Design of Accurate Vehicle Location System Using RFID

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***Abstract*—The simple GPS methods are unable to retrieve the real-time information of vehicle location and vehicle running state in some special circumstances such as tunnels and built-ups. Hence, the vehicle monitoring system to acquire real-time vehicle information is required. In this paper, by integrating technologies of RFID, GPS, GPRS and using LANDMARC method, an accurate vehicle location system in a variety of complex environments is proposed. The proposal is able to improve the precise vehicle location and get the mechanical information of vehicle status by the technology of wireless data communication.**

***Index Terms*—RFID, GPS, GPRS, accurate vehicle location, LANDMARC.**

I. INTRODUCTION

The modernization of transport, currently, is an important criterion to take the measure of urban modernization level. Developments in communication and network technology have been improved highly. Besides, the vehicle location, widely used in the road transport of dangerous goods (RTDG), logistics, armored car and other particular fields, becomes a core position in the modernization of transport. Thus, it is a hot research point.

Triangulation, scene analysis, and proximity are the three principal techniques for automatic location-sensing [1]. One of the most important technologies of location systems is Global Positioning System (GPS), a satellite-based navigation system made up of a network of 24 satellites placed into orbit [2].

Vehicle location devices with a single GPS technology-based have played an important role on the market [3]. Reliable in-car navigation only becomes possible with high position accuracy and up-to-date map database [4]. However, there are obvious shortcomings by using a simple GPS method in the aspect of positioning accuracy and coverage.

Therefore, many researchers pay attention to the combination of GPS and other relevant technology for facilitating accuracy of vehicle location. Many approaches have been proposed as follows.

Based on GPS and GSM, Farooq U. [5] proposed and implemented a solution for enhancing public transportation management services in Punjab province of Pakistan. And Thong S.T.S. [6] proposed an intelligent fleet management system. Congshan Qu [7] introduced a GPS and CDMA application system based on embedded Linux operating system.

Based on GPS and GPRS, Tao Ning [8] designed the new vehicular monitor system. Yougui Liu [9] achieved vehicle location tracking on Internet by using GPRS vehicle location terminal and combining with Internet technology and GIS technology. Al-Taee M.A. [10] presented a distributed system for remote monitoring of vehicle diagnostics and geographical position.

Although above-mentioned researches improved extensions of accuracy on vehicle location system, it is unable to acquire the real-time information of vehicle location and vehicle running state in some areas such as tunnels [11] and built-ups. For example, narrow streets among high-rise buildings blocking GPS signal paths provide limited visibility to satellites and cause multi-path effects. The accuracy of GPS location is not precise and the position drift for vehicle location is large. As a result, the management of vehicle is inconvenient and cannot meet the requirement of a high standard for managers.

With respect to developments of RFID technology, it has been widely used in many fields. Several key technologies of RFID, GPS and GPRS are independent and lack of relational connection, so their advantages could not be mingled with

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each other.

In response to such problems, by integrating with the technology of RFID, GPS, GPRS, an accurate vehicle location system in a variety of complex environments is proposed in this paper, which is able to improve the precise vehicle location and get the mechanical information of vehicle status by the technology of wireless data communication.

The rest of this paper is organized as follows. In Section II, a brief overview of RFID technology is given as background information. The LANDMARC approach shows in Section III. In Section IV, the scheme of accurate vehicle location system is given. Section V and VI, introduces the designation of accurate vehicle location system, including hardware and software. The experimental result is analyzed in Section VII. Finally, conclusions and future works are described in Section VIII.

II. RFID BACKGROUND

RFID is not a new technology. RFID technology is one of the pivotal enablers of the "Internet of Things" [12]. Today RFID is a generic term for technologies that use radio waves to automatically identify people or objects [13] and have revolutionized automatic identification and data capture technologies [14]. The system comprises two separate components, namely a transponder or tag usually located on the item to be identified or tracked and an interrogator or reader [15].

A tag (or a transponder) can include other information which opens up opportunities to other new application areas except the ID. RFID tags fall into two main categories: Active and Passive. Passive tags do not contain a battery or power source. Active tags have internal batteries and thus can work for longer distances as they do not depend on near field or the interrogator to transmit or receive [16].

