Journal of Advances in Computer Research
Quarterly pISSN: 2345-606x eISSN: 2345-6078
Sari Branch, Islamic Azad University, Sari, I.R.Iran
(Vol. 6, No. 1, February 2015), Pages: 1-7
www.jacr.iausari.ac.ir

A High Throughput CDMA-Based Reader Collision Avoidance Protocol for RFID Networks (HRCP)

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Received: 2014/03/08; Accepted: 2014/04/27

Abstract

A typical Radio frequency identification system (RFID) includes one reader and a number of tags. The reader transmit to commands to the tags with interrogation radio signals, and tags receive the command and then respond with their identification. Readers with interrogation signals can read tags' responses. In RFID systems, when multiple tags respond to one reader simultaneously, tag collision can occur. In addition, multiple reader to tag collision occurs when more than one reader wants to read one tag at the same time. RFID collision problems are a group of the open research topics. In this paper, a high-throughput reader collision avoidance protocol based on code division multiple access (CDMA) has been proposed to solve the reader collision problem with the help of RFID network systems based on orthogonal codes, which allow all readers to read the tags at the same time and frequency. Comparison of this protocol with the pulse protocol shows great improvement on the average read throughput.

Keywords:*Reader Anti-Collision, Smart RFID, Protocol RFID, CDMA, Throughput*

1. Introduction

A typical RFID system includes one reader and a number of tags, where the reader communicates with the tags through radio frequency channels, and reads the information of the tags. Nowadays, much attention is centered ona new generation of RFID systems, namely, "the smart RFID system". This kind of RFID system uses "smart RFID tags", that have more capabilities compared with normal ones. RFID systems soon gained popularity in industries and commerce, especially in supply chains, and they also replaced barcodes [1]. In a brief comparison between these systems with barcodes, one can notice their better features, such as simultaneous reading of several tags, not needing an operator, and a higher range in reading tags. But they also have a number of problems that have not been solved yet, most important of which is collision. In RFID systems, there are two kinds of collision: tag collision and reader collision [2, 3]. Tag Collision occurs when more than one tag respond to one reader simultaneously,if tag collision occurs, due to interference, the reader cannot recognize signals of the tags. Reader collision [4] occurs when readers are very closely situated in the vicinity of each other, and their query signals interfere with each other. The problem of reader collision is very serious. On the other hand, with the high interest in using RFIDs in work environments, and the increase in the intensity of readers, the problem of reader collision changes into a complex one. Reader collision is divided into two parts:

A: Collision of reader with reader [5, 6]: it happens when a powerful signal of a reader interferes with the weak signal of a reflected tag. Note that such interferences are possible even when the read ranges of the two readers do not overlap.

B: Collision of multiple readers with a tag [5, 6]: this kind of collision occurs when more than one reader want to read one tag at the same time. In this condition, queries which come from readers interfere with each other and therefore the tag won't be able to read any queries. This collision occurs for tags that are placed at the range of more than one reader. A third kind of reader collision was also proposed at pulse [5] namely, "the hidden terminal" which, in the [6] presence of this collision at real environments such as rooms, according to the capture effect [7] and the RFID path loss model [8],it can be rejected.

In the second section of the paper, the related works are introduced. In sections 3 and 4, the proposed protocol is introduced, and evaluated in detail, and the final section presents the conclusion.

2. Related Works

Solutions have been proposed to solve the collision problem of readers such as: LBT that is based on the CSMA method in which readers consider the status of the channel before sending messages, and if they find it empty, they will send their message[9].

Pulse divides the channel into two parts; the data channel and the control channel. The control channel is for communication of readers with each other through sending beacons, and the data channel is for communication between readers and tags. The reader that is connected with the tags, sends beacons on the control channel in a range farther than its interfere range, and any reader that receives this message, doesn't have permission to send a query and has to wait till the end of the beacon sending time. Thus, in this way, it can somehow prevent reader-reader collision and readers-tag collision. However, since each time only one reader can read tags, the amount of time and channel wasting in this protocol is a lot[5].

