An Improved Vogt Anti-collision Protocol with Early end Feature in the Mobile RFID Systems

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Abstract: Vogt protocol is a dynamic frame slotted ALOHA protocol. It has been used to the “I-code” system developed by Philips Semiconductors. Similar to many existing anti-collision protocols, The Vogt protocol aims at tag identification in static scenarios, that is, all tags keep still during the tag identification process. For the scenarios, Vogt’s system performance can be analyzed by performance metrics, such as throughput, the identification efficiency, the error rate of tag estimation and the identification delay, etc. However, there also exist many special scenarios, named mobile RFID systems, where tags move along a fixed path in the reader’s interrogation zone. In these scenarios, tags may leave the interrogation zone unidentified. These tags are called lost tags. In this paper, we propose an improved Vogt anti-collision protocol with early end feature in mobile RFID systems which can decrease tag loss by early terminating idle slots and lost tag slots in the mobile RFID systems. Simulation results show that the proposed protocol can significantly reduce the numbers of lost tags in mobile RFID systems. Copyright © 2013 IFSA.

Keywords: RFID, Tag identification, Mobile RFID systems.

1. Introduction

RFID (Radio Frequency Identification) is an automatic identification technology considered to be a better replacement of existing barcode technology. RFID has the advantages of contact-less identification and the ability to hold more data with respect to barcode technology. RFID uses tags to store electronic product codes (EPC). The tags also possess radio transceivers using which they can transmit the EPCs to the readers that probe these tags. RFID has applications in many environments such as supply chain management, inventory control, supermarket checkout process, pet identification, and toll ways.

In RFID systems, all tags and reader share a common communication channel. Therefore, when the multiple tags simultaneously transmit their signals to the reader, collisions will happen. To achieve this goal of efficient tag reading, a great number of anti-collision protocols [1-11] have been proposed for static scenarios where all tags keep still during the tag identification process. These algorithms can be classified into two categories: tree-based algorithms and aloha-based algorithms. In ALOHA-based systems, the channel time is divided into multiple frames. Each frame in turn is divided
into multiple time slots. Within a frame, each tag randomly selects a time slot and transmits its EPC to the reader in that slot. Note that, within each frame there exist three kinds of slots: (1) the idle slot where no tags reply; (2) the successful slot where only one tag replies; and (3) the collision slot where multiple tags reply. In tree-based systems, anti-collision protocols are based on binary trees and every root-to-leaf path in these trees denotes a unique tag ID. Compared with ALOHA-based algorithm, tree-based algorithms promise terministic identifications, but need a high number of reader-to-tag commands.

Among the aforementioned protocols, Vogt protocol [11] has been used to the “I-code” system developed by Philips Semiconductors since it have better performance than FSA ones [3]. Vogt protocol can adjust the frame length dynamically. Its frame length is set to the number of unidentified tag in the reader’s field. Vogt’s tag estimation functions is based on Chebyshev’s inequality and aims to minimize the distance $v_d$ between an actual read result vector $\langle c_0, c_1, c_k \rangle$ and the theoretically computed result $\langle a_0^{N_t}, a_1^{N_t}, a_k^{N_t} \rangle$, as represented by Eq. 1.

$$v_d(N_t, c_0, c_1, c_k) = \min_i \left( \begin{array}{c} 3 \times N_t^0 \times c_0^0 \times c_1^0 \times c_k^0 \\ 3 \times N_t^1 \times c_0^1 \times c_1^1 \times c_k^1 \\ 3 \times N_t^k \times c_0^k \times c_1^k \times c_k^k \end{array} \right)$$

In Eq. 1, the elements of the vector $\langle a_0^{N_t}, a_1^{N_t}, a_k^{N_t} \rangle$ correspond to the expected number of idle slots, success slots, and collision slots, respectively. The elements of the vector $\langle c_0, c_1, c_k \rangle$ respectively correspond to the actual number of idle slots, successful slots, and collision slots from read results. $N$ and $t$ denote the frame length and the number of tags in the reader’s interrogation zone, respectively.

To decrease tag identification time, ISO-18000-6A and EPCglobal Class 1 [8] presented frame slotted ALOHA with early end, as shown Fig. 1. From this figure, we can see that all idle slots (e.g. slot 1, 2, 3, 9) are terminated early, which can decrease tag identification time effectively.

However, in many applications, tags usually move along a fixed path in the reader's field, named mobile RFID systems [12-15]. A typical example of mobile RFID systems is the portal of a warehouse equipped with RFID reader to automatically identify passing tags and update the central database with the captured information. Another typical example of them is a conveyor belt in a factory or a logistic center where objects attached with RFID tags have to be identified [9]. In the scenarios, tags stay the reader's field only for a certain time (sojourn time). How to decrease tag loss is an important research issue in mobile RFID systems. Therefore, we regard tag loss ratio (TLR) as a critical performance metric, which is defined as the quotient between the number of lost tags and the total number of tags entering the interrogation zone [12, 13]. Obviously, TLR is related to other many system performance metrics, such as throughput, the identification efficiency, the error rate of tag estimation and the identification
delay [8]. For example, if the identification delay of protocol A is higher than that of protocol B, then TLR of protocol A is usually lower than that of protocol B. Compared with other performance metrics, the users of RFID systems put more emphasis on TLR because tag loss is often unpermitted for most RFID applications. So, we only focus on the performance metric TLR in the paper.

In mobile RFID systems, there exists a special type of slots, named lost tag slots, which is different from the idle, collision and success slot. The reason for its appearance is that one or more tags have left the reader’s fields unidentified when the reader identifies them, as shown in Fig. 3. So, in the mobile RFID systems, there are four types of slots: idle, collision, successful and lost tag slots. In the figure, slot 8, 9 are lost tag slots.