An RFID reader together with an antenna can read (or interrogates) and write tags. A reader detects the tags that is attached to or embedded in the selected items. It varies in location, size and other information. The reader communicates with the tag through the reader antenna, which broadcasts radio waves and receives the tags response signals within its reading area. After the signals from tags are detected, the reader decodes them and passes the information to middleware [17]. In the process of making the tag identification, a reader first sends a request signal to tags in its field, and then the tags, which received the request signal, respond by sending their ID to the reader immediately [18].

RFID systems mostly utilize Low Frequency (LF) at 125-134 kHz, High Frequency (HF) at 13.56 MHz, and Ultra High Frequency at 433 MHz and 860 MHz to 930 MHz and more recently Microwave Frequencies at 2.45 GHz [19]. The communication range with the tags in an RFID system is mainly determined by the output power of the reader.

The field from an antenna extends into the space and its strength diminishes with respect to the distance to tags. The antenna design determines the shape of the field so that the range is also influenced by the beam pattern between the tag and antenna.

III. LANDMARC APPROACH

The LANDMARC algorithm comes from an active RFID indoor positioning System. Due to some special circumstances such as tunnels and built-ups, the region can be seen as indoor situation by us. So the LANDMARC should be adapted into our vehicle position system.

The method of LANDMARC uses additional fixing the position of the reference tag to help position calibration and the reference tag are regarded as a reference point in the system (such as landmark in our lives). The main advantage of this approach is that it does not require a lot of expensive RFID reader, instead of using the extra cheap RFID tags. The algorithm of using the nearest neighbor data to improve the positioning accuracy of the system is essential for LANDMARC algorithm which is based on indoor positioning system introduced reference tags. The reader and method of placing reference tags, obviously, influence the overall system accuracy.

In the LANDMARC algorithm [20], suppose that there are n RFID readers along with m tags as reference tags and u tracking tags as objects being tracked and defined the Signal Strength Vector of a tracking/moving tag as $S= (S_1, S_2, \ldots, S_n)$ where S_i denotes the signal strength of the tracking tag perceived on reader I where $i \in (1, n)$. We regard tracking tag u as tag of the road where vehicle will pass by and regard reference tag m as the tag of road closed to tracking tag u. We also consider the Signal Strength Vector S of a tracking/moving tag as frequency of reading tracking tags u.

For the reference tags, the author denotes the corresponding Signal Strength vector as $\theta= (\theta 1, \theta_2, \ldots, \theta_n)$ where θ_i denotes the signal strength. We also consider θ as frequency of reading reference tags m. For each individual tracking tag p they define

$$E_j = \sqrt{\sum_{i=1}^{n} (\theta_i - S_i)^2} \quad j \in (1, m). \tag{1}$$

Based on Euclidean distance between two points P and Q is the length of the line segment connecting them i.e., $\overline{PQ}$.

If we assume P= $(p_1, p_2,\ldots, p_n)$ and $Q= (q_1, q_2,\ldots, q_n)$ are two points in Euclidean metrics, then distance between P and Q is given by

$$d(P,Q) = \sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2 + \ldots + (q_n - p_n)^2}, \tag{2}$$

results in

$$d(P,Q) = \sqrt{\sum_{i=1}^{n} (q_i - p_i)^2}. \tag{3}$$

The position of a point in Euclidean n-space is a Euclidean vector. Therefore, P and Q are Euclidean vectors. Euclidean length of a vector can be measured as following

$$\| P \| = \sqrt{p_1^2 + p_2^2 + \ldots + p_n^2} = \sqrt{p.p}. \tag{4}$$

Similarly

$$\| Q \| = \sqrt{q_1^2 + q_2^2 + \ldots + q_n^2} = \sqrt{q.q}. \qquad (5)$$

A vector can be described as a directed line segment from the origin of the Euclidean space to another point in that space. Thus, the distance between points P and Q may have a direction which can be shown by a vector given by

$$\| Q - P \| = \sqrt{(Q-P).(Q-P)}, \qquad (6)$$

which results in

$$\| q - p \| = \sqrt{\| P \|^2 + \| Q \|^2 - 2P.Q}, \qquad (7)$$

as the Euclidean distance in signal strength between a tracking tag and a reference tag r_j. Let E denote the location relationship between the reference tags and the tracking tag, i.e., the nearer reference tag to the tracking tag is supposed to have a smaller E value. When there are m reference tags, a tracking tag has its E vector as $E = (E_1, E_2, \ldots, E_n)$.

