A Cloud-Enhanced System Architecture for Logistics Tracking Services

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Abstract - With the fast development of logistics industry, logistic tracking services has drawn more and more attention around the world. However, conventional logistics systems are difficult to provide efficient and whole-ranged logistic tracking services for customers. In this paper, we design and implement a cloud computing supported logistics tracking information management system to support whole-ranged and real-time logistics tracking services. The proposed solution is based on technologies related to cloud computing and a few Internet of Things technologies such as two-dimensional code scanning and identification, GPS location and image recognition. The main technical issues in our proposed system model include security management, logistics vehicle management, user management and location information management. Through the implementation and evaluation, we show the feasibility and efficiency of our proposed solution**.**

Index Terms - Logistics tracking. Cloud Computing. Internet of Things.

1. Introduction

Cloud computing has been considered to be key technology in next generation information technology revolution and business application model innovation. The term "Internet of Things" has come to describe a number of technologies and research disciplines that enable the Internet to reach out into the real world of physical objects. The use of cloud computing model will let real-time dynamic management of the large number of items in the Internet of Things and intelligent analysis become possible. This mode is a promising service model in the logistics industry.

In recent years, the vigorous development of e-commerce has brought great opportunities to logistics industry. The intelligent logistics distribution system is the result of an effect on e-commerce and modern logistics [1]. According to research, accurate and timely tracking of the moving goods is the most important pre-condition in today's efficient logistic operations [2].

However, there are still a lot of challenges in the way of the development of Logistic network. One of the biggest problems is the difficulty of realizing real-time tracking services due to a few reasons listed [3]:

1) Technology unavailability: Because of vast intricate systems in logistics industry, the calculation and bandwidth for processing is too large if it implements real-time monitoring of cargoes. Therefore, the existing technologies are becoming unworkable.

2) High expense: A few approaches (combine technologies of RFID，and GPS, and corresponding back systems) have been implemented to allow for logistic tracking services, However, they are too expensive to widely deployed due to high cost of RFID hardware.

3) No elasticity: Conventional logistics systems lack of enough elasticity in hardware, software, and network capability. The system might overload and out of service as great amount of network user's access.

The goal of this paper is to propose an appropriate architecture that supports for real-time tracking functions (from mobile agent) via the combination of Internet of Things (IoT) technologies (e.g. 2D QR code, GPS position, mobile Internet technology) and back-end handling system based on cloud computing technologies. The system will not only greatly improve the efficiency of the logistics industry, but also reduce the operating costs of logistics enterprises.

2. Related works

A. Tracking technologies

Some technologies related to Internet of Things can achieve efficient tracking of goods in the logistics process. Internet of Things is a network using RFID, identifiable labels, infrared sensor, global position system and laser scanner to realize intelligent identification, positioning, tracking, monitoring and management of things. In autonomous cooperating logistics processes, the logistics objects are the "things" which the MAS enable to process information and communicate [13].

GPS is a satellites-based wireless aerospace and navigation technology which is not only global, high-precision but also secrecy. In the logistics industry, GPS is mainly used for real-time tracking and scheduling of vehicles.

RFID is a generic term for systems that read the unique identity of an RF tag [1]. Each RF tag has a unique electronic product code which can be used to identify the products. Most of the intelligent logistics companies are using RFID technology to do meticulous management. Although RFID technology has many advantages, but the popularity of RFID technology is a high wall for intelligent logistics. For the low-profit logistics industry RFID equipments are too expensive.

Bar code, especially the newly developing two-dimensional code, is becoming a very popular technique of authentication and data input. Terminal data scanning and recognition technology based on two-dimensional code precisely to solve this problem. As pointed out by H. Kato and K. T. Tan [5], two-dimensional code was designed to carry large storage capacity data and to be decoded at high speed. Each cargo can be assigned a unique two-dimensional code which is generated according to logistics information. The system can implement real-time monitoring and controlling for each cargo via receiving logistics status from vehicles periodically. Through the above analysis, the cargo tracking technology based on GPS and two-dimensional code can provide real-time logistics information for the logistics system.

B. Cloud Computing Platform

Cloud computing allocates huge amounts of computing task to a resource Pool made up by hundreds of computers, each application will be able to obtain required processing capacity, network storage and other software services [14]. Its definition is that without requiring any professional background knowledge, user easily gets the result through the network accessing other computers [6].

Current logistic systems in industry usually use SaaS cloud computing architecture to build a logistics information management system which can create large and meticulous cargo information database in the cloud server-side. Both small and large logistics enterprises can use the system to offer a wide range of logistics services to users. Logistics enterprises can also obtain detailed logistics information through accessing the cloud system. For logistics industries, the use of cloud computing technology can reduce costs, improve economic efficiency and improve service quality of the logistics system.

