

Initial Slot-Count Selection Scheme with Tag Number Estimation in Gen-2 RFID System

Intaek Lim, Youngtae Ryu, *Member, KIMICS*

Abstract—In Gen-2 RFID system, the initial value of Q_{fp} , which is the slot-count parameter of Q-algorithm, is not defined in the standard. In this case, if the number of tags within the reader's identification range is small and we let the initial Q_{fp} be large, the number of empty slot will be large. On the other hand, if we let the initial Q_{fp} be small in spite of many tags, almost all the slots will be collided. As a result, the performance will be declined because the frame size does not converge to the optimal point quickly during the query round. In this paper, we propose a scheme to allocate the optimal initial Q_{fp} through the tag number estimation before the query round begins. Through computer simulations, it is demonstrated that the proposed scheme achieves more stable performance than Gen-2 Q-algorithm.

Index Terms—RFID, Slot-count, Anti-collision algorithm, EPCglobal Class-1 Gen-2, Q-algorithm

I. INTRODUCTION

Radio frequency identification (RFID) systems provide an efficient and inexpensive mechanism for automatically collecting the identify information of an object. In RFID system, tags with unique identifiers communicate with a reader over a wireless multi-access channel. Recently, there has been a lot of effort towards the development of RFID systems for their many promising applications [1]. Especially, over the past decade, RFID technology has been widely adopted in a variety of applications such as purchasing and distribution logistics, electronic payment, and object tracking.

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. 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 [2].

Two major performance measures in RFID system are the tag identification delay and energy consumption [3]. The identification speed will be fast and the energy

consumption will be low as the number of read-cycle is small for identifying all the tags within the identification range of reader. Therefore, an anti-collision algorithm must be carefully designed for conserving low power consumption and fast identification.

There are two types of anti-collision algorithms in RFID systems: probabilistic and deterministic algorithms. EPCglobal Class-1 Gen-2 and ISO/IEC 18000-6 Type C use the probabilistic algorithm as the standard [4][5]. The probabilistic algorithms are based on ALOHA-like protocol that provides slots for the tags to send their data. Almost all the probabilistic algorithms use framed slot ALOHA (FSA), which has been advanced in function by adding slotting and framing on ALOHA. The tags send their identifiers at a randomly selected slot. When collisions occur, the tags that are involved in collisions retransmit their identifiers in the next query round. The probabilistic algorithms may have limitations on the completeness of tag identification because there is still a probability of failing to be identified in a limited time period. The deterministic algorithms are used in EPCglobal Class-0 and ISO/IEC 18000-6 Type B, which uses binary tree-walking scheme [6].

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 size based on the number of tags within the identification range of reader. 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 [7][8].

EPCglobal Class-1 Generation-2 standard proposed Q-algorithm to determine the slot-count for the next query round [4]. Q-algorithm determines the slot-count without conducting the tag number estimation scheme. Therefore, it wastes less computational cost and is simpler than other FSA algorithms. However, the initial value of Q_{fp} , which is the slot-count parameter of Q-algorithm, is not defined in the standard. The standard sets it as 4.0 only for demonstrating Q-algorithm. If we let the initial Q_{fp} be very large, the number of empty slots will be large during the query round. On the other hand, if the initial Q_{fp} is very small, there will be a lot of collided slots. As a result, the identification speed and efficiency will be declined because the frame size does not converge to the optimal point quickly during the query round. Therefore, this paper proposes a scheme to allocate the optimal initial Q_{fp} through the tag number estimation before the query round

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Intaek Lim is with the Department of Embedded IT, Pusan University of Foreign Studies, Busan, 608-738, Korea (Email: itlim@pufs.ac.)

Youngtae Ryu is with the Department of e-Business, Pusan University of Foreign Studies, Busan, 608-738, Korea (Email: youngtae@pufs.ac.)

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This paper is organized as follows. In Section II, we describe Gen-2 anti-collision algorithm and Q-algorithm. In Section III, we describe the problems of Q-algorithm and present the proposed scheme. Section IV shows the simulation results, and Section V concludes the paper.

II. RELATED WORK

A. Gen-2 anti-collision algorithm

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.

