A Multi-channel Anti-collision Algorithm in Multi-reader RFID Networks

Zhiyong Ding, Jianying Li, Mao Yang(✉), Zhongjiang Yan, Bo Li, and Wenhui Chen

School of Electronics and Information, Northwestern Polytechnical University, Xi'an, China
dingzhiyong@mail.nwpu.edu.cn, {yangmao,zhjyan,libo.npu}@nwpu.edu.cn

Abstract. In order to solve the problem of identification collision in multi-reader Radio Frequency Identification (RFID) systems, this paper proposes a multi-channel anti-collision algorithm based on grouping strategy named McAnCo. In this algorithm, the interference types among readers are classified and modeled, and then the vertex coloring algorithm in graph theory is used to group the readers with mutual interference. The readers in the same group can work at the same frequency and time slot, while the readers in different groups in the same set can work at the same time slot in different frequency, so that the maximum number of readers can work simultaneously without interference. Simulation results show that, compared with distributed color selection (DCS) algorithm, hierarchical Q-learning (HiQ) algorithm and neighborhood friendly anti-collision scheme (NFRA) algorithm, the proposed algorithm effectively prevent reader collision and raise the identification efficiency of the system.

Keywords: Anti-collision · RFID · Readers · Tags

1 Introduction

In recent years, the Internet of Things (IoT) [1] is developing rapidly and becoming increasingly popular. It has been found everywhere in our daily life, such as the Electronic the collection (ETC) system free of parking fees, the card swiping system on campus, the smart home system, and etc. According to official statistics, global Internet penetration increased from 12% in 2013 to 65% in 2019 [1]. The complete radio frequency identification (RFID) system includes reader and electronic tag application system [2,3]. As the core of IoT technology, RFID stores all kinds of data of physical infrastructure into tags, so as to integrate physical facilities and data center into an integrated platform and make the IoT run better [4].

In RFID technology, the core part is tag identification technology. The rate of tag identification determines the performance of RFID system. The configuration

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scheme of single reader is difficult to overcome new challenges. In many new scenario, it is required to complete the identification of a large number of tags in a short time. Therefore, there is a configuration scheme of placing multiple readers in RFID system. But in the multi-reader RFID system, there has a new form of collision called Multi-reader collision [5]. In the process of tag identification, multi-reader system will cause a lot of packet loss and of course identification failure due to this collision, which will seriously affect the performance of the system [11].

There are three types of collisions in multi-reader system: 1) the collision between tags [6], 2) the collision between readers [7] and 3) the collision between tags and readers [8]. The collision between tags is caused by multiple tags replying to the reader at the same time after the reader sends information to all tags. At present, there are many mature anti-collision protocols between tags, among which the most important one is the anti-collision protocol based on Aloha [9] and that based on Binary tree [10]. They mainly solve the collision problem between tags under the coverage of a single reader in the read range.

In the multi-reader RFID system, with the increase of the number of readers and the number of tags, the collision between readers becomes increasingly serious, so there are some interesting solutions. Distributed color selection (DCS) [12,13], a multi-reader anti-collision algorithm based on time division multiplexing (TDMA), is based on the principle that in case of reader collision, the colliding reader selects time slots randomly to avoid collision. This algorithm needs a long time to complete the global optimization. In dense scenes, with the increase of the number of readers, the optimization effect of the algorithm becomes weaker. In order to improve the DCS algorithm, a hierarchical Q-learning (HiQ) algorithm [14] has been proposed. This algorithm introduces the scheduler Q-server to achieve the global optimal effect. The Q-learning algorithm is invoked in Q-server to learn the relevant collision information collected by the reader, and then the optimal allocation scheme is made according to the learning result, so as to achieve the maximum number of readers working at the same time and the reader collision rate to a minimum. When the number of readers increases, a huge amount of collision information needs to be processed, which may affect the efficiency of the system.

In order to solve the problem of low efficiency of multi-reader collision processing in dense environment, this paper proposes a multi-channel anti-collision algorithm for multi-reader RFID system named as McAnCo. McAnCo introduces the anti-collision grouping strategy to put the readers that may collide into different groups, so that the readers can run at different frequencies or time slots. After processed by the algorithm, the readers in this RFID system can avoid collision and make greater use of channel resources, so as to improve the tag identification efficiency of the multi reader system.

Section 2 we mainly introduce the existing work about multi-reader anti-collision and the motivation of this algorithm. Section 3 mainly introduces the basic ideas, implementation process and procedure of the algorithm. Section 4 evaluates the performance. Finally Sect. 5 is the summary and prospect.

2 Related Work and Motivation

2.1 Related Work

DCS. A DCS algorithm based on TDMA is proposed in [13], in which all readers have the same frame size. The reader randomly selects time slots in the frame to compete for the right to identify tags. In DCS algorithm, the frame size is called "Max color", and multiple time slots in the frame are called "colors". If the reader does not collide when the frame is running, the color selected by the reader this time will be used as the selection when the next frame is running, and will not be re selected. When the reader collides, the collided reader will re randomly select color in Max color. After selection, it will send the new selection result to the surrounding readers. The surrounding readers will compare with their own color after receiving it. If the color is the same, they will immediately randomly select the color.

