Design & technology assessment of combined near & far field UHF RFID based specimen tracking & inventory management System

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Kailash Raghuwanshi

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Kailash Raghuwanshi

We the thesis committee for the above candidate for the

Master of Science degree,

hereby recommend acceptance of this thesis

Ted Teng, Advisor of Thesis

Professor, Department of Technology and Society

Vera Gorfinkel, Co-Advisor of Thesis

Associate Professor, Department of Electrical and Computer Engineering

This thesis is accepted by the Graduate School

Lawrence Martin
Dean of the Graduate School

Abstract of the Thesis

Design & technology assessment of combined near & far field UHF RFID based specimen tracking & inventory management System

By

Kailash Raghuwanshi

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This master thesis is about designing a UHF RFID based system for specimen tracking and inventory in hospitals .Specimen tracking is usually done manually which is susceptible to human error .There is a need of a automated and real time specimen tracking system in hospitals .The goal of the UHF RFID based system is to develop an automated real time tracking and inventory management of specimen in hospitals .This system uses a combination of near and far field RFID communication, that overcomes the problems faced in conventional systems to provide a reliable and robust system for specimen tracking .Apart from the implementation and deployment details of this system, impact of this system on hospitals and policy regarding the implementation of this system have also been discussed.

To My Parents

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Chapter 1

Introduction

1.1 Background

Hospitals and Clinical labs collect biological specimens from patients on a regular basis to diagnose the disease .During the process of specimen collection and analysis it undergoes numerous exchange from one place to another .Specimen tracking is all about keeping track of specimen from the time they enter a medical facility till the time they are kept in the archive .Another term specimen inventory which dealt with proper labeling of specimen with the correct information and keeping a record of it [60] .In a hospital specimen tracking and specimen inventory both play crucial roles since the identification and record of specimen of patient depends on them.

Consider the following incident, an OR(Operation Room) specimen was transported to a lab .The lab said there was no specimen in container .The specimen was a sample from a suspected cancer patient [61].The incident similar to above were a specimen went missing creates problems in the hospitals since it directly effects patient safety, care and delay in health recovery .Specimen errors like the one above has huge implication for patient safety since they leads to a delay in treatment or wrong treatment in some cases .The occurrence of specimen error is not rare [61].A study of specimen error at John Hopkins hospital found the following results .The specimen error rate found was 4.3% per 1000 surgical specimen .The errors were examined in 21,351 specimens taken from patients .In the above case all error cases were resolved without any harm [61].However, there have been cases due to the missing specimen were patients have suffered a lot and has lead to delay in patient recovery or some fatal accident at times.

Specimen error can be eliminated if effective measures in the direction of specimen inventory and specimen tracking are taken .Measures in the direction of effective specimen inventory have been taken from time to time which had lead to more efficient ways of specimen inventory beginning from hand labels to the most recent automated methods of specimen inventorying like RFID and barcode .However, specimen tracking is still mostly done using paper requisition where a paper is signed by the receiver of the specimen and returned back to the sender .Other methods of specimen tracking that provides real time tracking of specimen relies on technologies like Wi-Fi or RFID but, have certain drawbacks like a very small specimen sample cannot be tracked, cost of implementing such systems etc .All these methods have been discussed in chapter 2.

On the basis of above discussion there is a need for the development of a system for reliable, robust automated location tracking and inventory management system of specimen in hospitals .This project is an attempt towards development of such a system.

1.2 Our vision

The vision behind this thesis is as follows .All specimens will be tagged with RFID tags and RFID tags are also placed along the path where specimen movements needs to be tracked .Once specimen are tagged they are placed in a specially designed bucket, in the remainder of this text referred as specimen carrier .Further when the specimen carrier is powered up it starts remotely sending the specimen contents and its location by reading the RFID tags on the specimens and RFID tags placed in the path respectively to the Laboratory Information System[1] (LIS).In this way a real time tracking and automated inventory management of specimen can be done with one system.

There are many advantages of using this RFID based specimen tracking and inventory system .A first advantage is there is no need of deploying additional wireless access points since wireless communication is only used for data sending to the remote LIS and not for detecting location .A second advantage is this system can be used for automated inventory management and specimen tracking both so there is no need for buying a separate system for specimen inventory while using this system .A third advantage is the real time nature of this system so whenever a specimen went missing along the path of tracking the hospital administration can be notified at the same time .Other benefits have been discussed further in this thesis.

1.3 Roadmap

The rest of this report is structured as follows:

Chapter 2, Literature survey on specimen tracking & specimen inventory management, is a survey of work in this area.

Chapter 3, Overview, discusses the technology used to make this system working.

Chapter 4, Implementation, describes the hardware used and software algorithms implemented.

Chapter 5, Impact, brief description of impact of using this technology in hospital

[1] Laboratory Information System is software that receives process and stores medical facility information in a database.

Chapter 6, Policy, gives an insight into the policy needed to correctly implement this system in hospital.

Chapter 7, Conclusion, contains a summary of our results and ideas for future work.

Chapter 2

Literature survey on Specimen Tracking & Inventory Management in hospitals

As discussed in the previous chapter that specimen errors can lead to fatal and life endangering problems in hospitals .Hence, it becomes important to check whether the techniques employed for tracking and inventory these specimens are accurate & robust or not. This chapter discusses the various methods to track & inventory specimen in a Hospital .In section 2.1 a discussion of various technology used for specimen inventory are presented .Section 2.2 discusses technology used for specimen tracking when it moves from one lab to the other .And section 2.3 is a brief summary of the chapter .

2.1 Specimen Inventory

Every hospital has to keep a record of the specimen being collected from patients .Many techniques are used in order to inventory specimen containers in a hospital .In this section these techniques are discussed.

2.1.1 Handwritten label

When a specimen is taken from a patient it is then put into special container in a medium consisting of preservatives such as ice, water or formalin [1].The method of inventorying these specimen put into the special containers using handwritten labels work as follows .A handwritten paper label is a piece of paper on which the details of patient's specimen are either written directly or encoded into some number.

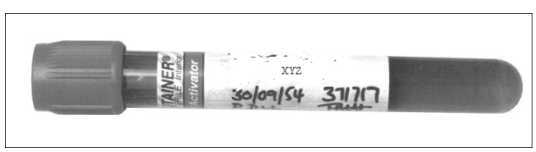

Figure 2.1 A specimen in a test tube with a hand written Label [2]

Once the details are written on the label, this label is put on the specimen container and a record of it being recorded in the LIS it is then ready to be taken to other labs for further testing or storage .When this specimen arrives at a new lab it is to be read & deciphered to know the details of the specimen so that a record of it could be entered into the LIS .In this way specimen are managed using Handwritten label.

Although, the process works hand labeling any item incorporates uncertainty into a process because of the many errors that could occur. Handwritten labels can be misinterpreted in any number of ways; the handwriting is illegible, the data is incorrect, or the written label smeared during handling. Entering incorrect or incomplete data for lab testing/results can mean disastrous results for the patients involved [3].

2.1.2 Printed label

To solve the issues faced with handwritten label like illegible handwriting ,incorrect data interpretation & smearing of hand written label printed label were introduced .Similar to the handwritten label ,printed label is also a piece of paper it is just that the details of the patient's specimen are printed rather than handwritten .

Printed labels solved the problems faced with handwritten labels but, there was a possibility of human error in this system .Since, printed labels are to be read by a human eye data could be incorrectly interpreted at time which can create errors in the specimen tracking procedure .Moreover, manually reading data at every lab and making log file records of specimen manually in the LIS is a time taking task.

2.1.3 Barcode

Barcode technology was introduced in hospital to automate the process of specimen management. Barcode is a machine-readable representation of data, which shows certain data on certain products [5].The machine needed for reading barcode is termed as barcode scanner .The barcode scanner upon reading the barcode adds the information related to the barcode to the computer attached to it.

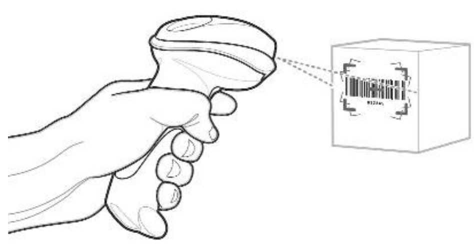

Figure 2.2 Figure representing a barcode scanner reading a barcode [6].

