# Internet of Things: a New Application for Intelligent Traffic Monitoring System

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***Abstract*—Constructing an intelligent traffic monitoring system firstly depends on automatic identification for vehicles. At present, automatic identification technology based on image and vehicle license plate is going to fall in the trap due to its low recognition rate and affection by adverse weather. Thus it is necessary to apply new technologies to solve this problem, and technologies based on Internet of Things provide a new approach for it. In this paper, we explored this issue and proposed a feasible scheme. At first, we took global unique EPC code as identity identification of vehicles in stead of vehicle license plate and utilized RFID reader to read EPC code by RF electromagnetic wave, which completely solved the problem of no all-weather operations. Secondly, we obtained positioning information of vehicles by using GPS technology. Thirdly, because GPRS provides high-speed wireless IP services for mobile users, fully supports the TCP/IP, we took wireless GPRS scheme to transmit data of mobile objects. The realization of automatic detection and transmission of data provided a fundamental guarantee for constructing an intelligent traffic monitoring system. And then, we designed and discussed in turn its network architecture, data flow analysis, hardware logic structure, software flow, as well as its intelligent decision-making module. Research and design show that it is feasible and inexpensive to construct an intelligent traffic monitoring system based on Internet of Things, and the intelligent traffic monitoring system based on Internet of Things has a number of advantages such low cost, high reliability, never affected by adverse weather, all weather operations etc. Therefore, it will have a broad applying perspective.**

***Index Terms*—intelligent traffic monitoring, Internet of Things, EPC, RFID, GPRS**

## I. INTRODUCTION

Intelligent traffic monitoring plays an important role for urban traffic and modern transportation. There are a lot of problems needed to be addressed in an intelligent traffic monitoring system, but how to automatically identify traffic tools is a crucial one among them. A general method for automatic identification is based on image-processing technology [6] [23] [25] [26] [27], but the capture of images by it is often impacted by climate and time. If it is in thick fog, in heavy rain or in night, the license plate can not be seen, so its image can not be captured and the system does not work well, leading to intelligent traffic monitoring system based on image-processing technology a great deal of limitations. The development of Internet of things based on EPC and RFID brings a good opportunity for intelligent traffic monitoring. At first, EPC assigns a unique electronic code for each traffic tool, ensuring the identification uniqueness for them similar to license plate. And then, RFID is a non-contact automatic identification technique and can identify traffic tools automatically and obtain related data via radio frequency signal, so the work of the monitoring system based on RIFD recognition is not affected by night or adverse weather. Therefore, intelligent traffic monitoring system based on Internet of things has broad prospects of development and expansion space.

Nowadays, more and more domestic and foreign scholars and specialists pay highly attention to intelligent monitoring technology and have achieved a lot of productions in many aspects of technologies. The following scholars took a lot of research for automatic identification. Jianhe Du et al. [1] used 12 ten-day real-world GPS travel datasets to develop, calibrate and compare three methods to identify trip start points in the data stream. The true start and end points of each trip were identified in advance in the GPS data stream using a supplemental trip log completed by the participants so that the accuracy of each automated trip division method could be measured and compared. R. Acharya U et al. [2] presented an identification of normal eye image and abnormal (consists of five kinds of eye images) classes using radial basis function (RBF) classifier. The features are extracted from the raw images using the image processing techniques and fuzzy K-means algorithm. Iphigenia Keramitsoglou et al. [3] developed a fully automated system for the identification of possible oil spills present on Synthetic Aperture Radar (SAR) satellite images based on artificial intelligence fuzzy logic. Oil spills are recognized by experts as dark patterns of characteristic shape, in particular context. The system analyzes the satellite images and assigns the probability of a dark image

