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IoT Sensor Data Retrieval and Analysis in Cloud Environments for Enhanced Power Management

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ABSTRACT

The current world's lack of resources is pushing people toward energy-efficient devices. Of all these resources, power is the one that has to be watched over and managed as needed because the amount of electricity consumed is rising daily. An environment of linked devices and applications based on the Internet is known as the Internet of Things (IoT). Through the seamless integration of physical devices and sensors into information nodes, the IoT creates an ecosystem that enables the delivery of creative and intelligent services that improve human well-being and efficiency. This study proposes the development of an innovative smart power management system that utilizes IoT technology integrated with cloud computing for efficient energy monitoring, analysis, and optimization. The system aims to enhance energy efficiency, reduce operational costs, and promote sustainability in both residential and commercial settings. Key components include IoT devices for real-time data collection, cloud-based infrastructure for data storage and analysis, advanced analytics for optimization, and user-friendly interfaces for visualization and decision-making. The expected outcomes include the creation of a robust system capable of optimizing power consumption practices, leading to improved energy efficiency and reduced environmental impact. IoT-based resource management strategies have been presented by numerous researchers. This study explores the suggested resource allocation strategies, identifying key factors that must be considered to enhance resource allocation in IoT networks. Additionally, it uncovers challenges and issues associated with cloud-based resource allocation in IoT environments.

1. Introduction

The most fundamental need for everyone in the current society is electricity. The graph of energy demand is increasing daily while the energy supplies are falling off in tandem. The quest for renewable energy sources and energy-efficient technology is becoming more feasible due to the rapid increase in power demand. Since prevention is always preferable to treatment, it is important

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to raise awareness of energy consumption everywhere before resources run out. About 37% of the world's energy is used by industrial users, 20% is used by personal and commercial transportation, 11% is used by residential appliances, and 5% is used by commercial uses. The remaining 27% of energy is lost during the transmission and generation of energy [1].

Energy waste will be reduced by the system's design, which continuously monitors and controls the electrical appliances. Among all the microcontrollers, Mbed is selected because of its characteristics, which include peripheral libraries, an online compiler, a smooth start-up, and ease of use. Since Mbed is compatible with 10/100MBit Ethernet, it can be interfaced to an Ethernet modem in order to implement IoT. A cloud database can be used to store and update the values from the sensors on a continual basis. There are several open-source cloud systems available for different dashboard devices, such as Ubidots, Xively, and Thing Speak. Xively provides Board Support Package (BSP) files and libraries for embedding [2].

For this reason, Xively was selected as the platform for storing tracked data from the existing measuring sensors. The other thing that can be done to save energy is to control the devices. Actuators such as relays can be used to turn appliances on and off based on demand. Users of online automation systems are able to control the system even when they are not in close proximity to it [3]. The idea of IoT has been introduced in this context. IoT stands for IoT, which means that devices are integrated over the internet and use IP addresses (Internet Protocol) as unique identifiers. Every Mbed that is interfaced to an Ethernet creates a distinct IP address. The user can give controllers to each room in the house, depending on the need and quantity of rooms [4]. The IoT refers to a group of interconnected smart devices and sensors. Devices are connected through wired and wireless network technologies to transmit and exchange data between nodes. Humans, software agents, smart devices, sensors, and sensor data are all components of an IoT infrastructure network [5]. To communicate information instantly and recognize that the Things are linked to the physical environment, these interconnected autonomous devices establish local networks and connect to the global network [6].

Every edge node in a cyber-physical ecosystem is meant to be an IoT device that can work dynamically with other networked devices to carry out one or more user-assigned activities that are connected to the system network. IoT networks typically have limited resources, even when cloud service providers supply the infrastructure and computational power. The resources consist of RAM, storage, network bandwidth, and computational power. IoT devices' sensors generate vast quantities of real-time data. The real-time data are stored in local networked data centers in the cloud and subsequently sent to global networked data centers for access by smart devices worldwide [7]. The author of this research looked at a number of resource allocation strategies for cloud-based IoT systems. These strategies have been categorized according to several criteria, including SLA, energy usage, cost, context, and quality of service. Additionally, the author covered a number of aspects related to IoT system resource allocation approaches [8]. IoT sensors are devices that collect data from their environment and transmit it to a database located locally, remotely, or in the cloud. We are able to distinguish actuators, portable sensors, and clever devices. The data that has been gathered is transmitted to the storage device. Various detecting equipment such as RFID tags, actuators, portable sensors, and smart sensors are utilized to collect data on objects. The IoT provides users with a multitude of benefits and services [9]. Therefore, a few things are required in order to use them correctly. This section will cover the IoT components. The components needed to achieve IoT capabilities are indicated in Figure 1.

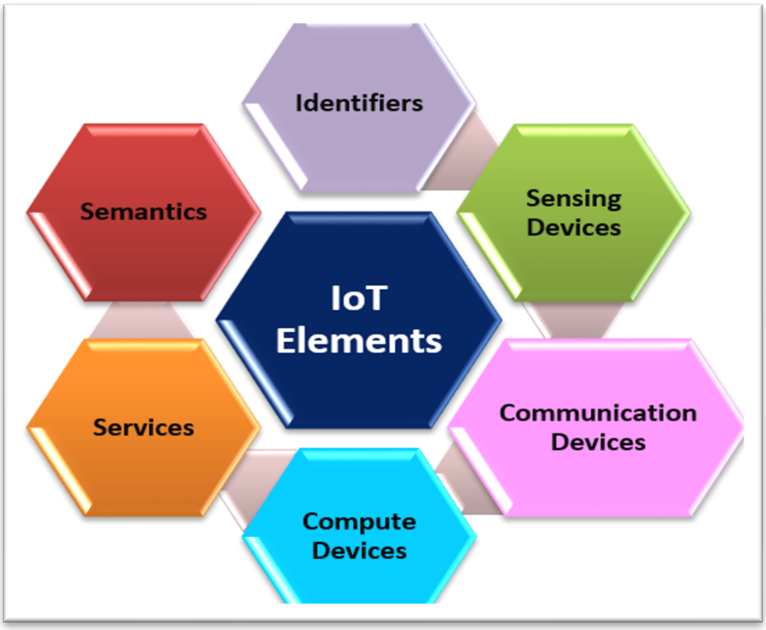

Fig. 1. Basic elements of IoT environment

Heterogeneous artifacts are communicated using IoT communication strategies and communication devices to achieve smart services. One of the main goals of the IoT is to enable devices to connect and communicate with one another. Through the communication layer, devices can transmit and receive messages, documents, and other kinds of data. A few of the numerous methods that facilitate communication are Bluetooth, Radio Frequency Identification (RFID), Long Term Evolution (LTE), Wi-Fi, and Near-Field Communication (NFC) [10].The items' collected data is computed by sensors. It is used in the creation of applications for the IoT. Software platforms depend on operating systems to work, while hardware platforms such as Raspberry Pi, Arduino device are used. There are many operating systems in use, including Tiny OS, Riot OS, Lite OS, and Android [11].

