sustainability

MDPI

Article

The Development of Reusable Luggage Tag with the Internet of Things for Mobile Tracking and Environmental Sustainability

Eugene Y. C. Wong * and W. H. Wong

Department of Supply Chain and Information Management, Hang Seng Management College, Hong Kong, China; collinwong@hsmc.edu.hk

* Correspondence: eugenewong@hsmc.edu.hk; Tel.: +852-3963-5355

Academic Editor: Bhavik Bakshi

Received: 13 August 2016; Accepted: 22 December 2016; Published: 31 December 2016

Abstract: With more than two billion passengers worldwide travelling by air each year, vast amounts of lost luggage and disposable paper adhesive luggage tags are pushing the aviation industry to improve luggage tracking and reduce the one-off adhesive luggage paper tags. This paper reviews the current application of Radio Frequency Identification (RFID) in the luggage handling system and proposes the Internet of Things' (IoT) development of the reusable luggage tag to facilitate aviation luggage handling, the tracking process and environmental conservation. A framework of IoT and its RFID components for the proposed reusable tag are presented. An integrated cyber-physical system, including a database management system and mobile app, for the reusable luggage tag is developed. Future studies will enhance the methodology of integrating the retail system, luggage tag, airport check-in counter, luggage handling system, aircraft, and the destination airport through the use of the tag, readers, antenna, and mobile devices.

Keywords: RFID; luggage tag; air transport; mobile tracking; sustainability

---

1. Introduction

The airline industry handles more than two billion passengers annually. With the huge number of luggage being handled, there is a considerable amount luggage lost and miss-handling in the airports worldwide each year. World airlines had a loss of 25 million pieces of passenger luggage in 2009 [1]. There were 26 million pieces of checked luggage that went astray on international flights in 2011 [2]. In 2012, 25.8 million pieces of baggage were mishandled, of which 85% were delayed and 15% were damaged or lost [3]. Society International Telecommunication Aeronautics (SITA) reported that there were still 21.8 million bags, or 6.96 per 1000 passengers being mishandled or stolen in 2013 [4]. The rate was still high in 2014, with 7.3 bags per 1000 passengers being mishandled or stolen [5]. In US airlines, about 1.8 million pieces of luggage were reported lost, stolen or damaged in domestic flights [3]. Some luggage is found within several hours after track and trace, while other items are reported permanently lost. Immense resources are drawn upon in airports and airlines to trace and return the lost luggage to passengers, at great cost. Swedberg [6] indicated an estimated annual cost of US$750 million to track and deliver lost luggage to its owner, through airline, airport, and courier.

The use of Radio Frequency Identification (RFID) in aviation luggage tracking has come to solve the problem. The RFID has been evaluated and implemented in some of the airports over the world, for example, Heathrow Airport in London, Kansai International Airport in Japan, and Hong Kong International Airport in Hong Kong, among others. The use of RFID in the airports facilitates the monitoring of luggage flow, minimises luggage mishandling, and assists identifying and tracking the lost luggage. Al-Ali et al. [7] assessed the feasibility of using RFID technology for baggage handling in airports. Mishra and Mishra [8] carried out an exploratory review on the applications of RFID in the aviation industry. DeVries [9] evaluated the state of RFID to solve the tracking of luggage in airports and airlines. The study reviewed the benefits and drawbacks on the use of RFID. DeVries reflected the importance of the development of the RFID infrastructure in order to achieve a successful track and trace of luggage. He revealed that cost is one of the major drawbacks to RFID implementation and the major challenge would be the cooperation between airports and airlines on the building of RFID infrastructure. Wyld et al. [10] investigated the application of RFID in baggage handling and security. The study provided the testing and development of RFID in baggage handling of Delta Airlines in the US.

Further studies have been carried out to improve the implementation of RFID for a better luggage and passenger flow in the airport. Hui [11] examined how the technology of RFID could enhance the efficiency of luggage tracking against the traditional barcode technology. Hui concluded that the technology of RFID has a higher capability but higher cost when compared to the use of bar code in luggage tracking. The paper illustrated how an integration of the application of RFID in luggage and passenger tracking can improve the airport operation efficiency. Zhang (2008) discussed the International Air Transport Association (IATA) protocol used as a standard to recognize baggage tags and the application of the RFID-based baggage tracking in the Beijing Capital International Airport (BCIA). Medeiros et al. [12] presented the use of a passive Ultra High Frequency (UHF) tag for suitcase identification and tracking in airport. The study concluded that RFID is superior to barcodes considering the identification capacities, average read rate, network, and labor costs involved. The UHF RFID could be reusable and reprogrammed. Operating costs could be reduced as self-service kiosks could be established.

With the popularization of the RFID technology, the implementation cost is being lowered. More benefits of applying RFID in operations are being realized. Roberti [13] evaluated the benefits of airlines after the implementation of RFID in luggage handling. It was found that the mishandling rates decreased after using RFID in the baggage handling system. He reviewed the cost involved in the implementation and recommended that both airport and airline should share the cost of implementing and maintaining the RFID luggage handling system. Zoltan [14] examined how RFID technology could benefit the airline industry in teaching shipments with the use of rewritable passive RFID tags. Nepal and Chotiyaputta [15] analysed the data in the RFID baggage tracking record and minimised the identified risk of mishandling rates in the airport. Other similar studies include Gupta et al. [16], Berrada and Salih-Alj [17], Ahmed et al. [18], Zhu et al. [19], Jacinto et al. [20], Ouyang et al. [21] and Cerino and Walsh [22].

