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Iot Based Smart Energy Meter using Wi-Fi and Gsm for Remote Monitoring and Control

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Abstract:

The growing demand for intelligent energy management systems has led to the development of Internet of Things (IoT)-based smart meters that provide real-time monitoring, remote control, and data analysis. This paper presents the design and implementation of a smart energy meter that utilizes Wi-Fi (ESP32), Bluetooth (HC-05), and GSM (SIM800L) technologies to monitor energy consumption and control connected appliances remotely. The system leverages an energy meter for measurement, a microcontroller for processing, a relay module for control, and a user-friendly communication framework. Experimental results validate the effectiveness of the system in real-world scenarios, with applications in residential, commercial, and industrial energy monitoring. The proposed system also supports integration with cloud platforms and mobile applications to enhance accessibility and improve decision-making.

Keywords: IoT, Smart Energy Meter, ESP32, GSM, Bluetooth, Energy Monitoring, Home Automation, Blynk, Real-time Monitoring, Remote Control

1. Introduction

With the rapid advancement of Internet of Things (IoT) technologies, smart energy metering has become a crucial part of smart grid infrastructure. Traditional energy meters provide limited functionality in terms of real-time feedback and user interactions. Smart energy meters have the potential to improve energy efficiency, reduce operational costs, and empower users with actionable insights into their consumption behavior. This study introduces an IoT-enabled energy meter that combines the advantages of Wi-Fi, Bluetooth, and GSM communication technologies to deliver a flexible and reliable monitoring and control system.

2. Literature Review

The evolution of smart metering systems has been well documented in the literature. Automated Meter Reading (AMR) systems paved the way for more sophisticated Advanced Metering Infrastructure (AMI). Research by Sharma et al. (2018) implemented GSM-based remote metering for rural applications, while Patil et al. (2020) demonstrated an ESP8266-based energy meter with Wi-Fi capabilities. While these systems offered certain advantages, they lacked redundancy and multi-communication versatility. Singh et al. (2021) introduced a wireless meter capable of basic load control. However, the integration of multiple communication technologies like Wi-Fi, Bluetooth, and GSM remains underexplored. This project aims to fill that gap.

3. System Architecture

The system design is modular and extensible, focusing on efficient energy measurement and seamless communication. It includes:

- Energy Meter:
- Calibrated to measure the current, voltage, and power factor using sensors such as the ACS712.
- Microcontroller (ESP32):
- Equipped with built-in Wi-Fi and BLE, it acts as the central controller managing all communications and processes.
- Relay Module:
- A 4-channel relay used to switch electrical appliances based on remote commands.
- Allows local device control via smartphone. GSM Module (SIM800L):
- Enables communication through SMS commands in remote or internet-limited areas. Power Supply Unit:

Converts high-voltage AC to stable 5V/3.3V DC required by various modules.

4. Hardware Integration

The hardware integration involves the precise interconnection of sensors, communication modules, and relays. The energy meter provides pulse outputs that represent the units of energy consumed. These were fed into the ESP32 GPIO pins. The relay module was controlled via digital pins to switch the loads. The GSM module communicated via UART, and the HC-05 Bluetooth module interfaced with the ESP32 using a serial

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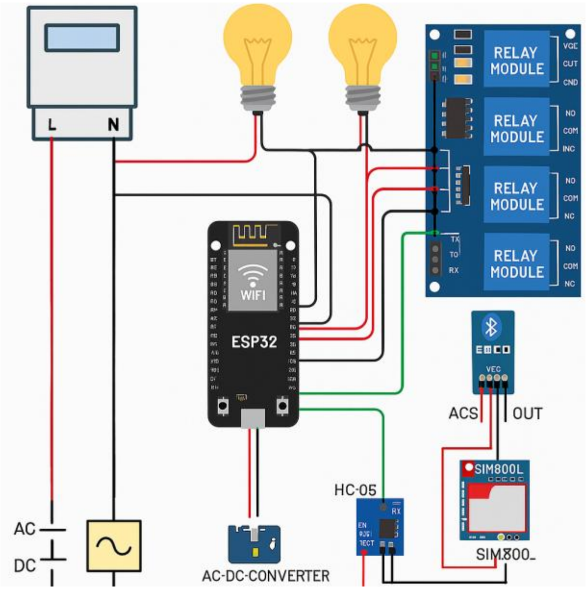
connection. Protection circuits and voltage regulators are used to ensure the safety and stability of the system.



