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Integration of POS Machines with IoT-Enabled Electronic Weighing Systems for Transparent Public Distribution

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Abstract: This paper presents a software simulation for integrating Point of Sale (POS) machines with IoT loadcell-based electronic weighing systems in Tamil Nadu's Public Distribution System (PDS) ration shops, ensuring accurate commodity distribution without hardware. For testing simplicity, a 6-digit alphanumeric ID is employed instead of QR-based scanning, not aiming to replace its efficiency in practice. Built using Flask, SQLite, and HTML/CSS, the system fetches entitlement data via manual ID entry, simulates loadcell weight dispensing within ±50g tolerance, and logs transactions to a dashboard mimicking Tamil Nadu Civil Supplies Corporation (TNCSC) oversight. Developed to automate billing and enhances transparency, achieving reliable data flow. While PDS currently uses QR scanning, the main motive is future IoT loadcell integration for real-time data exchange with POS machines.Leveraging 2023–2025 PDS automation trends, testing confirms functionality via simulated scenarios. Future work targets IoT hardware deployment, offering a scalable, cost-effective foundation for PDS modernization

Index Terms: POS Integration, IoT Loadcell, Public Distribution System (PDS), Software Simulation, Alphanumeric ID, Weighing System, Real-Time Monitoring, Transparency, Automation, Rural Connectivity, Tamil Nadu PDS, Smart Distribution.

I. INTRODUCTION

Tamil Nadu's Public Distribution System (PDS), with 33,609 ration shops as of 2022, ensures food security through subsidized commodity distribution [1]. Since 2016, POS machines with QR-based scanning have enabled efficient, paperless transactions [2]. However, manual weighing persists, risking discrepancies and inefficiencies [3]. Integrating POS with electronic weighing systems promises transparency, yet hardware implementation remains complex.

This paper proposes a software-only simulation to model POS integration with IoT loadcell-based weighing systems in PDS ration shops, developed as a final year project. Due to hardware constraints, a 6-digit alphanumeric ID replaces QR scanning for testing, not as a permanent substitute given QR's efficiency. The primary goal is to prepare for IoT loadcell deployment, enabling data exchange with POS machines for real-time weight verification and transparency.

Objectives include:

1) Simulate POS functionality with manual ID entry.
2) Model IoT loadcell weight dispensing and confirmation.
3) Provide a dashboard for TNCSC monitoring.

This simulation validates system logic cost-effectively, laying a foundation for future IoT enhancements in PDS.

II. RELATEDWORKS

1) Kumar and Singh [4] (2024) discuss PDS technological upgrades, emphasizing POS-weighing integration for transparency, aligning with our IoT motive
2) Rajesh and Shanmugam [5] (2023) propose an RFID-based PDS automation tool with GSM, contrasting our manual ID approach but supporting data exchange goals
3) Sahu and Nayak [6] (2023) present a web-based PDS system, similar to our software simulation, though without loadcell focus
4) Tamil Nadu's 2023 initiative to link POS with weighing machines [3] underscores practical relevance, inspiring this work

No prior studies simulate POS-IoT loadcell integration without hardware, making this a novel preparatory step.

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III. METHODOLOGY

The proposed system simulates POS and IoT loadcell integration in PDS ration shops using software, preparing for hardware deployment.

1) Data Collection and Preprocessing

- Data Source: Simulated user data (e.g., "ABC123", 5 kg rice) stored in SQLite.
- Preprocessing: Validates IDs, normalizes commodity quantities, and prepares session variables fortransaction tracking.

2) Feature Extraction and Engineering

- Entitlement Retrieval: Maps IDs to commodities (rice, sugar, wheat).
- Weight Simulation: Inputs mimic IoT loadcell data, checked within ±20g tolerance.
- Status Tracking: Session variables monitor dispensing stages (not started, in progress, completed).

3) Simulation Models

- POS Module: Flask-based interface fetches entitlements via ID entry.
- Weighing Module: Simulates loadcell output with manual input and confirmation logic.
- Dashboard Module: Logs transactions, simulating TNCSC oversight.

4) Real-Time System

- API: Flask routes handle ID entry, weight input, and transaction recording.
- Automation: Flags errors (e.g., weight mismatches) and syncs data to dashboard.

5) Performance Evaluation

- Metrics: Accuracy (correct dispensing), transaction time (~2 to 3 minutes), stability (concurrent sessions).

IV. SYSTEM ARCHITECTURE DESIGN

The system is designed to enforce physical dispensing of commodities, preventing POS operators from exploiting the system by buying entitlements for cash. The architecture comprises:

A. Overview

- The system includes POS terminals for beneficiary interaction, IoT-enabled weighing machines for physical dispensing,a central database for record-keeping, and a wireless network for device communication.
- Each POS terminal is paired with a weighing machine, connected via Wi-Fi or Bluetooth, ensuring real-time data exchange.

