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Integrating Fog Computing and IoT in Education: Campus Resource Management: Energy EffieciencyMonitoring

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Abstract:- The swift evolution of the Internet of Things (IoT) has led to the generation of immense sums of data that require effective processing and storage. Old cloud computing methods often struggle to meet the real-time processing and low latency necessities of IoT applications. To discourse these encounters, fog computing has developed as a proficient model that carries computing resources closer to the data sources.

➢ ***This paper presents an energy-efficient monitoring system for a school campus that integrates fog computing and IoT technologies to improve resource management. The projected system contains three main components:***

- **IoT sensor nodes positioned across the campus to collect real-time data on energy consumption, environmental conditions, and occupancy levels.**
- **Fog computing nodes that process the sensor data locally, do analytics, and make smart decisions to augment energy usage.**
- **A cloud-based platform that provides unified monitoring, reporting, and long-term data storage.**

➢ ***The Key Features of the System Comprise:***

- **Real-time monitoring and analysis of energy consumption designs**
- **Automated control of lighting, HVAC, and other building systems based on occupancy and environmental conditions**
- **Predictive maintenance of equipment to increase energy efficiency**
- **Centralized control panel for campus-wide resource management**
- **Secure and privacy-conserving data processing at the fog layer**

The paper summarizes 10 main results related to energy-efficient building management through the integration of fog computing and IoT. This work fills a major gap in the literature by presenting a holistic system that combines fog-based data processing, intelligent decision-making, and cloud-based reporting for energy optimization in an educational campus.

Simulations and real-world deployment in a small-scale setting show that the proposed system yields substantial gains in energy savings, reduced operational costs, and enhanced user comfort compared to traditional building management approaches. This study contributes new findings on the solutions for sustainable campus management and technology adoption in the education sector, building upon previous studies that have employed fog computing and IoT.

I. INTRODUCTION

Today's trend towards better building operation has been accelerated by the justified concerns of the growing global community about sustainability and energy savings. This brings us to the topic of comprehensive intelligent building management systems, which can truly make an impact by computing deals in terms of sustainable design. This is especially relevant to the education sector, as school campuses are large and operationally complex by nature, with energy consumption many times that of normal buildings (which can lead to lifelong technology lock-in), significant resource requirements for tender documents should an upgrade or new building be required, and a reliance on monolithic control and monitoring systems that react slowly to changing environments. The emergence of fog computing and the Internet of Things (IoT) have opened up new avenues for addressing these issues by enabling real-time distributed processing and decision-making near data sources. Another more innovative cloud-based paradigm called fog computing, which expands a cloud network's bounds to the very edge and was first suggested for Internet of Things applications, has the potential to improve energy efficiency on campuses as well. At the edge/fog layer, data supplied by sensors is computed using intelligent decision making.

➢ *Background and Problem Statement*

Complex and ever-changing, school campuses house a variety of energy-hungry systems, including HVAC, lighting, and electrical equipment. In these situations, manual monitoring and control are frequently used in the conventional approach to energy management, which can be ineffective and

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prone to human error. The development of more advanced and automated energy efficiency solutions for school campuses is made possible by the rise of IoT and fog computing technologies.

Effective energy management is extremely difficult to achieve on school campuses, which raises running costs and leaves a bigger environmental impact. The capacity of educational institutions to accomplish sustainable resource management is hampered by the absence of a thorough, integrated, and intelligent energy efficiency system.

