DESIGN AND IMPLEMENTATION OF A HYBRID RFID-GPS HUMAN TRACKING SYSTEM

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ABSTRACT

In pervasive computing research, object tracking and specification is an emerging trend. Researchers have been working on ways to allow people to work safely and freely within certain environments. With the use of RFID technology, objects can become part of real-world communication indoors while GPS tracking accommodates outdoor environments. The RFID-GPS hybrid system uses features from both technologies to provide a robust location tracking system that covers a wide variety of applications, including the tracking of animals, vehicles or people. This can be used to improve the safety of important or vulnerable members of society, particularly in developing countries where persecution and kidnapping are rampant. For example, the rate at which medical practitioners are being kidnapped has hit 41%, which makes it imperative for this study to develop an application that facilitates a safer commute and possible monitoring. To this end, an approach based on comprehensive studies is proposed using simulation to evaluate the suitability of epidermal RFID tags (implanted under the skin of participants) in a hybrid RFID-GPS tracking system operating under the IoT paradigm. The study's model aims at improving the safety of doctors by assigning them IDs using unique UHF passive RFID tags that operate at a frequency of 868 MHz, which is regionally altered. The RFID tag was designed and simulated through technical methodology using Matlab, the Simulink environment and relevant system middleware prototyped through the Microsoft ASP MVC platform. Using these technologies, the GPS coordinates of the research-based area and the virtual floor plan of the unified centre are included in the system. This was to allow end users to visualise system performance on Google Maps and within the building parameters. The results showed that the simulated tag had a high transmission rate with a corresponding factor of γ =0.6, almost 1.57 dBi power gain, and a reading distance of nearly 4 metres. The system's middleware contains outstanding features such as innovative, fast and accurate real-time location tracking. It has been proven to guarantee the safety of doctors in hospitals/fieldwork, and is ready for actual establishment at a unified centre.

Keywords: RFID, Hybrid RFID-GPS applications, Security threats, Human tracking system, GPS coordinates.

REKA BENTUK DAN PERLAKSANAAN SISTEM PENJEJAK MANUSIA HIBRID RFID-GPS

ABSTRAK

Dalam menyebarkan penyelidikan pengkomputeran, pengesanan objek dan spesifikasi adalah trend yang baru muncul. Pengkaji telah berusaha sedaya upaya untuk membolehkan orang bekerja dengan selamat dan bebas dalam persekitaran yang tertentu. Dengan menggunakan teknologi RFID, objek boleh dijadikan sebagai sebahagian dunia komunikasi dalaman manakala penjejak GPS menampung persekitaran luaran. Sistem hibrid RFID-GPS menggunakan ciri dari kedua-dua teknologi itu untuk menyediakan sistem penjejak yang mantap yang merangkumi pelbagai aplikasi, termasuklah menjejaki haiwan, kenderaan atau orang. Ia boleh digunakan untuk memperbaiki kepentingan keselamatan atau terdedah kepada ahli masyarakat, khususnya dalam negara-negara yang membangun yang mana penganaiyaan dan penculikan adalah berleluasa. Sebagai contoh, kadar pengamal perubatan yang diculik telah mencecah 41%, yang mana membuatkan ianya mustahak bagi kajian ini untuk membangunkan sebuah aplikasi, yang memudahkan lebih selamat berulang-alik dan pemantauan yang mungkin. Untuk pengakhiran ini, pendekatan berdasarkan kajian komprehensif adalah dicadangkan menggunakan simulasi untuk menilai kesesuaian epidermis tag RFID (ditanam di bawah kulit peserta) dalam sistem hibrid RFID-GPS yang beroperasi di bawah paradigma IoT. Kajian model bertujuan meningkatkan keselamatan doktor dengan menyerahkan ID mereka yang menggunakan unik UHF pasif tag RFID yang beroperasi pada frekuensi 868 MHz, yang mana secara serantau diubah. Tag RFID telah dibentuk dan disimulasi menerusi metodologi teknikal menggunakan Matlab, persekitaran *Simulink* dan sistem prototaip *middleware* yang relevan melalui platfom Microsoft ASP MVC. Menggunakan teknologi ini, kawasan yang berasaskan kajian kordinat GPS dan pelan lantai maya pusat bersatu dimasukkan ke dalam sistem untuk menggambarkan/mengakseskan prestasi sistem pada Google Maps dan dalam parameter bangunan. Keputusan menunjukkan yang tag simulasi mempunyai kadar penghantaran yang tinggi dengan faktor yang sama dengan γ =0.6, hampir keuntungan kuasa 1.57 dBi, dan bacaan jarak hampir 4 meter. Sistem *middleware* mengandungi ciri-ciri yang menonjol seperti inovatif, laju dan menjejak lokasi tepat masa sebenar. Ia telah terbukti untuk menjamin keselamatan doktor di hospital/di kerja lapangan, dan ia bersedia untuk penubuhan sebenar di pusat bersatu.

Kata Kunci: RFID, aplikasi Hibrid RFID-GPS, Ancaman keselamatan, Sistem penjejak manusia, Kordinat GPS.

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LIST OF SYMBOLS AND ABBREVIATIONS

IoT	:	Internet of Things
RFID	:	Radio Frequency Identification Technology
GPS	:	Geographical Positioning System
GIS	:	Geographical Information System
WSN	:	Wireless Sensor Network
EAS	:	Electronic Article Surveillance
ISO		International Organisation for Standardization
IEC	:	International Elector-Technical Committee
EAN	:	Electrical Article Numbering
GSI	:	Global Standards System
UPC	:	Universal Product Code
UCC	:	Uniform Code Council
EPC	:	Electronic Product Code
UHF	:	Ultra-High Frequency
UWB	:	Ultra-Wideband
LEO	:	Low Earth Orbit
IC	:	Integrated Circuit
CP	:	Circular Polarisation
RHCP	:	Right Hand Circular Polarisation
AR	:	Axial Ratio
ERP	:	Effective Radiated Power
EIRP	:	Equivalent Isotopically Radiated Power
ASP	:	Active Serve Page
GUI	:	Graphical User Interface

CHAPTER 1: INTRODUCTION

1.1 Overview

The first chapter covers the discussion on the application of RFID tags in various human tracking systems. This includes security concerns in different societies, the aim of the study, the motivation behind the use of IoT technology in human security and the boundary scope for system implementation.

1.2 Introduction

Pervasive computing is defined as 'platforms of different connected devices used to understand activities in surrounding environments.' In the late 1980s, researchers investigated the interfaces between human to human interaction using technology and, as a result, ubiquitous computing was formed. The concept of ubiquitous computing reveals that pervasive computing is not limited to just one platform. It can be embedded into many devices and used to exchange data any time. This makes it seem like almost every "thing" around us is interconnected and these are the main terms of IoT (Gubbi et al., 2013; D. Saha & Mukherjee, 2003). The IoT paradigm was launched with radio frequency identification (RFID) and wireless sensor technology in around 1991 by Kevin Ashton. He was working in the supply chain management and was the executive director of the auto RFID and sensor technology centre in MIT (Ashton, 2009; Shancang Li et al., 2015). During that time, the IoT was regarded to be an unsustainable vision. It was only later that competition and innovation began in the IoT sector to make everything around us interconnected using the word "smart". This ultimately brought qualitative changes in people's lifestyles. The emergent phenomenon of IoT technology became more dominated by physical objects linked to the Internet via various types of object recognition technologies such as GPS, GIS, WSN and RFID. RFID is an adhesive technology; its initial forms were continuous radio wave generators and transmitters in the late 1960s. The next generation was radar launched for use during World War II. The

RFID standards are gradually being strengthened making it a part of everyday life in the 21st century (Landt, 2005). Today, RFID is leveraged in many sectors such as manufacturing, healthcare, transportation and tracking applications that grasp human life towards smart life indoors (Bansal, 2003; Naskar et al., 2017). Additionally, GPS plays a more dominant role by providing information in outdoor environments compared to its counterparts. As a working pattern it uses radio signals received from satellites and transmitted to corresponding objects for tracking and navigation. However, GPS functions diminish underground and underwater, and it cannot accommodate indoor environments. In contrast, RFID is the fastest and most advanced technology that includes the fundamental features and facilities required for indoor tracking. It is also widely used and available at affordable costs.

RFID, GPS, GPRS and WSN technologies operate simultaneously under the IoT paradigm to identify and verify objects. Various RFID and GPS systems are built that can be used to track humans and are often incorporated into adhesive RFID tags (Abbasi & Shaikh, 2008; Al-Ali et al., 2008; D. Kravets, 2012; Deepika & Usha, 2016; Hutabarat et al., 2016; Kalid & Rosli, 2017; Karthika et al., 2015; Pang et al., 2018; Shaaban et al., 2013). Existing RFID systems can face difficulties caused by the ineffective placement of tags and readers. They may also have constraints caused by interface, scalability, privacy and security concerns. The most challenging application is the epidermal RFID tag, developed for health-related purposes. It has been reported that reduced efficiency and defects often range occur in many healthcare applications used to track patients for the sake of timely treatment (Amendola et al., 2015).

1.3 Problem Statement

Globally, with the increase in human security concerns, there is high demand on technology that enhances people's safety. Recent evidence shows that human security threats continue to rise in developing countries such as in Afghanistan, Pakistan, India, Nepal and Bangladesh. Medical practitioners and children are continuously abducted in such countries (Ambesh, 2016; Baykan et al., 2015). The abductions of medical personnel in Afghanistan and Baluchistan located in the western part of Pakistan has been a major cause of distress to doctors and their families. News reports from (Pajhwoknews, 2017) highlighted different incidents, where it was confirmed that 6 doctors were kidnapped for ransom in eastern region of Afghanistan. Neither the hospital nor their families were able to find them at the moment. Similarly, survey indicated the rate of kidnappings to be 41% in reports from areas this research was based upon (Appendix A).

The surveillance of people is a serious contemporary concern, especially for government authorities and human rights organisations. Fortunately, RFID and GPS technologies have shown great results when it comes to tracking and identifying people in both indoor and outdoor environments (Mautz, 2012). A variety of RFID and GPS systems have been used to track students in schools by applying embedded RFID chips into student clothing (D. Kravets, 2012). Attaching an RFID chip onto a student's bag resulted in better detection rates than tags embedded in pockets and neck accessories (Shaaban et al., 2013). RFID chips embedded in bracelets were tested in the global village of Dubai (Al-Ali et al., 2008). Other RFID applications included cards or key chains carried by intended individuals, depending on the applications (Abbasi & Shaikh, 2008; Deepika & Usha, 2016; Hutabarat et al., 2016; Kalid & Rosli, 2017; Karthika et al., 2015; Pang et al., 2018). Such RFID systems were perceived to have disadvantages in some features including handful mechanisms that have a tendency to be get lost, forgotten, damaged or misused by intruders or imposters. Interface limitations, security/privacy concerns, mapping coverage and the recording of real-time location tracking are also constraints that some systems faces. As such, the model used for this study is a sophisticated RFID and GPS coordinate-based human tracking system that utilises microflexible tag mechanisms implanted into a doctor's skin. The modelling of such a system will significantly improve the safety of medical practitioners and can potentially save their lives.

1.4 Research Aim

The aim of the present study is to develop a human tracking system that could monitors doctors' movements in hospitals and during fieldwork.

1.4.1 Research Questions

The following questions were established to achieve the aim of this study:

- What suitable mechanism can be applied to an RFID and GPS coordinate-based human tracking system to monitor doctor's movement in healthcare?
- How can RFID and GPS coordinate-based human tracking system be developed?

1.4.2 Research Objectives

The objectives of the study are:

a) To simulate and evaluate possible mechanisms for an RFID tag in a human tracking system.
b) To implement a human tracking system using RFID and GPS.
c) To test the developed human tracking system using RFID and GPS.

1.5 Motivation

Safety remains a big challenge in the era of modern globalisation. Many entities, especially human rights organisations, look for ways to provide best security to people. Researchers look for the best techniques on how to provide that security. Fortunately, new technologies such as the Internet of things (IoT), RFID and the global positioning system (GPS) can be used to create smart tracking systems that provide the best security assurance to people (Shancang Li et al., 2015). With RFID, objects can be traced within indoor environments while GPS is used in outdoor environments. It is best to combine the features of both technologies to produce sufficiently accurate real-time detection of objects within indoor and outdoor environments. RFID can identify and locate objects via attached tags that can transmit electromagnetic wave radiation to readers. This remarkable feature is one of the main motivations behind RFID systems. Other features are flexibility, ease of use, cost efficiencies and a wide range of benefits. Similarly, GPS plays a dominant role in real-time tracking and navigation. It provides enough precision for object detection outdoors (Mulla et al., 2015). The features of both RFID and GPS have revolutionised smart/automatic human tracking within the IoT paradigm facilitating detection and monitoring. This can be used to further reduce security threats and advance security measures (Bhayani et al., 2016; H. N. Saha et al., 2017).

Researchers have invented various types of smart human tracking systems for various purposes such as the safety of children going to school, providing timely medication for the elderly, navigation aid to people who are blind and the timely monitoring and control of patients with serious symptoms. But existing human tracking systems still have issues caused by ineffective placement of tags/readers as well as constraints in terms of interface, scalability, privacy and security concerns. In this study, a simulation model is proposed for an integrated RFID system with GPS coordinates using an epidermal RFID tag. Focus was also placed on chip and antenna fundamentals such power gain, polarisation and distance measurements to evaluate tag performance and whether or not it is suitable for epidermal applications in a human security. This would be applied to a tracking system for use to guaranteeing the safety of medical practitioners.

1.6 Scope of the Study

The Mirwais Regional Hospital in the Kandahar Zone was chosen as an appropriate future epicentre of such a prototype due to the high rate of kidnappings reported by survey there (approximately 41%). This research reflects on areas of all deserted societies where majority of medical practitioners are targeted. It also discusses the potential limitations and drawbacks of various RFID embedding solutions including tags in clothing, bracelets, student bags, cards and keychains. Have often feared to be miss-placed or being used by prohibited user or getting damaged.

1.7 Summary

This research examines security applications that can be employed for both general use as well as in areas or societies marked by high kidnapping rates. An analysis of barriers faced by different human tracking systems is conducted in the second chapter and has set the viable objectives. This will determine the most suitable method for embedding RFID tags for use with participants so that they operate within a tracking system to track the movement of doctors at the hospital or during fieldwork effectively, and significantly improving the safety of medical practitioners.

Many Researchers have built human tracking systems using RFID and GPS technology for different purposes. However, these systems still have issues caused by ineffective tags/readers placement as well as constraints in terms of interface, scalability, privacy and security concerns (Abbasi & Shaikh, 2008; Al-Ali et al., 2008; D. Kravets, 2012; Deepika & Usha, 2016; Hutabarat et al., 2016; Kalid & Rosli, 2017; Karthika et al., 2015; Shaaban et al., 2013). The epidermal RFID tag, developed for health-related purposes, poses one of the biggest challenges. It has been reported that reduced efficiency and defects often range occur in many healthcare applications used to track patients for the sake of timely treatment (Amendola et al., 2015). In this study, a simulation model is proposed for an integrated RFID system with GPS coordinates using an epidermal RFID tag. This system focuses on chip and antenna fundamentals such as power gain, polarisation and distance measurements to evaluate tag performance and whether or not it is suitable for epidermal use/for induced into skins; and development of the relevant middleware. These were combined to form a human tracking system that utilises the IoT paradigm, RFID and GPS coordinates to ensure the security of doctors.

1.8 Structure of Thesis

This document contains seven chapters. The first chapter consists of the analysis of core issues, goal setting, the scope of the study and the structure-setting of the thesis. The next chapter discusses the problems in human tracking systems discovered by different researchers. It further highlights the rise of security threats to people in the community that the research focuses on. Finally, a discussion on RFID and GPS integration into RFID mainstream under the IoT paradigm is provided. The third chapter illustrates the research methodologies employed. Chapter 4 provides a proposed solution to research objectives and the preferred design and architecture for the respective system. Chapter 5 presents a step-by-step implementation of the proposed solution. Chapter 6 discusses unit tests carried out to confirm system results. Finally, Chapter 7 summarises the conclusion and highlights the potential of future work.

CHAPTER 2: REVIEW OF THE LITERATURE

2.1 Overview

This Chapter examines previous studies undertaken by different researchers to improve human security by using different technologies such as RFID, GPS and combined forms under the IoT paradigm. It explains the methods used by researchers, which methods are preferred and how they are related. General security threats faced by medical practitioners in research based society and a broadly are also discussed. The various technologies (IoT, RFID, GPS) and their combined forms are analysed in order to choose the best fit or platform for this research.

2.2 Internet of Things (IoT)

Billions of objects are expected to play a leading role in future networks bringing physical world data into the digital world. Physical object identification and connection to the surrounding environment is in great demand today. RFID and GPS are the key technologies for object identification and work simultaneously under the IoT paradigm. The Internet of things (IoT) is a concept that encompasses a wide range of technologies and areas of research aimed at creating a smart surrounding environment. This is done by introducing interactions between objects via network shapes that function together and operate with a common set of protocols and minimal human intervention towards a shared goal. It has brought about a new generation of design called the smart object. IoT and adhering technologies are expected to bring a spike in global interconnection by using just one word: "smart". The idea of smart communication came from the 1980s but it gained popularity in the early 1990s. The first smart coke vendor's initiative was by Carnegie Mellon University; it used the internet to connect programmers to a vending machine allowing them to check cold drinks inside. The IoT outlet was withdrawn at MIT in the 1990s by the auto RFID and sensor technology centre (Atzori et al., 2014; Bhayani et al., 2016; Chase, 2013; López et al., 2012; Stankovic, 2014). In 1999, IoT was produced by Kevin Ashton who was working in the field of the supply chain management and was an executive director of the auto RFID and sensor technology centre, MIT (Ashton, 2009). Technology also improved by using wireless technologies such as Bluetooth, RFID, Wi-Fi and sensors. The Internet is evolving to change from a specific network involving only certain devices to a huge network formed via information, communication between everyday objects and specifications that define each object. This large web-based network is known as the Internet of things (IoT). Today, with IoT, there are over 9 billion connected devices and this is expected to increase to 24 billion by 2020.

IoT has various definitions. The auto RFID and sensor technology centre at MIT defined it as 'the network of interconnected worldwide objects being uniquely addressed via standard communication protocols.' Atzori et al. stated it to be 'The framework of three paradigms: middleware (Internet-oriented) design, sensory (things-oriented) design and knowledge (semantically-orientated).' A recent definition of IoT is 'any concept where physical objects are connected via the internet by providing unique identifiers to enable their identification to other devices and the ability to continuously generate and transmit data over the network' (Ndibanje et al., 2014). All other definitions of IoT tended to be similar to the ones listed above, stating that all objects under the IoT paradigm communicate over a particular communication protocol.

2.2.1 IoT Architectures

The architecture of the Internet of things (IoT) was designed such that it can handle a large amount of traffic along with a large mass of data in any instance. It is one of the most reliable structures that can be set up with any element of the smart device connected via the network. On IoT, billions of relevant objects will create superior streams of traffic that require more data storage. Investigators usually suggest various types of IoT architectures, but all previous architectures are based on three main sections, as highlighted below.

First is the hardware section. All devices that can sense and uniquely identify perceived data fall under this section. As a rule, these are sensors but can be RFID, GPS and/or smart devices. They are responsible for collecting raw data from the target, producing supporting information and submitting it back to the middleware section. The second section, known as middleware, has the responsibility of storing and analysing data. The third section is presentation, where data can be visualised. As a main part, GPS can be combined with RFID to enhance indoor location; something that could not be achieved via GPS alone (Al-Fuqaha et al., 2015; Bhayani et al., 2016; Gubbi et al., 2013; Stankovic, 2014; Vermesan et al., 2011; Wu et al., 2010).

2.3 Radio Frequency Identification (RFID) Technology

2.3.1 Brief Overview of RFID Technology

RFID or radio frequency identification is a wireless sensor technology and key component of automatic identification technologies such as barcodes, magnetic inks, biometrics and touch memory. RFID is the ultimate object identification technology. It stores and retrieves data via electromagnetic transmission to an RF compatible integrated circuit (antenna & microchip) known as an RFID tag. This is a proven technology that has been in use since the 1970s. The landmark theory behind this technology was developed through 1935 to the 1950s. There are a number of theoretical investigations of RFID techniques with published scientific papers. In the early 1960s, prototype systems of such technologies were developed by different inventors. In 1960, the first RFID tag was presented to the world by Ernst F.W. Alexanderson. His initial design was equipped with a continuous radio wave generator and a transmitter. The next generation appeared in the form of radar used during World War II in the early 20th century. The company

(Sensormatic and Checkpoint) launched the first commercial RFID application with the electronic article surveillance (EAS) system using a 1-bit RFID tag for anti-theft detection for use on high-value items in retail stores. In the late 1970s, the competition between researchers, developers and academic institutions was to incorporate RFID tags in a wide array of applications. In the 1980s, RFID applications were expanded to several areas. In Europe, RFID was used for animal tracking, roads and toll applications in Italy, Norway and Sweden. RFID was also implemented in different applications for healthcare, manufacturing, transportation, commercial and human tracking. It has gradually become a part of daily life by the 21th century (Ahson & Ilyas, 2017; Chiesa et al., 2002; Landt, 2005; Suhong Li et al., 2006; Roberts, 2006).

Today, the development of RFID standards, the utilisation of human tracking applications and RFID applications that allow for greater control of company production indicate that RFID is a progressive technology. It is also essential for competitive organisations to meet their demands in more precise and effective ways. All this helps to make people's lifestyles more advanced. The overall history of RFID is presented in **Figure 2.1** below (Bob Violino, 2005).

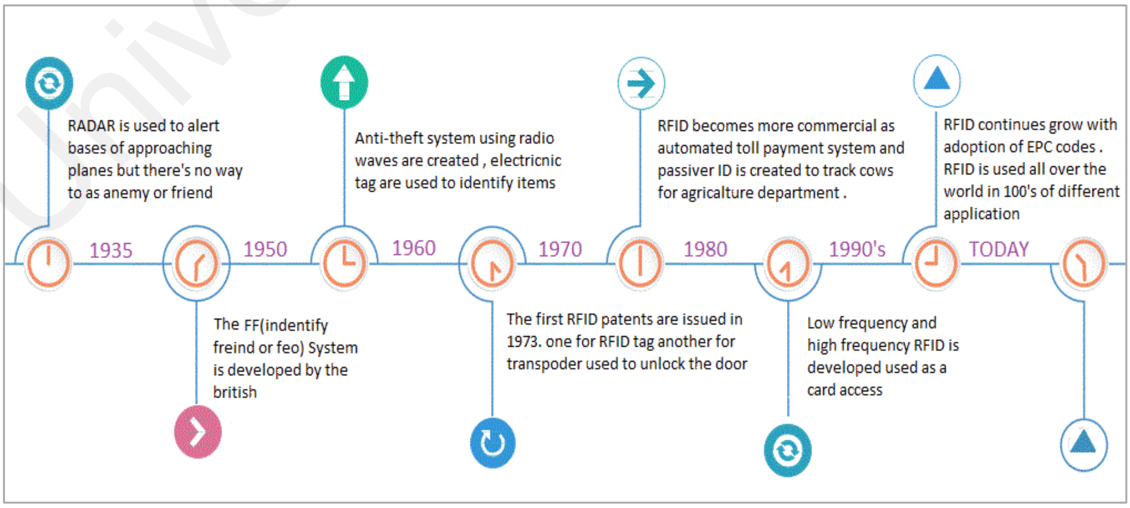

Figure 2.1: History of RFID Technology (Bob Violino, 2005)

In contrast to other automated technologies such as barcodes, magnetic inks, biometrics and touch memory, RFID can locate and specify objects from a distance (Chiesa et al., 2002). RFID is currently applied in many applications. In smart homes, it is used for monitoring elderly people for the sake of providing timely medication. It is employed in applications that help people with cogitative impairments. It is also used to control and monitor patients for serious symptoms and to maintain their records in hospitals. In marketing, RFID is applied for anti-theft and inventory purposes in retail stores. In government, it is widely employed by law enforcement as was seen in the case of Wal-Mart and the US department of defence (DOD) (Bansal, 2003; Naskar et al., 2017; Yan et al., 2008). Finally, manufacturers use RFID to control supply chains and for logistic services such as tracking container shipments.

