Solar Powered Smart Parcel Box System: Energy Efficient Solution for Modern Deliveries

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Abstract

Issues with existing smart parcel system using conventional power supply contribute to high energy consumption which lead to a significant carbon footprint and environmental pollution. To overcome the issue, this work introduces an innovative solution: the "Energy Efficiency Smart Parcel Box System Using Solar Energy." This system aims to revolutionize the parcel delivery and retrieval process by integrating smart technology and sustainable energy sources to enhance efficiency, security, and environmental sustainability. The proposed system consists of a network of smart parcel lockers strategically placed in residential and commercial areas. Each locker unit is equipped with solar panels to power its operations, QR code authentication, an infrared sensor for detection and automated door closure, and a user-friendly mobile application. Customers can conveniently receive and send parcels through a secure and automated process. This innovative methodology ensures an energy-efficient and eco-friendly operation by utilizing solar energy. Generally, literature and case studies have shown potential energy consumption reductions of up to 100% for certain periods under optimal conditions. However, for continuous and reliable operation, a combination of solar power and energy storage (batteries) is necessary. It also incorporates various advanced technologies, such as QR code scanning, infrared sensing, and GSM communication, to enhance security, automate processes, and provide a seamless user experience. The system's ability to operate independently using solar power makes it a cost-effective and sustainable solution for modern parcel delivery needs. This innovation aligns with the ongoing global efforts to create a greener and more sustainable future, providing a promising solution for the challenges faced in modern logistics and parcel management.

Keywords: smart parcel, solar power, energy efficiency, QR code, delivery system.

1. Introduction

Online shopping has indeed experienced significant growth, particularly during the pandemic, as it offers convenience and safety by allowing people to get their necessities delivered to their homes. However, the current or conventional parcel delivery system, while efficient in many ways, does have several limitations and challenges such as customer presence requirements, parcel theft, rescheduling delays, inefficient redelivery attempts, and lack of flexibility [1]. One of the main issues is leaving parcels unattended at doorsteps which leads to parcel theft. According to Penn Elcom's Global Package Theft Report 2022, more than one billion packages or roughly one in ten consumers suffered parcel theft or loss over the course of a year [2]. The US (13%), Australia (14%) and Canada (17% of the population) had the greatest rates of package loss, respectively, according to. One-third of consumers reported having had a package stolen or lost at least once in their lifetime, and all the regions surveyed saw an increase in parcel theft or loss between 2021 and 2022. The largest increase, however, was in the UK, which went from 7% between May 2020 and April 2021 to 12% for the same period the following year [3].

To address these problems, the proposed solution aims to introduce a new delivery modality that offers customers an alternative choice, reducing the need for customer presence and providing a more secure and flexible parcel delivery experience. By offering a range of delivery options that cater to different customer preferences, the goal is to improve customer satisfaction, enhance delivery efficiency, and minimize the impact of package theft on the overall online shopping experience [4]. The proposed solution involves implementing a smart parcel system using QR codes, an Arduino Uno GSM module, and mobile phones. Each courier or post is assigned a unique QR code, which is scanned by a QR reader installed in the mailbox. The scanned information is then transmitted via the GSM module to the authorized recipient's mobile phone, providing real-time notification of the parcel or mail arrival.

Implementing a smart parcel system using QR codes, an Arduino Uno GSM module, and mobile phones involves several steps and components such as hardware setup, QR code generation, database and authentication, parcel arrival and QR code scanning, data transmission and notification and finally recipient confirmation [5], [6]. Hardware setup consists of few modules which are the Arduino uno which is a microcontroller board that will be the brain of the smart parcel system. It will handle data processing, communication, and interaction with other components [7]. Following that, a QR code reader module, such as a camera or a dedicated QR scanner, will be connected to the Arduino Uno. It will read the QR codes placed on the packages. While the GSM Module which is an Arduino-compatible GSM module will be used for communication. It allows the system to send and receive data via mobile networks, enabling real-time

notifications to the recipient's mobile phone. Finally, the mailbox will be modified to accommodate the QR code reader and Arduino Uno. The QR code reader should be positioned in a way that it can easily scan the QR codes on the packages when they are placed inside the mailbox. By following this methodology approach, a smart parcel system using QR codes, an Arduino Uno GSM module, and mobile phones can be successfully implemented, providing real-time parcel arrival notifications and enhancing the security and efficiency of the delivery process.

