Efficient Heterogeneous Reader Anti-collision Methods for Passive RFID Systems

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Abstract—Passive RFID tags share a common channel and they use back-scattering modulation because of no self battery. It causes reader collision problems when signal from a reader interferes with signal from other readers. The evolving standards use CSMA based protocol called 'Listen Before Talk (LBT)' and FDMA based protocol called 'Frequency Hopping Spread Spectrum (FHSS)' to reduce reader collision problems. Moreover, these standards are not considered with real industry environment that a stationary reader and a mobility reader coexist with different operation methods and purposes in the same place. Therefore, we describe novel protocols to reduce reader collision problems by RSSI signal. They are mixed protocols between CSMA and TDMA based between a stationary reader and a mobility reader. Simulation results show that the proposed protocols improve RFID system performances.

I. INTRODUCTION

Ubiquitous computing is a post-desktop model of human-computer interaction which creates a combination of a ubiquitous environment and electronic spaces using each network by fixed ubiquitous chips that communicate with computers. For realization of ubiquitous computing, identified technique is basically needed, radio frequency identification (RFID) is in the limelight of it. RFID is auto-identified technique like barcode system that readers verify storage data from tags, labels, or cards using wireless frequency [1]-[2]. RFID system can identify many tags simultaneously and it is possible to transmit a mass data from tags to a reader. Therefore, with non-contact technique instead of existing barcode system, it is using for an identification and pursuit of objects at distribution and manufacturing industry and for an application at supply chain management (SCM.)

RFID system is divided by a type of tags that is a passive and an active type. RFID system consists of a tag, a reader, an antenna and server and offers practical service to link with internet through host. A reader transmits signal as a modulation of continuous wave with specific frequency to tags, the tags that receive the signal transmit their information to the reader. Here, a passive tag transmits its data to a reader as back-scattering modulation from the reader because a passive tag does not have any battery. It is a main cause to different between read range and interference range, and it gives reader collision problems like Fig. 1.

Among RFID system, there are two types of RFID readers, stationary and mobility reader. Stationary readers construct a network to connect wired, and can only read tags within range of the reader at its current location. However, stationary readers are connected to line power, so they have a much larger communication range. In addition, multiple stationary readers can be networked together to cover even larger areas and can quickly scan the inventory to locate an item or obtain information from multiple items. On the other hand, a mobility reader has that a user can transport to a remote area to read tags at that location. For mobility, it limits size and weight, so it is supplied to energy from small battery, so it has a limitation of communication range

RFID system is progressing practical worked, but it has a problem to be low identified efficiency by collision between readers or tags. Especially, the reader collision or the tag collision bring the decrement of identified efficiency and also identified speed, so they are main problems for industrialization of RFID system.

There are two types of a collision in RFID system, a tag collision and a reader collision. The tag collision is that many tags reply simultaneously to a request from a reader [3]. The reader collision is an interference that affects each reader to be located in the near field during identifying tags [4]. The reader collision classifies into frequency interference and tag interference. The frequency interference is the case that neighboring readers use simultaneously same frequency, so the collision originates between commands from readers to tags like Fig. 1. The tag interference is the case that many readers want to read same tag at the same time; a tag could not distinguish between each reader because of using backscattering like Fig. 2. Therefore, if each reader uses each different frequency, it could solve the frequency interference but the tag interference could not be solved.

Traditionally, RFID systems have been designed with only a single type of reader scenario in mind. However, with the increasing use of RFID in the industries and also huge scope for deploying mobility readers, increasingly more scenarios may require readers to operate in close proximity of each other leading to interference resulting in incorrect operation and/or slower tag read rates. In addition, as increasing to use a passive tag RFID system, there exist reader collision problems, especially reader-tag collision by a variety of readers’ type.

However, it is difficult to solve collision problem, because its system has only sleep-response operation using a passive tag. Therefore, it is hard to be dynamic coordination between
tags and readers. In addition, a passive tag cannot distinguish channelization readers. Hence, all RFID collision problems must solve at a part of readers by resource allocation problems between operation readers.

There are three types of practicable resource for solution. The first one is frequency, but it is no frequency selectivity ac a passive tag. The second one is space, and it is possible to be coordination or sensing between multiple types of readers by a directional antenna before interrogation. The third one is time. It is the most realistic method, but it exists access waiting time before operation.

