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A Lightweight Tag Grouping Algorithm for enhancing RFID Tag Anti-Collision MAC Protocol

Umelo Nnamdi H.[1,5], Onyibe Christian O.[2] , Okekenwa Emmanuel[2], Eziechina Malachy A.[3] , Ibe Perpetual N.[4]

[1]*Department of Computer Engineering Technology, Akanu Ibiam Federal Polytechnic Unwana, Ebonyi State, Nigeria, .*

[2]*Department of Electrical / Electronic Engineering Technology, Akanu Ibiam Federal Polytechnic Unwana, Ebonyi State, Nigeria .*

[3]*Department of Computer Science, Akanu Ibiam Federal Polytechnic Unwana, Ebonyi State, Nigeria.*

[4]*Department of Computer Science, Imo State Polytechnic, Omuma, Imo State, Nigeria.*

[5]*Wireless and Photonics Networks Research Centre of Excellence (WiPNET), Faculty of Engineering, Universiti Putra Malaysia (UPM), Serdang, Malaysia.*

The Corresponding author[1]: umelonnamdi@gmail.com

ABSTRACT : *Compared to previous automatic identification technologies (Auto-IDs), Radio Frequency Identification (RFID) has various benefits, such as wireless object recognition, the ability to identify many tags at once, and the ability to uniquely identify a certain product within the same item. RFID tags' signals frequently collide because they use the same communication channel to respond to queries from RFID readers. RFID anti-collision protocol is the attempt to resolve this collision and dynamic frame slotted ALOHA (DFSA) is the de-facto algorithm implemented in its medium access control (MAC) component. This collision becomes more likely with the widespread use of RFID, such as in Internet of Things (IoT) applications. Clustering technique is used in this research paper to group tags and reduce the likelihood of a collision. This paper uses a tag grouping principle that forces the reader to query a small number of tags (a tag cluster) at once, hence, minimizing the possibility of tags colliding. MATLAB was used to simulate and model a large-scale tag deployment. Simulation findings indicate that the clustering technique employed in this research, groups RFID tags uniformly, regardless of the number of clusters chosen. Through efficient tag grouping, the proposed approach shows promise in improving the current RFID tag anti-collision MAC protocol.*

KEYWORDS: *IoT, passive UHF RFID, DFSA, clustering, RFID tag anti-collision protocol.*

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I. INTRODUCTION

The role that Radio Frequency Identification (RFID) plays in bringing the Internet of Things (IoT)'s vision of worldwide accessibility and data exchange is no longer news. However, in order to realize this lofty goal, each of the trillions of items on the planet needs to have a unique identity [1]. This is where RFID technology, a type of wireless technology, comes into play. A typical RFID system constitutes of the RFID reader (equipped with a transceiver and antenna) which uses electromagnetic wave to query and read data from a set of unique RFID tags (transponder with unique ID). Compared to other auto-ID methods like biometrics, magnetic stripes, barcodes, etc., passive RFID offers a number of advantages. For example, passive RFID is very cheap and enables the simultaneous identification of many products wirelessly. However, there is a drawback to this benefit known as tag collision problem [2]. A situation in which signals from RFID tags collide when they try to reply to RFID reader queries because the tags share same communication channel [3]. Fig. 1 shows how tag collision problem of RFIDs occur. In fig. 1, signals from tags A and B collide in a bid to respond to reader query. The RFID anti-collision protocol is the name given to efforts made to address this [4], [5]). In the current EPC C1G2 RFID anti-collision protocol [6], [7] which is shown in fig. 2, dynamic frame slotted ALOHA (DFSA) is the de-facto algorithm. With its sophisticated design, DSFA may continue to change its frame size for each query round.

