

Framework for Object Tracking in Wireless Networks

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In collaboration with



**Napier University
School of Computing
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Abstract

At present, wireless sensor networks and radio frequency identification (RFID) are both emerging technologies with great potential in seamless applications. Integrating these two technologies would provide low-cost solution for object identification and tracking for wide range of applications where, object and location awareness is crucial and essential.

Healthcare is one of the industries, where object and location aware applications are most wanted, particularly in enhancing patient safety and reducing medical errors by patient identification (Murphy & Kay, 2004). Unfortunately, healthcare environment is challenging, where radio interferences are restricted and IT literacy of the staffs are limited. It gets further challenging in convincing patients of their privacy and ethical issues that surrounds patient tagging and monitoring.

The aim of this project is to review methods involved in object identification and tracking in wireless sensor networks and to design and implement a prototype of wireless enabled framework for object identification and tracking. It is to mainly address the needs of healthcare and other similar environments. This project is perused in collaboration with National Health Service (NHS) - University Hospital Birmingham (UHB), Napier University, ConnectRFID and other industry partners.

Based on onsite observation of IT infrastructure, and patient identification problems in hospital environment at UHB – NHS, a framework for object identification and location tracking is designed, implemented and benchmarked. It is developed using state-of-the-art tools and technologies in Visual Studio .NET, C#, MS SQL Server and ZPL for a variety of suitable equipments chosen to achieve the needs of this system.

To evaluate, the framework is benchmarked for the limitations and performance using extensive logging of all activities and round trip times within parts of the framework. The database involved is also monitored and measured for its size in comparison with the number of activities within the framework.

The main outcome of this project is a state-of-the-art framework that suits the needs of object identification and tracking within healthcare environment. With minor changes the framework can be implemented in wide range object and location aware application and solutions.

Two novel achievement of this work is, the framework is applied for patent protection (Patents, 2006) by NHS MidTECH on behalf UHB – NHS and Napier University and contributed to writing and acceptance of a paper in International Journal of Healthcare Technology and Management (Thuemmler et al., 2007).

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I would like to thank many more individuals and institutions, who have directly or indirectly helped me in this project. I have attached a list of individuals with the concerned institutions in the appendices section of this report as sign of appreciation (Appendix 10).

1.0 Introduction

Outdoor applications that needed location awareness have used GPS, Infrared, Ultrasonic, Cellular and RF based solutions (Agiwal et AL, 2004). For an indoor location aware application, there are wide range of research in various methods are undertaken by researchers(Zaruba et al., 2007), but still the need for real working framework for indoor location aware system is largely unexplored or unsuitable for challenging environments like healthcare(Murphy & Kay, 2004; Wang et al., 2006). This work here is contributed towards addressing this issue by building a proof of concept framework for patient identification in healthcare environment.

Wireless networks have significantly become popular among everyone in recent years. This interest is further fuelled by mobile computing devices with wireless capabilities, like pocket computers, mobile phones, game consoles, and personal music players. This emerging ability of wireless networked nodes has even enhanced network infrastructure in many organisations in retail, manufacturing, service and public sector. Even home networks nowadays has wireless enabled internet device.

Based on this widespread implemented wireless infrastructure, object and location aware applications are now looking positive. However, this infrastructure enables object and location identification of wireless enabled devices only. Therefore, to identify and locate objects that do not have wireless capability is still an issue.

Radio Frequency Identification (RFID) is another identification system that uses radio frequency for object and location identification (Borriello, 2005). In recent days, RFID has provided cost effective solution for object identification in areas like parcel distribution, airline luggage identification, security enabled smart keys and etc (Wang et al., 2006).

To identify a moving object within a wireless space that does not have wireless capabilities, the only possible solution is to integrate wireless networks and RFID tags (McKelvin et al., 2005; Ni et al., 2004). By this, a cost-effective way for tracking objects without wireless capabilities is achieved (Thuemmler et al., 2007). Thus, it provides intelligent object and location aware applications for wide range of industries including healthcare.

Healthcare is where such application is most wanted to enhance patient safety and to reduce medical errors by patient and object identification (Murphy & Kay, 2004; Thuemmler et al., 2007; Wang et al., 2006). The primary aim of this work is to review techniques of object tracking using wireless and RFID and to design an efficient framework for object tracking in wireless networks.

This work is achieved with help from various industrial partners and this work has contributed to writing and acceptance of a paper in International Journal of Healthcare Technology and Management (Thuemmler et al., 2007).

1.1 Aims and objectives

The main aim of this work is to design a frame work for object tracking and identification in wireless networks that is suitable for healthcare environments. The objectives are as follows:

- To review methods involved in object tracking, and in relation to signal strength and signal quality and to come up with a suitable framework that suits healthcare environment
- To determine signal strength and signal quality can be used to effectively and accurately trace the location of an object or a suitable method to do so within healthcare environment
- To review frameworks which will support object tracking and identification using object look up database with integrated security
- To design and implement a prototype of wireless framework which supports object tracking using object look up database and deliver a proof-of-concept framework
- To design this framework suitable or compatible for real-life experiments within NHS environment

1.2 Background

The idea for this research arose from ongoing work between Napier University, NHS and other industry partners related to location tracking of objects, especially using RFID technology.

Research evidence shows that often patients do not have wristbands or may carry misleading or inappropriate identification. These errors thus increase the risk of patients being misidentified and given the wrong care (Thuemmler et al., 2007; Royal College of Nursing, 2005; Cambridge Consultants, 2004). Between November 2003 and July 2005, the National Patient Safety Agency (NPSA) in UK received 236 reports of patient safety incidents and near misses relating to missing wristbands or wristbands with incorrect information (NPSA, 2005).

Normally wristbands consist of plastic strips with patient identification labels from paper attached to the surface. In some cases, patient names are simply written on the tag as ones which are phonetically understood by nursing staff. Thus, simple autographic mistakes or the lack of secondary identification, such as date of birth, quite frequently make the whole process of patient identification prone to error by mixed identity. All this needs to be understood in context with a growing number of patients who are not able to confirm their personal data due to conditions such as acute confusion, dementia, depression, intoxication, stroke, etc. [Thuemmler et al., 2007]

RFID technology offers an interesting and novel approach towards intelligent and highly reliable patient identification systems. Thus, labels and stickers could be abandoned as wireless sensors linked to memory can be embedded in wristbands

and can be read either by handheld devices or by antennae positioned in the hospital. The enhancements in authentication and privacy in wireless technology, such as the developments in WPA, allow a secure environment for collection, preservation, analysis and reporting of data. [Thuemmler et al., 2007]

1.3 Industrial partners

Industrial partners involved and the setup for this work is discussed here. To keep the information to a minimum a few lines about each institution involved and their role in this work.



Figure - Napier University (Napier University, n.d., CDCS, 2006)

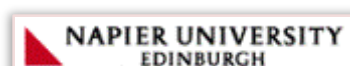
Napier University is a modern and vibrant university dedicated to supplying educational services which are relevant to the needs of today's students and employers. Napier has over 30 research teams operating across the University with a reputation for working closely with industry and business [Napier University, n.d.]



Role: As a student of Napier University, this work is undertaken for partial fulfillment of the requirements of Napier University for the degree of Master of Science in Advanced Networking



The Centre for Distributed Computing and Security at Napier University is a large and growing research centre with six RAE-focused academics and many researchers. This group focuses on enhanced security and forensic computing systems, ad-hoc routing over wireless networks, intelligent intrusion detection systems, the usage of mobile agents, location-tracking





of mobile devices, and on network emulation. At the core of its work is the successful transfer of knowledge between the research group and professionals, along with its excellent reputation for: its depth of skills; its links with industry and in enterprise; and, in its record on dissemination. It has extensive links with industry, and has developed a novel system for an agent-based system for ad-hoc routing over wireless networks, and innovative methods for device tracking and in content generation [CDCS, 2006]

Role: Healthcare is one of the interests of this research group. The research group brings together knowledge from two important domains: medical care and information technology. As part of various ongoing researches in healthcare, and this is where the idea for this work arose from.



Figure - Industrial Partners (ConnectRFID, n.d.; Zebra, n.d.; Motorola, 2007)



ConnectRFID with offices in Clonmel, Ireland and Leeds, England, is one of the leading accredited RFID solution providers. ConnectRFID is focused on delivering RFID solutions, system integration and consultancy services to clients throughout the EMEA region, with a strong emphasis on the Irish and UK markets [ConnectRFID, n.d.]

Role: ConnectRFID accepted to provide the equipments needed to design and implement the framework. ConnectRFID also agreed to fund for expenses and partially funded the work.



Zebra Technologies is a leading global provider of rugged and reliable specialty printing solutions, including on-demand thermal bar code label and receipt printers and supplies, plastic card printers, RFID smart label printer/encoders, certified smart media, and digital photo printers [Zebra, n.d.]

Role: Zebra is taking part by funding and providing the equipments through ConnectRFID



Motorola and Symbol Technologies, Inc. merged in 2007 to provide products and systems for enterprise mobility solutions, including rugged mobile computing, advanced data capture and radio frequency identification (RFID) [Motorola, 2007]

Role: Symbol is taking part by funding and providing the equipments through ConnectRFID



Figure - NHS & Concern (UHB NHS, n.d.; NHS MidTECH, n.d.; NHS, n.d.)



University Hospital Birmingham NHS Foundation Trust is the leading University Teaching hospital in the West Midlands. It is one of the highest performing and most successful trusts in the NHS and has been given the maximum three stars for the past four consecutive years [UHB NHS, n.d.]

The Trust provides a whole range of services including secondary services for its local population and regional and national services for the people of the West Midlands and beyond. The Trust has the largest renal kidney programme in the UK, is a major



specialist centre for burns and plastic surgery, neuroscience and specialist cancer centre [UHB NHS, n.d.]

The Trust also hosts the Royal Centre for Defence Medicine, which provides medical support to military operational deployments. It also provides secondary and specialist care for members of the armed forces [UHB NHS, n.d.]

Role: UHB – NHS has accommodated the author for onsite observation on an honorary contract and has agreed to implement the framework as pilot as a RFID Audit system initially in ten wards at Selly Oak Hospital under UHB - NHS trust in Birmingham.

MidTECH

NHS bodies are now required to operate under the Department of Health guidelines and framework for Managing Intellectual Property. MidTECH helps them do just this. They support and manage innovations for the NHS in the six counties of West Midlands, Shropshire, Staffordshire, Warwickshire, Worcestershire and Herefordshire. By working closely with commercial partners, MidTECH also identifies and exploits associated intellectual property, including patents and copyright [NHS MidTECH, n.d.]

Role: MidTECH has applied for patent protection of this framework on behalf of UHB – NHS and Napier University. MidTECH has also partially funded this work.

NHS

The NHS was set up in 1948 in the UK and is now the largest organisation in Europe. It is recognised as one of the best health services in the world by the World Health Organisation but there need to be improvements to cope with the demands of the 21st century. The NHS is changing the way it works to make sure patients always come first. This has brought about some fundamental changes in the way the NHS is structured and the way in which the different organisations within the NHS relate to each other [NHS, n.d.]

A Representation of the entire setup is displayed below in Figure (Napier University, n.d.; CDCS, 2006; ConnectRFID, n.d.; Zebra, n.d.; Motorola, 2007; UHB NHS, n.d.; NHS MidTECH, n.d.; NHS, n.d.).

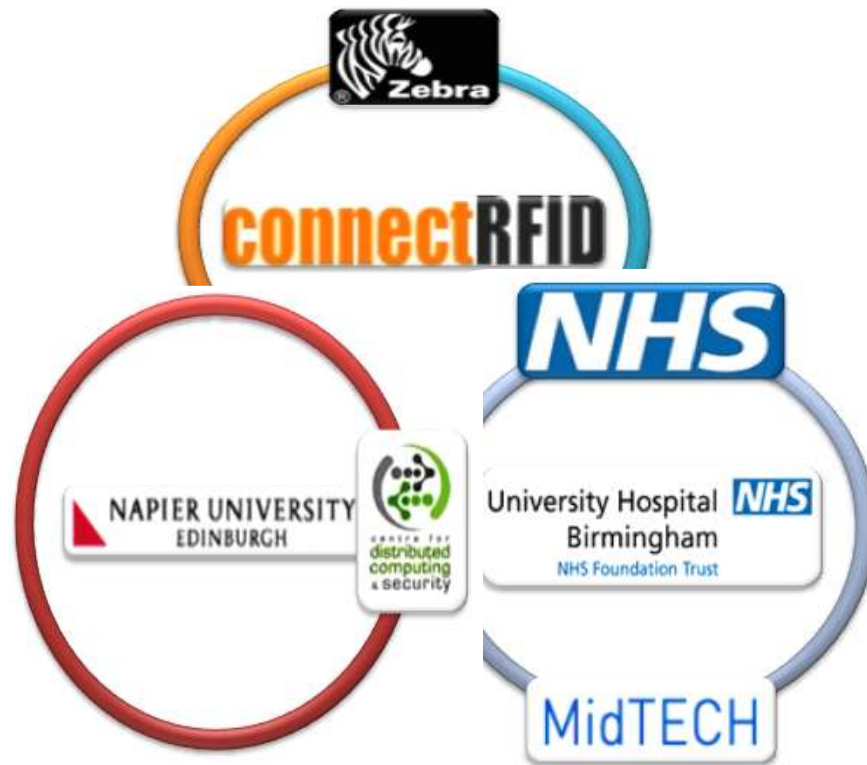


Figure - Collaboration Setup

1.4 Document Overview

This document is divided in to seven chapters:

- **Introduction** – Current section which gave an overview of the aims and objectives and general background information on industrial partners and overall dissertation.
- **Theory** – Outlines the basic concepts of the technologies involved
- **Literature Review** – Reviews all the possible solution in achieving a framework and also compares similar works.
- **Requirements and Design** – Analyse all the requirements for the design and outlines a suitable design.
- **Implementation and Testing** – the design implementation is given an overview with code extracts from the developments. Also outlines the tests that was implanted to analyse performance
- **Result analysis** – Analyses the test results for performance, load and stress capabilities.
- **Evaluation** – concludes by evaluating the objectives and examining the strength and weakness of the design with some suggestion to further work

2.0 Theory

Before examining the methods of object tracking in wireless and RFID systems, general background information for both Wireless and RFID technologies is discussed here. Thus, the problems in object tracking using these two technologies are easily identified in the literature review section (Section 3.0). A general overview of Wireless Networks and RFID are as follows...

2.1 What is a wireless network?

In general, there are wide ranges of wireless networks currently in use, like Wireless LAN, Wireless MAN, Wireless Loops, Cellular(GSM, CDMA, etc), Wireless ATM, Satellite and etc (Varshney & Vetter, 2000). In context to this work, wireless networks here mean Wireless Local Area Network (Wireless LAN). Work here is mainly aimed at building a framework for indoor wireless object tracking.

2.1.1 Wireless Networks (Wireless LANs)

Wireless LAN does exactly what it means. Wireless LANs redefine connectivity and without having to attach anything to device. It provides all the features and benefits of traditional LAN but without the need for any wires. (Cisco Curriculum, 2006)

Wireless LAN requires a physical medium to transmit and receive data similar to traditional LAN where cables are used. Wireless LANs are using Radio Frequencies (Cisco Curriculum, 2006) instead of wires.

Wireless LAN technologies are defined by IEEE 802.11 standards. Based on the radio transmission types within the frequency band the standards are further classified into 802.11a, 802.11b, 802.11g and further transmission techniques are currently under research like 802.11n and etc. Based on these transmission types the typical operating speed varies. (Cisco Curriculum, 2006)

2.1.2 Wireless Enabled Devices

Typically, wireless enabled devices mean that the device would have a built-in or add-on wireless adapter attached to it. Nowadays, it has become common for devices like laptop, PDA, mobile phone, personal entertainment devices and even traditional desktops PCs sometime have built-in wireless adapter.

2.1.3 Wireless Adapter

Wireless adapter gives the mobility and flexibility to operate with the wireless networks (Cisco Curriculum, 2006). Wireless client adapter are the key in enabling a device to wireless capable device. Usually, these client adapters comply with one of the IEEE802.11 standards in order for this device to communicate with other similar devices and wireless Access Points.



Figure - Wireless Network Adapters (Cisco Curriculum, 2006)

2.1.4 Wireless Network connectivity options

Wireless LANs offer two types of network connectivity options. This is typically One to One network or One to Many networks.

Ad- Hoc Networks

One to One network connectivity is called Ad-Hoc network, where two wireless enabled devices can access each other. This scenario is also seen in simple mobile phones, where one can send/receive a file or a media over one to one Bluetooth or infrared connection to another device that is capable of performing the same action.

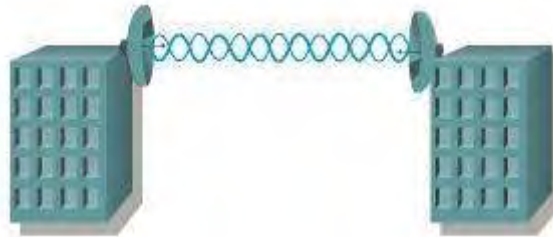


Figure - Ad - Hoc Network (Cisco Curriculum, 2006)

Access Point Networks

One to Many nodes network connectivity is called Access point networks. An Access Point device acts as a centre point of connectivity to all the devices in the wireless network. Access point also acts as a connection point between wireless and wired networks.

By this, Access Point networks are popular among corporate, medium and small scale business network infrastructure. Even home networks nowadays have a wireless access point to provide connectivity for variety of home computer and multimedia entertainment devices.

In this work, we would largely consider access point networks as this type of networks already exists in the hospital infrastructure. And it is fairly easy to install an access point and configure the devices to access the wireless networks.

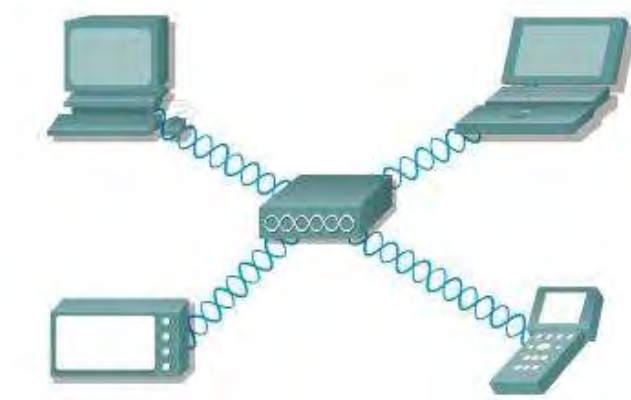


Figure - Access Point Network (Cisco Curriculum, 2006)

2.1.5 Wireless Access Points

As discussed in above section (Access Point Networks), Access Point (AP) acts as a centre point for wireless network and it also stands as a connection point between wired and wireless networks. It basically contains a transceiver to perform the wireless tasks. It has a typical coverage range of up to 100 meters, but it is simply depending on the antenna that is built-in in the AP to transmit and receive data. Antennas can be replaced to support long range if necessary.

APs generally comply with one or many of the IEEE 802.11 Standards to ensure interoperability (Cisco Curriculum, 2006). It is also easy to update the APs firmware anytime in order to support future IEEE 802.11 standards if the manufacturer releases firmware update for that purpose. APs can also be used as a repeater for wireless networks in order to increase the coverage of one or many networks (Cisco Curriculum, 2006).



Figure - Wireless Access Point (Cisco Curriculum, 2006)

2.1.6 Operating Frequency of Wireless networks

Wireless LANs use 2.4 GHz and 5GHz frequency band and these RF spectrums are reserved for wireless LANs in most part of the world. (Cisco Curriculum, 2006)

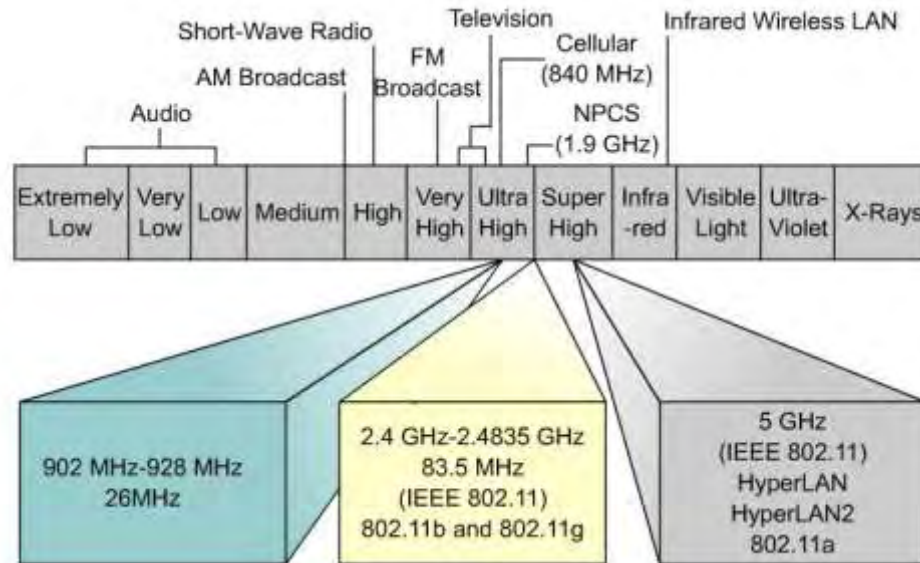


Figure - Wireless Operating Frequency (Cisco Curriculum, 2006)

2.2 What is RFID?

RFID stands for Radio Frequency Identification. RFID is a general term, where a device transmits the identity of an object in some of sequence of numbers and characters using radio frequency. RFID is an automatic identification, which can store and retrieve data remotely using a transponder device or otherwise called RFID Tag (Radio-frequency identification, n.d.; RFID, n.d.). In general RFID contains a microchip connected to an antenna mounted on a substrate (RFID Journal, n.d.). These microchips are capable of Storing data and it is usually a unique ID of that tag.

RFID comes under the Automatic Identification Technology, similar to barcodes, fingerprint, and retina scans. RFID is considered to be an intelligent replacement of barcodes (J.A. Wolff, 2006).



Figure - Various RFID Tags (EMS, n.d.)

There are three different kinds of RFID Tags and they are discussed in detail here

2.2.1 Passive RFID

Passive RFID tag is the simplest form of RFID tag. It does not contain an internal power supply (Radio-frequency identification, n.d.). When an incoming radio signal is received from a RFID tag reader, a minute current is induced in the antenna which is enough to power up the circuit inside and transmits a response (RFID Journal, n.d.).

Passive tags have much shorter reading range, when compared to other types of tags. The practical reading distance is only between few centimetres, which depend on the operating frequency of the tag (RFID Journal, n.d.). Just like wireless networks, the RFID is also standardised by EPC and ISO organisations for the industry (Radio-frequency identification, n.d.).

Passive tags are very small in size and it can be easily embedded into paper label, stickers, plastic cards, key fobs and etc (RFID Journal, n.d.).

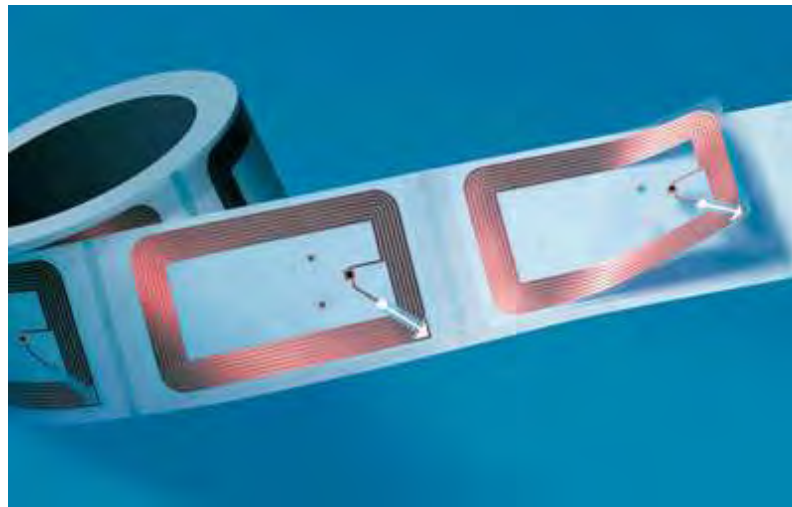


Figure - Passive RFID (Dumont, 2006)

2.2.2 Active RFID

Active tags have internal power supply of its own and it does not rely on the incoming signal from a RFID reader as a power source (RFID Journal, n.d.). Because of its onboard power supply active tags can transmit more powerful signal and thus, the range of active tags are typically very high from 20 to 100 meters and which also depends on the operating frequency of the tag.

Active tags are relative big in size when compared to passive tags because of its onboard power supply. But active tag has the option of having much higher storage capacity in the chips that is built-in. Active tags can also accommodate various sensors within for various application needs. Sensors like temperature sensor, pressure sensor, humidity, shock, light sensors and etc. (RFID Journal, n.d.)



Figure - Active RFID (ITP NYU, n.d.)

Active tags are further divided into two kinds, which are as follows;

Transponders: These kinds of tag wait for a read request from the reader and responds (RFID Journal, n.d.).

Beacons: These kinds of tags keep reporting to a reader in a timely fashion and these kinds of tags are mostly used for real time tracking applications (RFID Journal, n.d.).

2.2.3 Semi-Passive RFID

Semi-Passive tags are a hybrid of both passive and active tags. It has a power supply of its own but it is only used for read and write into the chips and the power received from a signal of a receiver is used to transmit the data to the reader just like passive tags (Radio-frequency identification, n.d.).

2.2.4 Operating Frequency of RFID

Active tags usually operate at 455 MHz, 2.45 GHz, or 5.8 GHz (RFID Journal, n.d.).

Passive usually operate at the following frequencies

- LF - 124 kHz, 125 kHz or 135 kHz
- HF - 13.56 MHz
- UHF - 860 MHz to 960 MHz (RFID Journal, n.d.)

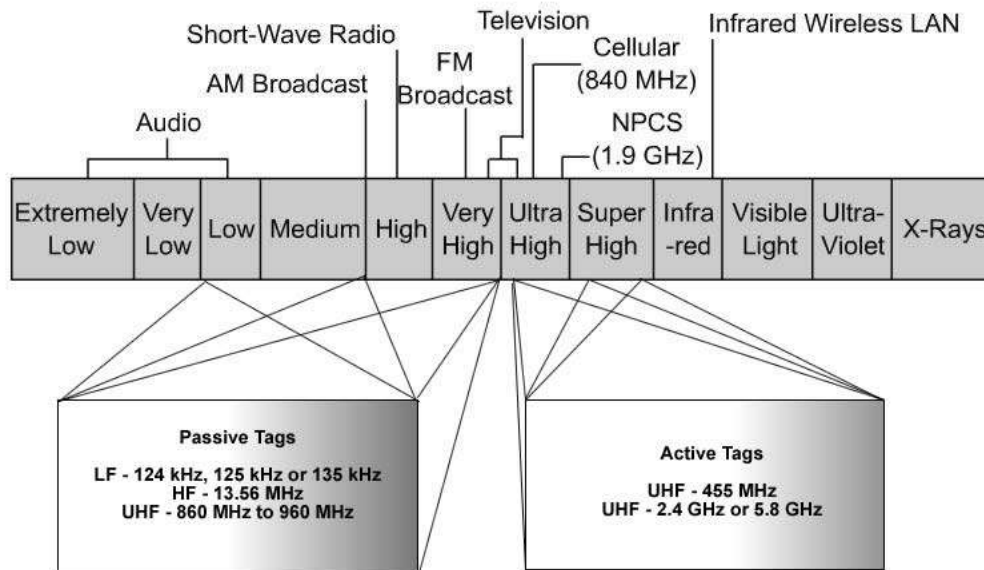


Figure - Operating Frequency (Cisco Curriculum, 2006; RFID Journal, n.d.)

2.2.5 Uses of RFID

RFID has been widely used in many industries and public sector for tagging objects. RFID is a big success in retail industry for security purpose. Places like wall-mart, have asked the manufacturers to inlay RFID tags in their products (RFID Journal, 2006).

RFID is also used in various industry and applications, like toll payments, vehicle identification, parcel tracking, industrial waste management, domestic waste management, passports, ID cards, key fobs, library, warehouse management and etc. (RFID Journal, n.d.; RFID, n.d.). The use for RFID is limitless and the above are only few examples and still RFID can be implemented in a wide range of applications that are still unexplored.

2.3 Summary

As discussed above (Section 2.2.5), Wireless network is a communication technology and RFID is an identification technology. Where both of these technologies operate in totally different radio frequencies and both are clearly separate from each other. Object tracking is possible with just using either one of these, but it poses many problems for a healthcare environment. The object tracking methods in each technologies and problems caused for healthcare environment are discussed in literature review section (Section 3.0) of this dissertation to obtain a possible solution by integrating these two technologies.

