Anti-collision Algorithm with Early Cancellation of Query Round in RFID Systems

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***Abstract*—**The performance of anti-collision algorithm in RFID systems, which are based on FSA algorithm, may be affected by the frame size a query round. In this paper, an anti-collision algorithm with early cancellation of query round is proposed to enhance the performance of EPCglobal Class-1 Gen-2. The Q-algorithm calculates a Q value to determine the next frame size during a query round. In the proposed algorithm, if the new Q value is different from the previous one, the reader transmits a QueryAdjust command to cancel the current query round. The simulation results show that the proposed algorithm can have a stable performance irrespective of the C value of Q-algorithm and the number of tags.

***Index Terms*—**RFID, Anti-collision algorithm, FSA, Q-algorithm, Early cancellation

I. INTRODUCTION

In recent years, radio frequency identification (RFID) technology has been widely adapted in a variety of application fields such as public transportation, production control, animal identification, and object tracking [1]. An RFID system consists of radio frequency tags attached to objects that need to be identified and one or more electromagnetic readers. When there is more than one tag in the identification range of a reader, all or some tags may send their response back to the reader at the same time [2]. If only one tag answers, the reader receives just one message which is correctly decoded. If two or more tags answer, their messages will collide on the RF channel and cannot be correctly received by the reader. This may lead to mutual interference, which is referred to as a collision. A technical scheme that handles multiple-access without any interference is called as an anti-collision algorithm [3][4].

Two major performance measures in RFID system are the tag identification time and the energy consumption. When the reader requests the tag identification code, the identification time is fast and the energy consumption is low as the number of read-cycle is small for identifying all the tags in the reader's identification range. Therefore, an anti-collision algorithm must be carefully designed for conserving low power consumption and fast identification of multiple tagged objects simultaneously.

There are two types of anti-collision algorithms: deterministic and probabilistic algorithm [5][6]. The probabilistic algorithm is based on an ALOHA-like protocol that provides slots for the tags to send their data. Almost all the probabilistic algorithms use framed slot ALOHA (FSA) [7]. Whenever a collision has occurred, another frame of slots is provided, and the tags that are involved in collisions will choose different slots in the next read cycle. EPCglobal Class-1 Generation-2 and ISO/IEC 18000-6 Type C standards use the probabilistic approach. The deterministic algorithm resolves collisions by muting subsets of tags that are involved in a collision [8]. By successively muting larger subsets, only one tag will be left and finally led to successful transmission. Binary tree and query tree algorithms are the two main methods of the deterministic algorithm.

A lot of researches have been performed to enhance the performance of FSA algorithm. Among those algorithms, DFSA (Dynamic Framed Slot SLOHA) dynamically allocates the frame length based on the number of tags in the reader's identification range. There are two main research areas in DFSA algorithm: i) tag number estimation scheme, and ii) dynamic frame size allocation scheme. Almost all the researches in DFSA algorithm have been carried out to estimate exactly the number of tags. But, due to the estimation errors, there are some problems that the performance degrades in spite of optimal frame size allocation.

EPCglobal Class-1 Generation-2 standard proposed Q-algorithm to determine the frame size for the next query round. Q-algorithm calculates the frame size without conducting a tag number estimation. Therefore,

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it wastes less computational cost than other DFSA algorithms. But the constant parameter C value, which is used for calculating the frame size of next query round, is not optimized. Also, though continuous collision or empty slots occur during a query round, a new query round begins after the reader finishes an identification process for the current frame. Therefore, it has a drawback that it will take a long identification time. We propose an anti-collision algorithm with early cancellation query round if there are continuous collision or empty slots in the query round.

This paper is organized as follows. In Section II, we describe EPCglobal Class-1 Generation-2 anti-collision algorithm. An anti-collision algorithm with early cancellation scheme is proposed in Section III, and Section IV shows the simulation results. Section V concludes the paper.

