

# A novel tag collection algorithm for iterative RFID tag collections

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**Abstract:** This paper proposes a novel tag collection algorithm for improving the performance of iterative tag collections in active RFID systems. In the proposed tag collection algorithm, a reader assigns fixed response slot numbers to the tags newly identified via a tag numbering phase, and then collects additional data sequentially from all the tags without tag collisions in the following tag collection phase, in which the tag responds in its own assigned slot. This lowers the cost of empty slots and collided slots during iterative tag collections. The simulation results showed that the proposed tag collection algorithm could achieve higher tag collection performances as the tag mobility was lower, compared with the standard tag collection algorithm and the modified tag collection algorithm that was proposed in a previous study.

**Keywords:** RFID, tag collection, framed slotted aloha, tag numbering

**Classification:** Electron devices, circuits, and systems

## References

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## 1 Introduction

Radio frequency identification (RFID) technology has recently been spotlighted as an emerging technology to replace legacy barcode systems in many industry fields that require inventory management. RFID systems can be roughly classified into two categories according to the tag's power supply: active or passive RFID systems [1].

Multiple tag identification, namely *tag collection*, is one of the major concerns in RFID systems. Via the tag collection process, an RFID reader collects unique IDs and data from all the tags located within its communication range. A tag collision, which is caused by simultaneous responses from multiple tags, is the major reason that tag collection performance deteriorates with a large number of tags. Thus, a tag collection algorithm based on an efficient anticollision protocol to solve the tag collision problem is very important for improving tag collection performance. The framed slotted ALOHA (FSA) is one of the most commonly used anticollision protocols in RFID systems. Recently, although many studies have been conducted to improve the performance of the FSA-based tag collection in RFID systems, they have considered the general case where the tag mobility is high [2, 3, 4, 5].

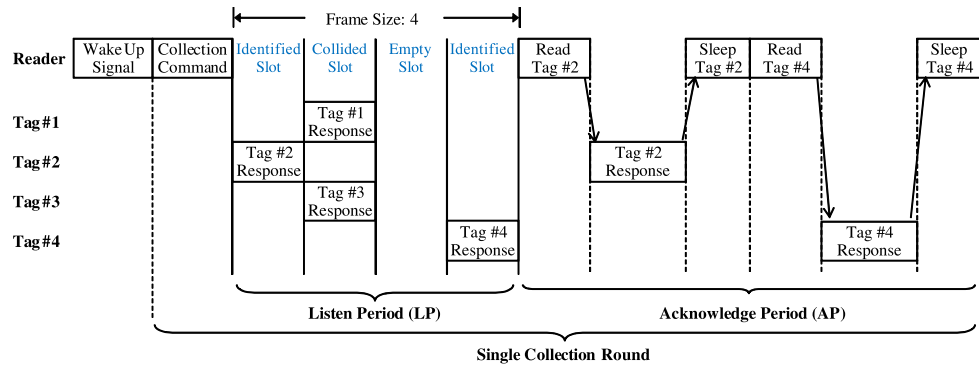
This paper proposes a novel FSA-based tag collection algorithm for improving the performance of iterative tag collections in active RFID systems. The proposed tag collection algorithm is very effective in active RFID-applied industry fields where the tag mobility is low.

## 2 Tag collection in active RFID systems

ISO/IEC 18000-7, which is a representative international standard for active RFID systems, defines a FSA-based tag collection algorithm [6]. Fig. 1 shows an example of the tag collection sequence and timing in ISO/IEC 18000-7.

After waking all tags in sleep mode, the reader collects data from the tags via iterative collection rounds. Each collection round is initiated by a *Collection* command from the reader, which is followed by a listen period (LP) and an acknowledge period (AP). Upon receipt of a Collection command, a tag randomly selects a slot within a frame in an LP and sends a small response containing its own unique tag-ID in that slot. Throughout the LP, the reader can collect tag-IDs from the identified tags.