3.0 Literature Review

3.1 Need for Patient Identification in Healthcare

A Department of Health Reports states that there are 850,000 estimated adverse events occur each year in UK hospitals with many involving patient being misidentified (Murphy & Kay, 2004). To be more precise with November 2003 and July 2005 there were 236 incidents reported to National Patients Safety Agency (NPSA) just for patients carrying incorrect information in their wristbands. (Thuemmler et al., 2007, NPSA, 2005)

Even though, patient safety is in the priority in the healthcare service and it is also being recognised by World Health Organisation (WHO), EU, and by many in American, European and Asian countries (Wu et al., 2005). Errors still occur and the seriousness is under estimated or under researched in many cases. (Wu et al., 2005)

Errors in Healthcare occur in mainly because of misidentification in many aspects of healthcare events like patient identification, medication intake, x-ray, patient file identification, blood transfusion, surgery, diagnosis, administration, bed allocation and etc (Royal College of Nursing, 2005; Cambridge Consultants, 2004; NPSA, 2005)

Also there is growing need for identifying patients, who cannot identify themselves like patients with confusion, dementia, depression, intoxication, stroke and etc. (Thuemmler et al., 2007)

A Result from UK Transfusion Practice Audit (Royal College of Nursing, 2005; Gray, Buchanan, McClelland, 2003; RCP/NBS, 2003) has shown that the cause for errors and its effects as below.

- 18% of patients had no identification check when the pre-transfusion sample was taken.
- 11% of blood components collected had no patient minimum data set check.
- 10% of patients were not wearing a wristband during their transfusion.
- 47% of patients had no vital signs monitored within the first 30 minutes of the transfusion.

Royal College of Nursing, 2005

“The percentage of hospital inpatient admissions resulting in adverse events has been estimated as 3.7% in the USA, 16.6% in Australia, and 10% in the UK (equivalent to 850 000 admissions each year). In the studies from Australia and the UK, it was considered that about half were preventable. The Australian study estimated that adverse events accounted for 8% of hospital bed days, and cost Aus\$4.7 billion a year. The UK study estimated that around 5% of the 8.5 million patients admitted to hospitals in England & Wales each year experienced preventable adverse events, leading to an additional 3 million bed days at a cost in extra bed days alone of £1 billion each year. In the USA, the Institute of Medicine

reported that between 44 000 and 98 000 deaths per year may be caused by medical error.” (Murphy & Kay, 2004)

3.1.1 Issues in Existing System

The current system in most of the UK hospital are using conventional wristband to prevent medical errors. (Thuemmler et al., 2007)

In most cases, conventional wristbands currently in use consist of a plastic strip with a paper based sticker attached to it (Murphy & Kay, 2004; Thuemmler et al., 2007). Usually, a system for printing the sticker is implemented, but still in some hospitals the name of the patient is simply handwritten by the nursing staff and some hospitals also print barcode based labels for the conventional wristbands. Most of this system also lacks secondary identification. (Thuemmler et al., 2007)

These forms of patient identification system are prone to a number of vulnerabilities caused by autographic mistakes, like wrong spelling, difficult hand writing, missing parts of names and etc (Thuemmler et al., 2007). Wristbands are also often damaged by chemical agents, like soap or disinfectants and based on the quality of the ink used to write or print the data; they are prone disappearing in matter of days. (Murphy & Kay, 2004; Thuemmler et al., 2007)

Along with this these systems use colour coded wristbands for identifying patients with allergy and infection (Thuemmler et al., 2007). Currently there is no standard for this colour coded wristbands and medical professionals are mostly go from one hospital to another (Thuemmler et al., 2007) and they misidentify the allergy and the patient is prone to the wrong treatment.


SHOT, a voluntary and anonyms reporting scheme in healthcare, highlights potential transfusion risks caused by misidentification and carelessness in typical blood transfusion are as below (Royal College of Nursing, 2005; SHOT, 2003).

- The blood sample was drawn from the wrong patient.
- Patient details were recorded incorrectly on the blood sample label or the blood request form.
- The formal identity check at the patient’s bedside was omitted or performed incorrectly at the time of the administration of the blood component.

Royal College of Nursing, 2005; SHOT, 2003

3.1.2 View of Public, Staffs and Professional organisations

As per report “Wristbands for hospital inpatients improves safety” by NPSA on 22 November 2005 states the following

	<p>Patient and public views on wearing wristbands</p> <ul style="list-style-type: none">• Patient identification is a very important issue;• Shorter stays in hospital can make it more likely that inpatients will not be recognised• Several patients had experienced inadequate identification including being left without a wristband for several days• Patients want effective identification methods, whether wristbands or other means <p>NHS staff views</p> <ul style="list-style-type: none">• All staff recognises the importance of wristbands for accurately identifying inpatients• There is wide variation in the information on wristbands and the way staff checks inpatients' identity• Training on checking patients' identity is not consistently available or provided for all staff groups <p>Professional organisations' views</p> <ul style="list-style-type: none">• There is not a standard or consistent training programme for NHS staff on identifying patients• Identifying patients is mainly covered as part of other training courses such as those on patient assessment or drug administration• Staffs are often unclear about the best way to identify patients, what information to include on a wristband, and when wristbands should be applied.
---	--

NPSA, 2005

All this clearly states, there is a strong need for proper patient identification and tracking system and the need for a standard framework, which is user friendly and error free. One such framework is definitely to contribute towards saving lives of many patients and Healthcare industry can reduce costs caused for patient safety and further treatments caused by misidentification errors. Also such system would reduce the pressure for healthcare workers where there is constantly growing number of patients and mostly understaffed hospitals are growing. Such framework could make trouble free and cost effective healthcare for everyone.

3.2 Object tracking in wireless networks

Ad-hoc networks also have one to one location tracking methods (Zàruba et al., 2007), but it is not in the best interest of this work. Thus, all the wireless tracking methods discussed here are for access point wireless network. All these methods include use of one or more access points.

Nodes (Objects) can easily be identified within a network using its MAC address or IP address and this is general practice for even authentication of nodes in some networks.

In general, object tracking in wireless networks are based on the signal strength from an access point to a node. There are several approaches for object tracking and they are discussed below.

3.2.1 Nearest or Closest Access Point Method

It is the least precise and the simplest form of tacking nodes in wireless space (Wexler & World, 2006). This method finds the nodes within the coverage area of a single access point and based on the assumption that this is the access point that the node associated with (Cisco, 2006).

Using this method can only locate the node within the range of an access point, but this may be in more than one room or more than one floor of a building based on the range of that Access Point (Cisco, 2006).

“The result might not provide the degree of accuracy necessary to pinpoint device locations. For example, if an access point covers (roughly) a 70 square foot area, then the closest access point method only narrows the location of a device down to a 4900 square foot area. This method is even less accurate for greater coverage areas” (Cisco, 2006)

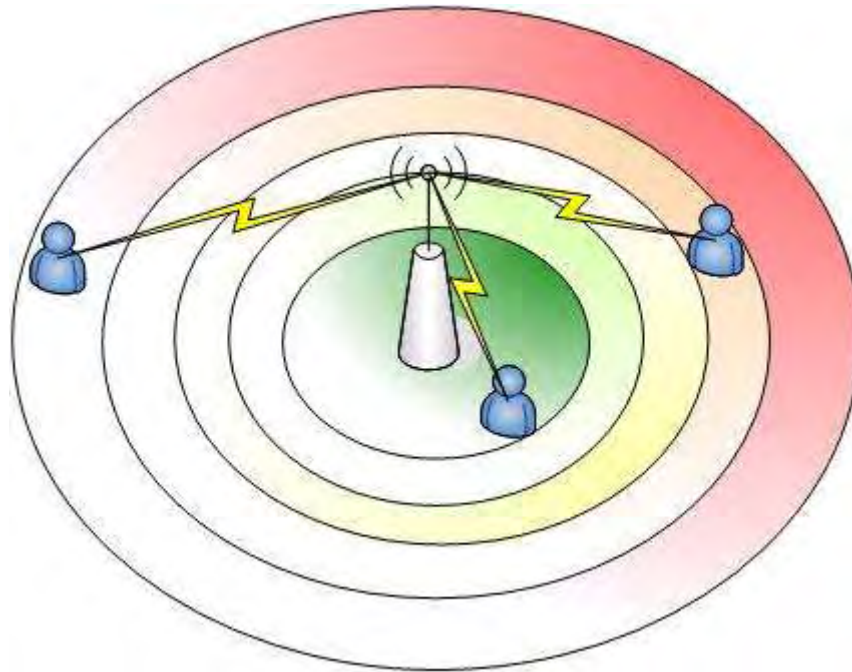


Figure - Nearest Access Point Tracking

3.2.2 Triangulation or Trilateration Method

Triangulation typically has more than one Access Point involved (Yasar et al., 2006). When the closest access point method is combined with other similar access point within range triangulation is possible (Wexler & World, 2006). Based on the Received Signal Strength (RSS), various algorithms can be used to determine the intersection point of the where is the device is most likely to be (Cisco, 2006, Yasar et al., 2006).

“Each access point that "hears" the device's signal responds to the request with information regarding signal strength. Access points that fail to hear the device do not respond. The more access points that respond, the greater the accuracy of the final result with the device's approximate location. The location tool then draws coverage circles on a map around each access point that hears the device. Each coverage circle defines the boundary of the signal strength of the access point receiving the signal from the device. Signal strength information provided by each access point is factored into the final determination of the device's location and it would identify a number of line intersections. Algorithms are then used to determine the most likely location of the device within the intersections” (Cisco, 2006)

Trilateration is similar to Triangulation, but the distance between the node and the access point is calculated and intersected rather than an algorithm for an intersection angle (Niculescu & Nath, 2004, Wexler & World, 2006).

This method is more accurate than the Closest Access Point method.

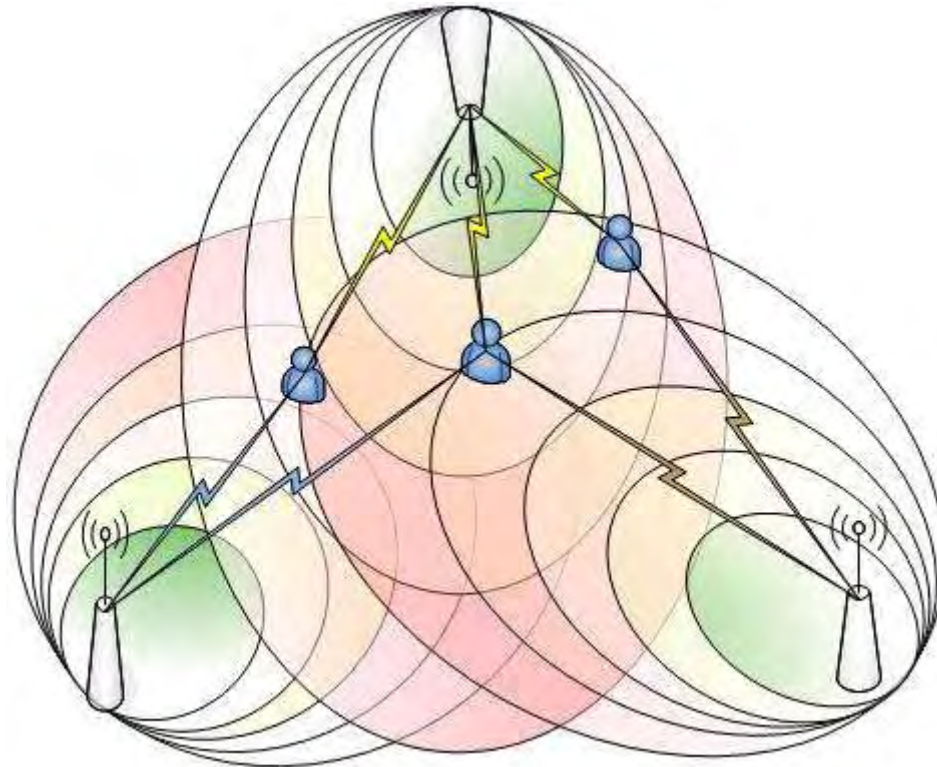


Figure - Triangulation Tracking

3.2.3 Radio Frequency (RF) Fingerprinting Method

It is a sophisticated method of tracking a node in wireless space and it is more accurate (Cisco, 2006; Wexler & World, 2006). This method also involves more than one access point.

An actual Fingerprint of the environment is calculated by walking around with a RF spectrum analysis device and then it is grid mapped to a floor plan (Cisco, 2006). For accuracy even the physical objects in the environment like mirrors, tables, doors and etc is mapped to the grid map (Wexler & World, 2006), even factors like reflection, attenuation, and multi-paths are calculated using RF prediction (Wexler & World, 2006; Yasar et al., 2006).

Then the system populates information about each co-ordinates based on signal strength and it is then used to create a database of locations with a number of grid maps (Wexler & World, 2006). Various algorithms are then used to locate the object within (Cisco, 2006, Wexler & World, 2006).

“Each access point involved replies with the signal strength of the devices it hears- just like in triangulation. However, with RF fingerprinting, the location tracking system takes the information it receives from the access points and matches it against its database of location fingerprints. When it finds a likely match, it is reported as the location of the device.” (Cisco, 2006)

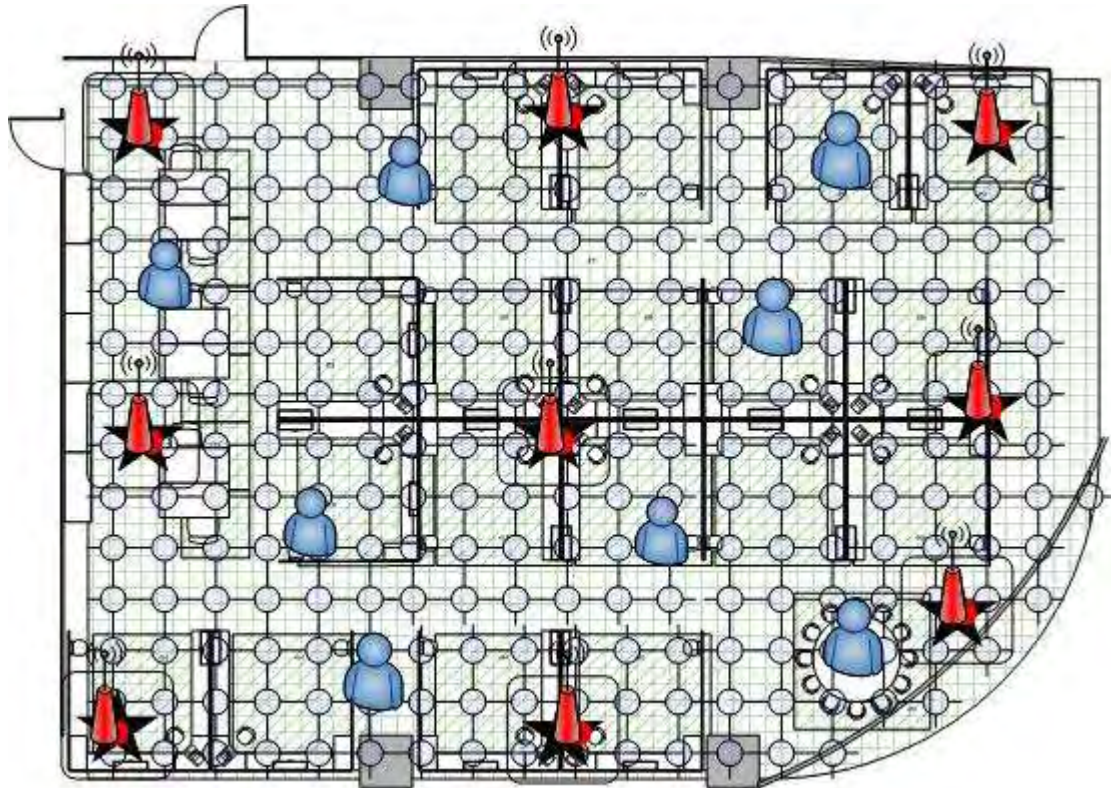


Figure - RF Fingerprinting

There are few other methods for tracking, which are various forms of combinations of the above methods.

3.2.4 Issues in using Wireless network only tracking solution

Regardless of the methods of tracking used in wireless networks, the main thing to consider is the object that needs identification tracking has to have a client wireless adapter (Section 2.1.3).

Possibility for tagging patients in hospital with a wireless client adapter is clearly not possible. Because

1. Radiation is one of the biggest concerns (Wang et al., 2006) particularly in Health care environment, where a typical 802.11 device signal can travel up to 100 meters (Cisco Curriculum, 2006).
2. Wireless adapter can only be used if it is made or integrated in some form of tag or wristband, which meets all the requirements and (HIPAA, 2001) healthcare standards.
3. Adapter needs considerable amount of power.
4. Adapter might need recharging if necessary.
5. Cleaning or clinically making the adapter clean from microbes and germs is impossible due to the components used. Unless if the device is specifically made for this purpose.

6. As known, the simple conventional tags that are being used are prone to chemicals and soaps (Thuemmler et al., 2007), and then wireless adapter does not stand a chance due to its electronic components.
7. Adapter enabled patients tags cannot be disposed, due to its cost.
8. Adapter cannot be reused to different patients due to fear of infections (Thuemmler et al., 2007).

3.3 Object tracking in RFID

Tracking using RFID needs either RFID access points or RFID readers (Wang et al., 2006) similar to wireless networks. There are various forms of RFID devices available to this purpose (ALR 9800, 2005). For tracking scenarios discussed these devices are put in use in relation to the type of the tag being used and the method of tracking.

Similar to Wireless Access Points, RFID Access points also act as centre point of communication and the connection between RFID and other types of networks. RFID readers are simply to perform read or write operation and they are mostly attached to a PC (RIGHTreader, 2006) or for example, at the checkout of a supermarket or entrance door for billing and security purpose (Hawkes, 1994).

3.3.1 Tracking Methods using Active RFID

Similar to Closest Access Point method of wireless object tracking, active RFID can also perform object tracking.

RFID Access Points are simply to read and write to RFID tags, and it performs in two methods according to the type of Active RFID tag that is being used. Either it receives a timely manner signal reading from a Beacon type Active RFID (RFID Journal, n.d.) or An RFID Access Point itself request a Transponder type RFID tag for response (RFID Journal, n.d.). These Access Points are usually wall or ceiling mounted and it can report to other type of networks other than RFID network (Wang et al., 2006). Such as report to a database system via tradition Ethernet and etc.

RFID readers can also perform similar tasks but unlike RFID Access Points these readers are attached to computers as a peripheral (RIGHTreader, 2006) or similar to Access Points report to database server or an alarm system via traditional Ethernet or similar network (Wang et al., 2006). These types of reader are usually placed in entry and exit points, to check the identity and used for security and automated inventory purpose (Hawkes, 1994).

As known, Active RFID have large memory and options to integrate sensors (Ni et al., 2004), and by default these carry a unique identifier in its memory to identify itself (RFID, n.d.).

Problem in using these tracking solutions is that these tags do not have an option to sense and report signal strength like wireless Client Adapters (Ni et al., 2004). Thus, methods of identification is possible for long ranges (Ni et al., 2004) and methods of tracking is possible for only like Closest Access Point or methods that are similar to Trilateration where using time the distance is calculated between many Access Points and a intersection is given as an object location.

There is one form of solution, which would provide much accurate tracking solution which is RADAR based system (Agiwal et AL, 2004; Ni et al., 2004), which is similar to aviation radars and the RFID access points act as radar and similar to Trilateration the distance between object is calculated based on the current direction of the Radar but not intersected.



Figure - RFID Wall Access Points (ALR 9800, 2005)

Issues in using Active RFID tracking solution

1. Radiation is one of the biggest concerns (Wang et al., 2006) particularly in Health care environment, where a typical Active RFID signals can travel anywhere from 30 to 100 Meters (RFID Journal, n.d.).
2. Active RFID can only be used if it is made or integrated in some form of tag or wristband, which meets all the requirements and healthcare standards.
3. Active RFID needs considerable amount of power.
4. Active RFID might need recharging if necessary.
5. Cleaning or clinically making the Active RFID clean from microbes and germs is impossible due to the components used. Unless if the device is specifically made for this purpose.
6. As known the simple conventional tags that are being used are prone to chemicals and soaps (Thuemmler et al., 2007), then Active RFID does not stand a chance due to its electronic components including battery.
7. Active RFID enabled patients tags cannot be disposed, due to its cost.
8. Active RFID cannot be reused to different patients due to fear of infections (Thuemmler et al., 2007).

3.3.2 Tracking Methods using Passive RFID

Passive RFID is simple and does not contain built in power source the read range is very low (RFID Journal, n.d.). Because of this Passive RFID has to be in really close proximity to the RFID reader or Access point (Wang et al., 2006; RFID Journal, n.d.). Unlike Active RFID, the Access point cannot be ceiling or wall mounted.

As known, passive RFID rely in the power source from signal received from a reader to power up its transponder (RFID, n.d.), the reading distance from reader to tag is based on the power of signal of the reader (RFID Journal, n.d.).

Wall and ceiling mounted Access Points can only be used, if the signal output is powerful enough to power up the transponder and send the response to reach the distance.

Passive RFID provide close proximity reading solution and when the reader is considered being a reference point in the tracking system, then the accuracy of tracking the object is not really accurate and it is mostly a general location, like a room or a hallway instead of intersection coordinates and even this is only possible if a RFID reader is placed in every door entrance and exit.

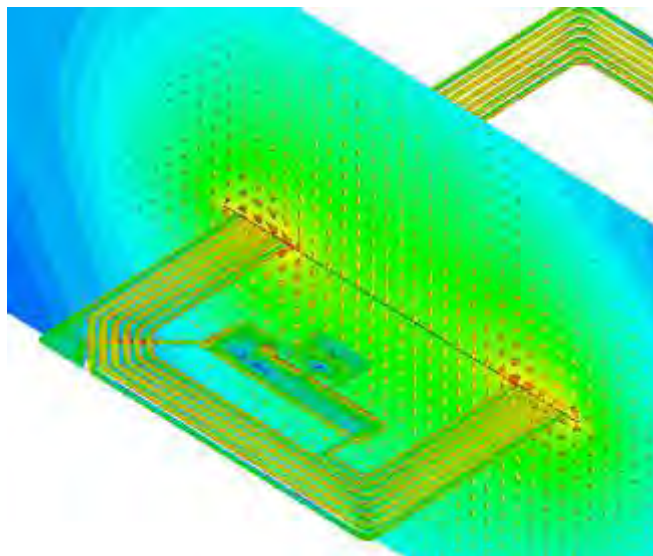


Figure – Magnetic Field of 13.56 MHz passive RFID (CST, 2006)

Issues in using Passive RFID tracking solution

1. High radiation RFID readers and Access Points should be avoided.
2. Reading range is very less
3. Reader is can only be in a fixed place attached to a PC or door
4. For individual patient identification need mobile solution
5. The Passive Tag has to comply standards for use in healthcare

3.3.3 Advantages of Active RFID VS Passive RFID

Advantages of Active and passive tags are compared (Table) in context with the healthcare environment.

Active RFID	Passive RFID
<ol style="list-style-type: none"> 1. Long range (Up to 100 Meters) 2. Option for integrated sensors 3. Beacon & transponder tags 4. Wall & Ceiling mounted Access Points 	<ol style="list-style-type: none"> 1. No Built-in power source 2. Small and thin in size 3. Easy to be integrated in anything 4. Low range and less interference 5. Really low cost 6. Have been accepted to use in healthcare environments by standards organization (Zebra, 2007) 7. Wristbands are readily available 8. They are also available with anti-microbial coating (Zebra, 2007) 9. They are tamper evident 10. Easy to use 11. Water proof (Zebra, 2007) 12. Resistant to chemical and detergents(Zebra, 2007)

Table - Active RFID Vs Passive RFID

3.3.4 Issues in using RFID tracking solution

As seen above, passive RFID is clearly the winner in healthcare over Active RFID. Even though, Passive RFID has short reading range, the purpose of this framework is mainly to improve patient safety in hospitals and the patient safety is given priority.

But RFID only solution poses with problems as it does not give mobile tracking and identification solution. Mobile Solution is much needed for Nurses and Healthcare professionals to verify patients identity wherever they needed.

3.4 Integrated Wireless network and RFID tracking Solution

It is now reasonably acceptable that passive RFID is the way forward for healthy and cost effective solution of identification and tracking within healthcare (Thuemmler et al., 2007). But the RFID only solution is not entirely serving the needs.

The need for a mobile identification and tracking as discussed in previous section (Section 3.3.4) is still at large. On exploring possible solution, which could suit healthcare environment, the possibility of integrating Wireless and RFID provides an intelligent solution.

PDA or portable pocket PCs are available and they have been used in healthcare previously for various solutions (Alsos & Svanas, 2006). Now manufacturers provided clinically accepted PDA for healthcare standards (Alsos & Svanas, 2006).

These portable mobile pocket computers now mostly consist of a built-in wireless adapter (Symbol MC70, 2006), which can be easily associated with wireless access points that are already in use in most of the hospitals (Alsos & Svanas, 2006; Symbol MC70, 2006).

A healthcare professional equipped with a wireless enabled mobile device is better than a patient with a wireless adapter enabled tag. By this, the number of wireless enabled device is significantly reduced equivalent to the number of healthcare professionals rather than equivalent to number of patients within healthcare environment.



Figure - Wireless Enabled PDA (Symbol MC70, 2006)

3.4.1 Integrating RFID and Wireless

Recently, there are Add-on RFID readers available to PDA devices and only recently they have become commercially available (POS Systems, 2006). These provide the exact solution that is needed for this framework.

By this, the passive RFID wristbands can be tagged to patients and a mobile device with a wireless and RFID reading capabilities can do just the job needed.

Even though, the short range of passive tag has overcome by the mobility of the integrated solution, the important aspect of identification is done but the accuracy of the tracking is poor. It would not actually provide real time tracking, but it could possibly provide alternative tracking solutions.



Figure - RFID add-on Reader for handheld device (POS Systems, 2006)

3.5 Conventional Wristband VS Passive RFID Wristband

Conventional Wristband	Passive RFID Wristband
<ol style="list-style-type: none">1. Require line-of-sight transmission2. Must be visible on surface3. Only contain an identification number or a bar code which represents the number	<ol style="list-style-type: none">1. Does not require line-of-sight transmission2. Can be embedded into wristband3. More robust4. Can contain other information, such as a unique ID, patient name etc

Table - Conventional Wristband Vs Passive RFID Wristband

3.6 Need for Security and Privacy

The possibilities of authenticating access to passive tags are literally impossible as the passive tags carry a unique identification, and memory space for storage of any additional data (RFID Journal, n.d.).

Access to this unique ID and to the data stored within cannot be authenticated. Even though, data stored within can be encrypted or hashed, it still poses the same risk of being accessed and cracked by a third party.

“There are possibilities for unauthorised access to patients' wrist-bands due to the lack of a mechanism for authentication in wristbands. Unprotected wristbands could be accessed and scanned by a third party to either identify the individual or provide valuable data to market researchers or competitors of an organisation” (Wang et al., 2006)

“An electronic system for the healthcare should comply with the HIPAA statute that requires reasonable and appropriate safeguards to protect health information.

The main goals are

- To ensure the confidentiality, integrity and availability of all electronic protected health information that the covered entity creates, receives, maintains or transmits
- To protect against any reasonably anticipated threats or hazards to the security or integrity of such information
- To protect against any reasonably anticipated uses or disclosures of such information that are not permitted or required under (the security rules)
- To ensure compliance with the (security rules) by its workforce” (Thuemmler et al., 2007; Wang et al., 2006; HIPAA, 2001)

This clearly state security should be a priority, when using the RFID wristbands capable of storing data within.

Possible solution for preventing security risks are that no data has to be stored within the tag and a RFID databases can be used to link patient data and a lookup operation could be performed when identification is needed.

