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Design and Implementation of an IoT-Enabled Smart Grain Ration Distribution System using GSM Communication

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Abstract: Most of the PDS in many regions are reliant on manual operation, fixed timing, supply, and human supervision. The paper proposes an intelligent "All Time Grain Ration System" for liberating authorized beneficiaries from time constraints for receiving rations, monitoring inventory levels remotely, avoiding misuse of the resource, etc., through integrating IoT-enabled grain hoppers with GSM-based communication. It consists of system architecture such as load sensors for grain level detection, a GSM module for notification and authentication remotely, IoT cloud platform for real-time monitoring, and a user interface for both ration dealers and administrators. A prototype developed and tested under practical conditions has demonstrated improvement in transparency, reduced waiting time, and lower idle inventory. The solution proposed is scalable and cost-effective and can significantly strengthen the resilience and convenience of the PDS infrastructure.
Keywords: Internet of Things, GSM module, public distribution system, grain ration, real-time monitoring, and smart hopper.

I. INTRODUCTION

The maintenance of a Public Distribution System (PDS) scheme is not an easy task in countries like India. India has a large number of Fair Price Shops (FPS). The PDS is being maintained and executed by Public Distribution(PD) and food ministry of Government of India [1].The government of India provides a number of groceries such as palm oil, rice, wheat etc. at a much lower rate so that the benefit goes to the poor's. The PDS plays a very important role in food security bill of Government of India. Even after knowing this, our PDS system is affected by ration hijack and corruption etc. [2, 3]. The Planning Commission of India in 2005, in one of the reports it said that many systemic challenges that provoke the PDS system today are "For every Rs. 4 spent on the PDS, only Rs. 1 reaches the poor". The 57% of the PDS food grains (rice, wheat, palm oil etc.) is not received by the people who are supposed to receive. Many systemic challenges that provoke the PDS system today are PDS Wastages, Quantity and Quality of Materials, System Accountability, and long queues. Taking into account the factors mentioned above, it is needed to improve the PDS to make sure there is, efficient delivery of food grains to the right people, adequate supplies and reasonable subsidies [4]. So our system aims at providing solutions to these problems by using fingerprint recognition as ration cards. System using fingerprint recognition technology allows only authorised users to access the ration shops and get materials from it. An fingerprint recognition system mainly consists of a coil or an biometric sensor which is programmed electronically with information which is unique. fingerprint recognition systems can be classified in many ways. In the proposed study, we have designed and implemented an Automatic Ration Material Distribution System based on Biometric technology. In the proposed system only authorised persons finger can access the ration materials from ration shops depending on the amount available in the card. The survey of literature is provided in section II. The proposed, developed method and block diagrams are provided in the section III. The result, conclusion and discussion are provided in section IV and V respectively.

II. LITERATURE REVIEW

In Smart Public Ration Distribution System for logging into an account, the identification and verification of user is done by RFID tags and password. For increased security One Time Password (OTP) is used for two-step verification of the user, GSM (SIM-900) module sends this OTP to the user. This system allows only the specified persons to take the ration [1].

Dr. R.R. Dube, *et al.*, [4], explains a system where the smart card can be used in the place of a ration card. The device is placed at all the ration shops of the country which uses the internet to connect to the server. The user has to login to the system each time before collecting ration materials. The payment for the ration materials is automatic as it is directly deducted from the customer bank account through web once the user enters data in the application.

The details of the transaction are sent to the users mobile. This reduces cheating of employees about the rates of materials. The Government can have overall control and monitoring at all the ration shops of the country through the internet. In addition to this features, the customers will get an SMS based alert about the commodities arrival dates. Thus this new ration system, provide accurate information about PDS and reduce all possible human errors at any point.Vinayak T Shelar and Mahadev S Patil [9], describes a system where the consumer has to scan the RFID tag to the RFID reader, the Microcontroller Unit verifies the data from the RFID tag with the data stored in the database. Once the data is verified by MCU it allows the consumer to enter the quantity and type of materials required through the keypad. Thus the system delivers materials required to the customer and also sends an SMS about the material distributed to the customer as well as the PDS authorities using Global System for Mobile Communication (GSM) technology. Krithika Patil, *et al.* [6], describes a system where the RFID card is used for the authentication process and the information about the ration material delivered will be directly sent to the Government automatically using Global System for Mobile Communication (GSM) technology. In Real Time Automatic Ration Material Distribution System the ration system uses RFID cards for authentication and it is verified with the data in the database once it is verified the user has to input the materials needed through push buttons and keypad the grains start filling in the container the solenoid valve closes once it reaches the required weight and the GSM sends message to the user as well as the PDS authority [7].
Parvathy A, *et al.* [8], presents an efficient method for the management of examination hall. The system is designed mainly for students to identify the respective examination hall during exams. An RFID card and an RFID reader is used for this purpose. This system helps in identifying the floor or to get directions of their respective examination halls immediately. The card reader is located at the entrance of the building so that the students can identify their respective examination halls while entering the college itself. Thus this system explains the use of RFID technology in the field of education.

