Estimation for the Number of Tags in the Slotted-ALOHA based RFID Systems

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Abstract - Recently, the RFID(Radio Frequency Identification) technology has gained significant attention. One of the performance issues in RFID systems is to resolve the tag collision among responses from RFID tags. In this paper, we proposed a new scheme for estimation of the number of tags in the reader filed. The scheme is used by anti-collision algorithm to identify multiple tags efficiently. And we also present the simulation result that shows the proposed scheme to estimate tags efficiently and also to improve the systems efficiency.

Keywords: RFID, Slotted-ALOHA, Anti-collision Algorithm, Number of Tags, Estimation.

1 Introduction

RFID(Radio Frequency Identification) system is an automatic identification system that is used to identify physical objects. In context of ubiquitous computing, the object idenfification is the most useful for applicaions. RFID technology plays a key role in ubiquitous computing. RFID technology is known to be well-suited to linking the physical and virtual world.

The RFID system consists of two essential components: the RFID tag, which is attached to the object to be identified and serves as the data carrier, and the RFID reader, which can read from and write data to the tag. The reader broadcast the request message to the tags, and tags will backscatter own id to reader.

Recently, the RFID technology has gained significant attention. One of the performance issues in RFID systems is to resolve the tag collision among responses from RFID tags. In the most of the cases, numerous tags can be present in the reader field. It will cause collision at reader among multiple tags.

The tag collision in RFID systems happens when multiple tags reflect the signal back to the reader. This problem is often seen whenever a large number of tags must be read together in the same reader field. For resolving this problem, anti-collision algorithms are adopted. An anti-collision algorithm enables a single reader to read more than one tag in the reader field.

The anti-collision algorithm can be categorized into tree based protocols and ALOHA[1,2] based protocols. For the most air interface protocol are adopted ALOHA based anti-collision algorithms, such as, UHF Gen2 protocol[3], 13.56MHz class 1 protocol[4] proposed by EPCglobal, ISO 18000-6 A type[5], ISO 18000-7[6] proposed by ISO.

In the Slotted-ALOHA[7,8,9] based RFID system, tags randomly select their slot number, that is response time, and send the response back to the reader when the slot number is zero. The maximum slot number is called a frame size or round size. if too many slots are performed, the delay will be high. If too few slots are performed, some tags might be missed because of tag collision. So, an optimal value for the maximum number of slots should be used.

In this paper, we proposed a new scheme for estimation of the number of tags in the reader filed. The scheme is used by anti-collision algorithm to identify multiple tags efficiently. And we also present the simulation result that shows the proposed scheme to estimate tags efficiently and also to improve the systems efficiency.

The rest of this paper is organized as follows. Section II reviews the related works. Section III describes our proposed new tag number estimation scheme. In section IV, the results of performance analysis will be explained. Finally the conclusions of the paper will be present in Section V.

2 Related works

In the Slotted-ALOHA RFID systems, after the reader has sent its request to the tags, it waits a certain number of times for tag response. This time is divided into a number of slots that can be occupied by tags and used for sending their ID. In the first step, the reader broadcast a frame start message to tags. The message contains frame size parameter that denotes the number of available slots for response. In the second step, tags randomly select one slot to send their ID back to the reader. As the result of one frame we get a triple of numbers $<c_0, c_1, c_k>$ that quantify the empty slots, slots filled with only one tag, and slots with collisions, respectively. In order to choose the optimal frame size N for the number n in the reader field, we have to estimate n based on the results of one frame $c = <c_0, c_1, c_k>$.

So far, two estimation schemes yield approximations for n. The first estimation scheme is obtained as follows. Chebyshev's inequality tells us that the outcome of a random experiment involving a random variable X is most likely somewhere near the expected value of X. thus, an alternative estimation function uses the distance between the frame result c and the expected value vector to determine the value of n for which the distance becomes minimal. We denote this estimation:

$$e_{vd}(N, c_0, c_1, c_k) = \min_n \left| \begin{pmatrix} a_0^{N,n} \\ a_1^{N,n} \\ a_k^{N,n} \end{pmatrix} - \begin{pmatrix} c_0 \\ c_1 \\ c_k \end{pmatrix} \right| \quad (1)$$

The problem of this scheme is hard to implement and performance of scheme determined by errors of estimated value, to some extent, which are more closed to average expected value, also, is affected in the range of value n.

