Improving RFID Read Rate Reliability by a Systematic Error Detection Approach

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Abstract **– Reliability, Security and Privacy are the key concerns with RFID (Radio Frequency Identification) adoption. While the mainstream RFID research is focused on solving the security and privacy issues, this paper focuses on addressing the reliability issues in general and detecting read rate failures in particular. We specifically consider the issue of detecting if some RFID tags are not read at all, and if the tags are not read an alarm should be activated. This is quite different from the main stream RFID reliability research which attempts to increase the read rate by developing new and powerful antennas or improving the surrounding environment. To address this issue, we present a novel solution which can detect missed readings and notify appropriate entity to take suitable action against it. The novelty of the proposed solution lies in the combined use of RFID reader along with a normal weighing machine. The concept is to compare the gross weight of the tagged items against the gross weight (of the same items) stored in a backend database. The backed database can only be accessed for those RFID tags which are properly read. If some tags are not read at all these weights would vary and hence incorrect readings could be identified. This paper provides the detailed theoretical foundation for the proposed solution. In addition we compare the proposed solution against existing solutions to demonstrate the success and potential of our solution for practical deployment of RFID in library or supermarket scenario.**

Index Terms – Read Rate Error, RFID, Reliability, RFID Readability Error Detection.

I. Introduction

A RFID tag is an electronic device that holds identification data. Typically, the RFID tag is attached to items and contains a serial number, which is used to uniquely identify them. RFID technology uses radio waves to automatically identify items which have RFID tags attached to it.

RFID technology is composed of three main components; *firstly,* a RFID tag, which contains the identification number, *secondly,* a RFID Reader, which activates the tag to broadcast its identification number and *finally*, a RFID Middleware, which integrates the information from the reader to the backend database systems. This is shown in Fig. 1.

This new generation technology was initially developed with the aim to manage and track items, but is used in many other applications these days e.g. supply chain automation, asset tracking, medical applications, people tracking, manufacturing, retail and inventory tracking, livestock tracking and tracking exact timing in sports events. As pointed out by RFIDExchange "*RFID applications are limited only by imagination*". It can be used any where and every where if possible.

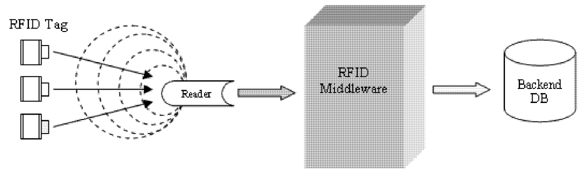

Fig. 1 RFID Architecture

The applications of RFID technology are enormous; however the potential of RFID can only be reached if the tags are consistently and reliably read. In the current scenario, achieving 100% read rate has been a daunting task for RFID based solutions. Apart from achieving the 100% read rates, the most important issues that need to be addresses is, in case 100% readings are not achieved, is it possible to determine that some tagged objects are not read? and prevent the incomplete information being propagated to the backend database? We found that currently not many solutions try to address this issue; hence we take this opportunity to present our solution.

The paper is organized as follows. In Section 2, we survey the existing literature on RFID reliability. In Section 3, we outline the proposed error detection approach. In Section 4, we provide a discussion and conclude the paper in Section 5.

II. Literature Review

Recent research in the field of RFID reliability has pointed out weakness with achieving 100% read rates. This is mainly attributed to the fact that radio frequency operates very well in certain environments. If the environment where RFID solution is deployed, is favorable to the RF, then the solution would work fine, however if the conditions are unfavorable then the RFID solution can be a nightmare. The problem of read rate errors was highlighted in a recent study [1], where the authors discussed their experimental results to show that achieving 100% read rate was not possible even in the most favorable RFID environment. The main aim of that experiment was to determine the relationship between different *product types* and tag orientation on the readability of RFID tags on shipping containers in a pallet load that was driven through a portal type reader [1]. It was concluded that the *contents* of the package dramatically reduced the read rate e.g. only 25% of tags on shipping containers containing water bottles could be read properly. In comparison to water bottles, the container with rice-jars showed a higher readability of 80.6%. The most interesting result of the experiment was that 100% readability was not achieved even when the shipping containers were left empty.

