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A Sift Distribution Multi-channel Reader Anti-Collision for RFID Systems

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Abstract

RFID system is a wireless technology that can transfer data between tags and readers via radio frequency. In an RFID network, readers are located close to each other to obtain optimal connectivity and sufficient coverage. In such an environment, which is called dense reader environment (DRE).Different types of collisions such as Reader-to-Reader and Reader-to-Tag ones, often lead to serious problems such as decreasing the performance. Accordingly, providing an appropriate method to resolve reader collision appeared to be one of the most important research topics in the field. To solve this problem, different methods have been introduced of which NFRA protocol has higher throughput. In this paper, we use multi-channel technique and sift distribution function on the NFRA protocol to improve RFID system throughput while avoiding increase in reader collision. In addition of supporting mobile reader, the proposed method provides higher throughput compared to other protocols in dense environments.

Keywords: *RFID System, Dense Reader Environment, Reader to Reader Collision, Reader to Tag Collision, Throughput*

1. Introduction

Radio frequency identification (RFID) is one of the most important automatic identification technologies that identify tagged objects via near/far-field wireless communication. An RFID system is capable of data storage, long transmission range, and quick identification. Mainly, it is used in commercial systems such as supply chain and transportation payment systems [1], [2].Additionally, warehousing, sports, tracking, and health care are the domains in which RFID are utilized. In other words, one can claim that an RFID system is replaced with traditional barcode systems, nowadays [3].

An RFID system consists of tags and readers. Tags are small electrical parts which are attached to objects for identification purposes. In particular, tags store information of the objects that have been attached to [4]. In terms of power source, tag scan be divided into two categories: passive and active. Passive tags have no power source and their required energy is provided with reader waves, while active ones need an external power source. An RFID system often uses a passive tag due to cost efficiency [5].

Reading area of a reader depends on its transmission strength. In some environments, a single reader is not sufficient to cover a particular area. Accordingly, aggregation of several readers in the RFID system is necessary. Such an environment in which multiple readers are required is called dense reader environment (DRE) [6]. Readers collect tag information by reader-to-tag protocol. Then, the collected information is sent to a central server via wireless or wired communications. The central servers are responsible for tasks such as information management [7].

A reader has two ranges: interference range and read range. In the latter, a reader is able to detect the tags around itself, and in the interference range, reader's transmission waves affect that of the other readers. The farthest distance between these two ranges depends on the strength of transmission waves [3].In this system, since the distance between readers is very short, several readers or tags are available in the read range of the reader, causing collisions between readers or tags. This collision leads to failure in recognizing tags which correspondingly lowers the performance of the system [8]. Thus, one of the main goals of active researches in scientific applications and RFID systems is to find a solution for aforesaid problem. In dense reader environments, three types of collisions may occur [9]:

1. Tag-to-Tag Collision: It occurs when multiple tags respond simultaneously to the same reader. As you can see in Figure1 (a), when tags want to communicate simultaneously with R_2, the collision happens [6].
2. Reader-to-Tag collision: It occurs when two or more readers try to read the same tag because of an overlap in their read ranges. As you can see figure 1(b), when R_1 and R_2 read simultaneously T_1, the collision happens. As the figure indicates, T_1 is in the both reader interference range [6].
3. Reader-to-Reader collision: It happens when the signal generated by on reader interfere with the reception system of other reader. As you can see figure 1(c), when R_1 interference range effects in R_2 read range and R_2 cannot read T_1, the collision happens [6].