Four different services are offered by applications. The first service linked to a particular identity. It is employed to determine the identification of the sending objects for the request. Another service that attempts to gather all the information about the objects is the aggregate of information. The processing is also done by the aggregation service [12]. The third service is a cooperative service that transfers appropriate rejoinders to the devices and takes decisions depending on the information gathered. The omnipresent service, which replaces devices instantly without imposing rigidity on time or location, is the final service [13]. Recent global technology developments have been closely linked to the information and industrialization processes. Thanks to the ideas of "Industrial Internet," "Industry 4.0," and "Made in China 2025," and the proposed national strategy, the IoT industry has expanded rapidly. The State Grid Corporation's IoT pilot project implemented the National Smart Grid Management IoT Application Demonstration Project in 2012, which was initiated by the National Development and Reform Commission. Smart grid IoT demonstration projects were implemented in many places, including Beijing, Shandong, Shanghai, Jiangsu, and Zhejiang. It has made a major contribution to the development of power systems and the deep integration of IoT [14].

The following three important issues are outlined in this paper: Concerns regarding safety and security. In the previous safety protection system, there were relatively few protective bodies and a concentrated distribution. However, more protective bodies were being dispersed, and this was done to make it easier to construct UEP-IoT. The old power system security protection method is not only exceedingly expensive to defend, but also is not well equipped to handle a huge number of widely dispersed protection subjects. There are glaring disparities between huge protection, security, and performance. Problems with information exchange. Traditional security systems transmit much of their data in a one-way fashion. It has fewer information data interaction, less security needs, and comparatively lower processing performance requirements. However, as smart grids are built, more data is being collected, and a vast volume of data need flexible access and real-time engagement. The traditional power system finds it difficult to enable the development of the ubiquitous power IoT due to the extremely high requirements for processing performance and security in the system. Problems with remote backup and data security. Large-scale area control is still lacking in backup data for the majority of power producing firms. Certain businesses burn optical discs to store data and use portable hard drives to replicate data. This method is inexpensive, but when the data needs to be reused, it becomes inconvenient due to its heavy burden. To facilitate the widespread development of the IoT, efficient steps must be implemented to accomplish synchronous data backup across many locations.

Ineffective power management is a problem in the contemporary energy landscape because it causes excessive energy consumption, high operating costs, and negative environmental effects. Conventional power management systems frequently have inadequate real-time monitoring features and optimization tactics, which leads to inefficient use of energy in both business and residential settings. Furthermore, the efficient analysis and application of energy data for decision-making is impeded by the absence of integration between IoT devices and cloud computing. The project's objective is to create a smart power management system that addresses these problems by utilizing cloud computing and IoT technologies. Real-time energy consumption monitoring, sophisticated data analysis for optimization, and intuitive user interfaces for well-informed decision-making will all be made possible by the system. The proposed system aims to minimize environmental effect in various locations, improve energy efficiency, and lower operating costs by optimizing energy usage and encouraging sustainability.

The pressing need to overcome inefficiencies in the current power management systems—which result in excessive energy consumption, high operating costs, and environmental degradation—is the driving force behind this research. Conventional systems are unable to apply optimization algorithms and track energy use in real-time, which leads to less-than-ideal resource use. The integration of IoT with cloud computing technologies offers a possible solution to these issues. We are able to improve energy efficiency, lower operating costs, and lessen our environmental impact by creating a smart power management system that makes use of IoT devices for real-time data collecting and cloud-based analytics for optimization.

In addition, there is a growing need for creative solutions that support eco-friendly and energy-efficient practices due to the growing need for sustainable energy practices. By minimizing energy use and encouraging environmental stewardship in residential and commercial settings, we hope to contribute to sustainable development goals through the creation of a comprehensive smart power management system. The overall goals of this research are to improve upon the weaknesses of the power management systems that are in place, to fully utilize the potential of cloud computing and IoT technologies, and to encourage sustainability and energy efficiency in a variety of settings.

2. Related Works

Things-oriented, Internet-oriented, and Semantically-oriented are the three viewpoints for an IoT architecture [15]. From a things-oriented standpoint, NFC and RFID technologies are employed to establish connections between intelligent, self-sufficient smart devices for certain daily uses. From an internet perspective, these smart devices create global connections among themselves through the use of standard communication protocols and unique identifiers, or IP addresses, to connect to the internet. Semantically speaking, IoT architecture leverages the data generated by IoT devices to provide useful information and use that information to solve architectural modeling problems [16].

The National Institute of Standards and Technology (NIST) defines cloud computing as a paradigm that permits end users to pay for the use of a shared pool of computing resources (network, storage, applications, and services) that is global, appropriate, and self-serviced with the least amount of effort or communication needed from service providers [17]. Because cloud computing services are inexpensive and have quick elastic features, IT professionals and industries are using them more and more for project deployment [18]. Cloud computing, an Internet-based technology, is characterized by its extensive network access, resource pooling, fast elasticity, measurable services, and on-demand self-service. Both service providers and users benefit from these features. For cloud computing, there are three service categories and four deployment strategies. Customers of the cloud utilize software hosted on cloud infrastructure under the software as a service (SaaS) model. Cloud customers can deploy their applications onto the provider's infrastructure by using the software design languages, libraries, and tools that the cloud infrastructure in the Platform as a Service (PaaS) model offers. Users can delegate storage, processing power, network, and other basic computing requirements to any operating system and applications that the cloud provider offers as a virtual machine (VM) under the Infrastructure as a Service (IaaS) model [19].

Furthermore, cloud computing offers four deployment models: public, private, communal, and hybrid, depending on the features and demands of the user. One of the many cutting-edge technologies that makes use of cloud computing is the IoT, which is made possible by its extensive feature set. IoT and cloud computing integration has been critical to many real-world applications, such as smart cities, healthcare, agriculture, transportation, smart cars, and many more [20]. The adoption of internationally connected smart devices is propelling the present wave of technical developments. Due to storage capacity constraints, this produces enormous volumes of data that are too big to store locally. All industries rely heavily on data, and without analytics, data cannot give useful information for next plans and strategies. The massive volume of data collected by smart, networked devices requires powerful computer systems that can process this volume of data. These data cannot be processed for analytics by the local systems due to their limitations [21]. These limitations on huge storage space, processing power, and network bandwidth can be addressed using the pooled resources provided by cloud computing. Cloud computing infrastructure is used as a hidden layer between applications and IoT devices to hide all capabilities from the development of IoT-based applications [22].

