Scientific Research Publishing

Advances in Internet of Things, 2018, 8, 39-63
http://www.scirp.org/journal/ait
ISSN Online: 2161-6825
ISSN Print: 2161-6817

A Uniform Parcel Delivery System Based on IoT

Yuhui Wang[1], Hongbo Zhu[2], Zechun Wang[3], Haolong Li[4], Guangyao Li[5]

[1]Hong Kong University of Science and Technology, Hong Kong, China
[2]University of Electronic Science and Technology of China, Chengdu, China
[3]Tianjin University, Tianjin, China
[4]Wuhan Yangtze International School, Wuhan, China
[5]Taiyuan University of Technology, Taiyuan, China
Email: ywangdq@connect.ust.hk

How to cite this paper: Wang, Y.H., Zhu, H.B., Wang, Z.C., Li, H.L. and Li, G.Y. (2018) A Uniform Parcel Delivery System Based on IoT. *Advances in Internet of Things*, **8**, 39-63.
https://doi.org/10.4236/ait.2018.84004

Received: September 3, 2018
Accepted: October 15, 2018
Published: October 18, 2018

Abstract

Nowadays, many different kinds of delivery companies transport their own kinds of parcels and offer their own services, which have caused a lot waste of resources. In addition, the volume of parcels in all cities that need to be delivered has been grown dramatically. To cope with these problems, a uniform parcel delivery system in a smart city which can offer service to all kinds of customers in the city including manufactures, department stores, restaurants, individual people and so forth was designed. This system uses IoT (Internet of Things) and RFID technology, combining computer network technology, wireless communication and cloud computing. With this system, the whole package delivery process including classification of packages, vehicle scheduling, path planning, transportation monitoring can be intellectualized as well as managed automatically, and the use of both material resources and manpower resources can be reduced accordingly.

Keywords

Internet of Things, Parcel Delivery System, RFID, GPS

1. Introduction

1.1. Background

The internet as we know did not just came to existence overnight, it was developed and improved gradually.

- The first wireless computer network is the ALOHA system [1] developed by Norman Abramson at the university of Hawaii in 1970. The most unique characteristic of the ALOHA system has to be its random access: the station

will transmit the packet immediately whenever it's ready. The key method used in this random access is that it would receive the message returned from the destination if the packet is delivered properly. If there is no such message returned in time, the station will assume the packet did not arrive and re-transmit the same packet at some time later.

- ARPANET [1] was an early packet switching network. As ARPAET continue to develop, protocols for interworking were developed so multiple separated networks could be joined into a network of networks. The variety of protocols was so wide that there was need for a standard networking protocol, which was the Internet Protocol suite.
- With the help of wireless network such as ALOHA system and slotted-ALOHA system, some other networks like SANET [1] and Packet radio networking [1] were also invented by DARPA [1] during 1972-1973. After we already had multiple different kinds of networks and may have more in the near future, all we need then is an internet to connect all of them together. For the simple of the design of the internet between different kinds of networks, there are several ground rules for the internet: First of all, each network should stand on its own and no internal changes are required. Secondly, networks should be connected by simple "black boxes" which means no information about the individual flows of packets passing through should be retained by gateways. Thirdly, communication would be on a best effort basis, the packet should be retransmitted immediately if it didn't make it to the final destination. Finally, there would be no global control at the operation level.
- In order to communicate clearly within or between these networks, a reference model was created which contains the abstract concepts underlying this field as well as the relationship between them. The first computer network reference model is the Open System Interconnection (OSI) [1] created by the International Organization for Standardization (IOS) and the International Telecommunication Union (ITU). The OSI is a seven-layer model and each layer will serve the layer above it and be served by the layer below it. From the lowest to the highest, all the layers are: physical layer, data link layer, network layer, transport layer, session layer, presentation layer and finally application layer.
- The World Wide Web is invented by English scientist Tim Berners-Lee in 1989 at CERN. There are multiple kinds of information on the internet web pages includes videos, images and audio. Uniform Resource Locators (URL) [1] is used to locate documents and resources on the servers, Uniform Resource Identifier is used to identify them, hypertext links is used to link different documents and the web pages is written by the hypertext markup language (HTML) [1]. The whole World Wide Web is built based on these basic rules.
- The Internet of Things, which refers to the connection of objects to the Internet, was first discussed in 1982, which is the modified coke machine that is

able to report its inventory and whether the drinks are cold. However, it was not until the invention of Radio-frequency identification that computers were able to manage all individual things. Just like the protocols that connected nodes and hosts together in the internet, the Radio-frequency identification connected objects in the Internet of Things. As technology develops in domain of communication, sensing, and computing, ways in connecting things also became more diversified. Users are not limited to Radio-frequency identification devices, but also use information sensing devices such as Quick Response code reading devices, infrared sensors, global positioning systems and laser scanners to connect things in accordance with the agreed protocol.

1.2. Application Domains

Today, Internet of Things has become ubiquitous and there are multiple application scenarios associated with IoT. The several main application fields are as follows:

1) Intelligent Logistics

Smart logistics refers to the realization of system perception, comprehensive analysis and processing in various links of logistics, including storage and distribution. The use of the Internet of things technology can promote the intelligent level of the whole logistics industry.

2) Intelligent Road Traffic

It uses information technology to closely combine people, cars and roads, improve the road environment, ensure traffic safety and improve resource utilization. Specific applications of Internet of things technology include intelligent bus, sharing bicycle, Internet of vehicles, charging pile monitoring, intelligent traffic lights and intelligent parking [1] [2].

3) Intelligent Security

The intelligent security guard can realize intelligent judgment through specific equipment. At present, the intelligent security system can transmit, store and analyze the images captured by surveillance cameras.

4) Smart Energy and Environmental Protection

The Internet of things technology is applied to the networking of traditional water, electricity and light energy equipment [1] [2]. Through monitoring, the utilization efficiency is improved and the energy consumption is reduced.

5) Intelligent Medical Treatment

Internet of things technology can effectively help hospitals to realize intelligent management of people and things. Intelligent management of people refers to the monitoring of people's physiological status data (such as heart rate, physical energy consumption, blood pressure, etc.) [1] [2] through sensors, mainly referring to medical wearable devices, which record the acquired data into electronic health documents for personal or doctor inspection. In addition, through RFID technology, medical equipment and articles can be monitored and managed, thus medical equipment and supplies can be visualized [1] [2].

6) Intelligent Building

At present, smart buildings are mainly embodied in energy conservation. By sensing, transmitting and realizing remote monitoring of equipment, they can not only save energy, but also reduce the operation and maintenance cost of building personnel.

7) Intelligent Manufacturing

The concept of intelligent manufacturing is very wide, involving many industries. It is mainly reflected in digital and intelligent factory transformation, including the monitoring of factory machinery and equipment as well as the environmental monitoring of factories. By installing corresponding sensors on the equipment, the equipment manufacturer can monitor, upgrade and maintain the equipment remotely anytime and anywhere [1] [2].

8) Smart Home

Smart home refers to using different methods and equipment to improve people's living ability and make the family more comfortable, safe and efficient [1] [2]. The Internet of things is applied in the field of smart home. It monitors the location, status and changes of household products, analyze their changing characteristics, and give feedback to a certain extent according to the needs of people.

9) Intelligent Retail

The Internet of things technology can be used for near and middle-distance retail, and is mainly used for near field retail, namely unmanned convenience stores and vending machines [1] [2]. Intelligent retail creates an unmanned retail model by upgrading and reforming traditional vending machines and convenience stores digitally.