5. Working Principle

The proposed smart energy meter works as follows:

- The sensors detect the electrical parameters and send the data to the ESP32.
- The ESP32 calculates real-time metrics and logs data locally and remotely.
- Users can monitor and control the devices via Wi-Fi (mobile app/cloud), Bluetooth (mobile app), or GSM (SMS commands).
- Alerts and energy usage statistics were periodically pushed to the user through Blynk, email, or SMS.
- The relay status, voltage, current, power factor, and energy consumption were visually available on the Blynk dashboard.
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6. Software Implementation

- Firmware Development:
- The Arduino IDE was used to program the ESP32 with the necessary libraries for the sensors and communication modules. Communication Libraries:
- Software Serial for HC-05, HTTP Client for Wi-Fi, and Tiny GSM for SIM800L.Cloud Platforms:
- Firebase and Thing Speak were explored, but Blynk was selected for its seamless IoT dashboard integration. Blynk IoT App:
- This mobile application allows real-time monitoring and control of appliances. It supports virtual pin mapping, notification alerts, and dynamic UI widgets, such as gauges, buttons, and charts. This integration ensures an enhanced user experience and remote accessibility. Security Measures:

Basic authentication mechanisms were implemented to restrict unauthorized access to critical control.

7. Results and Discussion

The system was tested over a period of four weeks in both lab and real-world settings. The key performance indicators included response time, communication reliability, power accuracy, and user experience. Wi-Fi was highly effective within covered areas, while Bluetooth provided fast and responsive local control. The GSM acts as a reliable fallback in rural regions. The relay operations were smooth and synchronized across the communication channels. The Blynk dashboard offers intuitive control and visualization, significantly enhancing usability. The data logs were consistent with the manual readings, affirming their accuracy.

8. Advantages

- Multi-communication support ensures robust operation under varying network conditions.
- Real-time data access and appliance control from any location are also possible.
- The scalable design allows expansion to multiple meters and appliances.
- Enhanced user engagement via an interactive Blynk interface.
- Energy optimization and cost reduction through better consumption insight.
- Fault detection and alert generation improve safety and maintenance planning.
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9. Applications

- Smart Homes:
- Automating lights, fans, and appliances based on usage. Industries:
- Monitoring high-load equipment and optimizing energy consumption in industrial settings. Off-grid Areas:
- GSM control is useful in regions with limited Internet access. Hostels and Apartments:
- Billing and consumption tracking per unit or room. Government Buildings:

Energy auditing and automated reporting.

10. Future Enhancements

Future iterations of this system could include the following features.

- Integration with voice assistants, such as Google Assistant or Alexa.
- Use of LoRaWAN for long-range, low-power communications.
- AI-based analytics to predict energy usage trends.

- Real-time billing and payment gateways are also available.
- The addition of temperature and environmental sensors for broader smart home applications.

11. Conclusion

This study presents a comprehensive IoT-based energy metering system that utilizes Wi-Fi, Bluetooth, and GSM for real-time monitoring and remote appliance control. The integration with Blynk enhances the flexibility and accessibility of the system, making it a viable solution for modern energy management. The prototype demonstrated reliability, scalability, and cost-effectiveness, making it suitable for deployment in various real-life scenarios. With further improvements, the system could evolve into a full-fledged smart grid node, contributing significantly to sustainable and intelligent energy ecosystems in the future.

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