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UNMANNED PARCEL LOCKER SYSTEM FOR LAST MILE DELIVERY VIA INTERNET OF THINGS

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ABSTRACT:
This paper proposes for a certain device – an unmanned parcel locker – to be included in the last mile delivery of a parcel delivery process in order to reduce the resources spent on adding stops to the delivery route of a delivery session. The proposed device has the ability to accept and store parcels quickly, notify the recipient of the parcels' delivery, and allows the recipients to be identified for parcel collection. Qualitative data are collected from existing parcel locker systems and delivery employees. Thus, observation and interview are carried out in the process of this research in order to explore possible problems that may occur that hinders the last mile delivery process. At the end of this research, it is expected that the proposed system can be utilised as a strong factor in influencing the last mile delivery problem.

INTRODUCTION

This paper details the development of a certain unmanned parcel locker system for the application of last mile delivery. Last mile delivery is a term that originates from the supply chain management or logistics industry, and refers to the delivery of an object to a final destination from a transportation hub. For said industries, the "last mile delivery problem", the optimal way to plan a route to deliver packages to a customer's doorstep in the most efficient way, is a constant topic for debate as it directly affects the engagement and affection of the customer towards the delivery company itself. [1] The urgency of this problem is further elevated by the ever-increasing rise of e-commerce

services satisfying the needs of consumers worldwide. As the number of destinations that a delivery route has to stop by increases, the more variables that has to be factored into the planning of the route. This has also caused the last mile delivery to be the most expensive part of the entire delivery process, with researches claiming that it takes up 28 to 41 per cent of the total costs of the delivery process. [2]

The unmanned parcel locker proposed in this document is aiming at the last mile delivery for the home delivery sector of the industry – packages being delivered to human residences. It is designed based on the idea of reducing the number of stops that has to be made during a delivery session made by the logistics company. It will also be equipped with special features such as having modular lockers for scalability and having automatic dimension screening.

LITERATURE REVIEW

Unmanned Systems

"Unmanned" is a word that is often interchangeable with the word "Autonomous". "Autonomous Surface Crafts" (ASCs) was used in [3] as an alternative name to Unmanned Surface Vessels (USVs). Unmanned systems are systems that requires minimal human-to-machine interaction to function. This statement can be supported by [4] as well as [5], with both developing unmanned vehicles with the aim of reducing human control over said systems. Although the term "unmanned" was used, the same papers still allow for a certain degree of control from humans, for embedded systems have not reached the level of maturity that allows the system to make decisions on its own. Contrary to popular belief, unmanned systems were not developed to completely take away job responsibilities reserved for humans; they were looked into and developed with the objective of assisting humans in said responsibilities by providing faster processing speeds, and accurate data analysis with visualization. A research process featured in [6] incorporated image processing into a substation to detect if a fire has broken out. In the system, humans are still needed to determine if a rapid increase in temperature means that a fire is happening, since not all increase in temperature can be because of a fire, albeit on a much smaller scale. While traditionally, fire monitoring requires at least one human per area, with the system proposed in said paper, one human is enough for several areas in fire monitoring. Taking away from this concept, while the proposed locker system is said to be "unmanned", certain amounts of human interaction will still be permitted for quality control purposes, for example, humans are required to perform depositing and withdrawing actions with the parcel locker.

Parcel Lockers

Parcel lockers are a branch of devices that belong to the Collection Delivery Points (CDPs) family. CDPs are an emerging industry suited for this era going forward, for they satiate the needs of the citizens of modern society that is online shopping and delivery. Ironically, the people who needs the services of online shopping and delivery are the people who spends working hours not at home, causing an increase in failed delivery due to the absence of receivers. This problem, when looked into in [7], has been found to have caused various

