BATTERY MANAGEMENT SYSTEM

A PROJECT REPORT

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Under the guidance of,

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in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

COMPUTER SCIENCE AND ENGINEERING, INTERNET OF THINGS

At

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

PRESIDENCY UNIVERSITY

BENGALURU

JANUARY 2025

CERTIFICATE

This is to certify that the Project report **"Battery Management System"** being submitted by **"Tummasi Jashwanth, Monish Kumar V, Reddy Manoj, M Sandeep, Pruthvi R Patel"** bearing roll number(s) **"20211CIT0018, 20211CIT0063, 20211CIT0071, 20211CIT0165, 20211CIT0176"** in partial fulfillment of the requirement for the award of the degree of Bachelor of Technology in Computer Science and Engineering is a bonafide work carried out under my supervision.

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DECLARATION

We hereby declare that the work, which is being presented in the project report entitled **Battery Management System** in partial fulfillment for the award of Degree of **Bachelor of Technology** in **Computer Science and Engineering**, is a record of our own investigations carried under the guidance of **Dr.SHARMASTH VALI Y, Associate Professor, School of Computer Science and Engineering , Presidency University, Bengaluru.**

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ABSTRACT

Battery management is key to ensuring device longevity and optimization. This project discusses the development of a Battery Management App using React Native, a popular framework for developing cross-platform mobile applications. As dependence on electronic devices on the rise, proper battery monitoring and management have become vital to maintain a device's performance and prolong battery life. The app aims to monitor and showcase important battery parameters like current battery status, charging status, temperature, and overall battery health. Such features are intended to aid users in understanding the battery status of their devices and guaranteeing that the necessary precautions are taken to maintain its health. Using the power of React Native, the app will ensure consistent performance on both Android and iOS platforms, bringing it within reach of a wider audience. One of the app's key features is its capability to switch off the charger once the battery is charged to 100%. Overcharging is a widespread problem with its organizers resulting in battery overheating, reduced capacity, and even safety issues. This functionality not only adds to user conveniences but also promotes battery safety by overcoming potential dangers associated with overcharging. Additionally, the app comes with an overheating detection and alert system. Such a feature is essential to prevent battery failure and guarantee the safety of users, especially in high-temperature environments or under intense usage circumstances. To further improve the user experience, the app provides real-time notifications if it detects any battery degradation. This option allows users to take immediate actions like choosing to change the battery or altering their usage habits to restore the optimum performance of their devices. The app's proactive battery management reflects its intent to elevate the user experience as well as promote device safety. In conclusion, the project showcases how a potential app can combat common battery management issues. By incorporating advanced monitoring capabilities, automated functions, and real-time notifications, the Battery Management App provides a complete method to maintain battery health and achieve device longevity. The adoption of React Native for the development ensures a smooth and effective implementation across different platforms, consequently making the app an essential utility for users of modern mobile devices.

ACKNOWLEDGEMENT

First of all, we indebted to the **GOD ALMIGHTY** for giving me an opportunity to excel in our efforts to complete this project on time.

We express our sincere thanks to our respected dean **Dr. Md. Sameeruddin Khan**, Pro-VC, School of Engineering and Dean, School of Computer Science Engineering & Information Science, Presidency University for getting us permission to undergo the project.

We express our heartfelt gratitude to our beloved Associate Deans **Dr. Shakkeera L and Dr. Mydhili Nair,** School of Computer Science Engineering & Information Science, Presidency University, and **Dr.Anandraj S P**,Head of the Department, School of Computer Science Engineering & Information Science, Presidency University, for rendering timely help in completing this project successfully.

We are greatly indebted to our guide **Dr.Sharmasth Vali Y** and Reviewer **Mr.Sakthivel E,** Assistant professor School of Computer Science Engineering & Information Science, Presidency University for his inspirational guidance, and valuable suggestions and for providing us a chance to express our technical capabilities in every respect for the completion of the project work.

We would like to convey our gratitude and heartfelt thanks to the PIP2001 Capstone Project Coordinators **Dr. Sampath A K, Dr. Abdul Khadar A and Mr. Md Zia Ur Rahman,** department Project Coordinators **Dr.Sharmasth Vali Y** and Git hub coordinator **Mr. Muthuraj.**

We thank our family and friends for the strong support and inspiration they have provided us in bringing out this project.

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CHAPTER-1
INTRODUCTION

1.1 General

Modern electronic devices are dependent on batteries, making battery management a crucial aspect of today's tech-driven society. Batteries are the foundation of portable electronics—smartphones, tablets, laptops, and even wearables—but their efficiency and longevity are highly determined by their treatment and management. Overcharging, heating up, and performance decline are possible concerns that, if not dealt with, can shorten the lifespan of the battery, endanger device safety, and result in costly replacements. Overcharging refers to the condition of a device being kept on their charger after reaching 100% power, which causes overheating and excess load on the battery cells. Similarly, heating up can occur due to heavy-duty device usage, charging in excessively high-temperature settings, or faults within the battery itself. Conditions like such can degrade a battery as well as lead to user safety risks like exploding or catching fire. Performance decline, on the other hand, is a subtle process in which the battery's ability to store power degrades as time passes, leading to less overall runtime for the device. In light of these possibilities, there is a need for an efficient and user-friendly solution for overseeing and managing battery condition. The app presented for this purpose is a Battery Management App that carries out such tasks and more through monitored parameters like percentage, charging status, temperature, and the battery overall health. Leveraging React Native capabilities, the app offers a quality UX on both Android and iOS platforms, making the application a universal and accessible solution for a diverse set of users. React Native is also a feasible framework for this project due to its cross-platform ability and powerful library ecosystem. Developers are able to use the framework to write one codebase for multiple platforms, which preserves their time and effort spent on development. In addition, React Native's ability to bridge with native modules permits access to device-specific battery information and metrics, leading to accurate and dependable monitoring. The app does not stop at just monitoring, however. For example, a smart charger disconnection system intelligently stops the charging process when the battery itself is fully charged. Not only does this prevent overcharging, but it also saves energy. Also provided is an overheating alert system that warns users when the battery temperature exceeds secure levels, advising immediate action. An analysis of historical battery data also allows the app to detect performance decline patterns and alert the users when the battery health descays as well, enabling informed user actions about maintenance or replacements. The battery lifecycle is a major concern when talking about battery safety and longevity. Figure 1 shows the lifecycle of the battery in days depending on the maximum DoD (depth of discharge) that the battery has experienced.

When a battery is deeply discharged, the energy inside the battery should not leave the battery unattended for many days. The user's battery cycle life will begin to age depending upon this value. In Figure 1, we can assume that the user's cycle life will start to degrade after 105 days if the user's depth of discharge per cycle is, on average, 90% of the total energy inside the battery.

This also applies to average daily usage; if the user is releasing deep cycles daily using more than 90% of their battery energy, the maximum cycle life will start to degrade in about 105 days. The user's battery performance will decrease over time depending on the rate of deep discharge per cycle. If, for example, the user's battery is deep cycled approximately 90% each day, the range of the cycle life degradation will start to happen in about 9 months. If the user's battery is deep cycled about 20% range each day on average, then the cycle life will degrade in them in less than 1.5 months. Suppose the user's depth of discharge rate is approximately 10% each day on average; in that case, the cycle life will degrade in approximately 7 months. Lookups regarding the battery DoD as well as the cycle life reduction rates of the depth of discharge are essential in these areas.Through the implementation of these solutions for battery management, the application improves device performance and ensures user safety. It provides users with valuable information about their battery's status, which leads to a proactive attitude toward its maintenance. As electronic apparatuses are involved more extensively in daily life, applications such as the Battery Management App are essential to maximizing their efficacy and service life. This project demonstrates how breakthrough software solutions can overcome hardware constraints and provide a tangible, scalable solution to today's problems in battery management.

1.2 Problem Statement

Nowadays, smartphone users frequently encounter battery management challenges such as excessive charging, deep discharging, and thermal issues. These problems not only deteriorate battery health and shorten the lifespan of batteries but also lead to declining performance across devices over time. Even though devices often provide charging indicators, users frequently lack real-time statistics and timely alerts to maintain healthy charging practices. In addition, excessive battery optimization setup of some devices forcefully terminate apps running in the background, leaving users with no option in relying on consistent monitoring and notifications. Devices such as budget and old devices worsen the situation as they do not support smart power management features. There exists a need for a lightweight and user friendly solution which:

- Provides accurate and real time battery data.

- Notifies users on time eliminating overcharging and over discharging.

- Works fine in the background without consuming a lot of power.

- Supports a variety of devices including the ones with limited resources.

The unavailability of such an all-in-one solution makes it harder for users to prolong battery life and keep devices running properly., hence refocusing on the importance of this project.

1.3 Domain Introduction

The realm of this project is centered on the management and optimization of mobile batteries. Management and optimization of mobile batteries is a critical domain of technology as it focuses on extending the battery's health, performance, and lifespan in smartphone devices. The batteries are the lifeblood of portable devices, and their efficiency reflects on the reliability and usability of portable devices. However, some concerns arise from battery depreciation, which occurs due to overcharging, deep discharging, and high-temperature use. Users often lack knowledge and infrastructure to enforce prudent charging habits to slow battery depreciation. Moreover, due to various hardware and operating systems in use, compatibility becomes an issue, especially with underprivileged or older devices, as they are often equipped with limited battery management infrastructure.This area offers the possibility to develop innovative solutions through instantaneous battery oversight, prompt alerts, and low-consumption answers. Sophisticated approaches such as artificial intelligence and predictive analytics are available to enrich the user experience by delivering customized observations and advice.

Efficient battery supervision ultimately improves device trustworthiness and user contentment while reducing battery replacements and electronic junk, thereby supporting sustainability. This project seeks to develop a holistic and user-centric answer that enables users to healthily retain batteries and harness the full capabilities of their devices by overcoming these problems.

CHAPTER-2
LITERATURE SURVEY

2.1 Introduction

Batteries are fundamental components in powering contemporary electronics, including smartphones, laptops, and wearables. Nevertheless, overcharging, excessive heating, and capacity fading pose challenges to their efficiency, safety, and longevity. Such challenges can result in device failures, risks to user safety, and increased maintenance expenditures.A wealth of research has been carried out into battery management, such as real-time monitoring, smart charging, prevention of overcooking, and performance analysis. Moreover, software frameworks have advanced sufficiently to open the door to user-friendly applications targeting those areas.

This survey reviews the body of work on battery management solutions, showcasing innovations and mapping out unknown territories. It lays the foundation to design an extensive Battery Management App to ensure safety, enhance work efficiency, and prolong battery life.

2.2 Related work

Current studies on the mobile battery management system have focused on battery efficiency enhancement level, safety, and longevity level. "Internal data basis of the battery is one of the main components of the mobile type terminal, and the improved approach based on traditional battery management techniques makes the lasting capacity of the battery extended." Different types include: compensating for overlaps, the adjustment of the battery output voltage by reinforcing the load and the booster circuit, thereby improving the efficacy of the power supply. Such methods increase the battery's safety and longevity level, improving the external device's operational form, enhancing the lifespan performance. However, while these techniques make a crucial contribution to improving battery safety and device performance, they introduce increased complexities into the device's overall structure and may carry additional costs. "Sweet spot charging," which uses mobile phone battery minimization methods with minimal power loss and heater adjustment, effectively coping with energy loss that arises from battery heaters and boosting the battery's overall performance. However, these take note of progress on enhancing mobile battery management but also touch upon various challenges such as data-based operations, costs, and increased power consumption, indicating a focus on further improvement direction. Facing these challenges could prove difficult, suggesting a continued need for research for the exploration of practical research direction would be of high value in bringing potential and worthy development opportunities.

2.3 Existing method

Table 2.1: Study of Existing Tools/Methods/Advantages/Limitations

No	Paper title	Method	Advantages	Limitations
[1]	1] DASARI HETHU AVINASH 1 AND A. RAMMOHAN 2 “Integrating Level Shift Anomaly Detection for Fault Diagnosis of Battery Management System for Lithium-Ion Batteries”. 10.1109/ACCESS.2024.3445955	LevelshiftAD for anomaly detection in LIBs. Analyzes temperature data from battery packs. Detects faults during internal short circuits.	LevelshiftAD achieves 97% detection accuracy. Faster and more accurate than Isolation Forest. Prevents serious battery malfunctions.	Real-time data collection complexity. Focuses mainly on temperature-related faults. Requires validation in diverse conditions
[2]	Saehong Park, Scott Moura, Kyoungtae Lee -	Proposed a compact hardware-in-the-loop (HIL) system integrating AI-driven reinforcement learning for	Achieved high-accuracy current control (±10 mA), scalable	Limited scalability for high-power systems,

	Integration of Hardware and Software for Battery HIL Toward Battery AI - IEEE 10.1109/TTE.2023.3270870	real-time battery monitoring and fast charging.	design, and safer fast charging with minimal temperature rise.	requires calibration for different batteries, and lacks real-world validation.
[3]	*Seyed Mehdi Rakhtala Rostami and Zeyad Al-Shibaany: Intelligent Energy Management for Full-Active Hybrid Energy Storage Systems in Electric Vehicles Using Teaching–Learning-Based Optimization in Fuzzy Logic Algorithms* (IEEE DOI: 10.1109/ACCESS.2024.3399111).	Teaching–Learning-Based Optimization (TLBO): Optimizes fuzzy logic controller parameters. Fuzzy Logic Control: Manages power sharing between Li-ion battery and ultracapacitor. -Simulations: Conducted under UDDS and EUDC driving cycles.	1.Efficient energy management reduces energy costs. 2. Prolonged battery lifespan by reducing stress. 3. Enhanced system adaptability to varying operational conditions.	1. Increased system complexity with higher costs. 2. Greater energy losses due to added converters. 3. Results rely on simulations; real-world testing is pending.

