Redundant Readers Elimination in Dense Radio Frequency Identification Network

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Radio frequency identification (RFID) is gaining popularity as a tool to monitor and identify tagged objects. The readers were installed at designated location to read the tags in the vicinity. The readings on the object is processed to turn it into useful information for the businesses. However, there are readers that can redundant permanently or only at certain time of period. This is because all the tag that read by the reader has been also read by adjacent reader. The particular reader also does not have any other tags to be read. During this period, the reader can be put into sleep mode to save some energy. For mobile readers, it can be removes from the location and be used in other areas that are much needed. Reducing energy consumption can increase the device lifetimes and promote sustainability such as releasing less emission to the environment. In this paper, we address the problem of identifying this redundant reader using a simple but effective approach. Our approach contributes to energy savings, reduce interference and duplicate readings in the dense RFID reader network. We compare our approach with others and proved that ours is simple but effective and accurate.

Keywords: RFID, RRE, Redundant Reader, Duplicate.

1. INTRODUCTION

RFID is emerging as a tool for monitoring, tracking and identifying objects with unique identification. It has been use in many areas including supply chain, healthcare, wildlife and farming. It enables process improvement on the area where it turns tedious manual works into simplified automated process. For example, instead of scanning the barcodes manually, RFID can simultaneously read all the tagged objects and return related data to the system on the fly. Before RFID, it is impossible to accurately verify a typical shipment of thousand items.

There are many advantages of RFID compare to the barcode. Besides simultaneous identification, it does not need line of sight to detect the object and able to provides timestamp and location on each reading. The timestamp is important to record when the object is present in the area. The location is presented by the reader ID which is fixed at the designated area. RFID tag can store more data such as expiry date and manufacturer information. System can be alerted when the items are approaching expiry date to avoid customer from buying it. Because of the no line of sight detection ability, objects monitoring it can be perform remotely by the system which reduce dependencies to human.

More applications will be emerged as RFID will help to improve the process in the business. More reader will be deployed to monitor the objects for tracking and security purposes. However, not all the time the reader needs to be monitor the objects. There are times where the reader can be put into sleep or removed from the area because there is no object to be read or the objects that they read have been covered by other reader. In literature, the problem is known as redundant reader removal and has been discussed in Refs. [5-10]. The problem is identified as NP hard as proved in Ref. [5]. This jobless reader need to be identified because we need to do energy savings that helps to extend the device lifetimes. Energy saving is very crucial in certain application. For example the mobile reader deployed in natural disaster need to save energy, in case the rescue effort takes longer time to finish. Mobile reader has been used in the rescue to detect the RFID tag attached to the employee card. We choose to focus on energy savings to highlight the benefits that gathered by identifying and remove or putting the jobless reader into sleep mode.
The problem addressed in this paper, aims to identify the redundant reader and remove it without compromising the reading process. By removing the reader, we can reduce the probability of signal interference that can cause noise reading. Noise reading need to be filtered or otherwise the information generated from the reader will be useless because of its non-accuracy. By turning off the reader number of duplicate readings are also can be reduced. Duplicate readings need to be removed because it contains no new information on the tag and only will cause unnecessary processing and storage. The proposed algorithm compares readings among the readers and decides which reader can be turned off. The approach also removed many prerequisite that highlight by others in the literature in order to solve the problem. The paper will be organized into 5 sections. The first section is the introduction and the second is the background which contains motivational application and related works. The next section which is Section 3 is on the proposed algorithm. Section 4 focused on the performance analysis and last section is on the conclusion.

2. BACKGROUND

2.1. System Architecture

Figure 1 shows the four main layers of RFID. The top layer consist of tags, the second layer consists of readers, third layer is the middleware and the fourth layer is the database and enterprise applications. RFID have three types of tag which can be passive, active or semi passive. Tags contain unique ID that used to identify physical object. The main different between the tags is their source of power to operate. Passive tag does not have its own power source. It harvests the power from the signal beacon by the reader. Once it gets enough power, it will send it signal back to the reader. Active tags have its own battery on board which make it more expansive than passive tag. By having its own battery it can achieve longer range to transmit the signal. However because of the battery it has limited lifetime. Semi passive tag also has battery on board, which is used only for internal processing. It still requires the signal from the reader to perform the communication.

A: the second layer, there are two types of reader: fixed and mobile reader. Fixed reader is locate at fixed location and can have more than one antenna to cover wider vicinity. It will beacon it signal to detect the objects in its area and the process is repetitive regardless the presence of the tag. A tag can be read more than once as long it resides in the reader vicinity. A tag also can be read by more than one reader if it resides in the overlapped vicinity. Mobile reader also works like fixed reader but it uses battery to support its mobility.

After the reader collects reading from the tag, it will be send to the middleware. We can save some energy here by filtering duplicate readings at the reader to ease the network load between reader and middleware. At the middleware the data stream is filtered and aggregate according to the system needs. After that it is send to the fourth layer which resides the enterprise and database application. At this layer the data will be turn into useful information to be used by the businesses.

