An Improvement of Bin-slotted Anti-collision Algorithm for Ubiquitous ID System

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ABSTRACT

In this paper, an overview of anti-collision algorithm for RFID system of a standard EPC Class1 protocol is presented, and the bin-slotted dynamic search algorithm (BDS) based upon the slotted ALOHA and binary tree procedure is proposed and analyzed. Also, the performance is evaluated as comparing the BDS algorithm with the standard bin-slotted algorithm (BSA) through the simulation program. The performance of the proposed BDS algorithm is improved by dynamically identifying the collided-bit position and the collided bins stored in the stack of the reader. As the results, the number of request command that a reader send to tags in the reader's interrogation zone and the total recognition time are decreased to 59% as compared with BSA algorithm. Therefore, the tag identification performance is fairly improved by resolving a collision problem using the proposed BDS algorithm.

Keywords: *RFID, Anti-collision Algorithm, EPC Class1, Bin-slot, Dynamic Search*

1. ITRODUCTION

Radio frequency identification (RFID) is considered as the key technology of the ubiquitous computing environments such as an ubiquitous sensor network (USN). International organization for standardization (ISO) and EPC-global organization have announced their documents for RFID Air-interface which is a standard communication protocol between a reader and tags at the 860~960MHz (ISO 18000-6, EPC Class1). In USN, RFID system can be applied to various such as supply chain management, inventory tracking and access control [1][2].

RFID system can simultaneously recognize several tags within a reader interrogation zone using anti-collision algorithm. Also, it can identify the unique tag ID, or other information included in microchip of a tag. A typical RFID system consists of a reader, tags and a middleware. For identify tag's serial ID, the reader communicates with tags through a radio frequency (RF) communication link. An individual tag is first identified from a group of tags in the reader's interrogation zone using anti-collision algorithms and then the communication occurs between the identified tags and the reader. A tag consists of an antenna and a microchip storing the object ID data. A middleware processes, controls, and manages the object data collected from the RFID reader. If there are several tags in the reader's interrogation zone, collision occurs between the data received from the tags. The collision can be resolved using anti-collision algorithms [3][4]. The capability of tag recognition and selection depends on the performance of anti-collision algorithm.

The anti-collision algorithms are binary search procedure (BS) and ALOHA procedure [5][6][7]. In the BS procedure, a tag is selected from a group by intentionally causing a data collision in the serial numbers transmitted to a reader following a request command. If this procedure is to succeed, it is crucial that a reader is capable of determining the precise bit position where the collision detected using a suitable data processing scheme. In the ALOHA procedure to resolve a collision, tags only transmit the defined data packets on the synchronous time slots to a reader. The synchronization of all tags necessary for this is controlled and checked by a reader.

In this paper, the bin-slotted dynamic search (BDS) algorithm based on the slotted ALOHA and binary tree procedure is proposed. Also, the performance of the proposed BDS algorithm and of the bin-slotted algorithm (BSA) which is standard EPC class1 protocol are compared and investigated. By dynamically identifying the collision-bins stored in the stack of the reader, we show that the performance of proposed BDS algorithm is improved. The remainder of the paper is organized as follows. In section 2, it explains RFID system based on the bin-slotted algorithm (BSA), which is based on the EPC Class1 protocol. In section 3, the bin-slotted dynamic search algorithm (BDS) is proposed. In section 4, the performance of those algorithms is compared, and the conclusion is given in section 5.

2. RFID SYSTEM BASED ON EPC CLAS1 PROTOCOL

In UHF EPC Class1 protocol regulated in the 860~930MHz frequency range, communication between a reader and a tag is performed in a packet based manner, where a single packet

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contains a complete command from a reader and a complete response from a tag. The communication method used between them is a half-duplexing scheme, meaning that a reader talks and tags listen, and the intended interrogation zone of a reader is nominally 2~10m area. A reader transmits a complete command which is modulated by RF signal to a tag. A tag receives both information and operating energy from RF signal of a reader. And then the tag transmits its stored data to the reader by backscatter modulation signal. Tag ID data of EPC is formatted by [HEADER] [DOMAIN MANAGER] [OBJECT CLASS] [SERIAL NUMBER], and its numeric is composed of 64 bits and 96 bits [8] [9].

