Communication Technologies for an Intelligent Bus Monitoring system

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Abstract. This paper highlights the implementation of an intelligent bus monitoring system using 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.

Keywords: Monitoring and Management System, Sensing Technologies, RFID, GPS, GPRS, GIS.

1. 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 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.

2. Integrated Technologies

3.1 Radio Frequency Identification (RFID)

RFID is a technology that is designed to enable readers to capture data on tags and transmit them to a computer system without any physical connection in a radio frequency range. An RFID system consists of three components: an antenna, a tag and a reader. The antenna, which is directly integrated with microchip [31], uses radio frequency waves to transmit a signal that activates the tag. When activated, the tag transmits data back to the antenna. Low-frequency RFID systems, i.e., systems that operate between 30 KH to 500 KH, have short transmission ranges that are generally less than six feet. High-frequency RFID systems i.e., systems that operate between 850 MHz and 950 MHz and 2.4 GHz to 2.5 GHz offer a longer transmission range, which is more than 90 feet. In general, as the frequency increases, the cost of the system also increases. Auto-ID technologies have been used to reduce the amount of time and labor needed to input data manually and to improve data accuracy compared to conventional inventory systems. RFID technology is used in a wide range of applications worldwide, including human identification, in automotive, contactless payment, laundry, library, livestock, pharmaceutical, retail supply chain management, and ticketing as well as an alternative to the bar code [32]. In human identification, the concerns on the possibility of personal information to be leaked out to strangers can be eliminated due to the safety measures taken to protect the privacy of one’s information [33]. RFID technology is still expanding rapidly and holds a promising future in both identification and monitoring systems.

3.2 Global Positioning System (GPS)

GPS is a satellite-based navigation system formed by satellites placed into the orbit to record locations on the earth. The satellites periodically emit a radio signal to GPS receivers to calculate and display accurate location, speed, and time and to convert two-dimensional or three-dimensional position information into a useful display format. GPS was originally created by the United States Department of Defense (DOD) as a military application. GPS works accurately in all weather conditions, day or night, around the clock and the globe. Over the years, research on GPS has been conducted aggressively to improve its performance [34]. Today, GPS is extensively used in motor vehicles to provide emergency roadside assistance, determine the position of a vehicle on an electronic map display and help drivers keep track of their position. Modern systems automatically create a route and give turn-by-turn directions to designated locations [35]. The implementation of GPS in this system is used to track the location and movement of the bus.

3.3 GSM/GPRS Technology

GSM is an open, digital cellular technology used to transmit mobile voice and data services with the Short Messaging System (SMS). GPRS is a wireless data service developed from the existing GSM system and can be associated with the Internet. It provides a link between mobile users and a data network as well as high-speed wireless Internet Protocol (IP). GPRS uses packet switching technology
that can take up to a certain number of wireless channels to transfer data at a rate up to 160 kbps. Using GPRS technology, users can always stay online. The GPRS network has wide coverage and can truly achieve real-time sending and receiving [36].

3.4 Geographic Information System (GIS)

GIS integrates software and hardware for storing, collecting, managing, mapping, and analyzing data and showing all forms of geographical information in a computer-based system. It helps analyze data visually and display patterns, trends, and relationships that might not be visible in tabular or written form. The tabular form is associated with spatial features, which are stored in a coordinate system of a particular place on the earth. Spatial data and associated attributes in the same coordinate system can then be layered together for mapping and analysis. A GIS is different from other information systems because it integrates common database operations, such as query and statistical analysis, with the advantages of visual and geographic analysis through maps [37-39]. GIS can be used for scientific investigations, resource management, monitoring and development planning. Thus, the use of GIS at the control center can enable the bus system to be monitored.

3. 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.

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.

4.1 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.

![Diagram](image-url)

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

![Diagram](image-url)

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

$$S = \{P, C, K, E, D\}$$

(3)
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 retrieves data interface with GIS. The RFID reader has to GPS data transmission using GSM & GPRS networks, and a framework of the bus monitoring and management system is monitor and manage bus transportation. The theoretical sensing technologies are integrated on a bus platform to determine the distance between the reader and the tag as follows:

\[ R \leq \frac{\lambda}{4\pi} \sqrt{\frac{EIRP_{\text{reader}} G_{\text{tag}}}{P_{\text{tag}}}} \]  

