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Smart Bus Fare Payment System for Urban Transit Using NFC Technology

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Abstract - This paper presents the implementation of a smart bus fare payment system utilizing Near Field Communication (NFC) and cloud-based technologies to deliver a secure, efficient, and user-friendly transit experience. The system is developed as an Android application with distinct modules for Admin, Conductor, and User roles. The Admin interface facilitates route management, fare structuring, user and conductor administration. Conductors are provided with real-time dashboards to manage bookings, monitor passenger counts, and view trip histories. Users can recharge their wallets, access NFC-based payment functionality, view timetables, save favorite routes, and get real-time bus location updates.

The system leverages Firebase for cloud storage, real-time database operations, user authentication, and seamless connectivity across all modules. NFC embedded enables contactless fare transactions, enhancing security and reducing dependency on physical currency. Additionally, features like feedback, helpline access, and transaction history improve transparency and user satisfaction.

This paper is demonstrates increased operational efficiency, enhanced passenger convenience, and reduced revenue leakage. By integrating modern technologies into the fare collection system, the project lays a practical foundation for scalable, secure, and sustainable smart transportation infrastructure**.**

Key Words: NFC, E-wallet, Bus fare system, Mobile smart payment, Authentication, Cloud Computing, Transportation systems, Real-time systems, Contactless payment.

1. INTRODUCTION

In the era of digital transformation, public transportation systems worldwide are under increasing pressure to modernize their infrastructure, particularly in the domain of fare collection. The traditional fare collection mechanisms—reliant on cash handling, paper tickets, and manual validations—not only cause inefficiencies and delays but also lead to revenue leakage and increased vulnerability to fraud. As urban populations grow and commuter demands evolve, there is a critical need for intelligent, secure, and user-friendly solutions that can support the vision of smart, connected cities.

One promising avenue lies in the integration of contactless technologies such as Near Field Communication (NFC), along with cloud-based infrastructure and mobile computing. These technologies offer the potential to automate fare collection, reduce operational complexity, and enhance both the commuter experience and administrative oversight.

This paper presents the design and implementation of a **Smart Bus Fare Payment System** that leverages NFC technology and Google Firebase within a modular Android-based architecture. The system is developed to streamline and secure fare payments, offering digital wallet capabilities, real-time data synchronization, and role-specific workflows for administrators, conductors, and users.

The implemented system comprises three key user roles:

- **Admin Module**: Enables transport authorities to manage routes, set fare structures, onboard users and conductors, and monitor the entire system's operations in real-time.
- **Conductor Module**: Provides conductors with an operational dashboard to view booking details, manage ongoing trips, access transaction history, and monitor live passenger counts—eliminating the need for manual ticket issuance.
- **User Module**: Focused on end-user convenience, this module offers NFC ID-based fare payments, wallet recharge functionality, route timetable access, favorite route marking, location tracking, and support for feedback and helpline services.

NFC-enabled smartphones and cards allow users to make swift, contactless fare payments by tapping their device at bus entry points. All transactional and user data is securely managed and synchronized using Firebase's real-time database, cloud storage, and authentication services. The wallet recharge system is integrated directly within the application, ensuring seamless top-ups without relying on third-party platforms.

By addressing key pain points in legacy fare systems—such as fare evasion, cash handling risks, and administrative overhead—this system delivers a scalable, secure, and highly efficient alternative. It exemplifies how modern technologies can transform public transit operations and contribute toward the broader goal of smart mobility.

2. PROBLEM STATEMENT

Despite the widespread adoption of digital technologies in public transportation, many fare collection systems remain inefficient, insecure, and inconvenient for both operators and passengers. Traditional cash-based fare systems lead to

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prolonged boarding times, increased risk of fraud and revenue leakage, and operational delays. Existing digital solutions often lack real-time monitoring capabilities and fail to support end-to-end management of transit operations, particularly in developing regions.

Moreover, current fare systems do not provide an integrated platform for multiple stakeholders such as administrators, conductors, and passengers. This results in fragmented operations, manual fare tracking, and limited visibility into passenger flow and revenue analytics. Contactless payments using NFC technology have shown potential but are often underutilized due to the lack of affordable, scalable implementation.

