Analysis of Factors Affecting Anti-Collision Performance of RFID Based Asset Tracking System In WSN Platform

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***Abstract*—In an RFID system, a reader identifies a set of tags over a shared wireless channel. When multiple tags communicate with the same reader simultaneously, some of the packets will be lost due to collision of data, thus jeopardizing the integrity of the RFID system. In this project, the performance of the anti - collision mechanism was investigated in the real environment by identifying the MAC parameters and external factors that could affect the system performance using the Design of Experiment (DOE) method and Analysis of Variance (ANOVA) statistical tools. The experimental results reveal that the performance of the designed remote asset tracking system's anti-collision mechanism is influenced by random slot delay, distance, and clear channel assessment.**

Keywords— Tag Anti-collision ,RFID, WSN, DOE, ANOVA

I. INTRODUCTION

Tracking systems, or systems that track devices or people, have become an increasingly pervasive technology. Various methods for tracking assets are available, including GPS, Bluetooth or Wi-Fi. The benefits of such technologies vary depending on the device implementation. For instance, Chadil et al. using GPS tracking device in a real time tracking system with an open system [1]. The system consists of a tracking device, a server and a database. The data from the tracking device is sent to the server through the GPRS network and stored in a database. From the database, the information can be searched and located using Google Earth software and Google map. This system, however, is not appropriate for indoor monitoring. A tracking system developed by Opoku et. Al. using Bluetooth with Central Monitoring System (CMS) [2] able to locate the initial location of the tracked device and will notify the user whenever the device is moved. The system, however, has a limited read - range and consumes a lot of power. Most of these systems have been designed for outdoor applications, where minimum blockage could occur between systems. The signal for the indoor asset tracking system, on the other hand, must be high enough to penetrate the building's signal barrier.

Active RFID is commonly used where a larger communication range is needed. This paper describes the active RFID based tracking system using 2.4GHz Xbee. Besides of low-cost, low power, a network node with a high bandwidth and wide communication range [3], this system provides a lot of benefits for all forms of asset management systems. Nonetheless, the RFID mass use of the asset monitoring system poses a range of new problems. Collision is one of the problems of RFID. This collision happens when simultaneous transmissions in RFID systems cause collision of data as the readers and tags usually operate on the same channel.

There are three types of collision which are tag to tag collision, reader to reader collision and reader to tag collision. When one reader transmits a signal that interferes with the activity of another reader and prevents the second reader from interacting with tags in its interrogation region, this is known as a reader to reader collision. When one tag is concurrently placed in the interrogation zone of two or more readers, and more than one reader tries to interact with that tag at the same time, this is known as reader to tag collision [4].

This proposed study focused on tag to tag collision. This sort of collision happens when the RFID reader simultaneously energizes numerous tags and their respective signals return to the reader simultaneously. This issue is often encountered where multiple tags are in the same reader zone where the reader can not differentiate. Collision with the tag is a significant issue to be tackled in order to make the identification faster [5]. In order to minimize the packet loss, this paper investigates various influential factors that could affect the collision of data.

For instance, to avoid interference signals from nearby tags, a specific time slot (delay slot) may be useful, where the tags in the interrogation zone are allocated a specific time slot so that they can communicate with the readers at any point in time [6].

According to a study by Yüksel and Findan, collisions occur when neighbouring tags are unable to interact with one another and determine if the channel is busy or not. If a collision occurs, the tag will retry to relay the frame after a random delay until no collision occurs [7].

When two nodes send information to a node at the same time, according to Chen et al., the channel utilisation shows a stepper decline slop as the distance between them increases [8].

Tytgat et al. suggested a collision avoidance scheme in Zigbee technology based on clear channel assessment (CACCA). The unit remains in receiving mode until a CCA time has passed, at which point it calculates the average power received. If the measured value exceeds the threshold, the system assumes the channel is occupied and backs-off. Otherwise, the radio switches to TRx2Tx mode and starts transmitting the packet. As a result, incorporating CACCA technology improves Zigbee's reliability by greatly reducing packet loss [9].

