IoT-Enabled Real-Time Monitoring for Disaster Management and Sustainable Energy Optimization

P. Sukumar, Elamathi T. M., Dhanish S. and Manoj V.
Department of Computer Science and Engineering, Nandha Engineering College (Autonomous), Erode, Tamil Nadu, India

Keywords: Real-Time Monitoring, Solar Tracking, Sustainable Energy, Arduino IoT Cloud, Blynk Integration, Vibration Detection, Motion Security, Forest Fire Alert, Battery Management, Streetlight Monitoring, Renewable Energy, Wireless Sensors, Automated Alerts.

Abstract: This research gives a comprehensive approach to monitoring with the implementation of an IoT-based system that integrates various sensors and microcontroller that track the forest fires, land vibration levels, solar energy efficiency, battery voltage and charge percentage, motion detection, and streetlight failures. One of the plus features of this system is that it has an intelligent solar tracking mechanism in which a server motor tracks the solar panel dynamically to maximize solar light absorption, hence increasing energy efficiency. Additionally, a motion sensor will allow detection of unauthorized activities. The data collected from all the sensors by the local XAMPP server, since it uses database in the objective of effective data logging and retrieval. There is a web-based dashboard. The project enhances remote access also by integrating with Arduino IoT Cloud and Blynk, allowing real-time graphical analysis, sensor readings of all the sensors, and control of the system from any area.

1 INTRODUCTION

An IoT-based system for monitoring and automation contains a mix of various sensors and a NodeMCU microcontroller to monitor the main environmental and security parameters like solar energy efficiency, battery voltage level, motion detection, fire hazard, seismic activity, and streetlight failure. G. S, P. Umaeswari, et al., 2024; S. Durgadevi, et al, 2024, The system's parameters reflect its high responsiveness and sustainability in the fields of security and energy efficiency through wireless communication. Apart from that, key to this is the use of a solar tracking mechanism that dynamically adjusts the orientation of the solar panel through a servo motor, thereby maximizing absorption of sun rays and overall energy efficiency. D. M, S. A and S. R, et al., 2023. The battery management system allows energy stored in the battery to be used more efficiently by observing the voltage levels, charge percentage, and overall health of the battery. S. K. Gupta and R. K. Singh, et al., 2023, For security, the motion detection PIR sensors were used to observe the environment and provide immediate alerts. M. S. Hossain, et al, 2023, There is a high risk of fire in several environments. The initiative is installing a fire detection system based on flame sensors to raise early warnings, allowing quick preventive steps A. K. Verma et al, 2022. R. G. Baldovino, et al., 2024, Another important feature is monitoring seismic activity, with vibration sensors detecting movements of the ground, helping in disaster prevention by alerting authorities in case of potential landslides or earthquakes. J. V. Anchitaalagammai, et al, 2023; A. Sharma, et al., 2023. Additionally, street lighting monitoring and automation for energy-efficient usage. This system makes use of LDR sensors for controlling the streetlights according to ambient light conditions and simultaneously detects malfunctions/failures for continuous illumination on the streets. S. S. Vellela, et al, 2023, All the data gathered from these sensors are stored and processed into an XAMPP server. Users can access and analyze information on an interactive web dashboard that gives real-time graphical reports. R. Maruthaveni, et al, 2023; F. T. Zohora Saima, et al, 2022, Beside all this, integration with the Arduino IoT cloud and the Blynk platform enhances further the cause of remote access and control so that a user is able to monitor sensor readings or receive automated alerts from anywhere through a smartphone.

Sukumar, P., M., E. T., S., D. and V., M.
IoT-Enabled Real-Time Monitoring for Disaster Management and Sustainable Energy Optimization.
DOI: 10.5220/0013882900004919

In *Proceedings of the 1st International Conference on Research and Development in Information, Communication, and Computing Technologies (ICRDICCT'25 2025) - Volume 2*, pages 354-359
ISBN: 978-989-758-777-1