The second estimation scheme is obtained through the observation that a collision involves at least two different tags. Therefore a lower bound on the value of n can be obtained by the simple estimation function:

$$e_{\min}(N, c_0, c_1, c_k) = c_1 + 2c_k \quad (2)$$

The problem of this scheme is that many big errors will occur when the number of tags is more than two times of the number of slots. According to this, it can be applied usefully only in the range of less than two times.

$$e_{\min}(N, c_0, c_1, c_k) = c_1 + 2c_k = 2N - 2c_0 - c_1 \leq 2N \quad (3)$$

In reality, in the most of the algorithms, they adopted multi-step procedure to estimate tags number according to result of one frame, such as fixed-slot increase-decrease scheme, proportion scheme, log slot increase-decrease scheme and so forth.

3 Proposed Scheme for Estimation of Tag Number

In this section, we first review the mathematical tools[10] about the slotted-ALOHA algorithms. The number of slots in a time frame available for tag response is called "frame size" and denoted by N. The number of tags is often denoted by n.

Given N slots and n tags, the number r of tags in one slots is binomially distributed with parameter n and $1/N$:

$$B_{n,\frac{1}{N}}(r) = \binom{n}{r} \left(\frac{1}{N}\right)^r \left(1 - \frac{1}{N}\right)^{n-r} \quad (4)$$

The number r of tags in a particular slot is called the occupancy number of the slot. The distribution (4) applies to all N slots, thus the expected value of the number of slots with occupancy number 0 is given by:

$$a_0^{N,n} = N \cdot B_{n,\frac{1}{N}}(0) = N\left(1 - \frac{1}{N}\right)^n \quad (5)$$

And the number of slots that loaded only one tag ID, is given by:

$$a_1^{N,n} = N \cdot B_{n,\frac{1}{N}}(1) = n\left(1 - \frac{1}{N}\right)^{n-1} \quad (6)$$

From (5) and (6), we get

$$a_0^{N,n} / a_1^{N,n} = N\left(1 - \frac{1}{N}\right)^n / n\left(1 - \frac{1}{N}\right)^{n-1} = n(N-1) \quad (7)$$

Put it in order, estimation of the number of tags is calculated by (8) as follows:

$$n = (N-1)/(a_0^{N,n} / a_1^{N,n}) \quad (8)$$

In this paper, the formula (8) is considered as a theoretical basis. But actually, we substitute c_0 for $a_0^{N,n}$ and substitute c_1 for $a_1^{N,n}$ in the algorithm, and get (9) as follows:

$$n = (N-1)/(c_0 / c_1) \quad (9)$$

According to (9), we can estimate the number of tags. But the accuracy is determined by the errors of surveyed value c, same as the first estimation scheme. After performing one read frame, we can compute the number of tags to estimate n.

4 Simulation Results

In this section, we analyze the performance of proposed estimation scheme for the number of tags and compare performance with the second scheme, which is the minimum estimation scheme that described above. The parameters assumed in the simulation are same as the follows. The number of tags in the reader field is 16 to 256, and the number of slots N has the value of 16, 32, 64, 128, and so on as maximum 256.

According to the increase of the number of tags, figure 1 shows the estimation number of tags (n_p) with proposed scheme and the minimum estimation number of tags (n_{min}) and real number of tags (n_r) when the number of slots is assumed by 64. According to the increase number of tags, even the errors of the estimation value are somewhat big, compare with the minimum estimation scheme, the figure shows that the proposed scheme produces the approached results. And when the minimum estimation scheme explained before is two times of the assumed number of tags, which assumes tags more than 128, is known as its errors are quiet big.

According to the estimated number of tags in figure 1, figure 2 compares and shows optimal value of the number of slots which can improve the system efficiency. We can know that the number of slots according to the estimation number of tags through proposed scheme and the produced number of slots according to the real number of tags are almost close. In contrast, the produced number of slots is seen to be assumed smaller than the number of slots minimized between the section of 64~84 and the section more than 142 according to the estimated number of tags through estimated scheme of the minimum value. In the case of being same with it, collided slots in all slots increase oppositely and occur low performance.

