RFID for Inventory of Medical Records

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Abstract

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The purpose of this project is to explore the feasibility and economic viability of the implementation of a radio frequency identification (RFID) system in a large-scale, medical office setting. Practitioners in fields such as; medicine, chiropractic, dentistry, nursing, pharmacy, allied health, and other care providers do not have a sufficient method for tracking filing forms. RFID has the potential to reduce wait time, improve checking-in time, and decrease the possibility of interchanging documents between patients.

The purpose of this RFID system is to improve upon the filing system already in place in any office setting. The major consideration behind this project is that there are thousands of files and folders for patients within any office setting. Therefore, a major overhaul of this system with a more high tech and relatively inexpensive RFID system may improve waiting times and ensure accuracy. This project is not focusing on any particular field or office, but focuses on a small-scale conceptual design and testing.

A RFID system will be designed and simulated to test the effectiveness in an office setting where filing forms is required. An analysis will be performed to compare the effectiveness of the RFID configuration and the legacy system to determine if using the RFID system is a viable option.

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Introduction

Radio Frequency Identification (RFID) consist of transmitting radio waves to receive data between a tag and a reader (also known as a transponder). This technology is most often used to track and identify inventory, usually in large quantities. The roots of RFID technology can be traced back to World War II. The Germans, Japanese, Americans and British were all using radar as a signal to warn people of approaching planes while they were still miles away. The problem was there was no way to identify who the planes belonged to. The Germans discovered a way to distinguish their planes from the enemies. They found that if pilots rolled their planes as they returned to base it would alter the signal that was sent, and therefore they knew it was their planes own plane. This crude method was the best solution at the time, but it gave birth to the field of RFID.

Thirty years later the first official RFID tags and transponders were patented and have evolved into a technology that has a variety of uses. For example, RFID is used in the production of automobiles, pharmaceutical products, clothing, or even implanted within people.

The purpose of this report is to explore the use of RFID identification and tracking of forms within an office space. It is applicable to a small clinic as well as a large-scale hospital. As an Administrative Assistant Intern at County Medical Service Program (CMSP), in San Luis Obispo, I realized the applicability of RFID to a medical office. CMSP is a health systems division of a health agency, which determines eligibility, provides utilization review and accounting services to ensure proper access to

health care for the medically underprivileged. My duties included handling paper-work, filing, copying, faxing, and some accounting responsibilities. As patients come in, they checked in at the front desk, and I get their names and pulled out their files from our cabinets. Often, I found that there were duplicate files, misplaced files and paperwork or lost files. Misplaced paperwork can be both tedious and a risk to the patients in an office. If the paper-work was not in the main cabinets then the next plausible place to look is the office of the technician that last handled their file. If we could not locate the file, then we started a completely new file for the patient. It appears unprofessional if files are not in order and readily assessable. In order to solve this problem, I want to propose the implementation of an RFID system within the office. I believe that this new system will help ensure the quality of performance from the staff, as well as gain the trust of the patients that use CMSP's services.

Problem Statement

Practitioners in medicine, chiropractic, dentistry, nursing, pharmacy, allied health, and other health care providers do not have a method for real time tracking of medical forms in place to reduce wait time, checking-in time and the possibility misplacing or interchanging documents.

Background

The goal of this project is to explore the use of RFID in an office setting for identifying and tracking forms that often get misplaced or lost. This project is important to individuals in the health care sector all around the world because it not only helps them keep their files in order, but increases effectiveness and efficiency. I will show that using RFID technologies for the inventory of medical forms is a cost effective and viable option to use. In order to test my hypothesis, I will run an experiment that uses RFID technologies on medical forms and folders, by simulating a real life office setting. The experiment and results will be presented after the following information of RFID; the tags used in RFID, current RFID medical tracking methods, and faults with current RFID medical tracking methods.

An Overview of RFID

Radio Frequency Identification is the use of radio waves to differentiate items by utilizing a reader or transponder, a tag or transceiver, and a computer database. The reader, usually a microprocessor device will decode and log the data received through one or more tags or transceivers. Figure 1 (below), displays an example of how RFID technologies work on a general level. The tag consists of an antenna and a small microchip that holds specific data about the object. The antenna transmits this data to a reader, and then the data is sent wirelessly from a reader to a computer. It is then sent to

a database where the read information is stored for that specific object. Data can be modified in real time and then updated to the database, allowing for continuous and updated information at all times.

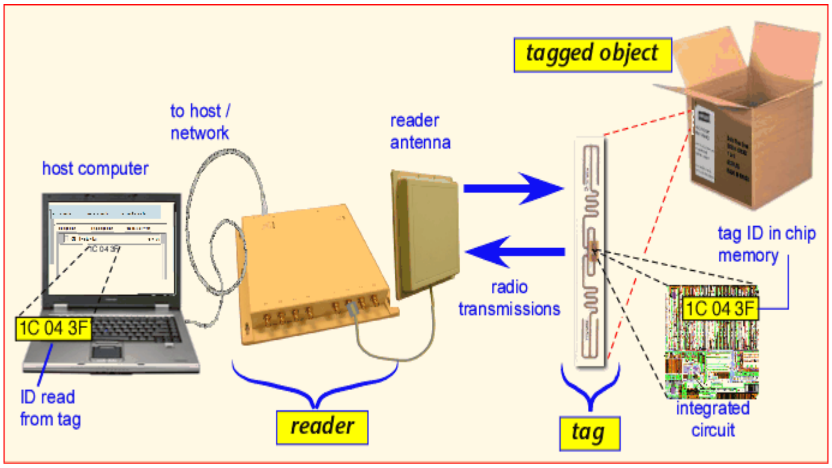

Figure 1: Schematic depiction of a simplified RFID system [14].