2.3.2 RFID Systems

RFID is a generic term for a technology that uses radio waves to identify objects automatically and remotely. There are several identification methods; the most common is to associate a unique RFID tag with an object or person. The RFID system presented in **Figure 2.2** is divided into three sub-components: transponders (RFID tags with antennas), transceivers (RFID readers with antennas) and middleware (host terminals).

Figure 2.2: Typical RFID System (Sardroud, 2012)

The RFID reader acts as the RF signal generator to provide the power required by the RFID tag to be activated. It emits electromagnetic waves via a processor to supply power and read tag contents. Fixed-location RFID readers must be set up in pre-defined locations inside and outside of buildings, while handheld-RFID readers can be used as portable devices. Modern RFID readers can be integrated into many modules like Wi-Fi, GPS and GPRS which can read from distances up to 25 m. Middleware is refer to the host terminal and appropriate interface of RFID systems. It is used to manage, analyse and display data from RFID tags fetched via RFID readers. The RFID system retrieves data via wireless networks and back-end databases then delivers them back to the RFID middleware. RFID tags are small portable memory devices that can store up to 32 megabytes of data and are condensed in a protective coating. They can be attached to objects such as wristbands, labels commonly used for sales products, hidden anti-theft tags used to secure products and capsules or cylinder rings with lengths of around 10 mm and diameters of 1 mm used to detect and track animals. RFID tags each have a unique ID and store dynamic information related to the objects they are attached to. This data is stored in electronic chips (IC) that are connected to small coupled antenna used to communicate with RFID readers (Al-Amir et al., 2008; Roberts, 2006; Sardroud, 2012).

2.3.3 Classification of RFID Tags

RFID tags are classified in terms of power sources (batteries), memory, security and privacy.

2.3.3.1 Power Source (Battery) Classification

RFID tags fall into three sub-categories in terms of power source classification. They can be with a power supply (active), without a power supply (passive) or in a combined form (semi-active). Active tags require power sources (batteries) throughout their lifetime and do not rely on the power of RFID reader. The current battery lifespan can reach up to 10 years and RFID tags that utilise batteries can be read from up to 300 feet via inferences. They are less effective in certain applications due to their higher cost, larger size and the limited lifespan of their power supplies. Passive tags are without batteries and rely on the energy obtained from RFID readers or interrogators. This means that they can remain active for unlimited periods of time. The trade-offs are limited data storage capabilities, shorter ranges and higher power requirements from readers. The advantages are their smaller size, cost efficiency, unlimited lifespans and noise-free electromagnetic environments. These make them ideal for most applications. Passive tags can be read from a maximum distance of 5-8 m and operate at frequencies ranging from ~850 MHz to ~960 MHz. They do not have a common unified frequency for all countries; each country is certified with its own regulated frequency. **Figure 2.3** presents the modulated signal between tags and passive RFID readers. The semi-active tag has a composite form in which the power supply runs the circuit of chip and the device must communicate with the reader to gain energy. Semi-active and active RFID tags are larger, more expensive and have limited life spans, making them unsuitable for many of today's applications (Domdouzis et al., 2007; Rao et al., 2005; Roberts, 2006).

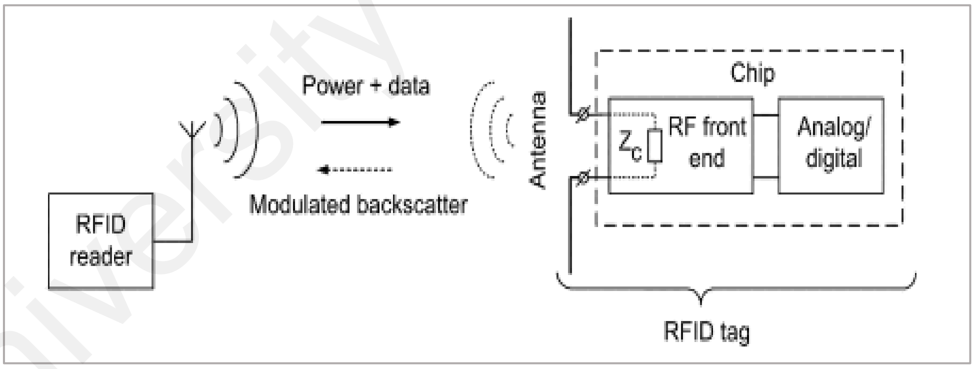

Figure 2.3: Passive RFID tag Operation (Rao et al., 2005)

2.3.3.2 Memory Classification

RFID tags can contain two types of memory structures: read only memory (ROM) and read-write memory (RAM). Read only memory tags are used to store protective data, unique IDs and operating system commands. Read-write memory tags are used to store data only if the RFID reader and tag are interactive (Roberts, 2006; Yan et al., 2008).

2.4 Security and Privacy Risks of RFID Systems

The security requirements of RFID tags are to reduce various vulnerabilities such as spoofing, unsafe operating environments, traffic analysis, eavesdropping and denial of service attacks that may affect the safety of RFID systems. Compromised location privacy, unauthorised user access and customer information leaks may threaten the privacy of RFID systems and cause harm to the security and privacy of organisations (Juels, 2006; Pateriya & Sharma, 2011). The security and privacy risks of RFID systems are a very extensive field of research involving many different circumstances that are beyond the scope of this study. This research focuses on human detection/tracking systems using RFID tags and only covers security and privacy risks related to RFID tags.

In terms of privacy and security, RFID tags can be divided into two types: basic and symmetrical. These are highlighted in the following sections.

2.4.1 RFID Basic Tags

Basic RFID tags are reserved for basic operations due to thousands of gates inside the tag. This drawback makes them unable to perform encryption operations, pseudo-random number generation and hash functions. This can result in numerous privacy and security breaches. For instance, the content of an insecure tag can be read by un-authenticated readers, and products with unprotected labels can be monitored by competitors performing silent scans. Alternatively, thieves can rewrite or replace tag data on expensive items with fraudulent data of low-priced items, threatening the privacy and profit of retail stores. Due to these serious risks, several approaches for managing user privacy and security have been suggested (Roberts, 2006; Weis et al., 2004). The "kill-command" approach by the Auto-ID Centre can permanently disable or put the RFID tag to sleep at the point of sale. RSA designed a "blocker tag" that detects silent scans in a private zone and a "soft-blocker tag" with certain modules that operate according to owner specifications. Re-encryption is an effective mechanism for hiding serial numbers with a cipher text in order to set tag credentials and decrypt them without any changes using the "minimalist" cryptographic approach for reuse. To replace the unique ID of a tag (storing the old ID for further use), the re-labelling approach may be performed by the RFID tag itself. The "proxy-enforcement" approach is also very popular for enhancing the security of RFID devices. For the authentication problem, the "yoking-proof" method has proven to be highly effective; it requires evidence confirmed by a trusted party at the point of scan (Juels, 2006; Pateriya & Sharma, 2011; Roberts, 2006).

2.4.2 RFID Symmetric Tags

Symmetrical tags can perform cryptographic operations, pseudo-random number generation and hash functions to enhance the security of RFID systems. RFID tag security is a major challenge due to potential authentication and privacy issues. The "tree approach" algorithm, which generates multiple keys to encrypt tags rather than one symmetric key, is the best solution for managing the overhead of privacy problems. The "silent walk-tree" algorithm synchronises the status between tags and valid RFID readers. If two or more tags respond to an appropriate RFID reader at the same time, a collision will occur until the "binary-tree" algorithm runs via the RFID reader to ensure valid access to corresponding tags.

With regards to authentication in symmetric RFID tags, "hash-based access control" has proven to be a highly effective approach. The memory portion of the meta-ID (hashing-key) of each tag is temporarily preserved in a locked state that only unlocks to accept valid requests. Using the "random access" approach, symmetric tags ignore queries sent by unauthorised users and accept those from verified readers. They do this by responding to reader queries with a hash function (r, h (ID ||)) that generates a random r value with a unique ID associated with that value sent to readers. The reader then needs to open a paired unique ID with the relevant [r] value via the hash-lock random scheme (Ahson & Ilyas, 2017; Juels, 2006; Pateriya & Sharma, 2011; Weis et al., 2004). These processes are shown in **Figure 2.4** below.

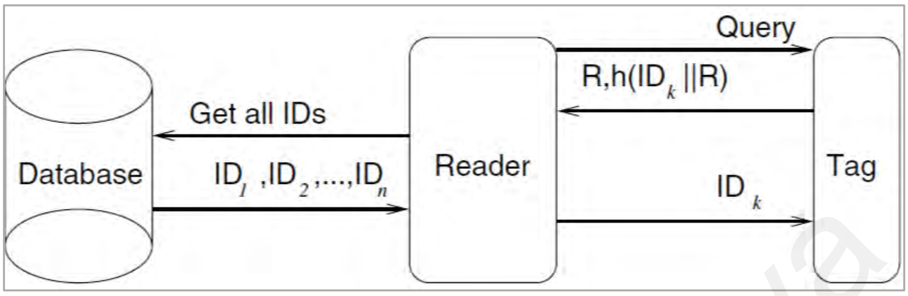

Figure 2.4: Random Hash Locking (Weis et al., 2004)

The "energy analysis" approach used by tag antennae defines multi-level authentication schemes by estimating distance levels. Longer distances mean less trust/ confidence and vice versa (Ahson & Ilyas, 2017; Roberts, 2006).

2.5 RFID Standards and Certified Frequencies

RFID helps companies control production, allowing competitive organisations to meet their production demands more effectively. The EAS (electronic article surveillance) was the first commercial application of RFID technology. RFID was gradually reinforced and became the backbone of commercial industries. This created the need for the RFID standards in the activities of commercial industries. RFID standards are terms and conditions for the explicit use of RFIDs. Most commercial standards are carried out by the ISO (International Standard Organisation) unity across 157 countries. The standards for electrical industries were developed by IEC (International Elector- Technical Committee). In 1999, EAN (Electrical Article Numbering) and UCC (Uniform Code Council) established the Auto-ID Centre at MIT. Auto-ID centre under the GSI (Global Standards System) adopted UHF regulations for RFID, while EPC (Electronic Product Code) adopted regulations for product labelling (Bob Violino, 2005; Impinj). EPC was then replaced by UPC (Universal Product Code) for sales products using bar-code labelling. Standards also vary depending on the nature of products. The GSI certified "EPC global class 1 (Gen2)" standard for UHF passive RFIDs made them differ between countries, devices and products under precise licenses (Bolic et al., 2010; Chawla & Ha, 2007). Passive RFID frequency spectrums depend on the tag for near-field and far-field coupling. The near-field coupling tag spectrum defines low to high frequencies to be from 128 KHz to 13.56 MHz with an approximate distance limit for object verification at 372 mm to 3.5 m (Want, 2006). The restrictions of this spectrum are low bandwidth, slower data rates and the need for coils with large antennas. However, it is much cheaper to use and is often employed for pet tracking. Far-field coupling tags have a global spectrum that spans UHF (Ultra-High Frequency) bands from 860 to 956 MHz, or microwave 2.45 GHz band frequencies. UHF bands vary across regions; bands from 866 to 869 MHz are used in Europe, 902 to 928 MHz in the United States and 950 to 956 MHz in Asian regions. The GSI certified an appropriate UHF bands for each country separately; it provides an official document respectively (Chawla & Ha, 2007; Rao et al., 2005).

2.6 The Integration of RFID Systems into Modern Technologies

The principle function of RFID systems is to identify and verify objects and their specifications. Such systems are ideal for verifying and locating objects within indoor environments. To maximise precision under various circumstances, RFID technology may operate simultaneously with other technologies such as Wi-Fi, Bluetooth, ultra-wideband (UWB), wireless sensor networks (WSN), the geographical positioning system (GPS) and Zigbee. WSN and RFID are complementary functional variants; RFID is used for identification and WSN for sensing. This hybrid provides a significant improvement in the detection and location of objects (Liu et al., 2007; Mejjaouli & Babiceanu, 2015). RFID and WSN hybrid applications are widely used in hospitals, grocery stores and smart homes. One such hybrid application is the use of RFID readers by WSN motes to measure user drug intake and relocate ECG data respectively (Hu et al., 2009). In smart homes, they can be used for intruder detection (Hussain et al., 2009) and to monitor cold chains during rapid temperature changes (Badia-Melis et al., 2014). Zigbee is the full version of WSN and is utilised with RFID in large scale applications due to its lower power consumption, higher data rates and large number of connected nodes (approximately 65000 nodes in short distances of approximately 100 m to 1 km). Zigbee is also used with RFID to improve the efficiency of medical staff management, reducing the amount of unexpected incidents (Shieh et al., 2016). Another short distance wireless technology (operating at 2.48GHz and achieving a 10 m range) is Bluetooth, and it can simultaneously operate with RFID. One such hybrid application (RFID and Bluetooth) is the INSIGHT navigator for people who are blind or vision impaired. A PDA with a Bluetooth interface is paired with passive RFID tags to support proper navigation (Ganz et al., 2010). Another recent application is FiSh tagging which also utilises RFID and Bluetooth technology (Bennett et al., 2016). Unlike Bluetooth and RFID technology, UWB (Ultra-Wideband) is a wireless technology that operates at 10.5 GHz and can transfer large volumes of data in short distances of up to 15cm. A hybrid RFID-UWB system was suggested under the IoT paradigm to locate and measure the quality of objects with a high degree of accuracy (Decarli et al., 2016).

Today, GPS (global positioning system) is the most effective system for object tracking. It uses radio signals received from satellites and transmits them to corresponding objects for tracking. However, GPS functions diminish underground, underwater and can not accommodate inside the building/indoors. For this reason, it can simultaneously operate with RFID technology in large-scale applications to achieve results that cannot be achieved only via GPS.

2.6.1 RFID Integration with GPS Technology

RFID technology can be combined with the GPS system to accommodate outdoor environments. This powerful combination uses the features of both technologies to detect the real-time location of an object in the surrounding environment. RFID technology can be paired with GPS using three approaches. The first approach has RFID tags and GPS receivers operate separately in one system. One such system was suggested for the real-time monitoring of the mechanical status and position of vehicles carrying hazardous materials (Yu et al., 2012). RFID tags were applied to dangerous cargo while the GPS receiver module was used to retrieve the vehicle's geographic position.

The second approach involves a hybrid RFID tag (GPS with RFID) and was developed for a system that can track any object on a global scale (Deepika & Usha, 2016). The RFID satellite tag is carried by the intended individual, while location coordinates are sent via a LEO (low earth orbit) satellite to the back-end server and the server responds with the exact location coordinates sent to Google Maps for the end users to view.

The third approach incorporates GPS coordinates (latitude and longitude) into RFID systems via the setup of GPS modules in RFID reader interfaces. Many systems have been built in accordance with this approach due to its low cost, high accuracy and reliability. A recent application of this system was constructed for smart ticketing and destination announcement. It used RFID and GPS coordinates to make trips more convenient for passengers (Chowdhury et al., 2016). Bus passengers could swipe the RFID tag as a token into the RFID reader fitted onto the bus, and once the verification process was complete, the passenger entrance location coordinates corresponding to the tag ID would be automatically stored in the database. As soon as the next stop arrives, the GPS location would be updated announcing the distance travelled by the passenger. This is the exact type of system suggested by Hutabarat et al. (2016) which uses RFID and

GPS coordinates . In such a system, GPS and RFID work simultaneously to track the user's position. For this study, this third approach (hybrid RFID + GPS) was chosen for the simulation and development of the proposed tracking system due to its reliability and cost effectiveness.

2.7 Integrated RFID System Simulation Model

The design and implementation of an integrated RFID (RFID + GPS) system requires considerable effort, funds and time to properly set up platform that made from specialised hardware, middleware and wireless networks. Scientists typically use simulations to model such systems. To simulate an integrated RFID system, the researcher need efficient simulators and modelling kits. Programming languages such as ASP.NET, JSP and PHP. DBMS including MS SQL and MYSQL servers are used for back-end databases. Simulation software like Simulink that enhance Matlab algorithms, OPNET modular, Sonnet and Comsol Multiphysics are used for simulations. The various RFID tag design frameworks that are employed in chip modelling and antenna design included CST, HFSS and Matlab programming (Zhang et al., 2010).

In the simulation of RFID systems, the tag component is crucial for the system to be tested efficiently. Most RFID systems have weaknesses in identifying objects with precise accuracy in areas with high tag-density (Konsynski & Smith, 2003). The most challenging application is the epidermal RFID tag being developed for healthcare-related purposes. It was reported that reduced efficiency and defects often range occur in many healthcare applications used to track patients for the sake of timely treatment (Amendola et al., 2015; Rajagopalan & Rahmat-Samii, 2010). Many researchers have relied upon RFID tag simulations to model and test applications under various circumstances. The simulation approach represents an effective model for performance analysis and helps researchers gain insight into the development of new solutions. In this study, a simulation model for the integrated RFID system with GPS coordinates was proposed for use with epidermal RFID tags. This system focused on chip and antenna fundamentals such as power gain, polarisation and distance measurements to evaluate tag performance and whether or not it is suitable for epidermal applications in a human security.

2.8 Human Tracking Systems

RFID and GPS technologies are used for numerous types of tracking systems such as animal tracking, vehicle tracking and human tracking. Many researchers have developed human tracking systems using an RFID/GPS combination for indoor and outdoor environments, respectively. In those systems, RFID tag placement follow two approaches. The first approach involves tags that wake up or activate via readers (unadhered RFID tag). The second uses planted RFID tags within objects or persons (adhered RFID tag). These approaches are described in the following sections.

2.8.1 Unadhered RFID-Based Tracking

Most researchers develop systems that activate tags via readers (unadhered RFID tracking systems). One such system estimates indoor locations via RFID technology by (Shiraishi et al., 2008). Initially, the system was built by separately placing RFID tags on ceiling surfaces at distances of 50 cm to detect the positions of inhabitants. The RFID reader is carried by the person of interest to accurately communicate with and receive signals from the mounted tags. The approximate location of the person is estimated via tag coordinates read by the reader. The server calculates the reader's position using the coordinates of tags detected. Another example is a system that utilises RFID on a floor surface that contains a grid ($43\ mm \times 43\ mm$) of passive tags (Tesoriero et al., 2010). The RFID reader is attached to a robot that could determine an accurate location by detecting multiple tags (up to 19). The goal of the system is to locate autonomous robots or eventually people in indoor environments. Similarly, Tsuboi et al. (2009) suggested an indoor human position tracking system to help the elderly recall their movement history so as to determine where they may have left items. The system estimates the user's position from the coordinates of captured RFID tags. Passive RFID tags are placed into a pre-defined x-y coordinate plane on the ceiling. **Figure 2.5** shows how this system operates. Tag information and coordinates are periodically read by RFID readers and stored in a central processor that runs positioning algorithms. Using this information, the application is able to sketch the movements of the target.

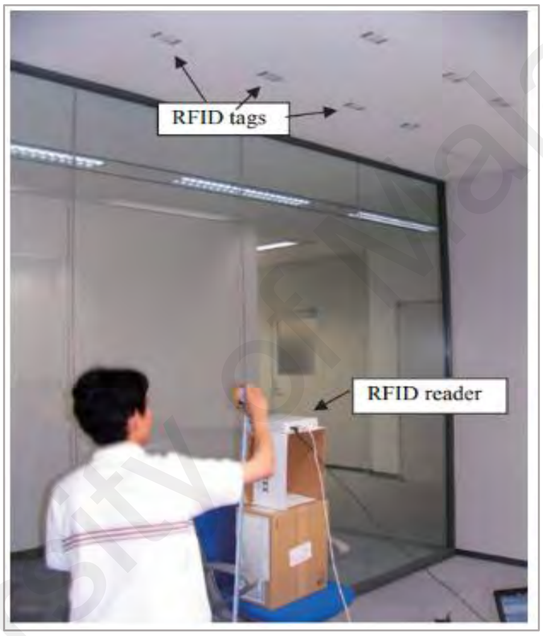

Figure 2.5: Indoor Positioning Techniques (Tsuboi et al., 2009)

Authors Gueaieb and Miah (2008) utilised a novel approach using a 3D array of RFID tags placed on the floor to make a virtual path. The pre-programmed robot equipped with RFID readers is supposed to navigate to the closest point on the 3D RFID array (for example, the 4th tag in the array [4, 9,6,7]) using the 3D locations path. Chumkamon et al. (2008) suggested another system to help blind people navigate by providing them with reliable paths to traverse. Tags are predominantly placed into stone blocks on the destination path to identify the correct route. This system uses a combination of RFID, GPRS and a rechargeable guidance module with headphones to provide voice instructions with capability up to 6 hours' charge. The navigation system was designed to automatically connect to the main server upon starting. The server would retrieve route information (location + distance) and calculate the optimum path according to a predefined algorithm. System tests were performed via virtual navigation by the simulation. Playback voice delay due to GPRS network communication lag was the main weakness of this system.

Another system was developed by Chang et al. (2008) to assist people with cognitive impairment in finding their way via a PDA interface. It uses RFID tags that are set on pathways-like road signs. The PDA would display the direction of the route along with the associated image to make it easier for people to find their destination. The system was tested using three different paths: A path on the same floor, an outdoor path and a path going downstairs from the 5th floor to an ATM on the ground floor. The results showed that 26% of 92 participants who were not familiar with PDAs were still able to reach their destinations, with 59% of participants succeeding in reaching their target destination very quickly and 7% of participants failing to do so. The system was effective in providing short paths that made navigation very easy for people with cogitative impairments. Its primary weakness was that the PDAs were not very user-friendly to some people. The system is presented in **Figure 2.6** below.

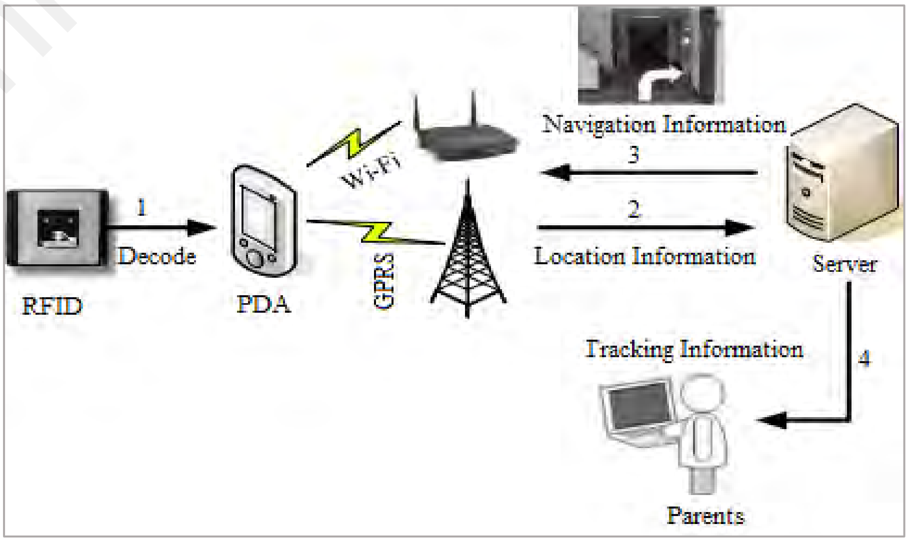

Figure 2.6: Wayfinding System (Chang et al., 2008)

Unadhered RFID systems are not flexible because they are not controlled by a unified system and have other limitations, as previously mentioned. It would be more effective and affordable to embed RFID tags into each individual to reduce the use of multiple devices to just one or two.

2.8.2 Adhered RFID-Based Tracking

In this type of system, RFID tags are attached to each participant instead of being placed in different locations. Adhered RFID-based systems help people work freely and safely within the environment. Kim et al. (2013) designed a system for tracking and assisting elderly people to administer medication in a timely manner. An RFID tag was attached to the participant and the system's middleware was connected to a healthcare system that would monitor the situation and quickly respond to any unexpected events or emergencies. Readers were placed in every room of the elderly house to send appropriate information from the tag to the central processor subsequently as the participant moved around the house. Unfortunately, extensive testing was not performed to demonstrate how functional and effective this system is.

