

Chapter 34

An Active Integrated Zigbee RFID System with GPS Functionalities for Location Monitoring Utilizing Wireless Sensor Network and GSM Communication Platform

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Abstract An active integrated Radio Frequency Identification (RFID) system that operates in 2.45 GHz ISM band frequency is developed to support indoor and outdoor real-time location monitoring by utilizing Global Positioning System (GPS) in Wireless Sensor Network (WSN) and Global System for Mobile (GSM) communication platform. The proposed active RFID system is based on an automated switching mechanism between indoor and outdoor location and the capabilities of the system is extended by providing a contactless communication between the tagged items or persons and the monitoring station. There are two types of communication protocol; Reader Talk First (RTF) and Tag Talk First (TTF) involved in the proposed RFID system. The effectiveness of the proposed RFID system is evaluated based on the communication protocols implemented and the capability of the proposed RFID reader to read multiple tags is tested by analyzing the tag collection process in the RFID system. From the results, it is shown that the system with TTF protocol is better than the RTF protocol in terms of data collision and average time delay while performing transmission and reception processes.

Keywords Global positioning system • Global system for mobile • Radio frequency identification • Reader talk first • Tag talk first • Wireless sensor network

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1 Introduction

Hajj (pilgrimage) is the largest gathering of Muslim worldwide and has a unique characteristics with regards to the people who attend it (pilgrims). According to figures released by the Central Department of Statistics and Information, more than three million pilgrims visited Saudi Arabia during the 2012 Hajj (www.saudiembassy.net, [14]). A total of 3,161,573 took part in the annual pilgrimage, with 1.4 million from Saudi Arabia and the majority around 1.7 million visiting from overseas and around 26 thousand pilgrims are from Malaysia and the total was up by eight percent in 2013. Such a setup poses a real challenge to the authorities in managing the crowd, tracking missing pilgrims and identifying lost, dead and injured pilgrims. In such a scenario, there is a need for a robust system for pilgrims to identify and track their locations especially during medical emergencies. However, the system is not limited to Hajj pilgrims application, but also suitable for other applications such as supply chain management [7], animal tracking [12], asset tracking [6], solid waste monitoring [2], crowd control application [15] and the most popular application demand have recently been is to support information and communication technologies in collaboration during emergency response [11] and disaster management [3].

Passive and active RFID systems have been tested in the past by [8] with limited success and other approaches such as image based tracking system are not suitable for a large crowd [5]. Thus the idea using WSN is introduced [9] to provide the location tracking for Hajj pilgrims. However, the work done by Mohandes et al. (2011) only focused on providing location data for outdoor environment. Thus, this research work combined the active RFID system and WSN platform in order to come out with a new RFID system consists of a modified active RFID reader and active RFID tag embedded with GPS and GSM in WSN platform. The proposed RFID system is developed by applying an automated switching mechanism in order to provide identification and sequence location detection for the indoor and outdoor locations, respectively. The RSS value is chosen to calculate the distance and perform the location tracking since it is an inexpensive Radio Frequency (RF) based approach with low configuration requirements and can be retrieved from the active RFID tag itself without using any external hardware devices [4]. This work, however, focused on the system design, implementation and testing of the proposed RFID system in order to evaluate the effectiveness of the proposed RFID system.

2 System Design

The work presented here is an extended version of previous research work done by Poad et al. [10] which focused on the automated switching mechanism for indoor and outdoor location tracking with embedded RFID and GPS in WSN platform. The GPS receiver covered outdoor location tracking that is fulfilled by satellite system,

while the active RFID tag provides an identification for each tag holder and covered indoor location tracking especially near or inside buildings, which cannot be tracked by GPS technology. In WSN, one of the methods uses to localize tag location is by measuring RSS, and translates the RSS value into the distance between reader, routers and tags. Since the RSS does not need any hardware modification in order to extract the value, it has been utilized in the proposed RFID system to estimate the location of the active RFID tag for indoor location tracking. The work presented by Poad et al. [10] is later extended to include the function of GSM communication in order to provide an alternative way when the active RFID tag is out of wireless network coverage. Thus make the active RFID system is a contactless system that can support two different types of communication technology on a single platform. Figure 34.1 shows the block diagram of the previous work done by Poad et al. [10], while Figs. 34.2 and 34.3 show the extended version of the embedded RFID tag and RFID reader presented in this work.

