

IoT Enabled Smart Ration Distribution Systems: A Review of Authentication, Automated Dispensing, Weight Verification, and Digital Monitoring

Ms.Prajakta Upadhye

Department of Electronics and
Telecommunication Engineering
G. H. Raisoni College of Engineering
and Management
Nagpur, Maharashtra, India

Devarsh Parshuramkar

Department of Electronics and
Telecommunication Engineering
G. H. Raisoni College of Engineering
and Management
Nagpur, Maharashtra, India

Labhpreet Juneja

Department of Electronics and
Telecommunication Engineering
G. H. Raisoni College of Engineering
and Management
Nagpur, Maharashtra, India

Mayur Sontakke

Department of Electronics and
Telecommunication Engineering
G. H. Raisoni College of Engineering
and Management
Nagpur, Maharashtra, India

Palak Rambhad

Department of Electronics and
Telecommunication Engineering
G. H. Raisoni College of Engineering
and Management
Nagpur, Maharashtra, India

Aryan Pounikar

Department of Electronics and
Telecommunication Engineering
G. H. Raisoni College of Engineering
and Management
Nagpur, Maharashtra, India

Khimakshi Gurve

Department of Electronics and
Telecommunication Engineering
G. H. Raisoni College of Engineering
and Management
Nagpur, Maharashtra, India

ABSTRACT

Public distribution systems have come a long way. Before this era, the technology was used in a single piece, for example: scan a card here; dispense there. The change is now coming about in systems where we no longer see a series of devices (who you are, what you owed, how that comes to you), and whether those records accurately represent that. It explores the integration of different components — RFID, smartcards, biometrics, QR codes, motorized actuators, load cell sensors, GSM and WiFi modules, cloud back ends, and early AI systems — in various systems. This paper draws on eleven studies published between 2018 and 2025 (one being an earlier review).

The literature shows what we see. It's clear that manual handling is giving way to sensor-assisted, electronically controlled distribution; newer systems do more than the older ones did — they link machine events to record that actually exist. This is not a small thing.

But the picture isn't clean. The hardware is not uniform. Test procedures differ. The deployment scale can be from lab benches to a partial field trial, while the success metrics vary and do not fit each other so well that there is no straightforward comparison to make. There are also several issues that remain unanswered: the accuracy of the dispense process in realworld environments; how to deal with varying commodity types in the supply chain; failure modes, including failures due to power outages or network failures; protection of sensitive information; compatibility with other components in the system; accessibility by users who may not be familiar with technical systems; and whether the new AI added to the system does what is claimed.

This sets up the experimental context for RationFlow, a closed loop design that brings together authentication, entitlement checks, dispensing, weight feedback, transactions, and inventory states in one integrated system.

INDEX

Public Distribution System, Internet of Things, biometric authentication, automated dispensing, loadcell verification, inventory monitoring, artificial intelligence.

TERMS

I. INTRODUCTION

The Public Distribution System runs through fair price shops that supply entitled households with subsidized essentials. A recurring theme in the technical literature is that several steps in this process — beneficiary verification, weighing, transaction recording, commodity release — are candidates for digital automation, and researchers have been testing that idea from different angles. Early work tended to focus on a single entry point. Verma et al. built an automated PDS architecture around smart cards and fingerprint identification, feeding into actuator-controlled dispensing and database logging [1]. Soby et al. took a somewhat wider view, designing a mechanized fair price shop workflow that

brought together RFID, GSM, and computerbased data handling for both distribution and inventory [2]. Later studies stopped trying to replace the whole workflow with one technology and started layering things instead. Deshmukh and Raut paired RFID identification with quota management in their smartPDS design [5]. Huilgol et al. kept RFID at the center but added fingerprint verification, automatic dispensing, stock sensing, and GSM notifications around it [6]. Gayathiri Ravi et al. did something similar RFID and fingerprint together, automated dispensing, loadcell measurement, then transaction confirmation [7]. Khan et al. shifted part of the interaction to mobile, using QRbased collection and Firebase for data [8].

The more recent work gets into tighter coupling between entitlement records, physical measurement, and live monitoring. Karuppasamy et al. model the handoff between POS entitlement data and simulated loadcell output through a software dashboard [9]. Jadhav et al. describe a vending architecture that ties fingerprint authentication, motorized dispensing, load detection, and cloud connectivity into one system [10]. AIRationMitra pushes further still, adding multiple authentication methods, voice interaction, cloud logging, inventory management, and AIbased usage analysis [11]. Taken together, these studies make a reasonable case for reviewing the distribution process end to end rather than picking at individual components one at a time.

