Energy Saving and Management using MQTT Protocol in Telecom Operators' Remote Computer Room

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***Abstract*— This study presents an energy-saving and management device based on the Internet of Things (IoT) for telecom operators' remote computer rooms (RCR). First, a system for management that utilized Internet of Things (IoT) technology was developed for RCR. The system uses technologies to enable RCR's infrastructure administration and real-time data visualization, including embedded systems, sensor technology, and Node MCU. The MQTT algorithm, a simple yet effective method for conserving air conditioning energy, is subsequently proposed. The MQTT algorithm reduces air conditioning energy use, accounting for approximately 35% of the overall energy consumption, while avoiding expensive installation expenses, increasing RCR's overall energy efficiency. Furthermore, the suggested approach has been deployed in the RCRs of numerous telecom operators located in various locations. Research findings indicate that the suggested system efficiently operates and controls RCRs and produces a 14% energy savings effect.**
Keywords— Energy saving, Internet of things, Energy Management, Remote computer room, MQTT

I.INTRODUCTION

In the future, the energy industry in diverse areas and countries will face the challenge of guaranteeing energy security as a guarantee for "sustainable development" and the foundation for addressing the requirements of future generations. The worldwide population growth, exponential increase, and urbanization process in information volume will necessitate more demanding criteria for eco-friendliness, energy security, energy efficiency, and energy infrastructure adaptability [1].

Historically, projects in the field of telecommunications were scheduled and carried out traditionally due to the significant cost required to establish large-scale public networks, from initial equipment manufacturer selection to equipment acquisition, followed by fundamental equipment and fiber-optic infrastructure [2]. Following construction, the system capability needs to be thoroughly calculated. After establishing the computer room's electricity, fire protection, and air-conditioning facilities in the appropriate position, the core network equipment is placed, and optical fibers and foundations are gradually spread to other locations in response to traffic growth. With careful and thorough planning, mobile network expansion is nothing more than trying to limit the risks associated with unknown scenarios and achieve the intended benefits from the invested resources.

For many years, the remote control room (RCR) idea has effectively supported a team of distant scientists at General Atomics (GA) in San Diego [3]. Aspera is a User Datagram Protocol (UDP)-based program for uploading plasma control system files and MDSplus to GA's Science DMZ, a network of servers designed for WAN information transfer at remote sites. Users in their region might utilize the information to assess and plan for the subsequent plasma discharge.

This is effective for the standard control room analysis within a small dataset, emphasizing connecting scientists to the narrow dataset required to alter the input controls in the next download [4]. This framework can improve such RCRs even further by leveraging global computing resources to extend the analyses available to researchers to make these modifications for future shoots.

IoT devices can automate and monitor activities via communication and sensor technologies. Devices and users can better control power usage by observing power consumption patterns over time using comprehensive information gathering and advanced data processing algorithms [5]. Companies like Google, EFT, and Kraft Energy focus on energy management.

A supplier-approved process enhanced using Internet technology can be utilized to establish whether a wireless or wired energy-managing architecture is responsible for the architecture's overall energy consumption.

Electricity usage, maximum/minimum voltage, and power factor are just a few indications that can be utilized to evaluate energy requirements and provide insight into potential energy constraints [6].

As a result, this article offers an IoT solution known as Message Queuing Telemetry Transport (MQTT) for the energy-efficient operation of telecom operators' RCR. The major contributions of the suggested system are outlined below:

- To introduce effective control and monitoring mechanisms to the Telecom Operators' RCRs for energy management.
- The suggested system uses IoT sensors, which engage in Telecom Operators' RCR systems that depend primarily on remote monitoring, control, and analysis.
- However, lowering energy consumption has become a primary issue in recent years; this research aims to analyze the issues presented in this work and the obstacles they present. The results are obtained using distributed energy management systems.

The remaining sections of this work are structured as follows. Section 2 summarizes previous work on MQTT for IoT networks. Section 3 includes information regarding the suggested technique. The results and discussion of the proposed system architecture are presented in Section 4. Section 5 presents the work's conclusions

RELATED WORKS

Navin Ra et al. (2023) suggested employing a switchable glass topology combined with solar cell storage to offer daylight passive heating ventilation and air conditioning (HVAC) in the control room of an electric vehicle charging station. The efficiency of the suggested system was tested in four different transient scenarios: clear, occasionally cloudy, low solar irradiance, extended cloudy, and frequent network disruptions. The suggested approach is global and thus helpful in increasing capacity [7].

