International Journal on Science and Technology (IJSAT)
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

# Smart Parcel Drop Box with Real-Time Monitoring and Alert System Using IOT

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**Abstract**
Security and smart delivery management systems have become increasingly important in modern residential environments due to the rapid growth of e-commerce and unattended parcel deliveries. However, conventional parcel handling methods often lack real-time monitoring and secure notification mechanisms, leading to risks such as theft, missed deliveries, or lack of awareness. This paper presents the design and implementation of a Smart Parcel Drop Box with Real-Time Alert System, developed using a low-cost microcontroller platform. The proposed system is designed to securely detect the placement of parcels inside a designated drop box and instantly notify the user through a mobile-based alert mechanism. The system integrates proximity sensing to identify parcel insertion events and employs a microcontroller-based processing unit to monitor and validate activity within the box. Upon detecting a valid parcel drop, the system triggers an automated notification to the user's mobile device, ensuring immediate awareness without the need for manual checking. The design emphasizes simplicity, cost-effectiveness, and reliability by eliminating the need for complex communication modules while maintaining efficient alert delivery. This solution provides an effective approach to enhancing parcel security and user convenience, making it suitable for residential and small-scale commercial applications where real-time delivery updates are essential.

**Keywords:** Smart Parcel Delivery System, Real-Time Alerting, IoT-Based Monitoring, Event Detection, Embedded Systems, Wireless Notification

## 1. Introduction

In the modern era of rapid digital commerce and increasing reliance on home deliveries, the need for secure, intelligent, and cost-effective parcel management systems has grown significantly across residential and small-scale commercial environments. Conventional parcel delivery methods often lack real-time monitoring and secure notification mechanisms, making them vulnerable to issues such as theft, missed deliveries, and lack of user awareness. While surveillance cameras and manual tracking systems provide partial solutions, they often fail to deliver immediate and actionable updates to users.

The core motivation behind this project arises from a common real-world problem: unattended parcel deliveries. In many households, parcels are left outside the premises without any secure storage or instant notification system. Existing low-cost solutions either rely on basic detection mechanisms or require complex and expensive infrastructure. These systems typically lack the ability to reliably detect parcel placement events and notify users in real time, leading to inefficiencies and potential security risks.

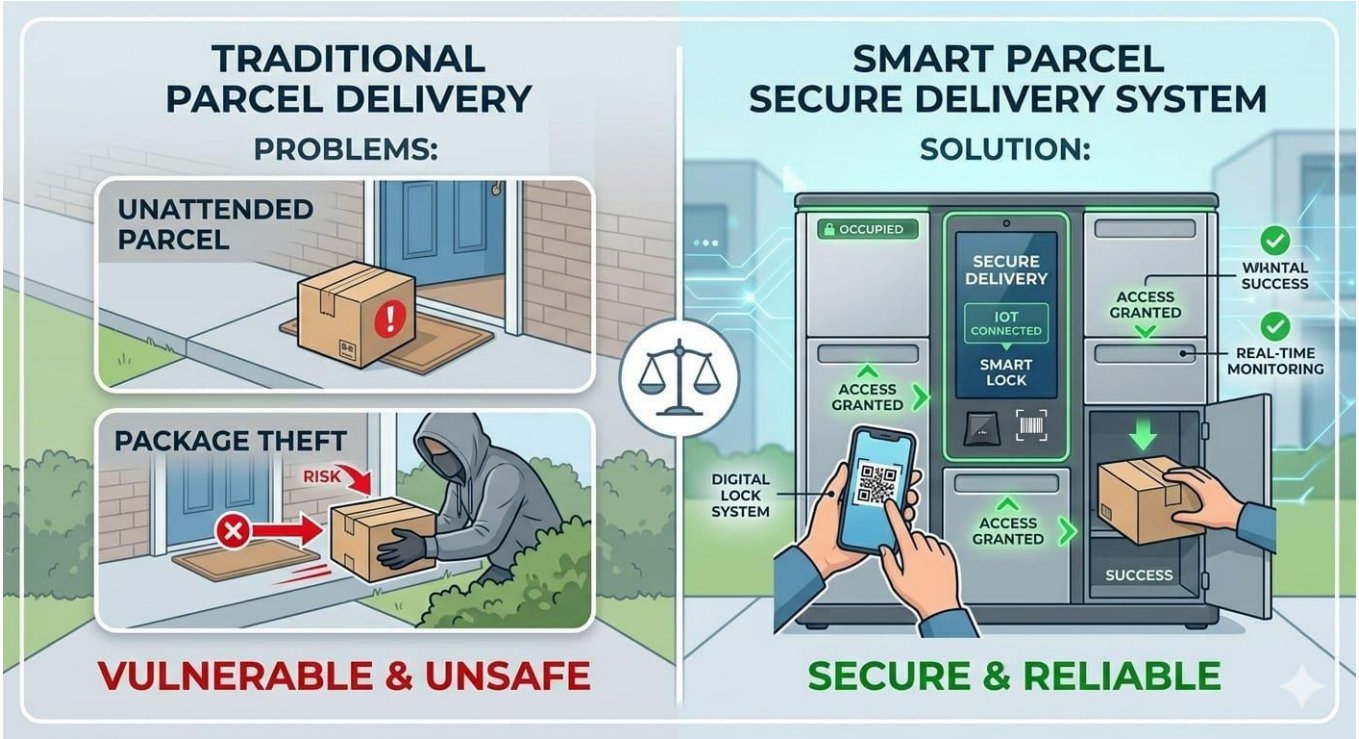


Figure 1: Performance Comparison of Traditional Parcel Box and IoT-Based Secure System

