CLOUD-BASED MQTT PROTOCOL FOR POWER MONITORING AND SOCKET CONTROL SYSTEM

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Abstract: An efficient system to monitor and manage home power usage and electrical sockets remotely is discussed in this paper. It collects power usage and environmental data from the home sensors, including current, voltage, temperature, and occupancy sensors. These sensors give real-time power monitoring and control information. Relays used in this system are remote-control electrical sockets and appliances. Relays allow users to remotely turn sockets on and off, making connected equipment easier to manage. The lightweight Message Queuing Telemetry Transport (MQTT) protocol is used in the system. The MQTT connects home sensors, relays, and cloud-based infrastructure. With the help of Wi-Fi, connectivity connects the devices. Users can log in remotely from any device with internet access. Users can monitor real-time power use, examine past patterns, and remotely regulate outlets and appliances. Cloud-based infrastructure stores, processes, and controls data. It analyses home sensor data to provide consumers with power usage insights. Data visualization, energy-saving suggestions, and interaction with other smart home devices are possible due to the cloud infrastructure. The technology simplifies home power monitoring and management. The technology helps consumers monitor power use, improve energy efficiency, and simplify their homes.

Keywords: MQTT Protocol, power monitoring, socket control, smart homes, internet of things.

I. INTRODUCTION

Automation technology simplifies life nowadays and replaces manual ones. The increasing growth of Internet users has made it part of life. The Internet of Things (IoT) is a new technology. Consumer and industrial items may be networked to exchange information and accomplish tasks remotely [1]. IoT lets users control house services from afar. It saves energy. Intel Galileo integrates cloud network and wireless connectivity for remote home appliance control and cloud data storage. Sensor data modifies the system automatically. The system controls several devices.

Using wireless smart sockets and IoT technologies, the home energy management system reduces home appliance energy use without sensors [2]. It offers peak-time control, energy-limit management, automated control, and user control. To improve energy control, the former two are used by all smart connects in a home, while individual intelligent sockets utilize the later two.

It uses IoT to monitor load power use and conserve energy. The IoT framework may be used for home automation and companies that connect physical objects to networks [3]. The proposed work uses IoT technology to gather data from smart energy meters via GPRS and display it on the website. This IoT system can gather load data and regulate it. The IoT tries to integrate these devices, and smart cities, industrial, medicinal, and domestic usage are some of IoT's applications. IoT can manage smart homes' household products like air conditioners, lights, and TVs [3]. Further research led to creation of an effective socket with a mobile app to control household electronics. Users can control devices for each socket using the system. This approach can avoid excessive electrical usage due to forgetting to shut off.

Households, businesses, and farms need energy. Energy conservation for appliances is crucial [5]. Coal, oil, and electricity production affect energy consumption. To save energy, smart classroom lighting systems have been developed. It built an Android-based smart home system to monitor power use to minimize anomalies. It offers a smart plug socket enabled by the IoT as a means of energy management system monitoring and control [6]. The data may be sent wirelessly to a home energy management controller. In addition, the transferred data may be viewed, stored, and analyzed through the associated web server and mobile device. An Android application is built from the ground up to connect the planned SPS to the web server and mobile device.

The capacity of a microgrid should be maintained; hence a load limiter is essential in areas like microgrid business centers [7]. This research planned daytime load distribution with IoT-based energy monitoring and central management software to minimize load variance. All microgrid loads may be balanced from one location utilizing data collected by IP-based smart meters and control mechanisms for measuring energy consumption. Currently, most initiatives solving this problem monitor energy use without giving necessary parameters or turning electrical devices on or off [8]. The suggested systems demonstrate the planning, building, and testing of a smart meter equipped with load control in a residential energy management system. The idea is unique in that it uses an entirely new electrical layout.

II. RELATED WORKS

Smart sockets are being developed to reduce standby energy loss from electric equipment. Some technological solutions address techno-economic gains in growth [9]. It proposes a power-efficient smart socket based on STM32F103 (Cortex-M3 core, 72 MHz CPU speed) to solve home electric appliance standby energy waste and related economic losses. Renewable energy limitations, primary energy supply, and energy carriers' prices confuse distributed energy system design [10]. The user-on-demand presence in intelligent energy management allows the grid to utilize uncertain power sources. End-users might affect system management and energy price volatility. Consumers may help grid operators by providing demand-side-resource auxiliary services to improve system dependability, robust planning, constraint management, and scheduling. Optimizing energy resources integrates demand response to renewable energy sources and manages the demand curve with load adaptability as needed.