RFID systems are widely used in schools worldwide for different purposes such as to ensure the safety of children on their way to school or to monitor students and employees along with valuable university assets. The first RFID system used in schools was tested in a pre-school in California by attaching RFID tags on student's clothing (D. Kravets, 2012). In Dubai, a city that attracts tourists from many countries, another such system was tested using RIFD tags attached to bracelets for the purpose of detecting missing children in a smart environment (Al-Ali et al., 2008). The system was able to record the child's route along with the last position visited via readers. The strength of the smart environment was slightly correlated to the number of readers; a larger number of readers achieved more accurate results. The reason for the effectiveness of bracelets was not mentioned in this study.

Shaaban et al. (2013) concentrated on tracking children on buses while riding to school to improve child safety. This system uses various technologies such as RFID, GPS and GPRS. The reader in the bus would automatically read corresponding data such as bus number, date, time and location of tags attached to student bags upon their entry. At the same time, an automatic SMS would be sent via GPRS to school authorities and parents. Lab test demos concluded that the detection rate of RFID tags attached to student bags had 99% more accuracy than tags pinned onto students' necks or on bracelets. The drawbacks of this system are that tags may be used by imposters, get lost or forgotten while SMS messages may not be reliable due to signal interruptions.

A more recent system was proposed by Kalid & Rosli (2017) to counter the child kidnapping rate in Malaysia. They also focused on school transportation for tracking children on their way to school. The system's architecture is presented in **Figure 2.7** which displays the use of RFID and GPS technology. Both the GPS module and the RFID reader are simultaneously set up in the bus and students would place their RFID tags close to the RFID reader before boarding. The main task of GPS module is to constantly track the vehicle's location in real-time.

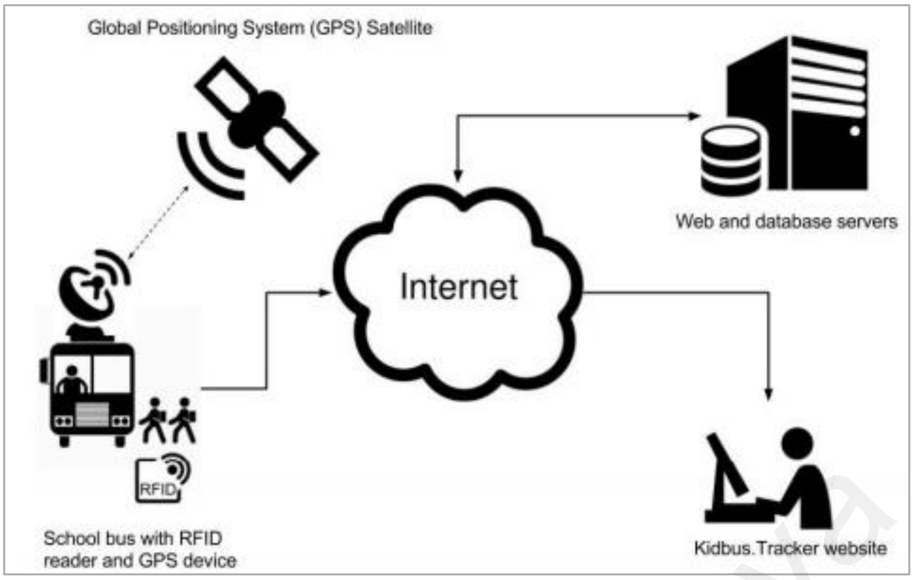

Figure 2.7: Prototype of KidBus-Tracker(Kalid & Rosli, 2017)

The middleware of the system is presented via a web application that parents could use to retrieve students' locations as they boarded buses to school. The main drawback of the system was the RFID binding mechanism; tags could be lost, stolen, or abused. Other issues were privacy concerns and the need for more value from the GPS technology.

Numerous studies were conducted to build smart universities within pre-defined areas. All such studies focused on locating university staff, students and assets. RFID readers were set in strategic locations and every person or asset was marked with a smart RFID card to track movement. Some of these systems have features such as room automation and e-attendance. Such systems have disadvantages due to the use of smart cards which could be exploited by intruders, lost or contain deficiencies limiting system functionality (Abbasi & Shaikh, 2008; Karthika et al., 2015).

Human tracking is an emerging field of research. Researchers and inventors are striving to improve the power and efficiency of such systems by utilising various technologies. The system proposed by Hutabarat et al. (2016) employs a combination of RFID and GPS in closed environments. It functions using tags assigned to users in the form of cards or key chains. The reader could read tags 3 metres away from the building and the GPS could trace the position of the user once outside. They use GPS coordinate systems (latitude and longitude) for the predefined closed area. The back-end server retrieves the appropriate coordinates of the tag from the reader to display the location of the intended individual to end users. The main flaw of this system was that users had to tap the RFID tag 50 cm away from the reader for tracking, and cards or keys can be potentially stolen or damaged. The pre-defined areas mapped with GPS coordinates are also very limited, comprising of a theme park or university campus.

Recently, a hybrid system (GPS + RFID) has been developed to track any entity on earth, especially people (Deepika & Usha, 2016). They use a novel RFID satellite tag that applies the functionality of GPS and RFID technology. RFID satellite tags could be carried by users, while the location coordinates of the tag can be sent via a LEO (low Earth orbit) satellite to the back-end server. This server then sends the exact location of coordinates to Google Maps for end users to view.

2.9 Security Risks for Medical Practitioners

Medical practitioners, especially doctors, play an important role in society due to the services they provide to people. Unfortunately, they are often victims of abduction and their lives are at risk. This is a cause of great distress for both them and their families. Recent evidence shows that security threats continue to rise in developing countries such as Afghanistan, Pakistan, India, Nepal and Bangladesh towards medical practitioners and children (Ambesh, 2016; Baykan et al., 2015). According to a study conducted by the Red Crescent, Afghanistan is one of the countries where health services such as medical transportation and proper health facilities are very lacking. As such, medical practitioners face trouble in the form of abduction, murder and molestation more frequently than in other countries (Terry, 2013). Pakistan, particularly Baluchistan, has witnessed many incidents of abduction and the targeted killing of doctors (Jawaid, 2013). Such incidents in the southern and eastern parts of Afghanistan and Baluchistan in western Pakistan have caused the most qualified doctors to leave those countries seeking a safer life in other countries. In the past 5 years, many safety risks to medical practitioners have been documented by the Human Security office of the Kandahar Regional Public Health Department in collaboration with the Human Rights Organisation (Appendix A). The surveillance of people, especially by government authorities and human rights organisations, is a serious contemporary concern. Guaranteeing medical practitioners safety as they travel between homes, hospitals and during fieldwork is a significant demand, especially in these two regions. Several measures have been taken however. In Baluchistan, the government assigned security guards to escort key specialists from their jobs. In Afghanistan, UNICEF provided expensive GPS receivers (costing up to $250) to track the locations of medical practitioners carrying out their duties. Unfortunately, these solutions do not offer realistic guarantees to these people's safety.

2.10 Summary of the Literature

It was noted in the literature review that RFID and GPS technologies play significant roles in large-scale applications aimed at detecting and tracking people within specific environments. RFID, GPS and GPRS technologies are able to operate simultaneously to achieve this. A concise summary of various RFID and GPS systems is presented in **Table 2.1** and **Table 2.2** below. In these systems, RFID tags operate using two approaches. The first involves tags that are activated by readers (unadhered RFID tags), while the second approach has tags that are bound to subjects for readers to detect (adhered RFID tags).

Table 2.1: Overview of the Unadhered RFID Systems

Year	Author	Mechanism for RFID Tag	Purpose of System
2008	Shiraishi	RFID tags were arranged on the ceiling in a grid	To identify a user's approximate location
2008	Chumkamn et al.	Placed RFID tags into stone blocks along a pathway	To identify the shortest path to help people with visual impairment
2008	Gueaieb et al.	3-D location RFID grid was created	To navigate the pre-programmed robot to the nearest 3-D location grid
2009	Tusboi et al.	RFID tags were arranged on the X-Y coordinates set on the ceiling	To track employees/students and to identify valuable staff assets
2009	Chang et al.	RFID tags were set in a pathway like road signs	To find a path for people with cognitive impairment
2010	Tesoriero et al.	RFID tags on the floor surface were arranged inside the building	Readers were installed on robots to detect their approximate location

Table 2.2: Overview of the Adhered RFID Systems

Year	Author	Mechanism for RFID Tag	Purpose of System
2004	D. Kravets	Bind RFID tags were inserted into student clothing	In the educational field RFID detection began in US schools to track students
2008	Al-Ali et al.	RFID tags were bound on children's bracelets	To locate children for safety reasons in open environments
2008	Abbasi et al.	RFID tag contents were stored in ID cards for students and staff members	To track employees/students and to identify valuable staff assets
2013	Kim et al.	RFID tags were attached to elderly people	To ensure the safety of elderly people
2013	Shaaban et al.	RFID tags were placed into student bags	To track and ensure the safety of students both in school and while boarding the school bus
2015	Kartika et al.	RFID tag contents were stored in ID cards for students and staff members	RFID technology was used to locate staff members or students in mobile restricted areas
2016	Hutabarat et al.	RFID tags were carried on cards or key chains by individuals	RFID and GPS technology was used to locate people in closed areas
2016	Deepika and Usha	RFID satellite tags were carried by the intended individuals	Hybrid (RFID+GPS) tags were used to validate the user locations
2017	Khalid & Rosli	RFID tag contents were stored in student cards	To track children during transportation between home and school for safety
2018	Pang et al.	RFID tags were carried as cards by students	A novel UHF RFID system was used to track children in public areas with a mobile app

While adhered RFID tags offer more flexibility than unadhered tags, they still face disadvantages such as the potential for loss, damage or abuse by imposters or intruders. Some systems also have interface, security and privacy concerns along with limitations in scope and feasibility (Deepika & Usha, 2016; Hutabarat et al., 2016). In the research conducted by Hutabarat et al. (2016), automatic detection could not occur without user interaction since users must tap cards 50 cm away from readers for tracking to ensue.

Cards also have the potential to get lost, stolen or damaged. Another issue was limited test areas typically comprising of theme parks or university campuses. In the case of the system proposed by Kalid & Rosli (2017) to counter the child kidnapping rate in Malaysia, their focus was primarily on school transportation for the detection of children. This system suffers similar disadvantages to the above since tags could be lost, stolen or abused. The use of GPS to report children locations only when in transit to schools was also very limited.

Considering this comprehensive background study, it was decided to simulate and evaluate the possible mechanism for an RFID tag. This tag is to be implanted under the skin and designed for use by physicians to prevent harm from easily removed or misused. This mechanism is to be applied with a tracking system interconnected with Internet of things (IoT) technology combined with RFID and GPS technologies to develop a certified model for accurate real-time location tracking of doctors in hospitals and during fieldwork. Doctors obtain their ID using a unique UHF passive RFID tag that operates at a frequency of 868 MHz. This frequency alters regionally and has a range of up to approximately 4 m achieved. In addition, the virtual floor plan of the unified centre is incorporated into the system's GUI application allowing users to view zoomed in real-time locations of members indoors/within building parameters. The GPS coordinates (latitude and longitude) of the Kandahar Zone were included in the system and it can display the outdoor locations of doctors on Google Maps to end users. In terms of security, the system is only available to authorised users, and only they can view the real-time location of members. To alleviate privacy concerns, the system is used only upon the mutual approval of families and doctors. Doctors can choose to accept or deny self-tracking.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Overview

In this chapter, an explanation of the step-by-step methodology undertaken for the completion of this study is provided. The overall methodology is explained with emphasis on how the problem statement and objectives were drawn from the literature and used to determine the best solution. How this solution was implemented and tested to confirm results is also highlighted (refer to **Figure 3.1**). Next, the experimental procedures are explained and illustrate the attempts to achieve the desired goal of the study. Lastly, the flaws in the methods employed by previous human tracking systems are highlighted along with the solutions this study provides to these problems.

3.2 Study Design

This study sought to find the most suitable mechanism for an embedded RFID tag to provide security to people, especially doctors who are often persecuted from various security threats, using a combination of RFID and GPS technologies. It features multidimensional aspects centred around RFID, Internet of things (IoT) and (GPS) technologies. To achieve the desired goal, it is important to demonstrate that the research design is an experimental design with results that can be implemented in the real world according to the requirements.

The main goal of this study is to provide best security to human, especially for doctors in a very effective and thorough manner/way. To this end, epidermal RFID tags were chosen to be implanted under the skin of participants to mitigate the potential of tags getting lost or harmed in any way. The tags are embedded so as not to be easily removed or used by unauthorised individuals. Various RFID and GPS systems are built that can be used to track humans and are often incorporated into adhesive RFID tags (Abbasi & Shaikh, 2008; Deepika & Usha, 2016; Hutabarat et al., 2016; Kalid & Rosli, 2017;

Karthika et al., 2015). As long as adhered RFID tags have the potential of getting lost, misplaced, damaged or stolen, a systematic procedure (presented in **Figure 3.1)** was used together with the relationship between each phase of the solution to propose an appropriate RFID mechanism. This mechanism is to be applied with a tracking system utilising Internet of things (IoT), RFID, and GPS technology to develop a certified model that guaranteeing the safety of medical practitioners.

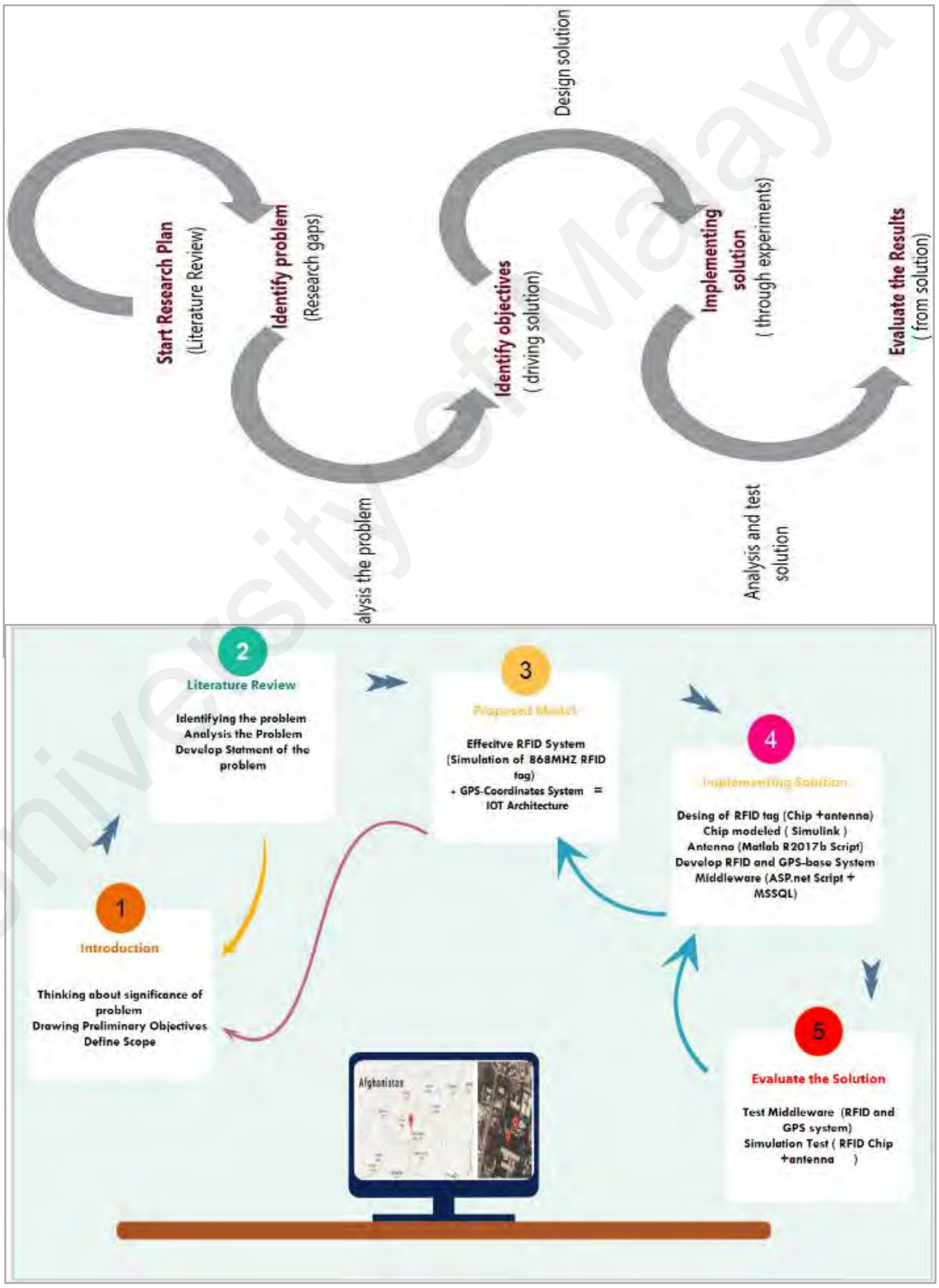

Figure 3.1: Overall Research Methodology

To implement and evaluate the system, the following two procedures must be acted upon.

3.3 Experimental Procedures

3.3.1 Simulation of RFID Tag

This system used RFID tags and GPS integrated RFID readers. The tag chosen for tracking was the passive 868 MHz UHF tag whose frequency is regulated in Afghanistan and Pakistan. Readers could be fixed in pre-defined places (highlighted by safety concerns) such as above of every OPD room door, in entrance halls, emergency operation theatres and dedicated hospital transmission buses that may be used by doctors. The researcher had to set up readers in every transport dedicated to medical practitioners despite his/her private transport. The virtual floor plan of the unified centre (Mirwais Regional Hospital) was drawn with readers that have ranges of about 10 m to be used with RFID tags that achieve a universal 3 m range. This is drawn in **Figure 3.2** below.

Figure 3.2: Virtual Floor Plan of the Unified Centre

The placement of readers in carefully selected pre-defined places (highlighted by safety concerns) is a core component of this RFID system because ineffective placement of readers was one of the main drawbacks of previous systems. The RFID reader in the system proposed by (Chang et al., 2008) was set up in a place where individuals needed to make decisions. No mention was made of any method of RFID reader placement in the research conducted by Kim et al. (2013). Shaaban et al. (2013) also did not demonstrate the effectiveness of reader placement. In their experiments, if a student missed the bus, neither parents nor school authorities could find them. As such, the decision to place integrated RFID readers (GPS + Wi-Fi) in all transports dedicated to medical personnel despite the use of personal transportation is highlighted. Moreover, researchers used fixed location and hand-held RFID readers in previous works (Hutabarat et al., 2016; Kalid & Rosli, 2017; Karthika et al., 2015). They reported the potential of incorrect readings, higher costs, signal loss and interaction difficulties.

An RFID tag consisting of a silicon integrated circuit (an 'IC' chip) was used for transferring RF signals. It was fitted with a small RFID antenna used to activate the IC or chip. This study modelled both components of the RFID tag (chip and antenna). The chip was modelled using the Simulink Multiphysics environment, and a custom circularly polarised antenna operating at 868 MHz was simulated using MATLAB version R2017b, Antenna toolbox and a PDE tool scripts. A step-by-step implementation of both components is detailed in Chapter 5.

3.3.2 Tracking System (RFID and GPS Coordinate Middleware)

The middleware portion of the system is represented via an online GUI interface that efficiently retrieves the real-time locations of medical practitioners. Middleware deployment requires appropriate design and implementation to model the system for end users. In this system, the middleware can run on both PC and Mobile platforms. The associated back-end server keeps tag data via corresponding readers. The middleware implements a user-friendly GUI encoded via .Net scripts with a MS SQL back-end database for complete functionality. The virtual floor plan comprising of simulated tags and readers along with the GPS coordinates of the research subjected society are incorporated into the system to visualise system performance for end users in both indoor and outdoor environments. The overall experiment methodology in the implementation of such system is shown in **Figure 3.3** below.

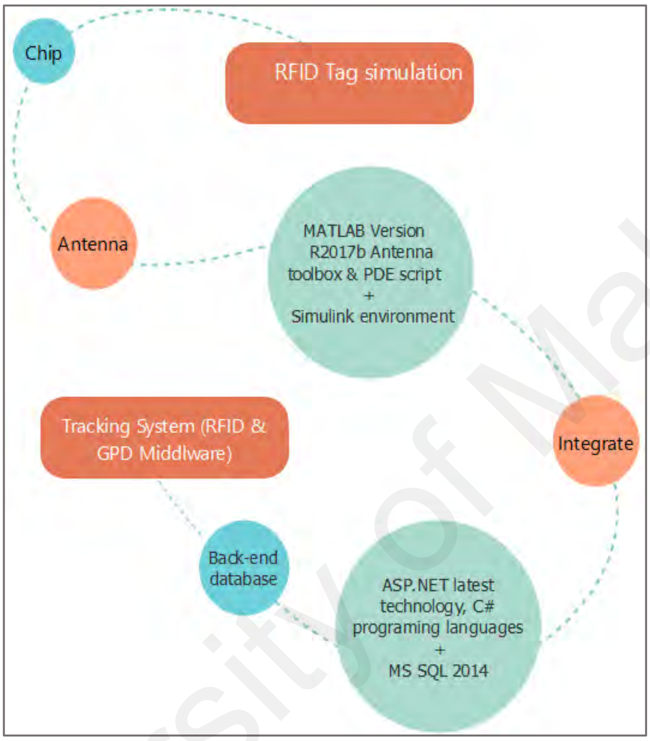

Figure 3.3: Experimental Methodology

3.4 Analysis and System Testing

Analysis and testing are used in experimental studies to evaluate the effectiveness and functionality of a model or framework. In this study, the researcher conducted mutual testing (test the results from RFID tags and the functionality of the system). Simulation testing refers to evaluating the results of simulation tags to check their performance and whether or not they are suitable for epidermal use /for induced into skins. System functions were tested using virtual RFID tags assigned to doctors' IDs by generating random coordinates. The coordinates were fetched by the back-end database and verified using the coordinates of the lookup table. If both coordinates matched, the system would display the precise location of the member. This would indicate that our tracking system is fully functional and could be ready for actual deployment.

3.5 Summary

This study features multidimensional aspects centred around RFID, Internet of things (IoT) and (GPS) technologies. To achieve the desired goal, it is important to demonstrate that the research design is an experimental design with results that can be implemented in the real world according to the requirements. There already exists a variety of RFID and GPS systems but they have limitations and drawbacks when it comes to tag placement (Abbasi & Shaikh, 2008; Deepika & Usha, 2016; Hutabarat et al., 2016; Kalid & Rosli, 2017; Karthika et al., 2015; Shaaban et al., 2013). As previously mentioned, tags have the potential of getting lost, misplaced, damaged or stolen. In addition, improper placement of RFID reader has been noted in many systems. For example, Shaaban et al. (2013) did not demonstrate the effectiveness of reader placement. In their study, if students missed the bus, neither the parents nor the school authorities could track them. In other studies, location error probability, higher costs, higher signal loss and interaction difficulties were reported (Hutabarat et al., 2016; Kalid & Rosli, 2017; Karthika et al., 2015). Considering these potential issues, the decision was made to set readers in every transport dedicated to medical practitioners despite the existence of their own private transports. Readers were also placed within hospitals in pre-defined areas selected in consideration of safety concerns (see **Figure 3.2**). A systematic set of procedures (see **Figure 3.1**) was used to produce a suitable RFID tag mechanism to be applied with a tracking system utilising Internet of things (IoT), RFID, and GPS technology to develop a certified model that guaranteeing the safety of medical practitioners. To implement and evaluate the system, a step by step experimental procedure that uses modelling technologies (see **Figure 3.3**) for tag simulation and system development was employed. Finally, unit testing was performed to evaluate system outcome.

CHAPTER 4: PROPOSED SOLUTION

4.1 Overview

Chapter 4 provides the proposed solution to the objectives of the study and discusses the preferred design and architecture of the system. The design section explains the design and simulation of tag components such as chip modelling, custom antenna simulation and the middleware design of the system. In the architecture section, a general overview of the system is presented together with its basic units. Finally, the overall working principles of the system are described and illustrated accordingly.

