A Real-time School Bus Tracking System for Enhanced Safety and Parental Assurance in Sri Lanka

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***Abstract*—Real-time, accurate School bus transportation has been a persistent difficulty for decades, partially because of insufficient timetables, limited communication, safety concerns for students, and the limitations of current school bus real-time tracking technology. To address these difficulties by using Global Positioning System technology (GPS) and a mobile application. The existing real-time location tracking systems for school buses provide position details but do not accurately provide real-time location updates identify traffics Manual interventions fail to adapt due to the complexity, and this greatly creates user disappointment. This research addresses these concerns via a completely designed real-time school bus tracking system for school buses. The system offers real-time monitoring of bus location, automatic attendance management, and rapid notifications for pickups, drop-offs, and handling emergency incidents. Novel features include a Lost & Found system for reporting and matching missing things an optional Buddy System notification that improve the students' post-drop-off moments. The chatbot feature provides quick user support, speeding the communication process. Data gathered via role-based questionnaires and conducted conversations with parents, children, and school bus drivers verify the system's requirement. Currently the system is fully developed, the framework is designed for smooth integration into existing school transportation systems, giving a cost-effective, scalable option for improving safety and parental trust. The system is meant to both economically practical, requiring decreased processing power, and giving a full solution for the challenges happening in school bus communication.**

Keywords— GPS, Student Tracking, Real-Time Monitoring, Attendance Management, Technological Innovation

I. INTRODUCTION

A major problem for school administrators and parents nowadays is the safety and security of pupils during their travel to school. School transportation safety has grown as a key concern for educational institutions globally, with Sri Lanka having specific challenges in managing student transportation successfully. The traditional approach to school bus management relies primarily on manual communication and lacks real-time visibility, leading to security risks and operational inefficiencies. Current issues in Sri Lankan school transportation include different communication between parents and drivers, difficulty in tracking bus positions during emergencies, lack of systematic event reporting, and insufficient safety monitoring techniques. These difficulties have been increased by the increasing number of safety incidents and the growing demand for transparency in student transportation. This research addresses these difficulties by presenting a comprehensive real-time school bus tracking and safety management system. This solution includes modern mobile technologies, GPS tracking, automatic communication to create a seamless experience for all stakeholders while prioritizing student safety and operational efficiency. Primary objectives of this research include analyzing current challenges in Sri Lankan school transportation through comprehensive stakeholder surveys, designing a customerfocused mobile application that addresses identified pain points, developing innovative safety features including emergency alerts and buddy system functionality, and creating a scalable technological framework suitable for Sri Lankan educational institutions.

II. RESEARCH MOTIVATION

The National Crime Records Bureau said that recent studies in India show that a child goes missing every eight minutes. The National Center for Missing and Exploited Children in the US also found about 800,000 children under 18 who were missing. The FBI's National Crime Information Center (NCIC) registered 462,567 missing

children in 2013 alone. These kinds of events make it clear how important it is to have effective child safety and monitoring systems all across the world. In Sri Lanka has comparably fewer reported but concerns regarding student safety during school commutes remain important. Particularly due to not sufficient transport monitoring and the absence of real-time communication between schools, parents, and drivers. These worldwide findings, together with local safety concerns, strongly encouraged for the creation of a fully working real-time school bus location tracking system for Sri Lankan school pupils. The goal of this system is to make school bus travel safer for kids, provide parents peace of mind, and help schools run their transportation operations more smoothly.