If there is only one tag reply for a Query or QueryRep command, it is a successful query round. However, if there is no tags reply or multiple tags reply, we consider it as a failure. Fig.1 and Fig.2 illustrate the timing diagrams for the case of single tag reply and collision or no tags reply, respectively. As shown in the figures, if only one tag transmits its RN16 for a Query or QueryRep command, the reader successfully receives without collisions, and then transmits an ACK command. If the tag receives the ACK command with a correct RN16, it backscatters its PC, EPC, and CRC-16.

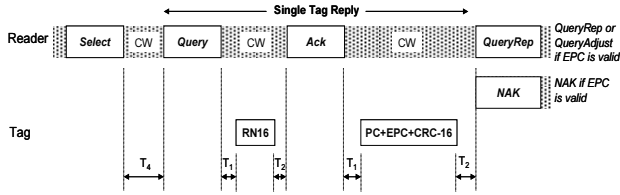


Fig.1. In the case of single tag reply.

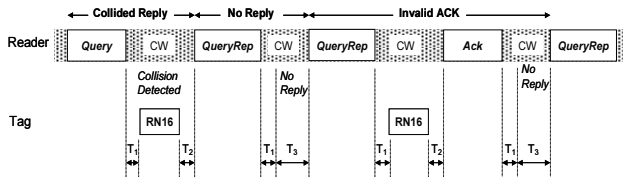


Fig.2. In the case of collision or no reply.

B. Gen-2 Q-algorithm

In EPCglobal Class-1 Gen-2 RFID system, Q-algorithm has been proposed to determine the slot-count in the next query round. Q-algorithm basically calculates the slot-count parameter Q based on the result of tag's reply in a slot. The slot status is classified into three categories: success, collision, and empty slot.

Fig.3 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 weight C value to the previous Q_{fp} , because it

means the slot-count is smaller than the number of tags. If the result of tag's reply in a slot is idle, which means that there are no tag responses in the slot, the reader subtracts the weight C value from the previous Q_{fp} , because the slot-count 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 weight C are $0.1 < C < 0.5$. EPCglobal Class-1 Gen-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.

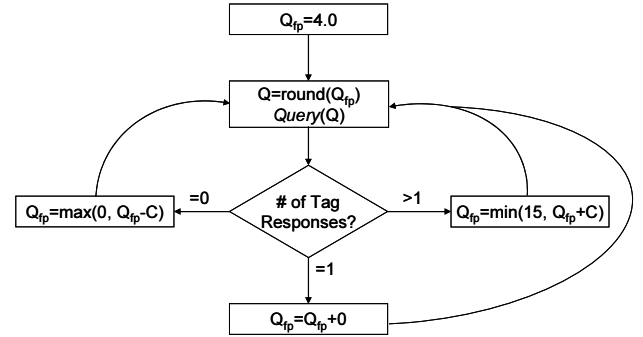


Fig.3. Gen-2 Q-algorithm.

III. PROPOSED SCHEME

A. Research motivations

In Q-algorithm of Gen-2 RFID system, the initial Q_{fp} is not defined in the standard. Therefore, we analyze how the performances of Gen-2 anti-collision algorithm are influenced by the initial Q_{fp} depending on the number of tags within the identification range of reader.

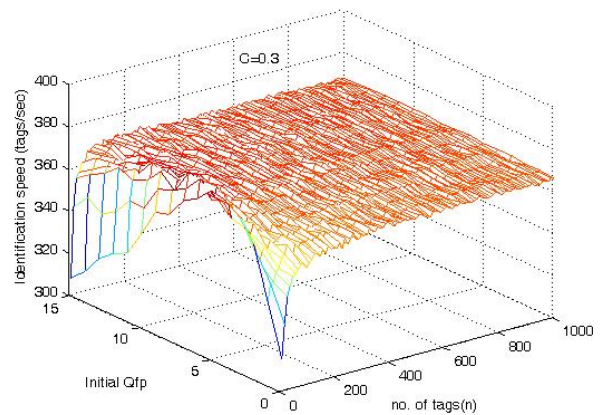


Fig.4. Identification speed according to initial Q_{fp} .

The performance analysis was done by the computer simulations. The simulation parameters are same as the reference [9]. We assume that the Query commands will be transmitted as follows:

- 1) When there is a successful reply, the reader transmits QueryRep command.

