RFID Tags Estimation through the Statistics Method for ALOHA

Xiaoqiang Zhang, Tingting Chen, and Fangjie Hu

***Abstract*—One of the key problems that affect the data integrity of passive RFID systems is the collision among the tags. A popular anti-collision algorithm which dominates the standards in HF and UHF passive RFID systems is framed slotted Aloha (FSA) and some variations of FSA. Throughput of the RFID system which determines the performance/efficiency of the system is reduced rapidly when the number of tags inside the interrogation zone is increased. Using larger frame sizes is not always the solution. The best performance can be achieved when the slot number is equal to the tag number for FSA algorithm. In order to estimate the number of tags, a lot of work has been done. The existing algorithm about the tags estimation has been discussed in this paper. And an idle slot number based estimation algorithm is proposed. The idle slot number based estimation algorithm uses the idle slots in a frame. For performance analysis, the idle slot number based estimation algorithm was evaluated with the parameters of 128 slots to estimate the number of tags. The proposed method considers two situation, one is applied only 128 slots in a frame and all of them are used to estimate the number of tags; the other is applied the first 128 slots in a frame with 1024 slots frame. The results showed that the proposed algorithm can improve the efficiency of the number of RFID tag estimation and provide a reliable solution for cases with a high density of tags in the area.**

***Index Terms*—Idle slots, tag estimation, FSA, RFID.**

I. Introduction

With the development of RFID technology and the Internet of Things, RFID tags are used more and more widely. One RFID read needs to identify more than one tag within very short time, and sometimes, it needs to recognize more than thousand tags in couple of seconds. When more than one tag respond the request of RFID reader simultaneously, tags feedback signals will collide at RFID reader side, which called tags collision. To solve this kind of problem, couples of methods were provided, which are classified two catalogs, namely is deterministic and probabilistic [1]. Deterministic algorithm is based on binary trees where each root-to-leaf path represents a unique tag id. Probabilistic algorithm is based on the slotted ALOHA framework, where the channel time is split into frames. A single frame in turn is divided into several time slots. During a frame, each tag randomly chooses a time slot and transmits its identifier to the reader in that slot.

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In tree-based protocols which are based on the collision resolution algorithm studied in [2], tags transmit at the same time, form a set. When a set causes collision, the mechanisms split them into two subsets and attempt to recognize two subsets in turn. The binary tree protocol, which uses random numbers for splitting, is adopted as the standard for RFID anti-collision in ISO/IEC 18000 Part 6 type B [3]. The query tree protocol splits a set of tags by the reader's queries. Although tree-based protocols do not cause tag starvation, they have relatively long identification delay due to the splitting procedure starting from one set including all tags.

Probabilistic tag reading protocols, which based on the ALOHA algorithm, can achieve smaller identification delays provided the amount of time wasted due to collisions and idle time slots is reduced [4]. Collisions occur when more than one tag transmits in the same slot, in which case all their identifiers are lost. Idle time slots occur when none of the tags in the reader's vicinity chose a particular slot for transmitting their identifier. The ISO/IEC 18000 Part 6 type A and ISO/IEC 18000 Part 6 type B [3] are adopting the ALOHA based anti-collision algorithms. The ALOHA algorithm includes pure ALOHA, Slotted ALOHA, Framed Slotted ALOHA (FSL), and Dynamic Framed Slotted ALOHA algorithm (DFSL). For those FSL based algorithm, the most important issue is to choose the right number of slots. There are two methods to select the number of slots. One is the static number of slots and the other is the dynamic number of slots. No matter what kind of ALOHA algorithm is using, the first step is to set the number of slots in a frame. For the GEN2 protocol, the slots are set by the Q-bit number, which can be used to divide one frame into $2Q$ slots. The value of Q is important to the efficiency of the ALOHA algorithm. The correct choice of Q in any round of the GEN2 protocol is critical to achieving optimal read rates. If the number of slots relative to the number of selected tags is very high, then the probability that there is collision in any given slot is low, and the number of correctly decoded tags is close to the number of selected tags. But, it may cause a lot of idle slots, which leads to waste of time. On the other hand, if the number of slots relative to the number of tags is low, then lots of collision can be expected, which leads to more rounds being required to completed the inventory process. So, the challenge is to develop an algorithm to estimate the correct number of tags with the RFID reader range, which can be used to find the correct Q which minimizes the total time required to inventory all tags within the range of the tags.

In this paper, we are focus on the fast tag estimation algorithm based on the statistics method, which is important to the MAC layer ISO/IEC 180000-6C RFID air interface protocol.

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The following of this paper is organized as follows: Section II gives an overview of different tag estimation methods, Section III gives out the algorithm details based on the idle slots. The simulation results are put forward at Section IV, and Section V concludes the work.

