Enhanced Anti-Collision Protocol for Identification Systems: Binary Slotted Query Tree Algorithm

Nam-Tuan Le* *Associate Member*, Sunwoong Choi*, Yeong Min Jang* *Lifelong Members*

ABSTRACT

An anti-collision protocol which tries to minimize the collision probability and identification time is the most important factor in all identification technologies. This paper focuses on methods to improve the efficiency of tag's process in identification systems. Our scheme, Binary Slotted Query Tree (BSQT) algorithm, is a memoryless protocol that identifies an object's ID more efficiently by removing the unnecessary prefixes of the traditional Query Tree (QT) algorithm. With enhanced QT algorithm, the reader will broadcast 1 bit and wait the response from the tags but the difference in this scheme is the reader will listen in 2 slots (slot 1 is for 0 bit Tags and slot 2 is for 1 bit Tags). Base on the responses the reader will decide next broadcasted bit. This will help for the reader to remove some unnecessary broadcasted bits which no tags will response. Numerical and simulation results show that the proposed scheme decreases the tag identification time by reducing the overall number of request.

Key Words : Query Tree, RFID, LED-ID, anti-collision

Ⅰ. Introduction

Radio Frequency Identification(RFID) are increasingly being used as the automated identification system. As more and more products become RFID enabled, fast tag identification mechanisms will become more important as well. The ability to recognize multiple tags simultaneously is crucial for many advanced RFID-based applications in these domains. However, multiple tags in the same reading range of a reader may interfere with each other, which make the reader hard to recognize the tags. Anti-collision for RFID are developed to cope with this problem and the performance of multiple tag recognition is greatly influenced by the algorithm applied.

In recent years, LED-ID[1], a new identification technique which is based on Visible Light Communication (VLC), will be more and more popular because of healthy and unrestricted advantages of visible light. Similar with RFID, LED-ID also deal with the anti-collision problem. Some anti-collision schemes for RFID can be a good reference for LED-ID application. VLC will become more and more poppular because there are numerous advantages that come from the visible light it uses.

This paper presents an enhanced scheme of a Query Tree, which is a representative of memoryless tree-based tag anti-collision algorithm. Our scheme will try to reduce the number of reader's query by setting two time-slots for receiving the tag's response. Assume that the query string has n bit length then the tags that have bit $n+1$ are 0 will respond in the first slot, otherwise they will response at second slot. Our scheme will reduce about half number of queries from the reader when compare with a traditional Query Tree.

The rest of this paper is structured as follows: In Section II, we provide an overview of existing anti-collision protocol and the ability of BSQT

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algorithm. Section III presents our scheme to enhance the QT algorithm. The performance of BSQT is evaluated through analysis and simulation in Section IV. Finally, concluding remarks are given in Section V.

Ⅱ. Related Works

Anti-collision is the most important issue in an identification system. From the early days of RFID technology, there have been many researchers who have tried to solve this problem efficiently and economically. Anti-collision protocol can be classified into two approaches: probabilistic and deterministic. Typical algorithms in the probabilistic approach are ALOHA and CSMA. The simplest probabilistic algorithm is the ALOHA procedure, where tags send their data randomly after being activated by the reader. When collision occurs, they wait for random time and retransmit. In slotted ALOHA algorithm, time is divided into numerous small discrete time slots, and a tag can send its data at the beginning of its pre-specified slot. In this way, there will be no partial collision so successful transmission will be improved. Although the slotted ALOHA algorithm can enhance channel utilization and throughput, it cannot guarantee reasonable response time when there are several tags near the reader. To guarantee the response time, the frame slotted ALOHA (FSA) algorithm is proposed based on the slotted ALOHA algorithm. In this scheme, *N* slots constitute a frame and each tag chooses a slot to transmit data in the frame. As the frame size *N* becomes larger, the probability of collision becomes lower, but the identification time becomes longer. Dynamic frame slotted ALOHA (DFSA) algorithm changes the frame size for efficient tag identification [2,12]. To determine the frame size, it uses information such as the number of slots used to identify the tag, the number of the slots collided and etc. However, the probabilistic algorithm or the ALOHA based algorithm cannot prevent collisions perfectly. It is hard to estimate the initial number of tags present in the field of the reader. Meanwhile, there will be tag starvation phenomenon, where a tag collapses repeatedly, it makes the tag not be identified for a long time.