4.2 Human Tracking System Design

The design of the concerned system followed two main steps. First was the design and simulation of the 868 MHz RFID tag which is ideally suited for epidermal use/for induced into skins. There are many skin tattoos in the form of RFID labels that can be placed within a gap of a few millimeters between the skin and label and these produce an acceptable read range (Occhiuzzi et al., 2008; Ziai & Batchelor, 2011). Unfortunately, they do face some potential problems. The epidermal RFID tag, which is directly incorporated into the skin, was reported that reduced efficiency and defects often range occur in many healthcare applications used to track patients for the sake of timely treatment (Amendola et al., 2015). The human body adversely affects the gain of the RFID tag antenna, reducing power available to the chip. In this study, the researcher concentrated on designing custom tag components for simulation. The chip and antennas used to evaluate the result had to ensure that the designed RFID tag is very suited for real integration into the skin. It aims to mitigate the effects of high metabolism, humidity, PH and skin temperatures, all of which cause the loss of signal strength. The chip was modelled using the Simulink Multiphysics environment along with an RFID 868 MHz circularly polarised antenna created using Matlab programming version R2017b, Antenna Toolbox and PDE tool scripts.

Second was the design and development of an innovative system that combines the functionality of RFID, GPS coordinates and the IoT architecture that aim to secure medical practitioners, the GPS coordinates (latitude and longitude) of the research based region were incorporated into the system. The GPS module was fixed to the RFID reader's interface or using modern integrated readers equipped with Wi-Fi functionality and GPS modules. This was done to demonstrate system output to Google Maps for end users to view outdoors. The virtual floor plan of the unified centre was included in the system to visualise its performance for users, indoors or inside the building. Finally, unit testing and analysis was conducted to evaluate the end result of the system and whether or not it is ready for actual deployment.

4.3 Architecture of Human Tracking System

The architecture of the human tracking system is divided into three subparts: simulated RFID tags, RFID readers with GPS modules and middleware. Based on the modular ideology of RFID and GPS applications, GPS along with Wi-Fi modules should be fixed on RFID reader interface through RS232 and RS485 ports. Alternatively, modern RFID (GPS + Wi-Fi module) readers can be used. RFID readers interconnect with RFID tags within the approximate range to connect to the server via the Wi-Fi module. When a reader begins to search for and detect the requested RFID tag, the GPS module captures the location coordinates of the tag and the reader sends the location, tag ID and time back to the server. The server processes the retrieved data for further handling, and the middleware portion visualises such data to an authorised user upon request. The prototype of the human tracking system was developed and integrated into a virtual hospital floor plan consisting of simulated RFID tags and readers that communicate over a Wi-Fi network. Similarly, the GPS coordinates (latitude and longitude) of the research-based area were included in the prototype to pinpoint a member's location on Google Maps. This top down architecture not only reduces the complexity of the system, but also enhances development and upgrade capabilities. This allows for an economic design that facilitates system reusability. Below is the summary of system architecture units.

4.3.1 Tag (RFID)

- Passive UHF Tag (operating at 865-868 MHz frequency)
- ISO 18000-6C Gen 2 (UHF EPC global protocol)
- Reading distance: up to 4 m (Achieved from experiment result with a normal -10 dBm threshold)
- Simulation and design technology: Simulink Multiphysics environment, Matlab programming tools such as Antenna toolbox & PDE script
- More data (up to 512 bit)

This is an epidermal RFID tag attached to the skin that cannot be removed without destruction of the tag, preventing tags from being stolen or misused.

4.3.2 Integrated RFID Reader

- Passive UHF integrated RFID reader (operating at 865-928 MHz frequency)
- UHF EPC global Gen 2 protocol
- Maximum reading distance: up to 10 metres
- Maximum reading rates: up to 760 tag/s
- Interface: Wi-Fi & GPS module

Readers can be fixed at each pre-defined location selected according to safety concerns. In this study, the researcher has to set up the readers in every transport dedicated to medical practitioners despite his/her private transport.

4.3.3 Human Tracking System (Middleware GUI)

- Programming languages: ASP .NET SCRIPT, C# and MS SQL
- Server: MS SQL server

- Platform: Windows OS 8, 10 and Android
- Web browser: Google Chrome, Mozilla, Internet Explorer and Safari

Middleware refers to an output unit in the form of web application that displays member information on the server. The middleware is only accessible by authorised users of the system. Users can only obtain the current location coordinates with the permission of the person being tracked. The entire architecture of the system is presented showing that the virtual hospital RFID system and responsive web application (Mobile/PC) falls under IoT (Internet of things). This means that the whole structure follows the IoT paradigm, as shown in **Figure 4.1** Below.

Figure 4.1: System Architecture

4.4 Human Tracking System Working Principles

In this study, the researcher had to propose a human tracking system based on the IoT paradigm utilising RFID and GPS technology. This was done to develop a model that provides accurate real-time locations of medical practitioners for monitoring. A user-friendly interface makes operation easy for end users, be it experienced or otherwise. The system starts retrieving data the moment an end user sends a request for the current location of their respective member (typically, a relative). The system is initiated through the login process which authenticates users by providing them with unique credentials. It should be noted that only authorised individuals can access the system and accounts are blocked after four failed login attempts (see **Figure 4.2** below).

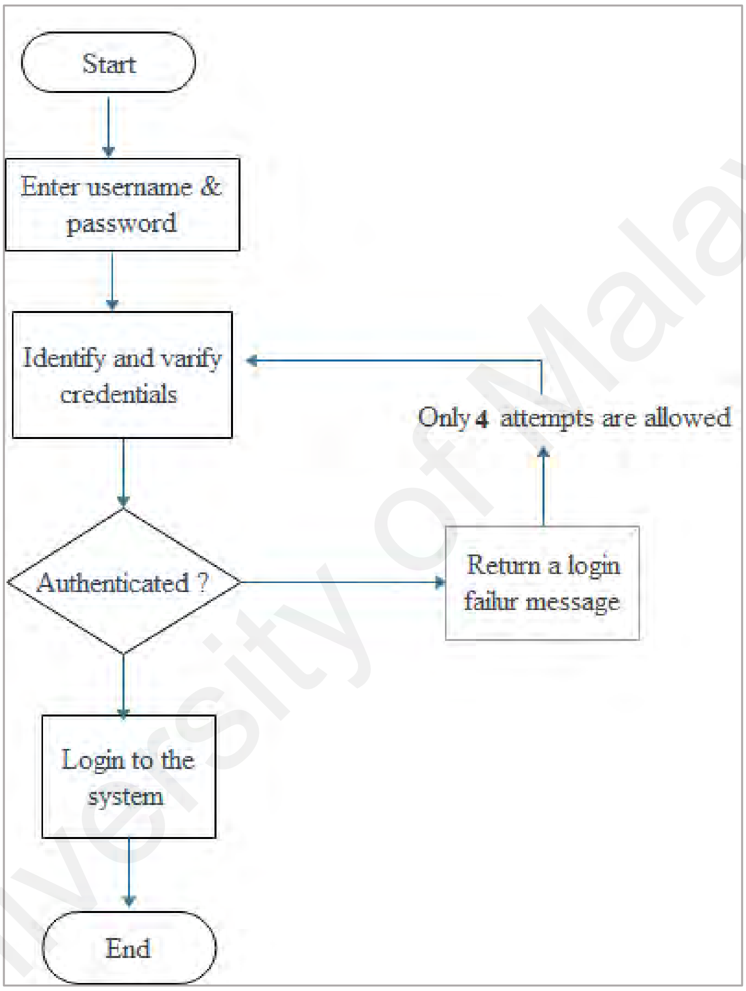

Figure 4.2: System Login Procedures

This step ensures that tracking can only be carried out by authorised users after their login process is authenticated by the system. After login, the system will start by connecting to the back-end server and reader via a Wi-Fi network to get the requested information of the intended member. The reader captures tag information, which contains tag ID, GPS location coordinates and time then sends them to the back-end server. This process continues by sending the retrieved information back to end users. The workflow of a user's request for a certain member's current location is presented in **Figure 4.3** below:

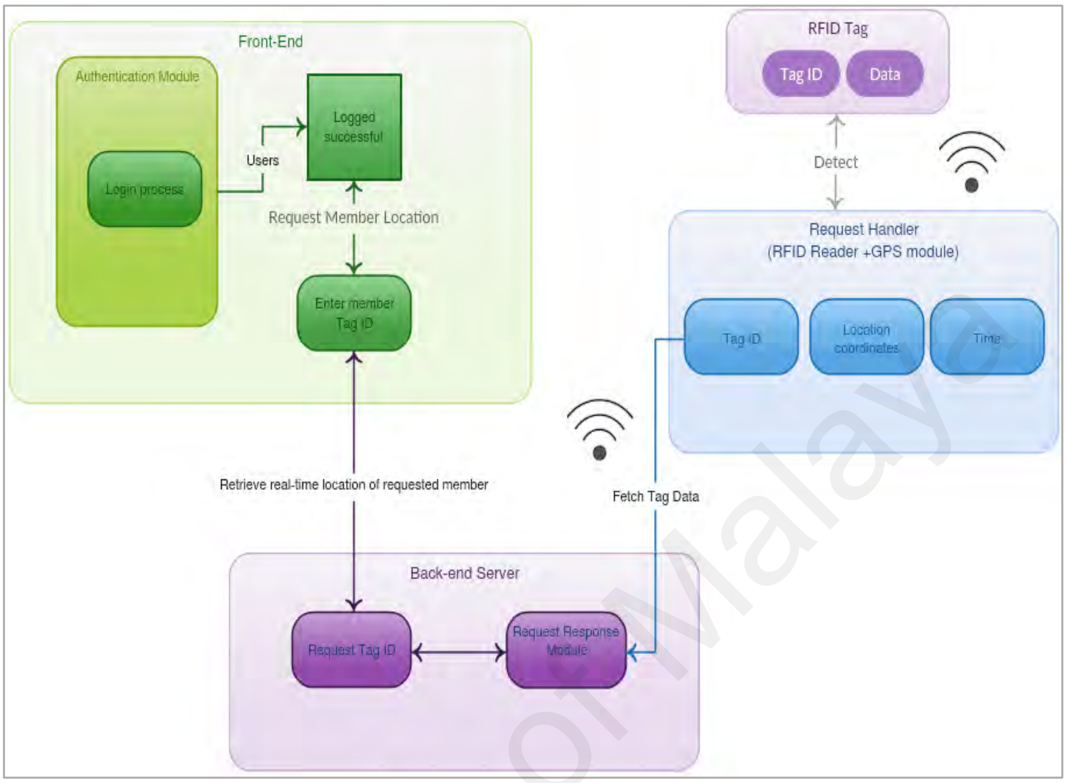

Figure 4.3: System Workflow

Only hospital authorities have total access and control over the system allowing them to include and exclude members. To alleviate privacy concerns, participants in this system can only be tracked by family members with the mutual consent of both parties.

4.5 Summary

The proposed solution is based on the objectives of the study. It aims to simulate and evaluate the possible mechanism for an RFID tag in a tracking system that uses Internet of things (IoT), RFID and GPS technologies. This was done to develop a model that ensures the safety of medical practitioners using an RFID-GPS based human tracking system. The core architecture of this system includes RFID tags, integrated RFID readers and relevant middleware. The tag serves to locate medical practitioners and is ideally suited for epidermal use/ for induced into skins. Thus, it is important to concentrate on tag simulations that aim to mitigate the effects of high metabolism, humidity, PH and skin temperatures on signal strength.

The solution relied on the design and simulation of tag components such as chip model, custom antenna design and relevant middleware of the system. The chip was modelled using the Simulink Multiphysics environment, and a custom circularly polarised 868 MHz antenna was formed using Matlab programming version R2017b, Antenna toolbox and PDE tool scripts. The associated back-end server was designed to store tag data obtained from readers. The middleware offered a user-friendly GUI that was encoded using .Net scripts and connected to a MS SQL back-end database. The location coordinates of research based society were incorporated into the system along with a virtual plan of unified centre for end users to view on Google Maps and within building parameters.

The system starts retrieving data the moment an end user sends a request for the current location of their respective member. The workflow starting from the user's initial request up until they obtain the location of the specified member is illustrated in **Figure 4.3**. Only hospital authorities have total access control over the system allowing them to include and exclude members. To alleviate privacy concerns, participants in this system can only be tracked by family members with the mutual consent of both parties.

CHAPTER 5: SYSTEM IMPLEMENTATION

5.1 Overview

This chapter discusses the step-by-step implementation of the solution for a suitable RFID mechanism. The implementation was divided into two steps. First was the design and simulation of tag components such as chip model and custom antenna design. Second was the development of the relevant middleware of the system. These were combined to form a human tracking system that utilises the IoT paradigm, RFID and GPS coordinates to ensure the security of doctors.

5.2 Simulation of RFID Tags

The core architecture of the human tracking system includes RFID tags, integrated RFID readers and the relevant middleware of the system. The tag serves to track and locate medical practitioners and is ideally to be suited for epidermal use/ for induced into skins. Thus, it is of utmost importance to concentrate on picking tag components correctly before covering other portions of the system that rely on it. An RFID tag consists of silicon integrated circuits ('IC' chips) used for transferring RF signals. They are fitted with a small RFID antenna used to wake up the tag's IC. Designing a tag for human identification requires maximising transmission power, and higher antenna power radiation is very important. The challenge was to achieve high tag input inductance with small antenna enough to be used in the human body (Amendola et al., 2015; Makarovaite et al., 2017).

The first stage was to simulate and design the core portions of the RFID tag consisting of the antenna and electronic chip. Usually, the chip contains identification data and is located between the terminal and the voltage of the antenna. It is activated and powered by electromagnetic waves radiated by the RFID reader. The chip model can make any UHF RFID tag variants that can have a great impact on its performance. Therefore, chip impedance should closely match antenna impedance in order to reduce power loss and obtain better reading distances. The design of an RFID antenna requires that various measurements match chip impedance (Ghiotto et al., 2010; Yeoman, 2014). The researcher modelled the chip using the Simulink Multiphysics environment. It consists of a capacitor (used to simplify tuning), an inductor and the resistance. The experiment results of the chip design showed the inclusive impedance of the chip to be Z_{chip} = *5.6832e-02 – 3.065+03i* and the near-field angle between the chip and antenna about *2.22*°.This is shown in **Figure 5.1** below.

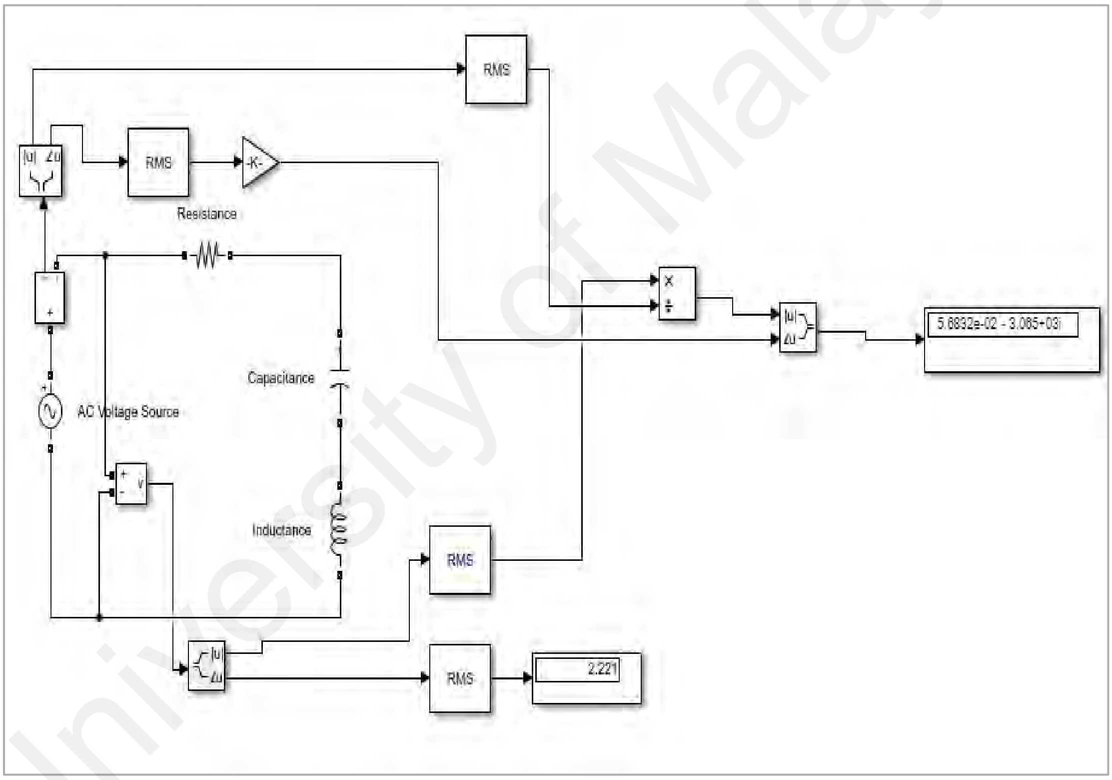

Figure 5.1: RFID Electronic Chip (Integrated Circuit)

The second core element that plays a crucial rule in the RFID tag's design is the antenna. Different antennas are used depending on application requirements. The antenna design process is typically based on trial and error-practiced and can be revised through several iterations until a good design that achieves the desired performance is reached. In this study, the researcher presented a very common circularly polarised custom antenna design and simulation based on various pre-requisites. These included a frequency band that regulates the frequency of the countries this research is based upon, a size suitable for implanting into the skin, effective isotropic radiated power (EIRP or ERP) to examine the reading distances using different EIRP voltages and polarisation to check effectiveness based on the directivity pattern of the antenna.

5.2.1 Frequency Regulation

In designing an RFID tag antenna, it is important to define the resonating frequency of the tag. The antenna attains this by operating at 868 MHz frequency. This frequency covers all frequencies in the range of 865-868 MHz, as previously stated. Each region has its own frequency used with UHF passive tags, as defined by the Global Standards System (GS1). Currently, the certified frequency range is 865-868 MHz in Afghanistan and Pakistan. They are sampled areas for this study and geographically, they are neighbours.

5.2.2 RFID Tag Size

In the design of RFID tags today, the biggest challenge researchers face is the design of small-sized antennas that ideally match the capacitive reactance of the chip 'IC' with a typical inductance. Most sizes of RFID labels embedded into skin or skins tattoos range from ~34 mm to ~65 mm. In this study, the size of the custom antenna was selected to be practical for epidermal use/ for induced into skins. A ground plane size of around ~22 mm × ~22 mm was determined to be the most suitable. To achieve this goal, the RFID antenna was simulated using Matlab programming version R2017b with Antenna toolbox and PDE tool scripts. To start the simulation, a new workplace was opened in Matlab and the PDE function was called. An antenna design script was generated and run using the Matlab ROZAR syntax to produce the antenna's geometry. The script snapshot is presented in **Figure 5.2**.

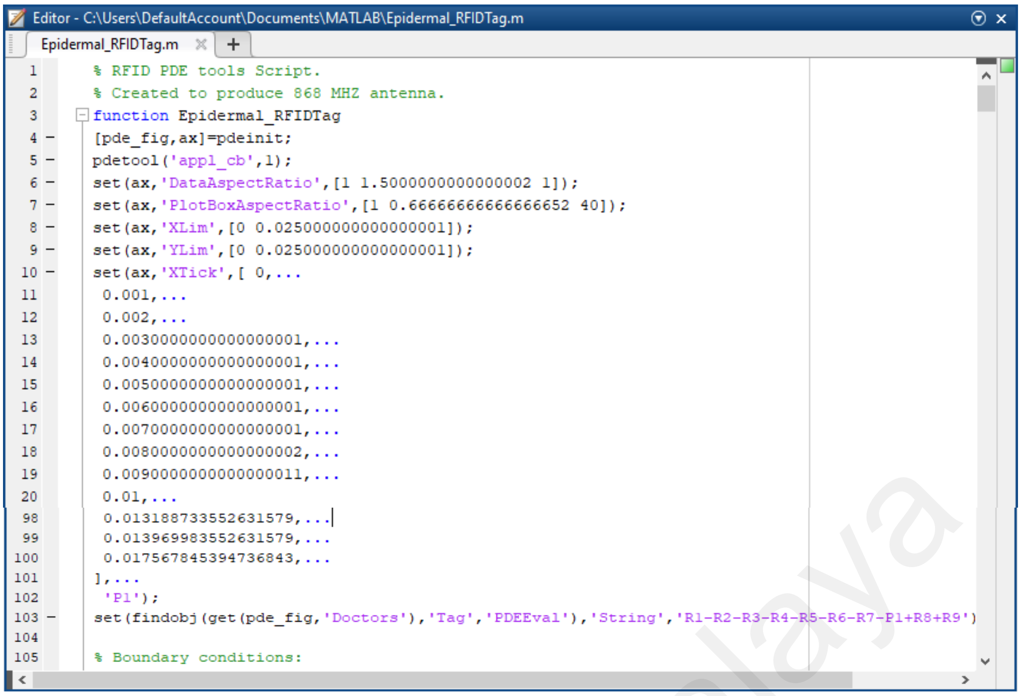

Figure 5.2: Epidermal_RFIDTag.m Script

The resulting geometry was made using several parameters with 8 connecting rectangles and a polygon P1 expressed by a unique function. It was sketched according to these parameters and presented in **Figure 5.3**.

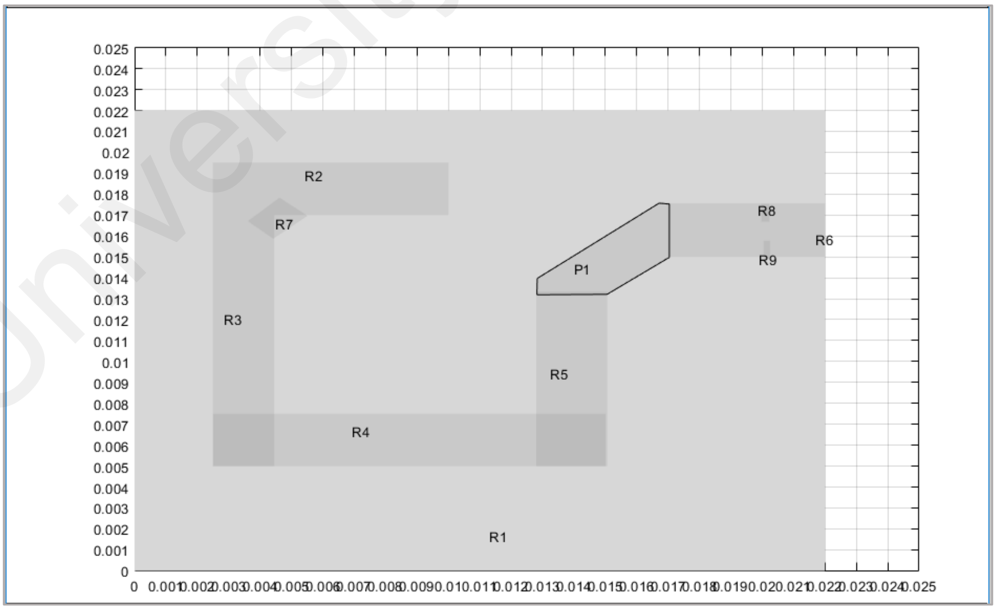

Figure 5.3: Epidermal_RFIDTag Geometry

RFID chips are placed in RFID antenna terminals powered by antennas that transmit electromagnetic waves. They react by varying their input impedance, thereby modulating the backscattered signal with data sent to the reader. To design an effective and suitable RFID tag, it is important to concentrate on impedance matching between chips and antennas because that really affects the reading distances and signal turbulence of the tag. To this end, the feed process helps to match chip impedance for better read ranges and to reduce power loss (Loo et al., 2008; Yeoman, 2014). How to feed an RFID antenna is a challenging task for antenna designers. Creating and modifying the feed according to the chip requires effort put into an antenna modification. To start the feed process, the mesh models were loaded into the Matlab workplace and the `createfeed(ant)` function was then called. The parameter `ant` represented the antenna's geometry. Modification of the feed was performed using various parameters to obtain the required $\sim Z_{ant}$ impedance. The process of modifying the feed is presented in **Figure 5.4** below.