HiQ. The HiQ algorithm proposed in [14] mainly includes R-servers, Q-servers, readers and tags to be identified. Q-server allocates time slots for R-servers. R-servers grant frequency and time slots for readers. Authorized readers can start to identify tags. When the reader works, record the collision times and types related to the reader, and wait for the completion of the reader to transmit these information to Q-server through R-servers. Q-server searches for more efficient frequency and time slot allocation by learning collision information from readers. This process is called Q-learning algorithm. The purpose of HiQ algorithm is to minimize the allocated consumption and make the maximum number of readers work without interference at the same time. When the success rate of the reader is large, the overall consumption of the system will be less. On the contrary, when the success rate of the reader is small, the overall consumption of the system will be more. HiQ algorithm is to use Q-learning to find the optimal allocation method to achieve the desired goal.

NFRA. In reference [15], a neighborhood friendly anti-collision scheme (NFRA) is proposed. The algorithm avoid reader to reader interference (RRI) and reader to tag interference (RTI) problems through centralized algorithms. Server broadcasts an array command (AC) that contains a random number range. Readers generate their 0wn random numbers by receiving AC. The server then issues a sort command (OC), and each reader compares the value in OC with its random number. If the numbers are equal, the reader issues a beacon to determine if a collision has occurred. After the beacon frame, they will send the frame to the adjacent readers when readers do not detect any conflicts. By the way the NFRA can prevent adjacent readers receiving the next OC from the server. The next OC is not identified due to of or the adjacent readers that detect beacon conflict are in the next AC. NFRA assumes that tag identification is not performed before using only one data channel, and it does not mention how the reader detects conflicts between beacons.

2.2 Motivation

With the rapid development of RFID technology and the continuous expansion of the application field, the number of tags in the RFID system is also growing exponentially. In the original RFID system, a single reader is used, and the algorithms are optimized. But the optimal tag identification efficiency is still limited, far from meeting the identification requirements of massive tags. Taking the algorithm based on Aloha anti-collision protocol as an example, the optimal value of tag identification efficiency in theory is 0.368/slot. For the scenario with thousands of tags, the maximum number of time slots in the frame is limited, which will cause serious tag collision. In addition, it is assumed that there is unlimited for the number of time slots in the frame. Due to the low efficiency of identification, the process of tag identification takes a long time and cannot meet the requirements of identification efficiency.

Therefore, using multiple readers in RFID system can solve this problem. When multiple readers are introduced, serious reader collisions will be introduced if reader's behaviors are not controlled. For the collision between readers, it is necessary focus distinguish the two concepts of read range and interference range. The read range is the tag can communicate and decode with the reader in the range, while the interference range is that the reader can interfere with the communicate of other tags or readers within this range. As shown in the Fig. 1, there are two readers R_1 and R_2, and two tags T_1 and T_2. The read range of the reader is represented by solid line, and the interference range is represented by dotted line. When multiple readers work at the same frequency, as shown in Fig. 1, R_1 sends commands first, T_1 receives commands from R_1 and then responds to R_1 after processing. At the same time, R_2 also sends a command. Since R_1 is in the interference range of R_2, the command from R_2 interferes with T_1's command, and the first type of collision occurs. In the same scenario where multiple readers work at the same frequency, as shown in Fig. 2, T_1 is within the read range of R_1 and the interference range of R_2. When reader R_1 sends a command, R_2 is also sending a command. At tag T_1, the command sent by R_1 cannot be received normally due to the interference of R_2 command, resulting in the second type of collision. In the scenario of multiple readers working at different frequencies, as shown in Fig. 3, T_1 is within the read range of R_1 and R_2. When reader R_1 sends the command, reader R_2 is also sending the command. Two effective read commands collide at tag T_1, which causes T_1 can not receive the command normally. This is the third type of collision.

In conclusion, in the RFID system with multiple readers, if the reader's behavior is not controlled, it will lead to serious collision, which will greatly reduce the identification efficiency. Then we will introduce the algorithm to avoid collisions.