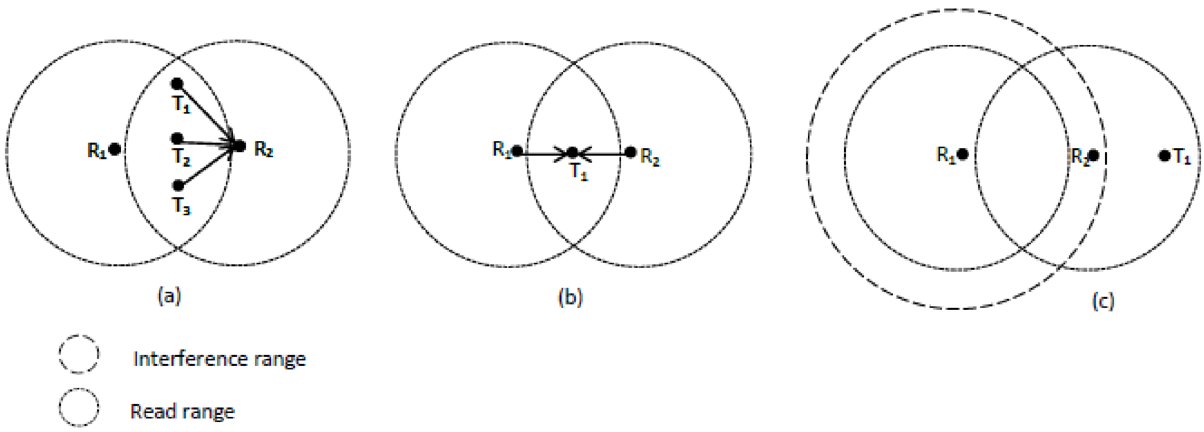

Figure1.(a):Tag-to-Tag collision, (b):Reader-to-Tag collision, (c): Reader-to-Reader collision

According to the description of these three types of collisions, a protocol is needed which can solve them. Some of the proposed protocols focus on minimizing Reader-to-Reader collision. Reader-to-Reader collision only occurs when two or more readers simultaneously work together. As a result, Reader-to-Tag collision can happen with

Reader-to-Reader collision as well. In other words, if Reader-to-Reader collision can be resolved, Reader-to-Tag collision also may be reduced [10].

In this paper, we propose a novel method based on NFRA protocol. Our proposed method converts NFRA protocol into a multi-channel protocol. Furthermore, instead of using uniform probability distribution for selecting a random number and random channel in each round, we utilize sift geometric probability distribution [8] which leads to increase in throughput. Sift probability function reduces collision between competing readers and increases the probability that a reader can transmit lonely in a round [8].

The rest of this paper is organized as follows. Section 2 introduces the related work. Section 3contains the details for our new proposed algorithm. Section 4 evaluates the results of the proposed algorithm under different scenarios. We present the conclusion of our work and future work in Section 5.

2. Related Work

Introduced protocols in RFID systems can be divided into two main categories: distributed and centralized. In the distributed mechanism, the reader is not dependent on a central server and thus independently operates. In the centralized mechanism, in the contrast, the central server communicates with readers via a wired or wireless communication network. The central server is responsible for managing the readers and sharing the resources in the network. In this section several protocols based on these two mechanisms are introduced [5].

2.1 Distributed Protocol

In [11] DCS protocol is introduced. In this protocol, a reader randomly selects only one time slot in a frame in order to compete and require time for tag identification. When more than one reader selects the same time slot, a reader collision occurs. Each time slot is divided into two parts; kick message and reader-to-tag communication part. If the collision occurs, reader chooses randomly a new time slot and in the next round, number of new time slots is reported to the neighbors as a part of the kick message. When the neighbor readers receive this message, they compare it with the number of their own time slots. If the numbers are the same, the neighbor readers will randomly change the number of their time slots.

In [12] PDCS protocol is introduced for increasing the performance of DCS protocol. In this protocol, readers change their own time slots with probability P, since the time slots in which readers are collided may stay free in a period of time and the readers again select the same time slots for their operations. For this reason, the efficiency of the system will be reduced, and hence the probability of P is used to select the new slot. The optimal value for the probability has been estimated to be 70%. In this protocol, readers use multiple channels for communicating with tags.

Furthermore, [13] introduces Color wave protocol which an improved version of DCS protocol. In this protocol, a round consists of some varying time slots. Each reader independently manages the number of time slots in each round. For change number of time slots, readers use two pairs of thresholds. Readers for changes the number of time slots. They announce the change in the number of time slots to their neighbors through transmitting the kick message. When neighbor readers receive this message, they estimate the percentage of their own successful reads and change their number of time slots, if necessary.

Last but not the least, [14] introduces LBT protocol. In this protocol, readers first listen to the channel, and if the channel is free, they will use it for communication with tag. In LBT protocol, multiple channel scan be used to communicate with a tag. This protocol performs poorly on collision management and cannot prevent collision in dense environments, leading to zero throughput.