Luo Ge et al. (2023) suggested a cloud-edge device- based control framework for central air-conditioning energy efficiency. This framework develops a human comfort prediction model using recurrent neural networks. Compared to traditional regulation approaches, the proposed real-time control systems could save energy utilization by up to 91%, based on the environment, while the advanced control systems save energy by an average of 4% [8].

Ali W. et al. (2022) anticipated carbon emission reductions, energy savings, and economic advantages by enhancing the energy efficiency of room ACs under various policy scenarios. The simulation model predicts that air conditioners will grow from 2.7 million in 2020 to 4.9 million in 2030.

The market average energy efficiency index in 2020 is projected to be 2.95, and the impact of an increase in the energy efficiency index on businesses is investigated [9].

DG Hettiarachchi et al. (2021) addressed the difficulty of predicting load by offering an IoT-based system for energy management that uses the Extreme Gradient Boosting (XGBoost) machine learning (ML) model to anticipate energy utilization. Energy-saving and management strategies are made up of an easy-to-use central dashboard that serves as a link between the cloud-hosted database
containing the ML algorithms and the NodeMCU device [10].

Lee D et al. (2020) created an artificial intelligence (AI) based on cloud data, capable of running AI algorithms and remotely controlling residential air conditioners. The two energy-saving technologies, model-based predictive control (MPC) and fuzzy with PID, were chosen and turned into two cloud-based artificial intelligence control systems. They explored if air conditioners' energy efficiency could be increased. Differential enthalpy test chambers are used to determine energy efficiency. Two metrics were evaluated: cooling season power factor (CSPF) and energy efficiency ratio (EER) [11].

2.1. Problem Statement

The energy management and saving of Telecom Operators' RCRs pose a critical challenge in the contemporary telecommunications landscape. As these remote facilities house many essential equipment, including servers, network infrastructure, and communication systems, their energy consumption is substantial. The problem statement revolves around optimizing energy usage in RCRs to reduce operational costs and environmental impact, improving overall sustainability. Additionally, the remote nature of these computer rooms necessitates efficient monitoring and management solutions to ensure seamless operations and swift response to potential issues. Balancing the demand for uninterrupted services with the imperative to curb energy consumption makes this challenge intricate, requiring innovative strategies and technologies to achieve a harmonious equilibrium in energy management and saving for Telecom Operators' RCRs.

PROPOSED METHODOLOGY

Telecom operators are increasingly focusing on energy-saving and efficient management strategies for their RCRs, and one innovative solution is the implementation of Message Queue Telemetry Transport (MQTT). MQTT, a lightweight and scalable messaging protocol, is pivotal in optimizing energy consumption and enhancing overall operational efficiency. By leveraging MQTT, telecom operators can establish a reliable communication framework between various components of their remote computer rooms, allowing for real-time monitoring and control. Based on demand and workload, this facilitates dynamic adjustments to the power usage of different devices, such as servers, cooling systems, and networking equipment.

The seamless communication and data exchange enabled by MQTT enables operators to proactively identify and address potential energy inefficiencies, leading to significant cost savings and a reduced environmental footprint. Integrating MQTT in energy management strategies underscores the telecom industry's commitmen sustainability and highlights the importance of leveraging cutting-edge technologies to enhance overall operational performance.

Energy Management And Service Platform (EMSP)

The EMSP built using Web and database technology consists of the following modules [12]:

a) System Management:

This module covers departments, users, role permissions, and record management. The super administrator could delete, add, alter, and query any department, role, user, or login information across the entire platform and grant local administrators the capacity to govern RCR in this region. On the other hand, regular users can only view data for a subset of RCRs.

b) Intelligent Information

This module's primary functions are historical data, real-time data, map display, and device information. The environmental distribution of all RCRs utilizing the technology will be shown on Baidu Maps. By selecting a certain RCR, users may verify that each device is operational. In addition, historical data and real-time data on current, voltage, power, electricity usage, and temperature inside the room are available for energy efficiency analysis.

c) Remote Control

This module lets us control your air conditioners remotely and implement energy-saving methods. The administrator can remotely turn the air conditioner on and off and alter the temperature set point based on the RCR's real- time functioning. Furthermore, engineers can assess previous power consumption and forecast future energy consumption based on changing weather conditions and indoor temperatures to create automated energy-saving mechanisms that cut energy utilization and free up manpower.

d) Alarm Module.

This module is liable for distributing real-time alarm data and analyzing previous alarm values, including PUE overload, ARM-embedded, and temperature anomaly devices unplugged.