A barcode scanner is put at every lab station when a specimen having barcode on it arrives in the lab it is read by the scanner and the information read is updated to the LIS .This method of specimen management adds automation to the process of reading labels every time .Additionally, data is always correctly read by the scanner not like printed labels where incorrect data could be read .Special barcodes like Reduced Space

Symbology (RSS) bar code have been made so that they can be used to put on small specimen containers [3].Figure 2.2 & 2.3 compares a traditional Code 128 bar code with a RSS limited bar code

Figure 2.3 Code 128 bar code[3]

Figure 2.4 RSS limited bar code [3]

Despite the fact, that barcode technology introduces automation in the process of specimen Inventory management in hospitals it has certain limitations like only one barcode can be read through the barcode at a time, the barcode scanner needs to be placed in the line of sight of the barcode in order to read the barcode and the information written on a barcode label is static

2.1.4 Radio Frequency Identification

Radio frequency Identification, abbreviated as RFID, technology is introduced to improve the automation in the specimen inventory system .A RFID system consists of a three main components a reader/writer ,tags & antennas RFID tags are written/read with the help of RFID reader with antenna attached to the reader .A detailed description of this technology is presented in section.

A RFID system used in hospitals consist of a RFID reader being installed in every lab and RFID labels being stick to the specimen container .When a specimen enters or exits a lab it is read by the reader and data is recorded into the LIS .Benefits of using RFID technology over barcode technology for specimen inventory are many like a RFID tag used for tagging is rewritable, the memory of a RFID tag is more than a typical barcode label, no line of sight to read the tag is needed, and at one time more than one specimen containers can be read by the reader.

2.2 Specimen Tracking System

Specimen tracking is usually done in the following manner .When a specimen is send from one lab to other a paper requisition is attached to the specimen sample which is signed by the receiver of the specimen signed and returned back to the sender .In this way the sender gets acknowledged that the specimen has reached its destination .However, consider a case when a specimen is taken from a lab to the other and gets dropped in the path somewhere and does not reaches its destination .In cases like above no record of the specimen dropped in the path could be made since we do not know at which place the specimen gets dropped off. The various technologies used to track specimen in real time while it is in the path from one lab to other are discussed here.

Real time specimen tracking is commercially done using Real Time Location Systems[2] .There are a number of technologies used in RTLS:

- Active RFID
- Infrared
- GPS (Global Positioning System)
- Passive RFID
- Ultrasound
- Wireless 802.11 based (Wi-Fi ID)
- Ultra Wide Band (UWB).

Commercially, active RFID, passive RFID and Wi-Fi ID based RTLS are used to track specimens.

2.2.1 Working of Real Time Specimen Tracking System

As discussed above commercially used system to track specimen are active RFID, passive RFID and Wi-Fi ID .These systems involve tags placed on objects and wireless access points deployed along the infrastructure. These access points detect the tags throughout the area of coverage and attempt to localize them using techniques based on received signal strength or time difference of arrival [1].

These systems are in use to track the path of specimen but, they have some limitations. In active RFID & Wi-Fi ID based systems the size of active tags is big so cannot be put on small specimen .Moreover, all these systems requires a high density deployment of access points which is expensive.

2.3 Summary

As discussed in section 2.1 a RFID technology based system offers an accurate inventory management system when compared to other methods .A specimen tracking system like the one discussed in section 2.2 is needed to track specimen along the path .But, deployment of very dense access points and inability to affix tags on small specimens made these systems inefficient .A complete end-to-end system is required which can manage the inventory and simultaneously track the specimens along the path from one lab to other without changing infrastructure and cheap .This project is an attempt to design such a system.

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[2] The systems that are used to collect information of a moving object are collectively called Real Time Location Systems (RTLS) [9].

Chapter 3
Overview of UHF RFID Based Real Time Specimen Tracking & Inventory Management System

As described in the previous chapter, that there is a need for an end-to-end solution that can do automated specimen inventory as well as real time location tracking of specimens .Our solution to the problem is based on RFID technology operating in UHF frequency band [1].This chapter gives an overview of the solution, combined near and far field UHF RFID based specimen inventory & tracking system .In section 3.1 RFID technology is discussed .Section 3.2 gives an overview of the solution , a complete description of which is presented in the next chapter.

3.1 Radio Frequency Identification

Radio-frequency identification, abbreviated as RFID, is the use of a specially made tag applied to a product, animal, or person for the purpose of identification and tracking using radio waves [11].RFID system contains, as with many other types of automatic identification systems, a set of interrelated components .Such components are Tags, Reader & Middleware [12].

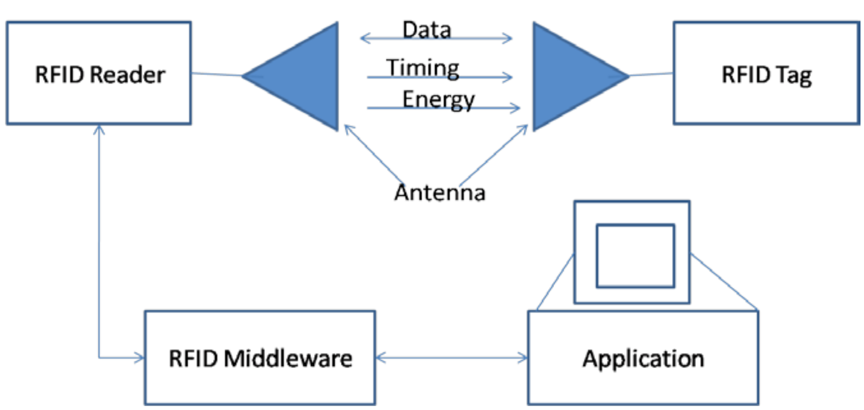

Figure 3.1 Typical RFID System Components.

3.1.1 Tags

Tags, also called transponders [14] [15] are the devices affixed to the items or material that is to be tracked Identified by the RFID system [14] [16] .Tags comes in many different shapes and sizes. Tag contains three basic parts [14] (see figure 3.2): electronic integrated circuit – to store some digital information [17]; a miniature antenna – to transmit the ID to the rest of the RFID system which is the primary function of the tag; a substrate- to hold the integrated circuit and the antenna together [16].

Tags can transmit over a spectrum of frequencies, from short range low frequency to long-range ultra high frequency and ultra high frequency and microwave frequencies [17].

Tags can be read-only – the stored data can be read but not changed; read/write – the stored data can be altered or rewritten; combination – some data is read-only while the rest is read/write [19].Tags are mainly classified on the basis of their operation as passive, active & semi-passive/semi-active .

Passive tags are small in both size and memory [17] .Passive tag consists of two main components a microchip and an antenna .They do not have any power source and gets activated only when they are in the range of a reader's signal – The RFID system antenna powers them through electromagnetic power [17] [16] .Due to the simplicity of their circuitry they are cheap and easy to manufacture .And; due to their small size they are used in application where size is a constraint.

Active tags are both bigger in size and expensive than their passive counterparts because they contain a battery source in them and hence less popular [16].The battery powers the circuitry and the antenna both due to which the range in which an active tag is read/written is far more than of a passive tag [16][17].

A semi-active and semi-passive tag has an onboard power source .This makes them more expensive than the passive tags but, they are cheaper than the active tags .They comes in between active and passive tags [16].However, there is a difference in the way semi-passive and semi-active tags operate.

- A semi-active tag uses a battery to power the signal but respond only when they are in the range of a reader [22].
- A semi-passive tag depends upon the energy from the signal, but can use onboard power to power the circuitry and other sensors on the tag [22].

3.1.2 Reader

Reader is needed to read and write a tag and at the same time they are connected to a computer so that data captured by the reader could be processed [23]. Attached to the reader is an antenna that actually sends and receives signals to and from the tag .The type of antenna to be attached depends upon the application for which the RFID system is to be used.

3.1.3 Middleware

Middleware is the interface needed between the RFID reader and the existing company database and information management software.

3.2 Overview of Combined near and far field UHF RFID based specimen Inventory and management system

As discussed in section 2.3 that there is a need of an end-to-end system that can do automated inventory management and real time specimen tracking of specimens .This project is an attempt to make such a system .In this section a brief discussion of this system is done .Our solution for the problem described in section 2.3 is a specially developed bucket called specimen carrier [1] .The specimen carrier will carry the specimens in it having passive RFID tags on them and the movement of the bucket will be tracked in the whole path using passive tags deployed along the path.

The specimen carrier consists of an integrated RFID reader and a controller module. There is a Wi-Fi antenna on the specimen carrier through which the system communicates with the Laboratory Information System .In addition there will be two types of antenna into the bucket attached to the reader.

- Near field antennas embedded inside the carrier .Its field of view is restricted only inside the bucket where specimens will be kept .And will read only the near field tags attached to the specimens.
- Far Field antennas attached to the outside of the bucket .It will read the tags deployed along the path of movement of specimen carrier.

The system works like this .When a specimen container needed to be taken to other lab it is first tagged with a passive RFID tag which is then put into the specimen carrier .Once the specimen container is put into the specimen carrier the near field antenna reads provides specimen contents by reading the RFID tag on specimen and the far field antenna gives location contents by reading the tag placed in the path .At the same time Wi-Fi antenna attached to the carrier remotely log the collective data obtained from the near and far field antennas into the LIS .When the specimen carrier starts moving the far and near field antennas attached to the specimen carrier keeps on updating the data in the LIS .Benefits of this system are listed below.