2.2 Centralized Protocol

NFRA protocol is introduced in [3]. In the NFRA, a polling server broadcasts the arrangement command (AC) to mobile readers. The AC includes the information for the beginning of a round and the range of random numbers, i.e., from 1 to max number (MN). The readers that are receiving the AC generate their own random numbers. After transmitting AC, the server issues an ordering command (OC) to readers. The readers then compare their random numbers with the value in the OC. If they are the same, the readers broadcasts beacons with short transmission range to determine whether a collision occurs or not. During the beacon transmissions, the server does not broadcast OCs to avoid collision between beacons and OCs, because they use the same frequency. After the beacon frames, if some readers do not detect any collisions, they send overriding frame (OF) to the neighboring readers. The packet OF prevents the neighboring readers from receiving the next OC from the server. The neighboring readers which do not identify the next OC due to the OF or which detect a collision of beacons do not actively operate, i.e., do not conduct identification of tags until the next AC.

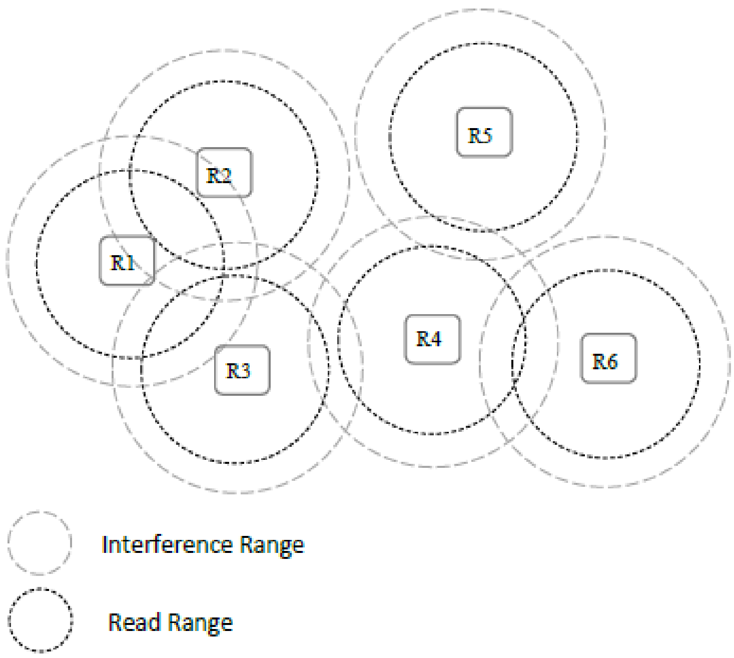

Figure2. Example of Network

Considering the network shown in figure 2, the following readers have collisions with each other: {R1, R2, R3}, {R3,R4}, {R4,R5} and {R4,R6}. We apply NFRA protocol on this network, and as you can see in figure 3, {R1, R2} readers experience beacon collision. Additionally, {R3, R5, R6} readers cannot do anything and should wait until the next round since they receive OF packet on this round. On the other hand, only R4 reader can use the channel and communicate with the tag. In other words, only one reader can communicate with the tag in this round.

Finally, in [7] introduces GDRA protocol. This protocol is a new protocol based on NFRA which minimizes reader-to-reader collision. This protocol manages frequencies, considers time slots as resources, and achieves better performance than NFRA. Moreover, it can be implemented without any additional hardware in real DRE. Readers randomly select one of the four frequencies recommended in the EPC [15] and ETSI [16] standards. When reader gets its turn for reading, if channel is busy in the current time slot, it leaves competition, selects randomly other channel and waits for start in the next round, however if the channel is empty, reader can communicate with the tag.