3.7 Similar work

RFID is already widely used in healthcare for various applications. Like monitoring elderly activities by using RFID tags on household objects and collecting information when the object is touched and used to generate reports of Activities of Daily Living (ADL) (Wang et al., 2006; Ho et AL, 2005), Using RFID to identify dental moulds and dental implants (Wang et al., 2006), hospital workflow monitoring by tracking equipments and patient transfer using RFID (Wang et al., 2006)

3.7.1 Elderly healthcare system using RFID to monitor medication intake

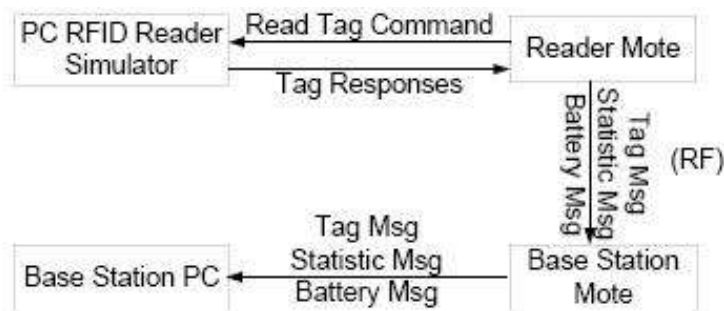


Figure - Elderly Healthcare Medication monitor system (Ho et AL, 2005)

“The learning phase investigates technology compatibility and capabilities through a sensor network interacting with a simulated RFID system. The development phase builds a system that consists of sensors and both HF and UHF RFID components. It is targeted for in-home medication monitoring. Simulating software modules are also described; they are needed when hardware purchases are limited. We are currently working on actual system testing” (Ho et AL, 2005)

3.7.2 An intelligent Magic Medicine Cabinet

“The Magic Medicine Cabinet is part of an ongoing research program in situated computing at Andersen Consulting’s Center for Strategic Technology Research (CSTaR). In this program, we attempt to integrate a wide range of sensory, computing, and communications technologies to create new types of consumer experiences. One central theme of our research is to explore ways for bridging the gap between the physical world in which we live, and the virtual world on which we are becoming increasingly dependent. The MMC prototype is a good example showing how informational and physical healthcare can come together in the form of a smart appliance.” (D.Wan, 1999)



Figure - Magic Medicine Cabinet (D.Wan, 1999)

3.7.3 A case study on a demonstration RFID project in a Taiwan hospital

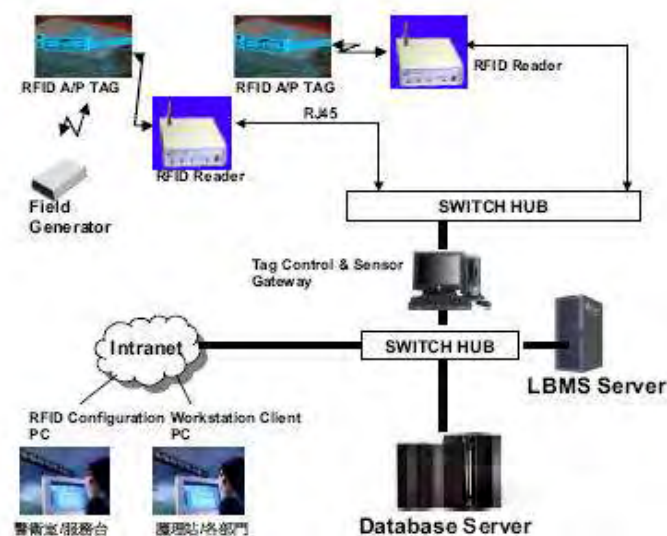


Figure - RFID project in a Taiwan hospital (Wang et al., 2006)

“RFID does have the potential to contribute to operating efficiency, good medical service and patient safety. Benefits and value derive from the infrastructure. RFID should be considered as a part of IT infrastructure, and the value of RFID is delivered through its applications in business. RFID as infrastructure provides a real option for the hospital. Device and data management are critical in building the infrastructure and the applications. In addition to the technology itself, the physical environment, the interference with radio waves, business practices, domain knowledge, the behavioural side of the persons to be tagged the movement of tagged objects and people, cost/benefit considerations, etc., all need to be considered.” (Wang et al., 2006)

3.7.4 Clinical Trials

“Clinical trials with 1000 patients or so have been conducted in Germany and the US but in neither trial were the passive tags directly linked to the central hospital patient database (Thuemmler et al., 2007; Collins, 2005).”

3.7.5 Need for Healthy and cost effective Framework

All these works discussed have used RFID, but it is either by using an Active RFID or a RFID tag with the data written in it. Mostly, the readers are fixed to a PC or ceiling and walls. One of which is a simulated trial, and none of them uses handheld and wireless networks.

The case study in Taiwan hospital used Active RFID and RFID Access Points, which is connected to database through traditional Ethernet, but it does not use wireless enabled handheld to provide nurses or healthcare professionals with an effective mobile identification solution.

All this clearly states, the need for a framework which can efficiently provide mobile solution for identification and tracking with the use of a central database in a secure manner.

3.8 Summary

Review has started by explaining the needs of object aware applications in healthcare, during this the problems in existing systems are discussed and the need for an intelligent framework is clearly recognised.

All possible methods for object tracking in wireless networks were discussed and the problems of using them within healthcare were learnt and wireless tracking solution is most unlikely for such a sensitive environment. Possibilities using RFID methods for object tracking and identification were discussed and the differences in active and passive RFID solution were seen. The passive RFID wins the need with most number of advantages and the least number of disadvantages but still the issues in RFID only solution is seen immobile.

Integrating wireless networks and RFID has provided hope for the healthcare environment due to its approach and the least damaging, when compared with the other solutions discussed.

RFID and wireless enabled solution seems very much suitable. Advantages and disadvantages of existing wristband over RFID enabled wristband were discussed and RFID proves a successful approach and it provides intelligent replacement for existing practice and opens the possibility of object and context aware application within healthcare.

Need for security and the standards to comply in healthcare were discussed and the RFID solution has a simple and most secure approach, if the tag is just used for identification and no data stored within.

Similar works using RFID within healthcare were discussed and some of them were not for patient identification, and only a few of them have tried RFID for patient identification. They are mostly using high frequency active RFID with the threat of radiation and radio interference for medical equipments. Also, only one case has tried using a centralised database, but in neither of the works there is a mobile solution for patient identification or tracking nor did they use wireless networks or passive RFID.

Only disadvantage of using Passive RFID is that it eliminates the possibility for object tracking using sophisticated real time tracking techniques, like triangulation or RF Fingerprinting unlike active RFID or wireless networks. Nevertheless, this approach using RFID and wireless enabled mobile devices is highly appealing and it is a cost effective and healthy solution to an intelligent framework for healthcare. Based on the onsite study, this approach proves to be acceptable by healthcare professionals and critics as a compromise towards a positive patient identification and locationing compared to existing systems.

4.0 Requirements analysis and Design

The main aim of this work is to design a framework for object identification and tracking in wireless networks that is suitable for healthcare environment. The project is intended to be implemented in an NHS hospital, as known from the collaboration and industrial partners details mentioned in the introduction (Section 1.0).

Even though, the development and implementation is to be done in a lab environment at first, the aim is to provide a compatible framework that is suitable for the existing hospital IT infrastructure and to make it easy to be implemented on successful completion of framework design and testing.

4.1 Framework Compatibility Requirements

Based on the onsite experience and some valuable information from the IT officials in the hospital, a general overview of the existing IT infrastructure setup and hardware devices in participating hospital are discussed.

If the framework is to be implemented in real life, then it is most necessary that the framework is compatible with the existing IT infrastructure without any major modification.

Note that the information provided here is just to grasp an idea of what is involved and the information presented here are not actual and accurate data or blueprint of IT is setup within NHS.

4.1.1 Hardware Availability & Operating Platforms

Workstations

Every ward in the hospital is equipped with reasonably new workstations for the use of the nurses and healthcare workers to perform their everyday routine with the use of many existing applications for various kinds of tasks.

Most commonly the PCs in use are manufactured by DELL. Typical hardware specifications are

- Processor – Intel Pentium 4 – 1.6 to 2.4 GHz
- RAM – 256 MB to 512 MB
- Hard Disk – 60 to 80 GB
- Monitor – LCD Flat Panel 15” inch

Typical port options available are 4 USB, 1 Parallel, 1 COM and other typical components like Video card, CD Drive, keyboard, mouse and etc. Access to all the ports, like USB, COM and etc are physically secured to prevent data theft.

All these workstations are networked using traditional Ethernet with an RJ45 socket and are connected to either a networked printer or a local printer. Mostly, these workstations do not have CD or DVD RW capabilities and do not have sound capabilities.

Tablet PCs

Some wards and healthcare workers are provided with wireless enabled tablet PCs, but unfortunately, it is locked down to use only a single application. This is currently being tested in the hospital to maintain patient health records.

Operating Platform:

All the workstations used are on windows platform and they are installed with Windows XP professional with sp2 and access to these workstations are protected with a centralized Active Directory Authentication (Light Weight Directory Access Protocol - LDAP)

4.1.2 Wireless & Network Infrastructure

Network Infrastructure

The hospital consists of various sites, which are physically far away from each other with centralized IT management to maintain the network from one site. All these sites are linked with underground Ethernet cables and linked to the central site.

The site has a typical Ethernet network with 100 Mbps speed and the network is internet and e-mail capable with all the other logical ports locked by network firewalls.

Wireless Network

Every ward, hallway, lounge, restaurants and mostly every corner of the site is wireless enabled with a Cisco Aironet wireless access points fixed to the walls and ceiling.

Every ward in the hospital has a Wireless Access point and all the access points are connected to the LAN typically. This wireless networks is capable of performing similar to LAN and has internet and email capabilities with all other logical ports locked down with network firewalls.

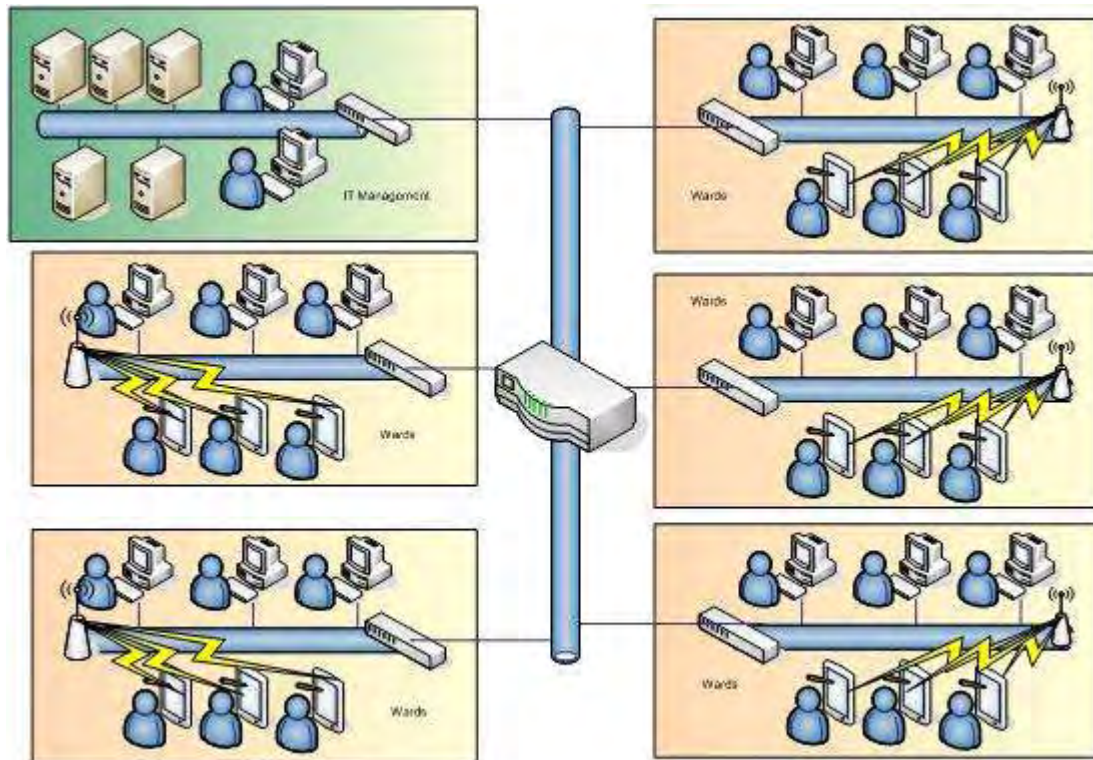


Figure - Hospital Network Infrastructure

4.1.3 Database System

The hospital involved has the most extensive IT infrastructure in UK and its databases hold more than a million individual patient records.

As known, generally healthcare system in UK (NHS) provides free healthcare for all the residents in UK and also funds all the registered General Practitioner (GP) for providing treatment and consultancy for the patients registered to their practice, who are within the locality of that GP. NHS also maintains and funds prescriptions for the patients and it has many more nationwide responsibility and services for the general public. This information is not relevant to the framework, but it helps to understand the database setup.

NHS provides a unique NHS number to every patient registered with a GP and all the patient details are centrally managed by NHS. So the patient can get care nationwide and his medical records are available to healthcare professional when needed.

Patients Database

The hospital involved has access to the centralized patient database of NHS and it can obtain patient information when needed and it synchronizes with a local database of all the patients who have been to this hospital.

This patient information generally consists of all the patients' personal details, GP details, and next of kin details, and etc...

Inpatients Database

The hospital also keeps records of the patients, who currently being treated in the hospital, and who have been treated before. The hospital is capable of having 7000 patients at a time in various sites. Based on this, there are at least 7000 patients' records in the inpatients database.

Inpatient information generally consists of admission date, discharge date, consultant's details, and etc...

Other Databases

There are various other databases kept, like details of all the GPs, details of the entire consultants working in the hospital, details of all the wards, and etc...

All the needed data required for this framework is made available within a separate database created for this work by the IT department of the hospital.

4.1.4 User and Data Security

User Authentication

All the users within the network are authenticated with Active Directory Services (LDAP) and all the users are classified based on their roles. Access to parts of network or data available in network is all filtered based on their roles. This is mainly to prevent unauthorized access to data by unauthorized users.

Data Usage Limitations

The database created for this work is given full control and can able to create separate tables or any other database related items needed for this work. The data driven from NHS database about patients and their related information are made available for this work is in read-only format. Therefore data available is not modifiable.

4.2 Hardware Requirements

Main hardware requirements to enable the framework to fit into the existing hospital IT infrastructure are simple.

The option of hardware to be used is decided by the manufacturers, as they have established industrial partnership ties with the hospital and the concerns involved as described in introduction section (Section 1.0) prior to the work granted for development. Based on the hardware requirements, the industry has supplied with suitable RFID wristbands, a RFID printer, a handheld device and a suitable RFID add-on device for that handheld device for developing this framework in lab environment. On successful completion, the hospital would be supplied with mass amount of tags and enough number of all the devices needed, based on the decision of the hospital.



Figure - Z-Band QuickClip RFID Wristband (Appendix 9)

- ✓ Suitable RFID wristband for healthcare environment to be tagged on to patients
-



Figure - Zebra R2844-Z RFID Printer (Appendix 8)

- ✓ Printer with capabilities of printing the RFID wristbands with patient information on top of the wristband as secondary identification
-



Figure - MC70 Rugged Mobile Computer from Symbol (Appendix 6)

- ✓ Suitable handheld device for healthcare environment with built-in wireless capabilities and with options to accommodate add-on devices
-



Figure - Multi-ISO HF RFID reader for Symbol MC70 (Appendix 7)

- ✓ Suitable add-on RFID reader that is compatible for the handheld device chosen.

As the framework is to be developed first in lab environment, the IT infrastructure of the hospital is simulated in the simplest form, which would just be able to develop and deploy the required application using the hardware provided.

To know more about the hardware devices provided and for further information, please refer to the datasheets of these devices in the appendices section of this document (Appendix 6 - 9).

4.3 Application Requirements & Design

From this point, the framework and design are considered in context with simulated lab environment and all the discussion here would be in a lab based development environment, where a wireless network, workstation and a central database server is used.

4.3.1 Database Requirements

All the patients data needed for the framework is provided from the existing NHS databases into the new database provided for designing this framework (Section 4.1.3).

In addition to the data provided, the database should be capable of accommodate the link information of a patient's wristband and the patient's data.

Currently, allergy and infection information are not available, as allergy and infections are possible to occur anytime and it is not a static data. Therefore, during patient's admission allergy information should be collected and stored in the database. And the database design has to consider this for accommodating allergy information. Logging all the events for tracking and the analytical test data has to be considered.

4.3.2 Database Design

As known from the compatibility requirements, the hospital has MS SQL Server to maintain its data. To suit this requirement and to enable a familiar environment, MS SQL Server is used to create all the tables provided from the hospital (Appendix 3) with mock data. These table schemas are provided from hospital IT department for this work and the schema is used to recreate the setup in lab environment. To know more about the schemas, please refer to the appendix section (Appendix 3).

Besides replication, the existing data available for the framework design, the main thing needed for this framework is to establish a newly wrist-banded patient with his personal records.

To perform this, a table is created with the RFID unique code and with the Patient Identification number which helps to



Figure - Tables Created for Framework

establish relationship to existing patient record.

Another requirement to be satisfied is to collect patients' allergy details and link it with the patients' wristband. To perform this, a table is created with possible allergy and RFID number field which links allergy information with the wristband.

There are also other tables, which are created for user authentication and events logging.

Queries

Standard SQL Queries were used to create tables and to create relationship between tables. SQL Queries is also used, when a patient has to be tracked from the logged information.

Stored Procedures

SQL Stored procedures are used for applications to perform defined tasks such as

- Identify patient in existing patient record
- Creating, updating and deleting patient
- Link RFID with the patient record
- Store allergy information
- Identify patient and the patient's allergy information
- Event Logging
- Analytical data logging

SQL Queries could also be used to do the same, each time when these actions have to be performed. But as the actions are defined and it is not a varying process, set of prewritten SQL Queries inside SQL stored procedures are used.

SQL stored procedure has many advantages over SQL Queries. One of the most important advantages is to improve performance and to reduce delays (Atwood, 2004; Carpentiere, 2004). Stored Procedures are definitely good in working at enterprise level environments (Atwood, 2004; Carpentiere, 2004).

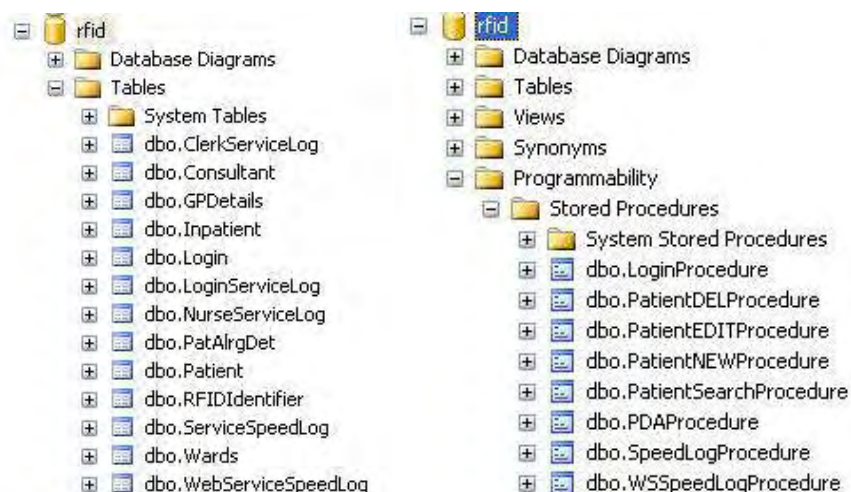


Figure - Tables and Stored Procedures in SQL Server

4.3.3 Communication Requirements

As the database which has the patient's record is situated in a centralized database and for this information to be used by the application in various parts of network, a means of interaction between these data in a network server with the applications has to be considered. Other things to be considered are firewall restrictions within the network infrastructure, where some communications in the network are blocked using firewalls for network security.

On such communication, all the events occurring with the framework has to be logged in order to track a patient when needed.

4.3.4 Communication Design

There are various means of interaction or communication available, such as directly connecting SQL server from a remote application host or by using a web application, and etc...

Web Services is chosen as means of communication and detailed information about web services are discussed further below

Web Services

“One of the newest innovations for the use of the network is Web services. Web services allow applications and network-enabled devices to easily communicate with one another and combine their functionality to provide services to each other, independent of platform or language. Web services are characterized by SOAP messages used to talk to a Web service, WSDL files that describe a Web service, and the UDDI used to find Web services. Conceptually, Web services are very understandable. They eliminate many of the complexities that have been required when there is a need for computer applications to interact with each other.” (Chavda, 2004)

“Web services allow developers to utilize four open Web standards: HTTP, SOAP, XML, and WSDL.

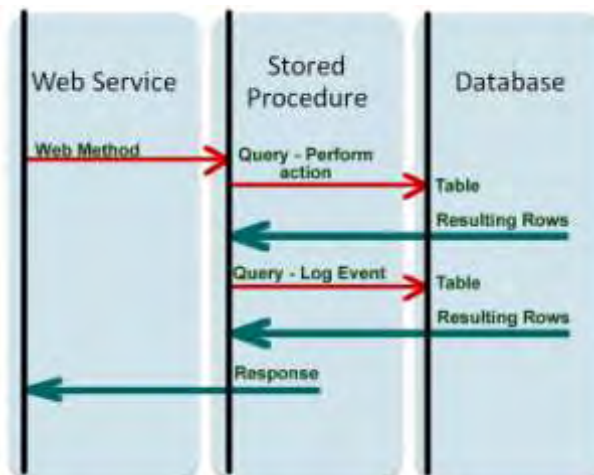
1. HTTP - Hypertext Transfer Protocol - the standard protocol used over Port 80 that traverses firewalls, which is responsible for requesting and transmitting data over the Internet.
2. SOAP - Simple Object Access Protocol - an XML inherent protocol enclosing a set of rules for data description and process that is the center piece paralleling and complementing the other three mentioned here, with which .NET utilizes nicely with Web Services.
3. XML - Extensible Markup Language - the prominent markup language that all this commonly understood information is written in.
4. WSDL - Web Services Description Language - an XML based method use in identifying Web Services and their access at runtime. .NET provides a tool called WSDL.exe which essentially makes it quite easy in generating an XML Web

service, rather an XML file containing all the methods and instructions the Web Service has, using SOAP as its default by the way" (Chavda, 2004)

Many web service applications are designed and created to satisfy the needs of the framework.

- **Management Application**
 - To identify patient in existing patient record
 - Store allergy information and to create link with RFID and the patient record.
 - Update allergy information and to create link with RFID and the patient record.
 - Delete allergy information and to delete link with RFID and the patient record.
- **Handheld Application**
 - Identify patient using the RFID Tag ID, sent from the application
 - Return patient and other related information required to the requesting application
- **Authentication**
 - Authenticating users by verifying user name and password
 - Return user role to the requesting application
- **Analytical data logging**
 - To log analytical data information from the applications and to log its analytical data collected.

All the web services act as means of communication between the application host and



the database. Hence, to perform each request by an application it calls the stored procedure with the database to address the action and returns its response.

Logs for Tracking

These web services are designed to perform logging of each request and all the details available about the request through stored procedures. By this, all the events occur with the framework are logged. Using this, patient can be tracked based on the last event logged, which is connected to the patient.

These web services are also collecting analytical performance data by calculating round trip time took to perform a request from the web service to database and then back to web service. This information is logged in the database through stored procedures.

IIS hosting

As web services uses HTTP as a standard protocol to communicate (logical port 80), it is necessary that these web services are hosted within a HTTP Server or otherwise called as web server.

As the database in use is Microsoft SQL server, and the entire platform used in the environment is windows based. Hence, Microsoft web server is used to host these web services, which is known as Internet Information Service (IIS). Even though, web service is not platform dependent, Microsoft IIS is chosen as this is a familiar application and fairly simple to be used with development tool.

In lab environment, this application is installed with the database server, to make implementation straight forward and to reduce the use of more than one server.

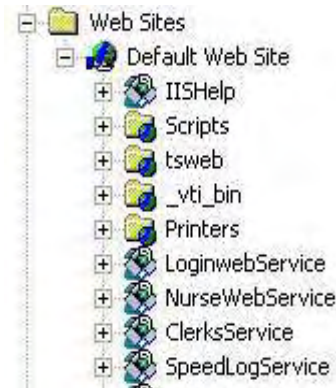


Figure - Web Services in IIS

Difficulties and Solutions

It is considered difficult to get the IIS setup with the right permission for each web services. Based on the previous experience and experience during this design, an easy solution is identified, which was already there but unknown. It is to develop web service separately and to host it in a virtual directory with IIS, rather than developing with IIS and troubleshooting for it to work.

4.3.5 Patient Management Application Requirements

Patient management application in context to this framework means the application that is used to provide wristband for patients.

In the hospital setting, such application will exist on the patient admission point, where a patient is received to be admitted in the hospital and allocated a bed in a suitable ward. This admission point is known as A&E Unit. Usually, a clerk is present at the desk and who is using a workstation to perform the patient admission task.

This would be the right place to provide a patient with wristband and the application typically is to be designed for the use of the clerk here. This application is sometime also mentioned as clerk's application, to make things easy.

The requirement of this application is structured based on the onsite experience from the hospital. The application should be capable of initially taking a patient unique

number from their existing methods of patient management and use that unique number to find the same patient's details from the database.

Once the patient is identified in the database, a wristband is to be printed with patient's name, date of birth, gender, patient's unique number and the unique RFID tag number on wristbands surface. This tag is then given to the patient.

To perform the printing operation, the application should be capable of calling the special RFID printer and sending the information needed.

On successful tag creation, the unique RFID tag number has to link up with the patient's record. The application also needs to perform additional tasks such as providing an existing wrist-banded patient with a new wristband in case of damage and capable of updating the link created earlier. The application also need to delete the patients RFID link, when the patient is discharged or in unlikely case, where a patient is dead.

Currently, allergy and infection information are not available, as allergy and infections are possible to occur anytime and it is not a static data. So during patient's admission allergy information should be collected and stored in the database.

4.3.6 Patient Management Application Design

From the designs of database and web services, it is clear that the method of communication between the database and the application is to use the web service hosted on an IIS server.

The patient management application design discussed here is to typically use the existing Ethernet link of the host computer to connect to the web service via the web server port 80. All communication requests are made to appropriate web service according to the action needed, and the application is designed to make web services accessible within the application where needed.

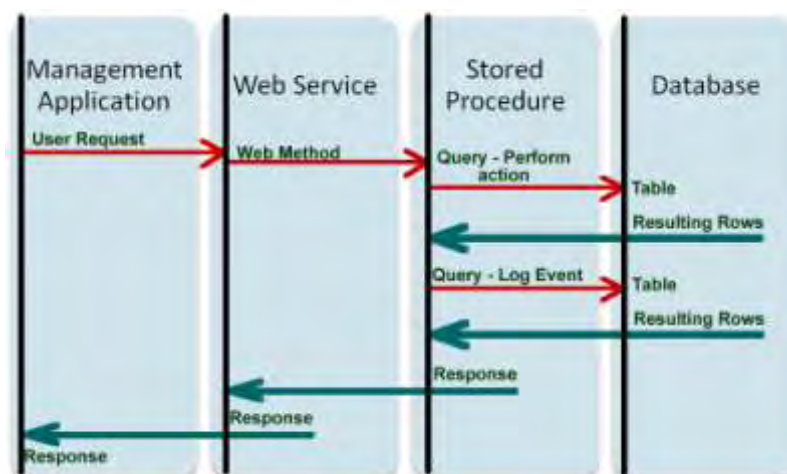


Figure - Sequence Diagram for Management Application

User interface design

Ease of use is the main priority, as known from the experience and from literature review (Section 3.1), the IT literacy and training of healthcare workers are limited. Thus, this application is designed to keep thing really simple and easy for everyone.

Parts of the user interface are shown and described in Figure .

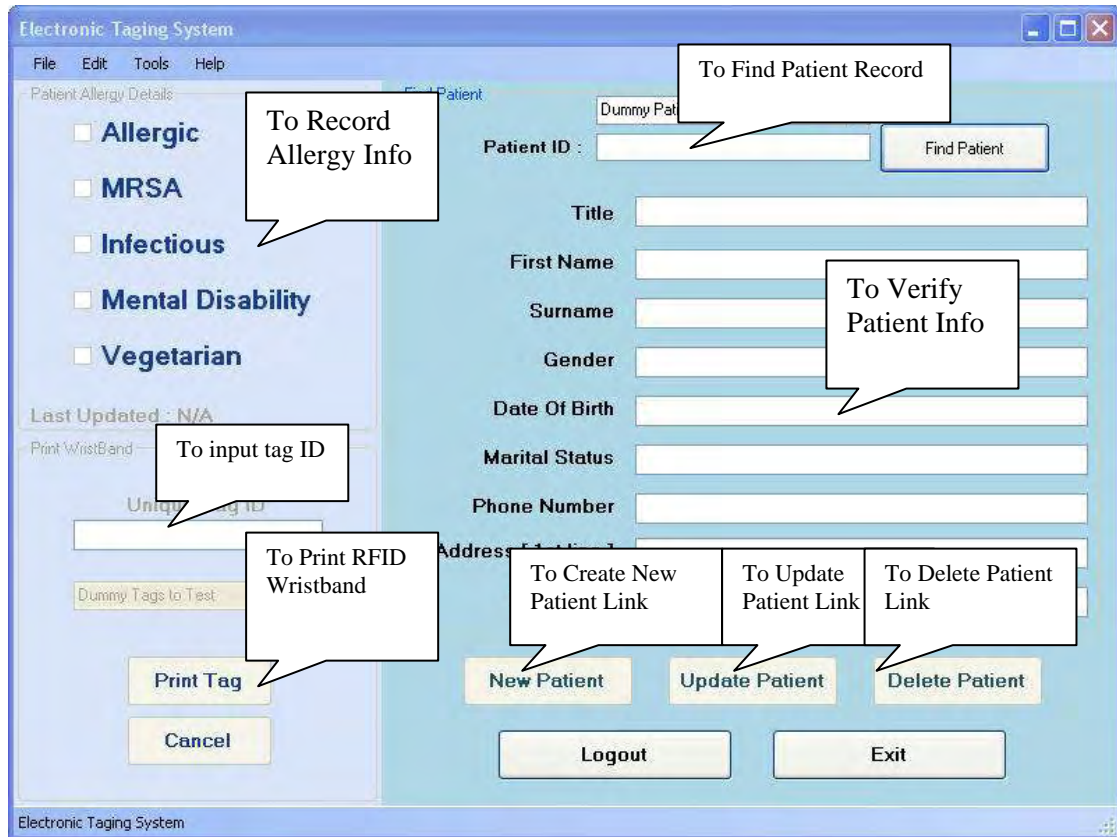


Figure - Management Application User Interface Design Snapshot

New Patient

On arrival of a new patient, the clerk at the admission point first obtain the patient id once the patient is admitted formally, and uses this patient id and this management application to find the patient's personal information, such as name, DOB, gender, address, telephone and etc...