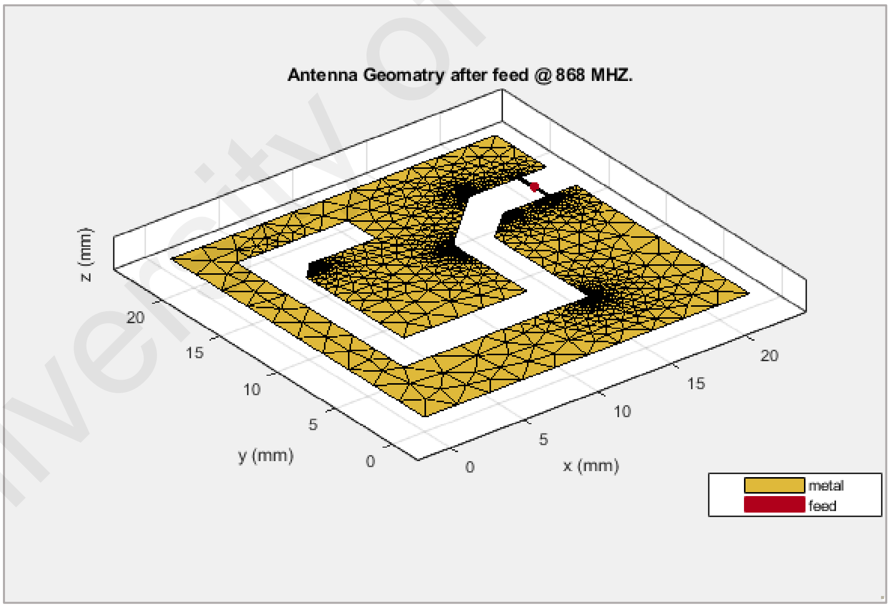

Figure 5.4: Feed Process for 868 MHz RFID Antenna

The workplace command line can perform relevant functions needed to further analyse the resulting antenna's geometry after the successful modelling of the feed process. The execution of the impedance for simulated antenna was performed by executing this line of code: `Z = impedance (ant, 868e6);` in the Matlab command prompt. The parameters were reloaded using the load function to acquire the corresponding output for impedance. The resulting impedance of the antenna was equal to *7.5470e-02 + 3.8062e + 03i*, and the code used is presented in **Figure 5.5**. The impedance examined was closer to that predicted for the chip.

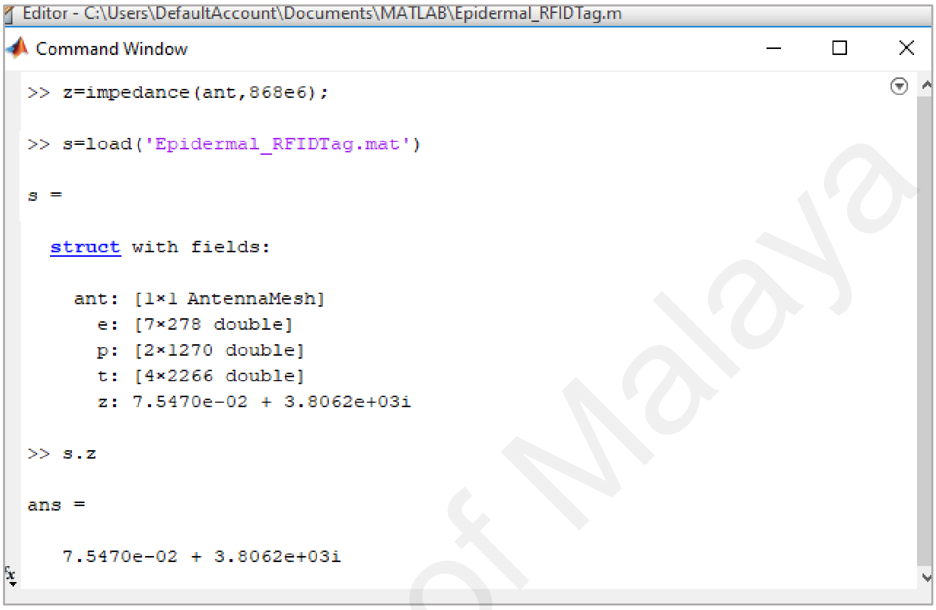

Figure 5.5: Examined Impedance of 868 MHz RFID Antenna

To further optimise the antenna with respect to the radiation intensity pattern (transmitting and receiving energy in space) and to measure the power gain of the simulated antenna, the radiation intensity process was performed. The radiation intensity of most antennas uses two or three dimensional spatial coordinates. The 3D rays of the simulated antennas are symbolised and presented in **Figure 5.6**. They were used to check the magnitude of the power in the direction described by equation: $G = \varepsilon \times D$. This equation determines the efficiency radiation intensity in a particular direction (Aironet, 2007; Orban & Moernaut, 2009).

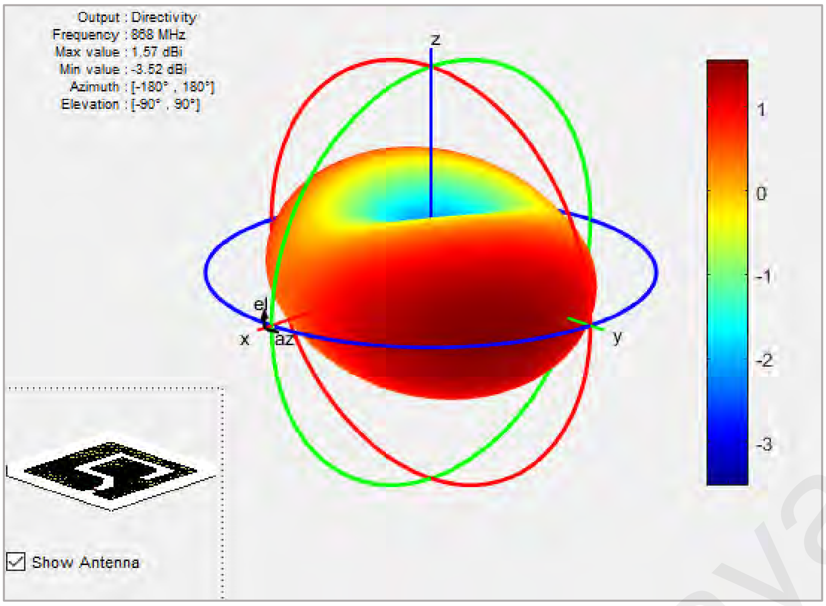

Figure 5.6: 3D Radiation Intensity of 868 MHz RFID Antenna

The power gain is usually plotted using a logarithmic unit scale such as decibels or the dBi unit. The power gain from the radiation intensity of the antenna was equal to *1.57* dBi. As can be seen, the tag had a better read range and acceptable coverage in 3D spatial coordinates.

When 3D radiation is sliced in the x-y plane, the Azimuth radiation can be obtained. It was obtained by executing the `Azimuth = patternAzimuth(ant, 868e6)` line of code in the Matlab command prompt. The blue curve marked the signal strength which was *1.57* dBi at 60° and moved clockwise to 30°. Power dropped to *1.46* dBi and the signal strength continuously fell to 0 at 330°. By moving down, the power strength simultaneously rose up to reach maximum value at 240°, as shown in **Figure 5.7**.

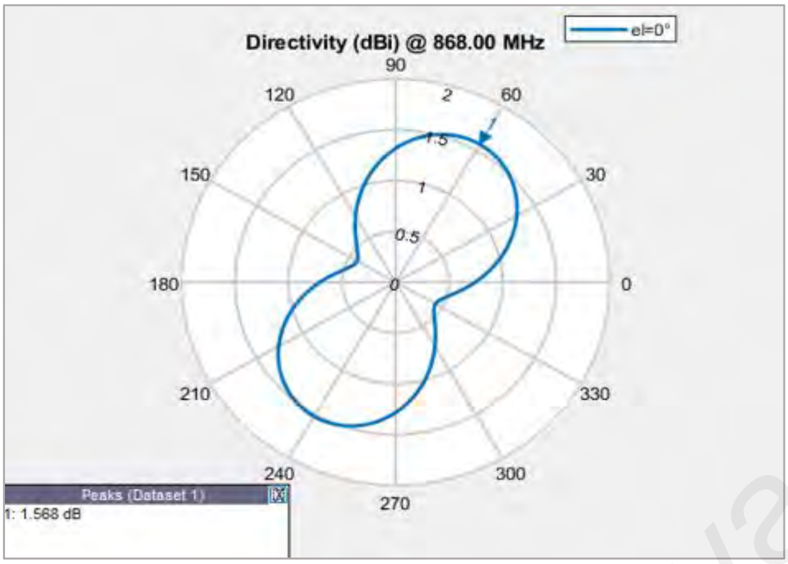

Figure 5.7: Radiation Azimuth for 868 MHz RFID Antenna

In the y-z plane, the elevation radiation was obtained by executing the `Elevation = PatternElevation(ant, 868e6)` command as shown in **Figure 5.8** below. Using both graphs, it was concluded that the antenna appeared to radiate in spherical coordinates.

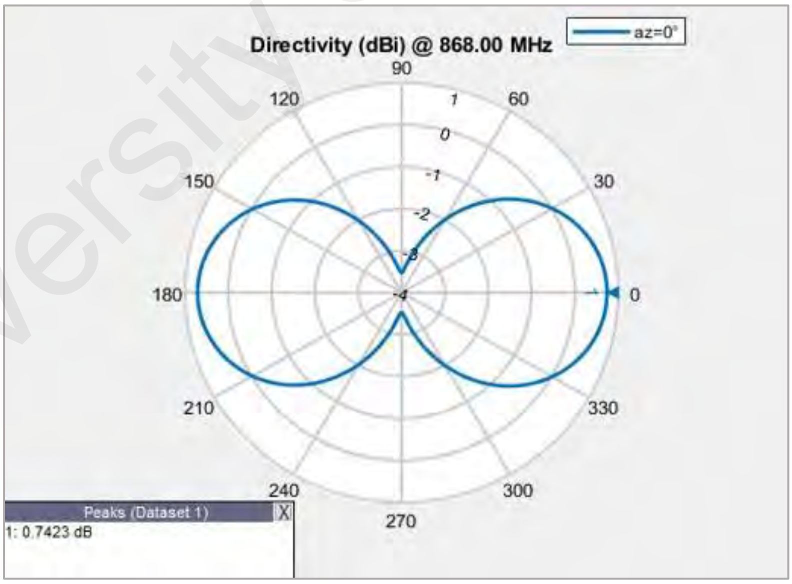

Figure 5. 8 : Radiation Elevation for 868MHz RFID Antenna

5.2.3 Polarisation of the RFID Tag

The concept of polarisation is derived from the optimisation of antenna position and its radiation of perceived waves in different directions. To locate an object, the radio frequency of the attached RFID tag and readers within the approximate range is calculated for accurate positioning. Circular polarisation antennas emit left and right-hand waves that have higher weather diffusion. Location accuracy is very high over linear polarised antennas. Most tags used in commercial applications are linearly polarised due to the simplicity and low cost of manufacture. However, they may have the null direction problem which sometimes causes mismatching signals between tags and readers that results in no response being sent back to the reader or for the reader to stop functioning (Luo & Zhu, 2013). In this situation, the optimisation of circular polarisation (CP) is very important for designers to consider. Polarisation is a broad field that depends on various circumstances beyond the scope of this study. It is impossible to achieve perfect circular polarisation. Therefore, it is usually generated as a function using elliptical curves. The wave is right-hand (clockwise) elliptically polarised if the field vector rotates clockwise. It is left-hand (counter clockwise) elliptically polarised if the field vector of the ellipse rotates counter clockwise. The rotation is determined using the same rules used for circular polarisation. Many researchers have attempted to achieve a higher CP bandwidth with the simplest antenna configuration that can be relied upon for use by different antennas with different performances (Lu & Chang, 2017). The bandwidth variation of CP antennas does not affect the dimension parameters of the antenna (Aironet, 2007). Considering this, the antenna was plotted using right-hand circular polarisation (RHCP) and was capable of radiating waves in a right or left-handed manner/way, as illustrated in **Figure 5.9**.

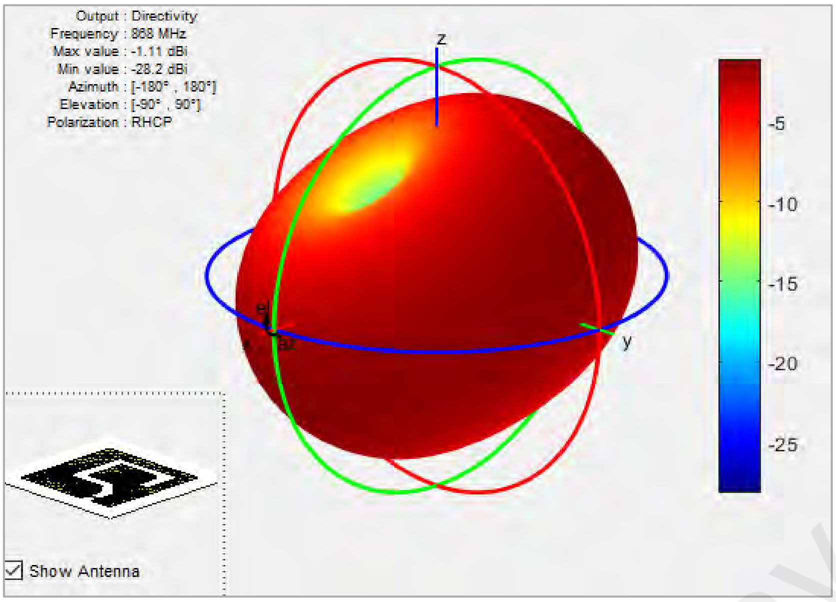

Figure 5.9: RHCP for 868 MHz RFID Antenna

When testing circularly polarised antennas, the pattern of directivity and axial ratio can provide additional information on how antennas emit in different ways. It presents more patterns, enhancing the reader's ability to choose the most suitable antenna for use in their application.

5.2.4 Directivity of the RFID Tag

As previously stated, the radiation pattern determines the efficiency of RFID antennas in a particular direction and this results in the production of power gain. Directivity is the bandwidth of the power gain defined by the following equation (Luo & Zhu, 2013; Orban & Moernaut, 2009).

$$D(\theta, \varphi) = \frac{U(\theta,\varphi)}{P_{total}/_{4\pi}}$$

The $U(\theta, \varphi)$ value represents radiation intensity, while θ and φ are the spatial coordinates representing the measurement between the radiation intensity and total radiated powers. The directivity of the simulated antenna was obtained by executing the code below in the Matlab command prompt:

- *[Directivity] = pattern (ant, 868e6, 0, 90);*
- *[Directivity] = pattern (ant, 868e6, 0, 180);*

The result showed that directivity shot up from *-3.52* dBi in the z-plane to its peak value in the x-y direction (0° and 180°) at *0.7064* dBi. A sample of the code executed in the Matlab command prompt is presented in **Figure 5.10**. This assumes that the simulated antenna radiated within a few coordinates of the sphere, increasing the possibility of circular polarisation.

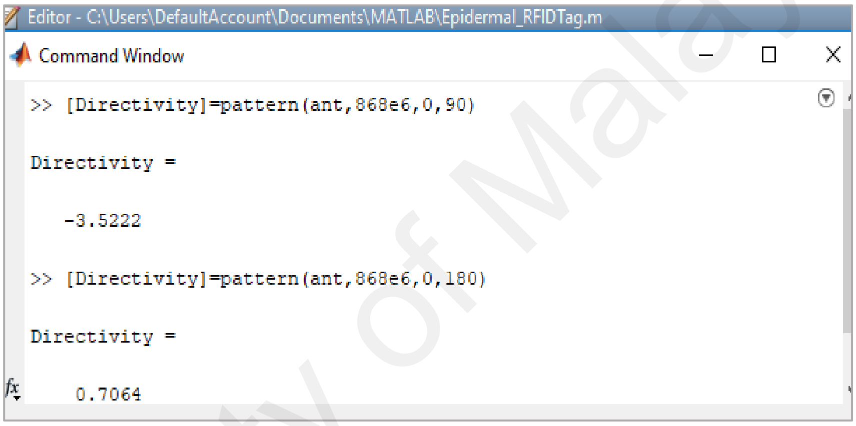

Figure 5.10: Directivity for 868 MHz RFID Antenna

5.2.5 Axial Ratio of the RFID Tag

Circular polarisation can also be defined by the axial ratio and the nearest value of AR to *0* dB, representing the extreme potential to become circular. The perfect circular polarisation AR can be equal to *3* dB, whereas linear polarisation has an infinite amount of values for AR that rely on geometry and antenna applications (Aironet, 2007; Luo & Zhu, 2013). The axial ratio was obtained by executing the *Ar = axialRatio (ant, 868e6, 20, 30)* line of code in the Matlab command prompt and indicated that the simulated antenna has a very good chance of being an ellipse or elliptical in polarisation. An image of the code used is presented in **Figure 5.11** below.

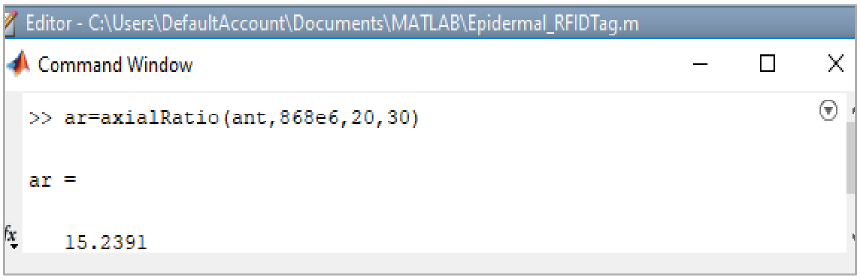

Figure 5.11: Axial Ratio for 868 MHz RFID Antenna

5.2.6 Reading Measurement of the RFID Tag

RFID reading range measurements rely on many factors including enhanced power gain, acquisition thresholds and effective isotropic radiated power (EIRP/ERP). EIRP is the maximum permissible voltage for RFID to be set in each country. It is affected by two main factors: $EIRP = P_t \times G_r$, which emphasises power emitted by tag antennas and the power gain (Penttilä et al., 2006). ERP voltages are variant and used to compare the reading efficiency of the designed tag. They are represented by the following equation (Rao et al., 2005):

$$r = \frac{\lambda}{4\pi}\sqrt{\frac{EIRP\ G_{at}}{P_{th}}}.\ \gamma$$

The G_{at} value represents power gain, while P_{th} is the maximum power received by the RFID tag to be activated. The γ value is the ideal factor for the impedance which should match between the chip and antenna. The maximum possible range ($\gamma_{max} = 1$) occurs only when the impedance is perfectly matched (Balanis, 2005). The RFID antenna was empirically tested at various EIRP voltages such as 1W, 2W and 4W for distance measurements. The results showed that RFID tag have better reading distances compared to the power transmitted by readers. The results are displayed in **Figure 5.12**.

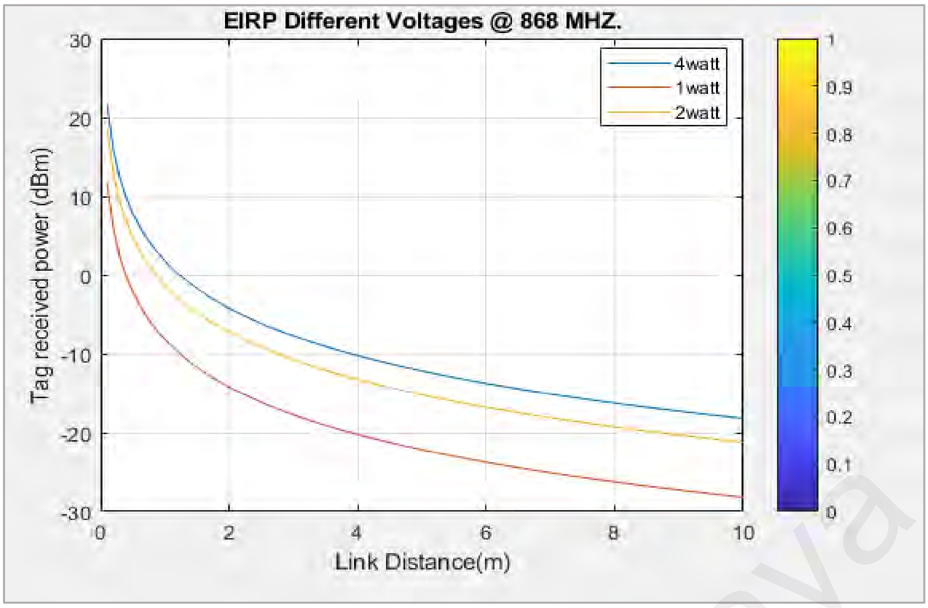

Figure 5.12: Examined Distance for 868 MHz RFID Antenna

5.3 Implementing the Tracking System (RFID & GPS Coordinate Middleware)

The implementation of the middleware for the human tracking system was split into two sub-sections:

- Database schema
- GUI application (middleware)

5.3.1 Database Schema

The back-end database stores all the necessary information of members being tracked along with some data related to authorised users who can retrieve tracked member locations. The middleware retrieves member location and time information upon request from the back-end database. The back-end database fetches the information of intended members from RFID readers using the Wi-Fi network, and updates are written into the back-end database for review. The MS SQL language was used in order to implement the back-end database of the system. An *RFID.db* main database was created and the schema of the back-end database was associated with important tables and their relationships. The schema is presented in **Figure 5.13** below.

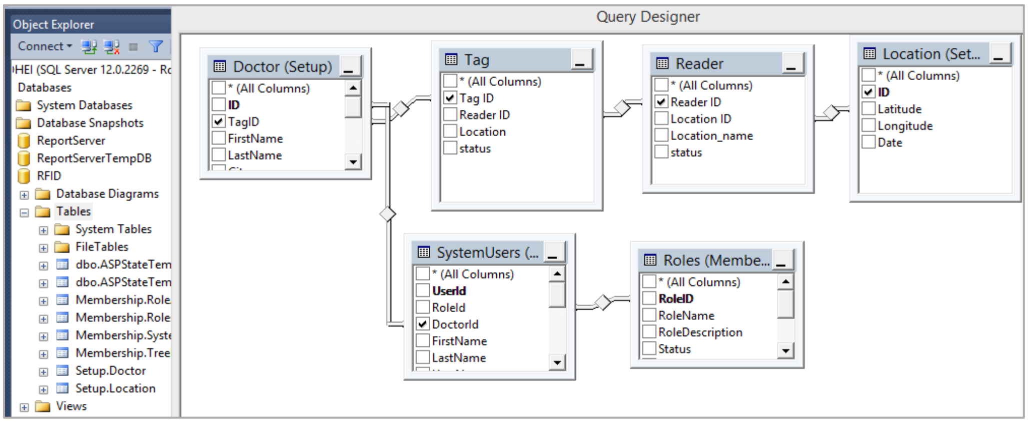

Figure 5.13: Schema for Back-end Database

5.3.1.1 Loading Data into Tables

The admin of the system has the right to include or exclude any members into/from the system. To include members, the admin has to enter the supplementary data of those members using the system GUI. In the back-end, this process is performed by specific insertion queries into the database. How data is stored in the back-end database is also taken into account. **Figure 5.14** presents supplementary tabular data form in MS SQL.

ID	TagID	FirstName	LastName	City	Street	Home	Photo
9	101	Azim	Rehman	Kandahar	15, Street 10 /80B	09	~/Assets/imag...
10	102	Nordaina	Ahmed	Kuala Lumpur	KK-12, FSKTM , ...	002	~/Assets/imag...
11	103	Salwana	Mat Surin	Kuala Lumpur	FSKTM , Resear...	003	~/Assets/imag...
12	104	Nasim	Bahar	Kandahar	District #9 ,Low...	080-89	~/Assets/imag...
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL

Figure 5.14: Typical Table in Back-end Database

5.3.1.2 Lookup Table

As previously stated, the system is scalable and capable of automatically reading the GPS coordinates of RFID tags. In the lookup table of the back-end database, GPS coordinates (latitude and longitude) of the research-based area (Kandahar Zone) were included. The lookup table contained location IDs and corresponding GPS coordinates, as shown in **Figure 5.15**.

