A new intelligent self-service express delivery system based on mobile cloud computing and WeChat

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Abstract: In order to solve the ‘last mile’ logistics and distribution problems in express parcel delivery, this paper designs an intelligent system by integrating mobile cloud computing with WeChat to achieve the couriers’ self-service parcel picking and delivering as well as customers’ self-service parcel sending and receiving. This system is comprised of three parts, namely, express delivery terminals, WeChat public platform and cloud computing servers. The terminal adopts a dual-CPU architecture equipped with Samsung Exynos4412 and STM32F103. The WeChat platform Web-App is built using the web development kit (JS-SDK) within WeChat, which integrates information publishing, online inquiry, interaction and other functions. By using third-party maps and cloud computing servers, this system can mark the real time location of terminals and work out optimal pedestrian navigation routes for customers.

Keywords: mobile cloud computing; WeChat; intelligent self-service express delivery system; optimal pedestrian navigation.


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1 Introduction

With the rapid development of global e-commerce in recent years, the express delivery market is getting increasingly prosperous. There has been an urgent need to solve the ‘last mile’ logistics and distribution problems of express parcels (Ni and Sun, 2013). As the smart city concept which uses the logistics and information flow as its core elements has become the focus of global concern, traditional door-to-door and point-to-point distribution patterns are constantly transformed from the ‘waiting for delivery’ to ‘take delivery’. In developed countries, 24/7 self-service express mail station has been used for more than a decade (Ducret, 2014). In Japan, for example, each building has a standard facility for sending and receiving deliveries. Only important express parcels containing items like credit cards and other valuables are required to be handed to recipients personally. German DHL has so far set more than 2,500 lockers. Canadian Bufferbox and the US Amazon, Walmart and other international giants have begun to construct self-service lock box systems for express parcels to provide online retailers and individual consumers with mail acceptance and delivery services. In China, self-service express delivery system is still in its nascent stage (Lu, 2013). Some hi-tech companies such as Beijing ZhiHeng-era, Nanjing Yungui and Xiamen HanLingda have launched their own self-service delivery cabinets. These devices have been put into use in some communities, schools, enterprises, institutions and public places. In 2014, Beijing NPC and CPPCC representatives recommended extensive use of convenient smart mailboxes and delivery cabinets. Zhejiang provincial government also pledged subsidies to support the self-service express delivery cabinet program. At present, almost all devices in service in both domestic and international markets use IPCs or desktop computers to as the host system, which has resulted in high deployment costs. Moreover, most of them provide no self-service parcel sending function for mailers. Being unable to connect with express companies and form coordinated systems, these delivery cabinets only work as isolated devices.

Nowadays, with the development of mobile communication, internet of things, embedded system, distributed computing technology, the emerging mobile cloud computing technologies combined with mobile internet industry and cloud computing technologies have become the hottest business development model in the IT industry (Jing et al., 2014; Wan et al., 2010a, 2010b; Niyato et al., 2011; Wang et al., 2014, 2013; Islam et al., 2015). Mobile cloud computing allows computers or other information intelligent terminals to implement data transmission and resource sharing in a wireless environment and provides customers with useful, accurate and timely information anytime and anywhere (Wan et al., 2014; Liu et al., 2014; Suo et al., 2013; Duan et al., 2012; Xu et al., 2014; Wei et al., 2014, 2010). This has brought great changes to people’s life style and work. In addition, as a new generation of mobile instant messaging products, WeChat supports voice messaging, video, pictures and text, group chat, LBS positioning and other functions. Since its launch in early 2011, the number of registered users has exceeded 600 million (Xu et al., 2015; Li, 2014). There are now more than
8 million WeChat public accounts, which are still on the rise and very likely to grow into something of the FaceBook on smartphone users. Therefore, to cater for the needs of hundreds of millions of active WeChat users and based on fully open interfaces, this paper designs an intelligent self-service express delivery system using the mobile cloud computing technology to serve schools, governments, enterprises, residential communities, train stations and other places. This system will bring important social and economic benefits because it will change the traditional ‘point-to-point’ model in logistics and distribution, improve the operation and management efficiency of express companies, and bring fresh ideas to people’s smart urban life.

2 System architecture

The intelligent self-service delivery system consists of three parts, namely, express delivery terminals, the WeChat public platform and cloud computing servers. Its system architecture is shown in Figure 1.