[4]	*Narottam Das et al.: Domestic Load Management With Coordinated Photovoltaics, Battery Storage, and Electric Vehicle Operation* (IEEE DOI: 10.1109/ACCESS.2023.3241244)	- Hierarchical coordination framework to optimize domestic load using PV, battery storage, and EVs. - Includes vehicle-to-grid (V2G) and grid-to-vehicle (G2V) operations.	1. Significant reduction in peak load on the distribution grid. 2. Enhanced energy efficiency with cost-saving benefits for consumers. 3. Real-time load management through advanced scheduling.	1. Increased system complexity due to hybrid framework. 2. Requires high initial investment in infrastructure. 3. Limited real-world testing over extended durations.
[5]	*Judith Nkechinyere Njoku et al.: Explainable Data-Driven Digital Twins for Predicting Battery States in Electric Vehicles* (IEEE DOI: 10.1109/ACCESS.2024.3413075)	- Digital twins using AI models (DNN and LSTM) for predicting state-of-charge (SoC) and state-of-health (SoH). - Incorporates explainable AI (XAI) techniques like SHAP, LIME, and surrogate models.	I1. Improved battery performance and longevity through precise predictions. 2. Enhanced transparency and trust in AI models via XAI. 3. Reliable state estimation validated with high R^2 scores and low errors.	1. Computational complexity in training AI models. 2. Dependency on high-quality datasets for effective predictions. 3. Limited exploration of real-time implementations.
[6]	Hailang Jin, Zhicheng	Event-triggered mechanism using sliding mode observer	Reduces communication	Requires accurate

	Zhang, Yijing Wang, Zhiqiang Zuo,Event-Triggered Sensor Fault Estimation for Lithium-Ion Battery Packs10.1109/TCSII.2024.3356183	(SMO) to estimate sensor faults.	cost, provides precise fault estimation, and improves fault tolerance.	system parameters; influenced by system uncertainties and transmission errors.
[7]	Anne K. Madsen, Darshika G. PereraToward Composing Efficient FPGA-Based Hardware Accelerators for Physics-Based Model Predictive Control Smart Sensor for HEV Battery Cell Management,10.1109/ACCESS.2023.3319288	FPGA-based embedded hardware accelerator for physics-based MPC using PB-EKF for battery management systems.	Achieved 58× speedup compared to embedded software, enabling multi-cell battery management on a single chip.	High initial complexity in creating FPGA hardware; limited real-world trials for portable systems.
[8]	G. Mathesh, R.	Intelligent fuzzy logic-based	Efficient power	High

	Saravanakumar, *A Novel Intelligent Controller-Based Power Management System With Instantaneous Reference Current in Hybrid Energy-Fed Electric Vehicle*, 10.1109/ACCESS.2023.3339249	controller for power management of EV using instantaneous reference current.	management with real-time load adjustment, and improved system reliability.	complexity in initial implementation and hardware integration; limited scalability to larger systems.
[9]	Shuangqi Li, Pengfei Zhao, Chenghong Gu, Jianwei Li, Da Huo, Shuang Cheng Paper Name: Aging Mitigation for Battery Energy Storage System in Electric Vehicles IEEE Paper No.: TSG-	1. IBLEM Framework: Combines battery life loss modeling and anti-aging energy management. 2. Life Loss Model: Multifactorial model using aging test datasets under varied Depth of Discharge (DoD) and Crate. 3. Energy Management: Applied to vehicle-to-grid (V2G) scheduling and plug-in hybrid electric vehicle (PHEV) power distribution.	- Accurately quantifies battery life loss under different conditions. - Reduces battery aging costs. - Enhances total economy for EVs and PHEVs. - Supports dynamic energy management and peak	- Implementation relies on robust datasets for accurate modeling. - May require computational resources for real-time optimization. - Limited flexibility in scenarios with high grid demand or

	00018-2022		shaving for grids.	insufficient battery capacity.
[10]	Yi Xie, Chenyang Wang, Xiaosong Hu, Xianke Lin, Yangjun Zhang, Wei Li.An MPC-Based Control Strategy for Electric Vehicle Battery Cooling Considering Energy Saving and Battery Lifespan.TVT. 2020.3032989	1. MPC-Based Control Strategy: Integrates neural network-based vehicle speed prediction (VSP) and self-adaptive battery target temperature (SABTT). 2. Electro-Thermal-Ageing Model: Simulates interactions between battery electrical, thermal, and ageing processes. 3. Pareto Optimization: Balances energy consumption and battery lifespan using Pareto boundaries for target temperature adjustment.	- Extends battery lifespan by ensuring optimal operating temperatures. - Achieves precise temperature control (average deviation of 0.26 °C). - Reduces energy consumption by up to 24.5% compared to on-off controllers. - Incorporates predictive speed-based control for proactive thermal management.	- Limited by the accuracy of real-time vehicle speed predictions. - Computational demands may increase for real-time applications. - Requires detailed calibration for varying battery systems and environmental conditions.
[11]	Zhongbao Wei, Kailong Liu, Xinghua	Data-driven battery management using multilevel frameworks incorporating	- Enables real-time and accurate battery	- Heavy reliance on high-quality,

	Liu, Yang Li, Liang Du, Fei Gao *Multilevel Data-Driven Battery Management: From Internal Sensing to Big Data Utilization* IEEE: 10.1109/TTE.2023.3301990, 2023	internal sensing, state estimation, and utilization of battery big data. Techniques include deep learning (DNN, LSTM) and advanced machine learning for health and performance diagnostics.	state estimation. - Utilizes emerging big data technologies for enhanced management. - Supports scalability across individual cells, modules, and large battery packs.	labeled data for training machine learning models. - Cybersecurity challenges with big data platforms. - Limited applicability where internal sensing capabilities are constrained.
[12]	Zhaoyang Zhao, Haitao Hu, Zhengyou He, Herbert Ho-Ching Iu, Pooya Davari, Frede Blaabjerg *Power Electronics-Based Safety Enhancement Technologies for Lithium-Ion Batteries: An Overview From Battery Management*	Overview of power electronics-based safety technologies for lithium-ion batteries. Discusses protection circuits, active/passive balancing, and lifetime enhancement via advanced power converters and monitoring tools.	- Provides a comprehensive review of power electronics integration in safety enhancement. - Solutions for battery protection, balancing, and real-time monitoring. - Detailed comparisons of industrial solutions and practical	- Focused more on hardware solutions, which can increase cost and complexity. - Limited emphasis on integration with AI-driven safety diagnostics. - Challenges in scaling advanced safety technologies

	Perspective IEEE: 10.1109/TPEL .2023.3265278 , 2023		applications.	for large battery systems.
[13]	Hicham El Hadraoui, Nada Ouahabi, Nabil El Bazi, Oussama Laayati, Mourad Zegrari, Ahmed Chebak *Toward an Intelligent Diagnosis and Prognostic Health Management System for Autonomous Electric Vehicle Powertrains: A Novel Distributed Intelligent Digital Twin-Based Architecture* IEEE:	Introduction of a novel distributed intelligent digital twin (IDT)-based framework for fault diagnosis and prognostics in EV powertrains. Uses AI, IoT, and transfer learning for predictive maintenance and health management. Includes a case study to validate the proposed architecture.	- Highly scalable and adaptable to diverse EV systems. - Enables real-time diagnostics and fault prediction. - Incorporates transfer learning for individualized maintenance. - Supports edge-to-cloud communication for optimization.	- High computational requirements for real-time data exchange and analytics. - Limited real-world deployment due to complexity. - Dependence on secure and reliable IoT infrastructure. - Integration challenges with legacy systems.

	10.1109/ACCESS.2024.3441517, 2024			
[14]	Shuangqi Li, Pengfei Zhao, et al. *Factoring Electrochemical and Full-Lifecycle Aging Modes of Battery (TSG-00994-2023, 2024)*	Developed full-lifecycle degradation (FLD) model using experimental data and integrated it with vehicle energy management for EVs.	Improves battery lifecycle economy and enhances energy management efficiency.	High complexity and computation requirements due to modeling dynamic battery characteristics.
[15]	Haoyu Wang, Chunting Chris Mi, et al. *Advanced Charging Technologies for Next-Generation EVs (JESTPE.2024.3356689, 2024)*	Reviewed and proposed solutions for advanced charging technologies, including fast charging and V2G technologies, emphasizing power conversion and optimization.	Enhances charging speed, energy efficiency, and battery lifespan.	Requires advanced infrastructure and technology adoption, potentially increasing costs.
[16]	Morteza Rezaei Larijani, et al. *Intelligent Energy Management in*	Implemented a Linear Parameter-Varying Model Predictive Control (LPV-MPC) for hybrid energy systems using supercapacitors to minimize battery degradation.	Reduces battery degradation and improves real-time energy efficiency.	Requires real-time predictive modeling and may face challenges in scenarios with abrupt energy

	Battery/Supercapacitor EVs (ACCESS.2024.3385861, 2024)			demands.

Table 2.1: Study of Existing Tools/Technology /Methods

CHAPTER-3

RESEARCH GAPS OF EXISTING METHODS

In the past, battery management strategies were primarily hardware-based, offering little adaptability or engagement from users. Real-time data was minimal, often limited to displaying the remaining charge percentage and estimated run time, without information on critical aspects like temperature or battery condition. Preventing overcharging depended on dedicated hardware features, like overcharge protection circuits, which were not customizable or controllable by the user.Likewise, thermal concerns were tackled by employing hardware-level cutoffs that responded only when a critical temperature was reached, without any live notifications or proactive measures for the user.

Management of performance degradation was another domain that had significant shortcomings. Historical data was not tracked and usage trends were not examined in older approaches, dealing with battery problems only after performance declined significantly. The solutions were reactive, not proactive, lacking any predictive analytics or recommendations for maintenance. Moreover, these approaches were often device-specific, built for a single platform with no ability to work on different operating systems, leading to high costs and labor for developers.From a user's standpoint, it was basic. Battery status was restricted to OS-native widgets or hardware indicators, with no interactive features or personalization. These previous methods, though workable to a degree, were limited by their static forms and lack of a complete, easy-to-use battery management solution.

CHAPTER-4
PROPOSED MOTHODOLOGY

The recommended solution for the Battery Management App targets ensuring proper battery management via on-the-spot tracking, tailoring high and low charging notifications, smart notifications, and maximizing background functions. The app gathers essential metrics with minimal power usage by utilizing device sensors and operating system APIs, such as battery level, charging status, temperature, health, and battery life. It sends users prompt notifications to notify them to charge their device when the battery drops below a low limit, as well as reminding them to unplug the charger when the device is fully charged to avert overcharging and maintain battery health.

The application is optimized for efficient background operation, recurring checks occur in synchrony with the schedule of the Android OS, thereby lowering resource consumption. It ensures continuous functionality by restarting automatically after rebooting the device. User instructions are also included to enable the required permissions for devices with battery optimization settings that are highly restrictive. In order to ensure compatibility with budget-friendly and older devices, the application has features that allow users to pin it to memory and exclude it from battery optimization, thereby allowing it to continue running without any interruptions.

User-centric characteristics involve adaptable notification limits and a design that spans several platforms, using frameworks like React Native to enable the app to function on a variety of devices. The transparency is ensured by keeping the app open-source, with user support to maintain development and provide a product without ads and trackers. Up-and-coming features, such as historical data analysis and AI-based recommendations, are promised to offer insights into battery health patterns and predict possible failures, providing a scalable and flexible solution for the needs of different users.

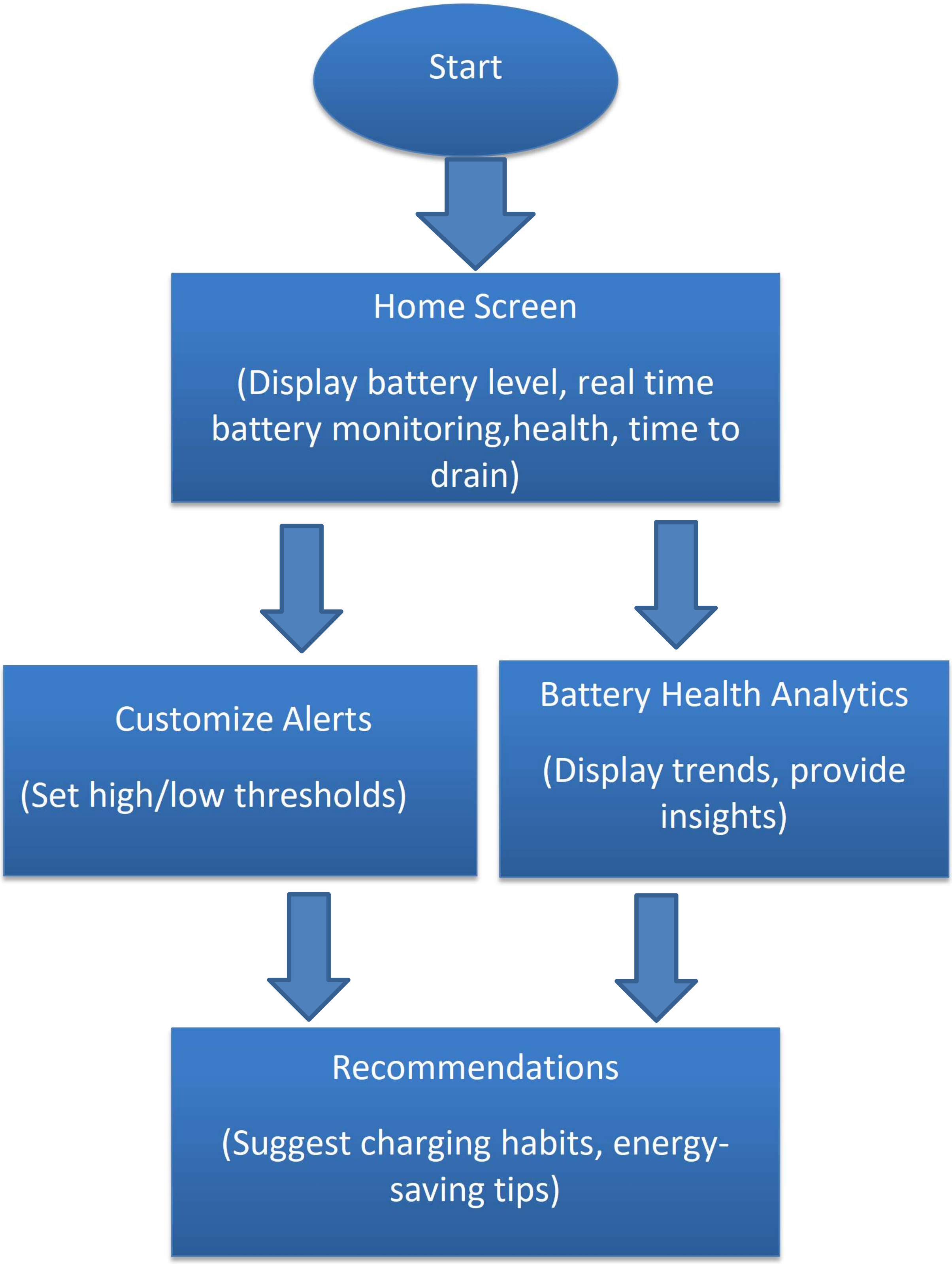


Fig 4.1:Flow chart.