The proposed embedded RFID tag will be given to each person that consists of 2.45 GHz active integrated ZigBee RFID embedded with GPS and GSM technology to provide tracking for the indoor and outdoor location which utilized WSN platform. However, the GSM technology will be activated only when the embedded RFID tag is out of wireless network coverage. All the information gathered from RFID tags will be networked to RFID reader connected to the host computer at the monitoring station via WSN platform, otherwise the location data from the embedded RFID tag will be sent through short messaging system (SMS) to an authorized person via GSM platform. The RFID tag periodically sends out location data obtain from GPS receiver to RFID reader at the monitoring station to track and trace the movement and sequence location of the tagged items or persons only when the GPS having valid signals from satellites. However, if there are no valid signals from satellites, the location tracking will be done with the RFID tag using

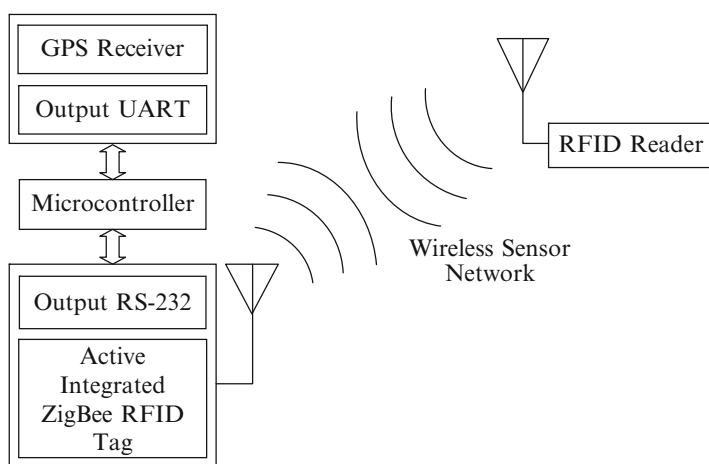


Fig. 34.1 Block diagram of existing embedded hardware (Poad et al. [10])