Data is transferred through radio waves and depending on the type of antenna, can operate at three different frequencies: Low, High and Ultra High. These different frequencies depend on the antenna type of the readers and tags. Low Frequency (LF) and High Frequency (HF) are composed of coil antennas and use induction for transmission of waves. Ultra High Frequency (UHF) consists of dipole antennas and backscattering transmission. Low Frequency and High Frequency are usually used in near field communication, while Ultra High Frequency is used in long-range communication. Certain companies and organizations require the use of RFID for all items they interact with such as: Wal-Mart, Target, Albertson's and the United States Department of Defense.

RFID Tags Types

RFID has three different types of tags: Active, Semi Active/Semi Passive, and Passive. In figure 2, it shows the difference in size between the three tags and the different frequencies associated with each tag. The main difference between active, semi-active and passive is that active and semi active tags possess an onboard battery. The battery in the active and semi active tags transmit information to the reader while passive tags respond only when there is a signal sent to it. The addition of the battery allows for the tag to constantly power the circuitry that handles more complex operations. The battery allows the tag to calculate GPS coordinates, temperature sensing, and extend the memory that is logged onto it.

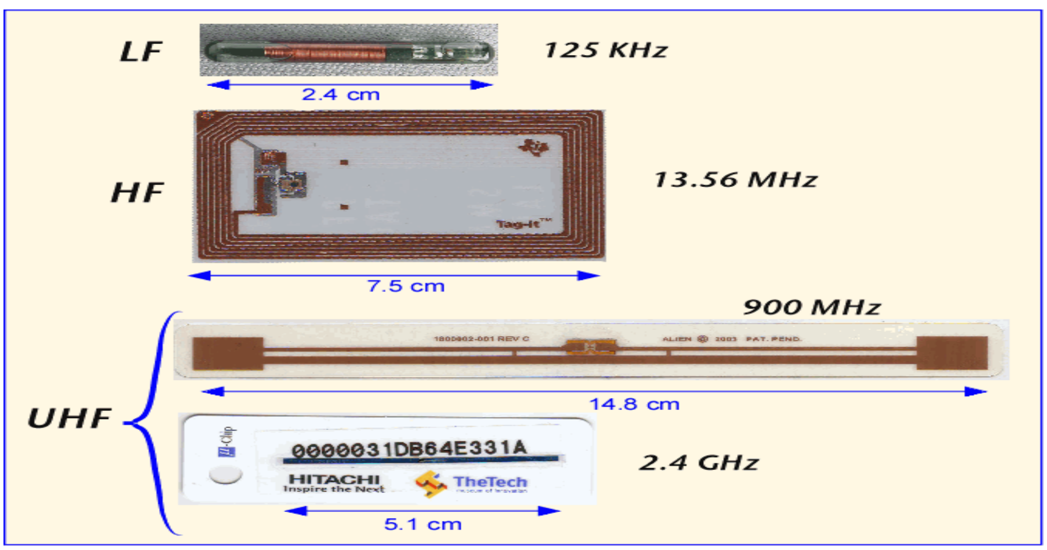

Figure 2: Summary of bands available for RFID use in the 860-960 MHz range [14].

The advantages of having an active tag are that it can be read at longer distances and reduces the power requirement of the reader. There are many disadvantages with the use of these tags though, such as: limited lifespan, environmental limitations, and cost.

The advantages of using passive tags in comparison to active tags are better cost, smaller size, and longer lifespan. The disadvantages of these tags are that they cannot be read from a long distance, and they require more power from the reader so that the tag can be activated. In figure 3, the diagram shows the difference is size and circuitry within an active and passive tag.

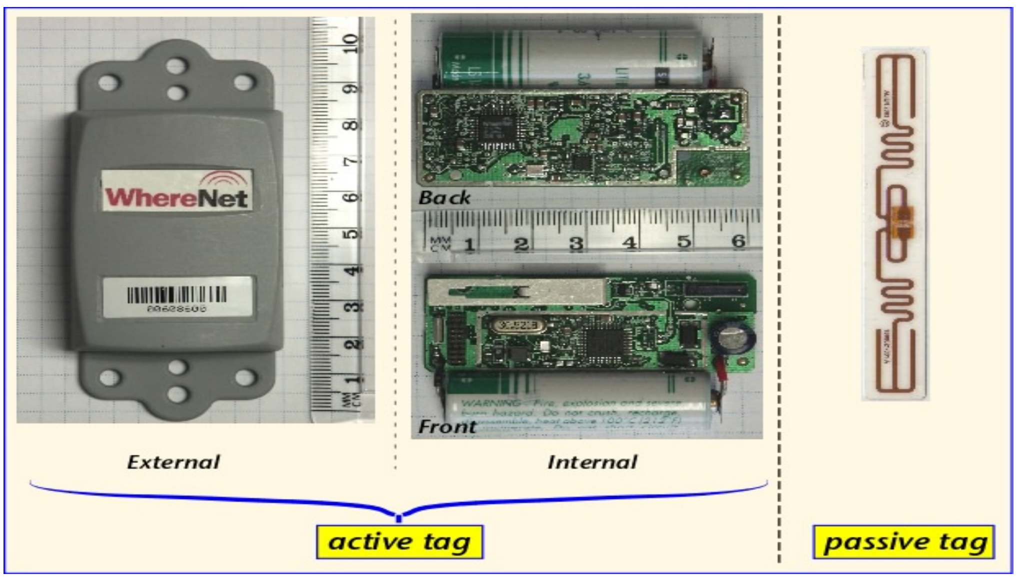

Figure 3: Comparison of active and passive tags depicted at the same scale [14].