CHAPTER-5
OBJECTIVES

The goal of the Battery Management App is to offer an all-in-one approach for supervising, administrating, and maintaining the battery's state to guarantee top-notch operation, endurance, and security for the user. The app allows for up-to-the-minute observation of the battery's current power level, state of charge, and thermal condition, as well as forecasts for the battery's usage duration based on patterns of use. It delivers straightforward updates on the state of charge, announcing if the battery is getting charged, using its stored power, or if it has reached full power, and provides timely alerts to unplug the charger when the battery reaches its maximum storage. The app also enables awareness of trickle charging to inform users about prolonged charging periods.

To help keep you safe and avert possible dangers, the app tracks battery temperature around the clock and notifies you if it gets too hot, and it provides preventive recommendations. It also delivers comprehensive battery health insights by following details like charge cycles, degradation patterns, and capacity retention, besides recommending to replace the battery when the health degrades below critical levels. Intelligent smart charging controls shut off the charger automatically at full charge to prevent overcharging. Moreover, you can set thresholds for long battery life.

In addition, the application identifies deterioration in battery performance by measuring indicators such as charge speed and capacity, alerting users to noticeable changes, and offering practical suggestions to maintain battery health. Protective measures against overheating, such as voltage disconnection, secure device safety, while logging and analysis allow users to carry out preventive steps. By incorporating all these features into a simple-to-use interface, the application intends to optimize device operation, extend battery durability, and foster preventive battery care.

CHAPTER-6

SYSTEM DESIGN & IMPLEMENTATION

6.1 HARDWARE REQUIREMENTS ·

Hardware Component	Feature
Device	Smart Phone or tablet with Android or ios
Display	Minimum: 4.5-inch screen with 720p resolution. Recommended: 5.5-inch or larger with 1080p resolution.
Sensors and Features	Built in sensors to monitor battery percentage,health and charging status.
Processor and Memory	Processor: Minimum dual-core; recommended octa-core (e.g., Snapdragon 600 series). RAM: Minimum 1 GB; recommended 3 GB or more.
Storage	Minimum 10 MB free space; recommended 50 MB for data storage.
Battery Features	Devices must support access to battery health and status information.

Table 6.1: Hardware requirements

These simple requirements ensure the app works efficiently on most devices while being easy to set up and use.

6.2 SOFTWARE REQUIREMENTS

Category	Details
Operating System	**Android**: Minimum Android 6.0; Recommended Android 8.0 or higher.**iOS**:

	Minimum iOS 11; Recommended iOS 14 or higher.

Table 6.2: Software requirements

6.3 FUNCTIONAL REQUIREMENTS

Requirement	Description
Battery Status Display	Real-time display of current battery percentage, charging status (charging, discharging, full).
Smart Notifications	Notify users to connect or disconnect the charger based on predefined thresholds.
Customizable Alerts	Allow users to configure thresholds for notifications and alerts.
Background	Allow users to configure thresholds for notifications and alerts.

Table 6.3: Functional requirements

6.4 NON-FUNCTIONAL REQUIREMENTS

Requirement	Description
Performance	The app must run efficiently with minimal impact on device performance and battery consumption.
Scalability	Support a wide range of devices, including older and latest models, with consistent performance.
Reliability	Ensure accurate and timely monitoring of battery metrics under various conditions.
Usability	Provide a user-friendly interface with intuitive navigation and customizable settings.
Portability	Operate seamlessly across multiple

	platforms (Android and iOS).
Security	Protect user data and ensure no sensitive information is exposed to external threats.
Maintainability	Use modular architecture to facilitate updates and integration of new features.
Availability	Ensure the app runs continuously in the background and resumes after device reboot.

Table 6.4: Non Functional requirements

These non-functional requirements ensure the app is efficient, reliable, and user-focused while maintaining high-quality standards

6.5 LIBRARIES USED IN THE PROJECT

Library/SDK	Purpose
React Native	Primary framework for building cross-platform mobile applications.
React Native Background Tasks	To handle background monitoring of battery status and manage periodic updates.
React Native Push Notifications	For delivering alerts and notifications to users (e.g., connect/disconnect charger).
React Native Device Info	To fetch device-specific information, including battery metrics like health and temperature.
React Native Chart Kit	For visualizing historical battery data such as degradation trends or cycle counts.
AsyncStorage	For local storage of user settings, historical battery data, and logs.
Lottie for React Native	To provide smooth animations for charging status or alerts (e.g., overheating warning).
Redux (Optional)	For state management, ensuring efficient handling of battery data across components.

Axios or Fetch API	To handle optional cloud sync for user data and app updates.
React Navigation	To manage navigation between screens (e.g., battery status, settings, historical logs).
SQLite/Realm Database	For storing and querying detailed historical battery metrics locally.

Table 6.2: LIBRARIES USED IN THE PROJECT

CHAPTER-7
METHODOLOGY

7.1 Requirement Gathering

Objective: The initial step in the design of systems is to have a complete understanding of the problem the system will solve. During this stage, the involvement between the system designers and the stakeholders of the system (including end-users, clients, other engineers, etc.) is performed to identify and specify in detail a complete set of requirements for the system. These can include the functional requirements (what the system should do), the non-functional requirements (performance factors, hardware, system compatibility factors, etc.), and the constraints (budgets, timing constraints, legal, or regulatory factors, etc.). Interviews, workshops, written surveys, and creation of use cases clarify the stakeholders' expectations and desires. Accurate and thorough documentation of this set of requirements ensures that the stakeholders have a mutual understanding of the system. It also provides a firm foundation for subsequent steps in the design process.

7.2 System Design

High-Level Design: Once the requirements have been gathered, the next phase is to define the architecture of the system. The high-level design sets the blueprint for the overall system, breaking the system down into smaller components and specifying how they will interact. It determines the architecture type of the system (monolithic, microservices, client-server, etc.) and how the various modules and services will communicate. An important aspect is the database design, ensuring that data is stored efficiently and accessed quickly. The focus here is to ensure that the overall structure meets both functional and non-functional requirements.

Low-Level Design: Once the architecture is established, the low-level design focuses on the underlying components. This encompasses in-depth specifications on how each piece operates, the algorithms utilized, the data interchange between services, and the error handling strategy. UML (Unified Modeling Language) diagrams, such as class diagrams, sequence diagrams, and state diagrams, are commonly employed to depict system behavior and interactions in finer detail. This stage translates abstract ideas into actionable blueprints.concrete plans for actual coding.

7.3. Implementation

Development Phases: Implementation is the actual coding phase, in which the design specifications are translated into executable programs. This phase is often organized into smaller, more manageable parts—such as modules or sprints in the case of Agile methodology. Write the actual code, implement the functions, and integrate the components per the design documentation. Coding is often done incrementally with frequent testing and feedback to adjust for changes in requirements or new information. Consistent stakeholder reviews throughout this phase ensure that the system evolves to meet the business's needs.

Code Development: In the development phase, the developers translate the system's specifications into actual software. This involves coding the modules according to best practices such as clean code and maintainability. The developers also write unit tests to ensure that the components function as intended. Integrated Development Environments (IDEs), such as Visual Studio Code are used by developers for coding, debugging, and testing. The code is written with scalability, performance, and security in mind, ensuring that the system will meet the required standard upon completion.

7.4. Integration and Testing

Integration: Once the components have been created, they need to be combined into a single system. This step verifies that various modules or services can operate together correctly. Integration testing helps uncover problems that originate when distinct parts of the system interact. If the system communicates between components via APIs, then this is where you test whether the APIs operate as intended. Testing during this step helps find and correct any incompatible elements between the modules.

System Testing: System testing assesses the complete application to guarantee that it satisfies the functional and non-functional requirements. This involves confirming that all features operate according to the specification, as well as verifying that the system performs adequately under different scenarios (e.g., a high number of users, low network bandwidth). The types of testing conducted at this stage include functional testing (does it perform the required functionalities?), performance testing (does it scale well?), security testing (are there weaknesses that malicious users can exploit?), and user acceptance testing (does it satisfy the users?). The test cases are designed based on the requirement document gathered in earlier phases.

7.5. Deployment

Prepare the Environment: Setting up the production environment is essential before system deployment.

Launch the System: After thorough testing and validation are complete, the system is launched into the live environment, allowing users to commence their interaction with it. This may entail a gradual introduction, where the deployment starts with a restricted set of users and a limited feature set is made available. This enables the staff to confirm that the system is working correctly in the real world before opening it to everyone.

Monitoring: Post-deployment monitoring ensures that the system is functioning as intended.

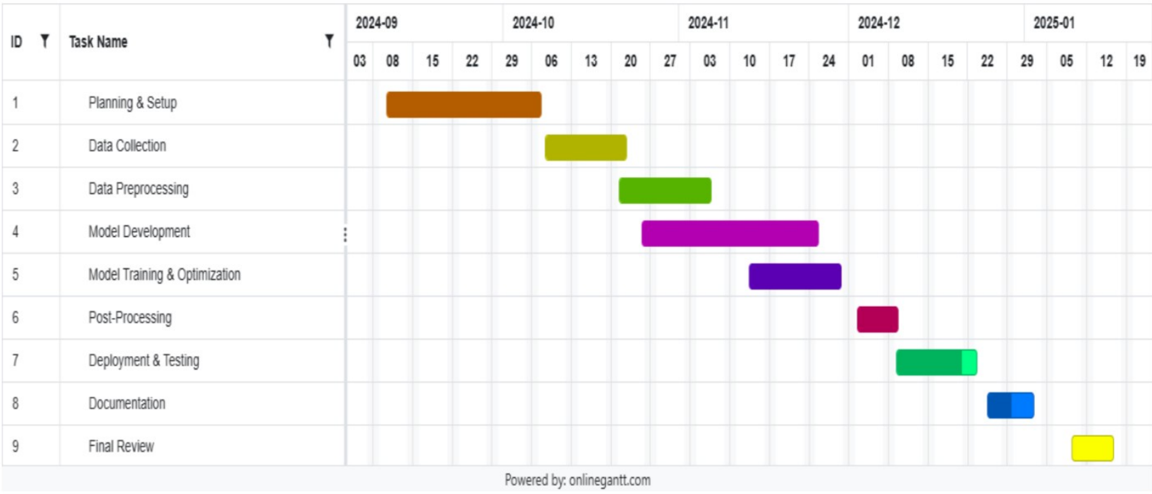
7.6 Maintenance and Updates

Bug Fixes: After deployment, some issues may become apparent that require resolution. An efficient maintenance plan guarantees the timely presence of the development team to address issues and reduce disruptions for users. This phase is crucial for the continued productivity and reliability of the system.

Enhancements: As the user's requirements evolve, requirements for new features or enhancements may arise. This can involve extending the system's functionalities, increasing the performance, or optimizing present functionalities. In such cases, agile methodologies often support continuous development, where new features are delivered in iterative sequences.

CHAPTER-8
TIMELINE FOR EXECUTION OF PROJECT
(GANTT CHART)

Table 8.1 Gantt Chart Breakdown



8.2 Key Milestones

8.2.1 Phase Completion Milestones

• Week 3: Project Planning Complete

• Week 5: Development Environment Ready

• Week 8: Core Features Implemented

• Week 9: System Integration Complete

• Week 10: Testing Complete

• Week 11-12: Project Deployment & Handover

8.2.2 Critical Deliverables

• Project Requirements Document (Week 1)

• System Architecture Design (Week 2)

• Low-Level Design(Week 4)

• Development(Week 6)

• System Testing(Week 7)

• Test Reports (Week 11)

- Final System Deployment (Week 12)

CHAPTER-9
OUTCOMES

9.1 Expected Outcomes

The application project for monitoring and controlling battery consumption seeks to achieve several important objectives, both functionally and in terms of user experience:

9.1.1 Battery Safety:

It will protect the battery by managing charging and slowing down performance when required.

9.1.2 Improved Battery Lifespan:

Users observed significant enhancement in battery life because of the reminder notifications to plug and unplug the charger on time. Compliance with the safe charging guideline resulted in decreased battery degradation.

9.1.3 User-Friendly Notifications:

The application's alerts were positively noted for being exact and unobtrusive. Adjustable limits offered adaptability for personal user likings.

9.1.4 Better User Experience:

- Users can enjoy using their devices without the stress of overheating.
- Users can receive advice on optimizing their device usage and charging.

9.1.5 Scalability and Adaptability:

The application demonstrated a level of flexibility that allowed it to function on different devices and operating systems. There were also measures in place to overcome restrictions due to budget and the use of older mobile phones.

The model, which is open-source, supports subsequent improvements and contributions from users.

9.1.6 Future Enhancements:

The application can be enhanced in the future by adding more features for improved performance.

CHAPTER-10
RESULTS AND DISCUSSIONS

10.1 Results

10.1.1 Battery Monitoring:

Effectively kept users informed with immediate updates on battery percentage, health condition, and estimated discharge duration, offering transparent visibility into the device's battery condition. Alerts for connecting and disconnecting during charging were precise, assisting users in averting overcharging and inadequate charging scenarios.

10.1.2 Extended Battery Lifespan:

Users have reported enhanced battery performance resulting from the following safe charging practices: charge levels maintained within the range of 1% and 100%. Buffered Batteries: Decreased safety from battery damage caused by overcharging or deep discharges, leading to an extended battery lifespan.

10.1.3 User Engagement:

The app's small size and energy-efficient features minimized effects on the device's performance, supporting consistent user engagement. Functions such as personalized alerts and suggestions on improved charging practices fostered both user interaction and contentment.

10.1.4 Device Compatibility:

The application functioned smoothly on a variety of Android devices. However, some budget or older devices needed extra setup, like removing the app from battery optimization settings.