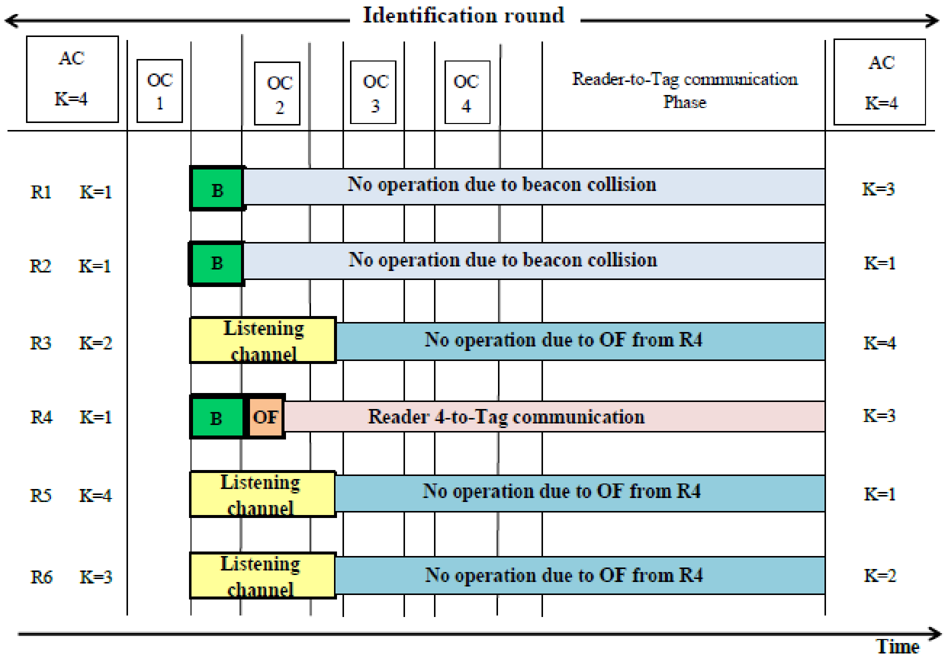

Figure3.Example of NFRA procedure

3. Proposed Algorithm

Our proposed protocol provides an algorithm which can efficiently reduce reader-to-reader collision. As we said above, the most important collisions are reader-to-reader and reader-to-tag ones. In addition, reducing reader-to-reader collision hopefully leads to decrease in reader-to-tag collision as well. In this study, we provide sift distributed multi-channel reader-to-reader anti-collision protocol (SDMRA) in RFID dense environment.

In this paper, we put the basis of our proposed algorithm on NFRA protocol. Although NFRA protocol has better performance compared to other protocols, but its throughput can be further improved if more than one frequency (channel)be used and negotiation method changes. This means that when an AC is broadcasted by server among readers, all of them should choose a number from the range (say choosing k from 1 to maximum number (MN)) that has been introduced by AC. In our proposed algorithm, we suggest to use sift geometric probability distribution function instead of uniform distribution function for choosing this number. Sift geometric probability function, which has been fully explained in [7], reduces collision between competing readers and increases the probability that a reader can communicate with the tag lonely in each round. Also for communicating with tag, our proposed algorithm suggests to utilize multiple channels instead of a single one, and exploiting sift geometric probability distribution instead of uniform distribution for selecting the channel in each round. In this situation, sift probability function reduces collision between competing readers in channel selection phase and hence increases the probability that a reader lonely selects distinct channel.

Like NFRA, in our proposed algorithm, SDMRA, packet lengths are as follows: AC packet length is equal to 2.83 ms, OC packet length is equal to 1ms, beacon packet length is equal to 0.3 ms and OF packet length is equal 0.3ms. According to these values, listening time to a channel and required time for determining whether the channel is busy or not, becomes equal to 0.3 ms, while this time is 5 ms in GDRA protocol. The proposed SDMRA protocol is consistent with mechanism in TDMA and is a combined version of FDMA. In this protocol, readers select one of the C available channels, using sift probability function. Thus, we will have C sets of readers so that each set has been coordinated by TDMA.

We apply the SDMRA proposed method, on the network depicted in figure 2. A round in this network is shown in figure 4. As it is evident in figure 4, R1 reader chooses channel 2, R2 reader chooses channel 1, R3 reader chooses channel 2, R4 reader chooses channel 3, R5 reader chooses channel 3 and R6 reader chooses channel 4.

