Utilising Contactless Communications for Next Generation of Mobile Ubiquitous Applications

By

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In fulfilment of the requirement for the degree of

Doctor of Philosophy

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Lancaster, UK

2010

To Mom & Dad

Declaration

I hereby declare that the work included in this thesis is my own except where mentioned otherwise. The work was carried out the Department of Communication Systems at Lancaster University. No part of this work has been submitted for a higher degree either at this university or at any other academic institution. Most of the research presented here has already appeared in the form of publications (journal articles, conference proceeding and book chapters).These publications are referenced throughout the text and listed in the appendix.

Omer Rashid

B38, InfoLab21, Lancaster University, October 2010

Acknowledgement

It is the end of a long and fascinating journey and I cannot help reflecting on the time spent and people who made it possible for me to reach the end successfully. I would like to take the opportunity to acknowledge and thank;

My parents, who have always supported me and encouraged me to follow my dreams, it would have not been possible for me to reach where I am today without their unconditional love, support, guidance and encouragement. I can never thank them enough for what they have done for me but I can only hope that my accomplishment will bring them great pride.

My supervisor Dr. Paul Coulton, whose guidance over the years has made it possible for me to achieve this goal. He introduced me to Mobile Communication Systems and sparked an enthusiasm that has made my work feel exciting. He has been my teacher, mentor and most importantly a friend who has always been there for me through good and bad times both at work and outside. I don't have the words to thank him for his support.

My wife Safoora and my 2 year old son Rahym for their support, love and understanding; working a fulltime job and spending weekends finishing this thesis I have not had the chance to spend much time with them. Rahym thanks for all the lovely hugs, kisses and smiles they always brighten my day and makes all the work seem easier. Safoora thanks for taking care of other matters allowing me to focus on this thesis.

My brothers and my sister, for their love and support throughout this journey.

Most importantly all thanks to God Almighty for blessing me with such great people in my life without whom I would be lost. I am lucky to have always found myself surrounded with great, loving and supporting people.

Last but not the least I wish I could have found some more time between work and other commitments to finish this thesis earlier before my mother passed away to honour her wishes. Mom I am truly sorry and wish that you were as proud of me as I am of you, I love you, rest in peace.

Abstract

Location plays an important role in current mobile applications and services whether it is social applications, gaming, entertainment or mobile commerce, the global market for LBS is projected to reach £13.26 billion by 2015 and a subscriber base of 1.24 billion. It is the well proven winning combination of location awareness and ubiquitous nature of mobile phones that is responsible for a steady increase in mobile data usage and it is predicted that by 2013 mobile devices will overtake PC as the most common web access device. Applications and services utilising traditional location tracking approaches of GPS and Cell id fail to provide a good experience indoors so alternative location positioning schemes need to be utilised. These applications claim to be truly ubiquitous however whether they are social applications, commerce, advertising, gaming or entertainment applications they still tend to engulf the user in computing process, for example if we consider location based or mobile mixed reality gaming it becomes clear that although location plays a part in the game play actual user interaction with the localised environment is often limited.

The work presented in this thesis explores the utilisation of implied location technologies to bridge the gap left by the current applications. In particular it investigates the use of Bluetooth and NFC in to locate the mobile user. The approach taken by this research is to look at utilisation of implied location technologies across a range of applications and services through real world experimentation. In particular their effectiveness has been researched in relation to three areas considered likely to benefit most from location based information: mobile advertising, mixed reality gaming and mobile social applications. Work carried out on providing location based advertising for existing mobile users via Bluetooth has shown that implied location technologies can be very useful to improve the diminishing response to mobile advertising. Mixed reality game, Pac-Lan demonstrates that NFC can not only be utilised as an implied location positioning scheme but also for improving user interaction with the real world. It has also shown that effective user interaction with physical objects can be achieved through NFC resulting in an enhanced user experience. Results presented within have also shown that implied location positioning schemes are effective in mixed reality gaming context and can lead to interesting tactics developing over subsequent game play. From a mobile social application perspective the work presented here shows that through use of NFC social inclusion can be achieved at both individual and group level. Moreover utilising NFC for mobile social applications can help achieve a symbiosis between user, device and environment where interaction space is not simply the space where interaction amongst users takes place but is an integral part the of the experience.

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Chapter 1

Introduction

1 Introduction

In the emerging world of m-commerce, mobile gaming and social applications users consistently cite location based information as one of the services that they increasingly use or would most likely utilise. However, solutions for obtaining the specific location of a mobile user predominately rely on the provision of additional hardware and/or software within either the mobile phone or system infrastructure. Further, these techniques are often inappropriate for indoor and highly urban environments, where they are often most useful, as the line of sight to the location measurement unit is often obscured resulting in inaccurate and unreliable positional information.

The opportunities provided by mobile phones and systems that aid the development of novel applications are features such as:

- high mobility (including always online connectivity);
- personalisation (through location, proximity, contextualisation, or feature evolution);
- large user demographic (currently four billon phones worldwide and rising across the whole range of age and gender).

Of these three features, personalisation arguably provides the greatest opportunity and is already a widespread activity for many current users who increasingly download ringtones, music, games, and wallpapers to personalise their mobile phones. The emergence of new and standardised operating systems (Rashid, Coulton and Edwards 2008) has enabled software developers to produce a richer variety of software applications for the personalisation of mobile phones and one of the principle methods of dynamically personalising this software is provided through location based information. Some applications may be very location-centric with this becoming the core of the entire service, for example, mapping applications and tools to find the shortest route and the closest restaurant. Other applications may use location information to provide information or advertisements relevant to a particular user at their current location, for example, suggesting their favourite type of restaurant in a town where they are visiting along with suitable place to park. Such location based information is expected (Kannan, Chang and Whinston 2001) to have a significant influence on user behaviour. Providing location information for these services is far from straightforward, often requiring significant change in the software and hardware of the mobile system and/or the handset, to ensure that the information is highly relevant to the user's actual position. Location information is essentially a two-stage process, in that we have to provide both the geographical position of the mobile user and the information on a particular product or service related to that location (Rashid, Mullins, Coulton and Edwards 2006). In context of a social application this will mean not only providing the users location along with information about points of Interest (POI) in their vicinity but also who within their social graph is also close by. In relation to location based mobile gaming or mixed reality gaming synchronised contextual information must be provided regarding game actions required at that particular location, location of other players (if applicable) and game state.

If we first consider the problem of locating the geographical position of the mobile phone users, this in fact is not a new problem, as all mobile phone systems effectively track a user's whereabouts at the cellular level. Each cell site has a unique Cell-ID, which enables the system to locate a mobile user so that it can route calls to the correct cell. This Cell-ID can be used as a filter for localised information although the accuracy is relatively crude, between 100 m and 12 km, because of the variation in cell sizes. To enable higher degrees of accuracy, between 1 and 50 m, other techniques treat location finding as a relative exercise, in other words the location of the mobile user must be estimated against some known framework. This framework could be elements such as the locations of the base stations of a mobile phone network, satellites of the global positioning system (GPS), or special measurement units added to the network to provide the functionality for the so-called enhanced observed time difference (EOTD) of arrival systems (Jagoe 2002). In the case of measurement, the calculations can be either performed at the handset or in the infrastructure and both require the system software to be upgraded to facilitate this process. Despite their high degrees of positional accuracy the disadvantage with these measured solutions is that they suffer inaccuracies when the line of site between the mobile user and the infrastructure is obscured. This is particularly evident for GPS based systems in urban environments where buildings can obscure a direct view of three satellites thus preventing measurements being made and creating the so-called 'urban canyon' effect.

An alternative approach is to ascertain location from the user's interaction with objects of known location where their position can then be implied. The interaction could be proximity within a physical area using communication technologies such as WiFi (Borriello, Chalmers, LaMarca and Nixon 2005) or Bluetooth (Eagle and Pentland 2004) or down to object level using one of the various forms of two dimensional (2D) bar codes, such as QR codes (International Organization for Standardization 2000) or radio frequency identification (RFID) tags. The advantage of 2D barcodes and RFID is that they can be passive solutions in that they do not require a power source in the object itself. The advantage of the implied solutions is that they avoid measurement problems and thus can readily be deployed in indoor and urban environments although they do require the area to be mapped in some form prior to use (Rashid, Mullins, Coulton and Edwards 2006) but they can provide new innovative location based services to mobile users in an indoor environment. Location enabled services and applications provide exciting new opportunities for providers and consumers alike.

1.1 Contribution

Location plays an important role in current mobile applications and services whether it is social applications, gaming, entertainment or mobile commerce, the global market for LBS is projected to reach £13.26 billion by 2015 and a subscriber base of 1.24 billion (CommunitiesandMarkets.com 2010). It is this well proven winning combination of location awareness and ubiquitous nature of mobile phones that is responsible for a steady increase in mobile data usage and it is predicted that by 2013 mobile devices will overtake PC as the most common web access device (Gartner 2010). GPS and cell based location tracking methods provide location information to these applications and services. New approaches to deliver content and services to mobile users have been proposed (Chehimi 2009), these approaches combine location data and utilise a range of sensors and novel interfaces to interact with them. On one hand these application and services provide new ways to interact with the application on mobile device and the ability to query and consume information based upon a user's location but on the other hand they tend to isolate the user from their environment.

Applications and services utilising traditional location tracking approaches of GPS and Cell id claim to be truly ubiquitous however they do not fulfil the definition of ubiquitous computing in its entirety i.e. *"model of computing where users have a level of interaction with their environment where the computing disappears into the fabric of the environment, so they only see the task"* (Weiser 1993; Weiser 1993; Weiser 1994). Nevertheless these applications whether they are social applications, commerce, advertising, gaming or entertainment applications still tend to engulf the user in computing process, for example if we consider location based or mobile mixed reality gaming it becomes clear that although location plays a part in the game play actual user interaction with the localised environment is often limited. Despite being played in the real world and based upon real world location data many games isolate the player from their environment in the interest of scalability (Rashid, Mullins, Coulton and Edwards 2006).

The main aim of this thesis is to explore the utilisation of implied location technologies to bridge the gap left by the current applications. In particular the research presented in this thesis investigates the use of Bluetooth and NFC in particular to locate the mobile user. During the course of this exploration the thesis also looks at why certain implied location technologies work better for certain scenarios than others e.g. NFC or QR codes etc. The approach taken by this research is to look at utilisation of implied location technologies across a range of applications and services through real world experimentation. In particular their effectiveness has been researched in relation to three areas considered likely to benefit most from location based information: mobile advertising, mixed reality gaming and mobile social applications. In particular the work presented here aims to answer the following;

Mobile Advertising

Can implied location technologies be useful to improve consumer response to mobile advertising since previous mobile advertising attempts seem to have a limited impact?

What implied location technologies will be more useful in this scenario?

What are the security and privacy concerns that may arise from use of such technologies?

Mixed Reality Gaming

Can implied location technologies be useful to improve the user interaction with the real world? Can their use produces effective user interaction with physical objects in the real world? Will use of physical objects enhance the user experience?

What is the effectiveness of an implied location- positioning scheme when the game players are moving quickly and how tactics develop over subsequent participation in the game?

Mobile Social Applications

Since mobile social applications are responsible for increase in data consumption on mobile devices can implied location technologies enhance the user experience?

Although mobile social applications are location and context aware they fail to overcome the phenomenon of social exclusion at both individual and group level, can implied location technologies be used to encourage social inclusion?

Can this result in a symbiosis between user, device and environment where the interaction space is not simply the space where interaction amongst users takes place but is an integral part of the experience?

1.2 Outline

Chapter 2 provides some background on locating a mobile phone user. It not only covers usual means of locating a mobile user i.e. through mobile network or through GPS but also looks into alternate approaches to locate or imply a user's location through short range personal wireless technologies or contactless communication through RFID/NFC or 2D barcodes. Traditional location tracking approaches do not work well in doors or dense urban areas; moreover user's interaction with physical location is greatly limited. Implying a user's location through short range personal wireless access or through contactless communication can circumvent these limitations. Furthermore this chapter provides an overview of why location is such an important aspect when it comes to mobile commerce, mobile gaming or mobile social applications.

