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NOVEL BINARY SEARCH ALGORITHM OF BACKTRACKING FOR RFID TAG ANTI-COLLISION

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Abstract—In RFID system, tag collision is a main problem for fast tag identification. On the base of binary search algorithm of backtracking, an enhanced binary anti-collision search algorithm for radio frequency identification (RFID) system is presented in this paper. By dynamically transferring the ID of the tag, the length of the data transferred can be decreased dramatically. Mathematical simulation result shows that compared with the binary search algorithm of backtracking, the proposed algorithm can save channel by more than 43.75% when handling multiple RFID tags simultaneously. Finally the proposed algorithm is successfully applied to a RFID device, which validates itself.

1. INTRODUCTION

Radio frequency identification (RFID) system has received more and more attention in many areas like manufacturing companies, material flow systems, etc. RFID technology is one of the branches of automatic identification technology. Compared with other automatic identification technology, RFID technology has lots of merits [1–6]. Therefore, RFID techniques are used widely in many industries, manufacturing companies, material flow systems, etc.

Collisions are divided into reader collisions and tag collisions [7–11], only the latter of which is considered in this paper. When the reader sends out a signal which supplies power and instructions to a tag, the tag transmits its ID to the reader and the reader consults an external database with received ID to recognize the object. The tag collisions occur in the case where more than one tag reflects their data at the same time, which make it difficult that the reader searches all the tags in interrogation zone. Therefore, for fast tag identification, anti-collision protocols, which reduce the collisions of received tag IDs are required.

Typically, there are two kinds of methods used to solve this problem. One is ALOHA-based algorithms and the other one is tree-based algorithms [1]. The ALOHA-based algorithms reduce the probability of tag collisions since tags are scheduled to transmit at distinct times. However, with the increase of the number of tags, the identification performance will be deteriorated sharply. The tree-based algorithms such as binary search algorithm [12] and dynamic binary search algorithm [13, 14] are able to identify tags correctly according to locating the collision bit. Recently, the binary search algorithm of backtracking is proposed [12, 15, 16], which is an improvement on binary tree searching algorithm. When there is no collision, the reader can acquire next request signal from superior layer.

On the base of binary search algorithm of backtracking, a novel anti-collision algorithm is presented in this paper. By dynamically transferring the ID of the tag, the length of the data transferred can be decreased dramatically. Therefore, the new algorithm is able to suppress the occurrence of collisions and improve the identification efficiency significantly.

2. THE PROPOSED BINARY SEARCH ALGORITHM OF BACKTRACKING

2.1. Principle of the Novel Algorithm

Firstly, on the base of binary search algorithm of backtracking it is known that the ID of tag is transmitted integrally between the reader and the tag. However, the bits before x are already given and the bits after x are always 1 (x represents the highest bit of collision). Therefore, it is not necessary to transmit these two parts.

Secondly, in order to achieve the proposed algorithm, an additional request should be explained:

Request (ID_{m-x}, x): When the reader sends ID_{m-x} which means the IDs from bit m to x, all the tags starting with these IDs response and transmit their IDs from bit $x-1$ to 0 (m represents the length of the encoding of the tag).

Finally, when collision occurs, the bit x which represents the highest bit of collision can be found according to the encoding of Manchester. Then, let bit x equal to 0 and keep the bits from m to x be invariable. Hence, next request will be obtained. When there was no collision, the reader can acquire next request from superior layer [14].

2.2. Example

The detailed process can be demonstrated from the following example. In this example there are 4 tags in the interrogation zone of a reader. Their IDs are 10110011 (tag1), 10100011 (tag2), 10110111 (tag3), 11100011 (tag4), respectively.

First time: All tags respond after receiving the request (NULL, 8) sent by the reader. According to the encoding of Manchester, data (1?1?0?11) can be get, which means that the collision occurs in D6, D4, D2 and D6 is the highest bit of collision. Hence, two parameters of the next request is known.