With the use of RFID in luggage tracking, the display and interaction between human and tracking data could be achieved with mobile apps. Mobile tracking allows users to track and trace the position of luggage anytime anywhere. The mobile app could further display the real-time flight information and assist the check-in process. It could also act as a platform for the communication between traveler and airline before departure. Airline shopping with business transaction carried out in the mobile apps could provide add-on service and customer retention. One of the recent researches on mobile tracking is the use of an interactive RFID-based bracelet [23]. The paper suggested the use of the bracelet to be worn around the passenger's arm. It is provided to the passengers in the check-in process. The database application processes the RFID signals and sends the messages to the bracelet whenever the luggage moves from a station to another. However, passengers are required to return the bracelets to the airline company at the end of the trip. It requires manpower of airline to collect and maintain the bracelet and the collection might incur additional time and inconvenience to the passengers. The use of smartphones and tablets with mobile apps can replace the bracelets on the luggage tracking.

Moving towards luggage tracking anytime anywhere, the use of mobile tracking, RFID sensor devices, database systems, and servers are connected by the technological development of the Internet of Things (IoT) to achieve intelligent identify, locate, track, monitor, communicate and manage the logistics activities of luggage handling. The concept of IoT was introduced by Massachusetts Institute of Technology (MIT) in 1999 and presented in the World Summit on the Information Society (WSIS) by the International Telecommunication Union (ITU) in 2005 [24–26] . The high penetration of internet service in consumer business increases the popularity of research development in IoT [27–32]. The data flow interaction among the components in Point-of-Sale system, database, RFID device, mobile app for the luggage tracking and other value-added services are connected through the IoT. The development of IoT in luggage tracking is crucial to support tracing and recovery action when handling lost luggage. The tightened luggage tracking anytime anywhere with the use of the tools developed through IoT can avoid luggage being mishandled and lost.

In terms of the importance of environmental protection and sustainability, can luggage tags be reused to reduce the use of paper adhesive luggage tags? With two billion passengers travelling by air each year, huge numbers of adhesive luggage tags are printed for the trip and disposed of after use. This phenomenon creates environmentally unfriendly wastage. IATA estimated that in 2013 airlines printed 2.95 billion adhesive luggage tags each year. This has led airlines to develop permanent digital luggage tags. British Airways announced in November 2013 that they will roll out digital tags to frequent fliers who can check-in for a flight with their own smartphones with the personalized digital tag. The tag uses the Near Field Communication (NFC), short-range wireless technology and electronic ink to display and pass the barcode information to the reader device. This method has reduced the use of adhesive paper luggage tags. Qantas Airways also introduced QBag Tag, which is a permanent electronic tag, in domestic flights with the use of RFID instead of NFC in transmitting the flight details into the tag. Aircraft manufacturer Airbus is also investigating a digitally-enabled suitcase with electronic tagging and GPS real-time tracking [33].

This paper proposes the development of an integrated reusable luggage tag, from the time of the purchase of luggage with RFID tag in the retail store to the airport check-in counter, luggage handling system, aircraft, destination airport, and the hotel. This paper presents the framework and components of the RFID for the reusable tag. A Database Management System (DMS) is suggested for the development. A mobile tracking device is proposed and developed. An integrated IoT system is developed for the tracking of reusable luggage tag. Further development and investigation will cover the methodology of integrating the retail system, luggage tag, airport check-in counter, luggage handling system, aircraft, and the destination airport through the use of the tag, readers, antenna, and the mobile devices.

2. Framework and Structure

Most of the recent developments of RFID in luggage tracking focus on replacing the bar code system [14,34,35]. Although some studies keep using bar code for luggage tracking [36,37], bar-code identification devices are not as accurate as the proposed IoT infrastructure with RFID tracking system for luggage tracking, considering the first-read rate [8,35,38]. Bar code is more prone to damage than RFID tag. The readability of bar code is also easily affected by external grease and dirt and it is limited by the line of sight identification. RFID removes the need for human intervention and it could hold considerable information, for example, name, milestone, weight, destination, etc. The implementation of RFID usually starts with a passive RFID luggage tag provided at the check-in counter and attached to an item of luggage for a single trip. The luggage tag will be disposed after the trip. Some previous researches replacing bar code with RFID have not included the mobile tracking capability [12,35,39,40]. Some researchers developed additional accessories to facilitate tracking and receive updates of luggage location, for example, bracelet [23] and smartwatch [41]. Instead of one-off RFID luggage tags, additional accessories and web-based tracking, the framework of the proposed RFID cyber-physical system is provided with an integrated reusable luggage tag attached with the luggage. Location of the luggage can be traced anytime with the use of mobile application devices. The framework and components of the proposed system are discussed in the following sections.

2.1. Framework and Components

The integrated cyber-physical model involves several parties, including the tag company, customer mobile apps, airline, airport check-in counters, and luggage handling system. The devices, components, and the system are made up of RFID readers that collect data from passive RFID cards in the retail store, airport, airline, and hotel. The RFID components are shown in Table 1. The retail store, with the Point-of-Sale (POS) systems and RFID readers installed, keeps the sales record of the luggage product, including the RFID tag. The tag will be registered at the time of the product being sold. The RFID tag, with its unique identification number, is of UHF with 862–900 MHz. This aligns with the global standard from The International Air Transport Association (IATA) of 850–950 MHz. frequency band for RFID luggage tags. The RFID antenna is used to identify the tag and receive the transmitted signal from the tag. The reader transmits the data to a DMS via the network. The DMS then processes the data and sends it to the mobile application. The DMS also integrates the data received from the airline, airport terminal, and the mobile app application. The mobile application is installed in a smartphone mobile device with Android operating system and enables the travelers to track their luggage with the mobile tracking functions developed in the apps.

Table 1. Radio Frequency Identification (RFID) components.