levels of social losses such as extra workload when additional trips are being made for the delivery, carbon dioxide emissions, etc. To add fuel to the fire, the increasing demand for online shopping and delivery increases the number of delivery vehicles on the road and in residential areas. IMRG, a data analysis company, released a report in 2006 stating that an estimation of 540 million parcels were delivered for online shoppers alone. [8] In the same paper, it was also implied that in the industry, there is an unspoken rule where the receiver needs to be present when the parcel in question is being sent – mailboxes are not designed to take in parcels, and often, a signature is needed from the receiver to consider a delivery job to be done. How CDPs come in to provide relief for this situation is through reducing the number of failed deliveries being made. A notion was pushed in [9] where it was suggested that by doing this, resources can be saved since no additional resources are being used by making extra numbers of delivery attempts, because the attempt can be successful on the first try using CDPs. The paper also classifies parcel lockers (referred to as "locker points" in the paper) in the *unattended* category, with *attended* category making up the rest of the category slots. Parcel lockers, as described in the paper, utilizes PIN codes to allow delivery by the carrier as well as collection by the receiver. The parcel locker was listed as one of the most innovative and viable solutions in the last mile delivery industry in [10], along with other methods, e.g. crowdfunding logistics. In depth analysis was done in [11] on the effectiveness of parcel lockers as a solution of last mile delivery in Poland. In said paper, parcel lockers were compared to other last mile delivery solutions, such as attended deliveries and controlled access system, among many. From the data collected and analysed by the same paper, it was found that most respondents reacted to parcel locker systems as a form of last mile delivery above average, with 28% of them giving a 10 on the 10-point Likert scale (with 1 being the worst and 10 being the best), when asked if they are satisfied with the utilization of parcel lockers. On the characteristics of parcel lockers, a few of them were suggested after having made a SWOT analysis in [12], summarized in the following table(s):

Table 1 Strengths and weaknesses of parcel lockers [12]

Strengths	Weaknesses
• Customers have access to their parcels 24/7	• Authorities do not have information regarding the contents
• Reduced emission of noise and energy consumption	• Final leg of the journey is carried out by the customers
• Lower delivery costs	
• No face-to-face interaction needed; reducing risk of delivery employee	

Last Mile Delivery

Last mile delivery was referred in [13] as the movement of objects from the transport origin to their final destinations. Last mile delivery optimization has been a popular conundrum in the logistics industry, as firstly, there are no definitive answers to the question, and the factors to be taken into consideration changes with the location, making the process of looking for a solution a case-by-case basis. Nevertheless, this is commonly referred to as the "last mile delivery problem", and has been simplified to be the "travelling

salesman problem", used in introducing the basics of artificial intelligence in decision making. Route planning was also suggested in [13] to be one of the fundamental problems in last mile delivery, which is the scheduling of delivery routes (i.e. sequence of origins and destinations) taken by different couriers. This problem can be seen in papers using the heuristic approach. The significance of optimizing last mile delivery increases exponentially with the increase of e-commerce, which led to more delivery vehicles on the road, as mentioned in the opening paragraphs of [11]. An informative analysis was carried out in [14] focusing on how the last mile delivery process impacts the roads with the explosion in e-commerce and online delivery. The factors that can affect the time taken for a delivery to be completed, as listed in the analysis, includes the following: Cooperation on the receiving end (long duration of time spent waiting for receiver to accept), driver knowledge and experience (driver pre-emptively knowing where to stop and unload shortens the time taken in stops), etc.

Essentially, approaches in trying to optimize the last mile delivery problem can be categorized into the following few types, referred from [15]:

- ***Placement of Logistic Facilities***

In this type of optimization, the location of logistics facilities, which is the last stop of the products before the destination, are changed. The aim is to maximize the coverage area that is delivered by the facility, while balancing it with other factors to achieve higher efficiency.

- ***Reducing time spent while delivering***

This method covers a lot of steps that can be taken, which can include, but not limited to:

- reducing the number of stops,
- reducing the time spent in every stop,
- reducing the distance of the delivery route,
- assign routes based on experience,
- prioritizing stops with higher demand, etc.

The aim of the method is straightforward, and mainly revolves around reducing the time spent during the delivery process.

Relating these issues with the proposed system, the proposed system is in line with reducing the time spent while the delivery is being made. The proposed system aims to reduce the number of stops being made during the delivery process (by providing access to recipients in a large area in a single stop), and reducing the time spent in each stop (by eliminating the need to input details of each and every parcel).