II. REVIEW METHODOLOGY

This review uses a structured narrative approach — the literature is too varied for anything else. Architectures differ, hardware differs, datasets differ, and the metrics authors choose to report rarely line up across papers. There are ten primary system studies that were published between 2018 and 2025, plus one earlier review. Lokhande and Shinde's work, although it has a similar focus on smart rationing but does not present experimental results at hand, is only included here to provide context about the field.

The analysis cuts across six dimensions: authentication; dispensing and control; physical quantity verification; connectivity and data exchange; quota, inventory, and transaction management; and AIenabled functions. Performance metrics are not pooled, and a common benchmark or testing protocol was absent between all the reviewed studies, making the task of measuring average performance meaningless. Rather, the review presents the stated capability levels with particular emphasis on how they were implemented and their limitations. This distinction is important; a software simulation is not the same thing as a field validated physical system, and treating them as equivalent will silently distort every conclusion.

A few questions drive the whole thing. What authentication methods show up in automated PDS access? How are commodities dispensed and how are quantity checks performed? What communication and data frameworks do these systems run on? How do authors represent the state of a

quota and transactions? Where does AI fit in, and how is it actually executing its tasks? And what technical or evaluation gaps keep reappearing across the literature?

III. EVOLUTION OF SMART RATION DISTRIBUTION

The scope of these systems has clearly widened over time. Early work was mostly about swapping out manual processes for electronic ones — identity checks, dispensing, that kind of thing. A 2018 architecture combined smart cards, fingerprint verification, microcontrolleroperated motors, and digital transaction logging [1]. Around the same time, Soby et al. looked at automating data entry, weighing, and distribution tasks [2].

2019 brought a review of smart ration concepts alongside a Raspberry Pi fingerprint system with motoroperated valves [3], [4]. By 2021, the link between RFIDbased identification and entitlement updates had gotten noticeably tighter [5]. Then in 2022, the Huilgol system pulled together RFID, fingerprint authentication, automated dispensing, load and liquidflow sensing, GSM messaging, and stock tracking — a lot happening in one design [6].

2024 added new ways of interacting with these systems: mobile QR workflows, combined RFIDfingerprint operations, loadcell measurement, SMS confirmations [7], [8]. The 2025 work goes further in a few different directions. One project — the POSweighing system — runs entirely as a software simulation covering entitlement checks, weighing, tolerance validation, and dashboard logging, with physical hardware left for a later phase [9]. Jadhav et al. bring together embedded controllers, biometrics, actuators, load sensors, and cloud monitoring [10]. AIRationMitra adds multimodal identity verification, voice interaction, and AI-driven analytics to the mix [11].

Honestly, "replacement" is the wrong frame for any of this. What's actually happening is accumulation — each generation keeps what worked and layers something new on top.

IV. AUTHENTICATION TECHNOLOGIES

A. RFID and Smart Cards

RFID and smart cards give systems something concrete to work with: a machinereadable credential tied to a household record and whatever entitlement data sits behind it. Verma et al. pair a smart card with fingerprint verification, while Deshmukh and Raut link an RFID identifier directly to beneficiary and transaction records [1], [5]. Huilgol takes a different approach, using RFID as the opening step in a longer, multistage authentication chain [6].

The operational side is messier. Jadhav (2025) revisits problems that earlier systems ran into card duplication, unauthorized use, damaged cards, reader compatibility failures [10]. None of this points to some fundamental flaw in RFID as a technology. It just means the credential itself is one piece of the puzzle, not the whole thing.

B. Fingerprint and Multimodal Biometrics

Fingerprint verification keeps showing up as a second check layered on top of a physical credential. Gayathiri Ravi et al. require both RFID and fingerprint confirmation before the dispenser will open, and Huilgol et al. follow roughly the same sequence [6], [7]. Jadhav et al. go a different direction entirely: fingerprint only, no ration card required [10].

AIRationMitra pulls in fingerprint, RFID, and facial recognition all at once [11]. Honestly, that sounds comprehensive, but here's the problem: none of these papers share a common dataset or a standardized testing protocol, so there's no clean way to put their numbers side by side. What you're left with is a structural observation rather than a verdict. Stacking biometric layers is clearly doable. Whether any particular combination is actually accurate, graceful under failure conditions, or usable by real people in the field—that's still an open question, and the answer probably shifts with every deployment context.