II. GEN-2 ANTI-COLLISION ALGORITHM

EPCglobal Class-1 Generation-2 uses a frame-based slot ALOHA algorithm as an anti-collision algorithm for identifying multiple tags within the reader's identification range. The reader begins a query round by transmitting a Query command. After issuing a Query command to initiate a query round, the reader transmits one or more QueryRep commands to detect each slot during a query round.

Fig.1 shows the operation for anti-collision algorithm that is proposed by EPCglobal Class-1 Generation-2. At first, the reader selects a tag population for a query process by transmitting a Select command. And it transmits a Query command to decide which tags participate in the query round. Query command contains a slot-count parameter Q, and the initial value of Q is 4.

Upon receiving a Query command, participating tags pick a random value in the range (0, 2^Q-1), inclusive, and load this value into their slot counter. Tags that pick a zero backscatter an RN16, which is a 16-bit random number. If the reader receivers an RN16 without collision, it acknowledges the tag with an ACK command containing this same RN16. If the tag receives the ACK command with a correct RN16, it transmits its PC, EPC, and CRC-16. The reader checks CRC errors with the received CRC-16 value. If no CRC errors are found, the reader assumes that this tag is successfully identified. After that, it reads from or writes to the identified tag.

In the EPCglobal Class-1 Generation-2 algorithm, the number of slots in the frame of query round is 2^Q slots. If a query round is not expired, the reader continues an identification process for the next slot by transmitting a QueryRep command. On the other hand, if unidentified tags still remain though a query round is terminated, the reader issues a new Query command to initiate another query round. The new Query command also contains a slot-count parameter Q, which is calculated through Q-algorithm described later.

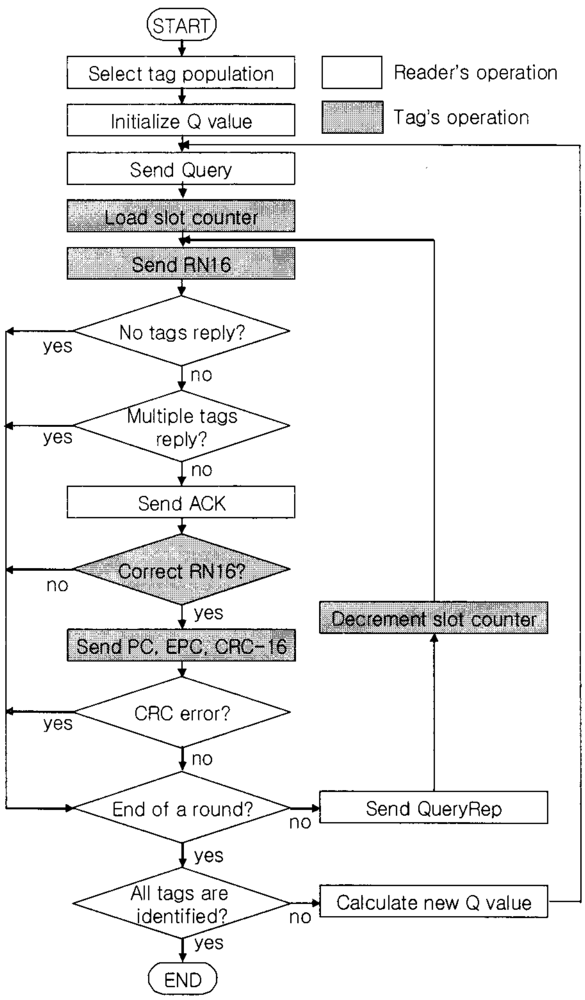

Fig. 1. Flowchart for Gen-2 anti-collision algorithm.

EPCglobal Class-1 Generation-2 proposed Q-algorithm to determine the number of slots in the next query round. Q-algorithm basically calculates the slot-count parameter Q based on the slot status that tags are responded. The slot status is classified into three categories: success, collision, and empty slot.