C. Information processing

In the logistics system, the two-dimensional code information and GPS data is considered to be the sources of information. According to the logistics information and customized bar code template, two-dimensional codes are generated to store the logistics information. GPS data received contain large amounts of data information: such as ephemeris (e.g. satellite position, etc.), location information (e.g. longitude, latitude, elevation, etc.), time information (e.g. date, time, etc.) and speed information. The information processing consists of three components as follows:

1) Receiving of information: We can obtain two-dimensional code images through the image scanning module of mobile device, and then get the two-dimensional code information by further image processing. The real-time location information can also be obtained through the GPS module of mobile device.

2) Information storage: The information in the logistics industry is a semi-structured data, using a traditional relational database implementation is difficult to meet the performance requirements. Especially when system does cross-table queries, it needs to spend a lot of memory resources. Semi-structured table (e.g. Hbase) can be used to meet the computing needs of data storage and improve information processing capabilities.

3) Secure data storage: Information security in the logistics system contains two aspects. One is to ensure the logistics information security in the cloud platform. The other is to protect the confidentiality of two-dimensional code data in the logistics process. Data fault tolerance and disaster recovery technologies can achieve safe and reliable data storage in the cloud platform. This prevents the out of service of the whole system caused by partial failure of some server nodes. Leakage of personal information in the logistics process has become worse. Two-dimensional code data is encrypted by using encryption algorithm which can protect the privacy of customers' personal.

3. Architecture Design

A. System overview

The proposed architecture involves three main parts: resources users, resources providers, and Cloud Computing Platform, as shown in Fig.1.

Resource users, which can be mobile devices, laptops, PC, etc., use a web browser to access the logistics cloud platform. The connection between the resource users and logistics cloud platform could be through either mobile or cable network. Resources user access services of resource providers through interaction with cloud platform.

Resource providers are a series of logistics companies. A smart logistics application must be installed on mobile devices of logistics vehicles. Users of logistics vehicle could go to our site to download the smart logistics application through web browser of mobile device, and then the rest happens automatically. The smart logistics application is used to scan two-dimensional code via mobile device's camera, and to get two-dimensional code information through image recognition technologies and decryption algorithm. Cloud Computing Platform communicates with mobile devices in the logistics vehicles through networks. The mobile devices should not only upload the GPS location information to the cloud platform in real time, but also must be ready to receive logistics scheduling from the cloud computing platform.

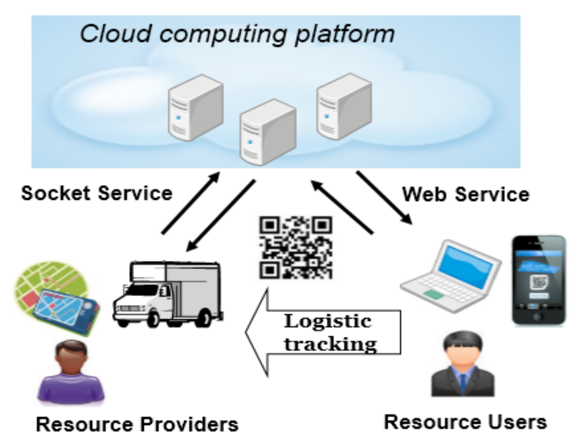

Fig.1. Architecture overview

Cloud Computing Platform is the key inter-working unit, acting as a bridge between resources users and resources providers. The main function of the cloud platform is to achieve efficient logistics tracking and fast operation of cloud services. It could supply resource users with dynamical, whole-ranged logistic tracking services.

B. User Privacy

Two-dimensional code that identifies a specific cargo could be directly attached to the packaging of cargo or printed on the waybill. The usage of two-dimensional code has a set of advantages such as low production costs, simple production process, high fault-tolerant capability and large storage; however, it is might lead to user privacy problem. We proposed an encryption algorithm based on RSA be applied to solve this problem. Any user can use the public key of the system to encrypt logistics information, which will protect two-dimensional code (on packaging of cargoes) from unwanted access. Only by system certified can users get private key to decrypt two-dimensional codes.

C. Secure data storage and efficient data processing

When a user wants to login and access the resources of the remote server, the user must be authenticated. Password authentication is widely used [7] [8] [9]. However, Information transmitted might be vulnerable to a set of security threats, especially in mobile internet. We propose to implement Elliptic Curve Cryptography (ECC) [10] to protect the connection between mobile terminal and cloud computing platform. It could ensure confidentiality and integrity of transaction information between participating parties.

A lot of logistics information, which is for most part unstructured data, is generated by the system every day. Therefore, data has to be stored securely, and backed up efficiently. Our system is based on Hadoop-based distributed architecture which provides robust, fault-tolerant Distributed File System (DFS), and parallel processing capability. [11]. Fig. 2 shows the cloud computing structure used in this paper.