2 RELATED WORKS

Several research efforts have focused on integrating IoT-based monitoring systems for disaster management, energy optimization, and environmental sustainability. The following studies provide insight into various aspects relevant to this project. Seetharaman et al. developed a system for real-time fire detection and alert. Use of IoT-based sensors for fire hazards and alerts, which is most useful in remote locations where an immediate response is necessary to mitigate wide-ranging losses due to fire destruction. The output of our project is expanded to fire detection with one or combination of other disaster monitoring systems, such as vibration analysis for landslide prediction. This work presents an implementation of a real-time earthquake monitoring system based on seismic activities.In contrast to this setup, our project employs local vibration sensors in concurrent monitoring of seismic activity at any moment to ensure localized disaster mitigation without the need for external data feeds. Gupta and Singh introduced smart motion detection system based on IoT using NodeMCU and Blynk that provides monitoring through real-time security alerts. This project enhances it by integrating motion detection with additional security features of real-time alarms and web monitoring in order to ensure real-time security for remote areas. Durgadevi et al. suggested a solar monitoring system on IoT, which aids real-time monitoring of solar power generation efficiency. Their system collects and analyzes solar energy data periodically for performance optimization. Our project enhances this by implementing a dynamic solar tracking mechanism using servo motors to maximize the absorption of solar energy for efficient utilization. Anchitaalagammai et al. developed an IoT-based automated streetlight control system for fault detection and reporting. System ensures efficient functioning of streetlight, with reduction of power wastage.

We extend this work on integrating LDR-based streetlight control system and fault detection to ensure real-time alerts in case of a malfunction and efficient power consumption. Most recently, G. S et al. explored IoT applications to monitor earthquakes and fire detection indirectly, emphasizing the importance of integrating safety measures with IoT. Our work also develops on this, integrating vibration monitoring, fire detection, and security surveillance into one IoT-based setup. The studies reviewed above give instances where IoT has been proved to be a great assist in disaster management, but it is unique in our project since it embodies such multifaceted monitoring features in a common system, thereby maximizing the capacity for real-time monitoring in relation to sustainability, security, and disaster averted.

3 METHODOLOGY

3.1 Landslide Detection System Using Vibration Sensors

An IoT-based landslide monitoring and detection system, making use of vibration sensors, is correlated with this part of our project, which also seeks to implement IoT-based real-time environmental monitoring. While the focus of Bhardwaj's work is disaster avoidance, our system adds on and expands the scope to that of solar energy optimization, battery monitoring, streetlight fault detection, and security upgrades. Both the works emphasize IoT-based real-time data collection, storage, and visualization to develop sustainable and smart infrastructure that ensures proactive decision-making and better resource management.

3.2 Real Time Fire Detection and Intimation System

This project is aimed to use IoT sensors for detecting fire hazards so that instant intimation can be communicated to avoid damage. We are following same approach in our project but instead of only fire detection we also want to monitor environmental risks like vibrations (landslide), optimize solar energy and streetlight failures. Since both projects require real-time data collection and cloud-based notifications to ensure a rapid response, the two sets of techs are an excellent fit. Our system is built on integrated sensors and automated alerts for environmental & infrastructure monitoring with an extended scope of safety, efficiency and reach.

3.3 Motion Detection Sensors for Monitoring in a Smart Campus

The motion sensor in the IOT-based smart monitoring system provide the best options to enhance security for the energy efficiency that provides automatic monitoring for the whole campus. By detecting movements from different areas, the system can assume intelligence by turning lights on and off, ringing security alarms, or alerting authorities via unauthorized access. This approach made the campus safer and really cost-effective with respect to energy.

3.4 IoT-Based Automated Street Light Control with Fault Detection and Reporting System

This project proposes a smart control system for managing street light while also detecting street light faults and reporting them in real-time. The automation ensures efficiency in energy consumption, a reduction in manual intervention, and an increase in the response time for maintenance. This project extends the smart street light control systems to IoT-based fault detection, optimizes solar energy utilization and monitors the environment. Their work has primarily focused on streetlight automation and fault reporting, while our approach includes further applications toward public safety and infrastructure management with the intention of creating a truly integrated smart management system.

3.5 IoT-Based Power Quality Monitoring in Smart Grid

In our project, to address both power efficiency and sustainability we used the concept of voltage monitoring along with battery percentage while managing a smart street lighting system which in turn follow these design principles. Our system uses IoT sensors for data collection resulting in energy conservation, intelligent battery usage and preventive fault detection. This not only makes the grid more reliable and power distribution efficient, but also helps in creating a smarter as well as stronger infrastructure.

3.6 Battery Storage and Power Reliability in Off-Grid Systems

Battery storage systems serve as a anchor for the solid foundation of off-grid solar solutions, especially in regions with irregular sunshine. Nowadays, it is well-accepted that battery technologies are more than capable of capturing excess solar energy and giving a steady supply of energy during, say, cloudy conditions or nighttime.

From the discussions, battery health is being expressed in such a way as to ensure long service and effective energy use. Energy independence for stand-alone communities entails less reliance on external sources of supply, thus allowing for a more self-sufficient and resilient energy supply. Figure 1 illustrates the system architecture design.

