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AN ENHANCED BINARY ANTI-COLLISION ALGORITHM OF BACKTRACKING IN RFID SYSTEM

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Abstract—On the base of the binary search algorithm of backtracking, an enhanced binary anti-collision search algorithm for radio frequency identification (RFID) system is presented in this paper. With the method of transferring the collision bit in place of the ID of the tag, the proposed algorithm can improve identification efficiency significantly. Mathematical simulation result shows that compared with the binary search algorithm, dynamic binary search algorithm and the binary search algorithm of backtracking, the proposed algorithm outperforms the three algorithms previous when handling multiple RFID tags simultaneously.

1. INTRODUCTION

Radio frequency identification (RFID) system is a contact-less automatic identification system. Now it has received much attention in many industries like manufacturing companies, material flow systems, etc. Compared with the barcode, a RFID system has many merits as follows [1]:

A. The information stored in a tag is much larger than that in a barcode.
B. The information stored in tags can be reprogrammed and tags can be used repeatedly.
C. A tag has a much longer life than a barcode especially when the working condition is extremely bad.
D. When there is a barrier in front of a barcode, the barcode can not be read by a reader, but a tag can be read due to the different working styles.

E. A tag can be scanned by a reader more quickly than a barcode.

RFID system consists of readers and a large number of tags [1]. A tag has an identification number (ID) and a reader recognizes an object through consecutive communications with the tag attached to it. 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 process of the identification is shown in Figure 1. The reader must be able to identify tags as quickly as possible. However, when multiple tags transmit their IDs simultaneously, data collision resulted from the data transaction between more tags and the reader at the same time occurs. Therefore, anti-collision algorithms are required to identify tags correctly and efficiently.

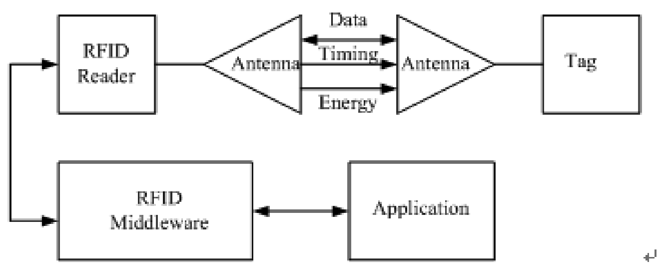

Figure 1. The structure of RFID system.

Nowadays, tag anti-collision algorithms are mainly separated into ALOHA-based and tree-based [1]. The ALOHA-based algorithms such as ALOHA, slotted ALOHA, frame slotted ALOHA and dynamic frame slotted ALOHA, reduce the probability of tag collisions since tags are scheduled to transmit at distinct times. However, they have a serious problem that a specific tag may not be identified for a long time, leading to the so-called "tag starvation problem". With the increase of the number of tags, the identification performance will be deteriorated sharply. Comparing to ALOHA algorithms, tree-based search algorithms such as binary search algorithm [2] and dynamic binary search algorithm [3, 4] are able to identify tags correctly according to locating the collision bit and do not cause the tag starvation as in the ALOHA-based algorithm. However, relatively long time is required for the reader to identify all the tags. Recently, the binary search algorithm of backtracking is proposed [2, 5], which is an improvement on binary tree searching algorithm. When there is no collision, the reader can acquire next request signal from superior layer. This algorithm has an advantage comparing with old algorithm in testing times of identifying n tags.

On the base of the binary search algorithm of backtracking, an enhanced algorithm is presented in this paper which can identify tags more efficiently. With the improvement on the length of the data transferred, the new algorithm has the potential to suppress the occurrence of collisions, shorten the total delay for recognizing all tags and improve the identification efficiency greatly.

2. BINARY ANTI-COLLISION SEARCH ALGORITHMS [1, 6]

In this algorithm, Manchester code is used so as to recognize the bits where there is a collision. In Manchester code, the ascending edge is coded as logical "0", and the descending edge is coded as logical "1". Therefore when the reader receives an identification code and the states of the code do not change in some bits, the reader can know where collisions occur.

Supposed there are two tags: 10110010 (tag1), 10101010 (tag2), these two tags will answer the reader at the same time when the reader sends a RQUEST command to them. It can be seen that D3 and D4 of tag1's identification code are logical "0" and logical "1" respectively, but those of the same bits of the tag2's identification code are logical "1" and logical "0" respectively, thus the states of the identification code received by the reader will not change in these two bits which are shown by the broken lines in Figure 2. Then the reader can know collisions occur in these two bits. In binary search algorithm, tags whose first collided bit is logical "1" do not respond to the reader's next request while tags whose first collided bit is logical "0" send their

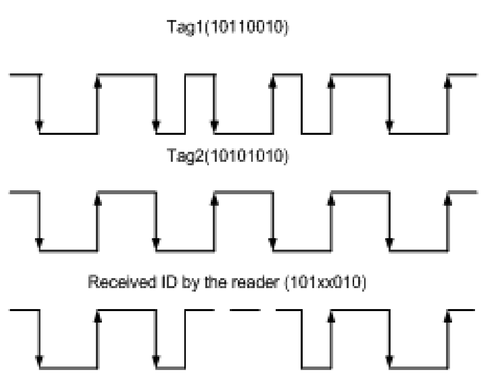

Figure 2. Collisions in received ID.

identification codes. After each request, the collided bits become less.