At the network's edge, near the source or data source, edge computing is an open, distributed platform that integrates network, processing, storage, and application activities. By providing edge intelligence services in the field, it may meet the fundamental needs of industry digitalization in terms of fast connections, real-time business, data optimization, application intelligence, security, and privacy protection. It can help create intelligent systems, intelligent gateways, intelligent assets, and intelligent services by serving as a bridge between the physical and virtual worlds [23].

There are benefits to both edge computing and cloud computing. Cloud computing excels in large-scale, long-cycle, non-real-time data processing and analysis on a global scale. Long-term maintenance, help with business decisions, and other things can be beneficial. Processing and analyzing local, real-time, short-cycle data is better suited for edge computing, which can help with local service execution and real-time intelligent decision-making. As such, rather than being a replacement for one another, edge and cloud computing have a complementary synergistic relationship [24].

They must be closely connected in order to optimize the application value of edge and cloud computing and better meet the expectations of various demand scenarios. Edge computing functions as both an execution unit close to the source and a gathering and preprocessing unit for high-value data in the cloud to better assist cloud applications. Similar to this, business rules and models are optimized using big data analytics in cloud computing. As a result, the edge nodes can receive them and function more efficiently. The specific edge-cloud computing collaboration paradigm is shown in Figure 2 [25]:

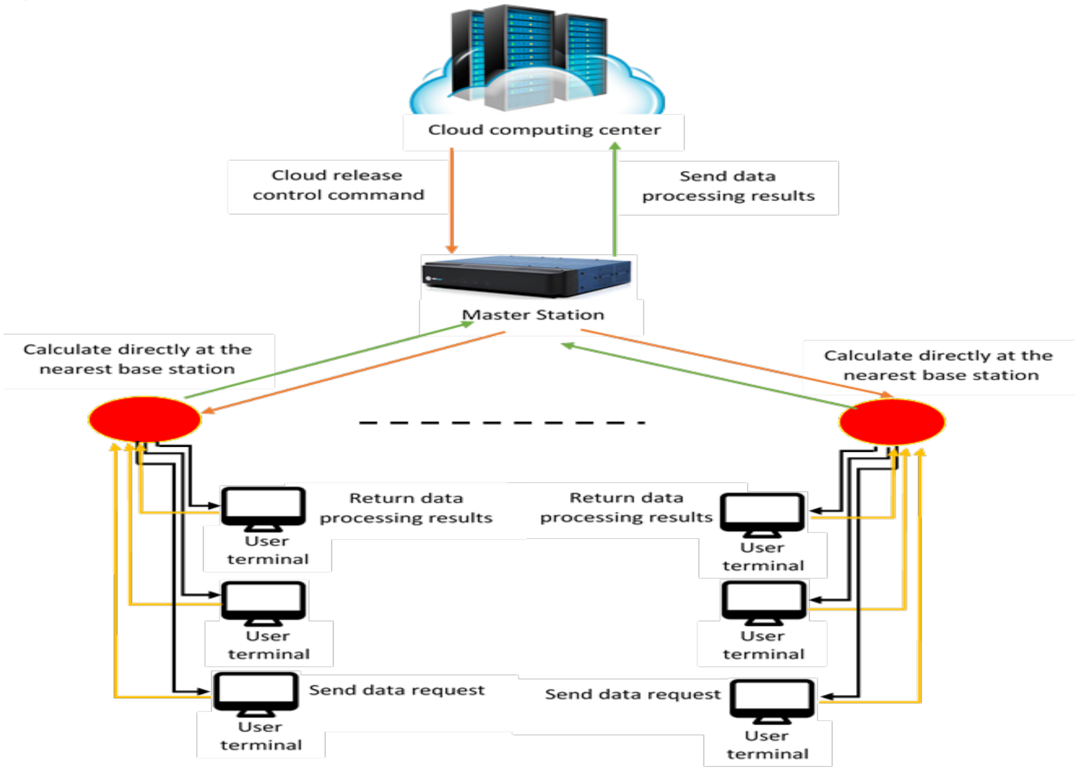

Fig. 2. Edge-Cloud computing collaborative model architecture

The authors provided a summary of IoT-enabled energy systems in [26]. A few of the issues mentioned include turning each physical thing into a distinct virtual object, which can be handled by using common communication protocols. The authors also asserted that, because system designers have made a variety of design decisions, there are multiple ways to enable an IoT-based energy system, suggesting that there isn't just one architecture. A smart load node (SLN), which was introduced by the authors of [27], enables traditional home appliances to operate well in a smart grid setting.

The fact that SLN doesn't require alterations to a home's electrical wiring or appliances makes it an inventive alternative. A load management unit (LMU) and smart meters are two additional devices that SLN connects with within a HAN to enable several smart grid applications within a home, like demand-response (DR) load scheduling. The authors in [28] provided a ground-breaking methodology that included the concept of green building in order to reduce energy usage. The authors claim that increasing public knowledge of energy-efficient appliances and homes, and power-saving practices, is essential. The services offered by public clouds have sparked a growing interest in creating applications that are powered by data. A smart home can incorporate data-driven applications such as alarms for anomalous load circumstances and appliance scheduling in the event of dynamic tariff systems. Amazon, Google, and Microsoft were the three cloud systems that were compared by the writers. IoT devices employed MQTT messaging to transfer data to cloud platforms, where a performance assessment was done to measure the message broker's service time rather than benchmark the maximum message throughput. There was also discussion of cost comparison and an explanation of the available tiers.

Despite significant advancements in smart power management systems leveraging IoT and cloud computing technologies, several research gaps remain that warrant further investigation. While cloud computing offers scalability and storage capabilities, integrating edge computing into smart power management systems can enhance real-time processing and decision-making capabilities. Research focusing on the integration of edge computing with cloud infrastructure to optimize energy management in distributed environments is needed. With the proliferation of IoT devices and cloud-based solutions, addressing cybersecurity and privacy concerns is paramount. Research focusing on developing robust security protocols and privacy-preserving mechanisms to safeguard sensitive energy consumption data is crucial for widespread adoption. The smooth integration and sharing of data is impeded by the lack of standardization and interoperability between cloud platforms and IoT devices.