To address this challenge, the proposed system introduces a Smart Parcel Drop Box equipped with an automated detection and alert mechanism. The system continuously monitors the interior of the drop box using a proximity-based sensing approach to identify parcel insertion events. Upon detecting a valid parcel drop, the system processes the event using a microcontroller-based platform and triggers an alert mechanism without requiring manual intervention. This ensures accurate and timely detection while maintaining system simplicity and affordability.

The system is designed to provide immediate feedback through a user notification interface, where real-time alerts are transmitted to the user's mobile device. By leveraging wireless communication capabilities, the system ensures that users are informed instantly about delivery events regardless of their location. This eliminates the need for frequent manual checking and enhances overall convenience.
By combining embedded system design with real-time alerting capabilities, the proposed solution offers a reliable and efficient approach to secure parcel handling. The system emphasizes low cost, ease of deployment, and practical usability, making it suitable for modern households seeking smarter and safer delivery management solutions.

## 2. Literature Survey

The domain of smart parcel management and delivery monitoring has become an important area of research, especially with the rapid expansion of e-commerce, embedded systems, and Internet of Things (IoT) technologies. The increasing number of unattended deliveries has created a demand for intelligent, reliable, and cost-effective systems capable of ensuring parcel security and providing real-time user awareness. A wide range of solutions have been explored involving different sensing techniques, microcontroller platforms, and communication methods. Reviewing these existing approaches provides valuable insight into their strengths and limitations, and highlights the gaps that the proposed smart parcel drop box system aims to address. Early parcel handling and monitoring systems relied primarily on traditional surveillance methods, most commonly using closed-circuit television (CCTV) cameras to observe delivery areas. These systems operated by continuously recording video footage, which could later be reviewed for verification. While useful for evidence collection, such systems lacked real-time intelligence and required manual intervention to identify delivery events. Furthermore, they were unable to provide immediate alerts to users, making them less effective in preventing parcel theft or ensuring timely awareness of deliveries.

Viola and Jones [1] proposed a rapid object detection approach using a Haar Cascade Classifier combined with the AdaBoost algorithm, primarily applied in vision-based parcel monitoring systems with fixed camera setups.

While the method demonstrated high detection accuracy under controlled lighting conditions, its performance degraded significantly in the presence of poor or dynamic lighting, leading to increased false detections. This limitation makes vision-based approaches less reliable for real-world parcel delivery systems, where lighting conditions and environmental variations cannot be controlled.

Niyogi and Adelson [2] explored optical flow analysis using spatiotemporal filtering techniques to perform motion detection in controlled environments such as laboratories and indoor spaces. The method demonstrated effective detection of motion trajectories; however, it is computationally intensive and highly sensitive to environmental disturbances such as camera instability and background noise. These limitations restrict its applicability in real-time parcel detection systems, particularly in low-cost embedded platforms. Such approaches highlight the challenge of achieving accurate detection while maintaining low computational complexity. The proposed system addresses this limitation by employing a lightweight sensor-based approach that avoids complex image processing and instead relies on simple and efficient parcel detection mechanisms.

Anderson [3] investigated sensor-based detection systems using infrared and proximity sensors configured with static threshold-based logic in indoor monitoring environments. The system demonstrated reliable object detection under stable conditions; however, it lacked adaptability to environmental variations such as lighting changes, dust interference, and unintended object movements. This reliance on fixed threshold values is a significant limitation, as it may lead to false triggers or missed detections over time. These observations highlight a critical gap in conventional sensor-based systems, which fail to adapt to changing environmental conditions. The proposed system addresses this issue by implementing a reliable detection mechanism for parcel placement events, ensuring consistent performance while reducing false alerts.

Microchip and Rowe [4] proposed a combined sensing approach integrating ultrasonic sensors with infrared-based triggering mechanisms for object detection in indoor monitoring systems. While this method improved detection coverage compared to single-sensor systems, it continued to rely on static threshold-based logic. As a result, the system exhibited inconsistent performance in environments affected by external disturbances such as ambient noise, reflective surfaces, or irregular object placement. These observations reaffirm a key limitation in traditional multi-sensor systems, where lack of intelligent validation leads to reduced reliability. The proposed system addresses this gap by using a simplified and application-specific sensing approach focused on accurate parcel detection and real-time alert generation.