In this paper, we propose a distributed medium access control method for the RFID system by air time division that is the most realistic method. A consideration scenario is like a super market or a library where each item in the inventory is tagged to increase the number of reading passive tags. They are suitable for a large scale deployment, and the readers form a stationary reader network with all the readers having unrestricted mobility and a mobility reader. The readers frequently join and leave the network. Possible applications in such a scenario could be inventory check by a number of mobility RFID readers.

The contents of this paper is shown as follows. First, we analyze the previous RFID anti-collision protocol in Section II. In Section III, we describe a system model and the proposed RFID anti-collision method by time coordination. And then, we simulate in Section IV, the summary and conclusions are discussed in Section V.

### II. RELATED WORKED

Table I shows the current proposed scheme comparison only for reader collision problems. There are four representative methods; EPCGlobal Class 1 Generation 2 UHF standard, ETSI EN 302 208, Colorwave, and Pulse protocol. The EPCGlobal Class 1 Generation 2 UHF standard satisfied by EPCglobal which is the standard group of GS1 based on FDMA [5]-[7]. It reduces reader interference using frequency hopping spread spectrum (FHSS.) ETSI EN 302 208 intends to listen before talk (LBT) protocol based on CSMA for avoiding collisions between readers [8]. Colorwave is made by Auto-ID Lab in MIT and based on distributed TDMA that each reader selects own time slot to transmit [9]. Finally, Pulse protocol is an anti-collision method based on CSMA using beacon signal [10]. It is that an operated reader transmits periodically beacon signal during identified tags for blocking up usage of other readers in interference region. Among them, we can select LBT protocol of ETSI EN 302 208 and Colorwave protocol of MIT as reference protocols, because there are reader operation as division of air time for heterogeneous RFID reader system.

LBT protocol operates that the reader first listens on the data channel for any on-going communication for a specified minimum time. If the channel is idle for that time, it starts reading the tags. Moreover, the reader which occupies subchannel at first acts as master of the subchannel, and it sends pre-pulse to other readers. If the channel is not idle, it chooses a random backoff and waits that time or it chooses another channel. However, a reader cannot detect collision for application LBT, so it cannot avoid collision with the carrier sensing alone.

Colorwave operates if a reader collides, the reader selects a new time slot and sends a "kick" to neighbors with information about a new time slot. We called this time slot to "color" and this kick message is a small control packet. If any neighbors have same color, the reader should select a new time slot and send a kick and this continuous. However, Colorwave requires time synchronization between readers, and readers cannot detect tag collision at each tag in RFID system. Furthermore, it can only operate regular number of readers during a frame, so it is not a good method at the current status which increases for the mobility readers to use.

### Table I

<table>
<thead>
<tr>
<th>Group Algorithm</th>
<th>Organization</th>
<th>Method</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>EPC Class1 Gen2</td>
<td>EPC</td>
<td>FHSS</td>
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<td>LBT</td>
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**Fig. 1.** A case of a reader-to-reader collision.

**Fig. 2.** A case of a reader-to-tag collision.
III. PROPOSED ALGORITHM

A. System model for heterogeneous RFID system

Recently, RFID System is usually using in a factory or a warehouse. There are using two kinds of readers; stationary reader and mobility reader. As a case of two kinds of readers’ operation in a space with different purpose, though a network is formed with a minimum collision between stationary readers, mobility readers exist to operate simultaneously in stationary readers’ read range. In this case, when they transmit signal to same tag, collision between a stationary reader and mobility reader is occurred inevitably, and it is a cause that efficient of tag identification is low. Therefore, we will propose a new scheme how to coexist with a stationary reader network and mobility readers like a Fig. 3. This figure is that a stationary reader network connects to a host and is controlled by the host server for the minimum collision and there exist mobility reader at the same space.

Fig. 4 is a simple version example of Fig. 3. Soon, we will explain our schemes based on Fig. 4. In Fig. 4, S is a stationary reader and M is a mobility reader. Therefore, there exist five stationary readers and eight mobility readers and they are operating simultaneously with host server. Each circle of readers presents each read range. A difference size of each circle shows a difference power level between a stationary reader and mobility reader.

To adapt for a stationary reader and a mobility reader, there exist some establish facts. Readers can communicate with each others to get their situations and each reader broadcasts their signal by RSSI. It is important that stationary readers already have a network which minimizes reader collision between stationary readers by graph coloring. In addition, stationary readers which operate to identify tags can communicate smoothly with each others. And then, we suppose that they operate through communications between a mobility reader and a stationary reader network.

