**Easy Parcel: An IoT-Based Smart Parcel Storage System for University Villages**

**Muhammad Afiq Zakaria[1], Siti Nurlaili Karim[1]**

[1] Department of Computing, Universiti Teknologi PETRONAS, Seri Iskandar 32610, Perak, Malaysia; 21001351@utp.edu.my

**Abstract**

This study presents the design, development, and evaluation of Easy Parcel, an Internet of Things (IoT) based smart locker system designed to address parcel management challenges in university residential villages. The system integrates an ESP32 microcontroller, a Flutter based mobile application, and a Supabase cloud backend to create a secure and automated solution for parcel delivery and collection. The hardware prototype features a servo actuated locker door, a keypad for input, and an LCD for user guidance, all controlled by the ESP32. The mobile application provides distinct interfaces for students and couriers, facilitating parcel registration, one time password (OTP) generation, and status tracking. System integration tests confirmed successful OTP based authentication, real time communication between all components, and accurate locker actuation. Functional and user acceptance testing demonstrated that the system effectively streamlines the parcel workflow, enhances security, and provides a user-friendly alternative to centralized collection methods. The results validate Easy Parcel as a viable, scalable foundation for improving campus logistics, aligning with sustainable development goals by promoting efficient and secure community infrastructure.

**Keywords:** Internet of Things (IoT); smart locker; parcel management; ESP32; Flutter; Supabase; OTP authentication.

---

## 1.0 Introduction

The rapid expansion of e-commerce has driven a substantial rise in global parcel delivery volumes, intensifying pressures on security, efficiency, and timely collection across last-mile networks [1]. This issue is particularly acute in high density living environments such as university campuses. Students, who are among the most active online shoppers, often face difficulties retrieving their parcels due to limited mailroom operating hours, inconvenient collection point locations, and security concerns associated with unattended packages [2]. At Universiti Teknologi PETRONAS (UTP), the centralized ParcelHub system, while handling large volumes, presents challenges including distant location from student villages, long queues during peak periods, and additional service fees, causing inconvenience and accessibility issues for students [3].

Traditional parcel collection methods struggle to cope with the demand for 24/7 accessibility and secure handling. In recent years, smart locker systems have emerged as an efficient, automated alternative for last mile delivery management. Studies suggest that integrating Internet of Things (IoT) technologies into parcel lockers can enhance security, improve accessibility, and reduce human intervention in parcel handling [4]. Existing commercial smart locker solutions, however, are often proprietary, costly, and not tailored to the specific needs and budget constraints of university environments [5]. Furthermore, many

research prototypes prioritize advanced security features like biometrics, which increase complexity and cost, overlooking the need for affordable, scalable solutions for student residences [6].

To address these gaps, this project develops Easy Parcel, a low cost, IoT based smart locker system specifically for university villages. The system leverages an ESP32 microcontroller, a cross platform Flutter mobile application, and an open source Supabase backend. It employs a one time password (OTP) mechanism for secure access, ensuring that only authorized users can retrieve parcels. This study aims to demonstrate the feasibility of an integrated hardware and software system that improves parcel management by making it more secure, accessible, and efficient for both students and couriers.

## 2.0 Materials and Methods

### 2.1 System Architecture Overview

The Easy Parcel system is composed of three main components integrated into a cohesive unit. The first component is the Hardware Prototype, which is a smart locker unit built around an ESP32 microcontroller. The second is the Mobile Application, a Flutter based app with separate interfaces for students and couriers. The third component is the Cloud Backend, a Supabase database for real time data management and authentication. The system operates on a client server model where the mobile application and ESP32 hardware communicate with the Supabase backend via RESTful APIs.

