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Reliable and Fast Estimation for Wireless Media RFID Systems

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***Abstract* - Radio Frequency Identification (RFID) has recently received much attention from various parties involved in supply chain management. It is believed that RFID can bring revolutionary changes to supply chain, replacing the existing barcode systems. In any RFID deployment the first question needs to be answered is how the system could make a quick estimation of the number of tags in the field with a desired level of accuracy. In this paper the further investigations will be made for fast and reliable estimation schemes in wireless media RFID systems based on related prior works in this area. We shall show that under the same accuracy, the time will be less than 20% and with the same time elapsed the accuracy will increase with 15% due to our "double checking" method.**

Index Terms - RDID, wireless media, reliable estimation tags

I. INTRODUCTION

Recently Radio Frequency Identification (RFID) attracts attention as an alternative to the bar code in the distribution industry, supply chain and banking sector. RFID systems also increasingly are used in control and tracking, medical monitor systems, and other daily managements and businesses. This is because RFID system that has advantages of contact-less type and can hold more data than the bar code. Nevertheless, RFID has disadvantages about the problem of identified data clearness, the slow progress of RFID standardization and so on. One of the largest disadvantages in RFID system is its low tag identification efficiency in a dense tag environment, in particular for passive tags, semi-passive tags that do not use their power source for transmission.

In general, there are many algorithms that enable identification and they can be classified into two major directions, namely deterministic methods [1-5] and probabilistic methods [6-12]. Even some related papers are discussing about RFID collisions, security, efficient performances, and others may use hybrids methods [13-18].

It is well known that a framed ALOHA scheme [12-14] is used where the reader communicates the frame length, and the tags pick a particular slot in the frame to transmit. The reader repeats this process until all tags have transmitted at least once successfully in a slot without collisions. In semiactive and active tag systems, the reader can acknowledge tags that have succeeded at the end of each frame, and hence those tags can stay silent in subsequent frames, reducing the probability of collisions thereby shortening the overall identification time. In passive tags, all tags will continue to transmit in every frame, which lengthens the total time needed to identify all tags.

The usual requirement for any identification algorithm is an estimate of the actual number of tags number, t in the system, which can be used to set the optimal frame size in framed ALOHA and to guide the tree based identification process for computing the expected number of slots needed for identification. Also it is important to know the numbers for "efficient identifications" in RFID system [11-12].

Kodialam and Nandagopal have presented an estimation scheme in a variety of circumstances in their paper [19], by which a tag set in a small amount of time can be computed in comparison with similar methods as they have shown in the paper.

This paper is going to show some corrections and improvements based on the further investigations, in particular the techniques potentially offer applications in other areas such as neighborhood estimation problems in wireless networks, the multiple RFID reader problems, and privacy related issues in RFID networks as [19] pointed.

In the next section the "estimation schemes modelling" created by [19] will be introduced. In order to make comparison we shall use the same notations and definitions. After that we shall make a further discussion by which we make some corrections. In the section four, we shall present our estimating method and section five will show our occlusion.

II. ESTIMATION SCHEMES MODELING

Consider a RFID system that consists of a set of readers and many tags. Assume that there exists a separate estimation phase for computing the cardinality of the tag set that precedes any identification process, and that this phase uses the framed-slotted ALOHA model for tags to transmit back to the reader. Given a frame of size f slots, tags randomly pick a slot based on a uniform probability distribution, and transmit in that slot. Tags cannot sense the channel, and hence, they merely transmit in the chosen slot. Slot synchronization is provided by the reader's energizing probe/request.

The entire system uses a single wireless channel/band for operation. The load factor of the system is defined as the ratio of the number of tags, t, to the number of time slots, f, in a frame, denoted as $\rho = t/f$.

The reader's transmission request can contain one or both options, namely (a) a desired frame size to be used by all tags and (b) probability of transmission to be used by tags for transmitting in a given frame. Following [19], we specify that accuracy requirement for the estimation process, specified the error $\beta>0$ and failure probability $0<\alpha<1$. Also the Z_α denoted the percentile for the unit normal distribution.