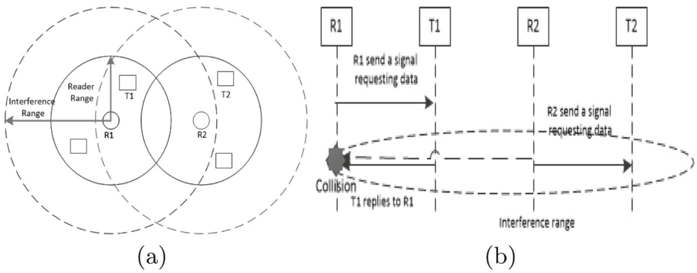

Fig. 1. (a) First type of collision and (b) procedure chart

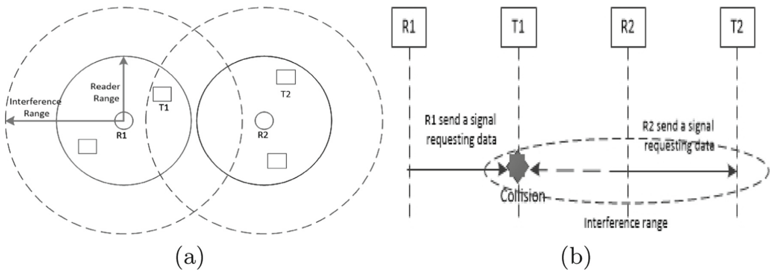

Fig. 2. (a) Second type of collision and (b) procedure chart

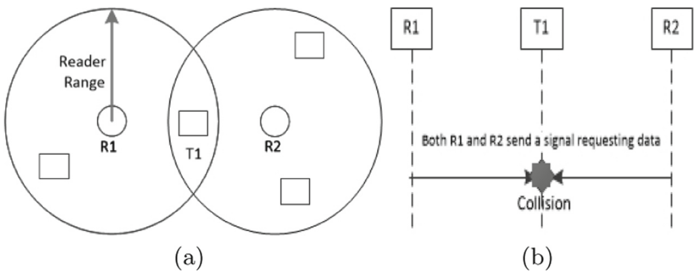

Fig. 3. (a) Third type of collision and (b) procedure chart

3 Grouping Multi-channel Algorithm Description

3.1 Basic Ideas

In the proposed McAnCo, polling server is introduced. As shown in Fig. 4, the effective range of signals broadcast by polling server can cover all readers. The readers only need to receive the commands sent by the polling server. The server and readers don't need to communicate with each other. In the practical application scenario, considering the cost and complexity, the arrangement of multiple readers is most likely to be arranged by fairly regular rules. As shown in Fig. 5, the rule in this paper is the readers are arranged in a square topology. The distance between two readers arranged in a straight line is $\sqrt{2}$ times the read range. And the distance between two readers on a diagonal line is twice the read range.

According to the read range and interference range, the collision of readers can be divided three types. The three types collisions is detailed introduction in Sect. 2.2. Then define Mutil-reader Interference Graph according to graph and network definition in graph theory. A graph G is an ordered pair (V(G), E(G)) consisting of two sets and an incidence function. The V(G) is the set of vertices, the E(G) is the set of edges. According to the definition of graph, each reader in multi-reader RFID system is represented by a vertex, all readers form a vertex set V(G), the interference between readers is represented by an edge, all the interference forms an edge set E(G). As shown in Fig. 5, build the reader topology graph as a Mutil-reader Interference Graph with V(G) = $[V_1,V_2,V_3]$, E(G) = $[e_1,e_2,e_3]$.

After obtaining interference graphs, we choose the classical vertex colouring algorithm in graph theory to process them. In the vertex colouring algorithm, a k vertex coloring of G refers to the assignment of k colors (1,2,3,...,k) to each vertex of G, so that any two adjacent vertices are assigned with different colors. If a graph G has a normal k vertex coloring, it is said that G is k vertex colorable. The chromatic number of G refers to the minimum value of the number k with normal vertex coloring of G, which is expressed by X(G) [16]. Given a k-coloring of graph G = (V,E), where V_i is the vertex set (i = 1,2,... k) colored with the i color in G, then each V_i is an independent set of G. Therefore a k-coloring of G corresponds to a partition of V(G) is $[V_1,V_2,...V_k]$, where each V_i is an independent set. The vertex chromatic number X(G) of graph G is the minimum natural number k. The algorithm steps of finding the chromatic number X(G) of graph G are as follows: 1) make H = G, select a pair of different vertices u, v that are not adjacent to H, and draw H+uv and H·uv. 2) Let H be the two graphs obtained in 1). If H is a complete graph, for example, if there are k vertices, then X(H) = k. If H is not a complete graph, make G = H and turn to 1) to continue.

After processed by the vertex colouring algorithm, we can get the reader sets and reader groups. A set contains multiple groups, and different groups in the same set can work at different frequencies to avoid collision. There is no collisions between each group of readers. Readers in the same group can work at the same frequency and time slot. Through this grouping mechanism, the maximum number of readers can work simultaneously without interference. Then the polling server broadcasts commands to make readers start to identify tags in their frequency and time slot. After the processing of the algorithm, as many readers as can work simultaneously without interference and meet the needs of the increase of the number of tags and the development of the working speed.

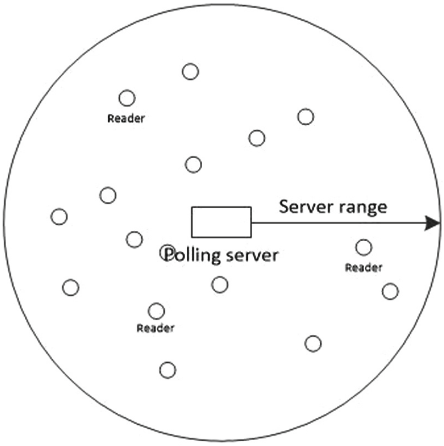

Fig. 4. The RFID system topology with polling server.

3.2 The Grouping Algorithm

For the three types of reader collisions, different measures can be taken to avoid these collisions. Set the read range are r_1, r_2, the interference range are i_1, i_2, and the distance between two readers to d. The first type and the second type of collisions are collectively called read range and interference range collision (RIC), the last type of collision is called read range and read range collision (RRC). RIC will occurs when:

$$d<r_1 + i_2 \tag{1}$$

So that readers with RIC can work at different frequencies to avoid the collision. RIC will occurs when:

$$d<r_1 + r_2 = 2r_1 \tag{2}$$

The readers with RRC can avoid collision only when they work in different time slots.