10) Intelligent Agriculture

IoT technologies helps to create new agricultural production mode with information perception, accurate management and intelligent control of the production process [1] [2] realizing multiple functions such as visualized agricultural diagnosis, remote control and disaster warning.

1.3. Value Proposition

In the era of information explosion, the internet of things exerts a huge influence on economic and social development, which improve the operation mode of various social activities by realizing real-time information transmission between people and things, promote social and economic value, and continuously improve the efficiency of economic activities in all aspects. It enables people to instantly access all kinds of information to make decisions better and faster [1] [2].

1) The Internet of things has spawned a new IT industry. Software services are not only for people, but more for things, such as industrial software for intelligent manufacturing scenarios. Electronics are no longer orphans, but interoperable and intelligent devices. At the same time, the real-time, reliable, multi-dimensional, credible and massive data generated by the Internet of things has

promoted the rapid growth of big data, artificial intelligence, cloud computing, VR/AR and other emerging industries. On the contrary, without the in-depth application of the Internet of things, big data and artificial intelligence will lost their meanings.

2) The Internet of things has transformed traditional industries. The Internet of things promotes the transformation of traditional industries to digital and intelligent ones. Almost all industries, products, production and marketing will turn to intelligence and automation in the future. Intelligent factory promotes the transformation from extensive production to intensive, green production.

3) The Internet of things creates an intelligent society. The Internet of things not only strengthens the connection between people through the sensory wearable devices, but also connects people with things, things with things, machines with machines, forming new social ecology such as smart city, smart community, and digital family. The Internet of things and social services have improved social governance and public services, such as smart street lamps and smart parking, to provide better public products.

1.4. Objective

In this paper, our aim is to design a uniform parcel delivery system in a smart city which can offer service to all kinds of customers in the city including manufactures, department stores, restaurants, individual people and so forth. It is capable of delivering a wide range of parcels from small objects like papers and documents to large objects like furniture and household appliances. On top of that, this system is also able to meet the demand for different parcels like priority and strict storage condition. And by regarding the city as a whole, this system can perform the delivery more efficiently and save both material resources and manpower resources. At last, Due to the difficulty of testing it in reality, our project is only a preliminary design and a view of the picture of future.

1.5. Advantages & Novelty

This new uniform parcel delivery system excels existing scattered systems in the following ways. 1) First, since every aspect in parcel delivery like the storage management, delivery arrangement, vehicle scheduling and parcel tracking are planned and monitored by the System via multiple sensors, the whole process will be secure, transparent and well organized. 2) Second, unlike the current situation that each parcel delivery company develops independent systems and delivers parcels using their own transportation resources, if this system described in this paper were put into practice, all parcels could be delivered via a uniform smart system in a centralized way, which will significantly reduce the overall money and time expenditure. 3) Finally, sensor data and delivery history stored in the central database can be further used for the system to make predictions about the customer demands and market distribution, which will contribute to the sustainable development.

2. Methods and Challenges

2.1. Methods

In order to have a thorough understanding of the current logistic system and to seek more inspirations for our system design, we did online researches to collect data about the current Chinese express market and managed to make individual surveys on two couriers after receiving their permissions.

2.1.1. Online Research

We did researches about the populations, delivery business amount and GDP in different provinces in China. By comparing these statistics, we drew conclusions on the reasons for the diversities.

In 2017, Shanghai Province had permanent inhabitants of 24.1833 million [3], GDP of 3013.386 billion Yuan [4] and delivery business amount of 1604.366 million [5]. In the same year, however, Sichuan Province had permanent inhabitants of 83.02 million [3], GDP of 3698.02 billion Yuan [4] and delivery business amount of 628.643 million [5]. It is true that economy played a part in the tremendous difference in delivery business amount, but we believed transportation factors were even more crucial. Shanghai Province lies in the east coastal areas of China where the terrain is flat and the transportations are well-developed. In contrast, Sichuan Province lies in the Sichuan Basin. Surrounded by high mountains, Sichuan is much harder to reach than Shanghai. As a result, the transportation costs differ on a large scale.

To minimize the influence of terrains, this node based parcel delivery system was designed. By setting delivery nodes in different parts in the city and promoting route specialization, this system can greatly reduce the transportation costs within the city. Besides, this node based system is flexible and scalable. Links between nodes are not rigid, which means extra nodes can be added to the existing system easily.

2.1.2. Individual Survey

To further explore the feasibility of our system, we did individual surveys on two couriers from SF Express and STO Express respectively. Investigations were made on their daily works and routines. Their works were basically composed of the same three parts: parcel pick-up (collecting parcels from branch companies), parcel delivery (delivering parcels to the customers) and information report (reporting accomplished transactions using a dedicated device).

Through the analysis of each of these three parts, two potential problems in the traditional process of parcel delivery were found. First, the arrangement of their routes was mostly based on their own experiences, which means an experienced courier can deliver much more parcels than a novice. Second, as different logistic companies ran their own businesses, the number of parcels delivered by couriers from different companies vary tremendously, causing huge lose to both the couriers and the companies.

These problems actually can be solved by system and node sharing, which is

the basic idea of our system. By sharing the delivery nodes and the information system, routes can be arranged in a centralized way and parcels can be stored and delivered in the shared delivery node, which will greatly reduce the time and money expenditures.

2.2. Challenges

There are three main challenges for designing this system, which are large scale, complexity and high analytic skill demand.

Complexity:

In modern society, the wide range of different kinds of parcels and their strict storage requirement is beyond our imagination. For example, some fresh food need to be stored in a very low temperature during the transportation which requires us to have precise control of the temperature to not be too high to damage the food or too low to waste the energy. In addition, there are always some emergent parcels that demand this system to achieve the delivering within a very short time. How to deliver them separately and how to expedite the whole transportation process is a huge problem.

Large Scale:

The main characteristic of cities is their large population which therefore leads to a large number of parcels need to be delivered everyday or even every hour. The ability to deal with such a large scale of parcels is extremely important and can also bring new problems like how to manage so many couriers and vehicles at the same time and how to coordinate many different local departments.

High Analytic Skill Demand:

As we all know, some cities especially those large ones can be filled with cars. In such a bad road condition, how to design the appropriate route to avoid the congestion become very difficult and it would require a complete and efficient information collecting system that put high demand on sensor distribution.

3. Results and Discussions

3.1. Topology

The IoT based logistic system use Delivery Centers as transportation nodes to support parcel storage, switching, distribution, vehicle arrangement and inter-node connection. These Centers are inter-connected by all kinds of vehicle from traditional trucks, trains to advanced autonomous cars. The system manages parcel flow among all the Delivery Centers, using the information collected from sensors, database and other sources to control every aspects of parcel delivery (**Figure 1** and **Figure 2**).

3.2. System Description

Based on RFID, GPS and multiple kinds of sensors, we design a heterogeneous parcel delivery system which includes comprehensive functions such as parcel identification, delivery service, transportation tracking, route arrangement and

so on. The system mainly consists of three inter-related systems, the Parcel Identification System, the Central Information System and the Transportation System (Figure 3).