Chapter 3 looks at the use of Bluetooth as both a short range personal contactless communication and implied location technology as Bluetooth technology is readily available on phones. The earlier sections of the chapter provide a technical overview of Bluetooth whilst the later sections focus on utilising Bluetooth on mobile phones to provide location based information to the users. The system outlined here allows content providers to provide location based information to mobile users and does not require users to carry out cumbersome device pairing. Users simply turn on Bluetooth on their mobile handsets as an indication or willingness to receive messages. It is important to note that this research predates the recent appearance of such commercial services. The chapter not only provides an overview of this system but also provides a complete system design and implementation. The work outlined here also identifies various use cases where such a system can be very useful and economical; one of those use cases being the provision of location based mobile advertisement to mobile users. Keeping the overall scope of the thesis in mind the chapter also takes a critical look on use of Bluetooth for such a system in terms of privacy, security and spam avoidance.

Chapter 4 provides details of RFID and NFC on mobile phones. Whilst much of the focus on RFID has come through asset tracking, another area that has greatly benefited from RFID is micro payments and pre-paid access services for mass transit systems which has seen huge take up in places such as Japan and Korea which has no-doubt fuelled the integration of RFID into the mobile phone feature set. This chapter covers the current availability and history of NFC enabled handsets. It also provides details about various NFC specifications released by NFC Forum that support a range of possible interactions.

Chapter 5 builds on chapter 4 and looks at use of RFID/NFC on mobile phones to support mixed reality gaming. Mixed reality is the merging of real and virtual worlds to produce a new environment where physical and digital objects can co-exist and interact. Mobile games industry has a tremendous opportunity for creating new gaming genres that will take advantage of the unique nature of the mobile phone and the broad range of users who possess them. One such opportunity is that of mixed-reality games; where players can interact with objects that are either fixed or mobile, which is a practical possibility with the emergence of mobile phones with in-built RFID/NFC readers. The chapter provides details of a novel mixed reality game name Pac-Lan. Instead of focusing on a comparison amongst contactless communication technologies the work described in this chapter looks at what RFID/NFC mixed-reality mobile phone games have to offer in terms of user experience, location tracking and game-play. Therefore, the objective of the work presented in this chapter was to create a readily deployable game which attempts to ascertain: if the use of physical objects enhances the user experience? Whether RFID/NFC produces effective user interaction with those objects? The effectiveness of RFID as an implied location- positioning scheme when the game players are moving quickly, and how tactics may develop over subsequent participation in the game.

Chapter 6 extends NFC utilization on mobile phones for Location based Mobile Social Applications. Mobile social applications build on the user's existing social capital and it is considered a good practice to design mobile social applications to support social capital, however in doing so it is important not to exclude those people lacking social capital. Moreover many location based mobile social applications have become mere extensions of their online counterparts where user location is merely used to provide social media and data for user's consumption and a user's interaction with the physical location is not considered. A symbiosis between user, device and environment needs to be reached, including those who are often excluded, to break new ground in terms of mobile social applications that address the issues around active citizenship, creativity, self-expression and raise awareness from daily activities. This chapter explores these issues by utilising NFC/RFID on mobile phones in context of mobile social applications. Two distinct application or test cases are considered. The First looks at use of NFC/RFID to support Graffiti culture. The work in no means encourages or discourages Graffiti but it is an interesting social phenomenon that often divides opinion with many considering it an act of mindless vandalism whist others consider it a political statement of their exclusion from mainstream society. The former arguably indirectly encourages exclusion of certain users, suppressing creativity, better interaction with urban environment and self-expression. The latter looks at raising awareness, active citizenship and better interaction with urban environments by encouraging use of public spaces. If mobile social applications are to become truly pervasive they need to become part of our daily fabric of life and engage users from all sectors of the society.

Chapter 7 draws conclusions based upon the work presented in throughout the thesis. Although a summary of the work is included at the end of each chapter to point out conclusions deduced but this chapter revisits the aims and contributions of the overall thesis. In the light if these conclusions this chapter also identifies possible future research in terms of how contactless communications and in particular NFC can be integrated into various existing services and how we can improve the user experience not just with the device but also with the environment in which they operate.

Chapter 2
Background

2 LOCATING THE MOBILE USER

Although we often consider the requirement for providing the location of a mobile user as a new problem, in fact all mobile phone systems effectively track a user's whereabouts at the cellular level. Each cell site has a unique id that enables the system to locate a cellular user so that it can route calls to the correct cell. To enable higher degrees of accuracy, other techniques treat location-finding as a relative exercise; in other words, the location of the mobile user must be estimated against some known framework. This framework could be the locations of the base stations of a mobile phone network or the satellites of the Global Positioning System (GPS). Each system will provide different levels of performance and capabilities, and we discuss these details in the following sections.

2.1 Cell ID

While the cell-ID has a typical location acquisition time of around 3 seconds, its accuracy depends upon the size of the cell (Trevisani and Vitaletti 2004). Cell sizes vary depending upon the capacity requirements of a particular geographical area (for 3G systems this could range between a cell radius of 100m to 10 km). While accuracy can be extremely variable, it requires no modifications to either the cellular handset or infrastructure.

2.2 Time Difference of Arrival

To estimate location, Time of Arrival (TOA) systems measure the differences among the multiple signals arriving at a device. In order to enable a two-dimensional calculation (i.e., latitude and longitude), TOA measurements must be made with respect to signals related to at least three geographically distinct framework elements. These measurements allow us to infer either the absolute or the differential distance of signal propagation between the framework elements and the device. A system that is based on differential distance estimation is generally referred to as Time Difference of Arrival or TDOA. TDOA requires a common timing base, which is fine for synchronous cellular systems like the Code Division Multiple Access One (cdmaOne), but for non- synchronous systems such as the Global System for Mobile (GSM) other solutions are required. The accuracy of such systems can be between 50 to 250m, and is extremely susceptible to multipath accuracy problems. Enhanced Observed Time Difference (EOTD) of Arrival. To speed GPS acquisition in both synchronous and asynchronous systems, additional network devices, called Location Measurement Units (LMUs), can be utilized. These devices measure TDOA at numerous sites and then calculate correction values. These values are collected and used to enable correction of the raw TDOA measurements. The corrections can be sent to either the cellular handset or the centralized infrastructure, as shown in Figure 2.1 (Andersson 2001), depending where the calculation is performed.

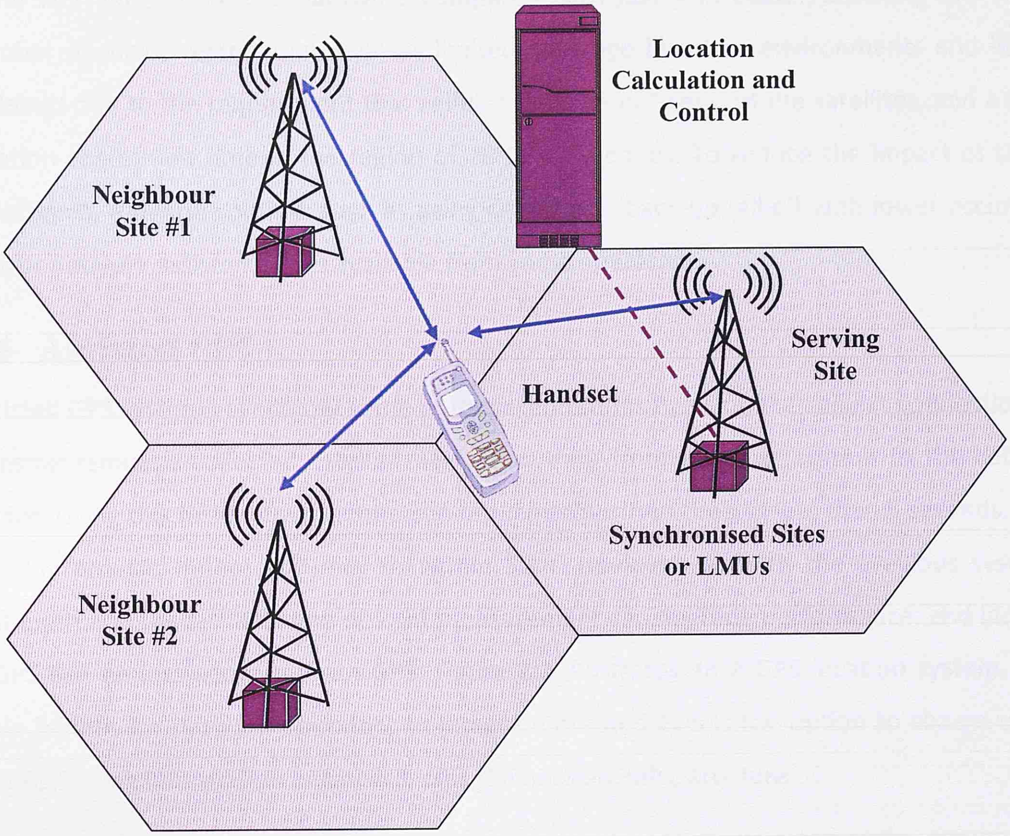

Figure 2.1: EOTD Solution

Generally, the number of LMUs will be less than the number of cell sites, and they can be located to maximize the precision of the measurement. The location measurement could normally be made in around 5 seconds and achieve an accuracy of 50 to 125m (Trevisani and Vitaletti 2004). However, if the line of sight measurement is unavailable and/or the signal undergoes a multipath problem, system accuracy will be severely compromised. Although new hardware would have to be used, only a software update is required at the handset. Software solutions have been introduced for Version 9.0 of Symbian (in version 8.0 only the connectivity to a Bluetooth GPS was offered)

2.3 GPS

GPS was originally developed by the US military for defence purposes; it is based on a system of 24 satellites that orbit the earth. A GPS receiver can triangulate its position using TOA methods as long as at least three satellites are visible. Typically, accuracy is around 2 to 10m, although higher resolutions can be achieved. The cost of GPS hardware continues to fall and GPS positioning remains a free service to consumers. Integrating GPS hardware technology into cellular phones is one of the main solutions now offered by network operators and handset manufacturers. This is evidenced by the fact that virtually all new smart phones come with integrated GPS hardware compared with just 4 in 2001. However, GPS has a number of major restrictions, such as limited coverage in urban environments and inside buildings due to the requirement that cellular users be in "view" of the satellites, and a slow location acquisition time in the region of 10 to 60 seconds. To reduce the impact of these constraints, a hybrid solution such as using cell ID as a back-up (albeit with lower accuracy) and/or network assisted GPS is available from some operators.

2.4 Assisted GPS

Assisted GPS systems overcome some of these limitations by using the cellular connection to transmit remotely-collected satellite navigation data from the base station to the cellular device. Using this fixed infrastructure can reduce acquisition time to less than 5 seconds, and possibly provide indoor accuracy to within 50m. However, as with the previous system, multipath and the lack of a line of sight measurement can degrade performance, and indeed A-GPS can be less accurate than GPS. Figure 2.2 illustrates an A-GPS location system. The main benefit for network operators to integrate assisted GPS is the option to charge users for positioning information because it uses the network infrastructure.

All GPS solutions are complex, in that they require both new handsets and additional infrastructure, and are can be severely detrimental to handset power consumption if used extensively. On a final note it is worth highlighting that the European Space Agency (ESA), a commercial alternative to GPS, was scheduled to come on-line in 2008 (subsequently delayed), and will potentially offer higher degrees of accuracy, particularly for areas in extreme latitudes. Also, advances in GPS chip technology could allow faster and more accurate location acquisition from weak satellite signals. For example, Infineon describes a device that it claims can detect a GPS signal that is 1000 times weaker than a normal "open sky" signal outdoors (Friedrich 2004).