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shape to be an oil spill. The output consists of several images and tables providing the user with all relevant information for decision-making. Katsunori Hoshi et al. [4] developed a computer-driven tracking system for the automated analysis of the locomotion of Caenorhabditis elegans. The algorithm for the identification of locomotion states on agar plates includes the identification of the worm's head and tail. The head and tail are first assigned, by using three criteria, based on time-sequential binary images of the worm, and the determination is made based on the majority of the three criteria. A.J. Sjolander et al. [5] gave research to enable the wireless module-tracking system (WMTS) to function with multiple harvesting machines of the same type in the same field – a common situation in commercial cotton farming. An RFID system was incorporated, and it enabled the WMTS to correctly and consistently differentiate among various harvesting vehicles. S. Messelod et al. [6] proposed a method for the automatic localization of text embedded in complex images, which permits to detect the spatial position and the skew of the text lines which are present in the scene and to return a binary representation of each text line. Ulf Ahlstrom et al. [7] outline a weather probe concept called automatic identification of risky weather objects in line of flight (AIRWOLF), which operates in two steps: (a) derivation of polygons and weather objects from grid-based weather data and (b) subsequent identification of risky weather objects that conflict with an aircraft's line of flight. Gang Wang et al. [8] implemented an automatic computer-aided identification system o recognize different types of welding defects in radiographic images. Image-processing techniques such as background subtraction and histogram thresholding were implemented to separate defects from the background. Ching-Liang Su et al. [9] used a new technique of image phase matching to extract the thumb, index, middle, ring, and small fingers and to perform a person's identification. Xingqi Wang et al. [10] proposed and implemented a bird identification system, BirdID. To identify birds, BirdID imitates bird experts to automatically direct birdwatchers to provide features. It also tries to list the most likely species after each feature is entered. In BirdID, entropy and fuzzy similarity are used to select most appropriate queried features and calculate similarity, respectively, which makes BirdID more intelligent and noise-tolerant. Francois Dion et al. [11] describes a low-pass adaptive filtering algorithm for predicting average roadway travel times using automatic vehicle identification (AVI) data. Mei Lam Tam et al. [12] presented a real-time traveler information system (RTIS) for journey time estimation using automatic vehicle identification (AVI) data in Hong Kong. This RTIS can also deduce the travel times on the other road links without real-time AVI data. The travel times, in RTIS, are estimated by the real-time AVI data, the off-line travel time estimates and the related spatial variance–covariance relationships between road links. Hanif D. Sherali et al. [13] developed an algorithm for optimally locating Automatic Vehicle Identification tag readers by maximizing the benefit that would accrue from measuring travel times on a transportation network. An optimization approach based on the Reformulation–Linearization Technique coupled with semidefinite programming concepts is designed to solve the formulated reader location problem.

For EPC applications, Pedro Peris-Lopez et al. [14] proposed a novel authentication protocol conforming to EPC-C1G2 standard and paying more attention to security. Pedro Peris-Lopez et al. [15] brought forward a new PRNG, named LAMED, which is compliant with the standards and successfully passes several batteries of very demanding randomness tests (ENT, DIEHARD, NIST, and SEXTON). A study of its hardware complexity shows that LAMED can be implemented with slightly less than 1.6 K gates, and that pseudorandom numbers can be generated each 1.8 ms. Chin-Ling Chen et al. [16] proposed a new authentication and encryption method that conforms to the EPC Class 1 Generation 2 standards to ensure RFID security between tags and readers. This scheme not only reduces database loading, but also ensures user privacy. S.K. Kwok et al. [17] presented a self-valuation and visualization system by integrating the RFID technology and EPC concept to protect products from counterfeiting by the means of mobile platform. A systemic architecture was proposed which is capable of integrating mobile technology and EPC-RFID applications. The implementation roadmap of such system architecture was examined and explained in the context of a case study. Samuel Fosso Wamba et al. [18] provided some insights into radio frequency identification (RFID) technology and the electronic product code (EPC) network and investigated their impacts on mobile B2B eCommerce. Based on empirical data gathered from interrelated firms of a supply chain, several scenarios integrating the RFID–EPC network have been tested in a pilot project and evaluated. Eleonora Bottani et al. [19] provided a quantitative assessment of the potential reduction in the bullwhip effect, and thus in safety stocks, in the supply chain, thanks to real-time visibility of product flows provided by the Radio Frequency Identification (RFID) technology and the EPC Network.