RFID Components	Description
Tag (Transponders)	Ultra high frequency (UHF)-band (862–900 MHz), wireless, passive, and unique identification number
Readers	Stand-alone, hand-held, and shelf readers
Antenna	UHF, and able to identify tag and receive transmitted signal
Printers	Baggage Printer
Information Systems	Enterprise Resource Planning systems and database management system (DMS)
Mobile devices	Smartphone with Android operating system
Point-of-Sale (POS) with RFID readers	POS system integrated with the DMS and RFID tag readers

2.2. Integrated Structure

The developed integrated system consists of a web server and a database server. The web server covers the operation of the webpage and the communication between the external workstations and internal servers. The communication includes queries and commands transmitted through the web server. The database server connects the RFID reader, stores the data, and manages the information of the RFID tag. The architecture of the integrated system as well as the communication protocol are shown in Figure 1. The reader, with two-way radio transmitter-receivers, sends signals to the tag and reads the received responses. The two-way protocol is shown in Figure 2. New tag identification is generated for the RFID tag by the Point-of-Sale (POS) system, and then the data will be passed to the Access database. Further customer personal information could be input in the POS or the database directly. The Access file is automatically exported to the Google Fusion Table, which stores the latest and historical record of the luggage tracking details. The information is updated in the Mobile App for users to trace the luggage and search useful information related to the luggage and flight schedules.

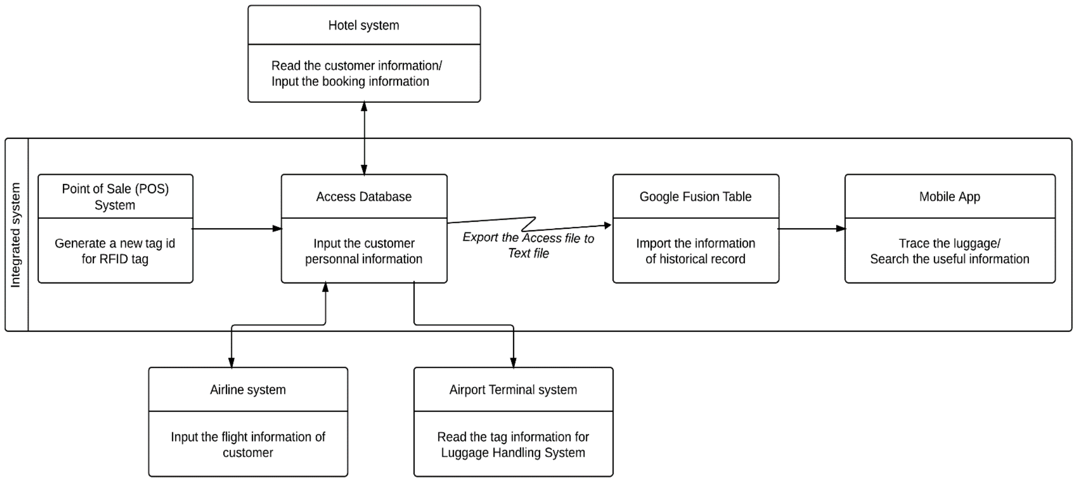


Figure 1. The architecture of the integrated system and the communication protocol.

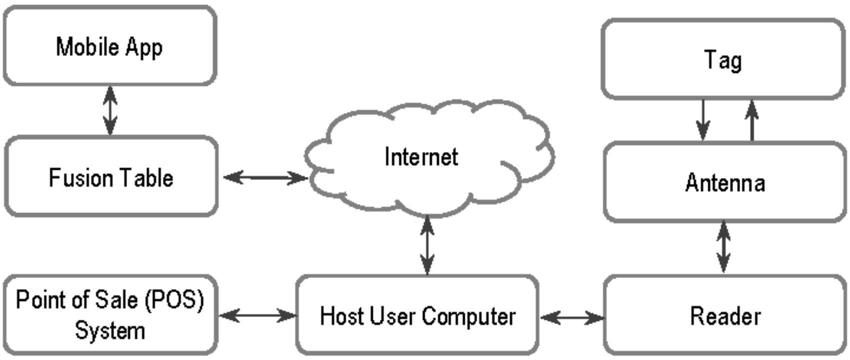


Figure 2. The two-way protocol between RFID tag and reader.

3. IoT—Database Management System, Fusion Table and Mobile Tracking

Here, a DMS and a mobile tracking device are developed to model the luggage tracking system. The DMS is developed using Microsoft Access, considering its compatibility and linkage with other databases, user-friendly development interfaces, and popularity in the industry. Efficient data storage and retrieval is found in Access with flight information, luggage tag personal information, and other data stored in an organised fashion. Queries and form functions are provided by Access for data retrieval and record transaction. Access also allows exporting information to Google Fusion Table for further mobile apps' data processing. In the DMS, nine tables are created, namely tag information, customers table, flight information table, stocks table, retail shop table, baggage history, baggage location, hotel table, and airline table. Most of the tables are connected to each another with the use of primary and foreign keys. The relationship starts from the retail shop in selling the luggage with RFID tag and reflecting in the POS, through to the traveler bringing the luggage to the airport during the flight trip. The relationship between customer and luggage is a one-to-many relationship as an item of baggage can be owned by only one customer while a customer can have more than one item of baggage. The relationship between the tag information, retail shop for tag, customer details, luggage location, hotel, and airline are shown in Figure 3. Besides the nine tables, the data structure includes five forms about the information on customers, hotel and tag. To allow travelers to track their luggage through the mobile devices, the tag identification number, time and corresponding location are shown in the luggage tag history table of Access. For example, a tag with identification number as '000000000176' located at the conveyor belt on 18 August 2014 19:19 will be shown in the mobile device of the traveler.

