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Animal Identification and Performance Analysis Based on RFID-IoT Smart Farming Applications

***Abstract**. The intelligent farming concept involves animal identification to monitor and count in the open farm. The embedment ideas of radio frequency identification (RFID) and Internet of Things (IoT) technologies have been a rise in the number of applications and have been successfully applied for animal tracking systems. In this paper, both RFID and IoT are implemented for a wireless tracking monitoring system. This implementation used for wireless animal monitoring in the open-farm can eliminate time wasted during manual counting of animals in the farm if they disappear. The tracked information can be recorded at any time (real-time monitoring). The RFID systems are embedded with the passive and active, and they are worked together over the wireless sensor network (WSN) platform. The WSN is helpful in case used in outdoor conditions when there is no WiFi-internet signal covering. The passive RFID card with a reader functioned low-frequency at 134.2 kHz, and they are embedded with active RFID using ZigBee-Pro through an IoT microcontroller. The RFID system integrated IoT platform evolves to transmit the information remotely to the farm-owner. This paper proposes the tag collection time and received signal strength indicator (RSSI) tests. The findings found that the embedded RFID end device achieves tag collection time performance compared to the standalone RFID of 9.26%. Moreover, the RSSI performance of the embedded RFID end device has a higher RSSI value than the standalone by ±10.32%. The individual test claimed that the embedded RFID end device achieves the outdoor condition use with a strong communication signal and sufficient time latency delay.*

Streszczenie.** Koncepcja inteligentnej hodowli obejmuje identyfikację zwierząt w celu monitorowania i liczenia w otwartej farmie. Pomysły dotyczące osadzania technologii identyfikacji radiowej (RFID) i Internetu rzeczy (IoT) spowodowały wzrost liczby zastosowań i zostały z powodzeniem zastosowane w systemach śledzenia zwierząt. W tym artykule zarówno RFID, jak i IoT zostały wdrożone w bezprzewodowym systemie monitorowania śledzenia. Ta implementacja wykorzystywana do bezprzewodowego monitorowania zwierząt na farmie otwartej może wyeliminować czas marnowany podczas ręcznego liczenia zwierząt w gospodarstwie, jeśli znikną. Śledzone informacje mogą być rejestrowane w dowolnym momencie (monitorowanie w czasie rzeczywistym). Systemy RFID są osadzone z pasywnym i aktywnym i współpracują ze sobą za pośrednictwem platformy sieci czujników bezprzewodowych (WSN). WSN jest pomocny w przypadku użytkowania w warunkach zewnętrznych, gdy nie ma pokrycia WiFi-internetu. Pasywna karta RFID z czytnikiem działała na niskich częstotliwościach przy 134,2 kHz i są one osadzone w aktywnym RFID za pomocą ZigBee-Pro poprzez mikrokontroler IoT. Zintegrowana z systemem RFID platforma IoT ewoluuje, aby zdalnie przesyłać informacje do właściciela gospodarstwa. W niniejszym artykule zaproponowano testy czasu zbierania znaczników i wskaźnika siły odbieranego sygnału (RSSI). Wyniki wykazały, że wbudowane urządzenie końcowe RFID osiąga wydajność zbierania tagów w porównaniu z samodzielnym RFID wynoszącym 9,26%. Co więcej, wydajność RSSI wbudowanego urządzenia końcowego RFID ma wyższą wartość RSSI niż samodzielne urządzenie o ±10,32%. W indywidualnym teście stwierdzono, że wbudowane urządzenie końcowe RFID osiąga warunki zewnętrzne przy silnym sygnale komunikacyjnym i wystarczającym opóźnieniu czasowym.* (Identyfikacja zwierząt i analiza wydajności na podstawie aplikacji RFID-IoT Smart Farming***)

Keywords: RFID, IoT, WiFi, WSN, ZigBee-Pro
Słowa kluczowe: RFID, WiFi, ZigBee

Introduction

By 2050, the world's population will grow to reach 10 billion people. Thus, supplying sufficiency people around the world is a challenge for agriculture and food producers. Hence, these producers play an essential role with people living, and they need to adopt the Hi-Technologies to improve their production efficiency. RFID is the solution that can enhance farmer's operations throughout the global food supply chain [1].