- No need of additional access points since wireless communication is only used for data sending to the LIS.

- This is an end-to-end solution so this single system works both for automated inventory management and real time specimen tracking.

- The algorithm for this system is written in a way so that data is pushed to the LIS only when there is a change in either location or specimen contents of the specimen carrier .So no redundant information is passed.

- The RF power output of the system is controlled by a power algorithm .The power algorithm is written in a way that it keeps the read power of the system to as low as possible values.

Selection of UHF frequency for this RFID system is made on the requirement of this system .As per the need of the current system about item level tagging two frequencies that were qualitatively studied and compared for a final selection are HF and UHF .The difference in the two is on the basis of the frequency at which they operate HF operate at frequency of 13.6 MHz while frequency range of UHF lies between 865-928 MHz [55].The various parameters on which the study was made are discussed below.

- Item Level Tagging: Item level tagging is traditionally done using HF tags .However, in present case HF tags do not fit on many of the specimens which are happened to be very small at times .Also, Far Field UHF tags also can't work out since they are also big in size and unable to fit on the small size of the specimens .But, the near field UHF tags can work in this case because their size is very small and can fit any size of specimen [51] [52].

- Performance in presence of Liquids: HF RFID is the only frequency which performs well in presence of liquids and metals which uses magnetic field for communication (also called near-filed communication) between tag and reader at 13.56 MHz .After recent studies in the field of UHF RFID it is evident that it can also provide fairly decent results if not equal to HF RFID in presence of liquid if near field mode of communication is used that is if the magnetic field component of RF wave is used [56]. The UHF RFID which communicates in magnetic field mode is called near-field UHF RFID [51].

- Cost of the system: A comparison between a UHF RFID and HF RFID system can be made on the basis of the cost of the components of the system .A UHF RFID reader is more expensive than a HF RFID reader .While, the UHF RFID tag are more cheap than a HF RFID tag .In our case we need more tags and few RFID readers which is also a reason for choosing UHF RFID system [57].

- Read Range: A UHF RFID system is used for system where long range is needed while a HF RFID system is used for places where short read range is required .In the system we need both short read range for specimen reading and long read range for location tracking which sets the path for selecting a UHF based RFID system for this solution.

Chapter 4

Implementation

In chapter 3, an overview of the RFID system is discussed .In this chapter the whole implementation of this system is described .Section 4.1 is an insight of various components of the system, section 4.2 discusses the flow of various events in the system; section 4.3 is a discussion on the hardware used for the system and section 4.4 discusses the software framework for this system.

4.1 Components of the System

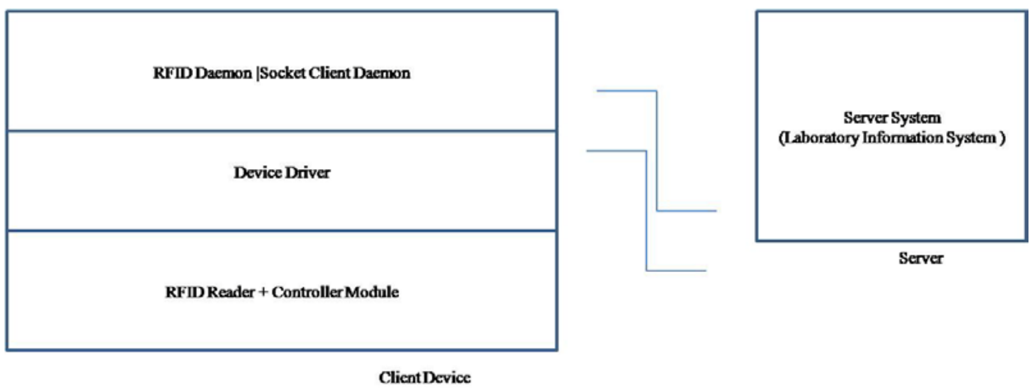

Figure 4.1 Architecture which shows components in the system

The client device hardware is a specially designed bucket, which is referred as specimen carrier in the rest of this thesis, in which sits RFID reader along with controller module which consist of antennas, gumstix[3], power supply and battery .Wireless communication is responsible for communication with server device which is enabled with the Wi-Fi antenna attached to gumstix .A device driver is written which forms the base of communication between application running on gumstix and RFID reader .In the application layer the software components of the client side consist of two concurrently

[3] Gumstix is a single board computer of size of a chewing gum and having all the basic functionalities of a normal computer [65].

running daemons on the gumstix .RFID daemon communicates with the RFID reader in order to keep track of location and specimen contents of the specimen carrier .And, client socket daemon communicates with the server device and sends the location and contents of specimen carrier through socket communication.

This RFID system is developed to be implemented in hospitals where it will be needed to communicate with the LIS present in the hospitals through wireless communication .However, during the course of this project and for testing purposes a dummy socket server is used in place of LIS.

4.2 Flow of events

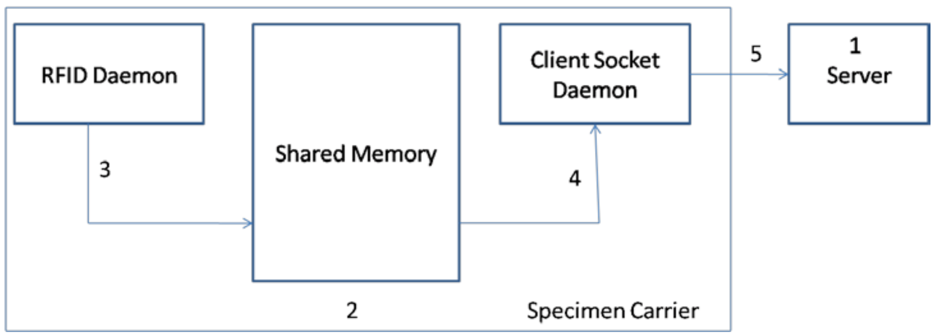

Figure 4.2 Flow of events in the system

1. Socket Server program is waiting at a specified port for a client connection.
2. Client device “specimen carrier” is turned ON.
3. RFID daemon starts writing the data collected through near and far field antenna to the shared memory region.
4. Data written to the shared memory becomes available to the socket client daemon
5. Data is send to the server side through socket communication.

4.3 Hardware

This section presents the hardware description used in implementation of the RFID system .The diagram below represents the hardware assembly including battery, power supply, gumstix, and RFID reader .All individual components are discussed in the sections below.

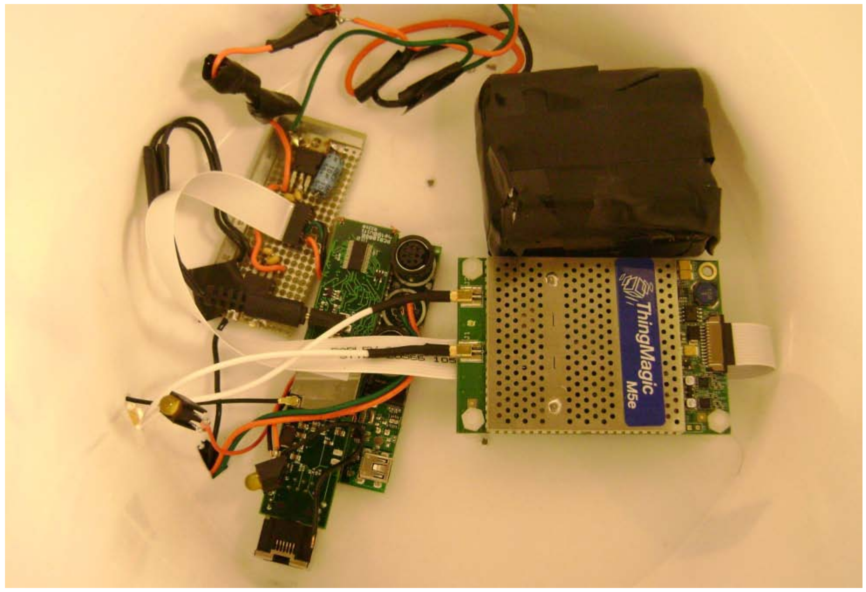

Figure 4.3 Hardware Assembly of Specimen Carrier placed inside the bucket

4.3.1 Gumstix

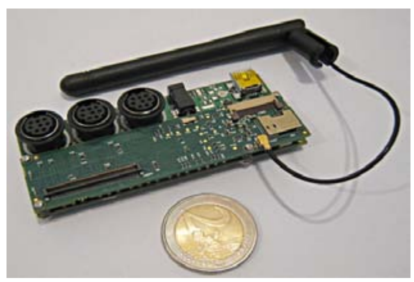

Figure 4.4 Gumstix Verdex-Pro compared with size of a quarter coin

Gumstix is a single board computer it offers a wide range of functions including Bluetooth, 802.11g wireless interfaces, USB, Ethernet, micro-SD card, synchronous and asynchronous serial and more in a very small form factor .It has a very small size and due to which it attracts many hobbyist and developers attention .Currently, it has two models Overo &Verdex-Pro both of them has a Linux Operating System pre-installed in them .Gumstix has a limited memory of its own but a memory card can be added to add memory to it.

