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A Review on Missing Tags Detection Approaches in RFID System

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***Abstract*— Radio Frequency Identification (RFID) system can provides automatic detection on very large number of tagged objects within short time. With this advantage, it is been using in many areas especially in the supply chain management, manufacturing and many others. It has the ability to track individual object all away from the manufacturing factory until it reach the retailer store. However, due to its nature that depends on radio signal to do the detection, reading on tagged objects can be missing due to the signal lost. The signal lost can be caused by weak signal, interference and unknown source. Missing tag detection in RFID system is truly significant problem, because it makes system reporting becoming useless, due to the misleading information generated from the inaccurate readings. The missing detection also can invoke fake alarm on theft, or object left undetected and unattended for some period. This paper provides review regarding this issue and compares some of the proposed approaches including Window Sub-range Transition Detection (WSTD), Efficient Missing-Tag Detection Protocol (EMD) and Multi-hashing based Missing Tag Identification (MMTI) protocol. Based on the reviews it will give insight on the current challenges and open up for a new solution in solving the problem of missing tag detection.**

***Keywords*— Radio Frequency Identification; RFID; missing tags; false negative; transition detection.**

I. INTRODUCTION

The RFID technology is an automated solution in identifying, monitoring, and tracking tagged objects that can be done from a distance. It has been increasingly popular, due to its automated feature and its practicality [1]. RFID has been applied in many different areas such as apparel [2], supply chain [3], and food industry [4]. However, there are still challenges to be solved in an RFID system, and one of them is the missing tag detection problem. Missing tag detection can happen due to signal collision [5], electrical interference [6] and unknown resources [7]. When an RFID reader missed detecting a tag, it will affect the data integrity of the system. The system will send incorrect data to the backend processing, and it will feed the user with misleading reports. For example, in a supermarket, the reader is installed on a rack to read all the tagged items [8], [9].

When a reader misses reading the items, it will feed the system with an incorrect total, which is less than the actual. The less number of items will trigger the system to instruct respective personnel to do item replenishment on the rack. The wrong instruction has been issued here because of the incorrect readings that have been made by readers. In another example, in some factory, they implement RFID to automate their system. When RFID miss read the item that is moving on the conveyor, the system will trigger incorrect action to the item at the next stop in the production. In the case of car assembly plant [10], incorrect paint color may be applied to the wrong parts because of the misreading problem. The missing tag detection is a severe problem that needs to be adequately attained to avoid significant system malfunction.

II. MATERIAL AND METHODS

Fig. 1 illustrates RFID missing tag scenario. The reader will read the tag and send the tag ID information to the middleware that resides in the computer. However, when there are multiple readings are made at the same time, a signal collision can occur, that lead to the missing tag problem. The scene shows that the reader is inconsistency in reading the tags. Where the items that receives from the supplier is placing in the warehouse and Receiving Items Door Reader will read the tags from the items. After that, the second point the Warehouse Door Reader from will receive the items through the warehouse door. However, Warehouse Door Reader cannot detect tags from Item C. Following the next point where the Warehouse Exit Door Reader will receive after the items move out from the warehouse store and unfortunately. Warehouse Exit Door Reader cannot read tags from item A. The last point is where the item will pass the Shipping Items Door Reader before the items lift into the content. Even, the Shipping Items Door cannot read tags from item B. This scene will delay the process because the worker needs to search the item, which may be lost, or the reader cannot read the data.

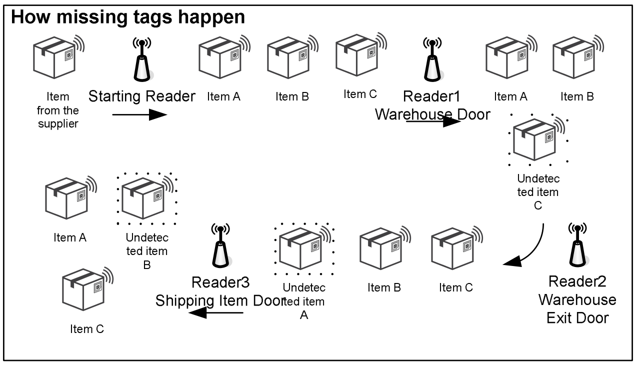

Fig. 1 RFID Missing Tags Scenario

The reader cannot detect RFID tags in the range can be because of extortion in the radio waves and tag malfunction [11]. Tags also can go undetected when it resides in the vicinity for a short period, causing it to be read below the specified threshold that decide whether it is false positive or true positive reading [12]. While the tag is true positive, it can be specified as false negative when it resides in a very short period. There are many other reasons why false negative happens [13]. Tags signal collision also can contribute to the existence of false negative where the signal becomes distort and modify the data its carries to be incorrect. In [14] discovers that false negative still have a modest impact to RFID data stream that has modest to high read rates.