An EPC Class1 tag containing a write-once-read-many (WORM) memory is designed to communicate its identifier and other information required to acquire the identifier during communication process. A Class1 tag includes error detection code, unique identifier and short password. The unique identifier is validated by representation of EPC and the error detection is verified by CRC. Class1 tag data are stored in the identical tag memory.

2.1 Reader Command and Tag Response

A complete command from a reader consists of eight fields and five parity bits over those fields. The commands enable selection based on the tag's CRC, EPC and password. The command format is as follows.

[PREAMBLE][CLKSYNC][SOF][CMD][P1][PTR][P2][LEN][P3][VALUE][P4][P5][EOF]

[PREAMBLE] is the continuous wave (CW) signal that supply energy to tags, and its duration is 64μs. [CLKSYNC] consists of a serial bit string of 20 binary zeros for on-tag clock synchronization. [CMD] specifies the command being sent to the tag and the number of bit is eight. [PTR] is the starting point for tags to attempt a match with data specified in the [VALUE] field and the number of [PTR] is represented using eight bits. [LEN] is length of data being sent [VALUE] field, and the number of [LEN] bit is represented using eight bits. [VALUE] is data that the tag will attempt to mach against its identifier, and length of [VALUE] is variable. [SOF] is the start of frame indicator and [EOF] is the end of frame indicator.

The commands that a reader sends to tags are divided into required commands and identifier programming commands. The required commands called reader commands are used in tag recognition process on product supply line. Identifier programming commands are used in identifier program before product supply line. The required command and programming commands are defined on EPC Class1 protocol[8].

A Class1 compliant tag will change its internal state or perform backscatter modulation in response to the commands. If a tag in interrogation zone is activated by a continuous wave signal (CW) of suitable power from a reader, the tag gets into 'Awake' state that can be changed into all possible state. The tag receives the required commands from a reader gets into reply state, and transmits its response signal to a reader. Whenever a reader selects tags, the reader transmits 'Quiet' command to the identified tag because the signal from the completely identified tag act as interference to the others. And the tag received the command gets into 'Asleep' state for a while to do not respond. Reader commands mainly used in tag recognition process are PingID and ScrollID. A tag gets into 'Reply' state whenever it receives PingID and ScrollID command. PingID command requires signaling of the tag, and ScrollID command matches and identifies the tag.

Fig. 1 shows tag response for PingID command and the bin-modulation procedure that represents the process. A collision occurs when several tags respond in one bin-slot. However, when one tag responds in one bin-slot, collision does not occur. In tag recognition process, a reader after transmitting PingID performs the bin-modulation work of 3-bit to tags in interrogation zone. The tags matching [VALUE] beginning at the location [PTR] respond by sending 8-bit of the tag identifier beginning with the bit at the location [PTR]+[LEN]. The 8-bit reply is communicated on one of 8 bins delineated by bin-modulation from the reader. If the collision occurs, the reader repeatedly transmits PingID adding the bin data on [VALUE] to the tag. And then if there is realized without the collision between tags, the reader transmits ScrollID adding the bin data on [VALUE] to the tag. The tag matched by ScrollID responds its entire ID to the reader. By checking the CRC of Tag ID, the reader completely identifies the tag.

2.2 RF Signal between Reader and Tag

There are five distinct phases in reader-to-tag communication. Reader-to-tag communication begins with transaction gap in the first phase ($1.25T_0$), followed by 64μs CW period in the second phase. The first and the second phase comprise the [PREAMBLE] of the reader command. The third phase is data modulation window that transmits command packet of the reader. A short tag setup period in the fourth phase provides time for the tags to interpret and begins executing the command just issued by the reader. Thereby, the reader enters a low modulation phase during the tags response to the just communicated command. This process is shown in Fig. 1.