It examines the development of the technologies used in home energy management systems and evaluates the notion of energy management systems for residential clients [11]. It emphasizes the fundamentals and compares and contrasts different technical methods. Concerns and obstacles related to smart technology, such as implementation and privacy, are also addressed. It provides one of the lowest-priced solutions for an autonomous, microcontroller-based demand-side energy monitoring system for use in a residential setting to decrease the standby power consumption of the devices under supervision [12]. It also monitors and adjusts the lighting to reduce energy use further. The suggested system is intended to function autonomously and to mitigate the impact of the development of wireless electromagnetic sources in home environments.

In [13] describes an intelligent power socket for IoT. Remote control, electricity protection, work automation, and monitoring are essential functions. This IoT smart power socket also has powerful software features for scheduling, grouping power sockets, managing operations, and assessing power use to optimize energy costs. Our solution suits smart and remote access home automation, industrial automation, security, and power use control systems. It provides a user-friendly method for keeping tabs on and adjusting the power usage of various home appliances via portable application devices [14]. The results demonstrate that the current errors provided by the proposed system for the hairdryer appliance are 0.6%, whereas those provided by the present Power Monitoring and Switching system are 7.8%.

In recent decades, technology and system design has been improved to increase production, transmission, and power efficiency [15]. The digital revolution has brought microcontrollers and IoT to the power crunch. Real-time data on system and equipment characteristics enables more radical and accurate methods for enhancing power system utilization and reducing natural resource use. The power socket enables easy plug-and-play management of home equipment and meaningful consumption/utilization statistics that families can utilize to save power expenditures.

III. PROPOSED SYSTEM

The system's objective is to provide efficient and reliable control of electrical use throughout the home environment. Users can monitor their energy use and power consumption in real time. The MQTT protocol and cloud computing enable the system's sensors, relays, and a centralized control interface to interact with one another in real time. Users can remotely monitor and control the operation of their electrical sockets and appliances, leading to improved usability, more efficient energy management, and lower monthly electricity costs. The technology also aims to provide a user interface with clear data visualization so that people may evaluate their own energy usage and home in on specific issues. To control of energy use, waste of power, and increased efficiency around the home.

A. Working Methodology

The system begins by collecting data in real time from a wide variety of sensors in the home, such as those for measuring voltage, current, temperature, and occupancy. These sensors keep a close eye on critical information and collect regular, accurate readings. After collecting data from the sensors, it is sent through Wi-Fi to the server in the cloud. The data is encrypted before being transferred to the MQTT broker, which acts as a central messaging hub for the home's sensors, relays, and control interface.

When it comes to devices with limited resources and low-bandwidth networks, the MQTT protocol shines because it guarantees constant and optimum data transfer with limited expense. Storage for data component within the cloud-based architecture processes and stores the sensor data. This opens the door to analyzing the past, finding patterns, and learning about current energy usage. The system could use data analytics to provide helpful insights and suggestions for reducing energy consumption.

At the same time, the interface inside the cloud infrastructure allows users to monitor and operate electrical sockets and appliances remotely. The user-friendly control interface can be accessed from any device with internet access, such as a smartphone or PC. The user-friendly interface makes controlling all connected devices with a switch flick convenient and straightforward.

Real-time data on energy usage, environmental factors, and occupancy levels are all readily available due to the system's continuous sensor updates. An easy-to-understand visual representation of the data is provided for the user to make informed decisions. Users can examine their energy usage habits, identify problem areas, and get advice on optimizing their energy use, all from the data generated by the sensors. Users are provided with the resources required to improve energy efficiency, minimize consumption, and save costs.

The overall approach system combines data collected from home sensors, a cloud-based infrastructure, the MQTT messaging protocol, and a straightforward control interface for remote power monitoring and management. Benefiting from real-time data analysis and smart suggestions for effective power consumption in the home, the system improves ease of use, energy management, and savings on money. Figure 1 shows the block diagram of the system.