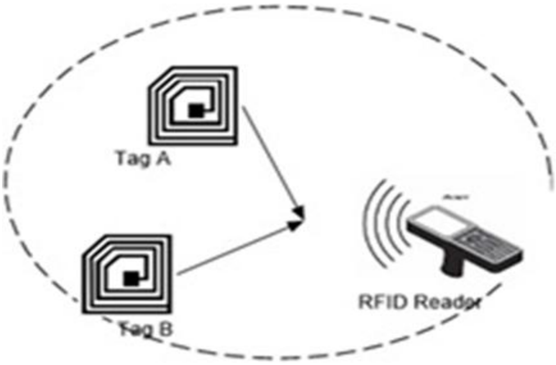

Fig.1. An illustrative example of tag collision problem of RFID

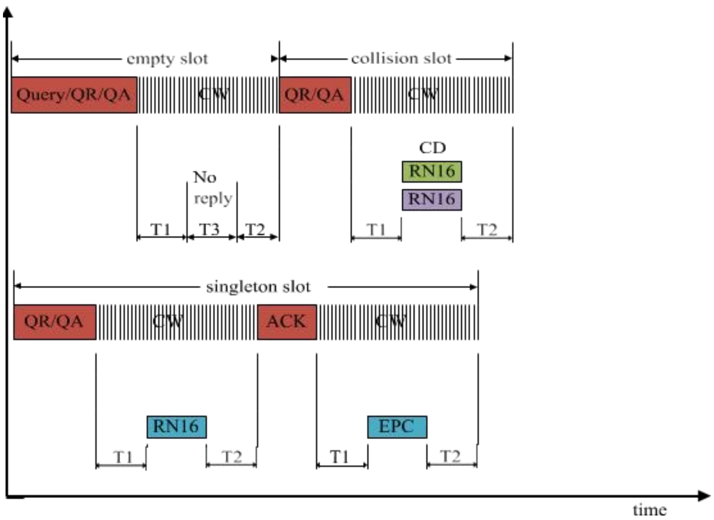

Fig. 2. Operational procedure of DFSA-based EPC C1G2 showing the different time duration for different slots [8]

Additionally, fig. 2 illustrates that there are three possible results for each query round that the reader performs: a singleton slot (a successful slot), an empty slot, and a collision slot. The time intervals T_1, T_2, and T_3 indicate how much each kind of slot costs the RFID system during the identification process. Query, QR, and QA are commands that the reader uses to query tags. To query tags with the same frame size or to alter the frame size, use query repeat and query adjust, respectively. The reader first performs handshaking of tags within its read range using RN16, a 16-bit binary number, and then reads the tags unique Electronic product code (EPC). In the meantime, collision slots indicate that two or more tags have clashed, necessitating more query rounds to read every tag. This degrades the system and makes using RFID in the Internet of Things difficult. In order to reduce the likelihood (probability) of tag signals colliding and the likelihood of further inquiry rounds, this paper presents a straightforward grouping mechanism that eliminates the rigorous tag handshaking by the reader in conventional DFSA, saving time and other resources. The current EPC C1G2 protocol, which is based on DFSA, is probabilistic [9], [10]. Therefore, a grouping technique that guarantees all tags have fair access to the shared channel is required.

II. RELATED WORKS

With the Internet of Things in mind, research on RFID anti-collision has reached an avalanche height. The importance of RFID in IoT cannot be overstated. The EPC C1G2 protocol [6] developed by the Auto-ID center of excellence at Massachusetts Institute of Technology (MIT) and EPC Global, standardized the physical layer and MAC sub-layer specifications for a passive Ultra-high frequency (UHF) tag RFID system that operates in the 860MHz–960MHz band [11]. This paper focuses on the anti-collision MAC protocol for passive RFID application in the Internet of Things (IoT) at the MAC sub-layer. The current anti-collision protocol is developed with DFSA, and efforts have been made to improve DFSA in order to meet the high tag density demands of the IoT, which calls for the widespread tagging of everything. Tag grouping in RFID literary works is becoming more common. Therefore, we analyze a few of these grouping-based literature ideas.

The work of [12] was improved in terms of tag success read rate, identification time, and system efficiency by the recently proposed collision-efficient approach by [3] which is based on k-means clustering. In order to address tag collisions more effectively, the authors in [3] split the identification procedure into two phases: initialization and identification. Fig. 3 illustrates the initialization stage, where tags are collected and counted. The counted tag number is then made available at the identification stage to provide an exact tag estimate to the RFID reader, enabling it to forecast the appropriate frame size for the tag identification. The disadvantage of this unique approach is that passive UHF RFID, which already has limited computational space and time, gains excessive computational weight and time during the initialization stage. Their protocol might be useful in some IoT applications where time is unimportant, but its applicability in the majority of IoT applications with few tags and where time is crucial is seriously in doubt.