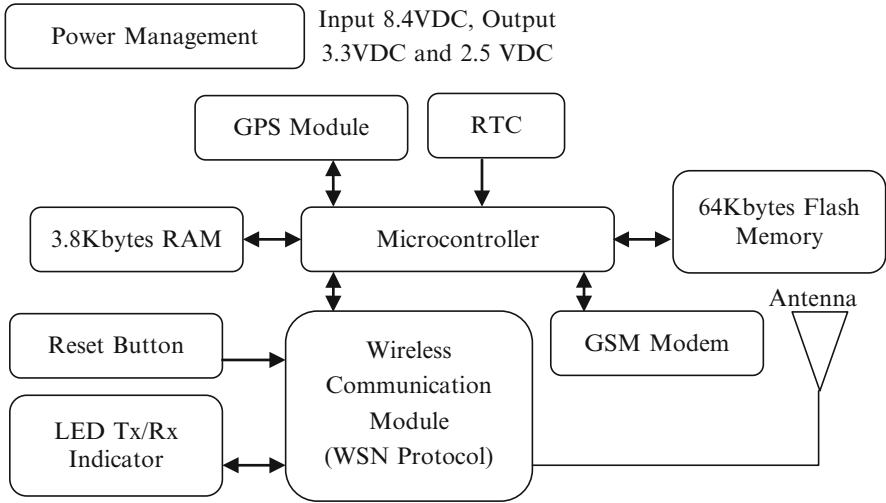


Fig. 34.2 Block diagram of the proposed embedded active RFID tag

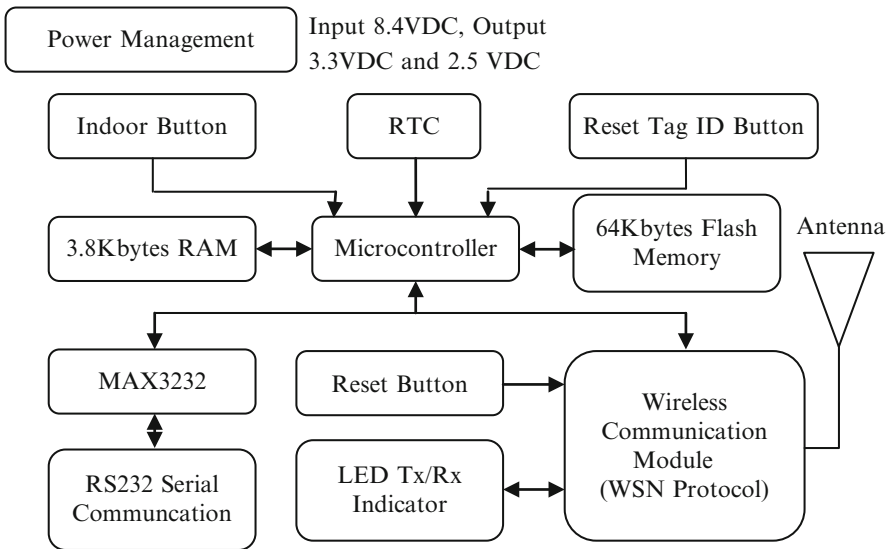


Fig. 34.3 Block diagram of the modified active RFID reader

the RSS values retrieved from the wireless module. The RSS value is periodically or manually request by the RFID reader from embedded RFID tag, which can be used later to calculate distance between the RFID reader and the RFID tag. Instead of tracking indoor and outdoor, the RFID tag node identification (ID) can be reset from the RFID reader based on user requirement and this application contributes to machine to machine (M2M) communication without human intervention.

Previously, the experimental studies are done based on the propagation in an indoor and outdoor environment by extracting the RSS value of the embedded RFID tag to analyze the differences in propagation between indoor and outdoor [10]. Moreover, a comparison also has been made between standalone RFID tag and embedded RFID tag to study the performance before and after of embedment of GPS functionalities. In this work, the experimental study related to data collision is performed in order to study the effectiveness of the proposed RFID system while performing transmission and reception processes and to ensure that the proposed RFID reader has the capability of multiple reading at one time by analyzing the tag collection process.

3 Collision Data Performance Analysis

The goal of this test is to ensure that the modified active RFID reader has the capability of multiple reading at one time by analyzing the tag collection process in the RFID system. The RFID system used the CSMA-CA algorithm for collision avoidance implementation [4]. Therefore, non anti-collision protocol cannot be performed. As the distance between reader and tag increase, the reader should identify a number of tags at one time. When there is more than one tag situated within the read range of the reader, all the tags could send data at the same time, which could possibly lead to mutual interference. This event will cause data loss and it is defined as a collision [13]. Therefore the collision data performance has to be evaluated in order to study the effectiveness of the proposed RFID system.

3.1 *Experimental Setup*

There are two protocols involved in developing the communication between embedded RFID tag and active RFID reader which are RTF and TTF. The active RFID reader is programmed with API mode while the embedded RFID tag is programmed in AT mode. The anti-collision test has been conducted for both communication protocols. The test is conducted in the laboratory for RTF protocol, where all the equipment's are placed on the table such as computers, power supplies and measurement devices, while for TTF, the test is conducted at outdoor environment (field) where the GPS can provide the location data. The tag collection process has been repeated ten times in order to get the average data for analyzing purposes. The arrangement of the test bed has been shown in Fig. 34.4, where tag 1 is situated at 90° to Tag 3, while Tag 2 is 45° to Tag 1 and Tag 3.