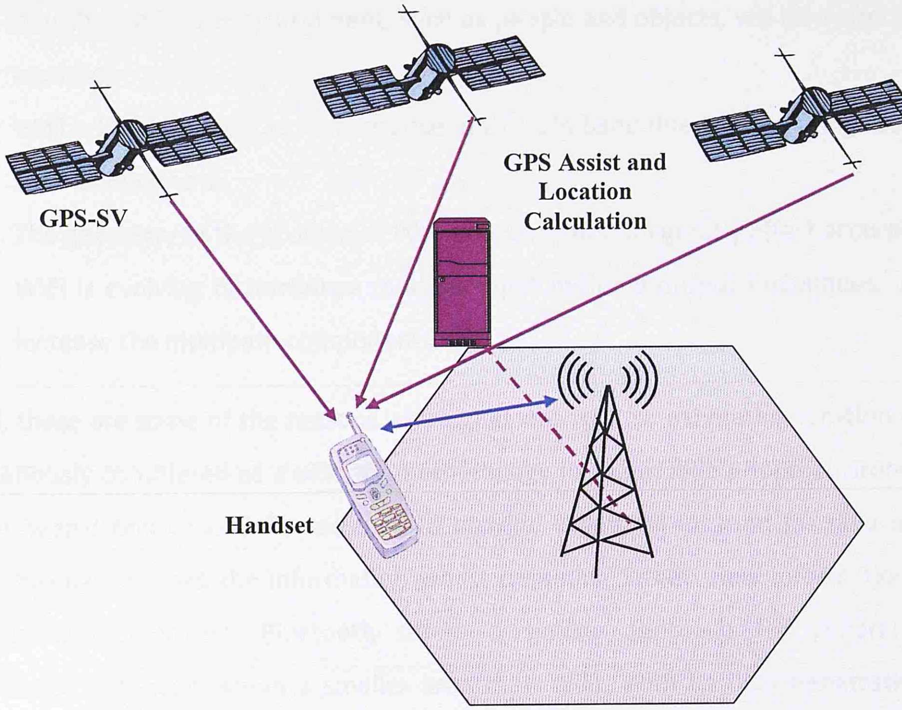

Figure 2.2: Assisted GPS

2.5 Implied Location Solutions

Implied solutions are systems where the cellular phone user can interact with objects or systems that have a known location relative to the cellular infrastructure. Thus a user's particular location can be implied by his/her interaction with the objects or systems. At the system level this could be the interaction with WLAN cells or Bluetooth piconets. WLAN cells have a relatively small coverage area, up to 100m, and as some cellular phones already include WiFi functionality, it could be used to provide a general location area; alternatively, there have been proposals to use signal strength and the interaction between different access points to obtain greater accuracy (Lin, Juang and Lin 2004). However, the use of signal strength has a number of significant limitations, which make its use outside of a very defined environment, such as a research laboratory, impractical. The limitations are as follows:

1. The frequencies used for Wifi mean that the environment is subject to multipath problems; signal strengths can vary over very small distances, and without complex ray-tracing techniques, time-consuming localized measurements become necessary.
2. As users may be moving at speed, they will introduce frequency-selective fading, which will introduce errors in mapping.

3. Any change in the environment, such as people and objects, will also affect mapping accuracy.
4. WiFi is highly subject to interference in the ISM band due to competing technologies such as Bluetooth.
5. The geometry of the position of WiFi access points can greatly affect accuracy.
6. WiFi is evolving to introduce multiple-input multiple-output techniques, which will increase the multipath components.

Indeed, these are some of the reasons why signal strength for estimating location has never been seriously considered as a primary methodology in the mobile phone environment and why we would recommend its use only to provide a general location (as now utilised by Google having obtained the information whilst obtaining Street View information) or as a communications channel. Bluetooth offers a similar approach for general location identification, although within a smaller area than WiFi. With its high penetration of the consumer market, greater robustness against interference; and low power requirements Bluetooth is arguably much more suitable for mobile phones than WiFi.

In terms of interaction with objects to determine a user's location, there are two main possibilities: two-dimensional bar codes and RFID tags.

2.5.1 Two Dimensional Bar Codes

Two dimensional bar codes come in a variety of forms: Quick Response (QR) codes; Semacodes (Semacode.org 2010); and Colorcodes (Coloezip.com 2010), all of which can contain an internet address, which when scanned prompts the phone to load the relevant page. In Japan, QR codes have become commonplace on business cards to allow people to easily upload contact details onto phones, or in some cases, allow blogging of pictures associated with physical locations (Tokyo Picturesque 2005). All these codes utilize cellular phones with in-built cameras to take an image of the code, which is either decoded on the phone with specialist software, or transferred to an Internet service for decoding.

2.5.1.1 QR Codes

QR code (QR Code 2010) is a two dimensional bar code which was originally created by Denso-Wave (Denso Wave Inc. 2010) for tracking parts in automotive industry. Since then it has been adopted by several other industries. They are widely used in asset tracking as well as for creating new ways to interact with objects through mobile phones. Often newspapers and magazines encode a URL or message or competition entry in a QR code, readers take a picture of that code through their mobile phones to decode the message or access the URL.

However having a camera available on the mobile phones is not the only requirement an associated application needs to present and running on the mobile device to successfully decode the QR code. QR code reader applications utilise image recognition techniques to scan the image captured by the phone's internal camera and translate it into useable or readable message. A QR code containing the URL http://www.mobileradicals.com is shown in figure 2.3 whilst 2.4 shows the how the information is stored and extracted by an application.

Figure 2.3: QR Code Sample (http://www.mobileradicals.com)

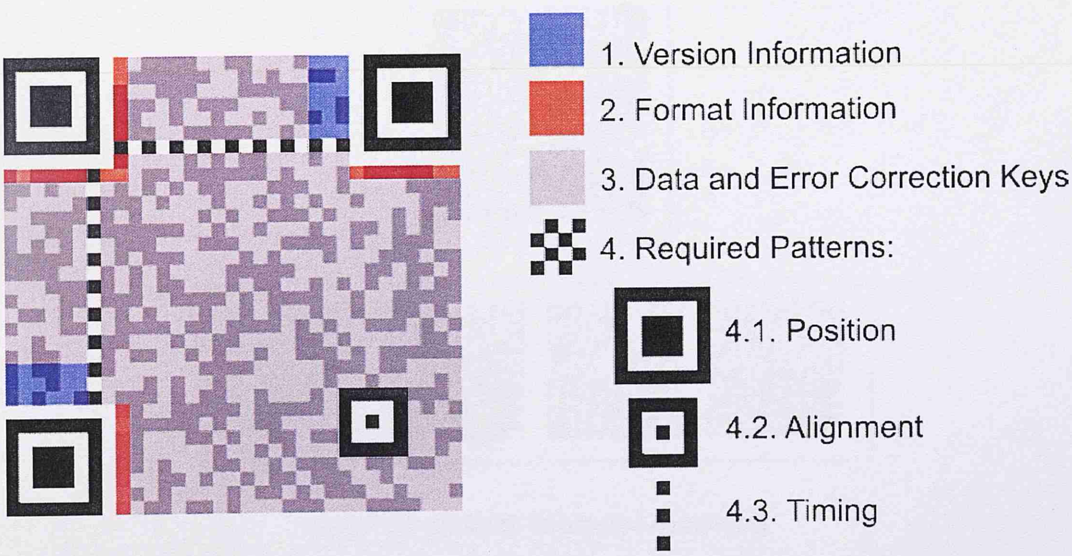

Figure 2.4: QR Code Structure

QR Code is open in the sense that the specification of QR Code is disclosed and that the patent right owned by Denso Wave is not exercised. QR codes have the ability to handle various data types e.g. alpha-numeric characters, Kanji, Kana, Hiragana, symbols and binary etc. A maximum of 7089 characters can be encoded into a QR code. Table 2.1 shows the data capacity of a QR code for various data types.

Data Type	Max Capacity (characters)
Numeric	7089
Alphanumeric	4296
Binary	2953
Kanji	1817

Table 2.1: QR Code Data Capacity

QR codes have a readability of 360 degrees, this is achieved by having a position detection patterns located at three corners of the QR code as shown in Figure 2.4. QR Code can be divided into multiple data areas. On the other hand, information stored in multiple QR Code symbols can be reconstructed as single data symbols. Same information can be read from the QR code in the upper part of Figure 2.5 as well as from the QR codes located at the lower end of Figure 2.5 (QR Code 2010).

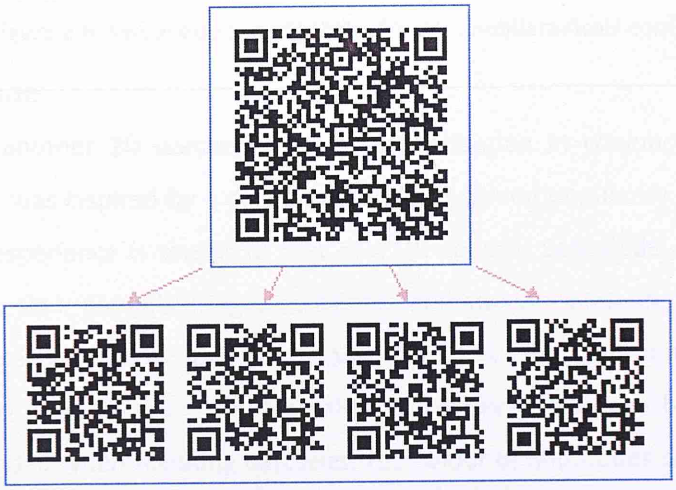

Figure 2.5: QR Code Structured Appending

2.5.1.2 Semacode

Semacode (Semacode.org 2010) is a machine readable two dimensional barcode which can be used to encode limited information e.g. an internet link. Like QR codes Semacodes are targeted for use with mobile phones which have a built in camera. Image of Semacode captured by the mobile phone's internal camera is scanned by a Semacode reader application on the mobile phone. The algorithm used in the Semacode reader applications identifies the presence of a barcode and decodes the information into a useable format. For example Figure 2.6 shows a Semacode which has the URL http://www.mobileradicals.com stored within. Capturing an image of this Semacode by mobile device triggers the corresponding Semacode reader application to decode the Semacode and reveal the URL. Depending upon device settings user can be redirected seamlessly to the URL by launching the phone browser or prompted if he/she wishes to open this link.

Figure 2.6: Semacode Sample (http://www.mobileradicals.com)

2.5.1.3 ShotCode

ShotCode is yet another 2D barcode targeted at utilisation in conjunction with mobile phones. The code was inspired by a dart board and has gained popularity in mobile tagging arena. The user experience is similar to that of a QR code or Semacode. User capture the ShotCode through their phone's integrated camera and an associated ShotCode application decodes the information into useable or readable format. All ShotCodes must be at least 3.5 cm in diameter to be read, and cannot be altered. However, although black and white is always recommended when scanning barcodes, the colour of ShotCodes can be changed. In addition, ShotCodes can be printed on almost any material, as long as there is a high contrast. Unlike QR codes and Semacodes ShotCode is not entirely free. A reader application is available free of charge however OP3 (ShotCode.com 2010) charge for creating ShotCodes. For individual accounts users can register for free and are allowed to create 1 ShotCode for free. However if any more ShotCodes are required users must pay a fee.

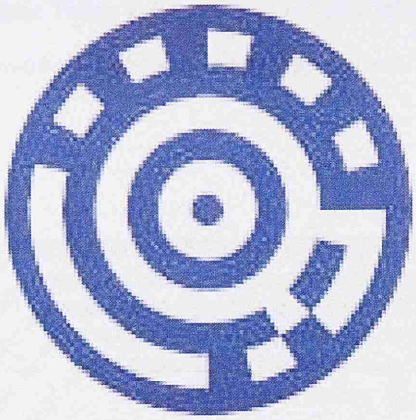

Figure 2.7: ShotCode Sample

2.5.2 RFID Tags

RFID (Ahson and Ilyas 2008) tags are devices that can transmit a radio frequency signal that contains information about the object to a suitable reader. Each RFID tag has a unique serial number, when RFID tag is coupled with an object or a person this unique serial number can be used to identify that object or person. Unlike barcodes RFID does not require contact or line of sight for information exchange. RFID tags can be read through clothing and other non-metallic materials.