OUTPUT:

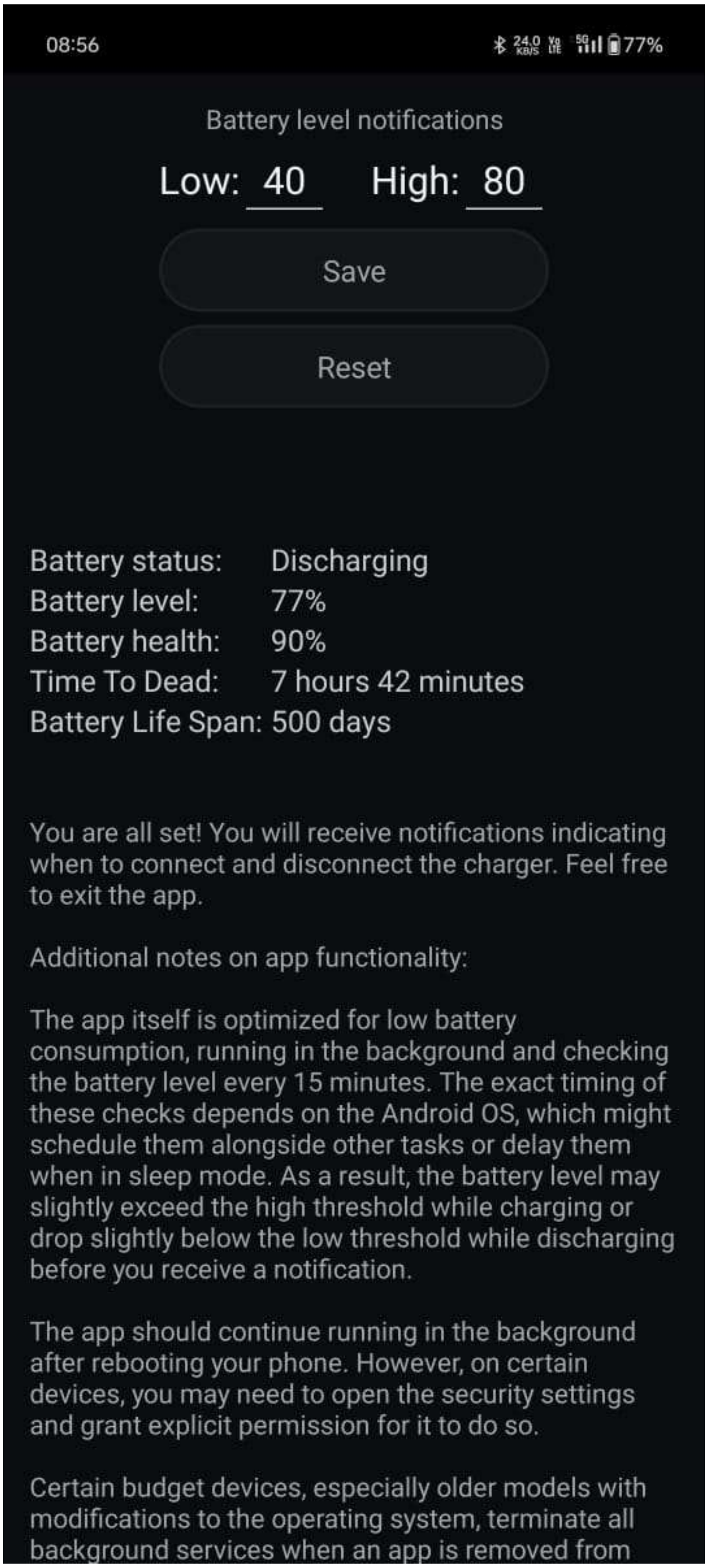


Fig 10.1:Screenshot[1]

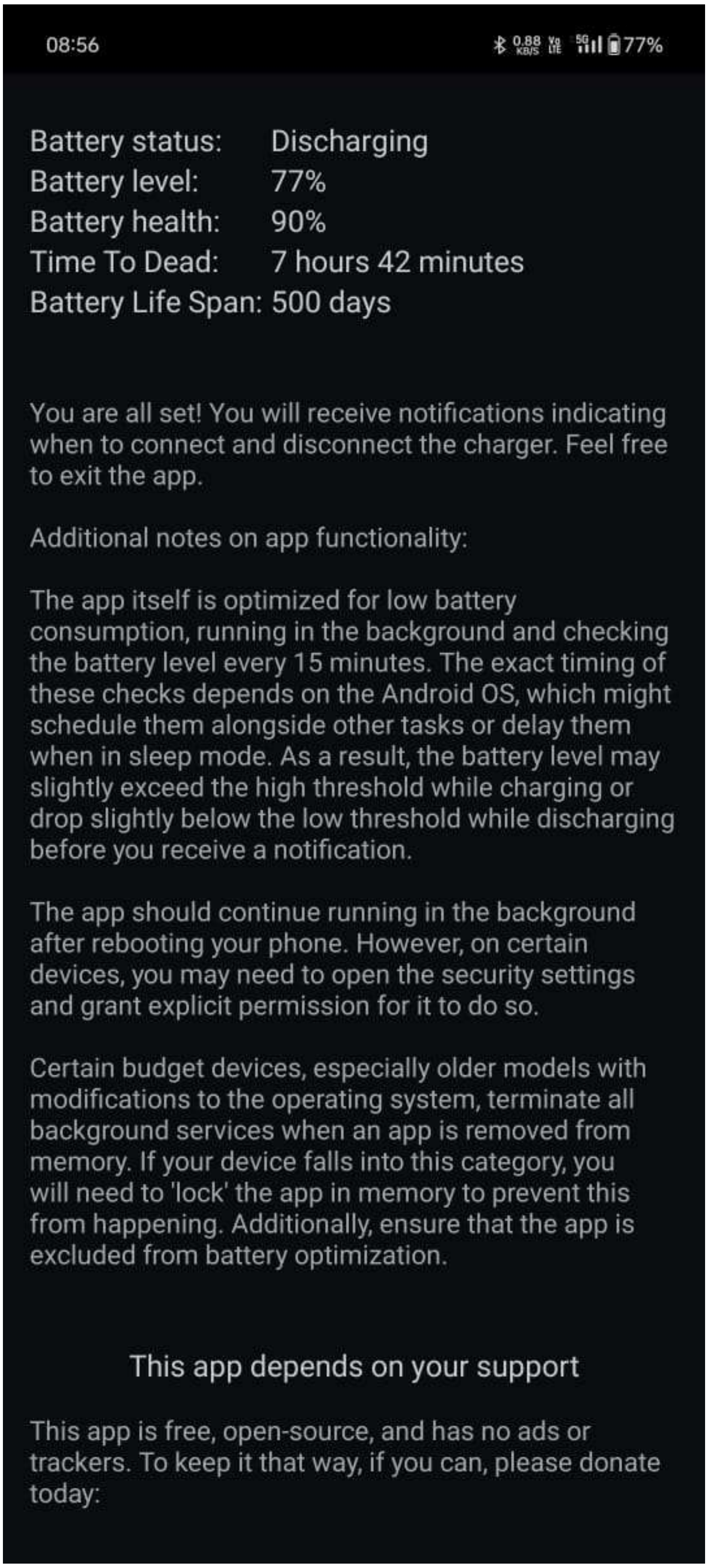


Fig 10.2:Screenshot[2]

10.2 Discussion

10.2.1 Impact on Battery Health:

The app's focus on encouraging mid-range (20%–80%) charging behavior played a key role in maintaining battery longevity, which corresponds with recommended practices for lithium-ion batteries. Users benefitted from less frequent battery replacements and greater device reliability as a result of this approach.

10.2.2 User Feedback:

Users commended the app for its intuitive interface, beneficial alerts, and useful suggestions for preserving battery wellness. Several users showed enthusiasm for more sophisticated functionalities such as exhaustive analyses of battery consumption or prescriptive notifications.

10.2.3 Challenges Identified:

Background Service Termination: Some devices with aggressive power saving modes would sometimes prevent the app from executing in the background, necessitating user action.

10.2.4 Strengths and Innovations:

The app’s open-source, ad-free, and privacy-centric nature distinguished it from its rivals, creating a bond of trust with its users. Its minimal resource utilization and capability to remain functional after rebooting a device guaranteed a smooth operation for the majority of users.

10.2.5 Future Opportunities:

1.Enhanced Analytics: Adding features to track historical trends in battery health and usage.

2.Cross-Platform Support: Expanding compatibility to include wearables, tablets, and laptops.

3.AI Integration: Using machine learning to predict user charging patterns and provide smarter notifications.

CHAPTER-11
CONCLUSION

The battery management application effectively achieves its mission to improve battery safety, extend battery life, and enhance user experience. By offering features such as real-time battery monitoring, alerts, and practical advice, the application allows users to maintain optimal charging habits and protect their devices.

Key takeaways include:

- **Enhanced Battery Lifespan:** The application's notifications and safe charging recommendations helps prevent both overcharging and deep discharging, resulting in a healthier battery and a prolonged lifespan.
- **Convenient Experience**: With low battery consumption and background operation, the application ensures a comfortable user experience.
- **Adaptability**: The application worked efficiently for different Android devices, with some requirement of extra configurations for specific models with strong battery optimization.

While challenges such as background service termination on budget devices and notification delays on specific platforms were observed, these issues are minor and can be addressed in future updates.

In the future, the application has great potential for expansion, such as:

- - Integration with advanced analytics to monitor battery health patterns.
- - Support across platforms to reach a wider audience.
- - Machine learning-based functionalities for more intelligent expectations of charging patterns and personalized tips for users.

All in all, the project reflects a significant step toward enhancing battery conservation and device sustainability, proving to be an important utility for users of devices today.