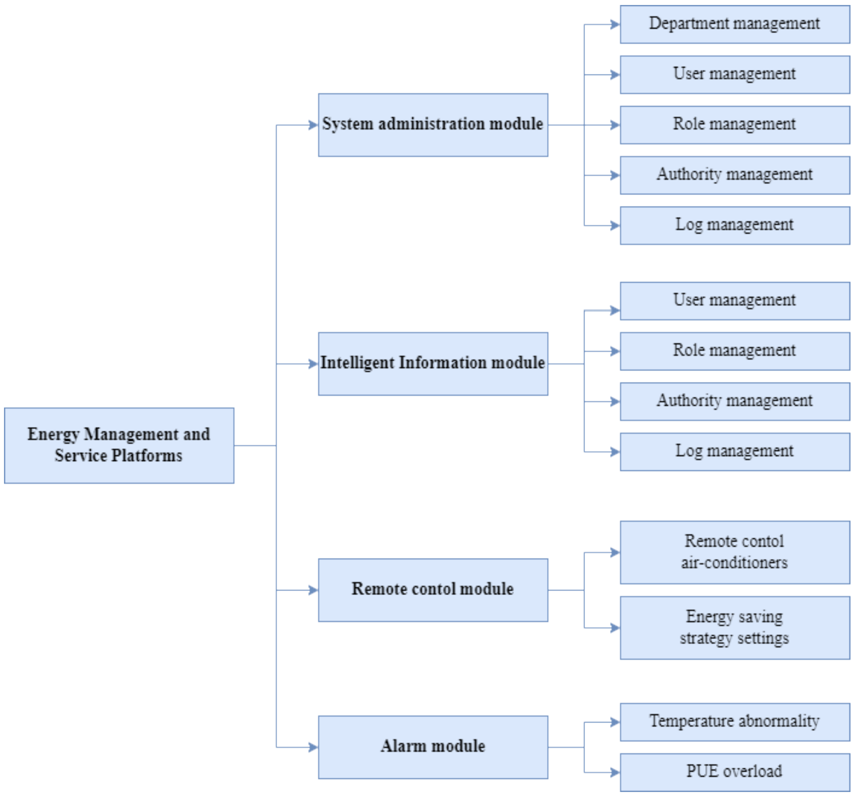

Figure 1 EMSP Framework

This communication protocol is built on a publish/subscribe mechanism that operates at the TCP/IP layer. It is a lightweight data transfer protocol intended to transmit devices that do not demand much bandwidth. This protocol improves dependability by limiting transmission rates. The protocol suits machine-to-machine communication, IoT, mobile devices, and applications requiring bandwidth and energy efficiency. The MQTT protocol was created in 1999 by Andy Stanley-Clark of IBM and Arlen Nipper of Arcom (now Eurotech). The MQTT broker (functioning as a server) is the primary communication element responsible for routing all messages between waiting senders and recipients. Every client who wishes to send a message via the server is referred to as a publisher in the MQTT protocol. The proxy filters incoming messages and routes them to clients interested in receiving them. Users who contract with a seller and are interested in a specific type of news are referred to as subscribers. As a result, both publishers and subscribers create relationships with the broker [13]. The MQTT server handles MQTT client authentication and permission. After successful authorization and authentication, the client can act as both a publisher and a receiver. Grafana is a server-side program that exclusively reads data from specific sources and visualizes it using various graphs or tables. The program does not allow you to notify the server or directly access information about the architecture; this is where InfluxDB (a database built to collect time-based metrics) comes in handy.

Currently, the designer provides three alternative versions of the software, which can be selected based on your requirements [14]. Grafana Cloud is a service offered in the cloud, so we do not have to install Grafana on our servers; instead, we may use the SaaS version hosted on client infrastructure.

Of course, the second product available is Grafana's corporate edition, designed for larger enterprises requiring comprehensive and prompt help while using the application.

Of course, the most recent version is the community or simply the open-source version, which can be easily installed on any server.

Throughout the installation procedure, consider that monitoring tools (such as Grafana) must not be deployed on identical instances as our application since this eliminates the ability to monitor and report anomalies efficiently.

MQTT's lightweight nature makes it ideal for scenarios where bandwidth and energy efficiency are crucial, such as in IoT deployments or mobile applications, ensuring reliable communication without excessive resource consumption.

Grafana could be deployed in whatever environment we want (MacOS, Windows, Linux), and complete installation instructions are available in the official documentation. InfluxDB is an entirely new time series database [15]. InfluxDB is part of a larger platform allowing time series data collection, monitoring, storage, visualization, and alerting. The InfluxData platform is based on an open- source core. The TICK stack comprises four fields: Telegraph, InfluxDB, Chronograph, and Kapacitor. Each tool serves a specific purpose: to collect metrics, store data, show time series, or define data post-processing routines (Figure 2).

