

Intelligent Bus Monitoring and Management System

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Abstract—This paper deals with the implementation of an intelligent bus monitoring system based on current challenges and problems. In this system, radio frequency identification (RFID) and integrated sensing technologies such as global positioning system (GPS), general packet radio service (GPRS) and geographic information system (GIS) are used to monitor the movement of a bus. A new theoretical framework and ruled based decision algorithms are developed for the system. An experimental setup is developed for the prototype implementation. The results show that the choice of integrated technologies used in the system is suitable to monitor and manage a vehicle transportation system.

Index Terms— Sensing Technologies, RFID, GPS, GPRS, GIS.

I. INTRODUCTION

RFID is a wireless identification technology that has been used in many fields, including solid waste bin monitoring [1][2], human, animal, goods, and object tracking [3-7], and in street trees management [8]. Past researchers have proven that the implementation of RFID in any identification and monitoring system can improve the overall performance of the system at affordable prices [9]. For that reason, RFID is chosen as one of the technology implemented in the bus monitoring system. Along with RFID, other sensing technologies such as a GPS, GPRS, and GIS can be used in a monitoring system. GPS, GPRS, and GIS have been integrated together in various studies, and the good results demonstrate that the technologies are compatible. From the reviews, RFID, GPS, GPRS, and GIS are chosen to be integrated and tested in the realization of a bus monitoring and management system.

An intelligent system is a system that is able to act according to its situation without having to be instructed by humans. For instance, in an intelligent car cruise system, image processing is used in order to detect the car, base on the image signal obtained [10]. In general, an intelligent system consists of a data processor, which can be an expert rule-based system or a machine learning system, such as an Artificial Neural Network (ANN), which is usually used as a data trainer [11]. A machine learning system fed into an

intelligent system enables the overall system to classify current events on its own. In addition to feeding a learning machine into a system, an intelligent system can also consist of a simple formula that produces a series of inputs and outputs, which can be interpreted by a finite-state machine [12].

Bus monitoring and management system intelligence studies fall under the category of Intelligent Transportation Systems (ITS), and ITS includes a public transportation control framework [13][14], road traffic management [15], and the application of traffic control [11]. There have been a number of previous studies addressing intelligent transportation and vehicle monitoring systems [16-18]. Intelligent transportation enables various technologies to be applied in transportation systems and is defined as the use of information and communication technologies to collect, process, and transmit traffic data to transport users and operators [19][20]. Vehicle monitoring systems, however, only take vehicles into account; for example, auto-positioning systems can be applied to vehicle monitoring, vehicle control, and vehicle management.

As mentioned previously, there have been a number of studies focused on transportation and vehicle monitoring systems. However, only a few studies have incorporated RFID technology and have integrated communication technologies in VMS [21]. Wang et al. [22] integrates RFID with GIS and GPS with Visual Basic.Net and Visual Earth as the software platform to build a real-time vehicle management system. A mobile RFID system had also been realized to ensure the safety of vehicles, in which RFID technology is embedded with Web-GIS [23]. RFID is also used to track vehicles in parking lots [24]. The incorporation of RFID in vehicles enables the vehicles to be tracked without using GPS. Although the tracking is not continuous, unlike GPS, the location of the vehicle can be easily determined at checkpoints where the RFID communication devices connect with each other. RFID in VMS is also beneficial in preventing car theft.

As mentioned earlier, GPS is one of the core technologies implemented in this research to enable effective wireless navigation system. GPS has been used widely for tracking and monitoring purpose and it functions on the wave radiation on satellites. Even though GPS is used vastly for navigation, it is still lacking and prone to errors. Chiang et al. stated that there are two important error sources for GPS, which are phase multipath and direction-dependent variations in the antenna phase center [25]. In 1996, Axelrad et al. mentioned about the signal multipath problem in GPS, which occurs when a signal faces obstacles along its way to the GPS receiver on ground, and its correction [26], while the error factor in the GPS based station reporting system was analyzed by Bo [27]. GPS functions were further enhanced when Lundberg presented two new closed form algorithms as an alternative for the GPS static positioning solution [28]. Xu et al. method was put forward on error

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compensation of velocity and position coordinates by the GPS using neural network [29] while in a study by Rashad and Aboelmagd, artificial neural networks (ANN) was utilized [30]. Although corrections and modifications had been made, GPS still faces challenges that can still be solved.