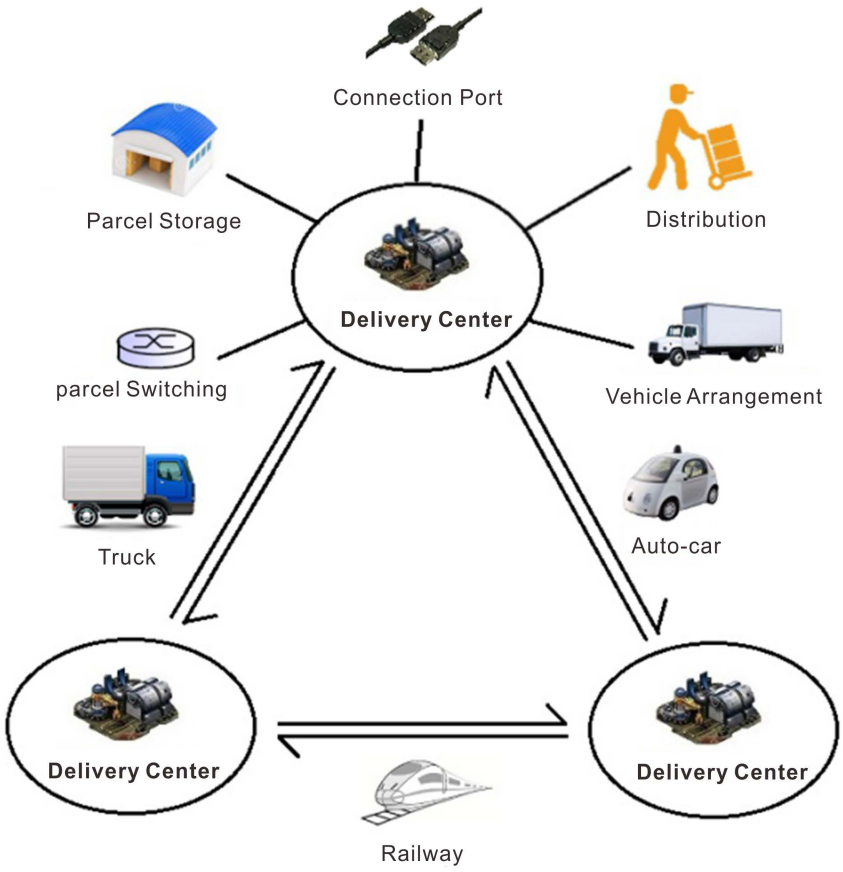

Figure 1. System topology.

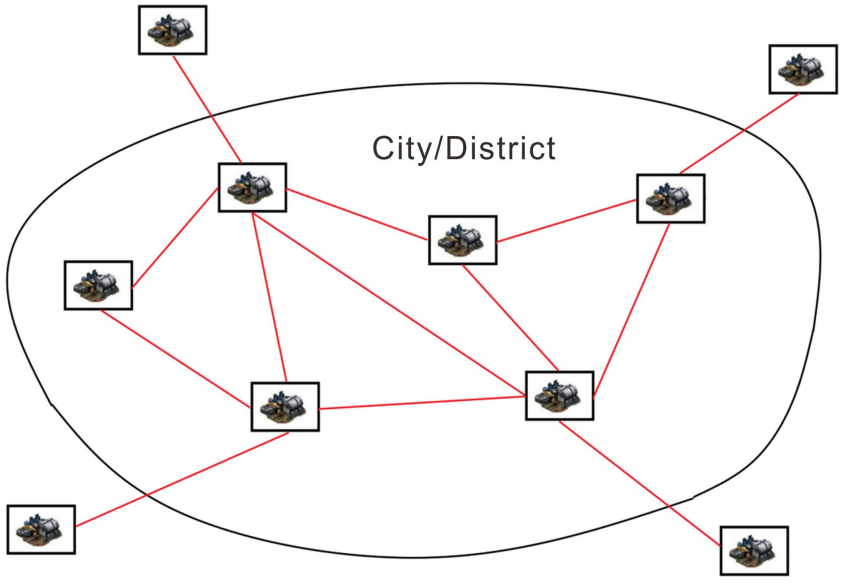

Figure 2. Physical distribution.

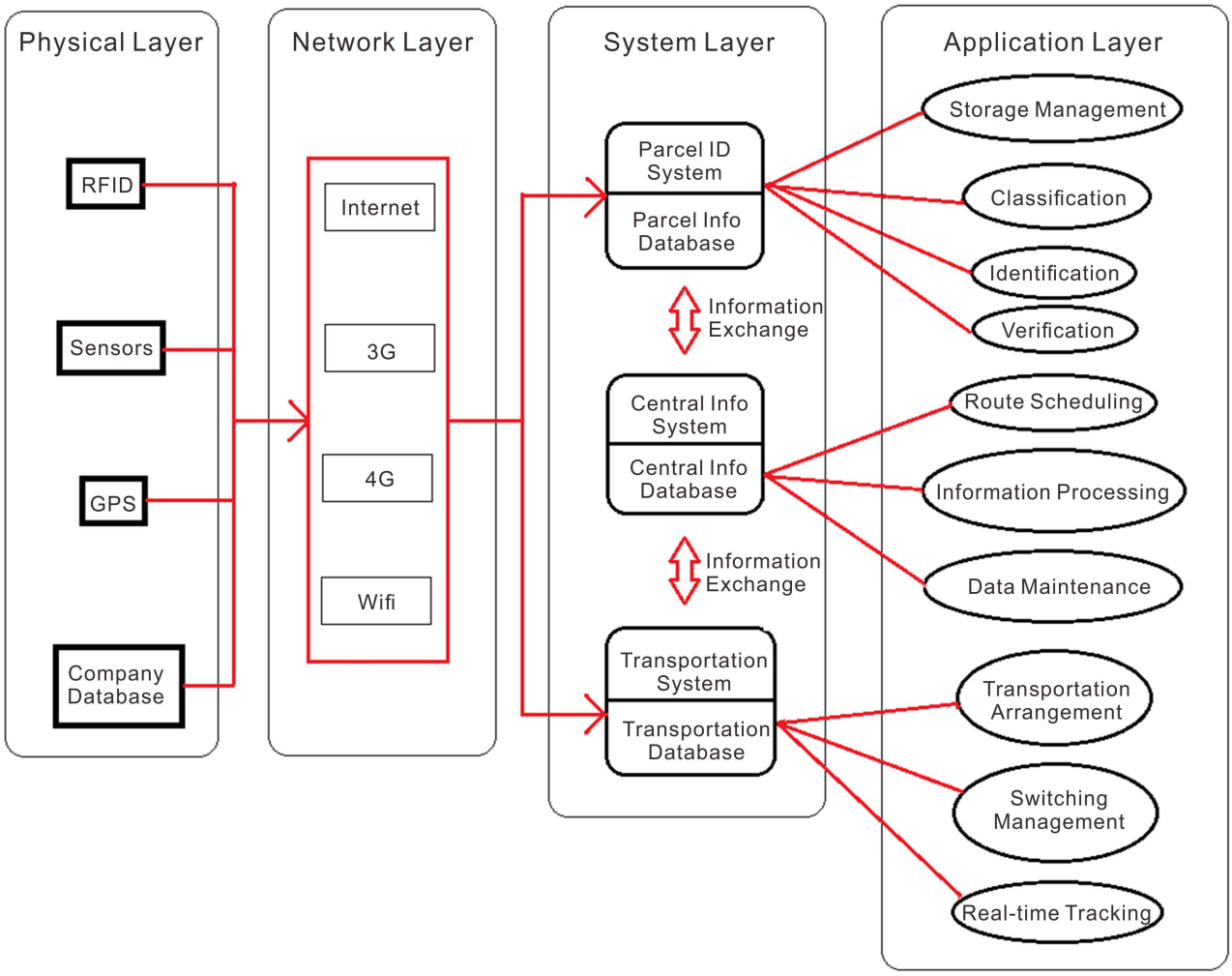

Figure 3. Subsystem function and information process.