Zappi [5] advanced detection systems by introducing a machine learning-based framework utilizing Support Vector Machines (SVM) for activity recognition in smart environments. While this approach significantly improved classification accuracy, it required extensive labeled datasets and high computational resources for training and operation. Such dependencies increase system complexity and limit deployment in low-cost embedded platforms. These limitations highlight the gap between advanced intelligent systems and their practical feasibility. The proposed system addresses this challenge by adopting a lightweight embedded design that does not require prior training or complex computation, while still providing reliable real-time parcel detection and alerting.

The survey of existing literature reveals a consistent gap in current parcel monitoring systems, particularly in achieving a balance between accuracy, simplicity, and cost-effectiveness. Vision-based approaches are sensitive to environmental conditions, while conventional sensor-based systems rely on static thresholds and lack adaptability. Although machine learning-based methods improve performance, they introduce significant complexity and resource requirements. The proposed Smart Parcel Drop Box system addresses these challenges by providing a simple, efficient, and real-time detection mechanism using embedded sensing and wireless alerting. This approach ensures reliable parcel detection, immediate user notification, and practical deployment in real-world environments.

| Ref | Authors | Method | Environment | Key Results |
|---|---|---|---|---|
| [1] | Viola & Jones | Cascade Classifier with AdaBoost for object detection | Vision-based parcel monitoring with fixed camera setup | High detection accuracy in controlled lighting; significant false detections under poor or varying lighting conditions. |
| [2] | Niyogi & Adelson | Optical Flow Analysis | Laboratory and indoor monitoring environments | Effective motion detection; computationally intensive and sensitive to environmental noise and instability. |
| [3] | Corey Anderson | IR/Proximity sensor-based detection with static threshold logic | Indoor object detection systems (homes/offices) | Simple implementation; lacks adaptability to environmental variations, leading to false triggers. |
| [4] | Microchip & Rowe | Ultrasonic sensing combined with IR-based triggering | Indoor monitoring and storage environments | Improved detection coverage; high false detections in presence of disturbances like reflections or irregular object placement. |
| [5] | Zappi et al. | Edge computing framework using SVM for event detection | Smart environment monitoring systems | Improved detection accuracy; requires large training datasets and high computational resources. |

Table 1: Summary of Existing Models for Smart Parcel Drop Box and Delivery Monitoring Systems

## 3. Parcel Detection Model


Figure 2: Parcel Detection model

The parcel detection model defines the operational space within which the smart parcel drop box system actively monitors for delivery events. Unlike perimeter-based intrusion systems, the detection zone in this model is confined to the interior volume of the drop box, where parcel placement is expected to occur. This enclosed detection region ensures focused monitoring and eliminates interference from external environmental disturbances.

The detection mechanism is centered around a proximity-based sensing approach, which continuously observes the internal state of the drop box. When a parcel is inserted, the sensor detects a change in distance or object presence within the predefined sensing range. This event is interpreted as a valid parcel delivery based on predefined logic conditions, ensuring accurate detection while minimizing false triggers caused by minor disturbances.

At the core of the system lies the Signal node, representing the microcontroller unit responsible for processing sensor inputs and managing system operations. This central unit continuously analyzes incoming data to determine whether a parcel has been placed inside the box. Upon successful detection, the system triggers an alert mechanism.

The User node represents the end user who receives real-time notifications on their mobile device. Once a parcel delivery event is confirmed, the system sends an instant alert through a wireless communication interface, ensuring that the user is immediately informed regardless of their physical location.

The enclosed detection model ensures reliable operation by limiting the sensing area to a controlled environment, thereby reducing noise and external interference. This design improves detection accuracy and system efficiency, forming the foundation for a secure and intelligent parcel monitoring solution.

## 4. Proposed Algorithm

1. The system is initialized by powering the microcontroller and establishing a Wi-Fi connection for communication.
2. The proximity sensor is configured to monitor the interior of the parcel drop box continuously.
3. A reference threshold value is defined to distinguish between an empty box and the presence of a parcel.
4. The system continuously reads sensor data to detect any change in distance or object presence inside the box.
5. The incoming sensor readings are analyzed to determine whether a parcel has been placed within the detection range.
6. A validation step ensures that the detected object corresponds to an actual parcel placement and not a temporary disturbance.
7. Once a valid parcel detection event is confirmed, the system processes the event using the microcontroller.
8. A real-time alert notification is generated and transmitted to the user's mobile device through a wireless connection.
9. The system updates its internal state to indicate that a parcel is present inside the drop box.
10. The monitoring process continues to track any further changes, such as parcel removal or additional deliveries.
11. The system operates continuously to ensure reliable detection and instant user notification.

