International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 04 Issue: 03 March 2026
Page No: 1105-1112
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2026.0156

An IoT-Integrated RFID System for Smart Canteen Payment Management

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Abstract

People really need a way to pay for food in school and office cafeterias. The old ways of paying with cash or tokens are causing a lot of problems. They make people wait in lines and sometimes the person taking the money makes mistakes. This project is about making a system for paying in cafeterias. It uses technology to make paying faster and more secure. The system is called a integrated RFID system for smart canteen payment management. It automates the billing and monitoring processes. In this system each person gets a special card with an RFID tag. When they want to buy something they just tap the card at the counter. The payment is made. The payment is made without touching anything. It is very convenient and easy to use. The integrated RFID system for smart canteen payment management is a good solution, for this problem. The RFID reader figures out who the user is. The IoT module then connects the system to a computer server on the internet. This server stores information about the food the user picks and the money they spend. The system adds up the cost of the food away using prices that were set before. It then takes this amount out of the users stored money. People in charge can see what is happening with transactions, user money and sales, on the internet at the time. This helps them make choices and take care of things better. The system makes waiting times shorter. It gets rid of the need to add up numbers by hand. The RFID system reduces the need to handle cash. This makes the whole service work better and faster. The system improves the service efficiency of the RFID system. Additionally, stored data helps analyze consumption patterns and supports inventory planning. Therefore, the proposed solution provides a reliable, scalable, and user-friendly digital payment platform that enhances operational efficiency and promotes smart canteen management using IoT and RFID technologies.

Keywords: *RFID, SmartCard , ESP32-Microcontroller, Fare Optimization, Cashless Payment, Canteen Management System, Real Time Monitoring.*

1. Introduction

1.1.Overview

In recent years, the rapid growth of digital payment technologies has transformed the way transactions are carried out in various institutional environments. Educational institutions, in particular, face significant challenges in managing canteen services due to the high volume of daily transactions involving students and staff. Conventional canteen payment systems that rely on cash handling or manual token methods often result in long queues, calculation errors, and inefficient service delivery. These issues negatively impact user experience and increase the operational burden on canteen administrators. To address these challenges, there is a growing need for automated, secure, and contactless payment solutions that can improve efficiency and accuracy in canteen operations. Smart card– based systems using Radio Frequency Identification (RFID) technologies offer a promising alternative to traditional billing methods. RFID technology enables fast and reliable identification of users through contactless card tapping, making the transaction process quicker and more convenient.This project proposes a Smart Card-Based Canteen Fare Optimization System using RFID technology, aimed at streamlining the billing process and optimizing fare calculation. By

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integrating smart cards with an automated billing system, the proposed solution ensures accurate fare deduction, reduces manual intervention, and enhances transaction speed. Furthermore, the system allows for centralized data collection, enabling real-time monitoring, consumption analysis, and better inventory management. Overall, the proposed system contributes to the development of smart campus infrastructure by improving canteen service efficiency, reducing operational errors, and enhancing user satisfaction. The adoption of RFID based fare optimization not only modernizes institutional canteen management but also provides a scalable and cost- effective solution suitable for educational environments.

1.2.Motivation

The motivation for this work stems from the operational inefficiencies observed in conventional canteen payment systems within educational institutions. Existing cash-based and manual billing mechanisms are time-consuming, prone to human error, and lack effective transaction traceability, leading to reduced service efficiency and user dissatisfaction. As the volume of daily transactions increases, these limitations pose significant challenges to canteen management and operational scalability. Recent advancements in contactless payment technologies, particularly Radio Frequency Identification (RFID) offer a secure and efficient alternative to traditional billing methods. The integration of RFID based smart cards enables rapid user identification, automated fare calculation, and real-time transaction processing with minimal human intervention. This approach significantly enhances transaction accuracy, reduces queue time, and improves overall system reliability. Additionally, centralized data collection facilitates real-time monitoring, consumption analysis, and inventory optimization, supporting informed administrative decision-making. Therefore, this work is motivated by the need to develop a scalable, cost- effective, and user- centric canteen fare optimization system that contributes to smart campus infrastructure and improves institutional service delivery.

