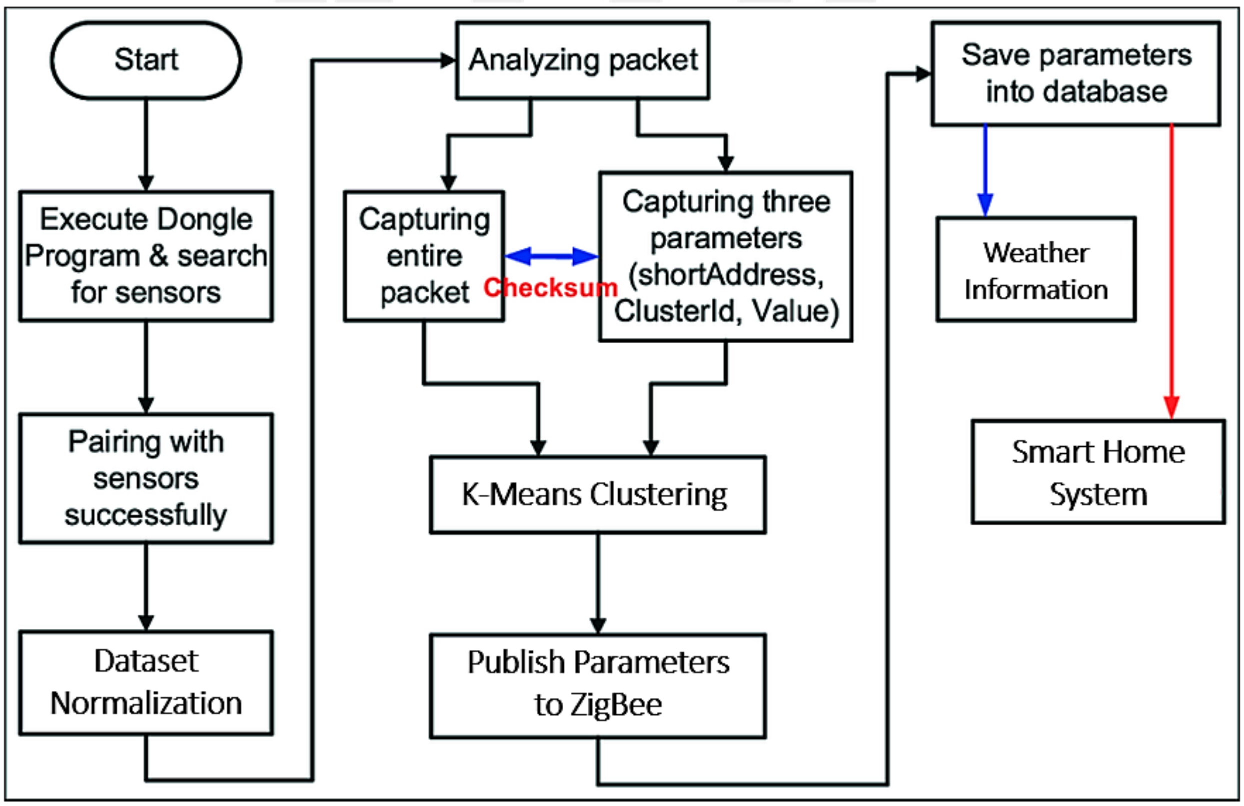

Figure 3.4: The flowchart of approach being followed.

Although this data is processed and presented in a tidy format, it needs to be cleaned. Cleaning the data means to detect and delete all the possible elements that could affect the well-being of the analysis, in this particular case:

a. we must select the sub-meters used in the research, as the column under the label contains both current and old sub-meters identifiers. Hence, this step will select only the valid sub-meters that are currently working and have consistent data.

b. from the selected sub-meters in the first step, we should detect and delete those data periods that contain "energy" as a measure. The "energy" values are quite common because the data communication system used is the Wi-Fi or router of the house, so when it is switched off, no data is sent and stored.

c. detect and select those periods that present the so-called "frozen" values. The "frozen" values are the repetition of the same value for consecutive observations due to a hardware problem during the data communication, which froze the measurement and repeated it over time.

It is essential to do these three steps to have a valid and verified analysis output and obtain more accurate results; otherwise, as the input data is somehow "corrupted," it may affect the analysis.

After the first step, the sub-meters dataset was reduced from the initial sub-meters to multiple meters and accounted for 7 cluster observations. The discarded sub-meters are due to facts that do not add value to the analysis, such as:

a. No data was stored

b. All the data stored were "zeros."

c. Only a few observations (less than a month) were stored

3.5 SMART HOME NETWORK DATA VISUALIZATION WITH ZIGBEE

Before doing the smart home network segmentation, knowing the data that will be analyzed is essential to get a sense of what is in the dataset, which particularities and problematic points could be found to deal with. Get familiar with the electricity usage data, and the "python programming" commands used when treating this data.

When exploring the data, three aspects should be taken into account:

First, the dataset format needs to be reshaped into the best format to have the desired graphical output in most cases.

Second, the dates' treatment is a challenge when exploring the data, as time-series data needs further and different approaches, especially if the division between weekdays and weekends or monthly distinction is needed.

Third, focus on the specificity of the electricity use data, studying which is the best path to extract the information or conclusions sought