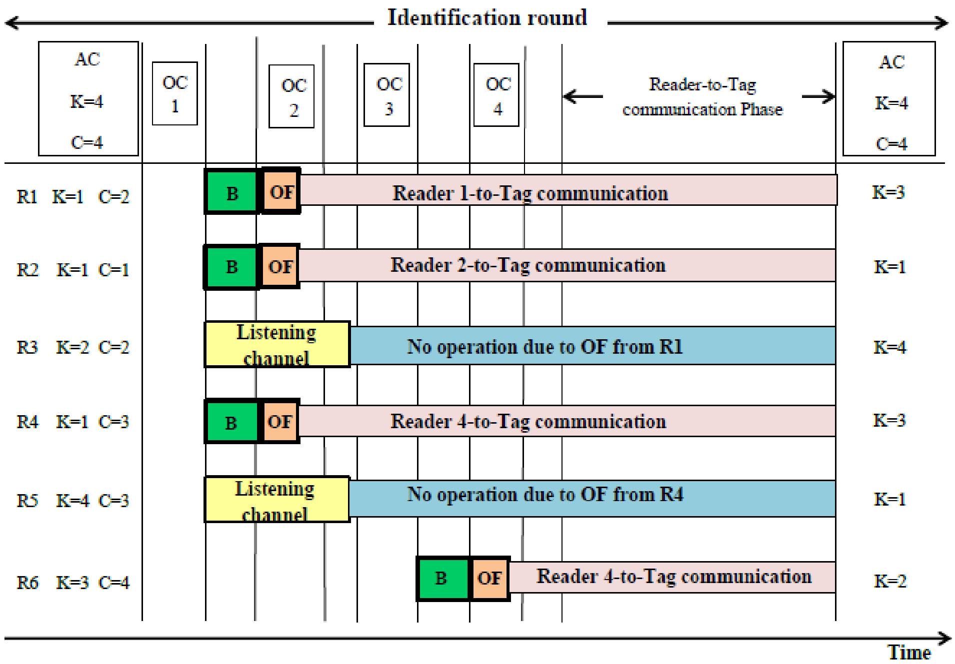

Figure4. Example of SDMRA procedure

Taking the selected values for K and C into consideration, although the value for K are the equal for both R1 and R2 readers, however they can simultaneously communicate with the tag since they are in different channels. Since R3 reader is in R1 reader's channel, it receives OF packet from R1 reader and cannot do anything. R4 reader can goes busy with reading the tag on channel 3 and also R6 reader can communicate with tag on channel 4, but as R5 reader and R4 reader are in the same channels and same interference range, R5 reader receives an OF packet from R4 reader and cannot communicate with tags.

As you see in figures 3 and 4, by applying NFRA protocol on the network in figure 2, just one reader could communicate with the tag, while by applying the SDMRA protocol on the same network, four readers can simultaneously communicate with the tag.

3.1 Algorithm procedure

Pseudo code for the SDMRA approach is demonstrated, in algorithm 1. In line 1, the central server introduces a numerical range from 1 to MN and a range from 1 to C in the AC packet. In line 2, reader chooses a channel in interval [1, C] by using sift geometric distribution function. Using the same distribution function, in line 3, reader chooses a number (time slot) in interval [1,MN]. In line 9 and 10, if the channel was busy, reader chooses a different channel number and waits to start a new round. The rest of the procedure is like NFRA protocol.

```
-------------------------------Algorithm1 SDMRA for each reader----------------------------
1: If a reader receives AC with the value of MN and the value of C from theserver
2:   - CH = Generates a channel (frequency) by sift function among [1, C]
3:   - K = Generates a number by sift function among [1, MN]
4:   - Wait for OCs from the server
5:   - Decodes every received OC to extract the number
6:   If ( K == the number in OC)
7:    - Broadcasts a beacon to neighbor readers in CH
8:     If a collision of the beacons between readers is detected (or CH is busy)
9:       - CH = generates a channel by sift function among [1, C]
10:     - Waits until the next AC  from the server
11:   Else
12:      - Broadcasts OF to neighbor reader in CH
13:      - Conducts identification of tags during CRT time
14:    End
15:   Else
16:     If OF is received
17:       -Waits until the next AC from the server
18:    Else
19:       - Waits for the next OC from the server
20:    End
21:  End
22:End
```

3.2 Sift Distribution Function

In NFRA protocol, readers select a time slot by utilizing a uniform distribution function. According to this probability function, the probability of collision in every time slot for competing readers is the same. Competing readers are known as the ones who are located in the interference range and are working in the same channel. In

CSMA/P^* protocol, the nodes of the network use a non-uniform probability distribution P^* for random selection of rival slots. The probability distribution function P^* is defined in formula 1. This distribution minimizes the collisions between competing nodes and maximizes the probability that a node lonely takes a slot [7].

$$P_K^* = \frac{1-f_{K-k}(R)}{R-f_{K-k}(R)}(1-P_1^* - P_2^* - ... - P_{K-1}^*) \quad (1)$$

For $1 \le k \le K$. $f_{K-k-1}(R)$ is a recursive function given by formula 2:

$$f_{K-k}(R) = (\frac{R-1}{R-f_{K-k-1}(R)})R-1 \quad (2)$$

For $K \ge 2$, $R \ge 2$ and $f_1(R) = 0$.