II. Tag Estimation Overview

The performance of Framed-Slotted ALOHA based algorithm depends on the number of tags and the frame size, and its optimal success probability is known as 1/e when the frame size equals to the number of tags [5]. So, for fast identifying the ID of RFID tags, an accuracy estimation number of RFID tags is key issue for Framed-Slotted ALOHA based protocol.

For those RFID tag estimation mechanisms, the first one is provided by Schoute in 1983. The Schoute method is based on the number of collisions in a frame [5]. The number of tags is estimated by multiplying the number of collision slots in a frame by the expected number of tags per collision slots, which the same for all frames regardless of various number of tags and frame size. In 2002, Vogt use the success, collision, and idle probability in a frame to estimation the number of tags. Cha and Kim proposed a kind of tag estimation method based on the number of tags (frame size) by using the probability of collision [6]. By using the probability decides the next frame size successively. In this method, if the number of tags is estimated to be very small compared with the actual number of tags, the estimated number of tags and the next frame size will become inaccurate. J. B. Eom used a frame-specific optimal constant and number of collision slots in a frame to estimate the number of tags and next frame size [7].The Eom's method is show better performance comparing with the other existing methods. The problem for this method is difficult to calculate the frame-specific optimal constant, which is time and capacity costly.

According to those exiting tags estimation algorithm, we can see that all of them are using three slot statuses, including the collision probability, successful probability and idle probability. It needs a huge calculation capacity in the reader side. Sometimes, it will spend much more time to calculate those probabilities. In our proposed algorithm, only need to calculate the idle slots within a frame to estimate the number of tags, which is one third of calculation capacity needed comparing with previous methods.

III. Proposed Tag Estimation Mechanism Based on Idle Slots

In FSA, each frame is split into 2^Q time slots. And each unread tag random selects one of these time slots of a frame. Unless the tag successfully transmits its information to a reader, it will try again in the next frame. If one slot is selected by one tag, this tag will successfully be identified. If one slot is selected by more than one tag, this time slot became a collision slot and those tags can't be recognized at this frame. If one slot is selected by none, this time slot is an idle slot.

We assume that the frame size is *L* and the number of tags is *n*. Sc, Ss and Si stand for the number of collision slots, the number of success slots and the number of idle slot in a frame, respectively. As it shown in Fig. 1.

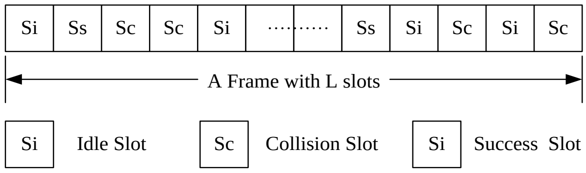

Fig. 1. A frame with *L* slots.

After each round of frame detection, Sc, Ss and Si can be calculated. In our algorithm, Si is used to estimate the number of tags.

The probability that *r* tags among n tags occupy a slot can be approximated by [1]

$$P_r = \binom{n}{r}\left(\frac{1}{L}\right)^r\left(1-\frac{1}{L}\right)^{n-r} \tag{1}$$

When *r*=0 in Eq. (1), it is means that no tags occupy a slot

$$P_0 = \binom{n}{0}\left(\frac{1}{L}\right)^0\left(1-\frac{1}{L}\right)^{n-0} = \left(1-\frac{1}{L}\right)^n \tag{2}$$

And the Si is standing for the number of idle slots in a frame, so

$$Si = P_0 \times L \tag{3}$$

From Eqs. (2) and (3), we can obtain

$$S_i = P_0 \times L = L \times \left(1-\frac{1}{L}\right)^n \tag{4}$$

For Eq. (4), the Si is measured in the frame of size *L*. *n* is the number of tags within the reader range. From Eq. (4), if we are given the total number of idle slots in a frame with L slots, we can estimate the number of total tags $\hat{n}$ (5).

$$\hat{n} = \frac{\log \frac{S_i}{L}}{\log(1-\frac{1}{L})} \tag{5}$$

$\hat{n}$ is the estimation of *n*, the number of tags within the range of the reader.

The backlog can be calculated by $\hat{n}$ and *Ss*. *Ss* also can be measured for a round of inventory process. Then, we can get the *Q*, which is use to decide the number of slot in a frame (6).

$$L = 2^Q \tag{6}$$

From the previous research, we know that the FSA achieve its best performance if the slots number equal to the number of RFID tags. The backlog (next frame size) is found as follows (7)

$$\widehat{back}\log = \hat{n} - Ss \tag{7}$$

And the parameter Q can be obtain by Eq. 8

$$\hat{Q} = \log_2 \widehat{back} \log = \log_2 (\hat{n} - Ss) \quad (8)$$

$\hat{Q}$ is the estimation of Q, which is used to set the frame size. For this algorithm, it aims to minimize the error between $\hat{Q}$ and Q. In order to provide an accurate estimation for $\hat{Q}$, the accurate estimation for n is necessary. So, in this algorithm, we are going to evaluate the performance of the proposed algorithm for estimation of n.

