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Design of an Energy Efficient IOT Enabled Smart System based on Dali Network Over MQTT Protocol

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Abstract: This project aims to harness the Internet of Things (IoT) to develop an energy-efficient network through the DALI (Digital Addressable Lighting Interface) protocol. The DALI network utilizes the MQTT (Message Queuing Telemetry Transport) protocol to provide robust security. We are employing compact, cost-effective controllers such as the Raspberry Pi, which can monitor sensor data and transmit it online. DALI is a state-of-the-art method for controlling electrical devices, and its integration with a web server or PC enhances the capabilities of a smart grid. The project involves overseeing a network of lighting fixtures with a Raspberry Pi as the controller and using MQTT for communication, thereby implementing IoT concepts seamlessly. Furthermore, web-based control methods are employed to manage various switching devices effectively.

Keywords: *DALI, MQTT, IOT server, variable protocols, Raspberry Pi.*

INTRODUCTION

The smart grid manages and distributes electricity in a more efficient, economical, and secure way and it integrates many different technologies, products, services to electric user side appliances with sensing, communications, and control technologies from generation,

transmission and distribution. With a smart meter, each device used in buildings and homes can be scheduled, remotely controlled and monitored by smart grid technologies. Designedstand-by power saving smart socket with wireless sensor network which has a similar design for plug system. But the system purposes only controlling the plug stand-by power. Our goal is that smart meter has an interactive user interface to give system scheduling management.

Reference [9] used Bluetooth to implement portable smart meter over smart phone. Design of a smart energy meter with Bluetooth low energy is presented in [10] . Reference [11] designed a smart meters that use magnetic flux. Smart energy meter design using GPRS communication is presented.

The main objective of the research is developing and testing Our SM offers consumers to read the real time data which give the idea of power consumption real time and pricing information. The other objective is to optimize home energy usage and help home energy cost saving.

TOU pricing is calculated in the PC side software system processes and stores the data of:

1) Power measurements;
2) Time and date;
3) Load priority; and
4) Prices of the electricity.

Also the software schedules loads from top consumption hours to low price energy generation hours with the user settings. The New approach of our design is the use of circuit breaker relay which gives the advantage of protection against over voltages. We detect also zero-cross of AC signal to calculate phase shift and turn on and off the devices with solid state relay which gives the advantage of fast switching and high current conducting. We measured power usage of three unit devices which are a LCD TV, satellite receiver and home theater sound system with the same hub.

We collected the data and transfer it with the communication path to the coordinator node and stored to the data base successfully.Smart Grid (SG) with its dynamic model has an exciting potential. Fig. shows evolutionary perspective of SG in past, present and future plans. Also Table I compares the standard grid to SG. SG provides two way communication and energy flow comparing to existing conventional grid. Fig. shows general communication architecture for smart grid from power generation, transmission, distribution to buildings and homes.

Smart grid information path starts with broadcasting from sensors or smart devices to smart meters and then passing to the control centers. In communication side the wireless networks are one the most researched area in smart grid power systems. The wireless networks served a couple of advantages in installation and large coverage, but limited bandwidth and interference is the main lacking.

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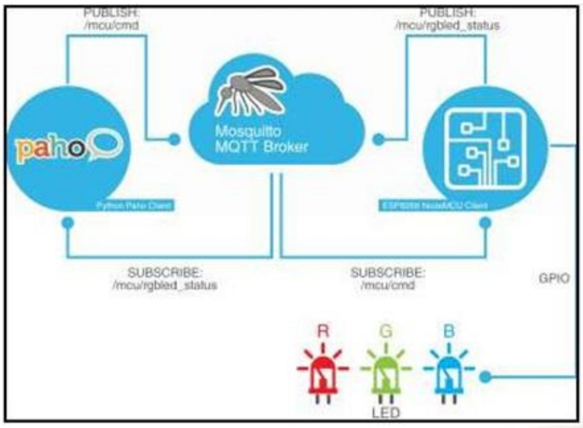

Fig.1.1 Model of communication protocol

OVER VIEW:

Electricity theft increases costs for consumers and poses serious safety hazards. It distorts cost allocation among suppliers, undermining competition and disrupting market efficiency. The costs for suppliers to detect theft can exceed the overall industry impact. When theft is detected, suppliers may incur additional liabilities related to generation, network, and balancing costs due to the estimated volume of stolen electricity entering the settlement system. However, this does not lead to higher costs for the industry at large.

