Multi-hop Performance of Smart Power Meter Using Embedded Active RFID with Wireless Sensor Network

W. Boonsong and W. Ismail

Abstract The implementation of Smart Power Meter (SPM) using embedded active RFID tag with Wireless Sensor Network (WSN) for identification and monitoring of data is presented to analyze and improve the link quality of multi-hop performance in real environment application. In the proposed system, ZigBee (IEEE 802.15.4) protocol standard with radio frequency of 2.4 GHz was embedded into a household Power Meter (PM) to obtain a higher performance in the data monitoring system. This proposed system, anti-collision algorithm is an effective method to handle and support the link quality through the single and multi-tag via multi-hop communication with several time intervals between messages sending as well. The finding indicated that the proposed SPM has successfully received massages of about 0.89 and 1.44 % higher than the standalone RFID for single and multiple tags over four hops communication respectively, with there is no difference at statistical significance level of 95 % reliability.

Keywords RFID · SPM · WSNs · PM · ZigBee

1 Introduction

In recent years, radio technology identification (RFID) technology has moved from obscurity into mainstream applications that improve the speed of handling manufactured goods and materials. It enables identification from a distance and unlike any earlier bar-code technology, it does so without requiring any line-of-sight (LOS) [1]. The applications of this technology have become very useful and convenient in our daily life, more manageable with their low cost as well as their

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ability to upgrade the reliability and efficiency of communication system. Therefore, it is important to obtain higher system reliability and this growing interest in sensor application has created the needs for protocols and algorithms in large-scale self-organizing ad hoc network that consist of hundreds or thousands of nodes [2].

Wireless sensor networking is an emerging technology that possesses a wide range of potential applications including environment monitoring, smart spaces, medical systems and robotic exploration. It normally consists of a large number of distributed nodes that organize themselves into a multi-hop wireless network. Each node has one or more sensors, embedded processors and low-power radios, and it is normally battery operated node. Typically, these nodes coordinate to perform a common task [3]. WSNs are networks made up of relatively low power mode which are connected wirelessly. There have been a large amount of researches done in many different aspects of WSN sensor placement [4], security [5] and other aspects of WSNs.

In addition, the anti-collision technology is one of the core technologies for the proposed SPM system. Usually-used anti-collision algorithms include the ALOHA algorithm and binary searching algorithm. The binary searching algorithm requires to repeatedly and intentionally collide for several times to carry out identification of the single and multiple SPMs with the multiple hops proposed [6]. Tag collection is the major issue for the proposed RFID system. Whenever the collection command is requested by the reader, SPM tags will respond to the reader. If there are multiple tags, their response to the reader simultaneously, a collision occurs. Hence, the reader will fail to read data for this reason caused the efficiency of RFID system will be downgraded. Therefore, ALOHS-based algorithm is more suitable for active RFID system [7].

Sequentially, this paper is organized as follows. In Sect. 2, the research methodology is divided into two parts which are Sect. 2.1: architecture design; Sect. 2.2: experimental method and experimentation setup based on real indoor environment test is in Sect. 2.3. Section 3 explains the experimental results and presents the discussion. Finally, the conclusions are summarized in Sect. 4.

2 Methodology

In this session, the scheme methodology of the multiple hops performance of the SPM using an embedded active RFID tag with the WSN platform is proposed, which are detailed as the following sections.

2.1 Architecture Design

The architecture design of both systems considers the identity structures between the proposed SPM and the standalone RFID tag which are as shown in Fig. 1.

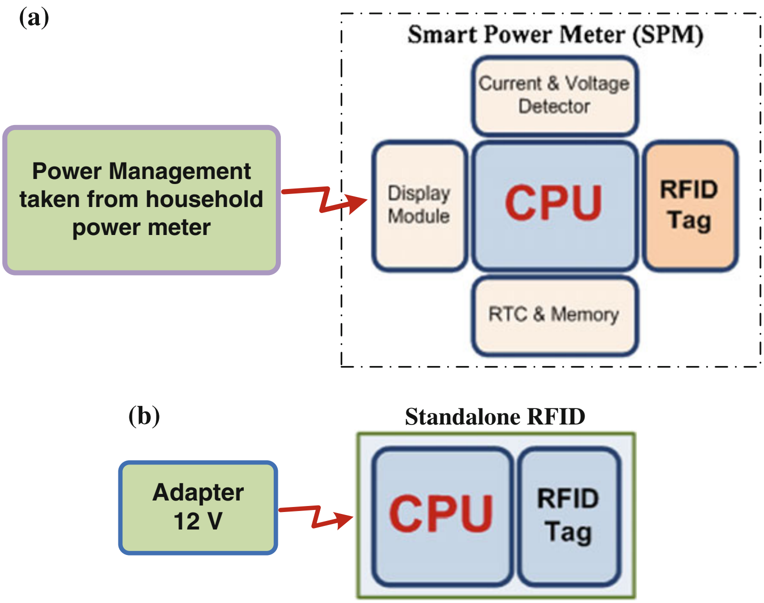

Fig. 1 The proposed architecture design of **a** the SPM and **b** the standalone RFID