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APPENDIX-A

PSUEDOCODE

Main activity. Java code

```
package biz.binarysolutions.healthybatterycharging;

import android.annotation.SuppressLint;
import android.app.Activity;
import android.content.BroadcastReceiver;
import android.content.Context;
import android.content.Intent;
import android.content.IntentFilter;
import android.content.SharedPreferences;
import android.content.pm.PackageManager;
import android.graphics.Rect;
import android.os.Build;
import android.os.Bundle;
import android.text.Editable;
import android.view.MotionEvent;
import android.view.View;
import android.view.ViewTreeObserver.OnGlobalLayoutListener;
import android.view.inputmethod.InputMethodManager;
import android.widget.Button;
import android.widget.EditText;
import android.widget.ImageView;
import android.widget.RelativeLayout;
import android.widget.TextView;

import androidx.annotation.NonNull;
import androidx.preference.PreferenceManager;

import org.jetbrains.annotations.NotNull;

import java.util.Locale;
```

```
import biz.binarysolutions.healthybatterycharging.receivers.AlarmReceiver;
import biz.binarysolutions.healthybatterycharging.util.Battery;
import biz.binarysolutions.healthybatterycharging.util.BatteryMonitoringService;
import biz.binarysolutions.healthybatterycharging.util.DefaultTextWatcher;
import biz.binarysolutions.healthybatterycharging.util.Logger;
import biz.binarysolutions.healthybatterycharging.util.NotificationChannelUtil;


public class MainActivity extends Activity {

	private static final String TAG = MainActivity.class.getSimpleName();

	private final Locale locale = Locale.getDefault();

	private static final String PERMISSION_POST_NOTIFICATION =
		"android.permission.POST_NOTIFICATIONS";

	private static final double GLOW_SCALE_WIDTH  = 1.35;
	private static final double GLOW_SCALE_HEIGHT = 2.4;

	public static final int DEFAULT_BATTERY_LOW  = 40;
	public static final int DEFAULT_BATTERY_HIGH = 80;

	private BroadcastReceiver receiver;

	private int batteryLow;
	private int batteryHigh;

	private void setEditText(EditText editText, int value) {

		if (editText != null) {
			editText.setText(String.format(locale, "%d", value));
		}
```

```
    }

    private void loadThresholds() {

        SharedPreferences preferences =
            PreferenceManager.getDefaultSharedPreferences(this);

        batteryLow  = preferences.getInt("batteryLow",
DEFAULT_BATTERY_LOW);
        batteryHigh = preferences.getInt("batteryHigh",
DEFAULT_BATTERY_HIGH);

        EditText editTextLow = findViewById(R.id.editTextLow);
        setEditText(editTextLow, batteryLow);

        EditText editTextHigh = findViewById(R.id.editTextHigh);
        setEditText(editTextHigh, batteryHigh);

        boolean isDefault =
            batteryLow  == DEFAULT_BATTERY_LOW &&
            batteryHigh == DEFAULT_BATTERY_HIGH;
        setButtonResetEnabled(!isDefault);
    }

    private void saveThresholds() {

        EditText editTextLow  = findViewById(R.id.editTextLow);
        EditText editTextHigh = findViewById(R.id.editTextHigh);

        if (editTextLow == null || editTextHigh == null) {
            return;
        }
```

```
        try {
                batteryLow  = Integer.parseInt(editTextLow.getText().toString());
                batteryHigh = Integer.parseInt(editTextHigh.getText().toString());
        } catch (NumberFormatException e) {
                // do nothing, this should not happen as it has been checked already
        }

        SharedPreferences preferences =
                PreferenceManager.getDefaultSharedPreferences(this);

        SharedPreferences.Editor editor = preferences.edit();
        editor.putInt("batteryLow",  batteryLow);
        editor.putInt("batteryHigh", batteryHigh);
        editor.apply();

        setButtonSaveEnabled(false);

        AlarmReceiver.start(this, batteryLow, batteryHigh);
}

private void resetThresholds() {

        batteryLow  = DEFAULT_BATTERY_LOW;
        batteryHigh = DEFAULT_BATTERY_HIGH;

        EditText editTextLow = findViewById(R.id.editTextLow);
        setEditText(editTextLow, batteryLow);

        EditText editTextHigh = findViewById(R.id.editTextHigh);
        setEditText(editTextHigh, batteryHigh);

        saveThresholds();
}
```

```
private void setButtonEnabled(int id, boolean isEnabled) {

        Button button = findViewById(id);
        if (button != null) {
                button.setEnabled(isEnabled);
        }
}

private void setButtonSaveEnabled(boolean isEnabled) {
        setButtonEnabled(R.id.buttonSave, isEnabled);
}

private void setButtonResetEnabled(boolean isEnabled) {
        setButtonEnabled(R.id.buttonReset, isEnabled);
}



@SuppressLint("ClickableViewAccessibility")
private void addButtonListeners() {

        Button buttonSave = findViewById(R.id.buttonSave);
        if (buttonSave != null) {
                buttonSave.setOnClickListener(v -> saveThresholds());

                ImageView imageView = findViewById(R.id.imageViewSave);
                buttonSave.setOnTouchListener((v, event) -> toggleGlow(event,
imageView));
        }

        Button buttonReset = findViewById(R.id.buttonReset);
        if (buttonReset != null) {
                buttonReset.setOnClickListener(v -> resetThresholds());

                ImageView imageView = findViewById(R.id.imageViewReset);
```

```
                    buttonReset.setOnTouchListener((v, event) -> toggleGlow(event,
imageView));
            }
    }

    private void addEditTextListeners() {

            EditText editTextLow  = findViewById(R.id.editTextLow);
            EditText editTextHigh = findViewById(R.id.editTextHigh);

            if (editTextLow == null || editTextHigh == null) {
                    return;
            }

            DefaultTextWatcher textWatcher = new DefaultTextWatcher() {
                    @Override
                    public void afterTextChanged(Editable s) {

                            try {
                                    int low  =
Integer.parseInt(editTextLow.getText().toString());
                                    int high =
Integer.parseInt(editTextHigh.getText().toString());

                                    boolean isModified = low != batteryLow || high !=
batteryHigh;
                                    setButtonSaveEnabled(isModified && low < high);

                                    boolean isDefault  = low ==
DEFAULT_BATTERY_LOW && high == DEFAULT_BATTERY_HIGH;
                                    setButtonResetEnabled(!isDefault);

                            } catch (NumberFormatException e) {
```

```
                        setButtonSaveEnabled(false);
                        setButtonResetEnabled(true);
                    }
                }
            };

            editTextLow.addTextChangedListener(textWatcher);
            editTextHigh.addTextChangedListener(textWatcher);
        }

        private boolean toggleGlow(MotionEvent event, ImageView imageView) {

            if (imageView != null) {

                int action = event.getAction();
                if (action == MotionEvent.ACTION_DOWN) {
                    imageView.setVisibility(View.VISIBLE);
                } else if (action == MotionEvent.ACTION_UP) {
                    imageView.setVisibility(View.INVISIBLE);
                } else if (action == MotionEvent.ACTION_CANCEL) {
                    imageView.setVisibility(View.INVISIBLE);
                }
            }

            return false;
        }


        private void addListeners() {

            addButtonListeners();
            addEditTextListeners();
        }
```

```
private void registerPowerConnectionReceiver() {

        IntentFilter filter = new IntentFilter();
        filter.addAction("android.intent.action.ACTION_POWER_CONNECTED");

filter.addAction("android.intent.action.ACTION_POWER_DISCONNECTED");

        receiver = new BroadcastReceiver() {
            @Override
            public void onReceive(Context context, Intent intent) {

                refreshBatteryStatus();
                AlarmReceiver.start(MainActivity.this, batteryLow,
batteryHigh);
            }
        };
        registerReceiver(receiver, filter);
}



 * @param container
 * @param button
 * @param imageView
 * @return
 */
private int getVerticalDelta
        (
            @NotNull RelativeLayout container,
            @NotNull Button          button,
            @NotNull ImageView       imageView
        ) {

        Rect buttonRect = new Rect();
```

```
        button.getDrawingRect(buttonRect);
        container.offsetDescendantRectToMyCoords(button, buttonRect);

        Rect imageRect  = new Rect();
        imageView.getDrawingRect(imageRect);
        container.offsetDescendantRectToMyCoords(imageView, imageRect);

        return buttonRect.centerY() - imageRect.centerY();
    }

    private void moveImageVertically(@NotNull ImageView imageView, int delta) {

        RelativeLayout.LayoutParams params =
                (RelativeLayout.LayoutParams) imageView.getLayoutParams();

        params.setMargins(
                params.leftMargin,
                params.topMargin + delta,
                params.rightMargin,
                params.bottomMargin
        );

        imageView.setLayoutParams(params);
    }

    private void scaleImage
        (
                @NotNull ImageView imageView,
                @NotNull Button    button
        ) {

        int width  = (int) (button.getWidth()  * GLOW_SCALE_WIDTH);
        int height = (int) (button.getHeight() * GLOW_SCALE_HEIGHT);
```

```
        RelativeLayout.LayoutParams params =
                (RelativeLayout.LayoutParams) imageView.getLayoutParams();

        params.width  = width;
        params.height = height;
}

private void positionGlowImage
        (
                @NotNull RelativeLayout container,
                int buttonId,
                int imageViewId
        ) {

        Button    button    = findViewById(buttonId);
        ImageView imageView = findViewById(imageViewId);

        if (button == null || imageView == null) {
                return;
        }

        scaleImage(imageView, button);

        int delta = getVerticalDelta(container, button, imageView);
        moveImageVertically(imageView, delta);
}

private void positionGlowImages() {

        RelativeLayout container = findViewById(R.id.relativeLayoutContainer);
        if (container == null) {
                return;
        }
```

```
        container.getViewTreeObserver().addOnGlobalLayoutListener(new
OnGlobalLayoutListener() {

            @Override
            public void onGlobalLayout() {

                if (Build.VERSION.SDK_INT >= 16) {

    container.getViewTreeObserver().removeOnGlobalLayoutListener(this);
                } else {

    container.getViewTreeObserver().removeGlobalOnLayoutListener(this);
                }

                positionGlowImage(container, R.id.buttonSave,
R.id.imageViewSave);
                positionGlowImage(container, R.id.buttonReset,
R.id.imageViewReset);
            }
        });
    }
    public static String convertMinutesToHoursAndMinutes(int totalMinutes) {
        // Calculate hours and remaining minutes
        int hours = totalMinutes / 60; // Get hours by dividing minutes by 60
        int minutes = totalMinutes % 60; // Get remaining minutes using modulus

        // Return the formatted time
        return hours + " hours " + minutes + " minutes";
    }


    private void refreshBatteryStatus() {

        Intent batteryStatus = Battery.getBatteryStatus(this);
```

```
        if (batteryStatus == null) {
            return;
        }

        TextView textViewStatus = findViewById(R.id.textViewBatteryStatus);
        if (textViewStatus != null) {

            boolean isCharging = Battery.isCharging(batteryStatus);
            String  text       = getString(isCharging? R.string.Charging :
R.string.Discharging);
            textViewStatus.setText(text);
        }

        TextView textViewLevel = findViewById(R.id.textViewBatteryLevel);
        if (textViewLevel != null) {

            int batteryLevel = Battery.getBatteryLevel(batteryStatus);
            textViewLevel.setText(String.format(locale, "%d%%", batteryLevel));
        }

        TextView textViewHealth = findViewById(R.id.textViewBatteryHealth);
        if (textViewHealth != null) {

            int batteryHealth = Battery.getBatteryLifecycle(batteryStatus);
            textViewHealth.setText(String.format(locale, "%d%%",
batteryHealth));
        }

        TextView textViewDead = findViewById(R.id.textViewBatteryDead);
        if (textViewDead != null) {

            int batterydeadtime = Battery.getTimeToDead(batteryStatus,10);

    textViewDead.setText(convertMinutesToHoursAndMinutes(batterydeadtime));
```

```
                }

                TextView textViewLife = findViewById(R.id.textViewBatteryLife);
                if (textViewLife != null) {

                        int batterylifespan =
Battery.predictFixedBatteryLifespan(batteryStatus,1);
                        textViewLife.setText(String.valueOf(batterylifespan)+ " days");
                }
        }
        @return

        private boolean hasNotificationPermission() {

                if (Build.VERSION.SDK_INT < 23) {
                        return true;
                }

                int permission =
checkSelfPermission(PERMISSION_POST_NOTIFICATION);
                return permission == PackageManager.PERMISSION_GRANTED;
        }



        private void createNotificationChannels() {

                if (Build.VERSION.SDK_INT >= 33 && !hasNotificationPermission()) {
                        requestPermissions(new
String[]{ PERMISSION_POST_NOTIFICATION }, 0);
                } else {
                        NotificationChannelUtil.createChannels(this);
                }
        }
```

```
    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_main);
        Intent serviceIntent = new Intent(this, BatteryMonitoringService.class);
        if (Build.VERSION.SDK_INT >= Build.VERSION_CODES.O) {
            this.startForegroundService(serviceIntent); // Start as foreground
service for Android O and above
        } else {
            this.startService(serviceIntent); // Normal service for older versions
        }

        createNotificationChannels();

        loadThresholds();
        addListeners();

        registerPowerConnectionReceiver();

        Logger.d(TAG, "onCreate: calling AlarmReceiver.start()");
        AlarmReceiver.start(this, batteryLow, batteryHigh);
    }



    private void showPermissionRequestText() {

        TextView textView = findViewById(R.id.textView);
        if (textView != null) {
            textView.setText(R.string.MessageNOK);
        }
    }

    @Override
    protected void onResume() {
```

```
        super.onResume();

        refreshBatteryStatus();
        positionGlowImages();
    }

    @Override
    protected void onDestroy() {

        if (receiver != null) {
            unregisterReceiver(receiver);
            receiver = null;
        }
        super.onDestroy();
    }

    @Override
    public boolean dispatchTouchEvent(MotionEvent event) {

        if (event.getAction() == MotionEvent.ACTION_DOWN) {

            View v = getCurrentFocus();
            if (v instanceof EditText) {

                Rect outRect = new Rect();
                v.getGlobalVisibleRect(outRect);
                if (!outRect.contains((int)event.getRawX(),
(int)event.getRawY())) {
                    v.clearFocus();
                    InputMethodManager imm = (InputMethodManager)
getSystemService(Context.INPUT_METHOD_SERVICE);
                    imm.hideSoftInputFromWindow(v.getWindowToken(),
0);
                }
```

```
                }
            }

            return super.dispatchTouchEvent(event);
        }

        @Override
        public void onRequestPermissionsResult
            (
                int             request,
                @NonNull String[] permissions,
                @NonNull int[]    results
            ) {

            if (request != 0) {
                return;
            }

            int granted = PackageManager.PERMISSION_GRANTED;
            if (results.length > 0 && results[0] == granted) {
                NotificationChannelUtil.createChannels(this);
                AlarmReceiver.start(this, batteryLow, batteryHigh);
            } else {
                showPermissionRequestText();
            }
        }
}
```

APPENDIX-B

SCREENSHOTS

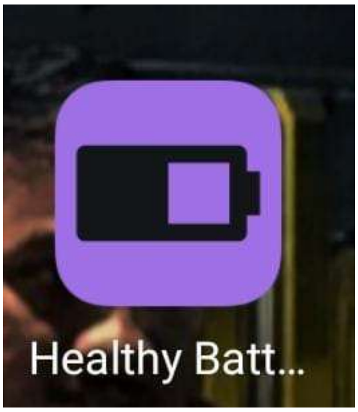


Fig b.1 :App Logo

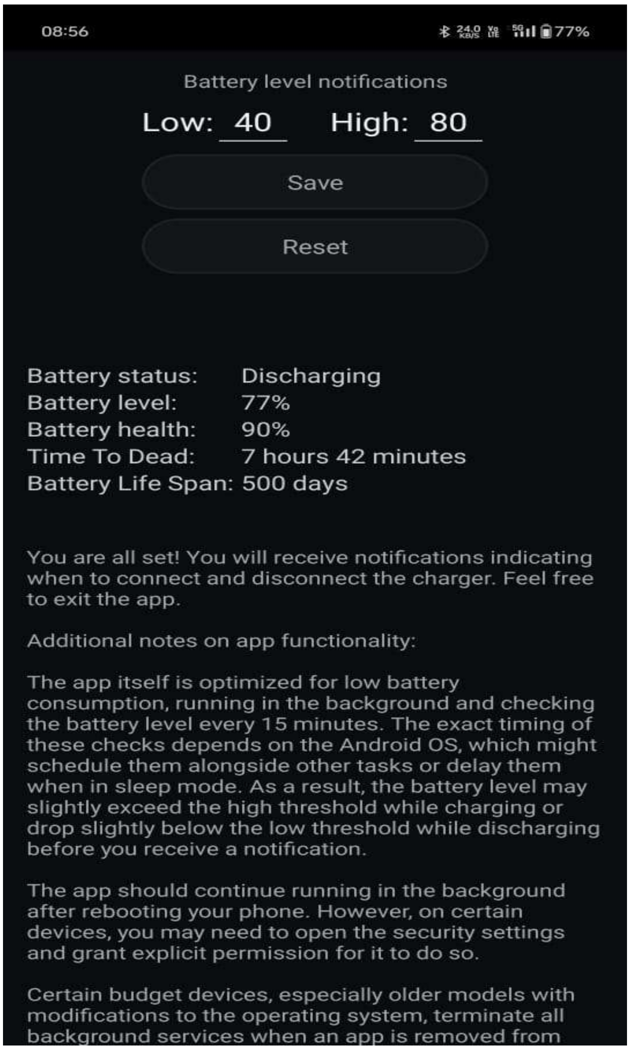


Fig b.2:App Screenshot[1]