In order to enable more seamless integration of disparate systems, research concentrating on creating compatible protocols and standards for cloud computing platforms and IoT devices can promote data compatibility and interoperability. As the number of IoT devices and data volume increases, ensuring scalability and efficient resource management in cloud environments becomes challenging. Research focusing on scalable architectures, resource allocation algorithms, and workload management techniques tailored for smart power management systems is needed to address scalability concerns. Exploring energy harvesting techniques integrated with smart power management systems can enhance sustainability by utilizing renewable energy sources. It is crucial to do research on the integration of energy collecting technologies, like solar panels or kinetic energy generators, with IoT devices in order to power sensor nodes and lessen dependency on conventional power sources. Addressing these research gaps can lead to the development of more robust, secure, interoperable, and scalable smart power management systems that effectively optimize energy consumption, enhance sustainability, and meet the evolving needs of modern energy management.

3. Methodology

Optimizing power management and data analysis through IoT in cloud-based environments involves leveraging Internet of Things (IoT) technology to improve the efficiency of power utilization and enhance data analysis capabilities within cloud computing infrastructures. By integrating IoT devices with cloud-based systems, organizations can collect real-time data on power consumption, environmental conditions, and operational parameters, enabling proactive power management strategies. These strategies may include dynamic workload allocation, energy-efficient scheduling algorithms, and predictive maintenance based on data analytics insights. Furthermore, IoT sensors deployed across cloud data centers and edge devices enable comprehensive data collection, facilitating advanced analytics and machine learning algorithms to extract valuable insights for optimizing resource utilization, improving performance, and reducing operational costs. Through the seamless integration of IoT devices with cloud-based environments, organizations can achieve greater agility, scalability, and sustainability in their operations, driving innovation and efficiency in power management and data analysis processes. Figure 3 shows the proposed architecture with four tiers.

3.1 Perception Layer

It takes into account various physical objects, sometimes known as "things," like sensors, smart plugs, and smart meters. Tasks on objects situated on the edge sub-layer, such as data processing, data storage, and action taking, are made possible by edge devices. A crucial component of the proposed architecture is the perception layer, which serves as both the final stage in appliance control and the initial step in gathering energy data. Material layer made of sensors which used for a variety of comfort-related purposes, such as light detection, humidity, and temperature. Between the appliance plug and the household power line, smart plugs (SP) act as a middleman. In addition to monitoring an appliance's energy use, SPs also control the amount of energy that is provided to it through the use of a relay.

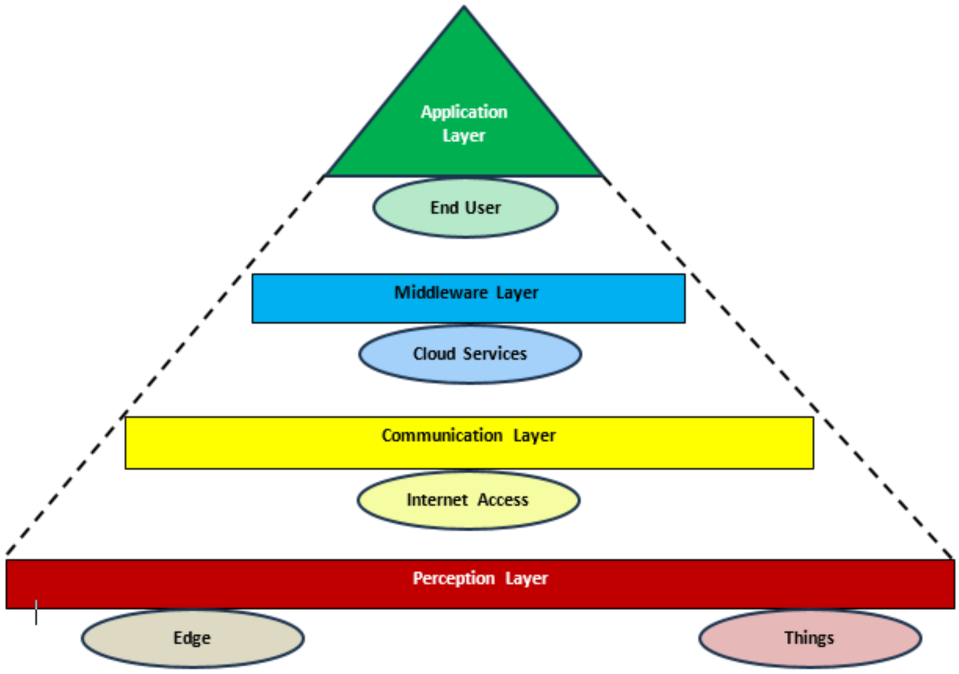

Fig. 3. Cloud-IoT HEMS architecture

The edge and the actuators are closest to one other. It provides the ability to obtain data and provide orders to "things." The edge layer perceives limited data processing and storage capacity along with low latency as accessible resources.

3.2. Communication Layer

The middleware layer and the perception layer can communicate more easily thanks to this layer. The availability, cost, coverage, and effective range (both short- and long-range) of a communication system are all factors in the technology selection process. An essential function of the network layer involves establishing a home area network (HAN) where devices within the perception layer can connect machine-to-machine (M2M) communication.

3.3. Middleware Layer

It is to fulfil the aforementioned duties, developers can select from a range of technology stacks and finish the implementation that is required. A few choices and problems around database election, cloud architecture design and deployment, programming language selection, and/or framework selection need to be made in order to guarantee a dependable system.

3.4. Application Layer

Smart grids, energy internet, and smart homes are just a few of the domains that a HEMS's data is meant for. Demand response, peer-to-peer energy trading, and user-aware energy usage monitoring are a few examples of data-driven applications for hybrid energy management systems. In the proposed architecture, these applications represent the final layer that is closest to the user.

4. System Design

A local HEMS and a cloud-based HEMS—are proposed to compare different HEMS methodologies. Conversely, a cloud-based system can enable several solutions and applications by gathering data through a gateway. The following functions are provided by both systems, allowing HEMS to carry out some smart home features. HEMS should record information on the primary load of the smart home and the power usage of the appliances that the smart plugs are used to monitor. To provide or refuse electricity, a resident should be able to communicate with appliances that are connected to smart plugs using HEMS. Certain characteristics that are necessary for both systems to function are included in this work's smart house. Two common categories for the implementation of these systems are identified by us. The items Smart meters and smart plugs are the identical end devices used in both case studies. The smart meter's job is to gather the house's overall power usage reading. Conversely, a smart plug has the ability to monitor an appliance's power use and regulate the amount of electricity it supplies. The system considered the WiFi capabilities of the smart home, which let devices talk to each other within a home area network (HAN). Some examples of devices that can establish a WiFi connection with the HAN are smart meters and smart plugs. It can also use the communications protocol that each device is compatible with to request direct energy consumption.