The simplest way to find the nearest reference tag to the tracking tag is to use the coordinate of the reference tag with the smallest E value as the unknown tag's coordinate, called this as1-nearest neighbor algorithm.

The unknown tracking tag's coordinate (x, y) is obtained by

$$(x, y) = \sum_{i=1}^{k} w_i (x_i - y_i), \qquad (8)$$

where w_i and (x_i, y_i) is the weighting factor to the ith neighboring reference tag and coordinate position. Empirically, in LANDMARC, weight is given by

$$w_j = \frac{1/E_i^2}{\sum_{i=1}^{k} E_i^2} \quad j \in (1, m). \qquad (9)$$

It may be explained by the fact that the signal strength is inverse proportional to the square of the distance.

Consequently, the LANDMARC algorithm can be used into our project rationally and effectively by the appropriate conversion of scene.

IV. FRAMEWORK OF ACCURATE VEHICLE LOCATION SYSTEM

The system architecture consists of four layers to regulate the vehicle location system, which are a physical layer, a device layer, a data transmission layer and an application layer. The framework is shown in Fig. 1.

A. *Physical layer*

The physical layer mainly consists of passive tags. The vehicle equipped with a controller sends electromagnetic waves to tags and retrieves the position information from tags. RFID tags are installed along lanes on a road in a manner which could maximize the coverage and the accuracy of position.

B. *Device layer*

The device is a vehicle controller, mainly composed by a RFID module, a GPRS module, a GPS module and a sensing module. It is the core of entire vehicle location system, which is used to collect and transfers information. The functions of device are the collection of ID information, GPS position and vehicle status, storage and transmission of that information to the management center and cloud by GPRS network.

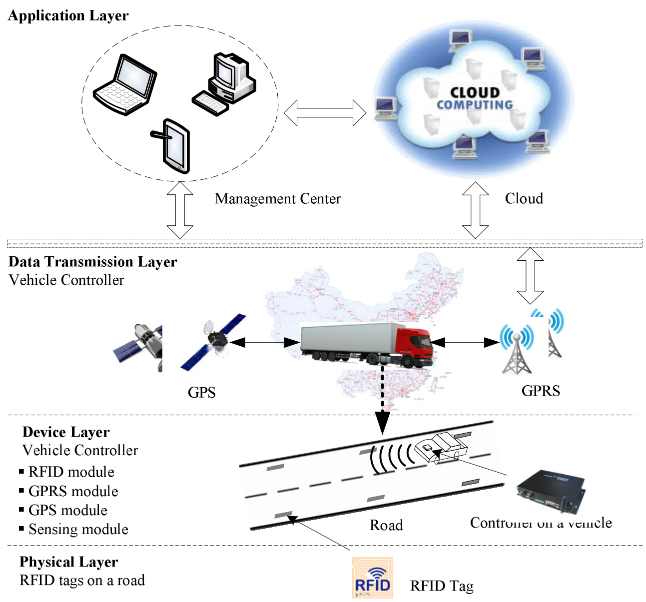

Fig. 1. Architecture of vehicle location system.

C. *Data transmission layer*

The main function of this layer can be used to transmit the data collected from the device layer by GPRS network. RFID tag's transmission rate is 256 kbps.

D. *Application layer*

Based on above layers' data and knowledge, the application layer, included the management center and cloud, can fulfill the mission to monitor and manage remote vehicles.

The cloud has a powerful function of processing, analyzing and storing the information, which involve position, vehicle status and real-time circumstance. Furthermore, the results of computing information from cloud terminal could give the administrator many effective suggestions. We will investigate and pay attention to this part in the future.