About the deterministic approach, they are Query Tree, Binary Tree, and etc. In EPC Gen2 standard the anti-collision algorithm used[2,7] is a framed slotted anti-collision algorithm. The identifying progress is described as follows. All the Tags receive a query command from Readers, and then set a time slot number between 0 and 2^{Q-1} randomly. A length of frame in a round is defined by Q-value, which is given in the query command. Because the number of time slots is given randomly, many tags may select the same time slot. In such a situation, collisions will happen among tags, thus, the reader cannot receive information from tags accurately.

The Query Tree (QT) algorithm[2,6,9] is a representative memoryless tree-based tag anti-collision algorithm developed at MIT's Auto-ID Center. It is a memoryless tag identification protocol, in which the tags do not need to remember their inquiring history. The QT algorithm consists of identification rounds. In each round, a reader transmits a query to the tags, and then the tags respond to it with their IDs. The reader makes its query by popping a query stored in the query queue. Each query contains *k*-bits long prefix string which each tag compares with the prefix of its tag ID. If it matches, the tag sends its whole tag ID as a response or simply ignores the query and makes no response otherwise. A queue of such prefixes is maintained and the queries are sent in order from this queue. When a query is done, its corresponding entry is removed from the queue. As the query queue is emptied, the reader makes a special query including the empty prefix string < ε >. Any tag receiving the empty prefix string < ε > query should respond. If there is only one response for a query, the reader can successfully recognize the tag. However, if there is more than one response, responses collide and the reader cannot recognizes the tag. In the case of such a collision, the reader creates two queries by appending '0' (zero) and '1' (one) to the previous query and stores them into the query queue. In case of no tags matches the prefix, there is no tag response. And the reader does noting and begins the next round. The algorithm repeats the above procedure until all queries in the queue are popped (i.e., empty).

The similar process in EPC class 1 UHF protocol[4] based on tree algorithm with 8 listening time slots at reader; the collision of tag can be reduced. But these schemes show inefficiencies in Tags identification time and power consumption when numbers of identified tags are small and non-periodically. Our scheme will optimize this time slot efficiently.

In binary-tree protocol[6] a reader will split the collided tags into two subsets until each set only has one tag. The process will be done in some time slot which the reader will broadcast bit 0 and 1 of i^{th} bit in tag ID string.

Choi et al.[11] proposed a Scanning Based Pre-Processing (SBPP) technique that uses Manchester coding (see Figure 1) to locate collided bits in tag responses. The reader notifies tags the collided bits and uses a QT algorithm to identify them.

BSQT proposed in this paper belongs to the class of single reader-multiple tag collision resolution protocols. It bases on QT and is improved to reduce the communication overhead in the dense tags scenarios. Next part, we will explain more detail about this scheme.

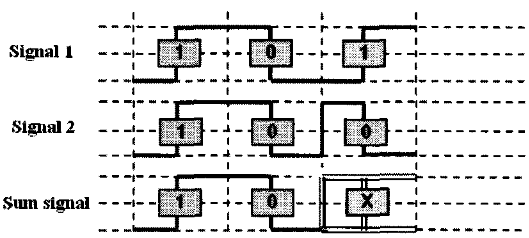

Fig. 1. Manchester coding

Ⅲ. Enhanced Query Tree Algorithm

In an RFID system, every Tag's ID is a unique binary string. So in the k tags identification process, it can be seen that one bit in n bit length is a Bernoulli distribution. From above analysis, the number of collision will reduce when we increase the number of listening slots in one duty cycle. Assuming that, the *efficiency of working slot* E_1 is the probability of occurring collision in one identification slot. It can be calculated as:

$$E_1 = \frac{Collision\_probability}{Number\_of\_slot} \quad (1)$$

Beside if we consider about the idle slots case, no transmission, the *efficiency of working Slot* E_2 can be calculate as:

$$E_2 = \frac{Idle\_probability}{Number\_of\_slot} \quad (2)$$

From equation1 (1) and (2), the optimization of number time-slots can be figure out in Figure 2. When number of time-slots is two we have best value of efficiency of working slot for "collision probability" and "idle probability" from equation (1) and (2).

In proposed algorithm, the reader should be able to trace the location of the collided bits and the number of the collided bits by using Manchester code [7,11] which is usually adapted for collision detection in the signals that tag returns to reader in deterministic algorithm.

