

RFID Technology Based Smart Shopping Cart

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Abstract: *Lately, navigating and selecting items in shopping centers has become a daily activity in urban areas, with a multitude of individuals engaging in shopping, particularly during holidays and weekends. The peak shopping periods coincide with special offers and discounts, leading people to purchase a variety of items and place them in shopping carts. Upon completing their purchases, customers are required to visit the billing counter for payment and invoicing. At the charging counter, the clerk readies the receipt utilizing a standardized tag scanner, a tedious cycle that frequently brings about lengthy lines. To overcome this problem, this paper proposed a smart shopping cart using RFID technology.*

Supermarket aisles with long lineups are not conducive to happy consumers. In actuality, the poll you cited presents a dismal image: Long lines are deliberately avoided by 86% of consumers, and 70% of them say they wouldn't even think about going back. The cause? It all comes down to annoyance. Consumers are frustrated by inefficiency and lost time, as they wish to finish their errand and go on with their lives. This affects a supermarket's bottom line directly; it's not simply a small annoyance. Revenue is lost and loyalty is weakened when clients depart. The good news is that there are workable solutions for this issue, all of them revolve on optimizing the checkout procedure.

This paper aims to address the issue of long lines at billing counters in malls. The proposed solution involves the use of a smart shopping cart that displays the total cost of the items stored within the cart. This allows customers to directly pay the amount either through a mobile application or at the billing counter, facilitating a quicker and more efficient checkout process. An Arduino Uno, an RFID Reader Module, an RFID Card, and a Bell are the hardware components. This framework wipes out the customary checking of items at the counter, essentially accelerating the whole buying process. In addition, the customer is made aware of the total amount that needs to be paid, which enables better personal savings-based financial planning.

Since the entire billing process relies on RFID technology, the likelihood of human errors is significantly reduced. The system also incorporates a feature that allows customers to remove scanned items, further enhancing the overall shopping experience. By adopting this innovative approach, customers can manage their shopping more efficiently, selecting items based on their budget.

Keywords: RFID, Arduino Uno

1. INTRODUCTION

The project integrates Arduino Uno, RFID sensing, and an Android-based mobile application to automate the end-to-end shopping workflow. Architecturally, the system is divided into two layers: electronic hardware and software. The Arduino Uno acts as an intermediary controller, bridging the RFID hardware layer with the software layer, specifically the Android application.

On the software side, users authenticate via secure login methods before accessing the system, thereby safeguarding personal data. The application additionally prevents accidental purchase of expired goods and grants shoppers instant access to rich product information—enabling side-by-side product comparisons directly on their phones.

This information-rich feature empowers consumers to select the most suitable product within their budget. A dynamic in-app shopping list reflects selections in real time, adapting to priority changes or spending constraints, and also reminds users of pending purchases. A back-end server, linked wirelessly to the smart cart, handles data exchange with the mobile app from any point within the store, enabling untethered, seamless product information retrieval and a consistently efficient shopping journey.

2. HARDWARE COMPONENTS

Table 1 summarises the key hardware elements that constitute the proposed smart shopping cart system.

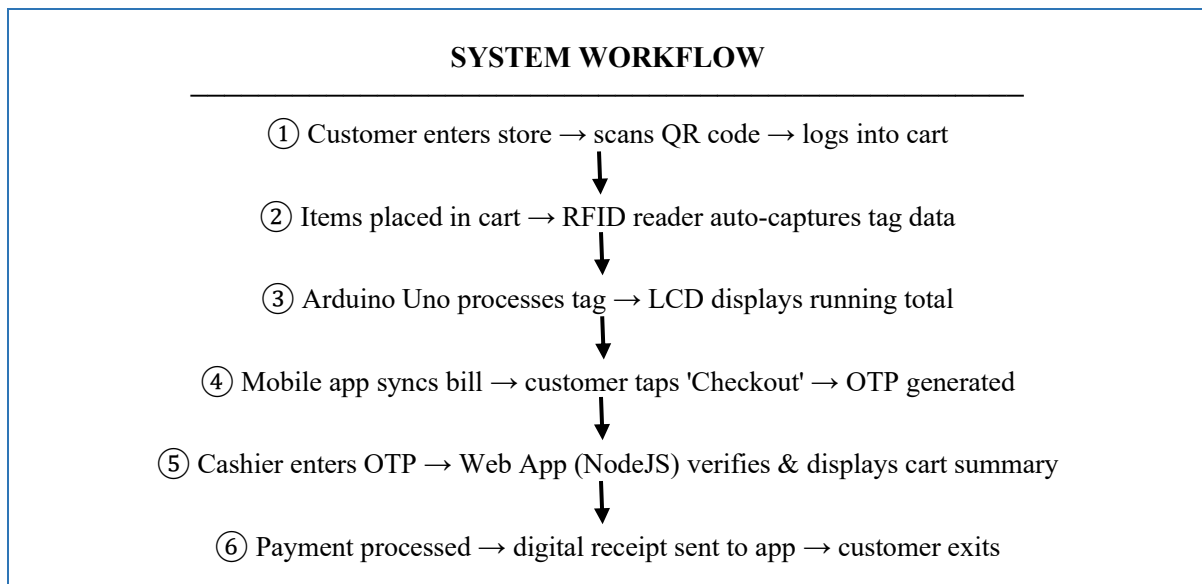
Table 1 Hardware Components of the Smart Shopping Cart System