For RFID applied to monitoring, E. Abad et al. [20] developed a RFID smart tag for real-time traceability and cold chain monitoring for food applications. This RFID based system consists of a smart tag and a commercial reader/writer. A. Vergara et al. [21] reported on the development of an RFID reader with onboard micro-machined metal oxide gas sensors aimed at monitoring climacteric fruit during transport and vending. The developed platform integrates a commercial off the shelf inductive coupling RF transceiver in the 13.56MHz band, fully compliant with the ISO15693 standard, micro-hotplate gas sensors, driving and readout electronics. Yoon Seok Chang et al. [22] dealt with the design and implementation of radio-frequency identification (RFID) based cargo monitoring system which supports tracking and tracing in air-cargo operation. After studing RF operational environment and testing different RFID frequencies, they designed and implemented tracking and tracing system applying EPC networks.

For traffic monitoring, Antonio Ferna′ndez-Caballero et al. [23] presented a visual application which allows a study and analysis of traffic behavior on major roads (more specifically freeways and highways), using as the main surveillance artefact a video camera mounted on a relatively high place (such as a bridge) with a significant image analysis field. J.W.-K. Hong et al. [24] presented the design and implementation of a portable, Web-based network traffic monitoring and analysis system called WebTrafMon, which provides monitoring and analysis capabilities not only for traffic loads but also for traffic types, sources and destinations. Jen-Chao Tai et al. [25] presented an image tracking system and its applications for traffic monitoring and accident detection at road intersections. Locations of motorcycles as well as automobiles are obtained in real time using the active contour model approach. Image measurement is further incorporated with Kalman filtering techniques to track individual vehicle motion. Zhigang Zhu1 et al. [26] presented a novel approach to automatic traffic monitoring using 2D spatio-temporal images. A TV camera is mounted above a highway to monitor the traffic through two slice windows, and a panoramic view image and an epipolar plane image are formed for each lane. Peter Reinartz et al. [27] aimed at showing the potential of using image time series frome cameras to derive traffic parameters on the basis of single car measurements and visual and automatic methods for the interpretation of images were compared. E. Planas et al. [28] was going to set up prototype of a new operational system for monitoring the transportation of dangerous goods in Europe based on regional responsibilities. This concept, based on systems used in air traffic control, aimed to provide civil security centers with real-time knowledge of the position and contents of dangerous vehicles circulating in their area of responsibility, and, in the event of a dangerous situation, to issue warnings, alerts and crisis management information, thereby allowing intervention teams to react immediately with maximum safety.

On Internet of Things technology, Dimitris Kiritsis [29] tried to shape the actual state and a possible future of the Product Data Technologies from a Closed-Loop Product. Amardeo C et al. [30] addressed problems associated with the diversifying of the Internet towards an Internet of things, and with increased ways to be reachable, whether the user wants it or not, in the digital world. Their paper presented two approaches to cope with the problem: The Identinet and a concept designated by the digital shadow, and an architecture based on these concepts.

From the current research situation mentioned above, we can obtain a conclusion: intelligent traffic monitoring based on Internet of things has not been studied fully. There is a less research taking intelligent traffic monitoring system as a part of Internet of Things. Therefore, in this paper on the basis of the above premise, we have made an exploration on intelligent traffic monitoring by using technologies of Internet of things, such as EPC, RFID, GPS, GPRS, Internet, WSN, and constructed a novel intelligent traffic monitoring system and discussed correlative technology problems.