3.2.1. Central Information System

The Central Information System (**Figure 3**) can be analogized to the CPU of a computer. It receives information from the other two systems, stores the information into Central Database, analyzes the information and gives feedback to the other systems or users. By collecting data such as the parcel collecting, transportation resources from the Parcel Identification System and the Transportation System and analyzing them in an integrated way, not only is the system able to monitor the parcel delivery in real time, but it can also give specific suggestions on various aspects like route navigation, parcel switching, time estimation and so on.

3.2.2. Parcel Identification System

The Parcel Identification System (**Figure 3**) consists of the Parcel Information Database and the management system. The Parcel Identification System provides a data transfer interface and establishes uniform standards to distinguish different parcels. Parcels are registered and categorized into diverse classifications according to their types, priority, and destination. Based on RFID, the system

assigns a tag with a unique electronic ID to each parcel and the information is stored in the Parcel Information Database. Whenever there is an order, the system will check the inventory catalog and then send the tag information to the Central Information System to bind with a courier or vehicle. Unless being transferred to another courier or received by the customer, the binding will not be modified or disappear, which guarantees the security of delivery process.

3.2.3. Transportation System

The Transportation System (**Figure 3**) serves as the basis for delivery planning and vehicle arrangement. Transportation resources such as the number and capacity of vehicle, road conditions are recorded and updated in real time, which will be further analyzed for transportation arrangement. With the help of GPS and other motion sensors, information about vehicle involved in parcel delivery such as velocity, acceleration and location will be recorded in the Transportation Database and the information will then be used for parcel tracking, route navigation and so on. Transportation history will be sent back to the Central Information System to guarantee the security and transparency of the delivery process. Besides, all varieties of sensors like the RFID sensors, temperature sensors and humidity sensors are deployed to detect the conditions of the parcel. With the Transportation System, all aspects in every procedure of transportation will be under monitor.

3.3. System Procedure

Based on this system, the process of parcel delivery (**Figure 4**) basically includes four phases, the Parcel Collection Phase, the Concentrated Transportation Phase, the Distribution Phase and the Final Phase.

In the Parcel Collection Phase, items are first wrapped into parcels and transported to the local Delivery Center. Then these parcels are labeled with unique RFID tags and registered in the Parcel Identification System. Relevant data such as the item type, priority and destination are stored in the Parcel Information Database. In the Concentrated Transportation Phase, all stored parcels are re-classified according to their attributes like priority and destination and loaded on different vehicle. The system figures out the best routes, gives specific instructions on parcel transfer and records the delivery history. Parcels will be transported and switched to different nodes and finally reach the Delivery Center in the destination area. In the Distribution Phase, couriers take the parcels to the destination addresses and the parcels are signed by the receiver. In the final phase, after the parcel is received and signed by the customer, the System will erase personal data such as phone number, home addresses to prevent personal information leakage.

3.4. Enabling Technology

1) RFID

RFID stands for Radio-frequency identification, it is defined as the wireless

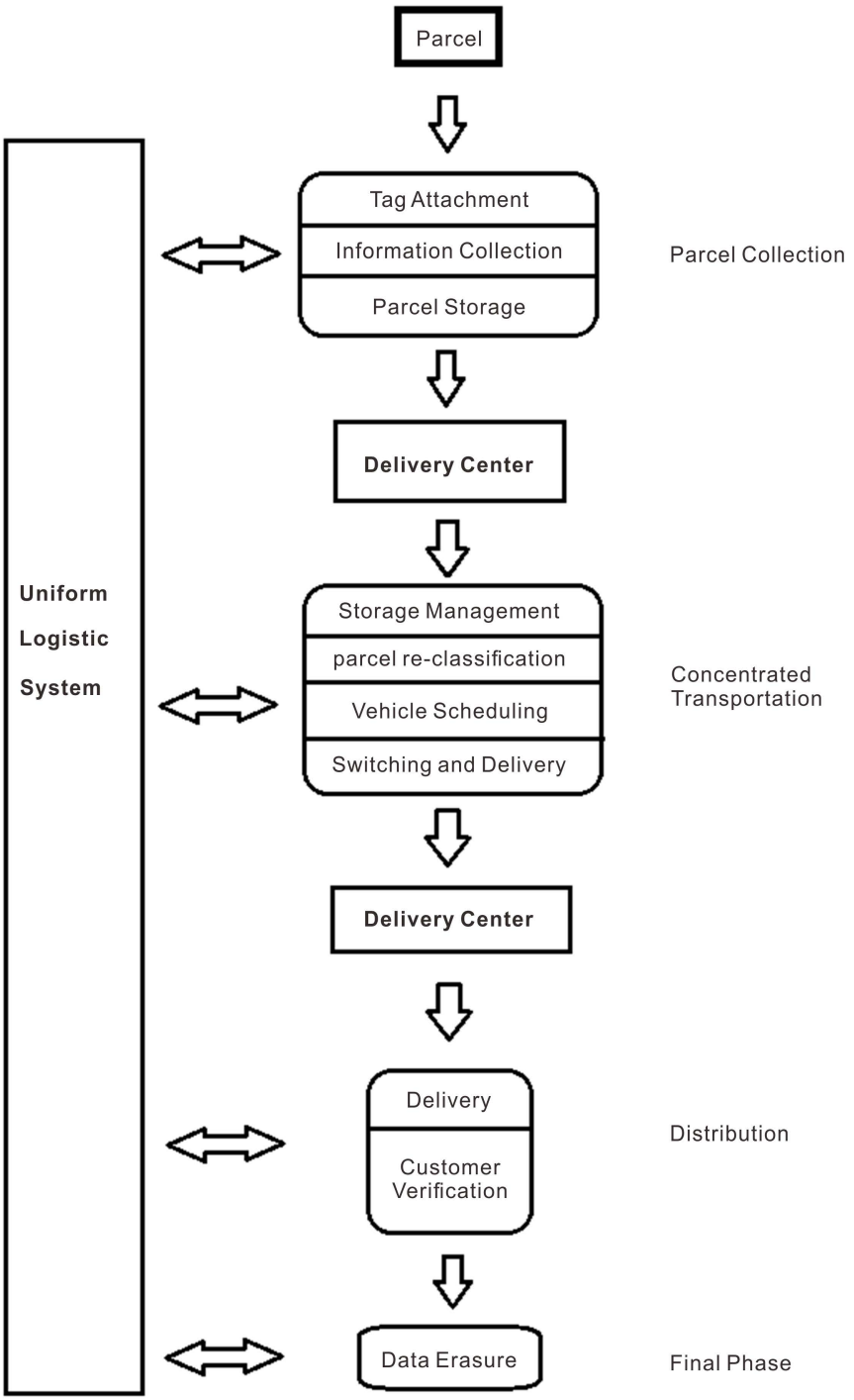

Figure 4. System procedure.

and automatic identification and capture of product identification data, which uses electromagnetic fields to automatically identify and track tags attached to objects. The tags contain electronically-stored information. RFID technology may use both powered and non-powered means to activate the electronic tags. Passive tags collect energy from a nearby RFID reader's interrogating radio waves. Active tags have a local power source and may operate hundreds of meters from

the RFID reader. Unlike a bar code, the tag need not be within the line of sight of the reader, so it can be embedded in the tracked object. RFID is an effective technology for Automatic Identification and Data Capture (AIDC).