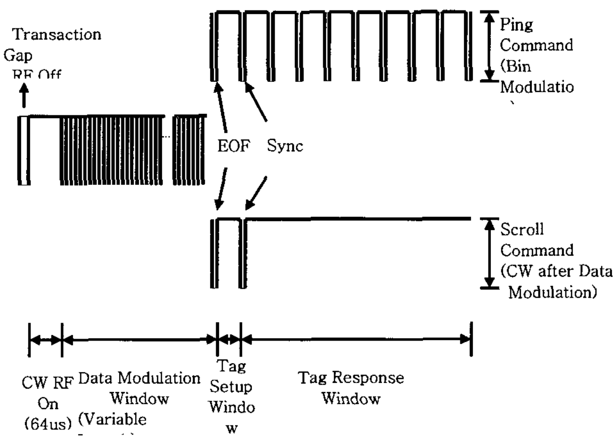

Fig. 1. Reader-to-tag modulation

At the beginning of data modulation, the reader provides a master clock signal to tags. This is [CLKSYNC] period of the command. The time between the negative-going edges of the low intervals determines the reader-to-tag data rate. In order for the tag to be able to detect the next transaction gap, the reader must start the next transaction within the coast interval. Coast interval has been regulated by maximum 20ms in the EPC Class1 protocol. Tags reply at the fifth phase is that response of tag's ID from ScrollID command and PingID command.

3. THE BIN-SLOTTED DYNAMIC SEARCH ALGORITHM

The bin-slotted dynamic search algorithm(BDS) is hybrid algorithm based on the slotted ALOHA procedure and binary tree procedure. In the binary tree algorithm scheme, a reader queries to all tags for the next bits of their ID number and typically searches by bit-by-bit scheme. The bin-slotted algorithm (BSA) searches by bin-by-bin scheme with just 3-bit in 8 bin-slots and sends repeatedly the request commands to recognize all tags without storing the collided bin response data in the stack of the reader. However, the bin-slotted dynamic search algorithm proposed in this paper searches from 3-bit up to the maximum 8-bit in 8 bin-slots using the collided bin response data stored in the stack of the reader. The number of slot is the same with that of BSA. On detecting the collision-bins, the reader splits the respond set and queries until there is only one tag response using the BDS algorithm. The bin extension form is illustrated in Fig. 2.

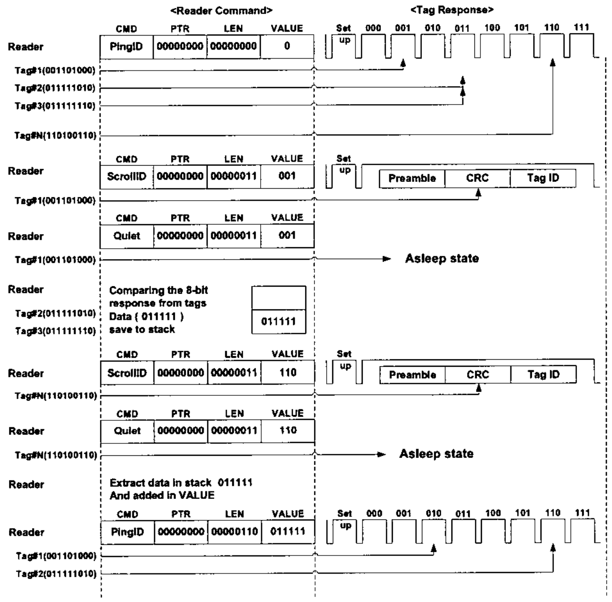

Fig. 2. Bin-slotted dynamic search algorithm

In the BSA procedure, tag recognition process is begun by that the reader transmits PingID command including 'Value = 0, Length = 0' to tags in the reader's interrogation zone. The reader executes bin-modulation work after transmitting PingID command and the tag coinciding with the bin data replies in each bin-slot. The reader examines bin-slots, and if the collision does not take place, the reader sends ScrollID command adding the bin data on [VALUE] to tags. The tags consistent with the value of ScrollID send their entire ID to the reader as the response for ScrollID command again. The reader achieves CRC check if there is no error for the stored ID data of tag. If the collision occurs in bin-slots, the reader restarts processing procedure by PingID command adding the bin data on [VALUE]. The bin-slots examination begins from the first bin-slot (the value of '000') again.