There are two types of active tags: Beacon and Turn On active tags. The Beacon tag is continuously running and constantly sending signals back and forth to the reader, it usually lasts about one year because of battery usage. The Turn On tag only turns on when there is a signal is sent to it; when the reader sends the signal to the tag the battery will turn on the chip and antenna,

and send the information back to the reader. The Turn On tags last much longer than the Beacon tags because it uses less power from the battery, it usually last about five years.

RFID tags fall into a class system called UHF Protocol and have six different classes of tags, each being more complicated than the last.

- Class 0: Passive, read only tag that is programmed at time of manufacture
- Class 1: Passive, read-only backscatter tag with one time, field programmable non-volatile memory.
- Class 2: Passive backscatter tag with up to 65 KB of read-write memory.
- Class 3: Semi-Passive backscatter tag, with up to 65 KB of read write memory and onboard battery.
- Class 4: Active tag that uses onboard battery to power transmitter signal.
- Class 5: Reader tag that communicates with other Class 5 tags and devices.

Figure 4, illustrates how tags transmit their data through two types of coupling methods: inductive coupling and electromagnetic backscattering. Inductive coupling between a reader and a tag occurs when the reader creates a magnetic field between the tags and itself thus supplying power. In backscattering, the reader sends a signal to a tag and then the tag backscatters data back to the reader [3].

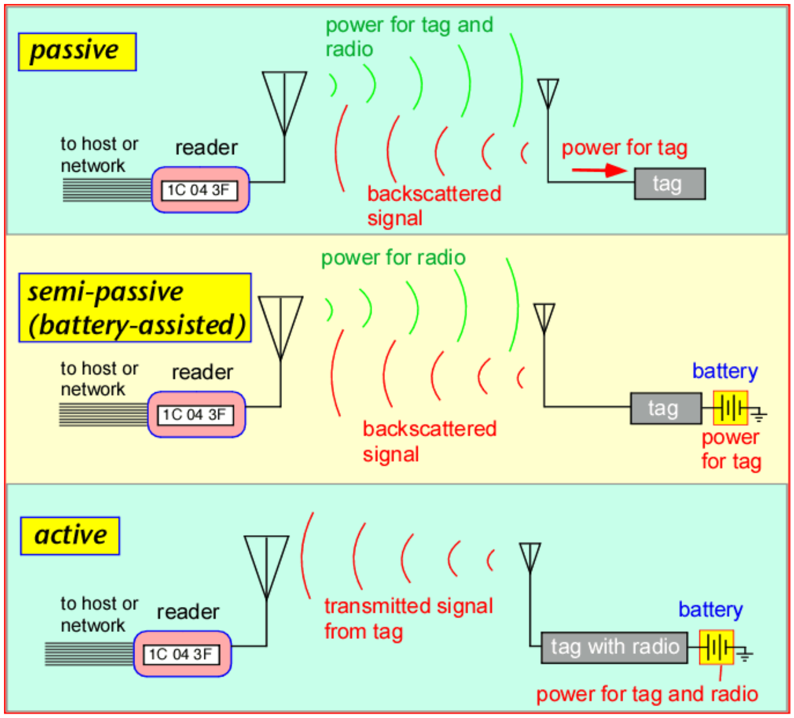

Figure 4: Approaches to providing power and tag-to-reader communications [14].

A big determinant of the success of RFID is the environment in which it operates. Environments that contain metal, liquid and multiple tags are suboptimal for RFID applications. This is because metals and liquids reflect and absorb RF waves and multiple tags create a shadowing effect which limits the readability of RFID tags [12]. The definition of shadow effect is the reduction in the strength of an ultra-high-frequency signal cause by some object between the points of transmission and reception.

RFID technology is a growing field with endless applications in countless sects of industry. There have been recent studies performed that prove the effectiveness of RFID performance in numerous environments along with a trend of increasing profits after implementation [18]. Furthermore, there have been studies that have tried to increase the readability of items within a

large inventory collection. One method that was explored was tagging the item multiple times in different locations. Another method was changing the orientation of tags. This was done in hopes of increasing the RFID system's readability and accuracies. A tags reliability to be read is defined as the number of tags that can be read in a given time period [17]. From figure 5, one can see how the RFID can be read and from what a variety of environments. RFID tags are not limited to being read from a hand held device, it is possible to read it from a camera or scanner in the room.

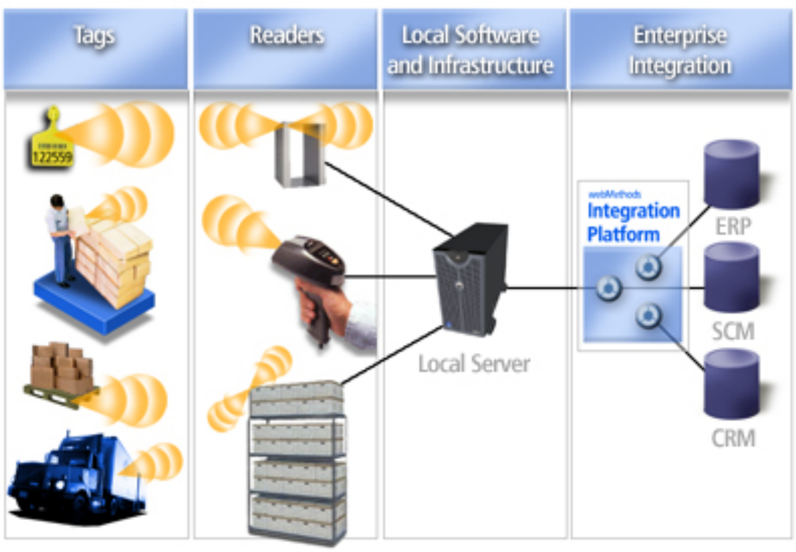

Figure 5: Different industry uses of RFID [15].