Typically, RFID systems consist of electronic tags, readers, miniature antennas, and information processing systems [2].

a) Electronic tag: a responder, which adheres to the object and stores the information of the object to be recognized.

b) Reader: also known as scanner, it can send radio frequency signals, scan electronic tags and obtain data. The reader comprises a high frequency module (sender and receiver), a control unit, a coupling element connected to an electronic tag, and an interface for data transmission with a Pc or other control device.

c) Miniature antenna: it transmits radio frequency signals between electronic tags and readers.

d) Information processing system: that is, computer system. In practical applications, RFID systems store electronic tags with agreed formatted data and attach them to the surface of the object to be identified. The reader sends out radio frequency signals with a certain frequency through the antenna. When the electronic tag enters the range of inductive magnetic field, it is activated to generate inductive current, which can obtain energy and send information. The identified information is then sent to the main computer system for related data information processing.

RFID is widely applied into the logistic and transportation field. This can be used with a database to identify multiple characteristics such as the origin, destination, weight etc. of the packages being carried. RFID technology enables precise tracking and real-time monitoring of each tagged item with minimal effort.

Through utilizing RFID to realize information collection and real-time monitoring, we can greatly improve the automation of the parcel distribution link, greatly reduce the error rate, as well as significantly improve the transparency and management efficiency of this parcel delivery system.

2) Sensors network

A sensor is a device, module, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics. Sensors are like the "five senses" of the Internet of things, and are used to gather information and convert it into specific signals, they can collect a variety of information of goods such as identity, motion status, geographical position, attitude, pressure, temperature, humidity, light, sound, smell and other information.

During the delivering process, the feedback of packages being carried need to be collected in real-time and sent to the central processing system to inform users and managers of the condition of packages. All kinds of data collected through the sensors network will be transmitted to the real-time monitoring system of transportation management system via WiFi network through the

interface of data sensing devices and be uploaded to the central data processing system at the same time for cloud computing.

In addition, since there are several different types of packages distinguished in the identification phase. The information and parameters needed for feedback collecting differ from one another. Thus, according to the product code as well as the priority code, which are stored in the RFID tags, packages need to be equipped with correspondent sensors in order to obtain significant information with high accuracy.

There are 7 general classes of physical parameters that are commonly used, namely movement (including type of movement as "being used", "running", "standing still", plus acceleration, rotation and vibration), force (including weight measurements and force attached to various parts of an object), light (in various wavelength like daylight or infrared light including parameters like light level and change over time), temperature (in various places of an object as environment temperature, temperature of an object laying on or filled into the object or temperature of the object itself), humidity (in various places as humidity of the environment or humidity inside the object), audio (including noise level, frequency spectrum but also the changes over time), and proximity/activity detection of the environment [6].

Apart from the common parameters such as movement and force which should be monitored the whole time, for some packages of special kinds, there are also other important parameters need to be taken into account. And sensors that are responsible for particular parameter monitoring need to be more precise and advanced.

To be more specific, for those goods which are easy to spoil such as fresh food and fast moving consumer goods, they need to be delivered fast and under low temperature, thus sensors detecting humidity are important. In addition, for goods that are inflammable or sensitive to environmental changes, such as paper and files kinds and chemical products which should avoid heat and direct sunlight, temperature and light are two extremely important parameters during the delivery which means the corresponding sensors demands higher precision and greater sensitivity. As for those fragile goods, they are easy to get deformation or shattered, thus the force and proximity of goods should be regarded as top concerns.

3) GPS

GPS technology, also known as global positioning system, is a new generation of satellite navigation and positioning system with comprehensive real-time three-dimensional navigation and positioning capabilities of sea, land and air. As a mobile sensing technology, at present, GPS is the most commonly used positioning technology. And it is an important technology that extends the Internet of things to collect mobile object information, as well as an important technology of intelligent logistics and intelligent transportation [7].

In this subsystem, GPS is used to track packages applied with RFID tags, for it

has stable signal connection, high positioning accuracy and wide range. Each express-delivery vehicle is equipped with GPS system to collect real-time position information. And these information will be sent to the central processing system to help driver do route planning and optimization.

3.5. Parcel ID System

3.5.1. Collection

The whole parcel delivery system starts with collecting the parcels from the customers, and it consists of three steps:

1) First Step:

Whenever the customers in this city want to delivery something, they should firstly fill in a form on the system's website to inform the system that there are parcels or goods there need to be delivered.

2) Second Step:

After the system have received this request, and have the all information about the goods based on the form the customers have filled, the parcel ID system can automatically generate a unique identification code for each good and parcel and store these information in the parcel info database. Meanwhile, it will inform the nearest station and make them send out the corresponding vehicles with the drivers and couriers.

3) The Third Step:

When the couriers have received the goods from the customers, they will attach a RFID tag on it which contains their identification codes generated by the parcel ID system and update the real-time state about the parcels in the database of the parcel ID system at the mean time. Then, they will bring them back to the nearest transfer station.

3.5.2. Identification Code

All the information about the parcels will be stored in the form of a code which will be contained by the tags attached on the parcels. The total length of this code is 37 bits and it consists of four different part: a company code of 10 bits length at the beginning that indicate which company this parcel belongs(There is also a special code for those parcels from individual customers in this place), a classification code of 6 bits that tells you what kind of good is in this parcel, a priority code of 2 bits that suggest is this parcel is emergency or not, and finally, a sequence code of 24 bits that includes all the other information of that parcel.

10 bits	6 bits	2 bits	24 bits

1) Company Code

After every company is found in the city, they will be given a unique code that they can use to send their products by this uniform parcel delivery system of the city. The company code is at the beginning as it indicates which company this parcel or good comes from. Besides, there will also be a special code filled in this

place if this parcels is from individual customers. Therefore, after all the parcels have been assembled, the first thing to do is to give each of them a company code to represent their companies, and when couriers want to know about detailed information other than those about the transportation, they need to reach the database of its own company.

2) Classification Code

The classification code includes the information about which category the item belongs to. When we have many parcels, one very important thing to consider is how to classify these parcels. To increase the efficiency in the delivery and transportation, a very good method is to separate different kinds of parcels and divided them into different groups. In this way, those parcels demanding conditions to delivery can be transported together while the courier can pay more attention to avoid causing damage. Meanwhile, those parcels which are very easy to delivery can also be put together to suggest that the courier need not to be so careful during the delivery and they can expedite their process. To be specific, this parcel delivery system will classify the parcel into following different groups:

- Paper and Files:

Paper and files are kind of good that is very convenient to delivery, they won't take up much space and has a very low weight. Because of these characteristics, assemble them together when delivering can save us lots of time. Meanwhile, these kinds of good also require some specific storage condition: they need to be store in a dry place to avoid getting wet during the delivery. If there are no specific request, the deadline of the delivery for this kind of good is 1 day.