This paper describes the development of an RFID-based real-time asset tracking system and investigates the factors that influence the anti-collision performance of the system. Many of the researches in the literature are focused on collision avoidance through simulation, however this study conducts the designed experiment in a real-world setting.

The following is a breakdown of the paper's structure. The project outline, system flowchart, software design, and DOE design are all discussed and explained in Section II. The findings of the study are discussed in Section III, and the conclusions are presented in Section IV.

II. METHODOLOGIES

A. System Overview

This project employs the XBee S1 transceiver as a communication module for tags and reader in a wireless sensor network. The conceptual idea of this proposed project is represented in the Fig. 1.

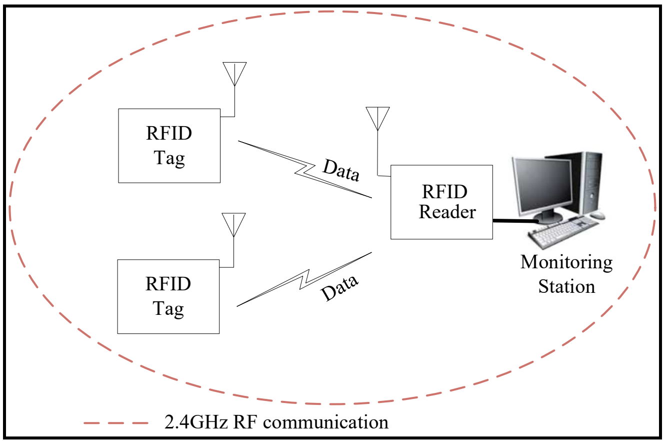

Fig. 1. Proposed System Architecture

The system consists of three components, which are the tags (end device), a reader (coordinator) and a monitoring station. In every network, there must be a coordinator device which acts as a parental device for all end devices. The reader sends a signal with a command requesting RSSI value to the tag. The tag is a device that has a unique serial ID. As the tag receives the command signal from a reader, it bounces back the signal with the requested RSSI value. The receiving data is displayed at the monitoring station and logged in the database.

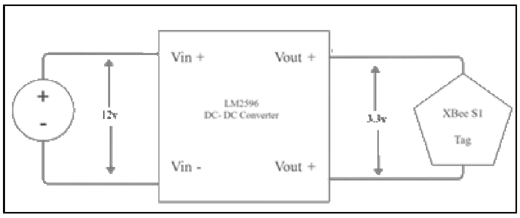

Fig. 2. RFID Tag Setup

The mobilise tag arrangement is shown in Fig. 2. The circuit of the tag consists of a power supply, LM2596 DC-DC converter and the transceiver. The input of Vin+ and Vin- on DC-DC converter are connected to 12 V of power supply. The converter acts as an adjustable step-down where it has a built-in potentiometer to adjust the conversion value of voltage. The converted voltage of 3.3 V is connected on the converter where the transceiver is attached through Vout+ and Vout-.

B. Collision Testing Method

Fig. 3 shows the operation flowchart of tag and reader of the proposed system. The system is constructed to test the performance of the anti-collision in RFID system. The Xbee is configured using XCTU software. According to research published in [10], probability of collision is proportional to the number of contending transmissions, N, where N should be two or more. In this experiment, two tags were employed to minimize the influence of a large number of competing transmissions.