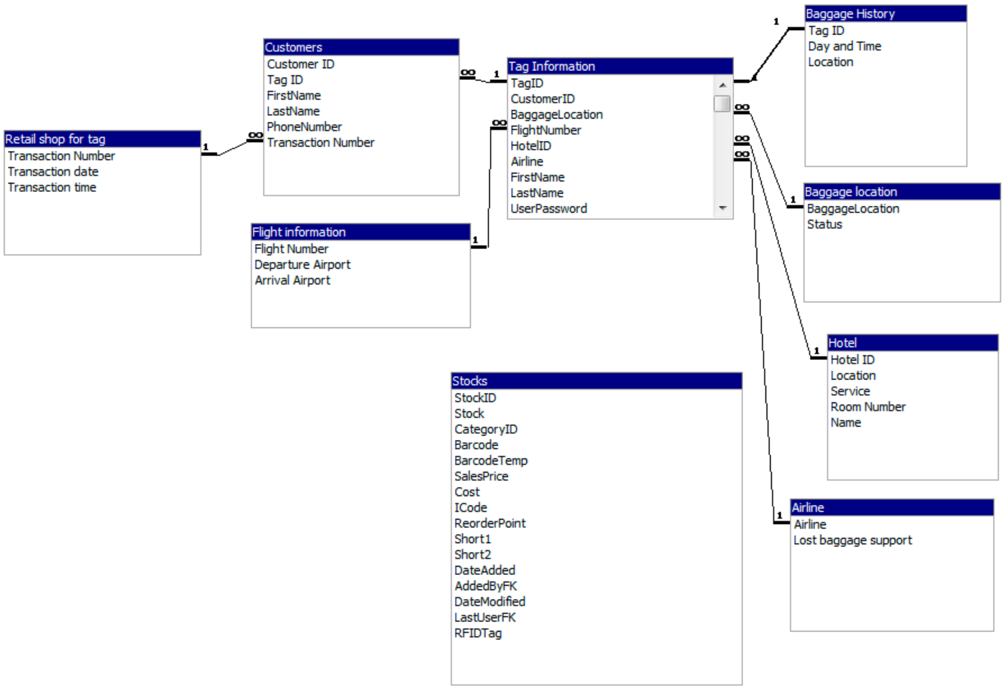


Figure 3. The relationship diagram of the database management system.

To establish the major milestones for the tracking and tracing of luggage, ten milestones are defined in the luggage process flow with RFID antenna set up as check points. The tag is given the default status of 'ready to use' after purchase in the retail store, as updated in the POS system. The luggage status is changed to 'airport area' when the traveler enters the airport premises and the status is further changed to 'check-in counter' after the luggage has been checked-in. Other luggage status, including 'conveyor belt', 'in-transit to airport', 'loading off', 'loading onboard' and 'onboard' illustrates the subsequent status at the outbound airport. The status 'onboard' will be displayed to the travelers in the mobile app in order to allow better handling of the luggage from the origin and destination of the traveler. At other subsequent statuses, for example, upon the time of arrival to the destination, the luggage will be loaded off and transferred to the conveyor belt. These two processes are displayed in the mobile app for travelers to check their luggage status. Figure 4 shows the major milestones of the luggage process flow. The process highlighted with an RFID antenna icon in the figure illustrates the area to be tracked and displayed in the mobile app.

The mobile app is developed with the use of an Android Software Development Kit (SDK) and MIT App Inventor 2 (AI2) [42]. SDK is used as it allows the creation of applications for the software package, hardware platform, and computer systems, and supports the coding platform of Java and C++ language. AI2 is a cloud-based tool running in the Google Chrome Browser with the built-in Adobe Flash Player. AI2 adopts Block Editors in building the mobile app. The luggage tracking, history log display and login features of the mobile app are developed with the use of the App Inventor block editor. The user interfaces on the login page and main menu page developed for the mobile app are shown in Figure 5. The login page allows user to login through e-mail address, barcode scanner, or Near Field Communication (NFC). The user interface includes the main page connecting to the Tracking, History, Information, and Setting modules. The mobile app is designed to display the latest status and the previous history on the last five statuses. Their user interfaces are shown in Figure 6. The connection from the Access database to the mobile app requires the use of Fusion table available in the Google tools. It uses IoT tools to store the data for displaying in the mobile app. Examples of the Fusion tables are shown in Figures 7 and 8. The developed IoTs are tested from the creation of tag in the POS, updating of tag and customer information, and subsequent statuses detected in the reader. The performance of the reading range has been reviewed in which the reading distance is greater than three metres with the tag moving around the circumference of the antenna. The reading performance is acceptable when compared with similar RFID performance tests [12]. The flow and status can be referred to Figures 2 and 4 described in the earlier sections. Considering the security and privacy matters, a luggage safe protector module in the mobile application is developed with login identification through validation of password, QR code or NFC scan. The information stored in the tag is limited to the name and mobile number for security reasons in the initial development stage.

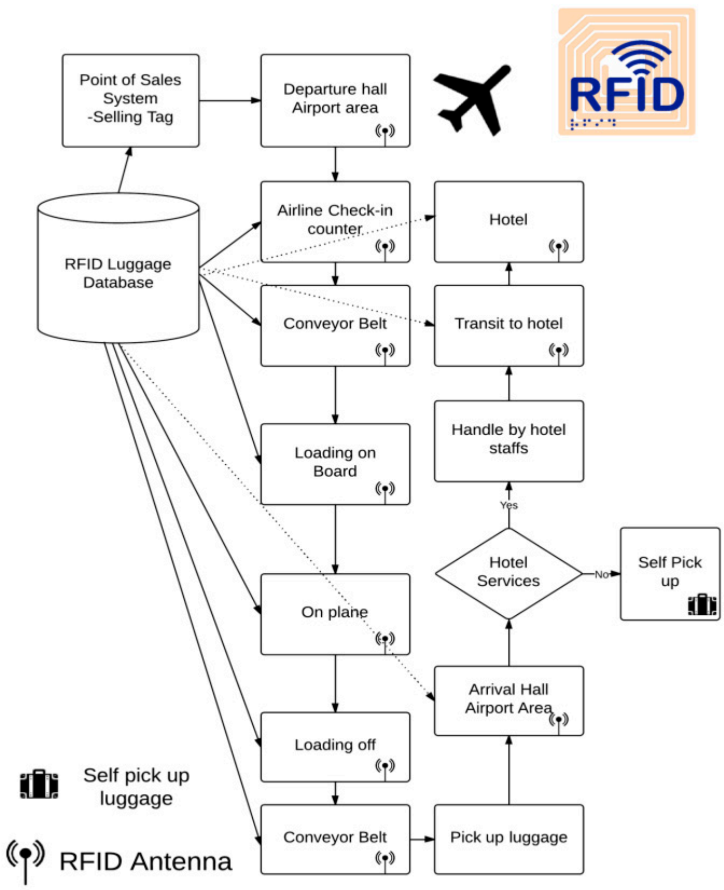


Figure 4. Major milestones in the luggage flow.