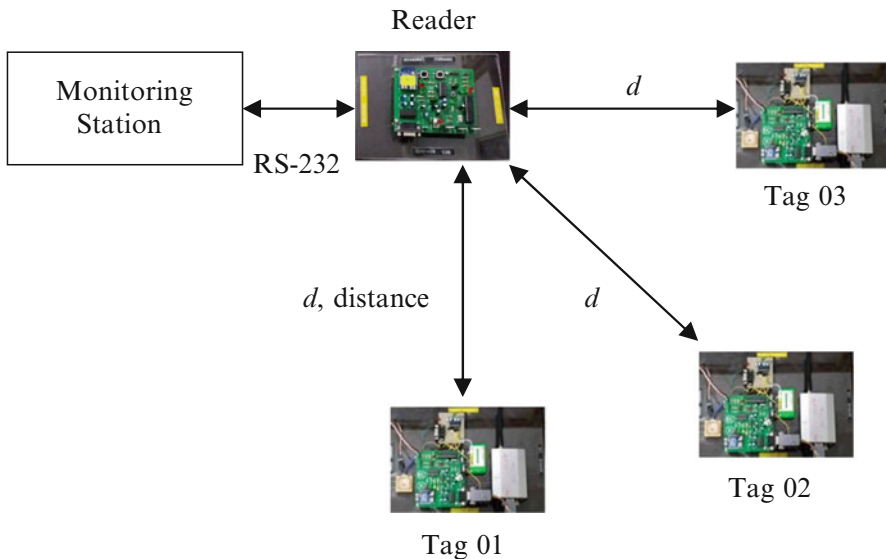


Fig. 34.4 Anti-collision performance test experimental setup

3.2 Anti Collision for RTF Protocol

The anti collision performance test for RTF is done by sending the collection command from the reader to the tags available in the network. The tags received the collection command, thus send an acknowledgment status and the requested data to the reader. This protocol is known as RTF. In this experimental study, three tags were used as a sample and the RFID reader broadcast a collection command for twenty times (once a minute). The tags received the collection command, send an acknowledgment to the reader and perform the reader request to measure the RSS in AT command mode. The anti-collision test for the tags with RTF protocol is conducted at 5 and 10 m distances due to the limited space of indoor locations. The reader will receive all the data send by the tags if no collision occurs. Thus, the percentage of data received will be 100 %. The percentage of data received can be calculated using Eq. 34.1

$$\text{Percentage of Data Received} = \frac{\text{Number of Data Received}}{\text{Number of Data Sent}} \times 100 \% \quad (34.1)$$

Data received from the tags are randomly received and displayed on the serial terminal as shown in Fig. 34.5. The variables of analyzing the data; 5 and 10 m distances have been utilized in order to see whether there are any differences in data losses. The tag collection process is performed for ten rounds to get an appropriate data variation. The data received are summarized in term of percentage as described

Fig. 34.5 Data randomly received from three embedded RFID tags based on RTF protocol

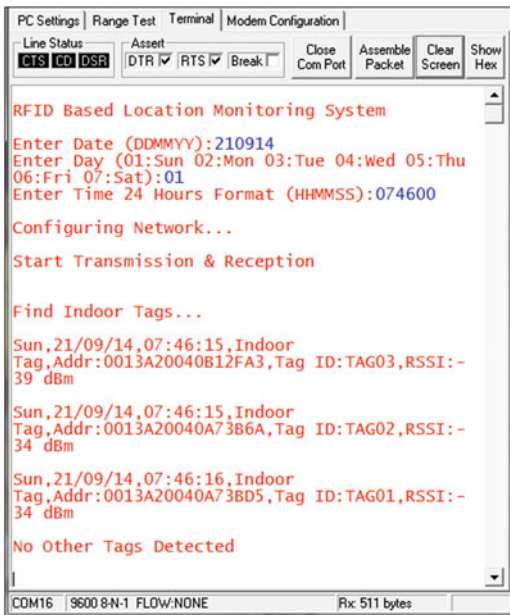


Table 34.1 The Percentage of data received at 5 m read range (RTF)

	Number of data received									
	1	2	3	4	5	6	7	8	9	10
Tag 01	16	16	19	17	19	17	17	17	17	15
Tag 02	17	18	18	17	17	19	19	18	18	18
Tag 03	18	17	20	14	15	17	17	17	17	18
Total data received (/60)	51	51	57	48	51	53	50	52	52	51
% Data received	85	85	95	80	85	88.3	83.3	86.7	86.7	85
Average (%)	86.2									

in Table 34.1. Each tag has sent 20 data to the RFID reader, but due to the collision, the reader only received 47 out of 60 total data in the first round of tag collection process. The total data received in the second and third round are 50 and 46 out of 60 total data. The reader has received 49 total data in the fourth round. The total data received in fifth round increased by three compared to the total data received in the fourth round. In the sixth round, the reader received 50 out of 60 total data. The reader received 47 total data in the seventh round and in the eighth round, the number of total data received is remained same with previous. The total data received in ninth and tenth round are 51 and 53, respectively. The average percentage of the data received for 5 m read range is about 81.99 %. The anti-collision test has been extended from 5 to 10 m distance between the tag and reader. The data received percentage of the RFID system for 10 m read range is summarized in Table 34.2. The Percentage of data received at 5 m read range (RTF) collection process has been