| Component | Model / Type | Function | Role in System |
|-----------------|---------------|----------------------------|-----------------------------|
| Microcontroller | Arduino Uno | Central processing unit | Coordinates RFID & software |
| RFID Reader | EM-18 Module | Reads RFID tags wirelessly | Captures item data |
| RFID Tags | Passive Tags | Stores item info | Attached to each product |
| Display | LCD Screen | Shows bill total | Real-time cost feedback |
| Alert | Buzzer / Bell | Audio confirmation | Item scan notification |

3. SYSTEM WORKFLOW

Figure 1 below illustrates the step-by-step operational flow of the proposed RFID-based smart shopping cart system, from customer entry to final payment.

Fig. 1 End-to-End System Workflow Diagram



3.1 Advantages of RFID system

Post-pandemic consumer behaviour has heightened sensitivity to hygiene and contactless interaction in public retail environments. The smart shopping cart directly addresses these expectations by enabling customers to shop with minimal physical contact with surfaces or other individuals. Variants such as the Super Mini smart cart even feature antibacterial handles rated at 99.99% effectiveness, reinforcing shopper confidence.

Beyond health considerations, RFID delivers substantial operational and commercial benefits across multiple domains. Table 2 provides a structured overview.

Table 2 Advantages of RFID Systems

| Category | Advantage | Impact |
|--------------|--------------------------------------|--|
| Inventory | Near-flawless scan accuracy | Reduces human error; maintains ideal stock |
| Inventory | Real-time stock visibility | Prevents stock-outs and lost sales |
| Supply Chain | Automated contactless identification | Faster receiving, shipping & sorting |
| Supply Chain | End-to-end product traceability | Greater accountability & efficiency |
| Supply Chain | RFID-based theft deterrence | Reduces shrinkage & asset loss |
| Operations | Workflow automation | Less manual labour; lower costs |
| Operations | Real-time data analytics | Supports faster, informed decisions |
| Operations | Asset utilisation tracking | Minimises equipment downtime |
| Extras | Product authentication via tag data | Counters counterfeiting |
| Extras | Digital returns/exchange processing | Personalised, rapid customer service |
| Extras | Reduced paper-label printing | Smaller environmental footprint |

Collectively, RFID systems generate measurable improvements in operational effectiveness, data accuracy, and supply-chain transparency across sectors as diverse as retail, healthcare, manufacturing, and logistics.

3.2 Limitations OF RFID System

One practical drawback specific to smart shopping carts is the absence of a child seating area—a concern for parents, particularly mothers who routinely bring young children to the supermarket. This design gap may influence adoption among that demographic.

At a broader technology level, RFID presents several well-documented constraints. Table 3 categorises these challenges for clarity.

Table 3 Limitations of RFID Systems

| Category | Challenge | Sub-Issue | Detail |
|-----------|-------------------------|----------------|---|
| Cost | High upfront investment | Tag cost | \$1–\$30 per tag vs. a few cents for barcodes |
| | High upfront investment | Reader cost | Roughly 10× the price of barcode scanners |
| | Integration overhead | Infrastructure | Existing systems need upgrades & software changes |
| Technical | Signal interference | Environment | Metal & liquids distort readings |
| | Tag collision | Density | Multiple nearby tags cause read conflicts |
| | Limited read range | Distance | Tags may be missed beyond rated range |
| Security | Privacy risk | Data breach | Encrypted protocols mandatory |
| | Hacking vulnerability | Cloning | Tags can be duplicated with off-shelf hardware |
| Misc. | Battery dependency | Active tags | Battery replacements add maintenance cost |
| | Environmental disposal | Hazardous | Some tags contain harmful compounds |
| | No universal standard | Protocol | Different frequencies hinder cross-system use |

A thorough cost-benefit analysis is therefore essential before committing to RFID deployment. The specific application context, infrastructure maturity, and security requirements must all be weighed against the technology's clear operational merits.

4. APPLICATION

4.1 Application for client and cashier

The dual-app architecture—comprising a client-facing Android application and a cashier-facing NodeJS web interface—streamlines the checkout process for both parties.