In the literature, there are few works that have been carried out by researchers in order to solve the delivery problem [8], [9], [10], [11], [12]. In Malaysia, Pos Laju Kiosk and Ezibox have been developed to secure the parcel delivery process. Furthermore, customers did not have to wait for the next delivery attempt or go to the post office to pick up their package when they were not at home. To pick up their package, they only need to travel to the nearby Pos Laju Kiosk or EziBox rather than the post office. In Malaysia, Pos Laju Kiosk and Ezibox are self-service parcel collection points developed by Pos Malaysia Berhad. The kiosk provides convenient pickup points for customers to collect their parcels when they are not at home during delivery attempts.

A smart packaging box was presented by Chaturvedi et al [13] that alerts the seller and the buyer when the package carrying the goods has been tampered with. This smart device consists of a circuit with a microprocessor, sensors, and the Global System for Mobile Communications. The work in [14] suggests a low-cost smart parcel box system with improved security that will be deployed at individual homes. All of the designed system's processes were controlled by an Arduino Mega 2560 in this system. The system will start when couriers message the user via applications with the tracking number for the package in order to obtain the password. When the message delivered by the courier matches the message that the user has specified, a password will be given for security reasons. Following that, couriers can insert the package into the smart parcel box by entering the specified password.

A mobile application and a smart personal delivery box make up DroParcel as presented by Alghfeli et al [15]. By scanning the QR-Code or bar code that is printed with the tracking number on the package's shipping label, users can gain access to the smart box. For the purpose of receiving parcel posts from the postal service, a smart box prototype has been designed as proposed in this work [16]. This system integrates IoT and solar energy technologies to offer services to a recipient in the interest of sustainable development. One of the main functions of this system is that when mail or package postings are dropped into the box, notifications or alerts are sent to the recipient using a mobile application called LINE Notify. A ParcelRestBox device equipped with an ESP8266 NodeMCU V3 microprocessor, an infrared sensor, and an Android mobile application [17]. The project deployment follows the Mobile Application Development Life Cycle (MADLC) approach as a general direction. The recipient interacts with the ParcelRestBox device using the ParcelRestBox smartphone application. The proposed system will track every package delivery, and send notifications to the ParcelRestBox mobile application.

The proposed “Energy Efficiency Smart Parcel Box System Using Solar Energy"aims to modernize parcel management by introducing an Energy Efficiency Smart Parcel Box System powered by solar energy. The core methods involve the strategic placement of smart lockers, harnessing solar power, incorporating intelligent technology, and enhancing security to achieve a more efficient, secure, and environmentally sustainable parcel management process.

2. Methodology

2.1 *System Architecture*

Fig. 1 shows the System Architecture of Energy Efficiency Smart Parcel Box System Using Solar Energy. Basically, the system will be initialized when the solar panel supply the electrical energy to the system. Before giving permission to open the door, the QR code scanner will start scanning the QR code on the parcel box. Next, door will be opened when the information on the QR code is tally with the information in the system. When the door is open, the parcel will be inserted into the parcel box. At the same time, the infrared sensor will detect the person in charge for delivery process. When the person in charge for delivery no longer detected, the door will be closed after few seconds. After that, GSM module will send the notification in SMS form to notify the user on the parcel delivery status. LCD screen will display all information given by the Arduino Mega 2560.

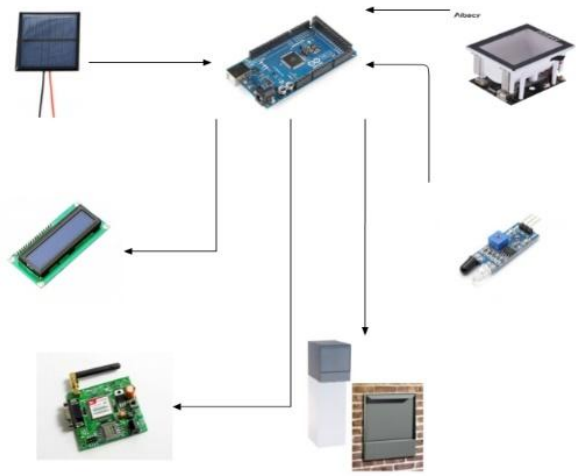

Fig.1 System architecture

2.2 *Flowchart*

Fig. 2 shows the flowchart of the Energy Efficiency Smart Parcel Box System (EESPBS) using Solar Energy. The system starts when the system is supplied with the electrical energy source from the sun. It is called as solar energy. As the PV module absorb the sunlight, it will

