Smart Trolley for Automated Billing and Shopping Assistance

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Abstract:
Retail inefficiencies caused by traditional billing systems continue to affect customer experience and store productivity. This paper presents a Smart Shopping Trolley system that leverages RFID technology and embedded system intelligence to enable real-time billing within the shopping environment. Unlike conventional barcode-based methods, the system performs automatic product detection and dynamic bill generation directly inside the trolley. The framework integrates an RFID reader with a microcontroller to identify tagged products and update the total bill instantly. A real-time display allows customers to monitor their expenses during shopping, improving transparency and decision-making. This approach reduces checkout time, eliminates long queues, and minimizes human errors. Overall, the system provides a scalable, efficient, and user-centric solution for modern retail automation, enhancing both customer satisfaction and operational efficiency.

Keywords: RFID Technology, Smart Shopping Trolley, Automated Billing System, Embedded Systems, Real-Time Billing, Retail Automation, IoT-Based Shopping, Microcontroller, Customer Experience.

I. INTRODUCTION

In the modern retail environment, efficient billing and seamless customer experience have become essential for supermarkets and shopping malls. However, traditional billing systems that rely on manual barcode scanning often lead to long queues, delays, and customer dissatisfaction, especially during peak hours and festive seasons. Additionally, these systems are prone to human errors such as incorrect billing, missed items, and duplicate entries, which affect both customers and store operations. This project introduces a Smart Shopping Trolley system, an automated retail solution that addresses these challenges by enabling real-time billing within the shopping process. By utilizing an RFID-based identification mechanism integrated with an embedded processing unit, the system automatically detects products placed in the trolley and dynamically updates the total bill. The system further provides real-time display of product details and expenditure, ensuring transparency and improved decision-making, thereby delivering a faster, smarter, and more efficient shopping experience.

II. LITERATURE REVIEW

Prior research in retail automation has primarily focused on barcode-based billing systems and basic RFID implementations for product tracking [1], [5]. While these systems improve inventory management and reduce manual effort, they still rely heavily on centralized checkout processes, leading to congestion and delays during peak shopping hours. As observed by Sharma et al. (2023), traditional automated billing frameworks lack real-time interaction within the shopping environment and fail to provide customers with dynamic cost monitoring capabilities [3].Recent advancements in Internet of Things (IoT) and embedded systems have enabled the development of smart retail solutions that integrate sensors, microcontrollers, and wireless communication technologies [2]. RFID-based smart trolley systems have been explored to automate product identification; however, many existing models operate as standalone units without efficient system integration or scalability [6]. Additionally, studies by Kumar et al. (2024) and Reddy et al. (2025) highlight that most implementations focus only on product detection and billing, without enhancing user interaction or improving overall shopping experience [7], [9].The proposed Smart Shopping Trolley system addresses these limitations

by integrating real-time RFID-based product detection with embedded processing and display modules. Unlike traditional approaches, the system enables continuous bill tracking within the trolley, reducing dependency on checkout counters. Furthermore, the design supports scalable deployment and can be extended with IoT-based connectivity for centralized monitoring and inventory management. This integrated approach provides a more efficient, user-centric, and practical solution for modern retail automation.

III. SYSTEM OBJECTIVES

1. To develop an RFID-based automated billing framework for real-time product identification within the shopping environment.
2. To integrate an embedded microcontroller system for accurate processing and dynamic bill computation.
3. To implement a real-time display module for continuous monitoring of product details and total expenditure.
4. To minimize billing time and eliminate long queues by reducing dependency on centralized checkout counters.
5. To enhance customer experience and retail efficiency through a scalable, cost-effective, and user-centric solution.

IV. METHODOLOGY

A. Data Acquisition and Detection

The system detects products using RFID tags attached to each item. When a product is placed inside the trolley, the RFID reader captures the tag information and validates the presence of the item within its scanning range. This ensures automatic and contactless identification without requiring manual input.

B. Embedded Processing and Billing

The core processing unit consists of a microcontroller that receives the scanned RFID data and retrieves the corresponding product details from a predefined database. It performs real-time bill computation by dynamically updating the total amount whenever products are added or removed. This eliminates the need for a separate billing stage and ensures continuous processing within the trolley.

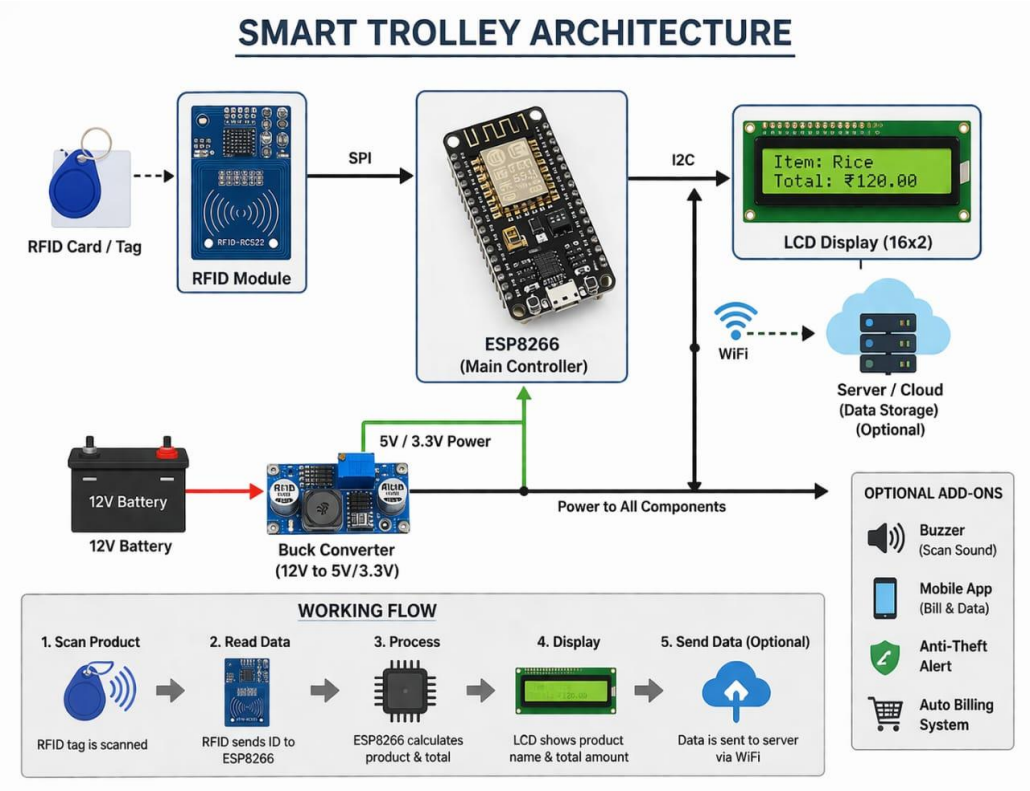
C. Real-Time Display and User Interaction