In RFID, there is also a probability of missed read when the tag resides in the reader's blind spot. Blind spot can happen to tag that is closed to the reader but has poor radio-link. The missed reading rate in an RFID system is between 30% and 40% and can be higher in some other environments [15].

The important metric for a missing tag identification protocol is execution time. Execution time must be efficient in developing the approaches to detect the missed readings. This is to ensure that the approach will not affect other operations in the system [16]. The process developed by reducing the labor and strengthening the RFID system. It identifies all the missing tag and help the system implement a reliable detection system.

In the case of missing tag approaches, they can be divided into two, which is deterministic and probabilistic [17]. The deterministic approach is slower than probabilistic, but it reports all the missing tags ID that will take time because of the repetitive process that taking turns. Probabilistic approach only returns the number of missing tags without identifying their ID and hence is much faster.

Some novel protocols have been presented in the literature to identify the RFID missing tags [18]–[21]. Luo [18] proposes EMD. The sampling probability and Trusted Reader Protocol (TRP) control this protocol. Meanwhile, Massawe [19] proposed Window Sub-range Transition Detection (WSTD), which works adaptively in data cleaning. It is based on some of the concepts proposed in SMURF by Jeffrey et.al. The protocol improved the SMURF with transition detection mechanism. Another approach is from Liu [20] where their research is focusing on efficient multicast transmission and aggregate queries in the large RFID data stream. They attempt to lower the total of empty slots and estimated collision slots and trigger the deficiency of the existing Iterative ID free Protocol (IIP) scheme.

According to Zheng [22], the searching challenges in a large number of tags have been yet under-investigated by the research community. There many published works that are focus on the tag-searching problem [21]. The probability occurring that could happen in searching in missing tags is when the handout result shows invalid tags or unidentified tags. The challenges in searching missing tags are when the missing tags could not be identified meanwhile the item is available and could not be found. This scenario could happen if false negative reading by the reader and this could waste time and energy to search one by one. In the next subsection, we will discuss more in-depth on the existing approaches.

A. *Efficient Missing-Tag Detection Protocol (EMD)*

Luo [18] minimizes the execution time of protocol in detecting the missing tag proposes EMD. For EMD, the solution is focusing on the similarity of two small subsets of tags in a large RFID data stream. The similarity also has a substantial probability of sharing a standard tag. An example, let M be the set of m missing tags, K be a subset of k tags that the reader randomly selects from the inventory list N of n tags currently in the system. The reader undergoes the process to authenticate the existence of these k tags. It sends the signal that contains a tag ID to each of the tags. The reader pauses for a little while and ready to receive for a reply after transmitting an *ID*. After the tag is received its *ID*, it will recognize its existence by sending a reply. If there is no reply from any tag, it means that the owner of the ID is missing. A report on the missing tag will be generated. In a case where the value of k is significant, there will be a high probability that K and M will share at least one common tag. There will be cases that the occurrence of at least one tag in K cannot be positively confirmed. Therefore they will conclude it is a missing tag event.

The EMD is that to address the limitations of the standard protocol. The pooling request is broadcasted by initiation of protocol execution by the RFID reader. The tag with probability p decides the decision to join in the polling request. The slot was randomly selected in the subsequence frame if the tag decides to join. Otherwise, the tag will be put into sleep mode and reschedule for the cycle of the protocol implementation. The decisions are carried out are pseudo-randomly and foreseeable via the reader.

However, the disadvantage of this approach is they are not time-efficient. It is because it costs much time to confirm the occurrence of every selected tag. Second, for every select tag, they only do one low transmission but involves a hefty number of bits which is not energy-efficient.

B. *Multi-hashing based Missing Tags Identification (MMTI)*

In another work, Liu [20] proposed the MMTI protocol. This protocol is to lessen the total of the estimated empty slot and an estimated collision slot. It also improves the utilization of period by increasing the amount of the expected singleton slots. MMTI aims at reducing the amount of estimated empty slot and estimated collision slot. The challenge faced by this approach is how to ensure that the accomplished singleton slots will not be chosen in the next hashing process.

The status of the slot in a given frame is predictable to the reader. The reader can assign 1 to mark the singleton slot and 0 for collision or empty slot. Singleton slot does not need to be selected will the collision, and empty slot can be selected in the next hashing process.

The MMTI is based on the slotted aloha communication mechanism. A slot clock is assigned to each tag and is initialized by a random number. Whenever the reader has indicated an ending of the current slot, a tag will deduct its slot clock by one when the tag slot clock reaches zero, only after this it will respond to the reader. If the response by each tag is at minimum 10 bits, the reader can categorize the type of slot. First, the empty slot in which no tag responds and second is the collision slot in which more than one tag responds. Otherwise, if the tag response is less than 10 bit, the readers can categorize two kind types of the slot, which is an idle slot, where no tag response and the busy slot are is at least one tag responds.