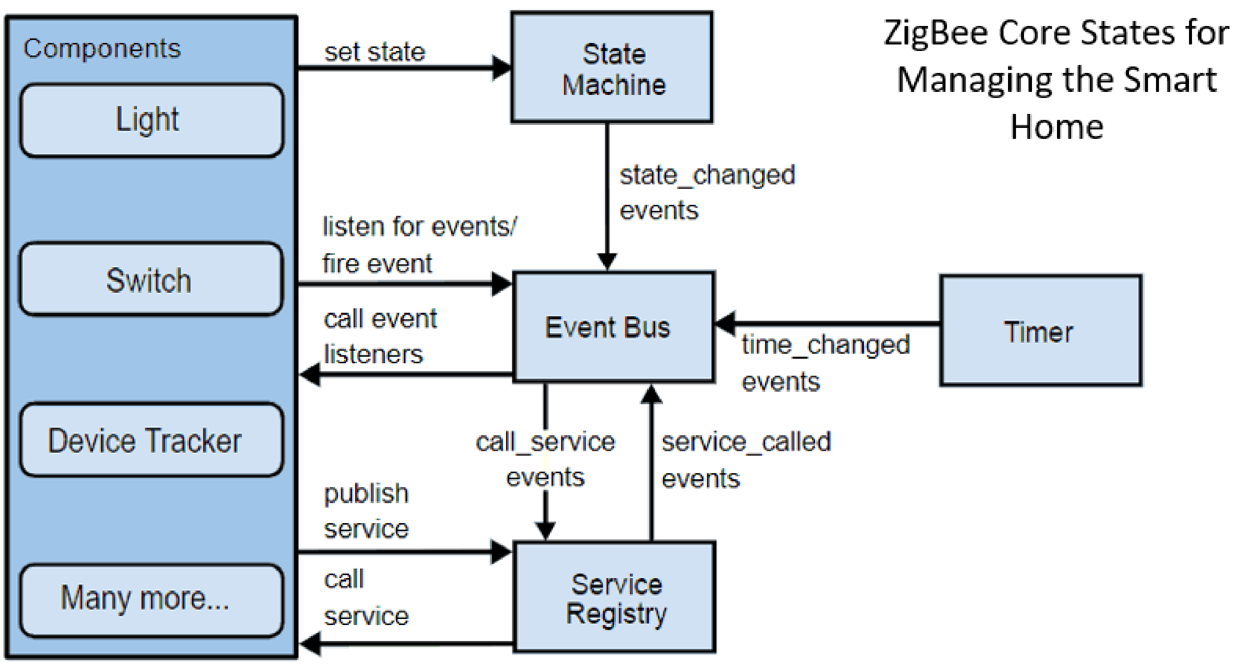

Figure 3.5: The badging of different between the smart home network from 2015-2020.

The research work is to organize and visualize all the data using different representations according to the specific goal of the visualization for smart and secure home and spectrum allocation in the smart home network. It is interesting to provide a tool that allows the visual representation for each customer and satisfies all the purposes sought. This facilitates the comparison among consumers; permits access easily to the individual electric consumption main characteristics that, for instance, facilitate a quick audit on its consumption and detect possible irregularities or problems.

Among these purposes are:

a. Differentiate the weekdays and weekends load profiles, are compare them to the load profile output accounting all days not differentiating weekdays and weekends.

b. Differentiate the load profile for each day of the week to know if the load profiles are similar.

c. Representation in absolute values, percentage of consumption per hour, accumulated in a period

d. Study if there is a consumption difference among months and seasons

e. Find the characteristic load profile per each month of the year

f. Be able to specify exact dates and plot the consumption at that period

g. Using different kinds of visualization graphs shapes (bars, points, lines, boxplots…) and colors to facilitate the information visualization

h. Facilitate the comparisons between users by using interactive graphs

3.6 CLUSTERING ALGORITHM FOR PREDICTION

Because it is impossible to establish significant differences among spectrum allocation of the smart home network, the K-means solution adopted was to cluster the data in 7 groups using the python programming language, but as said before, applying the algorithms could also be chosen. The number of members assigned to each cluster ranges from the minimum cluster number for smart and secure home data, so a distributed user's allocation is also achieved, avoiding clusters with 1 to 5 members who could mislead the analysis. Table 3.1 shows the within-distance clusters where, as expected, the clusters with many networks present a higher within-cluster distance.

Table 3.1: Number of members per each cluster defined by K-Means algorithm

K-Means Algorithm on smart and secure home Data using ZigBee Protocol							
Cluster Number	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Number of Networks	9	17	8	8	37	8	35

Cluster 1: there are two peaks, morning and evening, representing around 7% of the energy usage. It is similar to cluster 6. Although this cluster one presents a higher proportional value between peaks that ranges from 3-5%, it could mean that some activity is done for smart home networks.

Cluster 2: Presents a not sharp morning peak and a low consumption percentage during the day of around 3%, similar to the night hours' proportion; this means that there is no activity at home during the day.

Cluster 3: Presents a high morning peak. Around 9% of the daily energy use is consumed in that peak, that is around 8:00h. Then, there is no activity as the proportion of energy use in the afternoon decreases to 3%, similar to the night percentage, and there is a small evening peak of around 5% at dinner time.

Cluster 4: It presents two peaks prolonged in the morning (9:00) and the afternoon (19:00), following the schedule of a small business or local, also the night consumption proportion is so low. So, it seems it is not a residential consumer.

Cluster 5: This cluster presents a flat profile, with higher values during lunch and dinner time. It could mean that people stay home during the day.

Cluster 6: Presents two sharp peaks, one in the morning and the other in the evening, reaching almost 7% and 10%, respectively. Then the energy usage during the rest of the day and the night is so low, constant at 2.5%, so no activity during these periods; it means that the households are not home during the day; could correspond to working people with children.

Cluster 7: Presents a significant evening peak around 21:00h of almost 9%. There is also a small morning peak, almost not noticeable, which does not reach the 5% of energy usage. It also presents a continuous consumption of around 4- 5% until the evening peak during the days.