The processed data is transmitted to an LCD display module, which provides real-time updates of product details and total expenditure. This allows users to monitor their spending during shopping. The system is designed for simple user interaction, ensuring a seamless and efficient shopping experience without technical complexity.

V. SYSTEM ARCHITECTURE

The architecture consists of:

- ***Data Input Layer:*** RFID tags attached to products and RFID reader for automatic item detection.
- ***Processing Layer:*** Microcontroller unit that receives RFID data and performs real-time product identification and bill computation.
- ***Display Interface:*** LCD module for continuous display of product details and total expenditure.
- ***Control Layer***: Embedded system logic for handling add/remove operations and maintaining accurate billing flow.
- **Data Layer:** Predefined product database storing item details such as name and price for efficient retrieval.



ARCHITECTURE

VI. SYSTEM RESULTS AND EVALUATION

The system was evaluated under real-time shopping conditions using RFID-enabled products to analyse its performance, accuracy, and user interaction efficiency.

A. Billing Accuracy and System Performance Detection Accuracy

- Achieved high accuracy in identifying RFID-tagged products with minimal scanning errors during repeated operations.
- **Latency:** The average response time for product detection and bill update was observed to be less than 1 second, ensuring real-time performance.
- **User Impact:** Real-time display of billing information improved user awareness and helped customers manage their expenses effectively during shopping.

B. Automated Billing and Queue Reduction

A key focus of the evaluation was the system's ability to eliminate dependency on checkout counters.

- **Trigger Mechanism:** The billing process is automatically initiated when products are placed inside the trolley, removing the need for manual scanning.
- **Process Efficiency:** The system continuously updates the total bill without interruption, ensuring seamless operation throughout the shopping process.
- **Result:** The implementation significantly reduced waiting time at billing counters and eliminated long queues, improving overall store efficiency.

C. User Interaction and System Reliability

- **Display Interaction:** The LCD module provided clear and continuous updates of product details and total amount, ensuring transparency.
- **System Stability:** The system maintained consistent performance under continuous usage without major failures or delays.
- **User Experience:** The simple and user-friendly design allowed customers to use the system easily, enhancing convenience and satisfaction.

IX. SYSTEM INTERFACE SAMPLES

Figure 1: Product Detection and Scanning: Showing the RFID reader detecting the product when it is placed inside the smart trolley.

Figure 2: Real-Time Billing Display: A screen displaying the product details along with the dynamically updated total bill on the LCD module.

Figure 3: Final Billing Output: A view of the final total amount displayed after completing the shopping process, ready for checkout.

Figure 1-Product Detection and Scanning

Figure 2- Real-Time Billing Display

SMART TROLLEY

S.No.	Product	Rate
1	VIM	10.00
2	LUX	30.00
3	RIN	16.00
	TOTAL:	**56.00**

Figure 3- Final Billing Output

X. CONCLUSION

The development of the Smart Shopping Trolley system demonstrates the effectiveness of integrating RFID technology with embedded systems in modern retail environments. By enabling real-time product detection and automated billing within the trolley, the system provides a unified solution to overcome the limitations of traditional checkout processes. It achieves high accuracy in product identification and dynamic bill computation, significantly reducing billing time and minimizing human errors. The real-time display interface enhances transparency by allowing customers to monitor their expenses during shopping. Furthermore, the system improves operational efficiency by reducing dependency on billing counters and streamlining store management. This project proves that smart automation can play a vital role in transforming retail systems into faster, more efficient, and customer-centric solutions.

XI. FUTURE ENHANCEMENT

While the current Smart Shopping Trolley system provides a robust framework for automated retail billing, the following enhancements are proposed to further improve its functionality and scalability:

IoT-Based Smart Connectivity: Integrating IoT modules to enable real-time communication between the trolley and a centralized cloud system for inventory management, billing synchronization, and analytics.

Mobile Application Integration: Developing a mobile application that allows users to view their bill, receive digital receipts, and make cashless payments directly from their smartphones.

AI-Based Recommendation System: Incorporating artificial intelligence to analyze customer purchase patterns and provide personalized product recommendations and offers.

Automated Payment Gateway: Implementing secure digital payment options such as UPI, QR code scanning, and contactless payments to enable a fully checkout-free shopping experience.

Advanced Sensor Integration: Adding weight sensors or additional validation mechanisms to improve accuracy and prevent unauthorized item placement inside the trolley.

Scalable Retail Deployment: Enhancing the system architecture to support large-scale deployment across supermarkets, hypermarkets, and retail chains with centralized monitoring capabilities.

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