Gumstix uses Open Embedded software framework to build packages using bitbake recipes .It has a Wi-Fi antenna which helps in wireless communication with any remote wireless network .For more information about gumstix refer to [65].

4.3.2 Thing Magic Mercury 5e RFID Reader

The RFID reader used in this project is Thing Magic Mercury M5e UHF RFID reader .The main reasons for choosing this reader is its small form factor and support to

EPC global Gen2 tag protocol .Its dimensions are   .It has two antenna ports which can support one bi-static antenna or two mono-static antenna at one time when attached directly .In this application the two antenna ports are used for two different type of mono-static antennas .The maximum tag read rate is 170 tags per second(approximately) .The range of maximum and minimum read /write power is 30 dbm & 5 dbm respectively .The frequency range in which this reader works is UHF which varies from region to region , for USA the frequency range is 900-928 MHz .For more information about this reader refer to [66].

Figure 4.5 Mercury Thing Magic 5e RFID Readers

4.3.3 Near Field Antenna

Near Field antenna uses magnetic coupling to communicate with RFID tags .The near field antenna used in this application is a custom made one .The antenna is shown in the picture below .The design of this antenna is decided on the basis of various tests performed on different type of near field passive tags .The Near Field antenna has a very short range so that it can only read tags which are located within a short distance of the antenna.

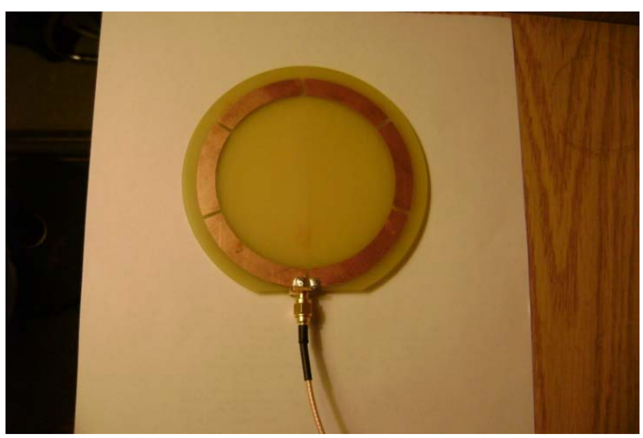

Figure 4.6 Near Field Antenna

4.3.4 Far Field Antenna

Yagi-uda Antenna (also termed as Yagi Antenna) of 6 dbi is used as the Far Field Antenna for this application .This antenna is used because the antenna needed for this application needs to have a long reading range and being directional in the axis perpendicular to the plane elements .For more information on Yagi Antenna refer to [68].

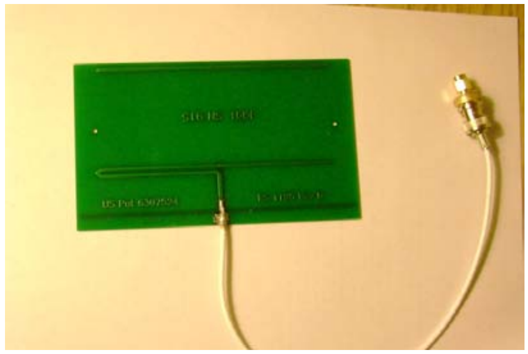

Figure 4.7 Far Field Antenna

4.3.5 Passive Tag

Passive Tag is an RFID tag in which the power is provided by the RFID reader since they does not contain any battery .A passive tag gets energized when radio waves from a reader are received by the tag; the coiled antenna within the tag forms a magnetic field from which it draws power .Once the tag is energized it sends the information encoded in the tag's memory [47] [48].The passive tag used in this project are Monza 3 tags to label specimen and Thin propeller tags to be placed on the path .

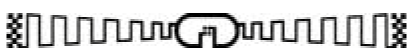

Figure 4.8 Thin Propeller passive RFID tag

Figure 4.9 Specimen containers with Monza 3 passive RFID tag

4.4 Software

4.4.1 RFID daemon

In this section, the implementation of RFID daemon is described .RFID daemon is an application that runs on the gumstix. It is started when the specimen carrier is turned on .RFID daemon[4] communicates with the RFID reader through which it gathers the data acquired by the near and far field antenna & puts it into shared memory to be read by socket client daemon .The flowchart below describes the function of the RFID daemon.

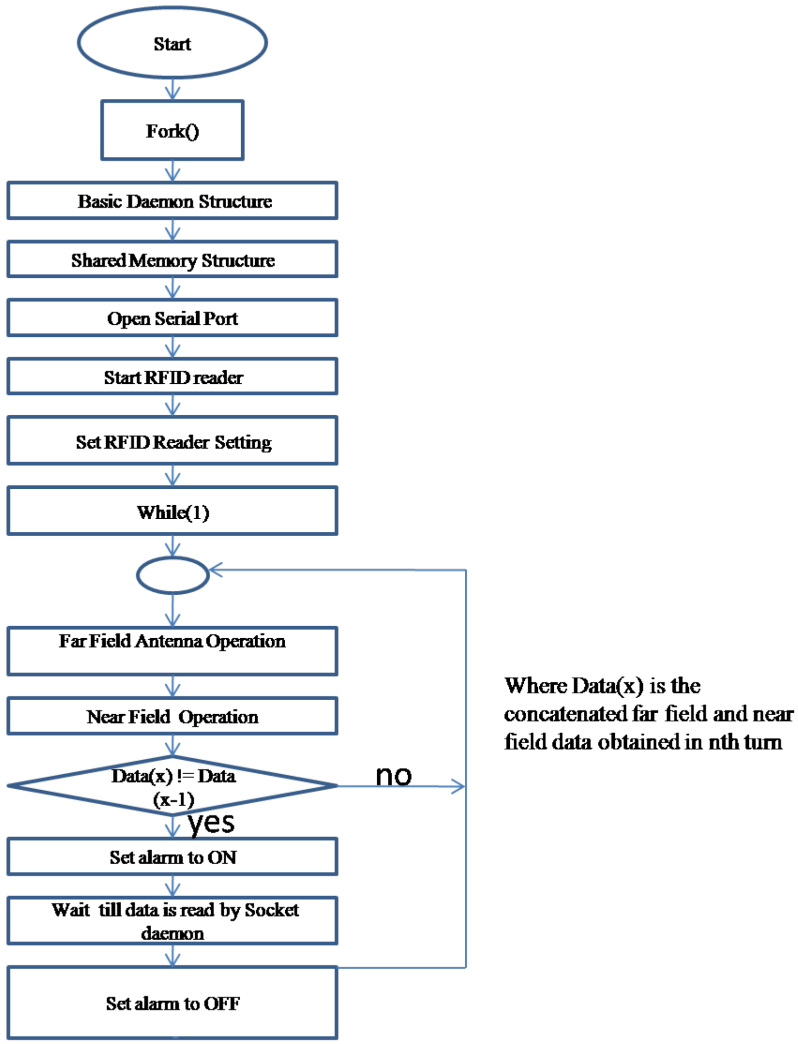

Figure 4.10 Flowchart representing the sequence of operation performed in RFID daemon

[4] A daemon is a process which runs in the background, rather than under direct control of a user; and provides some service to an application, on behalf of a user .The term "daemon" is generally used in association with a service running on a UNIX machine .Examples of daemons includes web servers and crond. (Definition taken from [62] [63])

RFID daemon is developed using Open Embedded tools in a Linux Environment .Open Embedded is a software framework to create Linux Distributions aimed for embedded devices but can be used for other developments too More information about Open Embedded can be found at [67].

One of the main goals in implementing RFID daemon was to provide an optimized program that can communicate effectively with the RFID reader .The following subsection give details of the various part of RFID daemon .The task in writing daemon was to code it as defensively as possible since debugging a daemon becomes a painful task .Moreover, log files are created for the same reasons while writing this daemon so that any error encountered and status of the daemon at regular interval can be recorded .The flowchart is explained in the next few pages.

4.4.1.1 Basic Daemon Structure

In order to make a daemon the following steps are needed.

- Fork off the parent process
- Change File Mode Mask
- Open Log Files to record status of the daemon and record the errors occurring
- Create a new session ID
- Change the working directory
- Close Standard File Descriptors

4.4.1.2 Shared Memory Creation

Shared memory are created for inter process communication between the two concurrently running daemons RFID daemon and socket client daemon .Two shared memory are created one for transferring data between the two concurrently running daemons and the other for raising alarm whenever data is pushed into the shared memory to be read by the other daemon.