This paper developed an intelligent campus bus identification, monitoring and management system using RFID and sensing technologies. A theoretical framework and interface algorithm utilizing RFID and communication technologies, i.e., GPRS, GPS and GIS, has been developed for a prototype. The interface algorithm in the control center is able to analyze the location of the bus, information about the driver and the status of the bus, and whether it follows the schedule. Thus, the proposed system should be able to enhance the efficiency of the campus bus system.

II. METHODS AND SYSTEM

Fig. 1 is the system architecture for the bus identification and monitoring system. A black box containing RFID reader, GPS, and GPRS transmitter is equipped in the moving bus. As the bus approaches a bus station with an RFID tag, the distance between the reader and the tag decreases and causes them to interact with each other. This communication produces data and the data obtained is sent to the monitoring center via GPRS.

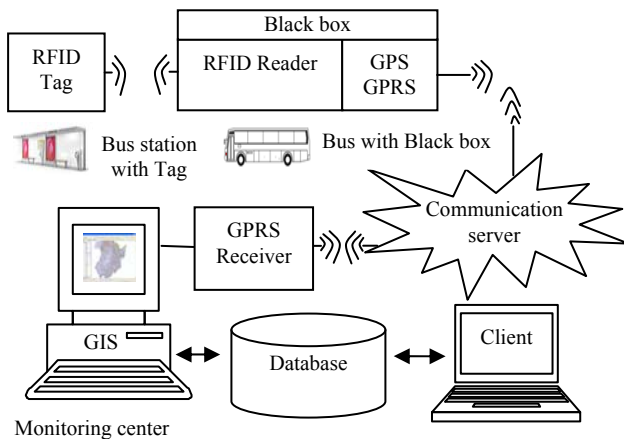


Fig. 1. Architecture of bus identification and monitoring system.

The method used to implement the proposed system is divided into two subsections: theoretical framework and interface algorithm. The prototype was developed using RFID, GPS, GPRS, and GIS to form an intelligent bus monitoring system.

III. THEORETICAL FRAMEWORK

The interface between the RFID and sensing technologies processes the data and updates RFID bus information, GPS and GIS in the system and a database using the GPRS network, as shown in Fig. 2. As mentioned in the previous section, the data only start to circulate when there is sensing between the RFID tag and reader. At the same time, the GPS module is activated and provides the location of the bus. Both RFID and GPS data are sent to the database through

the web server over the GPRS network. If the network fails to connect, the transmitter continues attempting to connect until the receiver is able to read the signal. Once the connection is established, GPS and RFID data are then stored in the database and include the location of the bus and the time of arrival. The stored data are retrieved by the user interface and updated accordingly. The data are updated at a required time interval, and the loop is run repeatedly until the system is shut down.

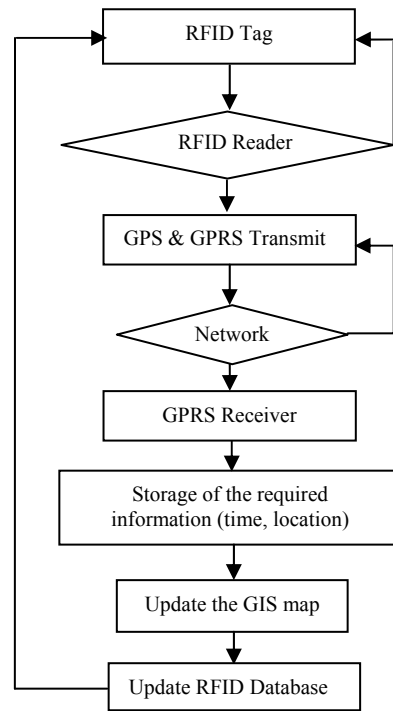


Fig. 2. The processes of updating the GIS and bus database.