## II. MATERIALS AND METHODS

### A. *Internet of Things*

Internet of Things (IoT) semantically means “a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols”, which is a novel paradigm that is rapidly gaining ground in the scenario of modern wireless telecommunications. The basic idea of this concept is the pervasive presence around us of a variety of things or objects – such as (RFID) tags, sensors, actuators, mobile vehicles, etc. – which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals [31].

Potentialities offered by the IoT make possible the development of a huge number of applications, of which can be grouped into the following domains [32]: ① Traffic transportation and logistics domain. ② Healthcare domain. ③ Smart environment (home, office, plant) domain. ④ Personal and social domain.

According literature [33], the three-tier architecture of the Internet of Things is as shown in Figure 1.

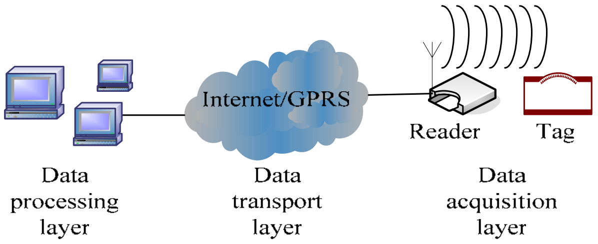

Figure 1. Three-tier architecture of Internet of Things

The bottom layer is an object-object network, namely a network that takes use of a variety of sensors, RFID to form object identification and data reading and writing between objects. This layer is data acquisition layer whose supporting technologies are mainly EPC, RFID, etc. When data pools together, it needs transmission, where a second layer is forms, which is called data transport layer. The network formation of data transport layer contains wired network and wireless network, its supporting technology mainly includes GPS, GPRS, the Internet and so on. The top layer of the Internet of Things is data processing and data exchange layer, whose task is to complete data exchange and data processing, data calculation, data storage and other functions.

Actualization of the IoT concept into the real world is possible through the integration of several enabling technologies, such as EPC, RFID, GPS, GPRS, Internet, WSN etc. The following is the further introductions for the principles of these key technologies.

### *B. RFID and EPC*

Radio Frequency Identification (RFID) systems provide direct object identity sensing. They use a small device (RFID tag) to receive and send remote commands. RFID systems contain tags, readers, hosts and antennae. There is a small low-cost tag in each RFID object that provides every product a unique identity—the Electronic Product Code (EPC). Once an RFID reader sends a request signal, the RFID tag responds to the reader's reading and writing request[16]. RFID offers wireless communication between the tags and readers with non-line-of-sight readability, which eliminates manual data collection and introduces the potential for automated identification process. The technology offers some unique advantages over the traditional barcode or smart card such as the flexible contactless identification range, multiple products identification, expressive read reliability and durability, massive data storage, and high level of data security.

In general terms, a RFID tag contains a microchip with some computational and storage capabilities, and a coupling element, such as an antenna coil for communication. Tags can be classified according to two main criteria: by type of memory or by source of power, as shown in Figure 2 [14].

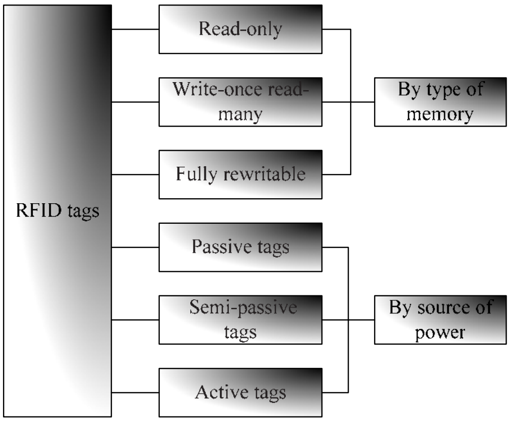

Figure 2. Classification of RFID tags

In Figure 2, a passive tag has no built-in battery and it uses the energy of the radiation emitted by the reader, while active tags have a built-in battery and can provide optional features such as environment sensing. There is a fully rewritable memory in fully rewritable tags, while a read-only memory is placed in read-only tags. Because a GPS positioning data for tracking mobile vehicles can be stored and transmitted by a RFID reader, a passive and read-only tag can be taken in intelligent traffic monitoring systems in order to reduce cost.