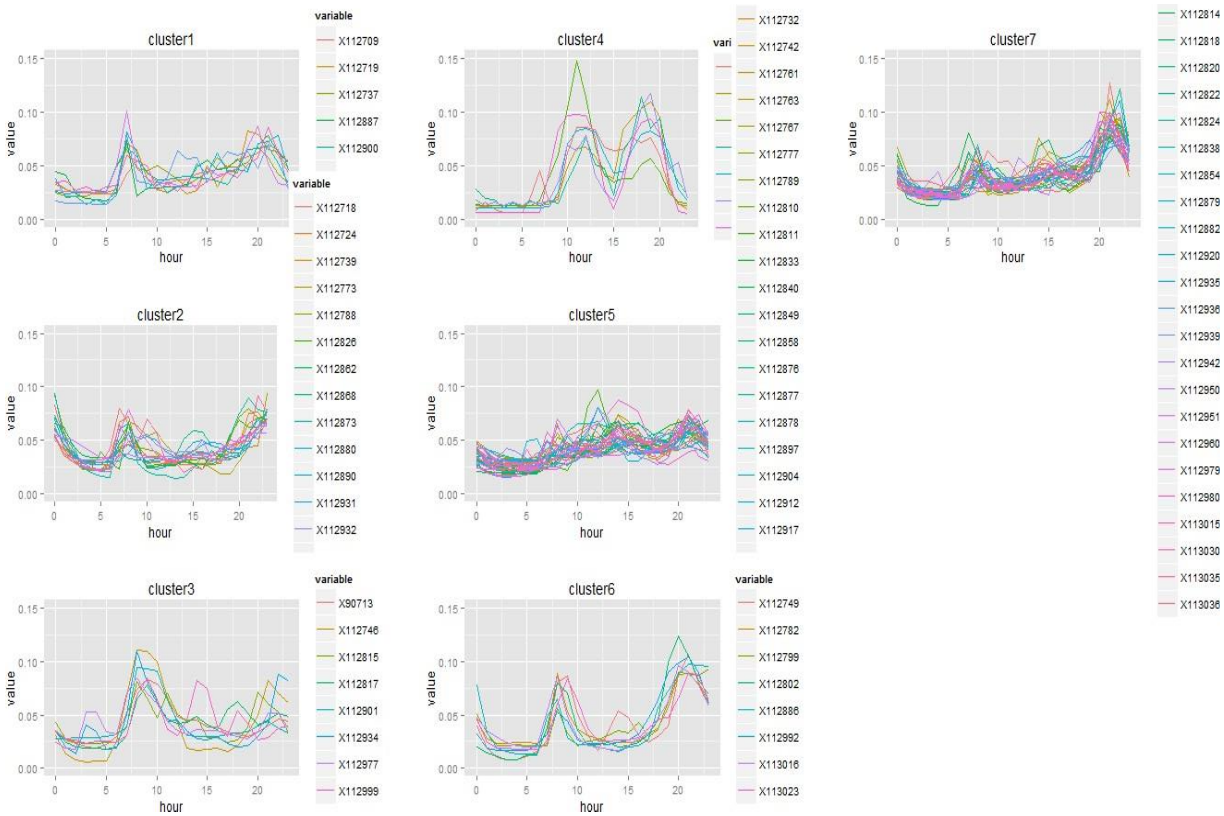

Figure 3.6: Plotting all the networks of each of the 7 cluster.

4. RESULTS

The electrical consumption is analyzed in different levels of detail. The procedure followed starts from analyzing the whole gross data and gradually moving towards a more detailed data analysis by segmenting and grouping the data for a more accurate study. Two values were used to plot the electrical consumption; the absolute units of power consumption [kWh] and the proportional hourly energy usage in percentages (%) were used. When analyzing each consumer individually, the critical values are the absolute units in terms of kWh, but to fairly compare various consumers' profiles is necessary to create a common normalized framework were to contrast the curves' shape; this can be done with the hourly percentages of energy consumption. As said before, depending on the analysis' goal, one parameter or another would be used with the ZigBee protocol. So, although the possible approaches to the consumption data an endless, below different representation ways, are shown that would be useful to know and better understand the consumer. This section uses various consumers for the different representations to see a variety of load profiles and test the validity of the illustrations. Remark that the scope of analyzing the features for each cluster would have been more adequate if a larger sample with better data quality and more specific features were available. So, the current process could not add any value to the research; but it is a procedure that could be followed when a more extensive dataset is available.

The load pattern for each customer is obtained by considering all data available without distinguishing between weekdays and weekends for the period selected. In the case presented in this work, the load profile in terms of hour proportion of energy usage of the ZigBee protocol is shown; this user has the highest in the evening and another peak of consumption at lunchtime. In this work, the load profile in terms of the power of the ZigBee protocol is displayed, and it can be seen as another evening peak. These illustrations are helpful to get a sense of the user's load profile in both absolute and percentage terms. The load profile was obtained by calculating the mean for each hour of the day input all the days available in the dataset. Among the multiple possible representations, the circular one illustrated in this work is another way to represent the load profile, emphasizing the hours that present the higher and lower consumption for spectrum allocation in broadband network

Empirical models are based on curve fitness, variance and covariance studies for selection and discrimination of variables (temperature, pressure, age, dosage, etc) apparently influencing significantly on an observable (yield, weight, velocity, etc). Parametric optimization based on studies over experimental data obtained from experimentation and Functions for prediction and/or explanation, these are common goals for empirical models, why empirical? because the mathematical background of the relations we wish to know are very difficult, hidden to us for now. Simulation modelling is not the right term for what we know is a more exact model of less uncertainty, this we prefer to call Deterministic models where linear, polynomial, exponential, and logarithmic backbones are empirically selected over the basis of correlation. When Newton established F=m×a he was certain it was an Universal Law, he that knew crops, iron castings, chariot wheels were based on reported experiences, recipes, data and empirical correlations but he was convinced God was guiding his hand on Principia Mathematical he did make experiments with balls of different masses, took time over measured displacements with various stratified forces applied, his experiments could have been made by another different Scientist (not a deterministic) searching for F≈m×a finding a formula like F= A×(m×a}+B establishing that A is approximately one and B is approximately zero if friction is minimum and the distances involved are not too long and that the confidence interval around F is +- 5.5 %.

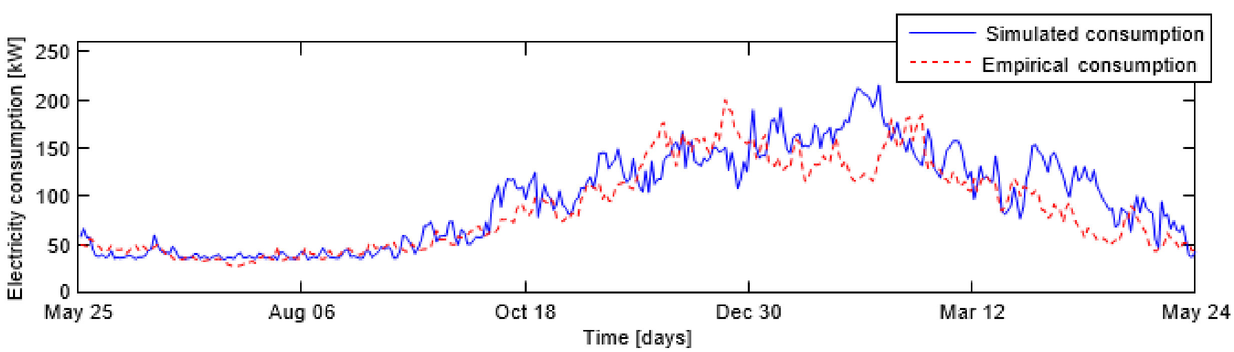

Figure 4.1: The smart home energy consumption expressed in absolute time

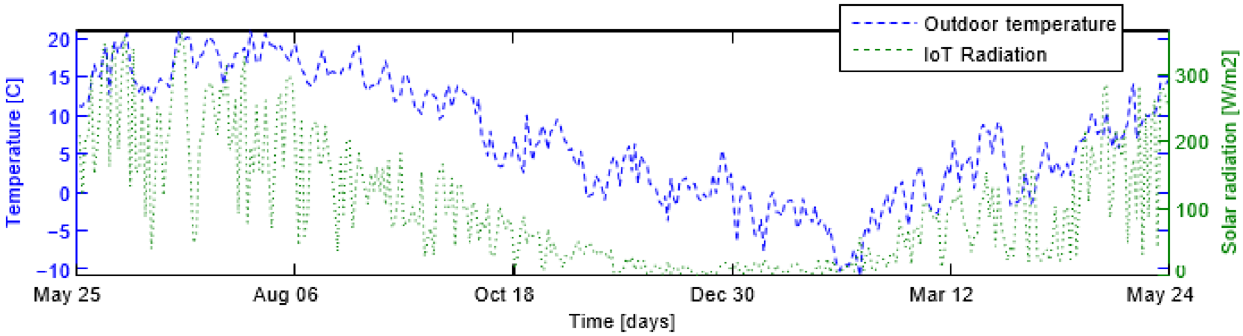

Figure 4.2: The energy consumption expressed in graph bars for outdoor temperature.