In this paper, by introducing the concept of stack and dynamic bin search in the bin-slotted algorithm (BSA), we reduce the number of PingID command, and the recognition time of tags.

First, tag recognition process is initiated by the reader sends PingID command to tags in interrogation zone. The reader performs bin-modulation after transmitting PingID command and the tag coinciding with the bin data responds in its bin during the bin-modulation. The reader examines the bins. If the collided bins do not exist, the reader adds the bin data on [VALUE], sends ScrollID command to tags and recognizes the tag IDs perfectly. Otherwise, if the collided bins exist, the bin response data are stored in the stack of the reader. In order to recognize the collided tags, the reader dynamically examines the collision-bit position of stored data in the stack. If the stored data have the collision, the reader transmits PingID command adding the data which is before until up to collision-bit position on [VALUE] to the tags. The above process progresses until there is no data in the stack. The BDS algorithm procedure is briefly illustrated as follows.

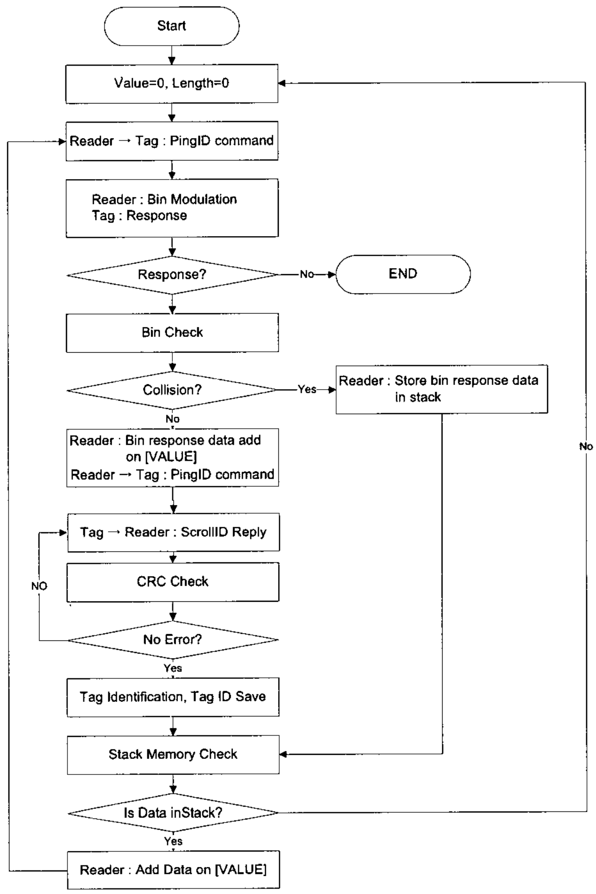

Fig. 3. Flow chart of the proposed BDS algorithm.

BDS Algorithm Procedure

Step 1. Set [VALUE] = 0 and [LEN] = 0 ,
Reader → Tag : PingID command

Step 2. Reader : Bin_modulation, Tag : PingID reply

Step 3. Reader : Bin check

Step 4. If there is no collision at the bin,
add the bin data on [VALUE]
Reader → Tag : ScrollID command
Tag : ScrollID reply
Reader : CRC check, If no error, save TAG ID

Step 5. If there is the collision at the bins,
store the bin response data in the stack

Step 6. Reader : check the stack

Step 7. If there are the collision data in the stack, extracts the data, dynamically examine the collision-bits position and add the data on [VALUE]

Reader → Tag : PingID command

Step 8. If there is no data in the stack, break

Step 9. Repeat Step 2 ~ Step 8.