IV. Simulation Results

The simulation is under a single reader and multiple tags environment with error-free channels.

The simulation is performed through the Matlab and Windows XP. To evaluate the performance, we compare the estimation accuracy of the proposed scheme with those of other schemes, and we use a fixed frame size of 128, which was used in [7].

Fig. 2 shows the mean estimation error which is defined as the mean difference between the real number and the estimated number of unread tags. For comparing with the result in [7], we use the same frame size with [7], and vary the number of tags from 1 to 260. From Fig. 2, it can be seen that the proposed algorithm present more precise estimation than [7].

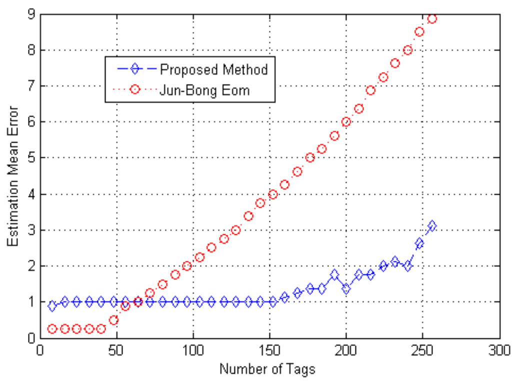

Fig. 2. Estimation with 128 slots.

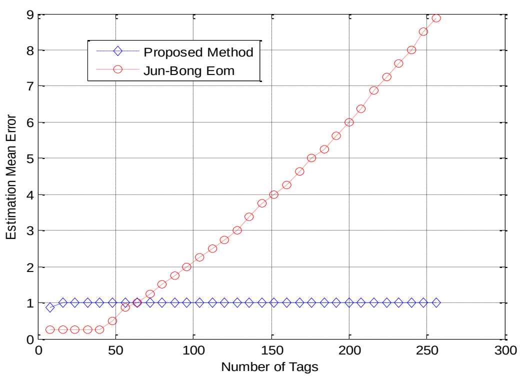

Fig. 3. Estimation with 1024 slots.

From Fig. 2, we find an interesting phenomenon is that the proposed method achieved best performance when the number of tags is far less than the number of slots. We design another process to investigate this phenomenon, and set the frame size from 1024. IF the number of RFID tags is varied from 1 to 128, the estimation errors with keep very lower level, as shows in Fig. 3.

In order to make this kind of low estimation errors, it is needed to scan all these 1024 slots, which waste a lot of time comparing with only 128 slots. In the following experiments, we design the algorithm with huge slots, and only scan the first 128 slots. After the scanning process, the idle slots can be counted. According the random distributed theory, it is need to multiple 2^3 to calculate the total idle slots in a frame. For this process, it is only needed to scan 128 slots, and can get a precise estimation of idle slots in a frame.

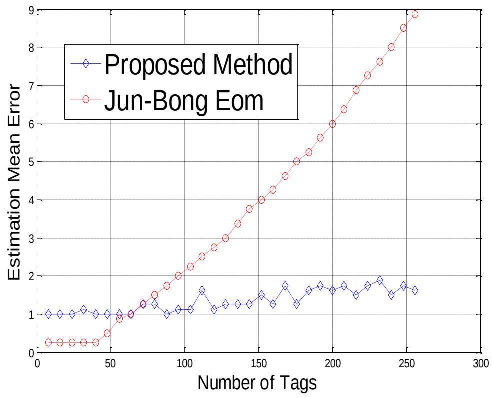

Fig. 4. Estimation number of tags with 128 slots in a 1024 slots frame.

Fig. 4 shows the mean error estimation for this algorithm. As shows in Fig. 4, the maximum estimation error is less than 5 tags. Comparing the result in Fig. 3 and Fig. 4, we found that the total scan process achieves very competitive results, only with 1 estimation error. The partly scan process is little worse. Comparing with the result in [7], the partly scan process still show much better performance.

V. Conclusions

In this paper, a kind of light-weight algorithm is proposed to estimate the number of tags within the range of a RFID reader. The proposed method only uses the idle slots in a frame, which is empty without any RFID tag choosing it as a communication slot. Normally, if the number of tags within a reader range is less than hundreds, the initial number of slots in an estimation frame can be set to 2^{10}. From the simulation result, we can see that mean estimation error is less than 3. If the number of tags within a reader range is more than the number of slots in an estimation frame, the estimation error rate will be higher, as show in Fig. 2 and Fig. 4. But the error numbers still is very lower, with less than 5 errors.

With partly scan process, the time spent to estimate the number of tags can be greatly reduced with higher estimation accuracy. It is especially useful for the scenario that the number of tags is not given.

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