

Intelligent Home Management System with Remote Monitoring and Fault Diagnostics using IoT

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ABSTRACT

The Intelligent Home Management System with Remote Monitoring and Fault Diagnostics using IoT is designed to enhance home automation, safety, and energy efficiency through real-time monitoring and intelligent control of household electrical appliances. The system is built around an ESP32 microcontroller integrated with current and voltage sensors to continuously monitor power consumption and identify abnormal operating conditions such as overcurrent, under-voltage, and irregular energy usage. Environmental parameters are monitored using a humidity sensor to ensure indoor comfort and safety, while a relay-based switching mechanism enables remote control of appliances including lights, fans, air conditioners, and water pumps. The collected sensor data is transmitted to an IoT-enabled platform, allowing users to remotely monitor appliance status, energy usage, and fault conditions through a web or mobile interface. Automated fault diagnostics and alert mechanisms help prevent electrical hazards, reduce energy wastage, and enable timely maintenance. The proposed system provides a scalable, cost-effective, and reliable solution for smart home management, supporting efficient energy utilization, improved safety, and enhanced user convenience [3].

Keywords:- Internet of Things (IoT), Intelligent Home Management System, Smart Home Automation, Remote Monitoring, Fault Diagnostics, ESP32 Microcontroller, Energy Management, Real-Time Monitoring, Sensor-Based Control, Home Security.

1. INTRODUCTION

The rapid advancement of the Internet of Things (IoT) has transformed traditional homes into intelligent environments capable of sensing, monitoring, and controlling household appliances in real time. Smart home technologies aim to improve user comfort, safety, and energy efficiency by enabling seamless interaction between devices, sensors, and cloud-based platforms. With the increasing number of electrical appliances in modern homes, there is a growing need for intelligent systems that not only automate appliance control but also monitor electrical parameters and detect faults proactively [3]. The Intelligent Home Management System with Remote Monitoring and Fault Diagnostics using IoT is designed to address these requirements by integrating sensing, control, and communication technologies into a unified framework. The system is built around the ESP32 microcontroller, which acts as the central processing and communication unit. It continuously monitors electrical parameters such as current and voltage using appropriate sensors to analyze power consumption patterns and identify abnormal conditions such as overloads, voltage fluctuations, or faulty appliances. Environmental parameters, including humidity, are also monitored to ensure indoor comfort and safety. Remote monitoring and control are achieved through an IoT-enabled platform that allows users to access real-time data and control appliances from anywhere using a mobile or web application. Household devices such as lights, fans, air conditioners, and water pumps are interfaced using a relay module, enabling automated and manual control based on sensor data or user preferences. Fault diagnostics and alert mechanisms provide timely notifications to users, helping prevent electrical hazards, reduce energy wastage, and support preventive maintenance [2].

Overall, the proposed system offers a scalable, cost-effective, and reliable smart home solution that enhances convenience, improves energy management, and strengthens household safety. By combining IoT connectivity with real-time monitoring and intelligent fault detection, the system represents a significant step toward the development of next-generation intelligent homes [4].

1.1 Problem Statement

With the rapid growth of electrical appliances in modern households, effective monitoring, control, and fault detection have become increasingly challenging. Traditional home management systems rely largely on manual operation and lack real-time monitoring, centralized control, and intelligent fault diagnostics. As a result, homeowners face issues such as excessive energy consumption, delayed fault detection, higher electricity costs,

and increased risk of electrical hazards including overloads, short circuits, and appliance failures. Existing automation solutions often focus only on remote control and do not provide continuous monitoring of electrical parameters such as current and voltage, nor do they offer timely alerts for abnormal operating conditions. The absence of real-time fault diagnostics and energy usage analysis limits preventive maintenance and reduces system reliability [5].

1.2. Research Objectives

- To design and develop an IoT-based intelligent home management system capable of monitoring and controlling household electrical appliances in real time.
- To implement remote monitoring and control mechanisms using an IoT platform that allows users to access appliance status and sensor data through a web or mobile interface.
- To monitor electrical parameters such as current and voltage for analyzing power consumption patterns and detecting abnormal operating conditions.
- To develop fault diagnostics algorithms for identifying electrical faults including overloads, voltage fluctuations, and abnormal energy usage.
- To enhance energy management and optimization by providing real-time energy consumption insights and automated control of appliances.
- To improve household safety and reliability by generating instant alerts and notifications during fault conditions or unsafe operating scenarios.