The Ultra-high frequency (UHF) RFID technology tends to move towards fast and real-time monitoring in the intelligent environment [2]. Indeed RFID systems have been significantly improved over the past several years where present one can contribute passive and active RFID integrated circuit (I.C.) with diverse processing and memory functionalities in the RFID tag module and, more recently, sensing capabilities that offer a new horizon of application [3, 4, 5]. In typical RFID systems, parameters such as sensitivity, backscatter signal strength, and read range or read rate are considered the most crucial performance parameters [6]. However, assessing throughput performance and time delay in the RFID system is also essential since it is a significant factor that must be considered when using RFID tags in real-time sensing applications [7].

The RFID system can work together with the IoT network to make it more efficient. The IoT is actively shaping many kinds of applications because it is an exciting concept regarding internet network communication, among various things. They can interconnect between each other wirelessly into the embedded sensor device [8]. Moreover, IoT refers to an ecosystem in which applications and services are driven by data collected from multi-sensor that sense and interface with the physical world. Furthermore, it is also related to Machine to Machine (M2M) communications; this solution between machines can communicate without human involvement [9]. IoT is very cheap cost and easy to learn about its communication system, which it links with the internet and cloud services.

This study brings the RFID and IoT technologies with network architecture using ZigBee. ZigBee is based on the wireless networking standard of IEEE802.15.4. Its advantages in low power consumption and low data rate as it is basically used for two-way communication between sensors and control systems. It can provide coverage range up to 100 m indoor, focusing on a simple data package for communication to obtain a low data rate and low power consumption environment. The table below shows the comparisons of fundamental specifications between ZigBee and WiFi technologies.

Table 1. Comparison of ZigBee and WiFi technologies

	ZigBee	WiFi
Distance coverage	1-10 meters	50-100 meters
Network topology	Ad-hoc, star, cluster, and mesh	Ad-hoc, very small networks
Frequency band	868 MHz, 2.4 GHz	2.4 and 5 GHz
Complexity	Low	High
Power consumption	Very low	High
Max number of nodes	65000	2007

Table 1 illustrates the difference between ZigBee and WiFi technologies. It indicates that ZigBee has the advantages of low power consumption, supporting various network topologies, and the high number of nodes.
The other significant difference is the support of several ZigBee network topologies, namely the star network, cluster tree network, and wireless sensor network [10].

The assumptions of this study are 1) to achieve effective results on tag collection time of the embedded RFID device compared to standalone RFID, and 2) to strengthen the RSS of the embedded RFID device more than the standalone RFID. This paper proposes animal identification based on RFID-IoT smart farming applications, which is organized according to the following Sections; 1) Proposed animal identification based on RFID-IoT smart farming applications, 2) experimental results, and discussions and finally 3) The conclusions. More details will be described according to the following Sections.

Proposed Animal Identification Based RFID-IoT Smart Farming Applications

This section provides the concept of the proposed animal identification based-IoT smart farming applications, which are divided into three essential parts are 1) end devices, 2) base station, and 3) data transmission network. The first part of the end devices is explained as follows.

1. End devices

The end devices are used for tracking and livestock animal on the farm, which using RFID tags. The RFID shorter range low frequency (LF) 134.2 kHz RFID ear tags are available as half-duplex (HDX) or full-duplex (FDX). RFID HDX tags work by replying to a signal sent out by an RFID reader, whereas RFID FDX tags communicate simultaneously with an RFID reader. The animal ear tags can operate in the temperature from -50 °C to 85 °C. The reader can read in the range of 7 meters away.