To employ CSMA/P^* protocol in a dense RFID system, every reader needs to estimate the number of its own neighbors. However, if the reader does not know the number of neighbors, it must use sift geometric probability distribution function (P_K) to choose a random value for this variable [7]. P_K is defined in formula 3:

$$P_K = \frac{(1-\alpha)\alpha^K}{1-\alpha^K}\alpha^{-k} \quad (3)$$

Formula 3 is established for $1 \le k \le K$, $0 < \alpha < 1$ and $\alpha = M^{-1/k-1}$. M is the maximum number of rival reader [7]. When M=1 then α=1 and the uniform probability distribution are in formula 4:

$$\lim_{\alpha \to 1} P_k = \frac{1}{K} \quad (4)$$

In sift probability distribution function, the probability of selecting higher range will increase. With this mechanism, the probability of selecting lower range by only a single reader will increase [7]. This reader quickly will won the competition. In sift probability distribution function; the probability that in presence of R neighbors, a node wins the competition is in formula 5:

$$P_c(R) = R\sum_{k-1}^{K-1} P_k (1-\sum_{z=1}^{k} P_z)^{R-1} \quad (5)$$

Proposed approach minimizes reader collision by using sift probability distribution function.

4. Simulation and Evaluation

In this section, results of simulations of our proposed protocol have been shown. R2RIS computer simulation is used to demonstrate the effectiveness of the network. [17] R2RIS new simulator is designed to evaluate the effect of reader to reader collision in RFID system.

Some simulation parameters are given in table 1. Other used, in accordance with the parameters are defined in [3].

Table 1. Simulation Parameters

Parameters	value
AC packet length	2.83 ms
OC packet length	1 ms
Beacon packet length	0.3 ms
OF packet length	0.3 ms
Geometric Probability	16
Reader-to-Tag communication length	0.46 s

In this study, we have defined three scenarios. In the first scenario, we have compared proposed SDMRA with different number of channel in the 50×50 meters environment with 25 readers and value for MN is 32 and Interference range is 50 meters and read range is 10 meters. As you can see in figure 5, throughput is increased as far as the number of channel is equal to the number of readers, and throughput remained constant thereafter.

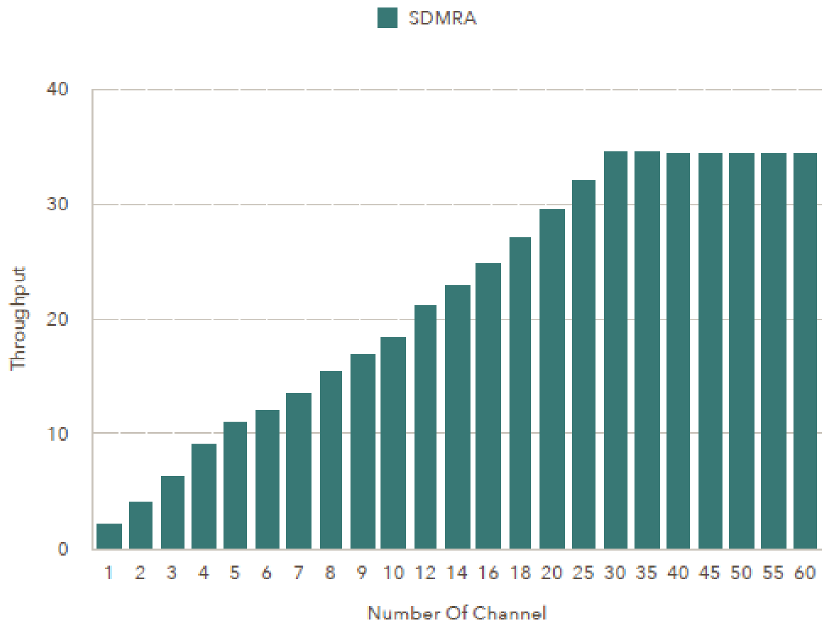

Figure5. Throughput of the evaluate condition in scenario 1.

In the second scenario, we have compared proposed SDMRA with NFRA protocol in 100×100 meters environment with 10,20,30…100 readers and value for MN is 32 and Interference range is 100 meters and read range is 10 meters. As you can see in figure 6, the proposed protocol throughput is more than NFRA protocol, because using multichannel and sift function makes rival reader communicate with tags simultaneously. As you can see in figure 7, the proposed protocol average waiting time is lower than NFRA protocol.