INTERNET OF THINGS

The Internet of Things (IoT) is, in short, a concept revolving around creating a network of physical devices that are interconnected, and are capable of exchanging data and information to and from each other. While conventional electronic devices such as smartphones and laptops are also under the physical devices in the IoT, the IoT mainly focuses on connecting unconventional objects (e.g. doors, lights, lockers, etc) to the Internet by installing sensors and

other components on these devices, so that they are able to collect and transmit information as well. Kevin Ashton is widely recognized to be the first person who had coined the term "Internet of Things". Ashton, in [16], stated that people are left out in conventional networking infrastructure, which normally only includes devices like routers, switches, etc; however, as humans are variable creatures from one to another – we have limited time, attention, and accuracy -- we have to rely on capturing data via objects that are used in our daily lives, instead of using data that we have captured ourselves. Also, mentioned in [17] was how machine-to-machine (M2M) communication will become prominent in the future, and that humans are only going to be the receiver of data, and rarely the generators of data, even less the generators of data traffic when everything that can be connected to the Internet has been connected to the Internet. [18] listed "making better use of public resources" to be one of the reasons IoT is employed in an urban context. As the paper suggests, the reason why the Internet of Things become a concept that is in the talks, in terms of cities, is because of data digitalization of government organizations. Traditionally, data has been measured by humans and data is recorded manually. However, as Ashton has stated, humans are susceptible to changes and mistakes can be made easily. By using sensors that can accurately record and represent data, then store the data efficiently, a point can be made that using IoT in cities can be optimal in terms of reducing resources spent in correcting mistakes that may happen due to human errors. Even though the vulnerability aspect on our lives due to massive data amounts of data collection has been causing some opposition in certain groups, a future built up from the foundation of IoT is inevitable, as stated in [19]. It was also mentioned in [19] how although change is always met with opposition in any era, it is also slowly influencing the way we think about objects every day. Industries that previously had nothing to do with the IT industry, now requires services that allow them to keep up with the era of big data. In the case of the proposed system, the logistics industry is the one which has found the most use pushed by the boom of the e-commerce industry. The proposed system is a sample of devices that are connected to the Internet of Things – lockers which are normally inanimate objects that are locked and unlocked manually. In this proposed system, IoT is implemented in terms of sensors are used to collect information about the parcel being deposited, and that the receivers are notified when the parcel is delivered through the Internet.

Similar Systems

In this section, the proposed unmanned parcel locker system (PS) will be compared to similar systems that are available on the market right now. The similar systems that will be used are Parcel Locker developed by Australia Post (PL), and PopBox developed by PopBox Asia Services (PB), based in Indonesia.

Parcel Locker is a series of devices developed by the Australian government business enterprise, Australia Postal Corporation (AusPost), which is the main provider of postal services in Australia. Parcel Lockers are free to use since AusPost is a government corporation, and it is available in over 330 locations currently. One of the jarring characteristics of Parcel Lockers is that the deposited parcel is to be withdrawn within 48 hours. The usage of the Parcel

Locker is as follows: Firstly, the receiver would have to register for a free account with AusPost, which, in the process, the user can select the closest Parcel Locker to their residence, or wherever they might prefer. Bundled with the account, they can obtain a unique ID number. When an online shopping action was made, the parcel is addressed to the location of the Parcel Locker. When the parcel arrives, the name and ID that is on the parcel is verified, and associating the user with the name, the user is informed of the parcel's arrival with a one-time password (OTP) via text. When the user reached the parcel locker, the OTP is manually entered into the built-in dialpad to verify the identity of the user, which, when verified, will allow the user to withdraw the parcel from the locker. [20]

Figure 1 A parcel locker by AusPost in use. Unlike PopBox, these parcel lockers are endorsed by an official government organization. [21]

Figure 2 One of the actions taken for a customer to access the parcel locker by AusPost, needing to press a physical dialpad. [21]