Current Uses of RFID in Medical Field

Radio Frequency Identification (RFID) is a young and growing technology, and continues to garner attention from all sects of industry. It is seen as a relatively low cost, efficient way of organizing products and inventory for many companies.

RFID technologies are currently being explored as an option for tracking medical forms. In 2007, California State University- Stanislaus launched a pilot to see if RFID could speed data collection within medical services. For 12 weeks, they had 200 students wear RFID tagged bracelets containing a unique ID number. Once a week these students would walk through the health center to see if a reader mounted at the RFID kiosk registered their arrival. The data was sent to the medical center's computer (MedicAlert's server), where a record was printed for the staff. This system was intended to eliminate the need for a patient to fill out a form upon each visit to the doctor's office. It is also designed to reduce the time spent by office workers to search for their files upon each visit [12].

Another application of RFID took place in Fort Hood, Texas. In 2006, the Army base was looking to use RFID technologies to tag records. The purpose of the project was to demonstrate the ability of RFID technology to inventory the medical record collection continuously and automatically without having to do so by hand. At the time Fort Hood had the nation's largest active-duty military post. They occupied 339 square miles and supported more than 150,000 soldiers. At that time, 3M Company was the leader in safety and security systems. The military used this system and attached passive RFID tags to all medical files at the post's six clinics. The RFID antennas were placed on shelves in rooms housing the files, allowing personnel to know the date and time a file was checkout and by whom. They would also be able to know the date and time the

file was checked back in and the specific clinic and shelf at which it is located. This project was expected to achieve some very basic and much needed benefits. It has been given the green light, and 3M's labs started to experiment with different passive high-frequency and ultrahigh-frequency tags. The RFID tags will replace the bar-code labels now used to track medical records at Fort Hood. Personnel presently scan the bar codes with handhelds as files are checked in and out of records rooms, a process that tracks the clinic at which each transaction was carried out [11].

RFID technology is increasing in popularity within the healthcare system. It has emerged as the standard for hospitals and healthcare centers to track valuable and strategic mobile assets in facilities. It has become an increasingly easy way to identify and locate patients and manage stuff. The introduction of RFID technology has brought much debate and speculation about its potential impact. A study conducted by the University of Texas at Austin by NXP shows the financial impacts of RFID in the US healthcare and retail stores. The key findings of this study can be summarized in the following list [18]:

- Companies in retail and he healthcare sector have experienced a 900 percent rate of return of their RFID investments
- Current adoption levels of RFID at the pallet and item levels in retail currently derive $12.05 billion in benefits from existing RFID applications

- Total benefits accruing to healthcare industry manufactures, distributes, and hospitals is equal to $45.9 billion
- Benefits to the healthcare consumer, through enhanced patient care, is estimated at $165.12 billion [19].

Faults with Current Technologies

Even after the two great projects of Fort Hood in 2006 and California State University-Stanislaus in 2007, there has been little to no development for RFID with respect to the tracking of medical forms. As pilot studies, the two experiments did not present conclusive results. According to Lee and Dozer 2007, there lies a "credibility gap" of the value of RFID thus calling for further application modeling [15]. It takes a lot for a company to be willing to completely switch to a whole new system. In order for potential users to feel more at ease about using this technology, there must be a proven case that the presented need can be satisfied by the RFID system. A company must be confident that the benefit will outweigh the costs. Many of the applications for RFID are mostly related to inventory management [16].

Inventory management systems are made of two parts: managing and locating the products. The end goal of any system that is implemented is that it should be cost effective. Many organizations struggle with this philosophy and experience high levels of inventory that is recorded incorrectly [13].This leads to a substantial loss of important documents and a suboptimal

performance on behalf of the hospital [17]. The many functions of inventory control begin with the act of counting and sorting through each file. The process is done periodically throughout an inventory lifecycle and the frequency is dependent on company policy. The purpose of sorting is to supervise and maintain the integrity of the files, to make sure that the files are up to date and in order [10].

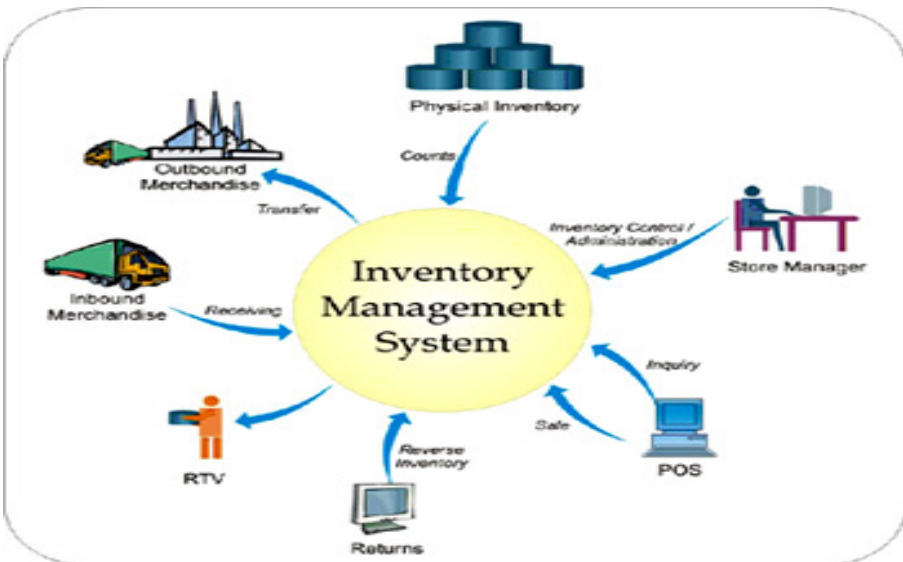

Figure 6: Inventory Management System [16].