1.3 Motivation

The increasing demand for comfort, safety, and energy efficiency in modern homes has highlighted the limitations of traditional home management systems. Most existing systems rely on manual operation and lack real-time monitoring, making it difficult for users to track energy consumption, detect electrical faults, or control appliances remotely. This often leads to energy wastage, delayed fault detection, higher electricity costs, and potential safety hazards such as electrical overloads and equipment failures [5]. The rapid development of the Internet of Things (IoT) has created new opportunities to address these challenges by enabling seamless connectivity between devices, sensors, and cloud platforms. IoT-based systems allow continuous monitoring of electrical and environmental parameters and provide instant access to data from anywhere. The motivation behind this project is to leverage IoT technology to create an intelligent, automated, and user-friendly home management system that enhances operational efficiency and household safety. Additionally, the growing focus on energy conservation and smart infrastructure has driven the need for intelligent solutions capable of optimizing power usage and supporting preventive maintenance. By integrating real-time monitoring, remote control, and fault diagnostics into a single platform, the proposed system aims to reduce energy wastage, improve user convenience, and contribute to the development of sustainable and smart living environments [5].

1.4 Research Gap

Existing smart home and home automation systems primarily focus on remote switching and basic automation of household appliances. While these systems improve user convenience, they often lack continuous real-time monitoring of electrical parameters such as current and voltage, which are essential for accurate energy analysis and fault identification. Most available solutions provide limited insights into power consumption patterns and do not support intelligent decision-making for energy optimization. Furthermore, fault detection mechanisms in current systems are either absent or reactive, detecting issues only after appliance failure occurs. Many systems do not integrate automated fault diagnostics capable of identifying early-stage anomalies such as overloads, voltage fluctuations, or abnormal energy usage [3]. Additionally, environmental monitoring is often treated as a standalone feature rather than being integrated with electrical safety and appliance control. Another significant research gap lies in the lack of a unified, low-cost, and scalable architecture that combines remote monitoring, intelligent automation, energy management, and fault diagnostics within a single IoT framework. Existing implementations frequently rely on complex or expensive hardware, limiting their suitability for widespread residential deployment. Therefore, there is a clear need for an integrated IoT-based intelligent home management system that provides real-time electrical and environmental monitoring, proactive fault diagnostics, remote accessibility, and energy optimization using affordable and scalable hardware platforms such as ESP32 [4].

2. LITERATURE REVIEW

1. L. Atzori, A. Iera, G. Morabito "The Internet of Things: A Survey" Provides a foundational overview of IoT concepts, architectures, and applications but does not focus on smart homes or fault diagnostics. The paper "The Internet of Things: A Survey" by L. Atzori, A. Iera, and G. Morabito is one of the most influential early works that systematically explains the concept, vision, and technological foundations of the Internet of Things (IoT). The authors define IoT as a paradigm in which every day physical objects are equipped with sensing, processing, and communication capabilities, enabling them to connect and interact over the Internet

without human intervention. The study presents a detailed IoT architectural framework, highlighting the integration of technologies such as Radio Frequency Identification (RFID), wireless sensor networks, embedded systems, and Internet protocols. The authors classify IoT systems into different perspectives things-oriented, internet-oriented, and semantic-oriented to explain how heterogeneous devices can be interconnected and managed efficiently [1].