Table 34.2 The percentage of data received at 10 m read range (RTF)

	Number of data received									
	1	2	3	4	5	6	7	8	9	10
Tag 01	15	16	16	17	18	19	16	15	17	18
Tag 02	17	16	13	16	16	16	17	17	18	18
Tag 03	15	18	17	16	18	15	14	15	16	17
Total data received (/60)	47	50	46	49	52	50	47	47	51	53
% Data received	78.3	83.3	76.7	81.7	86.7	83.3	78.3	78.3	85	88.3
Average (%)	82									

repeated for ten times and each tag sends 20 data (once a minute) to the reader. In the first and second round, the reader received 51 out of 60 total data from the three tags. The number of total data received by the reader in the third round is increased by six compared to the first round. The total data received from reader is 48 and 51 in fourth and fifth round respectively. The reader received 53 total data in the sixth and seventh round. In the eighth round, total data received is 50 out of 240. The total data received in ninth round increased by two compared to eighth round, while the total data received in the last round are 51 out of 60. The average percentage of data received for 10 m distance is 86.16 %.

From the results, it can be concluded that the efficiency of anti-collision for the tags with AT command mode system is 81.99 % and 86.16 % for 5 and 10 m distance, respectively. The results of data collection for 5 and 10 m distances are compared and it is show that the number of data losses increases as the distance between tag and reader increases.

3.3 Anti Collision for TTF Protocol

The anti collision performance test for TTF is done by sending the location data provided by the GPS receiver from embedded RFID tag to the RFID reader. Later, the RFID reader sends an acknowledgement packet to all tags that are successfully sent their packet, thus extracted and displayed the data from RFID reader to a host computer. This protocol is known as TTF. Three tags are used as a sample in the experimental study. The amount of data sent is set to be 70 for each tag. The tag collection process is performed for ten rounds to get an appropriate data variation. The anti-collision test for the tags with TTF protocol is conducted at 5 and 25 m distances. The efficiency of anti-collision for the tags with TTF protocol is 100 % at 5 m and 100 % at 25 m distance, respectively. Data transmitted from the embedded RFID tags are randomly received and displayed on the serial terminal as shown in Fig. 34.6. The percentages of data received are summarized in Tables 34.3 and 34.4 for 5 and 25 m, respectively. Since the tag developed with TTF mechanism is a non AT command mode, thus the system provided better anti-collision performance

Fig. 34.6 Data randomly received from three embedded RFID tags based on TTF protocol

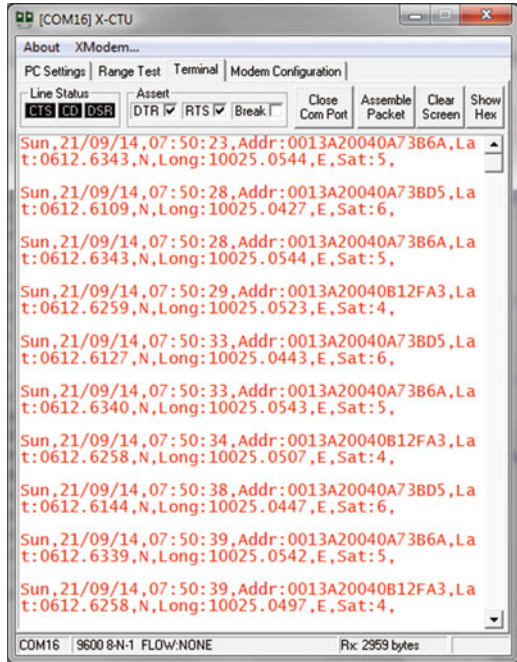


Table 34.3 The percentage of data received at 5 m read range (TTF)

