A Multicast Anti-Collision Protocol for FTDMA based RFID system

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Abstract: RFID **(**radio frequency identification) is a key technology supporting emerging solutions for the automation of the identification service and the mass product management. A key issue is to reduce the average time taken to identifying tags, which is called average identification time. Focusing on the issue, the paper proposes an efficient multicast protocol which is applied to the anti-collision protocol of FTDMA (frequency time deivision multiple access) based RFID system. Thanks to the compactness of a multicast protocol, simulation result shows 29.5% improvement of average identification time.

1. Introduction

Radio frequency identification (RFID) technology has been grown for a decade, along with the development of semiconductor technology. It is applied for many industrial fields such as the distribution industry, the inventory management, the medical treatment, and so on. By attaching a RFID tag to every product, the technology will contribute the establishment of the Ubiquitous environment. An important issue of RFID is the technology to accelerate the time identifying many tags. In order to do that, the collision between multiple tags should be efficiently compromised. This function is called anti-collision protocol.

Anti-collision protocol is to be classified into the ALOHA-based (or probabilistic) protocols and the tree-based (or deterministic) schemes, in terms of the method to obtain the opportunity accessing the channel. At the ALOHA-based protocols, tags access the channel by random priority. There are pure ALOHA, slotted-ALOHA, and frame-slotted-ALOHA protocols [1]. For the tree-based protocols, tags which satisfy the condition given by a reader try to access the channel. The tree-based schemes guarantee that every tag replies once during the identification time. For another point of view, the anti-collision protocols are categorized into TDMA (time division multiple access) and FDMA (frequency division multiple access). There is a hybrid scheme called FTDMA (frequency time division multiple access) as well.

There have been many previous researches because the anti-collision protocol is the important scheme to decide the performance of RFID system. At ALOHA-based protocol side, researchers mobilize many techniques, such as Slow-down, Terminating, and Early-end to accelerate tag identification time [6]. At tree-based scheme side, researchers seek to optimize the performance by employing DFS (depth first search) [2], adaptive splitting [3], bi-slotted tree [4], and reduction of the number redundant frames [5]. However, these proposed methods are restricted to TDMA. To author's best knowledge, there is still no work on detailed tuning method of the FTDMA protocol.

This paper consider the anti-collision protocol in ISO/IEC 18000-3 Mode-2 standard [7], which uses ALOHA-based and FTDMA protocols. The anti-collision protocol in the standard is optimized for the case identifying hundreds of tags. As a simple relative comparison, it can identify 500 tags in 390ms, compared to 8 seconds of ISO/IEC 18000-6 Type B [9], and 1.7 seconds of EPC global Class 1 Gen. 2 [10], [11].

Despite of good performance relative to other protocols, there is still a point to be revised. The protocol has one command channel for a reader and eight reply channels for tags. Whenever a reader and a tag try the frame exchange with unicast, it is the waste of bandwidth for reply channels beacause they will keep IDLE even while they don't share same channel. Successfully adopting multicast protocol, the paper solves this problem. As a result we observe 29.5% reduction of average identification time.

The rest of this paper is organized as follows. Section 2 states background knowledge of the anti-collision protocol defined in ISO/IEC 18000-3 Mode 2. Section 3 depicts the problem in current protocol and present a proposed method in detail. Finally, section 4 concludes the paper.

2. FTDMA Protocol in ISO/IEC 18000-3

ISO/IEC 18000-3 Mode 2 is the RFID standard used in high frequency (HF) band, and is targeted for mass product management [7]. The RFID system using this standard is composed of one reader and hundreds of passive tags. Multiple accesses of tags are controlled by a reader. Nine channels are used for the communication between a reader and tags: one command channel from a reader to tags and eight reply channels from tags to a reader. System parameters of the standard are summarized in Table I.

TABLE I
SYSTEM PARAMETERS OF ISO/IEC 18000-3 MODE 2

Parameter	Tag to Reader (Reply Frame)	Reader to Tag (Command Frame)
Carrier frequency	13.56MHz ± 3.013MHz	13.56MHz ± 7KHz
Sub-carrier frequency	969, 1233, 1507, 1808, 2086, 2465, 2712, 3013 KHz	7KHz
Data rate	105.9375 Kbps	423.75 Kbps
Data coding	MFM (modified frequency modulation)	
Modulation	BPSK	Phase Jitter Modulation

In this standard, a slotted-ALOHA-based anti-collision protocol is used to compromise the collision during the identification of tags. Tags randomly send their identifications (IDs) upon receiving a slot delimiter. The standard uses FTDMA as well. In response to a valid command from a reader, each tag randomly selects a channel on which it is about to transmit its reply.