For the proposed system, the theories for RFID and sensing technologies are integrated on a bus platform to monitor and manage bus transportation. The theoretical framework of the bus monitoring and management system is based on data communication among an RFID tag and reader, GPS data transmission using GSM & GPRS networks, and a retrieved data interface with GIS. The RFID reader has to obtain the data from the tag. To achieve this, the RFID reader continues radiating an RF signal, i.e., operating energy or effective isotropic radiated power (EIRP), to the RFID tag. If the bus station associated with the tag lies within the reader's range, an alternating RF voltage is induced on the reader's antenna. The voltage is then rectified to provide a direct-current (DC) supply voltage for tag operation [31]. The power level received by the tag determines the read/write range and identification range between the reader and tag as follows:

$$R \leq \frac{\lambda}{4\pi} \sqrt{\frac{EIRP_{reader} G_{tag}}{P_{tag}}} \quad (1)$$

where, EIRP is the effective isotropic radiated power, P_{tag} is the power required at the tag antenna output, G_{tag} is the tag antenna gain, and λ is the free-space wavelength of the

RF carrier. Other equations expressing the power available to the tag and power detected by the reader are as follows:

$$P_{av} = EIRP \cdot G_{reader} \cdot \frac{1}{4\pi R^2} \cdot \frac{\lambda^2}{4\pi} \cdot G_{tag} \quad (2)$$

where, P_{av} is the RF power available at the tag's antenna. In a passive RFID system, the power received by the tag directly determines the read/write (R/W) range and the identification range between the reader and tag. The tag must send sufficient power back to satisfy the reader's sensitivity, which is determined from the maximum allowable bit error rate (BER). Thus, the power link between the RFID reader and tag needs to be investigated carefully. However, before determining the distance between the reader and the tag, data encryption is needed in RFID technology as a safety measure. Data encryption protects the data in the RFID tag. If the data stored in the tag is not encrypted, any reader is able to read the information or the tag may not allow the rightful reader to view the information [32]. To prevent these events, the reader used must be authenticated with the tag, and only the rightful reader can retrieve the data contained in the tag. The data encryption mechanism is shown as follows:

where, P expresses the amount of plaintext, C expresses the amount of ciphertext, K is the key or the space key, E is the encryption algorithm and D is the decryption algorithm. After the data encryption has been performed, the distance between the reader and the tag can be calculated and verified using parameters such as the frequency of the reader, wavelength of the reader, period of time for tag detection, and the number of detections within a period of time [33]. Thus, the distance between the reader and the tag can be estimated as follows:

$$d_{x,0} = \frac{(f_x \times v_x \times p_x)}{(2 \times c_x)} \quad (3)$$

where, $d_{x,0}$ is the distance between the tag and reader x, f_x is the frequency provided by reader x, v_x is the wavelength of frequency provided by reader x, p_x is the period of time for tag detection and c_x is the number of tag detections within a period of time.

When the reader and the tag are in the required proximity, the system requires the message read by the reader to be sent to the system. In addition to RFID, GPS technology is also able to help the distance estimation between the RFID reader and RFID tag. GPS gathers location data from the satellite and sends them to the web server of the system along with RFID data. GPS data can be used to determine the minimum distance between the bus station location and the position of a bus equipped with a GPS module [34]. The minimum distance between the moving bus (reader) and the station (tag) is determined at the user interface as follows:

$$\min = (\sqrt{(x - x_i)^2 + (y - y_i)^2}) \quad (4)$$

where, min is the minimum distance between the bus station tag and bus reader, (x, y) is the GPS coordinates of the reader in the bus and (xi, yi) is a point at the tag segment.

Once RFID and GPS data are obtained, they are sent to the web server via GPRS. GPRS acts as a communication medium that enables the data to be sent wirelessly and performs integration between hardware and software [35]. The GPRS estimate of the distance between the GPRS transmitter and receiver is obtained as follows:

$$TA - distance = (TA \text{ value} + \frac{1}{2}) \times dTA \quad (5)$$

where TA-distance is the time advance distance, TA-value is the fixed value depends on the GPRS module and dTA is a fixed value of 554 m. TA value is the value of GPRS coverage by satellite. The range of TA value is from 50-53 dBW. Thus, the maximum TA distance obtained is 29.6 km, and GPRS provides best service in this distance.

Data collected by the RFID and GPS are saved in the database and are retrieved whenever prompted by the user. In the study, GIS is interfaced and used as the mapping tool. GIS is used in this study because of its layers and imagery perspective of transportation for extraction of the accessibility index. The Gutierrez and Gomez model is generated with actual transportation layers or a digital map as follows [36]:

$$A_i = \frac{\sum_{j=1}^n T_{ij} M_j}{\sum_{j=1}^n M_j} \quad (6)$$

where, A_i is the accessibility index of the extraction method at the i th node, n is the number of nodes in the map, T_{ij} is the travel time between the origin to the destination at the i th and j th nodes and M_j are the objective factors, such as population or job opportunity.