Once the patient is identified, a wristband is printed with the patients Name, DOB and gender with the tag ID and tagged to the patient.

Once printed, the tag id is keyed in and allergy information is collected from the patient and from the medical records, if any known and manually keyed on to application. On completion of the above a new patient is created and linked.

These design of this using simple windows application tools such as buttons, text boxes, list box as seen in user interface design (Section 4.3.6 USI).

All the communication is done in the background of the application using web services to and from the database as discussed in the design sections above (Section 4.3.4).

Update Patient

If an existing patient's wristband is damaged or allergy circumstances changes, the patient is provided with a new wristband by the clerk.

Design aspects of this are similar to creating a new patient, but here a new wristband is printed and the wristband ID is keyed in again and the patient link is updated.

Delete Patient

In case of patient being discharged or in the unlikely case of patient is dead, the patient's tag is removed and disposed. During this action, the patient link is simply deleted from the database.

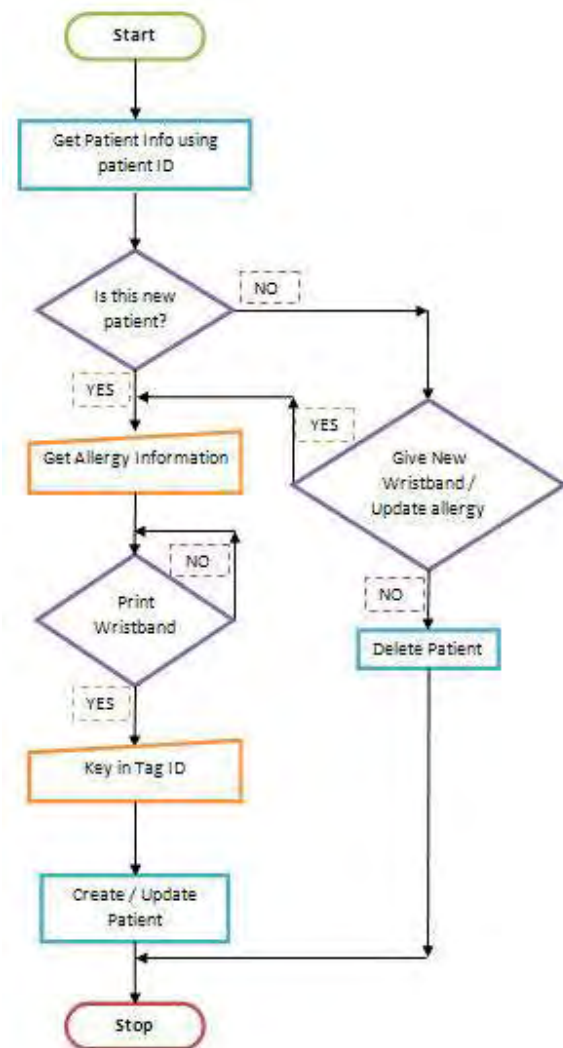


Figure - Management Application Flow Chart

Printing RFID Tags

Printing wristbands with secondary identification details on it, as mentioned it is very important to identify patient in some circumstances using this secondary details.

The printer is specially made for the purpose of printing RFID wristbands and labels; the printer only supports a manufacturer's custom programming language called Zebra Programming Language (ZPL).

Using ZPL, the wristband text orientation and the margins are set with options to obtain patient information, and this done within management application. Therefore, on a print command by the clerk the wristband is printed with the right information.

Difficulties & Solution

One of the main difficulties faced was programming using ZPL and wrapping this ZPL code within the windows application to print the wristband. This problem is solved with the help of Zebra's technicians, as they provided with a sample program. And an MSDN article helped for this code to be wrapped within the windows application for printing.

4.3.7 Handheld Application Requirements

Handheld devices are handed to be used in the wards to identify a patient. The handheld should be capable of detecting a RFID tag through the add-on RFID reader attached to the device. On successful detection, the RFID has to obtain the patient's record from the database with the help of wireless network and successfully display it on the handheld screen.

RFID reader should be constantly checking for RFID wristband nearby and when a tag is found the information should be displayed. Patient's allergy information is also to be given as warning on success identification of a patient to make the healthcare worker aware of the actions to be performed.

Once the patient is identified and patient's basic information is displayed, based on the user role of the handheld device, the application has to display additional information about the patient, like patient's consultant, patient's GP, patient's allergy information, patients ward information and etc...

4.3.8 Handheld Application Design

From the designs of database and web services, it is clear that the method of communication between the database and the application is to use the web service hosted on an IIS server.

The patient management application design discussed here is to wireless network connection of the handheld to connect to the web service via the web server port 80. All communication requests is made to appropriate web service according to the action needed, and the application is designed to make web services accessible within the application where needed.

User interface design

User interface design considerations are similar to that of Management application (Section 4.3.6 USI), but there were other things considered as the application is to be used in a handheld screen. The screen resolutions, screen size, touch screen capabilities and etc... Parts of the user interface are shown and described in Figure .

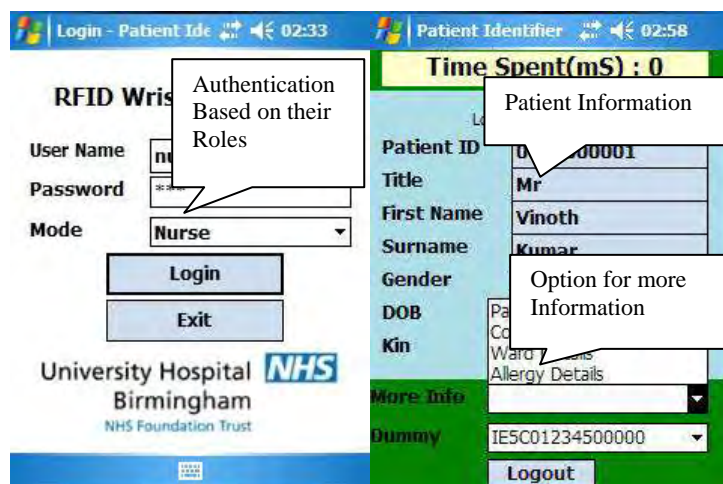


Figure - Handheld Application User Interface Design Snapshot

RFID Tag Reading

RFID reader (Appendix 7) is a driverless serial communication device, which is capable to be add-on to the handheld device (Appendix 6) on the COM1 port.

The application is designed to open the serial port on the application start and close it on application exit. In the mean time, the application reads the COM port for every few milliseconds to check, if there is RFID tag nearby. The application is also capable of finding, whether the device is attached or not.

On detection of a patient wristband (RFID Tag), it reads the unique tag ID and stores within the application for that value to be used in the patient identification.

Identifying Patient

With the use of reading unique tag id using RFID reader, the application communicates to the database through appropriate web service and obtains the patients information and stores within the application for display and some to be displayed on request.

Information Display & Warnings

Once the patient identification request is made, the application warns the user if the patient does not exist or if the patient exists the information is showed on the screen alongside with the warning of patient's allergy information. List of further option is provided to view more information about the patient. Due to the size of the screen, the information that can be displayed is limited, so the information is broken into chunk for ease of access.

The allergy warnings were displayed by changing the screen colour based on the allergy information. In case of more than one allergy, a list of the entire allergy is displayed in a warning message box.

Difficulties & Solution

One of the main difficulties faced was reading RFID tag value from the RFID reader, as the device is driverless and in .NET framework 1.0, which was initially planned for using in development, there is a no built-in solution and there was a need to build a custom driver for the device. This problem is resolved by moving on to the new version of .NET framework 2.0, where a readymade solution was available to read COM ports.

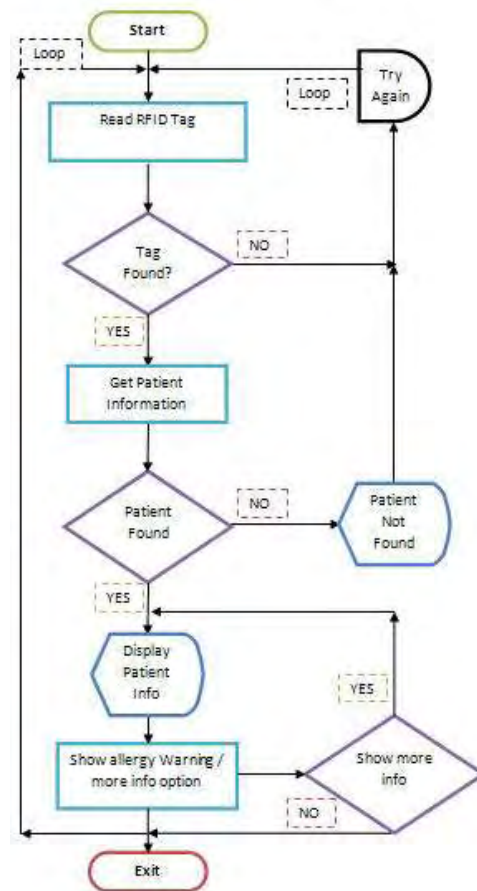


Figure - Handheld Application Flow Chart

Another difficulty was the method of displaying the allergy efficiently. Therefore, that it warns and appeals to the user, because of the small screen of the device. This problem is resolved by changing colour of the screen based on the allergy information.

4.3.9 Security Requirements

For security all the users to the handheld device and the users using the patient management application have to be authenticated.

In lab environment, a simple form of authentication is suitable to demonstrate, but on real implementation the authentication can be replaced with the hospitals existing user authentication system.

Besides authenticating the user, the data transferred from the database to the application within the framework needs security; because it is patients personal information and it cannot be compromised. Thus, a suitable data encryption system has to be put in place to serve this purpose.

4.3.10 Security Design

Designs and approaches put in use for user authentication and data encryption is described in detail.

Simple Custom Authentication

Custom authentication was performed by creating a simple table in the database which holds user information. Information stored was: user name, password and user role. The user role was necessary for role based authentication on accessing an application designed. The role based authentication provides way for preventing or limiting access to certain data based on the user role. The passwords stored within the table are hashed using simple hashing algorithm.

Figure - Authentication Form

This authentication is temporary and it is only for testing in the lab. On real implementation the authentication has to be integrated with the existing authentication system in the hospital IT.

TripleDES Data Encryption

When compared to other encryption algorithms, TripleDES proves to be more secure and reliable. Even though, the time it takes to decrypt the data is a bit slow, when considered to other algorithms. Security is given priority and as the best solution the TripleDES encryption method is chosen.

All the communication through the web service is encrypted and decrypted in corresponding endpoint. Thus it provides encrypted data over the network.

Difficulties & Solution

Difficulties faced were to obtain encryption keys from a certification server to encrypt and decrypt data using TripleDES. This problem is resolved by using a set of static keys suitable for the encryption and decryption using TripleDES within the application. This solution is only temporary and only for lab environment to test the framework. In real life implementation, existing certification server of the hospital or certification server subscriptions can be put to use.

4.3.11 Analytical testing Requirements

The framework is designed in a lab environment and in order to test and analyze the performance and capabilities of the framework, round trip time calculations has to be done for all the process occur within framework. Therefore, it might predict the cause for time delay and any performance issues in the framework.

4.3.12 Analytical testing Design

To test and analyze the performance and capabilities of the framework, round trip times for all the process occur within framework are calculated and logged in the database. This design is put in use in the applications discussed earlier (Section 4.3.6, 4.3.8).

Process Timing

All the communication process with the framework was timed using the timers. The management application, handheld application, and the all the web service methods were designed to time a process round trip time in order for these to be analyzed and evaluated.

System hyper threading timer was used in all these cases to time accurately as possible.

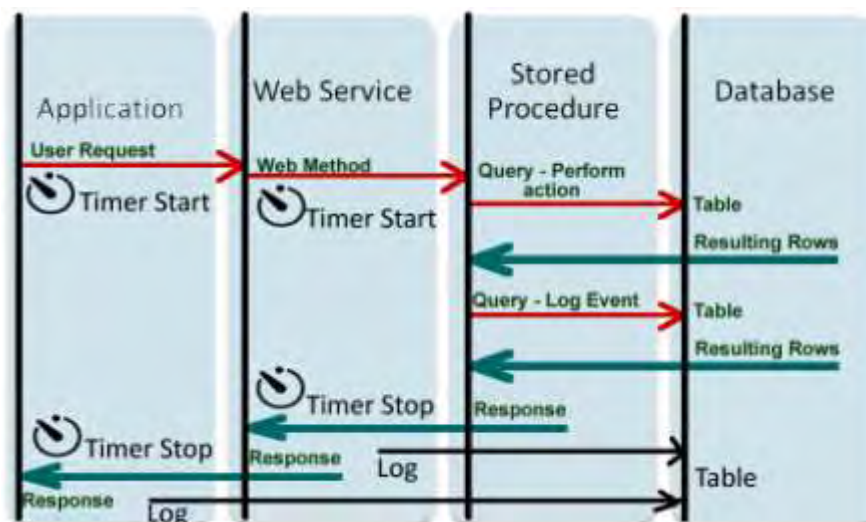


Figure - Sequence Diagram for Timing Events and Logging

Events Logging

All these analytical timing data acquired is logged in the database, in order for these data to be analyzed and used to generate reports and charts.

Difficulties & Solution

One of the main difficulties faced was the timer used to calculation the round trip times. At first a simple timer was put in use to store the current time at the start of a process and end of a process and the difference is obtained. This method only provided accuracy to the nearest second, which is not useful to analyze. Hence, system threading timer was used to time accurately with the help of system timer class within visual studio.

4.3.13 Design Overview

An overall graphical representation of the framework design in a hospital environment is shown in Figure .

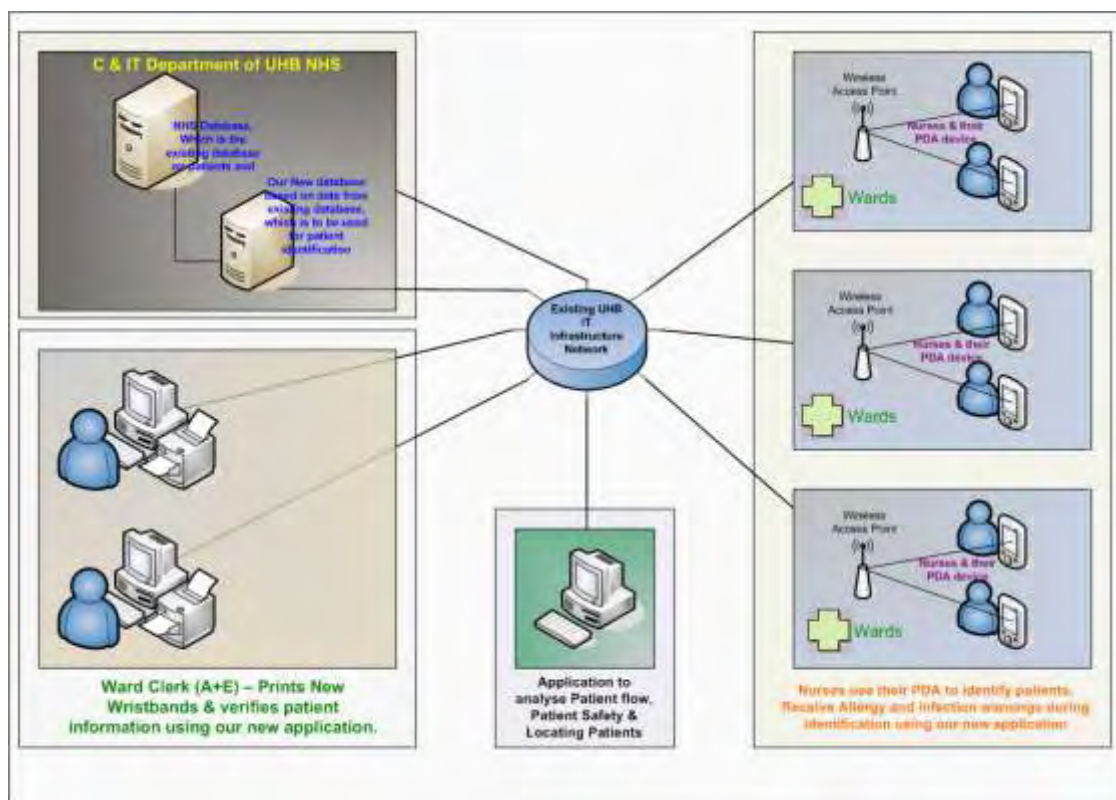


Figure - Design overview of the framework

5.0 Implementation and Tests

In this implementation section, the basic concepts used in programming to satisfy application needs are discussed. There is vast amount of programming codes involved in the implementation and discussing all of them is inappropriate. This implementation section discusses only selective appropriate code implementations that are needed to perform certain action required by the framework.

5.1 Implementation overview

A graphical overview of the implementation of framework is shown in Figure . The lab environment is simulated to represent (Section 4.1.3) and the implementation discussed here is only performed in the simulated environment.



Figure - Implementation Overview of the Framework

5.2 Database Implementation

There were thirteen tables in total that were created to make the framework perform all the necessary data storage and retrieval process. Out of the thirteen tables created, five of them were created to replicate hospital patient record with mock data and the remaining eight were created to be used for the framework, in various aspects.

Similar to tables there were eight stored procedures created to meet the requirements, a diagram with the stored procedures in the database is shown in Figure 42. List of tables that were made are shown below as well, a detailed relationship diagram is displayed in the appendix section of this report (Appendix 3).

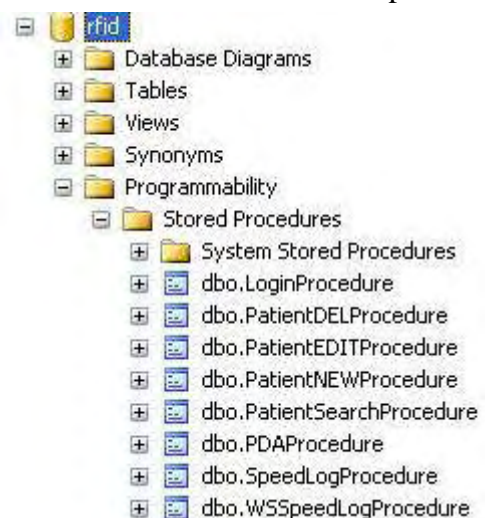


Figure - List of Stored Procedures in SQL Server

5.2.1 SQL Query

A table creation process using SQL command is shown in Table ; the table discussed here is to create a user authentication table, for authenticating the entire users in the framework.

```
/* create table "login" for user authentication with the
following feilds of datatype mentioned */
CREATE TABLE [dbo].[Login] (
    [UserName] [nvarchar] (50) NOT NULL,
    [password] [nvarchar] (128) NOT NULL,
    [Role] [varchar] (15) NULL,
    [LastLoginDate] [smalldatetime] NULL,
    [RegDate] [smalldatetime] NULL,
    [Active] [smallint] NOT NULL )
GO
```

Table – Code: SQL Query

The tables were created using visual studio management express, which even provides a GUI to create tables as needed without using Queries.

5.2.2 SQL stored procedure

A sample stored procedure is shown in Table . The sample is to authenticate user credentials and return user role information to the requesting web service.

The procedure handles an incoming request with a username, password and requesting IP address. It performs a query for matching user with the password specified and if that user is present, then it returns the role of that user from the table. If the user is not present then it returns 0 rows.

Procedure also logs this event with the details available into a table. Finally, it returns the user role or a '0'. This represents that the user is not present.

As mentioned in the (Section 4.3.4) there were many stored procedures created to meet the requirements of the framework.

```
/* create procedure Loginprocedure, which checks user credentials
and return the role of that user. It also performs */

CREATE PROCEDURE [dbo].[LoginProcedure]

-- declaring input variables, a procedure call in apps send these
val
    @UserID nvarchar(50),
    @PWord nvarchar(128),
    @Ip nvarchar(100) = Null

AS
BEGIN

-- Declare local variables
Declare @Role char(1),
@Ecode char(2)

-- get the user role, if the username and password matches
Select @Role = Role From Login Where UserName = @UserID and
password = @PWord;

-- if the user did not exist or password incorrect then set a
flag error
if @@RowCount = 0
Begin
Select @Ecode = '1'
End

-- For Logging this event in the framework, all the details are
stored
Insert Into LoginServiceLog (ReqIP,UserName,Role,DTime,ErrorCode)
Values
    (@Ip,@UserID,@Role,getDate(),@Ecode);
Select @Role

-- End of stored procedure
END
```

Table - Code: Stored Procedure

5.3 Web service Implementation

There were four web services created for the framework, to authenticate users, for performance logging, for management application and for handheld application.

All these web services serve the needs of the application as needed. Some code extracts of a web service is shown in Table , which authenticates users by calling a stored procedure in the SQL database.

```
//necessary to perform sql operations
using System.Data.SqlClient;
//create new sql connection con, using the connection string
private SqlConnection con = new SqlConnection("Data
Source=VINOTH\\SQLEXPRESS;Initial Catalog=rfid;Integrated
Security=True;User Instance=False");

//a webmethod within a webservice , which connects to DB to
authen user
[WebMethod]
public string xLogin(string UserID, string Pin, string ip)
{
    //create a local variable as string
    string r = null;
    //create sql data adapter to connect to the database
    SqlDataAdapter tadapter = new SqlDataAdapter();
    // to make the commad for calling stored procedure with the
values
    tadapter.SelectCommand = new SqlCommand("LoginProcedure '" +
UserID + "' , '" + Pin + "' , '" + ip + "'", con);
    //create a new data set, which would receive the output from
procedure
    DataSet ds = new DataSet();
    //use data adapter, send the command and get resulting
dataset in ds
    tadapter.Fill(ds);
    //convert the dataset into a string
    r = ds.Tables[0].Rows[0].ItemArray[0].ToString().Trim();

    //return string r, which has the user role, if auth fail it
returns '0'
    return r;
}
```

Table - Code: Web service

5.4 Security Implementation

As discussed in the design 4.3.10 Security Design, the users are authenticated within the framework, and the implementation shows (Section 5.2; 5.3), what is involved in user authentication. Data encryption is also implemented to protect data from possible hackers and other threats from malicious programs. Code extracts here in Table , show how a string is encrypted and decrypted using the built in crypto class in .NET

```

//necessary to perform crypto
using System.Security.Cryptography;

//a Symmetric algorithm variable mCSP is assigned with 3DES type
algorithm
private SymmetricAlgorithm mCSP = new TripleDESCryptoServiceProvider();

//predefined static key, used as an alternate to cert server, temp
solution
//2key 3DES, where the first key x is used again as 3rd key.
string x = "ahGmz+ZF8juDqq+jbPIuluQ85dP0AxaG";
string y = "E5tCLRglsCU=";

string r = "string";

//call encrypt function with string and store the encrypted val bac in r
r = EncryptString(r);

//call decrypt function with string and store the decrypted val bac in r
r = DecryptString(r);

//Encrypt string function, code
from MSDN article

private string
EncryptString(string Value)
{
    //...Code

    //use static string x,y
instead of a certification server

    mCSP.Key =
Convert.FromBase64String(x);

    mCSP.IV =
Convert.FromBase64String(y);

    //...Code...

    return
Convert.ToBase64String(ms.ToArray
());
}

//Decrypt string function, code from
MSDN article

private string DecryptString(string
Value)
{
    //...Code...

    //use static string x,y instead
of a certification server

    mCSP.Key =
Convert.FromBase64String(x);

    mCSP.IV =
Convert.FromBase64String(y);

    //...Code...

    return
Encoding.UTF8.GetString(ms.ToArray())
;
}

```

Table - Code: Data Encryption

The encryption encrypts the data in the web service and it decrypts the data in the other end at the application. The screenshots in Figure and Figure shows how data is encrypted and decrypted within application.

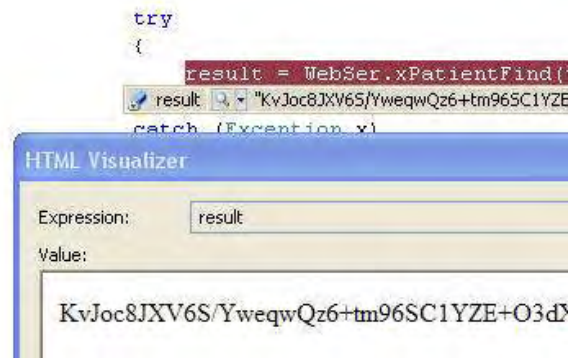


Figure - Encrypted Data

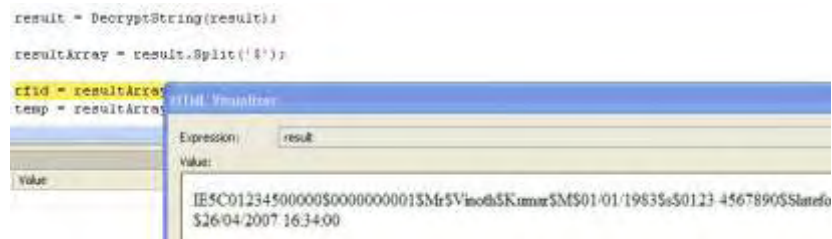


Figure - Decrypted Data

5.5 Patient Management Application

Patient management application uses web service for all the actions it needs to perform, such as finding patient information, creating, updating and deleting patient link. Code extracts in Table , shows the application uses the web service to find patient info

```
//make the webservice available to be used within the  
applicaition  
ClerksEnv.Clerks WebSer = new  
ClerksApplication.ClerksEnv.Clerks ();  
  
//get the user entered patient id into a variable and call  
webservice for //patient info  
  
temp = TxtPatientID.Text;  
  
result = WebSer.xPatientFind(temp, user, logstatus,  
Login.ip.ToString().Trim(), Acode, Ecode);
```

Table - Code: Using Web service

5.5.1 Printing Wristband

Wristband is printed using a special RFID printer and as discussed earlier it uses ZPL programming language to print. The ZPL code is written and wrapped as a string and sent to the printer as RAW data. Using help of MSDN, a code snippet to send the ZPL code directly to the printer is performed (MSDN, 2006).

The screenshot of the print process in the application and the ZPL code used to print wrist band and how it is wrapped within the .NET application is shown in Figure .