The searching process keeps going until the identification code of a tag is recognized and will be repeated from the beginning until the identification codes of all the tags are recognized.

3. THE PRINCIPLE OF THE PROPOSED BINARY SEARCH ALGORITHM OF BACKTRACKING

3.1. Principle of the Enhanced Algorithm

An enhanced binary anti-collision algorithm for RFID system is proposed in this paper based on the binary search algorithm of backtracking. When there was no collision, the reader can acquire next request signal from superior layer [5]. Furthermore, in this paper, the method of transferring the collision bit instead of the ID of tags to decrease the length of the binary encoding sent by the request order is proposed. As the change of the collision bit, the length of the data transferred varies for dynamic binary search algorithm, however, the length of the encoding which represents the collision bit is constant. For example, 3 bits can be used to represent the collision bit for the tags with the ID of 8 bits. Therefore, the reader just transfers the information of collision bit instead of the whole ID. Then the tags compare the number indicated in the request with "0" after receiving the request. If it is equal to "0", the tags continue to transmit their remaining IDs. Otherwise, the tags will not response to the following request until it receives the request in the next anti-collision cycle.

3.2. 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) sent by the reader.

Second time: Detecting the collision, the reader sends the first collision bit (001) to the tags and those tags whose D1 are "0" respond. Hence, tag2 and tag3 respond and send data from D2 to D7 to the reader respectively.

Third time: Detecting the collision again, the reader sends the request (011) and those tags whose D3 are "0" respond. Here, tag2 responds and sends the data from D4 to D7 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.

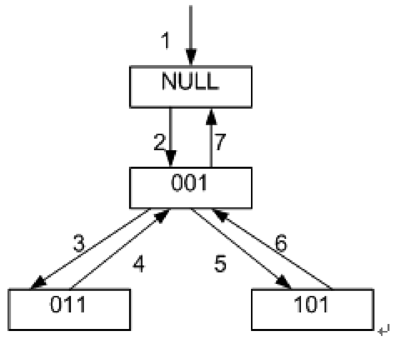

Figure 3. The process of identification by the proposed algorithm.

Fourth time: After identifying one tag successfully, the algorithm backtracks to the last request. Now, the reader sends the request (001) again and tag1 and tag3 respond.

Fifth time: The reader sends the request (101) 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 last request at the node again. Now, the reader sends the request (001) 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 last request and the reader sends the request (NULL). 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 3.

4. SIMULATION RESULT

Basing on the theory of the binary search algorithm, it is known 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 of the identification will take more time when more tags and longer UID are considered. N, n, m, M, S represent the total searching times, the number of the tags within 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 $N \times M$.

For binary search algorithm and dynamic binary search algorithm, if the number of the tags is n, the total searching times N can be expressed as $N = n(n+1)/2$ [7]. 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 [2, 5]. The length of the encoding sent by the reader each time M for dynamic binary search algorithm and the proposed algorithm is equal to $(m+1)/2$ and $\log_2 m$ respectively. Therefore, the total length of the data transferred during the researching process S is as follows:

Binary search algorithm:

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

Dynamic binary search algorithm:

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

Backtracking binary search algorithm:

$$S_3 = (2n-1) \times m \tag{3}$$

Proposed algorithm in our paper:

$$S_4 = (2n-1) \times \log_2 m \tag{4}$$

With $m = 64$, the total length of the data transferred during the researching process of the four algorithms is shown in Table 1.

Table 1. The total length of the data transferred of the four algorithms ($m = 64$).

S \ n	10	20	30	40	50	60	70
S_1	3520	13440	29760	52480	81600	117120	159040
S_2	1787	6825	15112	26650	41437	59475	80762
S_3	1216	2496	3776	5056	6336	7616	8896
S_4	114	234	354	474	594	714	834

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

Table 2. The total length of the data transferred of the four algorithms ($n = 10$).

S \ m	8	16	32	64	128
S_1	440	880	1760	3520	7040
S_2	247	467	907	1787	3547
S_3	152	304	608	1216	2432
S_4	57	76	95	114	133

The total length of the data transferred means the time of transferring the anti-collision requests based on the binary search algorithm. Therefore, it is obvious that the decrease of the length of the data transferred 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 remains stable and the number of the tags is equal to 10, the total length of the data transferred of the proposed anti-collision algorithm is 114. However, the figure for the binary search algorithm, the dynamic binary search algorithm and the binary search algorithm of backtracking is 3250, 1787, 1216 respectively. Hence, the performance of the proposed algorithm precedes the other three algorithms considerably. Meanwhile, the longer the bits of the encoding of tags and the bigger the number of the tags within the interrogation area of a reader, the better the performance is.

5. CONCLUSION

This paper proposed an enhanced binary anti-collision algorithm which can improve identification efficiency significantly. With transferring the collision bit, the length of the data transferred can be decreased dramatically. The simulation results show that the proposed algorithm has the superiority comparing to the three other algorithms.