A typical RFID system consists of at least 2 components i.e. RFID tag and RFID reader. RFID tag consists of an integrated circuit attached to a radio antenna. Integrated circuit is responsible for data storage, data processing and handling RF signal. RFID reader is a device that has one or more antennas that emit radio waves and receive signals back from the RFID tag. Depending upon the capabilities of the reader device it can process the information locally and take actions on that or pass it on to a processing system. In short RFID system enables data to be transmitted by a RFID tag which is read by an RFID reader and processed according to the needs of a particular application. The data transmitted by the tag may provide identification or location information, or specifics about the product tagged, such as price, expiry date, make and model etc. There are three types of RFID tags;

- Passive Tags: These tags do not have a power source of their own, such as a built in battery, and purely rely on the RFID reader device to power them.
- Active Tags: These tags have a battery and can transmit their signal autonomously.

- Battery Assisted Passive: These tags rely on an external power source to wake up but use their battery power to increase their transmission range as compared to the passive tags.

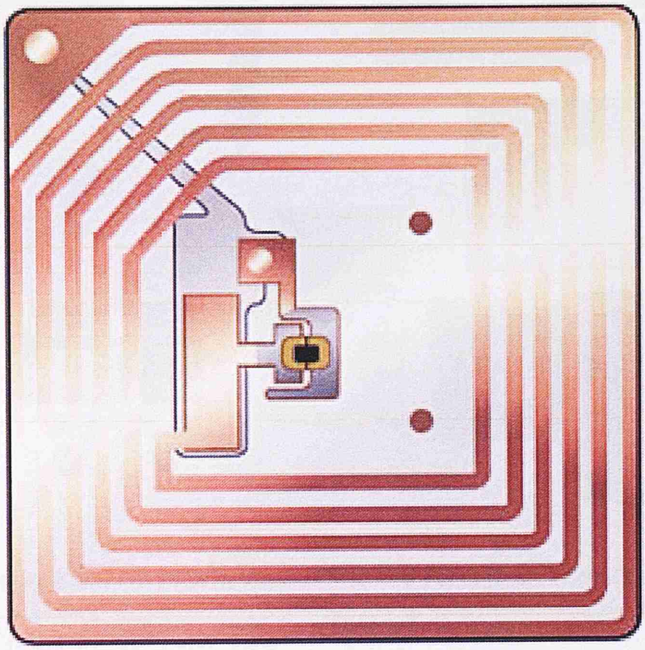

Figure 2.8: RFID Tag

RFID tags come in all shapes and sizes which makes it very easy to incorporate them into a range of objects unlike 2D barcodes which will require certain minimum size for the 2D code to be readable by the camera. A range of RFID tags are shown in Figure 2.9 to demonstrate their versatility. RFID technology has been used by thousands of companies for a decade or more. It is widely used in various industries for asset tracking, manufacturing and supply chain management. It is extensively used for security and Access Control. Payment handling companies have begun to incorporate RFID chips into credit and debit cards.

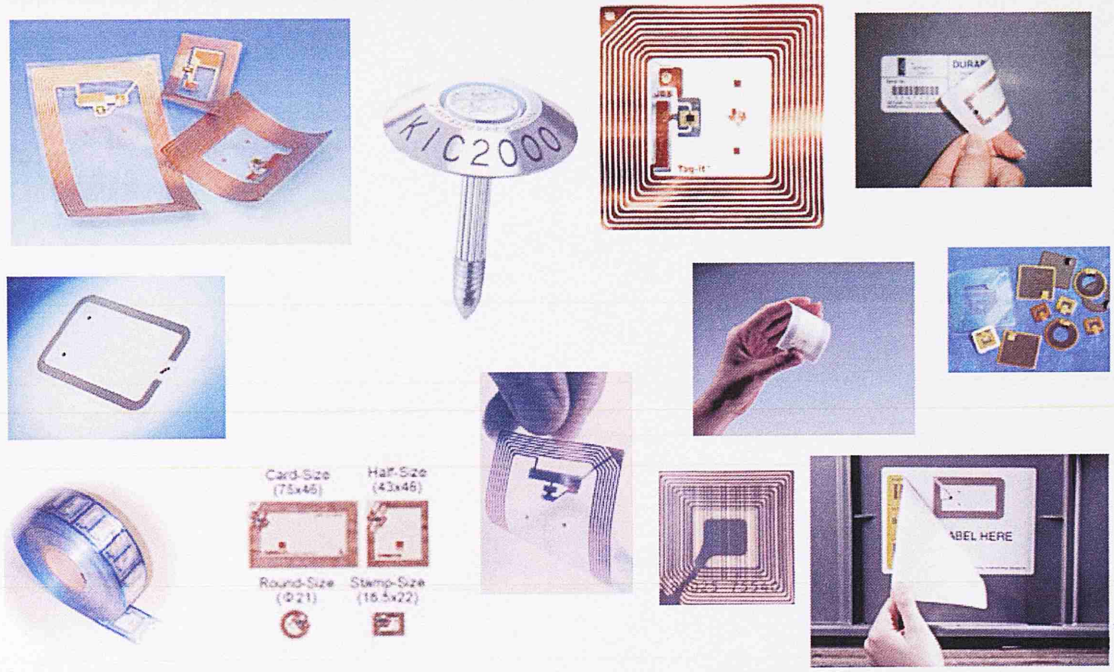

Figure 2.9: RFID Tags in Various Size and Form (Jesic Tech 2010)

2.5.2.1 Indoor Location Tracking through RFID

RFID systems can be used to track objects in an indoor environment. Objects embedded with passive RFID tags can be tracked as they pass through known narrow points equipped with RFID readers. Since location of these readers is known we can imply the location of the object. Active tags can be tracked much more efficiently and in real time mainly because they can transmit because of incorporated battery. This sort of tracking is generally used for complex buildings where the objects to be tracked are of higher value, mission critical, have a consequential impact if not quickly located, or there is an additional security, regulatory or health and safety requirement for such information.

Recently Nokia executive Anssi Vanjoki made an announcement during a key note that all new Symbian handsets launched in 2011 will include NFC as a default feature (Balaban 2010). NFC business news source 'Near Field Communication World' (Clark 2010) has reported that NFC is scheduled to be one of the new features in Symbian 4 platform. It was originally targeted to be part of Symbian 3 platform but was pushed back to avoid overall delays. Nokia's NFC roadmap on Symbian devices can be confirmed with recent release of Nokia C7 (Nokia 2010) handset which is going to have NFC (Balaban 2010). Future proliferation of NFC enabled mobile phones coupled with its very low power operation, make NFC a suitable candidate for games, as we shall see via the innovative games and social applications presented in later chapters.

Chapter 3
Bluetooth to Track a Mobile User

3. Using Bluetooth to Track a Mobile User

Some of the work presented in this chapter was originally published by the author in Journal of Personal and Ubiquitous Computing, Springer London, Volume 12 Issue 1, January 2008, pp 3-10. doi 10.1007/s00779-006-0121-4 and in Proceedings of IEEE Fourth International Conference on Mobile Business, Sydney Australia, July 2005.

3.1 Introduction

In terms of location proximity detection for mobile phone users one of the obvious choices is Bluetooth which, despite repeated predictions of its demise, is in fact increasing its growth as almost all new phones continue to be equipped with Bluetooth. This chapter details a system of how Bluetooth can be used to imply the location of a user through and subsequently provide information to the user based upon their location in an indoor environment. There are already a number of mobile Bluetooth proximity applications in existence which are often described as mobile social software (MoSoSo) and can be viewed as evolutions of Bluejacking. Bluejacking was/is a phenomenon whereby people exploit the contacts feature on their mobile phone to send messages to other Bluetooth enabled devices in their proximity. Bluejacking evolved into dedicated software applications such as Mobiluck (Mobiluck 2005) and Nokia Sensor (Nokia Sensor 2005) which provided a simpler interface, and in the case of Nokia Sensor, individual profiles could be used to initiate a social introduction (Clemeson, Coulton, Edwards and Chehimi 2006). The system described in this chapter could be regarded as a business orientated implementation of the Bluejacking phenomenon.

Section 2 of this chapter gives a brief overview of Bluetooth technology. It also covers the Bluetooth architecture and protocol stack to assist those new to Bluetooth technology. The sections conclude by introducing the concept of Bluetooth Profiles. Section 3 looks at the use and implementation provided by Java for Bluetooth and highlights why Java is a good choice for creating Bluetooth applications. A basic overview of Java API for Bluetooth i.e. JSR82 (Java Community Process 2010) concludes this section and provides the reader with enough knowledge to understand the system design and implementation discussed in later sections. Basic design and implementation of the system are discussed in sections 4 and 5 respectively. Section 4 covers only the core element of the system to simplify the explanation and understanding of how the final system will work and how these core units work together. Use cases scenarios are discussed in section 5 not only to provide a better understanding of the system use but also clarify the potential need and usefulness of such a system. Section 6 goes into detailed system design by providing the overall work flow of the system and then step by step details of its internal workings. Section 7 highlights how the system can be incorporated into other location based systems to provide integrated indoor and outdoor coverage and finally section 8 brings the chapter to a close by summarizing and discussing the advantages and disadvantages of the system.

3.2 Overview of Bluetooth

Bluetooth is a short range wireless technology which has low power consumption and was originally designed for ad hoc communication between Bluetooth capable devices (Bluetooth 2010). Since it is a low power technology the effective over the air coverage is between 10 to 100 meters with 100 meters being made possible at the expense of higher power consumption. Its short range and low power consumption makes it ideal for battery powered devices such as mobile phones. Mobile phone manufacturers have adopted Bluetooth readily as it is very low cost in terms of manufacture being royalty free and the operational cost of usage to end user is simply battery power.

Bluetooth in essence is a replacement for cable based connections e.g. connecting a mobile phone to a computer. The range of devices that can be Bluetooth capable is diverse e.g. televisions, projectors, home entertainment systems, desktop PC's, PC peripherals such as keyboard and mouse, mobile phones, point of sale terminals, kiosks, headsets etc. Any of these devices can communicate with each other over Bluetooth by forming a Personal Area Network (PAN). PAN is an ad hoc topology where number of end nodes is dynamic. The devices simply exchange information with each other by discovering the presence and capabilities of other devices. This PAN can be amongst different devices communicating with each other or one device such as a laptop communicating with other devices. These examples are shown in the figures below.

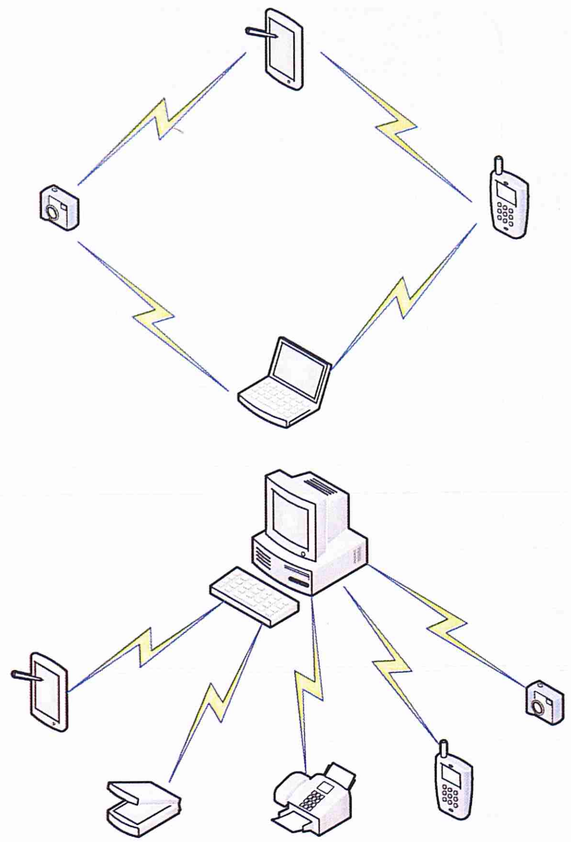

Figure 3.1: Ad hoc networking amongst Bluetooth devices

Bluetooth devices operate at a frequency of 2.4 GHz and uses frequency hopping where by each data packet is transferred using a different frequency for transmission. The sending device uses a hop sequence to send packets and receiving device must simply tune to the changed frequency in order to receive the data. Although frequency hopping makes the implementation more complex it provides a more robust link in the presence of interference. Maximum data rate is 1Mbps. At any given time a Bluetooth capable device can be connected up to 8 active devices or 200 passive devices Bluetooth 2.0 (Bluetooth.org 2007)introduced the Enhanced Data Rate (EDR) which enhances the data speed to 3 Mbps whilst Bluetooth 3.0 is capable of providing speeds up to 24 Mbps (Bluetooth.org 2009).