2. J. Gubbi et al. "Internet of Things (IoT): A Vision, Architectural Elements" The paper "Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions" by J. Gubbi et al. presents a comprehensive vision of IoT with a strong emphasis on cloud-centric architecture. The authors describe IoT as a global network of interconnected physical objects embedded with sensors, actuators, and communication capabilities that enable data collection and intelligent decision-making. The paper proposes a four-layer IoT architecture consisting of sensing devices, gateways, data management and analytics, and application layers. A key contribution of this work is the integration of cloud computing with IoT, where cloud platforms are used for large-scale data storage, processing, and analytics. This approach addresses challenges related to scalability, resource management, and real-time data handling. The authors also discuss various IoT application domains, including smart homes, healthcare, smart cities, and industrial automation. Additionally, the paper highlights important research challenges such as data security, privacy, interoperability, energy efficiency, and standardization. While the paper provides a strong conceptual and architectural foundation, it does not present a detailed implementation for appliance-level monitoring, energy management, or fault diagnostics in residential environments [2].
3. A. Al-Fuqaha et al. "Internet of Things: A Survey on Enabling Technologies" The paper "Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications" by A. Al-Fuqaha et al. provides an in-depth and systematic survey of the core technologies that enable IoT systems. The authors analyze IoT from multiple perspectives, including architecture, communication protocols, data processing, and application domains, making the work a key reference for IoT researchers and system designers. The paper explains a layered IoT architecture, typically consisting of the perception layer (sensors and actuators), transport layer (communication technologies such as Wi-Fi, ZigBee, Bluetooth, and cellular networks), and application layer (smart services). A major contribution of this work is its detailed comparison of IoT communication protocols, including MQTT, CoAP, HTTP, and RESTful services, highlighting their suitability for constrained devices and real-time data transmission. In addition, the authors discuss data management, middleware, and cloud integration, emphasizing the importance of interoperability and scalability in heterogeneous IoT environments. The paper also reviews various IoT application areas, such as smart homes, healthcare, transportation, and smart grids. Key challenges including security, privacy, mobility, energy efficiency, and standardization are thoroughly analyzed [3].
4. C. Perera et al. "Context Aware Computing for IoT" The paper "Context Aware Computing for the Internet of Things: A Survey" by C. Perera et al. presents a comprehensive review of context-aware computing techniques applied to IoT environments. The authors define context as any information that characterizes the state of an entity, such as location, time, activity, or environmental conditions, and emphasize its role in enabling intelligent and adaptive IoT systems. The study introduces a context-aware IoT framework consisting of context acquisition, modeling, reasoning, and dissemination layers. Various context modeling techniques such as key-value models, ontologies, and probabilistic models are analyzed, along with context reasoning methods including rule-based, machine learning-based, and hybrid approaches. These techniques allow IoT systems to make intelligent decisions based on dynamic environmental and user-related data. The paper also reviews multiple IoT application domains, including smart homes, smart cities, healthcare, and environmental monitoring, where context awareness improves automation and user experience. Key challenges such as data uncertainty, scalability, interoperability, privacy, and security are discussed in detail [4].
5. J. Han et al. "Smart Home Energy Management System Using ZigBee" The paper "Smart Home Energy Management System Using ZigBee" by J. Han et al. presents the design and implementation of a smart home energy management system that utilizes ZigBee wireless communication for low-power and short-range data transmission between household appliances and a central controller. The primary objective of the system is to monitor and manage energy consumption within residential environments. The proposed system consists of smart plugs, energy meters, and ZigBee-enabled nodes that collect appliance-level energy usage data and transmit it to a home gateway. Users can monitor power consumption and control appliances through a centralized interface, enabling basic automation and energy-saving strategies. The authors highlight ZigBee's advantages such as low power consumption, reliability, and suitability for home networks [5][2].
6. S. Kumar, P. R. Pati "GSM Based Home Automation System" The paper "GSM Based Home Automation System" by S. Kumar and P. R. Pati presents a home automation framework that enables users to control household appliances remotely using GSM technology and SMS communication. The primary aim of the system is to provide remote access and control in areas where internet connectivity may be unreliable or

unavailable. The proposed system uses a microcontroller interfaced with a GSM module to receive user commands in the form of SMS messages. Based on the received commands, appliances such as lights and fans are controlled through relay switches. The system also supports basic status notifications to inform users about appliance operation. This approach makes the system simple, cost-effective, and suitable for rural or low-connectivity environments. However, the system is largely command-based and does not support real-time monitoring of appliance status or energy consumption. It lacks integration with sensors for measuring electrical parameters such as current and voltage and does not include fault detection or diagnostics mechanisms. Additionally, the absence of cloud connectivity limits scalability, data analytics, and intelligent automation [6].