This study focuses on RFID data, GIS layer and imagery data. Thus, web sensed imageries are co-registered with actual transportation layers or a digital map.

IV. DECISION ALGORITHMS

In this study, there are three main decision algorithms that need to be considered to complete the communication between the technologies. The first decision algorithm is the reading range of the RFID technology devices. UHF RFID technology used in this study enables up to six meter reading range between the reader and the tag, thus, the following rules need to be satisfied:

- a) If $d_{x,o} \leq 6m$, then the reader obtains the information from the tag.
- b) If $d_{x,o} > 6m$, then the reader does not obtain the information from the tag.

When the RFID tag is in the vicinity of the reader, the tag does not immediately give permission to the reader to read it. This is because RFID tags used have been encrypted for safety purposes. Encrypted tags only allow related readers to access the information saved inside it. If unrelated readers try to rip off the information inside the tags, the tags block their attempts by not allowing access. The decision algorithm for the tag data encryption, S, is as follows:

- c) If all the mechanism in S is fulfilled, then data in the tag is encrypted and the tag only allows

authenticated RFID readers to obtain the information from it.

- d) If all the mechanism in *S* is not fulfilled, then data in the tag is not encrypted and the tag allows even unauthenticated RFID readers to obtain the information from it.

Once the communication between RFID reader and tag takes place, the data retrieved by the RFID reader and GPS are sent to the control center via GPRS. GPRS devices include a data transmitter and data receiver. The communication can only take place provided that both devices are in the required TA distance. The TA distance has been determined that 29.6 km is the maximum distance between GPRS transmitter and GPRS receiver. The decision algorithms are as below:

- e) If $TA \text{ distances} \leq 29.6 \text{ km}$, then the data is sent to the control center.
- f) If $TA \text{ distance} > 29.6 \text{ km}$, then the data is not sent to the control center.

Decisions of a), c) and e) are the rules that ensure the system works well. On the other hand, decisions b), d) and f) are the rules that cause the system to fail its purpose. When any one of the success rules is not obeyed, the system will not work and need to be troubles hooted.

V. RESULTS AND DISCUSSION

When the RFID tag is read by the reader, the sent data sent are processed, as are the GPS data. The status of the data processing can be seen in the GUI shown in Fig. 3. The information that can be obtained includes the URL of the server, the bus ID, the RFID data sent time, the last tagged station ID, and replies from the server and GPS. All the sensing settings are also visible in this GUI.

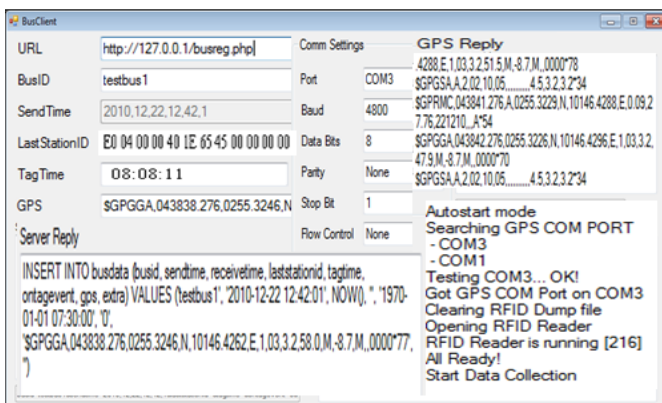


Fig. 3. The GUI showing the data processing status.

The processed data is saved in the database before the data can be shown to the end-user. Fig. 4 shows the database of the monitoring system, which contains the information transferred from RFID and GPS. The information in the database includes the bus ID, time and date of tagging, and the last station tagged.