PopBox, on the other hand, is a service provided by PopBox Asia Services, and has a system very similar to the proposed system and the Parcel Locker system. When the purchased product arrives at the addressed PopBox location, the deliverer can choose to deposit the parcel, which allows them to use their (the deliverer's) username and password for verification. Then, the barcode of the parcel is scanned, and the telephone number of the receiver is entered. An option is available for the deliverer to choose a suitable sized locker for the parcel, and the locker opens, allowing deposit to happen. An SMS is then sent to the receiver's phone with a OTP. Entering the code upon reaching the PopBox location will allow access to the specified locker, and the parcel can be collected. The difference in this system is that the deliverer has to be registered within the system, which is done by partnering with logistics company and registering each and every one of them so that they are eligible to deliver to said locations. [22].

Figure 3 A PopBox located in Bandar Sunway, Selangor, Malaysia [23]

Figure 4 A PopBox located in Sunway University, Selangor, Malaysia [23]

The table below highlights the main functions that is available/not available in the systems.

Table 2 Comparison of the main features between Parcel Locker (PL), PopBox (PB), and the proposed system (PS).

	PL	PB	PS
Targeted package deposit	✓	✓	✓
Targeted package withdrawal	✓	✓	✓
Delivery notification	✓	✓	✓
Deliverer authentication	×	✓	×
Withdrawal authentication	✓	✓	✓
Contactless withdrawal	×	×	✓
Automatic dimension screening	×	×	✓
Modular locker	×	×	✓

From the table, it can be seen that the proposed system shares a few functionalities with the similar systems suggested: all of them provides package deposit and withdrawing services, and is able to notify the receiver upon delivery, on top of authenticating the receiver to withdraw the parcel from the locker. However, Parcel Locker and the proposed system does not verify the identity of the deliverer during the delivering process. In the case of the proposed system, this is because the parcel is said to be bonded with the

identity of the deliverer before the process. The special features that set the proposed system aside from the others are the automatic dimension screening and the modular locker features. When a parcel is delivered to the locker, it is placed in a space built in with the device, which contains various necessary sensors. The dimensions (weight, height, width, length) of the parcel is then taken, and the locker that can fit a parcel of said size is then made available to the deliverer. This allows optimization to be made and to minimize insufficient lockers due to parcels taking up lockers of the wrong optimal sizing. Another feature, the modular lockers feature, is to allow for scalability. Since different areas might have different demands for usage of the device, it brings a lot of benefits when the lockers of the box can be attached to or detached from the device securely. The number of lockers that a device has can be suited to the demand in the area, which can be gauged by the data being sent to a server. If there are a lot of parcels that cannot be delivered due to insufficient lockers, more lockers can be installed to the device, and vice versa for areas that have an abundance of lockers. The modular design also helps to keep costs low as the lockers can be manufactured individually and be installed, in addition to being easy to be moved one by one, as opposed to moving the entire box if not modular. The contactless withdrawal feature refers to if the user needs to operate a panel or buttons in order to perform the withdrawal process. In Parcel Locker and PopBox, the user is required to enter the OTP through a physical numpad, while in PopBox, the OTP is entered through a touch screen panel. By using a QR code scanned by the device, the proposed system is able to reduce threats that may cause by contacting objects in public area, while providing a fast and safe method of withdrawing an object at the same time.

AIM AND OBJECTIVES

Aim

The main aim of this project is to develop a locker system that provides unmanned package holding, securing, and collecting services via the Internet of Things.

Objectives

- To evaluate the current approach in the domain and identify existing problems.
- To develop a locker system that can identify and recognize the dimensions of a delivery parcel.
- To develop a locker system that can hold and secure delivery packages of different sizes.
- To develop a series of lockers that can connect to each other via physical contact.
- To develop a software that can notify recipients of their parcel that the awaited package is in the locker system.
- To develop a software that can identify recipients and allow access to the locker system through QR code.

RESEARCH QUESTIONS

- How can a locker system identify and recognize the dimensions of a delivery parcel?

- How can delivery packages of different sizes be held and secured?
- How can the developed system identify and recognize the dimensions of a parcel?
- How can lockers connect to each other and share information via physical contact?
- How can the recipients of a parcel be notified for the delivery of their parcel?
- How can access be granted to the recipients of a parcel and identified for the collection of the parcel?