We assume that the random variable X_j is for the event that there is no transmission in slot *j*. Y_j = 1 denotes if and only if there is exactly one tag that transmits in slot *j* and V_j =1 defines if and only if there are multiple tags that transmit in slot j. Thus, we have $X_j + Y_j + V_j = 1$ for all slots. Let $N_0 = \Sigma^f X_j$, the total number of empty slots, $N_1 = \Sigma^f Y_j$, the total number of singleton slots and $N_C = f - N_0 - N_1$, the number of collision slots.

Kodialam and Nandagopal have presented [19]:

$$E[N_0] \approx f e^{-\rho},\ E[N_1] \approx f\rho e^{-\rho},\ \text{and } E[N_C] \approx f(1-(1+\rho)e^{-\rho}) \quad (1),$$

which can be shown in Fig1.

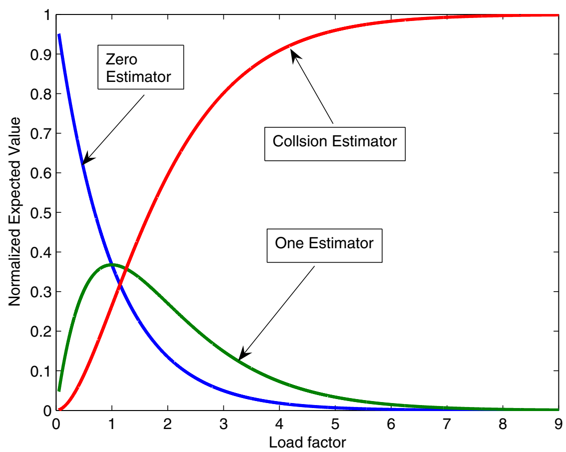

Figure 1: Normalized expected number of slots.

It is also provided that theorem 2 and shows that $[g_0(N_0)-g_0(\mu_0(t))] \sim N[0,\delta_0]$ and $[g_C(N_C)-g_C(\mu_C(t))] \sim N[0,\delta_C]$ where m_i is the mean and *gi* denotes unique inverse function of mean function. And the variances are [19]:

$$\delta_0 = t\frac{(e^{\rho}-(1+\rho))}{\rho} \quad (2)$$

$$\delta_C = t\frac{(1+\rho)e^{\rho}-(1+2\rho+\rho^2+\rho^3)}{\rho^3} \quad (3)$$

III. Further Investigations

It is well known that there is a straightforward way of reducing the variance of an estimator is to repeat the experiment multiple times and take the average of the estimates. If the final estimate is the average of *m* independent experiments each with an estimator variance of σ^2, then the variance of the average is σ^2/m.

It is noted that [19] used the ρ=1.15 (from its figure 6) and obtained incorrectly the result that the repeat the measurement at least ($0.87\ t/\sigma^2$).

In fact if we assume ρ=1.15 then we, from the definition of the load factor, have $f = t/\rho = (1/1.15)t = 0.87t$ (4). Then from equation (3) we have

$$\delta_C\,|_{\rho=1.15} = \sigma_C^2 = fe^{-\rho}[(1+\rho)-(1+2\rho+\rho^2+\rho^3)e^{-\rho}]$$
$$= 0.534t \quad (5)$$

Therefore, we have $m = (0.534t)/\delta_C$.

IV. Modified Estimation Method

In order to have minimum errors or increase accuracy of the estimators, we wanted the minimum variances of the estimated results. Therefore, we may take the differentiating for equations (2) and (3) and then let them equal to zero we have the curves of those two nonlinear equations shown in Figures 2 and 3.

From this diagram we have when ρ = 1.95 we may have minimum normalized estimator variance for the "collision estimator", by which we have $\delta_c = 2.38t$.

However, if we use the "zero estimator", by the same way we have Figure 3. From Figure 3, we have ρ = 1.4 if we are going to use "zero estimator", by which we have $\delta_0 = 1.19t$. Hence we can obtain the estimated tag number from the estimator's variances.