After completing the LP, the reader performs an AP to collect additional data from the tags identified in the LP. By sending a *Read* command with the previously obtained unique tag-ID, the reader acquires additional large data stored on a tag, and then sends a *Sleep* command to that tag. Any tag that receives the Sleep command shifts to sleep mode and does not participate in the subsequent collection rounds. When the collection round has been completed, the reader immediately starts the next collection round by broadcasting a new Collection command containing the estimated optimum frame size. This process continues until no more tags and collisions are detected during a minimum of two consecutive collection rounds.



**Fig. 1.** Standard tag collection in ISO/IEC 18000-7

As seen in Fig. 1, although collided slots and empty slots do not contribute to tag collection, many of them are produced throughout the entire tag collection process because the FSA is based on a stochastic approach. Thus, if the cost of collided slots and empty slots can be reduced, the tag collection performance will be improved.

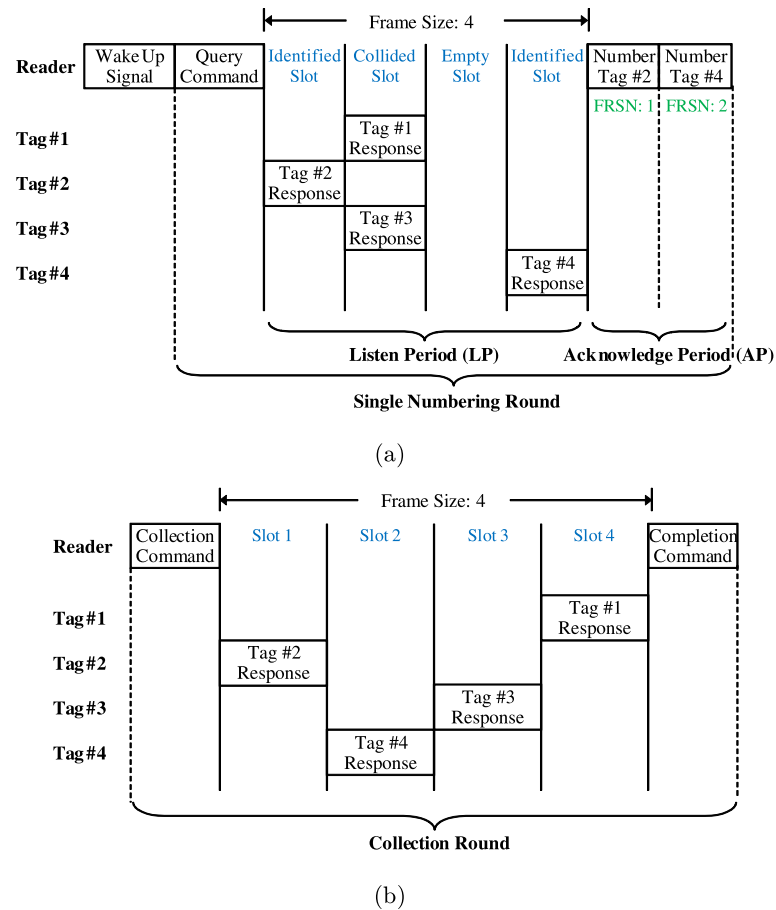
### 3 The proposed tag collection algorithm

This paper proposes a novel FSA-based tag collection algorithm for improving the performance of iterative tag collections in active RFID systems. A single tag collection consists of two consecutive phases: the tag numbering (TN) phase and the tag collection (TC) phase.

Via the first TN phase, the reader collects tag-IDs and assigns a fixed response slot number (FRSN) to each identified tag. The FRSN determines in which slot a tag sends its response containing additional large data in the following TC phases. The process in the TN phase is similar to the entire standard tag collection process. It consists of iterative numbering rounds, and each numbering round is initiated by a *Query* command from the reader, which is followed by an LP and an AP. However, the process in the AP is different from the standard tag collection process, whereas the processes in the LP are the same.

