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Blockchain-Based Energy Meter Reading System Using ESP32

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Abstract
Purpose: In many semi-urban and rural regions, energy billing is still performed manually, requiring human agents to visit households each month to record meter readings. This paper proposes a decentralized, IoT-enabled energy metering system using ESP32 and blockchain to automate energy consumption tracking and billing. The proposed system eliminates human intervention in meter reading by integrating real-time data acquisition through ESP32 and secure data logging through blockchain technology. This ensures transparency, tamper-proof records, and efficient energy management.

Keywords: IoT, Blockchain, ESP32, Energy Meter, Automation, Decentralization.

Introduction

Manual energy meter reading continues to be the standard practice in many regions, especially in developing countries. This process is labor-intensive, error-prone, and susceptible to manipulation. As urbanization increases and the need for smarter infrastructure grows, traditional methods fail to meet the demands of efficiency and transparency. To address these issues, this paper proposes a blockchain-based smart energy metering system using the ESP32 microcontroller to automate data capture and securely store usage records on a blockchain ledger.

Findings/Result: The system successfully automated energy meter readings and securely logged data on the blockchain without human intervention. It ensured tamper-proof, real-time access to consumption data for both users and utility providers.

Literature review:

Andoni et al. (2019) provided a comprehensive review of blockchain's transformative role in the energy sector, emphasizing transparency, decentralization, and automation. Mohamed and Elyousfi (2021) proposed an integrated IoT and blockchain framework for smart metering systems, highlighting real-time data integrity and consumer trust. Khan et al. (2017) discussed neural architectures supporting intelligent energy analytics. Complementary works by Chakraborty & Aithal (2023–2024) demonstrated ESP-based IoT innovations in energy and automation, using AWS Lambda and messaging bots. Collectively, these studies establish a foundation for secure, real-time, and decentralized energy metering using ESP32, IoT, and blockchain technologies.

Methodology: The system consists of three main components depicted in Figure 1:

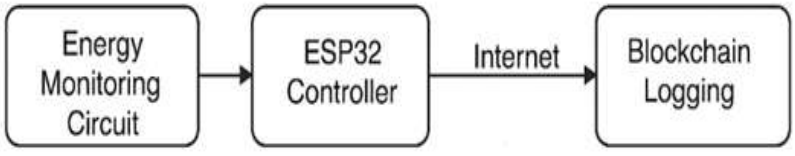

Fig. 1: Project Block diagram.

Energy Monitoring Circuit: A current sensor (e.g., ACS712) is connected to the energy meter to measure real-time power usage.

ESP32 Controller—The ESP32 microcontroller reads data from the sensor, calculates energy consumption, and connects to the Internet via Wi-Fi.

Blockchain Logging – The ESP32 pushes consumption data to a blockchain (e.g., Ethereum private chain or Hyperledger Fabric), recording each reading as a verified transaction.

The system uses smart contracts to log and verify energy readings. Each consumer has a unique identity on the blockchain, ensuring data integrity and ownership.

Recommendation

- Deploy the system in pilot regions to evaluate performance under real-world conditions.
- Integrate mobile or web dashboards for consumer access to real-time usage data.
- Use private or consortium blockchain networks to reduce transaction costs and latency.
- Implement over-the-air (OTA) updates for ESP32 to ensure long-term maintainability.
- Explore renewable energy integration for smarter, sustainable power management.

Conclusion

Integrating ESP32-based IoT systems with blockchain technology offers a practical solution to the inefficiencies of manual energy meter readings. The proposed method automates the billing process and ensures transparency and security in energy data management. Future work will enhance scalability and integrate predictive analytics for energy optimization.

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