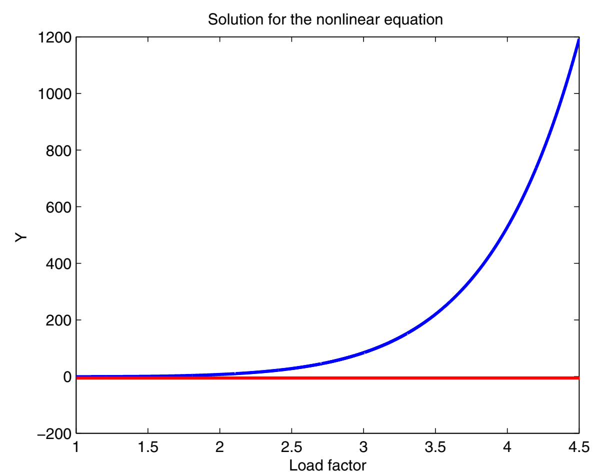

Figure 2: The differentiating equation (3) curve

Thus we have to decide which "estimator" is to be used for the existed system before we estimate it as [19] said that since for the "one estimator" only take care of the situation that when the only one tag is in each frame slot and from Figure we can see that the expected number of singleton slots attains a maximum when the load factor ρ=1, a fact widely used in identification algorithms to optimize the number of successful identifications in a single frame. If $\rho \neq 1$ the singleton slots cannot be used alone for estimating the number of tags. Thus we focus on the rest two estimators.

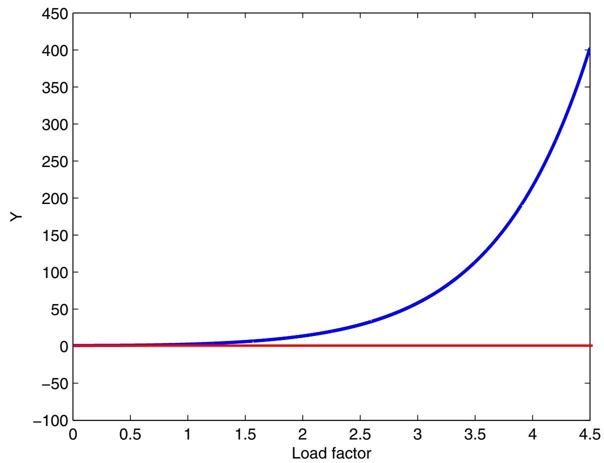

Figure 3: The differentiating equation (2) curve

In order to further investigate both estimators, we may plot equations (2) and (4) with the normalized estimator variances as shown in Figure 4.

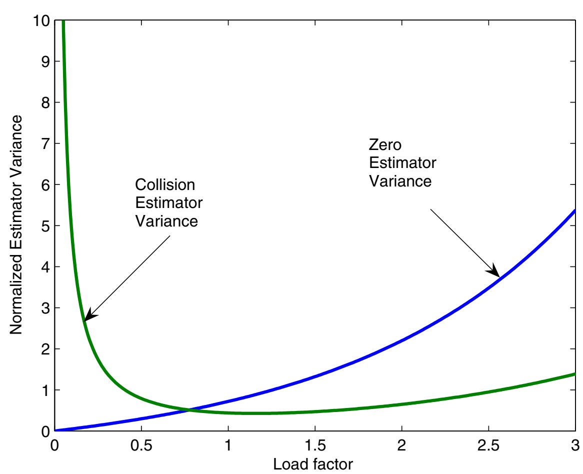

Figure 4: Normalized Estimator variances for equation (2), "zero estimator" and (3), "collision estimator".

From Figure 4 we can see that when $\rho < 1$ even collision estimator can be used but it has a limitation since it can goes lower than 0.43 (as [19] mentioned) but if we take the minimum variances for both estimators, which the ρs (i.e. ρ_0 and ρ_C) are larger than 1 as shown above, therefore there will be no worry about this.

We may have more information about the reason that those two estimators are so different from the Figures 5 and 6, where we extended the variable, load factor ρ, into two variables, tag numbers, t and frame size, f. From Figure 5 we find that the zero estimator can allow the load factor smaller but since $\rho = t/f$, if the tag number is very small such that smaller than the frame size, it would be much interest in how to choose the frame size. In real case we have the case is we did not know the tag number, which is waiting for finding out via the chosen estimator.