1.3.Objective

- To automate the canteen billing process using RFID based contactless smart cards .
- To ensure accurate and secure fare calculation with real-time balance deduction.
- To reduce transaction time and minimizmanual intervention at billing counters.
- To maintain centralized transaction records for monitoring and administrative analysis.
- To analyze food consumption patterns to support effective inventory management.
- To enhance user convenience and overall service quality in institutional canteens.
- To develop a scalable and cost-effective Solution suitable for smart campus environments.

2. Literature Review

The adoption of automated and cashless payment systems in institutional canteens has been widely studied to overcome limitations of traditional manual billing methods such as long queues, billing errors, and lack of transaction transparency. Rajesh and Suresh [1] proposed a Smart RFID- Based Canteen Automation System in which RFID cards are used for cashless transactions. The system reduced manual billing effort and improved transaction speed; however, it lacked advanced cloud-based monitoring and online recharge facilities. Ananya and Krishnan [2] developed an RFID- enabled cashless cafeteria payment system that enabled secure and contactless transactions through card tapping. While the system improved user convenience, it required RFID compatible infrastructure and did not support comprehensive balance management or recharge mechanisms. Balaji and Meenakshi [3] presented an IoT-based smart canteen management system integrating RFID with cloud connectivity, enabling centralized transaction storage and real time monitoring. Although transparency was improved, the system increased dependency on stable internet connectivity and system complexity. Nithya and Karthik [4] proposed a prepaid smart card system for institutional canteens, where users preload balance for payments. The system simplified transactions but lacked real-time logging, cloud integration, and digital payment support. Lissa'idah, Rosid, and Fitrani [5] designed a web-based RFID canteen payment system that reduced waiting time and cash

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usage. However, it did not support real-time online recharge or modern digital payment integration. From these studies, it is evident that existing solutions address individual aspects such as automation, contactless payment, or cloud storage. An integrated system combining RFID based payments, cloud database management, real-time transaction logging, and digital recharge facilities is still required. The proposed system aims to fulfill these requirements by providing a secure and user-friendly smart canteen fare optimization solution.

3. Methodology

3.1.System Overview

The proposed methodology presents a smart card-based canteen fare optimization system that enables fast and contactless payments using RFID cards. The smart card functions solely as a payment identifier, while billing is carried out manually by canteen staff, with all user accounts maintained in a centralized cloud database. Since the system follows a tap-to-pay model without PIN authentication, backend validation is performed to verify card ownership before payment authorization. Monetary transactions are handled using a point-based system, where recharges made through UPI via a web or mobile application are automatically converted into points and updated in the database. After each transaction, users receive a notification message displaying the payment details and remaining balance.

3.2. System Architecture

The system architecture follows a modular design in which all components are interconnected to provide secure and real-time payment processing. When the user taps the RFID card, the reader captures the unique card ID and sends it to the microcontroller. The controller verifies the user details with the server database through the IoT network. After successful authentication, the canteen billing module calculates the amount and deducts it from the user's prepaid balance. The transaction details are stored in the cloud database and a notification is sent to the user showing the remaining balance. If the balance is low, the system denies the transaction and asks the user to recharge the account.

3.3.Detailed Workflow

3.3.1. Card Detection and Data Acquisition

The workflow begins when the user taps the RFID smart card at the payment terminal located in the canteen. The system reads the unique identification number associated with the card. This card ID acts as a reference key to access the corresponding user account stored in the cloud database. No personal or financial data is stored on the card itself, ensuring data security.