V. DESIGN OF ACCURATE VEHICLE LOCATION SYSTEM-HARDWARE DESIGN

A. *RFID Tag*

1) *Data storage in tag memory*

A RFID tag memory is logically separated into four distinct banks, each of which comprises zero or more memory words. A logical memory map contains reserved memory, EPC memory, TID memory and user memory. And user memory allows user-specific data storage, thus, the location information mainly store in that memory map. A tag with Higgs-3 core has 512-bits of user memory for distributed data applications. Figure 2 shows a waterproof tag we have applied in the project. The format of location information in user memory is shown in Fig. 3.

Fig. 2. Tag agreement.

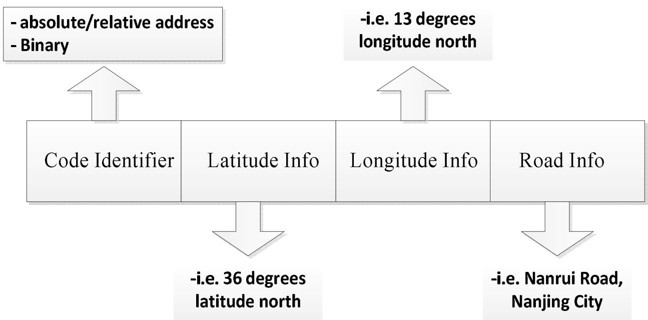

Fig. 3. Format of location information.

2) Tag Arrangement

We force on the tag arrangement on the road. According to different practical requirements, there are many methods of tag arrangement. Enzhan Zhang [21] presented the scheme called Active RFID Positioning (ARP). The proposal focused on tag and reader installation, positioning precision, and evaluated the relationship among reading range, vehicle speed, tag installation and inter-tag distance. Due to proposed theory, we arrange RFID tags along the road in Fig. 4 and match with the contacting time and vehicle speed, and balance the per cost and precision. Finally, we set the distance D of approximately six meters.

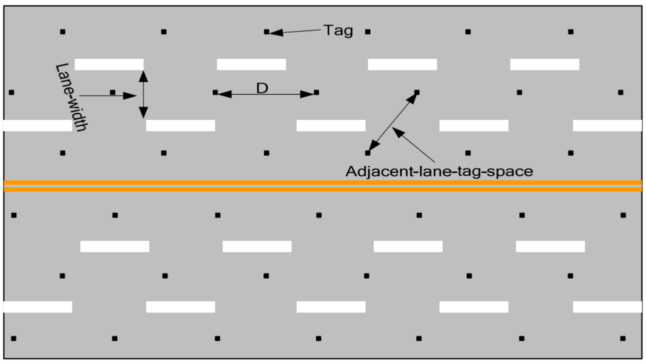

Fig. 4. Tag arrangement.

B. Vehicle Controller Components

The hardware of Vehicle Location is composed by power module, clock module, LED module, RFID module, GPS module, GSM module, sensing module and core controlling module. The structure of vehicle controller is shown in Fig. 5 and the vehicle controller is shown in Fig. 6. The fundamental function of above components is as follows:

1) A power module is used to mange, afford the power.
2) A clock module provides the basic clock signal for core controlling module.
3) A LED indicator displays the system state through different flicker.
4) A RFID module reads the information of RFID tags.
5) A sensing module is used to sense the state of environment and vehicle equipment. When vehicles encounter the severe turbulence, strong electromagnetic interference and sudden power-down, the controller will automatically save the current information and shut down for protection. If the environment status resume normally, the controller will continue to work.

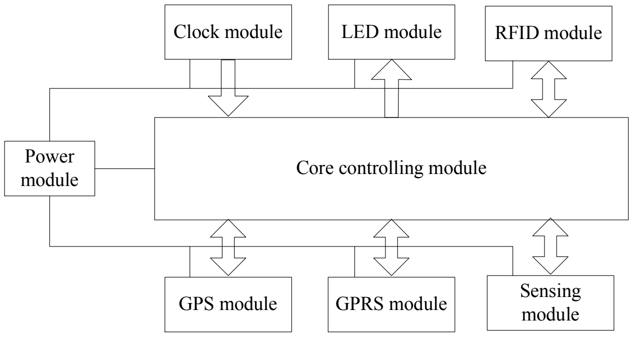

Fig. 5. Structure of vehicle controller.