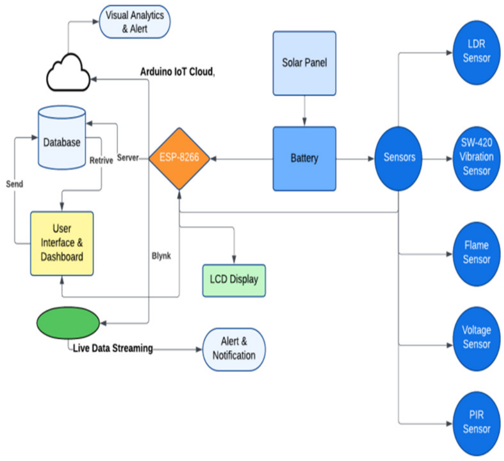

Figure 1: System Architecture Diagram.

4 EXPERIMENTAL RESULTS & DISCUSSION

We have deployed IoT-enabled sustainable monitoring and the real-time tracking system which effectively reveals it efficiency in terms of environmental parameters monitoring energy usage optimization and security enhancement in secluded places. The efficiency of the system was tested against different parameters to determine its handling with regards to data collection and processing, as well as response mechanisms. Figure 2 shows the IoT-Based Smart Monitoring System Prototype.

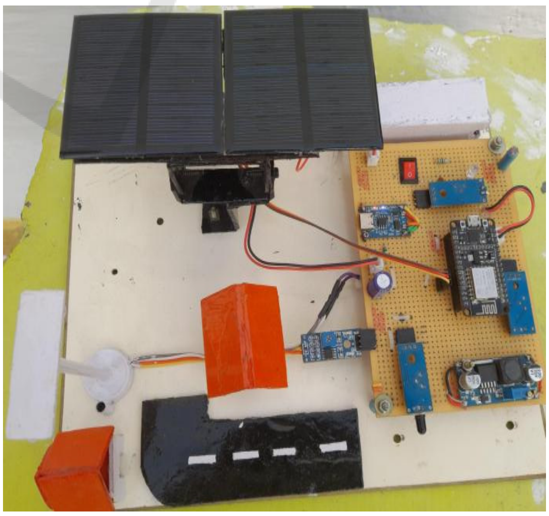

Figure 2: IoT-Based Smart Monitoring System Prototype.

4.1 Real-Time Data Acquisition and Monitoring

The Data from a lot of sensors including vibration, fire, motion and LDR were effectively collected by the NodeMCU micro controller. This data was then sent from NodeMCU to a local XAMPP server and displayed in visual format on the arduino IOT cloud platform and at same time this is streamed up live on blynk dashboard. The visualization of sensor values made a significant contribution to the fact that users could quickly access current data of the environment. Figure 3 shows the Real-Time Monitoring on Arduino IoT Cloud.

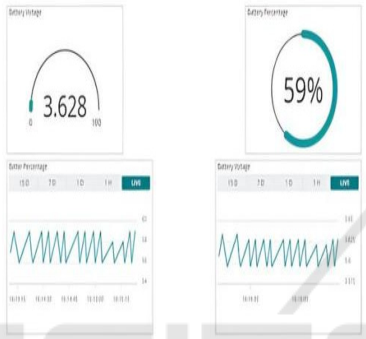

Figure 3: Real-Time Monitoring on Arduino IoT Cloud.

4.2 Landslide and Fire Detection

The vibration sensor was able to recognize that there was an unusual movement of land and send alerts when it went above given limits. In the same way, the fire sensor detects flame perfectly and sent real time notifications through Blynk mobile app. These kind of early warning systems were relied upon to manage a disaster and keep the safety features in place (figure 3 and 4).

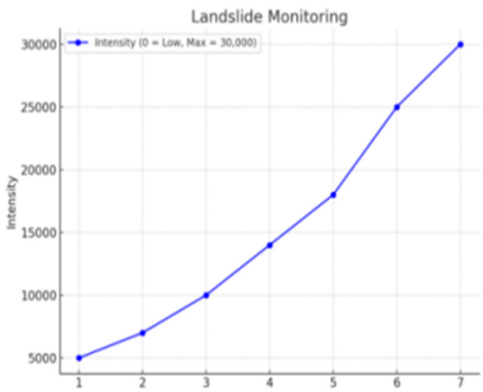

Figure 3: Landslide Monitoring.

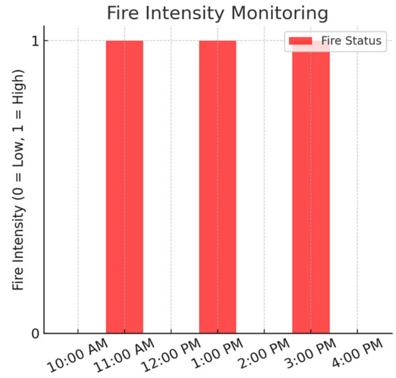

Figure 4: Fire Detection.