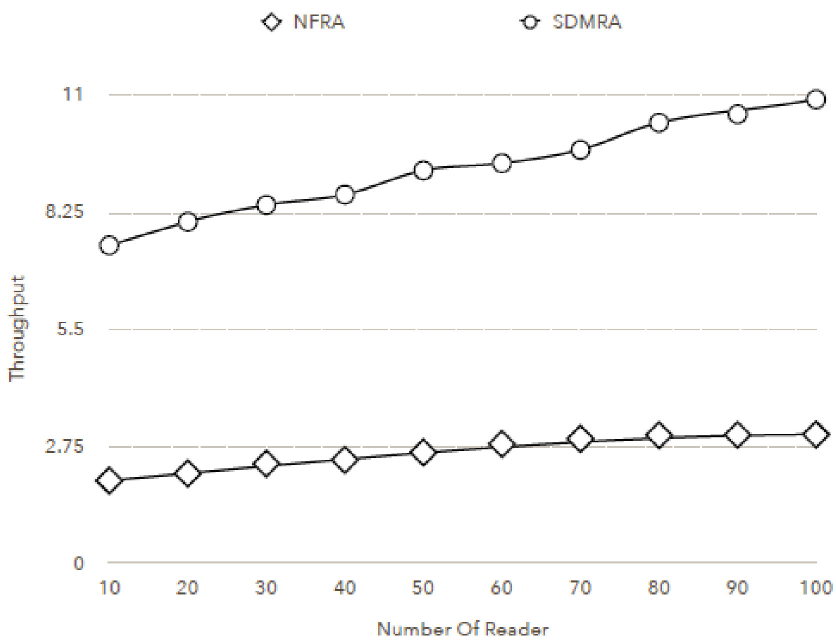

Figure6. Throughput of the evaluate protocols in scenario 2.

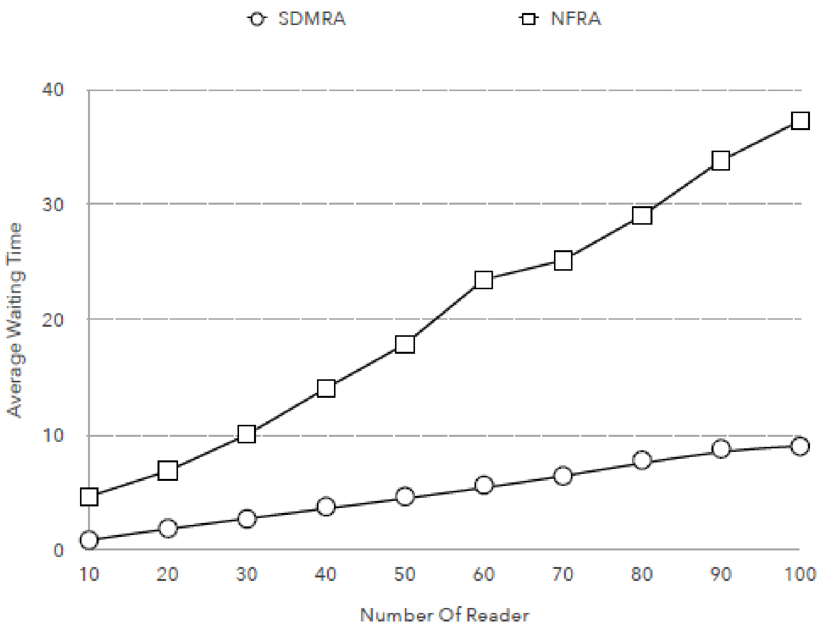

Figure7. Average Waiting Time of the evaluate protocols in scenario2.

In the third scenario, we have compared proposed SDMRA with multi-channel protocols such as GDRA and PDCS, in the 100×100 meters environment with 4 channels and 10, 20, 30…100 readers and value for MN is 32 and Interference range is 100 meters and read range is 10 meters. As you can see in figure 8, the proposed protocol has higher throughput than other protocols, because using sift function makes rival reader communicate with tags simultaneously. As you can see in figure 9, the proposed protocol average waiting time is lower than GDRA protocol and PDCS protocol.