To address these gaps, a comprehensive fare management system is required—one that ensures seamless NFC-based transactions, real-time cloud connectivity, and dedicated interfaces for all stakeholders. The need is to create a secure, efficient, and user-friendly fare payment platform that minimizes manual intervention, reduces cash dependency, and enables transparent, data-driven decision-making for transit authorities.

Objectives:

1. **To Design and develop** a secure, efficient, and convenient bus fare payment system using NFC technology.
2. **To Implement NFC-enabled smart cards/devices** for seamless transactions for Enhance passenger experience through streamlined payment processes
3. **Reduce cash handling** and revenue leakage for transportation authorities.
4. **To implement a centralized and scalable backend** using Firebase for real-time data synchronization, user authentication, trip monitoring, and transaction management.
5. **To build dedicated Android modules for three user roles**—Admin, Conductor, and Passenger—each tailored with specific functionalities such as route and fare management, booking monitoring, wallet recharges, and feedback handling.

3. LITERATURE SURVEY

Table -1: Literature Review

Author(s)	Key Focus	Technologies Used	Limitations
Vemulapalli Y. et al., 2024	Integration of IoT for seamless fare payments	IoT, Cloud Infrastructure, AI, Blockchain	Focuses only on fare collection; lacks practical mobile app implementation
Sathish M. et al., 2023	Mobile-based fare payment system for buses	Mobile Applications, Cloud Computing, Realtime Payment	Connectivity issues in rural areas; lacks user segmentation (admin/conductor)
C. Srun et al., 2023	NFC-enabled contactless bus fare transactions	NFC Technology	Security and scalability concerns; lacks integration with cloud/backend systems
Sri Sudarshan TR et al., 2023	Real-time bus tracking using RFID and GPS	RFID, GPS	Focused only on tracking; no fare processing or multi-role app integration
Current Work (This Project)	NFC-based Bus Fare System with Admin, Conductor, User Modules	Android, NFC, Firebase (Auth, Realtime DB), E-Wallet	Limited to Android platform; depends on NFC-compatible devices and Firebase

4. METHODOLOGY

The proposed bus fare payment system is implemented through an Android application utilizing Near Field Communication (NFC) technology and Firebase for real-time backend support. The system provides a seamless, secure, and cashless fare collection mechanism, improving operational efficiency and passenger convenience.

4.1 System Architecture and Components:

The system supports three major user flows: **Admin**, **Conductor**, and **User**:

- **Admin Module**: Responsible for managing bus routes, setting fare structures, adding conductor details, assigning routes, and managing travel passes (daily, weekly, monthly). Admins can also view registered users and overall system activity.
- **Conductor Module**: Provides conductors with a dashboard to monitor bookings, view trip history, track passenger count, and scan user passes using NFC. Conductors can view total passengers per trip and verify pass validity instantly.
- **User Module**: Users register and manage their profile, recharge their wallet, view and purchase passes, and tap their device or pass for boarding. Additional features include viewing favorite routes, feedback

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submission, helpline support, and bus timetable access.

4.2 NFC-Based Contactless Payment:

NFC technology enables quick and contactless fare validation. Users tap their NFC-enabled card or smartphone on the conductor's device. The application instantly verifies the pass via Firebase and confirms the transaction, ensuring minimal boarding time and eliminating the need for physical cash or paper tickets.

4.3 Firebase Integration:

Firebase serves as the core backend and provides:

- **Authentication**: Secure login and registration based on user roles.
- **Realtime Database**: Continuous synchronization of wallet balances, user profiles, routes, and pass details.
- **Cloud Storage**: Handling of app-related data including feedback and pass information.
- **Security Rules**: Role-based access and real-time validation of scanned data.

4.4 Wallet and Pass Management:

The in-app wallet can be recharged using digital payment methods. Users can purchase and store travel passes linked to their unique NFC ID. During boarding, the conductor scans the user's pass to verify its validity. The system ensures real-time deductions and updates.