In this paper, we will present an improved Vogt anti-collision protocol with early end feature which can decrease tag loss in the mobile RFID systems. The proposed protocol is named IVAEEMR protocol. The remainder of this paper is organized as follows. In Section 2 we offer IVAEEMR protocol in the mobile RFID systems. Section 3 provides the simulation results. Finally, Section 4 concludes.

2. IVAEEMR Protocol

Compared with Vogt protocol, the feature of IVAEEMR protocol is that if the reader detects no transmission after a small period of time, it terminates idle slots and lost tag slots early during reading tag process, as shown in Fig. 4. Slot 13 and slot 15 are lost tag slots. From the figure, the time spent by idle and lost tag slots are decreased effectively. With adjusting the frame length, please refer to section Introduction. The method of IVAEEMR protocol can be summarized as follows:

(1) At the beginning of a frame, the RFID Reader sends the Frame-begin command with a parameter $N$ where $N$ denotes the frame length. Upon hearing this command, unsilenced tags generate a random number from 0 to $N - 1$. Those generating ‘0’ reply immediately.

(2) If only one tag replies, the reader can identify it and send back the Silence command. Upon hearing this command, the replied tag will be silenced, that is, it will not respond to future commands, while the other tags decrease their counter values by 1 and contend the channel if the counters reach 0.

(3) If the reader detects a collision, the reader receives a collision sequence after a slot and the reader can not read it. Subsequently, the reader will send the Begin-slot command. Upon hearing this command, all the unsilenced tags will decrease their counters by 1 and contend the channel if their counters reach 0.

(4) If no tag replies, the reader will send back the End-slot command early. This means that an idle slot or a lost tag slot has occurred. In this paper, we assume that time cost of an idle and a lost tag slot is equal to 0.4 times of that of a successful slot. Upon hearing this command, all the unsilenced tags will decrease their counters by 1 and contend the channel if their counters reach 0.

(5) After one frame ends, the Reader recomputes the frame length $N$ according to the number of successful, idle and collision slots. For detailed adjustment method, please refer to section Introduction. Subsequently, the reader will begin a
new frame by sending the Frame-begin command if there are collision slots in the previous frame.

3. Simulation and Results

Now, we begin to evaluate the proposed protocol. Because TLR can be derived by mathematical model only for FSA and CSMA so far [8, 10], we offer a simplified mobile RFID experiment model. The model comprises 3 groups of mobile tags, as shown in Fig. 5 where \( T_1 \) denotes the arriving interval between the 1st and 2nd groups of tags, \( T_2 \) denotes the arriving interval between the 2nd and 3rd groups of tags, \( N_1, N_2 \) and \( N_3 \) respectively denote the number of tags in the 1st, 2nd and 3rd groups of tags, \( S \) denotes the tag sojourn time. Notice that in the paper, all time related parameters, such as \( T_1 \), \( T_2 \) and \( S \) are measured in slot. Parameters \( S \) have been defined in section I. The reasons for using the simplified mobile RFID experiment model are the following:

1. The simplified model is a basic cell of mobile RFID systems. The behavior of the 3 groups of mobile tags in the coverage area can reflect to some extent that of real mobile RFID scenarios.
2. As stated previously, there are no good mathematical methods that can help to compute the TLR of various anti-collision protocols in the mobile RFID systems so far.
3. The proposed experiment model can be very convenient to vary each experiment parameter, which is helpful to observe the behavior of various anti-collision protocols from different perspectives.
4. Based on the simplified model, we can offer the TLR of various anti-collision protocols by simulation conveniently, as shown in the following.

Below, we compare IVAEEMR protocol with Vogt [14] which is similar to the proposed protocol except that it is not characterized by early end. Our simulation based on Monte Carlo technique and the simplified mobile RFID experiment model.

In the Fig. 6 (a), we survey the relationship between TLR and the tag density by changing the number of tags \( N_2 \) in the second group. Related parameters in the experiment are: \( N_1=80, N_3=80, T_1=50, T_2=100, S=350 \). We can find that TLR of both protocols increases as the tag density increases. The reason is that the reader must identify more tags in the identical interval. Compared with Vogt, IVAEEMR protocol has better performance. For example, when the number of tags in the second group \( N_2 \) is equal to 60 tags, TLR of IVAEEMR is nearly 20 percent while that of Vogt is 38 percent.

Fig. 5. Simplified mobile RFID experiment mode.

Fig. 6. TRL of IVAEEMR and Vogt protocols.
both protocols decreases as $S$ increases. The reason is that the reader has more time to identify tags as $S$ increases. Compared with Vogt, IVAEEMR protocol has better performance. For example, when tag sojourn time $S$ is larger than or equals 300 slots, TLR of IVAEEMR protocol is 30 percent while that of Vogt is about 46 percent.

In the Fig. 6 (c), we survey the relationship between TLR and tag arrival rate by changing $T_1$. Related parameters in the experiment are: $N_1=80$, $N_2=80$, $N_3=80$, $T_2=100$, $S=350$. From the figure, we can find that TLR of both protocols decreases as the tag arrival rate becomes slow. The reason is that the reader has more time to identify tags when the rate becomes slow. Compared with Vogt, IVAEEMR has better performance. When $T_1$ is equal to 60 slots, TLR of IVAEEMR protocol is nearly 20 percent while that of Vogt protocol is equal to about 36 percent.

In general, the simulation results demonstrate that compared with Vogt, IVAEEMR protocol can reduce TLR and improve mobile RFID system performance remarkably since it can terminate idle and lost tag slots early.

4. Conclusions

This paper offers a term lost tag slot first in the mobile RFID systems. On this basis, IVAEEMR protocol is proposed. The protocol terminates idle and lost tag slots, which can decrease TLR effectively in the mobile RFID system.

References