ID	DoctorID	Latitude	Longitude	Date
1	1	32.29205676056...	64.78985608750...	2018-01-21 00:5...
2	3	32.12042061691...	66.73888341795...	2018-01-21 00:5...
3	1	32.43187533287...	65.40072714358...	2018-01-21 00:5...
4	3	31.98204635955...	65.26595876364...	2018-01-21 00:5...
5	1	31.95651839777...	66.43262689234...	2018-01-21 00:5...
6	3	31.51917353214...	64.95844506583...	2018-01-21 00:5...
7	1	31.92701981044...	64.81915222474...	2018-01-21 12:4...
8	3	32.32811244608...	66.55723359829...	2018-01-21 12:4...
9	1	31.36974999116...	65.718846052266	2018-01-21 12:4...
10	3	31.67254094466...	66.55527928227...	2018-01-21 12:4...

Figure 5.15: Lookup Table for GPS Coordinates

5.3.2 Algorithm Used to Verify GPS Coordinates

The GPS module can be set up in the RFID reader's interface to allow reading RFID tag location coordinates. Alternatively, modern RFID (GPS + Wi-Fi module) readers can be used. The algorithm illustrated in **Figure 5.16** was used to fetch the location coordinates of RFID tags and verify them using the lookup table in the back-end database. If RFID tag location coordinates correspond to a lookup table coordinates, the database can retrieve precise location data with the time interval to display to end users on Google Maps.

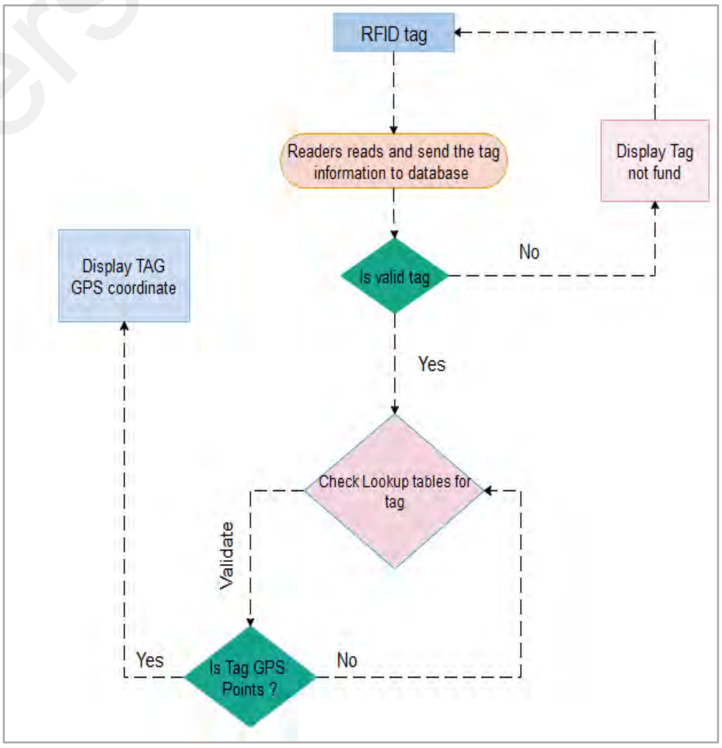

Figure 5.16: Validation Algorithms for Tag

5.3.3 Implementation of Middleware (GUI)

User-friendly middleware was developed in the form of a web application that displays doctors' locations retrieved from the server. A virtual floor plan of the unified centre was incorporated into the GUI application to visualise system performance for tracking members inside the building (see **Figure 3.2**). Middleware deployment requires appropriate design and implementation to effectively model the system for end users. The topmost portion of the middleware design is the login module illustrated in **Figure 5.17.** This ensures that only authorised users can access and use the system.

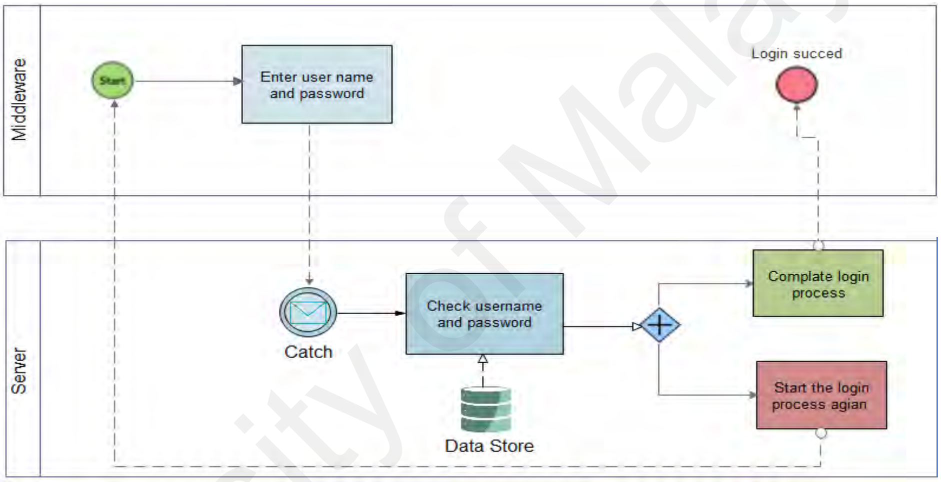

Figure 5.17: Login Module Workflow

The following requirements and proficiencies were taken into account when designing the middleware portion of the system:

- **Availability:** The availability of a system must be assured during hospital work hours. To prevent data loss, system backups should be performed periodically.
- **Reliability**: A reliable and technical error-free human tracking system was constructed to perform in accordance with its goal specifications. It should be maintained periodically to ensure functionality.
- **Scalability**: The system must be able to handle reading any additional tags and readers and must also be able to accommodate larger maps and zone levels.

The human tracking system was designed based on reliability, availability and scalability using .NET for the web-based application. On the server side, ASP.NET scripts were chosen to connect users with RFID reader information stored in the back-end database for retrieval upon request. An online RFID and GPS based human tracking system was developed to evaluate system functionality and practicality. This is shown in **Figure 5.18**.

Figure 5.18: Web Application System for Unified Centre

5.3.3.1 System Users

As a precautionary step, the login tracking system is required to ensure that only authorised users access the system. Once a user successfully logs in, they can track only members whose information they have access to. Only administrators have the right to include and exclude members and they should provide appropriate credentials for each physician, respectively. **Figure 5.19** indicates successful administrator login into the system.

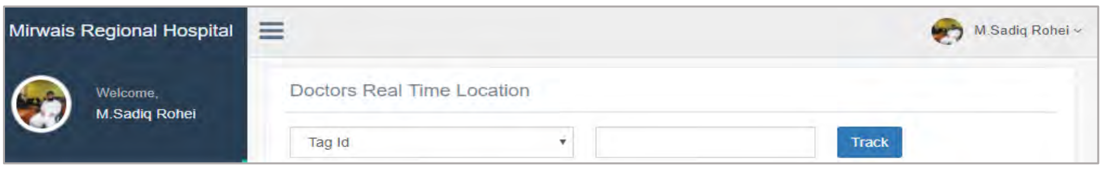

Figure 5.19: Successful Admin Login

Doctors have full privacy given that tracking can only be carried out by relatives with their consent. **Figure 5.20** displays the data of four doctors registered in the system.


All Doctors

S.No	Photo	Tag ID	First Name	Last Name	City	Street	Home	Action
1		101	Dr Nordiana	Ahmed	Kuala lumpur	DK12- FSKTM University of Malaya	098	
2		102	Azim	Rehman	Kandahar	15/Jalan 1/80b	S22-01	
3		103	Dr Salwan	Mat Surin	Kuala lumpur	FSKTM , research Lab , UKM	87-B	
4		104	Dr Daneil Crustoper	Bahar	Kandahar	PJS 22/8 , Low Wala Mirwais Regional Hospital	54/S-12	

Figure 5.20: Generated Data for Members

5.3.3.2 Tracking Principles

Only authorised users can request the location information of a particular member. Hospital administrators have the right to claim the real-time locations of all registered doctors inside and outside the hospital, while other end users are only allowed to view the information of members they are authorised to track. To alleviate privacy concerns, participants in this system can only be tracked by family members with the mutual consent of both parties. A screenshot of the real-time location tracking of registered doctors by admin inside and outside the hospital is presented in **Figure 5.21**. In the prototype, RFID tags were virtually assigned to doctors' IDs by generating random coordinates. The coordinates were then fetched by the back-end database and verified using a look up table in the back-end database. If the RFID tag location coordinates matched the lookup table coordinates, the database could retrieve precise location data with the time interval to display on Google Maps for end users to view outdoors (see **Figure 5.22**). The virtual floor plan of unified centre was incorporated into the GUI application and allows users to zoom in on real-time locations of members inside the Mirwais Regional Hospital building in every OPD room or department.

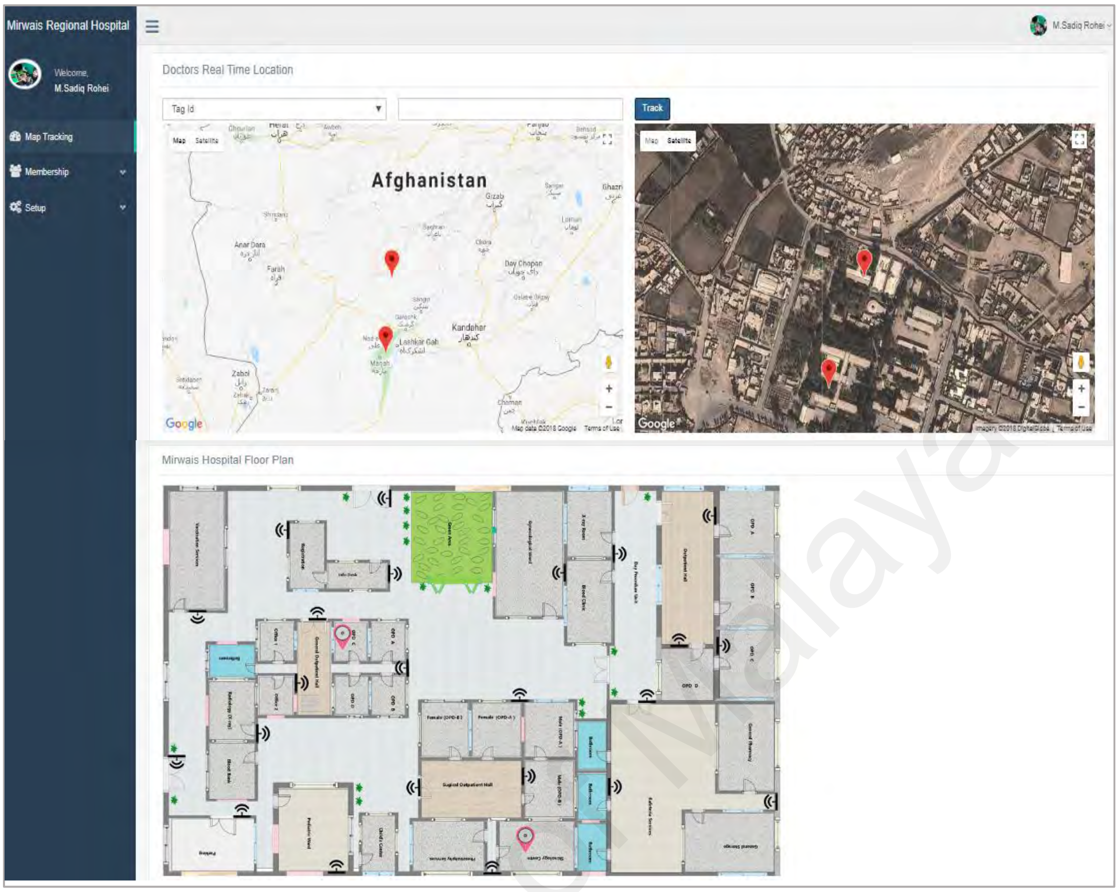

Figure 5.21: Tracking View for Admin

When a member being tracked is outside of the Mirwais regional hospital, the virtual floor plan view will not appear as it is only incorporated into the system for tracking within the parameters of the Mirwais Regional Hospital campus plan. The system displays information to authorised users depending on the location of the tracked member. When an end user clicks on the location marking a member's location on Google Maps, detailed information (GPS coordinates, date, time, status) along with the member's name appears. This information can help end users to find and locate respective members more proficiently. An example screenshot of the outdoor view is presented in **Figure 5.22**.

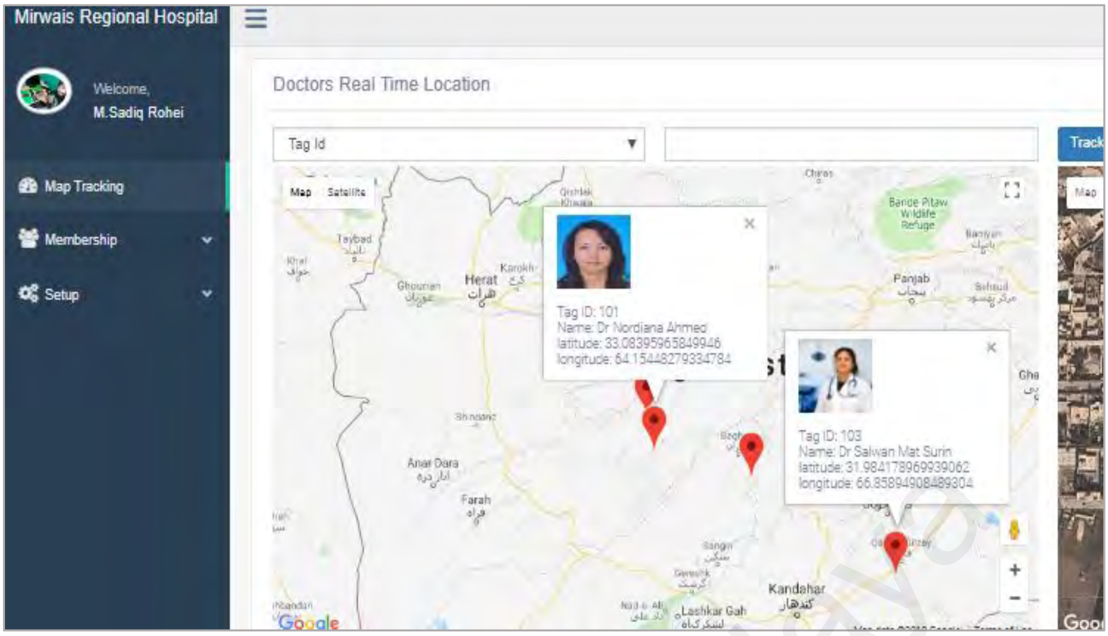

Figure 5.22: Outdoor View of the Members

Doctors can also use the system to view their own information. A screenshot of the tracking view that can be seen by doctors and their families is presented in **Figure 5.23**.

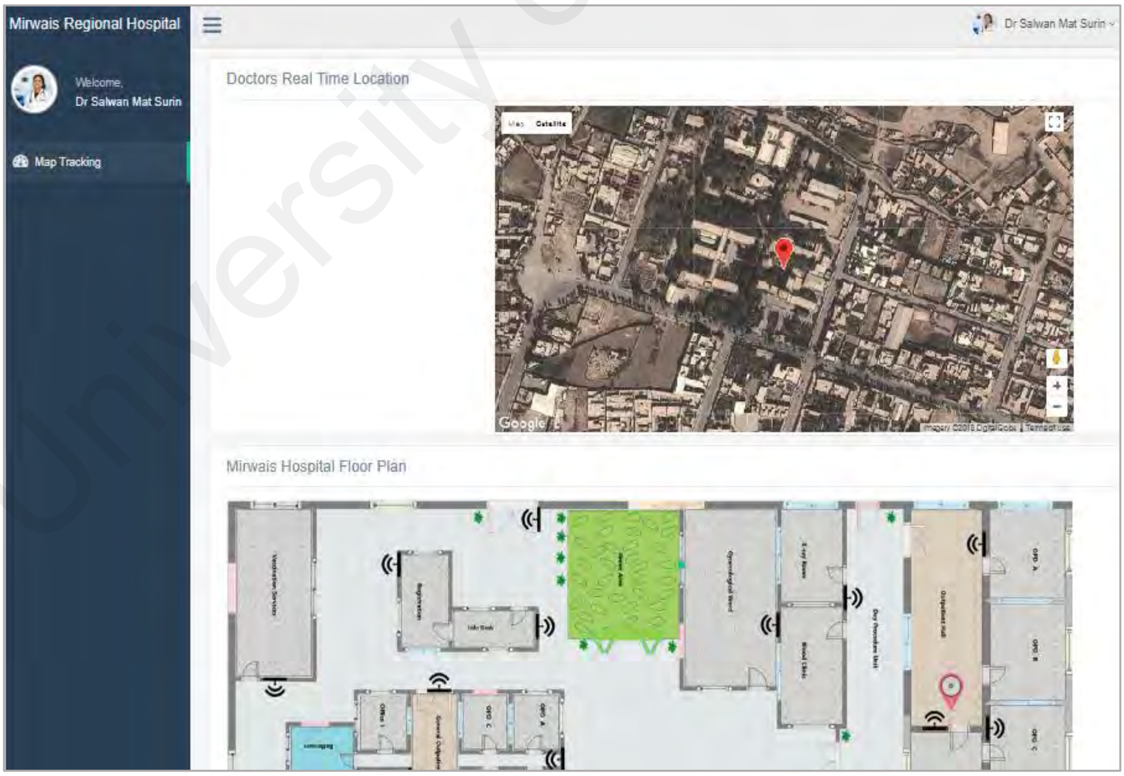

Figure 5.23: Tracking Look for Family Members

As previously mentioned, appropriate credentials for each medical practitioner are to be provided by administrators. Doctors can view the system just as their family members can, and they can refuse tracking entirely if they wish. The outdoor view (shown in **Figure 5.22**) displayed by the system middleware can be seen by both doctors and their relatives, if the location of the member is tracked outside the Mirwais Regional Hospital campus plan.

A very useful function of the RFID & GPS-based human tracking system is the recording of real-time location tracking history. A maximum of four history points of each member are recorded with date, time and location information stored in the back-end database for review. This makes surveillance simpler, allowing end users to follow location history points to determine previous and current locations. An example of the real-time location history view for a member is presented in **Figure 5.24**.

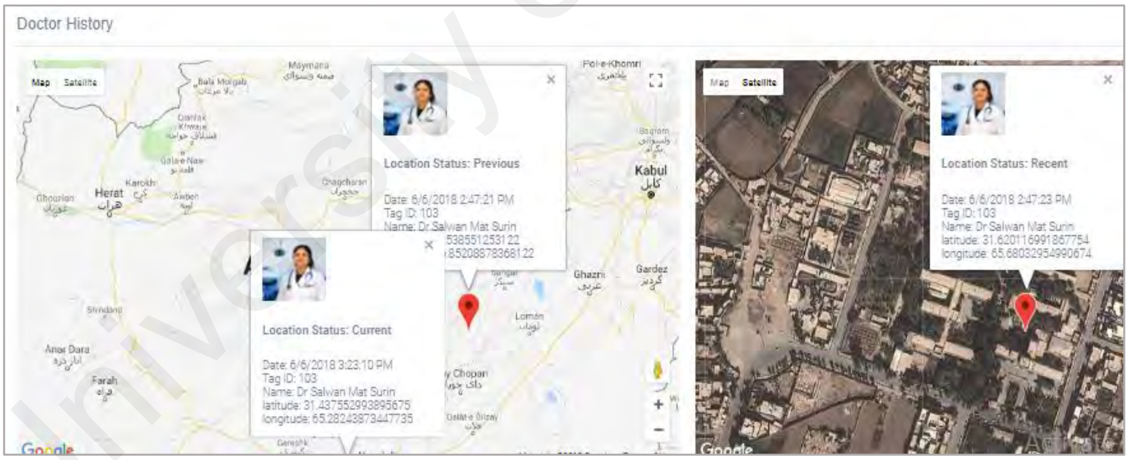

Figure 5.24: Member Tracking History

5.4 Summary

The implementation of the human tracking system was done by simulating RFID tag components (IC chip and antenna) and middleware development. The chip is usually located in the antenna terminal. It is activated and powered by electromagnetic waves radiated by the RFID reader. The chip model can make any UHF RFID tag variants that can have a great impact on its performance. As such, the utilisation of chip impedance in order to reduce power loss and reach better reading distances is very important. Thus, chip impedance must match antenna impedance (Ghiotto et al., 2010; Yeoman, 2014).

The chip was modelled using the Simulink Multiphysics environment, and simulation experiments displayed the inclusive impedance to be $Z_{chip} = 5.6832e\text{-}02 – 3.065{+}03i$ (see **Figure 5.1**). Similarly, a very common circularly polarised antenna was simulated using Matlab version R2017b, PDE tool script and the functions of Antenna Toolbox. Based on various pre-requisites, the RFID tag antenna had a ground plane size of about 0.02 × 0.02 m^2 and was customised to be suitable for embedding into the skins. Its frequency alters regionally for the sampled areas. The examined impedance of the simulated antenna was equal to $Z_{ant} = 7.5470e\text{-}02 + 3.8062e + 03i$ and was closer to the value predicted for the chip. The power gain from the radiation intensity of the antenna was equal to *1.57* dBi, indicating that the tag had better read ranges and acceptable coverage in 3D spatial coordinates. Regarding polarisation, the researcher plotted the antenna using right-handed circular polarisation (RHCP) which is capable of emitting either right or left-handed waves. The antenna seemed to be circularly polarised (see **Figure 5.9**). To evaluate the simulated antenna for circular polarisation, the directivity pattern and axial ratios were used to provide additional support on how antennas emit in different ways. The directivity of the antenna and the resulting axial ratio of *15.23* dB showed that the antenna could be in the form of an ellipse and emit in spherical coordinates. Another important factor was the EIRP (effective isotropic radiated power) which examines antenna reading variations.

In this study, the researcher empirically tested RFID antenna at various EIRP voltages such as 1W, 2W and 4W for distance measurements (see **Figure 5.12**).

The middleware portion of the system was developed to allow the display of real-time locations of physicians retrieved from the server. The back-end database was comprised of important tables and the relationships between them. It contained lookup tables (GPS coordinates) of the research-based area (Kandahar Zone) to allow visualisation on Google Maps for end users (see **Figure 5.15**). A user-friendly online application developed in accordance to the principles of reliability, availability and scalability was made using .Net technology (see **Figure 5.18**).

In the prototype, RFID tags were virtually assigned to doctors' IDs by generating random coordinates. The coordinates were fetched by the back-end database and verified using a specific algorithm (see **Figure 5.16**) with the coordinates of the lookup table. If the location coordinates of the RFID tag matched those of the lookup table, the system would display the precise location data and time interval on Google Maps for end users (see **Figure 5.22**). The system admin has the rights to access any physician's real-time location and this applies to all registered doctors (see **Figure 5.21**). Other users, including relatives of doctors or doctors themselves, can track only relative members/themselves using the appropriate credentials provided by administrators. Doctors have full rights to privacy and may view their own tracking information or refuse tracking altogether if they wish (see **Figure 5.23**). The virtual floor plan of unified centre was incorporated into the GUI application to allow users to zoom in on real-time locations of tracked members within building parameters. When a tracked member is outside the building, the virtual floor plan will not appear (see **Figure 5.22**). Finally, the system tracks the history of a member's movements in up to four points displaying locations visited along with the time of visit, further enhancing tracking capabilities (see **Figure 5.24**).

CHAPTER 6: TEST AND RESULTS

6.1 Overview

In this chapter, the process carried out for testing system functionality and real-world applicability is discussed. This study features multidimensional aspects centred around RFID, Internet of things (IoT) and (GPS) technologies. It presents a suitable mechanism for embedding RFID tags into people intended for tracking. The researcher has conducted unit tests on the system to demonstrate and confirm results.

6.2 Scope of System Test

Testing is the most significant phase in verifying results and system efficiency. In this study, mutual testing was conducted on RFID tags and system functions. Unit tests were performed in the RFID tag simulation to ensure that the designed tag was suited for epidermal use/ for induced into skins. This test aims to confirm the results of the reading distances that mitigating the effects of high metabolism such as high humidity, PH levels and skin temperatures, all of which cause the loss of signal strength. The functionality of the human tracking system was tested using virtual RFID tags assigned to each doctors' IDs by generating random coordinates, then compared using the back-end database lookup table. This resulted in the system displaying coordinates of a user's virtual location in the Kandahar area, this research was based upon.