III. RELATED WORK

School bus Tracking is one of the most popular research subjects and considerable work has been carried out in recent years. Ensuring the safety and effective management of school transportation.[1]A number of helpful methods have been proposed by various writers to track a vehicle. This chapter explains about the different works done by various researchers that deal with tracking a vehicle. [2] Implementation of the School Bus Safety Management Act in 2012, which places focus over the school bus, drivers etc. It a great solution for the safe transport of children became a significant importance in China.[3]

In these days, it is a uncommon for parents and guardians to worry about the well-being and safety of their child or children. [4], [5] In India, according to the study child goes missing every eight minutes according to the data analysis from national crime records bureau. [6] Existing approaches to school transportation management in Sri Lanka, India, Indonesia, and China kind of developing regions have not successfully addressed the necessity of real-time, safetyfocused school bus location monitoring[7], [8] While some schools and transport providers employ manual attendance records or basic GPS-enabled services these solutions[9],[10]As a result, parents have limited visibility[11] into their child's journey, delaying of responding to emergencies . [10], [12], [13] However, these are designed for efficiency rather than students' safety. Their costly infrastructure and subscription costs make them less practicable for widespread use in schools, particularly amid budgetary limitations. Recent developments in mobile technologies, cloud services, low-cost, scalable, and safetyoriented solutions for school transport. Mobile apps with integrated mapping APIs can now give live GPS updates, [14], [15] while push notification services such as Firebase Cloud Messaging (FCM) can instantly inform parents of pickup, drop-off, and delay events. These technologies can be implemented using minimal hardware investments, leveraging the GPS capabilities of drivers' and students' mobile devices instead of expensive dedicated tracking units. [16]In this research builds upon these advancements by offering a multi-role mobile application tailored for parents, drivers, and students. [6] It integrates real-time GPS tracking, automated alerts, and emergency handling with novel features such as a Buddy System for peer safety, a Lost & Found mechanism to recover misplaced items, and two-way communication paths between parents and drivers. In systems, it also addresses driver authentication security via biometric login, provides incident reporting workflows for breakdowns, road closures and student health issues. Key innovation is the system's focus on parental peace of mind and working efficiency. The platform not only improves visibility but also reduces delays caused by unnecessary stops and miscommunication.

Additionally, the system is designed for scalable deployment from a single bus operation to multi bus stops while keeping low operating costs with cloud-based architecture and serverless back-end services. By overcoming the constraints of current school transport monitoring technologies and creating a cost-effective, full of features, secure platform, this study has the potential of greatly improving the children' transportation safety and parental trust among Sri Lanka as well as globally.

A. System Designed Framework

System real-time school bus location was created to improve student safety, parental awareness, and operational efficiency in school transport services. The system combines GPS-based location tracking, cloud-hosted real-time data synchronization, and intelligent safety features such as emergency alerts, a Buddy System, and Lost & Found item recovery. The framework consists of three main components GPS and Location Services. Integrated within driver and student mobile devices, allowing continuous transmission of location data to the back end. Cloud-Based Real-Time Data Platform Hosted on Firebase, responsible for storing and updating live bus location, journey status, incident reports, and user alerts across all stakeholders. Multi-Role Mobile Application. A cross-platform application (React Native) with role-specific interfaces for Parents, Drivers, and Students allowing registration, live tracking, notifications, and safety workflows. This architecture minimizes infrastructure costs by leveraging existing smartphones and cloud services rather than needing specialized tracking hardware.

B. Data flow

Data flow of the system starts with real-time GPS location obtaining from the driver's mobile device. This device continually transmits latitude, longitude, speed, and heading to the cloud back end via secure WebSocket connections. Simultaneously, event-based events such as boarding, dropoff, or incident reports are started by the driver through the mobile app interface. For example, Boarding Events As each student boards the bus, the driver marks them present, giving both a timestamp and location to the back end. Drop-off Events: Similar updates are sent at the student's scheduled stop. The cloud back end processes and stores this information in Fire store, while also initiating push alerts to parents through Firebase

Cloud Messaging. Each notification includes contextual details such as the child's name, event type (boarded/dropped off), and live map position. For safety features, the data flow includes Emergency Alerts Triggered from a student's device, sending immediate notifications to parents, drivers, and potentially school administrators, along with real-time position tracking until resolved. Buddy System Alerts Proximity deviation detection on the student's device, sending alerts if a linked buddy moves outside a set drop-off zone radius. Lost & Found Reports Submitted by either the driver or parent, stored in the database, and matched using text and image-based algorithms to notify relevant parties of possible matches. This integrated data flow ensures continuous situational awareness, rapid incident reaction, and seamless reach among all stakeholders. By leveraging existing mobile device capabilities and cloud-hosted infrastructure, the system provides a cost-effective, scalable, and safety-centric solution for school transportation tracking.