According to the analysis of reader collision, the algorithm uses the content of graph theory to model the interference between readers. When the distance between two readers is less than 2 times the read range, that is, when the RRC occurs, there must be RIC. Therefore, according to the special rule of interference

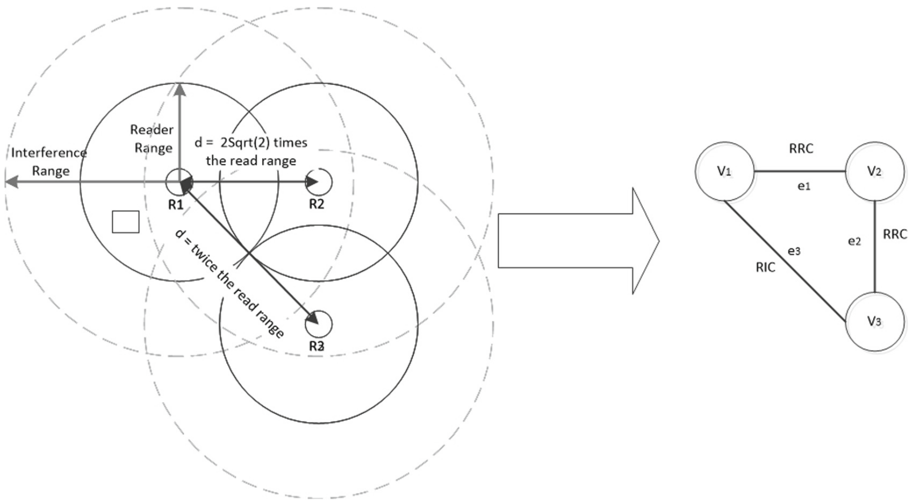

Fig. 5. The process generating interference graph.

graph, turn readers into hollow points and convert the collision between two readers to the solid line between two hollow points.

After getting the interference graph, the interference graph conforms to the concept of simple graph in graph theory, that is, there is only one solid line between two hollow points and the meaning of two points is not completely equal. The purpose of the interference graph is to divide the readers with interference into different groups. And the classical vertex coloring algorithm in graph theory can meet requirements. In the coloring algorithm, different colors represent different groups, and two points connected by solid lines are colored with different colors. The most important thing is to cover all points in the interference graph with the least colors. After processed by the algorithm, we can obtain the optimal grouping strategy and the least set number. This ensures that all readers can complete identification with a minimum of time slots.

In this algorithm, the concept of set is proposed. After RRC is completed, the number of colors needed for dyeing represents the number of sets. There is no RRC between readers in each set, and they can operate in the same time slot. There are still RIC between the readers in one set, that is, the distance between two readers is less than the sum of the read range and the interference range. Then the interference graph is constructed again for each reader in the set and processed by vertex coloring algorithm. The number of colors needed for dyeing represents the number of groups in each set. There is no reader interference between each group of readers. They can work at the same frequency and time slot, and different groups in the same set can work at different frequencies to avoid collision. This ensures that readers in a set can operation simultaneously with a minimum of channels.

3.3 Procedure of the Algorithm

In this algorithm, as shown in Fig. 6 and the abbreviate Table 1, the polling server broadcasts one or more message commands (MC) to the readers. MC contains the address information of readers, the corresponding set and group information. After receiving MC, a reader will compare its own address information with received information to check if they are the identical. If the result is identical, the reader will put the corresponding set and group information into itself. Otherwise, the reader will continue to wait. When all MC commands are sent, the polling server broadcasts multiple Start-Group-Command (SGC) to readers, SGC contains the group label with operation grant and the corresponding channel information has been assigned. The group labels contained in multiple SGC belong to a set. After receiving SGC, the reader compares the group label with its own group information. If they are equal, the channel information is received and waiting for the identification of the set information. If the two are not equal, the arrival of the next SGC is waiting. After multiple SGC are sent, the server will send Start-Sets-Command (SSC), SGC contains the set label that has the operation grant. After receiving the SSC, the reader that successfully matched the group information will compare the set information. If the comparison results are equal, it will start to identify tags according to the allocated channel. If the comparison results are not equal, it will wait for the SGC command. Readers that fail to match group information will not do anything after receiving SSC. After waiting for the communications between a reader and tags (CRTs), polling server will send multiple SGC containing group label and corresponding channel information. The rest of the process is similar to the previous process until all tags are identified.

Table 1. Abbreviate table.

Full name	Abbreviated name
Message command	MC
Start-Group-Command	SGC
Start-Sets-Command	SSC
Communications between a reader and tags	CRTs

3.4 Illustrative Example

Then, taking 36 readers in dense scenarios as an example to introduce the operation process of the algorithm. As shown in Fig. 7, the 36 readers are arranged in the special rule in the form of 6*6. In the rule, the distance between two readers arranged in a straight line is $\sqrt{2}$ times the read range. And the distance between two readers on a diagonal line is twice the read range The read range is 2 m, and the interference range is 6 m. The distance between two readers arranged