5. SYSTEM ARCHITECTURE

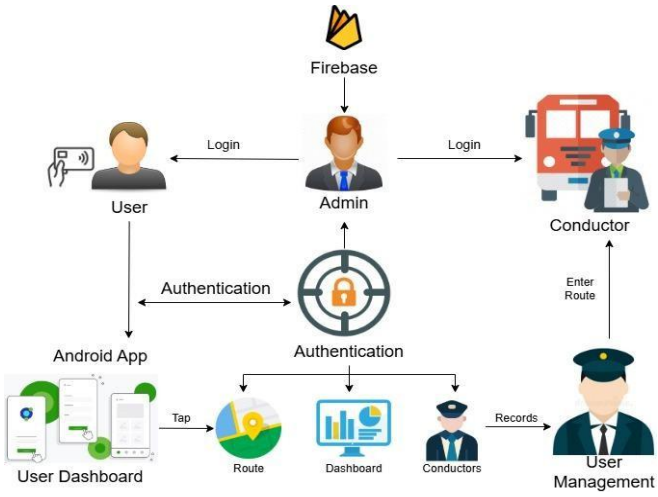

Fig -1: System Architecture

The proposed fare payment system is built using Android technology, integrating **NFC (Near Field Communication)** and **IoT** with **Firebase** as the backend. The architecture is designed to streamline public bus fare collection and support real-time data management.

The system consists of three main modules: **Admin**, **Conductor**, and **User**.

- **User Module**: Users register and authenticate through the Android app. Each user has an NFC tag linked to their profile. On boarding the bus, users tap their NFC card/device, which triggers fare deduction from their in-app digital wallet. The app also provides access to route timetables, location tracking, feedback, and a helpline.
- **Conductor Module**: Conductors log in through the app and select the active route. They can view tap-in details, monitor passenger count, and manage trip history. All data is synced in real-time to Firebase.
- **Admin Module**: The admin panel allows the administrator to manage routes, view analytics through dashboards, add/manage conductors, and maintain user records. The admin also has full access to all trip logs and transaction history.

Authentication and **role-based access control** are handled securely via Firebase Authentication. All real-time interactions—including fare deductions, wallet updates, and route monitoring—are managed through Firebase Realtime Database.

This architecture ensures:

- Fast NFC-based tap-in/tap-out for users.
- Secure, real-time data processing.
- Digital wallet integration for cashless payments.
- Clear separation of functionalities among Admin, Conductor, and User.

The system improves operational efficiency, enhances user convenience, and reduces manual fare handling, making public transport smarter and more reliable.

6. RESULTS

The Android-based NFC fare payment system was successfully implemented with Firebase as the backend, offering a secure, efficient, and user-friendly solution for public bus fare collection. The system was divided into three core modules: User, Conductor, and Admin. The initial screen of the application allowing users to select their role as User, Conductor, or Admin for accessing dedicated functionalities.

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Fig -2: Role Selection Interface

User Module:

Users could register, manage profiles, recharge wallets via UPI, and make quick tap-to-pay transactions using NFC. Additional features such as timetable access, location tracking, pass management (daily/weekly/monthly), feedback, and helpline were fully functional. Transactions were processed in real-time, with immediate confirmation.

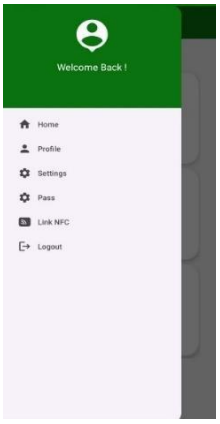

Fig -3: User Navigation Drawer

Fig -4: User Services Interface

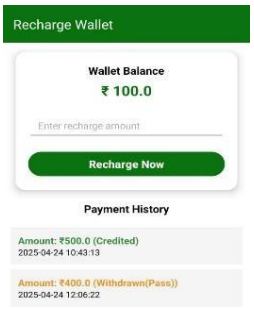

Fig -5: Wallet Recharge Screen

Fig -6: Bus Pass Booking Interface

Admin Module:

Admins managed routes, fares, and conductor assignments. They also monitored user data, transactions, and feedback. All changes were updated in real-time using Firebase.