3.2.1 Bluetooth Stack Architecture and Protocols

The Bluetooth stack can be divided into two major components i.e. Bluetooth host and Bluetooth controller. The Bluetooth host is also known as the upper layer stack and is implemented as a software layer while the Bluetooth controller is a hardware module integrated into the host device e.g. a laptop or a mobile phone etc. Host and Controller are interfaced through a standardized Host Controller Interface (HCI). The basic architecture of a Bluetooth stack is shown in the following figure 3.2 (Kumar, Kline and Thompson 2003).

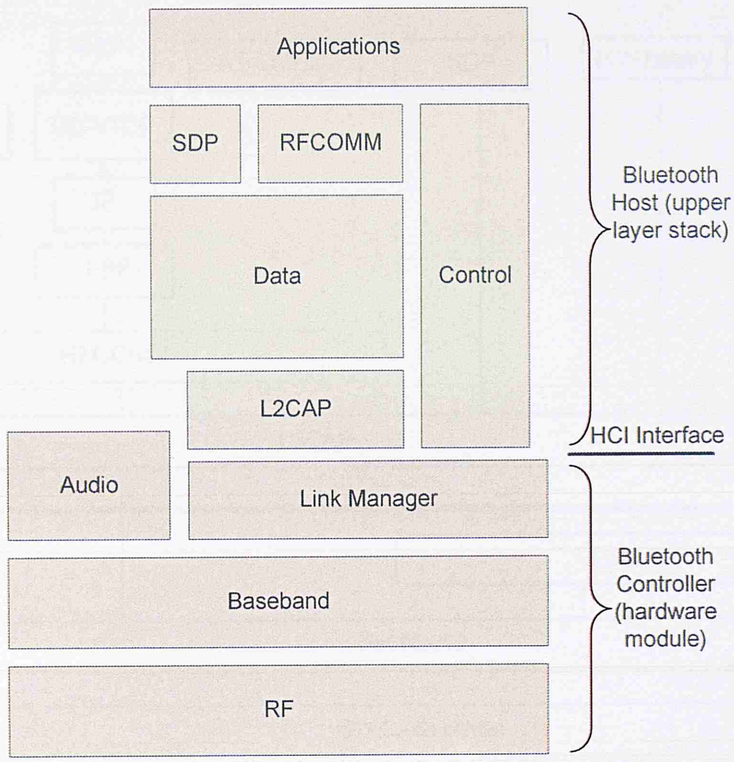

Figure 3.2: Bluetooth Stack Architecture

Figure 3.2 shows the Bluetooth Protocol stack (Jennifer Bray 2000). The Bluetooth protocol stack can be divided into four key categories based upon their functionality. There are listed in the following table.

Protocol Group	Protocols
Bluetooth Core	Baseband, Link Manager Protocol, L2CAP, SDP
Cable Replacement	RFCOMM
Telephony	TCS Binary
Adopted	PPP, UDP/TCP/IP, OBEX, WAP

Table 3.1: Bluetooth Protocol Classification

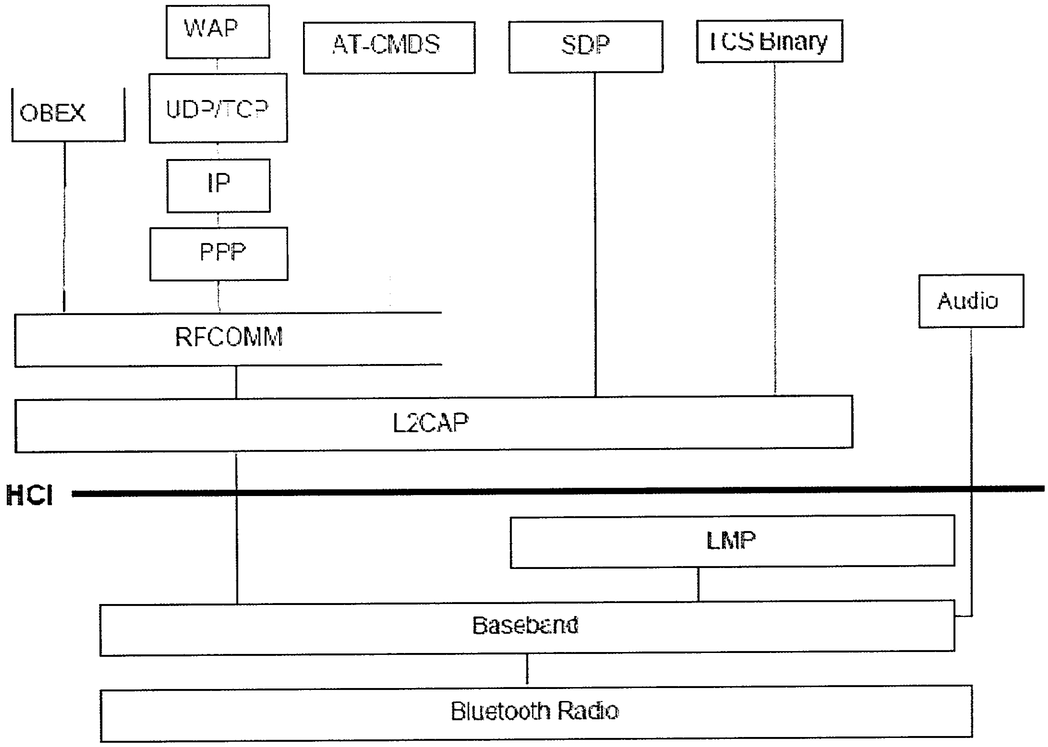

Figure 3.3: Bluetooth Protocol Stack

The Bluetooth radio layer is the lowest layer in the stack and is responsible for defining the requirements of the Bluetooth transceiver whilst the baseband layer enables the physical RF link between two Bluetooth devices engaged in a connection. Link Manager Protocol (LMP) handles the setup and security of the link e.g. authentication and encryption. LMP handles two types of physical links i.e. synchronous connection oriented (SCO) and asynchronous connectionless (ACL). The earlier is used to transfer real time audio whilst the latter is used to transfer data packets. HCI provides a common standardized interface to LMP, baseband and radio layers. It is a one-stop source for finding out capabilities of the baseband (capabilities of a Bluetooth device), actual status of the hardware and various control registers.

Logical Link Control and Adaption Protocol (L2CAP) abstracts the upper layer protocols from lower layer protocols. It multiplexes between various connections made by upper layer protocols. Audio data is directly routed to the baseband layer and bypasses the L2CAP layer unless the Voice over IP (VOIP) is being used. Service Discovery Protocol (SDP) is built on top of L2CAP and provides functionality for application to query services offered by a Bluetooth device. RFCOMM protocol provides serial port emulation and is widely used by many Bluetooth applications as serial ports are one of the most common interfaces used in computers and other electronic devices. Telephony Control Protocol Binary (TCS Binary) defines call control and establishment of both voice and data calls between Bluetooth devices. Some protocols have been adopted by Bluetooth are built on top of existing protocols e.g. as seen in figure 3.3 Object Exchange Protocol (OBEX) is built on top of RFCOMM. There are several other protocols defined in Bluetooth specification which are also built on top of existing protocols e.g. Audio/Video Control Transport Protocol is built on top of L2CAP.

3.2.2 Bluetooth Profiles

In addition to protocols the Bluetooth specification also introduces the concept of Bluetooth profiles. A Bluetooth profile defines a standard way of using various Bluetooth protocols that facilitate a particular usage scenario. A profile can be considered as a vertical slice through the protocol stack defining the features of each protocol needed for a particular profile. There are four generic profiles which are as follows;

1. Generic Access Profile (GAP)

   GAP is the base or parent profile upon which all other profiles are based.

2. Serial Port Profile (SPP)

   SPP defines the requirements for creating RFCOMM connection between Bluetooth devices.

3. Service Discovery Application Profile (SDAP)

   SDAP define the basic operations essential for service discovery.

4. Generic Object Exchange Profile (GOEP)

   GOEP is an abstract profile upon which concrete profiles can be built. GOEP based profiles use OBEX as their protocol. Hence a GOEP defines all key elements required for OBEX usage.

Figure 3.4 shows generic Bluetooth profiles and their relationship to each other.

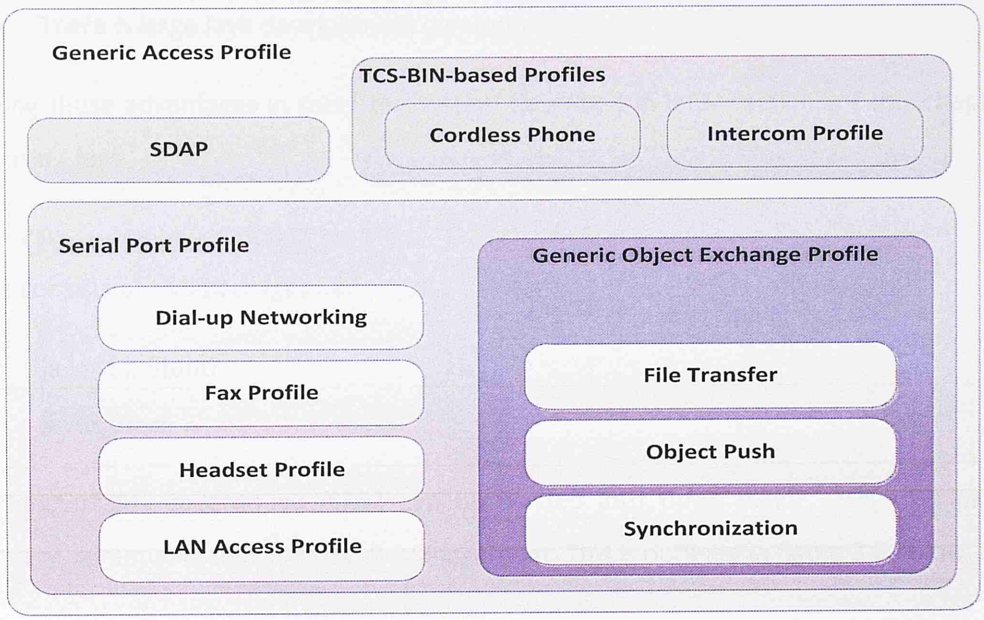

Figure 3.4: Generic Bluetooth Profiles

The dependency of a new Bluetooth profile on generic profiles becomes clear from the previous figure. For example File Transfer Profile is based upon GOEP which in turn is dependent on SPP which is based upon GAP.

3.3 Java and Bluetooth

The Bluetooth specification consists of many layers and profiles, it only defines the over the air (OTA) behaviour to ensure interoperability and compatibility of Bluetooth devices manufactured by different vendors. However it does not define a standard API to Bluetooth stacks. This has resulted in many different APIs. Java API for Bluetooth Wireless Technology (JABWT) provides a standard API for application development and is specified by JSR-82 (Oracle 2002). There are many advantages of using JABWT for Bluetooth application development. One of the key benefits being the fact that Bluetooth applications written in Java have the ability to work across many hardware platforms, operating systems and device classes. Other advantages of using Java for creating a Bluetooth application are

- Class file verification combined with security features provides protection against malicious applications.
- Rapid application development is possible due to better abstractions and high level programming constructs.
- Dynamic expansion to application functionality can be achieved by loading classes at runtime.