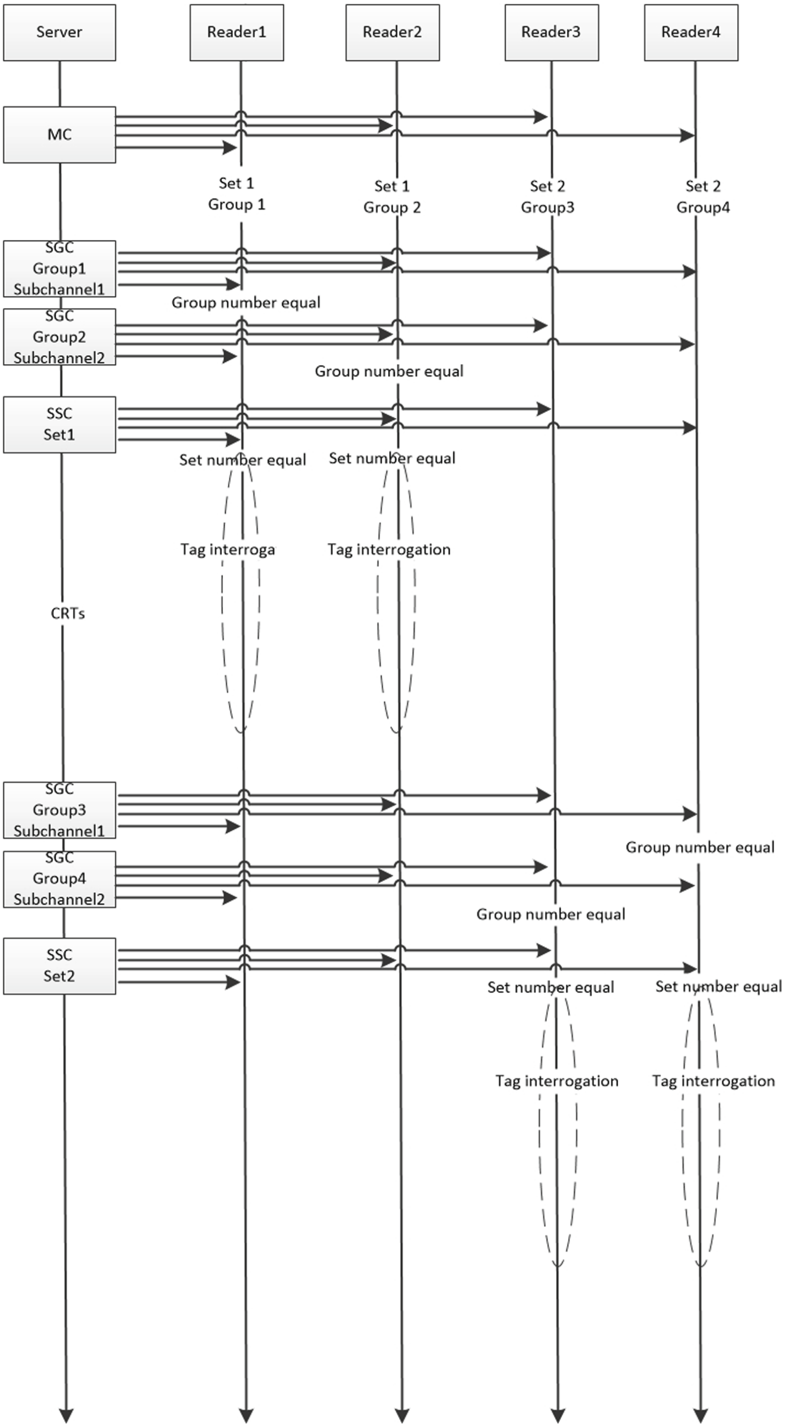

Fig. 6. Procedure chart of the proposed McAnCo.

in a straight line is $2\sqrt{2}$ m. And the distance between two readers on a diagonal line is 4 m. In this arrangement, the read range can cover the read area without omission, and no more complex overlapping occurs.

After the location information of 36 readers is imported into the polling server, the server grouping the readers for the first time according to RRC. The result is that the readers are divided into two sets, each set contains 18 readers, and the two sets of readers are cross distributed. Then, the readers of each set are divided into four groups according to the second grouping operation of RIC. The final grouping result is divided into 2 sets, each set contains 4 groups. The server adds the processed group information and set information to MC and broadcasts them to all readers. Then the server sends 4 SGC in turn, which contain four group label of the first set and corresponding channel information. After the server send all SGC, the SSC with set label of the first set will continue to be sent. After the reader receives the SSC, all tags of the first set will start to identification tags without any collisions in their channels. Wait for the CRTs time and start sending the command corresponding to the second set. After the processing of the algorithm, as many readers as can work simultaneously without interference and occupy the least channels, so as to achieve a higher identification efficiency, and meet the needs of the increase of the number of tags and the development of the identification efficiency.

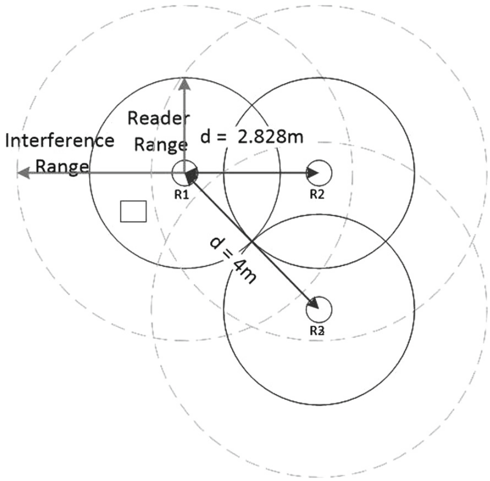

Fig. 7. Architecture of the illustrated example.