The next is Colorwave in which readers need extra communication among themselves, and there is a lot of time-wasting possibility. In Colorwave, each reader selects one timeslot randomly and reads its tag in its own time slot. If one reader chooses a timeslot that one of the neighbor readers had chosen, collision occurs and the reader should select another timeslot for itself and aware its neighbors of its timeslot. Colorwave isn't suitable for mobile RFIDs, because TDMA scheduling needs reader synchronization, while high mobility will generate lots of communication overhead for scheduling. The other defect of Colorwave is that this method doesn't use the multichannel mechanism and causes waste of channel and lowering of operational power[4].

The Gentel protocol, which is based on the CSMA method, uses channels to dispatch information. The previous methods usually used the TDMA techniques that focus on the operation of ordinal works[6]. In this paper, a protocol based on CSMA is introduced in which readers start to send queries simultaneously, and in one frequency.

In the following paragraphs, the protocol will be proposed and discussed in detail. The forth section will be devoted to simulation, and in the final section, conclusions and future studies will be observed.

3. HRCP

HRCP is a centralized and anti-collision protocol based on the CDMA method that enables cooperation of readers with each other [10, 11]. The protocol performs the process of tags' reconnaissance by several readers in 4 steps:

Cluster heads are elected in the first step. In the second step, unique codes are assigned to each reader, and in the third, the head cluster chooses which tags should be recognized by which readers, and in the final step, recognition occurs.

3.1 Production of head clusters

The concept of "cluster" is introduced in the light of the management of multi-readers. Readers which interfere with each other comprise a cluster. The cluster is categorized into two parts: a cluster header and some cluster members. The cluster header, generated by readers' election in a cluster, is regarded as the center of communication and control. Consequently, the RFID network can be divided into several clusters in which the cluster header is installed at the center. Fig. 1 shows the topology of the network.

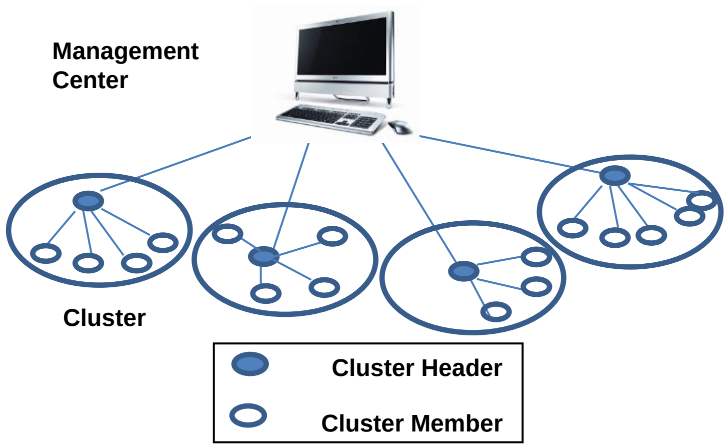

Fig 1: show the topology of the network.

Three procedures make up the process of the generation of the temporary cluster [12].

1) Election of the cluster header is fair. It is equal for each node to turn a cluster header. With the commencement of the election, each reader generates a random number between 0 and 1. Readers transmit the number to others. At last, the reader who has generated the minimum number is elected as cluster header.

2) The reader elected as cluster header should send its information to other readers to announce its status.

3) Other readers ascribed to cluster numbers should transmit information of registration requests to the cluster header.

The election will start afresh when the next group of tags arises [12].

3.2 Code words allocation algorithm

In this stage, the temporary cluster header will allocate code words to all readers which aim to use the CDMA technique. CDMA technology distinguishes between different users owing to the utilization of orthogonally or quasi-orthogonally of the code sequence. In the condition of the same frequency and time, different code patterns are employed by the receiving terminals to isolate the needed signals. The reserving codes used for distinguishing different readers are grounded on the Walsh Sequences [13]. Walsh Sequences are a group of spreading codes that have good autocorrelation and cross correlation properties which are zero at any point. The IS-95 system employs Walsh functions in the forward link for multiplexing the many different forward link channels, while Walsh sequences or code words are used in the reverse link for power efficient orthogonal modulation purposes [14]. In this stage, the cluster header will allocate Walsh Sequences to each reader. The procedure of allocating is described as follows:

1) First, the cluster head identifies the number of cluster members and produces one group of the Walsh codes, based on the number of readers of the cluster.