4.4.1.3 Communication with RFID Reader

In order to enable communication between RFID Reader and RFID daemon running on gumstix; UART asynchronous serial driver program has been written .This device driver program provides the RFID daemon to send message and receive response for those messages from the RFID reader .After the shared memory are created in RFID daemon the serial port is opened for communication with RFID reader .Once the serial port is opened the RFID daemon can send and receive response for those messages .This section describes a general sequence of messages or commands in order to read RFID tag.

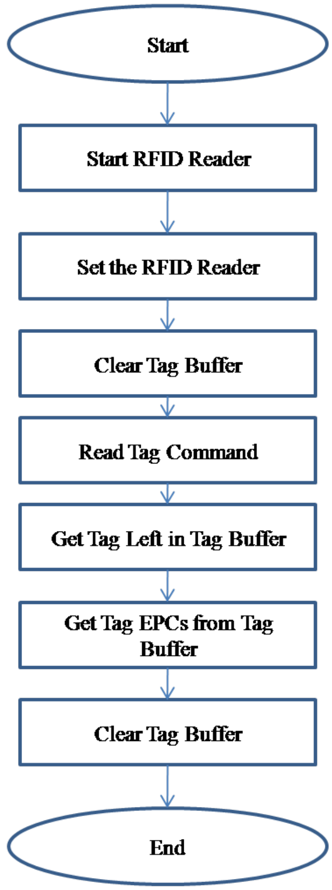

Figure 4.11 Flowchart representing sequence of steps to read a RFID tag

The flowchart above describes the steps involved in order to read tag from the RFID reader .Initially the RFID reader is started/initialized with start bootloader commands .Once the reader is initialized set application commands like set read power, set antenna port, set current protocol, set current region are used to set configurable values in the firmware .All of these commands returns an acknowledgement upon successful completion. Since these values are not stored in flash so the reader returns to default values when it is restarted .If needed get application commands are used to get values of settable parameters from the reader .Once the setting of parameters is done the reader is ready to read the tags present in the field .Application tag commands are used to read the tags the sequence of steps followed while reading the tag start with the clear tag buffer command .Tag buffer stores tags, and their metadata .The size of tag buffer is 200 for this RFID reader module .The clear tag buffer command clears the tag buffer of any existing tag entries .After the tag buffer is cleared another application command read tag multiple with select functionality is send which returns the number of tags found .The select functionality enables to search only tags meeting select criteria provided to the reader through tag singulation fields parameters .Get tag left is send to find the number of tags left in the tag buffer followed by get tag EPC command which provides the tag EPC of the tags present in the tag buffer .Once all the tags are read a clear tag buffer command is again send to the reader module to ensure no entries remain in the tag buffer.

4.4.1.4 Far Field Antenna Operation

The Far Field Antenna Operation relates to the operation done on far field antennas attached to the antenna port J1 of the RFID reader through switch in order to get the exact location of the specimen carrier based on the RFID tag read by the Far Field Antennas .Initially, while the development of far field antenna algorithm to read the far field tags the following problem were faced.

- The power level was initially set only once initially to read tags and the reader was reading tags at same power irrespective of change in densities of RFID tags encountered in the path.
- Many times tag was reading two or more tags leading to distortion in calculating the exact location of the specimen carrier.

The problem was resolved with the power algorithm described in the flowchart below.

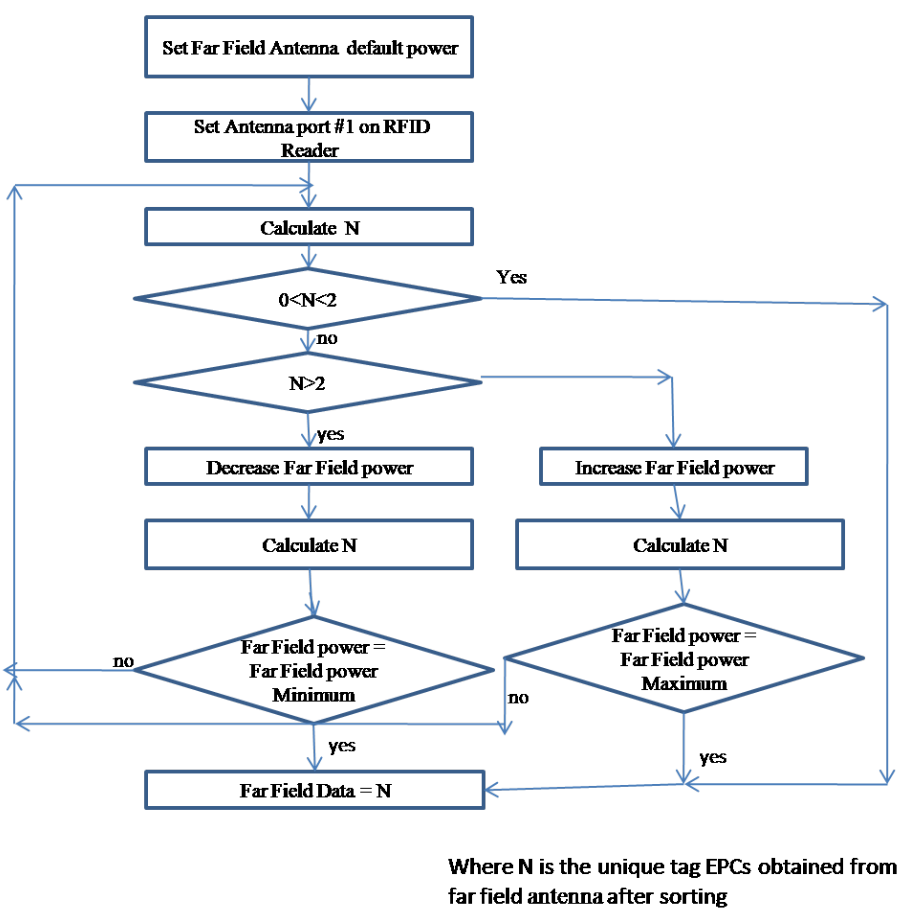

Figure 4.12 Flowchart representing Far Field Antenna Operations

The power algorithm works in the following ways .Initially the RFID power is set to a default value of 15 dbm .Then the antenna port J1 is set to which two far field antennas are attached through a switch .On each antenna read tag multiple command is send with select functionality, to read all the tags present in the range of far field antenna, followed by get tag EPC command to get the tag EPC[5]s are send .The tag EPCs obtained from both the Far Field antennas are sorted to get only unique tag EPCs(N) .If the number of unique tag EPCs is greater than one or less than 1 the power is decreased or increased respectively, until the point when either the power reaches the minimum or maximum level or the number of unique tag EPCs(N) becomes 1.Finally, the unique tag EPCs obtained constitutes Far Field data.

4.4.1.5 Near Field Antenna Operations

The Near Field Antenna Operation relates to the operation done on the Near Field antennas attached to the antenna port J2 of the RFID reader through a switch in order to get the total specimen contents in the specimen carrier based on the RFID tag read by the Near Field Antenna .The power is set to 30dbm which is the maximum power level of the RFID reader .Then the antenna port J2 is set to which the Near Field Antennas are attached through a switch .Four near field antennas are attached to the switch .On each antenna read tag multiple is send with select functionality, to read all the tags present in the range of near field antenna, followed by get tag EPC command to get the tag EPCs are send .The tag EPCs obtained from both the Near Field antennas are sorted to get only unique tag EPCs .Finally, the unique tag EPCs obtained constitutes Near Field data.

4.4.1.6 Data Aggregation and Handling

The Near Field & Far Field data obtained through the Near & Far field operations is made accessible to the socket client daemon only when there is a change in location of specimen carrier or contents of specimen carrier .On the basis of the above discussion to send data only when there is a change in location or contents of specimen carrier the data obtained in two consecutive runs is checked .If the data in two consecutive loop of daemon is same no data is pushed to the client socket daemon else the data is pushed to the client socket daemon.

4.4.2 Client Socket Daemon

Similar to RFID daemon Client socket daemon is also developed using Open Embedded tools in a Linux Environment .Client Socket Daemon runs concurrently with the RFID daemon when the specimen carrier is powered on .The main function of this daemon is to communicate with the remote server through socket communication and to send data obtained through the RFID daemon to the server .In this section before describing the implementation of the socket daemon the basic structure of hospital network and reason for selection of UDP socket for this application is presented.

[5] EPC is a family of coding scheme created as a next generation of barcode.