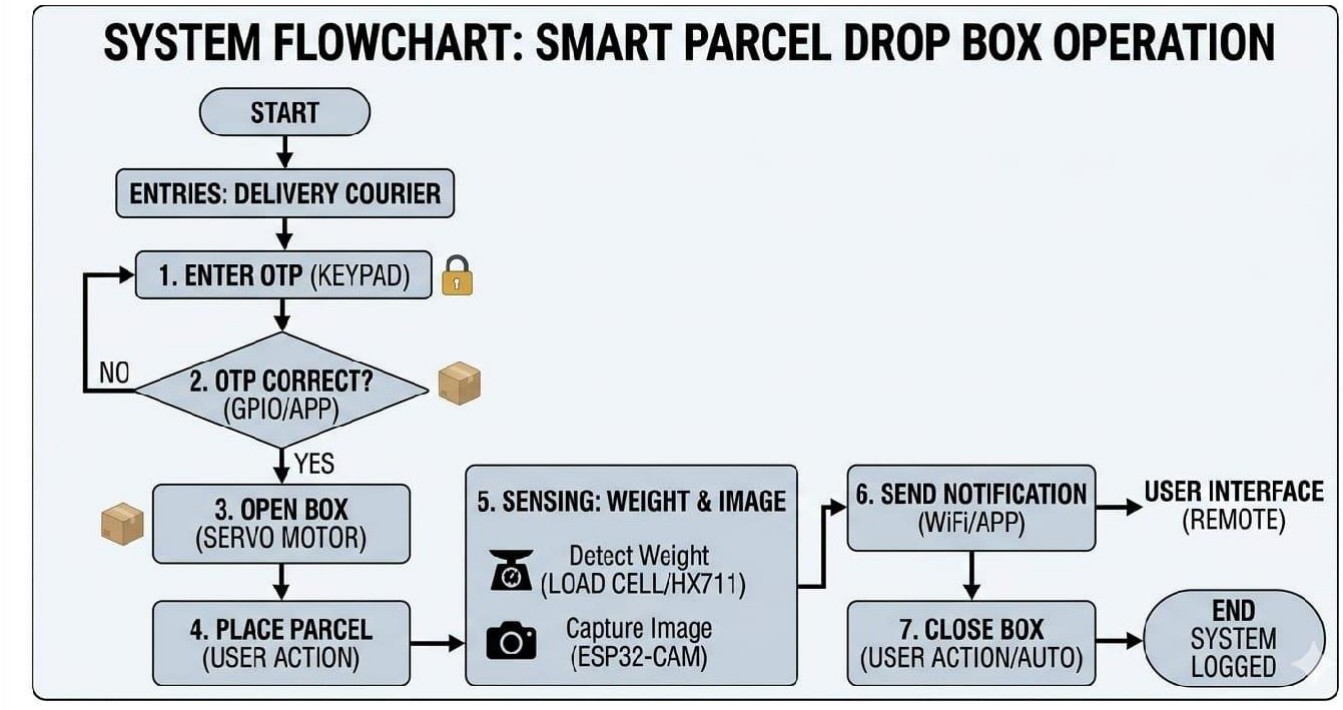


Figure 3: Flowchart of the Proposed Smart Parcel Detection and Real-Time Alert Algorithm

## 4. Mathematical Model

Load Cell Calibration using HX711

$$W=(R-R_{offset})/S$$

Where:

- R = Raw ADC value from HX711
- Roffset = Offset value (reading when no load is applied)
- S = Calibration factor (scale factor)
- W = Actual weight of the parcel Calibration Factor Calculation

$$S=(R_{known}-R_{offset})/W_{known}$$

Where:

$R_{known}$ = Raw value for a known weight $W_{known}$ = Known reference weight

The proposed Smart Parcel Drop Box system operates as an intelligent and secure delivery solution by integrating authentication, sensing, and real-time alert mechanisms into a unified framework. The system evaluates parcel delivery activity using a combination of password-based access control and sensor-based verification. The authentication mechanism ensures that only authorized users can access the parcel box, thereby preventing unauthorized entry. Upon successful password validation, the servo motor is activated to open the drop box, enabling controlled parcel placement.

The system further incorporates a load detection mechanism to quantify parcel presence based on weight variation. Higher weight readings indicate successful parcel placement, while negligible changes correspond to an empty or idle state. The sensitivity of the load detection is calibrated based on experimental observations to accurately distinguish between actual parcel delivery and minor environmental disturbances. In addition, the ESP32-CAM module captures real-time images of the parcel during delivery, providing visual confirmation and enhancing system transparency.

A real-time alert mechanism is implemented to notify the user immediately after parcel placement. This ensures timely awareness and reduces the risk of parcel theft or misplacement. The integration of sensing, image capture, and notification modules enables efficient decision-making within the system. Furthermore, the system is designed to operate reliably under varying environmental conditions, with stable performance ensured through proper threshold selection and component calibration. Overall, the proposed approach enhances the security, reliability, and automation of parcel delivery systems in modern smart environments.

