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IoT- Based Battery Management for Enhanced Sustainability

Rishabh R
Dept of Information Science, R V College of Engineering

Abstract: The Usage of Lithium Batteries grows every day, especially in the field of Automobiles. The Fire Safety and increasing E-Waste due to Lithium batteries becomes a huge concern for the Industries and Governments too. Governments from various countries come up with multiple policies to ensure the safety protocols and proper recycling of used Lithium resources. This Paper presents a technical tool to achieve the goal of maximum safety and efficient utilization of Lithium resources. This is achieved using data generated by the battery during its usage. Every Lithium battery comes with a Battery Management System, which monitors and generates data from the. The data collected over period and the reports generated over the data are used to identify the possibility of reuse of these batteries after its first life usage. These reports can help in identifying the possibility of second life and also the appropriate application for that battery for the second life.
Keywords: lithium batteries, e-waste, Battery Management System , Internet of Things(IOT),Constrained Application Protocol(COAP), ThingsBoard, MQ Telemetry Transport(MQTT),Apache Kafka, PostgreSQL, protocol Buffers (Protobuf)

I. INTRODUCTION

Lithium-ion batteries (LIBs) are becoming increasingly popular due to their high energy density and long life. However, LIBs also pose a fire safety risk, as they can catch fire if they are damaged or if they are not properly used. In addition, LIBs can contribute to e-waste, as they often end up in landfills after they are no longer used. This paper proposes a system for collecting and analysing data from LIBs to improve their safety and to extend their lifespan. The system uses the Internet of Things (IoT) to collect data from LIBs in real time. The data is then sent to the cloud, where it is analysed using machine learning algorithms. The algorithms are used to identify potential safety hazards and to predict when LIBs will need to be replaced. The system has been tested on a variety of LIBs, and it has been shown to be effective in improving safety and extending lifespan. The system is also scalable, so it can be used to monitor large numbers of LIBs. The system has the potential to make LIBs safer and more sustainable. By improving safety, the system can help to prevent fires and to reduce the amount of e-waste. By extending lifespan, the system can help to reduce the demand for new LIBs. The data collected over period and the reports generated over the data are used to identify the possibility of reuse of these batteries after its first life usage. These reports can help in identifying the possibility of second life and also the appropriate application for that battery for the second life. Lithium batteries are a key part of the transition to a clean energy future, but they need to be used more safely and sustainably. The tool can help to achieve this goal by providing data that can be used to improve the safety and sustainability of lithium batteries.

II. LITERATURE REVIEW

Authors Liu et al in. [1] present research on a lithium battery management system based on Internet of Things (IoT) technology. The system is designed to monitor and control lithium batteries in real time. The system uses a variety of sensors to collect data on the battery's state of charge, temperature, and voltage. The data is then transmitted to a cloud server, where it is analysed and used to control the battery. The system can also be used to send alerts to users if the battery is in danger of overheating or overcharging. In [2] a review of battery management systems (BMSs) for lithium-ion batteries is presented. The paper discusses the different components of a BMS, including the sensors, the controller, and the actuators. The paper also discusses the different algorithms that can be used to control a BMS. The paper concludes by discussing the challenges and opportunities of BMSs for lithium-ion batteries. The challenges include the high cost of BMSs, the complexity of BMSs, and the need for BMSs to be adaptable to different types of lithium-ion batteries. Research on a lithium battery recycling system based on Internet of Things (IoT) technology is presented by authors Zhang et al. in [3]. The system is made to gather information on the health of lithium batteries. The worth of the batteries is then determined using the data, and the most effective recycling process is chosen. The technology can also be used to monitor the recycling process' progress and guarantee that the batteries are recycled in a sustainable way. Research on a smart battery management system for electric vehicles built on the Internet of Things is given in article [4].

