CRC-16-BASED COLLISION RESOLUTION IN EPCGLOBAL CLASS1 GENERATION2 RFID SYSTEMS

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Abstract: The 900 MHz UHF passive RFID systems have drawn attraction because they have long access distance and rapid identification speed. One of the most representative international standards is EPCglobal Class1 Generation2 (EPCglobal Gen2). RN16 which is used in the EPCglobal Gen2 standard assists a reader to detect tag collision rapidly, but it may be removed because it does not have information of products. In this paper, we propose an algorithm to replace RN16 with CRC-16 to reduce the identification time. We show that CRC-16 has similar characteristics of RN16 and our proposed scheme reduces the number of bits required for one tag identification.

1 INTRODUCTION

Radio Frequency Identification (RFID) is a technology by which a reader recognizes the information of objects to which tags are attached for wireless communications with the reader. RFID systems have become prevalent in supply chain management, in manufacturing process, in the industries to require the identification of products, and so on, because they are able to transmit much data rapidly with the use of wireless channel. Indeed they are increasingly being used for automated identification systems and come into the spotlight for the realization of the ubiquitous society (R. want, 2006).

In RFID systems, a basic process for tag identification is that if a reader queries tags for information, the tags receiving the query signal transmit their IDs to the reader. When only one tag is in the reading range of the reader, tag identification is very simple and easy. When, however, many tags are in the reading range, tag collisions may occur due to the simultaneous transmission of their information. Thus an efficient RFID tag anti-collision algorithm is necessarily required in RFID systems to identify a lot of objects in real time. One of the most popular algorithms used for tag anti-collision is Framed-slotted ALOHA (FSA).

In FSA-based tag anti-collision algorithms, to reduce the probability of tag collision, a frame is divided into several timeslots. And each tag selects randomly one timeslot for the transmission of the ID. When a tag transmits its information in a timeslot, a reader can read the tag successfully. When, however, a timeslot experiences collision by more than one tag, the reader can not identify their information. Unread tags must retransmit their information in the next frame. This is inefficient due to waste of collision timeslots. Also if there are many idle timeslots in a frame, it is not efficient too. The throughput of FSA may become low as the number of tags increases. Thus it is necessary to change the next frame size appropriately for high efficiency after estimating the number of tags in the reading range as in Dynamic FSA (DFSA) (S. Lee, S. Joo and C. Lee, 2005). EPCglobal Class1 Generation2 (EPCglobal Gen2) (*EPCTM* Radio-frequency Identification Protocols Class-1 Generation-2 UHF RFID Protocol For Communications at 860MHz-960MHz Version1.0.9, 2005) is a representative international standard using DFSA.

Unlike general DFSA having fixed timeslots for success, idle, and collision, DFSA of EPCglobal Gen2 adopts different timeslots. To reduce the waste of time when a collision occurs, a relatively short Random Number with 16 bits (RN16) is transmitted before Electronic Product Code (EPC). Depending on the success or failure of RN16 reading, a reader decides whether it reads in the EPC of a tag or not. The RN16 does not contain any information of a

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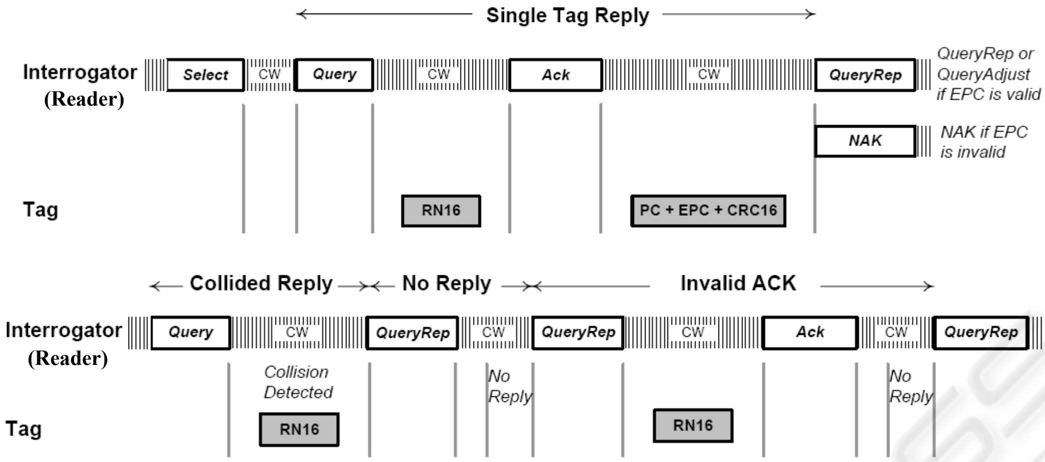

Figure 1: Tag identification mechanism using RN16 and having different time duration for success, idle, and collision.

product, and may consume extra time. Thus it would be useful to reduce it if possible.