In the AP of the TN phase, instead of requesting additional data from the identified tags, the reader issues a *Number* command containing a unique FRSN to each identified tag. The value of the FRSN is assigned sequentially to each identified tag in identified order. Once a tag is assigned its own FRSN, it never reacts to *Query* commands from the same reader afterward. Any tag that receives the *Number* command stands by for the subsequent TC phase without shifting to sleep mode. As in the standard tag collection, the TN phase continues until no more tags and collisions are detected during a minimum of two consecutive numbering rounds.

Fig. 2 (a) shows an example of the first numbering round in the TN phase. Because tag #2 was identified first in the LP, the reader assigns one to tag #2 as its FRSN in the AP. Similarly, tag #4 is assigned two as its FRSN. The collided tags #3 and #1 will be identified successfully and be assigned three and four as their FRSNs, respectively, during the subsequent second



**Fig. 2.** Proposed tag collection algorithm: (a) TN phase, (b) TC phase

numbering round.

Having completed the TN phase, by broadcasting a *Collection* command, the reader starts the second TC phase to collect additional large data from all the tags that have been assigned their own FRSNs. At this time, the frame size is set to match a value of the largest FRSN up to now. After receiving the Collection command, the tag sends its response containing additional large data in the slot corresponding to its pre-assigned FRSN. Because all tags are assigned different FRSNs from each other, no tag collisions occur in this process. After the frame period has expired, the reader finalizes the current tag collection process by broadcasting a *Completion* command to the tags. Any tag that receives the Completion command shifts to sleep mode again. Unlike the TN phase, the TC phase performs only one collection round.

Fig. 2 (b) shows an example of the process of the TC phase. The frame size is set to four because the value of the largest FRSN is four, and the reader successfully collects additional data from all four tags.

During the iterative tag collections, if a tag move out of the reader's communication range, an empty slot will be detected in the slot assigned to that tag as a FRSN. In Fig. 2 (b), if tag #4 has already moved out, the second slot becomes an empty slot. In such case, the reader releases the FRSN assigned to the moved tag, and then reassigns it to the tag that will

be newly identified via the TN phase in the following tag collection.

When the proposed tag collection algorithm is applied to active RFID-applied industry fields where the tag mobility is low, it can lead to a large improvement of the performance of iterative tag collections. In the first tag collection with the proposed algorithm, all tags participate in the TN phase and are assigned their own FRSNs. However, from the second tag collection, only the tags that have newly moved into the reader's communication range participate in the TN phase, and so the time required for the TN phase can be much reduced. In addition, with only one Collection command in the TC phase, the reader can collect additional large data from all the tags without collisions, and only a small number of redundant empty slots caused by tag movement occur. Consequently, the cost of collided slots and empty slots can be much reduced.

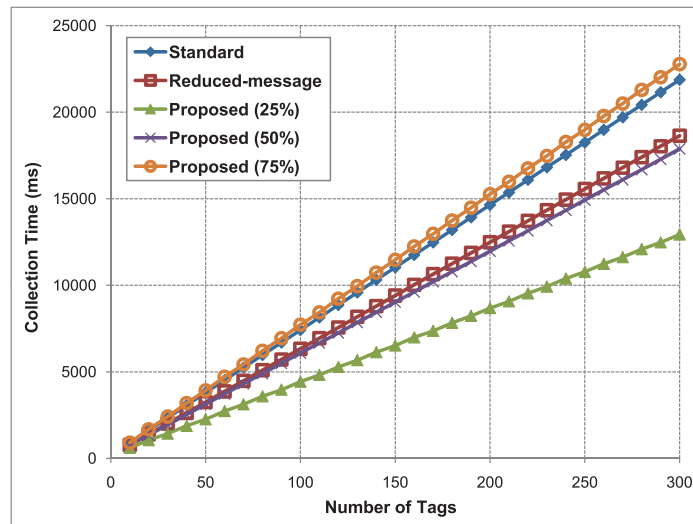
#### 4 Simulation results

We evaluated the proposed tag collection algorithm via simulations, compared with the standard tag collection algorithm and the modified tag collection algorithm with the reduced-message method that was proposed in the author's previous study [5]. The reduced-message method decreases the slot size for a tag response by reducing the response size from the tag in the LP and reduces the number of commands issued from the reader in the AP, resulting in an improvement of the tag collection performance. For the details, refer to [5].