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REFERENCES

1. Finkenzeller, K., *RFID Handbook: Radio-frequency Identification Fundamentals and Applications in Contactless Smart Cards and Identification*, 2nd edition, John Wiley, New York, 2003.
2. Jiang, L.-F., G.-Z. Lu, and Y.-W. Xin, "Research on anti-collision algorithm in radio frequency identification system," *Computer Engineering and Applications*, Vol. 15, 29–32, 2007.
3. Shih, D., P.-L. Sun, D.-C. Yen, and S.-M. Huang, "Taxonomy and survey of RFID anti-collision protocols," *Computer and Communications*, Vol. 29, No. 11, 2150–2166, 2006.
4. Law, C., K. Lee, and K. Y. Siu, "Efficient memory-less protocol for tag identification," *Proc. 4th International Workshop on DIALM*, 75–84, Boston, Massachusetts, ISA, 2000.
5. Du, H.-T., K.-L. Xu, and W.-L. Wang, "An anti-collision algorithm based on binary-tree searching of backtracking," *Journal of Yunnan University*, Vol. 28, 133–136, 2006.
6. Liu, L.-A., Z.-H. Xie, J.-T. Xi, and S.-L. Lai, "An improved anti-collision algorithm in RFID system," *Mobile Technology, Applications and Systems, 2005 2nd International Conference*, Nov. 2005
7. Ju, W.-C. and C.-F. Yu, "An anti-collision RFID algorithm based on the dynamic binary," *Journal of Fudan University*, Vol. 44, No. 1, 46–50, 2005.
8. Dai, X.-W., C.-H. Liang, B. Wu, and J.-W. Fan, "Novel dual-band bandpass filter design using microstrip open-loop resonators," *Journal of Electromagnetic Waves and Application*, Vol. 22, No. 2, 219–225, 2008.
9. Wu, B., B. Li, T. Su, and C. H. Liang, "Equivalent-circuit analysis and lowpass filter design of split-ring resonator DGS," *Journal of Electromagnetic Waves and Application*, Vol. 20, No. 14, 1943–1953, 2006.
10. Khalaj-Amirhosseini, M., "Microwave filters using waveguides filled by multi-layer dielectric," *Progress In Electromagnetics Research*, PIER 66, 105–110, 2006.
11. Chen, Z.-X., X.-W. Dai, and C.-H. Liang, "Novel dual-mode dual-band bandpass filter using double square-loop structure," *Progress In Electromagnetics Research*, PIER 77, 409–416, 2007.
12. Zhao, L.-P., X.-W. Dai, Z.-X. Chen, and C.-H. Liang, "Novel design of dual-mode dual-band bandpass filter with triangular resonators," *Progress In Electromagnetics Research*, PIER 77, 417–424, 2007.

13. Xue, W., C.-H. Liang, X.-W. Dai, and J.-W. Fan, "Design of miniature planar dual-band filter with 0° feed structures," *Progress In Electromagnetics Research*, PIER 77, 493–499, 2007.
14. Fan, J.-W., C.-H. Liang, and X.-W. Dai, "Design of cross-coupled dual-band filter with equal-length split-ring resonators," *Progress In Electromagnetics Research*, PIER 75, 285–293, 2007.
15. Fan, Z., S. Qiao, H.-F. Jiang Tao, and L.-X. Ran, "Signal descriptions and formulations for long range UHF RFID readers," *Progress In Electromagnetics Research*, PIER 71, 109–127, 2007.
16. Kim, D.-Y., H.-G. Yoon, B.-J. Jang, and J.-G. Yook, "Interference analysis of UHF RFID systems," *Progress In Electromagnetics Research B*, Vol. 4, 115–126, 2008.
17. Zainud-Deen, S. H., M. E. S. Badr, E. El-Deen, K. H. Awadalla, and H. A. Sharshar, "Microstrip antenna with defected ground plane structure as a sensor for landmines detection," *Progress In Electromagnetics Research B*, Vol. 4, 27–39, 2008.
18. Zhang, Y.-Q. and Z.-S. Wu, "The calculation of angular side-play amount produced by radiation pressure acting on the space object," *Progress In Electromagnetics Research B*, Vol. 4, 67–77, 2008.
19. Liang, C.-H., L. Li, and X.-J. Dang, "Inequality condition for grating lobes of planar phased array," *Progress In Electromagnetics Research B*, Vol. 4, 101–113, 2008.
20. Su, D., D.-M. Fu, and D. Yu, "Genetic algorithms and method of moments for the design of PIFAs," *Progress In Electromagnetics Research Letters*, Vol. 1, 9–18, 2008.
21. Zhang, X.-C., Z.-Y. Yu, and J. Xu, "Novel band-pass substrate integrated waveguide (SIW) filter based on complementary split ring resonators (CSRRs)," *Progress In Electromagnetics Research*, PIER 72, 39–46, 2007.
22. Zhao, X. W., C.-H. Liang, and L. Liang, "Multilevel fast multipole algorithm for radiation characteristics of shipborne antennas above seawater," *Progress In Electromagnetics Research*, PIER 81, 291–302, 2008.