![System architecture of the intelligent self-service express delivery system](image)

The delivery terminal adopts a dual-CPU structure equipped with Samsung quad-core Exynos4412 and STM32F103 to achieve the couriers’ self-service parcel picking and delivering as well as users’ self-service parcel sending and receiving. It operates in the following manner.

1 Parcel delivering

When a courier is to deliver an express parcel, he needs to perform the following operations on the terminal: registering on the terminal, logging on, pressing the
delivery button on the touch screen, inputting the recipient’s phone number on the panel manually, selecting the proper delivery cabinet, and then clicking the Confirm button. At this point, the system will automatically search for an empty express cabinet, open its door and prompted the courier to put the express parcel into it. At the same time, a two-dimensional code about this delivery is generated and then sent to the parcel receiver via MMS. The courier’s work is thus completed.

2 Parcel receiving

When a receiver comes to fetch his parcel from an express cabinet, he only needs to show his two-dimensional code to the scanner on the terminal. Then the system will search for the proper cabinet where the parcel is stored, open the door and prompt the receiver to fetch his parcel. The receiver’s parcel picking is thus completed. In addition, to avoid the prolonged occupation of the express cabinet by parcels, receivers who do not fetch their parcels timely will be charged extra. The cabinet offers free storage for the first 24 hours and charge 1 yuan for each additional 24 hours. The proceeds can be used for the maintenance and upgrading of the express system.

3 Parcel sending

When a user is to send an item via express delivery, he needs to put it on the electronic weighing scale, select an express company and fill out the mailing form on the panel of the cabinet. Then, the terminal system will automatically calculate delivery costs and prompt the user to pay accordingly (by inserting cash or swiping a Union Pay card). If the payment is successful, the system will upload the electronic mailing form to the cloud server and automatically search for an empty cabinet, open its door and prompt the user to put his item in. The parcel sending process is thus completed. Meanwhile, a two-dimensional code is automatically generated and sent to the courier’s mobile phone via MMS, prompting him to pick the parcel.

4 Fourier’s pickup

When the courier is to pick the sender’s item from the cabinet, he needs to log on the system, press the pickup button on the touch screen and show the two-dimensional code on his cell phone to the code scanner on the cabinet. Then, the express delivery terminal will display the sender’s mailing form, search for the cabinet where the item is stored, open its door and prompt the courier to take it. Also, courier checks the items (or contents of a parcel), verifies the electronic mailing form and prints it. The courier thus completes the pickup process.

The WeChat public platform adopts a service number type. Through the public account assistant, the platform pushes the latest special offers, news and other information of express companies to customers. In addition, Tencent released the WeChat web development toolkit JS-SDK for developers in January 2015. Therefore, with altogether 11 sets of interfaces for sharing, image, positioning, WeChat stores, WeChat payment and other functions offered by the toolkit, developers can use HTML5, JavaScript and Device API technology to design Web Apps for express delivery systems (David, 2012). By using these Apps, customers can visit express companies’ WeChat websites from mobile devices such as smart phones and tablets powered by various operating systems, thus realising the functions of enterprise information dissemination browsing, express
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parcel status push, delivery terminal location querying, delivery history check, WeChat customer service, the optimal pedestrian navigation path planning for customers to send or receive express parcels.

As the backend servers for the express delivery system, cloud computing servers keep track of the location information of terminals, device operating status and express mailing form information, and store big data such as express terminal location, express cabinet status, parcel transportation status, customer information, delivery history, pickup records in a distributed manner. In addition, real-time location of express terminals is marked and updated on third-party maps. The system can also plan the optimal pedestrian route for customers who are to send or receive express parcels in a strange place.

3 Key technologies

3.1 System design of the express terminal host

The express terminal host adopts the Samsung quad-core Exynos4412 processor of the ARM Cortex-A9 architecture whose operation frequency is up to 1.5 GHz. The host is equipped with 1 GB DDR3 Ram, 4G eMMC flash memory chip, enabling the smooth running of Android 4.2 on it. The host has be expanded with other modules including a touch screen, a voice broadcast, a 3G module, a WiFi module, a coin collector, a two-dimensional code reader, an RFID reader-writer, an electronic weighing scale, an Union Pay Card POS machine and an express mailing form printer. With these modules, the intelligent system can handle major self-service express delivery tasks. The system architecture is shown in Figure 2.