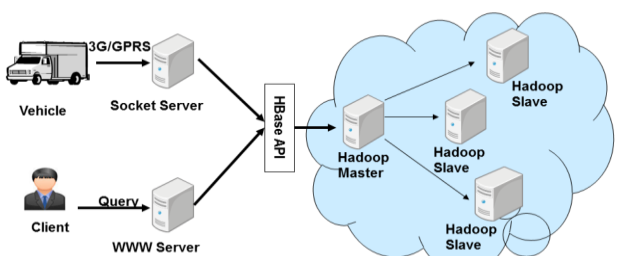

Fig.2. the cloud computing structure

Specifically, logistics related information is stored distributed in a set of cloud servers, assigned by a Hadoop master node. Data fault tolerance and disaster recovery technologies (already existed in Hadoop) is capable to achieve reliable and secure storage.

Map/Reduce algorithm is used for realization of parallel processing. It defines rule on how to splits one big task into multiple sub-tasks and assigns to a set of slave nodes, and this greatly improve the data processing efficiency.

D. Real-time tracking

Logistics tracking service is achieved via the combination and interaction of two-dimensional code, GPS technology, and cloud platform. A unique two-dimensional code represents relevant information (e.g. sender, address, address of receiver, number of logistics order, etc.) of cargos. On the other hand, logistics vehicle periodically uploads its GPS location information to the cloud. Through analyzing and processing, cloud platform is capable to understand real-time status of each cargo.

4. Prototype

A. Prototype Environment

We implement the prototype as a cloud-enhance logistics system with three use cases: Logistics request, Logistics tracking and Receiving of cargoes. The development element and development tools are listed in Table 1.

TABLE I Prototype Implementation Tools

Element	Tools
Cloud server:	HP server
Client:	Android mobile
Database:	HBase
Programming Language:	JAVA

B. Prototype Structure

A typical Hadoop includes a master node and multiple slave nodes. Cloud Computing Platform in the prototype is composed of a master and three slaves. Zxing is a Java based open source program that can recognize 1D/2D bar-codes on a mobile phone itself without communicating with a server [12]. Having reengineered Zxing program, we make it only to recognize the two-dimensional codes generated by our system. Fig. 3 illustrates the structure of prototype implementation. From message flow point of view, Cloud Computing Platform receives and handles user requests, and then deals with corresponding function. On the other side, mobile device of vehicle periodically transmits logistics information to Cloud Computing Platform via wireless network.

C. Draft Vehicle's Client Interface

Fig.3. Early Screenshots of the vehicle client's interface in the prototyping

The vehicle client's user interface was designed to communicate with Cloud Computing Platform automatically. Deliverymen can receive logistics tasks from the system server and upload logistics information to the system server everywhere via networks.

5. Evaluation

We use a HP server and install Red Hat Enterprise Linux 5.4 operating system. The cloud-enhance logistics system server, web service and HBase are built in Linux system. HUAWEI U8652 based on Android platform is used as a vehicle client test.

Before testing, the user profiles are manually configured in Cloud Computing Platform environment. We create one vehicle client instance (Android system), and then create two uses: Alice and Jim. Vehicle client has 3 G/Wi-Fi connections to Cloud Computing Platform. We assume that Alice wants to send a package to Jim and he sends a logistics request to Cloud Computing Platform. It is possible to create more user profiles for more tests.

We find sometimes Cloud Computing Platform can't obtain accurate location information of the vehicle. This could lead to at most 2000 meters position error. The problem might be that the GPS signals of mobile device are too weak to acquire accurate location information.

In a few cases when scanning two-dimensional codes, we found it is difficult to acquire accurate logistics information. One possible reason is that the camera on Android device is too low resolution, or the camera is not in functions of automatically focusing.

Errors might happen due to a few reasons (e.g. no GPS signal, high delay, error, etc.).For evaluating system reliability and performance, we randomly selected 50 locations which are twenty-five locations in the central city and twenty-five locations in the suburban area. The distance between two locations is 1 km at least. The delay time is defined as the difference between request sending and information receiving. , and the error distance is defined as the distance between reported location and actual location. The measurement result is illustrated in Table II, from which we draw conclusions that system performance depends on the accuracy of GPS system.

TABLE II The Measurement Result

	Average Delay Time	**Average Error Distance**	**Records of No GPS Signal**
Central city	16.53 s	13.14 m	4
Suburban area	23.34 s	11.87 m	2

6. Conclusion

We propose a cloud-enhance system architecture to support real-time logistics tracking services. The system architecture targets on Cloud Computing Platform. Following the system architecture is the main issue including security, storage, user privacy, and real-time tracking. To evaluate the concept and the architecture we implemented three use cases: Logistics request, Logistics tracking and Receiving of cargoes. And we show that our system works well in the real world scenarios.

With the development of mobile systems (e.g. Android, IOS, Blackberry OS, etc.), mobile devices would provide more and more mobile services support. For example， GPS navigation systems can be combined with our system to achieve an entire automated logistics chain

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