convert the heat energy to electrical energy. So, that is how the system will be supplied with solar energy. Then, the QR scanner installed in the EESPBS which is function to scan the QR code on the parcel box will scan the QR code and send the data to Arduino Mega 2560. QR code is always in matrix form so the software inside the QR scanner will converts the dots inside the code into numbers or character strings. Then the data will be sent to the Arduino Mega 2560. Data received from the QR scanner will be analyzed and if the QR code address information is exactly the same with the QR data for current address in the Arduino Mega 2560. Then, Arduino Mega 2560 will be granted access to open the door to allow the parcel to be inserted into the box. There is no timer set for the door to be open or closed because IR sensor will detect the postman in front of the parcel box. If the postman is still standing in front of the parcel box, it will detect the obstacle in front of it. So, the data will be sent to Arduino Mega 2560 to execute an instruction for the sliding door of smart parcel box to keep open. When the postman is no longer standing in front of the parcel box, IR sensor will send the information to the Arduino Mega 2560. Hence, the sliding door of smart parcel box will be closed. At the same time, GSM module will be sending notification through SMS to the recipients of the parcel.

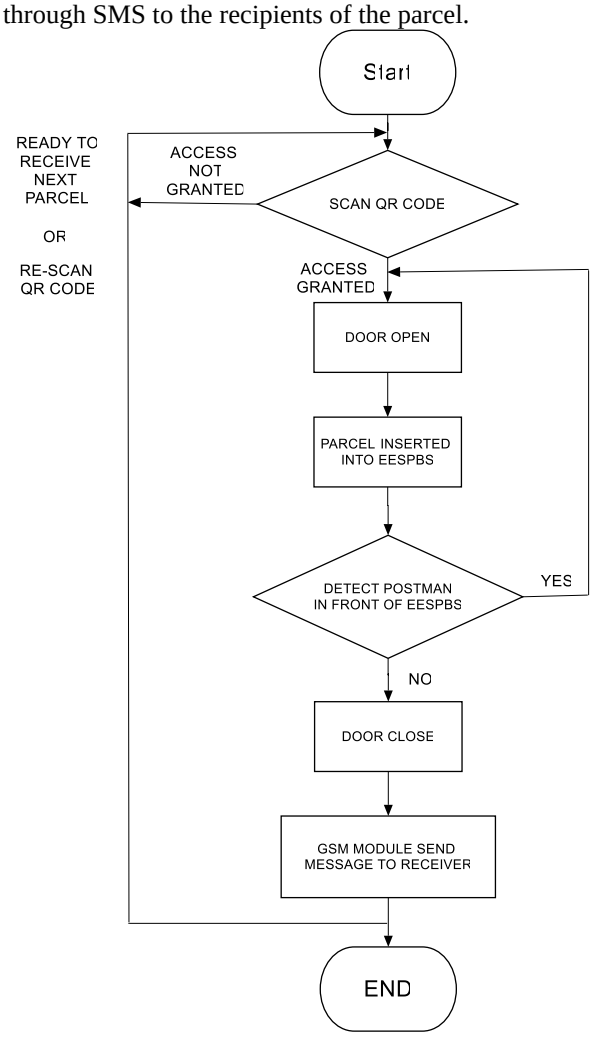

Fig. 2. Flowchart of the system

3. Results

Arduino system act as a brain for the smart parcel box. So, all operation that has been set to this box will not function if the Arduino system is not installed in this system or for the worst case is damage. That also will cause the system failed to operate. Fig. 3 shows the developed prototype of the Energy Efficiency Smart Parcel Box System using Solar Energy.

Fig. 3. Prototype of the Energy Efficiency Smart Parcel Box System

All solar cells are connected in parallel in order to generate 1 ampere of current. 1 ampere is the ideal amount of current that is needed to start up the whole system. As the system is switched on, all components used in the smart parcel box will automatically turn on. First, the LCD display operated well by displaying "Welcome, Please Scan QR Here" as shown in Fig. 4.

Fig. 4. LCD display

Later, the security of the smart parcel box have been checked by scanning two different QR code by using the QR scanner that have been attached to the smart parcel box. The first QR code is the correct QR code that will allow the door to open while the other QR code showed a wrong destination address which cannot be used to open the door of smart parcel box. The system used in this EESPBS is very unique because one QR code is specified only for one address. As shown in Fig. 5, the LCD displaying "Access Granted, Door Will Open". That indicate that the QR code that have been scanned by the scanner is the correct QR code which match the house address. Also, in the same figure, the LCD displayed "Access Denied, Wrong Address". One QR code is for one specific address. The reason why the system cannot grant permission for the postman to send the parcel box with the wrong QR code attached on it because that parcel belongs to another address.