A schematic diagram for HEMS design is shown in Figure 4. The smart meter, smart plugs, household appliances, and computer device acting as the local HEMS make up the left side of the system. This method takes into account a solution that, in a local setting, only monitors and controls the consumption of household appliances. Because this system is disconnected from the Internet, it offers advantages in terms of privacy. The main drawback of this kind of approach is the limited processing and storage capacity of the HEMS, which is closely related to the provided on premise hardware. As per the Edge perspective, devices such as smart meters and smart plugs are designed to collect energy consumption data by aggregating the energy consumption of individual appliances and the overall energy consumption of the primary residence.

The energy and data interactions are displayed, is where the Cloud-IoT HEMS design is displayed. Data linked to energy use can be collected with smart plugs and smart meters. Transferring the energy usage data to the cloud is the primary goal. In order to accomplish this, the devices transmit data to a gateway, which enables data bridging into the cloud. Databases and cloud micro services are used to store and process these data shown in Figure 5.

Applications for data-driven HEMS can be developed and implemented in a multitude of ways. Thanks to public cloud services' limitless scalability options, applications can grow as big as they need to. Cloud providers simplify the development process by managing the hardware and configurations required for any design to function properly. The execution sequence of Figures 6 starts with an Ethernet connection check. A serial terminal will display the IP address if the Ethernet connection is correct. Errors are displayed if there is an Ethernet issue. The server port setup is confirmed when the Ethernet connection is examined. A serial terminal error message will show up if there is a problem. A TCP socket connects, an RPC connection is made, and the server operates if the port setup is correct. Appliances can be controlled by the user via settings in the web server. The microcontroller acts are triggered internally by PPC commands. The HTTP server launches as soon as the TCP connection is established. The HTML5 code is then started as well. A webpage appears and background HTML5 code executes when the IP address is entered into the URL. In this way, the microcontroller acts in accordance with the signals provided by the user, and when the user provides signals, the relevant RPC is started.

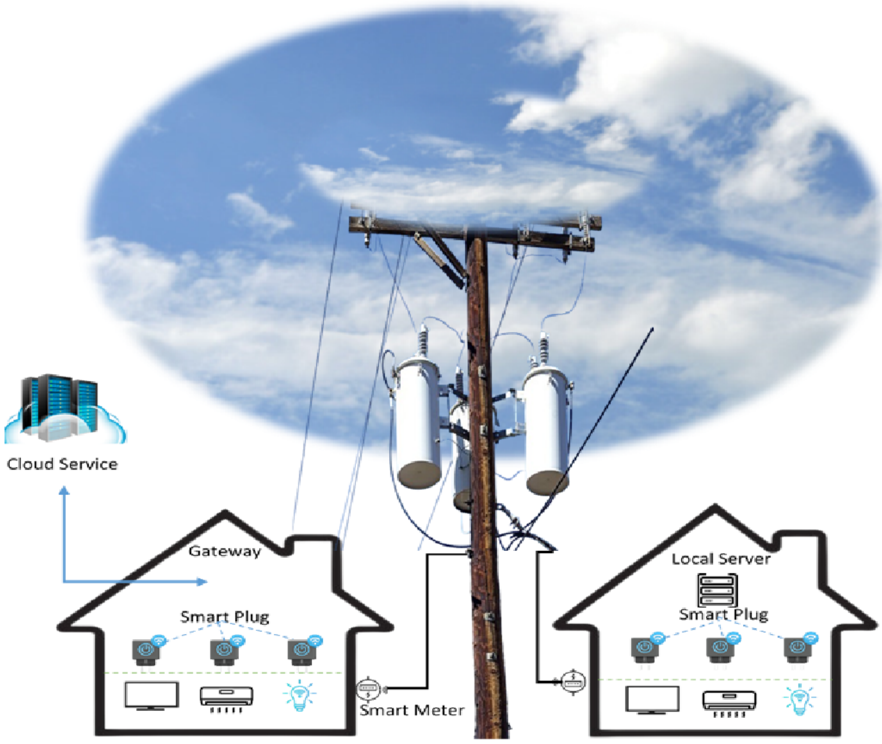

Fig. 4. Schematic Representation of Proposed System

Bidirectional intelligent electric power networks are replacing current unidirectional EPESs in order to address these issues. "The intelligent power network facilitates the bidirectional movement of data and electricity and is automated, flexible, intelligent, robust, and customer-focused. Bidirectional power flow is made possible by energy storage, allowing for active consumer participation in the purchasing and selling of power. It has the ability to measure and control intelligently, and self-heal. Furthermore, it offers the ability to monitor power networks in real-time for enhanced failure prediction and diagnosis, enabling the early detection of anomalies and weak spots. Intelligent electric power networks have several advantages, including increased energy efficiency, reduced expenses, better demand-supply response, and a reduction in T&D losses. The figure. 6 shows Ethernet Connection Flow Check.