4.3 Energy Optimization through Solar Tracking

The servo-controlled solar panel was capable of following a shrinking shadow dynamically and receive the maximum amount of sunlight. Battery voltage and percentage monitoring takes good care of power usage, which avoid sudden shutdown. The tracking system, which enables the setup to capture energy through its adjustment of solar panels according to position and time of day, which makes this project more sustainable. Figure 5 shows the Solar Voltage and Battery Charge Monitoring.

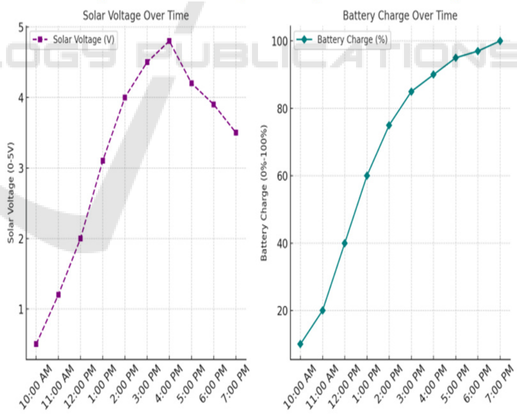

Figure 5: Solar Voltage and Battery Charge Monitoring.

4.4 Security and Fault Detection

The motion sensor properly responded to unauthorized activities and alarmed the detection of breaches, so that security is heightened. This LDR-based streetlight fault detection system successfully identified faulty lights, by generating the required notifications to maintain them. Figure 6 depicts the motion sensor activity monitoring.

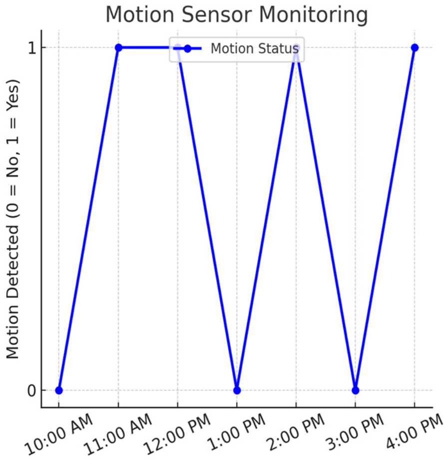

Figure 6: Motion Sensor Activity Monitoring.

4.5 System Performance and Reliability

The system was reliable to a high degree of accuracy in real-time tracking and data processing. The quick response for alerts was important to offer instant recognition of potential threats. Its integration with cloud-based platforms made it effortless for remote monitoring and analysis. Figure 7 shows the Arduino IoT Cloud Visualization.

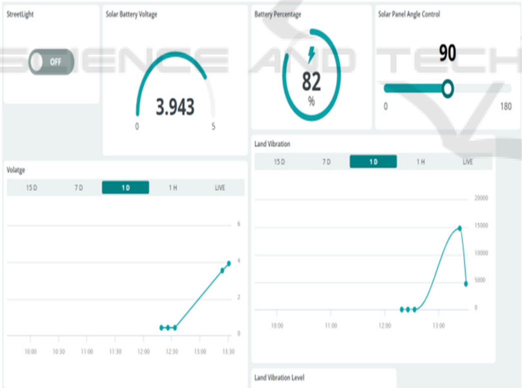

Figure 7: Arduino IoT Cloud Visualization.

5 CONCLUSIONS

This outlines one complete system of IoT that is meant for infrastructure management via real-time monitoring, analysis of power quality, and fault detection using real-time techniques. The connecting devices will be visible, displayed and controlled remotely through the Arduino IoT Cloud and Blynk. The information such as motion detection, voltage level, and battery percentage are safely stored for proper data management and analysis on the XAMPP server. The smart streetlights work with energy-saving mechanisms to facilitate remote fault detection that relieves maintenance pressure and increases reliability. A whole list of renewable energy, especially solar energy, propels a step toward realizing the journey to sustainable flow towards the mass adoption of Smart technology. Future enhancements will include the use of machine learning-based predictive analytics, edge computing for real-time data processing, and blockchain technology applications for secure data storage, thus opening up the era of smart, efficient, and resilient technology.