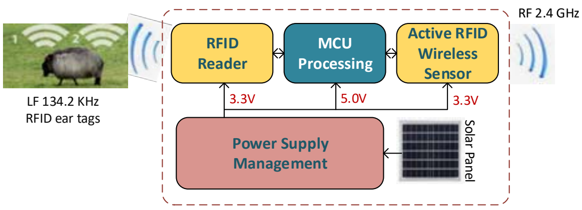

Fig.1 End devices block diagram

Figure 1 presents a block diagram of the proposed end monitoring module for animal identification-based RFID. This block includes both passive and active RFIDs. The passive RFID tag will communicate with the RFID reader using 134.2 kHz. While, the main central processing unit is to receive and transmit the obtained information to the host office through an active RFID wireless sensor, which works at an RF signal of 2.4 GHz. Based on IEEE standard 802.15.4, the ZigBee-Pro is used for wireless transceiver devices, the middleware unit to communicate between WAM and the host office. The WAM is designed by embedding the passive and active RFID altogether. Both RFID systems can work together effectively with other RF band communication. The embedment of both RFID systems perfectly works because an active RFID wireless sensor based on IEEE802.15.4 standard efforts to firmly transmit RF signal to the destination with a bandwidth rate of 250 Kbps with very little data loss. ZigBee-Pro development module can be designed as a WMSN, used in indoor and outdoor conditions. Thus, the proposed WAM system has achieved full use with quality of throughput evaluation, as the experimental results section proved.

2. Base Station

This section draws the infrastructure of the base station diagram. The active RFID wireless sensor is the crucial media to wireless communication between the embedded RFID device. The data packages collected from the RFID ear tag embedded with the animal in the farm will be travel to the base station using RF 2.4 GHz. The microcontroller in the base station side will be the center to distribute information to the base station and many users.

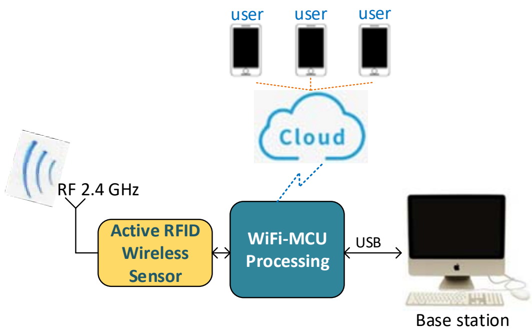

Fig.2 Base station block diagram

The proposed base station provides the supervisory control and data acquisition (SCADA) system [11]. The information data is received through the active RFID ZigBee-Pro wireless sensor will be linked to the base station. Microcontroller unit with WiFi module connected to the base station of the host computer and linked to the cloud internet network using IEEE802.11a standard [12].

3. Proposed Wireless Data Communication Based IEEE802.15.4 Standard

This subsection presents the essential wireless sensor network communication between the end device and the embedded RFID reader. The ZigBee-Pro worked on the IEEE802.15.4 standard can be exquisitely implemented in the indoor environment and the setting up in a wide area for a wireless mesh sensor network. The quality of the signal connection is due to the actual environment, such as path loss, size of spaces, transmit power, or the height of the reference node, which impact the signal strength [13].

The proposed data tracking system synchronizes real-time data transmission between the RFID reader device and base station. The RFID ear tags will be contained with information on animals that are being tracked. The monitored information will be automatically sent to the RFID reader and consequently memorized into the data storage system at the base station. The implemented wireless animal I.D. and tracking are designed as the efficiency of real-time data monitoring is 100%. Although it may be delayed but still minimized, it is controlled by microcontroller programming with anti-collision of information sending/receiving even though using multiple end transceiver tags. Development and implementation of the application of RFID technology using ZigBee-Pro IEEE802.15.4 standard based on WMSN platform had improved and contributed the main parameters to be compatible with the proposed application to achieve the concept.

Moreover, it is adequately designed to be sufficient in terms of the power management system. Furthermore, data collision and extensive network coverage matters are also considered. The communication formation between the end device tag and RFID reader is shown in Figure 3.