Inventory management is a driving force for all product based companies and it is still a problem for most. In figure 6, all the variables that a company must consider when dealing with inventory are shown. The research for RFID in the medical field generally consists of a real-time locating system (RTLS) of expensive medical equipment. Hospitals use this as a method for tracking their million-dollar equipment, and it has been shown to cut cost and improve efficiency. Companies are looking for the most cost effective and efficient way to catalog all their merchandise.

Companies must have a clear and simple method to use in order for employees to learn quickly and to know where everything is [17]. The goal is to cut the time it takes to teach employees a new system and the time it takes to show them where the merchandise in order to increase their profit margin. Inventory management policies vary depending on product type and desired customer service levels. However, there is one universal factor that has an impact on operating costs, which is the more inventory, the higher the cost will be.

Healthcare professionals usually perform a physical inventory count of patient's files every six months to a year. However, every company has their own policies regarding this point. The process requires that employees "purge" the files that have not been active for more than a year. Employees sort through the files one at a time in a filing cabinet and examines all the files. The process of checking is to go file-by-file and see if the patient has made a "recent" (defined by their last visit was within the past 6 months, anything more is not considered recent) visit or not. Office space and drawer space is most valuable to a business, and making the necessary room for new patients to garner new profits is a must. Having observed this operation in use I came up with three observations of the problems with how medical forms are currently being processed [2]:

- The procedure is extremely manual, slow, and inefficient;
- People's eyes and hands get tired of the tedious work;
- Often employees do not do it correctly because the task is too daunting.

Implementation of RFID technology will help to alleviate these current problems. It will allow all users to be easily incorporated into the infrastructure and help increase productivity, efficiency and effectiveness of the businesses. Healthcare professionals will be able to:

- Easily track where the files are located (i.e. in storage, technicians desk, open cabinets, or put away in a cardboard box);
- Be able to find missing files or forms for patients;
- Be able to see if a patient has duplicate files.

Methods

The Plan

In order to reduce the amount of manual labor associated with medical form filing, I will determine if RFID tagging is a viable tool for taking physical inventory counts. At the completion of data collection, analysis is performed and recommendations will be made regarding the RFID item level tagging and its ability to provide accurate readings of the files. With results analyzed and recommendations stated, an analysis is performed to measure if it is viable to use it or not a healthcare setting.

In order to perform the previously mentioned analysis, I define an experimental design that will introduce two or three factors to my testing that will help conclude the effectiveness of item-level RFID. Once I obtain my results I will determine if item level RFID tagging in a healthcare environment is accurate enough to justify implementing a similar system. The scope of this project is to test the capability of item level RFID implementation to assist organization, productivity and efficiency for those who work in the healthcare sector. I will not develop an operating RFID system to be implemented or any prototype of the sort.

For this project, I will tag each form/folder that would allow all personnel to keep track of each patient's records. Therefore, this would allow an elimination of human error in misplacing, losing or misfiling important documents. As seen in figure 7, everything is beginning to be tagged with RFID tags. Therefore, tracking where each product is located becomes relatively simple and efficient. In the context of healthcare inventory management system, item- level RFID implementation would be a viable solution to assist inventory counts if every file was tagged with RFID, it could be accurately accounted for on a consistent basis. Given the sheer number of files that are in cabinets, in addition to the others that are in use, things can get mixed up pretty easily. There are thousands if not tens of thousands of files in any given institution.

Figure 7: RFID tags use in a medical setting [16].

For the scope of this project passive filters will be used because it is the most cost effective choice compared to the other two options. However, there are numerous limitations to the effectiveness of item-level passive RFID that greatly affects a tag's readability such as: shadowing, RF wave absorption/reflection, and tag durability. In order to justify RFID implementation extensive application modeling is required for this project, and this report will outline the specific application of RFID for medical files.

Design

In order to determine if RFID can be used to supply accurate tracking of medical files, a simulation was chosen. Each form that is going to be tested will have certain defined characteristics. This will be accomplished by scanning fourteen folders with two ultra-high frequency passive tags attached to each folder. Two different scanning procedures are considered and their ability to perform in any

healthcare environments will be evaluated. The way these scanning procedures will be tested is by (1) scanning the folders without intentionally moving the files or storage box, and (2) scanning the folders while shuffling through the files in the cabinet by hand. This is to simulate actual use of the device by medical personnel. The two tags that will be placed on each folder will have an array of two rows and three columns. The tags will be placed at random on each folder. For each form, an analysis of display method is conducted to determine if the identified display state will affect the readability of the RFID wave propagation. With the application of the different displays of tags on the folders along with the scanning techniques used, it will help determine if the application of RFID use for medical forms will help enhance the performance in tracking the inventory.

Selection Criteria

In determining the best method for this project, many scenarios were analyzed. A list was then complied of the most common cases for professionals. The following are the categories that are believed to fit the list previously mentioned. Based on of the list the following are the criteria that will be examined: high throughput, low cost, and high inventory density.

- Throughput: measure the rate of forms moving from cabinet to table
- Inventory density: total number of files allocated in each file cabinet

The individual selection was also influenced by the difficulty of manual filing in an office setting. The following conditions were taken into account: ergonomics, level of use, and the type of users. These conditions were subjectively decided from my experience of performing manual physical filing and pulling files for patients, as well as discussing it with the manager at County Medical Service Program.