Other than the contents of the shipping container, readability of the tags is also affected by the *orientation* of the tags with respect to the reader antennae. If the tag is facing outward towards the antennae the readability is much better compared to other orientations [1, 2, 3, 4, 7]. In the experiments conducted in [1], it was shown that when the tags on the boxes filled with water bottles were faced downwards, none of the tags were read, which shows the importance of tag orientation and its key role in achieving higher readability.

Apart from the tag orientation the environmental factors also play a very important role. Wind, rain, electric motors, machinery etc. are some environmental factor that needs to be considered when trying to achieve higher readability. For examples, Ultra High Frequency (UHF) radio waves are impacted much more by wind and sun than High Frequency (HF) tags. Anyone that remembers what it was like to watch TV without a cable line experienced the impact of weather on tower transmission and reception at the TV. Other than that direct sunlight on the chip also distorts the read rates very significantly [4]. Electrical motors can also have a dramatic effect on the performance of RFID system [2, 3].

Literature shows that several studies have been undertaken to achieve 100% read rates in RFID deployment. For example, in [6], the authors develop a new antenna to tailor the requirements laid by cigarette cartons. They developed folded micro-strip patch-type antennae, to operate in a highly conductive aluminum foil environment, which is normally found in a cigarette box. The results indicated that they could achieve 80% readability. Similarly a novel tag was developed in [8] to operate in metallic environment, where the tag is attached to metallic objects. Similar studies to improve readability in metallic surrounding were conducted in [9], where the effects of metal plate to antenna parameters were presented when the antenna is horizontally placed near the plate.

It is observed from the literature study that most of the work in the area of reliability is done to improve readability of RFID tags by designing newer and smarter antennas, or by controlling the environment in which the RFID solution is deployed or putting constraints on how the tag should be placed to achieve maximum readability.

However we have found that not much work has been done to identify if all the tags are read properly or not i.e. if the readability in not 100%, can it be detected without introducing any additional configuration on the RFID middleware. This is an important issue and has many practical implications. It can be very useful in certain scenarios where it cannot be predicted as to how many tagged items would pass through a RFID interrogation zone, e.g. consider the library scenario where a student can walk with any number of books, the software cannot be configured to know how many books would be issued by the student, in which case if one of the book is not detected by the antennae it could be easily checkout out without being recorded.

There are some solutions that can be employed to address this issue. *Firstly* the use of second-generation RFID tags (Gen 2), these tags show a marked improvement in the ability to identify multiple items in the field compared to Gen 1 tags, however they are very costly compared to the Gen 1 tags.

Secondly, an intelligent middleware solution can be implemented to detect missed tag reads. But to identify which specific tag is missing would require a middleware solution that knows the items, which are supposed to be on a pallet before it hits the interrogation zone. The middleware would then identify which tags are read and it could tell you by deduction which ones it believes are missing. But this is entirely middleware dependent and usually requires some custom configuration, which is not feasible in the library scenario [10].

Another approach that the industry adopts is the use of light stacks. A light stack is only a colored indicator device, which is best used in a Yes/No kind of environment. The light stack again expects to see a predefined set of tagged items and if they are not detected it can raise an alarm, e.g. I am expecting to see 30 tags if I don't see 30 give a red alarm indicating errors, bit if I see all 30 then show the green alarm indicating everything is fine. This solution provides more of a Yes/No kind of answer [10].

Finally an electronic display board or an LCD monitor kind of solution can be implemented when one wants to know that a specific item number 'x' was not read [10].

However if we analyze each of these solutions it is quite clear that all of them require some prior information to act upon, e.g. the intelligent middleware solution need to know the number of tagged items that are entering the interrogation zone, similarly the light stack approach also requires to know the number of tags that are about to enter the RFID zone. Hence we find many reasons to believe that there are very few solutions that can address the issue that we are raising in this paper.

In this paper we propose a solution, which addresses the above, mentioned issue i.e. to detect if all the tags are read or to identify how many tags are read from a bunch. The solution was initially proposed to address the issue in a library scenario however it is later generalized to asset tracking in retail and supply chain. We now explain the proposed solution.

III. Proposed Solution

In this section, we give a general overview of proposed solution. Based on the limitations outlined in Section 1 and 2, we elicit the main requirements, followed by the design rationale where we discuss the basic design decisions for the proposed solution.