4.2 Client App (Android Flutter)

Scan & Track: The mobile interface allows shoppers to scan RFID-tagged items using their smartphones. Each scan instantly populates the in-app shopping list with the product name, price, and image.

Real-time Tracking: The cumulative bill updates dynamically with every scan, giving users full budget visibility and eliminating price surprises at the point of payment.

Checkout & OTP: Once shopping is complete, the customer taps 'Checkout.' The app generates and displays a unique One-Time Password (OTP) for handoff to the cashier.

4.3 Cashier Web App (NodeJS)

OTP Verification: The cashier enters the customer's OTP into the web portal, which retrieves and displays the complete cart summary along with the total payable amount.

Swift Evaluation & Payment: The cashier reviews the itemised list, confirms accuracy, and processes payment via the customer's chosen method—eliminating the need for manual item-by-item scanning.

Receipt & Done: A digital receipt is dispatched to the customer's app, and the transaction is closed without the customer ever having to stand in a conventional checkout queue.

5. RELATED WORK

Several prior studies have explored RFID and related technologies for retail automation. Table 4 compares these works against the proposed system.

Table 4 Comparative Analysis of Related Works

| Author / Year | Technology Used | Billing Method | Key Contribution | Limitation |
|----------------------|------------------------------|---------------------------------|---------------------------------|------------------------------|
| Sainath (2014) | Barcode | Central system via unique ID | Barcode-based automated billing | Requires line-of-sight scan |
| Budic (2014) | RFID | Checkout-counter queue | RFID queue optimisation | Still requires counter visit |
| KomalAmbekar (2015) | RFID + ZigBee | Central charging division | Wireless bill generation | Limited ZigBee range |
| Prateek Aryan (2014) | RFID + Bluetooth | Bill pushed to Android via BT | In-cart billing with Bluetooth | Short Bluetooth range |
| Proposed System | RFID + Arduino + Android App | OTP-verified, app-based payment | End-to-end automated checkout | Requires stable Wi-Fi |

6. PROPOSED METHODOLOGY

RFID technology is increasingly supplanting traditional barcode systems owing to its capacity for automatic, line-of-sight-free identification. In the proposed design, every shopping cart is equipped with an RFID module, and all store products carry corresponding RFID tags. On entering the premises, a customer scans a QR code to authenticate and activate the cart session. As products are added, the RFID reader logs each item automatically. At checkout, the system computes and deducts the total directly from the customer's linked digital wallet, rendering manual cashier intervention unnecessary.

6.1. RFID (Radio-Frequency Identification)

RFID employs electromagnetic fields to identify and track objects via embedded tags. Each tag contains a miniature radio transmitter and a transponder. When energised by a reader's EM field, the tag broadcasts a unique serial number back to the reader for identification.

6.2. INTEL 8051 Microcontroller

The MCS-51 is a single-chip microcontroller developed by Intel in the 1980s for embedded applications. Designed by John Wharton, it achieved wide commercial adoption through the late 1980s and early 1990s, and binary-compatible derivatives remain in active use today.

6.3. RFID Reader

An RFID reader retrieves data stored on RFID tags via radio-wave communication, enabling individual item tracking. Unlike barcodes, RFID tags require neither direct physical alignment nor line-of-sight access to the reader, significantly simplifying high-throughput scanning.

6.4. LCD Display

A Liquid Crystal Display (LCD) derives its name from the dual physical state of its active medium—simultaneously exhibiting properties of both a liquid and a solid crystal. It produces a visual output by modulating light through this liquid crystal layer.

7. FUTURE SCOPE

The RFID-based smart cart platform offers significant headroom for future enhancement. Table 5 outlines priority development directions.

Table 5 Future Development Roadmap

| Enhancement Area | Proposed Development | Expected Benefit |
|--------------------|--|----------------------------------|
| Tagging Technology | Ultra-wideband (UWB) RFID tags | Longer range, greater precision |
| Data Security | AES-256 encrypted tag communication | Prevents cloning & data breaches |
| Personalisation | AI-driven product recommendations | Tailored shopping experience |
| Autonomous Carts | Self-navigating cart robots | Hands-free in-store assistance |
| Payment | Integrated UPI / contactless NFC payment | Zero queue, instant settlement |
| Standards | Adoption of ISO 18000-6C (EPC Gen2) | Cross-vendor interoperability |

Employing the EM-18 reader alongside Arduino, the current system already makes notable strides in reducing billing delays and simplifying inventory oversight in high-footfall retail environments. Its potential to displace legacy barcode systems in the automation domain is considerable. Looking further ahead, autonomous carts capable of traversing store aisles and aggregating selected items represent a transformative horizon—one that advances in UWB tagging, data-security protocols, and AI-driven personalisation will progressively make attainable.

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