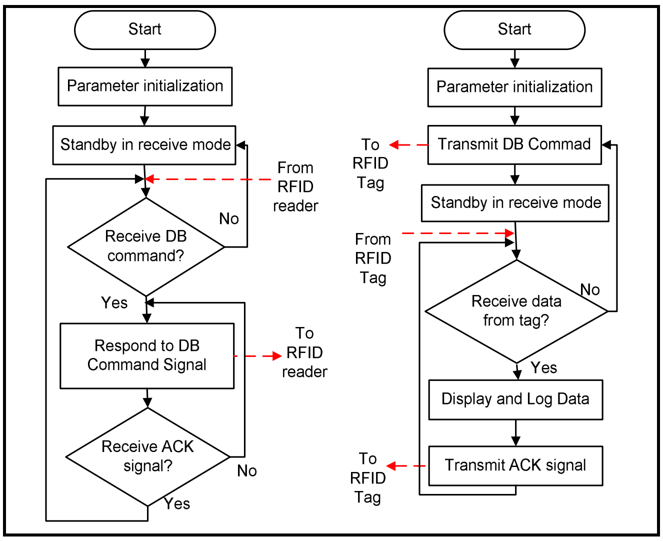

Fig. 3. Operation Flowchart of RFID Tag and RFID Reader

The communication begins with the tags receiving a DB command signal from the reader, and the tags immediately respond to the reader by sending back the data of the tag's ID and RSSI value to the reader. The acknowledgement data is transmitted for every successful data transmission between the tags and the reader. The reader received the data from both tags and displayed it at the monitoring station. Each test was repeated for 100 times with the same parameters [11].

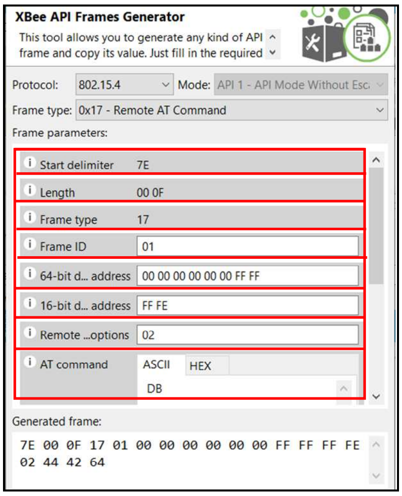

Fig. 4. Configuration of Transmission Frame

Fig. 4 shows the generated transmission frame for the reader to transmit the DB command to the tags. Every parameter of the payload is very important to make sure the signal from the reader can be received by the tags.

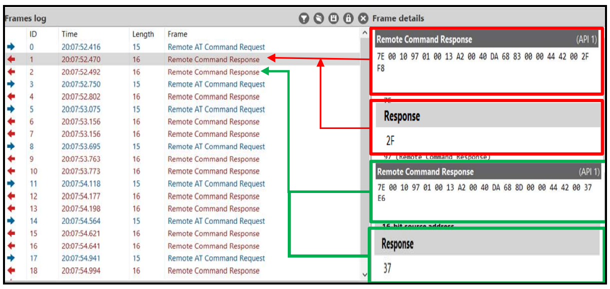

Fig. 5. Data received by RFID Reader from RFID Tags

If a collision does not take place, the reader will get responses from two tags following the broadcast DB command, as shown in Fig. 5. Each tag transmits data which contains the ID and received signal strength indicator (RSSI) value in hexadecimal. The response value (in hexadecimal) had to be encoded to decimal to obtain the RSSI value in dBm.

C. *Design of Experiment (DOE) Implementation*

DOE is considered to be a useful method for conducting a rigorous experiment [12] in order to identify factors that influence tag collision in this study. The levels of the respective factors that were examined in collision testing are shown in Table I. To increase the probability of identifying significant factors from the mentioned factors, the run order of the experiment is repeated twice.

TABLE I. FACTORS AND LEVELS OF DOE FOR DATA COLLISION

Factors	Level 1	Level 2	Level 3
XBee Retries, RR	2	4	6
Random Slot Delay, RN	1	2	3
Distance (m)	5	10	15
Power Level, PL	PL0	PL4	-
Clear Channel Assessment, CCA (-dbm)	44	80	-

Table II shows the generated run order list for collision testing in Minitab. There were 216 numbers of run order which represent the number of test setups that needed to be performed. The Packet Delivery Ratio (PDR) was recorded for every run in the data log from the 100 repeatations.