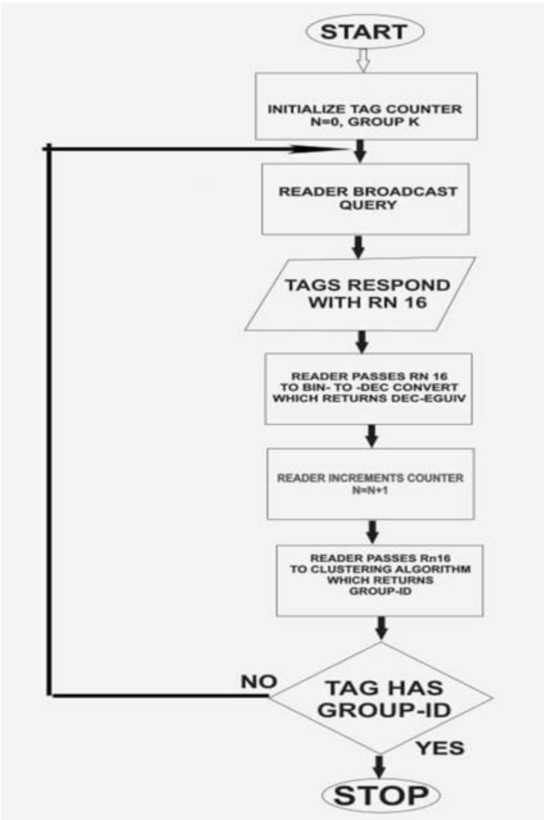

Fig 3. Flowchart illustrating Tag grouping and counting algorithm of the initialization stage of the proposed protocol by [3]

The authors in [5], [8], [13] created effective tag grouping-based algorithms for RFID anti-collision starting in 2020. However, their work is less relevant here because it takes a tree-based approach to RFID anti-collision rather than a DFSA-based (probabilistic) approach, which is the approach that this research aims to improve for EPC C1G2. However, it is noteworthy that whereas [2] conducted a performance evaluation of the current RFID anti-collision method, which is based on tag grouping, they only studied the previously existing methods in the literature but were unable to provide improvements to the current approach. Other proposals in the literature

[14]–[16] are either too computationally difficult, based on other approaches (not DFSA), or take too long to detect all tags. This study suggests a straightforward method for creating an effective RFID anti-collision protocol based on tag grouping that improves EPC C1G2 for IoT applications.

III. MATERIAL AND METHODS

A. PROPOSED RFID TAG GROUPING STRATEGY

The main workflow of the improved grouping strategy is given as follows.

Step I. With iteration, the reader queries tags and groups them into the following initial grouping result: $G = \{G_1, G_2, \ldots, G_n\}$

Where n is the initial number of groups

Step II. During optimization, the group size s is chosen randomly from a set **S**, (where **S** contains several possible group size values).

Step III. If n > Dimension/s, merge G according to Algorithm 1; else, the Tag number is optimized according to G.

Step IV. If the evolutionary degree of the population is not significant, the procedure is repeated from step II); otherwise, it is repeated from step III).

Algorithm 1 randomly arranges $G_1, G_2, \ldots, G_n$ before merging. Therefore, a different merged grouping result may be obtained at each merging. As the grouping results of the proposed method may not be completely correct, two interacting variables may be placed in different groups. The strategy of dynamically changing the group size and randomly merging the initial grouping result can increase the probability of placing interacting variables in the same group. In addition, when the merging is performed, the interacting decision variables from the initial grouping result always remain in the same group, which is good for the algorithm.