Fig.2 shows an algorithm that the reader might use for setting the slot-count parameter Q in a query round. In the figure, Q_{fp} is a floating-point representation of Q. As shown in the figure, the reader updates Q_{fp} in accordance with the slot status at every slot. When a collision occurs, it adds the constant C value to the previous Q_{fp}, because it means the frame length is smaller than the number of tags. If the slot is empty, which means that there are no tag responses in the slot, the reader subtracts the constant C value from the previous Q_{fp}, because the frame length is larger than the ideal one. When a new query round begins, the reader rounds Q_{fp} to an integer value Q in the Query command. Typical values for the parameter C are $0.1<C<0.5$. EPCglobal Class-1 Generation-2 standard suggests that the reader typically uses small values of C when Q is large and large values of C when Q is small. However, the performance of Gen-2 anti-collision algorithm, which uses the frame-based slot ALOHA, is dependent on the number of tags in the reader's identification range and frame length. Therefore, the reader must choose a parameter C value according to the number of tags in a query round.

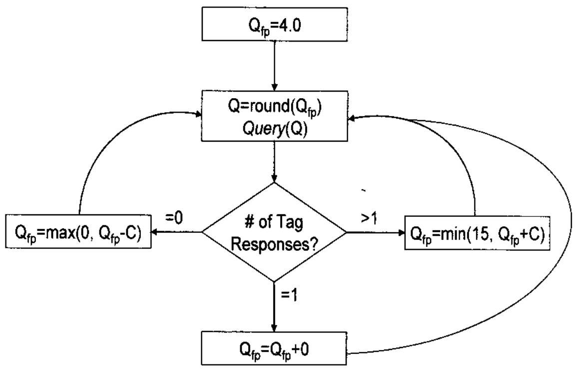

Fig. 2. Q-algorithm.

III. EARLY CANCELLATION OF QUERY ROUND

In this section, we propose an anti-collision algorithm with early cancellation of query round to enhance the performance of Gen-2 anti-collision algorithm. When collision or empty slots occur continuously during a query round, the slot-count parameter Q will be different from the previous one. The occurrence of continuous collision slots means that there are too many tags in the identification range. Also, the occurrence of continuous empty slots means that the frame length of query round is larger that the expected one. Therefore, in those cases, it is necessary that the reader starts a new query round with the updated Q value after the early cancellation of current query round.

The operation of anti-collision algorithm with early cancellation scheme is depicted in Fig.3. The reader runs Q-algorithm slot by slot. At the end of each slot, a reader adjusts the Q value obtained by Q-algorithm. If the new Q value is different from the previous one, the reader sends a QueryAdjust command. When all the tags receive a QueryAdjust command, they load a slot counter with the adjusted Q value.

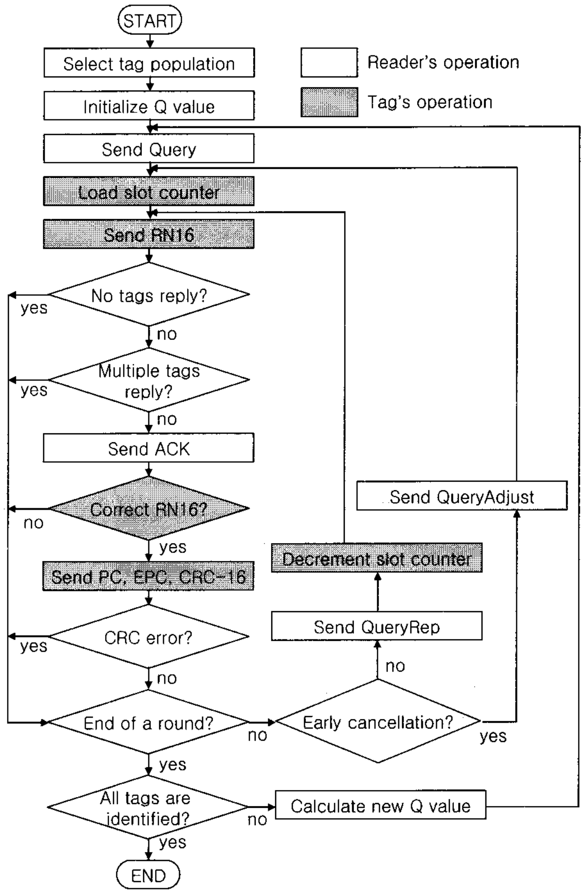

Fig. 3. Anti-collision algorithm with early cancellation.