- Fresh Food:

Fresh food means the kind of food which is easy to corrupt, need to be transported in a certain low temperature, require a high delivery quality and a fast delivery speed. The fresh food mainly includes fruits, seafood, fresh meat, chilled food like ice scream and other food needs to be stored in the similar environment. Due to the specialty of this kind of food, they will be separated from other parcels and delivered together. Finally, the deadline of delivery of this kind of good is 5 hours.

- Fast Moving Consumer Goods:

The fast-moving consumer good is another kind of goods that require to be delivered fast. As indicated by its name, the fast-moving consumer good is those goods that have a very short lifetime and a very high usage frequency, both of which suggest that we need to reduce the delivery time, reduce the delivery cost and increase the delivery scope. And those goods lie inside this category are personal nursing materials, drinks and food, cigarette and alcohol, health care products and OTC. The deadline of delivery of this kind of good is also 5 hours.

- Fragile Goods:

Fragile goods include glass products, porcelain and pottery. These products are very easy to be broken and therefore, need to be contained in some special

parcel for protection. Besides, couriers also need to be extremely careful when they are moving these products and slow done the speed during the transportation. The deadline of delivery of this kind of good is normally 1 day.

- Take-Out Food:

The take-out food means those kinds of food we order for lunch or supper from the restaurant. Because that everyone wants to get their meal as fast as possible and to avoid the food becoming cold, it is necessary for us to delivery this kind of good very fast. Therefore, the deadline of the delivery is limited to 1 hour.

- Furniture and Big Household Appliances:

For furniture and big household appliances, they are usually very bid and heavy and some of them can be extremely easy to get scratched. Thus, the courier to send this kind of good has to be young and strong enough. On top of that, these kinds of good are normally required to be sent directly to the customers' house to save their troubles. The deadline of this kind of good is 2 days.

- Other Normal Parcels:

Other normal parcels from customers that don't have some special requirement during the delivery and don't need to be sent very quickly will be put in this category. The deadline of the delivery of them is 1day.

3) Priority Code

It is quite usual in the modern city that some emergency happens, and the addresser want to send a parcel to someone very quickly. Under this circumstance, the system proposed in this paper can speed up the delivery of their parcels but with some extra charges. Normally, the delivery time of normal parcels is one day, but for those emergence parcels, it can be reduced to 1 hour by some special methods. For example, the courier can send out these parcels first, reduce the rest time, choose the faster vehicles and make use of the time at night. According to the emergency level of each parcel, this parcel delivery system will divide their priorities into following different groups:

- First priority:

This is for those parcels that are in extremely emergency. We shall immediately send out this kind of parcels and try our best to send them to the receiver's hand within 1 hour.

- Second priority:

The parcels in this priority are not so emergent but still, their addressers want them to be delivered fast. Therefore, the courier will send out this kind of parcels first compared with other normal parcels without specific request. And the deadline of delivery of parcels with second priority is 5 hours.

- Third priority:

All other parcels that don't have strict demand on the delivery speed have third priority. For this kind of parcels, we will deliver them according to the category they are in.

4) Serial Code

At the end of the parcel code is a serial code which is unique for every parcel

in one company and for individuals, which means that at any time, no two parcels in one company or from individual customers can have the same serial code. After the one parcel has been successfully delivered, the delivery company will delete its serial code and give it to the next one. The serial code doesn't have the information about their parcels themselves, but it can serve as a link to the address of the database of their company or a special database for individual customers that contains all the other information about their parcels including weight, size, addresser's address, destination address, addresser cell-phone number, receiver's cell-phone number, addresser name, receiver name and the detailed information about what good is in that parcel. To give every single parcel in one company and every parcel from individual customers a unique serial code, the length of this code should be relatively long. Therefore, the length of the serial code is 24 bits so that the total number of parcels it can identify is about 16 millions.

3.5.3. Smart Warehouse System

After we have assembled the parcels and goods at each local transfer station, there should be a temporary storage step for the system to further process the information and do the classification and loading according to their priority (**Figure 5**). Besides, this step is also necessary to manage the parcels in a well-organized way. Every local area transfer station in the city will have its own warehouse and their smart warehouse system have the following main function [8]:

1) System Database:

Every smart warehouse system has its own database to store the information of the parcels in this station. Meanwhile, it also records the real-time state of each parcel.

2) Monitoring Management:

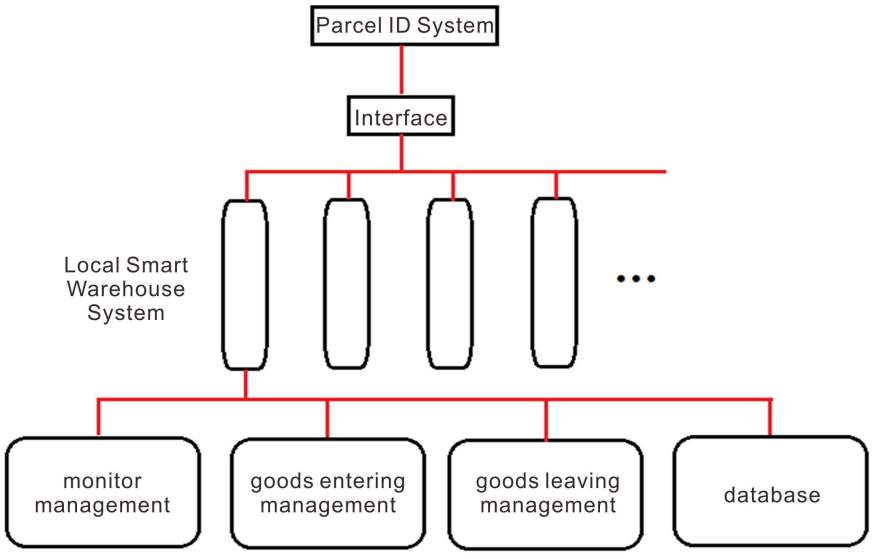

Figure 5. Parcel ID system.

The RFID readers put on the gateway of the warehouse can read the information in the tags embedded in the parcels and exchange it with the smart warehouse information system. It will send the information about the parcels to this system through Wi-Fi, and then the smart warehouse information system can automatically judge if this parcel is entering the warehouse of leaving and do the corresponding management and information processing.

3) Management for Goods' Entering the Warehouse:

When the goods are entering the warehouse, the smart warehouse system will automatically find the appropriate and idle place to store the goods with their kinds, update their information in the database and do the add function to the number of goods in this location and category. The classification procedure is also done in this process.

4) Management for Goods' Leaving the Warehouse:

When the goods are leaving the warehouse, the smart warehouse system will delete the corresponding information in the database and do the subtraction operation to the number of goods of this location and category. After that, it will automatically send the goods to the location of the vehicles for their kinds and destination address based on the order from parcel ID system. Meanwhile, it will also inform the corresponding couriers who are responsible to send these goods.

5) Interface with the Parcel ID System:

Every smart warehouse system has an interface between the parcel ID system and can exchange their data through this interface. It will send the information of the goods of each local warehouse to the parcel ID system and receive the orders about when to send out the goods and to what kind of vehicles they should send.

3.5.4. Parcel Check and Acceptance

The last step of this whole delivery procedure is the parcels' check and acceptance after the parcels have arrived at the destination. There will be a receive box of different size at each house, department and the warehouse with a RFID reader embedded in it. When the drones automatically drop the parcels in these boxes or the couriers put them in these boxes, the RFID reader will automatically read the information about the parcels and then update the corresponding real-time state of this parcel stored in the parcel ID system through the 4G. After the parcel ID system get informed of the arrival of each parcel, it will still remain its information in the database for 1 day in order to deal with some accident such as parcel damages and make compensation. After 1 day, the parcel ID system will delete all the data about the parcels in its database and give the serial code to the next parcel.