4. SIMULATION RESULTS

In this section, we simulate the BSA algorithm and the proposed BDS algorithm, compare the performance between them. The first algorithm is BSA algorithm based on the EPC Class1 protocol. The communication between the reader and tags and the recognition procedure are begun from the starting point of the procedure without depending on whether bin response data occur a collision during bin-modulation, or not. The second algorithm is BDS algorithm that is improved by checking after storing the response data of collision-bins in the stack. Performance comparison for two methods is analyzed by the simulation program coded by C language. According to processing procedure of algorithms, bin-modulation between the reader and tags is executed after transmitting every PingID command. In order to calculate the number of reader command identifying tags, the number of bit string of tag ID sets by 64 bits. The tag set is from 10 to 1000 tags. Table.1 shows average values of the number of PingID command to the number of tags for each anti-collision algorithm, and shows decrements of the BDS against the BSA. In detecting the collided bin response data, the BDS-static algorithm searches by the fixed 3-bit in the 8 bin-slots. The BDS-dynamic algorithm searches from the 3-bit up to the maximum 8-bit in the same bin-slots. An average value of the number of PingID command for each anti-collision algorithm is shown in Fig. 4. In the proposed BDS algorithm, the number of PingID command for the tag recognition is decreased to 80~84% for 100 tags and 88~89% for 1000 tags against that of BSA algorithm, respectively. Furthermore, the number of PingID command in the proposed algorithm reduces remarkably better than that of BSA algorithm according as the number of tag increases.

Table.2 shows reader command to the number of tag for each anti-collision algorithm, and shows decrements of BDS against BSA. In the proposed BDS algorithm, the number of reader command to recognize the tags is decreased to 48~49% for 100 tags and 59% for 1000 tags against that of BSA. In order to calculate total tag recognition time, pulse duration time (T_0) sets to 14.25μs that is regulated on EPC protocol. Initiating signal from the reader to the tag consists of five phases as shown in Fig. 1. The first phase is the transaction gap ($1.25T_0$) and the second phase is CW RF signal of 64μs. The third phase is the data modulation window, the fourth phase is the tag setup window ($8T_0$) and the last is the tag response part ($64T_0 + 2.5T_0$). In formatting the reader command, data modulation window is variable because the length of [VALUE] is variable. The excepted part of VALUE consists of 51-bit. In the proposed BDS algorithm, the data modulation window is allocated with 60-bit voluntary. The number of PingID command transmitted to the tags is equal to the number of PingID command. And the number of ScrollID and Quiet command are equal to the number of identified tag. If the time for processing one command between the reader and the tag is T_{1cycle}, total time for the tag recognition can be written as follows.

$$T_{1cycle} = 1.25T_0 + 64\mu s + 60T_0 + 8T_0 + 64T_0 + 2.5T_0 \quad (1)$$

$$T_{total} = (P_n + S_n + Q_n) \times T_{1cycle} \quad (2)$$

Where, P_n , S_n and Q_n are the required number of PingID command, ScrollID command and Quiet command, respectively. The calibration time of RFID system and the CRC check time are excluded from T_{total} because those have a little effect on the total tag recognition time.

Table.3 and Fig. 5 show the total recognition time for each case, and show decrements of BDS against BSA. In the proposed BDS algorithm, total recognition time for 100 tags is decreased to 48 ~ 50%, and 58~59% for 1000 tags against BSA.

Table 1. The number of PingID command and decrements.