The proposed SPM contained a central processing unit (CPU), current and voltage detectors, display module, real-time clock with memory unit and active RFID tag. Moreover, it is powered from the power management circuit design by taking the supply source from a household electrical power meter which the problem of lifetime of its power source is removed. At the meantime, the standalone RFID tag is only connected to a CPU with components less in order to compare the actual performance of the active RFID tag between the embedded RFID tag application and it is just standalone condition without any electronic accessories much, unless CPU only, which the standalone RFID system is powered by an adapter 12 V. The CPU is a brain or main part to process all sensor functions, which are current and voltage detectors. The sensors detect the current and voltage signals from the appliance load consumption. The real-time clock generates the integration period for the data packet, the memory unit is a unit to record and store information data and displays on LCD module. The information data process using RFID technology based ZigBee-Pro Series 2 was used for sending data with a radio frequency of 2.4 GHz communication between the end part of the SPM and the reader through the multiple routers [2].

2.2 Experimental Method

The experimental method that designed for this study focused on the actual performance of the multi-hop communication in terms of the successfully received messages versus time interval between message variable. The procedure of experimental scheme is presented by the flowchart form as in Fig. 2.

2.3 Experimentation Setup Based on Real Indoor Environment Test

All compositions that used for the experiment were available placed and setup according in Fig. 3. The SPM terminals were placed at the ground floor with a distance of 90 m to the router 1. The router number of 1, 2, 3 and the reader device were positioned at the ground, 1st, 2nd and 3th floor respectively. The height of each floor high since the distance between the ground and the ceiling was about 3 m. Meanwhile, the reader and host computer were placed with a distance away of 90 m.

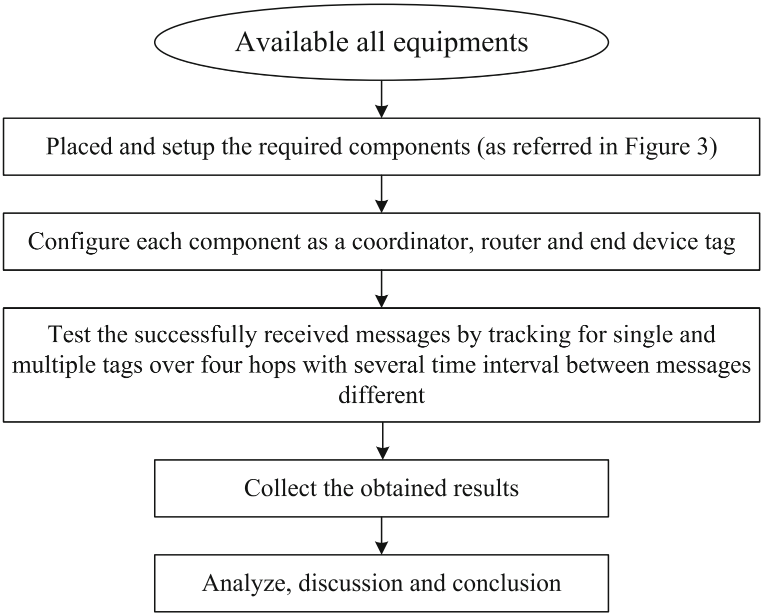

Fig. 2 The flowchart of the proposed experimental scheme

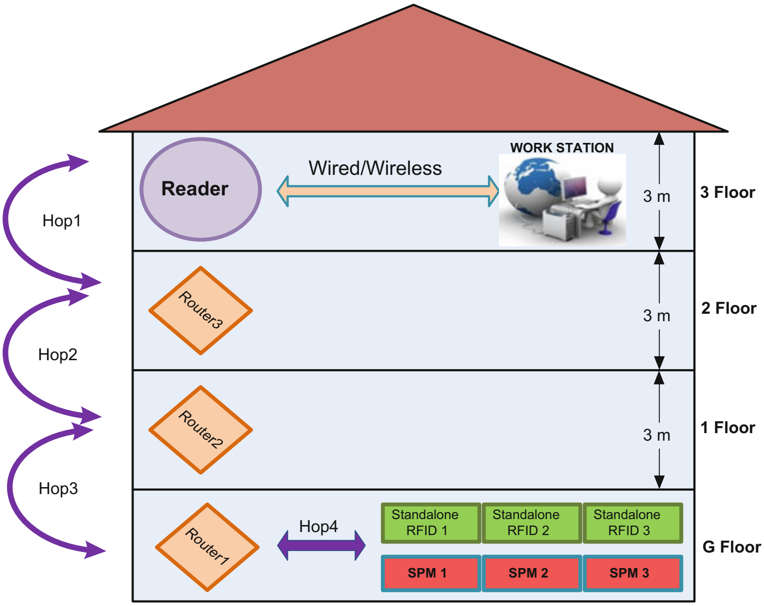

Fig. 3 Multi-hop communication setup for the SPMs and the standalone RFIDs with WSN

3 Experimental Results and Discussion

In this assessment, the multi-hop performance for the proposed SPM compared with the standalone RFID tag was evaluated. More details are enumerated as follows.