- There is large Java development community.

Keeping these advantages in mind the system described in later sections of this chapter is built using Java.

3.4 Overview of JSR82

JSR82 consists of two packages i.e.

- javax.bluetooth
- javax.obex

The functionality covered by JSR82 can be divided into three major categories namely discovery, communication and device management. This is outlined in figure 3.5 below.

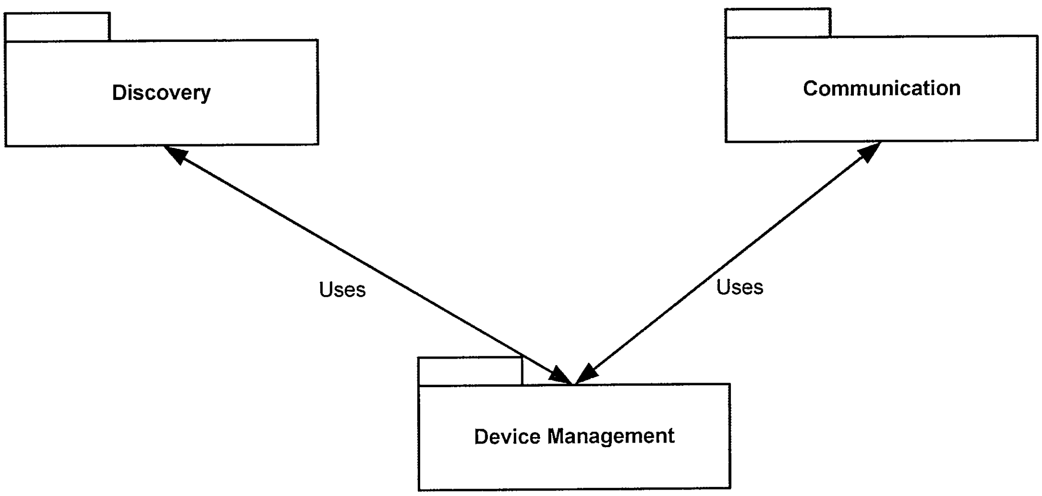

Figure 3.5: Functionality Provided by JSR82

Both packages require javax.microedition.io to work which is part of the Generic Frame Work (GCF) which in turn is part of J2ME. Javax.obex is adopted from IRDA and as such does not require javax.bluetooth or the Bluetooth radio itself to function. An OBEX message can be sent through this API using a different data bearer. The system described in this chapter uses OBEX over Bluetooth. JSR82 was designed as an optional package for J2ME and was built on top of CLDC. GCF has made its way into Java Standard Edition (Java SE) through JSR197 which allows a Bluetooth application written for J2ME to run without any modifications on Java SE platforms.

3.5 Implying User Location through Bluetooth

Consumers are becoming increasingly aware of the use and benefits of Bluetooth as demonstrated in the widespread use of Bluetooth dongles through which the users can connect their desktop machines to these devices. Other initiatives for Bluetooth have been seen in the automotive and medical industries in that manufactures have begun to include Bluetooth access in cars and medical monitoring equipment. By 2005 Bluetooth was present in 65% of all mobile phone handsets (Chehimi, Coulton and Edwards 2006) making a system such as the one described in the following sections, a very practical and worthwhile scenario. Now a days Bluetooth is one of the expected functionalities of the mobile phone.

The location based system described in this section enables Bluetooth to be used as a means of targeting users with specialized content in a specific area at a given time. For example, users in a supermarket could be informed about a certain discount offer based upon their purchasing habits (indeed such systems have emerged since this research was originally performed). Such messages can be sent to all the users in the area with a Bluetooth enabled mobile handset or PDA. In order that the system can service a diverse range of users and devices no client side application is required thus nothing has to be installed. The information is presented in a very familiar and simple form of a text message. Figure 3.6 shows the basic layout of a system for transmitting messages to all the devices in a given area.

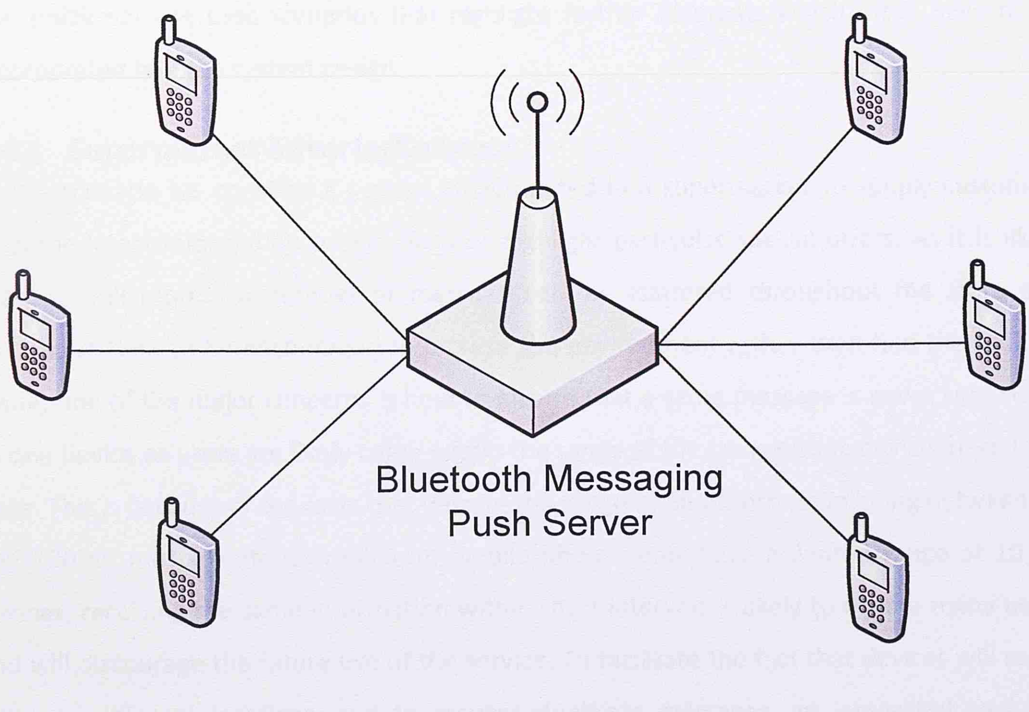

Figure 3.6: Basic Bluetooth Messaging System

The system uses OBEX over Bluetooth to send the information to target devices. Licensed by Bluetooth SIG from IrDA (Infrared Data Association 2010), OBEX has become even more popular than during its original period as means of transferring business details. OBEX is transport neutral, as with the hypertext transfer protocol (HTTP), which means that it can work over almost any other transport layer protocol. As mentioned in earlier section OBEX is defined as one of the protocols in Bluetooth and sits over RFCOMM protocol (Jennifer Bray 2000). Moreover, OBEX is a structured protocol which provides the functionality to separate data and data attributes. A clear definition of each request can be given which helps distinguish one request from another. Use of other protocols such as RFCOMM or L2CAP requires the applications sending and receiving information to know how the data is sent and when to send the reply. Like extensible markup language (XML) OBEX provides structure to the data being sent in contrast to other protocols such as RFCOMM which basically send bytes. Using this approach the following section illustrates through example how this configuration can be used to provide location based advertisement at point of sale or perhaps provide location based information for help/tour guide systems.

3.6 System Implementations

Although the basic technology of the system was discussed in the previous section there are specific operational issues dependent on how it is to be employed. This section will focus on two particular use case scenarios that highlight further elements which often have to be incorporated into the system design.

3.6.1 Supermarket Adverts/Coupons

In this scenario we consider a system implemented in a supermarket to supply customers with the latest information on products or highlight particular special offers. As it is likely that we will require a number of message centres scattered throughout the store and customers tend to be encouraged to browse the environment rather than find the optimal route, one of the major concerns is how to ensure that a same message is never sent twice to one device as users are likely come within the range of the transmitting device more than once. This is because of the facts that despite the range of Bluetooth radio being between 10 and 100 m, most Bluetooth radios on mobile phones only have a limited range of 10 m. Further, receiving the same information within short intervals is likely to irritate many users and will discourage the future use of the service. To facilitate the fact that devices will roam between different locations, and to prevent duplicate messages, an integrated backend information system is required. Figure 3.7 shows the layout for two sites, each of them pushing messages (adverts/coupons) to the potential customers.

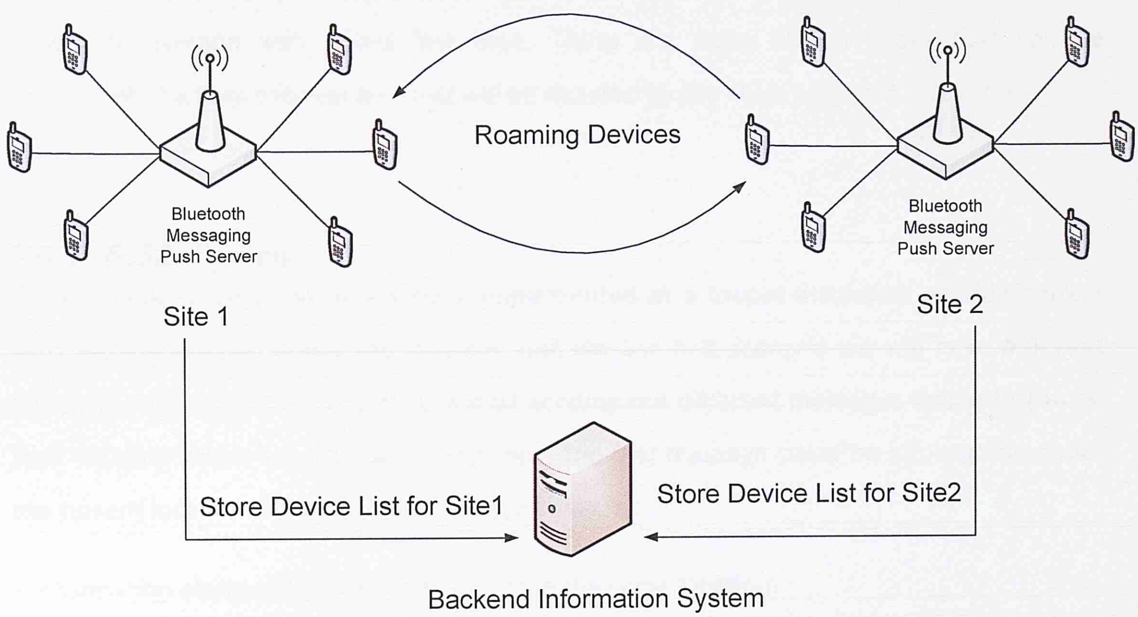

Figure 3.7: Roaming device between different Bluetooth sites

All devices discovered by individual sites are stored in the database along with the site where they were last recorded, and the messages delivered to them. Each Bluetooth push server launches a device discovery after a fixed interval of time. Devices discovered after each inquiry are cross checked with the database. Only newly discovered devices are recorded in the database and message is sent to these devices. Devices that received the message in the previous discovery do not receive the message again. If a new store promotion message is made available in the database, the next discovery will push the message to all the devices in the area. The messages themselves can be tagged to expire in the database after a certain amount of time or tagged to be activated within a certain time period. Within the same scenario the shopping centre could decide to pick a random device, as a lucky winner, to perhaps receive a discount on their purchase or perhaps a complimentary item. The winner is notified by a Bluetooth message and this message is dispatched to one device only. Searching for devices at a fixed interval means that the information system could obtain lots of information about different Bluetooth devices. This information can be flushed daily and some of it can be used to enhance the filtering mechanism, for instance, a Bluetooth device appearing on every search or at a particular message centre may belong to a store employee or perhaps to an employee of store next door. Such information can be used to improve the intelligence of the messaging system in identifying potential customers and the message to be sent out to them. To improve and better target potential customers, the information system can be altered to remember the devices that take advantage of the coupon. Upon their next trip to the store these devices can receive an advert targeted at the product for which the coupon was issued last time. There are many similar cases that can be implemented within this scenario and will be dictated by the store's current sales strategy.