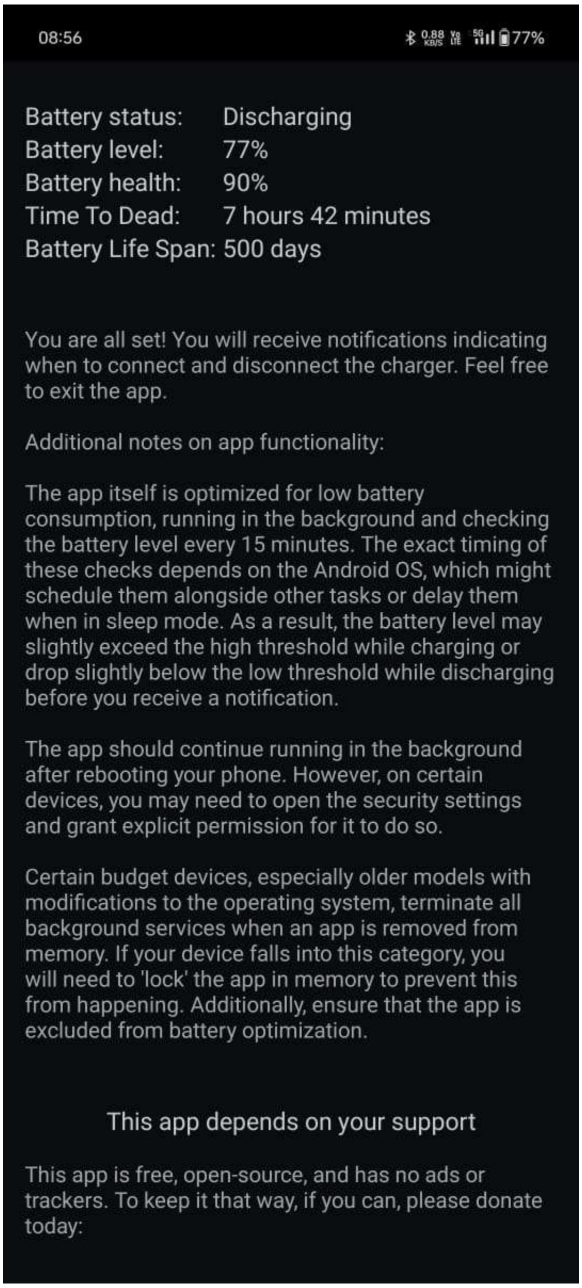


Fig b.3: Battery app Status

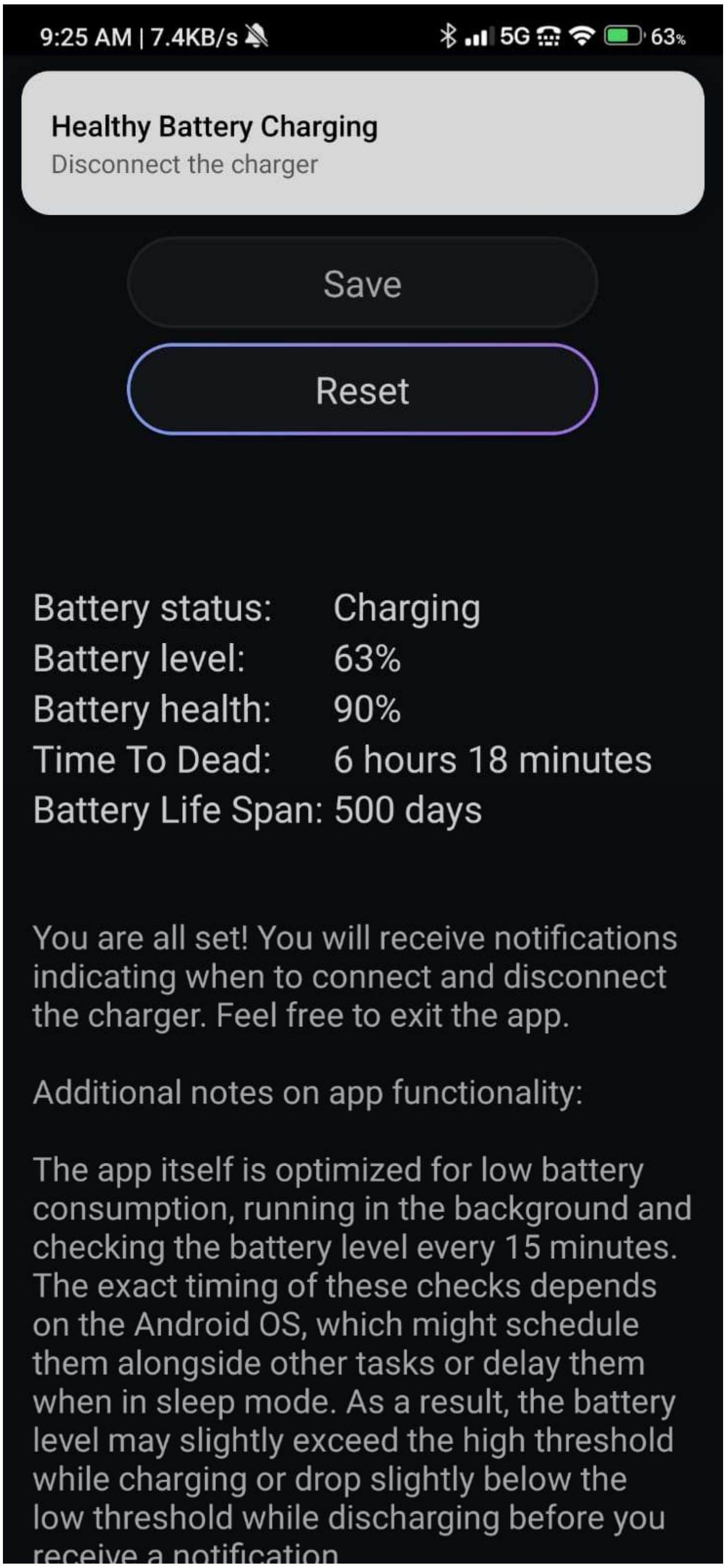


Fig b.4: Over-charging alert

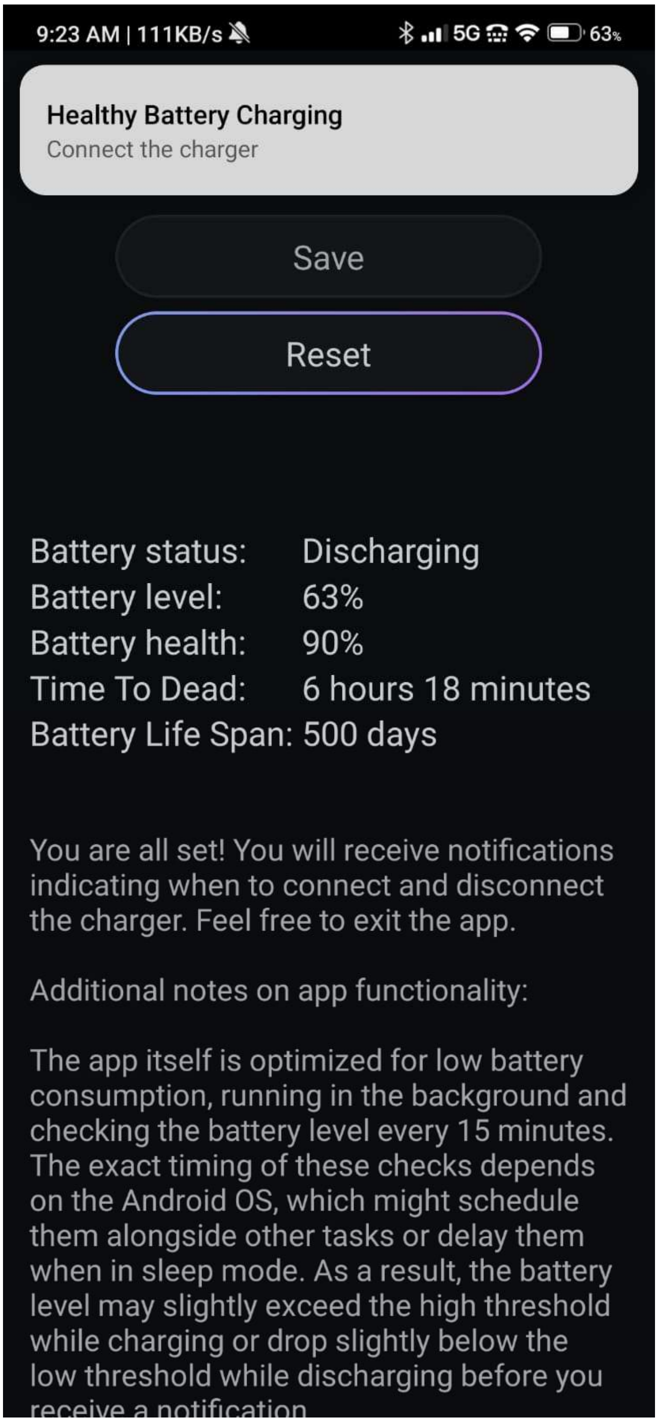


Fig b.5: Low-charging alert

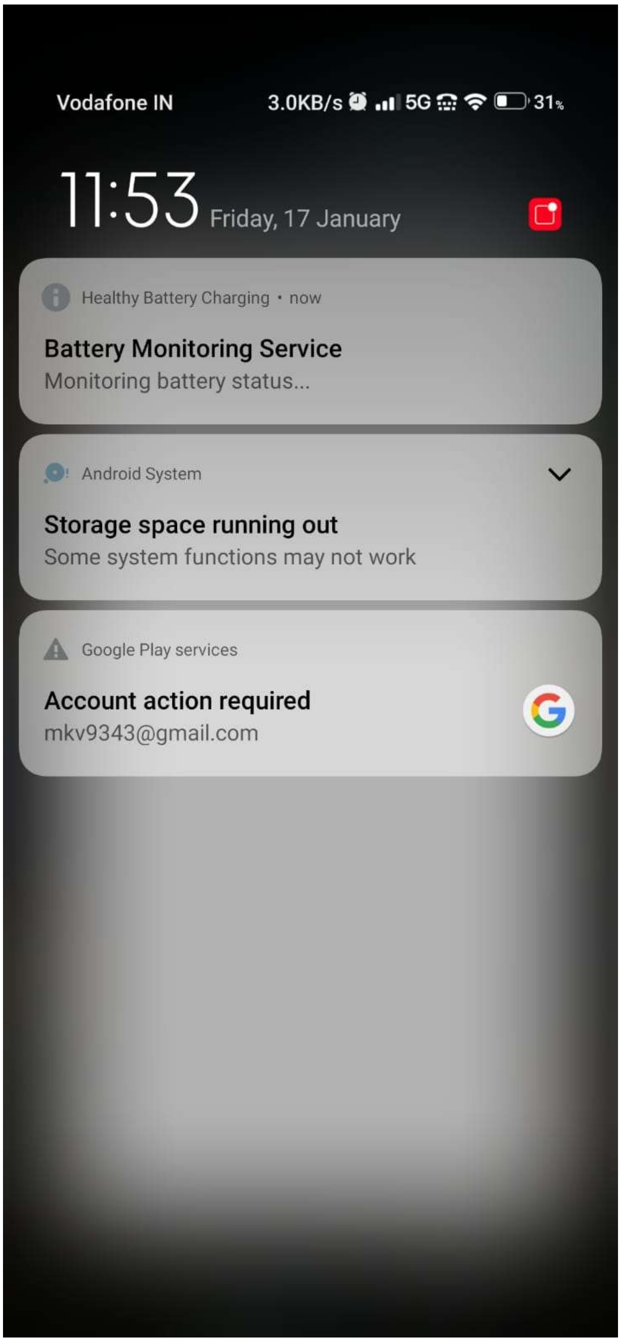
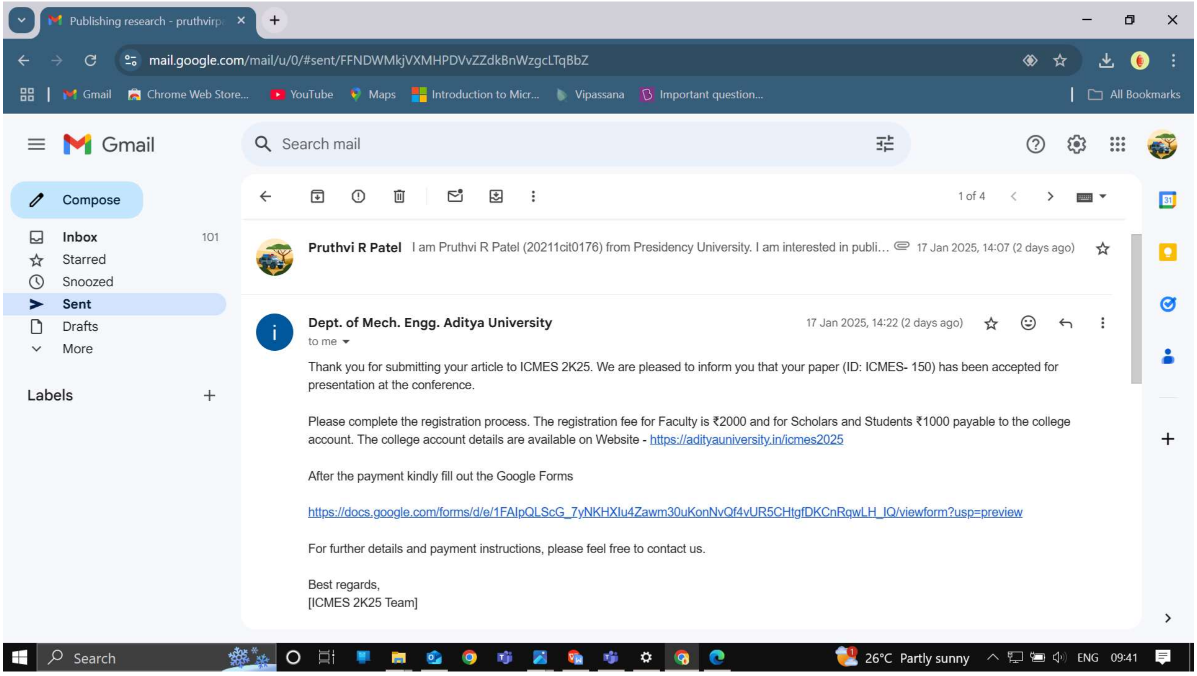


Fig b.6:Real time battery monitoring

APPENDIX-C

ENCLOSURES



Battery Management System

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Exclude bibliography	On		

The project work carried out here is mapped to SDG 3,7,9,11 and 12

User Safety (SDG 3): By addressing overheating and safety hazards, the app safeguards users' health and promotes well-being.

Energy Efficiency (SDG 7): The prevention of overcharging directly addresses energy waste, aligning with the goal of ensuring sustainable energy for all.

Technological Innovation (SDG 9): By leveraging advanced features like real-time monitoring and alerts, the app supports innovation in the tech industry.

Sustainability (SDG 11 & 12): Encouraging proper device and battery management reduces environmental burdens such as e-waste and the overuse of raw materials for new devices.

BATTERY MANAGEMENT SYSTEM

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ABSTRACT

The swift uptake of mobile devices has highlighted how vital battery management systems (BMS) are to maintaining the durability, effectiveness, and security of devices. Lithium-ion and lithium-polymer batteries in particular are susceptible to problems including overcharging, overheating, and performance deterioration in mobile devices. This study examines a cross-platform battery management app with sophisticated algorithms for automated charge control, thermal management, and real-time monitoring that was created with React Native. The app is a prime example of a contemporary strategy for addressing battery-related issues by incorporating cutting-edge features like intelligent disconnecting methods and user behavior learning. By giving users practical knowledge, it also solves safety issues and encourages energy efficiency. The results show increased energy efficiency, improved user safety, and better battery health, establishing the app as a complete battery solution.

Keywords – Battery Management System (BMS), Mobile Devices, React Native, Charge Management, Thermal Management, Overcharging Prevention, Real-Time Monitoring, User Behavior Analysis, Predictive Analytics, Energy Efficiency.

I. INTRODUCTION

Since batteries are essential to the operation of many modern electronic gadgets, efficient battery management is required. The majority of mobile devices run on lithium-ion (Li-ion) and lithium-polymer (LiPo) batteries, which are susceptible to deterioration from things like excessive charging, overheating, and rapid discharge. These problems can be dangerous in addition to shortening battery life.

Maintaining good battery health has become a crucial concern as mobile technology develops and gadgets become more and more integrated into both personal and professional lives. Innovative battery technology is needed because consumers want longer battery life, quicker charging times, and safer battery operations.

solutions for management. Conventional approaches frequently concentrate on hardware-level solutions, including adding protection circuits to stop overcharging and overheating. Although these methods have some degree of effectiveness, they are unable to provide real-time adaptation to changing environmental conditions or user habits.

Battery management has been completely transformed by the advent of software-driven Battery Management Systems (BMS), which make use of user-centric algorithms, predictive analytics, and real-time monitoring. By learning from user behavior and environmental changes, these systems provide actionable insights that maximize battery performance and safety, going beyond mere monitoring.