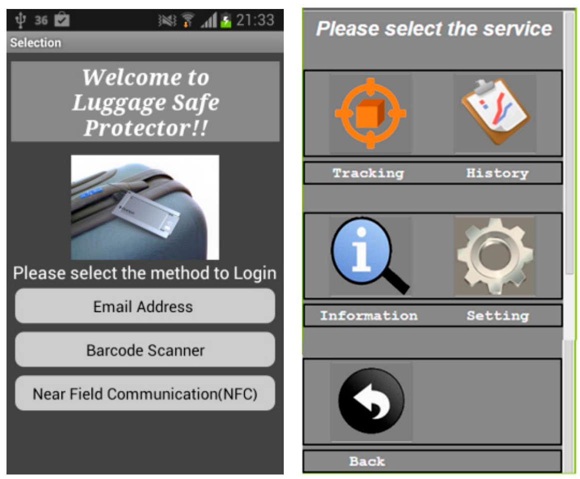


Figure 5. The user interfaces on login page and main page of mobile tracking app.

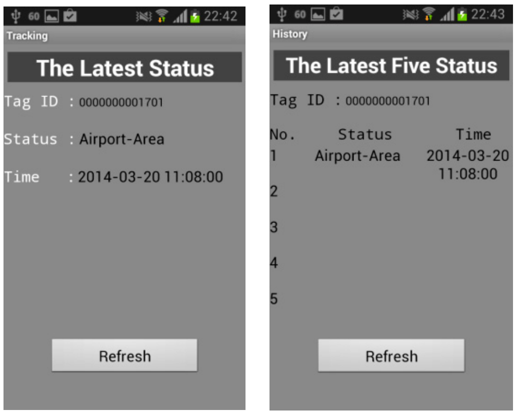
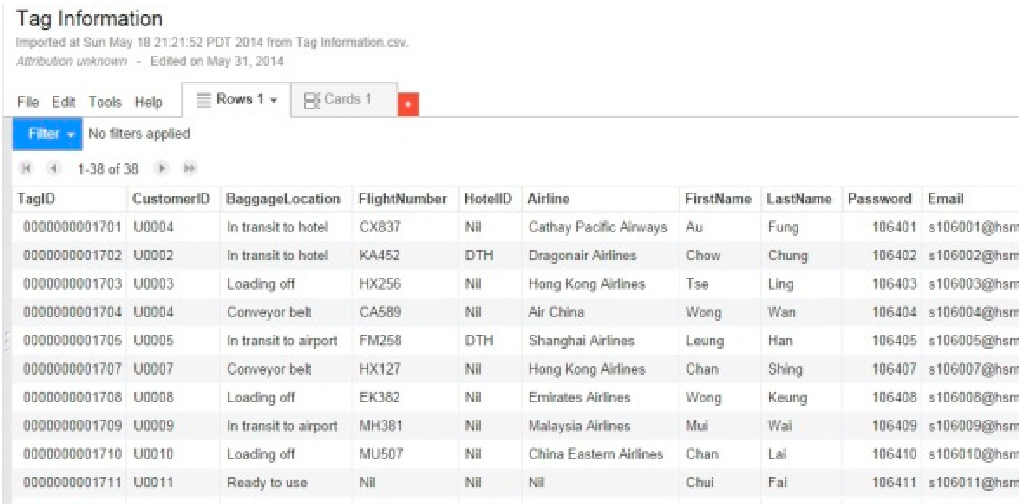


Figure 6. The user interfaces on the tracking page and history page.



TagID	CustomerID	BaggageLocation	FlightNumber	HotelID	Airline	FirstName	LastName	Password	Email
0000000001701	U0004	In transit to hotel	CX837	Nil	Cathay Pacific Airways	Au	Fung	106401	s106001@hsm
0000000001702	U0002	In transit to hotel	KA452	DTH	Dragonair Airlines	Chow	Chung	106402	s106002@hsm
0000000001703	U0003	Loading off	HX256	Nil	Hong Kong Airlines	Tse	Ling	106403	s106003@hsm
0000000001704	U0004	Conveyor belt	CA589	Nil	Air China	Wong	Wan	106404	s106004@hsm
0000000001705	U0005	In transit to airport	FM258	DTH	Shanghai Airlines	Leung	Han	106405	s106005@hsm
0000000001707	U0007	Conveyor belt	HX127	Nil	Hong Kong Airlines	Chan	Shing	106407	s106007@hsm
0000000001708	U0008	Loading off	EK382	Nil	Emirates Airlines	Wong	Keung	106408	s106008@hsm
0000000001709	U0009	In transit to airport	MH381	Nil	Malaysia Airlines	Mui	Wai	106409	s106009@hsm
0000000001710	U0010	Loading off	MU507	Nil	China Eastern Airlines	Chan	Lai	106410	s106010@hsm
0000000001711	U0011	Ready to use	Nil	Nil	Nil	Chui	Fai	106411	s106011@hsm

Figure 7. Fusion table in the web as linkage and database for mobile application.