Bus ID	Received Time	Last Station ID	Last Tag Time	On Tag	GPS Data
bustest01	2010/11/30 [11:...	E0 04 00 00 49 1	2010/11/30 [11:...	True	\$GPGGA,030508...
bustest01	2010/11/30 [11:...	E0 04 00 00 02 4	2010/11/30 [11:...	True	\$GPGGA,030458...
bustest01	2010/11/30 [11:...	E0 04 00 00 CE 2	2010/11/30 [11:...	True	\$GPGGA,030448...
bustest01	2010/11/30 [11:...	E0 04 00 00 CE 2	2010/11/30 [11:...	True	\$GPGGA,030438...
bustest01	2010/11/30 [11:...	E0 04 00 00 CE 2	2010/11/30 [11:...	True	\$GPGGA,030428...

Fig. 4. The database for the bus monitoring system.

The driver's information including the name, his worker's ID and some necessary notes can also be viewed by clicking on the bus ID button and is presented in Fig. 5. All the information sent out is saved in the database and then sent out whenever the control center is prompted for it.

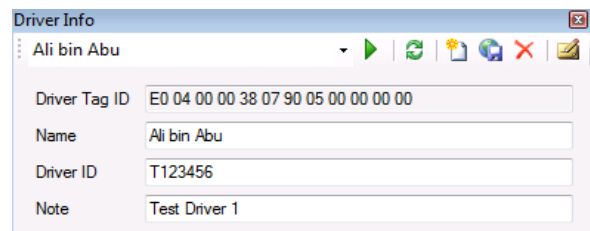


Fig. 5. Driver's detailed information.

At the end-users' side, the GIS is interfaced as shown in Fig. 6. The information retrieved from the GIS includes the following i) the continuous position of the bus, obtained from the GPS technology ii) time to reach the bus station, which is determined from the communication between RFID devices iii) Information about the bus stations and iv) information about the bus.

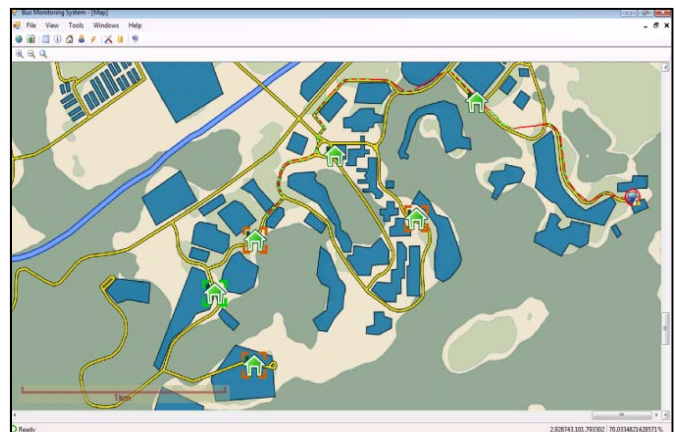


Fig. 6. GIS at the monitoring center.

A record of the bus routes and the time the bus passes each tagged station can also be determined from the GIS. Every time a bus passes a bus station and the RFID tag is tagged by the reader, the bus station icon in the GIS blinks and the tag time is recorded. The actual time of the tag time is compared to the scheduled time and represented in the GUI as shown in Fig. 7. Whether the bus is early, on time, or late, all these statuses can be observed and distinguished by color. Red indicates that the bus is behind schedule, pink indicates that the bus is too early, and green indicates that the bus is on time.

BusID:testbus1				
Created On:1/6/2011 12:50:16 PM				
KPZ	FKAB	DG	PTSL	FPend
EO 04 00 00	EO 04 00 00	EO 04 00 00	EO 04 00 00	EO 04 00 00
		12:13:13	12:25:10	12:29:23
12:33:55	12:37:07			

Fig. 7. The actual tag time compared to the scheduled time.

The authorities manage the whole system by analyzing the records and giving out feedback to the driver, which leads to a more reliable bus system. Thus, the records or the information make the system more intelligent and have the ability to automatically warn the driver if he is behind schedule.

VI. CONCLUSION

The intelligence implemented in the bus monitoring system can be achieved by compiling and feeding all the proposed theories and algorithms for RFID and other sensing technologies into the system. The ability of the system to act on its own can reduce the manpower required at the monitoring center. Bus drivers will also be more punctual to the bus schedules that have been established, resulting in a more efficient bus circulation system. The experimental results show that the system is intelligent enough and able to provide important information to the authorities for monitoring and management of the bus system.