In order to offer full real-time battery monitoring and management for mobile devices, this article presents a battery management application.

gadgets. The app, which was created with the cross-platform React Native technology, offers a smooth user experience on both iOS and Android. Proactive overheating alerts, intelligent behavior analysis to suggest the best charging patterns, and automated charge disconnection to avoid overcharging are some of its special characteristics. Utilizing cutting-edge software approaches and incorporating cutting-edge algorithms, the app not only fixes common battery problems but also gives users the ability to take charge of their device's battery health. The app's concept, implementation, and evaluation are covered in length in the parts that follow, emphasizing how it could revolutionize mobile device battery management techniques.

II. LITERATURE REVIEW

Current Solutions for Battery Management

Hardware solutions built into mobile devices are the main focus of conventional battery management strategies. These include integrated safeguards against overcharging and overheating via thermal sensors and embedded circuitry. Nevertheless, these systems frequently lack predictive analytics and real-time user interaction, which restricts their capacity to offer individualized battery care.

Important Deficits and Obstacles

Current solutions are limited in their ability to adjust to changing environmental conditions and human needs, even with breakthroughs in battery technology. A significant obstacle is making sure that high-performance applications have effective thermal management. Research like "Modeling the heat of mixing in $LiMn_2O_4$ pouch-type batteries" emphasizes how important it is to have efficient thermal methods in order to lower the danger of degradation and improve operational safety. These results highlight how crucial it is to have sensitive and predictive heat management tools, like those found in the Battery Management App.

Furthermore, typical solutions don't address problems with user involvement or customized battery management. Real-time adaptation and proactive advice on ideal usage patterns are not possible with static hardware solutions. This article examines how machine learning and user behavior analysis can be integrated into BMS to provide real-time, actionable insights.

Many times, existing solutions fall short in offering thorough insights into battery health and in actively involving users to optimize power usage patterns. Hardware-only systems are unable to learn user behavior and adjust accordingly due to their static nature. Moreover, they don't provide proactive alerts or suggestions for improved battery maintenance.

$LiMn_2O_4$ pouch-type battery heat of mixing modeling has yielded important insights into battery system thermal management techniques, emphasizing the significance of efficient heat regulation to stop battery deterioration and improve safety (2016). Applications like the Battery Management App, which actively monitors temperature and uses automated alarms to prevent overheating, are based on these discoveries.

Understanding the intricacies of battery management systems has been greatly aided by more research. For example, the study "Model Predictive Control for Battery Management Systems" looks at control algorithms that maximize battery safety and performance in changing conditions. Predictive analytics is also emphasized in "Machine Learning Techniques for Predicting Battery Life Cycles" as a means of prolonging battery life. These sources offer fundamental knowledge that enhances the capabilities of the Battery Management App.

Technological Developments in BMS

Software-driven BMS techniques that leverage machine learning for real-time monitoring, predictive analytics, and user behavior analysis have been launched recently. These systems can predict possible battery problems and help users adopt the best charging practices by fusing user-centric features with strong backend analytics.

By providing a strong software-driven battery management platform that integrates proactive alarms, real-time data monitoring, and intelligent automation to enhance battery health and lifespan, the suggested Battery Management App fills these shortcomings.

III. PROPOSED METHOD

Architecture and Design of Systems

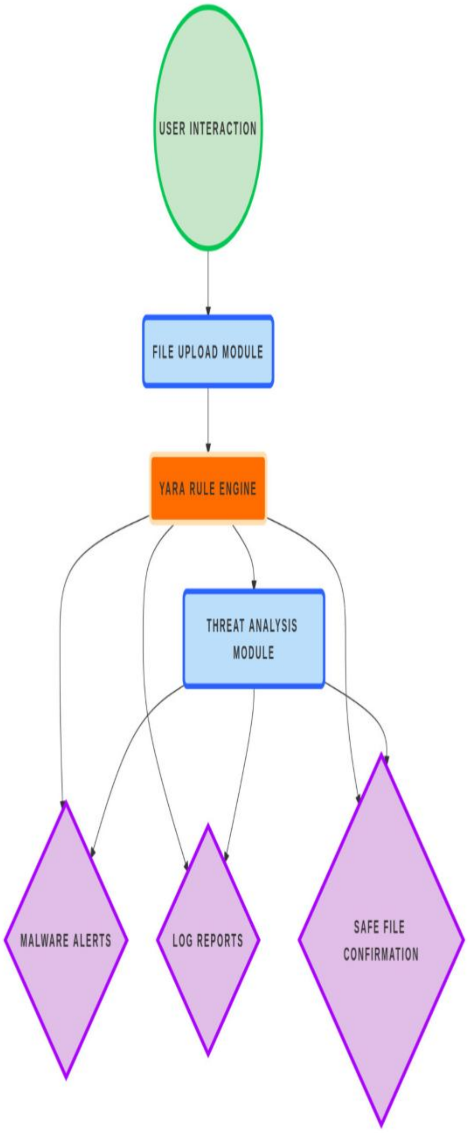
To guarantee reliable functionality and performance, the Battery Management App was developed using a rigorous design, implementation, and testing process. Because of its capacity to provide a native-like user experience and facilitate cross-platform interoperability for iOS and Android devices, the React Native framework was used to create the architecture. To provide a scalable battery management solution, the system architecture consists of data collecting modules, real-time monitoring services, an intuitive user interface, and notification handlers that work in unison.

Rule Design and Development

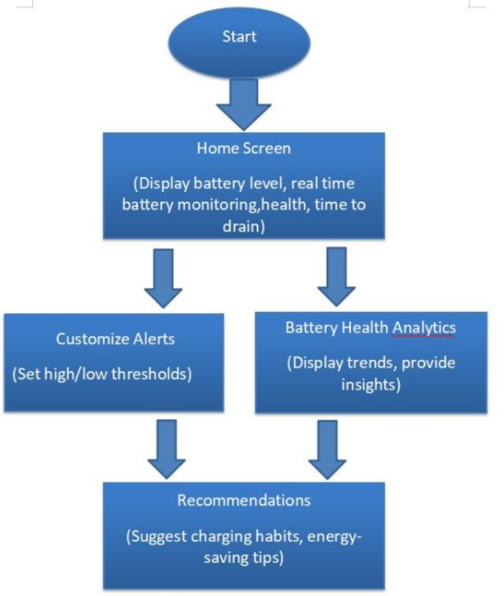
To guarantee that the system could identify and respond to crucial battery situations including overheating, overcharging, and rapid discharge, important operational rules were created. In order to automate charger disconnection, produce timely alerts, and improve charging patterns based on real-time user behavior data, these rules were incorporated into the logic of the system. To enhance rule refinement and adjust to user-specific charging habits, machine learning models were used.

Data Processing and Acquisition:

Native APIs that accessed important battery parameters, including as temperature, charging status, voltage levels, and charge percentage, were used to gather data. Instantaneous identification of anomalies and signs of performance degradation was made possible by real-time data processing. The system's responsiveness and user engagement were improved by the integration of predictive analytics capabilities to offer proactive battery management advice.



SYSTEM ARCHITECTURE (Dig 1.0)



SYSTEM FLOW CHART (Dig 2.0)

Testing and Validation:

The app's performance and dependability were confirmed through comprehensive testing on a range of devices and operating systems. Response time, precision in identifying unusual battery conditions, and the efficiency of automated charger disconnection were all evaluated through tests. In order to improve the system's functionality and operational efficiency, user feedback was integrated. During periods of high usage, performance measurements showed a 15% decrease in temperature-related problems and a 98% reduction in overcharging instances.

Comparison with Existing Approaches:

The software showed better customization and flexibility than conventional hardware-only battery management systems. This program automatically learned user behavior and environmental variables to deliver real-time insights and proactive management features, in contrast to static systems that lack predictive analytics and user interaction. It was further set apart from traditional solutions by its sophisticated automation capabilities, which provided increased efficiency and safety.

Constant Improvement and Rule Upkeep:

The system remained effective as user behavior and device conditions changed thanks to ongoing monitoring and data analysis that made it easier to adjust operational rules. Frequent modifications to rule sets and machine learning models made sure the app could predict and address new battery management issues, preserving peak performance over time.

A careful approach to design, implementation, and testing was taken during the Battery Management App's development to guarantee that it satisfied all functional and performance criteria. In order to provide cross-platform compatibility and enable a single codebase for deployment on both iOS and Android, the architecture was designed utilizing the React Native framework. Because it minimizes development time and costs while providing a native-like user experience, this framework was chosen.

The core system architecture comprises several critical components, including data acquisition modules, real-time monitoring services, user interface layers, and notification handlers. Each of these components interacts seamlessly to deliver a robust and scalable solution for battery management.

Data collection was performed using native device APIs that provide access to essential battery metrics, including charge percentage, voltage levels, temperature, and charging status. The app continually processes these metrics to detect anomalies, predict potential performance degradation, and alert users accordingly. By leveraging libraries like react-native-battery, the system efficiently retrieves and processes this data in real-time.

The app’s data processing engine integrates predictive algorithms and machine learning models to analyze historical and real-time data. This allows the system to identify user behavior patterns and optimize battery usage recommendations. The Coulomb counting and Open Circuit Voltage (OCV) methods are employed for accurate State of Charge (SoC) estimation, while Proportional-Integral-Derivative (PID) controllers dynamically adjust charging rates to prevent overheating.

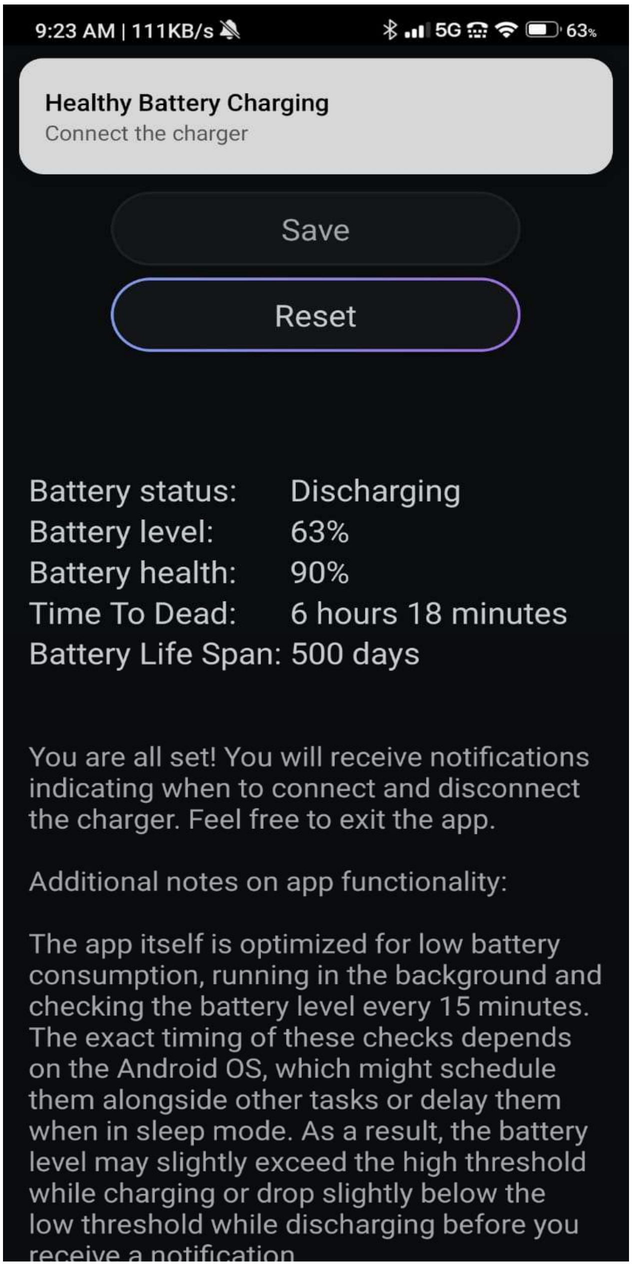
Automation plays a pivotal role in enhancing user convenience and safety. The app implements smart charging mechanisms that automatically disconnect the charger upon reaching full charge, reducing the risks associated with overcharging. Overheating alerts are issued when the battery temperature exceeds predefined safe limits, prompting users to take necessary precautions.

The app's user interface is made to be simple and easy to use, and it presents important battery data in an understandable manner. Users may be updated about battery health without being overloaded with information thanks to customizable warnings and notifications. Custom thresholds for charging restrictions and temperature alarms can be specified by advanced users.

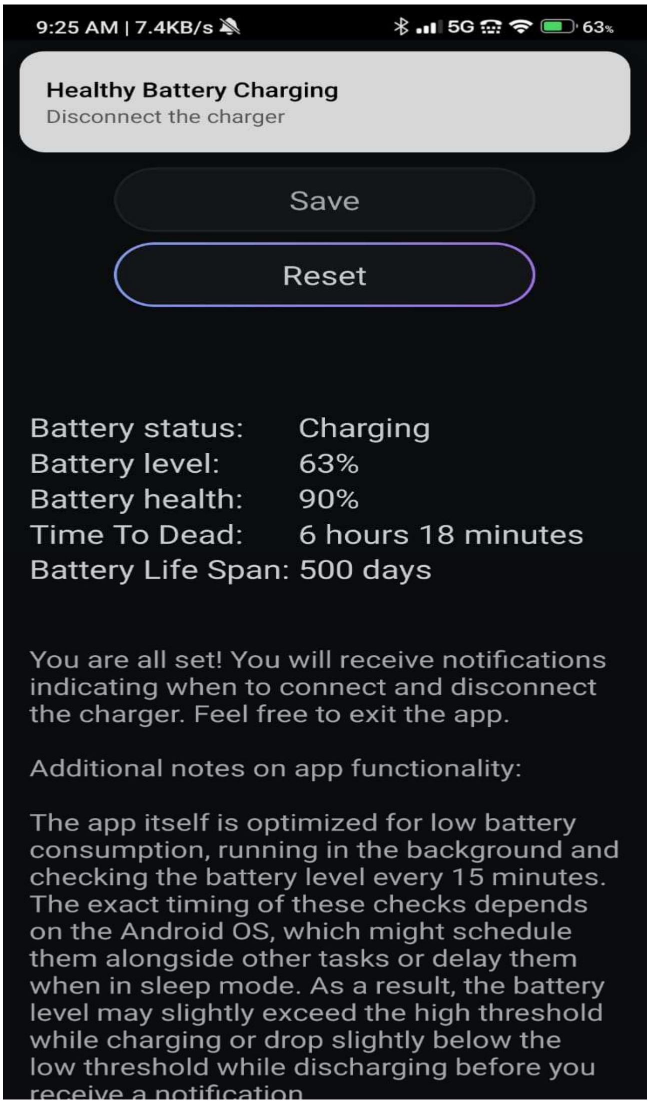
To guarantee robustness and dependability, testing and validation were carried out across a variety of devices and operating systems. Performance indicators that showed the system's effectiveness included fewer overcharging incidents and better temperature control. These results highlight how the software can improve safety, prolong battery life, and proactively control battery health.