6.3 RFID Tag Simulation Tests

To test the RFID tag simulation, the following procedures were required.

6.3.1 Test plan for Data Integrity

The data integrity test verifies that data has undergone any alterations on its way from creation to acceptance. The purpose of this test is to verify the techniques used to preserve the state of data entered. The processes employed to confirm the results were highlighted in **Figure 6.1** which shows the test plan used to verify the state of data entered.

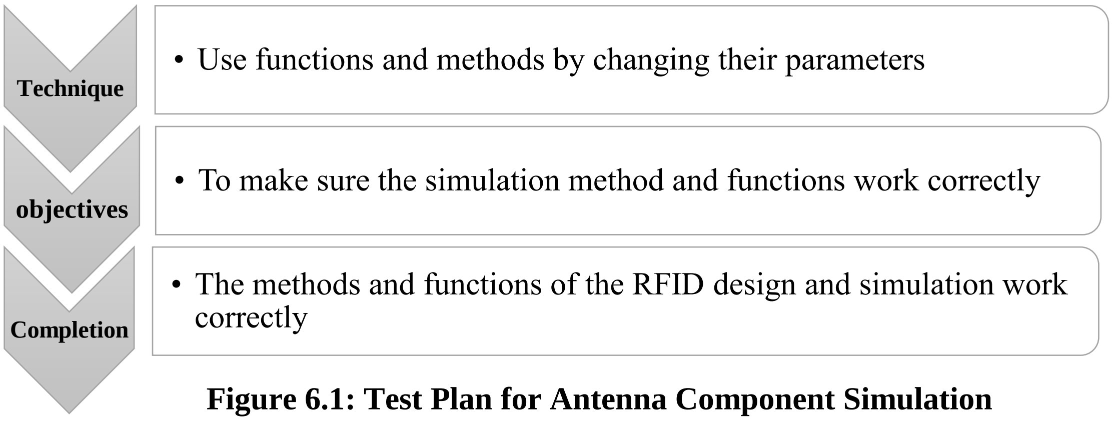

Figure 6.1: Test Plan for Antenna Component Simulation

6.3.2 Methods Testing

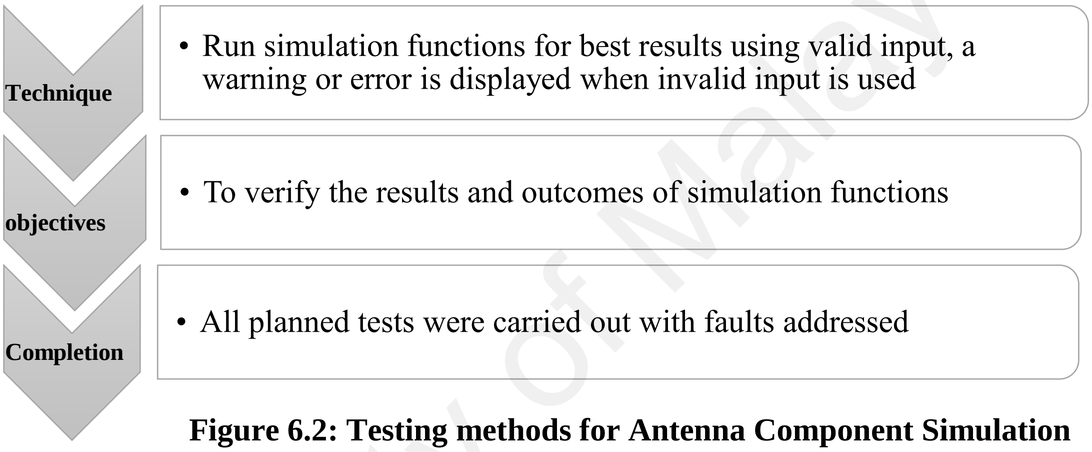

Figure 6.2: Testing methods for Antenna Component Simulation

- RFID chip simulation functions assurance and test process.

Table 6.1: Test Chip Functionality

Methods	Entry	Out put	status
Opened Blank Model (Simulink Environment)	Capacitance, resistance and inductance values, AC voltage sources.	IC "Chip"	√
Impedance measurement and angles measurement blocks	RMS and Divide Parameters, Frequency, Capacitance and voltage source values.	Impedance	√

➢ RFID Antenna simulation functions assurance and test process.

Table 6.2: Test Antenna Functionality

Methods	Entry	Out put	status
`ant = Antenna Mesh( p,t)`	Antenna points , edges and boundary parameters.	Antenna	√
`Z=impedance(ant,868e6)`	Array parameters of Antenna , Frequency.	Impedance	√
`Pattern (ant,868e6)`	Array parameters of Antenna , Frequency.	3D Radiation Graph	√
`PatternAzimuth(ant,868e6)`	Array parameters of Antenna , Frequency.	Azimuth Radiation	√
`PatternElevation(ant,868e6)`	Array parameters of Antenna , Frequency.	Elevation Radiation	√
`Pattern(ant,868e6, ‘ Polarization’ ,’ RCHP’ )`	Array parameters of Antenna , Frequency, RHCP Parameters.	RCHP Polarisation	√
`[Directivity]=pattern (ant,868e6, 0,90)`	Array parameters of Antenna, Frequency, Angles of Azimuth & Elevation.	Directivity	√
`Ar=AxialRation(ant,868e6,20,30)`	Array parameters of Antenna , Frequency, Angles of Azimuth & Elevation.	Axial Ratio	√

6.4 Test Middleware of Human Tracking System

The human tracking system middleware test was divided into two sub-sections:

6.4.1 Back-end Database Test

6.4.1.1 Test plan

This test was done to check the functionality of the back-end database.

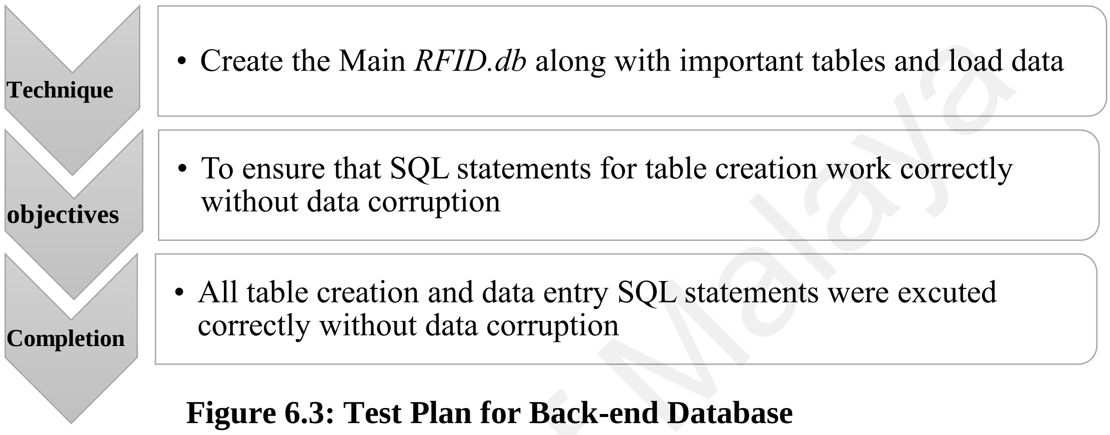

Figure 6.3: Test Plan for Back-end Database

6.4.1.2 Functions Testing

All planned tests were completed and faults addressed for the back-end database. The results obtained showed that valid input passed while invalid input produced a warning or error message that would be displayed. Only one table function was tested for the back-end database due to tables sharing very similar criteria, and this test is presented in **Table 6.3** below.

Table 6.3: Test Bake-end Database Functionality

Methods	Entry	Out put	status
CREATE DATABASE [RFID]	Name of database.	RFID database	√
CREATE TABLE [dbo]. [Doctor][ID][int] IDENTITY (1,1) NOT NULL, [TAG ID] [int] NOT NULL, [First Name] [nvarchar] (50), [Last Name] [nvarchar] (50), [Address] [varchar] (100), CONSTRAINT [ID] PRIMARY KEY,FOREIGN KEY [TAG ID] REFERENCES [TAG ID)	Set columns portions with keys (Primary & Foreign) for tables.	Tables with their rows and columns for back-end database	√

6.4.2 Tracking Middleware Test

6.4.2.1 Test Plan

This test is conducted during the middleware application stage.

6.4.2.2 Functionality Test

All planned tests were carried out and the anticipated result was achieved using valid inputs. Faults were addressed during middleware unit testing, as presented in **Table 6.4**.

Table 6.4: Test Middleware Functionality

Methods	Entry	Out put	status
Login Module	.Net Scripts connection with a back-end server.	Login Form	√
GUI (GRAPICAL USER INTERFACE) Module	Generate and run various ASP.NET scripts based on the back-end database.	Responsive Web App	√
GOOGLE MAP AP1 (GPS FUNCTIONS)	Create a lookup table in the back-end database, ASP.NET scripts and GPS coordinate system.	Location visualisation via Google Map	√
INDOOR AND OUTDOOR TRACKING MODULE	Assign virtual RFID tags and generates random coordinates and compare with a lookup table, include a virtual RFID floor plan (unified centre) to GUI using .Net script.	Pinpoint the virtual location of a registered Member outdoors and within a building parameters	√

6.5 System Results

6.5.1 RFID simulation Results

The RFID tag was designed to have a size of about 0.02×0.02 m^2 and specified in accordance to skin requirements. Its frequency alters regionally for the sampled areas. An RFID tag consists of silicon integrated circuits ('IC' chips) used for transferring RF signals. It is fitted with a small RFID antenna used to wake up the tag's IC. In designing RFID tags for use in the human body, maximising transmission power and antenna radiation intensity is very important. To this end, the examined impedance of the simulated antenna was equal to Z_{ant}= *7.5470e-02 + 3.8062e + 03i* and was closer to the predicted value of the chip: Z_{chip} = *5.6832e-02 – 3.065+03i.* This indicated that the tag had a 90% signal strength competency correlated to the matching factor $\gamma = 0.6$ value between the antenna and chip, but it was not perfectly matching ($\gamma_{max} = 1$). It also shows that the antenna had enough power transmission strength for the tag to be suitable for use in the human body; an environment that may put it under conditions that cause signal strength to drop due to humidity, PH levels and skin temperature. To gather more accurate results, a graph of reflection coefficients (commonly known as S11) was used to measure the power gain of the reflected antenna. The S11 graph presented in **Figure 6.4** concludes that at frequencies below 300 MHz, the S11 is almost 0 dBi. This means that the antenna will reflect all power radiated thereon. Additionally, the graph showed that the antenna emits best at 1000 MHz where S11 = -2 dB. This was beyond from the simulated antenna frequency range. It is also implied that the certified frequency range of 865-868 MHz provides the best power outcome, but it may need a slight decrease to give higher reflection and stability strength.

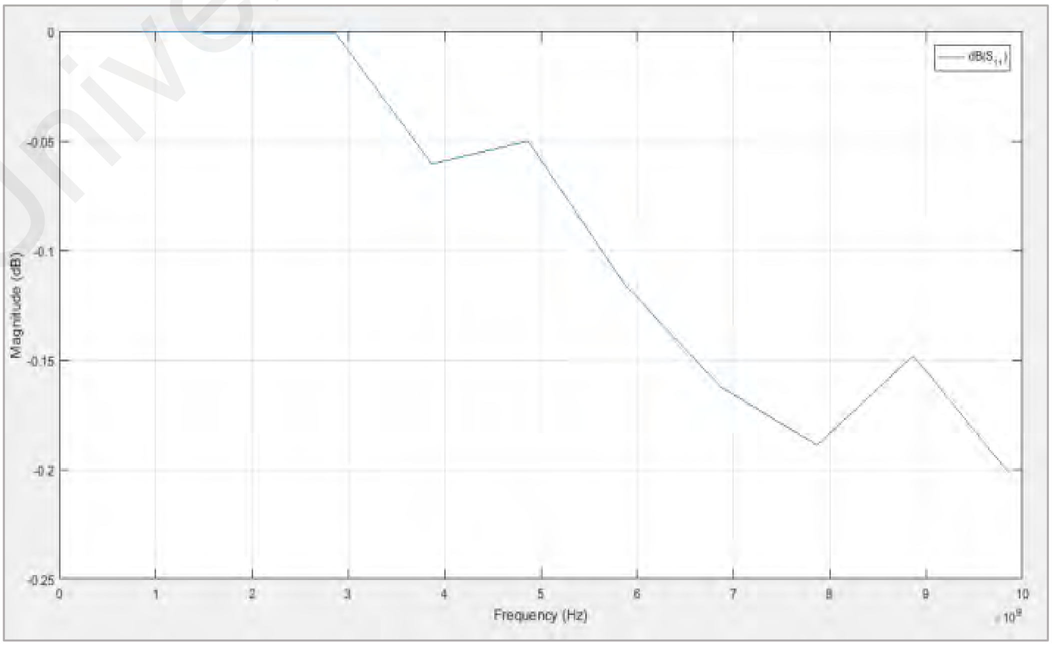

Figure 6.4: Reflection Coefficient Graph for 868 MHz RFID Antenna

The maximum or peak power gain (radiation intensity) achieved by the RFID antenna was equal to $G_{at} = 1.57$ dBi. The radiation intensity confirms that the power gain of the simulated RFID antenna was slightly higher. This suited the designed tag, had acceptable coverage in 3D spatial coordinates and had a better reading distance of almost 4 metres achieved.

Regarding polarisation, the researcher plotted the antenna using right-handed circular polarisation (RHCP) which is capable of emitting either right or left-handed waves. The antenna seemed to be circularly polarised (see **Figure 5.9**). To evaluate the simulated antenna for circular polarisation, the directivity pattern and axial ratios were used to provide additional support on how antennas emit in different ways. As previously stated, directivity is the factor correlated with power gain and antenna efficiency. The directivity can be equal to the antenna gain if there is no power loss, but this is difficult. The result showed that directivity shot up from *-3.52* dBi in the z-plane to its peak value in the x-y direction (i.e., 0° and 180°) at *0.7064* dBi. This indicated that the simulated antenna radiated in spherical coordinates or an ellipse which increased the likelihood of circular polarisation. Another important factor is the axial ratio which defines the probability of circular polarisation. The resulting axial ratio was equal to *15.23* dB of the RFID tag and offered the greatest opportunity for radiating in elliptical coordinates (elliptical polarisation) and circular polarisation.

6.5.2 Read Distance Results

The results of the distance measurements showed that the epidermal RFID tag had better reading distances in all EIRP voltages compared to the power transmitted by the reader based on many factors. The minimum energy or power required to wake the RFID tag (threshold value) and higher backscattered energy to the reader is slightly correlated with long distance reading. The other factor was the EIRP (effective isotropic radiated power) which addresses antenna reading variations. In this study, the researcher empirically tested the RFID antenna at various EIRP voltages such as 1W, 2W and 4W using different threshold values and the power gain realised by simulated antenna through the read range equation (Rao et al., 2005):

$$r = \frac{\lambda}{4\pi}\sqrt{\frac{EIRP\ G_{at}}{P_{th}}}.\gamma$$

1) $EIRP\ = 4\ watt$
2) $P_{th}\ (Threshold\ value)\ = -10dbm$
3) $G_{at}\ (\ power\ gain)\ = 1.57dBi$
4) $\gamma(\ impedence\ matching\ factor) = 0.6\ \ "Detemined\ by\ Matlab"$

$Then$:

5) $G_{at}\ (W) = 10^{Gr/10} = 10^{1.57/10} = 1.435489433\ watt$
6) $P_{th}(W) = 10^{(Pth(dBm)-30)/10} = 10^{(10-30)/10} = 10^{-4} = 0.0001\ watt$

$And:\ \ \lambda = \frac{C}{F} = \frac{3.10^8}{868} = 0{,}345622119\ (m)\ \ then\ \frac{\lambda}{4\pi} = 0{,}027503734$

$Last\ step: substituted\ the\ values\ in\ equation.\ \ r = \frac{\lambda}{4\pi}\sqrt{\frac{EIRP\ G_{at}}{P_{th}}}\ .\gamma$

$Then:\ r = 0{,}027503734(m)\sqrt{\frac{4\times 1.435489433(watt)}{0.0001(watt)}} = 6.59\ (m).(0.6) = 4m$

This calculation showed that higher power enhancements in the RFID tag simulation produced the best reading distance of nearly 4 m, as was tested and verified by rough calculations that expressed similar results to the experiments (see **Figure 5.12**). This measurement showed that the tag is most suitable for use in the human body. The above calculation was only for 4 watts at a -10 dB threshold but all voltages with different threshold values calculations are presented in **Table 6.5**.

Table 6.5: Distance Examined in EIRP Voltages

$Pth/\ EIRP$	$-10\ (dbm)$	$-20(dbm)$	$-25(dbm)$
$1\ watt$	$1.98(m)$	$6.25\ (m)$	$11\ \ (m)$
$2\ watt$	$2.80(m)$	$8.85(m)$	$15.8\ (m)$
$4\ watt$	$4\ (m)$	$12.50(m)$	$22.06(m)$

6.5.3 Tracking Middleware Results

The human tracking system middleware test results showed that the system was well-structured and able to interconnect hospitals with homes to facilitate safer commutes and greatly assist monitoring. The user-friendly GUI interface and the innovative, fast and accurate real-time location tracking were the most outstanding functionalities of the system. It proved to be a reliable, secure, scalable and responsive system that can operate on windows and android platforms. The virtual floor plan of unified centre was incorporated into the GUI application to allow users to zoom in on real-time locations of tracked members within building parameters (see **Figure 5.21**). For outdoor use, the GPS coordinates (latitude and longitude) of the research-based area were entered into the system to display outdoor locations of tracked members. For security purposes, the system was designed to be only available to authorised users and only they can access or request specific member locations. Regarding privacy concerns, participants in this system can only be tracked by family members with the mutual consent of both parties.

The system functions during hospital operation times and doctors are included in a network accessible only to authorised users at any time and from any location. To demo system functionality and real-world applicability, RFID tags were virtually assigned to doctors' IDs by generating random coordinates. The coordinates were then fetched by the back-end database and verified using a specific algorithm (see **Figure 5.16**) with the coordinates in the look up table. If the RFID tag location coordinates matched the lookup table coordinates, the system would retrieve the precise location data and time interval to display to end users on Google Maps (refer to **Figure 5.22**). To prevent data loss, the system carries out backups periodically.

The results also highlighted the RFID & GPS-based human tracking system's ability to record real-time location tracking history. A maximum of four history points for each member are recorded with date, time and location information stored in the back-end database for review (see **Figure 5.24**).

In conclusion, the system and mechanism of embedding RFID tags epidermaly for tracking is highly effective/suitable and guarantees the safety of doctors in hospitals and during fieldwork. The system and its components are acceptable and may be approved for deployment in a real unified centre.

6.6 Discussion on Findings

This is primarily an implementation project and the findings show the suitability of the proposed solution in a practical system. The results of the simulated tag demonstrated that higher power enhancements and impedance matching in the RFID tag simulation produced the best reading distance, which was nearly 4 metres. This was tested and verified using rough calculations that yielded results similar to those of other experiments. Similarly, Shaaban et al. (2013) used UHF passive tags (> 3 metres) in student bags in the hybrid RFID-GPS tracking system to improve child safety during school commutes. However, they did not mention the exact distance RFID tags were to be read from. In the system proposed by (Hutabarat et al., 2016), an RFID tag was implemented as a card/keychain mechanism for human safety purposes in certain areas. They tried to improve previous reading distance results (which were about 3 metres) to 3.27 metres, allowing RFID tags to be read from greater distances. In the case of the tracking systems proposed by (Kalid & Rosli, 2017; Pang et al., 2018) to counter child kidnapping in Malaysia and the United States, they used a tag with a 3 metre reading distance in the form of cards carried by students.

When it comes to the proposed RFID mechanism for this research (tags suitable for use in the human body), several other factors/patterns needed to be considered. These included maximising power transmissions, polarisation and higher antenna power radiation which affects reading distances. In terms of distance, a reading distance of 4 metres for the simulated tag was ideal for applications in the human body. Another challenge was achieving a high tag input inductance with an antenna small enough to be used in the human body; an environment that limits the power available to the chip (Amendola et al., 2015; Makarovaite et al., 2017). In this study, a custom antenna with a size of about $0.02 \times 0.02\ m^2$ was selected and specified according to skin requirements. The researcher thus attempted to maximise signal strength (power transmission) through a feed processes based on many trails. This process helps match chip impedance with that of the antenna and reduces power loss (Loo et al., 2008; Yeoman, 2014). The examined impedance of the simulated antenna was equal to $Z_{ant}= 7.5470e\text{-}02 + 3.8062e + 03i$ and was closer to the predicted value of the chip, which was $Z_{chip} = 5.6832e\text{-}02 – 3.065{+}03i$. This indicated that the tag had a signal strength competency of 90% which correlated to the matching $\gamma = 0.6$ value between tag components. The antenna had enough power transmission strength for the tag to be suitable for use in the human body. The graph of reflection coefficients (commonly known as S11) presented in **Figure 6.4** also concluded that the simulated tags provide the best power outcomes. Elliptical polarisation, empirically achieved by plotting RFID antenna in RHCP, signified that radiation in spherical coordinates (or an ellipse) increased the likelihood of circular polarisation. This served to avoid the problem found in system proposed by (Shaaban et al., 2013) where successful tag detection was based on the location of the tag. In that system, if the tag's direction was perpendicular to the reader's antenna, it could not be detected.

Some of the existing hybrid RFID-GPS systems developed for safety purposes (Deepika & Usha, 2016; Hutabarat et al., 2016; Kalid & Rosli, 2017; Shaaban et al., 2013) have interface, security and privacy concerns along with limitations in scope and feasibility. In the research conducted by Hutabarat et al. (2016), the scope was limited to geographical test areas typically comprising of theme parks or university campuses. The systems proposed by (Kalid & Rosli, 2017; Shaaban et al., 2013) mainly focused on tracking children during commutes to school. Other issues included privacy concerns and the need for more value and reliability from the GPS technology being used. In many of the above systems, access control and data security concerns were not mentioned despite their significant necessity.

The hybrid RFID-GPS system developed in this research included convenient features such as user-friendly GUI as well as innovative, fast and accurate real-time location tracking. It was proven to be reliable, secure, scalable and capable of tracking both doctors at their workplaces and during transportation. The system also included the GPS coordinates of the research-based area (at a state level) and the virtual floor plan of the unified centre. This was to allow end users to visualise system performance on Google Maps and within the building parameters. In terms of security and privacy, the system was designed to only be accessible to authorised users. Participants in this system could only be tracked by family members with the mutual consent of both parties. Regarding data security concerns, the system was designed to carry out backups periodically during hospital operation times. Finally, this study has developed a feature which is the recording of locations history with timestamps allowing easy location of members by following their movement history and this new enhancement by far from the researcher's knowledge has not being implemented in this field of study.

6.7 Summary

Unit testing of the human tracking system was done to verify the results of simulated RFID tags and system middleware. The first part of the test included verification of data integrity and a unit test plan for chip modelling and antenna simulation (refer to **Figure 6.1** and **6.2**). This was accomplished to determine the techniques that provided the anticipated results (refer to **Tables 6.1** and **6.2**). Faults were addressed in the unit tests using invalid inputs. The second test phase addressed the middleware of the tracking system. In middleware test, back-end database testing was performed only for one table due to shared criteria between tables in the database (refer to **Table 6.3**). Middleware GUI interface functionality was tested by running .Net scripts. The system performed very well and was free of technical issues and runtime errors (refer to **Table 6.4**).The results of the system display, the observed impedance of the simulated RFID antenna was $Z_{ant} = 7.5470e\text{-}02 + 3.8062e + 03i$ and was closer to the predicted value of the chip $Z_{chip} = 5.6832e\text{-}02 - 3.065+03i$. This showed that the tag had a 90% signal strength competency correlating to the matching factor $\gamma = 0.6$ value between the antenna and chip. This meant higher transmission rates and a power gain of nearly *1.57* dBi achieved. As a result, better reading distance of almost 4 metres produced (refer to **Table 6.5**). This also indicated that the tag was effective and suitable for use under conditions in the human body which may have led to weaker signals due to humidity, PH levels and skin temperatures. To gather more accurate results, a graph of reflection coefficients (commonly known as S11) presented in **Figure 6.4** conclude that the certified frequency range of 865-868 MHz provides the best power outcome, but it may need a slight decrease to give higher reflection and stability strength.