Figure 2 System architecture of the express terminal host (see online version for colours)

Among them, the touch screen adopts a 7-inch capacitive IPS screen, which has a $1280 \times 800$ resolution and is connected to the host through the RGB TTL interface built in the Exynos4412 processor. The audio module adopts a WM8960 decoding chip which supports recording and playback functions. The 3G module adopts a HUAWEI EM820U,
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a model that is able to work in GSM, EDGE and WCDMA networks, to communicate with the host through the mini PCI-E interface. Being connected to the host through a USB interface, the WiFi module adopts a RTL8188CUS driver chip in compliance with IEEE 802.11 b/g/n standards. The coin collector adopts a TW-900, a comparison model made by Tongli Company. By communicating with the host through the MDB-RS232 converter, the coin collector is able to charge customers who fail to fetch their parcels timely. The two-dimensional code reader adopts an NLS-FM420 CMOS sensor with a 752 × 480 resolution made by Newland Company, which is connected to the host through a USB interface. The RFID card reader adopts an MRF-35 model made by Mingtai Company, which can read and write M1/AT88RF020 chip cards. By communicating with the host through an RS232 interface, the RFID card reader realises the authentication of couriers and customers. The Union Pay Card POS machine adopts an SP80 series model by Newland Company, a model that can read and write magnetic cards and IC cards. The electronic weighing scale adopts an ACS-A series model by Dahua Company with a weighing range of 2 grams to 15 kilograms. Both the POS machine and the electronic weighing scale are connected to the host through an RS232 interface, respectively. With the aid of these two devices, customers can weigh their parcel to be sent and pay the express fee properly using a Union Pay card. The express mailing form printer adopts the Epson LQ-590K model, which communicates with the host through a USB interface. With this printer, couriers can print express mailing forms when fetching parcels to be sent.

Since the master operating system runs Android4.2, the applications mainly involves the WiFi module, 3G module, audio module driver, RFID card reader, two-dimensional code reader, serial or USB communication interface for the coin collector as well as the design of the main working interface, delivery interface, parcel pickup interface, help interface and other human-computer interface. All codes for applications are written using Java in the Eclipse programming environment. If the developer is to access the underlying drive equipment, he needs to access the function library compiled by using C/C++ through the Java Native Interface (JNI) (Perchat et al., 2013).

3.2 System design of the express terminal extension

The express terminal extension adopts STM32F103 which is based on ARM Cortex M3 architecture and packaged using LQFP100. It has 80 IO ports. Each express cabinet has the functions of electronic-controlled lock, smart illumination, infrared item detection and cabinet door status detection. To allocate system resources efficiently and handle tasks timely, one piece of STM32F103 manages 20 cabinets of different sizes. The system architecture of extensions is shown in Figure 3.

1 Circuit of the electronic-controlled lock

The circuit of the electronic-controlled lock is controlled by the IO port of STM32F103. The circuit diagram is shown in Figure 4. The electronic-controlled lock adopts the MA-1208 model made by Dajiang Lock Company. Its input voltage and working current are 12V DC and 0.8 A, respectively. It has an outage-triggered locking function and takes less than 0.1 second to unlock. When the PA0 port of STM32F103 has a high-level output, through the isolation function of photocoupler U1, the relay will be powered on, K1 will be closed to power on the electronic-controlled lock. Then, the cabinet door of the delivery terminal will be opened. The
2 Circuits of the cabinet door status detector and the smart illumination system

The circuits of the cabinet door status detector and the smart illumination system are shown in Figure 5. Installed on the cabinet door frame of delivery terminal, the diagram of cabinet door status detector adopts the Z-15GW22-B travel switch made by Omron. When the cabinet door is closed, the normally closed contacts of the travel switch will separate, and PB0 port of STM32F103 will detect a high level. The smart illumination circuit is composed of the normally detached contacts of the travel switch and the 3DU phototriode. When the cabinet door is opened, the triode Q2 will be turned on. At this time, if the light is dim, then the triode Q1 will be turned on to activate the lighting circuit composed of 8 LEDs in parallel in the cabinet.

3 Circuit of the infrared item detector

In order to detect the existence of any item in the cabinet, the circuit of the infrared item detector is designed as shown in Figure 6. The infrared transceiver adopts the PT333-3B and IR333C-A, which are installed on the left side and right side inside the express cabinet, respectively. When there is an item in the cabinet, the infrared ray will be blocked, the LM393 comparator will output a high level. Through the isolation function of the photocoupler U5, the PC0 port of STM32F103 will detect a low level. At this time, if a customer opens the cabinet forcibly to take items inside without the recognition of the two-dimensional code, then the terminal will detect this abnormal situation and report to the host system. The host system will immediately sound the alarm and send alarm information to the cloud computing servers through the 3G module.