II. LITERATURE REVIEW

The need for creative solutions to raise educational institutions' energy efficiency has been fuelled by the rising energy demand and growing concerns about environmental sustainability. School campuses offer a great chance to apply energy-efficient management techniques because of their varied facilities and resource-intensive operations. Researchers have looked into how to improve energy management in educational facilities by integrating cutting-edge technology like fog computing and the Internet of Things (IoT). [1]proposed a Fog-based IoT architecture for energy management in educational buildings. The authors demonstrated the benefits of processing data at the Fog layer, including reduced latency, improved response time, and better decision-making capabilities. However, the system was limited to monitoring and controlling HVAC and lighting systems, without a comprehensive approach to campus-wide resource management. Similarly, [2]developed an IoT-based energy monitoring and management system for university campuses. The system utilized sensors to collect data on energy consumption, environmental conditions, and occupancy patterns. While the study showcased the potential of IoT technologies, it lacked the integration of Fog Computing to enhance the real-time processing and decision-making capabilities of the system. In a different approach, [3]presented a cloud-based energy management system for educational institutions. The system relied on cloud computing to store and analyze data, which provided scalability and centralized control. However, the cloud-centric architecture may have limitations in terms of response time and localized decision-making, which could be addressed by incorporating Fog Computing. Researchers have also explored the use of machine learning algorithms to optimize energy management in educational settings. [4]developed a predictive energy management system for university buildings, utilizing machine learning techniques to forecast energy demand and optimize resource allocation. While this study demonstrated the benefits of advanced analytics, it did not integrate IoT and Fog Computing to enable real-time monitoring and decision-making. [5]reviewed the challenges and solutions in the context of the Internet of Things for smart home applications, highlighting the importance of interoperability, security, and privacy. Similarly, [6]conducted a survey of communication and networking technologies for smart grids, emphasizing the need for efficient and reliable data exchange. [7] explaining the relation between Fog Computing and Internet of Things, demonstrating how processing data at this network edge allows to obtain large benefits. [8]reviewed the wireless communication technologies for smart grid applications, emphasizing the importance of reliable and low-latency data transmission. [9]provided the NIST definition of cloud computing, which serves as a foundation for understanding the capabilities and limitations of cloud-based systems. [10]presented a comprehensive vision for the Internet of Things, outlining its architectural elements and future directions.

Fog computing is an extension of cloud computing that brings computing and storage closer to the data sources at the network edge.

Fog computing can address the limitations of cloud computing for IoT applications that require low latency and real-time processing.

[11] Improve the energy efficiency of fog computing environments) and appropriate management verbosity queues to avoid bottlenecks.

Investigate the integration of fog computing with other emerging technologies like software-defined networking (SDN) and network function virtualization (NFV).

[12]Fog computing can enable new IoT applications by providing low-latency, location-awareness, and real-time data processing.

[10]Fog computing can help reduce the load on cloud servers and improve the overall performance of IoT systems.

[11]Explore the use of fog computing for various IoT applications, such as smart cities, connected vehicles, and industrial automation.

[12]Develop efficient task offloading and resource allocation mechanisms for fog computing environments.