4.4.2.1 Structure of Hospital Network

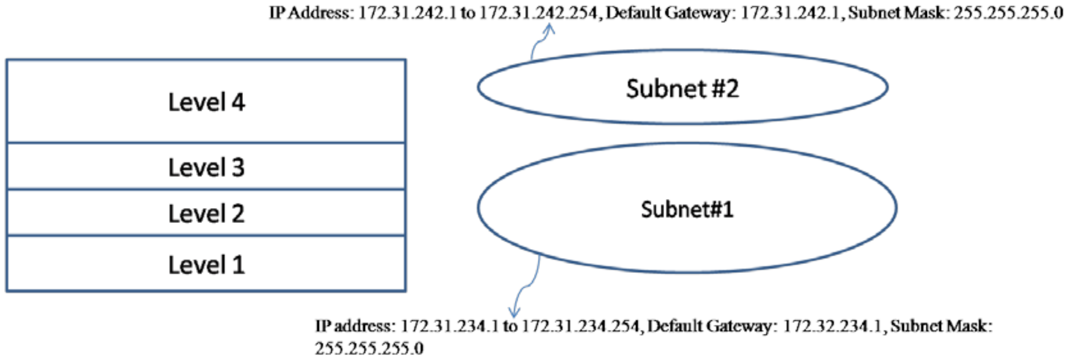

Figure 4.13 Diagram representing the various subnets and their properties

The hospital network is divided into many subnets .The implementation of this project is done on 4 floors from level-1 to level-4.Level-1 to level-3 consists of subnet#1 while level 4 comes under subnet#2 .

Subnet#1: IP address: 172.31.234.1 to 172.31.234.254, Default Gateway: 172.32.234.1, Subnet Mask: 255.255.255.0

Subnet#2: IP Address: 172.31.242.1 to 172.31.242.254, Default Gateway: 172.31.242.1, Subnet Mask: 255.255.255.0

4.4.2.2 Selection of Socket type for this application

UDP sockets are used for this application due to the real time nature of this application .A more detailed explanation goes in as follows .As seen in the Network structure of the hospital the path in which the implementation of this system is to be done consist of two different subnets subnet#1 andsubnet#2 .In this case when a TCP/IP socket is used and a transition is made from subnet#1 to subnet#2 the specimen carrier gets connected to subnet2 .However, the TCP/IP socket formed in the client socket daemon retransmits the packet 12 times in increasing time periods before forming a new socket for subnet#2 .So even when specimen carrier has moved from subnet#1 to subnet#2 and spent considerable amount of time there but, the client daemon taking time to connect to the subnet#2 voids of the application from its real time nature.

UDP socket does not have any retransmission of data facility in-built so once the data sent is failed it does not do any retransmission .And hence when the specimen carrier enters a new subnet the socket client daemon forms a new socket for this subnet and maintains the real time characteristics of this application.

4.4.2.3 Client Socket Daemon Structure

Basic daemon structure and shared memory formation in case of client socket daemon is similar to RFID daemon .In the socket client daemon once the basic daemon and shared memory is formed .The daemon enters the big loop, while(1), in the loop a UDP socket is formed which further waits for the condition when data is pushed to the client socket daemon through the raise of a alarm signal .Once the data is transferred to the socket send buffer of the UDP socket it is then send to the remote server through socket communication .If the socket communication fails at any point a new socket is formed and the communication with the remote server is initiated again.

4.5 Socket Server

As discussed in section 4.1 that during the course of this thesis work a dummy socket server program is written in order to test the proper working of the RFID system .The socket server program is a UDP server which waits for connection from the client .Once the client is connected it displays the specimen contents and location to the user of the system.

4.6 Deployment

Deployment of this system is explained in figure 4.14 .The far field passive tags were attached to the roof at a distance of about 6 meters apart .The near field tags after programming were attached to the specimen containers and put into the specimen carrier .The far field tags are attached on the roof and Yagi uda antenna is used so that no obstruction could come in the path of the antenna while it is reading the tag and a optimized performance could be obtained .After turning on the specimen carrier it starts reading the near and far field tags and starts remotely sending the information to the socket server program used for this application which will be replaced by the LIS in the future.

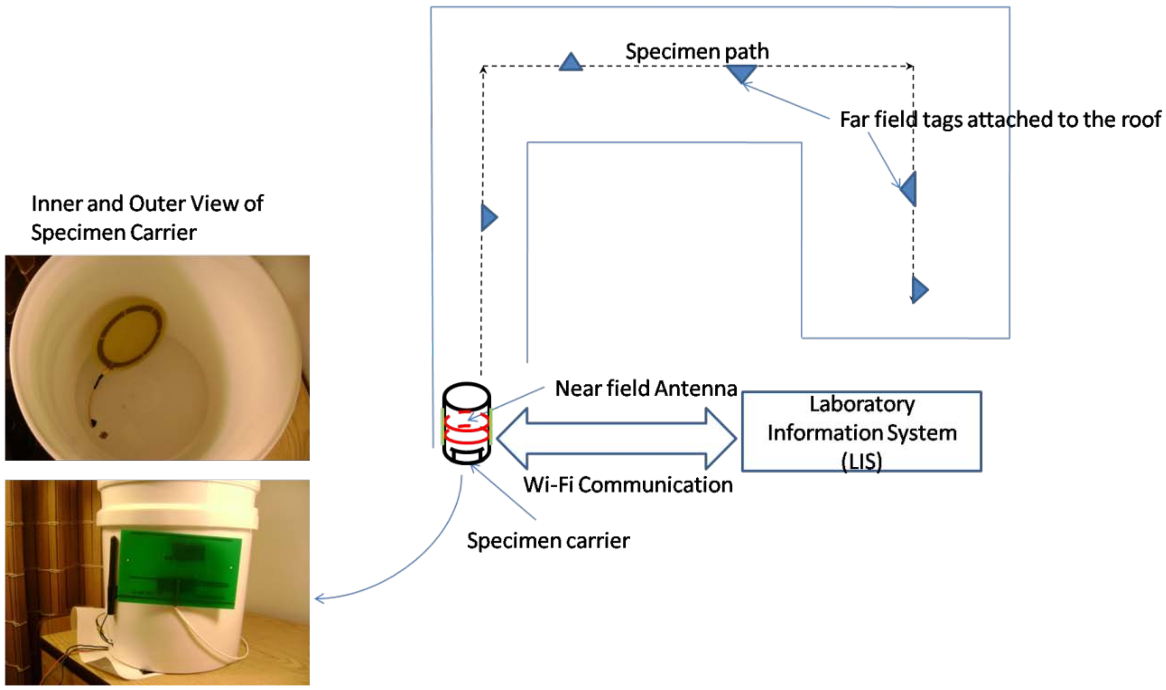

Figure 4.14 Deployment of the system in the hospital

Chapter 5

Impact of the System

RFID has proved that it can cut huge cost & provide an efficient and timely dispatch of goods from one place to other in supply chain & other industry .Its introduction to healthcare is seen as a positive sign for healthcare industry too .It has started to be used for a number of purposes that includes patient identification, assets tracking, employee tracking, workflow automation etc [40].

Radio Frequency Identification has the ability to improve patient care and safety by some of the following ways [40]:

- Tagging patients by RFID chips in order to track their movement and to provide them with the correct dosage of medication.
- Tagging patients by RFID chips and to store complete medical history of patient provides the physician and nurses to directly get detailed information without any huge paperwork.
- Tracking hazardous disposable items by affixing RFID chips to them.
- By attaching the RFID chips to specimen, they can be tracked.
- This is also used to track the staff and doctors in hospitals.

The UHF RFID based system presented in this thesis has also some underlying impacts when it is implemented in the hospital .This chapter is an insight to the various impact that this system will have on the hospitals .Section 6.1 discusses the impacts advantages of using this system, and section 6.2 is a short concluding summary of this chapter.

5.1 Impact

The UHF RFID based specimen Inventory and management system designed is a real time locating system that gives real time dynamic update of the specimen contents in the specimen carrier bucket .In Chapter 2 a discussion for the basic underlying idea and the problems faced with the prevailing commercial products has already been discussed .This section will elaborate the impact of this system on various fronts.

5.1.1 Workflow Automation

The workflow[6] [41] in a hospital has a direct relation with patient safety and care .Automation in any workflow will bring speediness and hence the same work can be completed in a less span of time .The UHF RFID based system will bring about workflow automation in the whole process of specimen transport .When specimen will be carried from one place to other in the specimen carrier it will add automation to the whole process in the following ways .RFID labels attached to the specimen container are machine readable, can be read from a long distance, and many labels can be read at a time .Whenever there is a change in the content or location of specimen carried it is automatically updated into the LIS .

5.1.2 Error Reduction

This system has a direct impact on reducing various errors caused in the process of specimen inventory and tracking .As discussed in the Introductory section of this thesis a specimen error can lead to a fatal accident and may be death of patient in certain circumstances .There is a need to eliminate these error from the process as much as possible .There are many circumstances involving these errors like wrong reading of a specimen label and feeding it into the LIS which can directly effects the patient safety and care .This type of error can be eradicated with this system since no manual reading of the labels is involved with the system .Moreover, RFID reader gives accurate results even when many specimen are present and are to be read.

5.1.3 Infrastructure

In this section effect of this system on hospital's infrastructure is discussed.