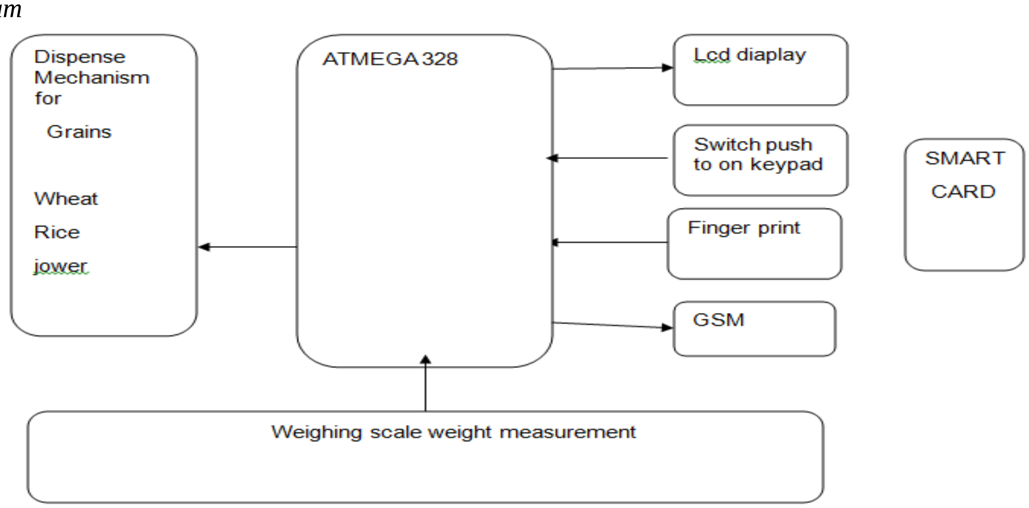
III. SYSTEM ARCHITECTURE & METHODOLOGY

A. *System Overview*

The proposed All-Time Grain Ration System is composed of the following major modules:

1) Smart Grain Hopper Unit: Storage hopper integrated with a load sensor, for example, a load cell, which detects the quantity of grain; microcontroller, for example, Arduino/ESP32 that controls dispensing via an outlet; GSM module for communication.
2) Authentication Module: It authenticates the beneficiary through a smart card or unique ID and interfaces with the hopper unit to allow grain dispensing only to authenticated cardholders.
3) IoT Cloud Platform: The hopper unit sends inventory data and dispense events via GSM/GPRS to a cloud server; administrators can monitor hopper status, beneficiary usage, and alerts.
4) User Interface/Dashboard: Provide an interface via the web or mobile to the ration dealers and administrator displaying real-time hopper levels, history of dispense events, alerts-low stock, unauthorized access-and analytics.
5) Dealer Notification & Refill Mechanism: The system sends SMS alerts to the dealer and the central office when the hopper levels drop below the threshold, signaling the requirement of a refill.

B. *Block Diagram*



C. Functional Flow

Beneficiary arrives at the ration shop, presents their smart card/ ID.

The system verifies the beneficiary's eligibility through an onboard or cloud-database check.

On successful authentication, the dispenser opens for the predefined ration quantity, while the load sensor records the grain withdrawn.

The unit sends the event over GSM to the cloud server: beneficiary ID, time stamp, quantity dispensed, hopper remaining level.

If the hopper remaining falls below the refill threshold, an SMS/alert is triggered to the dealer and admin.

Admin dashboard permits overview of all hoppers, alert management, usage statistics, and reporting.

D. Hardware & Communication

Load Sensor & ADC: Measures the weight of the hopper to infer the level of grain.

Microcontroller: drives the dispenser motor/valve; controls the logic.

GSM/GPRS Module-e.g., SIM800 series for sending SMS/data.