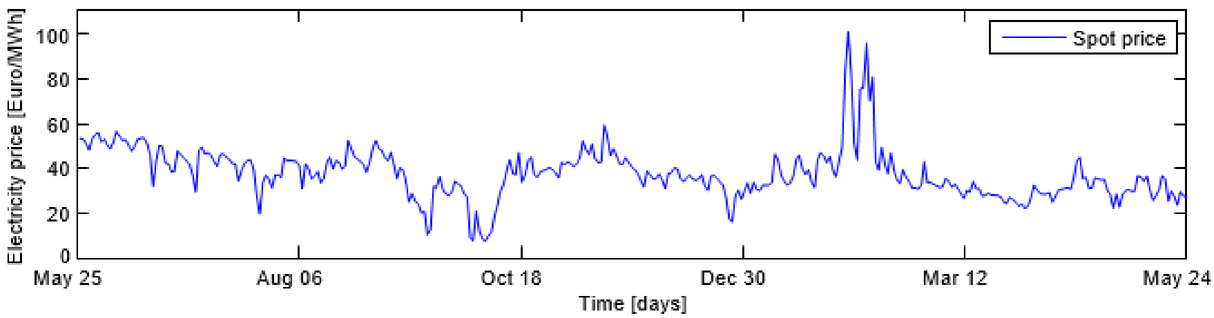

Figure 4.3: The energy consumption expressed in graph bars for spot price.