An RFID reader may consist of a read or read/ write module. When requested, it can send the pre-configured location and the identification of an object to a computer, which can initiate business processes automatically [18].

RFID is supported by the EPCglobal family of standards. These standards can be classified according to five main categories: contactless integrated circuit cards, RFID in animals, item management, near field communication (NFC) and EPC. Within these standards, one of the most important standards proposed by EPCglobal is the EPCglobal Class-1 Gen-2 RFID specification (EPCC1G2). This standard was adopted in 2004, and eighteen months later (March–April 2006) ratified by ISO and published as an amendment to its 18000-6 standard. Literature[15] afforded two main operations of EPC-C1G2 specification for managing tag populations as shown in Figure 3.

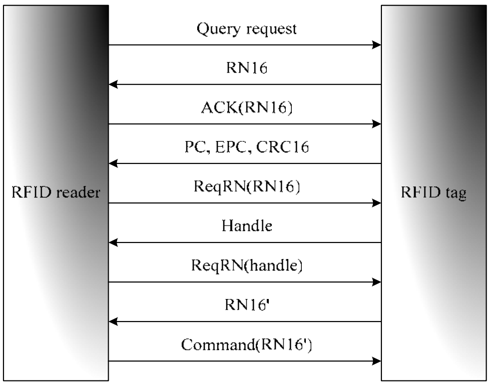

Figure 3. Two main operations of EPC-C1G2 specification

RFID systems allow tracking and tracing objects within a traffic monitoring network, thereby we will take RFID and EPC technology for it.

### *C. GPS*

A GPS consists of three discrete parts as it is shown in the following Figure 4. These three parts are: the satellites in orbit, the ground control stations, and the users (satellite receivers found in land, air, sea). For the part of satellites in orbit, twenty-four (24) satellites are in orbit, of which twenty to twenty-one (20–21) are in operation. Four (4) from these 21 satellites are visible at any time from any station on earth. The vertical and horizontal position for each specific station is feasible to be obtained in the form of $X$, $Y$, $Z$ coordinates (position vector). The information concerning the speed ($\frac{dx}{dt}, \frac{dy}{dt}, \frac{dz}{dt}$) of a vehicle, airplane, ship etc. is also available all over the world, at any time, and under all weather conditions[34]. Ground control station consists of master control station, monitoring station and injecting station. Master control station performs calculation of satellite ephemeris and correction parameters of satellite clock, and injection of these data into the satellites. Moreover it controls the satellite and issue a directive to it, and it also has the same function as a monitoring station. Monitoring station performs receiving satellite signals; monitoring the working status of satellites; injecting station performs injecting satellite ephemeris and correction parameters of satellite clock.

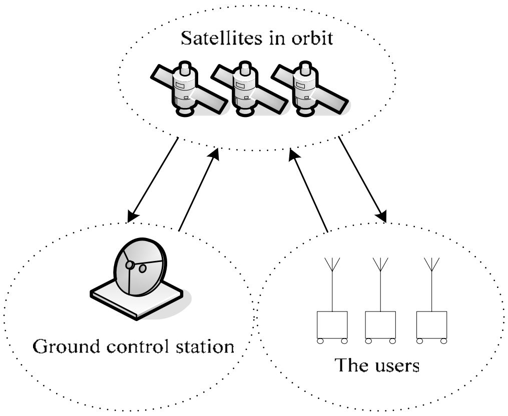

Figure 4. Parts of GPS

There are a lot of applications of global positioning system (GPS) technology in many scientific fields all over the world, among which, it allows the accurate positioning of an object using satellite signals.