Assume that all tags have n binary bits ID and unique together. Our protocol (BSQT) bases on Query Tree with Scanning Based Pre-Processing (SBPP-QT)[11] to control the interaction between the reader and tags efficiently. The scheme will exploit specific prefix patterns in the tag ID to reduce the communication overhead between the reader and the tags. Base on Query Tree protocol, at first the reader will broadcast a prefix string query (n-i) bits and listen in two circles. All tags receiving the query will response with their bits ID to the reader in two slots. Slot 0 is leaved for Tags which (n-i+1) string bits ID is 0. Slot 1 is leaved for tags which (n-i+1) string bits ID are 1. The reader will use Manchester coding to locate the collision in receiving tags ID and then update the prefix in the queue. The new prefix string is base on the position of bits collision. For example, when there is a collision at bit j in receiving tag

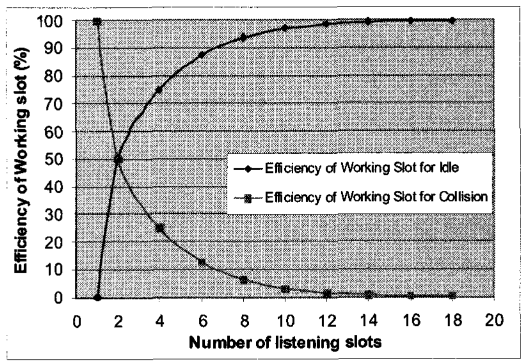

Fig. 2. The optimization of time-slots

ID string, the reader will create (*n-j-1*) bits prefix for the next broadcast. If the reader can not find any collision in receiving ID string, it will identify this tag ID and process data of this tag. The process will be finished when all tags are identified.

The following table is an example in processing steps of the proposed scheme. There are 3 tags with ID: 0000, 0010 and 1010. Table 1 shows the detail of identification processes of Query Tree with SBPP algorithm. And table 2 is the comparison with BSQT scheme.

Table 1. SBPP Query Tree processes

Step	Reader	Tag	Status	Queue
1	Start	0000 0010 1010 xxxx	Collision	{0,1}
2	0	0000 0010 00x0	Collision	{000,001,1}
3	000	0000	Identified Tag	{1,001}
4	001	0010	Identified Tag	{1}
5	1	1010	Identified Tag	{}

Table 2. Binary Slotted Query Tree processes

Step	Reader	Slot 1	Slot 2	Status	Queue
1	Start	0000 0010 00x0	1010	Collision Slot 1 Identified Slot 2	{00}
2	00	0000	0010	Identified Slot 1 Identified Slot 2	{}

Ⅳ. Performance Evaluation

The question motivating this research is, what protocol should the reader and the tags use so that the ID of each tag can be communicated to the reader as quickly and reliably as possible? Our scheme introduces a more challenging aspect to the problem, because of the severe computational and energy constraints in each tag. The following are its advantages over Binary Slotted Query Tree algorithm compared with the pure Query Tree algorithm: First, The reduction in number of bits transmitted by tag. Secondly, the reduction in number of bits transmitted by the reader. And finally, the reduction of the time of tag identifications is achieved. These can create power efficient and fast communication of within the system. This is an important role in the success of RFID system.

Assuming that the IDs are evenly distributed, the above inquiring process can be represented by a Binary Tree with depth $m = log_2k$, where k is the number of tags. Once the length of the prefix increases to m, no collisions can occur. This suggests that the remaining parts of the ID will be sent back without any further inquiry. This is equivalent to a depth-first traversal over a full binary tree where a node represents a prefix. The nodes on the Query Tree can be divided into two classes: type-I which corresponds to those lying on the levels less than m, and type-II which corresponds to those on level m of the tree. During the depth-first traversal, each arrival at a node of type-I requires the tag to experience [n (either receiving or sending data) +2(NULL) + 1] clock cycles. N is denoted the length of IDs configured inside the tags. The arrival at a node of type-II implies that a tag is identified, and two extra clock cycles are needed (in addition to $n + 2 + 1$ clock cycles as required for type-I node) for the reader to record the read-out ID. Thus, the total average number of clock cycles required is given by (note $m = log_2k$)[10]:

$$
\begin{aligned}
&E[Cycle_{query}] \\
&= (n+3)\,(2^0 + 2^1 + \ldots + 2^{m-1}) + (n+5)2^m \\
&= k\,(2n+8)-(n-3)
\end{aligned}
$$

It can be seen that the number of reader's request is also the number of identification collision. So with QT, the total average number of reader request is:

$$
R_{r\_QT} = (2n+8) - (n-3)/k
$$

To evaluate the performance of enhancement, we used C++ environment for testing the improvement of the proposed scheme with a traditional algorithm. The ID of the tag is chosen randomly and the results are the average of 50 simulation times for every ID's length. Figures 3 and 4 show the number of reader's queries and the tag's responses between Query Tree with Scanning Based Pre-Processing and Binary Slotted Query Tree when identifying 30 tag with different length of tag ID in the first simulation. Figures 5 and 6 show the numbers of reader's queries and tag's responses between SBPP-QT and BSQT with different number of tag at 10 bits length of tag ID.