In order to perform the anti-collision protocol, three types of frames are exchanged between a reader and tags. The first frame is the zero-length command frame broadcasted by a reader. It contains the muting set, which is the random variable which indicates the probability for a reader to obtain the channel access opportunity. Possible values of the muting set are given in Table II. For example, if the value is 3, each tag has a chance to access channel by 1/8 probability. (7/8 of tags are not replied.) The second frame is the reply frame transmitted by a tag. It contains ID of the tag, and transmitted by a tag which obtains the opportunity to access channel from the muting set and selects a channel from eight reply channels. The third frame is the mute command frame. A reader transmits this frame to the specific tag whose ID has been successfully received. When a tag receives this frame, it finishes the anti-collision protocol and does not reply by the zero-length read command.

TABLE II
VALUE OF THE MUTING SET

Value	Description	Value	Description
0	unmuted	4	31/32 muted
1	1/2 muted	5	127/128 muted
2	3/4 muted	6	511/512 muted
3	7/8 muted	7	fully muted

Figure 1 illustrates the operation. At first time slot (1), the reader broadcast the first zero length read command with muting set = 0 (unmuted). Muting set gives a probability that tags are reply for the request. Table II shows possible values. At (2), all tags within the reading range answers to the command in one of 8 channels. At (3), switch off the identified tag by sending mute command. At (4), too many tags are crowded in the preceding time slot causing many collisions, thus increase the muting set of the consecutive zero-length read command. Now broadcast zerolength read command with muting set = 1 (1/2 of tags are muted). From (5) to (12), the reader and tags repeat the same sequence until all the tags are resolved and temporarily muted so that there's no response to the zero-length read command with muting set = 0 (unmuted).

3. Multicast Anticollision Protocol

3. 1 Problem Description

The purpose of the anti-collision protocol is the acceleration of the time taken to identify multiple tags. One method is to improve the efficiency of the channel utilization. There are many methods such as link adaptation, burst transmission, multicast, and so on. In this first point of view, the ISO/IEC 18000-3 Mode 2 has a weak point to degrade the channel efficiency. While there are eight reply channels, only one command channel responses to multiple tag replies. As a result, eight reply channels remain IDLE when a reader sends a frame to a tag. It is a waste of shared resource. It is especially wasteful when a reader transmits multiple mute commands to multiple tags. For instance, three tags are successfully identified by a zero-length-read command. Then, three mute commands are transmitted by a reader. It implies that eight reply channels are remained in IDLE for three time slots.

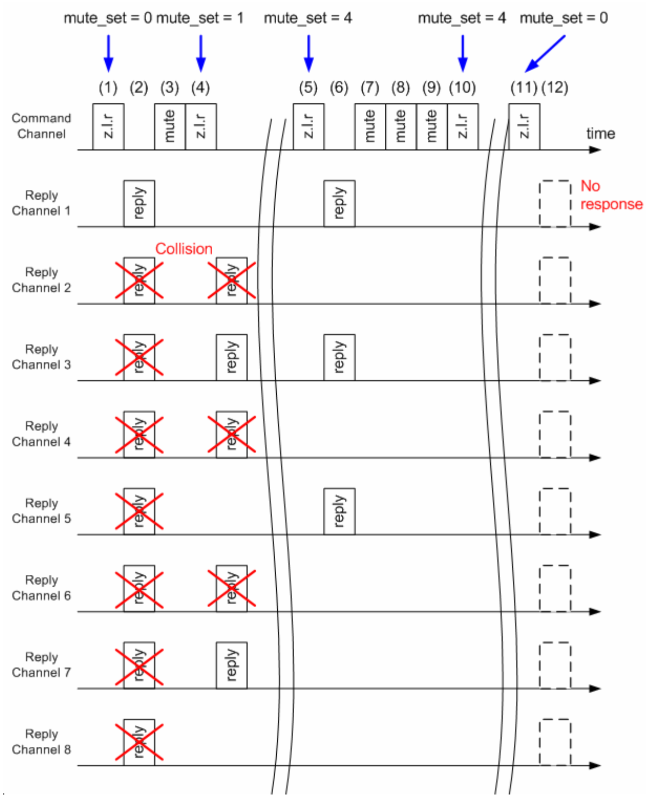

Fig. 1. Anti-Collision Protocol of ISO/IEC 18000-3 Mode 2 (z.l.r : zero-length read command)

3. 2 Proposed Scheme

In order to remove the inefficiency pointed in previous session, we designed a multicast mute command. The most primitive way to make multicast frame is the concatenation of destination addresses. However, the system needs additional control for the frame length variation. The frame becomes error prone because of longer frame length as well. In consequence, we conceive more compact and effective way focusing on the characteristic of ISO/IEC 18000-3 Mode 2 system.