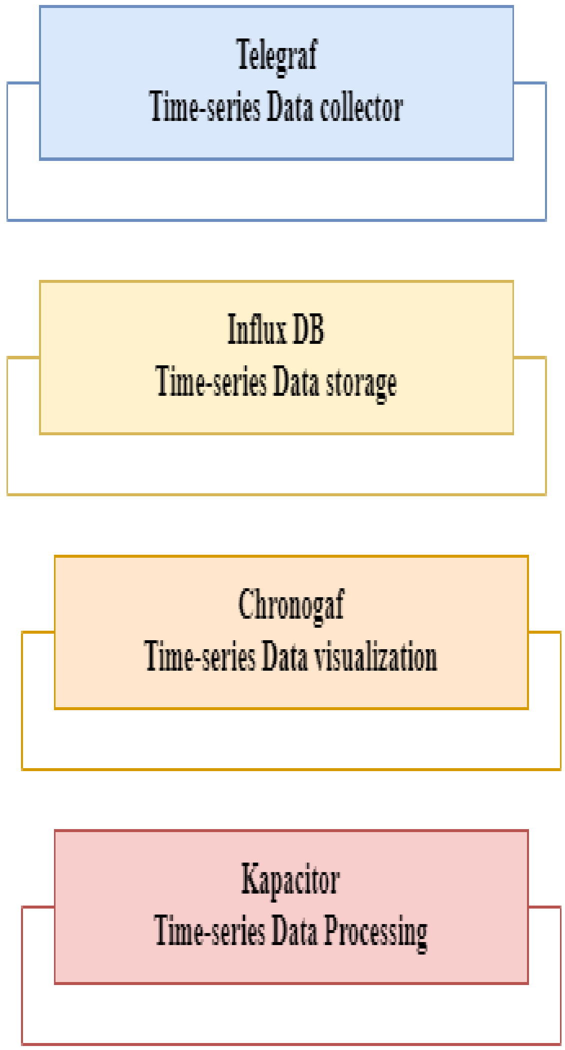

Figure 2 Data Post-processing routines

RESULT AND DISCUSSION

This section explains the framework and cost of the suggested method. Figure 3 depicts a block diagram for the outcomes of the proposed methodology.

The various serial protocols for connecting sensors, storage, and displays are depicted in the diagram, with UART for GPS and I2C for LCD screens. Depending on the experimental analysis necessary, the prototype communicates with an Adafruit cloud-based server or a web server via MQTT.

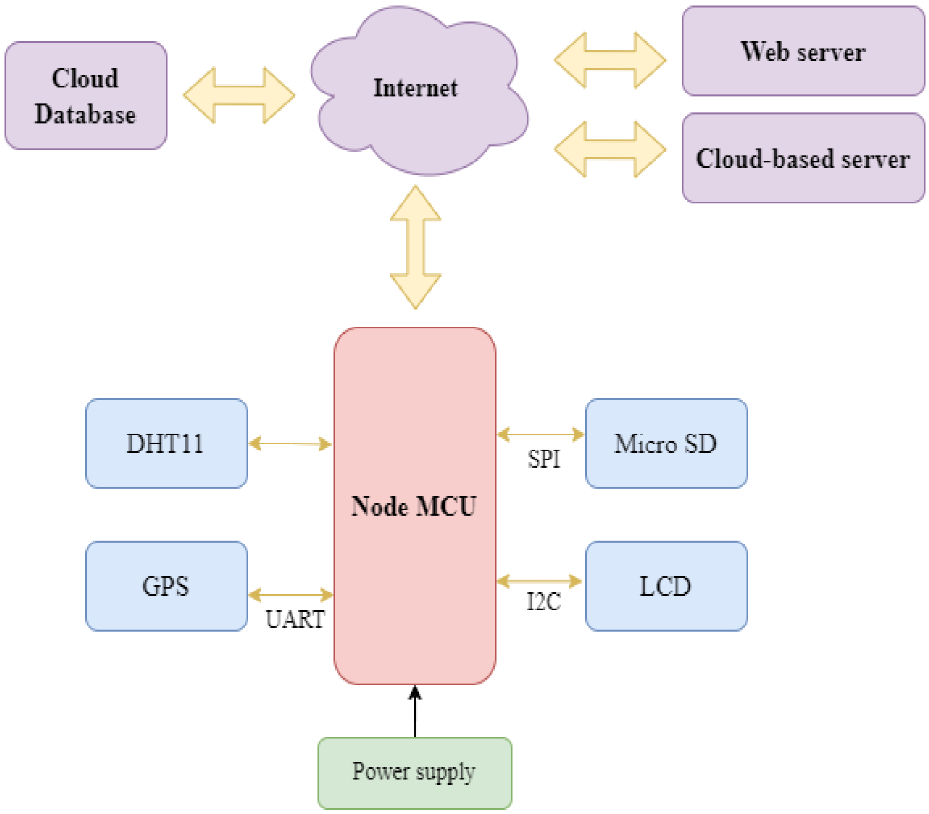

Figure 3 Block diagram of system prototype

The findings can be utilized to describe the activity of batteries in various protocol systems. Long-term experiments were carried out to validate and investigate this trait. Table 1 analyzes battery life findings and compares them to HTTP to measure performance.