- 2) When there is a collided reply or no reply, the reader sends QueryAdjust command if the slot-count gets changed or QueryRep command if the slot-count has no change.

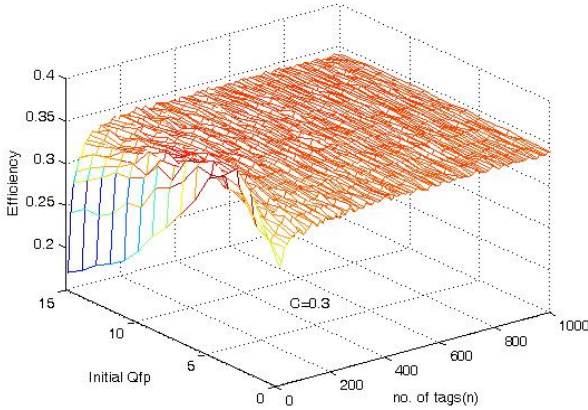


Fig.5. Efficiency according to initial Q_{fp} .

Fig.4 and Fig.5 show the identification speed and efficiency according to the initial Q_{fp} , respectively. The identification speed is defined as the number of tags identified in a second and the efficiency as the number of tags identified in a slot. The weight C value, which is added or subtracted to/from the slot-count, is assumed 3.0. As shown in the figures, if we let the initial Q_{fp} be very small or very large, the identification speed and efficiency decrease when the number of tags is very small. This is because: i) if we let the initial Q_{fp} is very small, almost all the slots will collide, ii) if the initial Q_{fp} is very large, there are a lot of empty slots. Therefore, in order to maximize the performance, the optimal initial Q_{fp} value should be allocated according to the number of tags within the identification range of reader. The number of tags can be estimated before the query round begins.

B. Initial Q_{fp} selection scheme

In this paper, the tag number estimation scheme is used for selecting the initial slot-count value of Q-algorithm. The reader estimates the number of tags by combining the information obtained after the tag number estimation process with the result of probabilistic analysis.

It is assumed that a frame consists of N slots during the estimation process and the number of tags is n . Let N_e and N_s be the number of empty slots and successful slots observed after the estimation process, respectively. If we assume that N_e and N_s are equal to their expected values, respectively, then N_e and N_s can be given as follows [9].

$$N_e = N \left(1 - \frac{1}{N}\right)^n \quad (1)$$

$$N_s = n \left(1 - \frac{1}{N}\right)^{n-1} \quad (2)$$

By solving Eq.(1) and (2) for the number of tags n , we

obtain

$$n = (N - 1) \frac{N_s}{N_e} \quad (3)$$

The number of colliding tags n_c can be estimated by subtracting N_s from Eq.(3) as following:

$$n_c = (N - N_e - 1) \frac{N_s}{N_e} \quad (4)$$

As shown in Eq.(4), if there are neither successful slots nor empty slots, it is hard to use the above equation. Therefore, the result of probabilistic analysis must be supplemented for the exact estimation. If we let α be the average number of tags in each collision slot, α can be given by

$$\alpha = \frac{\sum_{r=2}^n r N \binom{n}{r} \left(\frac{1}{N}\right)^r \left(1 - \frac{1}{N}\right)^{n-r}}{N - N \left(1 - \frac{1}{N}\right)^n - n \left(1 - \frac{1}{N}\right)^{n-1}} \quad (5)$$

The optimal performance for the identification speed and efficiency can be obtained when the frame size is equal to the number of tags. Therefore, from Eq.(5), the average number of tags in each collision slot is 2.4. If we let N_c be the number of collision slots, the number of colliding tags with the probabilistic analysis is give by

$$n_c = 2.4 N_c \quad (6)$$

By combining the observed result in Eq.(4) with the probabilistic result in Eq.(6), we can estimate the number of collided tags during the estimation process as following.

$$n_c = \begin{cases} (N - N_e - 1) \frac{N_s}{N_e} & , \text{if } N_e \neq N_s \neq 0 \\ 2.4 N_c & , \text{otherwise} \end{cases} \quad (7)$$