	Number of data received									
	1	2	3	4	5	6	7	8	9	10
Tag 01	70	70	70	70	70	70	70	70	70	70
Tag 02	70	70	70	70	70	70	70	70	70	70
Tag 03	70	70	70	70	70	70	70	70	70	70
Total data received (/60)	210	210	210	210	210	210	210	210	210	210
% Data received	100	100	100	100	100	100	100	100	100	100
Average (%)	100									

Table 34.4 The percentage of data received at 25 m read range (TTF)

	Number of data received									
	1	2	3	4	5	6	7	8	9	10
Tag 01	70	70	70	70	70	70	70	70	70	70
Tag 02	70	70	70	70	70	70	70	70	70	70
Tag 03	70	70	70	70	70	70	70	70	70	70
Total data received (/60)	70	70	70	70	70	70	70	70	70	70
% Data received	100	100	100	100	100	100	100	100	100	100
Average (%)	100									

compared to tag developed with RTF protocol. The variables of analyzing the data; 5 and 25 m distances have been utilized in order to see whether there are any differences in data losses due to the increased in range.

4 Conclusion

The extended version of an active RFID system is successfully implemented and the performance of the system is evaluated through the anti collision performance in order to study the effectiveness of the proposed RFID system while performing transmission and reception processes and to ensure that the proposed RFID reader has the capability of multiple reading at one time. The tag collection process has been repeated ten times for data analyzing purposes and the percentage of the data losses are calculated. Since there are two communication protocols; RTF and TTF, thus the anti-collision test is conducted for both communication protocols. In RTF protocol, three tags are used in the analysis, where the RFID reader starts the transmission by broadcasting the collection command for twenty times (once a minute). The tags received the collection command and perform the reader request to measure the RSS in AT command mode. The anti-collision test for the tags with RTF protocol is conducted at 5 m and 10 m distances due to the limited space of indoor locations. The results show that the efficiency of anti-collision for the tags with the AT Command mode system is 81.99 % and 86.16 % for 5 m and 10 m distance, respectively. The amount of data losses increased as the distance between tag and reader are increased. Based on these findings, it can be concluded that if a network having more than two devices operates in AT command mode approach, the data transmission and reception will face problems with data collision and time switching between in and out of the command mode.

In the TTF protocol, three tags are used in the analysis and the tags are triggered by a GPS receiver and send the location data to the proposed RFID reader. The anti-collision test for the tags with TTF protocol is conducted at 5 and 25 m distances, respectively. The efficiency of anti-collision for the tags with TTF protocol is 100 % at 5 m and 100 % at 10 m distance, respectively. By comparing the result between RTF and TTF protocols, the TTF protocol shows that the anti-collision is better with 100 % data received than the RTF protocol with 81.99 % efficiency. In comparison with Alejandro et al [1] , the anti-collision efficiency is nearly 100 % by using the proposed CSMA-MS algorithm using TTF protocol. In terms of time delay between transmission and reception for both protocols, the RTF protocol takes about 87.7 ms to complete the data transmission and reception, while the TTF protocol takes about 61.2 ms average delay to complete the transmission and reception between RFID reader and tag. Table 34.5 shows the average time delay in millisecond (ms) for RTF and TTF protocols.

From the results, it can be seen that the tag developed with TTF protocol provided better anti-collision performance and average time delayed compared to tag developed with RTF protocol.

Table 34.5 The average time delay for RTF and TTF protocol

Protocol		Average time (ms)	Total average time (ms)
RTF	Transmit and receive acknowledgement	43	87.7
	Reply to reader request and receive acknowledgement	44.7	
TTF	Transmit and receive acknowledgement	61.2	61.2

Acknowledgments The authors would like to thank the Malaysia Ministry of Higher Education (LRGS fund) for sponsoring the research and development of this project. Also, special appreciation to Prof. Dr. Mohamad Kamal Abdul Rahim from Universiti Teknologi Malaysia, head of the LRGS project and Associate Professor Dr. Alyani Ismail, Universiti Putra Malaysia for the support.

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