- No need of additional Wi-Fi access points

Most of the commercially available Real Time Locating System (RTLS) requires dense access points to track specimen movements along the path .While most of the hospitals do not have a dense access points in their infrastructure so adding a commercially available RTLS system would mean to first increase the density of access points in the hospital which will directly increase the cost of implementation of this system .However, the UHF RFID based system does not need any dense access points of network to operate since it relies on RFID tags to track the path .

- Cost of the system

The total cost of the system in case of a commercially available system will be more that the UHF RFID based system since a commercially available system requires dense network of access points to track the path which directly increases the cost of the system .Moreover, the cost is further increased due to the need of devices which needs to be put

[6] Workflow refers to tasks, people involved, tools required, input and output information for each step in a process.

along the path to track the tags attached to the specimen while the UHF RFID based system requires inexpensive passive tags deployed along the path to track the specimens.

5.1.4 Impact on Medical Devices

All Radio Frequency(RF) devices emit radio waves in order to work and are also called intentional radiators due to the same reason .These RF waves emitted produces Electro Magnetic Interference(EMI).According to a recent study at Journal of American Medical Association (JAMA), which states that Radio Frequency waves by producing EMI waves can interfere with medical devices and cause problems in their performance [42].The study was done in a non-clinical setting where RF devices were brought near medical devices and their effect on medical devices was observed .The results of the study shows that Electro Magnetic Interference(EMI) caused by the RF device can have effect ranging from significant to light depending upon the frequency & power used in the RF device .The frequency used in this test were 868 MHz and 125 kHz .A conclusion was brought out from this study that since Radio Frequency waves can have a life endangering effect on patient care since these waves can cause EMI in medical devices leading to problems like shutting down of IV pumps and crippling of defibrillators any RF device must be first tested for on-site EMI tests before its installation in hospital [42]. However, the study remains dubious since there are concerns over the environment in which these tests are made and are said to be unrealistic .It is said that the frequency used to test in the study are not similar to the frequencies popularly in use by most of the RFID devices and the power levels set for RFID devices are too high [43]. Although, the flaws in the study done by JAMA have been widely known still there is a need to ensure exhaustive testing of RFID devices before their implementation in hospitals [42][43].

The UHF RFID based system for specimen Inventory and management designed in this thesis uses RF waves to communicate with the RFID tags .The system is made in such a manner so that Electro Magnetic Interference (EMI) can be minimized to the lowest level possible avoiding any interference with other medical devices. The maximum operating read power of the RFID reader in our system is 1 watt which is in strict guidelines of the Federal Communication Commission(FCC) rules regarding RF devices power level in the Ultra High Frequency(UHF) range [45] .In the UHF RFID based system the far field antennas are for reading the RFID tags placed in the path in order to track the movement of specimen carrier in the path and the near field antenna is for reading the RFID tags labeled on the specimen container in the specimen carrier .According, to the power algorithm discussed in section the density of RFID tags placed along the path has an inverse relation to the power of the far field antenna.

Density of RFID tags along the path $\cong$ 1/Power of Far Field antenna (equation 5.1)

Total RF power output of the system = Far Field Antenna Power + Near Field Antenna Power (equation 5.2)

And the total RF power output of the device is sum of Near Field Antenna Power and Far Field Antenna Power according to equation 6.2.So, in close proximity of medical devices the density of RFID tags can be increased so that the total RF power output of the device can be kept low to avoid any possible interference.

5.1.5 Impact on Health

RFID system like the one used here uses RF technology for communication between RFID reader and RFID tag .In the process of communication between these two elements of the system RF rays are used to and fro .So the impact on health due to RFID devices is all due to RF rays .RF waves produces Electro Magnetic energy, this energy/radiation emitted is well known to cause thermal heating in living tissues .Tissue heating depends on the frequency of the source but, tissue heating depends on the frequency of the source and needs large amount of radiation to heat tissues .FCC has allocated certain frequency which are safe to work and have no effect on tissue heating 13.56, 27.12, 40.68, 915, 2450 MHz [58].The RFID system used in this thesis is based on UHF frequency which is working in the range of frequency provided by FCC so the effect of RF rays is minimal and hence no tissue heating is caused [1].

5.1.6 Impact on Environment

RFID tags are small in size but there numbers are huge when used for any application .After usage RFID tags are potential environment hazardous waste because they contain silicon, adhesives, nickel, copper, aluminum, or silver due to the presence of these elements the RFID tags are tough to be reused because they are contaminants for recyclers and manufactures who use recycled material [59] .There are some serious challenges like RFID tags when at times get mixed with other recyclable material make their reuse complicated since RFID tags are not recyclable for use [59].Most of the times RFID tags when attached for tracking certain items and when these items reaches the recycle bin they are non recyclable due to presence of the RFID tags [59].The RFID tags recycle issue can be sorted out if the RFID tags are cleanly tear off from the material to which they are attached to .The better way is to reduce the content of non-recyclable material or use some other material which is recyclable in RFID tags[59].On the base of the discussion of till the time a possible solution to the recycle issue of RFID tags is sorted out maximum efforts should be put in the direction to reuse the same tags by erasing the contents of it and rewriting new data to it .

5.1.7 Social Impact

RFID developments in the healthcare have the capability to improve patient safety, provide better care and reduce specimen errors .This RFID based system has tried to explore these capabilities .This system has helped in reducing specimen error and hence improving patient care .Better specimen tracking and specimen inventory management is provided with the system which provides the hospital with an efficient tool to improve patient care .However, there are privacy issues regarding the use of RFID in hospitals. Since the system works on the basis of RF communication in which a RFID reader reads the tag .A RFID reader when brought in the system by an outsider can read the sensitive information of patient encoded in the RFID tag and hence can be a big safety concern for the patient[69].

5.2 Summary

In this chapter the impact of UHF RFID based specimen inventory management & tracking system on various elements in hospital is discussed .In order to make this system for use in hospitals without any problems certain policy needs to be implemented .The study regarding these policies is the topic of discussion in the next chapter.

Chapter 6

Policy and Standard for use of RFID in hospitals

A certain set of policies needs to be followed by hospitals in order for it to work in a proper manner; Similarly, RFID based system installed in the hospital also needs to follow certain policy. In this thesis the system developed for specimen tracking and Inventory management in hospitals is based on RFID technology .This chapter is an attempt to describe these policies .In section 6.1 an overview is presented .Section 6.2 presents the policy related to RFID in hospitals, section 6.3 presents concept of standardization, types of RFID standards ,standardization organization for RFID and hospitals & sections 6.4 and 6.5 are the summary of this chapter where policy for this system are framed to be used in hospitals [25].

6.1 Overview

Hospitals always needed to follow a certain set of policy so that any mishap could be avoided and various departments work towards a common goal of better healthcare facility to patients .Every hospital follows a certain set of policies like general safety & health, emergency, electrical safety, chemical safety, fire safety, radiation safety, environment protection and many more [31] .In order to work in a proper manner all hospitals follow certain set of policies as listed above .Hospitals in each country follow a different set of policies but, a mutual agreement exists between them regarding this.

In hospitals there is always a high risk of failure since any failure in the system is directly or indirectly relates to patient’s safety.

$$\text{Risk} = \text{Probability} \times \text{consequences of harm}$$

The equation above tells risk as a factor of probability and consequences of harm [25].In a hospital the consequences of harm is always directly or indirectly related to patients health and probability tells the chances of mishap .Even when the probability is small considering the consequences of harm which can lead to death or some serious side-effect risk is really high [25].So in all cases where probability is not zero the chances of risk is always there .Only cases where probability tends to zero risk becomes zero .Accordingly, RFID implementation in hospitals has helped in patient identification, blood tracking, anti-counterfeiting of drugs, tracking equipment, patient, staff and documents [24] requires meeting all issued guidelines from appropriate agencies

[25].This chapter will describe the important policy being needed to successfully implement RFID technology in hospitals.

6.2 Regulation for RFID in hospitals

There are no defined guidelines for use of Radio Frequency Identification (RFID) devices in hospitals but, Food and Drug administration (FDA), USA and similar other institutions in different countries has issued draft guidelines for the proper use of RF wireless technology in medical devices [26].An insight into this draft is important for a successful implementation of RFID into hospitals .The FDA guideline addresses some important issues which are discussed below [26] [27].

6.2.1 Electronic Compatibility

Electronic Compatibility is the ability of a device to perform in the defined manner in its Electromagnetic environment and do not produce interference in other device performance due to excessive electromagnetic energy creation in the environment.

FDA has issued guidelines about the same stating that all medical devices that uses RF wireless technology (RFID in present case) must comply with IEC 60601-1-2:2001[26] [27] [29].

6.2.2 Electromagnetic Interference

Electromagnetic Interference (or EMI) also termed as radio frequency interference is a disturbance that affects an electrical circuit due to electromagnetic radiation emitted from an external source [30].