When a tag successfully transmits its ID to a reader, the ID becomes one of unique information which is shared by both entities. But, if we confine our scope into a time slot, the index of the channel where the ID has been successfully received can be the unique identifier. In other words, a tag transmitted its ID through the third channel can be muted when it receives a success flag for the third channel at the same time slot. Finally, we propose multicast mute command which has an 8 bit channel mask field.

Figure 2 shows the frame formats of an original mute command and a proposed multicast mute command. An original frame indicates the tag to be muted by transmitting ID on SID (specific identification) field. Read Address and Read Length fields are all zeros for the mute command. Instead, a proposed frame uses a channel mask field. Up to 8 tags can be muted by a single transmission of a multicast mute command. The frame length is 56 bits shorter compared to an original frame, even while it is a multicast frame. If three IDs are successfully received for a single zero-length-read command, it reduces 81% of overhead consumed by the transmission of mute commands.

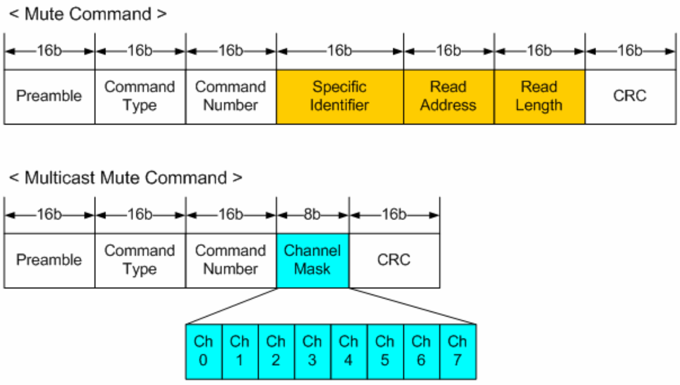

Fig. 2. Mute Command and Multicast Mute Command

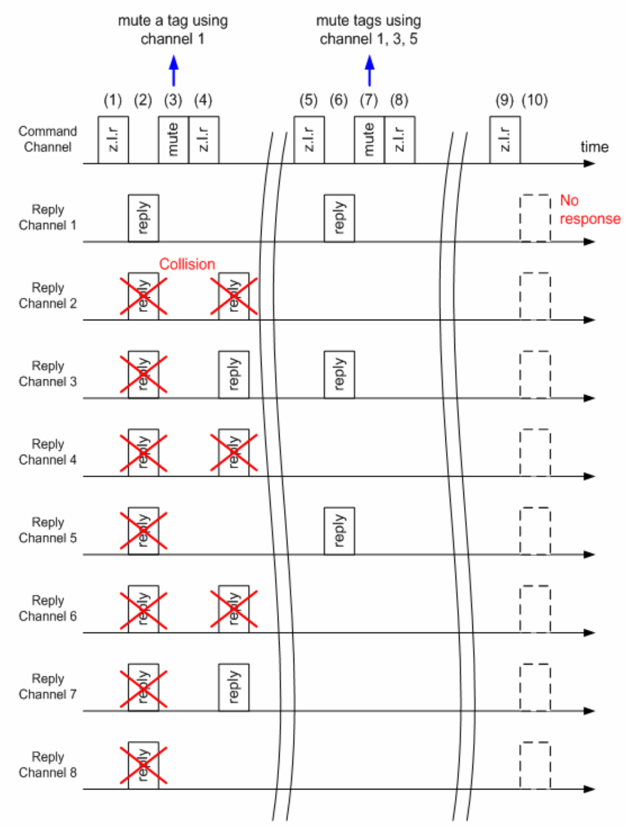

Fig. 3. Anti-Collision Protocol using Multicast Frame

Figure 3 shows the anti-collision protocol adopting multicast mute command. The illustration uses same scenario as Figure 1. At time slot (7), a reader transmits one multicast mute command to mute three tags, which had sent reply frames through replay channel 1, 3, and 5 respectively. For the interval from (5) to (9) in Figure 1, the proposed protocol saves two time slots.