Significance of the Work

The unmanned parcel locker system can serve to speed up time taken in the last mile delivery process, which is often caused by lack of coordination between the recipient and the delivery person (recipient not being available during delivery), or poorly optimized delivery routes (causing the delivery vehicle to spend more time in navigating the route). The unmanned parcel locker serves as a centralized location in an area for the delivery process to be sped up, and the routes be better planned. With the installation of unmanned parcel lockers in certain areas, the recipients can collect the parcels whenever they are available, and the delivery employee can be more efficient in having multiple parcels delivered in one stop. Having a modular design for the lockers also helps to keep the cost of the devices low since lockers of different sizes can be manufactured individually for ease of transportation and assembly to help with scalability and meeting demands in different areas. Besides, by having the device detect the dimensions of the parcel, the assignment of the parcels in the lockers can be optimized while minimizing the problem of having no suitable locker for the size of the parcel.

RESULTS AND DISCUSSION

Literature review has been done to identify the current problems and available solutions of the delivery methods in various industries. The study will also be backed by research methods using qualitative methodology including observation and interview, in order to reflect the real-life problems faced by the users of the available delivery system currently in use, that might be difficult to convey through quantitative data collection methods, when the experience might not fall under the options given. Thus, in this situation, it is better to allow the respondents to be able to convey their experiences freely. It is also expected that because qualitative data collection methods are used, the population and sample selected will be smaller due to time constraints.

Observation

The observation method to collect information is classified as a participatory study, as the researcher is required to be involved in the collection process – they are at the location that the process occurs to experience the way the process works, and taking notes to be referred to in later analysis. One advantage of this method is that certain details of the process that can be easily forgotten in recollection can be observed and taken notes of. However, a certain ethical issue might arise with this method as there exists participants who do not wish to be observed, especially when certain sensitive information is exposed in the process of last mile delivery. It is also significantly simpler for the observer to be biased in the process of observing the process due to

being affected by external factors, such as atmosphere and attention span. [24] The observation process should be carried out at prominent parcel locker locations and should aim to focus on the time spent and fluidity of the delivery process. The population of this data collection method is targeted towards 15 existing parcel locker locations in Sunway City, Kuala Lumpur, and these locations are further narrowed down using *judgement sampling* method, where the researcher can choose the sample members in order to conform to some criterion. In this case, because the population consists of locations and not people, judgement sampling is used to select 5 parcel lockers that has a high use rate within the observation period, e.g. parcel lockers that are used to deposit or withdraw parcels 7 times per day on average will be chosen over one that has 3 times of use per day. This is because of the nature of the data that is observing the process of parcel delivery, which is subjective and does not depend on any numbers, e.g. number of times delivery was made. Thus, the criterion was chosen to ensure enough data can be collected regarding the delivery process. Taking the time required for the observation process to be carried out into consideration, it was decided that 7 locations are chosen to be observed over a time period of 5 working days each.

Interview

Several interview processes should be carried out to collect information regarding the last mile delivery process. The reason interviewing method was chosen is because subjective first-hand opinions about the delivery session can be obtained from the interviewees. Non-verbal forms of communication, such as facial expressions and body languages, can also be picked up during the duration of the interview. *Snowball sampling* will be used to select 10 members from the population, which should be 15 employees of delivery companies that handles the delivery process, to the sample. When a member of the population is interviewed, they are asked to recommend someone they know that fits the population criterion. Together, they make up the sample. This method of sampling is used to ease the sampling process of looking for the samples from the population that fit the criterion, and can be said to be a form of outsourcing. Considering the time required to look for, recommend, contact, schedule, and interviewing the interviewee, it was decided that 10 samples are to be interviewed.