C. QRBased Identification

Khan et al. describe a mobile workflow: the user schedules a collection event and receives a QR code, which the dealer application scans to start the dispensing machine [8]. It's a neat shift away from physical cards, but the tradeoff is real—now the whole thing depends not just on the machine working, but on the user having a phone that's charged, connected, and actually accessible when they need it.

V. AUTOMATED DISPENSING AND CONTROL

The systems covered here use servo motors, DC motors, solenoid valves, and auger mechanisms—sometimes in combination. Verma et al. control motors and valves through a microcontroller once a user has authenticated and selected a quantity [1]. Deshmukh and Raut built their dispensing system around servos and tied it to quota tracking [5]. Gayathiri Ravi et al. went a different route, pairing motorized dispensing with a load cell for weightbased control [7]. Jadhav et al. describe a more layered setup: an ESPclass wireless controller working alongside an ATmega328, relaydriven actuators, and load sensing [10]. AIRationMitra takes yet another approach, using an auger mechanism together with solenoid valves to release commodities [11].

What this variety actually shows is that actuator choice is not generic. Granular materials, liquids, and powders don't all behave the same way when released—what works cleanly for rice may not work at all for cooking oil, and honestly that seems obvious in hindsight, but it's something a lot of these designs don't test explicitly. A strategy proven for one material needs controlled testing before you can trust it with another.

VI. WEIGHT MEASUREMENT AND VERIFICATION

While authentication confirms who's asking, it doesn't actually verify that the right amount was physically delivered. That gap is why so many of the systems reviewed here rely on load cells and electronic weighing hardware. Gayathiri Ravi et al. use a load cell in their automated distribution setup; Huilgol

et al. go further, pairing a load cell for solids with a flow sensor for liquids. Jadhav et al. fold load sensors into the dispensing process itself [6], [7], [10].

Karuppasamy et al. take a different angle. Their work traces data from entitlement records through to a simulated weight output and a monitoring dashboard [9], leaning on software simulation and tolerance checks rather than physical hardware which they flag as future work. So honestly, what they're validating is the workflow logic, not the load cell behavior in a real deployment. That distinction matters when you're trying to compare studies that share components but test them at very different levels of fidelity.

Across the literature, the same control loop keeps showing up: check the recipient, determine what they're owed, run the dispenser, watch the output, stop or adjust when the target is hit. RationFlow follows that same closedloop pattern, but uses it as an experimental base for actually measuring quantity error and how the system responds to feedback.

VII. IOT, CONNECTIVITY, AND DATA MANAGEMENT

Connectivity runs through GSM, WiFi, local databases, cloud platforms, and mobile or web apps. GSM handles transaction notifications across systems [4], [6]; the 2024 QR architecture pairs Android apps with Firebase [8]; and Jadhav et al. describe cloud monitoring and logging over WiFi [10].

What ties these technologies together is a shared job: linking a physical dispense event to a running digital record. Deshmukh and Raut walk through automatic quota updates and transaction notifications, while AIRationMitra tracks inventory, transactions, and hardware status in real time [5], [11]. The POSweighing study takes a different angle, connecting entitlement data with electronic weighing and a live dashboard [9].

Connectivity also multiplies the ways things can go wrong. A dispense might kick off while the network is up, then hit a dropout before the central record gets written. When that happens, the system has to hold the local transaction state and sync it later—without doubling a quota deduction or leaving the inventory count off. That's not a solved problem. The RationFlow project treats local processing and deferred sync as a design approach that still needs experimental validation, not something that already works reliably.

VIII. QUOTA, INVENTORY, AND TRANSACTION MONITORING

Recent literature is starting to treat the dispensing machine as a transaction endpoint, not just a piece of hardware. Deshmukh and Raut tie dispensing to monthly quota updates [5]. Huilgol et al. cover digital stock updates and user notifications [6]. Khan et al. surface allotment and transaction details through a mobile app, and AIRationMitra pulls together quota management, inventory reconciliation, dispensing logs, and hardware alerts [8], [11].

From these, a reasonable information model for a completed transaction would link the beneficiary, the commodity, the entitled quantity, what was actually delivered, a timestamp, and the resulting inventory state. Exception handling matters just as much, honestly. Low stock, sensor failures, power cuts, connectivity drops — any of these can leave a transaction half-finished, and the software needs to tell that apart from a clean dispensing cycle. If it doesn't, quota and inventory records get corrupted quietly, with no obvious sign anything went wrong.