3.6.2 Guide System

In this scenario we consider a system implemented at a tourist attraction providing users with key information about the location. Just like the first scenario we will have different message centres but this time they will be sending out different messages depending upon their location within a particular tourist spot. The first message could be information about the current location while the later messages may be:

- Information about other points of interest in the same location.
- A message that informs the user that this particular tourist spot will close in certain amount of time.
- May provide list to other tourist attractions in the vicinity and directions how to get there.

For example let us consider the system implemented at the historic site of Lancaster Castle. Upon entry to the castle the user can receive a brief history of the castle, i.e. its current use as a working gaol and court. Once the user gets within the range of another Bluetooth site, located near the castle courtyard, the user will receive another message giving details of the site were the Pendle witches were hung on 16 November 1812. Since it is a large site this implementation will differ from the one in the shopping centre in terms of how the messages are distributed and managed. Different Bluetooth sites within the castle provide different messages to the user. The information system will keep track of the devices discovered by each site and the messages sent to them. In this case each Bluetooth message centre sends out a particular message to the users unlike the shopping centre scenario where each device is working around the same set of messages. The database can be refreshed on a daily basis.

3.7 Application Design

In the previous section we defined two particular use case scenarios where a system, like the one presented in this chapter, can be implemented to distribute information to a diverse range of users. In this section we will look only at the design of the Bluetooth messaging system itself and the information system will not be discussed in detail as it tends to be situation dependent. Figure 3.8 illustrates the different processes involved, within the entire system, to discover and send messages to users (Rashid, Coulton and Edwards 2005).

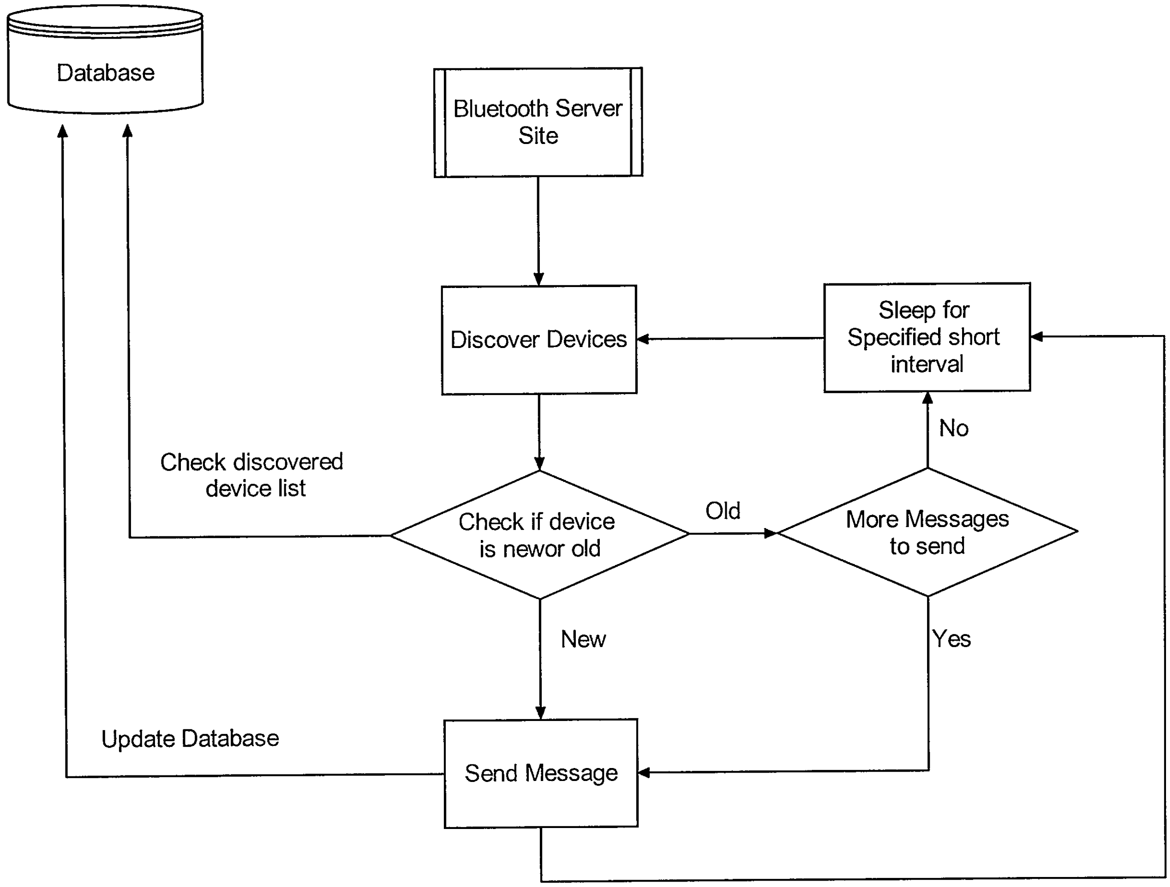

Figure 3.8: Overall Application Flow Diagram

Every site Bluetooth server initiates a discovery to find all the Bluetooth devices in the area; some filtering based upon the Bluetooth profiles is done to eliminate devices such as headsets, cameras, etc. Upon completion of the discovery process, a list of the devices found is passed to the database, where all entries are checked. The database returns with a list of devices that are new and those who have already received messages. Based upon these results from the database the system selects appropriate messages to be sent to different target devices. The rationale of the entire system is that the operation can be controlled by the information system that provides the overall control of the messaging system.

The specific details of the system operation are shown in Figure 3.9 which highlights the basic functions the application must perform on the server database.

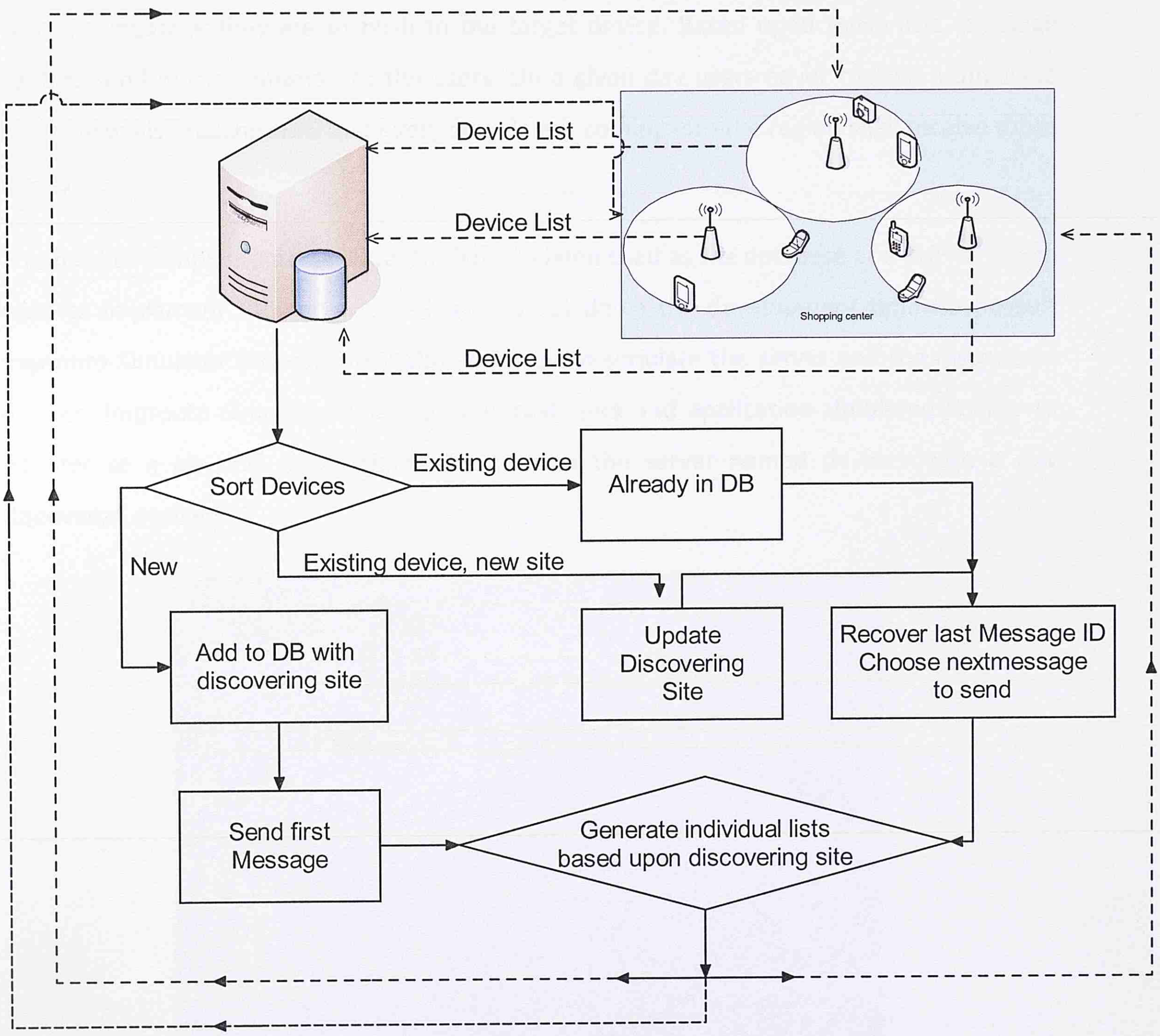

Figure 3.9: Messaging Sites Interacting with the Database

The database server periodically receives an individual list from each Bluetooth site associated with it. Each list consists of Bluetooth addresses of the discovered devices along with the ID of the discovering site. After receiving the list of discovered devices in the area the server sorts them out into three groups namely: new devices, existing devices discovered by a different message centre and existing devices within the range of the same message centre that discovered them last time. At this point, as shown in Figure 3.9, the system adds a message to each device group. Newly discovered devices are sent the first message or promotion of the day while the other two categories receive or do not receive a message based upon the last message ID, which was sent to them. Before message centres can receive the lists, database updates the message ID for every device currently under consideration. The application server once again sends out separate lists specific to each site with the message they are to push to the target device. Based upon these lists, message centres send out information to the users. On a given day users never receive a duplicate message whilst making sure that every new device coming into the region shall receive those messages.

This has been implemented in Java. MySQL has been used as the database and PHP has been used to implement the server side logic. To cut down the development time Rococosoft Impronto Simulator (Rococosoft 2005) was used to simulate the server and the discovered devices. Impronto Simulator works on a virtual stack and application simulated is easy to transfer to a physical stack. Figure 3.10 shows the server named device1 with a few discovered devices.

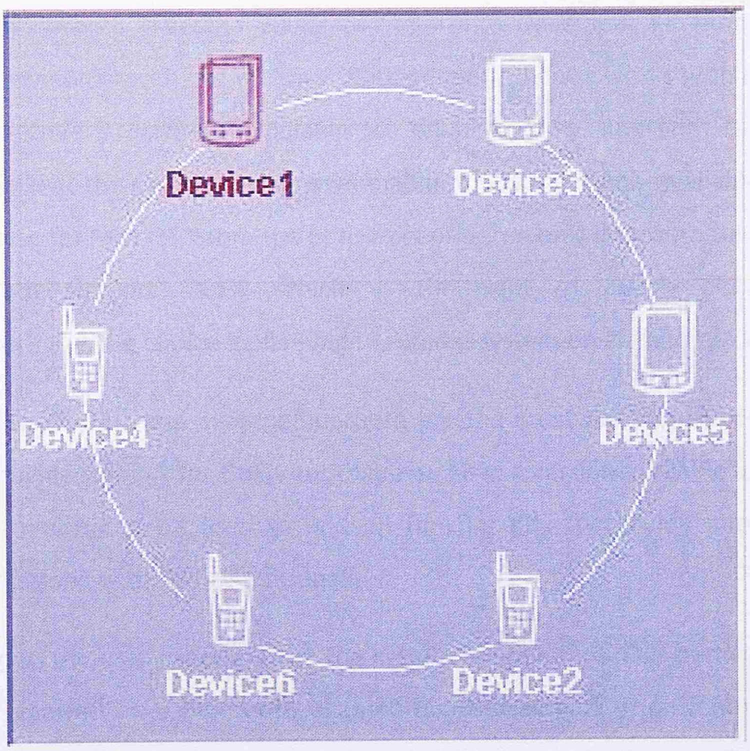

Figure 3.10: Simulating a Message Centre in Impronto Simulator

Simulator makes it easier to test different conditions in the system. For example during device discovery all devices shall be shown; both new and the ones discovered in the previous run.