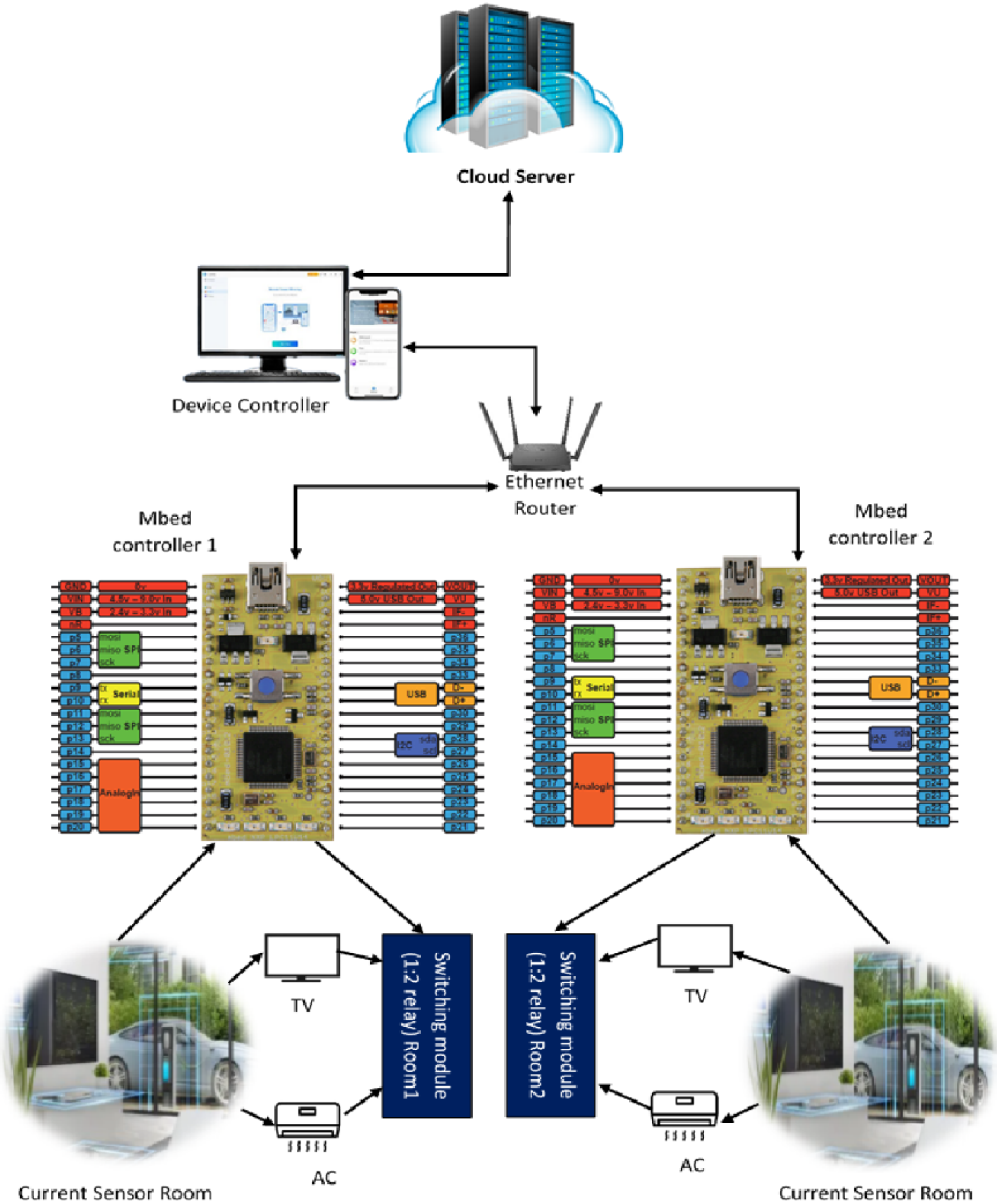

Fig. 5. Cloud-IoT HEMS Design

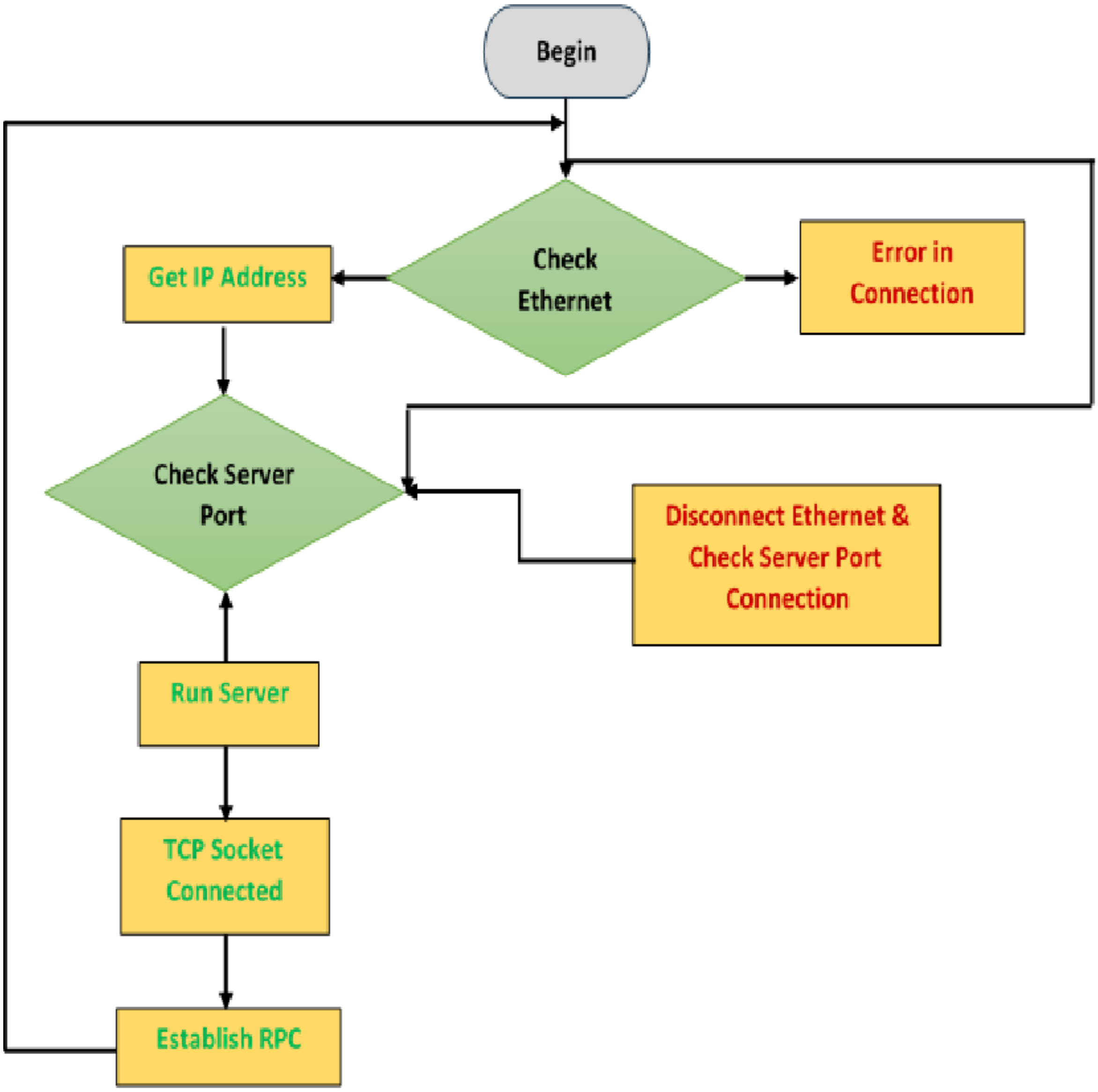

Fig. 6. Ethernet Connection Flow Check

5. Results and Discussions

Making the most of the IoT is essential if intelligent electric power networks are to become more flexible, asset-managed, reliable, and efficient. To increase the robustness of electric power networks, oscillations from decentralized generation from distributed energy resources (DER) integration must be taken into account. Smart inverters are one potential IoT solution to this issue. By leveraging the information from this data to inform their decision-making, stakeholders may be able to optimize the electric power network more successfully. Figure 7 shows the configuration of the full system with two nodes. An Mbed interfaced to sensors and relays makes up each node. A two channel relay is used to control two appliances, a 10 W LED lightbulb and a 12 volt DC fan. TheXively database may contain the measured data from the sensors. Xively provides an API key and feed id for every channel that has to be measured. After providing the mbed with the feed ID and API key, code is run to update the values in Xively. Figure 8 displays the results of Xively.