C. *Window* Sub-range Transition Detection (WSTD)

In order to reduce reading errors, RFID data cleaning is a crucial task in its middleware. The task is to allow the data streams to be used and to make sure the data is the correct interpretation. In WSTD [21] the goal is to give each tag chance to be read within the window by reducing or eliminate dropped readings. It is used as a data cleaning mechanism for low-level RFID data processing within a middleware system. Two opposing application requirements are needed to confirm completeness for the set of tag readings due to tag reader system unreliability. Large window sizes are good for ensuring completeness in order to detect out the missed readings.

The second requirement is by capturing tag dynamic based on the movement if the tag is going in and out from the reader's detection region. To detect tags transition, the small window size is enough to perform the task. However, missed readings are prone to occur in a small window. They lead the system to mistakenly conclude that present tags to be absent which is also known as false negative errors.

For missing tags, the variation within the window also become the cause and not only due to the transition. To reduce the number of false positives and false negative due to the transition, the WSTD is reducing the window size. WSTD also moves its window per single read cycle and generates output by reading the corresponding to the center of the window after the entire window has been read. If the tag is moving out and was not detected in the second half of the window size, the tag is assumed it exists in the detection range. However, the weakness is that the early exit transition for the tag will lead to a false negative reading.

D. *Intersection* Algorithm

The existing proposed algorithm is included intersection algorithm [23] for comparing the RFID data between the two readers. The situation that often happens is low-power hardware where false negative usually happen when the multiple tags are didn't detected and will cause the reader to identify the current tags that frequently dropped reading by the readers. The detection is through time slot when the reader signal will organize the clocks of tags were 1 as single slot, 1 or more than 1 is collision slot and 0 as an empty slot. Intersection algorithm will compare the EPC data between the two readers without including an empty slot for detecting the false negative reads.

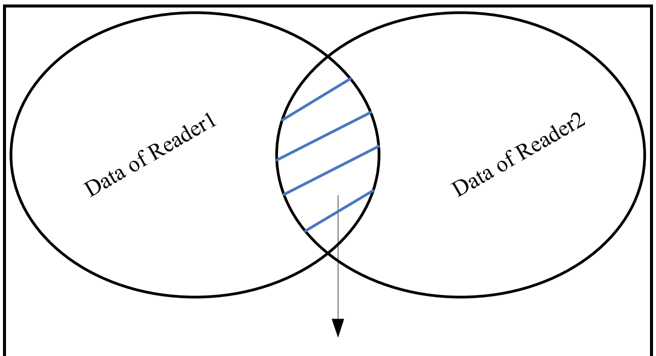

Fig. 2 Intersection data between the two readers

The intersection plays a role where the data will store by setting up the array. Fig. 2 illustrates the intersection is when there will be two readers as an input which is Reader1 and Reader2. Begin with reader read every data of Reader1 and Reader2. If every data from Reader1 is equal to every data from Reader 2 then the data will be placed into the Set A as a new output. Set A is a new set of data that merge the same data between data of Reader1 and Reader2.

Nevertheless, the research is focusing on detecting false negative reads by the reader was the readers cannot detect the data. This algorithm is only comparing the data between the two readers to find out if same data exist in both readers and will allocate into a new set. After all, the algorithm is selected for comparing the data to find out the different data that exist between the readers. However, the data will be hashed into the table for reducing the empty slot when the data is divided into another empty slot. The intersection algorithm will be merging with hashing and combine it with the R-PRN algorithm.

E. *R-PRN*

R-PRN algorithm [24] is used removing the false negative reads in the RFID data reader. The R-PRN algorithm starts the process set the pre-condition and Timestamp for the algorithm to identify the status of RFID data. The algorithm can be identified when the slot is ‘0’ for empty slot and ‘1’ for an available slot. Set t as time for every data where (t -1 =1; t + 1 = 1; t = 0) including the precondition = 1 or Timestamp = 1, the algorithm will detect the data as false negative read. Otherwise if (t-1=0; t+1 =0; t=1) including precondition = 0 or Timestamp = 1 the algorithm will detect false positive read.

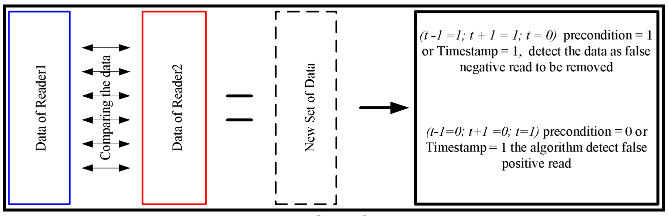

Fig. 3 R-PRN algorithm processes

Fig. 3 shows how the algorithm detects the false negative and false positive read. However, this algorithm is used to removing the false negative reads. The algorithm wants to clean the data in the RFID data to deal with anomalies false negative of high accuracy and less complexity. In this research, the algorithm is selected to merge with intersection algorithm. The algorithm is used for detecting the false negative reads from the new set of data that has been allocating by the intersection algorithm.