IV. SIMULATION RESULTS

In this paper, the various computer simulations are performed to compare the performance of proposed algorithm with Gen-2 anti-collision algorithm. In the Q-algorithm of Gen-2 anti-collision algorithm, the slot-count parameter for the next query round is incremented or decremented by the constant parameter C value according to the slot status. Therefore, it is anticipated that the performance of Gen-2 anti-collision algorithm will mainly depend on the constant parameter C value and the number of tags within the reader's identification range.

Fig.4 shows the total identification time of Gen-2 algorithm without early cancellation scheme according to the constant parameter C value and number of tags. The total identification time means the number of all consumed slots for identifying all tags. As depicted in the figure, the identification times of Gen-2 algorithm are various with the parameter C and number of tags. When the C value is 0.5, the reader can identify faster than other cases in spite of many tags. In the case of constant parameter C value with 0.2, 0.3, and 0.4, the identification time increases sharply when the number of tags is 200, 300, and 500, respectively. Moreover, when the number of tags is over 400, the identification time is similar to each other with the C value between 0.2 and 0.4.

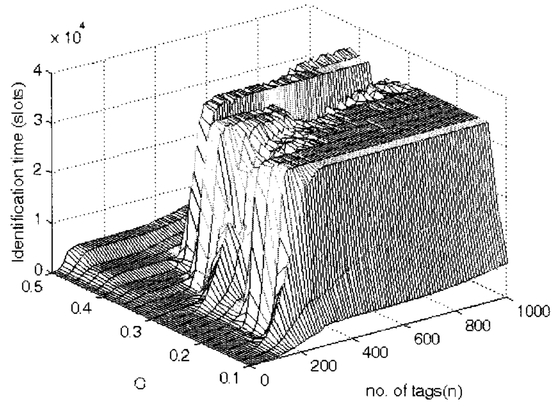

Fig. 4. Identification time of Gen-2 algorithm.

The system efficiency of Gen-2 algorithm is depicted in Fig.5 according to the C value and number of tags. The system efficiency is defined as the average number of singly occupied slots in a frame. In the case of C value with 0.5, the efficiency decreases sharply when the number of tags is over 40. Also, when the number of tags is over 140, the efficiency at C=0.1 is lower than at C=0.3. As shown in Fig.4 and Fig.5, the performance of Gen-2 algorithm without early cancellation scheme are affected by the constant parameter C value of Q-algorithm and number of tags.

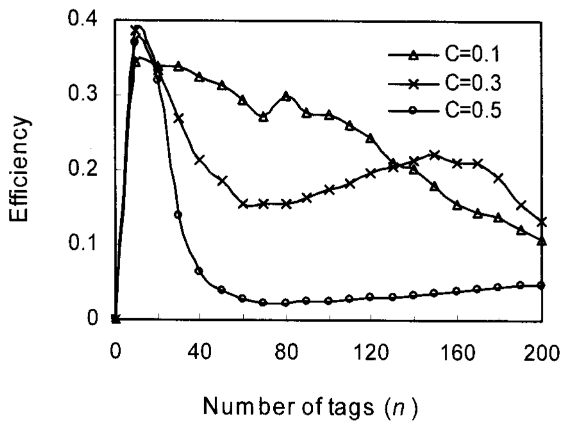

Fig. 5. System efficiency of Gen-2 algorithm.

Fig.6 and Fig.7 show the total identification time and marginal identification time of proposed algorithm with early cancellation scheme, respectively. All the figures are depicted according to the constant parameter C value of Q-algorithm and number of tags.