(1)

where, \( EIRP \) is the effective isotropic radiated power, \( P_{\text{tag}} \) is the power required at the tag antenna output, \( G_{\text{tag}} \) is the tag antenna gain, and \( \lambda \) 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:

\[ P_{\text{av}} = EIRP \cdot G_{\text{reader}} \cdot \frac{1}{4\pi R} \cdot \frac{\lambda^2}{4\pi} \cdot G_{\text{tag}} \]  

(2)

where, \( P_{\text{av}} \) 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 [41]. 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:

\[ \text{Encryption mechanism} = \text{Encryption (tag, reader)} \times \]  

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 [42]. Thus, the distance between the reader and the tag can be estimated as follows:

\[ d_{x,0} = \frac{f_x \times v_x \times P_x}{2 \times c_x} \]  

(4)

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 [43]. The minimum distance between the moving bus (reader) and the station (tag) is determined at the user interface as follows:

\[ \min = (\sqrt{(x - x_b)^2 + (y - y_b)^2}) \]  

(5)

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 \( (x_b, y_b) \) 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 [44]. The GPRS estimate of the distance between the GPRS transmitter and receiver is obtained as follows:

\[ TA\text{-distance} = (TA\text{-value} + \frac{1}{2}) \times \text{dTA} \]  

(6)

where \( TA\text{-distance} \) is the time advance distance, \( TA\text{-value} \) is the fixed value depends on the GPRS module and \( dTA \) is a fixed value of 554 m. \( TA\text{ value} \) is the value of GPRS coverage by satellite. The range of \( TA\text{ value} \) is from 50-53 dBW. Thus,
the maximum \textit{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 [45]:

\[ A_i = \frac{\sum_{j=1}^{n} T_{ij} M_j}{\sum_{j=1}^{n} M_j} \]  

(7)

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.

4.2 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:

- If \( d_{x,o} \leq 6 \text{m} \), then the reader obtains the information from the tag.
- If \( d_{x,o} > 6 \text{m} \), 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:

- 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.
- 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 \textit{TA distance}. The \textit{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:

- If \( TA \text{ distances} \leq 29.6 \text{ km} \), then the data is sent to the control center.
- 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.

4. Experimental Setup

Based on the monitoring function and operating principle, the system structure consists of four parts such as bus stations with attached RFID tags; black box i.e. a bus equipped with an RFID reader, GPS module, and GPRS transmitter; communication network and a monitoring platform interfaced with a GPRS receiver and GIS tools. The experimental setup for each of the part is explained in detail in the following.

5.1 Bus Stations attached with RFID Tags

Fig. 3 shows the setup of an RFID tag in a bus station. The tag is slotted into the tag bracket and installed in bus stations.

\[ \overset{\uparrow}{\updownarrow} \]

Tag with the bus station information

Tag bracket is positioned at selected bus station

\[ \overset{\swarrow}{\downarrow} \]

Tag is slotted into the tag bracket

\[ \overset{\swarrow}{\downarrow} \]

Fig. 3. RFID tag setup in bus stations.

The following must be considered when attaching the tag brackets such as i) the angle of the tag bracket must be set in a
suitable location so that the reader can easily read the tag when the bus passes through the station ii) the tag must be placed near the roadside at a measured distance so that the reader is able to sense the tag immediately in the required proximity.

5.2 Black Box

A black box consisting of an RFID reader, GPS and GPRS transceiver for the CELCOM broadband, the internet provider, is mounted in the bus as shown in Fig. 4. All these sensing technologies are connected to the central processor unit (CPU) for data processing. The processed data are then sent to the monitoring center wirelessly with the GPRS.

5.3 Communication network

The internet is the communication medium used to transfer data from the RFID and GPS to the control center. In a communication network, the data from a terminal have to be sent to the other terminal. To transfer the data, a data service must exist. GPRS is chosen as the data service because it is stable and easy to access.

5.4 Monitoring Platform

Fig. 5 shows the monitoring and management platform of the system. The data sent via the GPRS modem is received by the GPRS receiver attached to the CPU at the control terminal. All received data are processed and displayed in the monitor interfaced with GIS in the form of map.

5. 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. 6. 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.

The processed data is saved in the database before the data can be shown to the end-user. Fig. 7 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.

![Fig. 4. Black box installed in the bus with the communication technologies.](image)

![Fig. 5. Monitoring center as the control platform.](image)

![Fig. 6. The GUI showing the data processing status.](image)

![Fig. 7. Database of monitoring system.](image)
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. 8. All the information sent out is saved in the database and then sent out whenever the control center is prompted for it.

At the end-users’ side, the GIS is interfaced as shown in Fig. 9. 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.

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. 10. 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.

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.

6. 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