The number of tags within the identification range of reader consists of the number of collided tags and successful tags. Therefore, the number of tags n obtained during the estimation process is as follows:

$$n = n_c + N_s \quad (8)$$

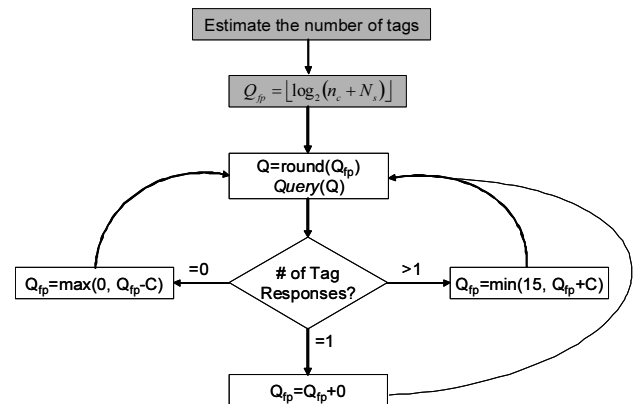


Fig.6. Revised Q-algorithm.

The frame size for maximizing the performance of FSA algorithm can be taken through analytical method. As a

result of performance evaluation of FSA algorithm through analytical method, the optimal frame size is same as the number of tags within the identification range of reader [10]. In Gen-2 RFID system, a frame size in the query round can be represented with powers of 2. Therefore, the initial slot-count, which is suitable for the number of tags obtained during the estimation process, can be derived as follows, and the revised Q-algorithm with this scheme is depicted in Fig.6.

$$Q_{fp} = \lceil \log_2(n_c + N_s) \rceil \quad (9)$$

IV. SIMULATION RESULTS

In this paper, we evaluate the performance for the proposed scheme through the computer simulations. The system parameters for simulations are same as the reference [9]. And it is assumed that the rules for transmitting Query command are same as Section III. We compare the proposed scheme with Gen-2 Q-algorithm. It is assumed that the weight C value for both algorithms is 3.0. And we assume that the initial slot-count Q_{fp} for Gen-2 A-algorithm is 4.0. All the results of simulation were averaged after iterating 100 times.

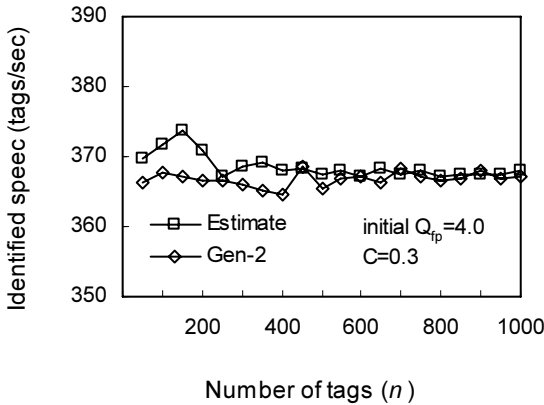


Fig.7. Identification speed (large number of tags).

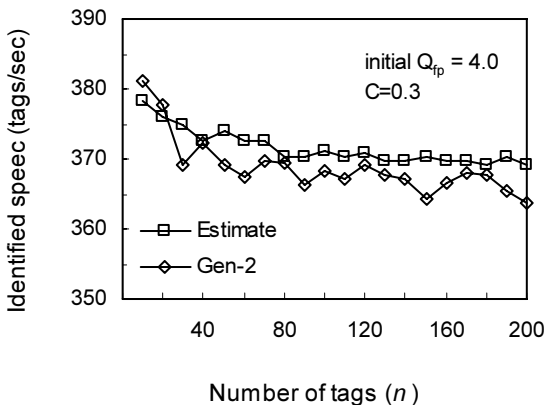


Fig.8. Identification speed (small number of tags).

Fig.7 and Fig.8 show the identification speed according to the number of tags within the identification range of reader. As shown in Fig.7, if there are a lot of tags, the identification speed for the proposed scheme and Gen-2 algorithm is nearly same as average 369 and 368 tags per a second, respectively. But when the number of tags is small, Fig.8 demonstrates that the identification speed for the proposed scheme is more stable than Gen-2 algorithm.