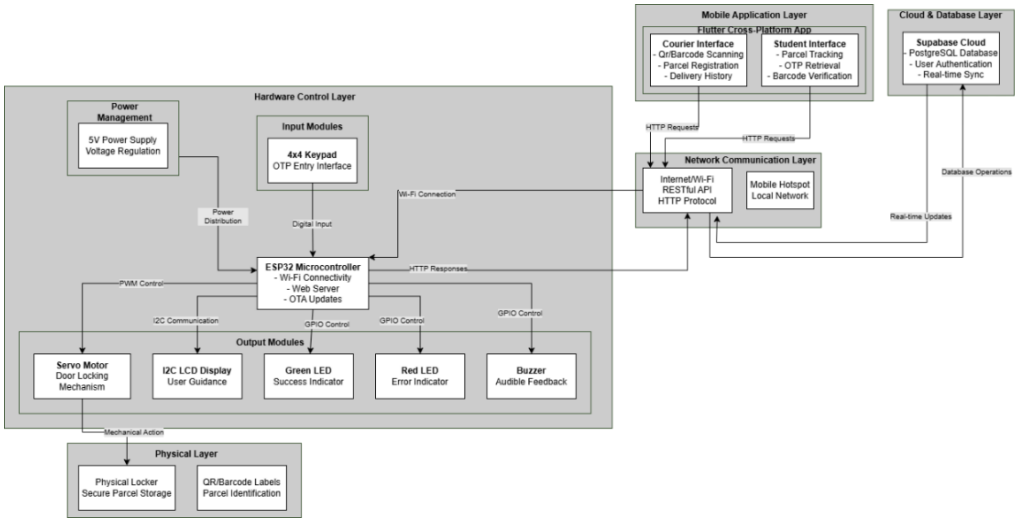



Figure 2.1: IoT Block Diagram

### 2.2 Hardware Development Components

The hardware prototype was constructed to demonstrate one functional locker unit. The key components were selected for their functionality, reliability, and cost effectiveness. The ESP32 Microcontroller serves as the central control unit, chosen for its built in Wi Fi capability and sufficient GPIO pins. A Servo Motor acts as the actuator for locking and unlocking the locker door. A Keypad module functions as the primary input device for users to enter OTPs. An I2C LCD Display provides real time user instructions and system status. LEDs and a Buzzer provide visual and audible feedback for user actions. Supporting elements such as a Breadboard, Jumper Wires, and Resistors were used for circuit assembly and stable

connections. The circuit was initially designed and simulated using Tinkercad for logic validation before physical assembly on a breadboard with an ESP32 extension board for stable power delivery.

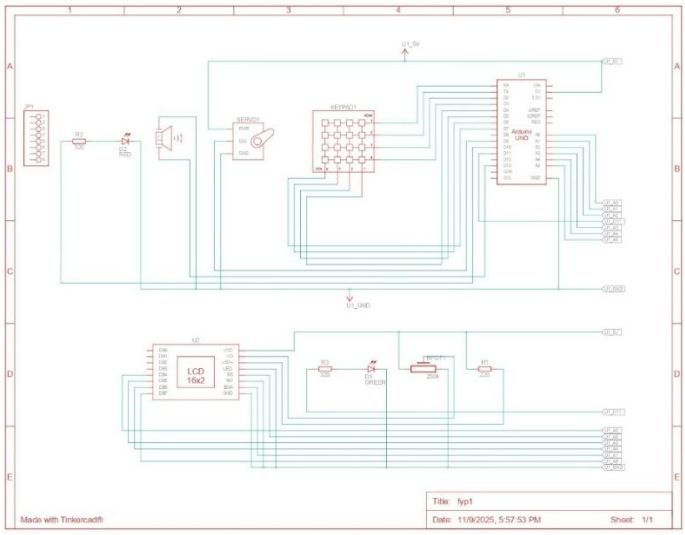
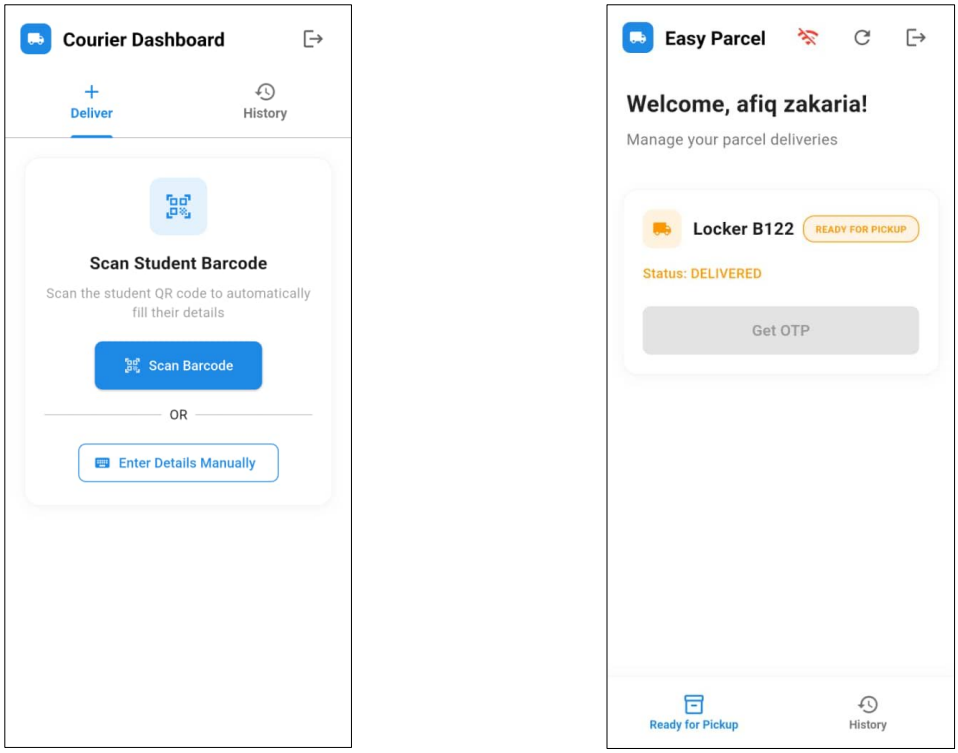