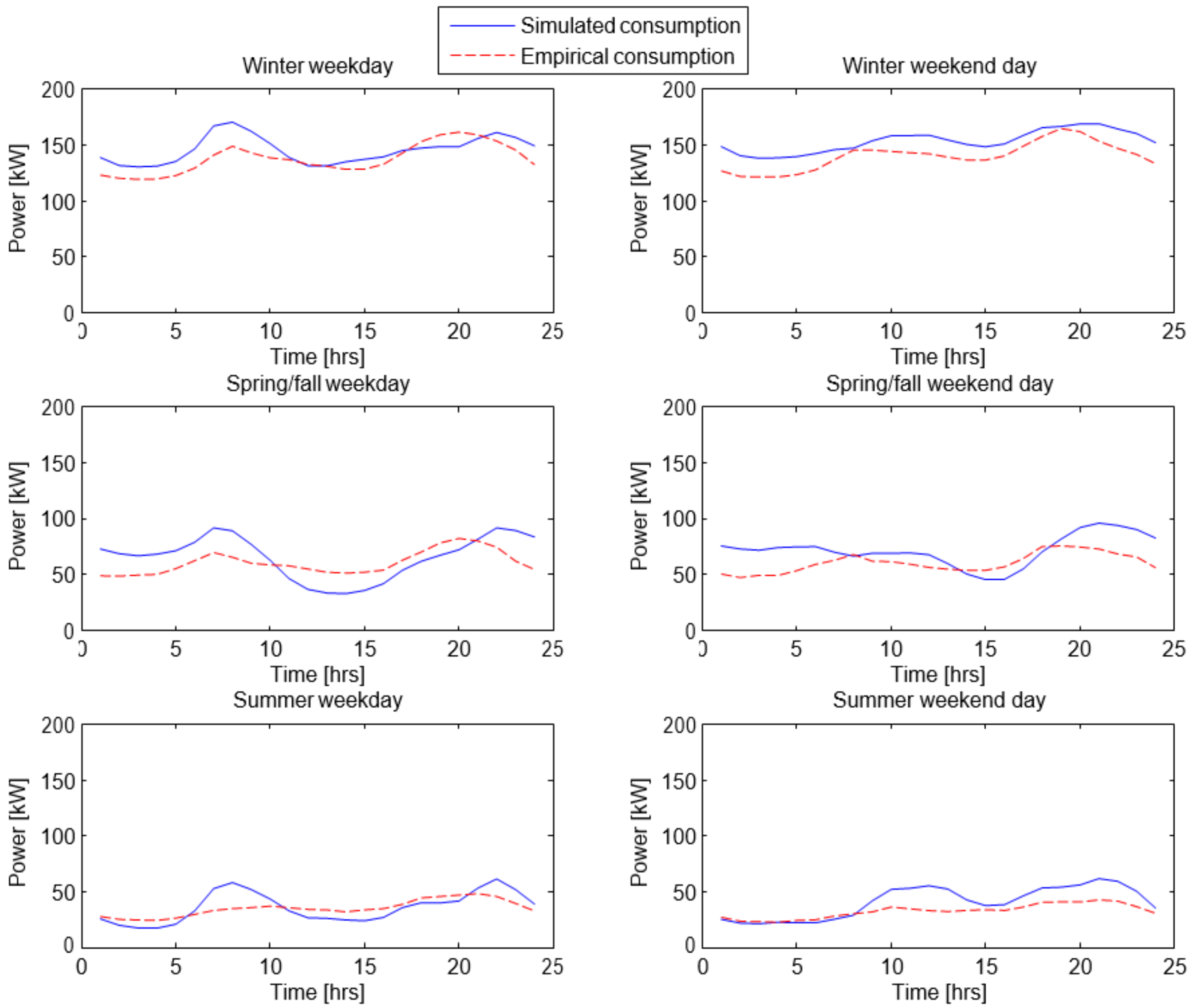

Figure 4.4: The power consumption plot per season of winter, spring, and summer

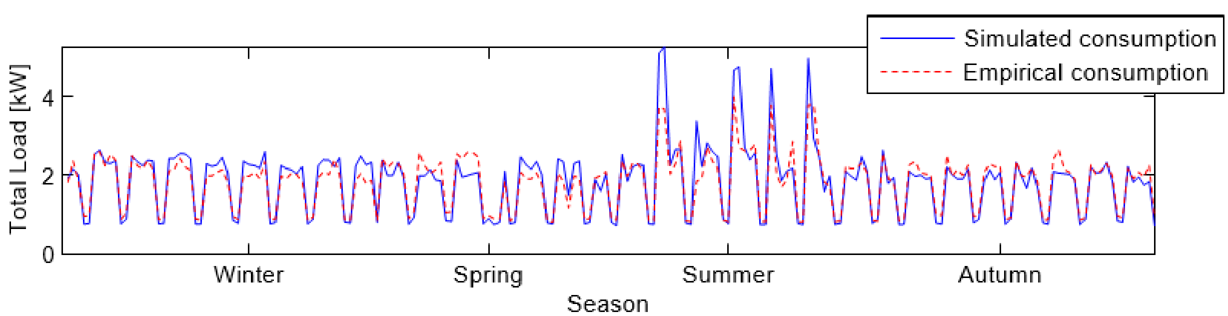

Figure 4.5: The prediction of energy consumption for all four season in a year

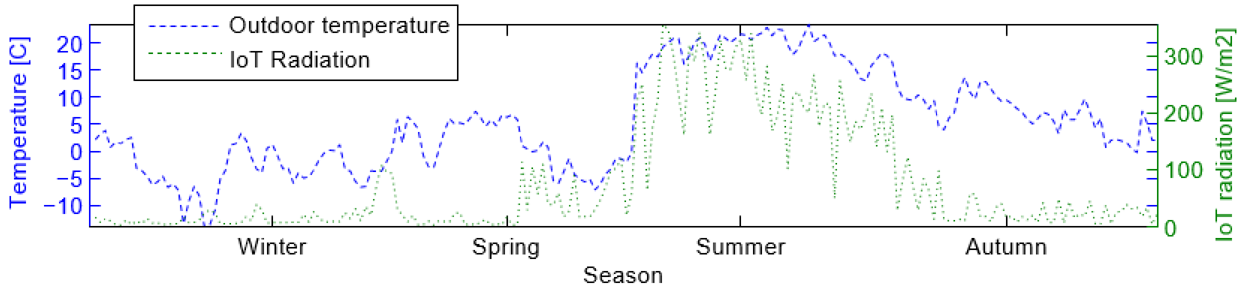

Figure 4.6: The prediction of all the four season in graph bars for IoT radiation.

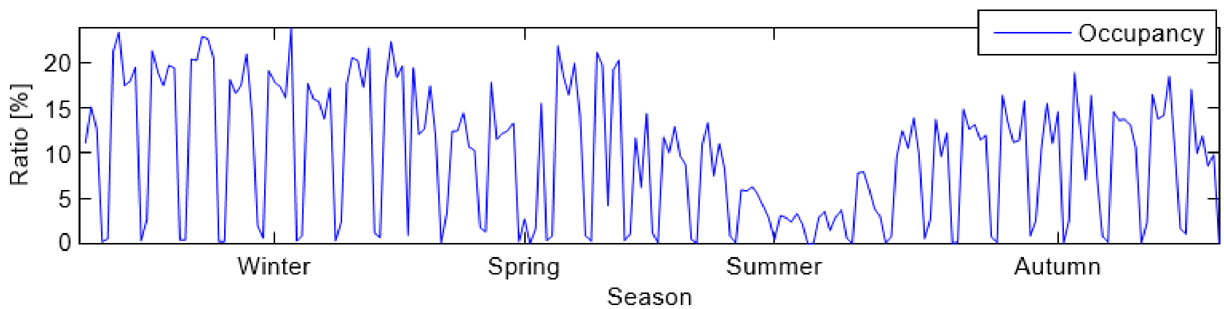

Figure 4.7: The prediction of energy consumption for in graph bars for consumer occupancy.

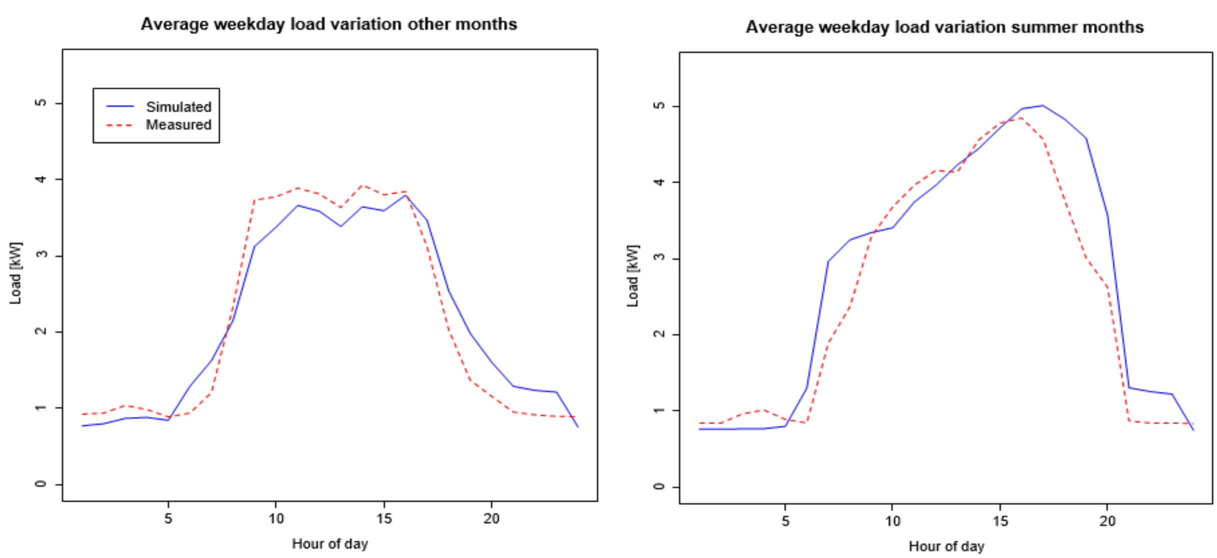

Figure 4.8: The average weekday load variation for summer and other months

The cluster analysis aims to group a set of observations based on various properties that make them similar; hence the objects inside the same group will be more similar to any other object placed in other groups. The analyst sets the properties to group or cluster according to the aim of the grouping; this means that the same set of observations can be clustered in many different ways; depending on what is considered similar, it is a task of the analyst to define the appropriate similarity/distance metric.