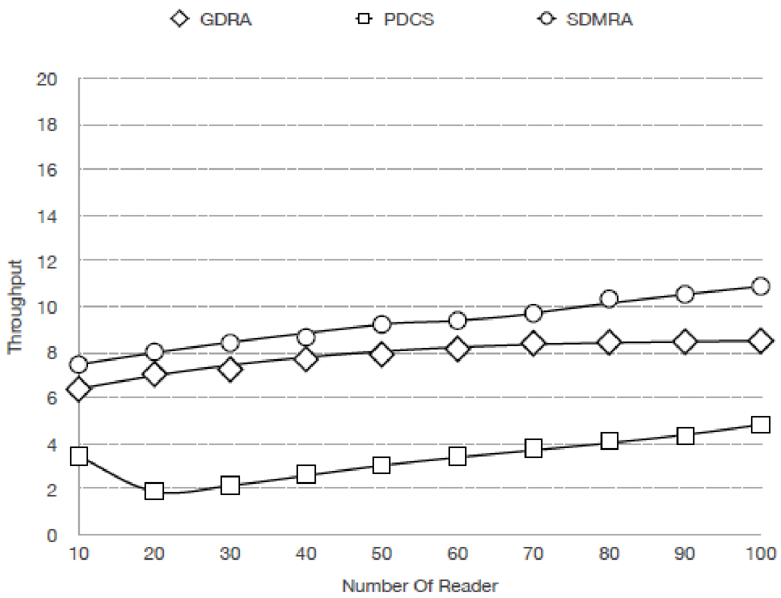

Figure8. Throughput of the evaluate protocols in scenario 3.

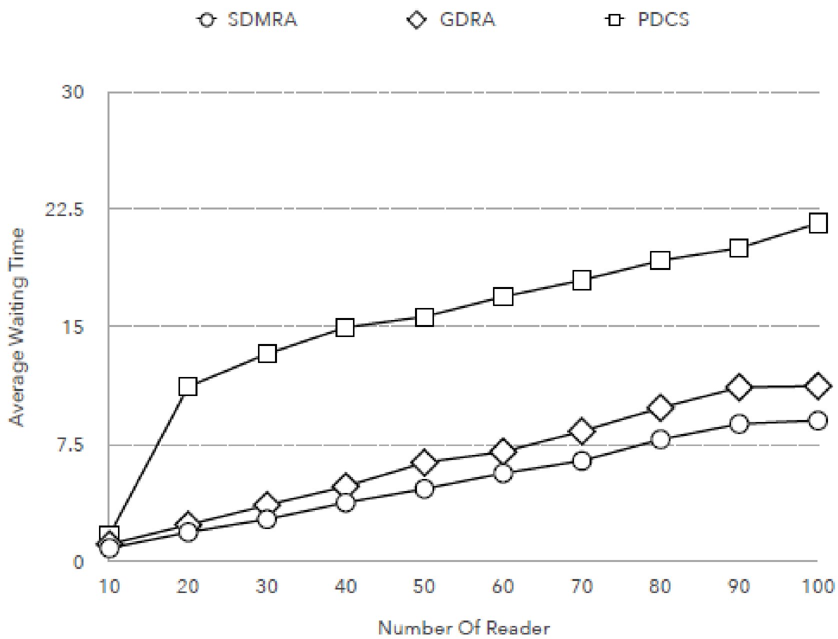

Figure9. Average Waiting Time of the evaluate protocols in scenario 3.

5. Conclusion and Future Work

One of the most important goals of an RFID system is increasing throughput while avoiding reader collision. In this paper, we proposed SDMRA protocol which is based on NFRA protocol. we suggested to use multi-channel mechanism and sift geometric probability distribution function in NFRA protocol so that a better choice can be used for choosing the number of channel and number of range, instead of uniform distribution function. Roughly speaking, we improve the NFRA protocol while avoiding reader collision. As shown in the simulation results, throughput of the proposed SDMRA protocol is better than NFRA protocol and other multi-channel protocols. As a result, the proposed protocol provides same chains m-based approach which is consistent with TDMA and is a combined version of FDMA. It also utilizes sift probability distribution function. Employing our proposed SDMRA protocol, throughput can be improved in the RFID system.

Future work: In this paper, we do not propose any solution for reader to tag collision. By establishing different accesses to channel, this problem can partly be resolved and hence better throughput can be obtained. In other hands, this protocol does not provide any proposal for fairness among readers, while with considering this issue, the throughput of the system can be further improved.

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