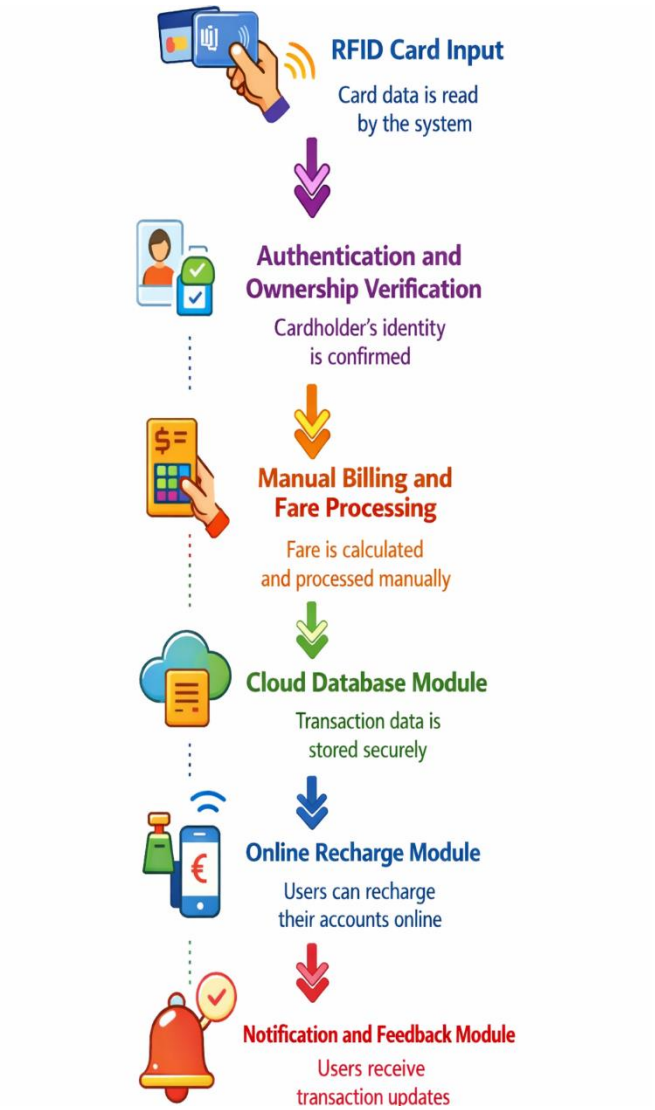

Figure 1 Flow Process

3.3.2. Card Ownership Verification and Authorization

Since the system follows a tap-to-pay mechanism without PIN-based authentication, an ownership verification step is performed. The captured card ID is validated against the cloud database to check whether the card is registered and active. The system

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generates a backend confirmation response indicating whether the card belongs to an authorized user. If the database returns a positive response, the transaction proceeds. If the response is negative, the transaction is immediately blocked, preventing unauthorized usage of lost or stolen cards.

3.3.3. Manual Item Scanning and Fare Computation

Once the card is authorized, the billing process is initiated by the canteen staff. Food items selected by the user are manually scanned or entered using a billing scanner or interface. Each item is mapped to a predefined price stored in the database .The system aggregates the prices of all selected items and computes the total payable amount. This approach separates billing from payment authorization, allowing the smart card to be used strictly for payment.

3.3.4. Balance Retrieval and Sufficiency Check

After fare computation, the system retrieves the user's current point balance from the cloud database. The calculated fare is compared against the available balance to determine whether the transaction can be completed. If the available balance is greater than or equal to the required amount, the system authorizes the payment. If the balance is insufficient, the transaction is declined and no deduction is performed .This step ensures error-free and reliable payment processing.

3.3.5. Point Deduction and Transaction Update

For approved transactions, the system deducts the required number of points from the user's account. The updated balance is stored immediately in the cloud database. At the same time, a detailed transaction record is generated, including card ID, transaction amount, timestamp, and remaining balance. This ensures transparency, traceability, and accurate record maintenance. Input: Approved fare amount

3.3.6. User Notification and Feedback Delivery

After successful payment, the system sends a confirmation message to the user's registered mobile number. The message includes transaction details such as the amount deducted and the remaining balance (e.g., "Payment successful: 100 points deducted. Available balance: 250 points"). If the transaction is rejected due to insufficient balance orinvalid card authentication, an appropriate alert message is sent to inform the user.

3.3.7. Online Recharge through Web or Mobile Application

For balance top-up, users access the dedicated website or mobile application linked to the system. The application displays the institution's UPI QR code for payment. Once the user completes the recharge using a UPI application, the payment confirmation is received by the system. The recharge amount is converted into equivalent points and automatically credited to the user's account through direct database updates, without any manual involvement. The updated balance is reflected instantly and is available for subsequent transactions.

3.3.8. Insufficient Balance Handling and Retry

If a user attempts a transaction with insufficient balance, the system denies the payment and sends an alert indicating low balance. The user can then recharge the account using the web or mobile application and retry the transaction. Once recharged, the updated balance is verified during the next card scan.