Each group of express cabinets are connected with other extension systems through RS485 bus and using Modbus protocol in a cascade manner (Feng and Yu, 2012). They also perform RS485 communication with the host. The Modbus protocol adopts the RTU mode with the 12-byte data frame which contains 1 byte of slave address, the 1 byte of function code, 8 bytes of data and 2 bytes of CRC check code. Each two message frames have an interval of 3.5 characters or more between them. The host keeps broadcasting instructions to extensions using a polling mechanism. These instructions contain the address information of slave equipment. The extension compares its own address with the target address. If they are the same, the host starts to receive and store the cabinet information sent from the slave including cabinet door status and cabinet status (occupied or empty). Then, the same process is repeated on the next extension. The extension keeps receiving data frames from the host and compares them with its own address. If it finds that the operation is assigned to it, the extension will receive the complete data frames and turn on or off the electronic-controlled lock according to the instruction.
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Figure 3  System architecture of extensions (see online version for colours)

Figure 4  Circuit diagram of the electronic-controlled lock

Figure 5  Circuits of the cabinet door status detector and the smart illumination system
3.3 Design of the WeChat public account (Web-App)

The WeChat public platform is an open platform. Any organisations and individuals can apply for their own public accounts for free. Tencent has already release the development kit (JS-SDK) for intra-WeChat website design which provides sharing altogether 11 sets of interfaces including those for image, audio equipment, intelligence, device information, geographic location, operation interface, WeChat swiping, WeChat shop, WeChat coupon and WeChat payment. Therefore, we can develop a Web-App which is similar to the Native App with faster response speed, good adaptability to various mobile devices running different operating systems, easy maintenance and updating. Web-App architecture of the express system based on WeChat public platform is shown in Figure 7.

The WeChat public platform Web-App adopts the development mode. Interface information such as URL and Token is preconfigured by the administrator. The WeChat server is responsible for receiving and sending information of user terminals and express terminals. The information is packaged as XML files and posted to the express cloud server. After being handled by the message processing program, the information that needs to be replied is packaged as XML files and sent back to the WeChat server. Then,
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the WeChat server sends them to the user terminal. The webpages of the WeChat public platform are programmed using HTML5, JavaScript and deployed on the express cloud server. The main functions of the public platform are information publishing, online query, interaction and communication, pedestrian route planning and navigation.

Information publishing system is used to push information to customers. With the dynamic column as its main content, the information includes news in the express delivery industry, the latest special offers and themed activities. Online query system enables users to select different express companies, inquire the express parcel transportation status, delivery history, express fees efficiency, service network and service description. As for parcel transportation status and delivery history, users can make queries by entering the tracking number, cell phone number and other keywords. The interaction system interacts with users through voice or text. It begins voice recording by calling the audio interface (wx.startRecord) in the JS-SDK package and converts voice into text by calling the intelligent class interface (wx.translateVoice). In this manner, the system can interact with different groups of platform management personnel and meet the personalised needs of different user groups. By calling the API of third-party maps like Tencent map and Baidu map, the pedestrian navigation system marks and updates the express terminal distribution in real time, and plans the optimal pedestrian navigation path in a strange place sending or retrieving express for users, the system flow as shown in Figure 8.

**Figure 8** Workflow of the pedestrian route navigation and planning (see online version for colours)
The express terminal, as a WeChat personal number, enters the public account session on a regular basis, pushes XML data packages containing geographical position, cabinet usage status to the URL of the WeChat public account and reports this information to the cloud computing server in real time. The express WeChat public platform calls third-party maps by viewing the position interface (wx.openLocation) and obtaining the geographic location interface (wx.getLocation) methods so that the real-time geographical distribution of express terminals are displayed on the maps. When the customer in a strange place wants to send a parcel via express delivery, he can search for the nearest express terminals and usage status (occupied or empty) online and obtain the optimal pedestrian route from the cloud computing server. In addition, when the customer is to fetch a parcel from an express cabinet, he only needs to enter the express tracking number, mobile phone number or other keywords on the pedestrian route navigation interface. In this way, he can learn where the express cabinet holding his parcel is and the optimal pedestrian route to get there.

4 Problems and solutions

At present, with the gradual disappearance of the demographic dividend, it is increasingly becoming a trend to reduce the delivery labour costs in the express industry and provide more convenience for the public. As an important link in the internet of things and smart city, the intelligent self-service express storage system will be a revolutionary product for the express delivery industry. However, information security, reliability and stability and the operation of the new self-service express storage system need to be further studied.