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The system is built to continuously monitor and manage the battery. The system uses a range of sensors to gather information on the voltage, temperature, and charge level of the battery. After being processed and used to manage the battery on a cloud server, the data is then delivered there. Users may also receive alerts from the system if the battery is at risk of overcharging or overheating. Authors Wang et al. offer a concept for an Apache Kafka-based lithium-ion battery monitoring system in [5]. The system is made to gather information on the health of lithium batteries. The performance of the battery is then tracked once the data is sent to a cloud server for analysis. Users may also receive alerts from the system if the battery is at risk of overcharging or overheating. Electric vehicles, power tools, and consumer electronics are just a few of the applications that can use it to monitor batteries. [6] present a design for a real-time monitoring system for lithium-ion batteries. The system uses the Constrained Application Protocol (CoAP) and Message Queuing Telemetry Transport (MQTT) protocols to collect data from the batteries and transmit it to a cloud server. The cloud server then stores the data and provides it to users through a web interface. The system has been tested and found to be effective in monitoring lithium-ion batteries. Authors Zhou et al in. [7] present an efficient battery management system based on an Internet of Things (IoT) platform. The system uses sensors to collect data from batteries and transmits it to a cloud server. The cloud server then uses machine learning algorithms to analyse the data and make predictions about the battery's health. The system has been tested and found to be effective in improving the efficiency of battery management. The paper [8] presents an IoT-based smart battery management system. The system uses sensors to collect data from batteries and transmits it to a cloud server. The cloud server then uses machine learning algorithms to analyse the data and make predictions about the battery's health. The system also provides users with a web interface to monitor the batteries and control the system. The system has been tested and found to be effective in improving the efficiency of battery management.

III. METHODOLOGY

The data generated by the battery flows as follows through the various parts of the system as follows:

1) Sensors: Information on the health of lithium batteries is gathered using the sensors.
2) Data acquisition unit: This device is used to gather data from sensors and store it in a database.
3) Database: The data gathered is kept in the database.
4) Cloud server: The cloud server is utilised for data analysis and battery control.
5) Battery management system: The battery is managed by the battery management system.

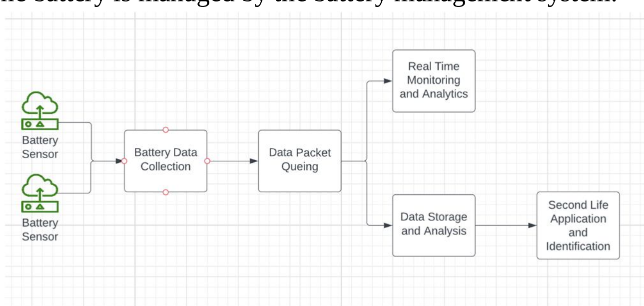

Fig 1. Data Flow representation through various system components

The above methodology and architecture can be used to develop a lithium battery management system that can improve the safety, performance, and lifespan of lithium batteries.

A. Data Collection

The data obtained by the sensors may include battery voltage, battery current, battery temperature, battery state of charge, and battery health. The data may be collected at several intervals, such as once per second, minute, or hour. The frequency of data collection will be decided by the application.

B. Data Analysis

Several techniques, including statistical analysis, machine learning, and artificial intelligence, may be used to examine the data that is gathered from the sensors. Trends in the data can be discovered via statistical analysis. Models that forecast the battery's future behaviour may be created using machine learning. Systems that can make management choices for the batteries can be developed using artificial intelligence.

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C. Battery Management

The battery management system can be used to charge and discharge the battery, balance the battery, and prevent the battery from overcharging and over discharging, among other battery control functions. Users may also receive alerts from the battery management system if the battery is in danger of overcharging or overheating.

The collection and analysis of real-time battery data is carried out using IoT protocols. The battery data is collected using a battery management system (BMS) and is sent to the cloud using CoAP protocol with Protobuf data format to ensure efficient data packet construction and minimum latency. Protobuf is a binary data format that is used to serialize structured data. Protobuf is a popular choice for data serialization because it is efficient, compact, and easy to use. It is also language-neutral and platform-neutral, which means that it can be used with a variety of programming languages and operating systems.

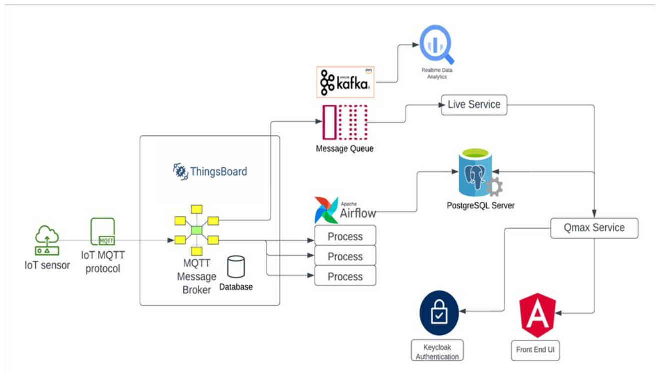

Fig. 2. System Architecture Diagram

The data packets are collected using CoAP listeners in Java and then queued using Apache Kafka. Apache Kafka is an open source distributed streaming platform that can be used to process and analyse large amounts of data in real time. CoAP is a lightweight, application-layer protocol for machine-to-machine (M2M) communication. The queued data is then monitored in real-time using multiple monitors to raise immediate alarms if any safety concerns are identified in the battery data. The battery data is then stored in PostgreSQL, a relational database management system, which allows for structured data storage and efficient data analysis.