3.6. Transportation System

Transportation tracking system (**Figure 6**) plays a significant role in the uniform parcel delivery system. This system is responsible for intelligent and automatic shipping management. It combines GPS technology, RFID technology

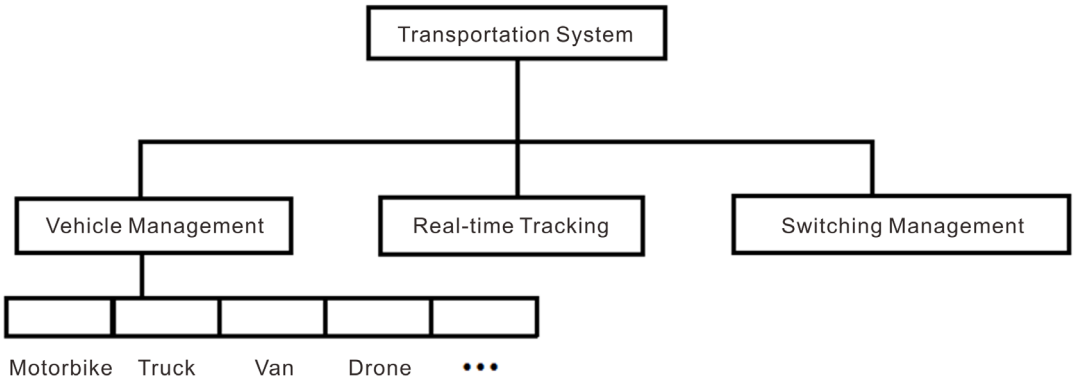

Figure 6. Transportation system.

and geographical information with intelligent algorithms to realize switching management, real-time tracking and vehicle scheduling to ensure optimized transport scheme.

In this system, all the information sensing devices connected to the system send sensory data to the server on a regular basis through the 3G/4G network according to the actual monitoring requirements. TCP/IP communication mode is adopted between the devices and the server. The server receives a perceptive packet by listening on a specific port.

3.6.1. Vehicle Management

One of the most important functions of transportation system is to manage all kinds of vehicles. All the vehicles of this system will be parked in each local delivery centers and their distribution will be depend on the amount of parcels at each area. Meanwhile, the delivery system will do the vehicle maintenance and can automatically decide what kind of vehicles to use according to the category and priority level of the parcels. Main types of vehicles in this system are as follows:

- Motorcycle:

For those parcels require a very fast delivery speed and high priority level or some take-out food which needs to be delivered very fast. The system will use the motorcycles to transport them as it can avoid congestions and can be more flexible.

- Truck:

The truck is used in the most of case in this system. For those parcels which do not require an especial condition or a high delivery speed, they will be transported by trucks as trucks have a much bigger space and can contain lots of parcels at the same time. Besides, trucks are more suitable to carry large size of parcels.

- Van:

Van can be used to delivery those small parcels which do not need a large space. Because its small size, it can be more flexible compared to trucks.

- Drone:

Drone is used to delivery very light parcels which are of highest priority, such as human organs delivery to hospital under emergency. It can save lots of manpower resources as it can automatically delivery the parcels without couriers. On top of that, drone can also be used to avoid the congestion on the road.

- Electrical Car:

Electrical car uses the electric energy to replace the gas and thus can save much cost and protect the environment on a large scale. However, the drawback of this kind of vehicle is that it takes time to recharge its battery at each delivery center which would take lots of time and sometimes even many hours. Therefore, it is used to perform delivery task that is not so urgent.

3.6.2. Real-Time Tracking

As for the real-time monitoring of packages during transition, GPS positioning System is utilized to automatically collect Information, so as to realize the real-time monitoring of delivery of goods transportation and dynamic vehicle routing planning. The transportation monitoring subsystem adopts the UHF (Ultra High Frequency) identification method to realize the binding between passive RFID tags and transportation vehicles locale measurement and control points [8].

RFID measurement and control points are set up in the transportation area. When vehicles pass the RFID reader, the information in those tags is automatically recognized by the reader. The reader then uploads information stored in tags to the transportation management system application software through the Internet of things platform, so as to realize monitoring the flow of packages transportation. When the retention time of parked vehicles in the monitoring area is too long, an alarm will be issued to remind the manager to recycle the vehicles to ensure the delivery capacity. Combined with real-time perceptive data, it provides online tracking and monitoring service for vehicle driving condition and transportation environment, realizing monitoring and warning of transportation process. Based on orders and electronic map, package delivery can be tracked throughout the whole process, providing users with statistics collected by sensors such as starting point, driving route, duration, temperature and humidity curve and extreme value throughout the whole process of delivery.

Those collected data will be sent to the Central Information Processing System (CIPS) simultaneously so that managers and customers can know the position of the goods accurately as well as know whether there are damaged goods according to the feedback, which can ensure that the goods will reach the destination on time and in good condition.

3.6.3. Switching Management

After receiving the instructions from the central system, the transportation system can do the following switching management according to the designed route. Every deliver center have many adjacent deliver centers, whenever a vehicle arrives a deliver center, it will be fully loaded again and then be switched to

the next deliver center on the route. Besides, if the destination address and source address is very close, the vehicles will not go to any deliver centers but directly send parcels from the source address to the destination address.

3.7. Central Information System

3.7.1. Central Information System Introduction

Central information system is a virtual central in the network and only responsible for calculation, analysis and planning. As one of the three systems in the big system, central information system is connected to the parcel identification system and transportation system. The parcel identification system can collect information and provide these data to the central information system. When the information of the parcel comes from database of the parcel identification system, the central system will start to work. The data analysis procedure will proceed in the internet efficiently and the result of the analysis will be transmitted to the transportation system, which includes the parcel route planning, parcel route transferring, customer demand forecast and so on. Through the analysis of the transportation networks, the central information system will get the latest situation of the delivery system and make the best adjustments. In fact, the delivery system will unite many current companies and use their resource to achieve a bigger goal and improve the delivery industry together. The central information system can be implemented with direct access, after the security management and authorization, users can access the central system with virtual machines, virtual applications or web service-based systems [9]:

1) Virtual Machines

Virtual machines refer to a special in of software that can create an environment between the computer platform and the end of user, who will operate the software based on the environment created by the software. Virtual machines can be controlled and deployed on demand by users by implementing the systems on the virtual machines in the central system.

2) Virtual Applications

The central system can be accessed through virtual applications on the internet without the limitation of operating systems or computers.

3) Web Service-Based Systems

Web Service technology enables different applications running on different machines to exchange data or integrate with each other without the need for additional, specialized third-party software or hardware. Applications implemented under the Web Service specification can exchange data with each other regardless of the language, platform, or internal protocol they use. Web services are also easy to deploy because they are based on common industry standards and existing technologies, such as subset XML and HTTP under the standard common markup language. Web services provide a common mechanism for the integration of business processes across an enterprise or even between multiple organizations.

