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Fast Transition for Couple-Resolution Blocking Protocol in RFID Systems

Hae-il Choi

School of Electrical Engineering
Kookmin University
Seoul, 136-702 Korea

Sunwoong Choi*

School of Electrical Engineering
Kookmin University
Seoul, 136-702 Korea
* Corresponding author

Abstract

RFID applications such as monitoring an object for a long time need to identify tags repeatedly within the scope of the reader. Re-identification process can be improved using the tag information obtained in the previous cycle. CRB protocol utilizes the blocking technique that distinguishes staying tags and arriving tags. Staying tags are re-identified by utilizing the previous tag information in the first phase. In this paper, we propose fast transition algorithm to improve the CRB protocol. If the staying tag ratio is lower than a certain threshold, reader immediately proceeds to the second phase where the existing query tree protocol is used. We show the fast transition improves the identification efficiency of CRB protocol through computer simulation.

Keywords: RFID, anti-collision algorithm, Couple-Resolution Blocking Protocol (CRB)

1 Introduction

A RFID reader may repeatedly identify tags in its communication range, for applications such as object locating, monitoring, and tracking. Many protocols [1, 2, 3, 4, 5] have been proposed for the problem. The basic idea is to keep the information acquired from the last process of tag identification. The reader can efficiently re-identify tags using the information. Also, the number of query messages can be reduced.

The CRB protocol [1] proposes the blocking technique. It prevents the collision between staying tags and arriving tags. The identification frame is composed of two phases. Staying tags are involved in the first phase, but arriving tags are identified in the second phase. The blocking technique makes the couple-resolution technique possible in the first phase. Using just one query, two tags can be simultaneously identified. Because CRB reader keeps the information of last identified tags, two tags can be simultaneously queried with one query. Even though the responses from two tags collide each other, the reader can know both tags are staying since no arriving tags are involved in this collision.

In this paper, we propose a fast transition algorithm for CRB protocol. The length of the first phase of CRB protocol, is determined by the number of tags identified in the last tag identification process, N. That is, the number of queries transmitted in the first phase is $\lfloor (N+1)/2 \rfloor$ because one query is required to identify two tags. Note that the all queries transmitted in the first phase can be a waste when there is no staying tag, that is, all tags have left. We propose to transit into the second phase immediately when tag staying ratio is lower than a certain threshold. The tag staying ratio can be estimated during the identification process of the first phase.

The performance of the proposed fast transition is evaluated via computer simulations. We show that the fast transition improves the CRB protocol when the staying tags ratio is less than 20%, from the simulation results.

The remainder of the paper is organized as follows. In Section 2, we review the CRB protocol and how it works. Section 3 proposes a fast transition algorithm for CRB protocol. In Section 4, we provide the simulation results, and then we conclude the paper.

2 Couple-Resolution Blocking Protocol

The CRB protocol focuses on repeated tag identifications for any purposes such as object tracking, locating, and monitoring. RFID reader may repeatedly identify tags in its communication range. The CRB protocol [1] proposes the blocking technique. It prevents the collision between staying tags and arriving tags. The identification frame is composed of two phases. Staying tags are involved in the first phase, but arriving tags are identified in the second phase. Preventing the collision between staying tags and arriving tags, the identification efficiency can be improved. It is noteworthy that each tag itself can determine whether it is a staying tag or an arriving tag using reader's ID and frame number.

CRB further improves the re-identification process, more specifically the first phase for identifying staying tags, using the couple-resolution technique. Two staying tags can be identified simultaneously with one query in the first phase. The query in the first phase includes two tags' ID prefixes. Each staying tag checks if the prefix of its ID is the same with the readers' query to determine whether it should respond with its ID. According to the received response, CRB reader can obtain information as follows:

1) Collision: Two queried tags stay and the two tags are re-identified.
2) One tag response: One tag stays and the other has left. The responded tag is identified.
3) No tag response: Both of the queried tags have left.

An example of the identifying process using CRB protocol is shown in Fig. 1. Suppose four tags whose IDs being 0000, 0010, 1001, and 1100 are identified in the *i*-th frame, f_i. The identification process in the next frame, f_{i+1} is our interest. Fig. 1 shows the identification process in f_{i+1} where tag 1100 has left and tag 0101 newly has arrived.