About identification time in Figure 7, BSQT also achieves some improvement. From the simulation results and analysis, it can be observed that the performance of our scheme is better than tradition algorithm. It also presents the Query Tree and our scheme is independent with the length of tag ID. Compare with traditional SBPP-Query Tree, the number of reader's queries is around 50% reduction. On the tag's responses and identification time, there is a little benefit

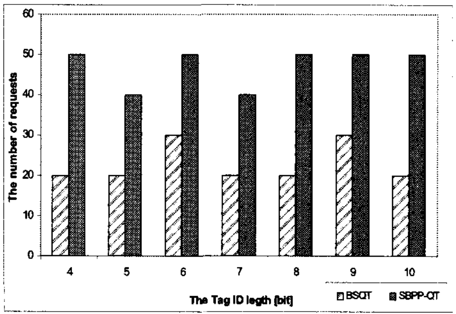

Fig. 3. The total queries from reader

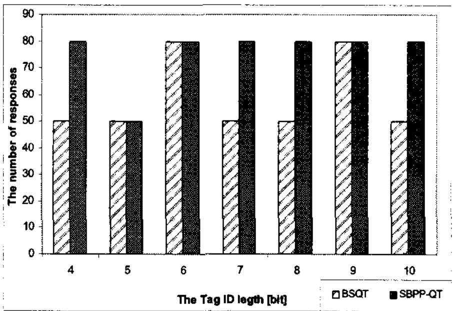

Fig. 4. The total responses from tag

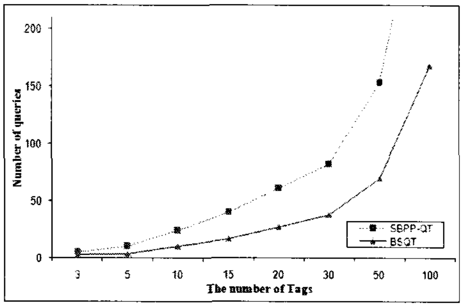

Fig. 5. The total queries from reader

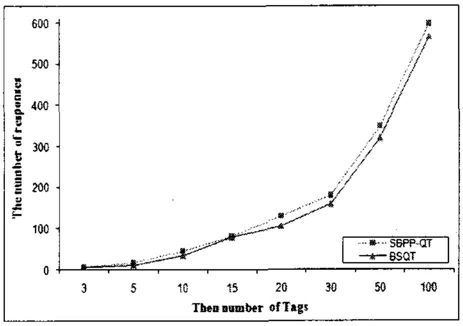

Fig. 6. The total responses from tag

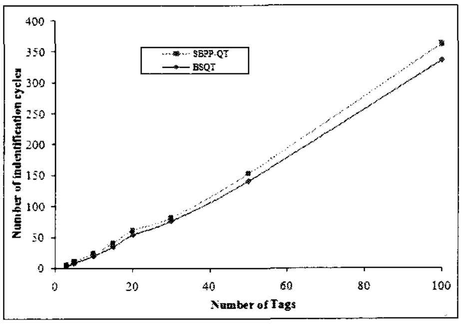

Fig. 7. Identification cycles

about 10% messages transition reductions and identification cycles. V. Conclusion

In this paper, we proposed a new scheme memoryless tree-based RFID tag anti-collision algorithm, Enhanced Query Tree, which is based on the Query Tree. From the simulation results, the proposed scheme showed a power efficient operation by reducing the number of reader's queries and the tag's responses. In the future, we will apply this scheme to the LED-ID system.

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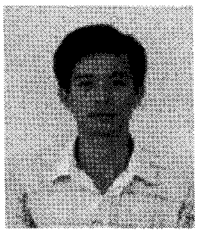

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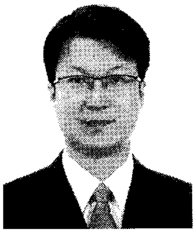

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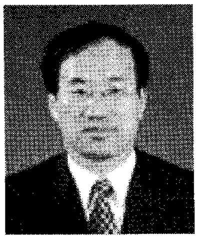

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