Fig. 5. LCD display

Next is on how the door operated in the system. Access to open the door is depend on the system. As the system grant access to open the door, the door will slide to the right and ready to receive parcel. As shown in Fig. 6, the door is opened and waiting for the postman to deliver the parcel. The LCD will display "Opening, Please Wait" when the door is sliding. An infrared sensor also had been installed in the system. To make sure that the door always open when the delivery attempt occurs, this sensor will detect the present of postman in front of it. As the infrared sensor detect obstacle in front of him, it will cause the door to stay open until the postman leave the smart parcel box. When he left, there is no obstacle detected by the infrared sensor. So, the system will now close the door and indicating that the delivery attempt has been complete. The LCD will display "Closing, Please Careful" and Delivery Attempt Is Success", as in Fig. 6.

Fig. 6. LCD display

Following that, after the delivery attempt completed by the postman, the owner of the smart parcel box will receive a message via SMS. GSM module will send a message to the box owner that the parcel has been delivered successfully. Fig. 7 shows the message sent by the GSM module to the owner of the smart parcel box.

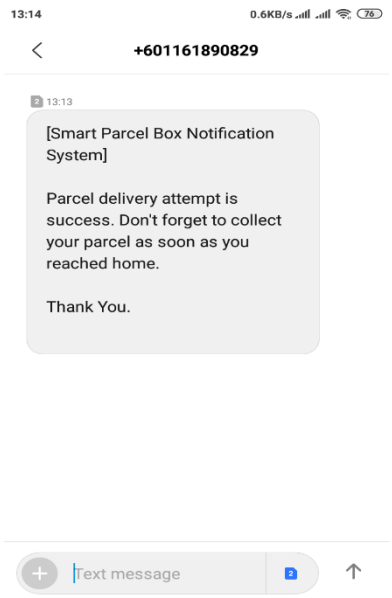

Fig. 7. Notification to user

As this smart parcel box use solar energy generated by small photovoltaic solar cell. It can reduce the amount of energy used from the direct electrical energy supplied by Tenaga Nasional Berhad (TNB) Malaysia. The electrical power used by this smart parcel box is fully comes from solar energy. Even though the energy used by smart parcel box is small, but the electrical energy used from TNB supply will also be considered as cost. So, the house that already installed PV module on their roof will have a lot of advantage than other house that did not use the photovoltaic module. Table 1 shows the total cost that need to be paid per kWh based on the domestic payment value from TNB.

Table 1 Total cost per kWh

Tariff Category	Unit	Current Rate
Tariff A – Domestic Tariff		
For the first 200kWh per month (1-200kWh)	Sen/kWh	0.218
For the next 100kWh per month (201-300kWh)	Sen/kWh	0.334
For the next 300kWh per month (301-600kWh)	Sen/kWh	0.516
For the next 300kWh per month (601-900kWh)	Sen/kWh	0.546
For the next kWh per month (901kWh onwards)	Sen/kWh	0.571
The minimum monthly charge is RM3.00		

4. Conclusions

This project presents an Energy Efficiency Smart Parcel Box System using Solar Energy which functioned to receive the parcel when there is no one at home. All modules and components have been integrated into the system to control the activity and process of this project. As for the security, the QR scanner just accept only 1 QR code which is the QR code that was set for the current address. On the safety part, there will be no other parcel

from another address that can be inserted into the parcel box. Next, GSM module that have been integrated together with this system gave a message to the user of smart parcel box. The message will notify user on receiving of parcel. As the message was received by the user which means that the delivery attempt at the user house is a success. So, the user was not worried about the condition of their parcel because of the security and notification system that has been provided to this developed system. In terms of energy saving, this proposed system used the solar cell as an electrical supply to the Arduino system. Thus, it will give a lot of advantage to the user because solar energy is one of the renewable energies which will give benefit to user in reducing energy consumption. The total energy use in kWh will determine the total cost that user need to pay to the energy consumer. So, by using solar energy as energy source in activating the system, the user will not be charged by TNB because the user did not use the electrical energy provided by the TNB to supply energy to the system of smart parcel box.

For future improvements, the size of the door for this prototype should be bigger because it is too small. Only items that have size up to medium size of parcel packaging could be inserted into this parcel box. This is also due to the limited area that this door can open. Other than using a sliding door, it is also recommended for the smart parcel box to use rolling door to give more space to insert a larger type of parcel. Solar energy generated by this PV module also did not stored. So, when it is cloudy, it will be less efficient. Hence, it will affect the performance smart parcel box. Thus, for the future purpose this smart parcel box can store energy to overcome this kind of weather problem.

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