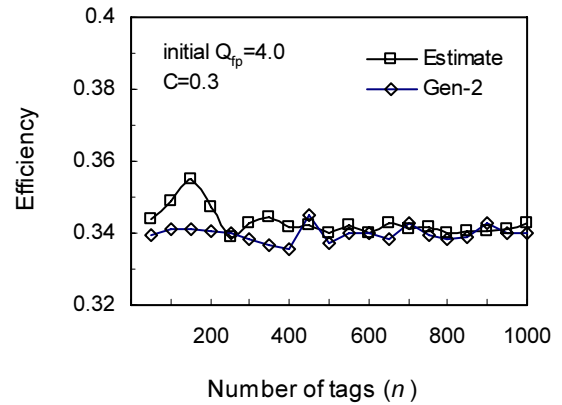


Fig.9. Slot efficiency (large number of tags).

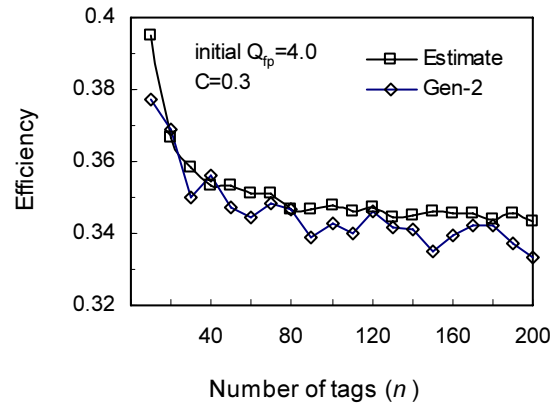


Fig.10. Slot efficiency (small number of tags).

Fig.9 and Fig.10 depict the slot efficiencies in the case that the number of tags is large and small, respectively. When the number of tags is large, the slot efficiencies for the proposed scheme and Gen-2 algorithm are 34.2% and 33.9%, respectively. If the number of tags is small, Fig.10 shows that the slot efficiencies for both algorithms are 35% and 34%, respectively. As a result, if there are a lot of tags within the identification range of reader, there are no significant differences in the performances between the proposed scheme and Gen-2 algorithm. But the proposed scheme outperforms Gen-2 algorithm, and the proposed scheme is more stable than Gen-2 algorithm. This is because the proposed scheme allocates the initial slot-count values depending on the number of tags.

V. CONCLUSIONS

In EPCglobal Slass-1 Gen-2 RFID system, Q-algorithm is proposed to determine the slot-count for the next query round. In Q-algorithm, when the result of tag's reply is idle, the reader subtracts the weight C from the slot-count. When a collision occurs, the reader adds the weight to the slot-count. But the initial slot-count values are not defined in the standard.

In this paper, we proposed a scheme to allocate the initial slot-count Q_{fp} based on the number of tags. We applied the tag number estimation scheme to the original Gen-2 A-algorithm. In the proposed scheme, the reader estimates the number of tags within its identification range before the query round begins. Then it allocates the optimal initial slot-count that is capable of maximizing the performances. The simulation results demonstrated that if the initial slot-count was fixed with very small or large values, the identification speed and efficiency fluctuate severely when the number of tags is small. But, because the proposed scheme allocates an optimal initial slot-count value at every query round, the proposed scheme shows predominant performance compared with Gen-2 algorithm. Moreover, the performance of proposed scheme is more stable than Gen-2 algorithm though the number of tags is small.

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Intaek Lim received the B.S. degree in computer science from University of Ulsan, Ulsan, Korea, in 1984, and the M.S. degree in computer science and statistics from Seoul National University, Seoul, Korea, in 1986. He received the Ph. D. degree in computer engineering from University of Ulsan, Ulsan, Korea, in 1998. From 1986 to 1993, he was a Senior Researcher at Samsung Electronics Co., Ltd. In 1998, he joined the faculty at Pusan University of Foreign Studies, Busan, Korea, where he is currently a Professor in the Department of Embedded IT. From July 2006 to June 2007, He was a visiting scholar at Cleveland State University in USA. His research interests include the MAC protocol design, ad-hoc network, RFID, and mobile computing.



Youngtae Ryu is associate professor, Department of e-Business at the Pusan University of Foreign Studies. He received Ph.D.(Major in ATTD and Minor in BCIS) from the University of North Texas in 1997, MBA(Major in Management Science) from the Pusan National University in 1983 and MBA(Major in BCIS) from the University of North Texas in 1992, and Bachelor degree in Business Administration from the Pusan National University in 1980. His current research interests focus on Information Systems Research, Database Management System, System Analysis and Design, ERP, and Knowledge Management.