Historically, detecting electricity theft has involved physical inspections of tamper-evident seals by field personnel and the use of balance meters. While these methods help reduce unmeasured and unbilled electricity consumption, they have their limitations. Tamper-evident seals can be easily circumvented, and balance meters, while effective in identifying fraudulent activity, often fall short in pinpointing the exact culprits.

Smart meters, despite some security vulnerabilities, present a promising improvement over traditional detection methods. Their high-resolution data collection capabilities can enhance metering, billing, and collection processes, and improve the detection of fraud and unmetered connections.

Common theft tactics include tampering with meter security or making direct connections to distribution lines. Additionally, payment defaults remain a major issue, often exacerbated by insufficient monitoring and enforcement measures.

LITERATURE SURVEY

1. IoT-Based Smart Energy Meter Billing, Monitoring, and Controlling the Loads

Authors: A. Subba Rao, Sri Vidya Garige

This paper presents the development of an advanced system for real-time monitoring and control of energy meters. The system incorporates a Remote Meter Reading System designed to automate energy monitoring and reduce production costs. It features a prepaid model and a virtual instrument software architecture compatible with IoT technology, allowing operation via a web server. The system monitors energy consumption and usage status, sending data to the web server and generating automated SMS alerts via GSM if anomalies are detected. Customers receive monthly bills based on current usage, and experts can remotely control high-power devices through a secure web portal. Utilizing an ARM processor for the sensor module and communication setup, the system provides a cost-effective, user-friendly solution for real-time monitoring and control of appliances.

2. IoT-Based Smart Energy Meter Monitoring and Theft Detection Using ATMEGA

Authors:

This paper focuses on an IoT-based system designed for electricity theft detection and meter reading monitoring. Traditional methods involving physical checks and balance meters are deemed insufficient. The proposed system uses IoT to send alert SMS messages to the owner when theft is detected and provides monthly meter readings and rates. It enables global access to meter readings and theft status, allowing users to monitor their data from anywhere at any time. The paper also addresses the need for improved regulatory measures and the role of Distribution Network Operators (DNOs) in theft prevention, suggesting that the system could enhance theft detection and communication with customers.

3. IoT-Based Smart Energy Meter

Author:

This paper introduces an energy meter system using Arduino technology to eliminate human intervention in electricity maintenance and detect theft. The system monitors both the main and sub-meter readings with Arduino. Discrepancies trigger a theft alert displayed on an LCD and posted on ThingSpeak. This setup allows customers to track their energy usage globally using their consumer number, providing a means to detect and address electricity theft effectively.

4. Design and Implementation of an IoT-Based Smart Energy Meter

Authors: Birendra Kumar Sahani, Tejashree Ravi

This paper offers a solution to the issues of manual energy meter reading and billing errors. It proposes an IoT and Arduino-based system that automates meter reading and billing, removing the need for a third-party intermediary.

The system modifies existing meters rather than replacing them and integrates a GSM module for SMS notifications and a web page for monitoring. Users can view real-time readings, billing information, and control the meter remotely.

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Features such as automatic on/off functionality and threshold value settings address common problems like billing errors and missed notifications.