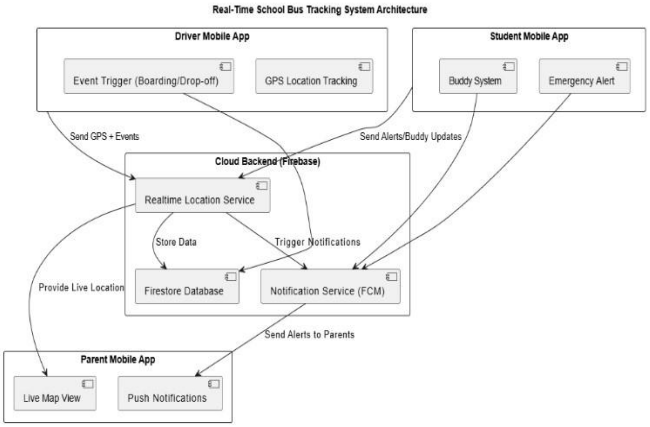

Fig 1 System Architecture Diagram

Fig 1 contains the three major role logins Driver, Student, and Parent sides. This system integrates with a cloud-based back end hosted on Firebase. School bus Driver handles GPS location monitoring and incidents such as student boarding and drop-off, transmitting these updates to the cloud back end in real time. Students offer safety features such the Buddy System and Emergency Alert, which send alarms or buddy updates directly to the back end. At the core, the Cloud Back end includes the Real-time Location Service, Fire store Database for persistent storage, and Firebase Cloud Messaging (FCM) for quickly push alerts. The back end processes incoming location and event data, saves important information, and generates notifications to stakeholders. From the parent's the perspective Parent provides a real time map view of the school bus location and receives timely push messages regarding boarding, drop-off, delays, and emergency occurrences. This design allows smooth, low-latency communication among all stakeholders, boosting both operational efficiency and student safety.

IV. METHODOLOGY

A. Framework

School Transportation Google Survey Prior to developing the school bus location tracking system, a comprehensive perception survey was conducted to assess the existing challenges faced by parents, drivers, and school administrators in monitoring student transportation. The survey, distributed online via Google Forms, collected data from parents of school-going children, bus drivers.

Questionnaire was designed to capture insights into, Frequency of delays and missed pick-ups/drop-offs. And also this is a role-based questionnaire. Level of parental concern during student travel. Awareness and usage of existing bus tracking solutions. Communication channels between drivers and parents. Common safety concerns (e.g., breakdowns, harassment incidents, lost items). Responses identify critical pain points, including the lack of real-time location visibility, delayed notifications, and manual communication methods prone to miscommunication.

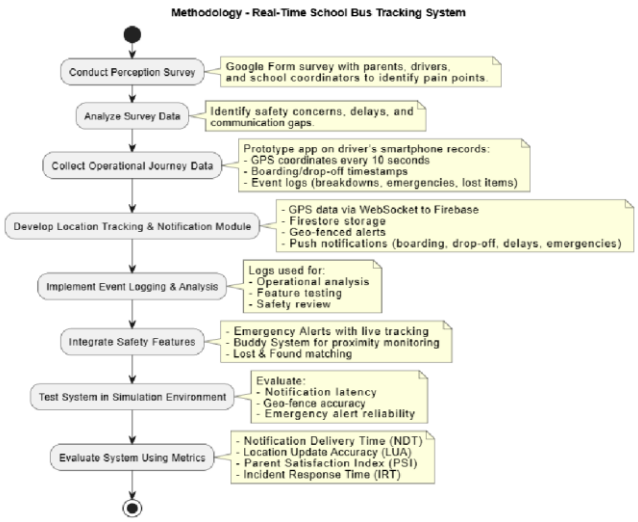

Fig 2 Used Methodologies to develop the System

The development and testing of the bus tracking system were carried out according to the process illustrated in this diagram. To begin, it conducts problem-finding surveys; next, it gathers GPS and journey data from a driver's app; then it builds location tracking and alerts; incorporates safety features; tests the system in simulations; and finally, it analyzes its performance using speed, accuracy, and user happiness.