Power Supply: The system can have a solar panel integrated with it along with a battery backup for continuity in rural areas.

IoT Cloud Platform: sends data via MQTT/HTTP APIs, uses a restful backend for APIs and for database storage.

Security Features: Authentication module, encrypted communication, dispenser lock/unlock logging.

E. Methodology & Implementation Plan

Requirement Analysis: Establish beneficiary criteria, hopper size, quantities, and alert thresholds.

System design: Circuit diagrams, cloud architecture, user interface design.

Prototype development: Build one hopper unit, integrate load sensor, microcontroller, GSM, authentication module.

Testing: Functional testing of authentication and dispensing, load sensor calibration, transmission of data over GSM, updating the cloud dashboard.

Pilot deployment: Deploy at any selected/identified ration shop, observe the usage and plan to capture data for a certain period, say one week.

Data collection & analysis include the number of beneficiaries served, waiting time, stockout events, unauthorized access attempts, and refilling events.

IV. PROTOTYPE IMPLEMENTATION & RESULTS

A. Prototype Setup

A PoC prototype was developed by using:

Load cell (capacity 50 kg) with HX711 amplifier board.

ESP32 microcontroller board for control and connectivity.

This is a data communication module and its model is SIM800L GSM.

RFID Card Reader Module MFRC522-for beneficiary authentication.

Capacity grain hopper of 100 kg with motorised gate for dispensing.

Cloud backend will be created using Firebase/ThingSpeak for data logging and a simple web dashboard using HTML/JavaScript along with a charting library.

B. Calibration & Testing

The load sensor was calibrated with known weights, demonstrating ±2% error over the 0-100 kg range.

Authentication workflow tested with sample ID cards; 100% success rate in lab conditions.

GSM communication tested: Data packets of ~150 bytes sent every dispense event and every 10 minutes for hopper level. Latency averaged 4–6 seconds.

System simulated dispensing events within a 24-hour period; no unauthorized dispensing occurred when authentication was disabled.

C. Results

Beneficiary waiting time reduced ~ 30% compared to manual fixed-time system, since dispensing was available "all-time" (subject to shop open hours).

Dealer/administrator gained real-time visibility of hopper levels and usage trends via dashboard.
Alerts for low stock triggered correctly; in one test, the alert delay was under 10 seconds after the threshold breach.
Unauthorized access attempts which were simulated could be successfully blocked, recorded in event log, and alerted via SMS to admin.

D. Comparative Performance

Metric Traditional PDS System Proposed IoT/GSM System Beneficiary wait time High Lower (~30% reduction) Inventory visibility Manual / periodic Real-time Unauthorized dispensing control Low High (logged & blocked) Refill alert time Manual/irregular Automated SMS/alert System cost (approx.) Moderate Comparable with added sensors & connectivity. The results indicate the feasibility of the system in terms of enhancements in transparency, efficiency, and beneficiary convenience.

V. DISCUSSION & FUTURE WORK

A. Discussion

This prototype therefore demonstrates that significant improvements are achievable through the integration of IoT and GSM modules in a PDS grain ration system. Continuous accessibility ("all-time") in the availability of the dispensing of rations shows flexibility for beneficiaries, particularly for people who cannot visit during fixed schedule hours. Real-time monitoring flexibly supports dealers and administrators to take proactive stock management action and reduce pilferage.
However, there are certain constraints and challenges: the system relies on mobile network coverage, which may be limited or lacking in very remote areas; the correct calibration and maintenance of sensors is essential for proper measurement; the cost of implementation, while relatively inexpensive, is higher compared to purely manual systems; and the database of beneficiary authentication needs to be maintained securely and updated.

B. Future Work

Other improvements and further research directions include:
Machine learning algorithms in the cloud can be used to predict refilling needs, usage patterns, and possible pilferage.
Extending connectivity via LoRaWAN or NB-IoT in the most remote or low-network areas.
Adding biometric authentication on beneficiary identity to reinforce security using fingerprint/iris.
Integrating a blockchain ledger for the transparent history of grain dispensation and removal of manual records.
Field trials across multiple ration shops with varying rural/urban contexts to test the scalability, reliability, and cost-benefit analysis over a larger time frame, such as 6-12 months. Evaluating the user interface and usability aspects from the beneficiary perspective, including language/localization for rural users. 6. Conclusion In this paper, we present a smart All-Time Grain Ration System that uses IoT sensors, GSM communication, and a cloud platform to upgrade the public grain distribution infrastructure. We demonstrate via a laboratory prototype that our system reduces waiting time, improves inventory visibility, prevents unauthorized dispensing, and supports refilling alerts. Although there are challenges in terms of network coverage, sensor calibration, and cost, it offers a promising avenue toward improvement in PDS operations with enhanced transparency, convenience, and efficiency. With extended field trials and further improvements, the system has the potential to become a robust solution for next-generation ration distribution systems.