Considerations from CMSP Office Setting

Photos courtesy of CMSP:

Figure 8: Hallway of CMSP, showing filing cabinets in the hallway as well as in the office

Figure 9: Front Office View #1

Figure 10: Front Office View #2

Figure 11: Front Desk Area

Figure 12: Medical Forms in Manila Folders

Figure 13: Cabinets A-M (Side View)

Figure 14: Cabinets A- M (Front View)

Figure 15: Cabinet N-Z (Side View)

Figure 16: Typical Office Setting

Timeline

Winter Quarter

- Week 1-3:
  - 12/15/11 Order parts and forms
  - 1/9/12 Go to a clinic in town to observe their day-to-day operations and make notes of how to improve their current system.
  - 1/11/12 Analyze the situation
- Week 3-4:
  - 1/18/12 Beginning initial design of how the form will look with the RFID tag
  - 1/20/12 Determine optimal positioning
  - 1/24/12 Begin implementation
- Week 5-6:
  - 1/30/12 Testing of tags to readers on medical forms
  - 2/6/12 Begin creating Database on Microsoft Access
- Week 7:
  - 2/14/12 Put the sample product together
  - 2/17/12 Implement sample product in a real world setting to test its authenticity
- Week 8:
  - 2/24/12 Last minute touch ups for the project

Materials List/ Budget Prediction

The following is a list of materials needed for this project. It includes cost, quantity, distributers and item number of each product. This information is given so that if future tests are run, it can be duplicated with the same materials.

	Cost (USD)	Quantity	Distributer	Item Number
Motorola RFID 9090 Reader	$2969.60	1	this and that	MC9090-GU0HJEQZ1US
Older Version WI-49-H3 Tags	$4.50 (0.15 cents/tag)	30	Sirit	ISO18000-6C
Medical Forms	$4.99	50	FreePrintableMedicalForms.com	280416806319
Manila Folders	$9.45	100	Tradecozone	310324723637

Table 1: RFID tags use in a medical setting.

Chart of Materials and Budget. [17].

NOTE: Some of these materials will be used from PolyGAIT RFID Lab.

Testing

To begin testing the implementation of using RFID on medical forms, I began by assembling all of my materials. First, I got the necessary items that would be present in any medical setting such as: folders, forms, tape, and a cardboard box (that is usually used for storage). Professor Freed provided a metal cabinet.

Next, I gathered thirty Ultra-High Frequency (UHF) tags, and a Motorola 9090 RFID Reader, which ran Windows Mobile. There was only one type of tag that I used for testing, and it fit the requirements for the system that I am proposing to implement.

However, when I began testing, the tags read at completely different distances than originally anticipated. The Ultra-High Frequency passive tag has a read distance of a few inches to sixty feet. The short tag reading distance is mainly due to the tag being placed in the same area as well as a confined space, thus there was a shadowing effect taking place. To try and reduce the shadowing effect, I placed the two tags in a random area out of six on the folder. Because of the space limitation of the folder, overlapping between tags is inevitable. With the high density of folder thickness and shadowing, RF waves from the reader are absorbed, making it harder for the tag to transmit information because the signal is weaker than normal.

Even with the weak signal read, I would still use the UHF tag because it is still the most useful and cost effective alternative. There is a possibility of reading multiple tags at once, but the checker would have the flexibility to eliminate that from happening.

The experiment was evaluated by the time it took to manually find the file and how long it took with the RFID system. Therefore, I gave myself a random folder to find within the cardboard box. I timed myself with a stopwatch timer. I then ran the test again but this time used the RFID system, again timing myself with the stopwatch. I then compared the difference in time between the two methods. I ran each

of these experiments three times. Table 2 below has the average time for both the manual sorting and the RFID system trail.

Manually Filing	RFID System
15.45 seconds	5.76 seconds

Table 2: RFID and Manual Filing system Average Service Times.

Obviously from the average times, it can be seen that the RFID service time is considerably faster than the manual filing service time. This may be due to the constant flipping between files when searching for a folder manually. The times from these two tests will be used to construct a simulation that will help model a large office storage facility, to show the true difference in times. Results will be discussed in the following section.

Model System Design

Once I gathered all the materials needed I was able to do a small-scale test that would replicate a large-scale setting. After getting a cardboard box, paper, folders, tape, tags and a reader I was able to perform the experiment.

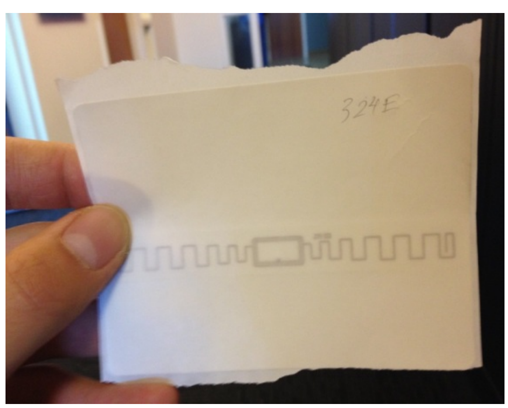

Figure 17: UHF Passive Tag written with its special coding on top right corner.

The first part of the experiment is to individually scan each tag one by one and write down the specific code for each tag. When scanned by the reader, each tag has sixteen leading zeros followed by a special four digits unique to each tag. The following table is a list of all the tags that were used in this experiment.

3205	3206	3207
3202	3212	3208
320B	320A	320C
320D	3212	320E
3211	3210	3214
3213	3215	3216
3218	3217	324B
324A	3249	324D
3218	3219	3203
3204	3201	3222

Table 3: Codes of Passive Tags Used.

The second part of the experiment is to then randomly assign two tags to one folder. Figure 18 (below) explains the six possible locations that the tags can be placed. Each folder will be randomly assigned tags. This is to reduce the shadowing effect and ensure more accurate results. Again, shadowing is defined as one tag having the possibility of obstructing the signal of another tag. The equation below shows the chance of overlapping. This percentage was calculated using a factorial equation. The numerator represents the six possible sections that the tags can be places. In the denominator there are two numbers, the left (4) is the remaining spots that are not used, and the right (2) represents the two spots that are used. The equation as a whole calculates the probability of shadowing.