2) Then the cluster head (according to the received random numbers in previous stage) first, sorts those random numbers, then sends unique codes for each reader associated with the rank of its random number in this sort of action from the later phase to use these codes for the recognition of tags. At the end of this phase, all readers will have a unique Walsh code.

3.3 Sending group codes for tags

In this phase, the head of the cluster sends group codes assigned to readers, for tags, and each tag selects one of them for itself. Each tag is recognized by one reader which has the same code with this tag, without collision and interference of other readers.

3.4 Tag identification

All readers begin to identify the tags at the same time based on the perfect synchronous. When identification begins, all tags respond to the readers with their own data. Similar to [12], the readers which have received the information use their own reserving codes to do the operation of cross-correlation. If the result is zero, the reader will drop the data, and if the result is not zero, the reader will be activated and identify the tag. Fig.2 shows the structure of the tag data.

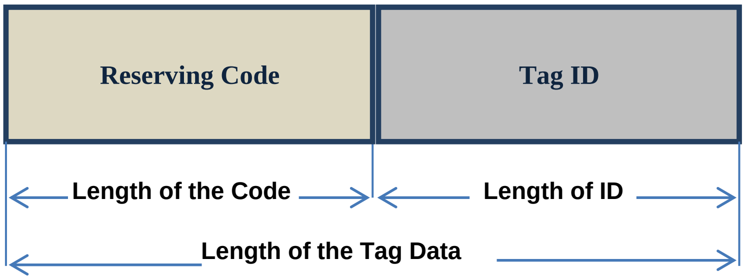

Fig. 2: The structure of the tag data.

4. Simulation Results

In RFID systems, the anti-collision algorithm is used for improvement of tag recognition rate. Table 1 shows simulation parameter values that we used in accordance with the LBT standard values. Our simulation range is 15*15 m^2 which is in accordance with the dimension of a common room. At first, we distributed readers and tags randomly in the room. Since the distance of reader collision, as mentioned in paper [2], reaches 70 m, all readers at pulse protocol are in collision with each other and make a cluster in the protocol in our simulation. We have considered 4 time slots for the process of choosing cluster headers and assigning code words to readers [12]. And following these 4 slots, readers begin to recognize tags associated with themselves. Because of random selection, allocation of asymmetric tagsto each reader can cause negative effects on efficiency.

Table 1: simulation parameters.

Parameter	Value
Simulation range	15m x 15m
Time to read one tag	5ms
Time to listen channel	5ms
Beacon period	5ms
Maximum Contention Window(CW)	5(pulse), 60(pulse)
Number of reader	10,20,30,40,50,60,70,80,90,100
Number of Tag	10,20,30,40,50,60,70,80,90,100
Reader to reader collision distance	70 m
Multiple reader to tag collision distance	2m(default),3m,4m,5m
Compared protocols	CDCIP, Pulse
Slots of tag reserving procedure	2
Slots of cluster header election	2
Antenna Polarity	Omni

For example, if we consider that two readers should recognize 10 tags, random selecting of codes for each tag may cause reader A to be responsible for the recognition of 8 tags, and reader C to be responsible for the recognition of 2 tags. Thus, the general recognition time depends on the final act of reader A, which means an 8+4 time slot. Measured the performance based on average read throughput. In our paper, throughput is defined asthe number of tags that are identified per unit of time.

4.1 Average read throughput using number of readers

In Figure.3, throughput of pulse protocol decreases with the increment of readers' numbers, because the number of collisions increases. But with an increment of readers, throughput in CDCIP increases and at HRCP, after solving the problem of CDCIP, through using most readers, throughput improves with a more upward slope.