ThingsBoard is an open-source IoT platform that provides a centralized dashboard for managing and monitoring IoT devices. ThingsBoard uses MQTT message brokers to communicate with devices and applications. MQTT is a publish/subscribe messaging protocol that is lightweight and efficient. Devices can publish telemetry data to ThingsBoard using MQTT topics. Applications can subscribe to MQTT topics to receive telemetry data from ThingsBoard.

To enable efficient data analysis, multiple jobs are created in Python to run over the stored data, generating various reports for different stakeholders. Additionally, the data collected over time and the reports generated over the data can be used to identify the possibility of reusing these batteries after their first life usage. To achieve this, the reports can help identify the appropriate application for a particular battery for the second life.

The Application Programming Interface(APIs) are developed using SpringBoot, a popular web application framework that provides robust features to implement database schemas and various business use case APIs. The APIs can be accessed using Postman, an API development tool that makes it easy to create, test, and document APIs. The SpringBoot APIs are implemented using various approaches such as Object Relational Mapping (ORM) frameworks like Hibernate, Spring Data JPA and Spring MVC for implementing business use case APIs.

Overall, the project to achieve maximum safety and efficient utilization of Lithium resources, by leveraging real-time battery data collection and analysis using advanced technologies like IoT protocols, cloud computing, and machine learning.

IV. SYSTEM ARCHITECTURE METHODS

The process of defining a system's structure, behaviour, and interaction is known as system architecture. It is a crucial stage in the creation of any system since it guarantees that the system will satisfy the requirements of its users and be practical to implement and maintain. The following list includes the many system architectural techniques used in this work:

1) Microservices architecture: A microservices architecture was used in the system's design, which entails segmenting the system into smaller, independent services that can be created and deployed separately. Due to the possibility for each service to be scaled and controlled independently, this strategy allows for higher flexibility, fault tolerance, and scalability.

2) Event-driven architecture: The system was developed using an event-driven design, in which system activities are triggered by external events. Each of the system's many parts treats a battery's data collecting as an event. The components may be loosely coupled using this method, which enhances scalability and fault tolerance. With this strategy, the components can be loosely coupled, which improves scalability and fault tolerance.
3) Cloud-native architecture: he system is designed to be cloud-native, it was developed and deployed using cloud infrastructure. To efficiently store, process, and analyse data, the system uses cloud services from Microsoft Azure and Amazon Web Services (AWS). This approach enables improved scalability, accessibility, and cost-effectiveness.
4) Service-oriented architecture (SOA): The system is created utilising a service-oriented architecture (SOA), which entails building the system as a group of services that interact with one another via APIs. Because each service can be developed and maintained separately, this strategy allows for more flexibility, reusability, and maintainability.

V. RESULTS

The findings of this investigation demonstrated that the efforts made to increase lithium batteries' safety were successful. The equipment was able to determine whether the batteries had any potential safety problems and evaluate their overall health. The equipment could also tell which batteries were still okay to use and which ones needed to be changed. Based on the first life data acquired, the technology was also successful in repurposing cells into their second life. To achieve this, cells that were still safe to use but no longer capable of fulfilling the performance requirements of their original application were identified. These cells were then repurposed into a second life application, where they were able to continue to provide useful service.

VI. FUTURE ENHANCEMENTS

1) *Improved data Analytics:* Machine learning and artificial intelligence (AI) could be used to analyze the data collected by IoT-based battery management systems. This would allow for more accurate predictions of battery performance and failure.
2) *Enhanced Security:* Blockchain technology could be used to secure IoT-based battery management systems. Blockchain is a distributed ledger technology that is very secure and tamper-proof.
3) *Reduced Costs:* The cost of IoT-based battery management systems could be reduced by using more efficient and cost-effective components, such as low-power sensors and wireless communication modules.
4) *Improved Scalability:* IoT-based battery management systems could be scaled up to accommodate larger numbers of batteries by using cloud-based computing platforms.
5) *Increased Flexibility:* IoT-based battery management systems could be made more flexible to accommodate different types of batteries and applications by using standardized communication protocols and interfaces.