REFERENCES

[1] AREBEY, M., M. A. HANNAN, BASRI, H., R. A. BEGUM, ABDULLAH, H. Integrated technologies for solid waste bin monitoring system. *Environmental Monitoring and Assessment*. 2011, vol. 177, no. 1-4, p. 399-408.

[2] ALIAGA, C., FERREIRA, B., HORTAL, M., PANCORBO, M. A., LOPEZ, J. M., NAVAS, F. J. Influence of RFID tags on recyclability of plastic packaging. *Waste Management*. 2011, vol. 31, no. 6, p. 1133-1138.

[3] CANGIALOSI, A., MONALY, J. E., YANG, S. C. Leveraging RFID in hospitals: patient life cycle and mobility perspectives. *IEEE Communications Mag*. 2007, vol. 40, no. 9, p. 18-23.

[4] MIN CHEN, GONZALEZ, S., LEUNG, V., QIAN ZHANG, MING LI. A 2G-RFID-based e-healthcare system. *IEEE Wireless Communications*. 2010, vol. 17, no. 1, p. 37-43.

[5] TAKIHIRO, F., TERUAKI, N. Monitoring system for farming operations with wearable devices utilized sensor networks. *Sensors*. 2009, vol. 9, no. 8, p. 6171-6184.

[6] YU, S. C. RFID implementation and benefits in libraries. *The Electronic Library*. 2007, vol. 25, no. 1, p. 54-64.

[7] LEE, C. H., CHUNG, C. W. RFID data processing in Supply Chain Management using a path encoding scheme. *IEEE Transactions on Knowledge and Data Engineering*. 2011, vol. 23, no. 5, p. 742-758.

[8] KIM, E. M., PYEON, M. W., KANG, M. S., PARK, J. S. A management system of street trees by using RFID. In *Web and Wireless Geographical Information Systems*, Hong Kong, China, December 2006, p. 66-75.

[9] POON, T. C., CHOY K. L., HENRY LAU C. W., FELIX CHAN T. S., HO K. C. A RFID case-based logistics resources management system for managing order-picking operations in warehouses. *Expert Systems with Applications*. 2009, vol. 36, no. 4, p. 8277-8301.

[10] DOBROVOLNY, M., BEZOUSEK, P., HAJEK M. Application of a cumulative method for car borders specification in image. *Radioengineering*. 2008, vol. 17, no. 4, p. 75-79.

[11] BELLOS, C., PAPADOPOULOS, A., FOTIADIS, D. I., ROSSO, R. An intelligent system for classification of patients suffering from chronic diseases. In *32nd Annual International Conference of the IEEE Engineering in Medicine and Biology*, Argentina, August-September 2010, p. 2890-2893.

[12] CHAO, H. P. The non-specific intelligent guided-view system based on RFID technology. In *Proceedings of the 19th International Conference on Advanced Information Networking and Applications*, Taipei, Taiwan, March 2005, p. 580-585.

[13] HU J., LI G. Design of city-bus intelligent control system framework. In *Proceedings of the 2006 IEEE International Conference on Mechatronics and Automation*, Henan, China, June 2006, p. 2307-2311.

[14] M. A. HANNAN, HUSSAIN, A., SAMAD, S. A. System interface for an integrated Intelligent Safety and System (ISS) for vehicle applications. *Sensors*. 2010, vol. 10, no. 2, p. 1141-1153.

[15] ROY, A., GALE, N., HONG, L. Automated traffic surveillance using fusion of Doppler radar and video information. *Mathematical and Computer Modelling*. 2011, vol. 54, no. 1-2, p. 531-543.

[16] HAN, S., HUH, K. Monitoring system design for lateral vehicle motion. *IEEE Transactions on Vehicular Technology*. 2011, vol. 60, no. 4, p. 1394-1403.

[17] DOĞAN, S., TEMİZ, M. S., KÜLÜR, S. Real time speed estimation of moving vehicles from side view images from an uncalibrated video camera. *Sensors*. 2010, vol. 10, no. 5, p. 4805-4824.

[18] HICKMAN, J. S., HANOWSKI, R. J. Use of a video monitoring approach to reduce at-risk driving behaviors in commercial vehicle operations. *Transportation Research Part F-Traffic Psychology and Behaviour*. 2011, vol. 14, no. 3, p. 189-198.