RELATED STUDY

The summary provides a clear and concise overview of an IoT-based energy meter system designed to enhance energy consumption management. This approach not only helps in reducing energy waste and increasing efficiency but also addresses the critical issue of energy theft through various integrated technologies. Here's a recap of the main components and their roles:

1. **Microcontroller Unit (ATMEGA328P)**: Serves as the system's brain, managing data collection from the energy meter and controlling communications and alerts.

2. **Theft Detection Unit**: Actively monitors for tampering or unauthorized use, sending immediate alerts to both consumers and service providers via SMS or email if any suspicious activity is detected.

3. **Meter Analysis and Communication Unit**: Collects and transmits energy consumption data to a central server or cloud platform, allowing consumers to monitor their usage through a web interface and gain insights into their consumption patterns.

4. **Communication Technologies**: Utilizes Bluetooth, Wi-Fi, RF modules, or other wireless technologies to connect the energy meter to the internet, enabling real-time data transfer and remote access.

5. **IoT Platform**: The central hub where energy data is uploaded, analyzed, and visualized, providing consumers with the tools to track usage, set targets, and receive alerts.

6. **Energy Management**: Offers detailed insights into energy consumption, empowering consumers to make informed decisions to reduce usage, conserve energy, and save costs.

7. **Security and Reliability**: Implements encryption and secure protocols to ensure secure communication and protect data integrity, preventing unauthorized access.

This comprehensive system not only empowers consumers with valuable information to manage their energy usage but also provides utility companies with tools to detect and prevent energy theft, contributing to a more efficient and reliable energy supply chain.

The integration of IoT technologies in energy management represents a significant step towards addressing the global energy crisis and promoting sustainability.

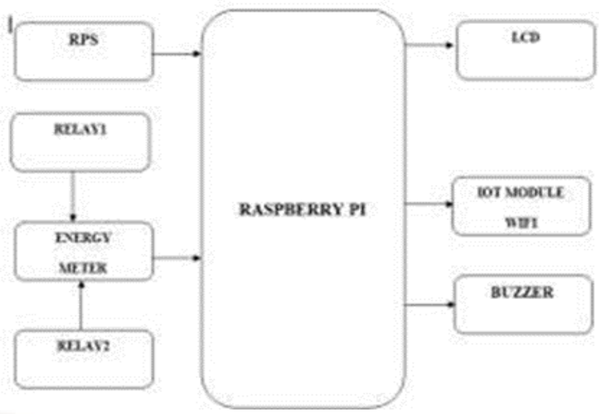

Fig.1.2 Proposed system block diagram

PROPOSED SYSTEM

Your description provides a comprehensive overview of a smart home appliance control system using IoT technologies. The system effectively integrates various components to provide users with a seamless and efficient way to manage their home energy usage. Here's a detailed summary of the system:

System Components and Operation

1. **Android Smartphone Interface:**

○ **User Interaction:** Users interact with the system through a smartphone app. The app offers a user-friendly interface where users can log in and select specific controls for their home appliances.

○ **Command Sending:** Users can send command messages by clicking buttons within the app. These commands are transmitted to the home information center via the IoT network.

2. **Digital Addressable Lighting Interface (DALI):**

○ **Protocol for Lighting Control:** DALI is a protocol that facilitates digital communication between lighting systems and a central server or computer.

○ **Efficient Control:** DALI integration allows for precise control of lighting, aiding in the development of a smart grid by optimizing energy usage.

3. **Raspberry Pi as MQTT Broker:**

○ **Broker Functionality:** The Raspberry Pi functions as an MQTT broker, mediating communication between the smartphone app (publisher) and home devices (subscribers).

○ **Efficient Communication:** MQTT is used for message queuing and telemetry transport, offering low bandwidth requirements and efficient data transfer, making it ideal for IoT applications.

4. **MQTT Protocol:**

○ **Publishing and Subscribing:** Devices communicate by

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publishing and subscribing to specific topics. Each topic corresponds to a particular control command for appliances.

○ **Real-Time Interaction:** The system ensures real-time control and feedback as subscribers listen for topics and execute corresponding operations when a matching topic is received.