3.7.2. Mesh Networks and Internet

Wireless mesh networks (WMNs) have developed and play an important role for next-generation wireless networking. Now wireless mesh networks can be applied in many fields, including the parcel delivery field. The core of WMNs is to let every node in the network send and receive signals, which solve the problem of low scalability and transmission reliability of ordinary wireless technology in the past. In the network, many terminal devices can automatically connect to the network structure through wireless. Each node in the network has the function of automatic routing, and each node only communicates with its neighbor nodes. Therefore, it is a self-organized and self-managed intelligent network, which can build a flexible network without the backbone network. The traditional wireless communication network must be designed and arranged in advance and its transmission path is fixed, while the transmission path of mesh network is dynamic [10].

3.7.3. Data Analysis

1) Significance

Many companies have accumulated a large number of data after operating for many years. These data from enterprises like a buried treasure, and through analyzing these data can provide enterprises with a lot of valuable information. For example, the operation data of all vehicles in the company, such as GPS positioning and tracking data, vehicle driving time, driving distance and completed tonnage kilometer number can be analyzed and find out the internal laws to carry out delivery planning more effectively. Data analysis, of course, has far more potentials in the parcel delivery system.

2) Data Analysis Hierarchy Model

We use data analysis hierarchy model to help deal with the huge amount of data better. The data that central information system will use to analyze is come from the identification system database and transportation system database. These data will send to central system database firstly and be divided into two layers:

- Basic Resource Layer:

In this layer, the data to be collected are mainly human resource data, equipment resource data, cargo location resource data, container resource data and so on. Resource-level data is mainly used to describe the properties, quantity and state of various resources in the delivery center.

- Delivery Process Layer:

In this layer, the data to be collected are mainly data of several processes, including data of the receiving process, data of the delivery process, data of the car delivery process, data of the store return process, data of the supplier return process and so on. The data in the delivery process layer is mainly used to describe the operation of the process. The data that needs to be collected includes the objects, processes, inputs, outputs and so on of each process.

3) The Data Analysis Model

In the central information system, the data from different layers will be used play different roles. The data analysis model is divided into two parts, the data analysis platform part and the data part. The data analysis platform can be an independent analysis tool or a software and the core is to provide a tool for data computing. The data part includes basic data center and delivery process data center. In the data part, each data center contains several data sets. The platform can invoke the data set independently or invoke the data set comprehensively to form a multidimensional data view, so the selections are diversified.

3.7.4. The Transportation Dispatch System

The transportation dispatch system will be used to issue relevant delivery information to the airborne system and the selected optimal delivery route to the driver for guidance. With the help of communication network, this subsystem carries out transportation scheduling command through the airborne system, providing guidance for vehicle transportation tasks.

According to the information of packages in each pallet, the corresponding pallet transportation schemes are determined, and the routes of different vehicles are then automatically planned to complete the intelligent allocation and route selection of vehicles. Based on the delivery routes and distribution of orders, combined with real-time traffic network data, it provides optimization services for drivers in the shortest time, shortest path, minimum cost and other optimization ways, so as to improve the delivery efficiency.

3.8. Privacy and Security

This system is a uniform parcel delivery system that delivers all the parcels in the whole cities. During the process of delivering, it inevitably needs lots of private information from a huge number of customers such as their addresses, names, cell-phone numbers and so on, which makes the information and data protection a very big issue. Therefore, this system will use three methods to make sure that the privacy information from addressers can be prevented from stolen.

1) Information Hidden System

Unlike other existing parcel delivery system, this new system proposed in this paper won't direct write the information about the parcels and their owners on the packaging. Instead, it will store all the information in their RFID tags and only the couriers who need this information can use the corresponding readers to read them, otherwise, this information can be properly protected.

2) Information Access Control

Among all the information of one parcel, there are some that only related with the transportation and delivery parts and others that directly indicate the personal information about the addressers and receivers. For the former kind of information like classification of the goods and the priority of the parcels, they can directly read by any readers in this system and thus can significantly increase the delivery efficiency. For the latter kind of information, they will be put in the database of each company or the database of the individuals and the serial code in

tags can point to them. On top of that, there will be a very strict access control system between the RFID readers and these databases. Only the readers from this parcel delivery system on parcels' necessary routes have the access authority. Furthermore, even for those readers who have the access authority, they can only read the information about the destination address and cannot read other information like the name and cell-phone number of the receiver. At last, this personal information can only be got by the courier or devices who are responsible to directly deliver the parcels to the receivers' hands.

3) History Record Clearance

After each parcel has been successfully delivered, the system will get noticed and automatically delete any information and data about this parcel and its owner. Therefore, the possibility of personal information leakage can be significantly reduced.

4. Conclusion

Based on technologies such as RFID, IoT and cloud computing, this smart system provides a uniform interface for parcel delivery service including storage management, parcel distribution, transportation arrangement and so on. By treating a city as a whole, it integrates every aspects of delivery process in this city from the beginning such as sales companies to the end which are customers and is capable of delivery every different kinds of parcels like fresh food and household appliances from different clients. Moreover, the priority levels and storage demand can also be satisfied according to the type of parcels and demand of customers. With this system, every people, companies and suppliers can deliver parcels to the destination in a more convenient and secure way.

Acknowledgements

We would first like to thank my thesis advisor Professor Fouad Tobagi of the Department of Electrical Engineering at Stanford University. Prof. Tobagi was always willing to offer a hand when we ran into a trouble or had questions about our research or writing. He consistently gave us precious suggestions to steer us in the right direction.

We would also like to thank the Cathaypath Institute of Science (CIS) for providing us the chance to take part in the summer research sessions. Without the passionate participation of the teachers and TAs, the research could not have been successfully conducted.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Atzori, L., Iera, A. and Morabito, G. (2010) The Internet of Things: A Survey. *Computer Networks*, **54**, 2787-2805. https://doi.org/10.1016/j.comnet.2010.05.010

[2] Minerva, R., Biru, A. and Rotondi, D. (2015) Towards a Definition of the Internet of Things (IoT). *IEEE Internet Initiative*, **1**, 1-86.

[3] China Commercial Industry Research Institute (2018) Population Growth List of Provinces and Cities in 2017. (In Chinese) http://www.askci.com/news/finance/20180320/115408120108.shtml

[4] China Commercial Industry Research Institute (2018) GDP Data of 20 Provinces and Cities Released in 2017. (In Chinese) http://www.askci.com/news/finance/20180124/112309116741.shtml

[5] China Commercial Industry Research Institute (2018) List of Express Business Volume of 31 Provinces and Cities in the First Half of 2018. (In Chinese) http://top.askci.com/news/20180718/1015001126164.shtml

[6] Beigl, M., Krohn, A., Zimmer, T. and Decker, C. (2004) Typical Sensors Needed in Ubiquitous and Pervasive Computing. *Proceedings of INSS*, 22-23.

[7] Grewal, M.S., Andrews, A.P. and Bartone, C.G. (2013) Global Navigation Satellite Systems, Inertial Navigation, and Integration. John Wiley & Sons, Hoboken.

[8] Zheng, J.S. and Meng, W. (2015) Design and Application of Coal Mine Intelligent Storage and Logistics Transportation Management System Based on Internet of Things. *Industry and Mine Automation*, **41**, 108-112.

[9] Chen, S.L., Chen, Y.Y. and Hsu, C. (2014) A New Approach to Integrate Internet-of-Things and Software-as-a-Service Model for Logistic Systems: A Case Study. *Sensors*, **14**, 6144-6164. https://doi.org/10.3390/s140406144

[10] Kodym, O. and Unucka, J. (2016) Gathering Information from Transport Systems for Processing in Supply Chains. *Open Engineering*, **6**, No. 1.