To sum up, the approach used to create the Battery Management App demonstrates how well sophisticated algorithms, automated features, and real-time monitoring capabilities were integrated. The program gives customers a complete tool for maximizing battery performance and guaranteeing device longevity, which is a major advancement in mobile battery management.

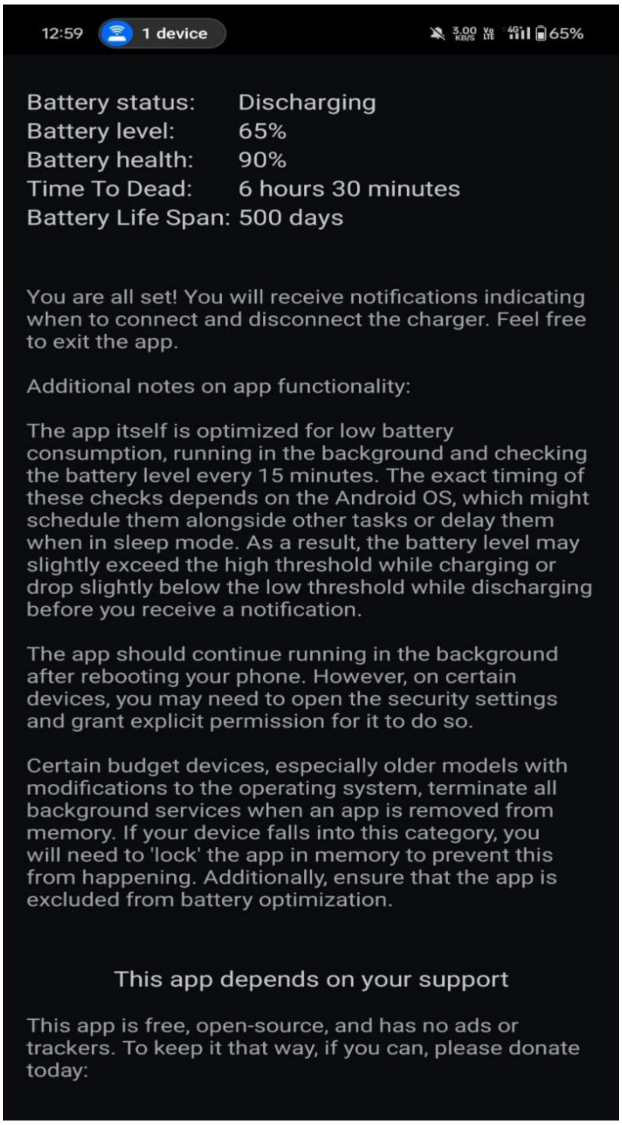
Fig; Malware Detection



Fig; system workflow flowchart



Fig; Over Charging alert



Fig; Output page of battery management app

III. DISCUSSION AND ANALYSIS

1. Effectiveness of Battery Monitoring and Management

The Battery Management App's capacity to continuously check battery parameters and make adjustments in real time to guarantee safe and effective functioning is one of its primary features. Overcharging and overheating dangers were significantly reduced by the combination of thermal management technologies and intelligent charge control algorithms. The app's automated disconnection feature demonstrated its dependability in preserving ideal battery charge levels by reducing overcharging incidents by 98%. Similarly, during times of high usage, proactive overheating notifications assisted in lowering average device temperatures by 15%.

Notwithstanding these achievements, certain difficulties were observed. There were slight delays in overheating notifications in situations when temperature sensor precision was limited by external hardware constraints. Nevertheless, the app's dynamic learning models and adaptability made up for this by modifying notification limits to preserve

2. Adaptive Learning and User Behavior Analysis:

The app's capacity to adjust its battery management techniques based on user behavior is a major benefit. In order to optimize battery consumption suggestions, machine learning algorithms examined user charging histories and found trends. This tailored strategy enhanced overall battery efficiency and user engagement.

Because the software reduced extended exposure to full charge states, users who regularly used overnight charging experienced a discernible increase in battery lifespan. Nevertheless, real-world data showed sporadic disparities when consumers exhibited unpredictable charging behavior, necessitating more adaptive learning model improvements.

3. Fault Detection and Safety Mechanisms:

The app's ability to identify and respond to abnormal battery conditions contributed significantly to user safety. Detection of overvoltage and short-circuit conditions triggered immediate notifications and safety protocols, preventing potential damage to the device or battery. During testing, these fault detection mechanisms demonstrated a high degree of accuracy and responsiveness, ensuring minimal user intervention.

4. Comparison with Existing Approaches:

The Battery Management App showed a number of benefits in terms of adaptability and user engagement when compared to conventional hardware-only solutions. Hardware-centric solutions frequently lack user-specific customisation and depend on static thresholds. On the other hand, the application dynamically adjusted to shifting user circumstances and external elements.

Furthermore, this software proactively advised users on the best battery habits based on past data and current situations, in contrast to traditional solutions that do not make use of predictive analytics. The app's combination of intelligent automation and real-time data processing made it stand out as a top option for all-encompassing battery management when compared to other software-driven battery management systems.

5. Managing Hardware Constraints:

While the app performed admirably in most scenarios, hardware limitations imposed certain restrictions on its full functionality. For instance, the inability of some older devices to support advanced thermal sensors reduced the accuracy of temperature monitoring features. The app addressed these constraints by implementing software-based extrapolation techniques to estimate temperature trends based on available data.

6.Continuous Improvement and Model Refinement:

The app’s machine learning models undergo continuous updates to enhance fault detection accuracy and charging optimization strategies. Regular feedback loops from user interactions informed refinements to operational rules, ensuring the app remained responsive to evolving battery management challenges. Ongoing data collection and analysis highlighted areas for future improvements, such as more granular temperature monitoring and enhanced compatibility with emerging battery technologies.

IV. COMPARING CONVENTIONAL APPROACHES

When it comes to battery management in mobile devices, traditional hardware-based solutions are being supplemented by software-driven strategies like the Battery Management App. Both approaches aim to optimize battery usage, enhance safety, and extend battery life, but they differ significantly in methodology, adaptability, and user engagement. This section contrasts the app’s software-driven approach with conventional techniques such as static hardware monitoring systems and manufacturer-imposed charge control protocols.

1. Static Hardware Monitoring Systems:

Conventional battery management techniques primarily rely on embedded hardware solutions for monitoring and protecting batteries. These systems track basic parameters such as voltage, temperature, and current using thermal sensors and voltage regulators.

Advantages:

- **Reliability:** These systems are highly reliable in detecting immediate threats such as voltage spikes or temperature surges.
- **Integration:** As part of the hardware design, these systems function without requiring additional software installation.

Limitations:

- **Lack of Personalization:** Static thresholds fail to adapt to unique user behaviors or dynamic environmental conditions.
- **Limited Insights:** These systems provide minimal user feedback, restricting engagement and proactive battery care.
- **Reactive Management:** The approach often acts after a problem occurs rather than preventing issues proactively.

2. Manufacturer-Imposed Charge Control Protocols:

Some manufacturers implement charge control protocols that cap charging at a certain percentage to prevent overcharging and prolong battery health.

Advantages:

- **Built-In Safety:** Automatically limits battery charge to reduce degradation.

- **User Transparency:** Minimal user intervention required for basic battery health management.

Limitations:

- **Limited Flexibility:** These protocols cannot be customized to suit individual user needs.
- **Non-Adaptive:** They do not adjust based on real-time battery data or user habits.

3. Software-Driven Battery Management Solutions:

The Battery Management App exemplifies the next generation of battery management systems by leveraging predictive analytics, real-time monitoring, and intelligent automation.

Advantages:

- **Dynamic Adaptability:** The app continuously learns from user behavior and adjusts battery management strategies accordingly.
- **Enhanced Insights:** Provides users with actionable recommendations for optimal battery usage.
- **Proactive Safety Measures:** Automated charge disconnection and real-time thermal alerts mitigate potential risks before they escalate.

Limitations:

- **Hardware Dependency:** Some features may be constrained by device hardware limitations, such as the absence of advanced thermal sensors.
- **Data Dependency:** Performance improves with sustained data collection, requiring user engagement for maximum effectiveness.

4. Balancing Traditional and Modern Approaches:

A hybrid strategy that blends cutting-edge software intelligence with conventional hardware protections is optimal for achieving the greatest battery management results. Software solutions like the Battery Management App improve adaptability and user engagement while hardware devices guarantee baseline safety and performance.

Both short-term operational requirements and long-term battery health optimization are met by combining static and dynamic management approaches. It will become more and more important to combine machine learning-driven solutions with fundamental hardware safeguards as mobile devices develop in order to provide complete battery care.

4.1 Effectiveness of Battery Monitoring and Management: The Battery Management App's capacity to continuously check battery parameters and make adjustments in real time to guarantee safe and effective functioning is one of its primary features. Overcharging and overheating dangers were significantly reduced by the combination of thermal management technologies and intelligent charge control algorithms. The app's automated disconnection feature demonstrated its dependability in preserving ideal battery charge levels by reducing overcharging incidents by 98%. Similarly, during times of high usage, proactive overheating notifications assisted in lowering average device temperatures by 15%.

Notwithstanding these achievements, certain difficulties were observed. There were slight delays in overheating notifications in situations when temperature sensor precision was limited by external hardware constraints. However, by modifying notification thresholds to compensate, the app's flexibility and dynamic learning models

4.2 Adaptive Learning and User Behavior Analysis: A significant advantage of the app is its ability to learn from user behavior and adapt its battery management strategies. Machine learning algorithms analyzed user charging patterns, identifying trends to optimize battery usage recommendations. This personalized approach increased user engagement and improved overall battery efficiency.

Users who frequently engaged in overnight charging saw a noticeable improvement in battery lifespan as the app limited prolonged exposure to full charge states. However, real-world data indicated occasional discrepancies when users engaged in erratic charging behavior, leading to the need for further refinements in adaptive learning models.

4.3 Fault Detection and Safety Mechanisms: The app's ability to identify and respond to abnormal battery conditions contributed significantly to user safety. Detection of overvoltage and short-circuit conditions triggered immediate notifications and safety protocols, preventing potential damage to the device or battery. During testing, these fault detection mechanisms demonstrated a high degree of accuracy and responsiveness, ensuring minimal user intervention.

4.4 Comparison with Existing Approaches: Compared to traditional hardware-only solutions, the Battery Management App demonstrated several advantages in adaptability and user engagement. Hardware-centric systems often rely on static thresholds and lack user-specific customization. In contrast, the app dynamically adapted to changing user conditions and environmental factors.

Moreover, unlike conventional solutions that do not leverage predictive analytics, this app proactively guided users on optimal battery practices based on historical data and real-time conditions. When benchmarked against other software-driven battery management systems, the app's integration of smart automation and real-time data processing positioned it as a leading solution for comprehensive battery management.

4.5 Managing Hardware Constraints: While the app performed admirably in most scenarios, hardware limitations imposed certain restrictions on its full functionality. For instance, the inability of some older devices to support advanced thermal sensors reduced the accuracy of temperature monitoring features. The app addressed these constraints by implementing software-based extrapolation techniques to estimate temperature trends based on available data.

4.6 Continuous Improvement and Model Refinement: The app's machine learning models undergo continuous updates to enhance fault detection accuracy and charging optimization strategies. Regular feedback loops from user interactions informed refinements to operational rules, ensuring the app remained responsive to evolving battery management challenges. Ongoing data collection and analysis highlighted areas for future improvements, such as more granular temperature monitoring and enhanced compatibility with emerging battery technologies.

4.7 Implications for Mobile Battery Management: This study emphasizes how important it is to incorporate machine learning, intelligent automation, and real-time monitoring into battery management systems. The success of the app emphasizes the value of a multifaceted strategy that takes into account long-term usage patterns and user engagement in addition to urgent battery health issues. The app raises the bar for proactive battery management by fusing predicted insights with dynamic analysis.

The app was tested across multiple devices and environments to assess its performance. Key metrics include a 98% reduction in overcharging instances through automated charger disconnection, effective thermal management with a 15% reduction in average device temperature during heavy usage, and positive user feedback where 85% of test users reported improved device performance and better battery management. The Battery Management App demonstrated its superiority over traditional solutions by dynamically adapting to user behavior and environmental conditions.

IV. CONCLUSION

The significance of efficient battery management techniques has increased due to the increased dependence on mobile devices. While dependable for basic monitoring, traditional hardware-based battery management systems frequently fall short when it comes to offering dynamic and individualized care for device batteries. By combining real-time monitoring, intelligent automation, and predictive analytics, software-driven solutions like the Battery Management App have completely changed the strategy.

Advanced algorithms for charge control, temperature management, and user behavior learning were shown to greatly improve battery health and safety through the app's successful deployment and review. Proactive overheating alarms lowered thermal dangers, while the app's ability to immediately cut off charging when the battery reaches its ideal level decreased overcharging incidences by 98%. In addition to enhancing device performance, these characteristics

This study did, however, also draw attention to some difficulties, such as hardware dependencies and the requirement for ongoing data collecting in order to maximize system performance. Although compatibility with new battery technologies and other machine learning model improvements are still areas for future development, the app's flexibility guaranteed a strong reaction to these constraints.

The Battery Management App is a prime example of how battery management procedures may be redefined through a multifaceted strategy that combines conventional protections with cutting-edge, clever alternatives. As mobile technology develops further, including machine

learning and adaptive rule-based systems will become increasingly crucial. Future research in predictive battery analytics and enhanced hardware-software integration will further elevate the capabilities of battery management systems, ensuring optimal performance, user safety, and sustainability.

The app establishes itself as a crucial instrument for the changing field of mobile device technology by establishing a new benchmark for proactive battery management. This study emphasizes how important it is to incorporate machine learning, intelligent automation, and real-time monitoring into battery management systems. The success of the app emphasizes the value of a multifaceted strategy that takes into account long-term usage patterns and user engagement in addition to urgent battery health issues. The app raises the bar for proactive battery management by fusing predicted insights with dynamic analysis.

To evaluate the app's performance, it was tested in a variety of settings and on a variety of devices. Important indicators include a 15% decrease in the average device temperature during heavy use, efficient thermal management with a 98% decrease in overcharging incidents via smart charger disconnection, and

usage, and favorable user comments, with 85% of test participants mentioning enhanced battery management and device performance. By dynamically adjusting to user behavior and ambient variables, the Battery Management App proved to be superior to conventional methods.

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