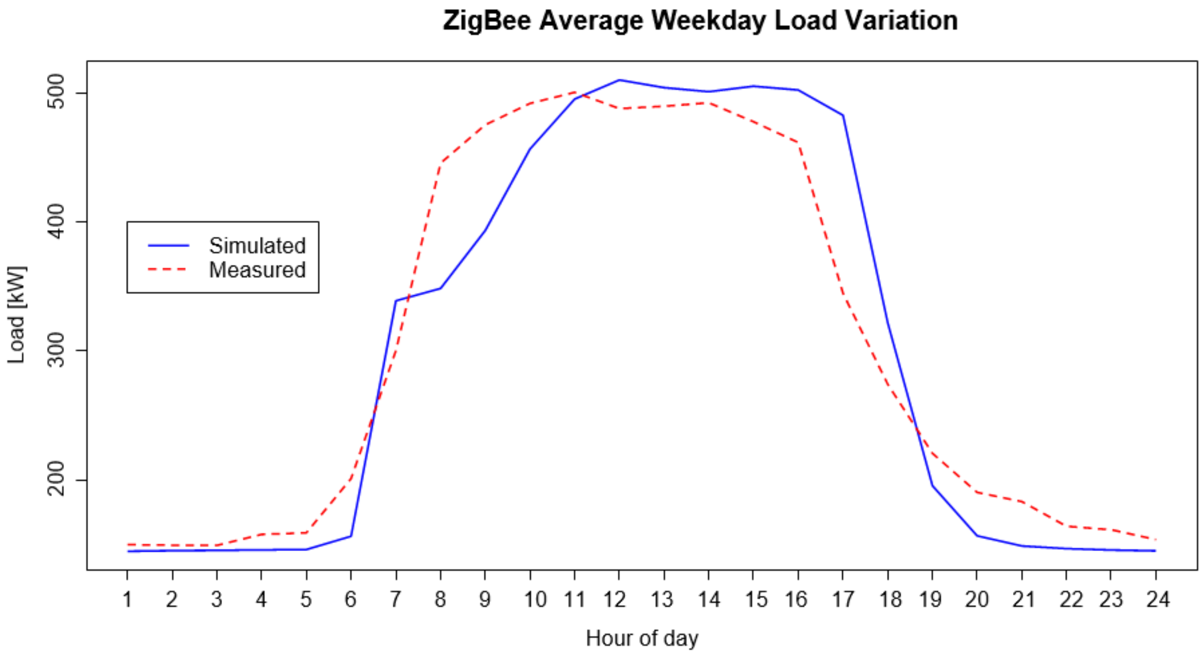

Figure 4.9 : The ZigBee average weekday load variation in hour of day load curves.

In addition, there are many clustering algorithms and techniques to group observations; each one may also lead to a different grouping result. The selection of the appropriate technique is essential to perform the desired clustering analysis; also, the typology of the input data to be clustered is the main factor that will make choose one technique or another, taking into account that not every algorithm is valid for a specific problem. Finally, again, the analyst should create an easy visualization of the results and interpret and communicate the finding to the easy understanding of the audience.

The program code has a function that only runs during the device initialization of intelligent home transformation. Thus, our device initializes and sets the initial values related to the components pins, the Wi-Fi network properties, the home server address, and the ZigBee broker address in this intelligent home function. Then, it sends the registration messages to the home server, using Wi-Fi, to register itself and all of its components and properties. Finally, the device connects to the ZigBee broker and subscribes to the topics related to its components. As its name suggests, the function is a function that will be executed continuously until the board is switched off or reset, allowing our program to change and respond in each iteration. We have implemented in this function the ZigBee protocol loop that checks, for each main loop iteration, if there are new ZigBee messages from the subscribed to IoT-based ZigBee broker for the implementation of home automation system. The system has, per default, one user role: An IoT-based ZigBee broker has assigned the maximum permissions level: it allows to change all the devices, components, and properties values; to create a new load balancer in roles and assign them to a specific part of the intelligent home; to create new rooms and also to create new permissions with the help of ZigBee broker with low error rate percentage.

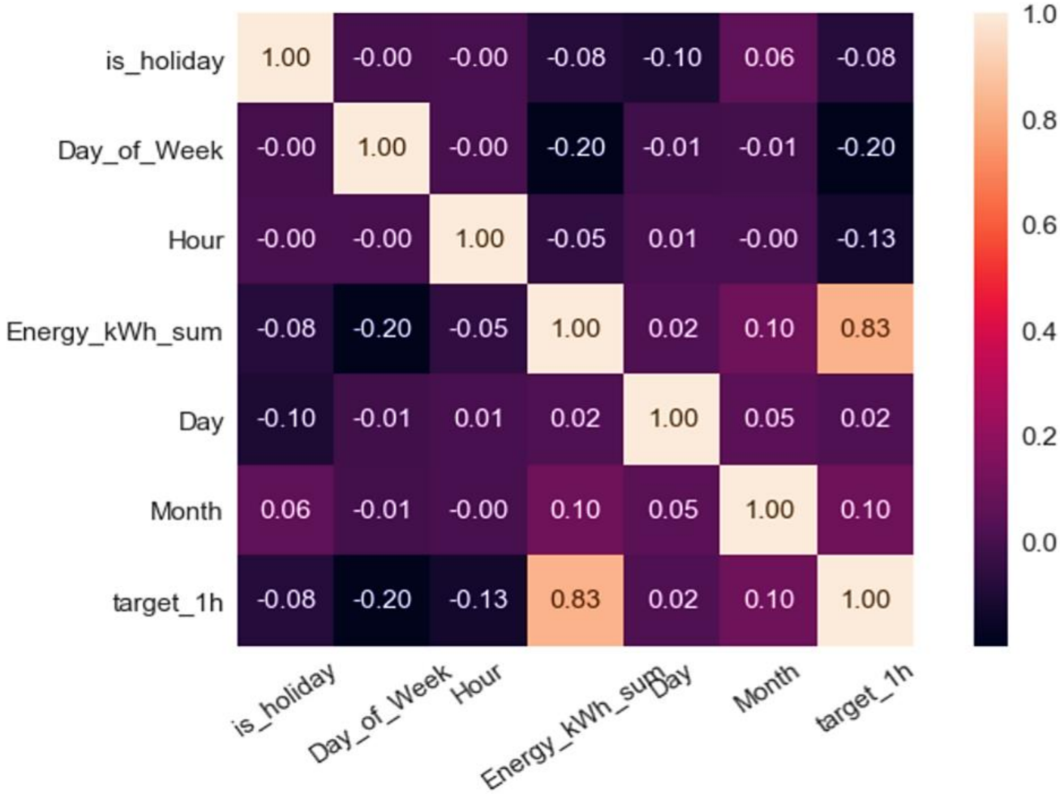

Figure 4.10: The confusion matrix for average energy usage per week .