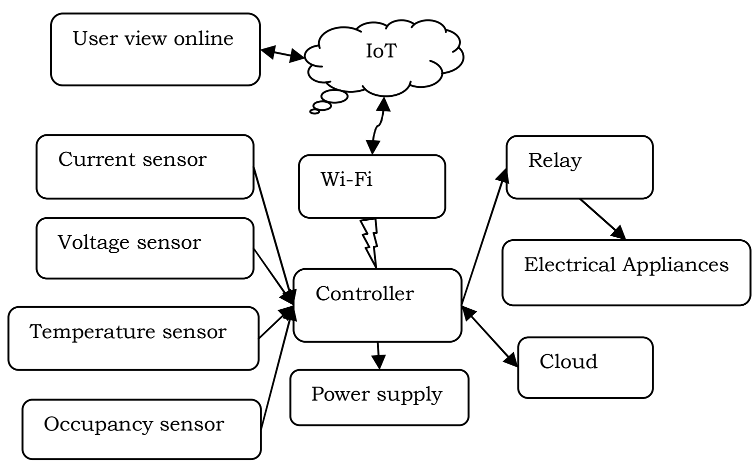

Fig. 1 Block diagram

B. Materials

The system needs IoT devices like sensors and relays to monitor power use and manage sockets. These Internet-of-Things devices were designed to work with the other setup to provide reliable information. Wirelessly connecting the IoT devices to the local network requires a Wi-Fi module. This component facilitates communication between sensors and the cloud service, allowing continuous monitoring and control. In addition, the system stores data processes it, and makes it accessible remotely through a cloud platform. Sensor data can be stored, analyzed, and made available from anywhere with an internet connection due to the cloud platform.

C. Methods

To begin, the system must be installed and configured and setting up the Wi-Fi module, cloud, and IoT sensor protocols. After all is set up, information about energy consumption and other significant parameters will be collected by sensors attached to the IoT devices. Before being sent to the cloud, this data receives transformation via the MQTT protocol.

The data is sent to the cloud platform through the MQTT protocol and posted to the relevant MQTT topics. For an additional measure, it subscribes to predefined MQTT topics in order to receive commands and instruction from the cloud service. In response to messages sent from a cloud service, the system analyzes the data and acts accordingly. This might include anything from analyzing sensor data to interacting with sockets to modifying the system's state in response to incoming instructions.

Through a cloud-based architecture, the system also controls user interaction by taking in input from users and providing responses to user requests. Users may provide input and take control of the system from afar in this way. In addition, the system is continually monitoring for system events like a shutdown command or network/MQTT connection problems. Error-handling methods are built to deal with any hiccups during normal use.

C. Sensors used

The system includes a number of sensors that can be used to monitor and store information about factors such as power use and environmental conditions.

Current Sensor

It measures the quantity of electricity passing through a given circuit or set of devices. Installing current sensors at either the main electrical panel or at each outlet allows for continuous monitoring of the power consumption of all device sockets.

Voltage Sensor

It determines the amount of power sent to a circuit or device. To detect power quality problems, voltage sensors can track and analyze voltage variations.

Temperature Sensor

This sensor can detect the surrounding temperature. It may monitor equipment temperatures and alert users to abnormalities that signal wasteful energy usage or impending breakdown.

Occupancy Sensor

Occupancy sensors, often called motion detectors or presence detectors, monitor the activity level of an area to determine if people are present or leaving.

D. System Configuration (MQTT)

An essential part of establishing a system is configuring the system in MQTT. An MQTT broker must first be selected and set up for device-to-device communication. A well-defined subject structure is built to better organize and classify the published messages inside the system. Considering the system's need for dependability, the optimal Quality of Service (QoS) level is established. Authentication and encryption are used as security techniques to ensure confidential information exchanges. MQTT clients, such as home sensors, relays, and the control interface, are set up to communicate with the broker by providing the broker with connection information and topic subscriptions. Messages stored may be used to advise newly connected clients of the system's default settings or starting status. The MQTT communication is tested and analyzed extensively to confirm its proper operation to provide a stable and reliable setup.