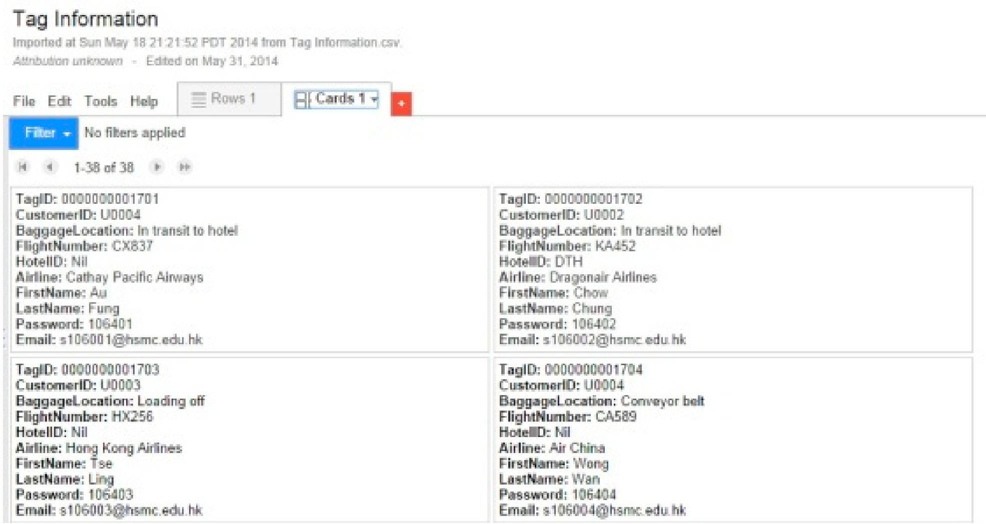


Figure 8. Fusion table for tag ID and its corresponding tag details.

Trials and implementations of RFID on luggage handling have been carried out in airlines and airports in recent years. The use of RFID in airports was first deployed in 2005 at Hong Kong, Milan Malpensa and Las Vegas McCarran airports [43]. The implementation results show a read rate of over 97% compared with around 80% for conventional bar codes. RFID is estimated to reduce 20% of mishandlings through more accurate tag reading and better visibility over the entire baggage operation. Trials have also been carried out in other airlines and airports, for example, British Airways at Heathrow, Japan Airlines in Kansai International Airport and Hong Kong International Airport, Kuala Lumpur International Airport, Korean airports, etc. The benefits of RFID on luggage handling are not only those of eliminating the number of mishandlings and having better visibility but also better tracking and reducing the use of paper adhesive luggage tags. The technology and development should move forward to the reusable luggage tag through the collaboration among the airport, airline and the luggage manufacturer for luggage tracking anytime anywhere. The use of the reusable luggage tag by the RFID tag being installed in the luggage could reduce the disposal of billions of adhesive luggage tags each year. This brings a positive environmental impact through eliminating environmentally unfriendly wastage. The use of mobile tracking on luggage handling further connects the luggage location and flight information to the passenger. Hotels involved in the development can enhance their check-in process and provide better customer services with luggage tracking. With the developed IoT with DMS, fusion table and the mobile tracking functionalities, further development will involve the integration along the systems, including the POS, DMS, mobile apps, airport check-in counters, destination airports and hotels.

4. Challenges and Benefits

The full implementation of the luggage tracking from retail to airport, and further to hotel systems encounters various challenges ahead. Liaison and partnership among various counterparts throughout the chain is required, including luggage manufacturer, retail store, airport, airline, hotel and customs. Platforms described in earlier sections on data sharing, system integration, and information flow among various parties need to be established. Another hurdle for the successful rollout is the acceptance from the parties involved. Workers who are used to the current practice rely on the Kanban system in daily operations. Turning from paper adhesive luggage tags to digital information requires training and education to the frontline workers. Upon detection of the luggage location from a reader, it is able to track the location of the luggage but not the direction. Lack of vector information could be derived from the system. For example, detection of whether the traveler is arriving or departing the airport after several signals are detected in the same spot could be controversial. The implementation of the IoT luggage tracking might not be able to fully eliminate the luggage lost. Theft could still occur at the airport luggage pickup area. The mobile app developed is also limited by the mobile phone operating system. It is only available in the Android system and not the Apple iOS system due to security and policy issues. The development is limited by Google account when using the Google map and fusion table. Security would be an important aspect to protect increasing user information stored into the tag as well as the interfaces between tag, readers and the IoT systems. To avoid the RFID tag being removed from the luggage or the luggage ID being replaced, the RFID tag is permanently embedded in the luggage. Security measures could be further developed by creating a unique ID number encoded in the tag which links to a protected and encrypted database. Reader-tag authorization and shifting data into backend could be implemented to enhance the security system.

Implementing the reusable luggage tag through the development of IoT brings benefits to the traveler, airline, airport terminals, and the environment. The traveler benefits not only from the capability of luggage tag on track and trace but also value-added service provided in the tag and mobile app. Latest flight information, airport and hotel information could be communicated through the mobile app. Frequent travelers can eliminate the need of disposing the paper adhesive luggage tags in each trip. Reusable RFID luggage tags can shorten the time required in the check-in procedure without the need of printing the tag, speeding up the check-in process. Reusable luggage tag can reduce the cost involved in the airlines as there are over billions of paper tags reported being torn off and discarded after the flights. Besides reducing the paper tag costs, airlines and airport terminals can reduce the cost in mishandling and luggage lost reparation by tracking, tracing and monitoring the location of the luggage through the UHF RFID readers and tag. The use of reusable luggage tags can save huge amount of adhesive luggage tags being printed and operates in a more environmentally friendly way. The permanently-embedded RFID tag in the luggage facilitates the continuous use of tracking the position of the luggage in multiple trips. Following the 'onboard' milestone indicating that the luggage has been loaded onboard, the tracking of luggage could be continued with 'in transit to hotel' and 'at hotel' for transporting the luggage to the hotel and arriving at the hotel. The usage of reusable luggage tag is sustained for subsequent trips without the need for the airport printing huge amount of adhesive luggage tags.