B. Data Collection

The data collection of this research in two complementary phases.

1. Survey Data Collection – survey results provided qualitative and quantitative data on user needs, preferred features, and pain points in existing school bus monitoring practices.

2. Operational Journey Data Collection – To gather real-world bus location and event data, driver mobile application was installed on the primary driver's smartphone. This application recorded GPS coordinates, speed, and time-stamped boarding/drop-off events during a two-week pilot period on a single school route. Data captured included,

- GPS location updates at 10-second intervals.
- Boarding and drop-off confirmations with timestamps.
- Triggered event logs for breakdowns, delays, and emergency button presses.
- Lost & Found reports initiated by either driver or parents.

The collection process relied on smartphones with built-in GPS modules, eliminating the need for costly dedicated tracking hardware. This approach ensured feasibility for deployment in resource-constrained school environments.

A. C. Location Tracking and notification module

The real-time tracking module is powered by GPS data from driver devices, transmitted via secure WebSocket connections to a Firebase-hosted backend. Upon each location update, the system:

1. Stores the coordinates and speed in Fire store.
2. Updates the bus's live position on the parent's app map using Google Maps API.
3. Triggers geo-fenced notifications when entering/exiting designated pick-up or drop-off zones.

This module also integrates push notifications via Firebase Cloud Messaging (FCM) f

- Boarding and drop-off confirmations.
- Estimated Time of Arrival (ETA) changes due to delays.
- Emergency alerts from students or drivers.

D. Event logging and Analysis

All journey events boarding, drop-off, incident reports are logged in the real-time database along with metadata such as location, time, and driver ID. This dataset is used for,

- Operational Analysis - Identifying delays and route inefficiencies.
- Feature Testing - Validating Lost & Found and Buddy System functionalities.
- Safety Review- incident frequency and emergency response times.

E. Safety feature Implementation

1. Emergency alert workflow

Students get alerts from their app. Parents, drivers, and driver get instant push notifications with location. Live location sharing stays active until alert resolution.

2. Buddy System

Paired students' devices monitor at drop-off places. Alerts are sent to both sets of parents if deviation from the drop-off zone exceeds the provided range.

3. Lost & Found Matching

Driver and parent reports are saved with item details and optional photos. Matching algorithms run periodically to find possible matches and notify users.

F. System Testing Environment

Before deployment in a live school environment, the system was tested in a controlled simulation using recorded GPS route data. This allowed review of,

- Notification latency under changing mobile network conditions.
- Accuracy of the message alerts.
- Reliability of emergency alerts

These simulations decreased the risk of communication failures during live operation and allowed iterative refinement of the mobile app UI and back-end event handling.

G. Evaluation Metrics

To measure how well the system works, we will use Time delayed between the occurrence of an event and the receiving of an alert is known as the Notification Delivery Time (NDT).
LUA, or Location Update Accuracy, the difference between the user's reported and real GPS location.
User satisfaction after deployment can be measured by the Parent Satisfaction Index (PSI), which based on surveys.

Time it takes for the responsible party to recognize an emergency alert is known as the incident response time (IRT).

V. RESULTS

This School Bus Real-Time Location Tracking was a fully developed system with important milestones previously completed in both feature design and system process the process of execution. The core functional modules with real-time GPS monitoring, parent and driver notification systems, emergency alert handling, Lost & Found reporting, Buddy System have been created and fully implemented. A full user flow for all critical scenarios such as, morning pick-up, afternoon drop-off, emergency incident notification, and lost item matching has been mapped and validated through mockup simulations. System flows ensure easy interaction between different user roles while maintaining high standards of safety and communication. The backend architecture and technology stack have been specified, with Firebase Authentication, Fire store real-time database, and Google Maps API selected for real-time location updates and notifications. Initial integration testing with Firebase Cloud Messaging have verified that push notifications can be accurately generated from simulated driver actions to the parent app UI. System demonstrations show that the GPS tracking module can record and transfer location data from the

driver's app to the parent's app with little latency under controlled test conditions. Testing is entirely completed and analyzed location accuracy in diverse the environment and network situations.