Algorithm 1: Procedure for Merging Tag Groups

Input: initial grouping results $G = \{G_1, G_2, \ldots, G_n\}$
initial number of groups n, selected group size s
Output: merged groups in $MG = \{MG_1, MG_2, \ldots, MG_{nm}\}$
the number of groups in n_m in MG

```
Randomly select G_1, G_2, ..., G_n defined as
            G = {G_1, G_2, ..., G_n}
k = 1, i = 1, MG = {φ}:
/* Main loop
While i < n do
    MG_k = {φ}:
    while MG_k < s, && i < n do
        MG_k = MG_k, G_j:
        i ++;
    k ++
n_m = k;
```

B. PERFORMANCE EVALUATION

This section offers a performance assessment of the grouping strategy used in this article. The evaluation took into account DFSA algorithms that adhered to EPC C1G2. MATLAB software (8.5.0, Mathworks, Nathick, Massachusetts, USA) was used for all simulations. In order to make the results easier to see, 200 tags were simulated in MATLAB and used in a large-scale Monte Carlo simulation.

C. SIMULATION PARAMETERS AND DATA

Every RFID tag has a unique identification called an Electronic Product Code, or EPC. They are used to uniquely identify any physical object in the world, much like barcodes. Because of this feature, RFID is essential to achieving the Internet of Things, which allows everything to be connected. Tag EPC is available in the cloud through EPCIS (EPC information service) and has a bit rate of 96. EPC is lengthy and compliant with EPC C1G2, as Table 1 illustrates. In this research, we utilize only 16 bits of the 96 bits available for assessment. The four components of the EPC code are displayed in Table 1. The manufacturer uniquely identifies the tag from the organizational side in the domain management, and the first eight bits specify the version of the RFID tag [2]. The EPC management uses the 24-bit object class to determine the type of item, and the 36-bit serial number is unique within each object class. The basis for our grouping in this paper is this unique serial number, which is created randomly in MATLAB to simulate the RN16 of the tags using 16-bit binary data. In our investigation, the suggested algorithm's tag clustering (grouping) uses this 16-bit data ID.

Table 1. RFID Tag coding

EPC 96-bit ID	Version no.	Domain Management	Object Class	Serial no.
No. of bits	8	28	24	36

The simulation was run with the assumption of an error-free channel using a single reader and several tags. The assumption that no tags leave or enter the RFID read range was also included. Table 2 lists the parameters that were used in the simulation and are compliant with EPC C1G2. In order to simulate the EPC code of RFID tags, 200 sets of 16-bit binary data were created at random using the MATLAB software during the simulation period. It is noteworthy that, in our evaluation, the suggested grouping algorithm was implemented utilizing the various right time slots values for the success slot, collision slot, and idle slots T_1, T_2, and T_3, respectively. This is similar to the EPC C1G2 standards.

Table 2. Simulation Parameters

Parameters	Value	Parameters	Value
Reader-to-tag data-0	1 Tari	RTcal	37.5 µs
Reader-to-tag data-1	2 Tari	TRcal	50 µs
Reader-to-tag rate	80kbps	T1	62.5 µs
Tag-to-reader rate	160kpbs	T2	62.5 µs
Tpri	6.25 µs	T3	100 µs
Tari	12.5 µs	Probe	4bits
Feedback	3 bits	RN16	16bits
Query	22 bits	ID	96bits
Query Adj	9 bits	Ack	18bits
R-T Preamble	112.5 µs	QueryRep	4bits
T-R Preamble	37.5 µs	Framesync	62.5 µs

IV. RESULTS AND DISCUSSION

During the simulation experiment, the 200 tags were grouped into 4 scenario:
(1) 3 groups
(2) 4 groups
(3) 5 groups and
(4) 6 groups

This was done to observe how the proposed grouping method clusters tags and to see whether or not it is stable and consistent in the desired fairness in grouping which is the desire of probabilistic approach to RFID anti-collision. For the first scenario which involves grouping the 200 tags into three, the algorithm got into convergence after series of iteration and the result is shown in fig. 4. As can be seen in fig. 4, and subsequently in figs. 5, 6 and 7, with the proposed grouping algorithm, the reader was able to firstly, count or handshake all 200 tags. This strongly suggests the proposed grouping method comfortably addresses the tag collision problem (TCP) of DFSA based (probabilistic approach) RFID anti-collision protocol in all the four grouping scenarios. Secondly, a close observation of tag alignment in all figs. 4, 5, 6 and 7, the RFID tags were evenly distributed into the areas of each group. Most research authors in RFID anti-collision [3], [5], [12], [17]–[22] agree that the efficiency of the RFID system using DFSA as multi access technique is maximum when tags have optimal fairness in accessing the shared channel. This implies that the grouping method proposed in this paper guarantees fairness in assigning group IDs while ensuring RFID tags are given fairness in accessing the shared channel. Hence, guarantees improved efficiency of the RFID tag anti-collision protocol.