Figure 2.2: Hardware Schematic Diagram

**2.3 Software and Application Development**

The software component consists of the microcontroller firmware and the mobile application. The Microcontroller Programming was done using the Arduino IDE with C++. The firmware handles Wi Fi connectivity, hosts a lightweight web server to receive OTPs from the mobile app, and controls the servo motor, keypad, LCD, and feedback components based on a state based logic flow. Over the Air (OTA) update functionality was also implemented for wireless firmware updates. The Mobile Application was developed using the Flutter framework. It features role based interfaces, including a Courier Interface for logging in and registering new parcels, and a Student Interface for viewing parcels and retrieving OTPs. A barcode scanner is integrated for parcel collection verification. For Database Integration, Supabase, an open source backend platform utilizing PostgreSQL, was employed. Tables were created for users, parcels, and lockers. The Supabase Flutter client managed all operations, including user authentication and real time data streaming.




**(a)** **(b)**

Figure 2.3: Student Homescreen interface **(a)** Courier homescreen **(b)** Student homescreen

### 2.4 System Integration and Testing

The integration process involved connecting the mobile application, Supabase database, and ESP32 hardware. A local Wi-Fi network was used for communication. The testing methodology included Functional Testing to validate core workflows such as parcel registration and OTP based unlocking. Integration Testing ensured seamless data synchronization between the app, database, and hardware, and stable HTTP communication. User Acceptance Testing was conducted via a structured survey using a five point Likert scale distributed to a small group of students and couriers to evaluate usability, interface clarity, and overall satisfaction.

## 3.0 Results and Discussion

### 3.1 Hardware Prototype Performance

The hardware prototype demonstrated stable and responsive performance throughout testing. Upon initialization, the ESP32 connected to Wi-Fi and displayed its IP address on the LCD. When an OTP was sent from the mobile application, the system prompted the user for input via the keypad. Upon correct OTP entry, the servo motor rotated 90 degrees smoothly to unlock the door, accompanied by a green LED and a confirmation beep. The LCD displayed "Access Granted." The system successfully handled incorrect OTP attempts by triggering a red LED, an error tone, and an error message, thus confirming robust authentication logic and user feedback.

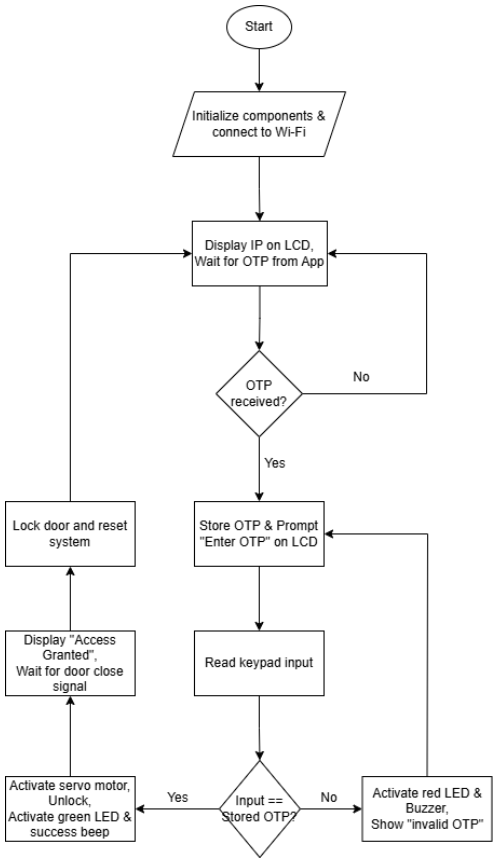



Figure 3.1: Microcontroller Program Flowchart

### 3.2 Mobile Application and Database Output

The Flutter application performed reliably for both user roles. Couriers could successfully create parcel entries, which were instantly stored in the Supabase database and generated a unique OTP. Students could view their parcels and retrieve the OTP, which was then sent to the ESP32 via an HTTP POST request. The barcode scanner feature accurately read QR codes, and upon collection, the parcel status in the database was updated from "delivered" to "collected" with a timestamp. Real time synchronization between the application and the database was consistently maintained with no observable data delays or inconsistencies.