## 5. System Implementation Architecture

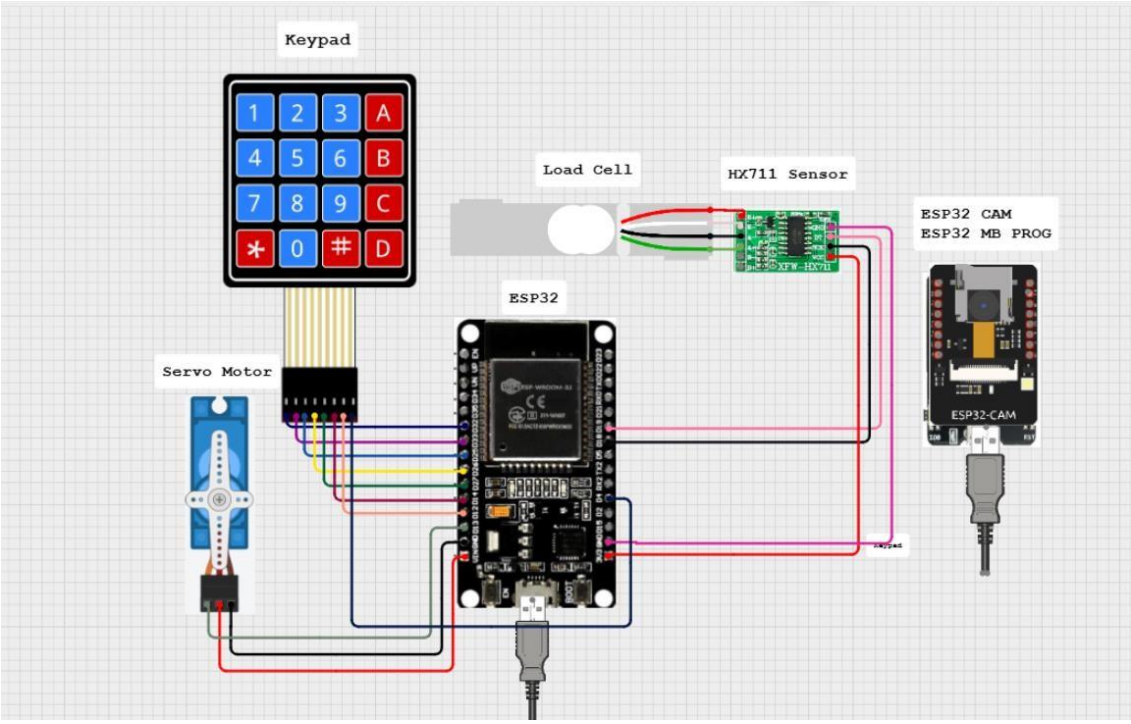


Figure 4: Overall Circuit Diagram of the Project

The implementation architecture of the proposed Smart Parcel Drop Box system integrates multiple sensing, control, and communication components within an IoT-enabled secure delivery framework. The system is built around an ESP32 microcontroller, which functions as the central processing unit, interfacing with a keypad, load cell sensor, servo motor, and ESP32-CAM module. The keypad is used for password-based authentication, ensuring that only authorized users can access the parcel box. The load cell sensor continuously monitors weight variations to detect the presence of a parcel, while the ESP32-CAM captures real-time images for delivery verification.

All sensor data is transmitted to the ESP32, where real-time processing and decision-making are performed. During the initial stage, the system operates in an idle monitoring state, maintaining baseline conditions for an empty box. When a user enters a valid password, the controller activates the servo motor to open the parcel box, enabling secure placement or retrieval of parcels. Once a parcel is deposited, the load cell detects a significant change in weight, which is used to confirm successful delivery.

Upon detection, the ESP32-CAM captures an image of the parcel, and the system triggers a real-time alert to the user via Wi-Fi communication. Notifications are sent instantly to the user's mobile device, ensuring immediate awareness of parcel delivery. In case of incorrect password attempts, access is denied, and the system maintains its locked state to prevent unauthorized entry. The integration of sensing, authentication, image capture, and wireless communication ensures a reliable and efficient smart parcel management system, enhancing both security and user convenience in modern IoT environments.

## 6. Simulation setup

The implementation and working setup of the proposed Smart Parcel Drop Box system is designed to validate its performance under real-time operating conditions. The system integrates multiple components including a keypad for authentication, a load cell sensor for parcel detection, a servo motor for automated access, and an ESP32-CAM module for image capture. All components are interfaced with the ESP32 microcontroller, which performs real-time processing and control operations.