3.4.Hardware and Software Specifications

3.4.1. Hardware Specifications

Table 1 Components and Specifications

Component	Specification
Microcontroller	ESP32
RFID Reader	RC522 RFID Reader Module
Smart Cards	RFID Reader Module
Matix keypad	To enter amount
Display Unit	Computer
Network	Stable Wi-Fi Connection
Power Supply	5V Regulated Power Supply
User Device	Smartphone

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3.4.2. Software Specification

Table 2 Software and Purpose

Software/Tool	Purpose
Arduino IDE	Programming and firmware development
MFRC522 Library	RFID reader communication
Firebase Arduino Library	Cloud database connectivity
Web Application	Online recharge and user access
Mobile Application	Recharge and balance monitoring
Cloud Database (Firebase)	User data ,balance &transaction storage
UPI Payment Interface	Digital recharge using QR code
Web Browser	Access to admin and user dashboards

4. Implementation

The proposed smart card-based canteen fare optimization system is implemented by integrating RFID technology, cloud-based data management, and digital payment services. The implementation focuses on reliable authentication, accurate billing, automated recharge, and real-time user notification.

4.1.Tools and Technologies Used

The system employs both hardware and software technologies to ensure seamless operation. RFID technology is used for contactless identification and payment authorization. An ESP32 microcontroller is used as the processing unit to interface with the RFID reader and cloud services. The system is developed using the Arduino IDE, which provides an efficient environment for programming the microcontroller. The MFRC522 library is used to communicate with the RFID reader, while the Firebase Arduino library enables real-time interaction with the cloud database. A web-based application and a mobile application are developed to support online recharge and balance monitoring. UPI payment services are integrated through QR code-based transactions to facilitate digital recharge.

4.2.System Setup and Initialization

The implementation begins with registering users in the cloud database along with their personal details, mobile number, and assigned RFID card ID. Each user account is initialized with a point- based balance, where points represent monetary value. Food items and their corresponding prices are predefined and stored in the database for billing purposes. The RFID reader and processing unit are configured to maintain continuous connectivity with the cloud database through a stable Wi-Fi network.

4.3.Card Registration and Database Linking

Each RFID card is uniquely mapped to a user account in the cloud database. The card stores only a unique identification number, while all sensitive information such as balance, transaction history, and contact details are securely maintained in the database. This design enhances data security and simplifies card replacement if required.

5. Authentication and Ownership Validation

During a transaction, when a card is tapped at the payment terminal, the system reads the card ID and sends it to the cloud database for validation. Since the system does not use PIN-based authentication, ownership validation is performed at the backend by verifying whether the card corresponds to an active and authorized user.If the card is valid, the system allows the transaction to proceed. If the card is invalid or blocked, the transaction is immediately rejected.

6. Manual Billing and Fare Calculation

Billing is performed manually by the canteen staff using a scanner or billing interface. Each selected food item is scanned or entered, and the system retrieves the corresponding price from the database. The total payable amount is calculated by summing the prices of all selected items.The RFID card is used strictly for payment authorization and does not participate in the billing calculation process.

7. Balance Verification and Payment Processing

Once the total fare is calculated, the system retrieves the user's point balance from the database. If sufficient balance is available, the required points are deducted automatically and the updated balance is stored in the database. If the balance is insufficient,

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the transaction is declined and the user is notified.

8. Online Recharge Implementation

The system supports balance recharge through a dedicated website or mobile application. Users recharge their account by scanning the institution's UPI QR code. After successful payment, the recharge amount is converted into equivalent points and credited directly to the user's account in the cloud database without any manual intervention.

9. Transaction Notification and Feedback

After each transaction, the system sends a confirmation message to the user's registered mobile number containing details such as the deducted amount and remaining balance. In the event of insufficient balance or invalid card usage, an alert message is sent to notify the user.

10. Data Logging and Monitoring

All payment and recharge transactions are recorded in the cloud database along with timestamps. These logs allow administrators to monitor system activity, generate reports, and maintain transparency in canteen operations.

11. Results and Discussion

The proposed smart card-based canteen fare optimization system was tested under real-time canteen usage conditions to evaluate its effectiveness, reliability, and usability. The system successfully performed contactless transactions using RFID cards, where authentication and ownership verification were handled through backend database validation without the use of PIN-based security. Manual billing by canteen staff ensured accurate fare calculation, and the payment process was completed only after sufficient balance verification. The point-based balance mechanism effectively represented monetary value and allowed secure internal processing. Online recharge through the web or mobile application using UPI was observed to update user balances instantly in the cloud database without any manual intervention. Transaction records were stored in real time, and users consistently received notification messages indicating the deducted amount and remaining balance after each payment. In cases of insufficient balance, transactions were correctly declined and appropriate alerts were generated. Overall, the system demonstrated reliable performance, reduced transaction time ,transparency and minimized billing errors, making it suitable for deployment in institutional canteen environments.