### 3.3 System Integration and Usability

Integration tests confirmed that the end-to-end workflow operated as intended. The communication between the mobile app and the ESP32 hardware was stable under standard network conditions, with OTPs being transmitted and received without noticeable delay. The modular design allowed for easy troubleshooting. User acceptance feedback was overwhelmingly positive. Participants found the application interface intuitive and easy to navigate. The automated process was rated as significantly more convenient and faster than traditional manual collection methods, validating the system's usability and effectiveness.

### 3.4 Achievement of Objectives and Comparison with Existing Systems

The Easy Parcel system successfully met all its objectives. An IoT based smart locker was designed and developed; a functional mobile application for students and couriers was built; a secure OTP based locking mechanism was implemented; and the system's usability and effectiveness were positively evaluated through user testing. When compared to traditional centralized parcel collection, Easy Parcel reduces waiting times, operational hours constraints, and human dependency. Unlike commercial smart lockers that are often proprietary and expensive, Easy Parcel leverages open-source technologies and low cost components, making it a highly adaptable and affordable solution suitable for budget conscious environments like universities.

## Conclusion

The Easy Parcel system was successfully developed and validated as an effective IoT based solution for parcel management in university villages. The integration of the ESP32 hardware, Flutter mobile application, and Supabase backend resulted in a secure, automated, and user-friendly system that streamlines the parcel delivery and collection process. Testing confirmed reliable OTP authentication, stable real time communication, and a positive user experience. This project demonstrates the practical potential of using affordable, modern technologies to solve logistical challenges, contributing to the development of smarter and more sustainable campus communities. Future work will focus on enhancing network stability, developing a multi locker configuration, and adding administrative features for large scale deployment.

**Acknowledgment:** The author would like to express sincere gratitude to his project supervisor, Dr. Siti Nurlaili Bt Karim, for her invaluable guidance, continuous support, and insightful feedback throughout the duration of this research. Her expertise and encouragement were instrumental in the successful completion of this project. The author also wishes to acknowledge Universiti Teknologi PETRONAS for providing the academic platform and resources necessary to facilitate this work.

## References

[1] R. Raj, A. Singh, V. Kumar, T. De, and S. Singh, "Assessing the e-commerce last-mile logistics' hidden risk hurdles," *Cleaner Logistics and Supply Chain,* vol. 10, p. 100131, 2024/03/01/ 2024, doi: https://doi.org/10.1016/j.clscn.2023.100131.

[2] N. Kaur. "A Statistical Analysis of E-Commerce in Malaysia. ." Wecorporate. . https://wecorporate.com.my/blog/statistical-analysis-ecommerce-in- malaysia/ (accessed 10/11/2025.

[3] F. Yusoff, *The Future of Deliveries: Parcel Locker Intentions*. 2023, pp. 70-82.

[4] N. H. Quan, N. T. Binh, and B. T. Ly, "Impact of smart locker use on customer satisfaction of online shoppers in Vietnam," *Humanities and Social Sciences Communications,* vol. 9, no. 1, p. 403, 2022/11/04 2022, doi: 10.1057/s41599-022-01428-6.

[5] A. A. Alzhrani, M. Balfaqih, F. Alsenani, M. Alharthi, A. Alshehri, and Z. Balfagih, "Design and Implementation of an IoT-Integrated Smart Locker System utilizing Facial Recognition Technology," *Engineering, Technology & Applied Science Research,* vol. 14, no. 4, pp. 16000-16010, 08/02 2024, doi: 10.48084/etasr.7737.

[6] A. Prima Atmaja, L. Dwi Setia, M. S. Fajar, and M. H. R. Ismar, "Low Cost IoT Based Home Smart Locker to Receive Online Shopping Packages," *Andalasian International Journal of Applied Science, Engineering and Technology,* vol. 2, no. 3, pp. 126 - 132, 10/09 2022, doi: 10.25077/aijaset.v2i03.57.