Fig. 6. Vehicle controller.

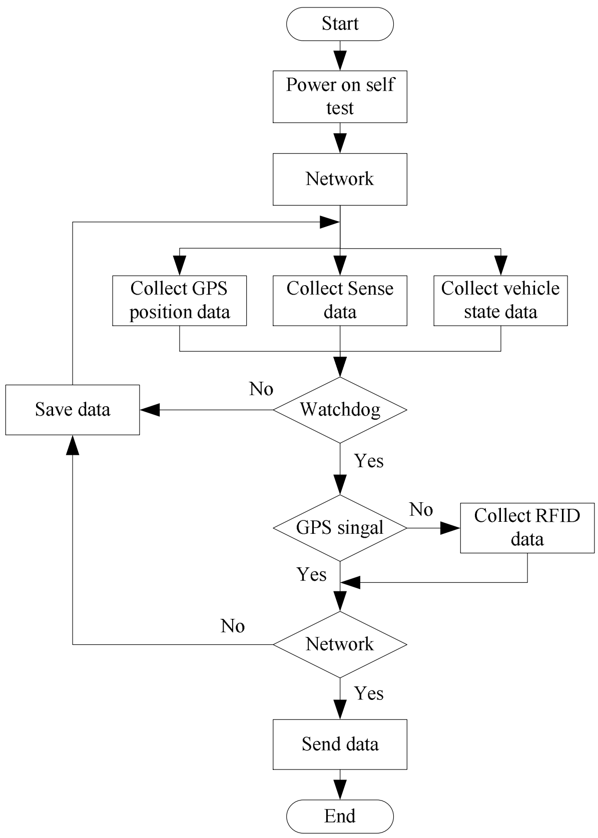

Fig. 7. Work flowchart of vehicle controller.

A GPRS module is the core module of real-time monitoring vehicle system for automatically connecting the GPRS network after booting, automatically reconnecting to the network and uploading data. As a result, it can achieve the function of connecting the network and sending information.

(1) A GPS module is used to locate the vehicle through the GPS global positioning system. It can acquire the information of vehicle location, current time and vehicle movement speed, etc.

(2) A core controlling module is used to achieve functions of tag data proofreading, reader coordination, data transmission, data storage and task management.

Figure 7 shows the work flowchart of vehicle controller. When the vehicle is traveling in tunnels, underground parking and other circumstance that traditional GPS cannot be accurately positioned, the controller mounting on the vehicle starts the RFID module to read RFID tags on the road. And the information of tags and vehicle status store in the controller memory cell. After reconnecting to the network, the controller will continue to transmit data and upload it to the cloud terminal and management center.

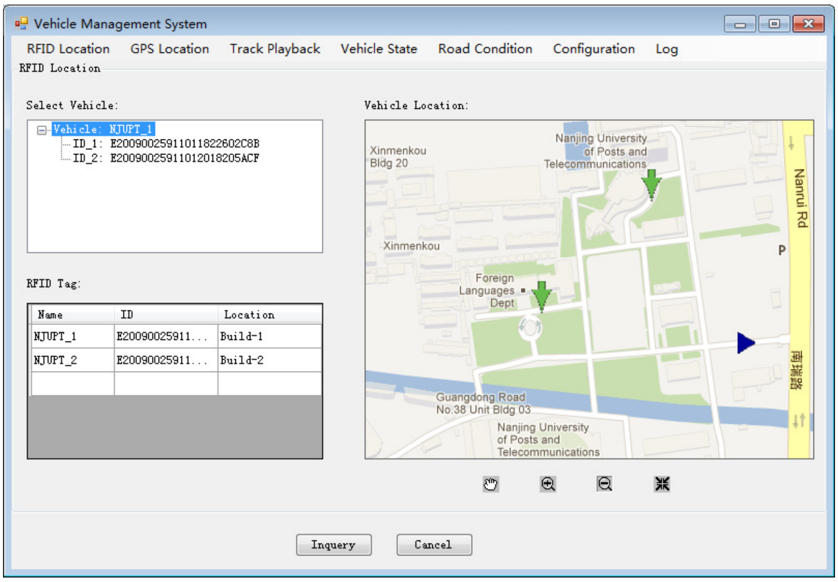

Fig. 8. Interface of RFID location.