No. of Tag / No. of PingID command	10	30	50	100	200	500	1000
BSA	29	78	134	296	649	1815	3974
BDS_static	16	24	35	58	102	257	491
BDS_dynamic	9	16	27	48	88	228	441
BSD_static Decrement [%]	45	69	74	80	84	86	88
BDS_dynamic Decrement [%]	69	79	80	84	86	87	89

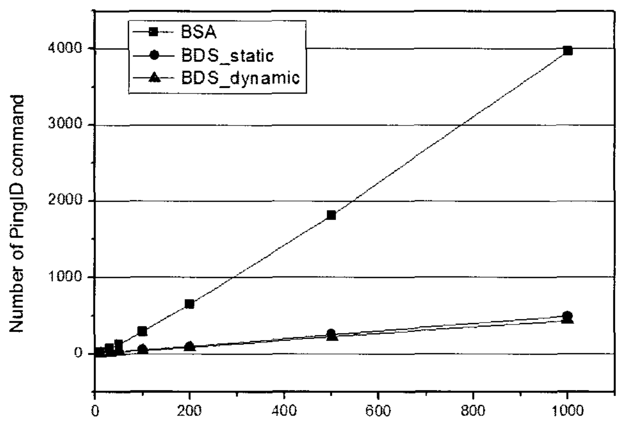

Fig. 4. Number of PingID command

Table 2. The number of reader command to the number of tag, and decrements.

No. of Tag / No. of Command	10	30	50	100	200	500	1000
BSA	49	138	234	496	1049	2815	5974
BDS_static	36	84	135	258	502	1257	2491
BDS_dynamic	29	76	127	248	488	1228	2441
BDS_static Decrement [%]	26.5	39.1	42.3	48	52.1	55.3	58.3
BDS_dynamic Decrement [%]	40.8	44.9	45.7	50	53.4	56.4	59.1

Table 3. Total recognition time to the number of tag, and decrements.

No. of Tag / Recognition Time [ms]	10	30	50	100	200	500	1000
BSA	98	276	468	992	2098	5630	1194 6
BDS_static	72	168	270	516	1004	2514	4982
BDS_dynamic	58	152	254	496	976	2456	4882
BDS_static Decrement [%]	27	39	42	48	52	55	58
BDS_dynamic Decrement [%]	41	45	46	50	53	56	59

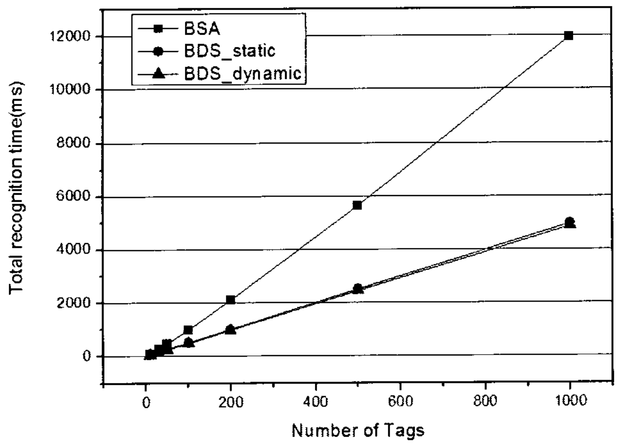

Fig. 5. The total tag recognition time

5. CONCLUSION

We proposed and analyzed the BDS algorithm for RFID system. We also compared the performance of the proposed BDS algorithm with the BSA algorithm based on EPC Class1 protocol. The proposed algorithm processes at first the bins that the collision does not occur, and then the collided bins stored in the stack are processed after dynamically searching the collision-bit position of collided bin data. By comparing the tag recognition time and the number of PingID command, we proved that the performance of the proposed BDS algorithm is improved. The number of reader command and the tag recognition time of BDS algorithm for 1000 tags are reduced almost 59% against that of BSA, and also an average value of the number of PingID command is reduced to 89%. Consequently, the performance of the proposed algorithm is better than BSA algorithm according to increasing the number of tag.

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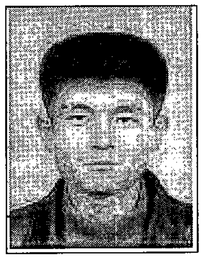

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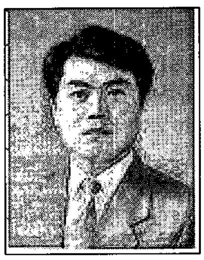

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