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III. PROPOSED SYSTEM MODEL

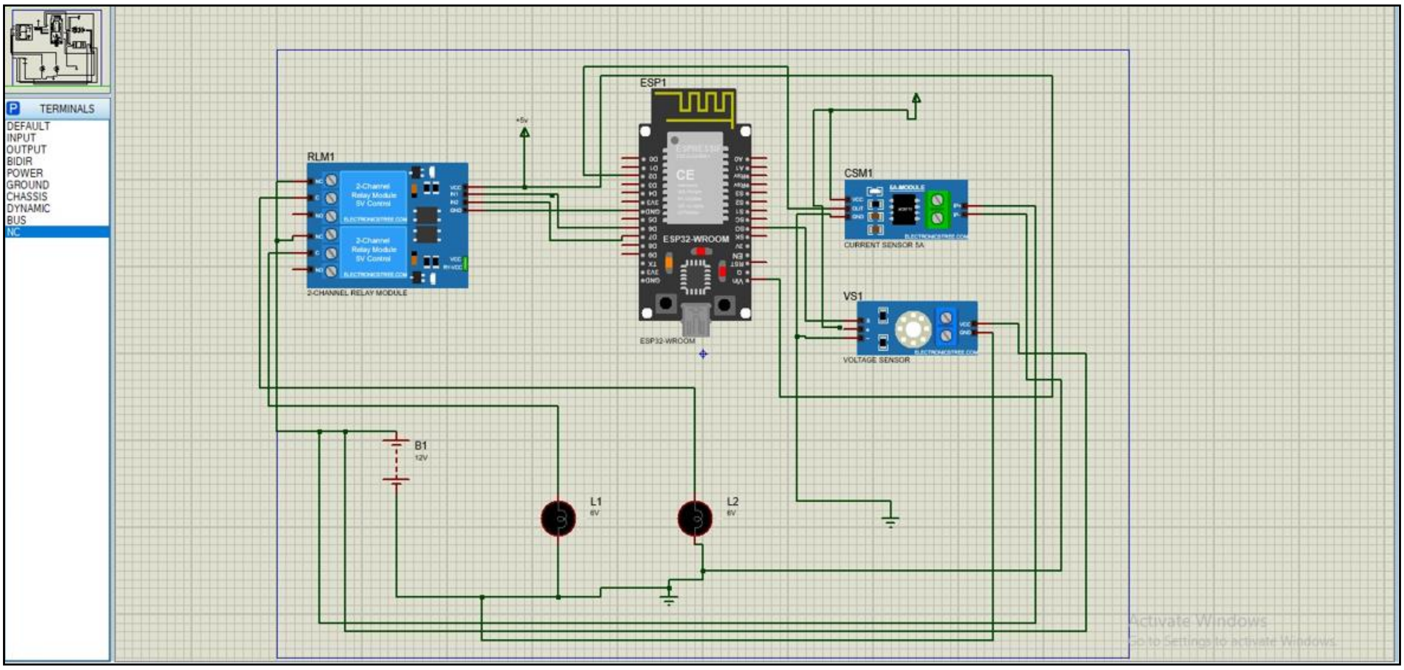

Fig 1 Proposed System Model

➢ *The Researchers Designed a Model of an IoT-based [13]Current Sensor:*

- Measures the current consumption of the electrical bulbs.
- Provides the ESP32 with real-time current data.

➢ *[14]Voltage Sensor:*

- Measures the voltage supplied to the electrical bulbs.
- Provides the ESP32 with real-time voltage data.

➢ *Channel Relay Module:*

- Allows the ESP32 to control the on/off state of the two electrical bulbs.
- Enables the ESP32 to switch the bulbs on or off based on energy efficiency algorithms.

➢ *Electrical Bulbs:*

- Represent the electrical loads being monitored and controlled for energy efficiency.

[15]This energy efficiency system is designed for a school campus, where the ESP32 microcontroller can be used to monitor and manage the energy consumption of the electrical bulbs. By integrating fog computing and IoT, the system can leverage the following benefits:

➢ *Fog Computing:*

- Allows for local processing and decision-making at the edge (ESP32 microcontroller), reducing the load on the central cloud infrastructure.
- Enables faster response times and improved reliability for energy efficiency management.

➢ *IoT:*

- Enables the system to collect and transmit sensor data (current and voltage) to a central monitoring and control system.
- [16]Allows for remote monitoring, control, and optimization of the energy efficiency measures across the school campus.

➢ *Block Diagram*

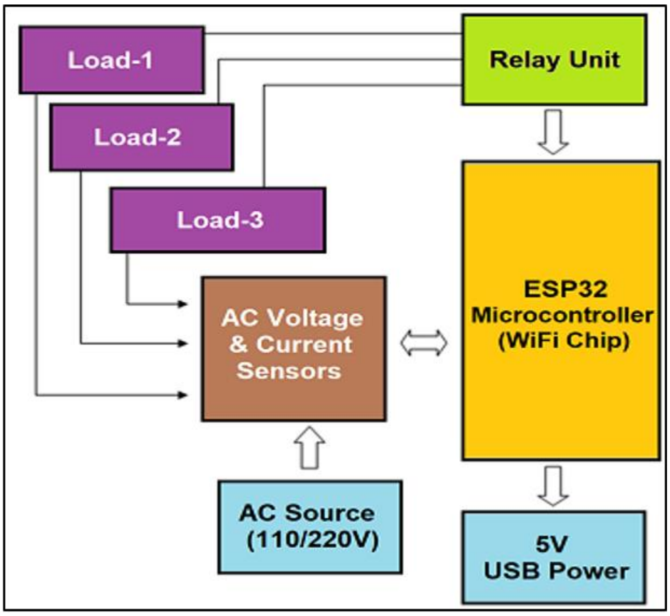

Fig 2 Block Diagram

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The above block diagram shows the main components of the system model. The IoT AC Energy Meter is built around the ESP32 microcontroller, which is equipped with Wi-Fi capabilities for internet connectivity. The AC voltage and current sensors, including the SCT-013 current sensor and ZMPT101B voltage sensor, measure the connected loads to calculate power and energy consumption. Relay unit acts as a switch to makes on-off of the connected loads. The electrical loads, such as lights, heaters, and motors, are powered by a 110/220V AC source and their energy consumption is monitored and controlled by the system, which is powered by a 5V USB power source.