IX. ARTIFICIAL INTELLIGENCE IN SMART PDS

Most of the architectures surveyed run on explicit rules — identity checks, entitlement logic, actuator commands, log writes. Nothing fancy. On the other hand, AIRationMitra is a clear outlier: it combines a multilingual voice interaction interface with pattern recognition and anomaly detection techniques, which are learned behavior rather than hardcoded logic [11].

It's important to distinguish learned behavior from hardcoded logic. In addition, connectivity to the cloud is not AI. A system that sends sensor readings to a server and fires back a threshold alert is automated, not intelligent, and conflating the two muddies any honest review. In other words, if the paper claims that the system operates using AI-based methodology, the authors must present the data input, the objective of the model, algorithm or architecture used, what they have trained or calibrated it on, and how the performance has been evaluated. Without this information, what is "AI-driven"? For applications like smart PDS, there are different tasks at hand such as demand forecasting, anomaly detection, predictive maintenance, or conversational assistants, with varying degrees of complexity, and there is no single set of benchmarks that covers all of them. The sources reviewed do not share a common evaluation framework; direct comparison between these different functions is not possible.

X. COMPARATIVE ANALYSIS

Table I maps out the technologies from the reviewed literature — architectural representation, not a performance ranking. Blank fields mean the source didn't give enough detail for that category.

One pattern shows up consistently: functions are becoming more entangled with each other. Identification has moved away from cards and RFID toward biometrics and multimodal approaches. Dispensing is picking up sensor assistance. Transaction data that used to sit in local records is migrating to dashboards and cloud services. And the more recent work is folding in AI for interaction and analytics [1], [6], [11]. None of this confirms which system is best — it's a picture of what capabilities are being covered.

The comparison also exposes a real evaluation problem, and honestly it's one worth sitting with. A prototype might include a load cell but say nothing about how it was calibrated or how errors distribute across readings. A connected system might demonstrate data transfer without ever testing what happens

when the network drops. So the presence of a component doesn't tell you much about how the thing actually performs in the field. performance.

XI. RESEARCH CHALLENGES AND GAPS

A. Nonuniform Evaluation

The studies employ different hardware, commodities, test conditions, and performance measures. Some are conceptual or prototype descriptions, while Karuppasamy et al. evaluate a software simulation [9]. A shared evaluation framework could include authentication success rate, dispensing error, transaction duration, communication availability, recovery time, and consistency of transaction state.

B. Hardware Validation and Commodity Dependence

Physical dispensing is affected by commodity type, moisture or flow behavior, and mechanical geometry. A controller-level demonstration is therefore insufficient to generalize performance across rice, wheat, sugar, oil, and pulses. Reproducible experiments should report calibration procedure, target quantity, number of trials, and error distribution.

C. Network and Power Resilience

Cloud-linked systems require explicit handling of temporary disconnection. A local-first design can buffer transaction events, but synchronization must be designed so that repeated delivery or repeated quota deduction cannot occur after reconnection. Power-failure handling should likewise define which states constitute completed, interrupted, or recoverable transactions.

D. Security and Privacy

Biometric and transaction records need careful handling: controlled access, secure storage, the whole thing. The sources reviewed do stress authentication, which matters, but none of them pull together a single framework covering data minimization, access control, key management, secure storage, and retention. That gap doesn't bite you hard during prototyping. It does once the system goes live.

TABLE I

ARCHITECTURAL FEATURES REPRESENTED IN THE REVIEWED SMARTPDS STUDIES					
Study	Authentication	Dispensing / Measurement	Connectivity / Data	Evaluation Scope	
Verma et al. (2018) [1]	Smart card + fingerprint	Motor/valve dispensing	Database / messaging	Automated architecture	
Sobya et al. (2018) [2]	RFID	Mechanized distribution	RFID / GSM / computer data	Modeloriented system	
Sureshkumar and Arunadevi (2019) [4]	Fingerprint	DC motors / valves	Raspberry Pi / IoT	Prototype architecture	
Deshmukh and Raut (2021) [5]	RFID / smart card	Servobased dispensing	Quota and transaction records	System proposal	
Huilgol et al. (2022) [6]	RFID + fingerprint	Motor, load cell, flow sensor	GSM / stock records	Prototype implementation	
Gayathiri Ravi et al. (2024) [7]	RFID + fingerprint	Motorized dispensing + load cell	SMS / transaction record	Prototype implementation	
Khan et al. (2024) [8]	QR / mobile workflow	Automatic dispenser	Android + Fire base	Applicationoriented prototype	
Karuppasamy et al. (2025) [9]	Manual ID simulation	Simulated load cell	Flask + SQLite + dashboard	Software simulation	
Jadhav et al. (2025) [10]	Fingerprint	Motorized dispensing + load sensing	WiFi / cloud	Embedded prototype	
AIRationMitra (2025) [11]	Fingerprint + RFID + face	Auger/solenoid weight sensing	+ Cloud + AI analytics	Integrated proposed system	