OVERVIEW OF THE PROPOSED SYSTEM

Envisioned Usage of the System

When making an order online, the recipient sets the parcel locker as the delivery address. The parcel gets through the delivery process in the logistics company as usual. Delivery employee reaches the location of the parcel locker. The employee scans the barcode on the surface of the parcel under the scanner on the locker. The details regarding the parcel (weight, size, contact information) are read. An empty locker space that matches the dimensions of the parcel is unlocked. The delivery employee inserts the parcel into the locker. Upon closing of the locker door, the locker is locked. The recipient and the delivery company are notified of this action. The recipient also receives a unique QR code. During collection, the recipient scans the QR code received at the embedded scanner. The associated locker is unlocked, and the parcel is available for collection. Upon closing of the locker door, the locker is locked.

The delivery company is notified upon the completion of this action. The delivery process is considered to be complete.

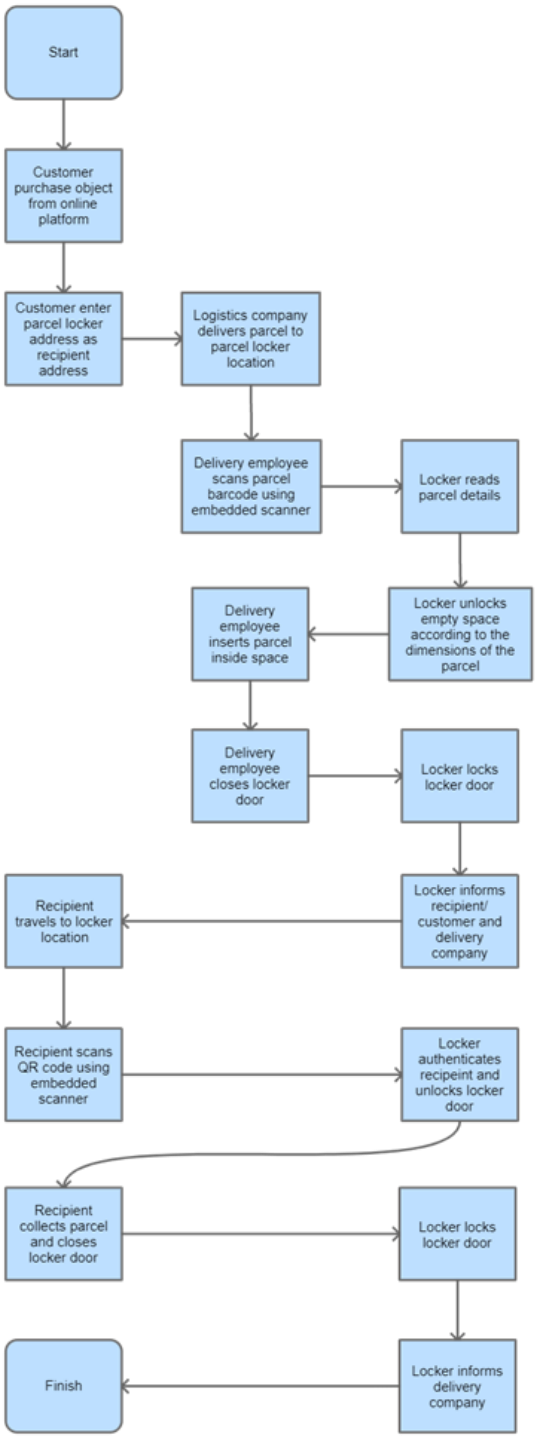

Figure 5 Flowchart of the proposed system when in use when deployed

CONCLUSIONS

In a nutshell, the proposed system, a parcel locker that can allow parcel deposit and withdrawal in order to contribute to the optimization of last mile delivery by reducing the number of stops and the time spent in each stop for each delivery process made. While retaining the features of a delivery point, it also has its unique features, which are being modular, automatic dimension

screening, and touchless withdrawal. Several aspects of the concept need to be looked into in future iterations, namely security (how can the lockers be secured, i.e. not be detached and stolen, while maintaining its modularity?) and quality enhancements for error tolerance (e.g. what happens if the locker door is closed but the parcel is still in the locker?). It is believed that the proposed system is a viable and practical option to be included as one of the solutions that can effectively allow for optimization in the last mile delivery problem.

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Figures

Tables

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