5. **Communication Process:**

○ **Topic Selection:** Users select a control command topic via the smartphone app, which serves as the publisher.

○ **Broker Facilitation:** The MQTT broker (Raspberry Pi) receives the topic and manages communication between the publisher and subscriber (home devices).

○ **Operation Execution:** When the publisher and subscriber topics match, the subscriber performs the operations linked to that topic, allowing for real-time lighting adjustments.

6. **Implementation and Outcome:**

○ **Optimized Energy Usage:** The system optimizes electricity usage by controlling the intensity of LEDs dynamically, as demonstrated in the CDAC smart building.

○ **Immediate Feedback:** Users can see immediate results in lighting adjustments based on their inputs, such as changing brightness levels of lights.

ADVANTAGES

● **Energy Efficiency:** Utilizing the DALI protocol and MQTT communication ensures optimal control of lighting, leading to reduced energy consumption and cost savings.

● **Remote Accessibility:** The smartphone app allows users to control appliances from anywhere, offering convenience and flexibility.

● **Scalability and Flexibility:** The system can be easily expanded by adding new topics and subscribers, accommodating additional appliances or functionalities.

● **User Engagement:** The intuitive interface encourages users to manage their energy usage actively and make informed decisions.

This IoT-based control system exemplifies the potential for integrating smart technologies into daily life, enhancing energy efficiency, and increasing user convenience.

By leveraging established protocols like DALI and MQTT, the system provides reliable and scalable communication, paving the way for smarter and more sustainable living environments.

RESULTS

EXPLANATION:

Fig.1.3 Hardware kit

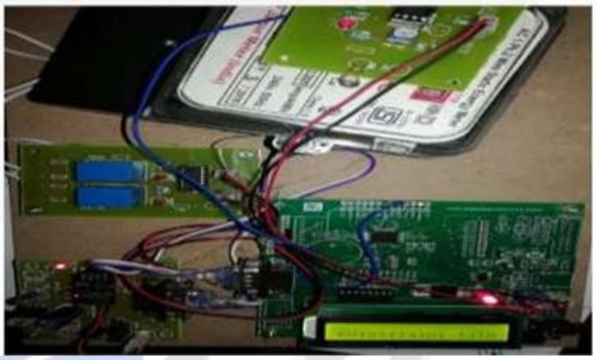

Fig.1.4 Wife module installed

Fig.1.5 Energy meter

Fig.1.6 Relay on position

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Fig.1.7 Units and cost displayed in the LCD

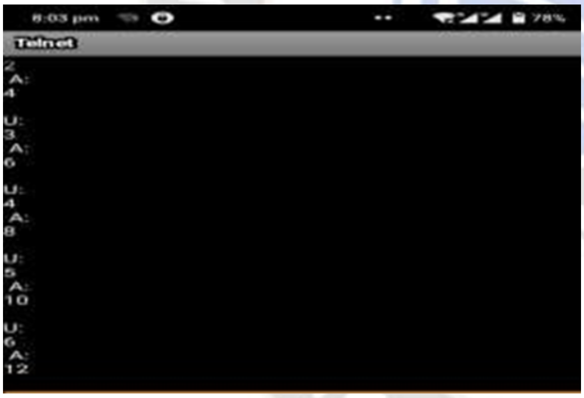

Fig. 1.8Output across the grid side

1. CONCLUSION

In this paper Wireless Sensor Home Area Network (WSHAN) with IOT interfaced smart meter was designed, implemented and tested. Our system measures energy usage logs data real time and controls any device connected to power outputs.

The power usage was measured by the smart meter prototype and the calculated data was transmitted through wifi communication to PC (Personal Computer). With the PC software, scheduling with TOU pricing showed that it creates an economic expenditure for consumer and it's all the same for the utility side. Our contribution is a smart meter system with consumer control in energy saving events corresponding to smart grid concept.

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