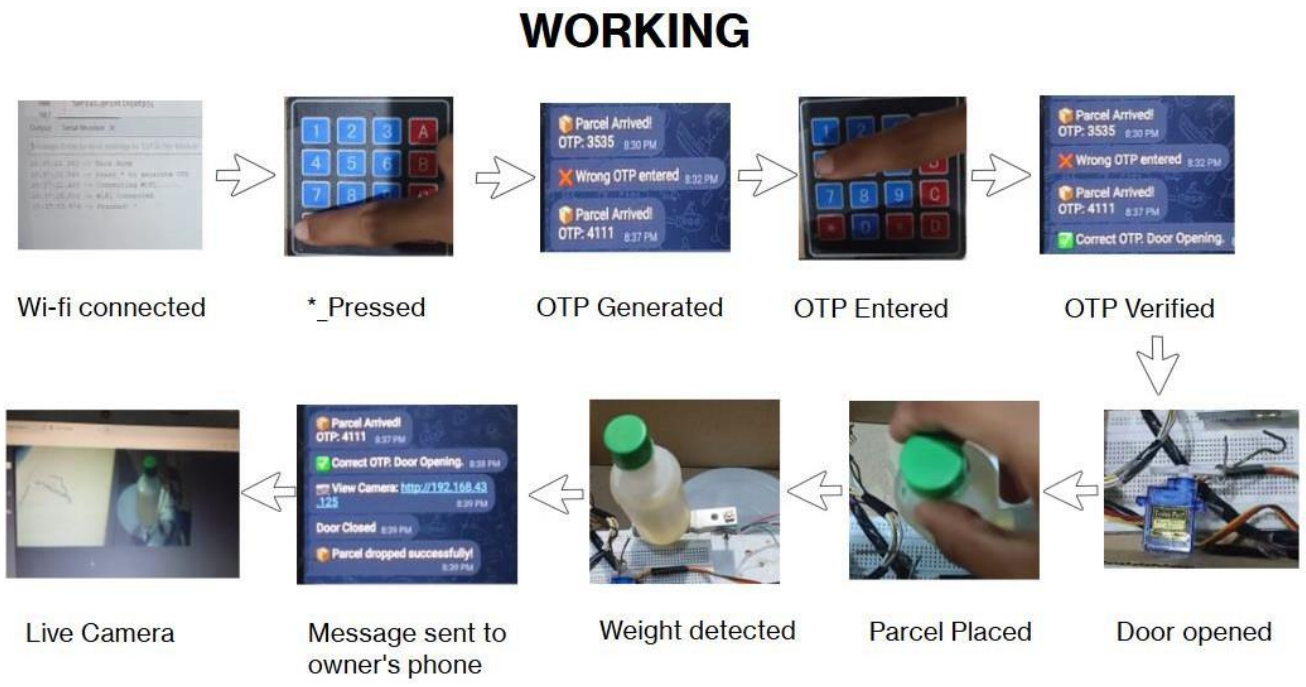


Figure 5: System Operation

The implementation and working setup of the proposed Smart Parcel Drop Box system is designed to validate its performance under real-time operating conditions. The system integrates multiple components including a keypad for authentication, a load cell sensor for parcel detection, a servo motor for automated access, and an ESP32-CAM module for image capture. All components are interfaced with the ESP32 microcontroller, which performs real-time processing and control operations.

During the initial stage, the system operates in an idle monitoring state where the parcel box remains locked. The keypad-based authentication mechanism ensures that only authorized users can access the system. When a valid password is entered, the ESP32 verifies the credentials and activates the servo motor to open the parcel box. In case of invalid input, access is denied, thereby maintaining system security.

Once the parcel is placed inside the box, the load cell sensor detects a change in weight, which confirms the presence of the parcel. This weight variation acts as a trigger for the next stage of operation. The ESP32-CAM module is then activated to capture an image of the parcel, providing visual confirmation of delivery.

Following parcel detection and image capture, the system sends a real-time notification to the user through Wi-Fi communication. This alert mechanism ensures that the user is immediately informed about the parcel delivery, enhancing both security and convenience. The system continuously monitors the status of the parcel box and remains ready for subsequent operations.

Fig. 4 illustrates the overall working of the Smart Parcel Drop Box system. It represents the complete

flow of operations, including authentication, parcel detection, image capture, and alert generation. The diagram clearly shows how each component interacts with the ESP32 controller to achieve an automated and secure parcel handling process.

The results demonstrate that the system performs efficiently under different operating conditions. The authentication mechanism ensures secure access, the load sensor accurately detects parcel placement, and the alert system provides timely notifications. The integration of these modules enables reliable and real-time operation, confirming the effectiveness of the proposed system.

## 7. Experimental Results

The experimental setup of the proposed Smart Parcel Drop Box system is designed to evaluate its performance under real-world operating conditions. The system was tested in indoor environments with different usage scenarios such as authorized access, incorrect password attempts, parcel placement, and idle conditions. A total of 15–20 test cases were conducted to analyze system performance in terms of authentication accuracy, parcel detection reliability, and alert responsiveness. The objective of these tests was to validate the efficiency, security, and real-time functionality of the proposed system.