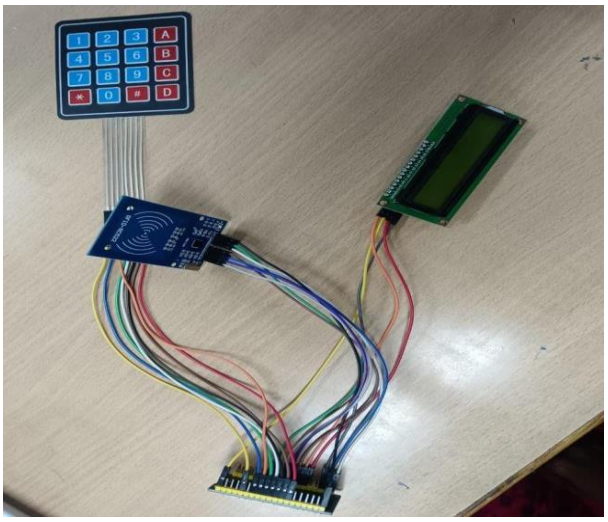

Figure 2 Cables

RFID-based Canteen Payment System. It consists of an RFID reader, keypad, LCD display, and microcontroller connections, which together handle user input, card verification, and real-time display of information.

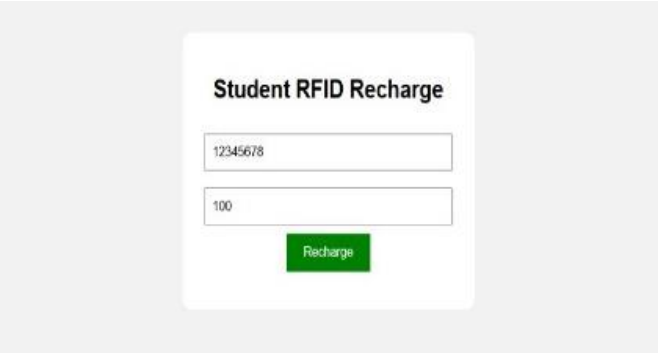

Figure 3 Student RFID Recharge

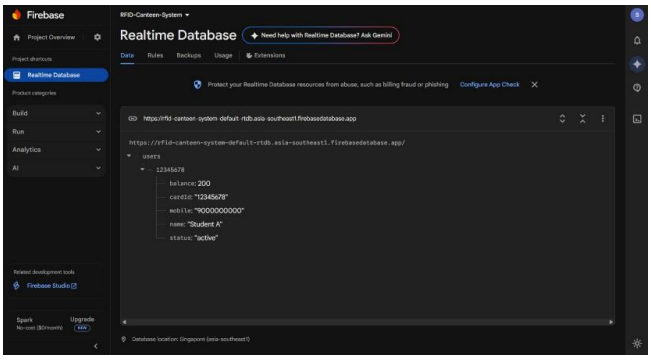

Figure 4 Real Time Database

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RFID Card Number Field This field is used to enter the unique RFID number assigned to a student. Recharge Amount Field This field is used to enter the amount that needs to be added to the student's RFID balance. Recharge Button When the Recharge button is clicked, the system processes the request and updates the student's balance in the database. This image represents the Firebase Realtime Database used in the RFID Canteen Payment System. It acts as the central backend storage, where all student-related data is stored and managed in real time. Firebase ensures that any update made in the system (such as recharge or payment) is instantly reflected across all connected devices.

Conclusion

Existing canteen payment systems predominantly rely on cash-based or partially digital methods that result in long queues, manual billing errors, limited transaction transparency, and inconvenience for users. To address these limitations, this paper presented a smart card- based canteen fare optimization system using RFID technology integrated with a cloud database. The proposed system separates manual billing from automated payment authorization, enabling secure and contactless transactions through backend card ownership verification without PIN-based authentication. A point-based balance mechanism is employed to enhance security, where online recharges made via a web or mobile application using UPI are automatically converted into points and updated directly in the database without manual intervention. Real-time transaction logging and user notifications improve transparency and user confidence. Experimental results indicate that the proposed system significantly reduces transaction time, minimizes billing errors, and offers a reliable and user-friendly solution suitable for institutional canteen environments.

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