TABLE II. FACTORIAL DESIGN TABLE FOR COLLISION TESTING

C1	C2	C3	C4	C5	C6	C7-T	C8	C9-T	C10
StdOrder	RunOrder	PtType	Blocks	XBee Retries (RR)	Random Slot Delay (RN)	Power Level (PL)	Distance	Clear Channel Assessment (CCA)	Packet Delivery Ratio
161	1	1	1	2	3	Highest	15	2C	72
84	2	1	1	6	3	Highest	5	50	60
34	3	1	1	2	2	Lowest	5	2C	63
138	4	1	1	6	3	Lowest	15	50	42
101	5	1	1	4	1	Highest	10	2C	45
51	6	1	1	2	1	Lowest	5	2C	66
118	7	1	1	2	3	Lowest	5	50	52
147	8	1	1	2	2	Highest	10	50	20
171	9	1	1	6	3	Lowest	10	2C	68
100	10	1	1	2	2	Lowest	5	50	49
110	11	1	1	2	2	Highest	15	2C	67
136	12	1	1	4	2	Highest	5	50	44
157	13	1	1	4	2	Highest	10	2C	71
89	14	1	1	6	1	Lowest	10	2C	13
38	15	1	1	2	1	Lowest	10	50	40
165	16	1	1	2	3	Highest	10	50	35
190	17	1	1	2	3	Lowest	15	2C	62
97	18	1	1	6	1	Lowest	15	2C	66
156	19	1	1	4	1	Highest	5	50	45
29	20	1	1	2	3	Highest	10	2C	67
146	21	1	1	2	1	Highest	15	50	25
140	22	1	1	2	3	Lowest	5	2C	41
215	23	1	1	4	1	Lowest	15	50	41
45	24	1	1	4	1	Highest	15	2C	38
1	25	1	1	4	1	Lowest	5	2C	53

The packet delivery ratio is computed using the following equation:

$$\text{PDR}\ (\%) = \frac{\text{total data packet received}}{\text{total data packet transmitted}} \times 100\% \qquad (1)$$

III. RESULTS

A. *Investigation of Significant Factors Affecting PDR*

Fig. 6 shows the prototype system which consists of two tags and a reader used in the testing. The data of the Packet Delivery Ratio (PDR) was analysed using Analyse of Variance (ANOVA).

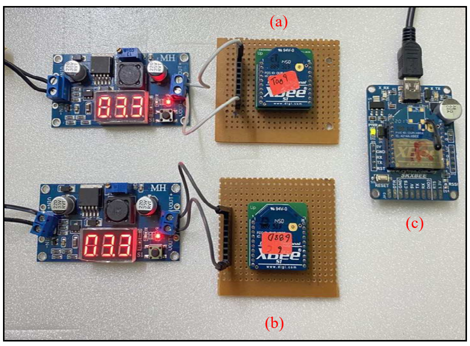

Fig. 6. The prototype of the proposed system (a) RFID Tag1, (b) RFID Tag2 and (c) RFID Reader.

1) *ANOVA Analysis of Packet Delivery Ratio*

Table III shows that there are four factors that obtained p-value ≤ 0.05. Those factors are Random Slot Delay, Distance, Clear Channel Assessment and Random Slot Delay, RN * Distance, d with p-value of 0.008, 0.027, 0.000 and 0.05, respectively. This result shows that these four factors do effect the PDR performance in this system.

TABLE III. ANOVA RESULT OF PDR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
XBee Retries, RR	2	345.3	345.3	172.7	0.54	0.585
Random Delay Slot, RN	2	3145.2	3145.2	1572.6	4.90	0.008
Power Level, PL	1	444.9	444.9	444.9	1.39	0.241
Distance, d	2	2369.4	2369.4	1184.7	3.69	0.027
Clear Channel Assessment, CCA	1	5953.5	5953.5	5953.5	18.55	0.000
*RN * RN*	4	2154.0	2154.0	538.5	1.68	0.157
*RR * PL*	2	225.1	225.1	112.5	0.35	0.705
*RR * d*	4	1281.1	1281.1	320.3	1.00	0.410
*RR * CCA*	2	1242.7	1242.7	621.4	1.94	0.147
*RN * PL*	2	753.1	753.1	376.5	1.17	0.312
*RN * d*	4	3112.1	3112.1	778.0	2.42	0.050
*RN * CCA*	2	830.1	830.1	415.0	1.29	0.277
*PL * d*	2	257.8	257.8	128.9	0.40	0.670
*PL * CCA*	1	78.2	78.2	78.2	0.24	0.622
*d * CCA*	2	440.4	440.4	220.2	0.69	0.505
Error	182	58405.7	58405.7	320.9		
Total	215	81038.6				

The p-value for XBee Retries and Power Level are 0.585 and 0.241, respectively. Thus, these factors do not influence the PDR performance.