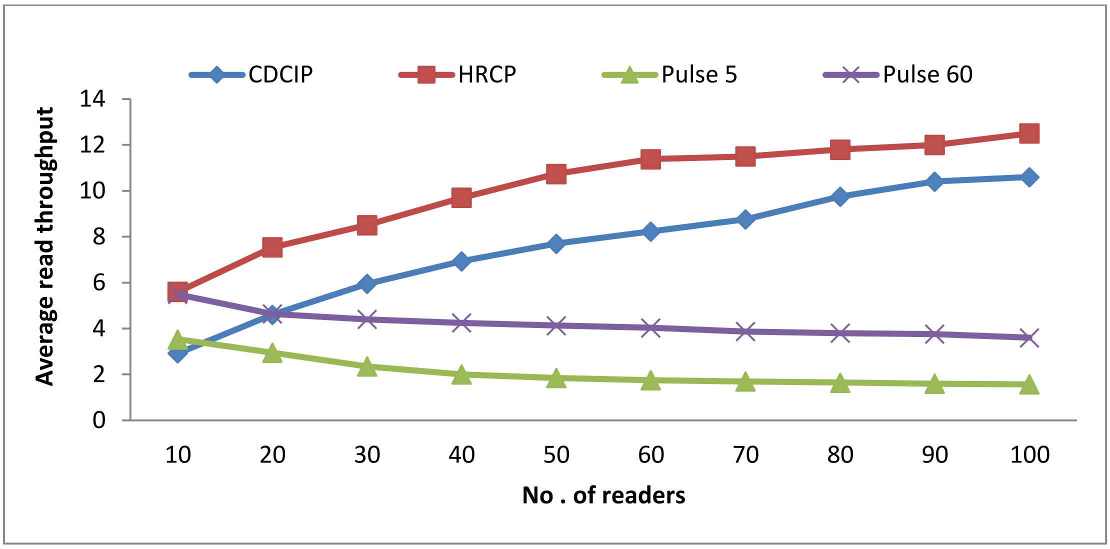

Fig 3: system average read throughput of CDCIP and PULSE and HRCP.

4.2 Average read throughput using number of tags

Figure.4 shows different average read throughputs for 60 readers and variable numbers of tags. Through increasing the number of tags and increasing density of tags in the environment, throughput declines in pulse, and this is worse in pulse5. With increase in the number of tags, the proportion of tags to each reader in HRCP is less than CDCIP, and this causes the rate of read throughput in HRCP to be better than in CDCIP.

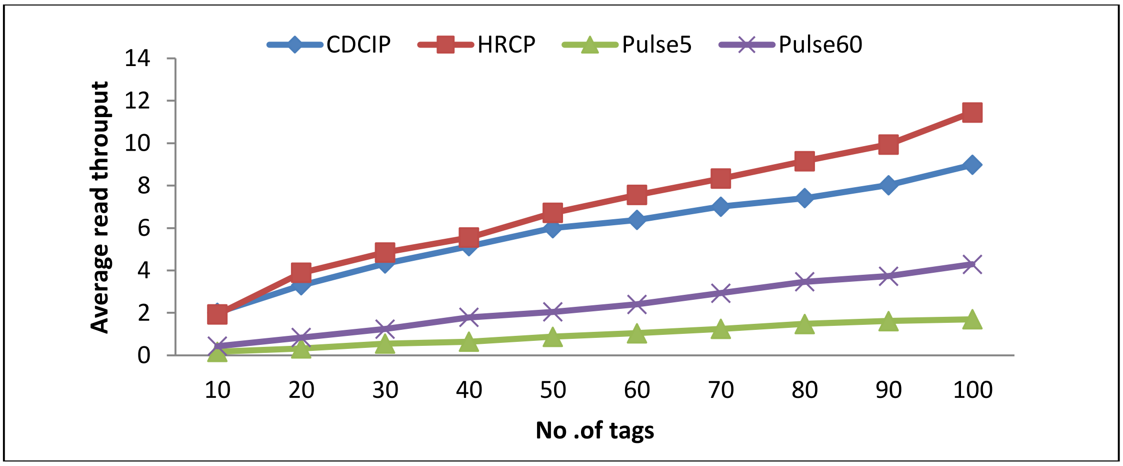

Fig 4: system average read throughput CDCIP and PULSE and HRCP in state 60 reader.

5. Conclusion and future studies

In this study, a cooperative protocol has been suggested for the purpose of solving the reader collision problem. This protocol, which is based on the CDMA method, allows readers to identify tags at specific times and in specific frequencies. This simultaneousness in the readers' performance start time results in preventing a waste in time, and also allows for an intense increase in throughput. A comparison between the throughput of the suggested protocol with that of the Pulse protocol, clearly indicates such an improvement. We can refer to the usage of other orthogonal codes and specification of codes to balanced tags on this protocol as future studies which may cause an increment in throughput.

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