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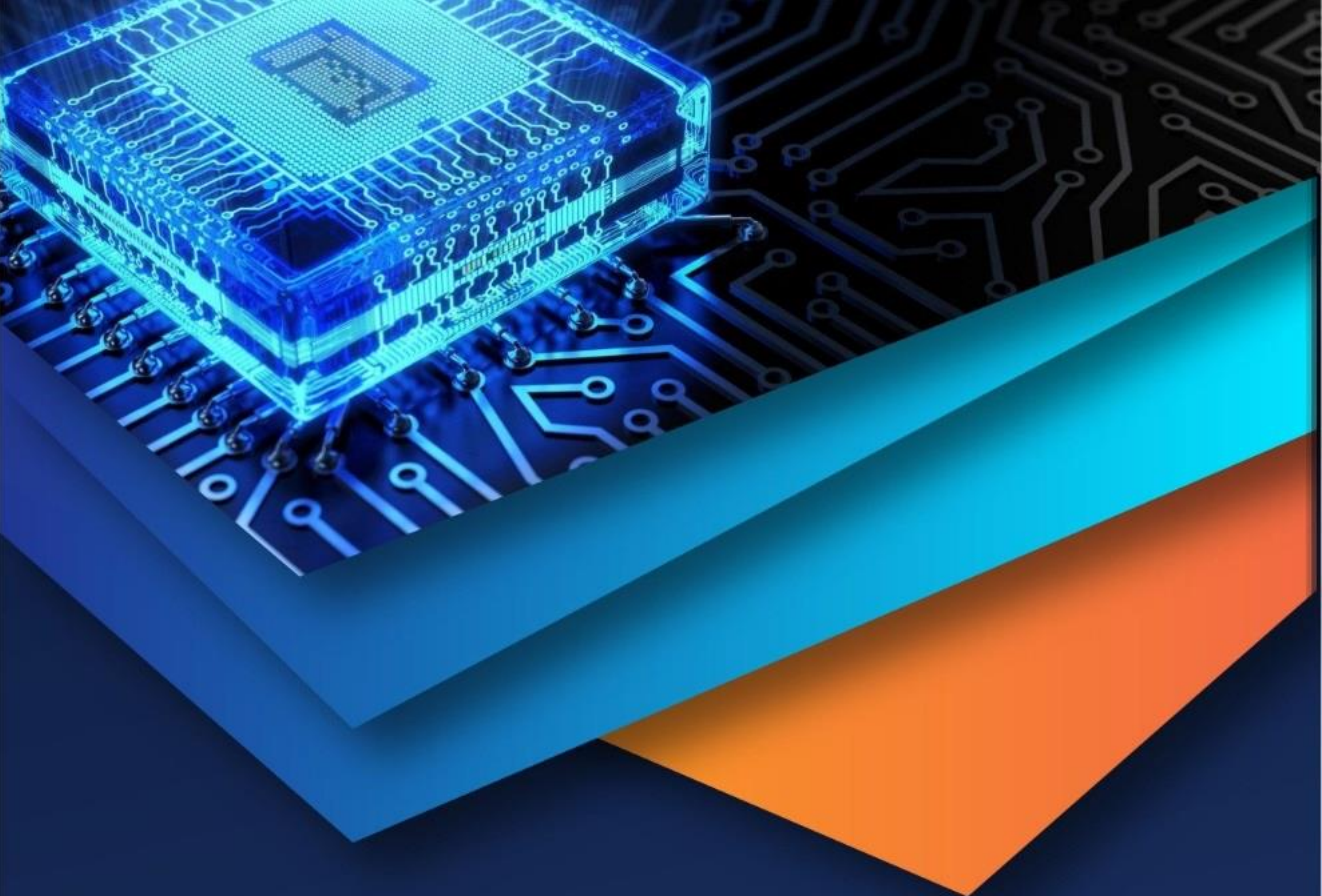

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