Slot	Reader query	Tag response				Received response	Identified tags
		Tag 0000	Tag 0010	Tag 0101	Tag 1001		
	First-phase						
1	000, 001	0000	0001			Collision	0000, 0001
2	10, 11				1001	1001	1001
	Second-phase						
3	0			0101		0101	0101
4	1					No response	

Figure 1. An example of CRB: The procedure in f_{i+1}.

In the first phase, the reader check if the tags stay. In the first slot, the query includes two ID prefixes, 000 and 001 to check if a pair of tags stay. The reader can assure that two tags, 0000 and 0001, stay from the collision of responses. In the second slot, query includes two ID prefixes, 10 and 11. The reader receives a response from tag 1001 only since tag 1100 has already left. Once all staying tags are queried, the second phase begins. QT [6] is used in the second phase. In the third slot, tag 0101 is identified and finally the reader correctly identifies all tags in f_{i+1}.

3 Fast Transition for CRB Protocol

In this paper, we propose a fast transition algorithm for CRB protocol. The length of the first phase of CRB protocol, is determined by only the number of tags identified in the last process of tag identification, *N*. That is, the number of queries transmitted in the first phase is $\lfloor (N+1)/2 \rfloor$ because one query contains two tags' ID prefixes. We note that the all queries transmitted in the first phase can be a waste when there is no staying tag, that is, all tags have left. We propose to transit into the second phase immediately when tag staying ratio is lower than a certain threshold. The tag staying ratio can be estimated during the identification process. Reader can count the number of staying tags, $n_s(i)$, and the number of leaving tags, $n_l(i)$, according to the tags' responses. When the i-th response is received at the reader, $n_s(i)$ and $n_l(i)$ are updated as follows:

1) Collision: $n_s(i) = n_s(i\text{-}1) + 2$.
2) One tag response: $n_s(i) = n_s(i\text{-}1) + 1$, $n_l(i) = n_l(i\text{-}1) + 1$.
3) No tag response: $n_l(i) = n_l(i\text{-}1) + 2$.

The estimated tag staying ratio after the i-th query, $R_s(i) = n_s(i)/(n_s(i) + n_l(i))$. We propose to transit into the second phase immediately if the estimated tag staying ratio, $R_s(i)$, is lower than a fast transition threshold, θ.

3.1 Fast Transition Threshold

The fast transition threshold, θ, should be determined. For that purpose, we compare the number of queries to be required to identify all tags. Let the number of tags identified in the i-th frame, f_i, be N. We are interested in the identification process in the next frame, f_{i+1}. Let the number of newly arrived tags in f_{i+1} be N_A. Let the tag staying ratio be R_s, that is, $N{*}R_s$ tags are staying in f_{i+1} out of N tags. The number of queries to be required to identify all tags with CRB protocol, $Q_{\mathrm{CRB}}(N, N_S, N_A) = Q_{\mathrm{CRB}}(\text{first phase}) + Q_{\mathrm{CRB}}(\text{second phase}) = \lfloor (N+1)/2 \rfloor + Q_{\mathrm{QT}}(N_A)$.

If we do not use the blocking technique, that is, the first phase is omitted, CRB operates like QT protocol. Then, the number of queries to be required to identify all tags becomes $Q_{\mathrm{QT}}(N{*}R_s + N_A)$.

It is known that Query Tree protocol requires between 2 and 3 queries for one tag identification on average [7]. We take the conservative number, 3 queries. Then, $Q_{\mathrm{QT}}(N) = 3N$.

We can obtain the condition that CRB works worse than QT,

$$\lfloor (N+1)/2 \rfloor + 3N_A \geq 3(N{*}R_s + N_A).$$

We have,

$$R_s \leq \lfloor (N+1)/2 \rfloor / (3N).$$

Hence, we set the fast transition threshold, $\theta = \lfloor (N+1)/2 \rfloor / (3N)$.