2.2. Motivational Applications

One of the common RFID applications is the object's monitoring in the warehouse. Most of the time the objects are static unless during object's arrival and shipment. In the warehouse, RFID readers are used to monitor the object for security and documentation purposes. It is to ensure that the objects are safe and located at the right place in the warehouse. This is because some objects have special requirement like extra security for high-valued item or cold storage for perishable items. Other than that the readers can ease the tracking process of the objects when the time comes for shipment. However, the occupancy rate in the warehouse are not always hundred percent. As shown in Figure 2 there is vacant area that left reader R3 and R4 having no objects to be read. The object reads by R3 is T10 and T11 already have been covered by reader R1. Since goes to reader R4 where T12, T13 and T14 also have been read by reader R2. Therefore both reader R3 and R4 can be put into sleep mode until new deliveries arrived and fill in the vacant area with tagged objects. The need to removed or put the redundant reader into sleep mode is because of three reasons:

(i) achieve energy efficient to reduce cost and contribute towards environmentally friendly computing,
(ii) reduce interference that could results in noise readings, and
(iii) reduce duplicate readings.

The energy consumes by common RFID reader in different mode is shown in Table I. During idle the reader
Fig. 2. R3 and R4 are underutilized because no tagged object is in their vicinity.

only use 3 watts compared to 13.5 watts during typical operations hours. That’s give a 78% reduce in energy consumption where 9.5 watts can be saved per hour. It seems a little savings for businesses but it is accumulate through a year and includes all RFID readers can be found in a given country, it does bring a big savings for the nation.

2.3. Related Works

The most essential problem in RFID collision is signal collision, which can be categorized into two groups: Tag Signal Collision and Reader Signal Collision. RFID systems usually use SDMA, FDMA and TDMA to solve the collision problem, such as slotted Aloha\(^\text{18}\) based on the Aloha algorithm. In Ref.\ [\text{19}], a modified Aloha algorithm is proposed to avoid RFID collision. In Ref.\ [\text{20}], an application theory of Colorwave that based on TDMA is proposed to avoid collision. Using TDMA, some scholars proposed\([\text{21}, \text{22}]\) exploiting the identification codes of tags to avoid the tag collision; their algorithm is based on the Manchester code, similar to a binary search.

To avoid collision, another solution is focusing on reducing the number of readers; this is the main issue addressed in this work. The use of redundant readers does not only increase the loading of the RFID system, it is also wasteful because of limited battery power.

One of the weaknesses of RRE\(^\text{3}\) is it cannot give the best decision on which reader to be turn off when tags are covered by readers as shown in Figure 3.

Table I. Power value in each reader mode.

<table>
<thead>
<tr>
<th>Power supply</th>
<th>Idle</th>
<th>Typical</th>
<th>Long distance charges</th>
</tr>
</thead>
<tbody>
<tr>
<td>+30 dBm</td>
<td>3 W</td>
<td>13.5 W</td>
<td>6 W</td>
</tr>
<tr>
<td>+32.5 dBm</td>
<td>3 W</td>
<td>15 W</td>
<td>6 W</td>
</tr>
</tbody>
</table>


In Figure 3 there are three readers that are more than enough to cover tag T1 to T5. RRE algorithm work as followings:

1. Every reader take turns reading tags in their vicinity
2. The reader writes the number of tags it reads with its ID to every tag in its vicinity only if it is larger than the previous.
3. Reader without tags is declared redundant.

RRE works by looking tags to the reader that read the highest number of tags. Based on Figure 3, RRE will start with R1. R1 read the tags in its vicinity and read T1 and T2. T1 and T2 have not been locked by other reader and R1 will lock the tag by writing its ID and the number of tags is covered on each of the tags. Then R2 will do the read tags where it reads T3, T4, and T5. It can overwrite data on T2 because R2 read more tags than R1. So it writes its ID and number of tags which 3 on T2, T3 and T4. The last reader R3, will start reading and finds T3, T4 and T5. It cannot write on the T3 and T4 because the number of tags its covered is not bigger than R2. It only can write on T5 which has not been locked by any other reader. By using RRE all the 3 readers are needed to read all the tags. R1 read on T1, R2 read on T2, T3 and T4 while R3 read on T5. No reader will be turn off because all reader have tags to be read. This is not efficient since the best solution is only R1 and R3 need to be turn on as they can cover all these tags.

In Ref.\ [\text{2}] they came out with new approach and claimed it is better than RRE. Basic operations of the proposed work can be summarized as follows: All readers in the RFID network send commands to all tags in their interrogation zones. Each reader’s coverage information is sent to the central host station, i.e., how many tags (with IDs) each reader has read. For each tag in the RFID network, the proposed algorithm checks how many readers have read it. Further, the algorithm compares the weights of readers that have read the tag. The reader having the maximum weight owns the tag. All the readers of the network with no assigned tags are eliminated as redundant readers.