➢ *Flow Chart*

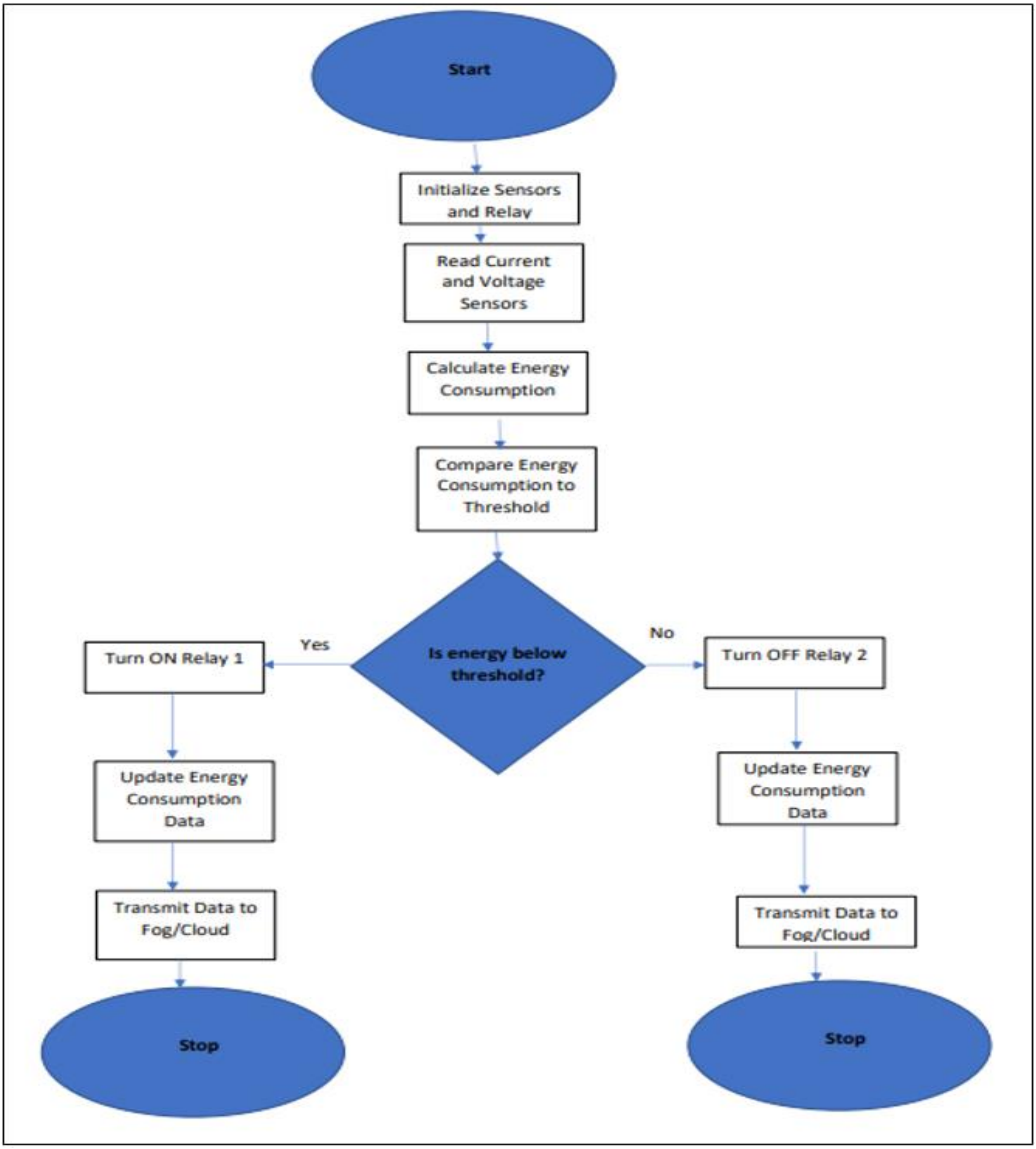

Fig 3 Flow Chart Representation of the IoT-Based Virtual Fence System to Control Population and Deter Quelea Birds Invasion using Automated nets

As can be seen in the above diagram, a microcontroller is responsible for initializing the modules and making decisions about what to do based on the state of the sensor data that it has read. The flow chart provides a visual representation of the system that demonstrates how the program flows. This helps to give a bigger picture when demonstrating the pseudocode of the system.

IV. RESULTS AND DISCUSSION

[17] The researchers have created an energy-efficient solution that makes use of fog computing and IoT integration for a school campus. The ESP32 microcontroller module, which is connected to a voltage, current, and 2-channel relay module, forms the basis of this system. Two lightbulbs, which stand in for the electrical parameters for energy efficiency, are monitored and their energy consumption is controlled by this system.

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