E. Wi-Fi Module with Cloud

Wi-Fi modules are hardware components allowing wireless connectivity through the Wi-Fi protocol. Microcontrollers, development boards, and IoT devices are just some of the devices into which it may be included. These devices may access the internet wirelessly to the module by connecting to Wi-Fi networks. It devises cloud connectivity discussing their capacity to communicate with resources hosted in the cloud. Storage, processing, data analysis, and application and service hosting are all made possible by the cloud's integrated architecture. Figure 2 shows the flowchart diagram of the cloud-based power monitoring and socket control system using the MQTT protocol.

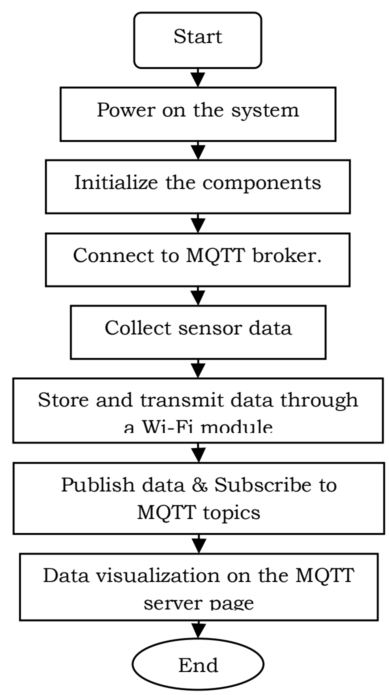

Fig. 2 Flowchart diagram

When devices have a Wi-Fi module connecting to the cloud, users may access the internet and interact with the cloud's services. The Wi-Fi module manages the wireless connection, which also supplies the required networking protocols and security procedures for data transfer. Data can be sent and received to and from the cloud once the device is online. Things like sensor readings, device status reports, and command inputs fall within this category. The information is often sent over to MQTT.

The information is sent from the device to the cloud-based services or platforms and processed there. Data can be stored in databases, real-time analysis can be performed, automatic actions can be triggered, and a user interface can be provided to allow remote monitoring and control. Other capabilities, such as authentication, control of access, and scalability, are also often available on cloud-based applications.Users can control and monitor their devices, establish rules and processes, and connect to other services and infrastructure with the help of these tools. Connection, data interchange, and control between devices and the cloud are all simplified when a Wi-Fi module is coupled with a cloud connection. The ability to remotely monitor, control, and automate processes is a significant offering feature for many IoT applications and systems.

III. RESULTS AND DISCUSSIONS

This technology makes Real-time power monitoring possible since users can keep updated on their energy use and home in on any hotspots or unnecessary wasters. Users can optimize their energy use, find energy-efficient appliances, and implement energy-saving techniques by evaluating the collected data. Users can manage their electrical appliances from anywhere by adjusting the power outlets and distribution from their mobile phones or other devices. In cases when users need to switch appliances off and on from a distance, this feature is a helpful enhancement.

The system may significantly help energy savings by monitoring and limiting power consumption, resulting in lower electricity costs. Cost savings for homes and companies may be realized by detecting and eliminating unnecessary energy use. The technology encourages a more sustainable energy management method by decreasing energy use and limiting carbon impact. The technology aids conservation and sustainability by encouraging energy-efficient activities and optimizing power use.

Information on energy consumption patterns, peak demand times, and ways to save costs may be acquired from the data gathered by sensors and evaluated. Users may use this data-driven method to assess their energy usage patterns and make well-informed choices on increasing energy efficiency. A wide range of controllable devices can easily be integrated into the system. Thanks to its scalability, the system may be customized to meet the needs of its users by adding support for new sensors and appliances.

In addition, power usage and device functioning are continually monitored, and the system may help identify defects. Changes in power use or behavior that don't make sense might be signs of a problem. Since problems can be addressed quickly after being spotted, downtime is reduced, and system dependability is enhanced. The system may be altered and modified to suit the specific needs of each user. The user may customize schedules, automation rules, and energy-saving profiles to fit their habits and minimize wasteful energy use. Because of this adaptability, users may make the system work best for them.

Using the data from the sensors, the system can compile detailed reports and analytics on consumption procedures, economic breakdowns, and efficiency measures. These discoveries aid users in making based on data decisions, establishing energy-saving goals, and monitoring their success over time. Solar panels and wind turbines are only two examples of renewable energy sources that may be easily linked with the system for monitoring and optimizing energy use. Smart power management between the grid and renewable allows consumers to make the most of sustainable energy while decreasing their consumption of fossil fuels.