Table 1 Battery duration (%)

Hours	HTTP	MQTT
0	100	100
8	91	94
16	85	90
24	81	87
32	76	82
40	70	76
48	60	70
56	51	59

Furthermore, the simulation predicts a linear battery discharge, supported by experimental information obtained over 56 hours, as illustrated in Figure 4. HTTP's slope is steeper than the MQTT protocol's two-line graph.

The graph illustrates that the MQTT protocol's battery level with service quality lasts longer than the batteries in other protocols due to its lower power consumption. To present battery life data, use a line chart. The following equation provides the linear equations for battery capacity:

$$B\ (\%) = 100 - mT \quad (1)$$

Where "m" represents the slope, "T" represents the duration in hours, and "B" represents the battery level in percentage. The value 100 represents an ideal battery percentage that will decline over time at the rate of change "m". HTTP and MQTT protocols exhibit varying change rate values across three scenarios. The linear equation for battery
% is written as follows,

$$B\ (\%)\ MQTT = 100 - 0.8746T \quad (2)$$

$$B\ (\%)\ HTTP = 100 - 0.9308T \quad (3)$$

Table 2 displays the energy consumption statistics for a long- running test and compares it to HTTP to measure performance, while Figure 5 depicts the energy consumption curve.

Energy Con

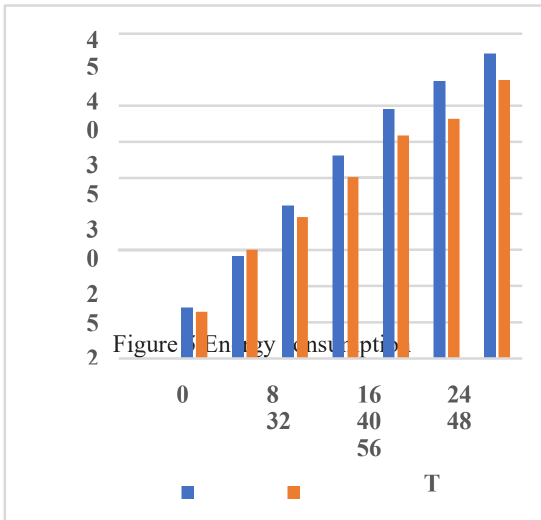

Figure 5 Energy Consumption

Table 2 Energy consumption (Wh)

Hours	HTTP	MQTT
0	0	0
8	07.05	06.45
16	14.18	15.01
24	21.15	19.56
32	28.07	25.12
40	34.56	30.89
48	38.45	33.16
56	42.21	38.56

Table 3 examines the relative error percentages. Figure 6 depicts the HTTP and MQTT protocols' relative error (%) plot. We observed that the error rate increases as errors accumulate over time. The HTTP's relative error is greater than the MQTT protocol. After 48 hours, the relative error no longer acts linearly but rather as a higher-order function, as illustrated in the figure.

Table 3 Relative error (%)

Hours	HTTP	MQTT
0	0	0
8	0.80	0.45
16	0.98	0.75
24	1.75	1.55
32	2.14	1.85
40	2.89	2.05
48	3.50	2.45
56	8.05	6.20

CONCLUSION

This work proposed an IoT-based telecom operators' RCRs energy management and saving approach. The hardware platform incorporates smart meters, temperature modules, infrared modules, and ARM9 integrated control systems, while the software platform employs EMSP. In addition, MQTT energy management and saving strategies are suggested to manage the air conditioner's maximize energy efficiency. Also, this paper describes the design and deployment of an inexpensive IoT protocol for real-time remote monitoring. Using our prototype, we conducted studies comparing HTTP and MQTT protocols with varying quality of service levels to determine the best IoT solution for the transportation industry. The protocols were studied with a 10-second sampling rate between each data transfer and transmission to the MySQL database. Another benefit of MQTT protocol is that if a cloud-based server is employed (as in the prototype displayed), no energy is lost in the broker. The MQTT protocol uses a device-to-gateway paradigm, with the cloud-based server as a gateway. The MQTT protocol has a lower relative error than HTTP.

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