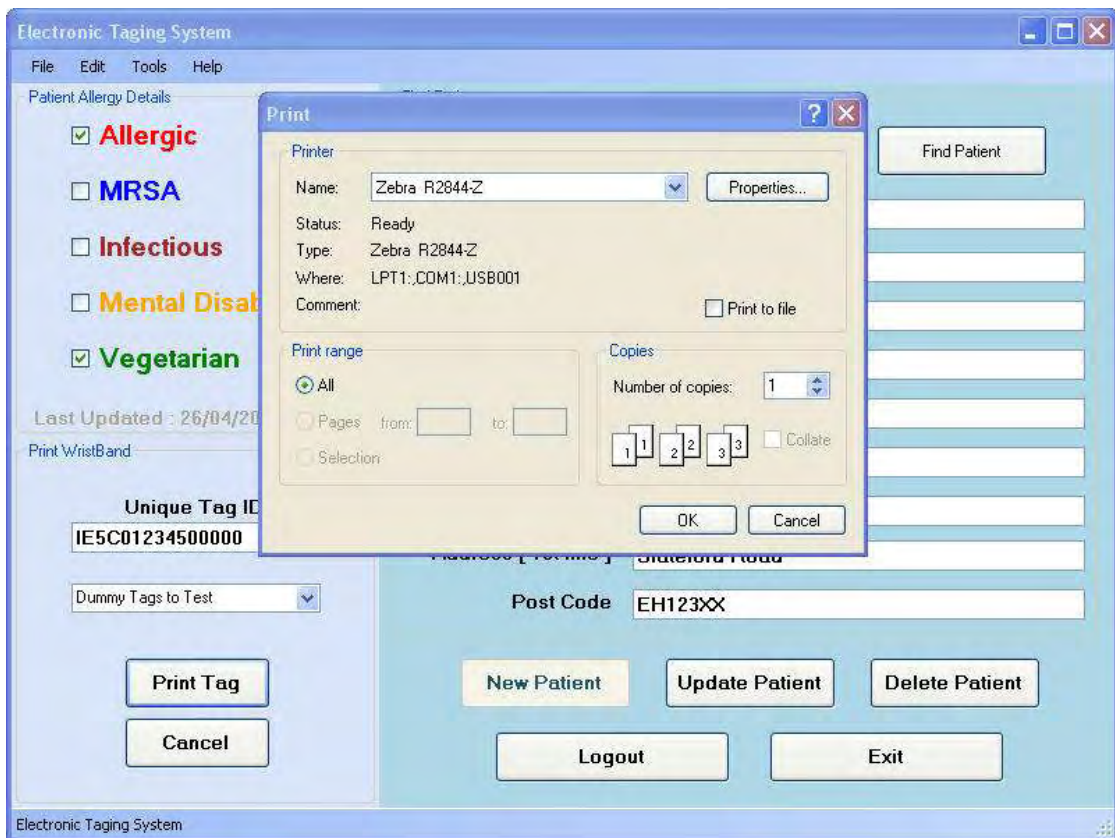


Figure - Wristband Printing

Once, the print tag button is clicked a printer dialog comes up. User would typically select the RFID printer from the list of available printers. It could be a local or a network printer and where the RFID tag would be ready to be collected on print completion.

The code here in Table , is executed when the print tag button is clicked.


```
//for printing wristband
private void BtnPrintTag_Click(object sender, EventArgs e)
{
    //zpl starts here - first line to page setup
    string s = "^XA^MNW^PW240^LT0^LH0,0^FS\n";

    //RFID setup read and print rfid id on tag
    s = s + "^FX RFID set-up ^FS\n";
    s = s + "^RS1,0,203,1,N^FS\n";
    s = s + "^RI990,0,1,1^FS\n";

    //send patients secondary info to be printer - patient id
    s = s + "^FO40,1675^A0B,35,35^FDPatient:" +
    TxtTitle.Text.ToString().ToUpper() + ". " +
    TxtFirstName.Text.ToString().ToUpper() + " " +
    TxtSurname.Text.ToString().ToUpper() + "^FS\n";

    //gender
    s = s + "^FO120,1760^A0B,35,35^FDSex|DOB:" +
    TxtGender.Text.ToString().ToUpper() + ": " +
    TxtDOB.Text.ToString().ToUpper() + "^FS\n";

    //rfid id
    s = s + "^FO160,1795^A0B,35,35^FDBand ID:^FS\n";
    s = s + "^FO160,1510^A0B,35,35^FN990^FS\n";

    //print the nhs, napier name and web url
    s = s + "^FO150,875^A0B,35,35^UHB - NHS^FS\n";
    s = s + "^FO190,795^A0B,35,35^FDSelly Oak - Birmingham^FS\n";
    s = s + "^A0B,25,25^FO30,835^FDWWW.UHB.NHS.CO.UK^FS\n";
    s = s + "^A0B,25,25^FO55,835^FDWWW.NAPIER.AC.UK^FS\n";
    //finish printing
    s = s + "^XZ";

    //zpl ends - call the printer dialog for user to select rfid
    wristband printer
    PrintDialog pd = new PrintDialog();
    pd.PrinterSettings = new PrinterSettings();
    if (DialogResult.OK == pd.ShowDialog(this))
    {
        RawPrinterHelper.SendStringToPrinter(pd.PrinterSettings.Pri
        nterName, s);
    }
}
```

Table - Code: Printing Wristband

5.6 Handheld Application

Similar to management application, handheld application makes use of the web service for all the communication between database and the device. There were lots of other parts involved in developing the handheld application, some of them are generic to all handheld application in windows mobile devices and only the main aspects are discussed here

5.6.1 Reading serial port

To read from the RFID reader, the application uses the following code extracts.

```
// needed for communicating with ports.
using System.IO.Ports;
// create a new serial port component
SerialPort Sport = new SerialPort();

// set the baudrate to 19200 as per rfid reader
Sport.BaudRate = 19200;
// needed open the serial port
Sport.Open();
// needed when a data is received from the serial port move to handler
Sport.DataReceived += new
SerialDataReceivedEventHandler(SPort_DataReceived);

// receive the value and convert it to string and store it in a var
void SPort_DataReceived(object sender, SerialDataReceivedEventArgs e)
{
    rfid = Sport.ReadLine().ToString().Trim();
}

// dispose all the resources used by port, before closing

Sport.Dispose();
// close the serial port
Sport.Close();
```

Table - Code: Reading RFID Tag

In the code shown in Table , where Sport is an instance of a serial port which is opened and read and closed on exit.

5.6.2 Display allergy information and warnings

Allergy information and warning are performed with the use of code extracts shown in Table . It simply changes the background colour of the application, when detecting an allergy and displays a list within a message box.

```
// change app back color if allergy found
this.BackColor = Color.Orange;

// display allergy warnings
MessageBox.Show("This Patient is \n" + alg, "Info",
MessageBoxButtons.OK, MessageBoxIcon.Exclamation,
MessageBoxDefaultButton.Button1);
```

Table - Code: Alerts and Warning

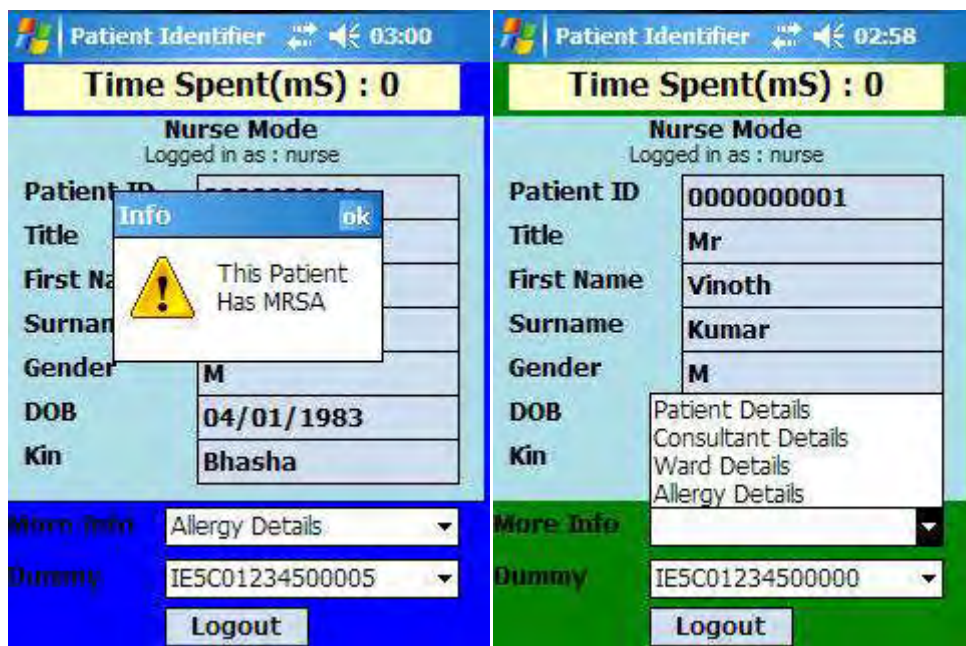


Figure - Allergy Warnings

The screenshot in Figure shows, how allergy information is displayed in the handheld to warn the user.

5.7 Analytical testing

5.7.1 Timing events

For analysing the performance, all the communication events occur within the framework are timed using the above code extracts shown in Table . With the use of Timers within the .NET a system timer is used to measure accurately, similar to a stop watch and the result is then logged on to a database. The table in Figure shows the logged timing events using the code implementation.

```
// needed for using timers and stopwatch
using System.Timers;
//create a new Stopwatch instance
StopWatch = new Stopwatch();
//before a process start stopwatch
StopWatch.Start();

//-----Process-----

//after process stop stopwatch
StopWatch.Stop();

//calculate elapsedmillisecond and stored in a var
Elapseddms = StopWatch.ElapsedMilliseconds.ToString()

//reset all the values within stopwatch
StopWatch.Reset();
```

Table - Code: Timing Events

Speed	ReqIP	ActionCode	UserName	Role	DTime	LogID
349	[192.168.1.68 192.168.1.68 vinoth	1	nurse	n	04/05/2007 10:24:30	1
2	[192.168.1.68 192.168.1.68 vinoth	1	nurse	n	04/05/2007 10:24:33	2
1	[192.168.1.68 192.168.1.68 vinoth	1	nurse	n	04/05/2007 10:24:34	3
1	[192.168.1.68 192.168.1.68 vinoth	1	nurse	n	04/05/2007 10:24:34	4
1	[192.168.1.68 192.168.1.68 vinoth	1	nurse	n	04/05/2007 10:24:34	5
1	[192.168.1.68 192.168.1.68 vinoth	1	nurse	n	04/05/2007 10:24:34	6
1	[192.168.1.68 192.168.1.68 vinoth	1	nurse	n	04/05/2007 10:24:34	7
1	[192.168.1.68 192.168.1.68 vinoth	1	nurse	n	04/05/2007 10:24:34	8
1	[192.168.1.68 192.168.1.68 vinoth	1	nurse	n	04/05/2007 10:24:34	9
1	[192.168.1.68 192.168.1.68 vinoth	1	nurse	n	04/05/2007 10:24:34	10
1	[192.168.1.68 192.168.1.68 vinoth	1	nurse	n	04/05/2007 10:24:34	11

Figure - Speed Log Table

5.7.2 Database monitoring

The database is constantly monitored for the growth of its size in context with the number of events occurs in the framework.

6.0 Results Analysis

As known from the design and implementation, events are timed to measure the performance and the capabilities of the framework. There were also other general tests done in order to evaluate. This section would discuss briefly the results gathered from the various tests and from the logs in the database.

One of the important aspects is that the tests here are based on the lab environment and when it is implemented this would generally improve. It is due to many facts that, there could a better performing, multi processor server, when compared with a simple PC used as a server in the lab environment.

6.1 Server and Host Performance Analysis

Based on the logged event timings, the difference between the server and the host performance can be achieved. Round trip times of every communication event in the framework in measured and logged as discussed in design and implementation of the analytical testing. The chart in Figure shows a typical difference between the times took by server to process a request by the server and the time took to process a request by the application.

Performance at 0 hops, this is when the application is in the same machine as server, is compared in chart at Figure .



Figure – Chart: Server Vs Host Performance at 0 hops

Performance at 1 hop, this is when the server is on the network, is compared in chart at Figure .

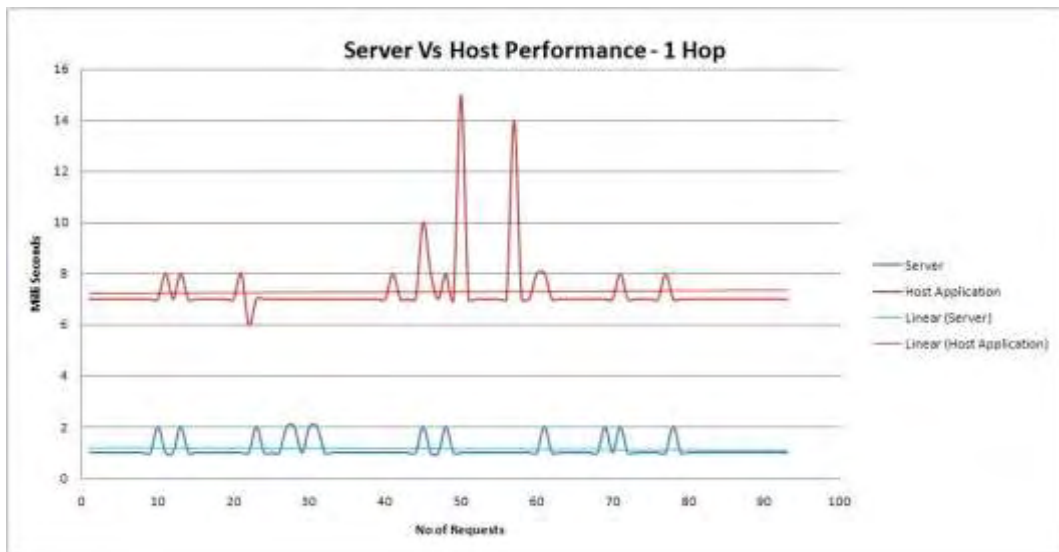


Figure - Chart: Server Vs Host Performance at 1 hop

On comparing these two charts, the performance of the server is the same, which is around 1 to 2 Milliseconds. But the application performance varies according to the usual network round trip time.

In general, at 0 hops the approximate round trip time in the network is around 0 milliseconds and at 1 hop it is 1 millisecond within a local network. When the 0 hops is taken as baseline, then the application used in a network with a round trip time of 32 milliseconds will have typical application process round trip time of 37 milliseconds.

Round trip time could be simply the time taken for a packet to travel from one end to other and back again. This can be determined using a simple network ping. Thus, the server performance is the same regardless of the requesting host, but the host application performance relies on the network hops and the average network latency. The chart in Figure shows logged analysis between thousands of responses made to various hosts in a network.

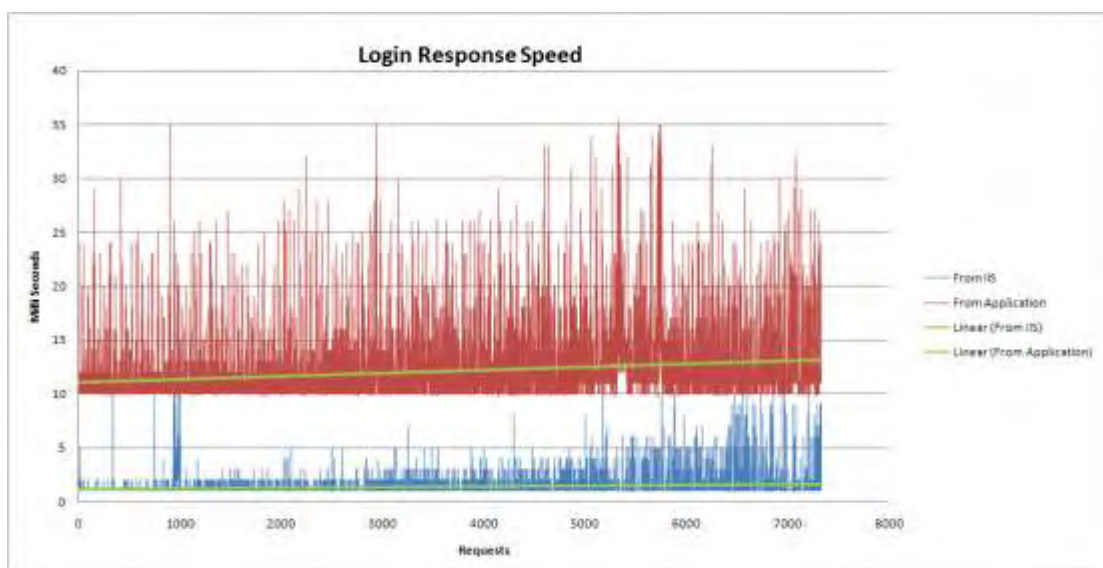


Figure - Chart: Performance Log Analysis

6.2 Overall Performance Analysis

In order to analyse the performance, first a baseline of expected concurrent users and the acceptable response time has to be predicated based on the requirements.

As a hospital, there would be at least two nurses and a consultant in a ward and there may be a number of wards within. Based on the needs of the hospital, the framework is initially to be implemented in ten wards. Thus it makes a minimum of 30 users and roughly a maximum of 50 users.

Also learnt from the onsite experience, that the response time should be fairly quick or else it might annoy the users and they might perform actions before a response. The response time should be at least within a second.

- Expected concurrent users = 30 to 50
- Expected response time = within a second

Note that these are just assumptions and a rough estimation based on the requirements.

The framework is capable of performing many requests within a second. Number of successful response within a second is compared with the number of concurrent users and the chart in Figure shows the framework is well capable of performing up to the expectations.

The server used in the lab environment only supports up to fifty concurrent connections due to the software restrictions, thus only fifty concurrent users were tested, but a linear average is projected to further number responses according to the number of users that the framework could respond to within a second.

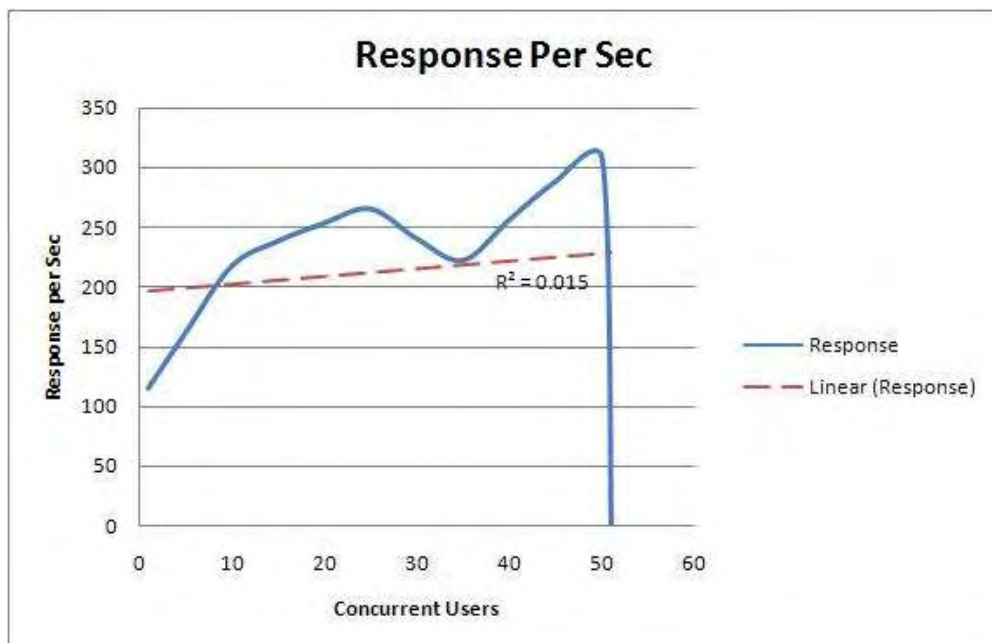


Figure - Chart: Performance Per Second

6.3 Load & Stress Analysis

As the events take place through the network, the network bandwidth utilised by the framework is calculated. Based on the number of number of concurrent users and responses the data transfer occurs in server and the host were measured. The average bandwidth used by the framework in context to number of concurrent users is shown in Figure .

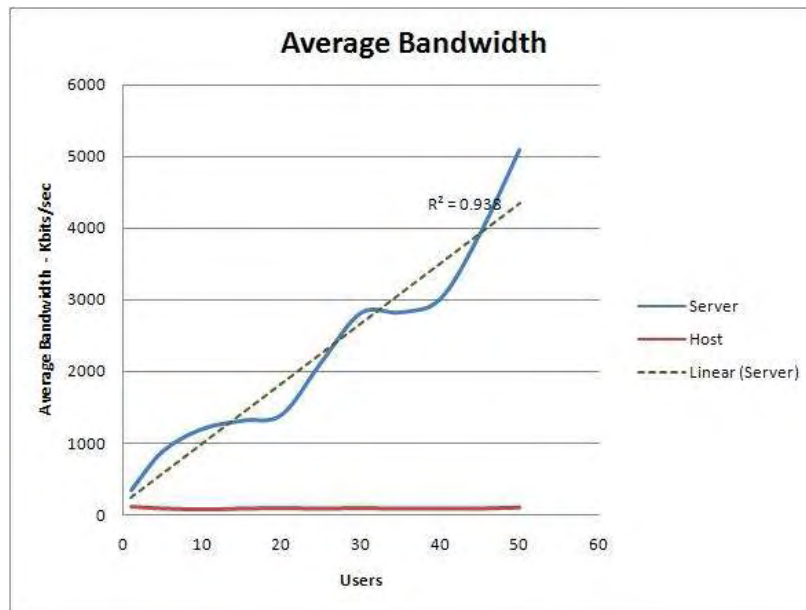


Figure - Chart: Average Bandwidth

When concurrent users are trying to continuously request to the server and when the server exceeds its capability, it could not handle requests. Server would typically send error message for those request that it couldn't handle. The percentage of error occurs when the server is stressed in context to the concurrent users is shown in Figure .

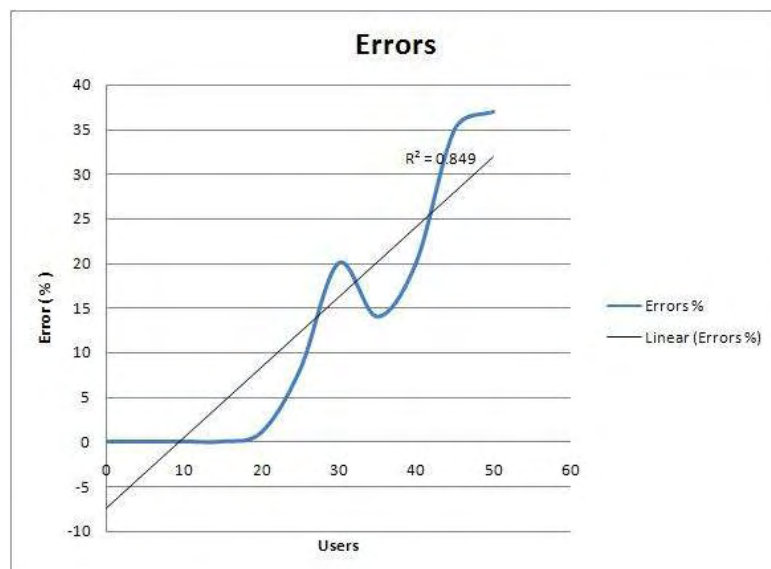


Figure - Chart: Errors

6.4 Database Growth

Database size was monitored to roughly estimate the scalability, when framework is at its maximum use. On each thousand requests the database size is monitored and around 0.25 MB of data size is increasing. Based on this the chart in Figure is shown.

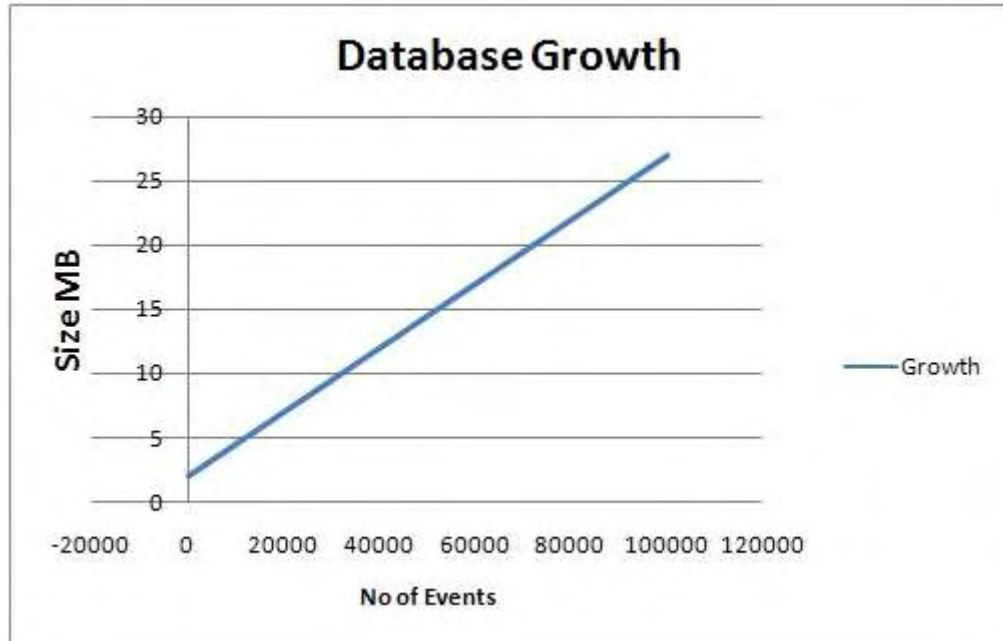


Figure - Chart: Database Growth

Based on the size measurement of database for each 1000 requests up to 10000 requests, the below in Table is predicted. The total size of the table is determined based on the n number of requests increments.

N + Requests	Size MB
Initial Size	2
+1000 Requests	2.25
+10000 Requests	4.75
+50000 Requests	17.25
+100000 Requests	42.25

Table - Database Growth

Based these analysis, the framework is capable to perform up to the needs; it is scalable, robust and acceptably quick in responding user requests.

7.0 Evaluation

This work is drawn to a close, by presenting analysis of the framework and more importantly to examine whether the framework is advantageous over existing object identification and tracking systems within critical environment such as healthcare. Evaluation here discusses the project objective, strengths and weaknesses, further recommendation and a conclusion.

7.1 Objectives evaluation

The main aim of this work is to design a frame work for object tracking and identification in wireless networks that would be suitable for healthcare environment. This aim is achieved in steps, starting with a critical review of using radio frequency based solution, which is presented in section (Section 3.3), where passive RFID is concluded to be the best suitable (Section 3.3.3) in healthcare environment with the help of wireless networks and databases for mobility and security.

This work is then compared with similar works (Section 3.7) in healthcare using RFID, which helped optimize the idea further and to provide better solution. Based on the review, the framework then took shape to satisfy the needs. A prototype of the framework is designed and implemented in lab environment with the hospital environment requirements in mind. The framework is also tested for critical analysis and the results were analysed stating the framework is well suitable to perform up to the requirements.

Review of all the main methods involved in object tracking using both wireless networks and RFID in relating to signal strength and signal quality were discussed (Section 3.2) and a suitable framework is identified by integrating both wireless and RFID technologies which is suitable for healthcare environment.

It is determined that signal strength from a passive RFID can be used to effectively identify an object in close proximity (Section 3.3.2), where the RFID signal can only travel to a very short range of up to 3 inches. This is an advantage in healthcare environment to prevent radio interference to medical equipments and also in addressing major concerns of public and patients regarding radiations. But as a negative effect, the object tracking is not possible in real-time and object can only be traced based on the object identification events took place in framework, which is logged onto a database (Section 4.3.2). The tracking is possibly only by querying the database and it is similar to the last seen by or last seen at scenario in real world. However, tracking is made possible and with the least damage and concerns within the healthcare environment.

There were only a handful of similar frameworks tested or demonstrated. One of them is reviewed in the similar work (Section 3.7) and the two other were clinical trials and a brief description is quoted, mainly because no publications were available on those works. Regardless, none of these attempts used passive RFID, or used a wireless enabled mobile device. Only one of them has used a database lookup operation. Thus

makes the proposed framework, unique and advantageous over the other framework ever tried by providing mobile, secure, cost-effective way.

The prototype is designed (Section 4.3) and implemented (Section 5.0) with the use of a centralised database and database lookup operation is performed on every request in the framework. The framework does not store information within RFID tags and by using secure object lookup, where data is encrypted and transferred by avoiding major security and privacy threats. The designed prototype is a proof-of-concept framework, by being unique and providing mobile and cost effective solution for hospital in patient identification. A paper publication is accepted based on this framework and a patent application is pending to protect this unique and effective framework as mentioned in introduction (Section 1.0).

All possible measures were taken to ensure the framework is suitable and compatible (Section 4.1) for real-life experiments within NHS. The framework is also suitable to deploy in the hospital IT infrastructure without any major modifications.

7.2 Conclusion

The primary aim of this work is to review techniques of object tracking and identification using wireless networks and RFID technologies and to design an efficient framework that suits the needs of a critical healthcare environment (Section 1.1).

The process to achieve this began with knowing wireless networks (Section 2.1) and RFID technologies (Section 2.2) and a question of how they could be used in object tracking in indoor wireless area is answered by a critical review of the tracking techniques in wireless network (Section 3.2), like RF Fingerprinting, triangulation and etc. RFID tracking techniques based on Active RFID and Passive RFID tags were also reviewed (Section 3.3) to obtain a suitable solution.

It is concluded that the RFID or wireless only solution is possible, but is not suitable for healthcare environment (Section 3.2.4; 3.3.4), as either it does not provide the exact solution needed or it causes major concerns regarding radio interference and radiations in such environment (Section 3.7.5). Also known from the review that the Passive RFID is the least damaging (Section 3.3.3) and based on existing wireless enabled devices and wireless access points within healthcare (Section 4.1.2) environment, a new solution to address the issues is derived by integrating the technologies available (Section 3.4). This is by using a wireless enabled mobile device capable of reading RFID tags and that would look up objects from a centralised database to prevent security and privacy risks (Section 3.6).