3. 3 Simulation Result

The simulator is established by C++ and verified by the reference simulation result in ISO/IEC 18000-3 standard [7]. We configured 1 reader and 50 to 700 tags during the simulation, which is targeted to the management of mass product. Only short replies with zero-length payload are involved with the anti-collision protocol. Uniform random number generator gives the next frequency hopping sequence to each tag. Rx-Tx Turnaround times of the reader and the tag are fixed to their minimum values (zeros). No channel error is used to focus on the anti-collision protocol.

Figure 4 shows the performance improvement when the multicast mute command is applied. Thanks to the increment of channel efficiency, the great improvement is watched. In the graph, average 29.5% of the average tag identification time is reduced.

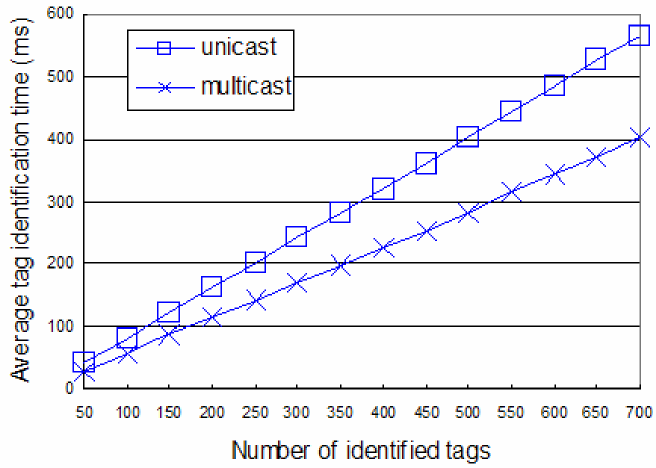

Fig. 4. Average tag identification time

4. Conclusion

In this paper, we fixed a inefficiency in multicast protocol for FTDMA based RFID system, ISO/IEC 18000-3 Mode 2 standard. Instead of individual mute command defined in the standard, we proposed a multicast mute command to remove inefficiency. Successful adoption of the proposed frame results in 29.5% reduction of average identification time, when the other conditions are same.

References

[1] F. Schoute, "Dynamic Frame Length ALOHA," IEEE Trans. Commun., vol. 31, pp. 565-568, Apr. 1983.

[2] S. Kim and P. Park, "An efficient tree-based Tag Anti-collision protocol for RFID systems," IEEE Commun. Lett., vol. 11, pp. 449-451, May, 2007.

[3] J. Myung, W. Lee, and J. Srivastava, “Adaptive binary splitting for efficient RFID tag anti-collision,” IEEE Commun. Lett., vol. 10, pp 861-863, Dec. 2006.
[4] J. H. Choi, D. W. Lee, and H. J. Lee, “Bi-slotted tree based anti-collision protocols for fast tag identification in RFID systems,” IEEE Commun. Lett., vol. 10, pp. 861-863, Dec. 2006.
[5] D. K. Kwon, W. J. Kim, and H. N. Kim, “An efficient tree-based Tag Anti-collision protocol for RFID systems,” IEICE Trans. Commun, vol. E90-B, pp. 2120-2125, Aug. 2007.
[6] L. A. Burdet, “RFID Multiple Access Methods,” ETH-Zurich, Tech. Rep., Aug. 2004.
[7] *RFID for item management – Air interface, Part 3: Parameters for Air interface communications at 13.56MHz*, ISO/IEC Std. 18000-3, 2004.
[8] G. Murdoch and T. Frost, “A Comparison of the ISO 15693 and ISO 18000-3 MODE 5 Magellan Protocol,” Magellan Technology, Tech. Rep., Apr. 2001.
[9] *Information technology automatic identification and data capture techniques – radio frequency identification for item management air interface – part 6: parameters for air interface communications at 860-960 MHz*, ISO/IEC Std. 18000-6, 2003..
[10] *EPC radio-frequency identification protocols class-1 generation-2 UHF RFID protocol for communications at 860MHz-960MHz* Ver. 1.0.9 EPCglobal Std., 2005.
[11] J. H. Choi, D. W. Lee, and H. J. Lee, “Query Tree-Based Reservation for Efficient RFID Tag Anti-Collision,” IEEE Commun. Lett., vol. 11.