A. General Overview of the Solution

The proposed solution is designed to ascertain if some RFID tagged items are read or not read at all. To achieve this, the proposed solution relies on the combined use of RFID reader antennae along with a normal weighing machine. The idea is to compare the gross weight of the tagged items against the gross weight (of the same items) stored in a backend database. The backed database can only be accessed for those RFID tags, which are properly read. If some tags are not read at all these weights would vary and hence incorrect readings could be identified. In order to address the issues of detecting missed RFID reading, the following requirements are laid for the proposed solution.

B. Requirements

1. Detect Missed Reads: The solution should be capable to detect missed reads. It should be able to generate an exception in case a tag is not read.
2. Reliable Detection: The solution should be reliable and detect incorrect reads every time.
3. No prior information on products: The solution should not rely on an intelligent software program, which would provide some prior information to the reader regarding which tags to expect.
4. Generic Solution: The proposed solution should be scaled over multiple domains. It should not be restricted to just a few areas.
5. Yes or No solution with any prior information about the number of product arriving in the interrogation zone.
6. Cost effective solution: The solution should not introduce unreasonably higher cost.
7. Ease of Deployment: It should be easy to deploy
8. Independent of the tags capabilities: The solution should not depend on the type of tag being used i.e. the solution should work with either Gen 1 or Gen 2 tags.

The theoretical foundation is proposed to satisfy the requirements outlined above. The following design decisions are proposed in this solution.

C. Design Rationale

1. The proposed solution uses a normal weighting machine to assure that if the tags are not read an alarm is activated. (Req. 1, 2)
2. No prior information is required except the gross weight of the product, which in this case is assumed to be stored in the database when the RFID tag is written. With this information the system can easily provide a Yes or No answer. (Req. 3, 5)
3. The only additional equipment that is required to make the system work is a weighting machine, which is not a major expense compared to the cost of the RFID readers and antennae. (Req. 6)
4. There are no additional software and hardware configuration required except capturing the weight of the total tagged items in the interrogation zone. (Req. 7)
5. The proposed solution is independent of the tag type because the information is stored in the backend database. (Req. 8)
6. The proposed solution can be used in a library or in a supermarket hence it is very scalable. (Req. 4)

We now discuss the theoretical foundation for the proposed solution.

D. Theoretical Foundation

The proposed framework is shown in Fig. 2. The key components of the framework include the:

1. RFID Interrogation Zone
2. Weighting Machine
3. Backend RFID Database

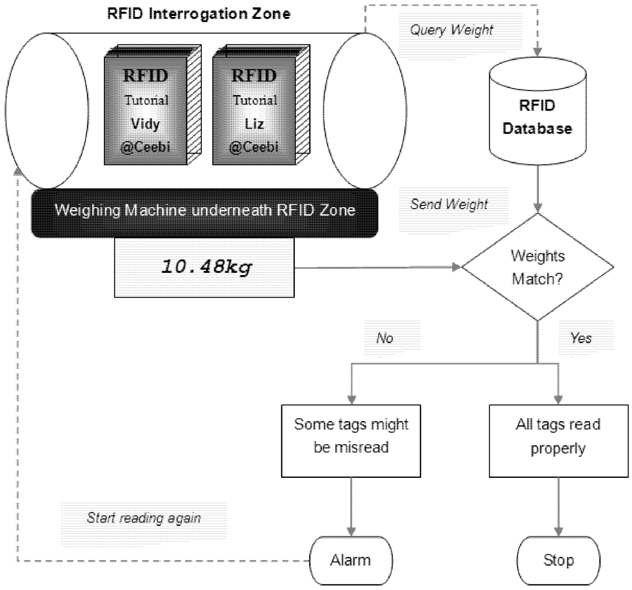

Fig. 2 Proposed Framework for Detecting Incomplete RFID Reading

The proposed approach can be divided into four main steps as follows:

A. RFID Tag Writing

This is the first stage in the proposed approach where the RFID tag is written and attached to the item under consideration. This step is not unique to this approach but is a generic step and is included in this description to cover all possible steps from the beginning of the RFID process.

B. Appending Backend Database

This stage is the key stage in the proposed solution. Here the gross weight of the RFID tagged item is calculated using a weighting machine and this information is stored in the backend database along with the RFID tag details.

The stages A and B are the preliminary stages that should be undertaken if the read rate errors are to be detected and attended. The second stage i.e. B, provides the infrastructure for read rate error detection and should be carefully completed before putting this system in use. The next two stages show system in action.