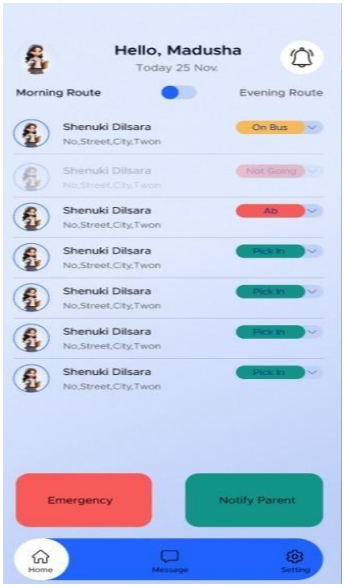

Fig 3 Parent's Home Screen

The above Fig shows the parent view of the system, and it displays the status of their child, recent notifications, emergency situation handling button features.

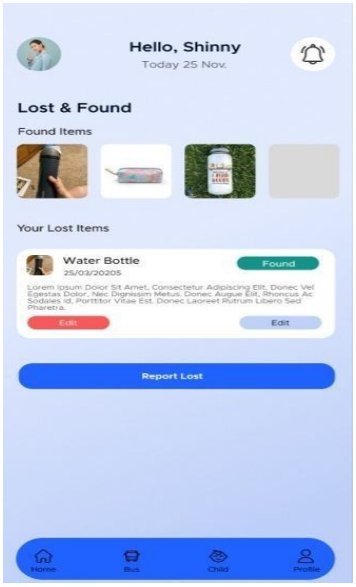

Fig 4 Lost & Found Reporting System

The above Fig shows users to report as well as track their losing things on the school bus. The interface displays a picture of recently found objects, a list of the user's reported missing items with updated status, there are options to edit or update reports. The "Report Lost" button provides speedy submission of new entries, supporting text descriptions and photographs for accurate and efficient item finding within the school bus.

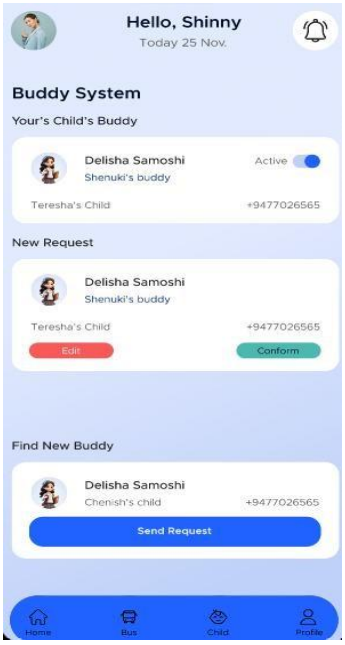

Fig 5 Buddy System

The above Fig shows the Interface of the new feature buddy system. It allows parents to watch their child's journey with trusted buddy connections. It allows viewing current trusted buddies, managing new trusted buddy requests with choices to accept or reject looking for new trusted mates. This feature improves child safety and companionship during school bus commuting.

The Buddy System's pairing feature has also been successfully finished. It finished testing on conducting live field tests using an actual school bus, enhancing the system's performance based on feedback from real users.

VI. CONCLUSION

The new real-time school bus location tracking system that is the focus of this study has been developed to increase student safety, increase parental awareness, and improve school transportation operations. The system's practical implementation survival has been shown by its inclusion of GPS tracking, automatic alerts, and safety-oriented features. Large-scale deployment, improving system performance under diverse operating scenarios, and evaluating the system's adaptability across several schools for wider adoption should be the main objectives of this study.

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