### D. GPRS

The general packet radio service (GPRS), a data extension of the mobile telephony standard GSM, is emerging as the first true packet-switched architecture to allow mobile subscribers to benefit from high-speed transmission rates and run data applications from their mobile terminals. It is a GSM-based wireless packet switching technology, providing end to end and wide-area wireless IP connectivity, whose purpose is to provide packet-based form of data services for GSM users. GPRS provides high-speed wireless IP services for mobile users, fully supports the TCP/IP, dynamically allocates IP addresses for the mobile sites and achieves mobile Internet functions, accessing to the Internet through GGSN. Any kind of business in the fixed Internet will also be able to be achieved through GPRS mobile networks [35].

Two new network nodes GGSN and the SGSN are introduced for transmission and reception of GPRS data packets. Node GGSN is a gateway connecting GPRS network with external data network, by which GPRS packet data packets can be performed protocol conversion, so these data packets can be sent to a remote TCP/IP. The main role of node SGSN is to record the current location information for mobile terminals and complete the sending and receiving of packet data between mobile terminal and GGSN. GPRS terminal obtains data from the client system through the interface and treated GPRS packet data are sent to GSM base station. And then after the data are packaged by the SGSN, the communication begins between GPRS backbone network and the gateway support node GGSN. GGSN performs a corresponding processing to packet data and sends them to the destination network Internet. GPRS architecture is as shown in Figure 5[36][37][38].

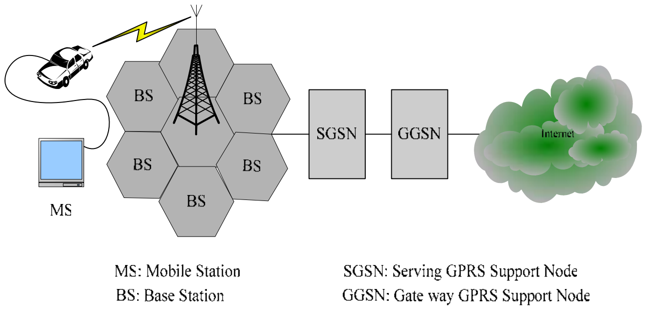

Figure 5. GPRS architecture

## III. RESULTS AND DISCUSSES

### A. Design of Network Architecture

The objective of intelligent traffic monitoring system is to actualize automatic monitoring for traffic vehicles. In order to reach this objective, we should firstly solve three problems. The first one is how to identify and detect these mobile objects. The next one is how to obtain the positions of them. At last, detected data of these mobile objects should be transmitted from outside to monitoring center for processing and calculation, and when mobile vehicles are far from cities beyond the range covered with Internet, how to carry the data for them?

To solve these problems, we have designed a novel network architecture for intelligent traffic monitoring as shown in Figure 6.