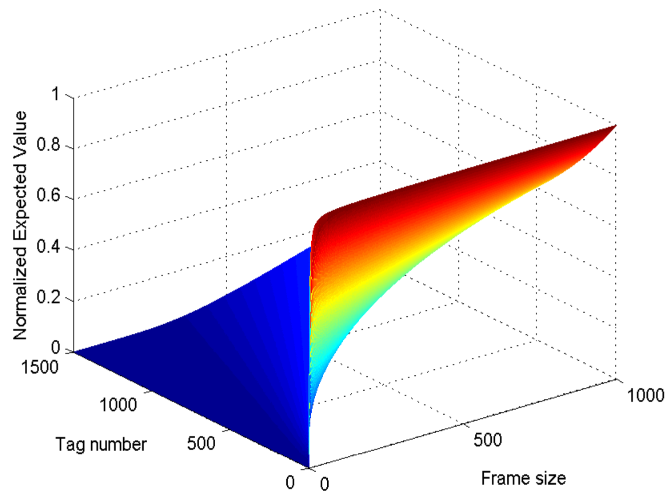

Figure 5: The normalized expected value for tag number and frame size for the "zero estimator"

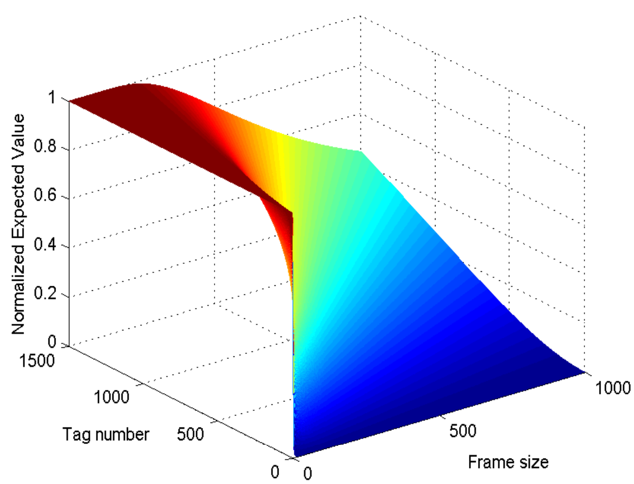

Figure 6: The normalized expected value for tag number and frame size for the "collision estimator"

We may think that what we need is to focus on the "zero" estimator, which seems reasonable due to the nature of the "zero" estimator, however this is not always true showing by Figure 7. We can see from Figure 7 that if $\rho >> 1$ the zero estimator may not work, which is reasonable since we may physically under this situation as that the tag number is very large and hence very hard to get the "zero" state as defended.

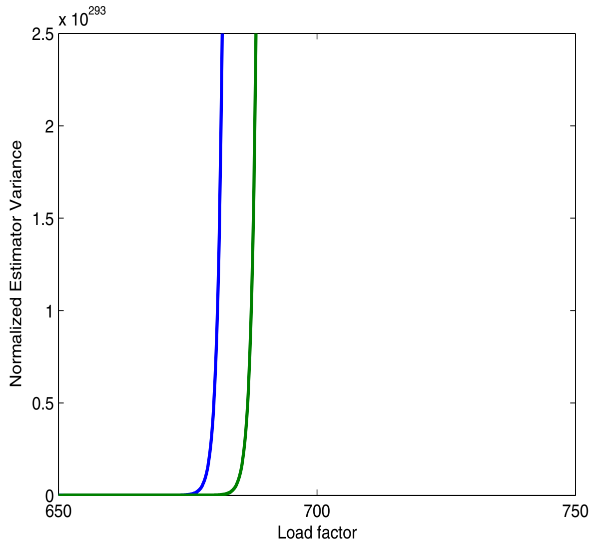

Figure 7: the same plotting when the ρ goes very large.

Therefore if we take the ρ = 1.14 from Figure 1, we may either use "zero estimator" or "collision estimator" the estimator results should be about "comparable" and hence can be used to "one is estimator" another one is "checker" for the obtained results, which makes the estimator work more efficiently, for example under the same accuracy, the time will be less than 20% and with the same time elapsed the accuracy will increase with 15% due to the "double checking".

IV. Conclusions

As estimated tag number in a system deals with important techniques that will be potentially used not only in RFID system but also other wireless multimedia systems, such as neighbourhood element estimations, multiple sensor networks, processing query systems, etc. We have made our further investigations based on similar papers. We particularly appointed some correction and developed estimating methods and make the system faster, more reliable and more efficiently, for example under the same accuracy, the time will be less than 20% and with the same time elapsed the accuracy will increase with 15% due to the "double checking".

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