Second time: Detecting the collision, the reader sends the request (10, 6) to the tags and those tags whose ID starts with (10, 6) respond. Hence, tag1, tag2 and tag3 respond and send data from D5 to D0 to the reader respectively.

Third time: Detecting the collision again, the reader sends the request (1010, 4) and those tags whose ID starts with (1010, 4) respond. Here, tag2 responds only and sends the data from D3 to D0 to the reader. As no collision occurs the reader reads the data from tag2 and sends the order of UNSELECT to let tag2 be inactive.

Fourth time: After identifying one tag successfully, the algorithm backtracks to the previous request. Now, the reader sends the request (10, 6) again and tag1 and tag3 respond.

Fifth time: The reader sends the request (101100, 2) after detecting the collision again and only tag1 responds. As no collision occurs, the reader reads the data from tag1. The reader sends the UNSELECT order to let tag1 be inactive.

Sixth time: The algorithm backtracks to the previous request at the node again. Now, the reader sends the request (10, 6) again and only tag3 responds. Then, the reader reads the data from tag3 and let it be inactive.

Seventh time: The algorithm returns back to the previous request and the reader sends the request (NULL, 8). Here, only tag4 responds and the reader reads the data from it. Until now, all the tags are successfully identified.

The working-flow of this identification can be seen in Figure 1.

2.3. Simulation and Comparison of Two Algorithms

It can be seen that the searching time depends on two factors. The first one is the number of the tags within the interrogation area of a reader and the other one is the UID (Ubiquitous Identification). The process

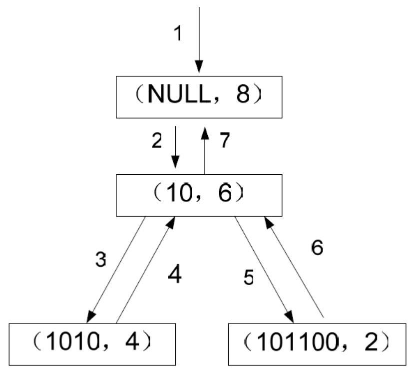

Figure 1. The process of identification by the proposed algorithm.

of the identification will take more time when more tags and longer UID are considered. N, n, m, M and S represent the total searching timesthe number of the tags in the interrogation area of a reader, the length of the encoding of the tags, the length of the encoding sent by the reader each time and the total length of the data transferred during the researching process respectively. Therefore, S is equal to $N \times M$.

In order to identify the four tags in the previous example using proposed algorithm, the total searching times N can be expressed as $N(4) = (4 - 1) \times 2 + 1 = 7$. The formula of $N = 2n - 1$ to calculate the total searching times can be obtained by mathematical induction [15, 17, 18]. The length of the encoding M is equal to m and $(m+1)/2$ for binary search algorithm and the proposed algorithm respectively. Therefore, the total length of the data transferred during the researching process S is as follows:

Binary search algorithm of backtracking:

$$S_1 = (2n - 1) \times m \tag{1}$$

Proposed algorithm in this paper:

$$S_2 = (2n - 1) \times \frac{(m + 1)}{2} \tag{2}$$

With $m = 8$, the total length of the data transferred during the researching process of the two algorithms is shown in Table 1.

With $n = 10$, the total length of the data transferred during the researching process of the two algorithms is shown in Table 2.

It is obvious that dynamically transferring the ID of the tag can improve the efficiency of the identification. According to the first table above, it can be seen that when the length of the encoding of the tags

Table 1. Identification efficiency of the two algorithms ($m = 8$).

n	S_1	S_2	Economization rate of channel $\left(\frac{S_1 - S_2}{S_1}\right)$
10	152	85.5	43.75%
30	472	26505	43.75%
50	792	445.5	43.75%
70	1112	625.5	43.75%
90	1432	805.5	43.75%
110	1752	985.5	43.75%

Table 2. Identification efficiency of the two algorithms ($n = 10$).

m	S_1	S_2	Economization rate of channel $\left(\frac{S_1 - S_2}{S_1}\right)$
8	152	85.5	43.75%
16	304	161.5	46.87%
32	608	313.5	48.44%
64	1216	617.5	49.22%
128	2432	1225.5	49.61%
256	4864	2441.5	49.86%

remains stable, the new algorithm is able to save channel by 43.75%. Meanwhile, as shown in the second table, when the number of the tags remains unchanged, the new algorithm can save channel by more than 43.75% and the longer the bits of the encoding of tags in the interrogation area of a reader, the better the performance are. Hence, the performance of the proposed algorithm precedes the binary search algorithm considerably.