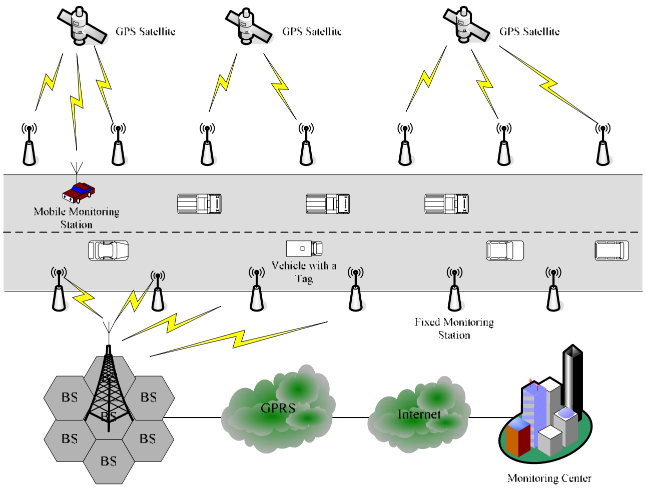

Figure 6. Network architecture

Here, each vehicle is equipped a RFID tag in which a global unique EPC code is taken as its identity identification. When it comes by a fixed monitoring station or a mobile monitoring station, the RFID reader will read the EPC information in RFID tag on it. In such a way, a mobile vehicle can be identified. Synchronously, a GPS receiver installed in a monitoring station can communicate with GPS satellites to obtain its position information that is taken as a position parameter of the vehicle. So with this method the position data of mobile vehicle is also captured. To solve the third problem, we take wireless GPRS scheme to transmit data of mobile objects. GPRS provides high-speed wireless IP services for mobile users, fully supports the TCP/IP, dynamically allocates IP addresses for the mobile sites and achieves mobile Internet functions, so it can be connected with Internet seamlessly[39][40][41].

In order to enlarge monitoring capability, we divide monitoring stations into two categories as in Figure 6: fixed monitoring station and mobile monitoring station. Fixed monitoring station installed RFID reader inside is located beside highways to monitor passing vehicles by reading EPC code information in their RFID tags. Mobile monitoring station can be a mobile car which is equipped with RFID reader, so it can track mobile objects for sustaining monitoring by reading EPC code information in their RFID tags.

## B. Data Flow Analysis

Because a GPS positioning data for tracking mobile vehicles can be stored and transmitted by a RFID reader, in the scheme we take a passive and a read-only tag in vehicles in order to reduce cost. When a vehicle with a EPC tag comes by a fix monitoring station or a mobile monitoring station, the RFID reader on them will reading the data in the EPC tag. After dong that, they transmit the EPC code to monitoring center over GPRS and Internet. The data flow is unidirectional from tags to monitoring stations, while it is bidirectional between monitoring station and wireless GPRS network as in Figure 7[17].

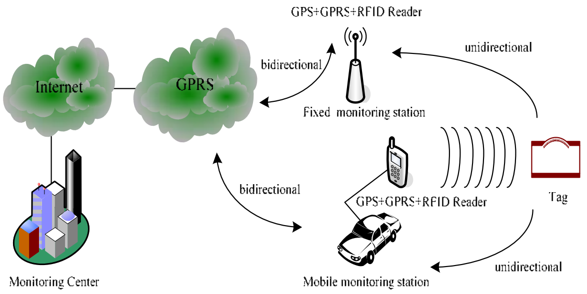

Figure 7. Diagram of data flow

## C. Design of Logic Structure for Monitoring Station

Monitoring station should perform the following functions: ①Because passive tags do not have internal source of power. They harvest their power from the reader that sends out electromagnetic waves. So the RFID reader in monitoring station should have enough RF electromagnetic energy for both power afforded for tags and communication with them. ②Although a little error is hard to avoid, we assume the position of monitoring station stands for the one of mobile vehicle, because when a monitoring station is reading an EPC tag of the vehicle, the distance between them is small. Therefore, GPS receiver is located in monitoring station, which is used to communication with GPS satellites to obtain position information. ③Transmit data of EPC code and GPS position via GPRS and Internet. Thus it should support an interface for wireless GPRS network.

In order to accomplish the functions mentioned above, we designed a hardware logic structure for monitoring station as shown in Figure 8.

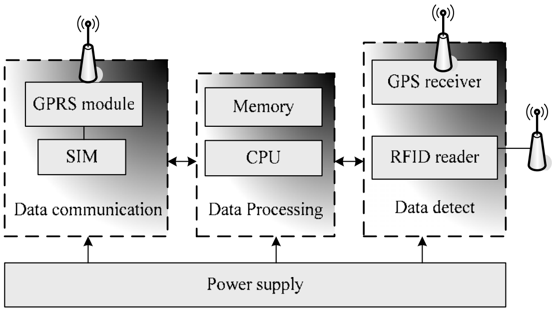

Figure 8. Hardware logic structure of monitoring station

## D. Design of Software

*a) Software of monitoring station:* Compared with monitoring center, the software complex of monitoring stations is comparatively simple, with two primary works: reading data and sending data. Its software flow is shown as following in Figure 9.