4 Performance Evaluation

4.1 Simulation Scenarios and Simulation Configurations

Next, the proposed McAnCo is compared with the typical DCS algorithm, HiQ algorithm and NFRA algorithm in the RFID system multi-reader anti-collision algorithm. The NS3 simulation platform is used to simulate the system efficiency, the number of control command collisions and the control command efficiency. The simulation parameters are shown in Table 2. The collision between tags is not considered in the anti-collision algorithm of multi reader in RFID system, so the time for readers to identify tags in the simulation process is fixed time. Using the type A tag identification algorithm, the time to identify 100 tags is 0.46 s. In the proposed McAnCo, the channel resource used is twice the comparison algorithms. Therefore, the McAnCo algorithm spend twice the time of the comparison algorithm when the readers and tags send commands. And the simulation result is the time for the reader to identify 100 tags is 0.58 s in the McAnCo. When the number of readers is less than 100, the time required for MC is 10 ms, and the time required for each additional 100 readers MC is 10 ms, a single SGC and SSC takes 1 ms.

Set up two kinds of simulation scenario, dense scenario and sparse scenario. In dense scenario, there are many readers, the number of which is from 100 to 1000, and the distance between two readers arranged in a straight line is $2\sqrt{2}$ m, and the distance between two readers in a diagonal line is 4 m. In the sparse scenario, there are few readers, the number of which is from 10 to 100. The distance between two readers arranged in a straight line is $4\sqrt{2}$ m, and the distance between two readers in a diagonal line is 8 m. In order to reduce the influence of accidental factors on the performance of the algorithm, the experimental results take the average data of 100 times of simulation.

Table 2. Simulation parameters.

Parameter	Value
Number of tags for each reader	100
Comparing algorithm	DCS, HiQ, NFRA
Time to identify 100 tags (Proposed McAnCo)	0.58 s
Time to identify 100 tags (Comparing algorithm)	0.46 s
Read range of a reader	2 m
Interference range of a reader	6 m
Number of channel	4
Dense reader scenario Number of readers	 100, 200, 300, 400, ..., 1000
Sparse reader scenario Number of readers	 10, 20, 30, 40, ..., 100

4.2 Simulation Results

The simulation results in Fig. 8 compare the system efficiency of different algorithms when the number of readers increases from 100 to 1000 in dense scenario. From the simulation results, we can see that when the number of readers is less than 200, the system efficiency of the proposed McAnCo is slightly lower than NFRA and HiQ algorithm. When the number of readers is greater than 200, the system efficiency of this algorithm is the highest, NFRA algorithm and HiQ algorithm are lower than the proposed McAnCo, and DCS algorithm is relatively low in this scenario. When the number of readers increases, the probability of reader collision of DCS algorithm increases, resulting in the increase of free time slots and the slight decrease of work efficiency. With the increase of readers, NFRA algorithm and HiQ algorithm can still deal with the relationship between adjacent readers and avoid collision. But there are some limitations in resource allocation and utilization, which leads to the final work efficiency tends to a fixed value. The proposed McAnCo maximizes the readers that can simultaneously work by using the operation of polling server. With the increase of readers, they can work without interference in each group increases correspondingly. Therefore, the efficiency of the proposed McAnCo is almost linear growth. In the case of limited channel resources, the McAnCo algorithm's efficiency of reader identify tags is lower than comparison algorithms. Therefore, when the readers is fewer, the efficiency gain brought by grouping cannot offset the efficiency drop caused by frequency division, result in the efficiency will be lower than NFRA algorithm and HiQ algorithm.

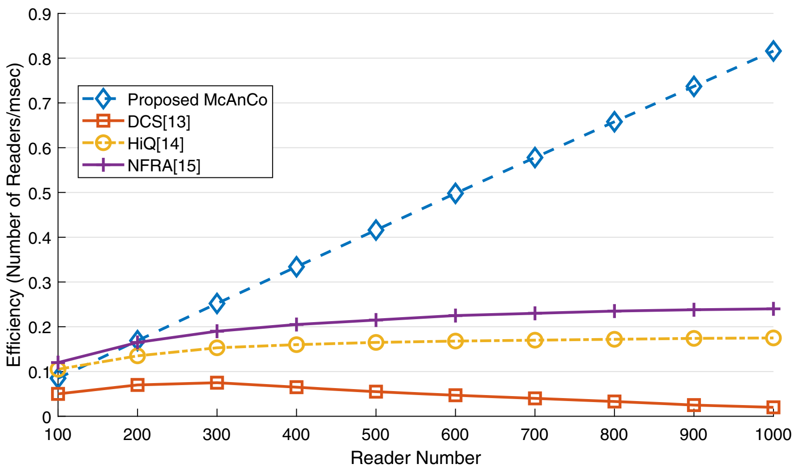

Fig. 8. Efficiency with the vary number of readers in dense scenario.

The simulation results in Fig. 9 compare the system efficiency of different algorithms when the number of readers increases from 10 to 100 in the sparse scenario. From the simulation results, we can see that when the number of readers is less than 30, the system efficiency of this algorithm is basically the same as NFRA algorithm and HiQ algorithm. When the number of readers is greater than 30, the system efficiency of this algorithm is the highest. NFRA algorithm and HiQ algorithm are basically the same, but slightly lower than this algorithm. The efficiency of DCS algorithm is the lowest. Because in the sparse scenario, the reader placement can reduce the occurrence of a collision. This algorithm can avoid reader collision by putting the reader in groups. NFRA algorithm and HiQ algorithm can also adapt to the changes of the scene very well, so the efficiency of these three algorithms is not much different. However, DCS algorithm can not avoid reader collision completely, which will still cause serious impact on efficiency.