Table II. Number of tags that each reader read in RRE.

<table>
<thead>
<tr>
<th>Reader</th>
<th>Tag’s read</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>T1</td>
</tr>
<tr>
<td>R2</td>
<td>T2, T3, T4</td>
</tr>
<tr>
<td>R3</td>
<td>T5</td>
</tr>
</tbody>
</table>
The assumption is the coordinate of the reader need to be known to assign the weight for each reader and the coverage information i.e., the number of tags each reader has covered in initial round can easily be obtained by data processing subsystem. This approach needs a lot of computation such the coordinate of each reader which is not practical in wireless RFID network. The algorithm also needs to iterate few times before producing the best output.

3. ALGORITHM

We proposed new approach that will evaluate the readings based on priority in terms of duplication. Our approach, PRIOR is giving more accurate results than RRE where the number readers that can be minimized is higher. To use PRIOR, all the readings need to be process centralize. Readings will be taken by each reader on the tags and it will be sorted based on the tag’s ID.

From Algorithm 1 the readings that will be gathered is shown in the first column of Table III. PRIOR need to identify and flags three types of tags in the tuples: (i) unique, whereas this tag is only read by one reader, (ii) dup1, where first occurrence of tag that have duplicate readings and (iii) dup2, where the following occurrence of tags that have duplicate readings. Based on the readings we will get the tuples as shown in Table III. Reading (T1, R1) is flagged as unique because there is no other reading on T1. Reading (T2, R1) is flagged as dup1 because it has duplicates and it was the first occurrence of the duplicates. The next reading (T2, R2) is flagged as dup2 because it has duplicates previously. If there are any other duplicates of T2, it will be flagged as dup2 too.

**ALGORITHM 1 (PRIOR).**

BEGIN
INPUT: Get readings from all reader
REQUIREMENT: Sort all tags with its reader based on the tag ID.

1. LOOP
2. IF the tags is not covered by any other reader
3. Flag tag as unique
4. Flag reader’s tag as active
5. ELSE IF tag is the first duplicate

The algorithm started by locating unique readings, where in this example is (T1, R1). R1 will be flagged as active indicating that the reader will be put into reading mode. The algorithm then will search any other readings that covered by R1 and flagged it as active, where in the example is (T2, R1). Then the next unique reading (T3, R3). R3 is not active yet so it will be put into active mode. The algorithm then searches other tags under this reader which is T3 and T5 and flagged the reading as active too. After the unique reading, the reading with dup1 flag will be evaluated. The first dup1 is going to be evaluated is (T2, R1). Because R1 is in the active mode this tuple will be ignored and the algorithm moves to the next dup1 tuple, (T3, R2).

The algorithm search back whether R2 has been activated or T3 has been covered by another reader that is in active mode, which is true because T3 is covered by active R3 previously. The tuple is ignored. The same case for the next dup1 which is (T4, R2), where T4 already has been covered by active R3. After reading on dup1 type tags, the algorithm moves to dup2 type which is (T2, R2). However T2 has been covered by active R1 while (T3, R3) and (T4, R3) already activated. By then only two readers need to be activated which is R1 and R3. Column 3 in Table III shows the final status of the readers.

4. PERFORMANCE ANALYSIS

Experiment is conducted by doing simulation on placing number of tags randomly to 50 readers. The number of
tags is started from 50 and increase by 50 until 500 for each sample. The purpose of this experiment is to investigate the minimum number of reader that will be put into operation to monitor the tags. The lower number of the reader used is the better.

Figure 4 shows the result of the experiment. On all samples PRIOR always have about 10% lower in number of readers used to cover the tags compare to RRE. One thing that make PRIOR is better than RRE is because PRIOR performed centralize processing after getting all the readings from the reader. This make the decision taken by PRIOR is more justified because it consider the whole situation based on the location of the reader and tags. In other hand RRE has produced the decision first by locking tags to particular reader. It makes decision without considering the overall system situations. There can be better solution if RRE take times to consider other option before locking into the solution.

The second experiment is conducted to compare the performance of PRIOR and RRE under different number of readers deployed. The readers are increased by 50 from 50 readers until 500 readers. The number of tags is 200 and constant throughout the time. The tags are set to be read randomly by the readers. Figure 5 shows the results from all the samples PRIOR performs better than RRE. All the samples show about 10% reductions in the number of readers used by PRIOR compared to RRE. This proves that PRIOR performs more efficient than RRE and can achieve more energy savings when used.

5. CONCLUSION

An RFID reader can become redundant at certain point when all the tags in its vicinity have been read by other readers. In this paper, we suggest to put such reader into sleep mode to save energy consumption. The results from the simulation show that significant performance showed by PRIOR compare to other existing approach. By reducing the number of reader, we lowered the chances of signal collision that is the source of noise readings. The number of duplicate readings also been reduced because the tag only been read only on one particular reader. Indirectly the algorithm will help in producing clean RFID data stream from noise and duplicate and promote sustainability for the energy saving.

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References and Notes

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