3. APPLICATION IN RFID SYSTEM

To demonstrate the accuracy and applicability of the proposed algorithm, a RFID device has been programmed with *C* Language on the base of the proposed anti-collision algorithm [11–14]. As shown in Figure 2, eight different tags are stuck to a board and a reader is prepared to send out signals.

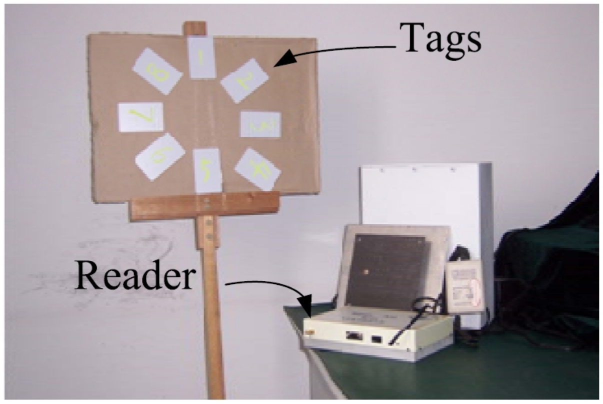

Figure 2. The photograph of the RFID device.

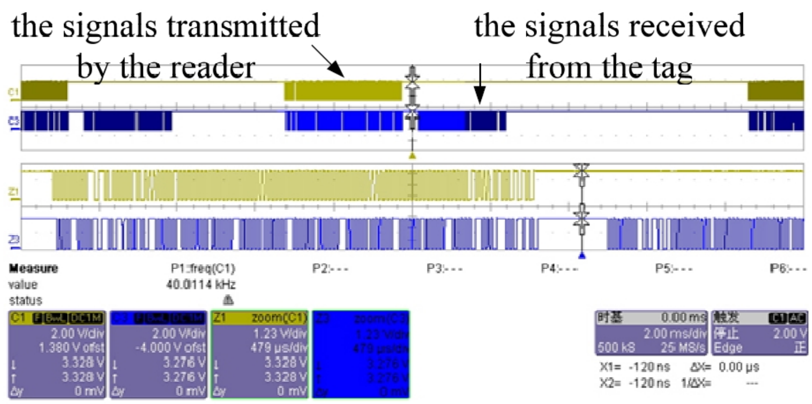

Figure 3. The photograph of an oscillograph monitoring the process of identification.

An oscillograph is used to monitor the process of multiple tags identification [15, 16]. Figure 3 shows the photograph of the reader reading the signal from one of the eight tags. Channel C1 and Channel C3 represent the signals sent and received by the reader respectively. Channel Z1 and Channel Z2 are the figures magnified from Channel C1 and Channel C3 respectively. It can be seen from Figure 3 that the reader can identify the tag accurately on condition that seven other tags exist.

4. CONCLUSION

Collision caused by tags is a major factor in deferring tag identification of RFID systems. This paper proposed a novel binary anti-collision algorithm which can improve identification efficiency significantly. Dynamically transferring the ID has the potential to decrease the length of the binary encoding transferred. Therefore, the new algorithm is able to save channel by more than 43.75% when handling multiple RFID tags simultaneously. Moreover, the longer the bits of the encoding of tags, the better the performance are. Performance evaluation by simulation and the application in a RFID device show that the proposed algorithm has the superiority comparing to the binary search algorithm of backtracking.

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