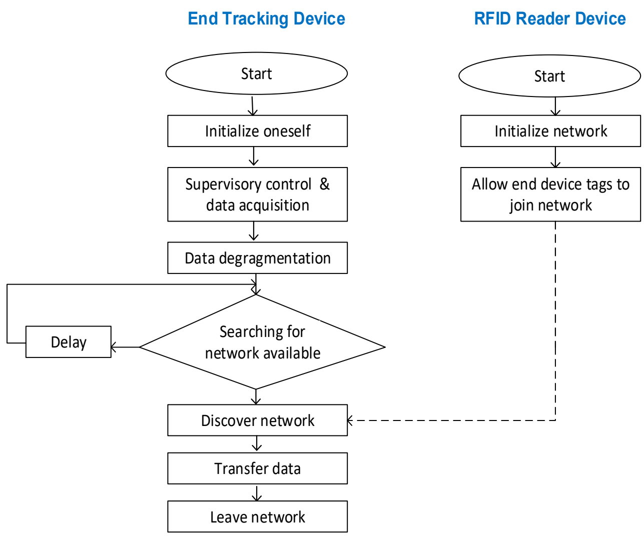

Fig.3 Proposed RFID communication network

The RFID reader acts as the head of each network to call for all end transceiver devices. The primary duty of an RFID reader is to verify the traffic congestion, which it requests to scan an end device and connect to another router automatically. The characteristics of WSN will search the route to transmit its tracked data to the base station quickly by selecting the shortest distance connection. When there is no coming information condition, the system will go to the sleep-mode function to save power consumption when the network is idle.

Experimental Results and Discussions

In this section, the experimental results on the proposed animal identification based on RFID-IoT were demonstrated. The data packages were tracked and verified the tag collection time and RSSI tests on end device tags. Both data packages received were analyzed the tag collection time between standalone-ZigBee module without embedment, embedded-ZigBee module, and base station. Both tests as mentioned, are performed in line of sight (LOS) condition without obstructions. The details will be demonstrated as follows:

1. Tag Collection Time

This sub-section presents the tag collection time test to analyze the tag collection time test of embedded RFID device compared the standalone, and base station. The data packages transmission at three stations was tested as mentioned above. The results are presented in Table 2.

Table 2. Tag collection time test of three checkpoints

No. Test	Checking completed data package	Tag Collection Time Test		
		Standalone ZigBee (s)	Embedded ZigBee (s)	Base Station (s)
1	✓	1.485	1.237	1.617
2	✓	1.554	1.396	1.754
3	✓	1.680	1.561	1.799
4	✓	1.985	1.898	2.331
5	✓	2.332	2.198	2.486
6	✓	2.949	2.543	3.213
7	✓	3.181	2.795	3.763
8	✓	4.275	3.785	4.521
9	✓	4.388	4.167	4.476
10	✓	5.237	4.792	5.492
	Average	1.485	1.237	1.617

Based on the individual experimental results of the tag collection time test of three places of data packages received. The experiment used 10 data packages to transmit from the end device to the base station through the transmission line USB port. The findings indicated that the average tag collection time of the embedded end device and the base station received were 1.237 s, and 1.617 s, respectively.

Three data collections were plotted into the graph form according to Figure 4.

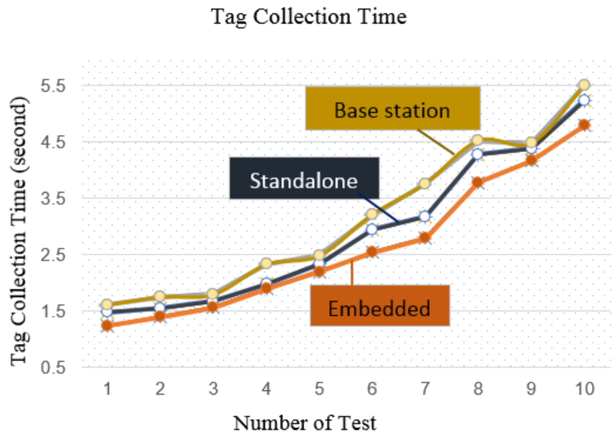

Fig. 4 Tag collection time analysis

Three data packages for the tag collection time test were analyzed. First, the standalone ZigBee compared the embedded device found that the embedded device receives the 10 data packages from the RFID ear tags faster than the ZigBee standalone 9.26 %. At the same time, the data packages received by the base station take more time than the embedded reader device and standalone device at 16.15 % and 7.59 %, respectively. The embedded RFID device can act better for collection time than standalone because battery backup and programming design support a quick response between the RFID ear tag and an embedded RFID reader device.

As a result, it is more suitable for an appliance to implement animal identification-based on RFID-IoT innovative farming application using ZigBee network technology and an IoT platform. In addition, the nodes require low power or long battery life.