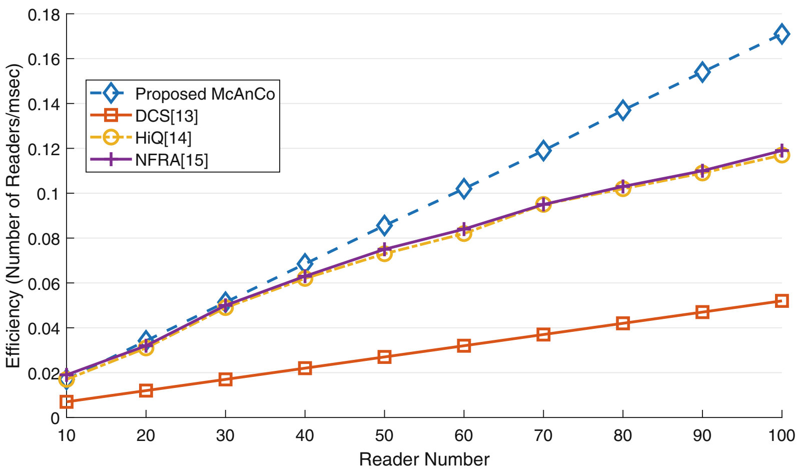

Fig. 9. Efficiency with the vary number of readers in sparse scenario.

The simulation results in Fig. 10 compare the failed number of control command of different algorithms when the number of readers is 25, 75, 150, 300, 500, 750, 1000 in dense scenario. When the control command cannot avoid reader collision, the control command is called failed. The simulation results show that the number of control command failures of DCS algorithm is the most. The number of failed command of HiQ algorithm is less, NFRA algorithm and the proposed McAnCo can completely avoid reader collisions, so the number of failed control command is 0. In DCS algorithm, when there is a collision, the color of adjacent readers will be updated to avoid collision, so when the readers number is large, the collision will inevitably be more. In the HiQ algorithm, the Q-learning algorithm can better allocate resources by learning the type and quantity of collisions. Therefore, there will be some collisions, but the collision probability will be much less than that of the DCS algorithm.

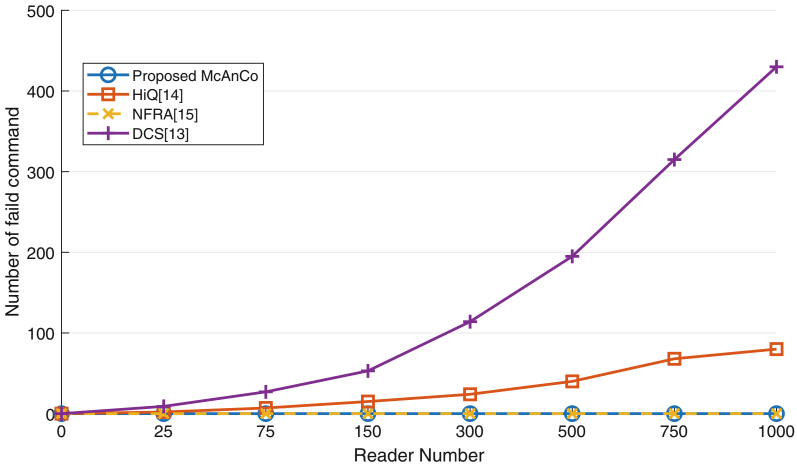

Fig. 10. Failed control command with the vary number of readers in sparse scenario.

The simulation results in Fig. 11 compare the system control efficiency of different algorithms when the number of readers is 25, 75, 150, 300, 500, 750, 1000 in the dense scenario. The success rate of system control is defined as:

$$System\ control\ efficiency\,(\%) = \frac{Command_{success}}{Command_{all}} * 100\,(\%) \quad (3)$$

In the comparison algorithm, the control success rate of DCS algorithm is relatively low, and the success rate of HiQ algorithm using Q-learning real-time adjustment is greatly improved. NFRA algorithm and the proposed McAnCo can successfully avoid all collisions through control commands, so the control success rate is 100%.

The simulation results in Fig. 12 and Fig. 13 compare the system efficiency of different algorithms when channel resources are unlimited in dense and sparse scenario. In the proposed McAnCo and other algorithms, the time a reader to identify 100 tags is 0.46 s when the channel resources is enough to meet the demand. Other simulation parameters are consistent with the preceding part of the text. From the simulation results, we can see that the system efficiency of the proposed McAnCo algorithm is the highest, NFRA algorithm and HiQ algorithm are lower than the proposed McAnCo, and DCS algorithm is relatively low in dense and sparse scenario. When readers are fewer, the system efficiency of this algorithm is still superior to other algorithms due to the enough channel resources. Thus, it can be concluded, the efficiency gain brought by grouping can fairly improve the system efficiency.