EMI can lead to distortion in performance of other devices in the vicinity of the RFID device .Therefore, FDA has issued guidelines that RF output of a medical device using RF wireless technology should be kept to lowest possible level [27].

6.2.3 Performance of Wireless Devices

Manufacturer of RFID devices must provide documents relating to the following [27].

- RF specification of the device
- Test performed on the device during its manufacturing
- Certification stating that the device will operate safely and effectively in the hospital environment

6.2.4 Wireless data security

Wireless data security is an important issue considering the fact that data transferred is directly or indirectly relevant to the patient .According to the guidelines issued by FDA the following points are important with respect to data security [27].

- As much as possible data should be transferred through wired network .Since, wired network reduces the chances of eavesdropping and other similar issues.
- Wireless transfer of data should be supported by strong encryption technique so that possibility of third party intrusion becomes very low.

6.2.5 Data Integrity

Wireless devices using license free bands must implement techniques for the following.

- Minimum Interference
- Support Error Handling
- Provide Data Buffering Techniques

6.3 Standards for RFID

Before describing the various standards for RFID an introduction of the topic standardization is necessary. Standardization is the series of steps involved to develop and agreeing upon technical standards. A standard is a document that establishes uniform engineering or technical specifications, criteria, methods, processes, or practices. Some standards are mandatory while others are voluntary. Voluntary standards are available if one chooses to use them [32].

In RFID concept, standardization is an approach for increasing commonality of a part, process and information. Non-standard RFID does not make sense at all. The main usability of RFID is providing a product with a unique code, and what does unique mean if there is no unique universal coding system for RFID; So RFID and standardization are two inseparable concepts [25].

The number and use of standards within RFID is quite complex, it involves many bodies and is in development phase .Standards are needed for the following four areas of RFID application and its use [28] [25]:

- Technology standards
- Data Standards
- Conformance Standards
- Application Standards

A complete description of these RFID applications is presented after an introduction of various standard organizations that develop & define the standards for RFID development.

6.3.1 Standard Organizations for RFID

It is been said that RFID lacks standardization although, it is not true RFID has many well defined standards and many other are emerging standards [28] [34] . The only issue concerned with RFID standards is the fact that there is no universally accepted standard for RFID [35].Many organizations are involved in this task including.

6.3.1.1 International Organization of Standardization (ISO)

ISO is an international organization that sets various commercial and industrial standards [36][37].ISO has created standard for many RFID applications [34].The major ISO RFID standards are ISO 11784 which describes how data is structured on tag, ISO 11785 for air interface protocol, ISO 18047 for testing conformance of RFID tags and readers and ISO 18046 for testing performance of RFID tags and readers [34][37]

6.3.1.2 EPC Global Inc.

EPC Global Inc. is an organization set up for adoption and standardization of Electronic Product Code Technology [38] [39]. Currently, the main aim of this group is to make a worldwide RFID standard and using internet to share data through EPC global network [39]. Electronic Product Code (EPC) code gives a unique identification to each product by sticking an EPC tag to it .Each EPC code has four main elements: header, EPC manager number, object class, and serial number of object in order to generate a unique identification [39] [25].

6.3.2 Description of RFID standards

6.3.2.1 Air Interface Standards

Air interface standard defines the way in which communication between a tag and a reader takes place [28].Depending on the type of Standardization organization followed during implementation the air interface standard varies. On the basis of the two international standard organization discussed in section 5.3.1 .A brief discussion of this will be presented.

- ISO standards:_Air interface standards based on ISO was released in September 2004[28] [37].ISO 18000-1 provides generic parameters for Air interface for globally accepted frequencies.ISO 18000-2 is for frequencies below 135 kHz, ISO 18000-3 for 13.56 MHz, ISO 18000-3 for 2.45 GHz, ISO 18000-4 for 860-960 MHz and ISO 18000-7 for 433 MHz
- EPC Global Inc standards: EPC global has released its own set of air interface standards for UHF frequencies. The air interface protocols in use for UHF frequencies following are called UHF GEN2 protocol [28] [39].

6.3.2.2 Data content and encoding

Need for a standard form for the identification of products leads to development of data content and encoding standards.EPC Global has helped in the development of this standard .It has developed the unique identification system protocols (Electronic Product code) for tag to reader communication, specification of middleware system to handle EPC code, a markup language and the Object naming Service [28] [39].

6.3.2.3 ISO testing & Conformance standards

These standards are ISO 18047 is for testing conformance of RFID device to operating requirements and ISO 18046 is for measuring performance of the RFID device [28] [39].

6.3.2.4 Interoperability between application and RFID systems

RFID tags and readers are a whole inseparable part of an RFID system. Most of the RFID application users keeps the unique identification data that communicates between a tag and a reader as a 'key' and every key has a backend data related to it in the database. To develop this standard EPC Global has developed an EPC network architecture which was discussed in section 5.3.1 in detail [28][39].

6.4 Policy for UHF RFID Based Near & Far Field Specimen Inventory & Tracking System

As discussed in the section 6.1 the importance of policy for a RFID system to be implemented in a hospital .A framework comprising of the various policies for various components present in the system is presented in this section .The RFID reader used for making this system is a UHF RFID reader .This UHF RFID reader follows the guidelines of FCC which are framed so that EMI produced by RFID devices could be minimized so that any possible interference can be avoided with devices which came in the proximity of a RFID device [45].According to the FCC regulation the maximum output power of the RFID reader needs to be up to 4 Watts; this UHF RFID reader has a maximum power of 1 Watt which reduces the possibility of interference with other devices .Moreover , the frequency set for most of the UHF RFID devices in USA is in the range of 902-928 MHz [45] which is not used by medical devices so possibility of interference is reduced to a large extent .

The RFID standard used for this system is based on EPC Global UHF GEN2 standards .In order to avoid Electromagnetic Interference the RFID system is using a power algorithm due to which the RF output power is kept at a minimum level and the power can be reduced by increasing the density of the tags in the region where other medical devices are present so that a tolerable level of interference could be caused to other medical device present in there .Moreover, the frequency at which the UHF RFID device operate are free from any interference since they operate in the range of 902-928 MHz which is free of any possible frequency collision with any other medical devices .

Although, wired system of network is recommended according to FDA guidelines but, since the system is based on wireless communication for its working so the possibility of using wired network is not here. The wireless network security is a major area concerned since the data send through the network is critical and confidential so any possibility by which this data could be available to any intruder can be a big issue .In order to keep up with the FDA guidelines the system is running on a WPA encrypted wireless network where the possibility of any intrusion is low .The WPA key enables a high level of security to the system and the patient data and other information passed through this is secured.

6.5 Alternative Policy option for RFID System

In the wake of growing potential of RFID in healthcare further policy action regarding the use of RFID in hospitals needs to be implemented so that RFID technology in hospital reaches its full potential .The policy discussed in the previous section for the proper usage of this RFID system are sufficient .An alternative "opt-in" policy for RFID unsafe is described here .In this policy users will have the access to take part in any human decision making process .In this policy the following issues need to addressed.

Transparency

The users of this system needs to get acquainted with the whole RFID system the reader, tag and the software of this system and further be represented by consumer protective organization when RFID design decision needs to be made.

Privacy Options.

The privacy options and the level of privacy of the system needs to be selected by the user of this system .For example, whether to kill a tag or reuse it after it is used in a process decision like this needs to be made on the basis of input from the user of the system.

Security Options

In order to enhance the security of this system and to prevent from any intrusion into the vital information various security options can be installed like privacy enhanced identification management and enhanced information security [70].

In the future a proper documentation to be provided to the user of the system with the entire test performed the specification of the various parts of the devices and a certification that this device will work similar in performance as during the tests performed will be very critical.

Chapter 7
Conclusion

7.1 Summary

This thesis project explain an implementation of a RFID based Specimen Tracking and Inventory Management .In the first chapter, an introduction to the problem of specimen tracking and inventory management in hospitals and clinical labs is presented .In the second chapter, a literature survey on the existing technologies and methods used for specimen tracking and inventory is presented .In the third chapter, an overview of the solution which is based on combined near and far field UHF RFID to effectively track and inventory the specimen is described .In chapter four, the complete implementation of this system including its hardware, software and deployment is explained .Algorithms used to read the tags have also been completely explained .Impact of using this system and policy needed for its installation in hospitals is presented in chapter five and chapter six respectively.

7.2 Conclusion

The technology envisioned for this thesis has turned out to be feasible .We have succeeded in constructing a functional system, where a specimen can be tracked in a real time environment and simultaneously inventoried .In the testing done in hospital during the course of this project specimens were effectively tracked between different labs.

The algorithm written for the near and far field antenna operation worked well in the system we built .The socket daemon written for wireless communication between the specimen carrier and remote server also worked between different subnets in the hospital .In the future integration of this system with hospital LIS is important .The results provided by this system are very accurate which provides a reliable real time implementation for tracking and inventory specimens in hospitals.

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