

An RFID Tag Identification Protocol Considering Capture Effect

Jaeyoung Lee¹, Jongho Park¹, and Tae-Jin Lee¹⁺

¹ College of Information and Communication Engineering, Sungkyunkwan University,
Suwon, 440-746, Republic of Korea
jylee11@skku.edu; tamalove@ece.skku.ac.kr; tjlee@skku.edu

Abstract. In radio frequency identification (RFID) systems, tag anti-collision is important to mitigate the collision problem. Channel error and capture effect may occur due to distance and channel state between a reader and tags and it causes some unidentified tags. Conventional tag anti-collision protocols have been studied under ideal channel condition. In this paper, we propose an efficient tree-based anti-collision protocol considering capture effect. Simulation results show that the proposed tag anti-collision protocol improves performance of RFID systems.

Keywords: RFID, anti-collision, tree-based, channel error, capture effect.

1. Introduction

To mitigate the tag collision problem in Radio Frequency Identification (RFID) [1], an anti-collision protocol is required [2]. Tag anti-collision protocols are categorized into ALOHA-based anti-collision protocols [3] and tree-based anti-collision protocols [4]. In the former, e.g., frame slotted aloha (FSA), and dynamic frame slotted aloha (DFSA), a reader estimates the number of tags and decides the frame size for the next frame. In the latter, the collided tags are randomly separated into two subsets to identify the tags until they are resolved. However, the protocols have been usually studied in the ideal channel condition, i.e., no channel error or capture effect. Passive RFID tags receive continuous wave (CW) from a reader and reflect the CW by backscattering. The CW and backscattered signal are susceptible to noise or interference in a practical environment [5]. Even if a tag transmits its own ID at a slot by itself, the tag may not be identified due to the channel error.

In the ideal channel, when multiple tags send their IDs at the same slot, all packets are considered to be lost. However, the packets with stronger signal than the other can be decoded and recognized by the reader. This phenomenon is called capture effect [6]. In conventional tag anti-collision protocols, the tags involved in the capture effect are assumed to be unidentified although they can be identified. A tree-based anti-collision protocol general binary tree (GBT) considering the capture effect is proposed in [7]. In GBT, the collided tags in a capture-enabled slot are identified in the next binary tree cycle. In this paper, we propose an efficient tree-based anti-collision protocol considering the channel error and capture effect. Our proposed protocol identifies the remaining collided tags directly at the next slot right after the collision or error when channel error or capture effect occurs. Thus, our proposed protocol can save the wasted slots and identify tags in a shorter time.

The rest of this paper is organized as follows. The proposed tree-based anti-collision protocol in channel errors is described in section 2. In section 3, we show simulation result to compare performance and explain about the result. Section 4 concludes the paper.

⁺ Corresponding author. Tel.: +82-31-290-7149; Fax: +82-31-290-7983.
E-mail address: tjlee@skku.edu.

2. Proposed Tree-based Anti-collision Protocol

Our proposed anti-collision protocol identifies all tags in RFID systems with capture effect during a round. The proposed anti-collision protocol is based on the binary tree protocol. We assume that channel is not ideal, i.e., channel error or capture effect may occur. A reader is assumed to be capable of distinguish capture effect and channel error. The identification procedure is as follows. A reader broadcasts command to inform the beginning of an identification round. In the next slot, all tags received the command respond their IDs to the reader. Since there is one initial slot in the binary tree protocol. So, all tags collide at the initial slot and the tags in the slot are randomly splitted into two groups. The group corresponds to a slot and the tags in the first group can send their IDs to the reader faster than the tags in the second group.

If the tags send their IDs simultaneously at the same slot, the slot becomes a collided slot and the tags at the slot are split until there are no collision slots. If only a tag sends its ID to the reader at a slot, the tag is identified. If no tags send their IDs to the reader at a slot, the slot becomes an idle slot. However, we have to consider channel error and capture effect. Although a tag sends its ID to the reader, the tag may not be identified by channel error and the tag retransmits at the next slot. Also, a tag among the collided tags may be identified by capture effect. Except the identified tags, the other tags retransmit their IDs at the next slot until they are identified. In order to retransmit at the next slot directly, we give the remaining tag a different waiting time shorter than other tags. By identifying the remaining tags in a single collision during a binary tree round, the reader identifies all tags in one round. Thus, all tags are identified within a short duration.

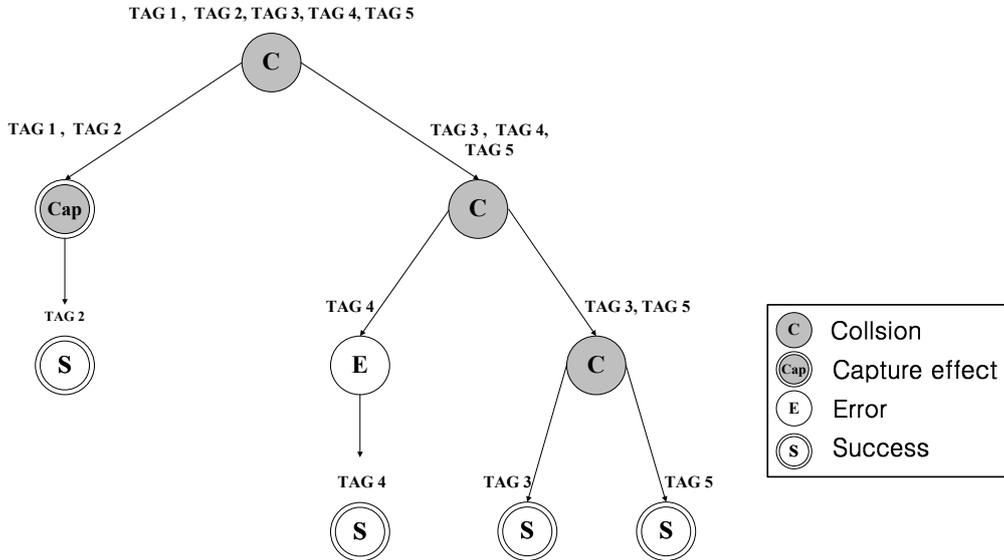


Fig. 1: An Example of the Proposed Binary Tree-based Protocol.