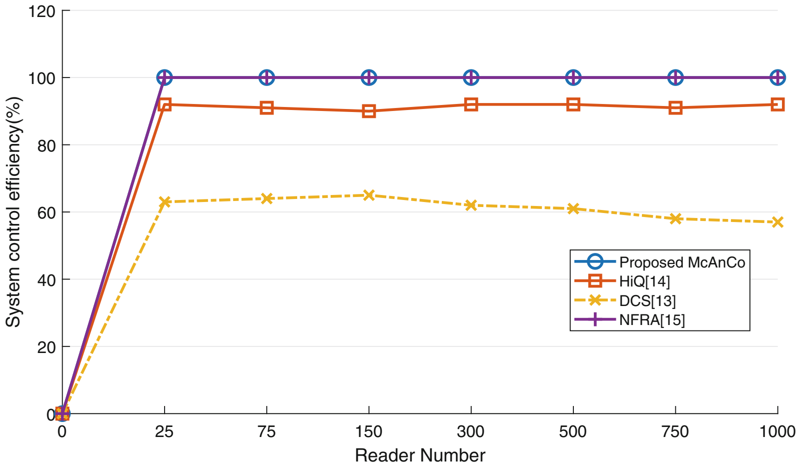

Fig. 11. System control efficiency with the vary number of readers.

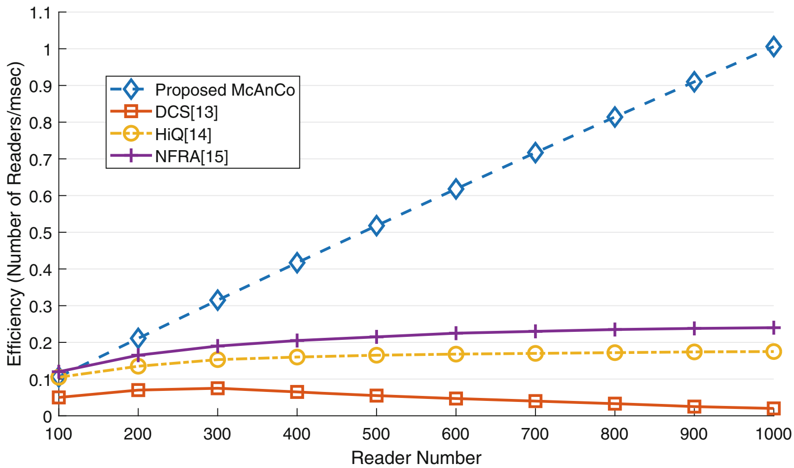

Fig. 12. Efficiency with the vary number of readers in dense scenario when the channel resources are unlimited.

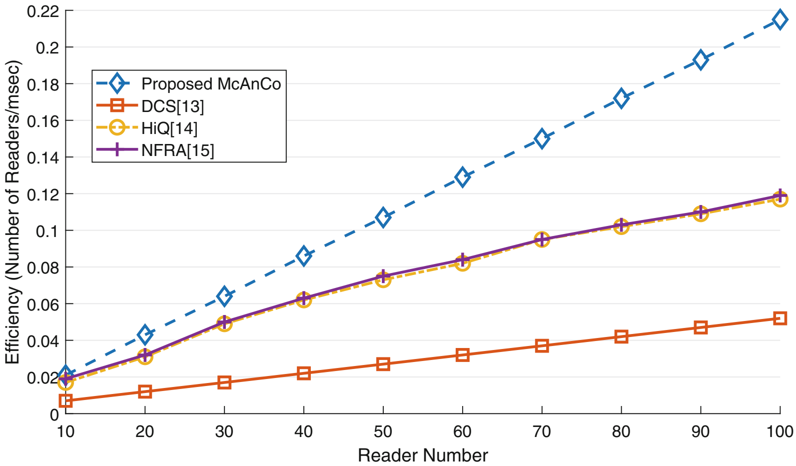

Fig. 13. Efficiency with the vary number of readers in sparse scenario when the channel resources are unlimited.

The above simulation results can prove that the proposed McAnCo algorithm can effectively avoid all kinds of reader collisions in dense or sparse scenes, and achieve the goal of making as many readers work simultaneously without interference. And the efficiency of the two scenarios is better than the comparison algorithm. But the proposed McAnCo needs more channel resources, which makes the time for the reader to identify tags increase. When readers are fewer, the efficiency gain brought by grouping cannot offset the efficiency drop caused by channel division. Result in the identification efficiency of the McAnCo algorithm is affected. In the case of unlimited channel resources, the identification efficiency of McAnCo algorithm is better than comparison algorithms when the number of readers is fewer.

5 Conclusions

This paper presents an efficient anti-collision algorithm for multi-channel RFID multi-reader named McAnCo. The algorithm uses polling server to process the interference graph with vertex coloring algorithm in graph theory, to get reader sets that can avoid interference, and then uses algorithm to process readers in each set to get multiple reader groups. There is no interference between the readers in one group, which can achieve the same frequency and time slot operation without interference. There are RIC among different groups in a set, and readers in different groups can work without interference by running in different channel of the same time slot. The readers with interference between different sets can only be avoided by running in different time slots. The maximum number of readers can work without interference in the same time slot by sending information to the readers through the polling server. Compared with DCS algorithm, HiQ algorithm and NFRA algorithm, this algorithm groups readers by polling server, avoiding the possibility of reader collision. The simulation results show that the proposed McAnCo is better than other algorithms in system identification efficiency and system control efficiency. Therefore, this algorithm can be applied to RFID real-world scenarios where readers are sparse or densely distributed.

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