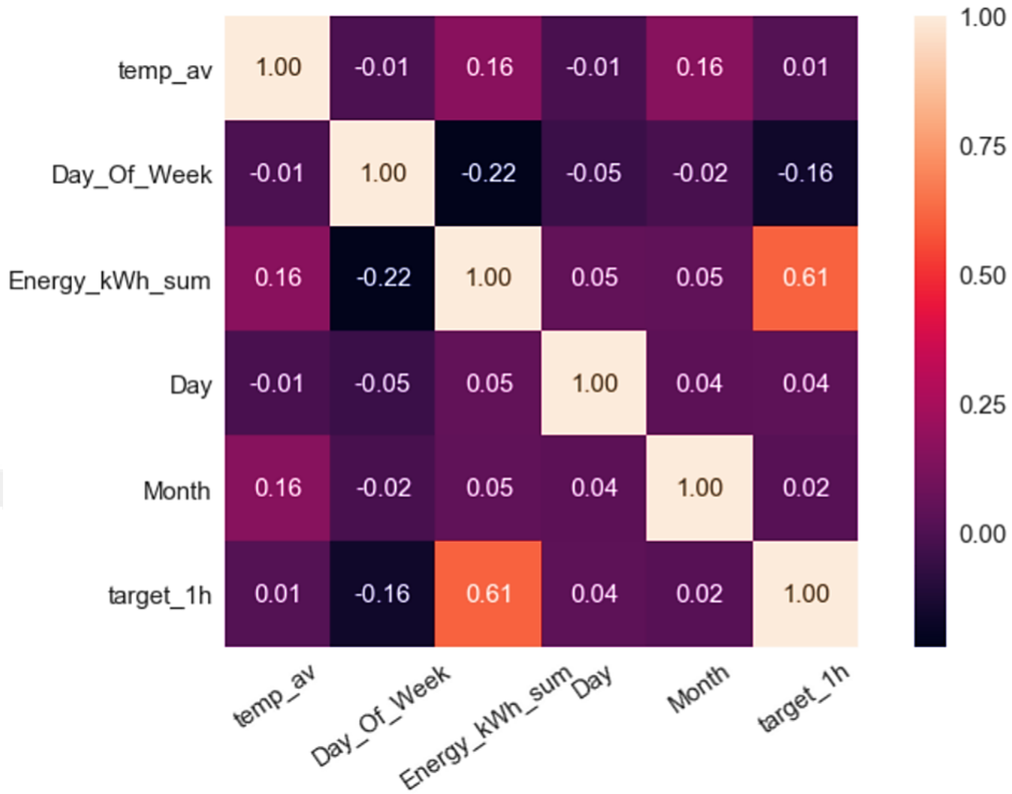

Figure 4.11: The confusion matrix for average energy coefficient for single households.

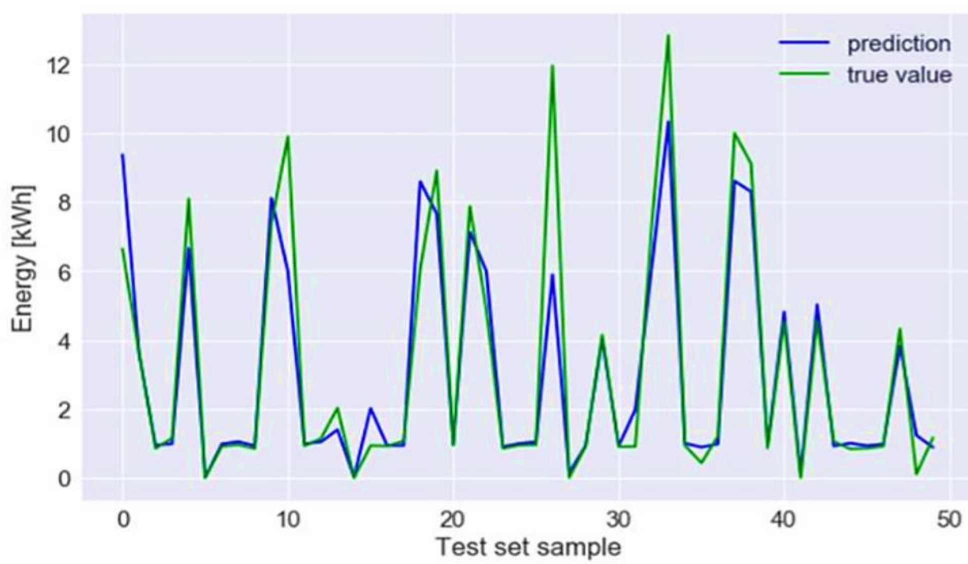

Figure 4.12: The forecast of energy usage in terms of true value and prediction.

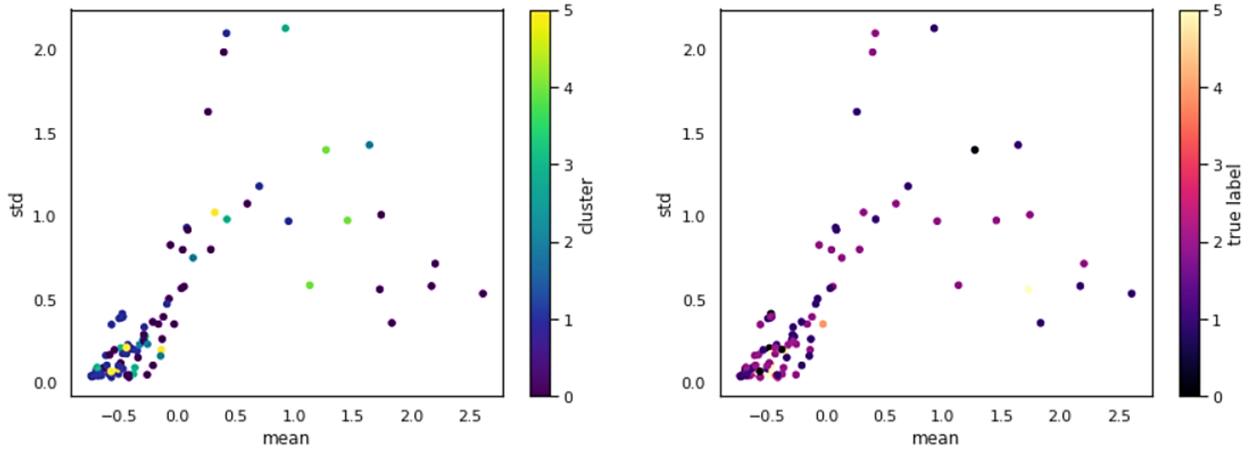

Figure 4.13: The Clustering the Energy Consumption with its relation to home appliances.

5. DISCUSSION

Energy management tools are not extended within the residential sector. The savings obtained do not pay off the investment since the energy consumed is small compared to businesses and industries. However, there is room for providing such tools to residential consumers, for instance, by creating a community as the ZigBee protocol is doing with the collaboration of public administrations and electricity utilities.

This research is an example of a public administration pioneer initiative to engage the consumers and foster energy efficiency among them, aiming to provide energy knowledge, understanding, and guidance to the user to reduce its consumption on average up to 10%. Nonetheless, it was seen that providing the technical consumption data in kWh to the householders has limited influence and effect, so it is necessary to go beyond and translate the technical information into call-to-action measures, guiding the user to smart energy choices (like a GPS), have a better response from the householder. Also, the need for sub-metering devices to obtain the consumption data limits the scalability, as the cost associated is significant.