STATE		Collision	Capture effect (Tag 1 success)	Success	Collision	Error	Success	Collision	Success	Success
READER	Command		TAG1 ACK	TAG2 ACK			TAG4 ACK		TAG3 ACK	TAG5 ACK
TAG 1		ID	ID							
TAG 2		ID	ID	ID						
TAG 3		ID			ID			ID	ID	
TAG 4		ID			ID	ID	ID			
TAG 5		ID			ID			ID		ID

Fig. 2: An Example of the Proposed Binary Tree-based Protocol under Channel Errors.

Fig. 1 shows an example of the proposed binary tree-based protocol and Fig. 2 shows an example of the identification process of the proposed tree-based anti-collision protocol. First, a reader broadcasts a

command to all tags, like the conventional binary tree-based anti-collision protocol. All tags they respond their IDs at slot 0 and they collide at the same slot. TAG 1 and TAG 2 select the first group and TAG 3, TAG 4 and TAG 5 select the second group. The tags in the first group send their IDs at slot 1 simultaneously. TAG 1 is identified at slot 1 by capture effect and the reader acknowledges the receipt of the ID to TAG 1. TAG 2 is not identified in slot 1. So it retransmits its ID at slot 2 and it is successfully identified. After finishing the first group, the tags in the second group send their IDs at slot 3 and the collision occurs at the slot. The tags at the collided slot (i.e., TAG 3, TAG 4 and TAG 5) select either the first subgroup or the second subgroup. TAG 4 selects the first subgroup and TAG 3 and TAG 5 select the second subgroup. TAG 4 sends its ID at slot 4, and it is not identified due to channel error. So, TAG 4 retransmits its ID at slot 5. The ID of TAG 4 is identified successfully at slot 5 and the reader acknowledges the receipt of the ID to TAG 4. After finishing the first subgroup, the tags in the second subgroup (i.e., TAG3 and TAG 5) send their IDs at slot 6. The tags collided at slot 6 randomly select new sub-subgroups. TAG 3 selects the first sub-subgroup and sends its ID and TAG 5 in the second sub-subgroup sends its ID.

3. Simulation

In this section, we perform simulation to evaluate the performance of the proposed protocol. The parameters of simulations are shown as Table. 1. We use a network topology where a reader is fixed at the center and tags are distributed randomly within the identification range of a reader. We assume that the size of a timeslot is fixed. Fig. 3 shows the total number of timeslots of anti-collision protocols. In the simulation results, GBT and DFSA consume about 4425 and 4740 timeslots, respectively when 1000 tags send their IDs to the reader. The proposed anti-collision protocol consumes about 0.91%, 0.98% fewer timeslots than DFSA and GBT, respectively. In simulations, the proposed anti-collision protocol uses the smallest number of timeslots than the other protocols. Thus, our proposed anti-collision protocol identifies tags fast under capture effect and channel error. DFSA consumes more slots than our proposed anti-collision protocol since it does not consider channel error and capture effect. It has to retransmit the unidentified tags due to channel error or capture effect in the next frame. GBT consumes more slots than our proposed anti-collision protocol since it identifies the unidentified tags due to channel error or capture effect in the next round with the same collision probability regardless of the capture effect and channel error experience in the tree collision resolution procedure.

Table.1: Simulation Parameters.

Parameters	Values
Number of tags (n)	100~1000
Reader's reading range (R)	15 m
Tag ID size	96 bits
Bandwidth	500 KHz
Frequency	900 MHz
Thermal noise density	-174 dBm/Hz
Reader's transmission power (P_{TX})	15 dBm
Reader's antenna gain (G_{reader})	0 dBi
Tag's antenna gain (G_{tag})	-6 dBi

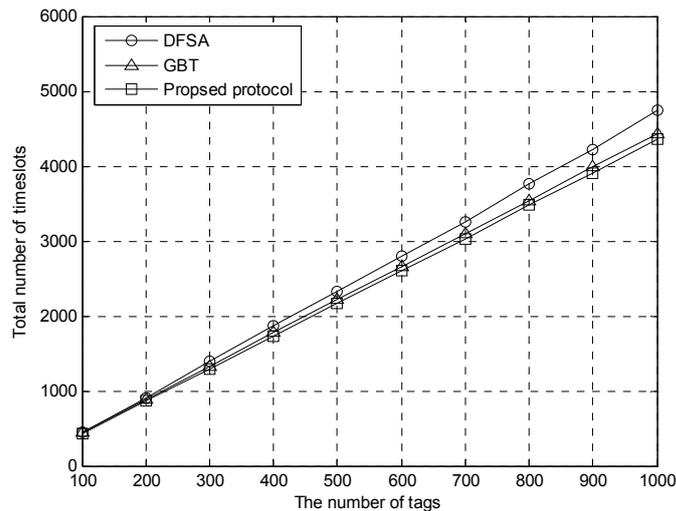


Fig. 3: Comparison of total number of timeslots.

4. Conclusion

In this paper, we have proposed an efficient tree-based anti-collision protocol for RFID systems. Path-loss and interference effect is conceived to take capture effect and channel error into consideration. Our proposed protocol can identify all tags quickly in the coverage of a reader. Simulation results show that proposed anti-collision protocol consumes less time slots than the original binary tree protocol with channel error.

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