5. Conclusions

To address the huge amount of lost luggage and the disposal of adhesive luggage tags after travelling by air, this research has been initiated to develop a reusable luggage tag with the use of IoT, including POS, RFID, Fusion table, and a mobile app. This paper reviewed the latest developments of IoT, the current application of RFID in the luggage handling system and proposed the development of reusable luggage tag to facilitate the aviation luggage tracking process. A framework and components of the RFID for the proposed reusable tag are presented. Instead of an additional one-off RFID tag and separate tracking device required to be built for the luggage tracking system, a novel integrated IoT for a reusable luggage tag is developed. A database management system and a mobile app on a smartphone device are proposed, facilitating luggage track and trace anytime anywhere. The setup and trial run are successful, demonstrating the information flow from the data detected by RFID, received by the POS system, passed to the database management system, and displaying the data in the mobile app of a smartphone. The latest status of the luggage can be provided to the traveler. Challenges to the cooperation among various stakeholders, data flow along various parties, hurdles from the frontline workers who are resistant to change, and lacks of vector information are some of the major issues ahead. Further enhancement of the methodology of integrating the retail system, luggage tag, airport check-in counter, luggage handling system, aircraft, the destination airport, and hotels using tag, readers, antenna, and mobile devices, as well as upgrading the security and privacy of the IoT system can be explored regarding the challenges ahead. Upon system enhancement, a thorough performance test could further be carried out in various orientations of luggage, reader antennae and mobile devices, different conveyor belt systems and both empty and full luggage situations.

Acknowledgments: The work described in this paper was partially supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (Project Reference No. UGC/FDS14/B16/16).

Author Contributions: Eugene Y. C. Wong conceived the theoretical approach, performed the experiments and wrote the paper; W. H. Wong validated the concepts, analyzed the data, and commented on various drafts of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Carmichael, S. Airlines Losing 3000 Bags—Every Hour of Every Day. Available online: http://www.gadling.com/2010/03/26/airlines-losing-3000-bags-every-hour-of-every-day/ (accessed on 9 April 2014).
2. Peterson, B.S. Why Do 26 Million Checked Bags Go Missing Every Year? The Informer. 2012. Available online: http://www.cntraveler.com/travel-tips/flying/2012/07/airlines-baggage-luggage-checked-fees-missing-bags (accessed on 10 April 2014).
3. Yogerst, J. Best and Worst Airlines for Lost Luggage. Travel and Leisure. 2013. Available online: http://www.travelandleisure.com/articles/best-and-worst-airlines-for-lost-luggage (accessed on 10 April 2014).
4. McCartney, S. Baggage Claim: Airlines Are Winning the War on Lost Luggage. Available online: http://online.wsj.com/articles/baggage-claim-airlines-are-winning-the-war-on-lost-luggage-1401922595 (accessed on 3 December 2016).
5. Bates, J. *Lost Luggage Rates Continue to Decline—New Report*; Aviation Media: London, UK, 2015.

6. Swedberg, C. Reusable Electronic Baggage Tag Powered by RFID. Available online: http://www.rfidjournal.com/articles/view?7928/ (accessed on 10 April 2014).
7. Al-Ali, A.S.A.; Sajwani, F.; Al-Muhairi, A.; Shahenn, E. Assessing the feasibility of using RFID technology in airports. In Proceedings of the IEEE 2007 1st Annual RFID Eurasia Conference, Istanbul, Turkey, 5–6 September 2007.
8. Mishra, A.; Mishra, D. Application of RFID in aviation industry: An exploratory review. *Promet Traffic Transp.* **2010**, *22*, 363–372. [CrossRef]
9. DeVries, P.D. The state of RFID for effective baggage tracking in the airline industry. *Int. J. Mob. Commun.* **2008**, *6*, 151–164. [CrossRef]
10. Wyld, D.C.; Jones, M.A.; Totten, J.W. Where is my suitcase? RFID and airline customer service. *Mark. Intell. Plan.* **2005**, *23*, 382–394. [CrossRef]
11. Hui, J. RFID in Airports—Baggage and Passenger Tracking. Available online: http://www.winmec.ucla.edu/rfid/course/2008s/RFID%20in%20Airports.pdf (assessed on 10 December 2016).
12. Medeiros, C.R.; Costa, J.R.; Fernandes, C.A. Passive UHF RFID tag for airport suitcase tracking and identification. *IEEE Antennas Wirel. Propag. Lett.* **2011**, *10*, 123–126. [CrossRef]
13. Roberti, M. Airlines Could Benefit From RFID-Enabled Baggage Handling. 2013. Available online: http://www.rfidjournal.com/articles/view?10992 (accessed on 10 December 2016).
14. Zoltan, K.A.T.O. Using RFID and GIS technologies for advanced luggage tracking. *SEA Pract. Appl. Sci.* **2015**, *3*, 229–234.
15. Nepal, S.; Chotiyaputta, V. Operation risk management: A case study of baggage logistics technology at Munich Airport. *Panyapiwat J.* **2016**, *8*, 273–282.
16. Gupta, V.; Kumar, R.; Mishra, R.G.; Semwal, A.; Siwach, S. Design and optimization of luggage tracking system on airport. In Proceeding of the International Conference on Intelligent Communication, Control and Devices, Dehradun, India, 2–3 April 2016; Springer: Singapore, 2017; pp. 833–838.
17. Berrada, A.; Salih-Alj, Y. An Efficient RFID-Based Tracking System for Airport Luggage. Available online: http://elvedit.com/journals/IJACSIT/wp-content/uploads/2015/11/IJACSIT-Paper-Format.pdf (assessed on 10 December 2016).
18. Ahmed, T.; Calders, T.; Pedersen, T.B. Mining risk factors in RFID baggage tracking data. In Proceedings of the 2015 16th IEEE International Conference on Mobile Data Management, Pittsburgh, PA, USA, 15–18 June 2015; Volume 1, pp. 235–242.
19. Zhu, X.; Mukhopadhyay, S.K.; Kurata, H. A review of RFID technology and its managerial applications in different industries. *J. Eng. Technol. Manag.* **2012**, *29*, 152–167. [CrossRef]
20. Jacinto, C.; Romano, M.; Montes, A.; Sousa, P.; Nunes, M.S. RFID tuning methodology applied on airport baggage tracking. In Proceedings of the IEEE Conferences on Emerging Technologies & Factory Automation (ETFA 2009), Palma de Mallorca, Spain, 22–25 September 2009; pp. 1–4.
21. Ouyang, Y.; Hou, Y.; Pang, L.; Wang, D. An Intelligent RFID Reader and its Application in Airport Baggage Handling System. In Proceedings of the 4th International Conference on Wireless Communications, Networking and Mobile Computing (WiCOM'08), Dalian, China, 12–14 October 2008; pp. 1–4.
22. Cerino, A.; Walsh, W.P. Research and application of radio frequency identification (RFID) technology to enhance aviation security. In Proceedings of the IEEE 2000 National Aerospace and Electronics Conference (NAECON 2000), Dayton, OH, USA, 10–12 October 2000; pp. 127–135.
23. Sennou, A.S.; Berrada, A.; Salih-Alj, Y.; Assem, N. An interactive RFID-based bracelet for airport luggage tracking system. In Proceedings of the 2013 4th International Conference on Intelligent Systems, Modelling and Simulation, Sabah, Malaysia, 8–10 February 2013.
24. Chen, X.Y.; Jin, Z.G. Research on key technology and applications for internet of things. *Phys. Procedia* **2012**, *33*, 561–566. [CrossRef]
25. Sun, C. Application of RFID technology for logistics on internet of things. *AASRI Procedia* **2012**, *1*, 106–111. [CrossRef]
26. International Telecommunication Union (ITU); Strategy and Policy Unit (SPU). *ITU Internet Reports 2005: The Internet of Things*; International Telecommunication Union (ITU): Geneva, Switzerland, 2005.
27. Gubbi, J.; Buyya, R.; Marusic, S.; Palaniswami, M. Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Gener. Comput. Syst.* **2013**, *29*, 1645–1660. [CrossRef]
28. Xia, F.; Yang, L.T.; Wang, L.; Vinel, A. Internet of things. *Int. J. Commun. Syst.* **2012**, *25*, 1101–1102. [CrossRef]