To reproduce this kind of research on a large scale, access to the data from the utilities smart meters is necessary. So, the combination of smart meter deployment and big data analytics are called to play an important on the energy sector. The smart meters generate large amounts of raw data that need to be managed and once analyzed, can be converted into useful information that benefits both the utility and the consumer to improve customer engagement and the quality of the service. Creating new business opportunities, mainly related to data science and data analysis in response to the market needs.

A brief description of each cluster feature and possible correlation suppositions are presented below:

a. **Cluster 1:** big ZigBee protocol, probably occupied by a couple of networks with little sub-networks or a couple with a pair of grown network links considered sub-network in the analysis. Not using electricity for heating and cooling as no air conditioning neither electric heating is installed. The power contract is the highest one among all the clusters related to the broadband network spectrum.

b. **Cluster 2:** relatively small networks, low power contracted below 5kW, may be sub-network with no ZigBee protocol as no links are in this cluster. The occupancy of small ZigBee protocol could explain the peak at night.

c. **Cluster 3:** The spectrum is allocated for the whole network with a relatively small and modern ZigBee protocol with a low spectrum value. There is no electric heating, but some electric appliances could be used with the help of a broadband network.

d. **Cluster 4** is almost the same number of networks and sub-networks in this work, with a spectrum of less than 100 GHz, built for high energy consumption networks. It could be families with small sub-networks as the number of networks in this cluster is higher than the other clusters.

e. **Cluster 5:** almost only adults are present in this more significant number than in other clusters (2-4 sub-ZigBee protocol), no links, no spectrum issue, less electric consumption, different schedules.

f. **Cluster 6:** The new ZigBee protocol could perform better in taking low energy. Links may occupy it with small nodes of the network. There is no electric consumption, but air conditioning and electricity consumption are the issues with the broadband network. The time of waking up and bring the broadband network to the up state could cause the peaks.

g. **Cluster 7:** There is no data available as the initial aim of the research was devoted to the broadband network. The technical audits and the online info-house are not yet adapted to the high spectrum.

It was possible to detect any pattern or clear evidence that could relate some of the features analyzed to cause a load profile in a broadband network pattern or another. Issues, such as the small dimension of the sample studied, the number of missing values ("NA") in it, and the fact the features available were not the most suitable (adding, i.e., type of employment, people home during the day…); made not possible to reach the desired output when analyzing the features in each load profile cluster.

Table 5.1 :The comparison of proposed method of implementation

ARTICLE	TECHNIQUE	ACCURACY
[54]	Convolutional Neural Network (CNN)	89.97%
[55]	Support Vector Machine (SVM)	96.73%
Proposed	ZigBee based IoT Protocol with K-Means	98.46%

Most home appliances features are common to each cluster, with energy usage data in the broadband network and not available data for the domestic hot water system. Also, it does not exist any significant difference among the house properties and the sociological features in the different clusters in order to be able to affirm that one or some specific features are the cause of the load profile pattern.

Remark that the scope of analyzing the features for each cluster would have been more adequate if a larger sample with better data quality in ZigBee protocol and more specific features were available in the result section of this research. So, the current process could not add any value to the research; but it is a procedure that could be followed when a more extensive dataset is available.

6. CONCLUSION

6.1 CONCLUSION

Smart home energy consumption prediction is the key to properly analyzing and extracting reliable conclusions from it. In this study, the dataset was optimal in terms of quantitatively and qualitatively.

This Kaggle dataset utilized well as instance counting for thousands of users would have been adequate to the purpose of the study than the small sample studied of only users. In addition, the electrical consumption data from the sub-metering equipment presented some issues that difficult the analysis at some point and demanded a pre-clustering stage for treating and cleaning the data. As the communication between the sub-metering device and the server is done through the consumer's broadband network, when it is switched off, the consumption data is lost and counted as high spectrum allocation as if it had been no consumption.

So, when the possibility to access the hourly smart meter consumption data becomes a reality, the current study purposes will find a suitable framework since the numbers of users could be much higher, and the data quality should be almost perfect, as are the measures from the electricity utility to bill their customers. The methodology used in this research is simplified compared to the procedures of the referenced papers, as larger datasets and more complex parameters are used. Normalize the electricity consumption considering the weather and seasonal effects, although there was no temperature data for the present study.

The K-Means clustering technique was tested and compared, giving the best prediction of accuracy 98.46% for all energy load profiles with a high spectrum of 100GHz. The solution from the ZigBee Protocol-based K-Means clustering is the one that better adapts to the segmentation sought, which is used as the base of the post-clustering stage to obtain the final energy consumption segmentation. This normalization is advisable as it mitigates the electricity consumption correlated to the temperature; however, this is more appropriate for aggregated daily consumption. However, for instance, the electricity consumption is not normalized with the temperature. Most of these methodologies use the absolute values in 100 kWh, focusing on identifying the users with higher energy savings potential. However, for the segmentation purpose, using percentages of energy usage fulfills the expectations sought. They provide consumers segments similar to the load profile archetypes from the power study basis of the current study (i.e., Evening peaks, double peaks, spectrum allocation, consumers). The methodologies have some similarities, mainly regarding the pre-clustering phase of cleaning the data and the clustering phase as the K-Means algorithms using the ZigBee Protocol.

6.2 FUTURE RECOMMANDATION

Consumer segmentation allows the utility to understand individuals and groups of a broadband network offering tailored services. Not all the spectrum allocations are equal, so each need different personalized energy-savings recommendations at a different time of the day. Providing that will improve the effectiveness of energy efficiency programs and affect the energy reduction recommendations and improve the effectiveness of the demand response programs aiming to shift the energy usage time to avoid peaks or reduce the duration of the peak for ZigBee Protocol with high spectrum allocation.

a. We would use the broadband network to a larger and complete dataset using deep learning, for example, the utility smart meter data. More advanced deep learning techniques could improve some stages of the procedure and a deeper literature review regarding smart meter data treatment and segmentation for broadband networks.

b. We will perform a precise analysis that can incorporate different figures or processes, leading to even more accurate results. Such as the use of energy normalized electricity consumption data, use more features than only the 24h vector to cluster, eliminate outliers when finding the mean load profile of a user, perform the same study using the weekend's profiles, also, apply other and more advanced deep learning techniques.

c. However, in the future, we would calculate the energy consumption for hourly data was enough for clustering load profiles with high spectrum allocation, but if what is sought is to determine the cause of the curve shape and the peaks, hourly data will not be enough. So that, it will make necessary to use high spectrum allocation through electricity consumption data and detailed appliances and features data.

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