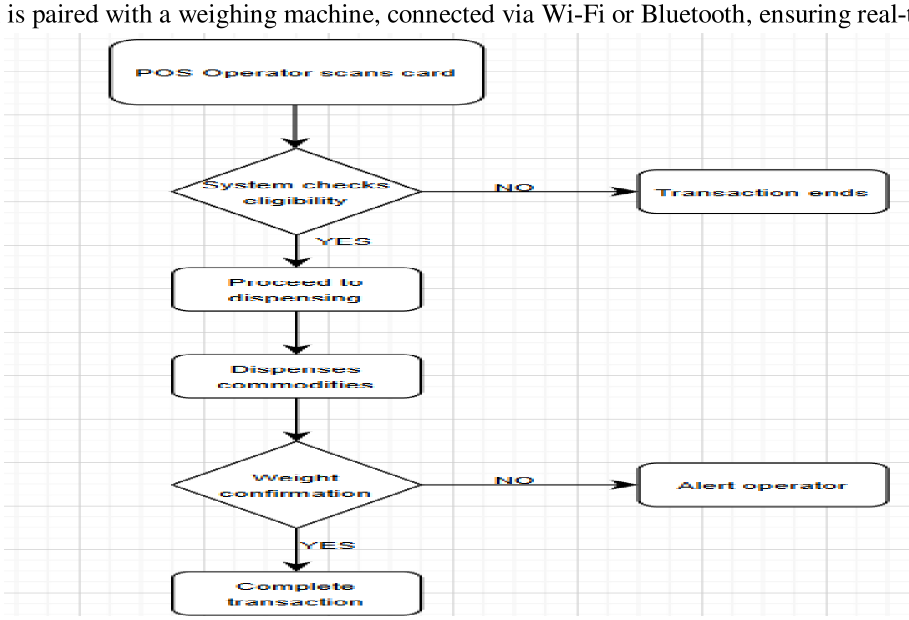

Figure1. POS machine integration with weight machine via IoT device

- The database, hosted on a server, stores user entitlements, transaction records, and stock levels, accessible via the network.

1) *Components:*
- POS Terminal: Equipped with a card scanner, display, and wireless module for communication.
- IoT-Enabled Weighing Machine: Digital scale with wireless capability to measure and transmit weight data, ensuring ±20g accuracy.
- Central Database: SQLite or similar, managing user data, transactions, and stock for real-time updates.
- Wireless Network: Local Wi-Fi network or Bluetooth pairing, facilitating device integration.

2) *Data Flow:*
- Beneficiary scans card at POS → POS queries database for entitlement → If eligible, POS sends dispensing request to weighing machine via wireless → Weighing machine dispenses commodity and sends weight data back → POS verifies weight against entitlement → If correct, updates database; else, flags transaction.

B. Hardware Selection and Configuration

Selecting and configuring appropriate hardware is critical for system reliability and scalability**.**

1) *POS Terminal:*
- Must support Wi-Fi or Bluetooth for wireless communication.
- Requires sufficient processing power to run POS software and handle real-time data.
- Compatibility with weighing machine protocols is essential, ensuring seamless integration.

2) *Weighing Machine:*
- High precision (±20g tolerance) to measure commodities accurately.
- Integrated wireless module (Wi-Fi or Bluetooth) for data transmission.
- API or protocol support for interfacing with POS terminal, ensuring real-time weight reporting.

3) *Wireless Protocol:*
- Wi-Fi: Suitable for larger outlets with existing network infrastructure, offering longer range and higher bandwidth.
- Bluetooth: Ideal for smaller setups, simpler pairing, but limited range (10–100 meters).
- Selection based on outlet size, cost, and reliability, with Wi-Fi preferred for scalability.

C. Wireless Communication Setup

Establishing secure and efficient wireless communication is key to system operation.

1) *Network Configuration:*
- Set up Wi-Fi routers or configure Bluetooth pairings based on the chosen protocol.
- Ensure stable connectivity, testing for signal strength and interference in the outlet environment.

2) *Protocol Implementation:*
- Use standard protocols like MQTT for IoT devices, ensuring efficient, lightweight data exchange.
- Implement error handling for connection drops, ensuring data integrity during transmission.

3) *Security Measures:*
- Encrypt wireless communications to prevent data tampering or interception.
- Use authentication mechanisms to ensure only authorized devices communicate.

D. Software Development

Software components manage user interactions, device communications, and data storage, ensuring system functionality.

1) *POS Software:*
- User Interface: Enables card scanning, displays entitlements, and initiates dispensing.
- Communication Module: Handles wireless requests to the weighing machine, receiving weight data.
- Database Interaction: Queries entitlement data, updates transaction records, and flags discrepancies.

2) *Weighing Machine Firmware:*
- Receives dispensing requests via wireless, controls the scale mechanism.
- Measures weight and transmits data back to POS or directly to the database.