29. Atzori, L.; Iera, A.; Morabito, G. The internet of things: A survey. *Comput. Netw.* **2010**, *54*, 2787–2805. [CrossRef]
30. Kortuem, G.; Kawsar, F.; Fitton, D.; Sundramoorthy, V. Smart objects as building blocks for the internet of things. *IEEE Intern. Comput.* **2010**, *14*, 44–51. [CrossRef]
31. Geum, Y.; Lee, S.; Kang, D.; Park, Y. Technology roadmapping for technology-based product-service integration: A case study. *J. Eng. Technol. Manag.* **2011**, *28*, 128–146. [CrossRef]
32. Ehrman, K.S.; Ehrman, M.L.; Jagid, J.M. Mobile Portal for RFID Luggage Handling Applications. U.S. Patent 7,656,273, 2 February 2010.
33. Baskas, H. Digital Bag Tags Could Make Paper Luggage Tags Obsolete. Available online: http://www.cnbc.com/id/101188221 (accessed on 10 April 2014).
34. Collotta, M.; Pau, G.; Tirrito, S. A preliminary study to increase baggage tracking by using a RFID solution. In Proceedings of the International Conference on Numerical Analysis and Applied Mathematics 2014 (ICNAAM-2014), Rhodes, Greece, 22–28 September 2014; AIP Publishing: Melville, NY, USA, 2015; Volume 1648, p. 780005.
35. Mishra, D.; Mishra, A. Improving baggage tracking, security and customer services with RFID in the airline industry. *Acta Polytech. Hung.* **2010**, *7*, 2.
36. Song, J.G.; Kim, D.H.; Na, D.G. Apparatus and Method to Control Taking Airport Baggage. U.S. Patent 9315278 B2, 19 April 2016.
37. Bravman, R.; Wang, Y.P.; Toedt, D.C., III; Vingsbo, S.G. Traveler Security and Luggage Control System. U.S. Patent 5,866,888, 2 February 1999.
38. Chang, Y.S.; Oh, C.H.; Whang, Y.S.; Lee, J.J.; Kwon, J.A.; Kang, M.S.; Park, J.S.; Ung, Y.P. Development of RFID Enabled Aircraft Maintenance System. In Proceedings of the 2006 IEEE International Conference on Industrial Informatics, Singapore, 16–18 August 2006; pp. 224–229.
39. Brennan, P. RF-ID tag and video passenger location in airports. *J. Airpt. Manag.* **2007**, *2*, 56–66.
40. Zhang, T.; Ouyang, Y.; He, Y. Traceable air baggage handling system based on RFID tags in the airport. *J. Theor. Appl. Electron. Commer. Res.* **2008**, *3*, 106–115.
41. Ghazal, M.; Ali, S.; Haneefa, F.; Sweleh, A. Towards smart wearable real-time airport luggage tracking. In Proceedings of the 2016 International Conference on Industrial Informatics and Computer Systems (CIICS), Sharjah, UAE, 13–15 March 2016; pp. 1–6.
42. Wolber, D.; Abelson, H.; Spertus, E.; Looney, L. *App Inventor Create Your Own Android Apps*; O'Reilly Media, Inc.: Oakville, ON, Canada, 2011.
43. Airport Business. Making RFID Work—The Most Effective Solution to Lost Baggage? Airport Business, Baggage Handling. Available online: http://www.airport-business.com/2009/03/making-rfid-work-the-most-effective-solution-to-lost-baggage/ (accessed on 12 April 2014).