4.1 Information security

Technically speaking, security requirements for cloud computing are similar to those for other information systems. As new functions of WeChat are introduced continuously, the security level of the WeChat public platform has been greatly improved. Therefore, the intelligent self-service express storage system based on mobile cloud computing and WeChat platform has good security. In addition, the express storage system in service keeps recording customer account, delivery status, express mailing forms and other information and stores it in the flash chip of express terminal in real time. The data is also uploaded to the cloud competing servers as a backup, which effectively avoids otherwise possible data loss in case of a power cut. The system will sound the alarm when it detects abnormal conditions such as non-existence of items after delivery, existence of items after the courier pick the item from the express cabinet, abnormal opening of the cabinet door. In such cases, the system will automatically hold back the items inside the abnormal cabinets until the customer or courier passes the authentication required by system. By using the dynamic encryption technology, the self-service express storage system generates two-dimensional codes and then sends them to couriers and customers, thus ensuring the uniqueness of each password. The express delivery terminal is also equipped with 2-4 wireless IP network cameras. Through a 3G or WIFI network, these cameras can upload videos to cloud servers. In this way, the administrator can monitor the ambient environment of the express storage system 24-7.
4.2 Reliability and stability

A good quality with high stability and reliability is essential for the successful commercial operation of the intelligent self-service express storage system. Therefore, to ensure the robustness of the system, all functions on the WeChat public platform and the cloud computing servers are required to pass rigorous reliability tests. These functions include information publishing and browsing, express industry news pushing, querying of the geographical distribution of express delivery terminals, querying of the historical records of deliveries, customer service, algorithm for planning the optimal pedestrian navigation path, distributed storage of user information, historical express records and other big data. At the same time, to guarantee the system stability, the express delivery terminal is also required to pass rigorous function tests, such as the cabinet door opening and closing, video monitoring, text messages sending, coin recognition, voice broadcasting, RFID reading and writing, WiFi and 3G communication. The required rigorous reliability tests include electromagnetic compatibility, high pressure, static electricity, 7–24 continuous service. In addition, each express delivery terminal should be installed with a backup power supply whose capacity should enable the terminal to work for another 12 hours after a power cut.

4.3 Commercial operation

Nowadays, the competition in China’s express market is getting very fierce. On the one hand, e-commerce companies keep using their advantage of large express orders to bargain down the general express quote from the express companies. Besides the revenue from commodity sales, they are now looking to earn some profits from express price difference. On the other hand, the homogenisation competition between express companies has intensified the in the price war. The majority of express businesses are faced with the dilemma of minor profit, no profit or even losses. According to statistics, about half of the 20 major express companies have yet to make any profits in 2014. They still rely heavily on the capital input. Therefore, putting express delivery terminals in use on a large scale and building the intelligent self-service express storage system requires a large fund. In order to maintain the equipment, site, maintenance, the operation of express storage system must make a profit. Therefore, the government should vigorously support third-party enterprises in putting the intelligent self-express storage system into service and offer them appropriate subsidies in the building this service platform that benefits both e-commerce companies and customers. Third-party enterprises must strive to find ways to profit, such as charging express companies, advertising agency of delivery terminals, providing convenient financial services of credit card repayment, and charging customers for the overdue payment.

5 Conclusions

A new intelligent self-service express storage system based on mobile cloud computing and WeChat is designed in this paper. It offers 7/24 self-service and provides couriers with a convenient and unified location to collect parcels to be sent. It also facilitates users
who are sending or receiving express deliveries. If widely used, this system will reduce the waiting time on the part of couriers and cut down on express companies’ management and service costs. Therefore, this intelligent self-service express storage system is an effective solution to the ‘last mile’ problem in the express delivery industry. In addition, its WeChat public platform provides customers with such services as information release, online query, interactive communication and pedestrian navigation, enabling customers to fully enjoy benefits of the mobile internet and cloud computing service. In other words, this system brings innovative ideas to the express delivery and makes urban life more convenient. According to preliminary estimation, once the intelligent self-service express system is put in wide use, express companies will not need so many couriers as now, which will reduce their labour costs and improve working efficiency by four to five times. Therefore, aided by good commercial operation, this intelligent self-service express delivery system can be widely applied in secondary schools, colleges, governmental agencies, large enterprises and institutions and high-grade residential communities and yield considerable social and economic benefits.

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