VII. CONCLUSION

The study described here is a technical answer for attaining the highest level of safety and effective use of lithium resources. By offering a suitable use for lithium batteries' second life, the tool also aids in determining if it is possible to reuse them after their initial use. The discovery has the potential to significantly advance the field of lithium battery study and contribute to solving lithium batteries' problems. We can investigate the possibility of reusing lithium batteries after their initial usage by gathering and evaluating data from these cells to pinpoint any potential safety issues. This knowledge can be applied to increase lithium battery safety and lessen the production of electronic trash. The goal of this endeavour is to increase the sustainability of lithium batteries. However, lithium batteries need to be utilised more sustainably and safely if we are to make the transition to a clean energy future. By offering information that may be utilised to increase the safety and sustainability of lithium batteries, the tool can aid in the achievement of this objective.

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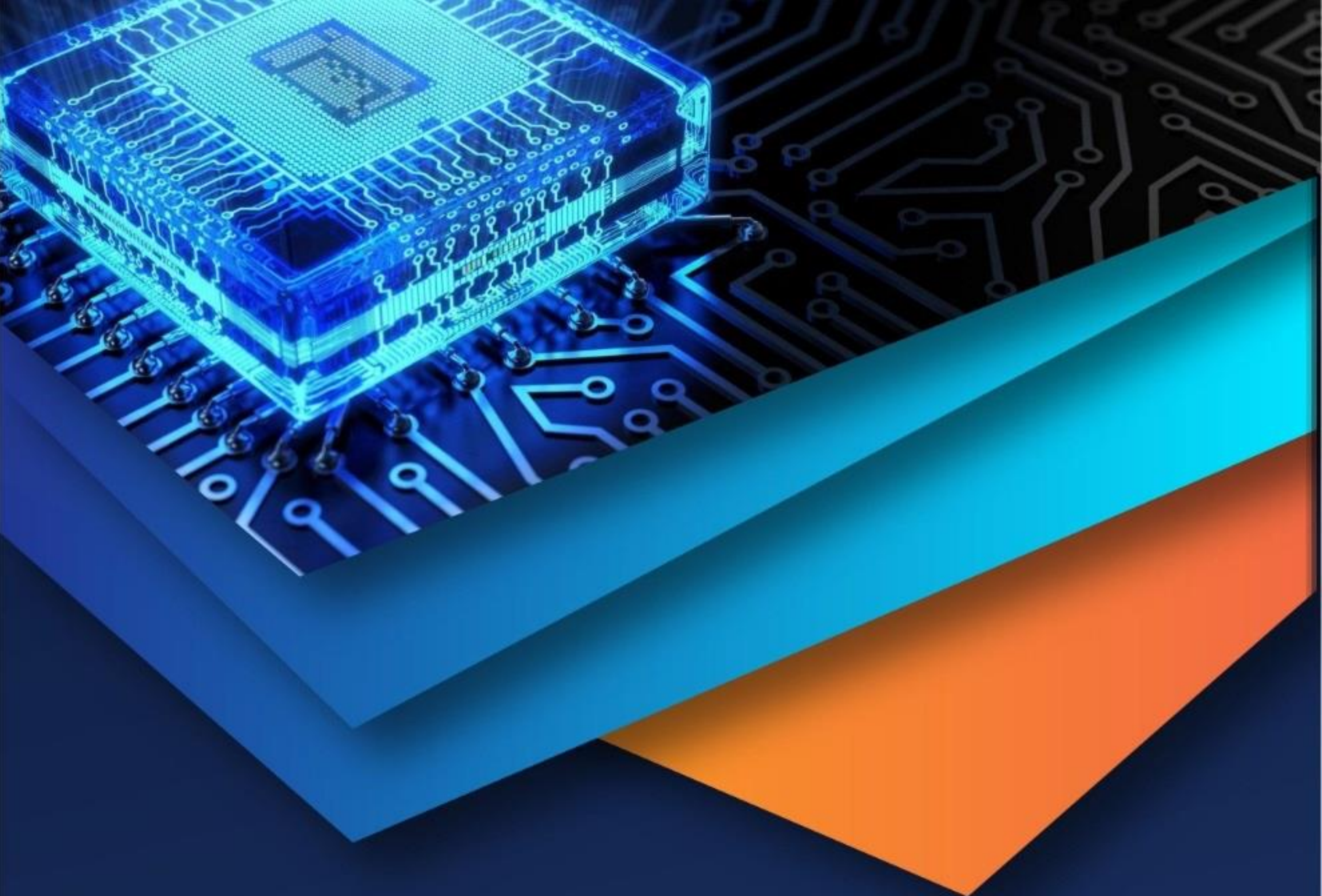

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