2) *Main Effects Plots for Packet Delivery Ratio*

Fig. 7 shows the main effects plot for the PDR. There are three factors that show stepper slope. First, RN's graph depicts a continuous stepper up slope from 1 to 3. Second, there is a stepper down slope at the 5 m and 10 m, with a continual decrease until 15 m distance. CCA has a stepper down slope from -44dbm to -80dbm. These three factors determine that there is an effect between the RN, d, and CCA on the PDR. The RR and PL graphs only show a small deflection on the horizontal axis which indicates that it has a minor impact on the PDR and it is not really significant.

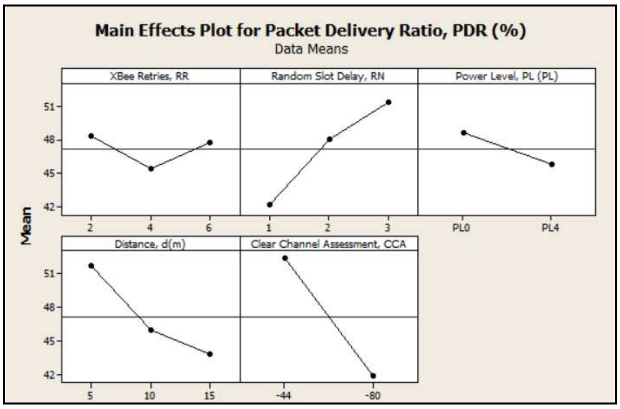

Fig. 7. Main Effects Plot for PDR

3) *Interaction Plot for Packet Delivery Ratio*

One of the advantages of implementing DOE in this study was its ability to analyse the interaction of five factors, which are XBee retries, random slot delay, power level, distance and clear channel assessment. It was found from the General Linear Model that most factor interactions were not significant which had p-value > 0.05. The interaction plot in Fig. 8 illustrates the insignificant interaction between the five factors. Nevertheless, there is one significant interaction between random delay slot and distance which is at 0.05 p-value. The number of packet delivery ratio worsens when the parameter of RN is changed to 1 at a distance of 10m to 15m. These factor interactions revealed that the random delay slot and distance are important parameters to PDR percentages.

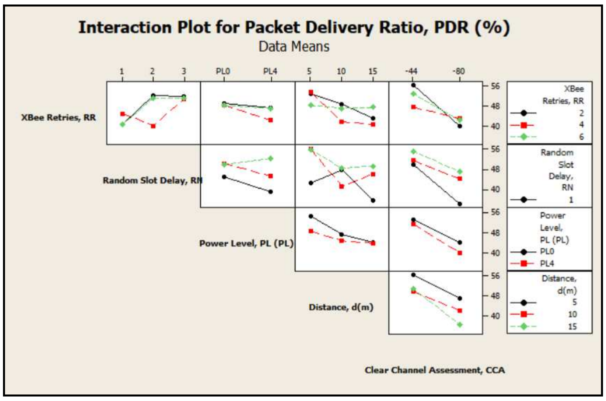

Fig. 8. Interaction Plot for PDR

IV. CONCLUSION

The design and prototype of the proposed system monitoring system using WSN technologies have been successfully developed. Based on the statistical analysis for collision testing that was conducted, the XBee retries, the power level and the interaction factors do not influence the packet delivery ratio of the tags to the reader. While for the random slot delay, the distance and the clear channel assessment, these parameters do influence the PDR performance.

The system can be improved in the future by adding more RFID readers and RFID tags to investigate different sorts of collisions, such as reader-to-tag and reader-to-reader collisions.

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