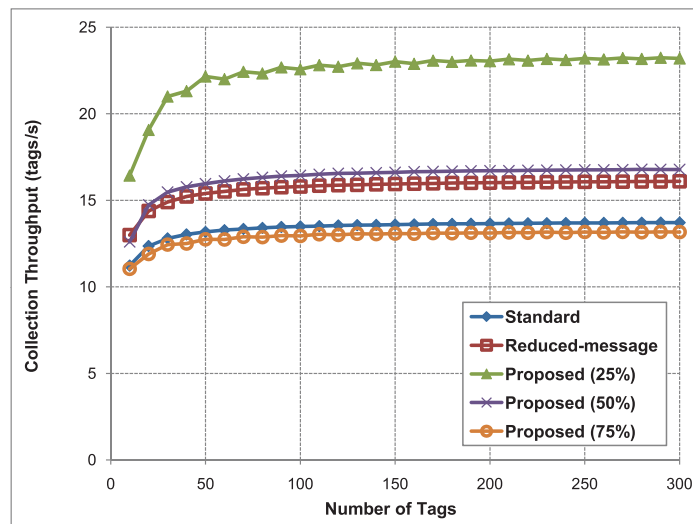
Link parameters and command/response formats were set with reference to ISO/IEC 18000-7. It was assumed that the reader would collect 50 bytes of additional data from the tags. 10,000 simulation trials were performed to measure the average values in each case, varying the number of tags and the mobility<sup>1</sup> of tags. Fig. 3 shows simulation results.

As shown in Fig. 3(a), the proposed tag collection algorithm showed lower collection time as the tag mobility was lower. When the tag mobility was 50% or less, the proposed tag collection algorithm outperformed the other two tag collection algorithms. On the contrary, when the tag mobility went over 75%, the proposed tag collection algorithm showed higher collection time than even the standard tag collection algorithm. The collection throughput in Fig. 3(b), which represents the number of tags collected by the reader per second, showed similar results to the collection time. The proposed tag collection algorithm showed higher collection throughputs as the tag mobility was lower. When the tag mobility was 25%, the proposed tag collection algorithm could achieve 40.08% lower collection time and 67.05% higher collection throughput on average than the standard tag collection algorithm. These simulation results indicate that the proposed tag collection algorithm is very effective in improving the performance of iterative tag collections in active RFID-applied industry fields where the tag mobility is low.

<sup>1</sup>The tag mobility of  $x\%$  is specified as follows: in each tag collection,  $x\%$  of existing tags move out and the same number of new tags move into the reader's communication range.



(a)



(b)

**Fig. 3.** Simulation results: (a) Tag collection time, (b) Tag collection throughput

## 5 Conclusion

This paper has proposed a novel FSA-based tag collection algorithm for improving the performance of iterative tag collections in active RFID systems. In the proposed tag collection algorithm, a reader assigns the FRSNs to the tags newly identified via a TN phase, and then collects additional data from all the tags without tag collisions in the following TC phase, in which the tag responds in its own assigned FRSN. The simulation results showed that the proposed tag collection algorithm could achieve higher tag collection performances as the tag mobility was lower, compared with the standard tag collection algorithm and the modified tag collection algorithm that was proposed in a previous study. Although the proposed tag collection algorithm is designed for active RFID systems, the main idea can also be applied to passive RFID systems.