2. Received Signal Strength Indicator (RSSI) Test

This subsection demonstrates the RSSI test of the proposed animal identification based on RFID-IoT technology using for smart farming applications. The prototype was testbed the performance of RSSI value, which highlights the received signal strength of how the proposed device can hear a signal from an access point. It's a valuable factor that is useful for determining of good enough signal to achieve an effective wireless connection.

The RSSI values were measured from the reference sensor nodes. Practically, the RSSI value is not exactly the received power at the RF pins of the radio transceiver. Therefore, it has to be converted to the actual power values in dBm using the following expression [13, 14]. In imitating the distance from RSSI, an appropriate signal strength prediction model needs to be chosen. The log-distance model is commonly used to predict the RSS P_i from an AP *i* at a given distance d_i. Formally given as

$$Pi = (RSSI_i + RSSI_{offset}) \qquad (1)$$

P_i is the actually received power from beacon node i.$RSSI_i$: The measured RSSI value for reference node i stored in the RSSI register of the radio transceiver. $RSSI_{offset}$ is the RSSI offset that is found empirically from the front end gain [15].

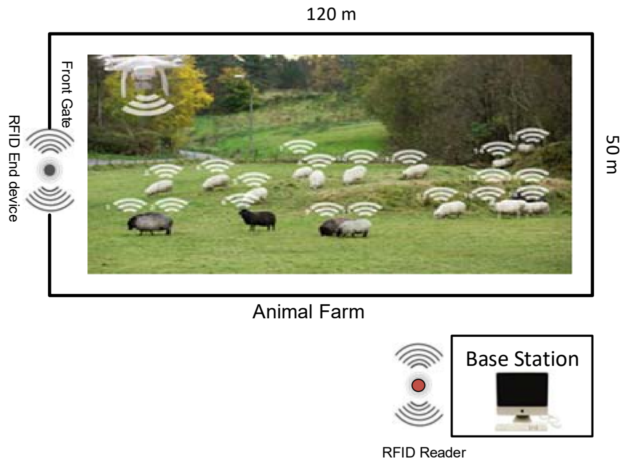

Fig. 5 Outdoor RSSI test

Figure 5 shows the concept of RSSI test in the animal farm. The animals will be tracked and counted using RFID ear tags embedded into their ears. The RFID signal of 2.4 GHz that transmits between the RFID end device and RFID reader will be tested the received signal strength by the base station. Based on the experiment, the RFID end device tag was tested compared to the standalone RFID without embedment when both devices were sending data packages to the RFID reader. The experimental results are organized as in Figure 6.

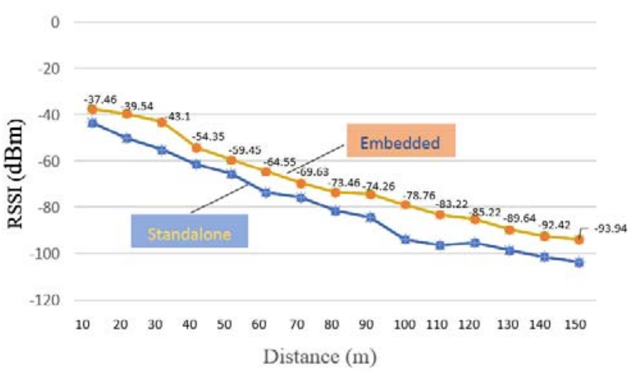

Fig. 6 RFID performance analysis

Figure 6 presents the RSSIs of the embedded RFID and standalone in the actual application according to the various distance. The data analysis found that the embedded RFID device works more efficiently than the standalone by ±10.32%. Author claims according to the stability of the power supply system and schematic design of loss reduction management.

Conclusions

As the animal identification-based RFID-IoT smart farming application by using RFID technology and WSN platform. The integrated network is needed to convenience and to solve the problem in farming management. This paper discusses the usefulness of RFID capability to receive, store and transfer data to a remote sink source for the safety of children. Namely, the proposed application has utilized the versatility of RFID and Bluetooth, implementing functional and automatic The results achieved the research goals, which reduced the time of manual attendance checking and the information data recorded systematically.

Conflict of Interests

The author declares that there is no conflict of interests regarding the paper.

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