$6!4!2!=115=$ 6.66% chance of overlapping (shadowing)

Equation 1: Determining the Shadowing Effect

This aspect is very important to this experiment because with hundreds of files in a cabinet it is easy to lose the signal of a particular file. This layout will try to alleviate the amount of files that would not have been read otherwise.

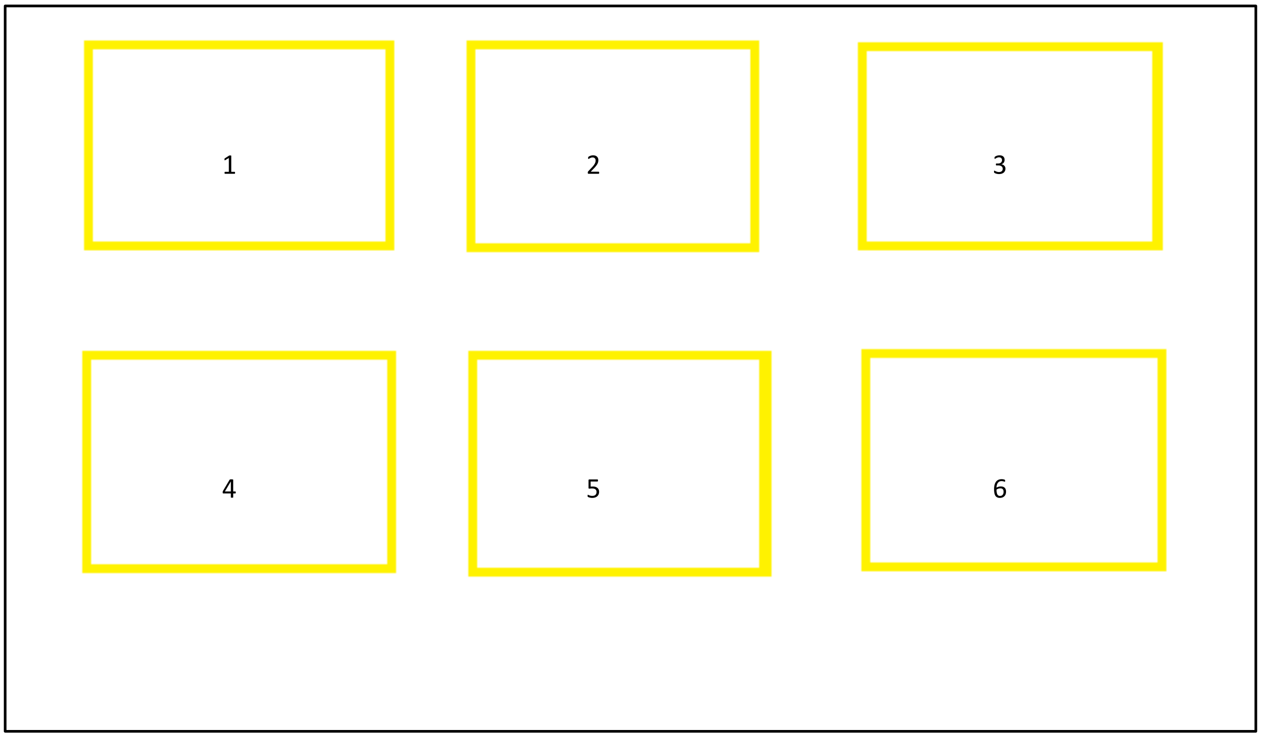

Figure 18: Typical Folder with Placement for Tags.

If the figure above presents a typical folder a random arrangement of possible placements for the tags was made. After tagging all of the folders, I began to put in one folder at a time into the cardboard box. Then I would calculate the time it took to read each folder. After tagging each folder, I made the following assumptions for the experiment:

- Assumption 1: When scanned, if it picked up even one tag, it would count as a fully read folder
- Assumption 2: By scanning the folders one at a time, when it would not read all the folders, an additional five seconds was adding to the allotted time period. Because a normal office setting

would have thousands of files in their cabinets, this does not give us a clear understanding of how long it actually takes to scan the files.

- Assumption 3: If there was a scanned output of a tag that was not present in the sample; that would not qualify as a count.
- Assumption 4: To replicate an actual office setting, dummy folders containing no actual documents or tags were added for depth.
- Assumption 5: Because tags cannot be read through regular cabinets, the experiment was performed in a cardboard box. The only way to actually scan files inside a metal cabinet would be to physically open it and rummage through the files until something was read. Therefore, there were only simple experiments involving the metal container.

After reading the time it took to read each file as it was put into the box, the next step was to see if putting dummy folders (folders containing no tags or information) would affect the reading.

Results

For part one of my experiment, I added one folder at a time and scanned the files with the reader from a distance of six to nine inches away without touching the files or box while scanning. The scanning processes consisted of scanning the tags and correlating how many folders were scanned to the total number of folders in that order to, check if every folder was accounted for. The following table shows the findings for part one.

Scan (# of Tags)	# of tags Read/ Amt of Tags	Read Every Folder? Y or N?
Begin Reading at 5 Seconds		

2	**2/2**	**Y**
4	**3/4**	**Y**
6	**5/6**	**Y**
8	**5/8**	**Y**
10	**7/10**	**Y**
12	**5/10**	**N**
14	**5/14**	**Y**
*ADDED 5 Seconds	**Now Reading at 10 Seconds***	
16	**12/16**	**Y**
18	**11/18**	**Y**
*ADDED 5 Seconds	**Now Reading at 15 Seconds***	
20	**15/20**	**Y**
22	**15/22**	**Y**
24	**13/24**	**N**
*ADDED 5 Seconds	**Now Reading at 20 Seconds***	
26	**20/26**	**Y**
28	**19/28**	**N**
*ADDED 5 Seconds	**Now Reading at 25 Seconds***	
30	**21/30**	**Y**

Table 4: Data Collected through 15 rounds of testing with RFID.