4 Performance Evaluation

We evaluate the performance of the fast transition and compare with the original CRB protocol in this section. We investigate the effects of the number of staying and arriving tags on the performance through computer simulation.

The simulation setup is as follows. One RFID reader identifies multiple tags. Tag ID is 96-bit long, and it is randomly chosen from a uniform distribution and the uniqueness is guaranteed. The simulation results are provided with average values from 100 simulations for each case.

We are interest in the performance in the $(i+1)$-th frame, f_{i+1}. Let N_i be the number of tags identified in the last frame f_i. Let r_s be the ratio of the number of staying tags over N_i, and r_a be the ratio of the number of arriving tags over N_i, respectively. We set N_i to 500, but the staying ratio r_s and the arriving ratio r_a are varied.

Fig. 2 shows the impact of the staying ratio, r_s. We vary r_s from 0 to 1 while the arriving ratio is fixed to 0.5, that is, the number of the arriving tags is 250. We compare the performance of fast transition with that of the original CRB protocol in terms of the number of queries in f_{i+1}. We can observe that fast transition improves the performance of the CRB protocol when the staying ratio is lower than 0.2.

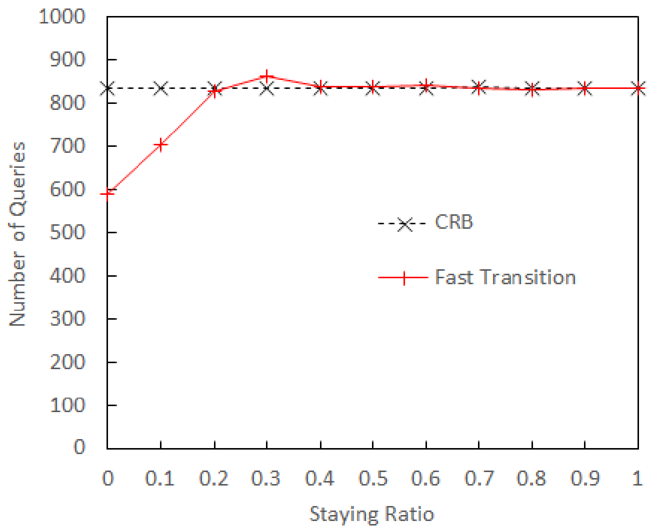

Figure 2. Impact of r_s (r_a = 0.5)

Fig. 3 shows the impact of the arriving ratio, r_a. The staying ratio is fixed to 0.1, that is, the number of the staying tags is 50. We can observe that fast transition improves the performance of the CRB protocol regardless of r_a.

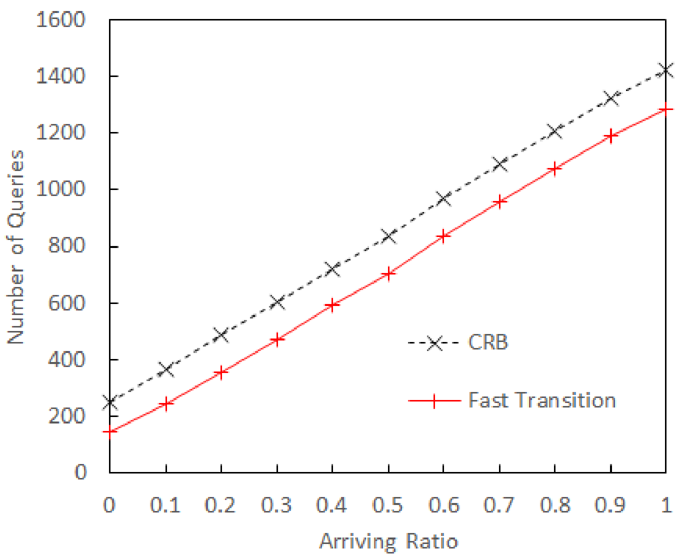

Figure 3. Impact of r_a (r_s = 0.1)

5 Conclusion

In this paper, we proposed a fast transition algorithm for CRB protocol, where CBR protocol immediately transits into the second phase when estimated tag staying ratio is lower than a certain threshold. We showed that fast transition can improve the performance of CRB protocol when tag staying ratio is low.

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