TABLE I
COMPARISON AMONG APPROACHES

Approach	Advantages	Disadvantages
Intersection Algorithm	• Clear set of data which separated by the intersection algorithm which able the data to be compared among readers	• Cannot detect which tags are missing
EMD	• The protocol allows energy-time tradeoff that achieve the minimum execution time • Lower energy cost	• Involve a hefty number of bits in one short transmission
WSTD	• Improve transition detection mechanism • To determine the suitable window size they use the binomial sampling concepts\which improves accuracy. • Use comparison for two windows sub-range for more accurate results. • Uses smaller window size which takes shorter processing time.	• Produces slightly more negative errors
R-PRN Algorithm	• Detecting other than false negative using pre-condition or timestamp.	• Take longer time because detecting others anomalies too.
MMTI	• Aim to reduce the Reducing the estimated empty slots the estimated collision slots. • Not suffering from the limitation of storage. • Utilizing the time slot efficiently to enhance the results.	• The channel inaccuracies often degrade the performance MMTI which can increase the false negative results. • Not efficient when there is an error in the channel

III. RESULTS AND DISCUSSION

As we discussed earlier, by not paying attention to the effect of false negatives on the RFID performance systems may lead to an overestimation of the benefits attainable with RFID [25]. The problem with RFID inaccurate reading can result in a business loss such as a lost track of the exact count of the items dispatched to the customer [26]. The business also did not know the real cause of the missing tag detection either it was the weakness in signal transmission or a case of theft is involved. If the signal is corrupt, it is still acceptable and can be corrected because the items are still in the business possession. However, if the reading is missing because the actual object has been missing, then it will be a loss to businesses. That is why the system needs to detect the missing tag reading in a very short time many and recover it to verify their existence. Further action can be taken if the objects are really missing from the reader’s vicinity.

One simple approach is by having a list of the tags that represent all the items sends to the customer. The reader can connect to the database that keeps all the tags ID. When the reader collects the IDs directly from the tags, we still do not know which tags are missing because the missing tags are not sending their signal to us. Suppose, if the tags exist, we will detect the tags through the time slots. Time-slotted is a communication between the reader and the tags. Reader signal will synchronize the clocks of the tags. In which, the reader issues a request in a time slot, one or more tag will respond in the time slots. If only one tag is replying it is called as a singleton slot. If the tag response is more than one, it is called a collision slot. The slot is called an empty slot if there is no response from the tag.

We can use hash functions approaches such as Bloom filters to speed up the identification of missing tags. Hash functions will hash the ID of the tags, and then we can compare it quickly with the list in arrays. In the array, we can store the count of the unique tag such as in [30]. If the count is less than it supposed to be, there is a case of missing tags. However, the weakness of using a hashing system is they cannot recognize the ID of the missing tags. This is because they are storing the ID in the form of hash and not in their original forms. The combination of hash and pointers can be worked out to solve this problem. Another weakness of hash functions is the occurrence of a small amount of false positive because it can hash difference ID into the same places.

The missing tags can happen when a signal collide. When the signals collide, all the readers involved need to the assigned new slot to read the tags. However, assigning a new slot will delay the reading on the tag. If the tag is leaving the vicinity before the new slot starts, false negative will occurs [19]. This is because the collision slot holds more than one tag which is possibly having the missing tags in the slot that the reader read as false negative. With that, by using a Multi-hashing process, this could assist the tags divided into the other empty slots. By reducing the empty slots could make the detecting missing tags easier. If the missing tag assigns to the empty slot, reader enables to read the tag and report which is the actual missing tag. By overcoming the collision issues, the missing detection tags is much easier because the tag can be read in each slot. Also, the unread tag can be detected by identifying the number of tag minus by an actual number of tags that read by the reader. The result will display the number of missing tags.

IV. Conclusion

The RFID technology is rapidly becoming more common in our lives, but do still exist. As it becomes ever cheaper and smaller, we are bound to see even more creative uses of RFID. Even so, the missing tag detection also could affect the RFID system if the missing tags cannot be identified. To overcome this problem, we make a review that can be used in missing tag detection. The review shows us that require having a small gap in reducing the time detection and more accurate in missing tag detection. In this overview, by combining multiple hashing and slotted aloha, this can be used to detect the tag and enhanced missing RFID tags identify performance. Therefore, further development of this research work is needed to be explored for the possibility of the enhanced algorithm from the existing literature to achieve better results and reliability.

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