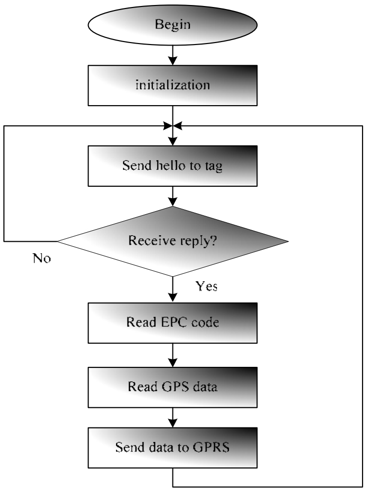

Figure 9. Diagram of software flow in a query manner

Here, RFID readers communicate with tags in a manner of query, but because there is not a power supply in tags, they can not communication with RFID reader in a manner of interruption. Another problem that should arouse attention is that if tag content includes sensitive information, tags and readers should be authenticated or the information should be encrypted to correct this problem.

*b) Software of monitoring center:* Intelligent monitoring includes two implications. At first, automatic identification and automatic transmission in front-end should be actualized. The other implication is that automatic managements in back-end should be realized too, where construction of traffic decision-making support system for traffic management is the core of the all problems. Because of finite length of the paper, here we introduce a module of traffic decision-making support subsystem for intelligent traffic monitoring system. The software structure of traffic decision-making support subsystem is shown in Figure 10.

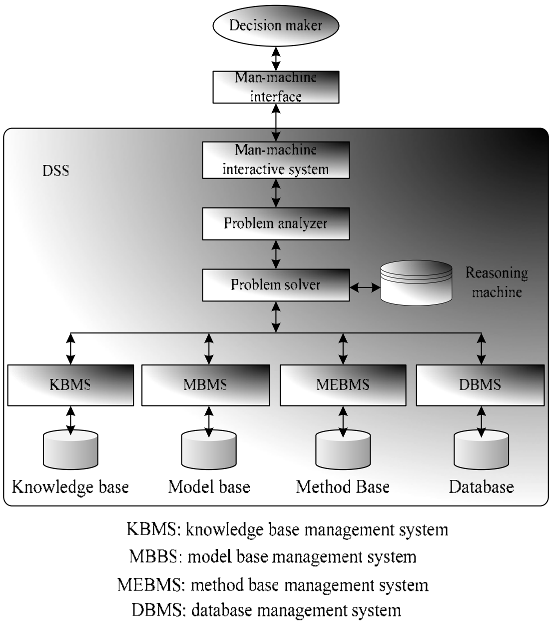

Figure 10. Software structure of traffic decision-making support subsystem

Traffic decision-making support subsystem consists of man-machine interactive system, problem analyzer, problem solver, KBMS, MBMS, MEBMS, DBMS etc. A reasoning machine of problem solver for highway congestion control and scheduling, which is based on the data of EPC code, GPS positioning and vehicle speed, is designed in traffic decision-making support subsystem, which provides the subsystem a very highly intelligence.

## IV. CONCLUSIONS

From the above design and analysis, we can obtain the following conclusions. Firstly it is feasible to utilize EPC, RFID, GPS, GPRS and network, upon those technologies Internet of Things is found, to construct an intelligent traffic monitoring system, which makes the latter as a part of the former. Secondly, intelligent traffic monitoring system based on Internet of Things has a number of advantages such low cost, high reliability, never affected by adverse weather, all weather operations etc. Thirdly, the technologies of Internet of Things makes it possible that a complete automation in monitoring system from data detect to data transmission, and to intelligent decision-making, from vehicle management to highway congestion control. Because fully automatic monitoring and management for vehicles and highways in an intelligent traffic monitoring system based on Internet of Things can completely realized, it will have a broad applying perspective.

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