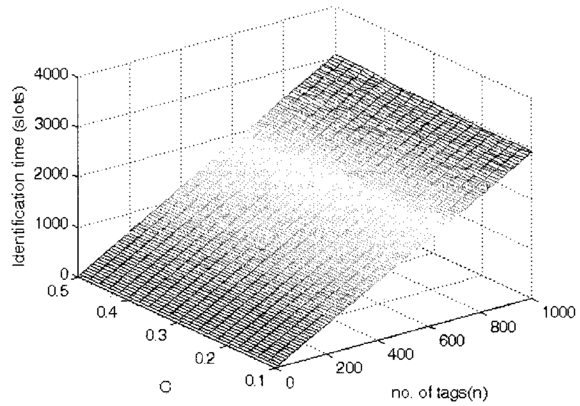

Fig. 6. Identification time of early cancellation scheme.

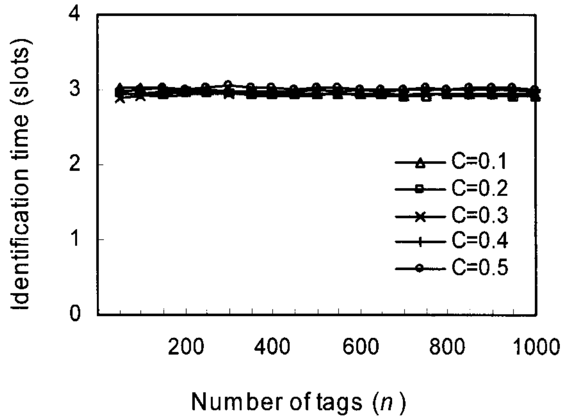

Fig. 7. Identification time per a tag.

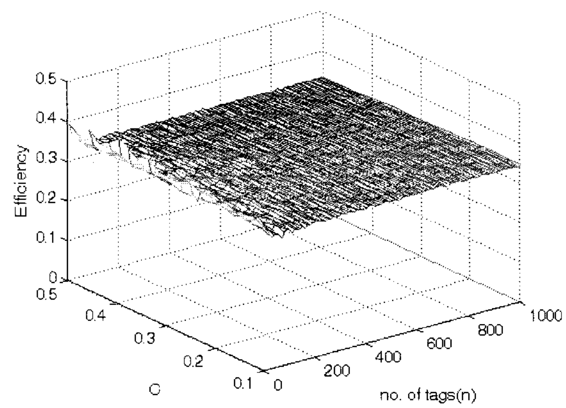

Fig. 8. System efficiency of early cancellation scheme.

The marginal identification time denotes the average number of slots used for identifying a tag. As shown in the figures, the identification time with early cancellation scheme is independent with the constant parameter *C* value of Q-algorithm. This is because a new query round begins with a new slot-count parameter *Q* when the slot-count parameter is decremented or incremented. The average identification time for identifying a tag is 3 slots.

Fig.8 shows the system efficiency of proposed algorithm with early cancellation scheme. As shown in the figure, the system efficiency is also independent with the C value. The efficiency of proposed algorithm shows 0.34 that is almost same as that of slot ALOHA algorithm.

V. CONCLUSIONS

This paper proposed an anti-collision algorithm to enhance the performance of EPCglobal Class-1 Generation-2 anti-collision algorithm. The proposed algorithm applied early cancellation scheme of query round. The reader calculates the slot-count parameter *Q* at every slot through Q-algorithm. If the calculated *Q* value is different with the previous one, the reader transmits a QueryAdjust command to cancel the current query round and begin a new round. A lot of computer simulations were performed. The simulation results showed that the performances of standard Gen-2 anti-collision algorithm were affected by the constant parameter *C* value of Q-algorithm. However, the proposed algorithm with early cancellation scheme showed stable performances regardless of the *C* values.

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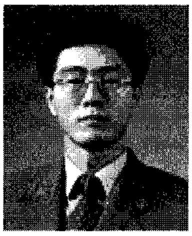

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