With all the requirements of hospital environment and the hospital IT infrastructure (Section 4.1), the framework is designed, implemented, tested and analysed based in lab environment (Section 5.1).

On comparison with similar frameworks designed or demonstrated by others, the framework proves to be unique and much advantageous (Section 3.7.5). As known from the review there are only a few trials and demonstrations performed or

documented in such environments before (Section 3.7), this framework is unlike the works discussed. Mainly in the aspects mentioned below;

1. Low frequency Passive RFID solution, with short range radio signal emission and with least radio interference and radiation. While comparing with the high frequency Active RFID (Section 3.7.3).
2. Mobile RFID reading and identification solution with the help of wireless enabled mobile devices that are also much easy to use and integrate, when compared with the fixed RFID readers to a workstation or onto walls and ceilings (Section 3.7.3; 3.7.4).
3. Centralised data storage, and encrypted data communications are highly addressing the security and privacy concerns, when compared to data storage within the RFID tag or within the mobile device (Section 3.7.4).
4. Enables intelligent tracking solution, even though it is not real-time, it provides a reasonable tracking mechanism that makes way to many other intelligent applications which could be used in patient flow management, patient management, beds and equipments managements and even possibilities to control and track infection spreading by analysing logs (Section 4.3.2).

As a result, the designed framework is applied for patent protection (Patents, 2006) by NHS MidTECH on behalf UHB – NHS and Napier University and also contributed to writing and acceptance of a paper in International Journal of Healthcare Technology and Management (Thuemmler et al., 2007).

On personal conclusion, if implemented in real-life as intended by the industrial partners, the solution would be state-of-the art, high performance, cost-effective, user friendly, intelligent framework that would help prevent medical errors and save hundreds of life and mistaken treatments every year. It would also help in easing the work load of the healthcare workers and mainly improve healthcare services available to everyone.

7.3 Further work

Mainly due to limited resources, very limited funds and the time factor many of the aspects thought to be implemented as an enhancement are still to be addressed. Many areas are unexplored and still largely available to research and develop intelligent context, object aware applications and even data mining and security applications can be explored.

One of the main aspects is to implement this framework in real-life. But unfortunately, due to delays and issues between manufactures and the hospital the implementation is still due. The moment to implement could be in near future, but the time is limited to complete this work besides the starvation faced for recourses and funds to meet basic requirements.

Further works that could be carried out to enhance are listed here

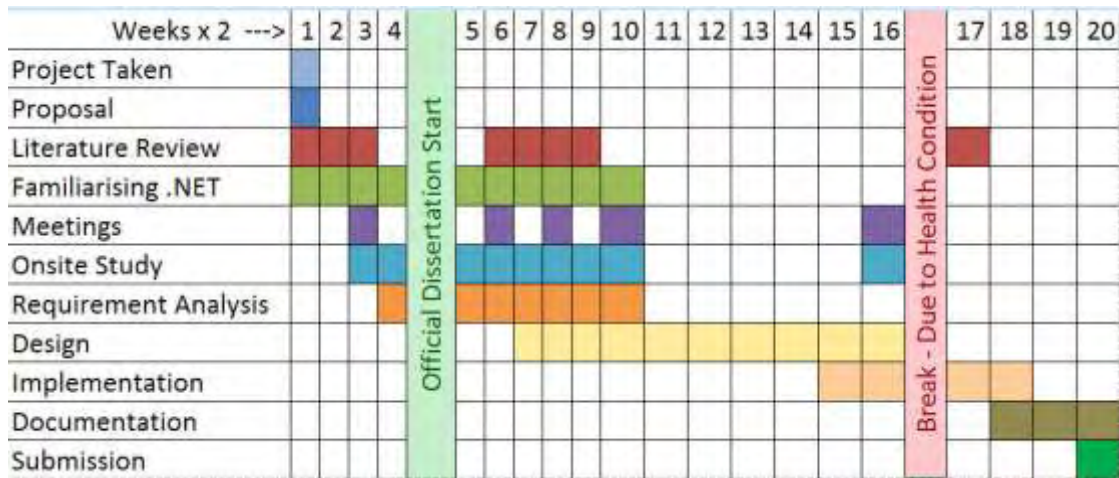
1. Implement the framework and evaluate in real-life real environment
2. Design and implement a form of communication system for healthcare workers to leave notes and ease the shift handover process using the mobile device and patient identification possibilities
3. Design and implement a web based management application that could manage and generate intelligent documentations needed.
4. Explore possibilities of using active RFID tags and real time locationing within healthcare as the active RFID is currently under consideration to be manufactured for healthcare
5. Custom Design and Develop a special handheld device with the RFID and wireless capabilities specially for this purpose, which would reduce the possibilities of germs and bacteria that could be untreated with a complex device
6. Can develop intelligent data mining application, which could help healthcare professionals to understand the patient flow and etc...
7. Improve security within implementation

There is the possibility to seamless number of enhancements that could be done based on this framework.

8.0 Appendices

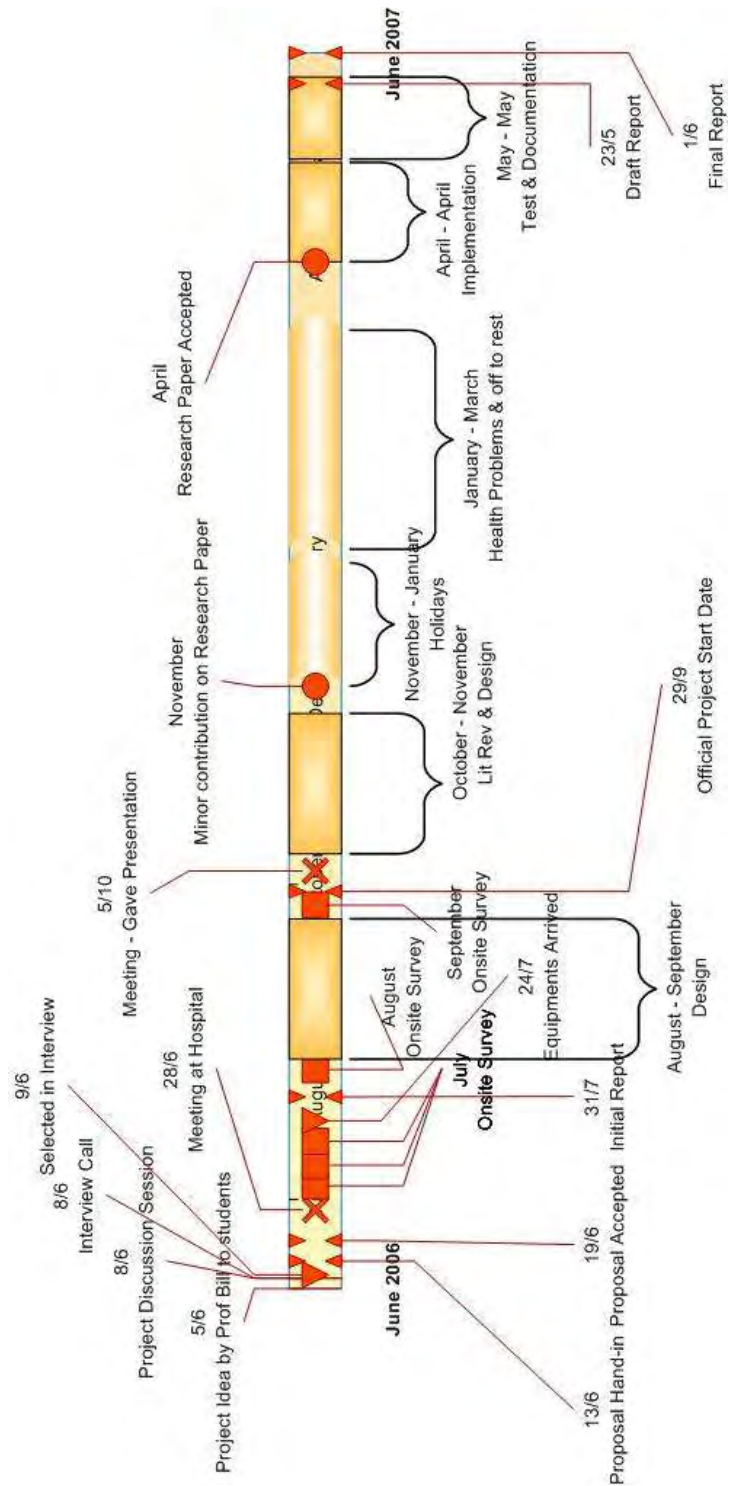
Appendix 1: Gantt chart

The intended project time was initially agreed as six months, due to the nature of the project.



Please note: Project was only officially started in October due to circumstances and as agreed with the course leader. Even though, unofficially began working on project. There is also a period of time where a break occurred due to seasonal holidays and followed by a severe health condition which needed rest. The weeks mentioned above are over the duration of the project and excluding the break time. Please refer to the time line for further information. The representation is only a rough estimate and not accurate to the date.

Appendix 2: Time Line

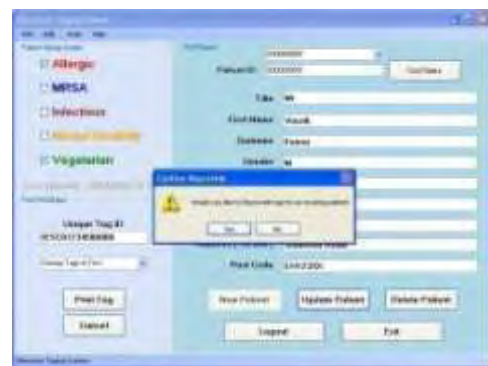
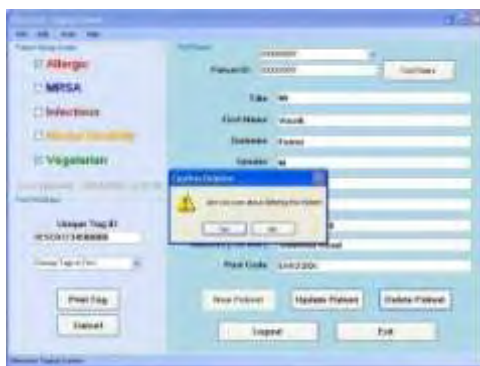
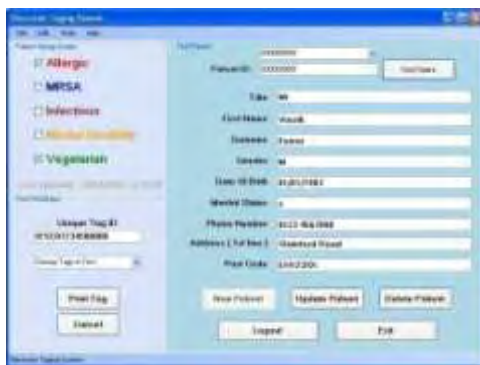
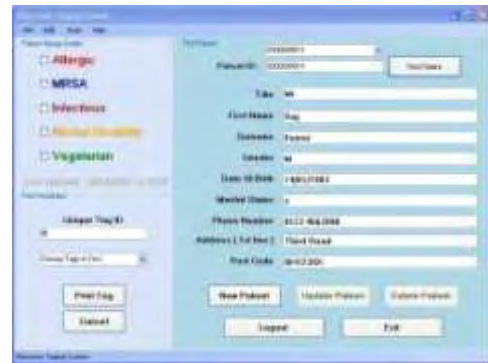


Appendix 4: Application Screen shots

Handheld Application



Management Application



Appendix 5: Research Paper

(Int. J. Healthcare Technology and Management, Vol. 8, No. 5, 2007)

Int. J. Healthcare Technology and Management, Vol. 8, No. 5, 2007

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Setting safety standards by designing a low-budget and compatible patient identification system based on passive RFID technology

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Abstract: This paper outlines a large-scale audit for the enhancement of quality of care and staff and patient safety using passive RFID (Radio Frequency ID) wrist bands, which link to a patient's database, in order to reduce errors in patient care. It has been developed with a collaboration between the University Hospital, Birmingham, UK and Napier University, UK. The key feature of the work is the usage of passive RFID tags as an integral part of a low budget out-of-the box strategic patient information system which should be compatible with most hospital IT systems.

Keywords: e-health; integrated patient management; passive RFID; patient identification; pervasive computing.

Reference to this paper should be made as follows: Thuemmler, C., Buchanan, W. and Kumar, V. (2007) 'Setting safety standards by designing a low-budget and compatible patient identification system based on passive RFID technology', *Int. J. Healthcare Technology and Management*, Vol. 8, No. 5, pp.571–583.

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security and networking and has a forthcoming textbook on security and network forensics. He has developed an extensive range of network emulation software, covering advanced studies in networking and security. He has also won several awards for excellence.

Vinoth Kumar is a postgraduate student at the School of Computing at Napier University, Edinburgh, UK undertaking an MSc in advanced networking. Vinoth Kumar received his BEng in electronic and computer engineering from the Robert Gordon University, Aberdeen, UK and an Honours diploma in computer technology from the State Board of Technical Education & Training (India). His research interests include RFID, location-aware computing, wireless, mobile and sensor networks, networking security, distributed networks, web technologies and database and .NET application development.

1 Introduction

Research and anecdotal evidence has shown that often patients do not have wristbands or may carry misleading or inappropriate identification. These errors can thus increase the risk of patients being incorrectly identified and given the wrong care (Cambridge Consultants, 2004; Guthrie, 2003; Human Reliability Associates, 2004; National Blood Service and Royal College of Physicians, 2003; Royal College of Nursing, 2005). To highlight the problem, between November 2003 and July 2005, the National Patient Safety Agency (NPSA)¹ in the UK received 236 reports of patient safety incidents and near misses relating to missing wristbands or wristbands with incorrect information.²

Normally, conventional wristbands consist of plastic strips with patient identification labels from paper attached to the surface. In some cases, patient names are simply written on the tag as ones which are phonetically understood by nursing staff. Thus, simple autographic mistakes or the lack of secondary identification, such as date of birth, quite frequently make the whole process of patient identification prone to error by mixed identity. Another source of failure is the vulnerability of the paper stickers to chemical agents like soap or disinfectants. Stickers often become unreadable or they dissolve causing extreme difficulties with identification. Along with this, there is currently no standard colour used for wristbands for allergy and infection details. It has been observed that medical professionals can go from one hospital to another and the hospitals use different colours for these details.

All this needs to be understood in context with a growing number of patients who are not able to confirm their personal data due to conditions such as acute confusion, dementia, depression, intoxication, stroke, etc. The rapidly developing area of RFID technology offers an interesting and novel approach towards intelligent and highly reliable patient identification systems. Thus, labels and stickers could be abandoned as wireless sensors linked to memory can be embedded in wristbands and can be read either by handheld devices or by antennae positioned in the hospital. The enhancements in authentication and privacy in wireless technology, such as the developments in WPA, allow a secure environment for collection, preservation, analysis and reporting of data.

2 Background

Bar codes have been used extensively in commerce, especially in identifying products, to give a Unique Product Code (UPC). In fact, the first one was on a pack of Wrigley's chewing gum on June 26, 1974. The example in Figure 1, from a book, shows that the ISBN code is mapped to the bar code identifier. Unfortunately, bar codes suffer from several weaknesses including:

- bar code readers normally require a line-of-sight transmission
- RFID can be read from a bigger distance
- they must be viewable on the surface of an object
- bar codes only contain manufacturer and product information.

Figure 1 Example bar code



The enhancement to bar codes is to use a wireless transmission mechanism with local memory to store information. This type of technology has many applications, including pet tracking, automated checkouts, food safety, remote telemetry, ID cards, automated tolls, etc. (Figure 2). This type of technology, typically named RFID, has several advantages including:

- RFID does not require a line-of-sight transmission
- RFID can be embedded into a device and thus is more robust
- RFID can contain other information, such as a unique ID or the manufacturing factory.

The radio frequencies that these tags use have been fitted into three main gaps in the RF (radio frequency) spectrum (Figure 3) and the most common tags use the 13.56 MHz frequency, which is a globally defined standard. This allows the tags to have a reasonable range, while still having a relevantly small antenna. The usage of high-frequency tags gives the opportunity of using extremely small tags but their range tends to be less wide than lower frequency tags.

Along with the choice of operational frequency, a key design feature is whether the tag is active or passive. An active tag has its own power source, such as from a local battery and is, thus, relatively large but has a good wireless range. A passive tag, on the other hand, does not have a local power source, thus it uses the radio energy that is sent from an RF reader to gather enough energy to return the identification. These types of tags are, thus, fairly small but they lack the range of the active tags and the typical reading distance of a 13.56 MHz is from 30–50 cm as it works in the near field (Cole, 2003). The great advantage of passive tags, though, is that they are relatively inexpensive when compared with active tags. The challenge in this research project is to use these tags to identify patients. An inexpensive method

will, thus, allow new tags to be used for every patient in the hospital and allow them to be destroyed when they leave, whereas active tags would be too expensive in cost if they were to be lost.

Figure 2 Applications of RFID

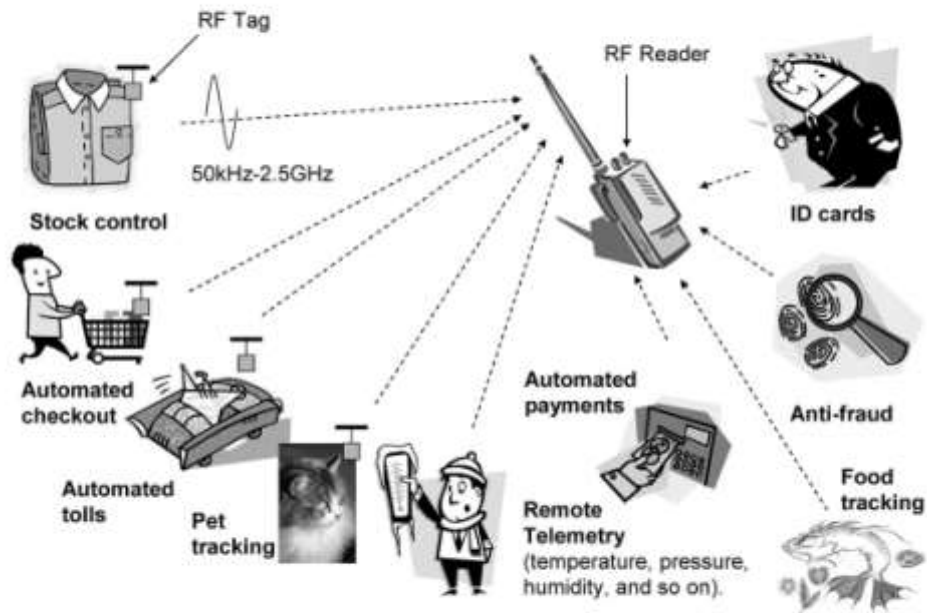
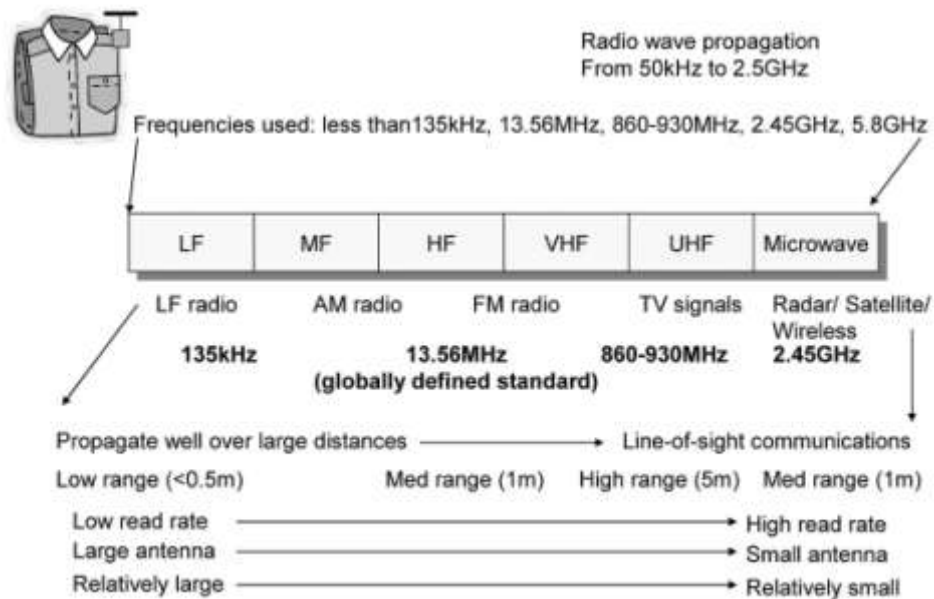


Figure 3 RFID radio spectrum



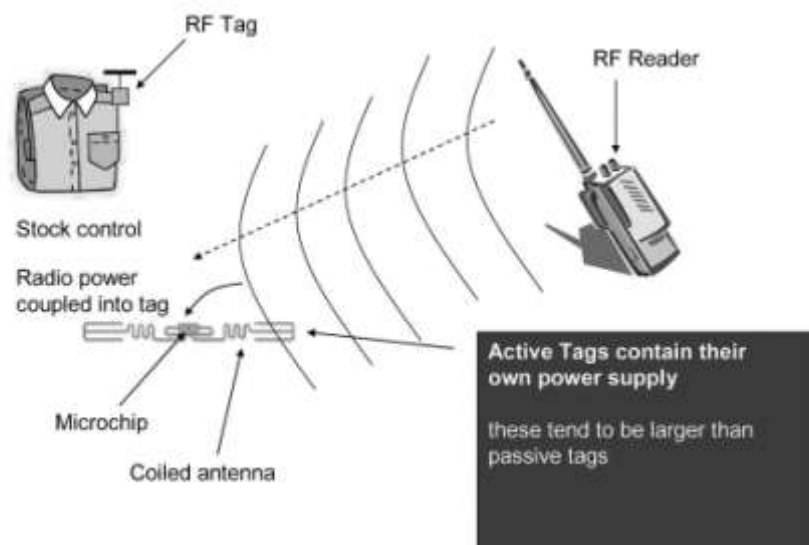
3 Literature review

As RFID is the intelligent replacement,³ it is the ideal and recommended solution for overcoming patient identification problems (Murphy and Kay, 2004) in the healthcare environment.

RFID is already being used in a wide range of intelligent healthcare applications, such as elderly healthcare systems which monitor the patients' medication intake (Ho et al., 2005), a research project by Intel for monitoring elderly activities by sticking tags on household objects and collecting information when the object is touched and used to generate reports of activities of daily living (ADL) (Intel Research Seattle, 2005) so that it could be used for further research in improving elderly healthcare.

There was also some interesting work conducted on applications for healthcare and other potential areas, such as hospital workflow monitoring, by tracking equipment and patient transfers (Exavera Technologies, 2006), dental moulds and dental implants (Ilic, 2004), Magic medicine cabinet (Wan, 1999) and some work done on sociophysiology in honeybees and its role for bee health.⁴ For this research, a large number of bees were tagged with passive RFID tags to study their behaviour (Figure 4). The main focus for many RFID-based patient ID systems is on active tags which allow patients or machinery to be identified and located anywhere within designated areas (Davis, 2004; Fry and Lenert, 2005). The disadvantage of these tags, as previously mentioned, is that they are relatively expensive, although they have been successfully introduced to high-risk areas, such as neo-natal wards where child abduction has become a serious issue in recent years.^{5,6} Another area of application is surgery, where relatively simple setups have been used to write and read relatively small amounts of information to/from passive RFID tags in order to eradicate medical errors and to prevent litigation⁷ (Macario et al., 2006).

Figure 4 Passive tags



There has been a growing interest in passive tagging recently (Malkary, 2006). Some passive tags typically do not actually store extensive patient information that needs protection and there are possibilities for unauthorised access to patients' wrist-bands due to the lack of a mechanism for authentication in wristbands. Unprotected wristbands could be accessed and scanned by a third party to either identify the individual or provide valuable data to market researchers or competitors of an organisation (Sarma and Engels, 2003). In addition, passive tags do not need to be cleaned and disinfected as they are disposable and will not be reused. Furthermore, they are not prone to over-the-air spoofing attacks or other manipulations with criminal intent (Halamka et al., 2006).

Clinical trials with 1000 patients or so have been conducted in Germany and the US but in neither trial were the passive tags directly linked to the central hospital patient database⁸ (Collins, 2005).

A key feature of an electronic system for the health sector is that it should comply with the HIPAA statute that requires reasonable and appropriate safeguards to protect health information. Its main goals are:⁹

- to ensure the confidentiality, integrity and availability of all electronic protected health information that the covered entity creates, receives, maintains or transmits
- to protect against any reasonably anticipated threats or hazards to the security or integrity of such information
- to protect against any reasonably anticipated uses or disclosures of such information that are not permitted or required under (the security rules)
- to ensure compliance with the (security rules) by its workforce.

Key objectives of the plan include review and consideration of the following security-related areas:

- design network communication configurations (wireless LAN, WAN, internet) for strong encryption and audit trail reporting
- design organisational procedures regarding access to information
- develop transition plans for transmission of data not currently implemented into the LAN/WAN environment
- consider recommended infrastructure needs such as new or additional computing devices (including wireless devices, laptops, Pocket PCs and tablet PCs)
- develop necessary training assistance for facility staff.¹⁰

4 Design objectives

This design describes the implement framework which proposes to be a low cost system for hospitals and is protected under UK patent law.¹¹ The design of the RFID system takes on several key features:

- integration with the existing NHS database, which will be a read-only data transfer
- complete compatibility for all software elements for the software
- overcomes firewall problems, which can often block applications. Most NHS IT systems have extensive firewalls which do not allow the transfer of communication which do not conform to strict specifications
- soft linking of the RFID tag to the database
- coding of highly relevant conditions, such as allergies or infectious diseases, by different colours of the display and standardisation of these colours
- logging of accesses to the patient.

5 Equipment used

The selected equipment for the audit includes:

- *SYMBOL MC70* (EDA enterprise digital assistant). This is a rugged handheld mobile device which has the RFID reader connected to it. The main advantage of the MC70 is that it is approved for medical use.
- *RFID Reader*. This is a TSL Multi-ISO HF RFID reader which plugs into the Symbol MC70 device. It contains the RFID antenna and allows tags to be read and written by a variety of transponders at 13.56 MHz which includes ISO 15693, ICODE (I and II) types.
- *RFID Printer*. This is a Zebra R2844-Z RFID printer/encoder and can be used to create and read the tags. It uses the R2844-Z printer/encoder which is a programming language for reading and writing to tags.
- *RFID Wristband*. These are Zebra Z-Band QuickClip Wristbands and use thermal technology to print onto the ribbon, which makes the changing of wristbands easy.

The specification of the reader defines a distance of up to 8 cm, in most trials of the system the reading distance was only up to 4.8 cm. Also, it was observed that placing a metal strip directly behind the tag does not enhance the distance, as most of the time the tag cannot be read, while a strip placed just 2 mm above the tag gives a reading distance of up to 3.5 cm. Passive tags thus placed directly onto metal, such as in tagging beds and assets should, thus, be placed away from direct contact with metal.

6 Framework implementation

Often, software fails in its implementation as elements of it do not fit together well, thus the proposed system uses the .NET environment, which is a completely integrated software system that binds Windows programmes with web services and with the underlying Windows networked infrastructure. Users and their roles can be

easily authenticated through a Windows domain system. Along with this is a major problem in that often, firewalls block communications for unwanted TCP ports, so to overcome this problem the system uses web services which, because they use the same TCP port as normal web traffic, are not blocked by firewalls (Figures 5 and 6).