In this paper, we propose to use CRC-16 instead of RN16 in EPCglobal Gen2 protocol, resulting in reduced identification time. The outline of this paper is organized as follows. In Section II, we summarize the EPCglobal Class1 Generation2 standard. Our proposed scheme is presented in Section III. Performance evaluation and comparison via simulations are presented in Section Ⅳ, and finally Section Ⅴ draws conclusion.

2 EPCGLOBAL C1 GEN2

In EPCglobal Gen2, RN16 is used by a tag when it sends the information to a reader. If long Protocol Control (PC), EPC, and CRC-16 are transmitted directly without transmitting short RN16 first, when a collision occurs, it may waste time since another PC, EPC and CRC-16 needs to be transmitted. Figure 1 shows the mechanism using RN16 with different time duration in success, idle, and collision. In Figure 1, each tag randomly selects a timeslot, and it transmits the 16 bit RN16 in the timeslot. If the reader does not detect any such signal, it tries to read tags in the next timeslot after waiting for few time slots. If the reader identifies RN16 successfully, it attempts to read the tag information by sending an ACK command to the tag. When, however, RN16 is not identified correctly, or there is no reply to ACK, the reader comes to a conclusion that a collision occurs.

In EPCglobal Gen2, communication between a reader and tags is conducted through the steps of Figure 2. A reader uses a *Select* command to select a particular slot in which it identifies a tag. To identify tags, the reader transmits some commands to the tags in the Inventory round. The Access state of a reader means that the reader reads from or writes to individual tags after the tags are uniquely identified

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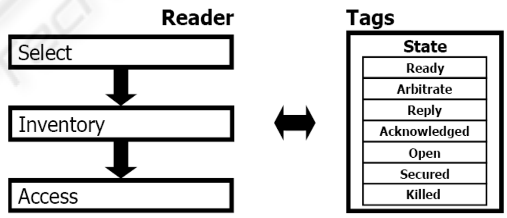

Figure 2: Reader/Tag operation and the state of tags.

The tags receiving the Select command prepare for operation and stay at the Ready state until it receives a *Query* command. The tags which receive the *Query* command generate their slot counters ($0 \sim 2^Q-1$), i.e., RN16, depending on the Q value (0~15) during the *Query* command by their Random Number Generator (RNG). When the value of the slot counter of a tag is decremented to 0, the tag goes to the Reply state and backscatters its RN16 to the reader. If the reader does not detect a collision of RN16, it issues an *ACK* command including the RN16 of the tag. After the *ACK* is received, the tag changes its state to the Acknowledged state. If the received *ACK* is valid, the tag backscatters its PC, EPC and CRC-16, and the reader conducts the CRC

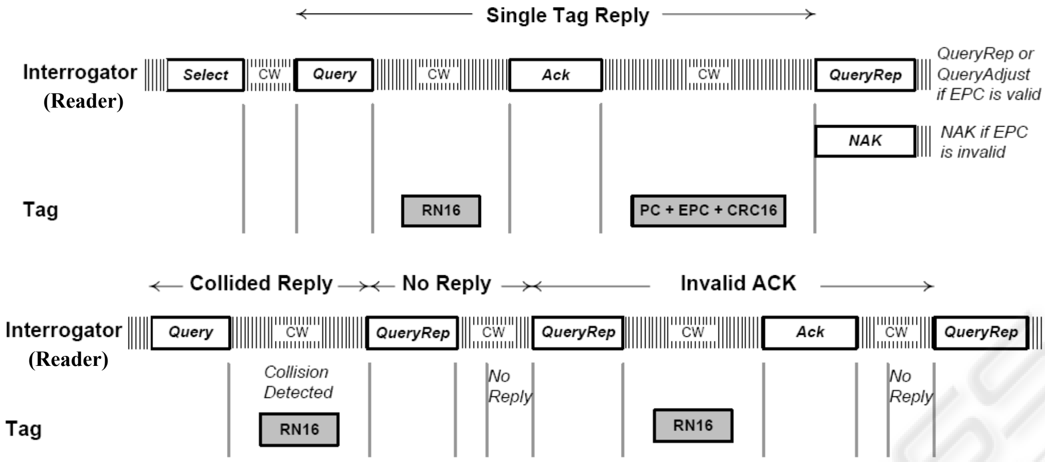

Figure 3: The proposed tag identification mechanism using CRC-16 and having different time duration for success, idle, and collision.

check. Without any error, the reader identifies the information of the tag successfully. Until the value of the slot counter becomes 0, tags stay in the Arbitrate state, holding state. And, the tags in the Arbitrate state do not participate in the current Inventory round until their slot counters become 0. The tags shall decrement their slot counters by 1, every time they receive a *QueryRep* command. If a round to identify tags is over, but there are still unread tags, the reader broadcasts a *QueryAdj* command to the tags.