7. M. Reddy et al. "IoT Based Smart Home Automation Using ESP8266" The paper "IoT Based Smart Home Automation Using ESP8266" by M. Reddy et al. presents the design and implementation of a low-cost smart home automation system using the ESP8266 Wi-Fi module. The primary objective of the work is to enable remote control of household appliances through the internet using a web or mobile-based interface. In the proposed system, the ESP8266 acts as the central controller, connecting appliances such as lights and fans through relay modules. Users can monitor appliance status and issue ON/OFF commands remotely via an IoT platform. The system demonstrates the effectiveness of Wi-Fi-based communication for real-time control and highlights advantages such as low power consumption, reduced hardware complexity, and affordability. However, the system mainly focuses on basic automation and remote switching. It does not incorporate electrical parameter monitoring such as current or voltage measurement, nor does it include fault detection or diagnostics mechanisms. Energy consumption analysis, safety alerts, and predictive maintenance features are also not addressed in this work [7].
8. M. Islam et al. "Cloud-Based Smart Home Monitoring System" The paper "Cloud-Based Smart Home Monitoring System" by M. Islam et al. presents an IoT-enabled smart home framework that leverages cloud computing to enable remote monitoring of household environments. The primary goal of the system is to collect sensor data from home devices and store it on a cloud platform, allowing users to access real-time information through a web or mobile interface. In the proposed architecture, various sensors are deployed to monitor parameters such as temperature, humidity, and appliance status. The collected data is transmitted to the cloud using internet connectivity, where it is processed, visualized, and made accessible to users for continuous monitoring. The system demonstrates how cloud integration improves scalability, data storage, and remote accessibility, making it suitable for smart home applications. However, the work mainly focuses on monitoring and data visualization and does not address active control strategies, energy consumption analysis, or electrical parameter monitoring such as current and voltage measurement. Additionally, the system lacks fault detection and diagnostics mechanisms, limiting its ability to detect abnormal conditions or ensure electrical safety in real time [8].
9. N. Kumar et al. "Smart Energy Meter Using IoT" The paper "Smart Energy Meter Using IoT" by N. Kumar et al. presents the design of an IoT-enabled energy metering system aimed at monitoring electrical energy consumption in real time. The primary objective of the system is to provide accurate and continuous measurement of power usage and transmit the collected data to an online platform for user access and analysis. In the proposed system, current and voltage sensors are interfaced with a microcontroller to calculate power and energy consumption. The measured data is sent to a cloud server using IoT connectivity, allowing users and utility providers to remotely monitor energy usage through a web-based dashboard. The system also supports features such as automated billing, consumption history tracking, and real-time usage visualization. While the system effectively improves energy monitoring and transparency, it primarily focuses on metering and data reporting. It does not incorporate appliance-level automation, environmental sensing, or fault detection and diagnostics such as overload or abnormal power conditions. Additionally, the system is designed mainly for energy measurement rather than intelligent control or safety management [9].
10. R. Patel, M. Shah "IoT Based Home Automation System" The paper "IoT Based Home Automation System" by R. Patel and M. Shah presents a basic IoT-enabled framework for automating and remotely controlling household electrical appliances. The primary objective of the system is to enhance user convenience by allowing appliance control through an internet-connected interface. In the proposed system, a microcontroller with IoT connectivity is interfaced with a relay module to control appliances such as lights, fans, and other household devices. Users can send control commands through a web or mobile application, and the system responds by switching appliances ON or OFF accordingly. The work demonstrates the effectiveness of IoT technology in enabling remote accessibility and centralized control. However, the system mainly focuses on simple appliance automation and does not include real-time monitoring of electrical parameters such as current, voltage, or power consumption. Additionally, the system lacks fault detection and diagnostic capabilities, environmental sensing, and energy optimization features. As a result, the system provides limited support for safety monitoring and preventive maintenance [10].