C. Identification of Read Rate Errors

In this stage a number of RFID tagged items enter the interrogation zone. The reader or the middleware is not aware of the number of items and hence cannot help to detect if any items are not read. Now let us consider the scenario when the RFID antenna cannot detect a few items in the interrogation zone. Under the normal circumstances it would go unnoticed because neither the reader nor the middleware knows the total number of items in the interrogation zone. In such a scenario the proposed solution could be very useful. Now let us consider that the proposed solution is implemented, which means that the middleware has additional intelligence, which can be used to detect missed reads. Since the proposed solution assume to have a weighting machine, whenever a set of RFID tagged items enter the interrogation zone, they would be weighed, at the same time the middleware along with the reader would determine the number of RFID tagged items. If the weight of the tagged items measured by the weighting machine and that retrieved from the database is equal then it can be concluded that all the items have been read, if not then it indicates some items were missed during the interrogation process. In short the basic idea behind the proposed solution can be summarised as follows:

1. Introduce a new field in the backend RFID database to store the weight of each tagged item. For example, most of the tagged books would weigh between 1kg to 5kg (rough estimation).
2. Select a weighing machine which can weigh at least 20 items (or depending upon how many items would be interrogated in the RFID zone).
3. To identify if the RFID reader does not read some items we weigh all the items and then compute the weight of all the items based upon the entries in the database. If both the weights are the same we can safely assume that all the books are read.
4. To automate this process we can build a small RFID interrogation zone attached with a weighing machine, something similar to a checkout lane at a supermarket. If all the items are read there would not be any alarm, if however some items are not read (which can be inferred from the comparative weights) the alarm would beep and the items might have to be rescanned.
5. The proposed solution can be used for reliable tracking of assets at an affordable cost.

V. Discussion and Validation

In this section we discuss the library scenario and show how the proposed solution can be very effective in such a situation. We also discuss why we chose to use the weighing machine alternative rather than other possible solutions.

Let us consider all the Books, CDs, DVDs, Journals in a library are tagged with a RFID tag. Similarly we also assume that the students have a Student ID card tagged with a RFID chip, which is something like a smart card. When the student wants to borrow some books from the library, s/he picks these books and goes to a self checkout lane. The Student ID Card along with all the books are scanned by the RFID reader and the system gets updated with this information. The main issue in this scenario is to ascertain that all the books and the Student ID Card is scanned properly. If the Student ID Card is not scanned the system can give an alarm because there is no entity to which the books can be lend. However the system cannot alarm if the reader does not read some of the books. This means the system would only allot those books, which are read by the reader. The possibility would be some books get lost because its not associated with any Student ID.

One way to address this situation is to let the librarian count the books and then scan it and associate it with the Student ID, however this removes the main advantage of RFID, which is no user intervention, and non-line of sight. This solution is no different than a traditional bar code approach.

Another approach to address this situation would be to install multiple readers in order to read the tags from all possible directions. However the drawback with this approach is, *firstly* cost associated with extra readers and *secondly* the same reliability as the above scenario, we cannot assure if all the books are read.

Another solution could be to tag one item with multiple tags, so that the read rate can be improved. The drawback with this approach are similar to the above solution i.e. increase in cost and no reliability. This solution is even worse because the cost keeps increasing with increasing assets. However in the former case the cost was limited to multiple readers.

Looking at the above solution we realize that most of these solutions provide mechanism to improve the read rate, which is not bad. However we would like to detect flaws in read rates, which is more important from asset tracking point of view. The main motivation for asset tracking is lost if assets are not scanned and are lost. In order to address this issue we proposed a solution based on RFID technology and traditional weighing machines, which was the best alternative compared to the other options.

VI. Conclusion and Future Work

In this paper we proposed a solution to address the issue of detecting if all the RFID tags are read or not. We found that the mainstream RFID research focused on solving the security and privacy issues, however we focused on addressing the reliability issues in general and detecting read rate failures in particular. Here we presented a novel solution, which can detect missed readings and notify appropriate entity to take suitable action against it. The novelty of the proposed solution was in the use of RFID reader along with a normal weighing machine. The idea was to compare the gross weight of the tagged items against the gross weight (of the same items) stored in a backend database. If any inconsistencies were identified it indicated incorrect readings. We provided a detailed theoretical foundation for the proposed solution.

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