3 PROPOSED IDENTIFICATION SCHEME

In this paper, we propose to use CRC-16 which has the similar role of RN16 in the EPCglobal Gen2 protocol. In EPCglobal Gen2, when tags transmit their information to a reader, RN16 shall be generated before tags backscatter the information. RN16 generated by RNG shall meet the following randomness criteria (J. Choi, D. Lee, H. Lee, 2007).

- **Probability of a single RN16:** The probability of an RN16 shall be bounded by $0.8/2^{16} < P[RN16 = j] < 1.25/2^{16}$, where j is a number created by RNG.
- **Probability of simultaneously identical sequences:** For tag population up to 10,000 tags, the probability that any two or more tags simultaneously generate the same sequence of RN16s shall be less than 0.1%.
- **Probability of predicting an RN16**: An RN16 shall not be predictable with the probability greater than 0.025%.

We first investigate the property of CRC-16 whether it resembles that of RN16, and present the proposed identification mechanism

3.1 A Uniformly Random Characteristics of CRC-16 as in RN16

All burst errors of length less than or equal to the degree of the polynomial can be detected by CRC (B. A. Forouzan, 2003). In CRC-P, assuming random information of P bits and applying CRC-P mechanism to the information, the CRCs from two different random information should be different. If the CRCs of two different information bit sequences are the same, a burst error can not be detected by the CRC check when one information bit sequence becomes the same with another by channel error. It is against the fact that all burst errors of length less than or equal to the degree of P can be detected. For example, let us consider two arbitrary information part of PC+EPC, 1111000011110000 and 1100110011001100, and assume that they have the same CRC R made by the CRC generator. When a sender transmits the 1111000011110000 and R to a receiver, and the altered information, 1100110011001100 and R by channel error, is received, the receiver can not identify the error. Thus each information with sequential P bits should have only one corresponding and unique CRC-P.

In EPCglobal Gen2, a tag uses CRC-16 to check the integrity of PC and EPC, backscattered from the tag to a reader. And, as we examined before, all of the CRC-16s are uniquely different for every sequential 16 bits. It means that the probability of any CRC-16 is $1/2^{16}$ and it has uniformly random characteristics as in RN16. Thus, we can know that probability of a single CRC-16 is bounded by $0.8/2^{16} < P[\text{CRC-16}=j] < 1.25/2^{16}$, where j is a CRC-16 number, like that of a single RN16. It also meets the second characteristic of RN16, because the number of tags that all 16 bits of CRC-16 are the same is found by multiplying 10,000 by the probability of a single CRC-16 and it is less than 0.1% of 10,000 tags. When a reader identifies tags, the tags might be randomly selected and the probability of predicting a CRC-16 might be $1/2^{16}$. And the probability that a CRC-16 is predictable is not greater than 0.025%.

3.2 Proposed Identification Mechanism using CRC-16

Figure 3 shows a simple proposed mechanism using CRC-16 instead of RN16. In the proposed scheme, slot counters of tags are also determined and decremented by *Query*, *QueryRep* or *QueryAdjust* commands. When the value of the slot counter of a tag is 0, the tag backscatters the CRC-16 to the reader. Note that the CRC-16 is generated from the PC+EPC. After the tag backscatters its CRC-16, if the reader receives CRC-16 of the tag correctly without collision, the reader requests PC and EPC information of the tag by transmitting an *ACK* command to the tag. The reader receiving PC and EPC conducts the CRC check with the already backscattered and received CRC-16. In the case that a collision of CRC-16 occurs or an invalid *ACK* command is transmitted to the tag, the tag does not reply to the reader. And, if there is no reply during the predetermined time, the reader tries to read the tag with the next smallest slot counter.

4 PERFORMANCE EVALUATION

We evaluate the performance of the mechanism using proposed CRC-16 and the existing mechanism with RN16. We set the length of tag ID and the commands of a reader as follows (see Table 1).