Remote Procedure Calls (RPC) is used for client-server communication. The communication protocol in use is HTTP. Between the client and server, commands and parameters are carried across. Therefore, two distinct mbed controllers in this system generate two different IPs. When the IP address is supplied in the URL, the webpage is configured to allow the user to control fans and lights by selecting which buttons to turn on or off shown in Figure 9.

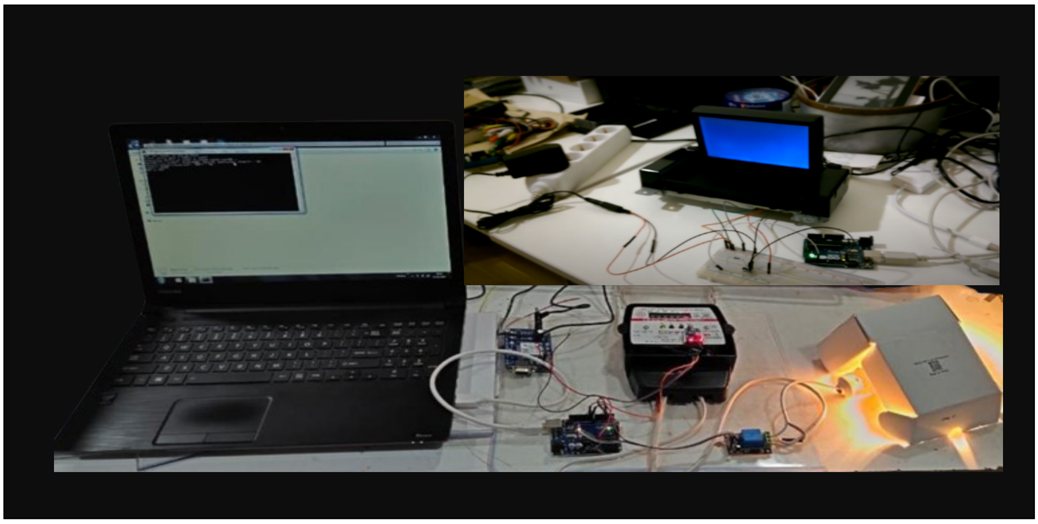

Fig. 7. Setting up the entire system

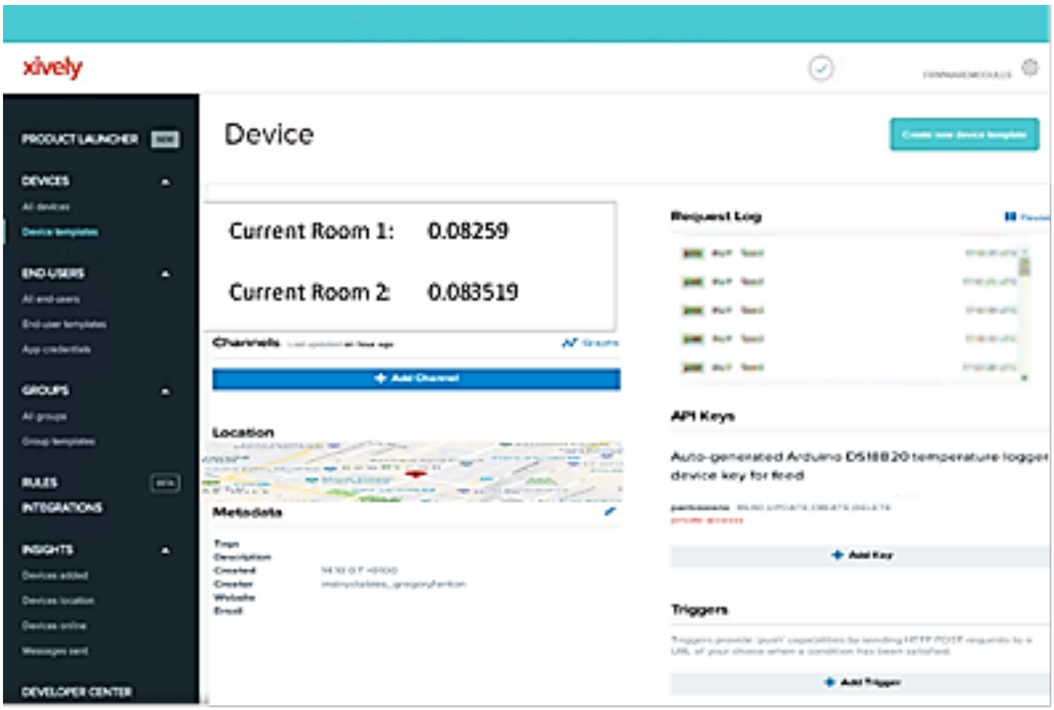

Fig. 8. Xively output

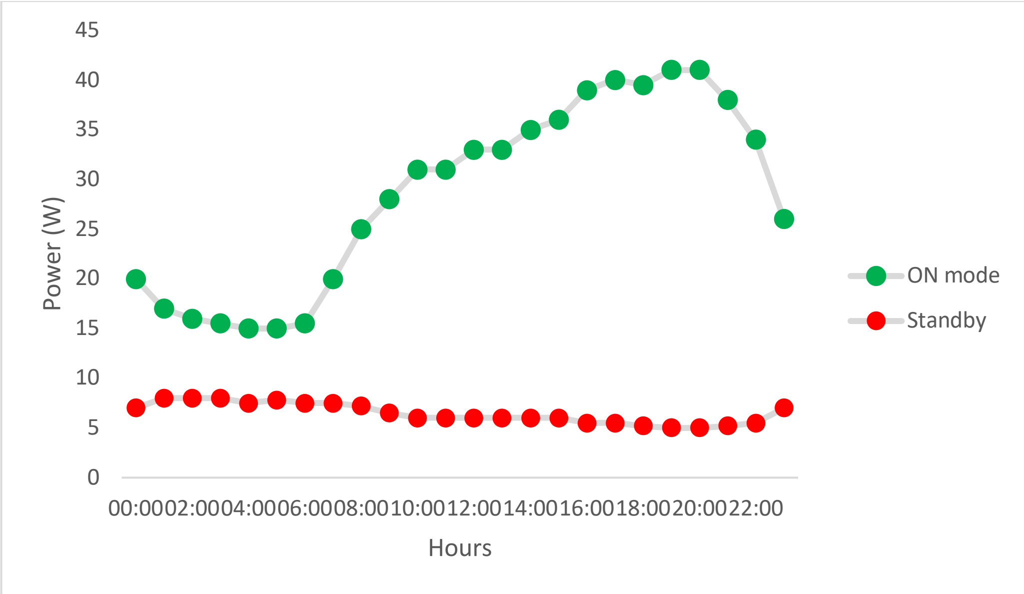

Fig. 9. Hourly Energy Consumption Graph in Test System

This arrangement offers a single outlet to connect the appliance to and a single plug to connect the device to the house's power outlet. As shown in Figures 10 (a) and (b), a smart plug was attached to each appliance. To setup these devices, Tasmota, an open-source firmware, was used. This firmware makes it easier to design, making it possible to manage smart plug setups more easily. The WiFi connection with the HAN was established via the web interface. MQTT was configured on the smart plugs by providing the necessary connection parameters using the web user interface (UI). Every smart plug publishes and/or subscribes to messages using a different MQTT topic. Using Tasmota's telemetry capability, the Sonoff devices were set up to transmit a single measurement every ten seconds. Using the JavaScript Object Notation (JSON) structure, message data were sent.

Fig. 10. eGauge unit has collected major load for the home in terms of data visualization.

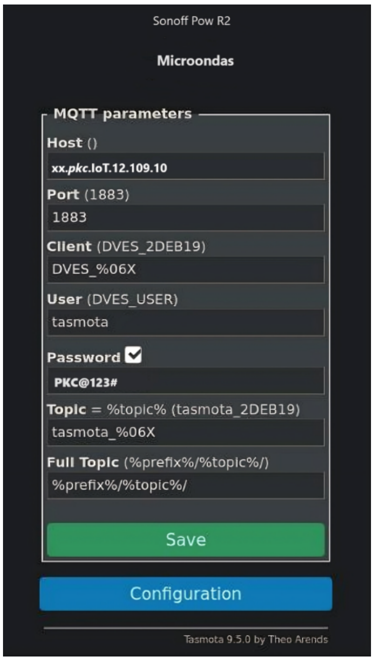

Fig. 11. Precise Energy Consumption

Figure 11 shows the precise energy consumption for the house's main load, washing machine, freezer, refrigerator, and freezer on December, 2023, throughout a two-hour period.

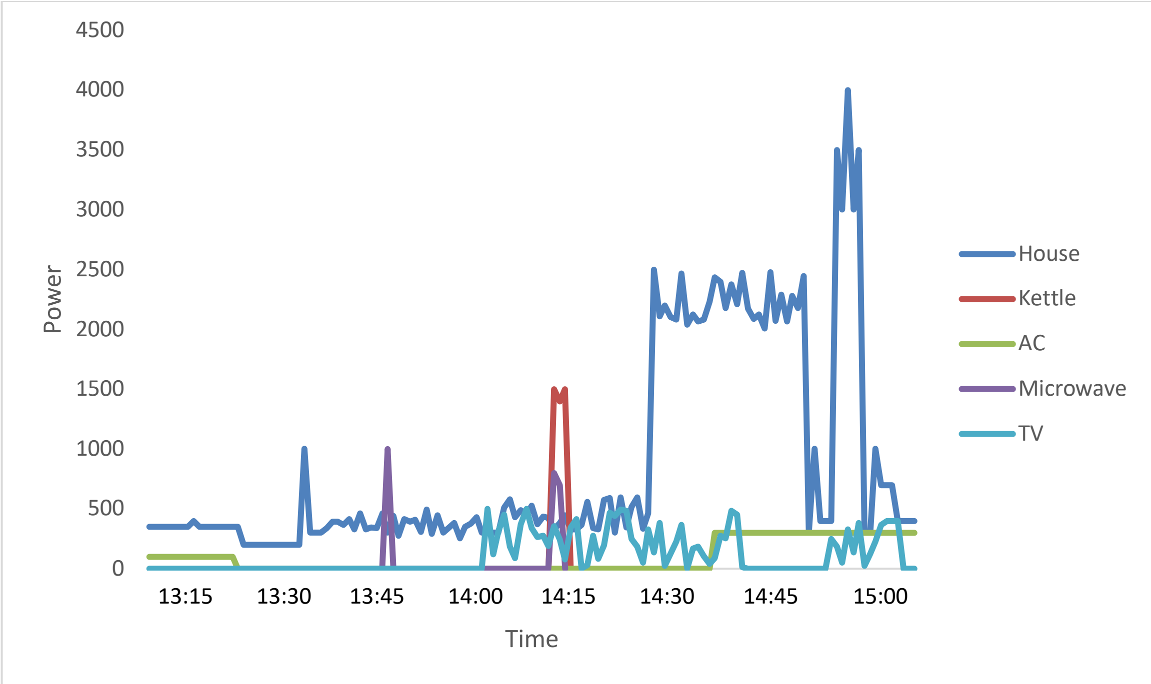

Fig. 12. House hold appliances power consumption data