When it came to polarisation, the researcher plotted the antenna using right-handed circular polarisation (RHCP) which is capable of emitting either right or left-handed waves. The antenna seemed to be circularly polarised (see **Figure 5.9**). The directivity of the antenna and resulting axial ratio (*15.23* dB) indicated that the antenna had a chance to emit in an elliptical fashion within spherical coordinates, increasing the likelihood of elliptical polarisation and circular polarisation. Distance reading measurements were performed using calculations that presented a good reading distance of nearly 4 m with a normal threshold of -10dbm for an EIRP of 4W achieved but for all voltages with different threshold calculation was shown(refer to **Table 6.5**).

The human tracking system's middleware proved to be reliable, secure, scalable and well-structured. It interconnects hospitals with homes to facilitate safer commutes and greatly assists monitoring. A responsive platform that can be operated on both windows and android was also provided. The system was designed to be only accessible to authorised users, and only authorised users can view their respective member's real-time location. Regarding privacy concerns, participants in this system can only be tracked by family members with the mutual consent of both parties.

The system was designed to function during hospital operation times and include doctors in a network accessible only to authorised users anytime from any location. To demo system functionality and real-world applicability, RFID tags were virtually assigned to doctors' IDs by generating random coordinates. The coordinates were then fetched by the back-end database and verified using a specific algorithm (see **Figure 5.16**) with coordinates from the look up table. If the RFID tag location coordinates matched the lookup table coordinates, the database would retrieve the precise location data with the time interval to display on Google Maps for end users to view. The system was also designed to carry out backups periodically.

In conclusion, the system and the mechanism of embedding RFID tags epidermaly for tracking is highly effective/suitable and guarantees the safety of doctors in hospitals and during fieldwork. The system and its components are acceptable and may be approved for deployment in a real unified centre.

CHAPTER 7: CONCLUSION AND FUTURE WORK

7.1 Introduction

This chapter concludes with a concise report highlighting the achievement of study objectives as well as research contributions this study offers. It also includes study constraints and limitations while providing recommendations on directions future research can take.

7.2 Fulfilment of Research Objectives

This study presented a Hybrid RFID-GPS system with the potential to help save lives in communities with high crime/kidnapping rates. A smart human tracking system was proposed and simulated to evaluate possible mechanisms of RFID tags in human tracking systems. The approach taken was to first simulate RFID tags implanted epidermaly so as to leave no possibility for removal without the destruction of the tag. During experimentation, the simulated tag had a higher power transmission rate which correlated with higher signal strength competency. This was about 90% considering the impedance matching factor ($\gamma = 0.6$) between the antenna and the chip. The higher power gain enhancement value of 1.57 dBi allowed for a reading distance of nearly 4 metres to be achieved. This measurement along with elliptical polarisation fusion signal emission and the reflective coefficients measured in the S11 graph made the tag ideal for use within the human body.

The other objectives were to implement and test the human tracking system using RFID and GPS technologies. An innovative, smart, real-time location tracking system was developed using a combination/hybrid of these technologies under the IoT paradigm. It functioned to track doctors in hospitals, campuses, field work and during commutes between these locations. The system could track doctors and their respective transportation, be it private or public. A virtual floor plan of the unified centre along with the GPS coordinates of the research-based area were incorporated into the system to allow end users to view the real-time locations of tracked members within building parameters and on Google Maps. In addition, four history points of member locations are recorded with timestamps allowing for easy location of members by following their movement history. The system's middleware was tested as a lab demo for real-world applicability and proved to be reliable, secure, scalable and well-structured. Tags were evaluated in the tracking system in such a way that they were virtually assigned to doctors' IDs by generating random coordinates. The coordinates were then fetched by the back-end database and verified through specific algorithms whereby the system would pinpoint and display the precise location-coordinates of the intended tags. Finally, analysis and testing concluded that the system and mechanisms used for RFID tags were highly effective and ideal for guaranteeing doctors' safety in hospitals and during fieldwork. The system and its components have also been shown to be acceptable and may be approved for deployment in a real unified centre.

7.3 Research Contributions

In this study, a smart hybrid RFID-GPS human tracking system was proposed to track the movement and real-time locations of members both indoors and outdoors. The following are the research contributions made by this thesis:

- The main contribution of this research was the design and implementation of a human tracking system that used a hybrid of RFID and GPS technologies.
- It exposed the potential limitations of human tracking systems proposed in previous research. For example, tags embedded in clothing, bracelets, student bags, cards and keychains had the potential to be lost, damaged or used by imposters.
- It proposed a mechanism for embedding an RFID tag epidermaly leaving no possibility of easy use or removal without tag destruction. Experimentally, it

showed higher power transmission rates and had better reading distances, making it most suitable for use in the human body.

- An innovative, smart, RFID-GPS hybrid real-time location tracking system was applied using these tags to produce a certified model that aims to help save lives in communities with high crime/kidnapping rates.
- As stated previously, ensuring the safety of medical practitioners is a significant demand, especially in the two regions mentioned in this study (Afghanistan and Pakistan). As such, a lab demo test of the system concluded that it will be able to meet these needs and is ready for actual establishment.
- This research plans for at least one journal to be published, providing future recommendations for overall system optimisation.

7.4 Research Limitations

Every research project encounters various limitations during trial and development phases such as time and resources. Similarly, in this study there were also certain constraints that could not be met. The design and implementation of a hybrid (RFID+GPS) system requires considerable effort, resources and time to properly set up and meet community needs. This research encountered data privacy concerns and opposition from the relevant departments in the research-based area in the data collection phase. During system modelling, as the researcher used simulation kits for RFID tag components (chip and antenna), certain modules, controllers and libraries were not licensed in the latest version Matlab R2017b and Simulink Multiphysics subscriptions used in the University of Malaya. Similarly, implementing code-based RFID tag geometry and system middleware by considering GPS coordinates is challenging and was attempted plenty of times by experts. However, this was primarily an implementation project. The findings showed the suitability of the proposed design in a practical system carried out in simulation environments and lab demo applications. Lack of infrastructure, funding and greater time resources were the main obstacles to real usability testing of the system at a unified centre.

It is also important to note that there were constraints that this study was unable to meet. The proposed mechanisms for RFID tags were merely simulations that were not considered at prototype levels as this was beyond the scope of this study. Regarding mean polarisation, achieving perfect polarisation is a major challenge for researchers considering various circumstances. Fortunately, elliptical polarisation was empirically achieved by plotting RFID antenna in RHCP, signified that radiation in spherical coordinates (or an ellipse) increased the likelihood of circular polarisation. Still, slight improvement is required to achieve the best location accuracy between RFID tags and readers. In this study, RFID readers were considered only in term of the GPS module; additional consideration was not given to readers' performance in a human tracking system integrated with other modules. Another constraint the system could not meet was usability testing in a real environment. Nevertheless, lab demo tests concluded the system and its components were acceptable and may be approved for deployment in a real unified centre.

7.5 Recommendation for Future Research

This work was primarily an implementation project. The research goals have been achieved and make for a significant contribution to the security field, especially human security. Future research is recommended for enhancing visual tracking, best location accuracy and the deployment of the system in a real environment.

It is recommended that future work further enhance this system by integrating RFID readers with camera modules to visually locate/track objects. Other work may concentrate on the circular polarisation of antennas to achieve the best location accuracy between RFID tags and readers. Physical/usability testing at a unified centre by authorised personnel is needed to ensure that the smart tracking system meets community needs in a real environment. The future of human tracking systems will see prototyped RFID tags being implemented for epidermal use.

REFERENCES

Abbasi, A. Z., & Shaikh, Z. A. (2008). *Building a smart university using RFID technology.* Paper presented at the Computer Science and Software Engineering, 2008 International Conference on.

Ahson, S. A., & Ilyas, M. (2017). *RFID handbook: applications, technology, security, and privacy*: CRC press.

Aironet, C. (2007). Antenna Patterns and Their Meaning. Retrieved from https://www.cisco.com/c/en/us/products/collateral/wireless/aironet-antennas-accessories/prod_white_paper0900aecd806a1a3e.html

Al-Ali, A., Aloul, F. A., Aji, N. R., Al-Zarouni, A. A., & Fakhro, N. H. (2008). *Mobile RFID tracking system.* Paper presented at the Information and Communication Technologies: From Theory to Applications, 2008. ICTTA 2008. 3rd International Conference on.

Al-Amir, Z., Al-Saidi, F. A., & Abdulkadir, H. (2008). *Design and implementation of RFID system.* Paper presented at the Systems, Signals and Devices, 2008. IEEE SSD 2008. 5th International Multi-Conference on.

Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of things: A survey on enabling technologies, protocols, and applications. *IEEE Communications Surveys & Tutorials, 17*(4), 2347-2376.

Ambesh, P. (2016). Violence against doctors in the Indian subcontinent: A rising bane. *Indian heart journal, 68*(5), 749-750.

Amendola, S., Milici, S., & Marrocco, G. (2015). Performance of epidermal RFID dual-loop tag and on-skin retuning. *IEEE Transactions on Antennas and Propagation, 63*(8), 3672-3680.

Ashton, K. (2009). That 'internet of things' thing. *RFID journal, 22*(7), 97-114.

Atzori, L., Iera, A., & Morabito, G. (2014). From" smart objects" to" social objects": The next evolutionary step of the internet of things. *IEEE Communications Magazine, 52*(1), 97-105.

Badia-Melis, R., Garcia-Hierro, J., Ruiz-Garcia, L., Jiménez-Ariza, T., Villalba, J. I. R., & Barreiro, P. (2014). Assessing the dynamic behavior of WSN motes and RFID semi-passive tags for temperature monitoring. *Computers and Electronics in Agriculture, 103*, 11-16.

Balanis, C. (2005). Antenna Theory Analysis and Design 3rd edition, A John Wiley & Sons. *Inc., Publication*.

Bansal, R. (2003). Coming soon to a Wal-Mart near you. *IEEE Antennas and Propagation Magazine, 45*(6), 105-106.

Baykan, Z., Öktem, İ. S., Çetinkaya, F., & Naçar, M. (2015). Physician exposure to violence: a study performed in Turkey. *International journal of occupational safety and ergonomics, 21*(3), 291-297.

Bennett, A., Barrett, D., Vandor, I., Soltan, K., Cho, Y., Lutcavage, M., & Lam, C. H. (2016). *Fish tagging via RFID and bluetooth: Crowdsourced fish tracking through better reporting tools.* Paper presented at the OCEANS 2016 MTS/IEEE Monterey.

Bhayani, M., Patel, M., & Bhatt, C. (2016). *Internet of Things (IoT): In a way of smart world.* Paper presented at the Proceedings of the international congress on information and communication technology.

Bob Violino, M. R. (2005). "The history of RFID Technology and its standards". Retrieved from https://www.cardintegrators.com/the-history-of-rfid/ ,http://www.rfidjournal.com/articles/view?1335

Bolic, M., Simplot-Ryl, D., & Stojmenovic, I. (2010). *RFID systems: research trends and challenges*: John Wiley & Sons.

Chang, Y.-J., Chen, C.-N., Chou, L.-D., & Wang, T.-Y. (2008). *A novel indoor wayfinding system based on passive RFID for individuals with cognitive impairments.* Paper presented at the Pervasive Computing Technologies for Healthcare, 2008. PervasiveHealth 2008. Second International Conference on.

Chase, J. (Producer). (2013). The evolution of the internet of things. *Texas Instruments*.

Chawla, V., & Ha, D. S. (2007). An overview of passive RFID. *IEEE Communications Magazine, 45*(9).

Chiesa, M., Genz, R., Heubler, F., Mingo, K., Noessel, C., Sopieva, N., . . . Tester, J. (2002). RFID: a week long survey on the technology and its potential. *Harnessing Technology Project-Interaction Design Institute Ivrea*.

Chowdhury, P., Bala, P., Addy, D., Giri, S., & Chaudhuri, A. R. (2016). *RFID and Android based smart ticketing and destination announcement system.* Paper presented at the Advances in Computing, Communications and Informatics (ICACCI), 2016 International Conference on.

Chumkamon, S., et al. (2008). A blind navigation system using RFID for indoor environments. Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, 2008. ECTI-CON 2008. 5th International Conference on, IEEE.

D. Kravets. (2012, 08 07 2012). "Tracking School Children With RFID Tags? It’s All About the Benjamins,". Retrieved from http://www.wired.com/2012/09/rfid-chip-student-monitoring/

Decarli, N., Guidi, F., & Dardari, D. (2016). Passive UWB RFID for tag localization: Architectures and design. *IEEE Sensors Journal, 16*(5), 1385-1397.

Deepika, K., & Usha, J. (2016). *Investigations & implications on location tracking using RFID with Global Positioning Systems.* Paper presented at the Computer and Information Sciences (ICCOINS), 2016 3rd International Conference on.

Domdouzis, K., Kumar, B., & Anumba, C. (2007). Radio-Frequency Identification (RFID) applications: A brief introduction. *Advanced Engineering Informatics, 21*(4), 350-355.

Ganz, A., Gandhi, S. R., Wilson, C., & Mullett, G. (2010). *INSIGHT: RFID and Bluetooth enabled automated space for the blind and visually impaired.* Paper presented at the Engineering in Medicine and Biology Society (EMBC), 2010 Annual International Conference of the IEEE.

Ghiotto, A., Vuong, T., & Wu, K. (2010). *Chip and antenna impedance measurement for the design of passive UHF RFID tag.* Paper presented at the Microwave Conference (EuMC), 2010 European.

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future generation computer systems, 29*(7), 1645-1660.

Gueaieb, W., & Miah, M. S. (2008). An intelligent mobile robot navigation technique using RFID technology. *IEEE Transactions on Instrumentation and Measurement, 57*(9), 1908-1917.

Hu, F., Celentano, L., & Xiao, Y. (2009). Error-resistant RFID-assisted wireless sensor networks for cardiac telehealthcare. *Wireless Communications and Mobile Computing, 9*(1), 85-101.

Hussain, S., Schaffner, S., & Moseychuck, D. (2009). *Applications of wireless sensor networks and rfid in a smart home environment.* Paper presented at the Communication Networks and Services Research Conference, 2009. CNSR'09. Seventh Annual.

Hutabarat, D. P., Hendry, H., Pranoto, J. A., & Kurniawan, A. (2016). *Human tracking in certain indoor and outdoor area by combining the use of RFID and GPS.* Paper presented at the Wireless and Mobile (APWiMob), 2016 IEEE Asia Pacific Conference on.

Impinj. "RFID STANDARDS". Retrieved from https://www.impinj.com/about-rfid/rfid-standards/

Jawaid, S. A. (2013). Kidnapping and target killing of doctors in Baluchistan. *Pulse International, 14*(22).

Juels, A. (2006). RFID security and privacy: A research survey. *IEEE journal on selected areas in communications, 24*(2), 381-394.

Kalid, K. S., & Rosli, N. (2017). KidBus. Tracker: The Development of a Schoolchildren Identification and Transportation Tracking System. *International Journal of Innovative Computing, 7*(2).

Karthika, P., Priya, J. H. R., & Pandian, A. R. (2015). Indoor Location Tracking System Using RFID Technology. In: Citeseer.

Kim, S.-C., et al. (2013). "RFID-based indoor location tracking to ensure the safety of thelderly in smart home environments." Personal and ubiquitous computing 17(81699-1707.

Konsynski, B., & Smith, H. A. (2003). Developments in practice x: Radio frequency identification (rfid)-an internet for physical objects. *Communications of the Association for Information Systems, 12*(1), 19.

Landt, J. (2005). The history of RFID. *IEEE potentials, 24*(4), 8-11.

Li, S., Da Xu, L., & Zhao, S. (2015). The internet of things: a survey. *Information Systems Frontiers, 17*(2), 243-259.

Li, S., Visich, J. K., Khumawala, B. M., & Zhang, C. (2006). Radio frequency identification technology: applications, technical challenges and strategies. *Sensor Review, 26*(3), 193-202.

Liu, H., Darabi, H., Banerjee, P., & Liu, J. (2007). Survey of wireless indoor positioning techniques and systems. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), 37*(6), 1067-1080.

Loo, C., Elmahgoub, K., Yang, F., Elsherbeni, A., Kajfez, D., Elsherbeni, T., . . . Kivikoski, M. (2008). Impedance Matching for RFID Tag Antennas. *24th Annu. Rev. Prog. Appl. Comput. Electromagn*, 749-753.

López, T. S., Ranasinghe, D. C., Harrison, M., & McFarlane, D. (2012). Adding sense to the Internet of Things. *Personal and Ubiquitous Computing, 16*(3), 291-308.

Lu, J.-H., & Chang, B.-S. (2017). Planar Compact Square-Ring Tag Antenna with Circular Polarization for UHF RFID Applications. *IEEE Transactions on Antennas and Propagation, 65*(2), 432-441.

Luo, Q., & Zhu, F. (2013). *Circularly polarized antennas*: John Wiley & Sons.

Makarovaite, V., Hillier, A., Holder, S., Gourlay, C., & Batchelor, J. (2017). Miniature on skin passive UHF RFID antenna sticker.

Mautz, R. (2012). *Indoor positioning technologies.*

Mejjaouli, S., & Babiceanu, R. F. (2015). RFID-wireless sensor networks integration: Decision models and optimization of logistics systems operations. *Journal of Manufacturing Systems, 35*, 234-245.

Mulla, A., Baviskar, J., Baviskar, A., & Bhovad, A. (2015). *GPS assisted Standard Positioning Service for navigation and tracking: Review & implementation.* Paper presented at the Pervasive Computing (ICPC), 2015 International Conference on.

Naskar, S., Basu, P., & Sen, A. K. (2017). A Literature Review of the Emerging Field of IoT Using RFID and Its Applications in Supply Chain Management. *The Internet of Things in the Modern Business Environment Advances in E-Business Research*, 1-27.

Ndibanje, B., Lee, H.-J., & Lee, S.-G. (2014). Security analysis and improvements of authentication and access control in the internet of things. *Sensors, 14*(8), 14786-14805.

Occhiuzzi, C., Calabrese, C., & Marrocco, G. (2008). *Body-matched slot antennas for RadioFrequency identification.* Paper presented at the XXIX URSI General Assembly.

Orban, D., & Moernaut, G. (2009). The basics of patch antennas, updated. *RF Globalnet (www. rfglobalnet. com) newsletter*.

Pajhwoknews. (2017). "Doctors, kin kidnapped this year". Retrieved from https://www.pajhwok.com/en/2017/12/24/20-nangarhar-doctors-kin-kidnapped-year

Pang, Y., Ding, H., Liu, J., Fang, Y., & Chen, S. (2018). A UHF RFID-Based System for Children Tracking. *IEEE Internet of Things Journal, 5*(6), 5055-5064.

Pateriya, R., & Sharma, S. (2011). *The evolution of RFID security and privacy: a research survey.* Paper presented at the Communication Systems and Network Technologies (CSNT), 2011 International Conference on.

Penttilä, K., Keskilammi, M., Sydänheimo, L., & Kivikoski, M. (2006). Radio frequency technology for automated manufacturing and logistics control. Part 2: RFID antenna utilisation in industrial applications. *The International Journal of Advanced Manufacturing Technology, 31*(1-2), 116-124.

Rajagopalan, H., & Rahmat-Samii, Y. (2010). *On-body RFID tag design for human monitoring applications.* Paper presented at the Antennas and Propagation Society International Symposium (APSURSI), 2010 IEEE.

Rao, K. S., Nikitin, P. V., & Lam, S. F. (2005). Antenna design for UHF RFID tags: A review and a practical application. *IEEE Transactions on antennas and propagation, 53*(12), 3870-3876.

Roberts, C. M. (2006). Radio frequency identification (RFID). *Computers & security, 25*(1), 18-26.

Saha, D., & Mukherjee, A. (2003). Pervasive computing: a paradigm for the 21st century. *Computer, 36*(3), 25-31.

Saha, H. N., Auddy, S., Chatterjee, A., Pal, S., Sarkar, S., Singh, R., . . . Sarkar, R. (2017). *IoT solutions for smart cities.* Paper presented at the Industrial Automation and Electromechanical Engineering Conference (IEMECON), 2017 8th Annual.

Sardroud, J. M. (2012). Influence of RFID technology on automated management of construction materials and components. *Scientia Iranica, 19*(3), 381-392.

Shaaban, K., Bekkali, A., Hamida, E. B., & Kadri, A. (2013). Smart Tracking system for school buses using passive RFID technology to enhance child safety. *Journal of Traffic and Logistics Engineering, 1*(2), 191-196.

Shieh, H.-L., Huang, C.-C., Lyu, F.-S., Zhang, Z.-C., & Zheng, T.-S. (2016). *An emergency care system using RFID and Zigbee techniques.* Paper presented at the Computer, Consumer and Control (IS3C), 2016 International Symposium on.

Shiraishi, T., Komuro, N., Ueda, H., Kasai, H., & Tsuboi, T. (2008). *Indoor location estimation technique using UHF band RFID.* Paper presented at the Information Networking, 2008. ICOIN 2008. International Conference on.

Stankovic, J. A. (2014). Research directions for the internet of things. *IEEE Internet of Things Journal, 1*(1), 3-9.

Terry, F. (2013). Violence against health care: insights from Afghanistan, Somalia, and the Democratic Republic of the Congo. *International Review of the Red Cross, 95*(889), 23-39.

Tesoriero, R., Tebar, R., Gallud, J. A., Lozano, M. D., & Penichet, V. M. R. (2010). Improving location awareness in indoor spaces using RFID technology. *Expert Systems with Applications, 37*(1), 894-898.

Tsuboi, T., Shiraishi, T., & Komuro, N. (2009). *Indoor human positioning tracking technique to support high-quality life.* Paper presented at the ICCAS-SICE, 2009.

Vermesan, O., Friess, P., Guillemin, P., Gusmeroli, S., Sundmaeker, H., Bassi, A., . . . Eisenhauer, M. (2011). Internet of things strategic research roadmap. *Internet of Things-Global Technological and Societal Trends, 1*(2011), 9-52.

Want, R. (2006). RFID explained: A primer on radio frequency identification technologies. *Synthesis Lectures on Mobile and Pervasive Computing, 1*(1), 1-94.

Weis, S. A., Sarma, S. E., Rivest, R. L., & Engels, D. W. (2004). Security and privacy aspects of low-cost radio frequency identification systems. In *Security in pervasive computing* (pp. 201-212): Springer.

Wu, M., Lu, T.-J., Ling, F.-Y., Sun, J., & Du, H.-Y. (2010). *Research on the architecture of Internet of things.* Paper presented at the Advanced Computer Theory and Engineering (ICACTE), 2010 3rd International Conference on.

Yan, L., Zhang, Y., Yang, L. T., & Ning, H. (2008). *The Internet of things: from RFID to the next-generation pervasive networked systems*: CRC Press.

Yeoman, M. (2014). RFID Tag Read Range and Antenna Optimization. Retrieved from https://www.comsol.com/blogs/rfid-tag-read-range-antenna-optimization/

Yu, M., Deng, T., & Fu, J. (2012). *Application of RFID and GPS technology in transportation vehicles monitoring system for dangerous goods.* Paper presented at the Remote Sensing, Environment and Transportation Engineering (RSETE), 2012 2nd International Conference on.

Zhang, Z., Lu, Z., Chen, Q., Yan, X., & Zheng, L.-R. (2010). *COSMO: CO-simulation with MATLAB and OMNeT++ for indoor wireless networks.* Paper presented at the Global Telecommunications Conference (GLOBECOM 2010), 2010 IEEE.

Ziai, M. A., & Batchelor, J. C. (2011). Temporary on-skin passive UHF RFID transfer tag. *IEEE Transactions on Antennas and Propagation, 59*(10), 3565-3571.