B. Novel protocols by time coordination

We can divide protocol between a stationary reader network and a mobility reader by priority of a stationary reader network. Operation of a mobility reader is starting with a message (MSG) from a stationary reader network. There are three kinds of a scheme to operate with them. First, operation of a mobility reader starts after finishing operation of a stationary reader network. At this time, a stationary reader network is transmitting ‘invitation MSG’ to a mobility reader. Second, operation of a mobility reader starts middle of operation of a stationary reader network. At this time, a stationary reader network is transmitting ‘release MSG’ and ‘restraint MSG’ to a mobility reader. Finally, operation of a mobility reader also starts middle of operation of a stationary reader network. At this time, the stationary reader network is transmitting ‘Isolation MSG’ to the mobility reader. Now, we introduce each scheme to be detailed.

First, a case of transmitting ‘invitation MSG’ explain by Fig. 5. Each stationary reader has five states. At ‘Power off’ state, a stationary reader gets power and changes to an ‘Initialization’ state. In this state, the stationary reader is decided by a controller to operation order such as graph coloring. And then, it goes to a ‘Ready’ state. In this state, each reader achieves three kinds of operations. First one is a waiting of reader after finishing graph coloring. If color of a reader matches a current slot color, the reader moves to ‘R-to-T comm.’ state. Second one is a waiting of reader until finishing fixed period. This waiting is for the reader to finish ‘R-to-T Comm.’ and it is for the stationary reader network to transmit starting point to a mobility reader. Third one is a waiting of reader until finishing operation of mobility period. ‘R-to-T comm.’ state is to operate EPCglobal Class 1 Gen.2 for identifying tags at fixed color. ‘Tx Invitation MSG’ state is to transmit ‘Invitation MSG’ that tells to start mobility period to a mobility reader. After finishing fixed period, stationary readers that power on transmit simultaneously this MSG. On the other hand, each mobility reader also has five states and operates basically LBT. At a ‘Ready’ state, it waits ‘Invitation MSG’ from a stationary reader to start its operation. At a ‘Waiting’ state, it wait during invitation window to get ‘Invitation MSG’ from
the stability range of readers was a uniform grid of readers. For simulation, the initial placement was adjusted to -45dBm, to make the read range 5 feet as is the case with UHF RFID readers.

We used the following simulation setup. Tag setup used a field of 100m X 100m area with grid 4000 tags. For stationary reader simulation, all the readers were randomly placed in the field. For simulation of mobile readers, the initial placement of readers was a uniform grid of readers. For simulation, the RFID application generated a packet(query) to be sent to that tag with exponential interarrival time of average 500ms throughout the simulation time of 60 seconds.

We compared our protocol which is the protocol with a case of transmitting release MSG and restraint MSG, LBT protocol, Colorwave, Pulse protocol, and FHSS. They operate with a listen time of 15ms and time slot of 10ms. In addition, each
window interval is set as 5ms. Using similar settings for these protocols help us evaluate the MAC protocols in an unbiased manner.

Fig. 9 shows a simulation result by throughput. As the number of readers in the system are increased, the throughput of proposed protocol is better in all topologies as compared to protocols. It shows an improvement as high as 18% with 40 readers over Pulse protocol and 83% with 28 readers over colorwave protocol. The proposed protocol and pulse protocol is the best performance results, because these protocols are considered with different types of readers; stationary and mobility readers. The other side, FHSS and colorwave protocol shows much low performance results because of no consideration of them. In addition to, FHSS cannot solve ordinary tag interference because a passive tag do not have frequency selectivity. Colorwave protocol is only efficient when readers can detect collision and the number of readers are fixed, so it is not a suitable protocol to apply RFID systems.

Fig.10 shows a simulation result of average waiting time for operation of mobility readers. FHSS is the best, but its throughput is very low. The proposed protocol is the second one, but its throughput performance is the best than other protocols. Therefore, we can get a conclusion that the proposed protocol is a suitable method for the current RFID systems.

V. CONCLUSION

In this paper, we propose methods to coexist with stationary reader and mobility reader. As increasing a usage rate of RFID systems, coexistence operation is an important factor for passive RFID systems, because reader collision, especially tag interference cannot solve to use existence method. Therefore, we should consider them and solve these problems. In this paper, we introduce simple methods to solve problems for heterogeneous RFID system. Each mobility reader can use before, middle and after usage stationary readers’ operation. Numerical results show that the proposed protocol is the best method. If readers operate based on this method to communicate with them, we could solve easily reader collision as increasing a usage of readers and increase efficiency of RFID systems to identify tags.

ACKNOWLEDGMENT

This work was supported by the IT R&D program of MKE/TTA. [2009-P1-14-08I91, Mobile and next generation RFID technology standards development]

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