Therefore, technologies like Neighborhood Area Network (NAN) that use a fog layer as data concentrators inside the neighborhood should be taken into mind when considering to install a HEMS in many households within a community. One of the new tools that looks like an interesting alternative to web interfaces like the AWS dashboard for speeding up service deployment is the AWS Cloud Development Kit (CDK). The code is made up of the configurations required for the required services, which are merged and sent into AWS through cloud formation.

5. Conclusions

In conclusion, this study has demonstrated how IoT devices and cloud computing infrastructure may be combined to build a smart power management system that enables efficient energy optimization, monitoring, and analysis. The system's incorporation of real-time monitoring features, cloud-based analytics, and intuitive interfaces has yielded encouraging outcomes in terms of augmenting energy efficiency, curtailing operational expenses, and advancing sustainability in residential and commercial environments. Through the acquisition of real-time energy consumption data, analysis of consumption patterns, and application of data-driven insights to optimization techniques, the smart power management system presents a substantial opportunity to enhance energy management practices.

Additionally, the integration of edge computing, addressing cybersecurity and privacy concerns, promoting interoperability and standardization, improving scalability and resource management, and investigating energy harvesting techniques for sustainability are just a few of the research gaps and areas that need to be further investigated. All things considered, creating a thorough smart power management system is a big step toward maximizing energy use, lessening environmental effect, and encouraging sustainable energy behaviors. By filling the research gaps and advancing this topic, we can eventually help create a more sustainable and energy-efficient future by improving the capabilities and impact of smart power management systems.

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