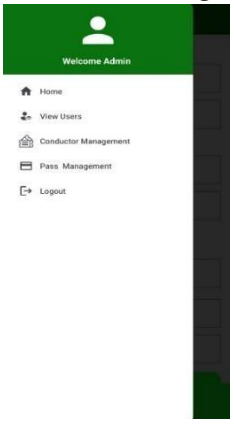

Fig -7: Admin Sidebar Navigation

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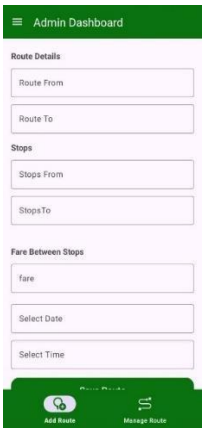

Fig -8: Route Management Interface

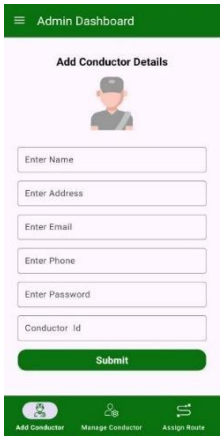

Fig -9: Conductor Management Screen

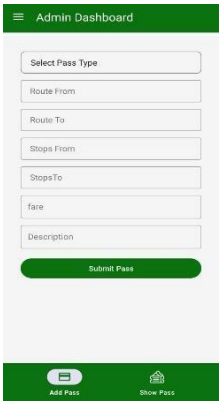

Fig -10: Pass Creation Interface

Conductor Module:

Conductors accessed booking data, trip history, and real-time passenger counts via a dedicated dashboard. NFC scanning enabled instant fare/pass verification, reducing boarding time and minimizing fare evasion.

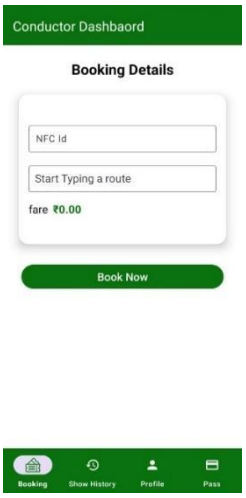

Fig -11: Conductor Booking Interface

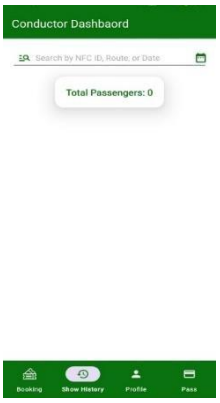

Fig -11: Passenger Count View

Fig -9: Conductor Profile Screen

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Fig -10: NFC Pass Verification Interface

7. CONCLUSIONS

The developed NFC-based Android application has successfully modernized the bus fare collection process by introducing a secure, efficient, and contactless solution tailored to the needs of passengers, conductors, and administrators. By leveraging Firebase for real-time synchronization and Near Field Communication (NFC) for tap-to-pay functionality, the system has significantly improved user experience and operational transparency. The integration of role-based dashboards, wallet recharge, live route tracking, and feedback mechanisms has streamlined transport management while enhancing passenger convenience. Furthermore, the platform's scalability, cost-efficiency, and minimal hardware dependency make it a viable solution for widespread deployment in smart public transportation systems. The project not only addresses the limitations of traditional systems but also paves the way for future enhancements like dynamic fare pricing and deeper integration with GPS and transport APIs, marking a progressive step toward smart city transit infrastructure.

Compared to existing systems, this project offers significant advantages:

- Contactless fare collection via NFC technology makes transactions faster, safer, and more hygienic.
- Elimination of cash handling, which not only speeds up the boarding process but also reduces the risk of fraud or theft.
- Real-time data synchronization across users, conductors, and admins via Firebase ensures operational transparency and data integrity.
- Scalability and adaptability, as the platform is Android-based and can be deployed across a wide range of devices without requiring specialized hardware.
- Low maintenance and cost-effectiveness, making it a practical solution for developing cities or budget-conscious transit systems.

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