3) Database Management:
- Schema Design: Tables for users (ID, name, entitlements), transactions (ID, shop, date, status), and stock (shop, commodity quantities).
- Real-Time Updates: Ensures data consistency across multiple outlets, supporting real-time monitoring.

E. Testing and Validation
Thorough testing ensures the system prevents misuse and operates reliably in real-world conditions.
1) Unit Testing:
- Test POS software for card scanning and wireless communication.
- Verify weighing machine accuracy (±50g) and data transmission.

2) Integration Testing:
- Ensure POS and weighing machine communicate seamlessly via wireless.
- Test data flow from card scan to database update, verifying end-to-end functionality.

3) Scenario Testing:
- Simulate operator attempts to bypass weighing (e.g., scanning without dispensing).
- Validate system responses, such as flagging transactions and blocking further scans for the user.

F. Deployment and Maintenance
Deploying the system to PDS outlets and maintaining its performance is the final phase.
1) Installation:
- Set up POS terminals and weighing machines in each outlet, ensuring wireless connectivity.
- Configure network settings and test initial operation.

2) Training:
- Educate operators on using the new system, focusing on card scanning, dispensing, and error handling.
- Provide guidelines for addressing alerts and maintaining equipment.

3) Monitoring:
- Implement monitoring tools to track system performance, such as transaction success rates and connectivity status.
- Regularly check for anomalies, such as frequent bypass attempts, and address them promptly.

V. RESULTS AND DISCUSSIONS
The proposed Smart Public Distribution System (PDS) Monitoring System seamlessly integrates Point-of-Sale (POS) terminals with IoT-enabled weighing machines through wireless connectivity, ensuring accurate and transparent commodity dispensing. The system leverages real-time data synchronization and a centralized database to enforce mandatory physical dispensing, preventing operators from bypassing the process or engaging in fraudulent cash transactions. A user-friendly interface, developed using Flask and Bootstrap, empowers operators to manage transactions efficiently while adhering to PDS regulations.
Key outcomes of the system include:
1) Mandatory Dispensing Enforcement: Transactions are only validated once the IoT-enabled weighing machine confirms the correct commodity weight, eliminating opportunities for operators to sell commodities without dispensing them.
2) Real-Time Oversight: A centralized dashboard provides live tracking of transactions, stock levels, and operator activities, enabling swift identification of irregularities such as unverified weight entries.
3) Streamlined Operations: Wireless integration (via Wi-Fi or Bluetooth) reduces hardware complexity, offering a scalable and low-maintenance solution compared to traditional wired systems.

VI. LIMITATIONS
Despite its promising performance, the Smart PDS Monitoring System faces several limitations:
1) Commodity Identification: The system cannot determine which specific commodity is being weighed, making it possible for operators to weigh a different commodity than the one specified by the POS machine. This could lead to inaccurate dispensing records if not closely supervised.

2) Connectivity Dependence: The reliance on stable wireless connectivity (Wi-Fi or Bluetooth) poses a challenge in rural or underdeveloped areas with inconsistent network coverage, potentially disrupting real-time data updates.
3) Hardware Reliability: The system's accuracy hinges on the proper functioning and calibration of IoT-enabled weighing machines. Malfunctions or calibration errors could result in incorrect weight readings and transaction disputes.
4) Operator Workarounds: While safeguards are in place, determined operators might still attempt to manipulate the system (e.g., tampering with hardware or falsifying inputs), necessitating ongoing vigilance and audits.

VII. FUTURE WORK

Future enhancements will aim to address the system's current limitations and expand its capabilities for broader deployment. Key development areas include:

1) Commodity Verification: Incorporating barcode scanners or RFID tags on commodity packages to confirm that the weighed item matches the POS-specified commodity, reducing substitution errors.
2) Improved Connectivity Options: Investigating alternative technologies, such as cellular networks or low-power wide-area networks (LPWAN), to ensure reliable data transmission in areas with poor wireless coverage.
3) Enhanced Hardware Integration: Developing self-diagnostic features for IoT weighing machines to detect and report calibration issues or malfunctions, improving system reliability.
4) Fraud Detection Algorithms: Implementing machine learning models to analyze transaction data and identify patterns indicative of fraud, such as consistent weight discrepancies or irregular operator behavior.
5) Scalable Deployment: Extending the system to support a network of PDS outlets with a unified dashboard for regional or national monitoring, enhancing oversight and resource management.

VIII. CONCLUSION

This software simulation effectively models POS-IoT loadcell integration in Tamil Nadu's PDS, using a 6-digit alphanumeric ID for testing simplicity, not replacing QR scanning's efficiency. It automates billing, enhances transparency, and prepares for hardware deployment, validated through simulated scenarios. Challenges like manual ID entry efficiency persist, but future IoT loadcell integration will address these, fostering a scalable, smart PDS framework.

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