3.1 *Tracking for Single Tag Over Four Hops*

This section investigates the capability of a single tag with four hops communication. The information data packet was sent from the single SPM terminal to the reader through multiple routers. The time interval in sending messages between each message of the terminal device was set within the range from 2s to 10 s with 1 s increment, which can be verified by using the developed Graphic User Interface (GUI) at host computer as shown in Fig. 4.

The information data was specified in the amount of 100 sending messages to slowly maintain the validity and reliability for low and high traffic load. The number in identifying successfully received and wasted message was repeatedly recorded for 10 times [8]. The data transmitted with this multi-hop communication from the end part of the SPM to the reader was also monitored by employing GUI on a host computer.

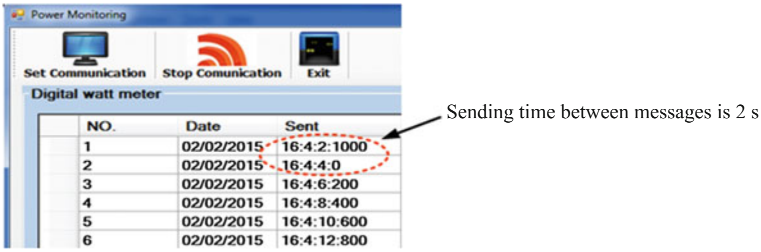

Fig. 4 Sending time between messages on user application

The comparison of both systems indicated that the average successfully received messages were higher than 97 % as illustrated by the SPM which achieved 98.00 % while the standalone RFID possessed 97.11 %. The finding indicated that the SPM owned higher successfully received messages by 0.89 % with no statistical significance at reliability of 95 %.

By the experimental results found that the time interval between messages sending impacted the successfully of received messages in terms of percentage for both systems. Namely, when the time interval between messages is set to be increased up, the successfully of received messages will also slightly increased up in which consistent with the research of Abdullah [9]. In addition, it was found that the reader has achieved to receive the total messages that sent from the SPM 100 % at time interval between messages setup of 8 s in which closer to the defined maximum time of 10 s, while the standalone RFID has succeeded to obtain the 100 % received messages at time interval between messages setup of 10 s. This is another one of issue which shows that the proposed SPM has better performance than the standalone RFID due to the schedulers designed to reduce collisions and additional issues that supported this achievement are the advantages of the embedded system and power management design as well.

3.2 Tracking for Multi-tag Over Four Hops

The experimental results show the performance of the multiple tags with four hops communication of both systems. The finding proved that the proposed SPM has the successfully received message to be higher than the standalone RFID by 1.44 % with no statistical significance at reliability of 95 % due to the same reasons as mentioned in the discussion of Sect. 3.1. Namely, the proposed SPM is arranged with the embedded system and power source management. In addition, the schedulers designed to reduce collisions to success more efficiency for multiple hops communication as well in terms of achievement received messages at the destination of work station in which consistent with Vales-Alonso's research [8].

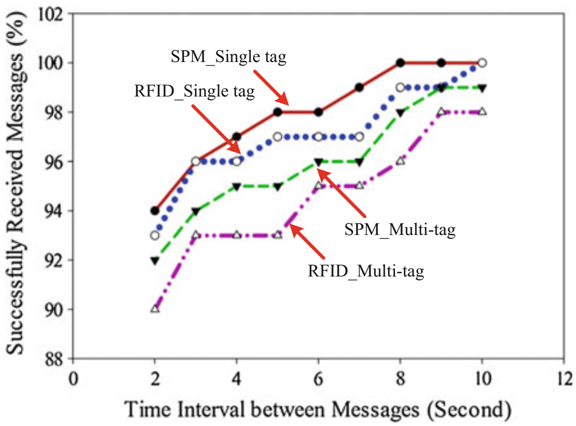

Fig. 5 The successfully of received messages with multi-hop communication

The results obtained from Tables 1 and 2 are explicitly plotted as shown in Fig. 5.

According to the results, it can be confirmed that the proposed SPM is a new features concerning the routing (multi-casting, many-to-one routing) and advanced security mechanisms (symmetric-key key exchange). ZigBee Coordinator, Routers and End-device are the types of defined devices, symmetrically reflecting by roles, functions and capabilities of the ones introduced in IEEE 802.15.4. Even though the network topologies (star, mesh and cluster tree) partially remind the one in IEEE 802.15.4, the concept of the multi-hops routing is still peculiar to Zigbee, in which the routers act to extend the network coverage [10]. The multi-hop communication suits for deploying inside the building, utility companies, factories and data transmission between the buildings.

4 Conclusion

In this paper, the multi-hop performance of the SPM using embedded active RFID with WSN platform is proposed to be compared with the standalone RFID for its reliability in the usage. The finding indicated that the proposed SPM system has successfully received message with low collision of multi-tag collection higher than the standalone RFID by average 1.44 %. This is due to the schedules arrangement of data transmission to reduce the collision of the proposed SPM and in addition factors are because of its stability of embedment system and power management design application. The experimental results of the succeeded received messages for the proposed SPM have been succeeded with a good enough reliability and effective to facilitate some daily life processes by replacement a human source instead with machine-to-machine (M2M) communication concept in which can reduce the errors in the information system that are omitted by humans.

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