The system may improve safety and security by tracking energy use and looking for out of the usual actions. Power use that suddenly increases or decreases might indicate electrical risks or interference. Users can be notified immediately of such events, allowing them to respond quickly and reduce associated risks. Information about users' energy use habits, preferences, and comments may be gathered from the system. Using this data, users can be stimulated to implement more sustainable practices and get more tailored advice.

The sensor data acquired at a specific timestamp are provided by the MQTT server shown in Table 1. The Current Value column represents each sensor's current reading, while the Timestamp column provides the date and time when the data were collected. Table 2 shows an overview of all the system aspects, describing their functions and purpose.

TABLE. 1 Sensor Values

Sensor	Location	Current Value	Timestamp
Current	Main Power Panel	10.5 (A)	2023-06-03 09:15 AM
Voltage	Main Power Panel	230 (V)	2023-06-03 09:15 AM
Temperature	Living Room	23.5 (°C)	2023-06-03 09:15 AM
Occupancy	Kitchen	Occupied (Presence)	2023-06-03 09:15 AM

Table. 2 Aspects of the system

Aspect	Description
Power Monitoring	Real-time monitoring of power consumption to track usage patterns and identify energy waste
Socket Control	Remote control of electrical sockets to turn devices on/off and manage power distribution
Cloud Integration	Integration with cloud services to store and retrieve data, enabling remote access and control
MQTT Protocol	Use of the MQTT protocol for efficient and reliable communication between devices and the cloud
Sensor Integration	Integration of various sensors (current, voltage, temperature, occupancy) for data collection
Energy Optimization	Analysis of collected data to identify energy-saving opportunities and optimize usage
User-Friendly Interface	The user interface for easy control and monitoring of the system
Security and Privacy	Implementation of robust security measures to protect user data and prevent unauthorized access
Integration with IoT Devices	Compatibility with other IoT devices for a connected and smart home ecosystem

The effectiveness of the system can be measured in a number of ways. Time the system takes to react to events or user inputs such as device turning on/off or changing power settings. A quicker and more responsive system is shown by decreased reaction times. Determine how the MQTT protocol sends data between devices and the cloud. Analyze metrics like the message delivery rate, the delay, and the packet loss. Better efficiency provides quick and reliable data exchange.

Monitor the power sensors, communications modules, and other system parts used up. Maximizing the system's energy efficiency will reduce its power consumption and maintenance expenses. Verify that it can add more users, devices, and sensors to the system without slowing down. The capacity to scale up the system without compromising on performance is essential.

Evaluate the system's dependability concerning availability and uptime. Monitor how often and how long the system breaks to ensure there are few interruptions. Ensure the acquired sensor data is precise and accurate, reflecting the actual power use and environmental circumstances. For successful energy-saving choices and measures, consistent accuracy of data is essential.

Collect information on how users feel about the system and how happy they are with its performance, usability, and features. Discuss how the user interface, device control, and data accessibility will feel to the end user. Performance bottlenecks may be found, and the system can be optimized and improved with continuous monitoring and analysis of these parameters.

IV. CONCLUSIONS

There are several advantages when using a cloud-based MQTT protocol for power monitoring and socket management system in the home or office. The system integrates multiple sensors and devices for remote control and monitoring with IoT technology. The MQTT protocol ensures reliable and effective communication between the various parts of the system and the cloud. The system's installation provides continuous power monitoring, enabling users to analyze energy changes and identify improvement potential in real-time. Using current, voltage, temperature, and occupancy sensors together allows for precise monitoring and control of electrical appliances and sockets. An essential factor to consider is the system's efficiency. Response time, communication efficiency, power usage, scalability, dependability, and data correctness are all important metrics for determining its value. Only by constant monitoring and optimization of these performance factors can the system provide a faultless user experience while contributing to energy efficiency and cost savings. The system provides an innovative and easy solution for managing electrical currents in private residences and commercial structures. Its integration with cloud services, remote device management, and energy use monitoring put the power of automation and energy efficiency in the hands of its users. Further improvements and adjustments to the system will be predicted as technology develops, allowing for even better command, efficiency, and longevity in power monitoring and socket management.

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