Figure 5 Framework with databases

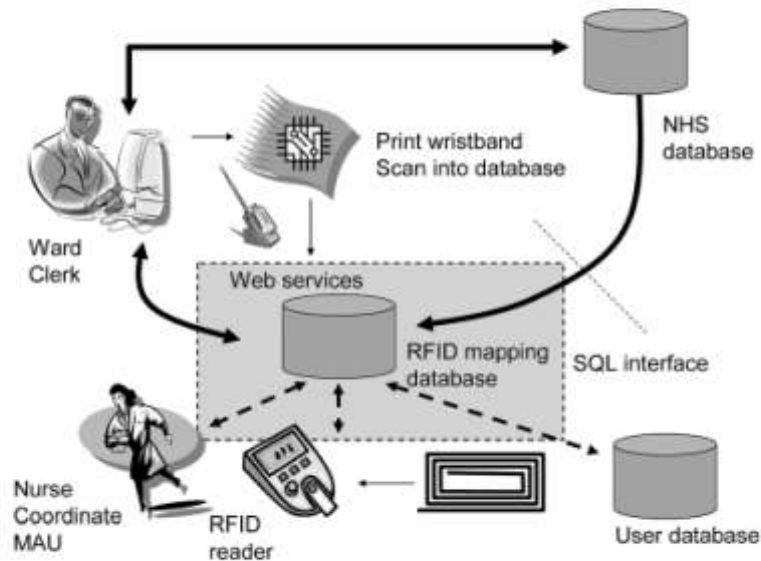
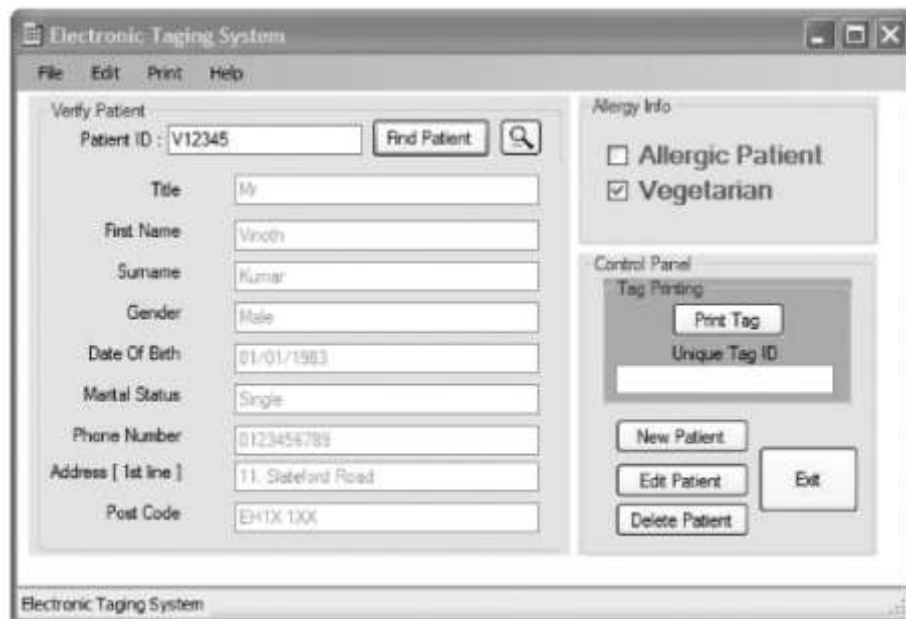


Figure 6 Initial registration



The local database thus stores the mapping of the RFID tag to the patient ID and also the users on the system, which are authenticated again via the main user account system. To simply the security of the system, a range of roles have been defined, which define the data that the viewer is allowed to view. These are:

- *Wardclerk*. This role defines a registration role of the system and the main details for the patient can be viewed, such as their name, address, etc, but no actual details can be shown.
- *Nurse*. This defines a limited subset of the data that can be viewed, such as the details of patient visits and notes. This role is set up from an administration panel.
- *Consultant*. This defines the highest level of viewing and it is possible, through levels of authentication, to view the full details of the patient.

All of the accesses to the local database are achieved through web services, thus no direct access can occur to the local database. Along with this, all of the data transferred between the clients and the web service are encrypted before transmission and then decrypted by the web service and vice versa.

Figure 7 provides an overview of the system, where an RFID reader is used to read the wristband. The operation of the system is then:

- *Initial registration*. Initially the ward clerk registers the patient by using their existing unique patient ID which would help to download the patient information into the local database. The ward clerk then reconfirms the information with the patient and adds any allergy and vegetarian information to the database. The ward clerk then prints the RFID tag to a Zebra RFID printer. A key feature of the system is the colour coding on any access for allergies and for vegetarian requirements. These have been colour coded as red and green, respectively (Figure 8). As the tag is printed the RFID ID is then mapped in the database between the patient ID and the tag. It is only this mapping which links the patient details to the tag (Figure 9).
- *Usage*. The main details then displaying include name, DOB, sex, Hospital ID number, date and time of admission, current ward, link to previous admissions within the last 18 months, link to note pads (nurses), link to note pad (doctors only) and link to picture. Allergies are coded in red writing on the screen, such as for penicillin and yellow for infectious, such as for MRSA, HIV and so on.

A key factor in the adoption of the system is to create user interfaces which are not overloaded with information but which should give links to other related data. An example of the screen for nurses on the PDA is shown in Figure 10 and for the consultants in Figure 11. Unauthorised use of the wristband RFID handheld reader may violate privacy of the patient. To prevent this, the security of the system is enhanced with the use of a role-based approach to the login procedure, where users login with the user role as shown in Figures 12 and 13 and the information available to each user is limited according to their job role.

Figure 7 Overview of system

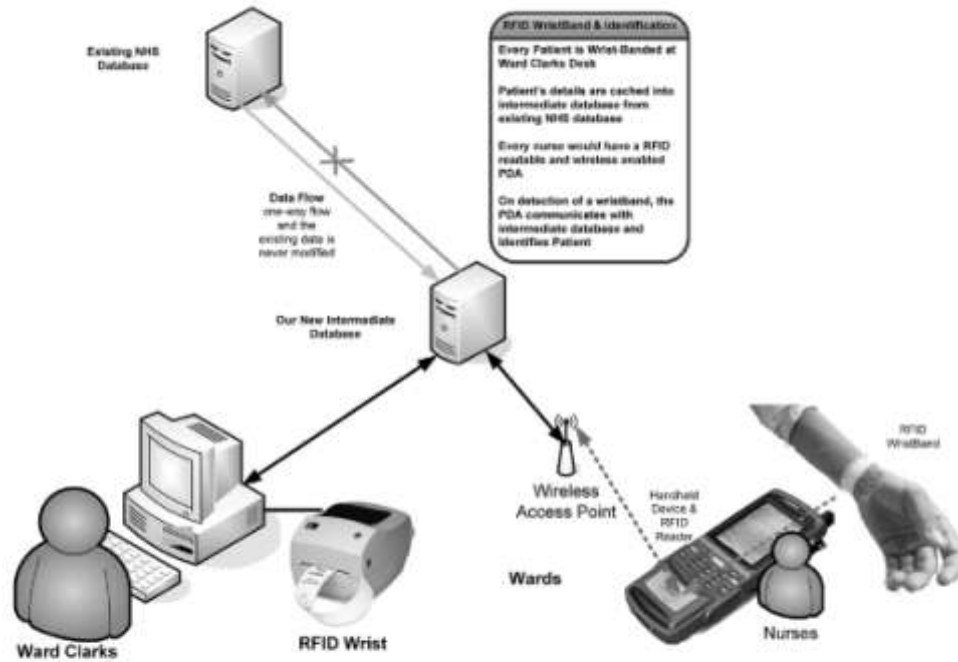


Figure 8 Allergy/vegetarian alert

Allergy Info

Allergic Patient

Vegetarian

Figure 9 RFID tag details

Control Panel

Tag Printing

Print Tag

Unique Tag ID

New Patient

Edit Patient

Delete Patient

Exit

Tag Printing

Print Tag

Unique Tag ID

IE5C01234500000

Figure 10 Main PDA screen interface (nurse)



Figure 11 Main PDA screen interface (consultant)



Figure 12 Role based security for login



Figure 13 Role based security for login

RFID Identify 4:08

RFID WristBand Wand

User Name vinoth

Password *****

Mode Nurse

Login

University Hospital **NHS**
Birmingham
NHS Foundation Trust

7 Conclusions

Our approach not only allows unique low-cost patient identification but, in addition, offers intelligent features which could be used to protect vulnerable adults within the hospital environment. Patients fitted with RFID wristbands will be clearly identifiable and it will prevent those high-risk patients from accidentally leaving the hospital or certain wards or from entering potentially dangerous areas such as X-ray departments.

References

- Cambridge Consultants (2004) 'Ensuring patients are correctly matched with samples or specimens taken from them and treatment planned for them', January 2004, available from: www.npsa.nhs.uk.
- Cole, P.H. (2003) 'Fundamentals in radiofrequency identification', unpublished, available from: <http://www.eleceng.adelaide.edu.au/Personal/peter/peter>.
- Collins, J. (2005) 'RFID delivers healthy return for hospitals', *RFID Journal*, 2 May.
- Davis, S. (2004) 'Tagging along. RFID helps hospitals track assets and people', *Health Facil. Management*, December, Vol. 17, No. 12, pp.20-24.
- Exavera Technologies (2006) 'eShepherd overview', available from: <http://www.exavera.com/healthcare/eshepherd.php>.
- Fry, E.A. and Lenert, L.A. (2005) 'MASCAL: RFID tracking of patients, staff and equipment to enhance hospital response to mass casualty events', *AMIA Ann Symp Proceedings*, pp.261-265.
- Guthrie, D. (2003) *Positive Patient Identification. Frontiers in Laboratory Medicine*, February. London: The Royal College of Physicians.
- Halamka, J., Jules, A., Stubblefield, A. and Westhues, J. (2006) 'The security implications of VeriChip cloning', *J. Am. Med. Inform. Assoc.*, August, epub ahead of print.
- Ho, L., Moh, M., Walker, Z., Hamada, T. and Su, C. (2005) 'A prototype on RFID and sensor networks for elder healthcare: progress report', *The ACM Portal*.

- Human Reliability Associates (2004) 'Mismatching between planned and actual treatments in medicine – manual checking approaches to prevention', available from: www.npsa.nhs.uk.
- Ilic, C. (2004) 'Using tags to make teeth', *RFID Journal*, available from: <http://www.rfidjournal.com/article/articleview/1206/1/1>.
- Intel Research Seattle (2005) 'Caregiver's assistant and CareNet display: making eldercare easier', downloaded 10 April 2005, available from: <http://seattleweb.intelresearch.net/Projects/active/Dcdemo/>.
- Macario, A., Morris, D. and Morris, S. (2006) 'Initial clinical evaluation of a handheld device for detecting retained surgical gauze sponges using radiofrequency identification technology', *Arch. Surg.*, July, Vol. 141, No. 7, pp.659–662.
- Malkary, G. (2006) 'Active RFID popular pick. ROI for the passive form is weak, but overall prospects look better, says study', *Healthc. Inform.*, February, Vol. 23, No. 2, p.108.
- Murphy, M.F. and Kay, J.D.S. (2004) 'Patient identification: problems and potential solutions', *Vox Sanguinis*, Vol. 87, No. 2, pp.S197–S202, Blackwell Publishing.
- National Blood Service and Royal College of Physicians (2003) 'Comparative report for blood transfusion in England', November 2003.
- Royal College of Nursing (2005) 'Right blood, right patient, right time', RCN guidance for improving transfusion practice, London.
- Sarma, S. and Engels, D.W. (2003) RFID Systems, 'Security and privacy implications', Auto-ID center white paper, Feb 2003, available from: <http://www.autoidlabs.org/researcharchive>.
- Wan, D. (1999) 'Magic medicine cabinet: a situated portal for consumer healthcare', *Proceedings of the International Symposium on Handheld and Ubiquitous Computing*, Karlsruhe, Germany.

Notes

- ¹ http://www.npsa.nhs.uk/site/media/documents/1440_Safer_Patient_Identification_SPN.pdf
- ² <http://www.npsa.nhs.uk/press/display?contentId=4405>.
- ³ RFID tags – an intelligent bar code replacement, J.A. Wolff, IBM Global Services, <http://ibm.com/services>.
- ⁴ <http://www.biozentrum.uni-wuerzburg.de/fileadmin/REPORT/ZOO2/zoo2006.htm>.
- ⁵ <http://www.verichipcorp.com/content/solutions/hugs>.
- ⁶ <http://www.verichipcorp.com/content/solutions/halo>.
- ⁷ <http://www.bjhc.co.uk/news/1/2005/n502016.htm>.
- ⁸ <http://www.rfidjournal.com/article/articleprint/2169/-1/1>.
- ⁹ <http://wireless.ittoolbox.com/pub/MM020102.pdf>.
- ¹⁰ <http://www.hipaadvisory.com/tech/wireless.html>. Proposed Hipaa Solution.
- ¹¹ Patent application number GB0619694.3.

Appendix 6: Symbol MC70 Datasheet

SYMBOL SAFETY



MC70

Enterprise Digital Assistant



FEATURES

Industry leading double aspect testing setup and nimbly, IP54 sealing, integrated antennas
Lightweight yet rugged, built for professional use in heavy-duty environments.

Intel's latest processor, designed for mobility: XScale PXA270 @ 624 MHz
Delivers high performance with lower power requirements.

Microsoft's latest operating system, Windows Mobile 5.0 Premium or Phone Edition
Integrated multimedia, extensive memory and 128-bit secure architecture.

The first rugged enterprise digital assistant
The flagship MC70 Enterprise Digital Assistant (EDA) is a rugged handheld mobile device that incorporates a mobile phone, PDA, computer, scanner and imager in a single unit designed for the rigors of all-day, everyday usage. This compact, lightweight device combines multi-mode wireless networking, voice and data communications, and advanced data capture in an enterprise productivity tool that can support nearly any application in any environment. Superior voice functionality includes outstanding acoustic performance and voice quality, handset, headset and speakerphone modes. Your mobile workers will have everything they need to increase productivity and efficiency inside and outside your four walls — from field workers reading meters and repairing equipment to drivers delivering packages, hospital workers checking lab results and medication orders, and more.

Built-in WWAN/WLAN/WPAN
The MC70 offers robust and cost-effective anytime, anywhere voice and data connectivity. For workers outside of your facility, support for GSM/EDGE and CDMA-EVDO networks delivers global coverage, fast wireless data speeds that enable rich applications, and enterprise level security. Inside your facility, the MC70 connects to your wireless LAN for voice and data communications, providing better control over wireless WAN usage — and costs. And wireless PAN functionality, via Bluetooth, further increases employee productivity through wireless printing and more.

Rugged construction delivers a low TCO
The industry leading innovative mechanical design and technology platform offer superior construction and expandability, delivering outstanding investment protection and a low total cost of ownership (TCO). Engineered to withstand rigorous use in extreme environments and working conditions, the MC70, including the internal WLAN and external WWAN antennas, can endure multiple drops, a wide range of temperatures, moisture, dust, and more and still deliver reliable performance.

Reduce the cost and complexity of mobility
The versatile, effective MC70 is a smart investment, providing a cell phone, PDA and more — all in a single rugged device. Capital expenditures and IT support costs are significantly reduced. Superior manageability enables you to easily and remotely provision, track and support all your MC70 devices from one central location through our Mobility Services Platform. A full suite of accessories provides maximum application flexibility. And when you purchase Service from the Start with Comprehensive Coverage, we will repair damaged displays, plastics, keyboards, circuit boards, and other internal and external components at no extra charge — helping you protect your investment and maintain peak performance. For more information on the MC70, contact us at +1.800.722.6234 or +1.831.738.2400, or visit us on the Web at: www.symbol.com/mc70

SPECIFICATION SHEET

MC70

WWAN: GSM/EDGE and CDMA-EVDO Rev. 0 compatibility

Voice and high-speed wireless data

WLAN: 802.11a/b/g tri-mode radio; comprehensive VoIP support

Cost-effective voice and data connectivity in the office

WPAN: Bluetooth v1.2, Class 1

Wireless modem, printing, synchronization, and more

High quality speakerphone, microphone and transceiver

Superior voice quality and performance

On-board advanced data capture: 1D and 2D bar code scanning from near contact to 55 in./139.7cm

Automate and extend proof data collection and increase productivity

3.5 in. QVGA color screen

Easy to view in any lighting

Multiple keyboard options: QWERTY or numeric

Flexibility to meet diverse user and application needs

Support for standard and extended cards

Provides additional memory and expansion functionality

Multiple battery options: standard and extended

Ample power for full shifts to reduce sleep interruptions

MC70 Specifications

Physical Characteristics

Dimensions	6 in. L x 3.1 in. W x 1.5 in. D 15.3 cm L x 7.8 cm W x 3.7 cm D CDMA/EVDO Rev. 0 configurations: 5 in. L x 3.1 in. W x 1.7 in. D 15.3 cm L x 7.8 cm W x 4.4 cm D
Weight (including standard battery)	LAN/WAN config: 11.2 oz./314 g WAN/LAN/WAN config: 12 oz./336 g CDMA/EVDO Rev. 0 config: 14.1 oz./400 g
Display	Transflective color 3.5" QVGA with backlight, TFT-LCD, 65K colors, 240 W x 320 L (QVGA) pixel
Touch Panel	Glass etching resistive touch
Backlight	LED backlight
Main Battery	Rechargeable Lithium Ion 2 PV, 1900 mAh Smart Battery
Ext. Cap. Battery	Optional 3 PV, 3900 mAh Smart Battery
Backup Battery	16-MH battery (rechargeable) 20mAh 1.2V, 2 cells (not user-accessible)
Expansion Slot	User accessible SDIO slot (with secure cover), accommodates extended cards (with cover removed). NOTE: terminals with extended cards cannot be accommodated in the charging cradle and will not be sealed
Network Connections	Ethernet (via cradle), full-speed USB, host or client
Notification	Vibrator and LED
Keypad Options	26 Numeric key, 44 QWERTY key
Audio	Speaker, receiver, microphone, headset jack, software support for full duplex record and playback (text)

Performance Characteristics

CPU	Intel® Scale™ 624 MHz processor
Operating System	Microsoft® Windows™ Mobile 5.0 Premium, Microsoft® Windows™ Mobile 5.0 Premium Phone Edition
Memory	64MB RAM/128MB ROM or 128MB RAM/128MB ROM
Interface	RS-232, USB 1.1

User Environment

Operating Temp	14°F to 122°F (-10°C to 50°C)
Storage Temp	-40°F to 140°F (-40°C to 60°C (w/o battery)
Humidity	95% non-condensing
Drip Spec	4 ft. drip to concrete, 6 drops per 6 sides over operating temperature range; 5 ft. drip to concrete, 2 drops per 6 sides at ambient temperature 73°F/23°C
Tumble Spec	1,000 1.6 ft./5 m tumbles @ 900 drops
Sealing	IP54
Electrostatic Discharge (ESD)	±15kV air discharge, ±8kV direct discharge

Wireless WAN Data and Voice Communications

WWAN Radio	GSM/EDGE 850, 900, 1900 and 1800 MHz CDMA-EVDO Rev. 0
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Wireless LAN Data and Voice Communications

WLAN Radio	Tri-mode IEEE 802.11a/b/g Note: 802.11a not available in Thailand
Data Rates Supported	1, 2, 5.5, 6, 9, 11, 12, 18, 24, 36, 48 and 54 Mbps
Operating Channels	Chan 8-165 (5040 - 5940 MHz) Chan 1-13 (2412-2472 MHz) Chan 14 (2484 MHz Japan only) Actual operating channels/frequencies depend on regulatory rules and certification agency
Security	WPA2, WEP (40 or 128 bit), TKIP, TLS, TTLS (MS-CHAP), TTLS (MS-CHAP v2), TTLS (CHAP), TTLS-MD5, TTLS-PEAP, PEAP-TLS, PEAP (MS-CHAP v2), AES, LEAP
Spreading Technique	Direct Sequence Spread Spectrum (DSSS) and Orthogonal Frequency Division Multiplexing (OFDM)
Antenna	Internal for LAN, External for WAN
Voice Communication	Integrated Voice-over-IP ready (P2P, P2P, P2T), Wi-Fi™ certified, IEEE 802.11a/b/g direct sequence wireless LAN

Wireless PAN Data and Voice Communications

Bluetooth	Class 1, v 1.2
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Data Capture Specifications

Options	1D (near), 2D imager
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Linear 1D Scanner (SE950)

Optical Resolution	~0.004 in. minimum element width
Roll	±35° from vertical
Pitch Angle	±65° from normal
Skew Tolerance	±50° from normal
Ambient Light	10,000 candles
Scan Rate	104-147 TPI standard, bi-directional
Scan Angle	47° ± 3° default 35° ± 3° reduced

2D Imager Engine (SE 4400) Specifications

Optical Resolution	640 H x 480 V pixels (gray scale)
Roll	260°
Pitch Angle	±40° from normal
Skew Tolerance	±50° from normal
Ambient Light	Total darkness to 3,000 ft. candles (86,500 Lux)
Focal Distance from Front of Engine	Near: 5 inches Far: 5 inches
Aiming Element (LED)	650 nm ± 5 nm
Illumination Element (LED)	635 nm ± 20 nm
Field of View	Horizontal: 32.2°, Vertical: 24.5°

Peripherals and Accessories*

Communication and Charging Cables	Serial and USB v1.1 charging cables, printer cables, vehicle charging cable, power/charging cable
Battery Chargers	4-slot battery charger (1X and 2X, universal battery charger requires adapters for 1X and 2X capacity batteries)

Vertical-specific attachments:	Snap-on magnetic stripe reader, snap-on trigger handle, rigid case
Electrical Safety	Certified to UL / cUL 80950-1, IEC / EN60950-1.
EMi/RFI:	USA: FCC Part 15, Canada: ICES 003 Class B, Europe: EN55022 Class B, EN 55024, EN60601-1-2, Australia: AS/NZS CISPR A 22
For countries outside USA, Canada, European Economic Area, Japan or Australia, consult your local Motorola representative	
*For a complete list of MC70 Peripherals and Accessories, go to www.symbol.com/mc70 .	
Regulatory	
Electrical Safety	Certified to UL / cUL 80950-1, IEC / EN60950-1
Environmental:	RoHS-compliant
WLAN and Bluetooth:	USA: FCC Part 15 247, 15.407, Canada: RSS-210, EU: EN 300 328-1, EN 301 893, Japan: ARIB STD-T33, ARIB STD-T88, ARIB STD-T71, Australia: AS/ACIF S-018, AS TS 001
Quad Band GSM/EDGE (850, 900, 1800 and 900 bands)	Global: 3GPP TS 51 010, GCF approved module, USA: FCC Part 22, Part 24, Canada: RSS-102, RSS-133, EU: EN301 511, Australia: AS/ACIF S-018, AS TS 001
RF Exposure:	USA: FCC Part 2, FCC OET Bulletin 65 Supplement C, Canada: RSS-102, EU: EN 30380, Australia: AS/NZ 2772.1, ARPANSA
CDMA-EVDO Rev. 0	Verizon/Sprint/AllTel/Bell Mobility For latest information, contact your local Motorola representative
EMi/RFI:	North America: FCC Part 15, Canada: ICES 003 Class B, EU: EN55022 Class B, EN 301 485-1, EN 301 489-7, EN 310 489-17, EN 60601-1-2, Australia: AS/NZS CISPR A 22
Laser Safety:	IEC Class 2/FDA Class II in accordance with IEC90625-1/EN90625-1
For countries outside USA, Canada, European Economic Area, Japan or Australia, consult your local Motorola representative	
Warranty	
The MC70 is warranted against defects in workmanship and materials for a period of 12 months from date of shipment, provided that the product remains unmodified and is operated under normal and proper conditions.	



A full suite of accessories and 3rd-party peripherals provides convenient charging of MC70 devices and batteries as well as customization for a variety of vertical applications, from trigger handles that increase user comfort to Global Positioning Systems that provide 24-hour, three-dimensional position, velocity and time information to magnetic stripe readers that enable on-the-spot credit card processing and more.

GSM/EDGE Network Support



CDMA-EVDO Rev. 0 Network Support



Appendix 7: Multi-ISO HF RFID Reader Datasheet



Multi-ISO HF RFID reader for Symbol MC70 Terminal



The reader provides the Symbol™ MC70 with High Frequency (HF) RFID functionality. The HF RFID attaches as a snap-on to the Symbol terminal and houses both the RFID reader and the antenna. Power for the reader is obtained from the MC70. The HF RFID reader provides the ability to read and write to a wide variety of transponders at 13.56 MHz including ISO 15693, ICODE (I & II) and the complete Mifare family of ISO14443 (A&B). Flash upgradeability of the RFID reader firmware provides future proofing of the reader. The data output from the RFID reader may be simply incorporated into a Pocket PC application using the Software Development Kit (SDK).

The Reader is available as an Explorer kit which contains the reader, sample RFID tags, a Software Development Kit (which includes a demonstration application, the source code for that application and full reader documentation)

Applications include: e-Payment, e-Toll Road Pricing, Authentication, e-Ticketing for Events & Public Transport, Logistics & Supply Chain Management

Features and benefits:

- Mounts on the base of the MC70 terminal
- Symbol MC70 retains full laser bar code functionality and wireless LAN
- RFID reader is powered from the host terminal
- Multi ISO RFID reading and writing at 13.56 MHz
- High frequency (HF) industry standard ISO 15693 smart labels including Texas Instruments Tag-it™ and Philips ICODE II ISO15693 – 13.56 MHz
- Complete Mifare family of ISO14443 transponders
- Software development kit (SDK) available for development of custom applications
- Integrated SAM interface
- Customer installable assembly - easily removed from handheld but with the option of locking screws where a more permanent attachment is required.
- Compatible with existing Symbol single slot desktop docking/charging cradle. USB and MC70 charge connections are brought through to the base of the HF RFID reader to allow charging and ActiveSync over USB with the Reader attached.