In the EPCglobal Gen2 standard, the Q selection algorithm that tags choose Q values from *Query* command is used for tag anti-collision. The Q selection algorithm based on Framed Slotted ALOHA (FSA) adjusts the number of timeslots in the next round as the number of collision and idle timeslots and tags select different random counter values again from the reader reissuing *Query* or *QueryAdjust* command. However, the Q selection algorithm is not specified in the standard (G. Khandelwal, K. Lee, A. Yener, and S. Serbetli, 2007). So we apply Dynamic Framed Slotted ALOHA (DFSA) instead of the Q selection algorithm to solve the problem of tag collision. And we assume that the reader can knows the number of tags accurately.

Table 1: The length of the tag ID and the reader commands.

Command	No. of bits	Command	No. of bits
RN16	16 bits	Select	44 bits
PC	16 bits	QueryAdj	9 bits
EPC	64 bits	QueryRep	4 bits
Query	22 bits	ACK	18 bits
NAK	8 bits	RN16	16 bits

Figure 4 depicts that CRC-16 is uniformly random. When an arbitrary CRC-16 is given, the x axis denotes the simulation number, and y axis represents how many repetitions are needed until the CRC-16 of PC and EPC of a randomly selected tag and the given CRC-16 becomes the same. If CRC-16 is uniformly random, the same CRC-16 might be repeated every 2^{16}=65536 on average. The difference between the expected mean, 65536, and the simulation mean, 65869, is very close within about 0.5%. Thus, we can verify the uniformly random characteristics of CRC-16.

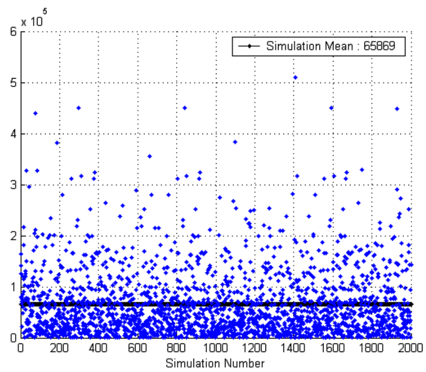

Figure 4: The uniformly random characteristics of CRC-16.

Figure 5 shows the number of used bits per one tag identification with the varying number of tags under no channel error. When the number of tags is

256, the proposed scheme needs 149.7 bits for one tag identification and the scheme using RN16 requires 165.48 bits for one tag identification. The difference between the number of bits required in the proposed scheme and that in the existing scheme is about 16 bits because it does not use as many bits as RN16. Thus the performance of the proposed scheme is improved up to 9.53%.

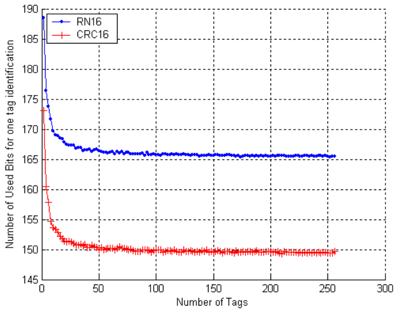

Figure 5: The number of used bits for one tag identification with the varying number of tags, PER=0.

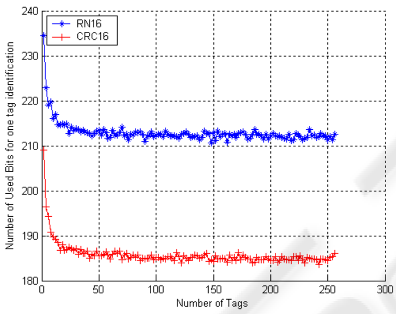

Figure 6: The number of used bits for one tag identification with the varying number of tags, PER=0.3.

There may be lots of channel errors in RFID systems because of low power backscattering of tags. Figure 6 demonstrates how much improvement in our proposed scheme is achieved under error-prone environment. The figure shows the number of bits per one tag identification with the varying number of tags. Under channel error environment, when the packet error rate (PER) is 0.3 and the number of tags is 256, the proposed scheme uses 186.09 bits for one tag identification, while the scheme using RN16 uses 212.62 bits for one tag identification. This result also depicts that the proposed scheme consumes less time than the scheme using RN16, about 16 bits because 16 bits of RN16 are saved as in the case of no channel error. Thus, we can see that our proposed scheme is shown to improve the performance about 12.5%.

5 CONCLUSIONS

We have proposed a simple and efficient tag identification mechanism using CRC-16 instead of RN16 in EPCglobal Gen2. In this paper, we have verified that CRC-16 is uniformly random like RN16, and thus it can provide the similar role of RN16. According to the simulation results under both error-free and error-prone environment, the proposed algorithm using CRC-16 instead of RN16 requires less time than that using RN16 as in EPCglobal Gen2

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