The data in table 4 illustrates that adding more and more files increases the time it takes to read every single folder. In a real cabinet with tens to hundreds of folders to flip through, it could potentially take a long time to read every single one. Therefore, another test was created in order to determine a method to alleviate the time it takes to read each folder. The implementation of the shuffling method

was used. This method consisted of the user shuffling the files and creating movement within the box. When tags are in movement is creates better readability by the reader. It is an unexplainable trend that occurs, and was brought to my attention by Professor Freed. Therefore implementing this shuffling method was the correct decision because it helped increase the amount of tags being read and provided more accurate results. Table 5 illustrates the data collected while using the shuffling method and table 6 illustrates the data collected without using the shuffling method. Both tests were run three times, to create an average amount of tags that is scanned using each method. These tables are shown subsequently to compare the effectiveness of each method. The left hand side of the table shows the amount of tags scanned. It is 30 every time because that is the number of files in the cabinet. I used the number 30 because it is the minimum number used for statistical analysis. The right hand side illustrates the actual number of tags that were read.

Amt of Tags Scanned	Amt of Tags Read
30	25
30	21
30	18

Table 5: Amount of folders read with shuffling method.

Amt of Tags Scanned	Amt of Tags Read
30	24
30	18
30	8

Table 6: Amount of folders read without shuffling method.

From the above tables, it can be seen that there is a notable difference in the amount of tags being read with the shuffling method. On average, the shuffling method will read 4.64 more folders.

That is a 15.46% increase in the amount of folders read, which would greatly increase efficiency by just adding this simple task. The maximum time allotted for this experiment was 25 seconds per trail. If the files were all read before the time expired then that would be noted in the analysis. Typically the time would expire without each tag being read, that is why a hard cap for time had to be placed.

There were a few limitations to the system that I created. With one hand on the reader and the other flipping through the files, it was not an exact replica of the process each time. Therefore, there were some biases within the results. Another limitation was that there was no computer database program that was created that could have made tracking the files easier, thereby allowing the RFID system to be faster and more efficient. This database program could potentially produce a more realistic system for implementation in a real life setting. The final limitation of the project is the lack of standardization in manually sorting the files. The data for manually sorting was generated by picking a random folder with an RFID code on it and seeing how long it took me to find it. There are not nearly as many files in my experiment as there are in a real office setting. Therefore, the time was above the average for finding the files using RFID, at 1 minute and 32 seconds with five rounds of testing. So from this analysis it would seem that an RFID system would be more efficient than manually sorting these files.

I did not accurately interpret some of the results when I first began testing and collecting data. At first, I wanted to scan each trial with the exact same time of 5 seconds. However, after a few trial runs, I noticed that it was not working the way I envisioned it. I was puzzled to see that with this approach a large majority of tags that were not being read. After assessing the situation I determined the cause to be the shadowing effect, the 6.66% rate. The shadowing effect was evident because it took more time after each interval to read the tags. This is when I realized that just simply scanning the files would not suffice, that is when I implemented the shuffling method.

Based on the observations and results of this experiment, a prediction can be made on the number of seconds it takes to read RFID tags with a sample size of 15 folders and 30 tags. One optimal solution that can be gathered from this data is based on the following criteria for an RFID system:

- Average reading time is 25 seconds (less than a half a minute)
- Shuffling method will increase readability of tags by 15.46%
- On average the RFID system was faster than the conventional manual filing by 1 minute in this small sample size

There are some future recommendations for this project as well as some notes that I would like to make regarding this project. Since this project and experiment is still very raw, there are some tests that could help in further evaluating if this project would be ideal in an office setting. The first test would be to run the same experiment but with a wall mounted antenna. The reason for using a wall mount antenna is that the signal is much stronger than a hand held reader. This in turn could further expedite the reading process of files in a room. Another test that can be ran to test the efficiency of this project is to hang the tags on or near the files. Then by installing a fan to blow the tag, it will enable the reader to catch the files faster. It is unclear why the blowing technique works better, but it is similar to the shuffling technique that I used. The results of the shuffling technique showed that it was actually really useful; therefore if there was a blowing test I believe there would be some positive results coming from that. Another option for a future project is making an automated shuffling system. This device could be built into each filing cabinet and shuffle the folders in a uniform and efficient manner. It could maximize the tags exposure to the reader and potentially give the user better results.

Conclusion

This project was based on the problem that offices do not have an electronic system that can accurately and quickly verify a patient's files within the office. My objective for this project was to find a system, and test it against the conventional manual filing system that is used and compare the two systems systemically. My approach to this project was to gather data about both systems and then model this data in a simulation model. This would then allow me to determine each system's effectiveness.

Here are my conclusions from the project:

- The RFID system that was tested gave extremely quick times at all levels of the simulation model in terms of the amount of files that kept being adding to the total.
- The conventional system quickly deteriorates in terms of manual labor where employees can get tired or miss the file.
- The RFID system is an expensive system to implement but it will help alleviate the wait time, checking time, and the possibility of interchanging documents between patients.

Based on the results of this project it appears that an RFID system is the next step to explore within an office setting, not only to improve service time but also to improve patient satisfaction and accuracy. From this project I learned that an RFID system can do extraordinary things that completely surpass conventional systems, its implementation has not been fully explored. This technology has the potential to make positive changes in certain situations. RFID can add a lot to a system, but it takes a lot to change the existing process to a new complex system like RFID. That is probably the main reason delaying RFID implementation across different industries. However, this project illustrates that RFID offers substantial gains.

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