[19] QIN, K., XING, J., CHEN, G., WANG, L., QIN, J. The design of Intelligent Bus Movement Monitoring and Station Reporting System. In *Proceedings of the IEEE International Conference on Automation and Logistics*, Qingdao, China, September 2008, p. 2822-2827.

[20] SHIN, K. C., SONG, W. N. RAC-multi: reader anti-collision algorithm for multichannel mobile RFID networks. *Sensors*. 2010, vol. 10, no. 1, p. 84-96.

[21] M. A. HANNAN, HUSSAIN, A., SAMAD, S. A., MOHAMED, A., WAHAB, D. A., IHSAN, K. A. M. Development of Intelligent Safety System for occupant detection, classification and position. *International Journal of Automotive Technology (IJAT)*. 2006, vol. 7, p. 827-832.

[22] WANG, Y., OSCAR HO, K. W., GEORGE HUANG Q., LI, D. Study on vehicle management in logistics based on RFID, GPS and GIS. *International Journal of Internet Manufacturing and Services*. 2008, vol. 1, no. 3, p. 294-304.

[23] HSIEH, W. H. HO C. J., JONG G. J. Vehicle information communication safety combined with mobile RFID system. *International Conference on Intelligent Information Hiding and Multimedia Signal Processing*, Harbin, China, August 2008, p. 1021-1024.

[24] PALA, Z., İNANÇ, N. 2007. Smart parking applications using RFID technology. *1st Annual RFID Eurasia*, Istanbul, Turkey, September 2007, p. 1-3.

[25] CHIANG, K. W., PENG, W. C., YEH, Y. H., CHEN, K. H. Study of alternative GPS network meteorological sensors in Taiwan: case studies of the plum rains and Typhoon Sinlaku. *Sensors*. 2009, vol. 9, no. 6, p. 5001-5021.

- [26] AXELRAD, P., C. J. COMP., P. F. MACDORAN. SNR based multipath error correction for GPS differential phase, *IEEE Transactions on Aerospace & Electronics Systems*. 1996, vol. 32, no. 2, p. 650-660.
- [27] BO, Z. Design of GPS report station system and analysis of error factor. *Journal of Nantong University (Natural Science)*. 2006, vol. 15, no. 2, p. 92-94.
- [28] LUNDBERG, J. B. Alternative algorithms for the GPS static positioning solution. *Journal of Applied Mathematics and Computation*. 2001, vol. 119, no. 1, p. 21-34.
- [29] XU, G. GPS- Theory. *Algorithms and Applications*. Springer Heidelberg: Deutschland, Germany, 2003.
- [30] RASHAD, S., ABOELMAGD, N. Sensor integration for satellite-based vehicular navigation using Neural Networks. *IEEE Transactions on Neural Networks*. 2007, vol. 18, no. 2, p. 589-594.
- [31] MA, J. H., ZHANG, Z. Y., REN, Y., SUN, M. C. Safety application on radio frequency identification and communication based train control system in Qinghai-Tibet railway. *Progress in Safety Science and Technology*. 2002, vol. 3, p. 772-777.
- [32] WANG, J. F., ZHANG, Y., CHENG, Y. H., WANG, H. S. Research on the radio based cab signal system used for Qinghai-Tibet railway. *Journal of the China Railway Society*. 2002, vol. 24, no. 3, p. 112-117.
- [33] RICCI A., GRISANTI, M. Improved Pervasive Sensing With RFID: An Ultra-Low Power Baseband Processor for UHF Tags. *IEEE Transactions on Very large Scale Integration Systems*. 2009, vol. 17, no. 12, p. 1719-1724.
- [34] WANG, Y., ZHAO, X., WU, Y., XU, P. The research of RFID middleware's data management model, In *Proceedings of the IEEE International Conference on Automation and Logistics*, Qindao, China, September 2008, p. 2565-2568.
- [35] TIN, T. H., ZAW, M. A. Design approach to fish data identification tag via RFID, In *International Conference on Future Computer and Communication*, Kuala Lumpur, Malaysia, April 2009, p. 505-509.
- [36] THONG, S. T. S., HAN, C. T., ABDUL RAHMAN, T. Intelligent fleet management system with concurrent GPS and GPRS real-time positioning technology, In *7th International Conference on ITS Telecommunications*, Sophia Antipolis, France, June 2007, p. 1-6.