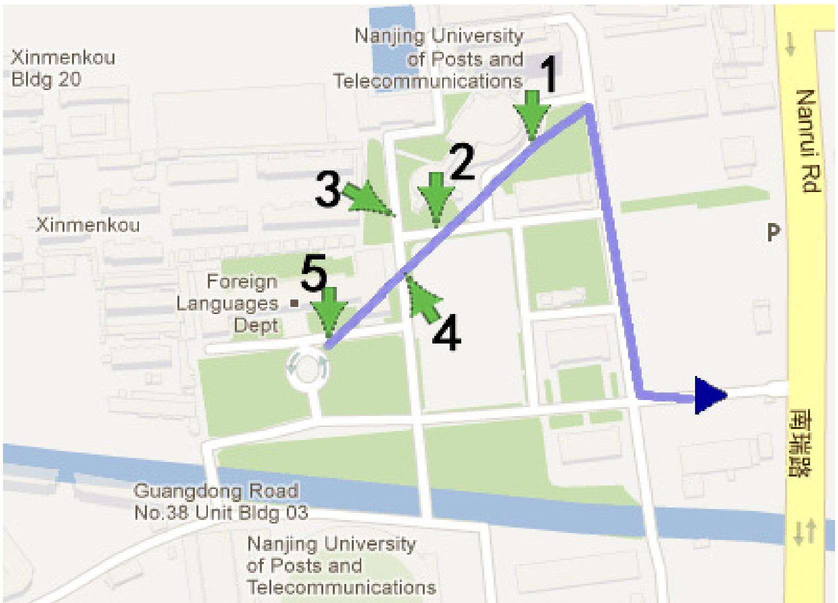

Fig. 9. The effect of experiment in the field.

VI. Design of Accurate Vehicle Location System-Software Design

The software is programmed by Microsoft Visual Studio 2008 and the large database system is designed by Microsoft SQL Server 2005 Developer to create and manage ID and position of vehicle used in the system.

This system is tested in Nanjing University of posts and telecommunication and Fig. 8 shows the practical system interface of RFID vehicle location. There are three functions displayed below:

1) Select Vehicle: Display the vehicle name and ID that a controller reads on the travel route.

2) RFID Tag: Display RFID tags corresponding to the position information.

3) Vehicle Location: Display the current position of vehicle and the location of RFID tags.

VII. EXPERIMENTAL RESULTS

In Fig. 9, blue triangle represents the current vehicle position. The path from blue triangle to position 1 could locate by GPS. But position 1 and position 5 could not search the GPS signal because of intensive buildings, so we adapt RFID tags to locate a vehicle position.

In Fig. 9, the green arrow indicates the position of RFID tag on the road and the information, which contains code identifier, latitude info, longitude info and road info, has store in these RFID tags of user memory. When the vehicle arrives at position 1, the controller mounting on the vehicle starts the RFID module to read RFID tags on the road and upload the information by GSM.

Suppose that the vehicle drives from position 2 to position 5. When the vehicle is at a fork among position 2, position 3 and position 4, the RFID controller may read tags of every direction on the road. In this sense, it is necessary to use LANDMARC method to distinguish and predict which direction the vehicle will drive, and upload the data from above steps. At last, vehicle routing will be displayed on the system through computing the latitude and longitude of two nearest tags.

VIII. CONCLUSIONS

The vehicle location system integrated with RFID, GPRS and GPS could locate the accurate vehicle position under complex environments. Meanwhile, it has reached high satisfaction for administrators to manage and monitor the vehicle. Viewed in this sight, the system can be regarded as an efficient tool since the vehicle location does not remain blind, even some areas such as tunnels and built-ups. As a direction for future, we will investigate on combination with cloud terminal of powerful information processing and analysis capabilities. This need for our system is more complicated, so we will pay more attention to the high stability and reliability in our future.

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