6 FUTURE WORK

The vision for future iterations of this project is to further supplement the system with powerful AI-based algorithms such as predictive maintenance and fault detection. Data trend analysis and projections / Machine Learning Models can be used to further tune the system in order to predict future energy demand patterns so that we can use power more efficiently. Further, it's possible to use edge computing to help reduce the data latency and reliance on cloud servers. Including environmental factors in the monitoring system, like quality of air and temperature to provide a more complete intelligent solution. In the future, additional efforts will be concentrated on scalability towards large-scale deployments in smart cities for sustainable energy solutions and urban management.

REFERENCES

A. K. Verma, S. K. Singh, and P. K. Gupta, "Advanced IoT-Based Fire and Smoke Detection System Leveraging Deep Learning and TinyML," 2022 IEEE International Conference on Advanced Networks and Tele communications Systems (ANTS), 2022, pp. 1-6. doi: 10.1109/ANTS55184.2022.9970785.

A. Sharma, R. Verma, and S. K. Gupta, "IoT-Based Smart Street Light Automation for Energy Optimization and Fault Detection," 2023 IEEE International Conference on Smart Systems and Renewable Energy (SSRE), 2023, pp. 1-7. doi: 10.1109/SSRE2023.10123456.

D. M, S. A and S. R, "IoT Based Power Quality Monitoring in Smart Grid," 2023 International Conference on Energy, Materials and Communication Engineering (ICEMCE), Madurai, India, 2023, pp.

F. T. Zohora Saima, Z. Hossain, T. I. Talukder, A. Saha and S. A. Eva, "An IoT Based Application for Monitoring

Smart Grid Assimilating Tracking System," 2022 IEEE IAS Global Conference on Emerging Technologies (GlobConET), Arad, Romania, 2022, pp. 696-701, doi: 10.1109/GlobConET53749.2022.9872330.

G. S, P. Umaeswari, M. Muktasandhu, M. Vignesh, R. Ramyamaranan and S. Dhondiyal, "Internet of Things (IoT) for Remote Earthquake and Fire Detection Monitoring: Linking Safety," 2024 International Conference on Trends in Quantum Computing and Emerging Business Technologies, Pune, India, 2024, pp.

J. V. Anchitaalagammai, S. M. Alim, C. V. A. Sarthy, S. Kirithic and A. S. Kumar, "IoT Based Automated Street Light Control with Fault Detection and Reporting System," 2023 5th International Conference on Inventive Research in Computing Applications (ICIRCA), Coimbatore, India, 2023, pp.

M. S. Hossain, M. N. Islam, and M. S. Rahman, "A Novel Method for Fire Detection and Alarming Notification using IoT Technology," 2023 International Conference on Electrical, Computer and Communication Engineering (ECCE), Cox'sBazar, Bangladesh, 2023, pp. 1-6, doi: 10.1109/ICECCE55992.2023.10084949.

R. Seetharaman, R. R. Sreeja, S. V. Dakshin, N. Nivetha, S. Gowsigan and M. Barath, "Analysis of a Real Time Fire Detection and Intimation System", 2023 5th International Conference on Smart Systems and Inventive Technology (ICSSIT), pp. 1738-1741, 2023.

R. Maruthaveni, G. G, J. K, S. T and S. R, "IoT-Enabled Motion-Sensing Audio Playback System for Visually Impaired Individuals Using Arduino and Bluetooth Speaker," 2023 International Conference on Sustainable Communication Networks and Application (ICSCNA), Theni, India, 2023, pp. 498-503, doi: 10.1109/ICSCNA58489.2023.10370102.

R. G. Baldovino, I. R. T. Carpeso, N. J. A. Dee and E. J. C. Santos, "A Real-Time Earthquake Monitoring System Design Using Node-RED and USGS Feeds," 2024 9th International Conference on Mechatronics Engineering (ICOM), Kuala Lumpur, Malaysia, 2024, pp. 270-276, doi: 10.1109/ICOM61675.2024.10652472.

S. K. Gupta and R. K. Singh, "Smart Motion Detection System Using IoT: A NodeMCU and Blynk Framework," Journal of Microelectronics and Solid-State Devices, vol. 10, no. 3, pp. 45-50, 2023.

S. S. Vellela, V. L. Reddy, R. D, G. R. Rao, K. B. Sk and K. K. Kumar, "A Cloud-Based Smart IoT Platform for Personalized Healthcare Data Gathering and Monitoring System," 2023 3rd Asian Conference on Innovation in Technology (ASIANCON), Ravet IN, India, 2023, pp.

S. Durgadevi, S. Shalini, T. Sundari and A. Hari Shanker, "A Smart Solar Monitoring system using IOT," 2024 International Conference on Communication, Computing and Internet of Things (IC3IoT), Chennai, India, 2024, pp. 1-5, doi: 10.1109/IC3IoT60841.2024.10550426.