Revision 1.2
Date: 23rd April 2007



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Technical specifications:

Performance Characteristics

RF Transmit Frequency	13.56MHz
Supported RFID Standards	ISO14443A, ISO14443B, ISO 15693, ISO 18000-3, iCODE
Supported Tag-ICs	Tag-it HF-I Tag-it HF-I Light S Philips iCODE SL2 Infineon ISO15693 MIFARE® Standard MIFARE® 4k MIFARE® Pro MIFARE® Ultralight MIFARE® DESFIRE MIFARE® SmartMX SLE 55Rx SRF55xxP +S SLE 66CL160G SLE 66CLX320F SR 176 SR D4K LR112 LR1164 LR1512 EM4105 KSWTemp Sense Sharp S ASK GTML ASK GTML 2ISO TOSMART P064 Jewel Tag (IRT0302B11 KSW) ISO14443A Tags ISO14443B Tags ISO15693 Tags
Reading distance	Up to 8cm (3") using ISO7810 size credit card format transponders.
RF Transmission Speed	Up to 848 kBits

SAM support

SAM clock	3.39MHz
SAM VCC	5V
SAM type	Form factor compatible with GSM SAM footprint

Current consumption

Current Consumption	< 150 mA during RFID read < 30mA in standby mode 0mA in shutdown mode
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User indication

Red, Green LEDs	Flash indicating activity (function may also be customised)
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Connection Interfaces

Physical interface	USB and power in to charge MC70
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Reader power supply	Powered from host terminal via USB
ActiveSync	
Physical Characteristics	
Dimensions	90x82x32mm (3.54"x3.23"x1.28")
Weight	95g (3.35 oz)
Enclosure material	Polycarbonate
Colour	Grey
Material finish	Spotted surface
Mechanical attachment	Snap-on action with optional locking screws
Docking	Attachment maintains dockability with Symbol docking cradle for charging and ActiveSync
Environmental	
Operating Temperature	-10°C to +50°C (-14°F to 122°F)
Storage Temperature	-40°C to +60°C (-40°F to 140°F)
Humidity	Up to 90% Relative humidity (Non-Condensing)
Drop specification	1.3m (4.26ft) to concrete, 6 drops per 6 sides over operating temperature; 1.5m (5ft) to concrete, 2 drops per 6 sides at ambient temperature 23°C (73°F)
Sealing	Internal components conformal coated
Electrostatic discharge	+/-15kV air discharge, +/-8kV direct discharge
Construction	RoHS compliant
Regulatory	
EMVRFI	EN 300 330, EN 301 489, CE marked
Electrical Safety	USA - FCC Part 15 Europe - EN60950-1 USA - UL60950
Notes	
All PCBs are conformality coated	



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Appendix 8: Zebra R-2844Z RFID Printer Datasheet

Specifications at a Glance*		 R2844-Z	<p>The compact R2844-Z is ideal for low-volume printing/encoding in space-constrained areas, such as for applications in:</p> <ul style="list-style-type: none"> • Healthcare/pharmaceutical • Assessment parks/entertainment venues • Libraries • Express parcel offices
<p>Standard Features</p> <ul style="list-style-type: none"> • RFID write/label printing and encoding • Direct thermal and thermal transfer printing of bar codes, text, and graphics • Compact design for easy mobile handling • Compact width (48 mm) for installation • Fully enclosed (17.5 x 17.5 cm) ready-to-use printer • 300 dpi DPM resolution • 300 dpi resolution (image quality) • Auto calibration • Auto-recovery (100 and 200 power modes) • Heating control 	<ul style="list-style-type: none"> • DirectPrint™ - TrueView readability speeds checkout • IntelliMail™ - requires optional IntelliMail™ PostNet™ (100) - 200 - and Intelligent Mail™ addresses for verification of postage rates charges • IntelliMail™ 8000 <p>Zebra Programming Languages</p> <ul style="list-style-type: none"> • Zebra programming languages: ZPL™ 2.0, ZPL™ - command language for Zebra printers • ZPL™ - works with ZPL™ to control and enhance text and data • Higher-level graphical extension (ZPL™) printer programming language: Zebra's optional data and ZPL™ to ZPL™ via ZPL™ to ZPL™ encoding 		
<p>Operating Characteristics</p> <p>Environment</p> <ul style="list-style-type: none"> • Operating temperature: 0-100°F (0-40°C) • Storage temperature: -40 to 140°F (-40 to 60°C) • Operating humidity: 10% to 90% non-condensing • Storage humidity: 5% to 95% non-condensing <p>Electrical</p> <ul style="list-style-type: none"> • Auto-detects RFID frequency (for Zebra's encoding) <p>Communications and Interface Capabilities</p> <ul style="list-style-type: none"> • Connects to parallel, USB, and wireless ports • RS-232 serial interface • 100 ft. l 	<p>Agency Approvals</p> <ul style="list-style-type: none"> • FCC Part 15C, Subpart C, Class B • FCC Part 15B, Subpart B, Class B (FCC ID: A64948) • CE Marking (EN 60950) • CE Marking (EN 60950) • CE Marking (EN 60950) • CE Marking (EN 60950) 		
<p>Media Characteristics</p> <p>Smart Labels</p> <ul style="list-style-type: none"> • Minimum label and label length: 100mm (4") • Maximum label and label width: 100mm (4") • Minimum label diameter: 100mm (4") • Maximum label diameter: 100mm (4") • Minimum label diameter: 100mm (4") • Maximum label diameter: 100mm (4") • Minimum label diameter: 100mm (4") • Maximum label diameter: 100mm (4") • Minimum label diameter: 100mm (4") • Maximum label diameter: 100mm (4") <p>Ribbon Characteristics</p> <ul style="list-style-type: none"> • Outer diameter: 30mm (1.18") • Inner diameter: 15mm (0.59") • Ribbon length: 100m (328ft) • Width: 30mm (1.18") • Ribbon type: Full-width ribbon • Core ID: 15mm (0.59") 	<p>RFID from your desktop</p> <p>The R2844-Z features a programmable print engine for flexible transponder placement. With a compact footprint and powerful processor, it delivers an economic and efficient solution for low-volume RFID desktop applications. Because the R2844-Z is fully upgradable, new RFID protocols can be added as they are developed.</p>		
<p>Fonts/Graphics/Symbologies</p> <p>Fonts and Character Sets</p> <ul style="list-style-type: none"> • Standard fonts: 10 Embedded, 1 variable-width (Zebra's Zebra™ Bold Condensed) • Supports user-defined fonts • BMP, GDI, Page 255 International Character <p>Graphic Features</p> <ul style="list-style-type: none"> • Supports user-defined graphics - including raster images <p>Options and Accessories</p> <ul style="list-style-type: none"> • 2000mAh battery with run-time of up to 10 hours • 2000mAh battery with run-time of up to 10 hours • 2000mAh battery with run-time of up to 10 hours 	<p>Barcode Symbologies</p> <ul style="list-style-type: none"> • Linear: Code 39, Code 128, Code 128B, Code 128C, Code 128F, Code 128G, Code 128H, Code 128I, Code 128J, Code 128K, Code 128L, Code 128M, Code 128N, Code 128O, Code 128P, Code 128Q, Code 128R, Code 128S, Code 128T, Code 128U, Code 128V, Code 128W, Code 128X, Code 128Y, Code 128Z, Code 128AA, Code 128AB, Code 128AC, Code 128AD, Code 128AE, Code 128AF, Code 128AG, Code 128AH, Code 128AI, Code 128AJ, Code 128AK, Code 128AL, Code 128AM, Code 128AN, Code 128AO, Code 128AP, Code 128AQ, Code 128AR, Code 128AS, Code 128AT, Code 128AU, Code 128AV, Code 128AW, Code 128AX, Code 128AY, Code 128AZ, Code 128BA, Code 128BB, Code 128BC, Code 128BD, Code 128BE, Code 128BF, Code 128BG, Code 128BH, Code 128BI, Code 128BJ, Code 128BK, Code 128BL, Code 128BM, Code 128BN, Code 128BO, Code 128BP, Code 128BQ, Code 128BR, Code 128BS, Code 128BT, Code 128BU, Code 128BV, Code 128BW, Code 128BX, Code 128BY, Code 128BZ, Code 128CA, Code 128CB, Code 128CC, Code 128CD, Code 128CE, Code 128CF, Code 128CG, Code 128CH, Code 128CI, Code 128CJ, Code 128CK, Code 128CL, Code 128CM, Code 128CN, Code 128CO, Code 128CP, Code 128CQ, Code 128CR, Code 128CS, Code 128CT, Code 128CU, Code 128CV, Code 128CW, Code 128CX, Code 128CY, Code 128CZ, Code 128DA, Code 128DB, Code 128DC, Code 128DD, Code 128DE, Code 128DF, Code 128DG, Code 128DH, Code 128DI, Code 128DJ, Code 128DK, Code 128DL, Code 128DM, Code 128DN, Code 128DO, Code 128DP, Code 128DQ, Code 128DR, Code 128DS, Code 128DT, Code 128DU, Code 128DV, Code 128DW, Code 128DX, Code 128DY, Code 128DZ, Code 128EA, Code 128EB, Code 128EC, Code 128ED, Code 128EE, Code 128EF, Code 128EG, Code 128EH, Code 128EI, Code 128EJ, Code 128EK, Code 128EL, Code 128EM, Code 128EN, Code 128EO, Code 128EP, Code 128EQ, Code 128ER, Code 128ES, Code 128ET, Code 128EU, Code 128EV, Code 128EW, Code 128EX, Code 128EY, Code 128EZ, Code 128FA, Code 128FB, Code 128FC, Code 128FD, Code 128FE, Code 128FF, Code 128FG, Code 128FH, Code 128FI, Code 128FJ, Code 128FK, Code 128FL, Code 128FM, Code 128FN, Code 128FO, Code 128FP, Code 128FQ, Code 128FR, Code 128FS, Code 128FT, Code 128FU, Code 128FV, Code 128FW, Code 128FX, Code 128FY, Code 128FZ, Code 128GA, Code 128GB, Code 128GC, Code 128GD, Code 128GE, Code 128GF, Code 128GG, Code 128GH, Code 128GI, Code 128GJ, Code 128GK, Code 128GL, Code 128GM, Code 128GN, Code 128GO, Code 128GP, Code 128GQ, Code 128GR, Code 128GS, Code 128GT, Code 128GU, Code 128GV, Code 128GW, Code 128GX, Code 128GY, Code 128GZ, Code 128HA, Code 128HB, Code 128HC, Code 128HD, Code 128HE, Code 128HF, Code 128HG, Code 128HH, Code 128HI, Code 128HJ, Code 128HK, Code 128HL, Code 128HM, Code 128HN, Code 128HO, Code 128HP, Code 128HQ, Code 128HR, Code 128HS, Code 128HT, Code 128HU, Code 128HV, Code 128HW, Code 128HX, Code 128HY, Code 128HZ, Code 128IA, Code 128IB, Code 128IC, Code 128ID, Code 128IE, Code 128IF, Code 128IG, Code 128IH, Code 128II, Code 128IJ, Code 128IK, Code 128IL, Code 128IM, Code 128IN, Code 128IO, Code 128IP, Code 128IQ, Code 128IR, Code 128IS, Code 128IT, Code 128IU, Code 128IV, Code 128IW, Code 128IX, Code 128IY, Code 128IZ, Code 128JA, Code 128JB, Code 128JC, Code 128JD, Code 128JE, Code 128JF, Code 128JG, Code 128JH, Code 128JI, Code 128JJ, Code 128JK, Code 128JL, Code 128JM, Code 128JN, Code 128JO, Code 128JP, Code 128JQ, Code 128JR, Code 128JS, Code 128JT, Code 128JU, Code 128JV, Code 128JW, Code 128JX, Code 128JY, Code 128JZ, Code 128KA, Code 128KB, Code 128KC, Code 128KD, Code 128KE, Code 128KF, Code 128KG, Code 128KH, Code 128KI, Code 128KJ, Code 128KK, Code 128KL, Code 128KM, Code 128KN, Code 128KO, Code 128KP, Code 128KQ, Code 128KR, Code 128KS, Code 128KT, Code 128KU, Code 128KV, Code 128KW, Code 128KX, Code 128KY, Code 128KZ, Code 128LA, Code 128LB, Code 128LC, Code 128LD, Code 128LE, Code 128LF, Code 128LG, Code 128LH, Code 128LI, Code 128LJ, Code 128LK, Code 128LL, Code 128LM, Code 128LN, Code 128LO, Code 128LP, Code 128LQ, Code 128LR, Code 128LS, Code 128LT, Code 128LU, Code 128LV, Code 128LW, Code 128LX, Code 128LY, Code 128LZ, Code 128MA, Code 128MB, Code 128MC, Code 128MD, Code 128ME, Code 128MF, Code 128MG, Code 128MH, Code 128MI, Code 128MJ, Code 128MK, Code 128ML, Code 128MM, Code 128MN, Code 128MO, Code 128MP, Code 128MQ, Code 128MR, Code 128MS, Code 128MT, Code 128MU, Code 128MV, Code 128MW, Code 128MX, Code 128MY, Code 128MZ, Code 128NA, Code 128NB, Code 128NC, Code 128ND, Code 128NE, Code 128NF, Code 128NG, Code 128NH, Code 128NI, Code 128NJ, Code 128NK, Code 128NL, Code 128NM, Code 128NN, Code 128NO, Code 128NP, Code 128NQ, Code 128NR, Code 128NS, Code 128NT, Code 128NU, Code 128NV, Code 128NW, Code 128NX, Code 128NY, Code 128NZ, Code 128OA, Code 128OB, Code 128OC, Code 128OD, Code 128OE, Code 128OF, Code 128OG, Code 128OH, Code 128OI, Code 128OJ, Code 128OK, Code 128OL, Code 128OM, Code 128ON, Code 128OO, Code 128OP, Code 128OQ, Code 128OR, Code 128OS, Code 128OT, Code 128OU, Code 128OV, Code 128OW, Code 128OX, Code 128OY, Code 128OZ, Code 128PA, Code 128PB, Code 128PC, Code 128PD, Code 128PE, Code 128PF, Code 128PG, Code 128PH, Code 128PI, Code 128PJ, Code 128PK, Code 128PL, Code 128PM, Code 128PN, Code 128PO, Code 128PP, Code 128PQ, Code 128PR, Code 128PS, Code 128PT, Code 128PU, Code 128PV, Code 128PW, Code 128PX, Code 128PY, Code 128PZ, Code 128QA, Code 128QB, Code 128QC, Code 128QD, Code 128QE, Code 128QF, Code 128QG, Code 128QH, Code 128QI, Code 128QJ, Code 128QK, Code 128QL, Code 128QM, Code 128QN, Code 128QO, Code 128QP, Code 128QQ, Code 128QR, Code 128QS, Code 128QT, Code 128QU, Code 128QV, Code 128QW, Code 128QX, Code 128QY, Code 128QZ, Code 128RA, Code 128RB, Code 128RC, Code 128RD, Code 128RE, Code 128RF, Code 128RG, Code 128RH, Code 128RI, Code 128RJ, Code 128RK, Code 128RL, Code 128RM, Code 128RN, Code 128RO, Code 128RP, Code 128RQ, Code 128RR, Code 128RS, Code 128RT, Code 128RU, Code 128RV, Code 128RW, Code 128RX, Code 128RY, Code 128RZ, Code 128SA, Code 128SB, Code 128SC, Code 128SD, Code 128SE, Code 128SF, Code 128SG, Code 128SH, Code 128SI, Code 128SJ, Code 128SK, Code 128SL, Code 128SM, Code 128SN, Code 128SO, Code 128SP, Code 128SQ, Code 128SR, Code 128SS, Code 128ST, Code 128SU, Code 128SV, Code 128SW, Code 128SX, Code 128SY, Code 128SZ, Code 128TA, Code 128TB, Code 128TC, Code 128TD, Code 128TE, Code 128TF, Code 128TG, Code 128TH, Code 128TI, Code 128TJ, Code 128TK, Code 128TL, Code 128TM, Code 128TN, Code 128TO, Code 128TP, Code 128TQ, Code 128TR, Code 128TS, Code 128TT, Code 128TU, Code 128TV, Code 128TW, Code 128TX, Code 128TY, Code 128TZ, Code 128UA, Code 128UB, Code 128UC, Code 128UD, Code 128UE, Code 128UF, Code 128UG, Code 128UH, Code 128UI, Code 128UJ, Code 128UK, Code 128UL, Code 128UM, Code 128UN, Code 128UO, Code 128UP, Code 128UQ, Code 128UR, Code 128US, Code 128UT, Code 128UU, Code 128UV, Code 128UW, Code 128UX, Code 128UY, Code 128UZ, Code 128VA, Code 128VB, Code 128VC, Code 128VD, Code 128VE, Code 128VF, Code 128VG, Code 128VH, Code 128VI, Code 128VJ, Code 128VK, Code 128VL, Code 128VM, Code 128VN, Code 128VO, Code 128VP, Code 128VQ, Code 128VR, Code 128VS, Code 128VT, Code 128VU, Code 128VV, Code 128VW, Code 128VX, Code 128VY, Code 128VZ, Code 128WA, Code 128WB, Code 128WC, Code 128WD, Code 128WE, Code 128WF, Code 128WG, Code 128WH, Code 128WI, Code 128WJ, Code 128WK, Code 128WL, Code 128WM, Code 128WN, Code 128WO, Code 128WP, Code 128WQ, Code 128WR, Code 128WS, Code 128WT, Code 128WU, Code 128WV, Code 128WW, Code 128WX, Code 128WY, Code 128WZ, Code 128XA, Code 128XB, Code 128XC, Code 128XD, Code 128XE, Code 128XF, Code 128XG, Code 128XH, Code 128XI, Code 128XJ, Code 128XK, Code 128XL, Code 128XM, Code 128XN, Code 128XO, Code 128XP, Code 128XQ, Code 128XR, Code 128XS, Code 128XT, Code 128XU, Code 128XV, Code 128XW, Code 128XX, Code 128XY, Code 128XZ, Code 128YA, Code 128YB, Code 128YC, Code 128YD, Code 128YE, Code 128YF, Code 128YG, Code 128YH, Code 128YI, Code 128YJ, Code 128YK, Code 128YL, Code 128YM, Code 128YN, Code 128YO, Code 128YP, Code 128YQ, Code 128YR, Code 128YS, Code 128YT, Code 128YU, Code 128YV, Code 128YW, Code 128YX, Code 128YY, Code 128YZ, Code 128ZA, Code 128ZB, Code 128ZC, Code 128ZD, Code 128ZE, Code 128ZF, Code 128ZG, Code 128ZH, Code 128ZI, Code 128ZJ, Code 128ZK, Code 128ZL, Code 128ZM, Code 128ZN, Code 128ZO, Code 128ZP, Code 128ZQ, Code 128ZR, Code 128ZS, Code 128ZT, Code 128ZU, Code 128ZV, Code 128ZW, Code 128ZX, Code 128ZY, Code 128ZZ 		
<p><small>*Specifications subject to change without notice. See the Zebra website for the most current specifications. © 2007 Zebra Technologies Corporation. All rights reserved. Zebra, DirectPrint, IntelliMail, and Zebra are trademarks of Zebra Technologies Corporation. All other trademarks are the property of their respective owners.</small></p>		<p>R2844-Z</p> <p>Maximum Print Area Width: 104mm (4.09") Height: 300mm (11.8")</p> <p>Resolution 300 dpi per inch (1200 dpi)</p> <p>Maximum Print Speed 300mm (11.8") per second</p> <p>Memory Standard: 64KB (256KB available for user) 4MB flash (2.5MB available for user) Optional: up to 8MB flash with optional dock (128MB total)</p> <p>Physical Characteristics Width: 104mm (4.09") Depth: 146mm (5.75") Height: 175mm (6.89") Weight: 1.4kg (3.08lb)</p> <p>Media Specifications Label and liner width: 25.4mm (1") to 109mm (4.25")</p>	

Appendix 9: Zebra Z-Band QuickClip RFID Wristband Datasheet



Zebra 54M™ printer for thermal wristband printing
Affordable and easy to use, the full-sized 54M printer offers outstanding value with its wide range of connectivity options, durable metal frame and case, and full 8 inch wristband roll capacity for high volume admissions.

Zebra H 2824-Z™ direct thermal wristband printer
The economical, compact H 2824-Z printer is ideal for printing bar coded patient identification wristbands in seconds. Use it to print on a variety of wristband types and sizes, including narrow pediatric widths.

Zebra wristbands now feature our new antimicrobial coating!
Laboratory tests prove that it eliminates the three leading causes of hospital infections in the United States.

>Create sharp, clean wristbands that last — with Zebra's wristband family.

☺

For optimum print quality and printer performance, use Genuine Zebra Supplies. Need a custom solution? Call +1 866 250 9405.

	<p>Z-Band® Direct Wristbands</p> <p>Z-Band Direct wristbands meet healthcare patient ID and safety requirements, including those defined by JCAHO and HHS/A.</p> <p>Band sizes • Adult, Child, Neonatal</p> <p>Closure • High-performance, pressure-sensitive, acrylic based adhesive with tamper-evident slit.</p>
	<p>Z-Band QuickClip® Wristbands</p> <p>Zebra's Z-Band QuickClip is a durable and secure system ideal for positive patient identification. Direct thermal technology requires no printer ribbon, so changing wristband rolls is quick and easy.</p> <p>Band sizes • Adult</p> <p>Closure • Color-coded clip: White, Red, Blue, Green, Yellow, Pink.</p>
	<p>Z-Band 4000 and Z-Band 4000 Void</p> <p>Zebra's Z-Band 4000 wristbands offer excellent print quality for accurate patient tracking. A tamper-proof (VOID) version is available for an added level of security on sensitive patient identifications. Thermal transfer printing transfers the image via a ribbon.</p> <p>Band sizes • Adult</p> <p>Closure • Z-Band 4000: Permanent, acrylic based adhesive. Z-Band 4000 VOID: Pressure-sensitive acrylic based adhesive. The word "VOID" is revealed if the wristband is removed. U.S. Patent 5,364,110.</p>



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Appendix 10: Acknowledgements Continued...



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9.0 References

Agiwal, A., Khandpur, P., and Saran, H. 2004. LOCATOR: location estimation system For wireless LANs. In Proceedings of the 2nd ACM international Workshop on Wireless Mobile Applications and Services on WLAN Hotspots (Philadelphia, PA, USA, October 01 - 01, 2004). WMASH '04. ACM Press, New York, NY, 102-109.

ALR 9800. (2005). Device Profile: Alien Technology ALR-9800 RFID reader, LinuxDevices.com (2005), Retrieved May 2007, from <http://www.linuxdevices.com/articles/AT6045402903.html>

Alsos, O. A. and Svanæs, D. 2006. Interaction techniques for using handhelds and PCs together in a clinical setting. In Proceedings of the 4th Nordic Conference on Human-Computer interaction: Changing Roles (Oslo, Norway, October 14 - 18, 2006). A. Mørch, K. Morgan, T. Bratteteig, G. Ghosh, and D. Svanaes, Eds. NordiCHI '06, vol. 189. ACM Press, New York, NY, 125-134.

Atwood, J. (2004). Who needs a stored procedure anyways? Programming Horror. Retrieved May 2007, from <http://www.codinghorror.com/blog/archives/000117.html>

Borriello, G. 2005. Introduction. Commun. ACM 48, 9 (Sep. 2005), 34-37.

Cambridge Consultants (2004) `Ensuring patients are correctly matched with samples or specimens taken from them and treatment planned for them', January 2004, from <http://www.npsa.nhs.uk>

Carpentiere, C (2004). An Evaluation of Stored Procedures for the .NET Developer, .NET Development (General) Technical Articles, MSDN 2004. URL = <http://msdn2.microsoft.com/en-us/library/ms973918.aspx>

CDCS, Napier University (2006), Centre for Distributed Computing and Security, P2, Retrieved May 2007 from http://www.dcs.napier.ac.uk/~bill/res_main.html

Chavda, K. F. 2004. Anatomy of a Web service. J. Comput. Small Coll. 19, 3 (Jan. 2004), 124-134.

Cisco (2006), Wi-Fi Based Real-Time Location Tracking: Solutions and Technology, Wireless Network Security, White Paper s (2006). Cisco Press. URL = http://www.cisco.com/en/US/netsol/ns340/ns394/ns348/ns386/networking_solutions_white_papers_list.html

Cisco (2006), Wireless Curriculum, Introduction to Wireless LANs, C1 and 3-5 Retrieved May 2007 from Cisco Online

ConnectRFID (n.d.), About Us Information, P1-2, Retrieved May 2007 from <http://www.connectrfid.ie/aboutus.htm>

CST (2006), RFID Transponder operating at 13.56 MHz, Computer Simulation Technology, Retrieved Aug 2006, from <http://www.cst.com/Content/Applications/Article/137>

D. Wan, "Magic Medicine Cabinet: A Situated Portal for Consumer Healthcare" in Proceedings of First International Symposium on Handheld and Ubiquitous Computing (HUC '99), September 1999.

Dumont Y (2006), SATO HF RFID Tags, News, Retrieved May 2007 From http://www.satoeurope.com/en/news/2006/060227_UPMraflatac.html

EMS (n.d.), HF Tags, Products, Retrieved May 2007, from <http://info.ems-rfid.com/mainmenu1/products/hf/tags/index.html>

Hawkes, P. (1994). Supertag – Stock Counting off Its Trolley. MCB University Press. Sensor Review, 14(3), P23-25

HIPAA. (2001). HIPAA Security for Wireless Networks. Netmotion Wireless (2001). URL = <http://www.hipaadvisory.com/tech/wireless.html>

Ho, L., Moh, M., Walker, Z., Hamada, T., and Su, C. 2005. A prototype on RFID and sensor networks for elder healthcare: progress report. In Proceeding of the 2005 ACM SIGCOMM Workshop on Experimental Approaches To Wireless Network Design and Analysis (Philadelphia, Pennsylvania, USA, August 22 - 22, 2005). E-WIND '05. ACM Press, New York, NY, 70-75.

ITP NYU(n.d.), Active RFID Tag from Texas Instruments, Blog Archives ITP NYU, Retrieved May 2007, From http://itp.nyu.edu/~gml229/blog/archives/IMG_2333.JPG

J.A. Wolff, RFID tags - an intelligent bar code replacement, IBM Global Services, Retrieved Oct 2006, from <http://ibm.com/services>.

McKelvin, M. L., Williams, M. L., and Berry, N. M. 2005. Integrated radio frequency identification and wireless sensor network architecture for automated inventory management and tracking applications. In Proceedings of the 2005 Conference on Diversity in Computing (Albuquerque, New Mexico, USA, October 19 - 22, 2005). TAPIA '05. ACM Press, New York, NY, 44-47.

Motorola (2007), Timeline of Motorola, P35, Retrieved May 2007 from <http://www.motorola.com/content.jsp?globalObjectId=7632-10812>

MSDN (2006), how to send raw data to a printer by using Visual C# .NET, help and Support, Retrieved Nov 2006, from <http://support.microsoft.com/kb/322091>

Murphy, M.F. and Kay, J.D.S. (2004) 'Patient identification: problems and potential solutions', Vox Sanguinis, Vol. 87, No. 2, pp.S197±S202, Blackwell Publishing.

Napier University (n.d.), Information for prospective international students, P1, Retrieved May 2007 from <http://www.napier.ac.uk/international/default.aspx>

NHS (n.d.), About the NHS, P1-2, Retrieved May 2007 from <http://www.nhs.uk/England/AboutTheNhs/Default.cmsx>

NHS MidTECH (n.d.), About MidTECH, P1, Retrieved May 2007 from http://www.midtech.org.uk/about_midtech.html

Ni, L. M., Liu, Y., Lau, Y. C., and Patil, A. P. 2004. LANDMARC: indoor location sensing using active RFID. *Wirel. Netw.* 10, 6 (Nov. 2004), 701-710.

Niculescu, D. and Nath, B. 2004. VOR base stations for indoor 802.11 positioning. In *Proceedings of the 10th Annual international Conference on Mobile Computing and Networking (Philadelphia, PA, USA, September 26 - October 01, 2004)*. *MobiCom '04*. ACM Press, New York, NY, 58-69.

NPSA (2005), Wristbands for hospital inpatients improves safety, Safer Practice Notice, 22 November 2005 (11), 1-6, From http://www.npsa.nhs.uk/site/media/documents/1440_Safer_Patient_Identification_SP_N.pdf

Patents (2006). *Patents and Designs Journal* No 6130. *The Patents and Designs Journal*, 15 November 2006 (6130), 5606.

POS Systems (2006), Giga-TMS RWD145 PDA RFID reader/writer, Products. Retrieved May 2007, From http://www.pos4u.nl/product_info.php?products_id=433

Radio-frequency identification. (n.d.). Wikipedia. Retrieved May , 2007, from <http://www.answers.com/topic/radio-frequency-identification-1>

RFID Journal (2006), Wal-Mart Details RFID Requirement, NEWS, Retrieved May 2007 From <http://www.rfidjournal.com/article/articleview/642/1/1/>

RFID Journal (n.d.), a Guide to Understanding RFID, Retrieved May 2007, From <http://www.rfidjournal.com/article/gettingstarted/>

RFID. (n.d.). *Computer Desktop Encyclopedia*. Retrieved May, 2007, from <http://www.answers.com/topic/radio-frequency-identification>

RIGHTreader (2006). Next Generation RFID Systems, Products. Retrieved May 2007, from http://www.righttag.com/buyrfid/index.php?main_page=product_info&cPath=1&products_id=40

Robling Denning, D. E. 1982 *Cryptography and Data Security*. Addison-Wesley Longman Publishing Co., Inc.

Royal College of Nursing (2005) 'Right blood, right patient, right time', RCN guidance for improving transfusion practice, London.

Symbol MC70 (2006), MC70 Rugged Enterprise Digital Assistant Mobile Computer from Symbol, Retrieved May 2007. From <http://www.symbol.com/products/mobile-computers/enterprise-class/mc70>

Thuemmler, C., Buchanan, W. and Kumar, V. (2007) Setting safety standards by designing a low-budget and compatible patient identification system based on passive RFID technology, *Int. J. Healthcare Technology and Management*, 8(5), pp.571 - 583.

UHB NHS (n.d.), About the Trust Profile, P1-5, Retrieved May 2007 from <http://www2.uhb.nhs.uk/About/Trust%20Profile.aspx>

VanLengen, C. A. and Haney, J. D. 2004. Creating web services using ASP.NET. J. Comput. Small Coll. 20, 1 (Oct. 2004), 262-275.

Varshney, U. and Vetter, R. 2000. Emerging mobile and wireless networks. Commun. ACM 43, 6 (Jun. 2000), 73-81.

Wang, S., Chen, W., Ong, C., Liu, L., and Chuang, Y. 2006. RFID Application in Hospitals: A Case Study on a Demonstration RFID Project in a Taiwan Hospital. In Proceedings of the 39th Annual Hawaii international Conference on System Sciences - Volume 08 (January 04 - 07, 2006). HICSS. IEEE Computer Society, Washington, DC, 184.1.

Wexler J and World N. (2006). All about Wi-Fi location tracking. Mobile Computing & Wireless Networking Briefings (April 2006). TECHWORLD 2006. URL = <http://www.techworld.com/mobility/features/index.cfm>

Wu, F., Kuo, F., and Liu, L. 2005. The application of RFID on drug safety of inpatient nursing healthcare. In Proceedings of the 7th international Conference on Electronic Commerce (Xi'an, China, August 15 - 17, 2005). ICEC '05, vol. 113. ACM Press, New York, NY, 85-92

Yasar, A., Ansari, M. A., and Farooqui, S. 2006. Low cost solution for location determination of mobile nodes in a wireless local area network. In Proceedings of the 2006 ACM SIGCHI international Conference on Advances in Computer Entertainment Technology (Hollywood, California, June 14 - 16, 2006). ACE '06. ACM Press, New York, NY, 68.

Zàruba, G. V., Huber, M., Kamangar, F. A., and Chlamtac, I. 2007. Indoor location tracking using RSSI readings from a single Wi-Fi access point. Wirel. Netw. 13, 2 (Apr. 2007), 221-235.

Zebra (n.d.), Corporate Background Information, P1-2, Retrieved May 2007, from http://www.zebra.com/id/zebra/na/en/index/about_zebra/our_company/corporate_background.html

Zebra. (2007) Laboratory Testing of Zebra's Z-Band® Direct Thermal Wristbands with Antimicrobial Coating, Technical Specifications. Retrieved May 2007, from <http://www.Zebra.com>