3. PROPOSED METHODOLOGY

The proposed methodology aims to develop an IoT-based Intelligent Home Management System that enables real-time monitoring, automated control, and fault diagnostics of household appliances. The system is centered on an ESP32 microcontroller, which interfaces with current, voltage, and humidity sensors to continuously acquire electrical and environmental data. Household appliances such as lights, fans, air conditioners, and water pumps are connected through a relay module, allowing both manual and automated control [7]. The collected sensor data is processed locally by the ESP32 to identify abnormal operating conditions such as overcurrent, voltage fluctuations, or irregular power consumption. Relevant data is then transmitted to a cloud-based IoT platform via Wi-Fi, enabling users to remotely monitor appliance status, energy usage, and system health through a web or mobile dashboard. Fault diagnostics algorithms generate instant alerts and can automatically isolate faulty appliances to enhance safety. Additionally, energy consumption data is analyzed to optimize appliance usage and reduce power wastage. This integrated approach ensures improved energy efficiency, enhanced safety, and convenient remote management of smart home environments [10].

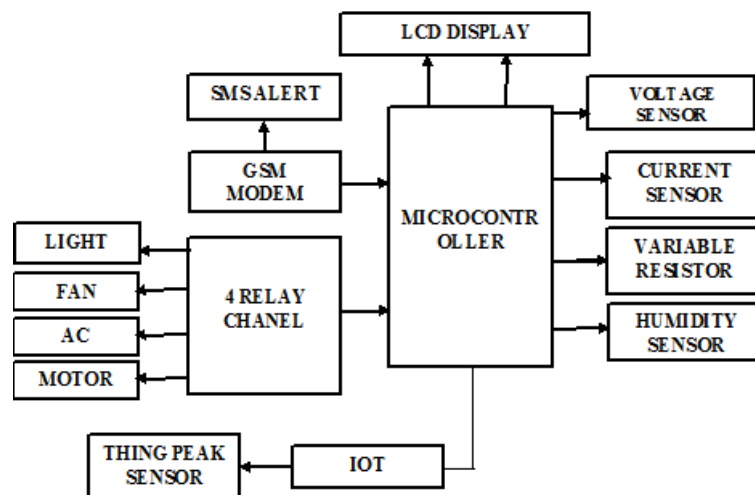


Fig 1: Block diagram

4. LIMITATIONS

- Dependence on Internet Connectivity**
 The system relies on continuous internet access for real-time monitoring, cloud communication, and remote control. Any network failure may affect system performance and accessibility.
- Limited Fault Prediction Capability**
 The system mainly detects faults based on predefined threshold values and does not include advanced predictive analytics or machine learning models for early fault prediction.
- Scalability Constraints**
 As the number of connected appliances increases, the system may face limitations in processing capacity and response time without additional hardware or optimization.
- Security and Privacy Risks**
 IoT-based systems are vulnerable to cyber threats such as unauthorized access and data breaches if proper encryption and authentication mechanisms are not implemented.
- Hardware Dependency and Accuracy**
 Sensor accuracy depends on proper calibration and quality of hardware components. Faulty or low-precision sensors may lead to incorrect readings and false alerts.
- Initial Setup and Maintenance Cost**
 Although cost-effective compared to commercial systems, the initial installation, sensor deployment, and periodic maintenance may increase overall expenses.
- Limited Environmental Parameters**
 The current system monitors a limited set of environmental parameters (e.g., humidity) and does not include advanced sensing such as gas leakage or fire detection.

5. CONCLUSION

The Intelligent Home Management System with Remote Monitoring and Fault Diagnostics using IoT presents an effective solution for enhancing home automation, energy efficiency, and safety. By integrating an ESP32 microcontroller with current, voltage, and environmental sensors, the system enables continuous real-time

monitoring of household appliances and electrical parameters [10]. The use of IoT connectivity allows users to remotely control appliances, visualize energy consumption, and receive instant alerts during abnormal operating conditions. The implemented fault diagnostics mechanism helps in early detection of electrical faults such as overcurrent and voltage fluctuations, thereby reducing the risk of appliance damage and electrical hazards. Additionally, the system supports efficient energy management by providing insights into power usage patterns and enabling optimized appliance operation [16]. Overall, the proposed system is cost-effective, scalable, and suitable for modern smart home environments. It demonstrates how IoT-based technologies can be effectively utilized to improve convenience, safety, and sustainability in residential applications, while also providing a strong foundation for future enhancements and intelligent automation [15].

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