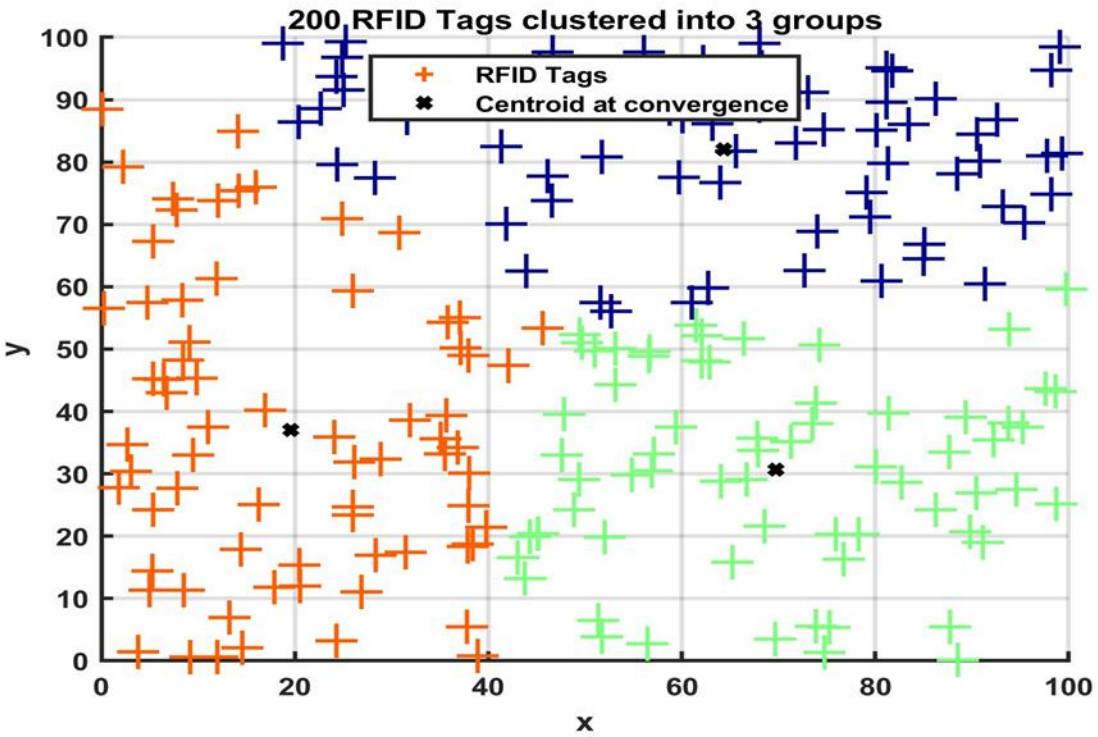

Fig. 4.Result showing accuracy and fairness in grouping RFID tags into 3 groups

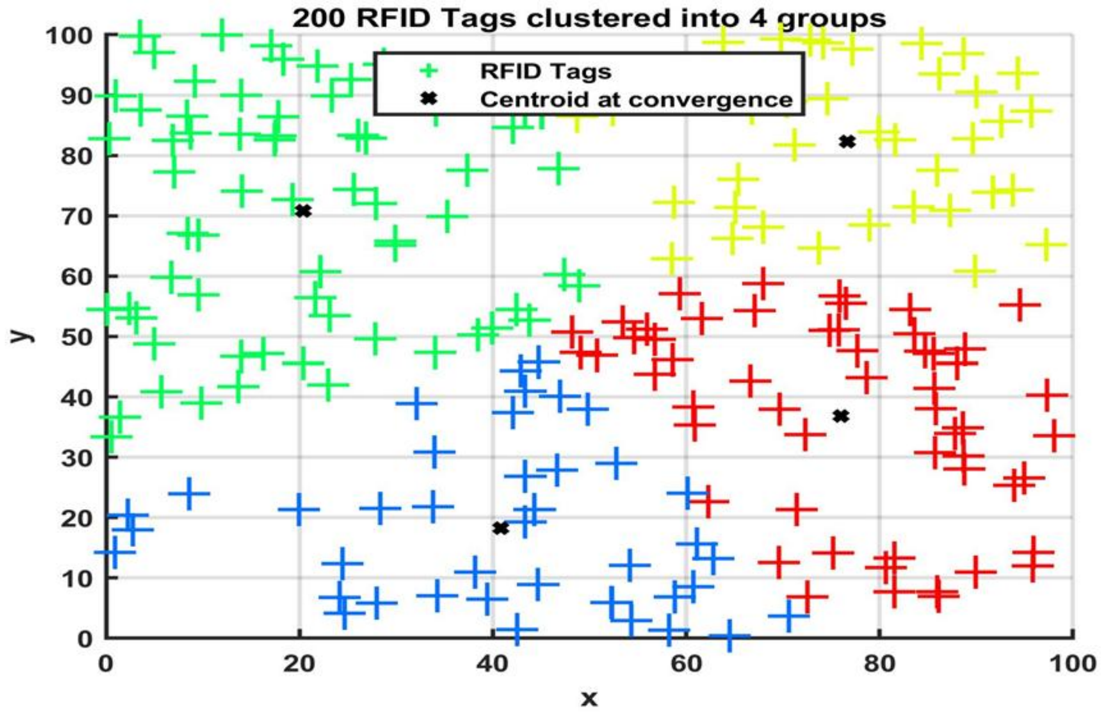

Fig. 5. Result of grouping RFID tags into 4 groups showing accuracy and fairness

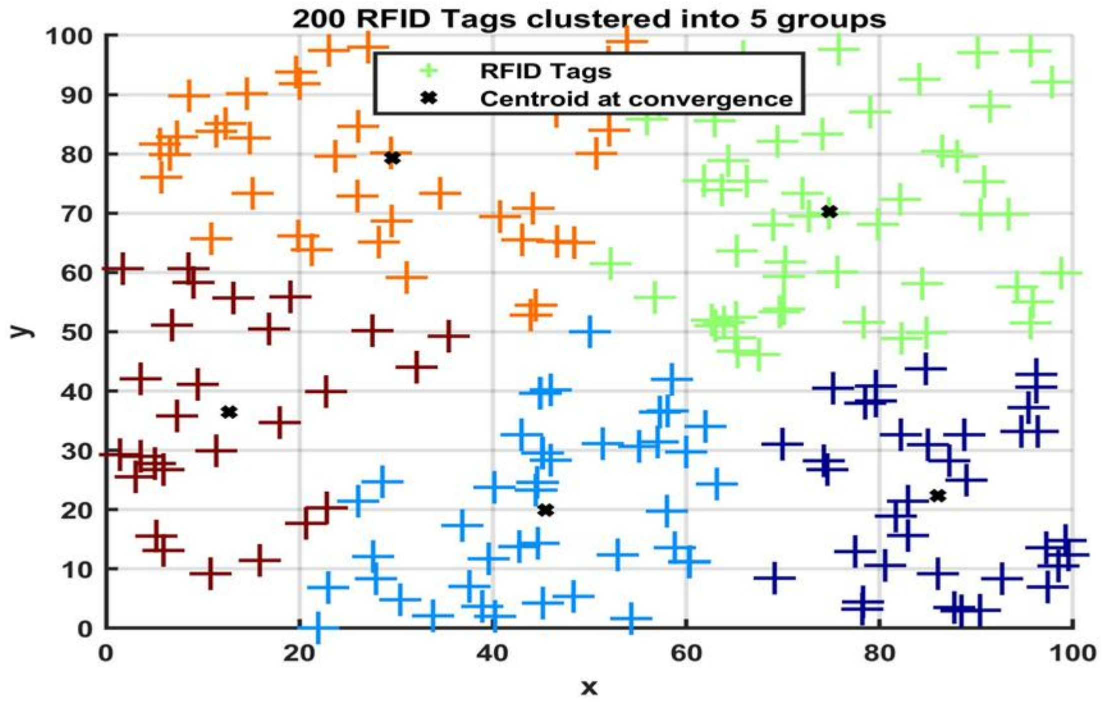

Fig 6 Result of tag grouping into five groups showing accuracy and fairness

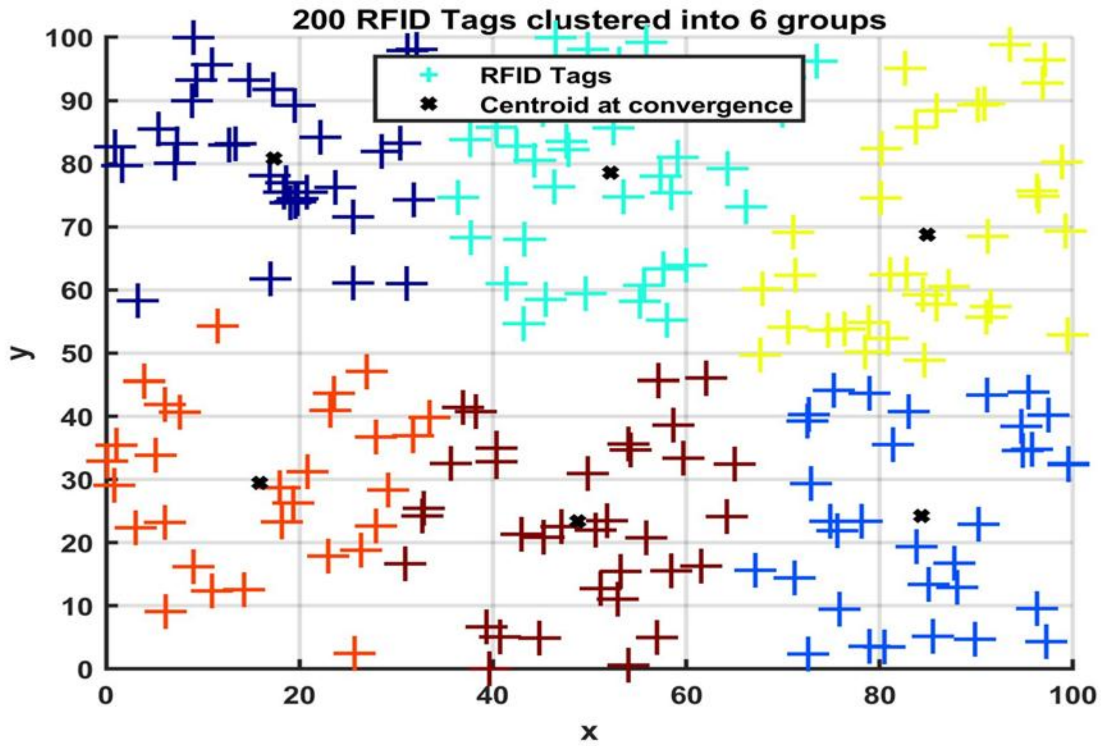

Fig. 7 Result of tag grouping into six groups showing consistency in accuracy and fairness

V. CONCLUSION

This paper presents a means of enhancing an already existing MAC protocol used for RFID anti-collision; EPC C1G2. This protocol specifies MAC and Physical layer standards for passive UHF RFID systems. Tag grouping is becoming popular in literature towards enhancing this EPC C1G2 protocol which is based on DFSA; the latest variant of ALOHA multiple access technique. This paper uses simple clustering to group RFID tags and also merge them after each query round to get an accurate tag estimate for the next query round. Unlike most works in literature the tag grouping proposed in this paper is easy to implement and results of our simulation strongly suggest it is very useful for enhancing DFSA and consequently, EPC C1G2 RFID anti-collision. In future, we shall consider evaluating with mobile readers and tags scenario.

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