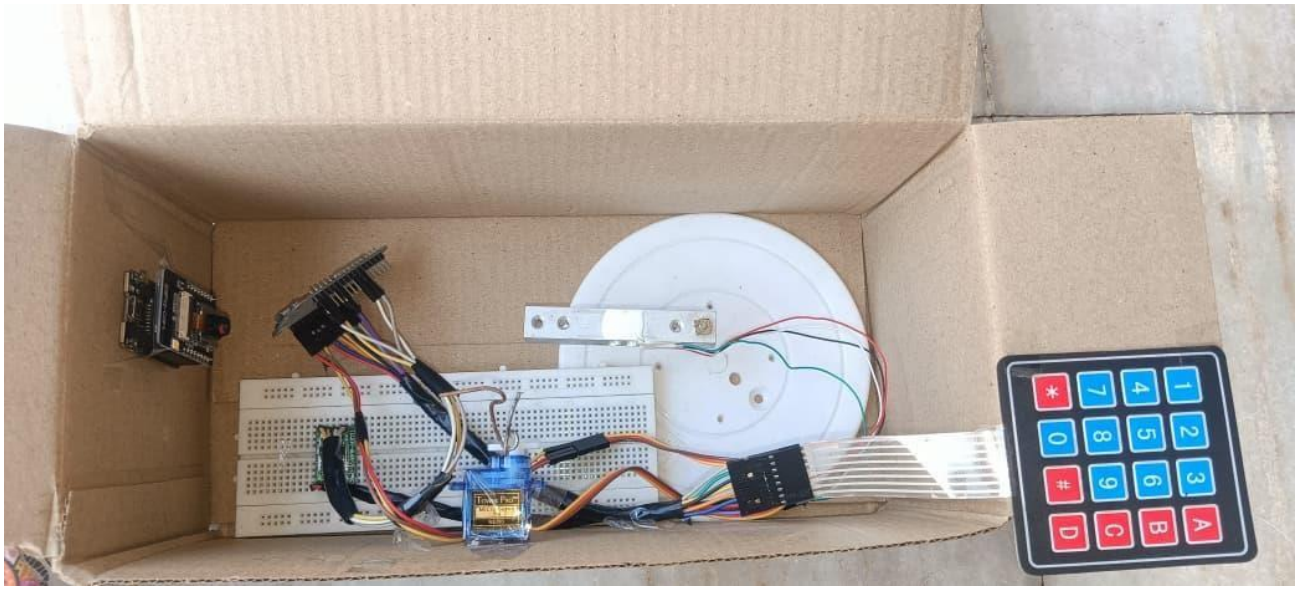


Figure 6: Hardware Setup

The hardware setup consists of an ESP32 microcontroller interfaced with a keypad, load cell sensor, servo motor, and ESP32-CAM module, all powered through a stable power supply. The keypad is used for secure password entry, while the servo motor controls the opening and closing of the parcel box. The load cell sensor is placed at the base of the box to detect weight variations caused by parcel placement. The ESP32-CAM module is positioned to capture images of the parcel during delivery for verification purposes.

During operation, the system initially remains in a locked and idle state. When a user enters a valid password through the keypad, the ESP32 verifies the input and activates the servo motor to open the parcel box. In case of incorrect password attempts, access is denied, ensuring system security. Once a parcel is placed inside the box, the load cell sensor detects a significant change in weight, confirming successful delivery. This triggers the ESP32-CAM to capture an image of the parcel.

Following parcel detection, the system sends a real-time alert notification to the user via Wi-Fi communication. This ensures immediate awareness of parcel delivery and enhances user convenience. The system continuously monitors the parcel box status and resets to the idle state after each operation, making it ready for subsequent use.

The experimental results demonstrate that the system performs reliably across all tested scenarios. The authentication mechanism accurately differentiates between valid and invalid users, preventing unauthorized access. The load cell sensor effectively detects parcel placement without being affected by minor disturbances, ensuring accurate operation. The alert system successfully delivers notifications in real time, and the image capture feature provides clear visual confirmation of delivery.

| Sr. No. | Parameter | Observation | Result |
|---|---|---|---|
| 1. | Password Authentication (Valid Password) | Correct password entered and verified by the system | ✔ Successful |
| 2. | Unauthorized Access (Invalid Password) | Incorrect password entered and verification failed | ✔ Secure |
| 3. | Parcel Detection (Load Cell Sensor) | Weight of the parcel detected and recorded accurately | ✔ Accurate |
| 4. | Servo Motor Operation | Servo motor opened and closed the box smoothly | ✔ Smooth |
| 5. | Image Capture (ESP32-CAM) | Parcel image captured clearly by ESP32-CAM | ✔ Verified |
| 6. | Real-Time Alert Notification | Notification sent to user instantly via Blynk/Telegram | ✔ Fast |
| 7. | System Response Time | System responded quickly to events | ✔ Efficient |
| 8. | Overall System Performance | All modules worked together as expected | ✔ Excellent |

Table 2: Performance Evolution of Smart Parcel Drop Box System

To further evaluate system effectiveness, a comparative analysis was performed with a basic parcel box system without IoT features. The conventional system lacks authentication, real-time alerts, and delivery verification, making it vulnerable to unauthorized access and parcel theft. In contrast, the proposed system integrates authentication, sensing, and communication mechanisms, significantly improving security, reliability, and user awareness. These results confirm that the proposed Smart Parcel Drop Box system is a robust and efficient solution for modern automated parcel management applications.