F. Validation of AI Functions

Functions built around AI need replicable evidence — not just a named algorithm or interface. Any evaluation worth taking seriously should spell out the data source, define the task, set a baseline, describe the model, walk through training and testing where that's relevant, and include a performance metric.

This matters most for demand forecasting and anomaly detection. Get those wrong and you're making stock decisions on bad information.

XII. IMPLICATIONS FOR RATIONFLOW

The RationFlow initiative outlines a selfcontained process where the authentication of beneficiaries is succeeded by the verification of entitlements, automated distribution, weight confirmation, and the recording of transactions. The system's specified components encompass embedded control, fingerprint detection, loadcell/HX711 measurement, motor management, user interface or display, and communication with local or server systems. These operations align precisely with the key technological aspects highlighted in the literature reviewed.

The literature indicates that the defensible contribution of a new RationFlow implementation should be demonstrated through measurable system behavior rather than by claiming novelty for individual components. RFID, biometrics, automated actuation, load sensing, cloud logging, and AI analytics have already appeared in prior systems in different

combinations [1], [6], [7], [9]–[11]. RationFlow can therefore be evaluated on systemlevel questions such as transaction integrity, quantity accuracy, behavior during connectivity or power interruption, consistency between local and server states, latency, and usability.

Three experimental questions follow directly from the review. First, how reliably does weight feedback terminate dispensing near the target quantity? Second, what state does the system preserve when communication becomes unavailable during a transaction? Third, after recovery, does synchronization restore the correct transaction and inventory state without duplication? These questions convert the literature gaps into measurable evaluation criteria for a subsequent research paper.

XIII. FUTURE RESEARCH DIRECTIONS

Future work in this field should look beyond the laboratory and include largescale controlled dispensingaccuracy trials with multiple commodities and different target quantities, the assessment of authenticity (including failure) and accessibility conditions, the comparative study of the buffering and synchronization of local transactions, the development of mechanisms for privacyaware storage and rolebased access, the creation of labelled transaction data for anomaly detection purposes, the validation of the quality of a robust demand forecasting model by comparing it with a simple statistical baseline, an assessment of the impact of multilingual voice interaction technologies on retail transactions, the interoperability testing of electronic weighing equipment, embedded control modules, pointofsale (POS) systems, and monitoring dashboards, and the full disclosure of information

on calibration and hardware details including test scenarios and datasets.

XIV. CONCLUSION

aim of this paper was to examine the applications of a new technology, i.e., the IoT-enabled smart ration distribution system by looking at its various components like authentication, dispensing, physical measurement, connectivity, inventory management, and analytics. Looking at existing literature there seems to be a trend away from focusing on automation of individual ration shop tasks towards a move towards more integrated architectures that connect identity, entitlement, actualization and digital transaction status. The basic building blocks appear multiple times: RFID, fingerprint authentication, smart motors and valves, sensors (load cells, etc.), mobile networks (GSM/WiFi), cloud computing, interactive interfaces (dashboards). Newer work has started folding in multimodal biometrics, voice interaction, and AI-based analysis. Comparing these systems head-to-head is genuine difficulty, but. Hardware varies, commodities vary, deployment scope varies, and evaluation methods are all over the place. Most contributions are still in the prototype or proposal stage, and one study on POS weighing reviewed here is a software simulation only [9], which matters more than it seems when you're trying to draw performance conclusions. Therefore, pursuing quantitative rankings across systems seems less useful. The better way forward is to use consistent and standardized experimental criteria. In the case of RationFlow in particular, we believe that a comprehensive experimental study will involve closed-loop dispensing, transaction state integrity, failure resilience (communication and power failures), privacy protection, accessibility, and the ability to reproduce these results in other research settings. Not a wish list — a scope.

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