Along with above, it means that system efficiency can be improved in the case of using the proposed scheme to estimate, it is to compare with the estimated scheme of minimum value.

The proposed scheme of the number of tags based on the triple status information of slots ($c= <c_0, c_1, c_k>$) can't estimate the number of tags when either c_0 or c_1 or both of them are close to 0 or errors of the estimated value is big. In contrast, when the number of slots is too much than the number of tags, the estimated number of tags is more accurate because the collided slot(c_k) is close to 0 or contains much information than c_0 or c_1. In general, when the number of tags is four or eight times of the estimated number of slots, because c_0 and c_1 are close to 0, using the formula (9) above-mentioned, the number of tags can not be estimated. In the same case, the rate occupied by c_k in the total number of slots can be calculated and estimated through an experiment. In reality, there are 300 tags in reader field for estimating, if the number of slots is assumed as 128 at the beginning, the number of tags can be assumed accurately through the proposed scheme in almost all the sections.

The results from viewing above use surveyed value in real algorithms instead of average expected value. Therefore, errors of estimated value are determined by what surveyed value is, to some extent, close to average expected value, and the system efficiency will be affected. As a result, the most of surveyed values can see that they are distributed around average expected value but some surveyed values have quite big errors. Also, it will be distributed more around the average expected value if the number of slots is too bigger. A part of errors is limited as minimum value when it is smaller than the estimated minimum value through the estimated scheme for minimum value among big surveyed values. Also, maximum value of estimated value is limited through using the maximum value from experiment and through using status information of slots. By the same scheme as above, errors with average expected value can be reduced.

5 Conclusions

In this paper, we proposed new tag number estimation scheme for Slotted-ALOHA based RFID systems and the simulation result are also presented. The simulation result shows that the proposed scheme to estimate tags efficiently and further to improve the systems efficiency.

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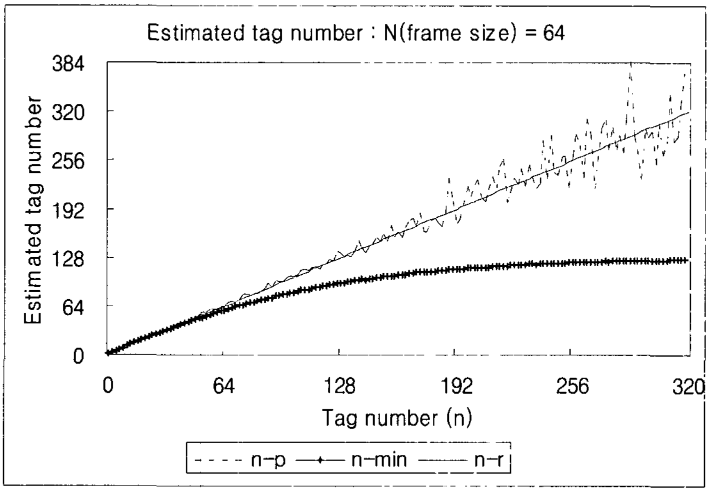

Figure 1. estimation result of the number of tags

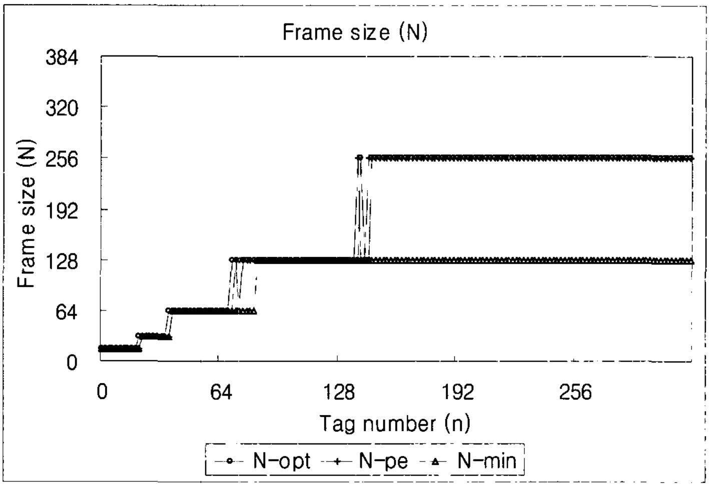

Figure 2. optimal frame size