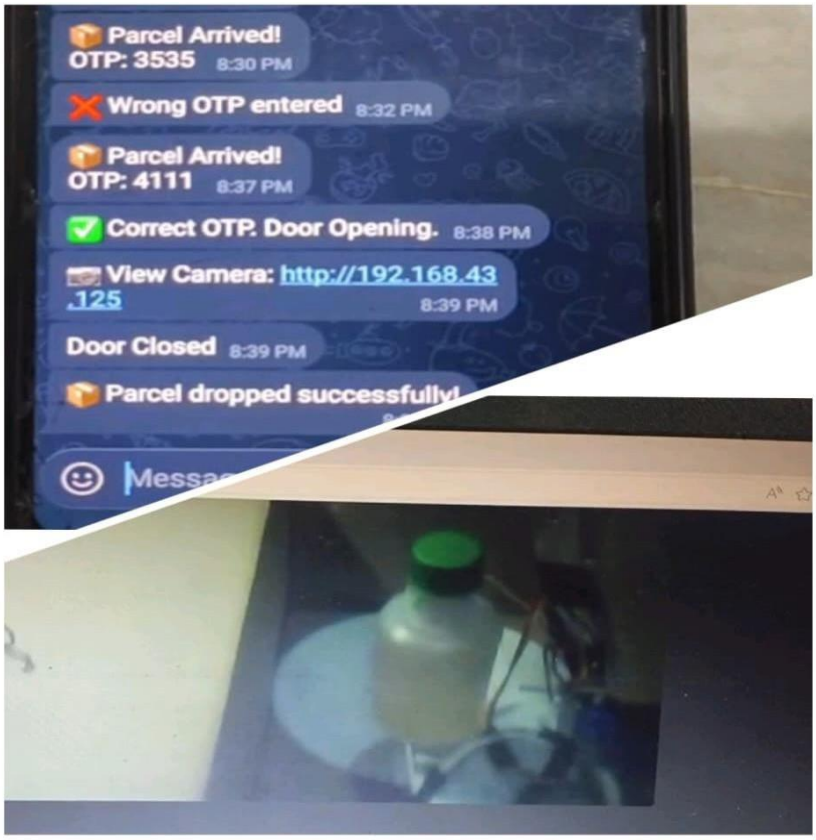


Figure 7: Output of Smart Parcel Drop Box System

The output of the proposed Smart Parcel Drop Box system is illustrated in Fig. 6. The figure represents the real-time operation of the system during parcel delivery. It can be observed that the system successfully performs all intended functions, including secure authentication, parcel detection, and alert generation.

When a valid password is entered through the keypad, the system grants access by opening the parcel box using the servo motor. Upon placing the parcel inside the box, the load cell sensor detects the weight variation and confirms successful delivery. The ESP32-CAM module captures an image of the parcel, providing visual verification.

Following this, a real-time notification is sent to the user through the IoT platform, ensuring immediate awareness of the delivery. The output clearly demonstrates that the system responds accurately and efficiently to user inputs and environmental conditions.

The results validate that the proposed system operates reliably, with seamless integration of hardware and software components. The successful execution of authentication, detection, and communication processes confirms the practical feasibility and effectiveness of the Smart Parcel Drop Box system in real-world applications.

## 8. Conclusion

This work presents the design and implementation of a Smart Parcel Drop Box system that enhances the security and efficiency of conventional parcel delivery methods. By integrating components such as a keypad for authentication, a load cell sensor for parcel detection, a servo motor for automated access, and an ESP32-CAM for image capture, the system provides a complete and reliable solution for secure parcel handling. The combination of these modules ensures that only authorized users can access the parcel box, thereby preventing unauthorized access and improving overall security.

A key contribution of this project is the integration of sensing, authentication, and real-time communication within a single embedded platform. The system not only detects parcel placement accurately using the load cell sensor but also captures visual proof of delivery through the ESP32-CAM module. Unlike traditional parcel boxes, which lack monitoring and verification features, the proposed system provides real-time notifications to users via Wi-Fi, ensuring immediate awareness of parcel delivery.

The use of the ESP32 microcontroller enables efficient processing and seamless coordination between hardware components while maintaining low cost and low power consumption. This demonstrates that advanced features such as automation, real-time alerts, and delivery verification can be achieved without requiring complex or expensive infrastructure. The system is therefore both economically viable and suitable for real-world deployment.

The experimental results confirm that the system operates reliably under different conditions, with accurate authentication, precise parcel detection, and timely alert generation. The integration of multiple functionalities into a compact system improves user convenience, enhances security, and reduces the risk of parcel theft.

Overall, the proposed Smart Parcel Drop Box system offers a practical, scalable, and cost-effective solution for modern parcel management. It bridges the gap between traditional delivery systems and smart IoT-based solutions, paving the way for future enhancements such as mobile application integration, cloud storage, and advanced security features.

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