To implement this system aveLink Bluetooth stack was used from Atinav (Atinav 2005). There are other stacks available that have a JSR82 implementation but not all of them support OBEX. There are two basic approaches that one can take to implement such a system; use a Java API with Bluetooth stack built in or use Java API that uses an external stack. One of the major reasons aveLink was selected for this application was the fact that at the time this work was carried out it possessed a fully implemented and self-contained Java Bluetooth stack. Other choices in the same category can be Harold (Lund University - Department of Automatic Control 2005) or Java Bluetooth (JavaBluetooth 2005) but neither of them are a complete implementation of JSR82 and do not support OBEX. Although all of them are platform independent but Harold and Java Bluetooth stacks require javax.comm (SUN Microsystems 2005) to be installed on the machine running these stacks.

Options in Java API accessing external stacks are Blue Cove (Bluecove 2005), JBlueZ (JBlueZ 2005), avetanaBluetooth (Avetana 2005) and Impronto Developer Kit (Rococosoft 2005). Apart from avetanaBluetooth the rest are OS dependent. JBlueZ works with BlueZ stack for Linux and Blue Cove is currently available for Windows only. Impronto Developer Kit is available for Linux at the moment while avetanaBluetooth is not only available for Windows and Linux but also for Mac OS. From the options considered only Impronto Developer Kit and avetanaBluetooth support OBEX, which in the light of above discussion makes avetanaBluetooth a viable choice if planning to run the system on an external stack.

In author's view aveLink and avetanaBluetooth are the most suitable choices as they not only do they provide support for OBEX but they also have a version available for Java 2 Micro Edition (J2ME) which can be used to add on functionality to provide information as to "Who's around" along with "What's around".

Figure 3.11 shows the user experience of the system in operation. This particular example is of a message received on a Bluetooth enabled handset as part of an information system implemented in the Informatics Group of Infolab21 at Lancaster University, UK in 2005.

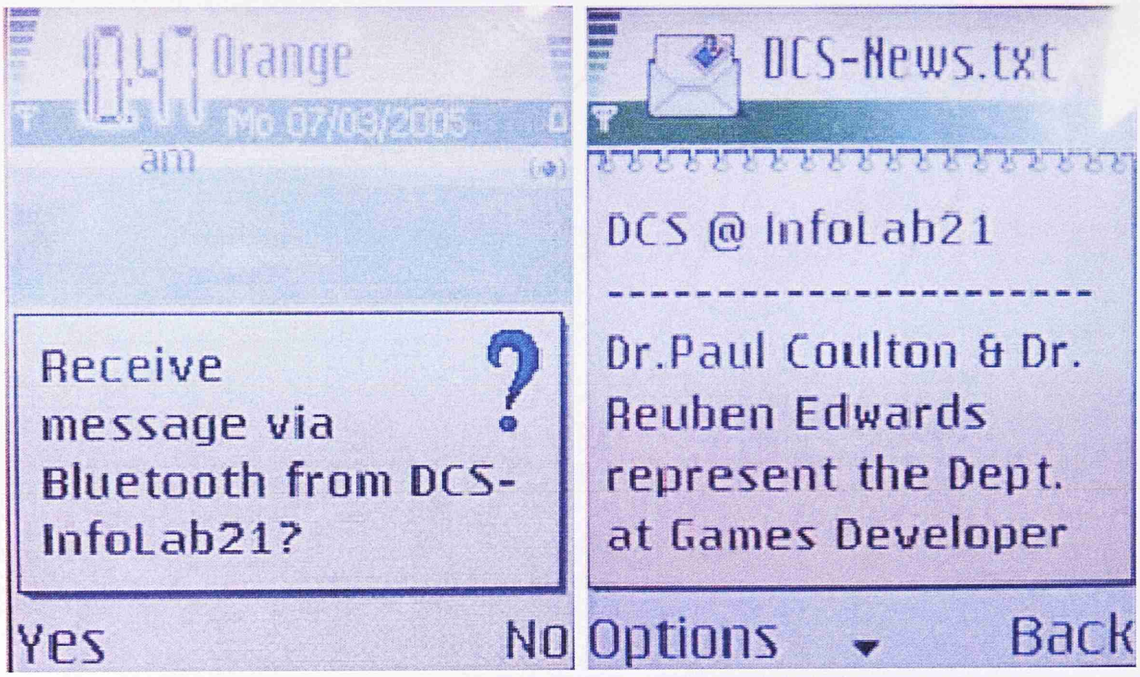

Figure 3.11: Bluetooth News Alerts at InfoLab21

As can be seen from the screen shot on the left of Figure 3.11, users can choose not to accept a connection if they do not want to receive advertisements which means that the system is permission based and thus alleviates potential concerns over privacy. In this system a further element is implemented in that the Bluetooth message centre informs the information system that a particular device does not wish to receive promotions and thus it is effectively opted out of the service. In this case the opt out is only for the current visit although this could be arranged such that it covers all future visits thus preventing possible complaints from user not wishing to participate.

3.8 Incorporation into Other Location Tracking System

The system outlined in this chapter can easily be incorporated into existing location based systems to complement other means of location tracking e.g. GPS, EOTD etc. The system could feed the vital indoor and urban information to reduce acquisition time and improve accuracy. With this enhancement a much broader range of LBS can be made available to the users at a variety of locations. User profiles can be made accessible between different shopping centres or it could even be implemented as portable platform, for instance in a backpack that allows the wearer to transmit advertisements to public at concerts or fairs.

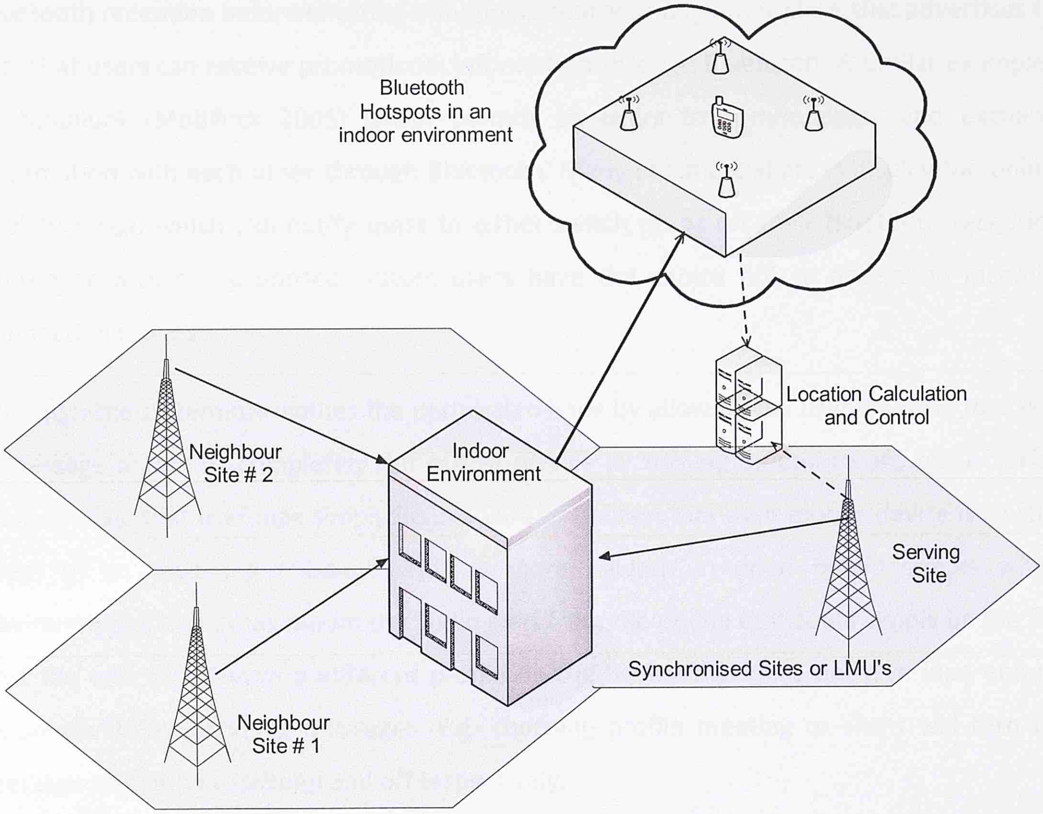

Figure 3.12: Bluetooth complementing EOTD in Indoor Environments

3.9 Summary

Obviously there are many other scenarios than those already mentioned in earlier sections and the proposed system could easily be adapted to a number of other possible uses. One of the great benefits of this system is the fact that it can be deployed without requiring the users to do anything more complicated than switch on their Bluetooth capability and accept the message although this limits the content to text based messages. It is already evident through the wide scale adoption of SMS that text only communication is perfectly acceptable as it is the information content that is important. According to Barwise & Strong (Barwise and Strong 2002), in SMS madvertising, 81% of the test subjects viewed all the messages before deleting them and 77% of them did that as soon as they received the advertisement. This predicts a healthy response from the users for this system. Since this information is being delivered at POS, users are more likely to take advantage of the offer.

The proposed system is targeted towards personal devices such as mobile handsets which users wear almost everywhere and all the time. Users do not want to receive spam or receive information without their permission. With the system presented in this chapter users can choose whether they want to receive information or not. They can simply turn off

Bluetooth reception before entering a shopping centre or any other place that advertises the fact that users can receive promotional information through Bluetooth. A similar example is of Mobiluck (Mobiluck 2005) which permits its users to communicate and exchange information with each other through Bluetooth. Many commercial areas display the unique Mobiluck sign which can notify users to either switch on or off their Bluetooth reception. Moreover with our proposed system users have the choice not to accept an incoming connection request.

Although the system overcomes the permission issue by allowing the user whether to accept a message or not or completely opt out of service by turning Bluetooth off, but it suffers from the fact that user may simply be unaware of the fact that their mobile device is alerting them of an incoming message. This is more evident in open public spaces where environmental noise may drown the audio alert from the phone or it could simply be the fact that the user has chosen a different profile on the device that does not give loud enough audio alerts for incoming messages. E.g. choosing profile meeting or silent will turn the message alert tone to a beep and off respectively.

A Bluetooth link will be secure with in itself however there is another security concern which arises from the fact that a user receiving a message through OBEX push basically trusts the fact that the sending device is actually the device that it claims to be. A hacker can simply give his/her device a same or similar name and try to send spoof messages to unsuspecting users. For example in case of supermarket adverts/coupons scenario discussed in earlier sections a hacker could simply set the friendly name of his/her device to be similar or synonymous to the actual Bluetooth push messaging nodes in use by the supermarket system. An unsuspecting user will have no way to differentiate if the message he/she is about to receive is coming from the supermarket itself or from a malicious source. This drawback points out a weakness in the system, this weakness being the fact that the first contact is initiated by the system not the user. Despite the fact that the system described in this chapter is permissions based whereby after first contact/discovery user is prompted if they want to receive the message or not but the true identity of the sender remains doubtful.

This can be avoided by initiating the first contact by the user; if Bluetooth is to be used in this case a user will have to go through the process of discovering, pairing and utilizing an advertised service, which is tedious process and once again user and system will need to be aware of any malicious presence in their surroundings. The use of RFID and NFC alongside

Bluetooth will essentially eradicate this problem. A user can initiate the first contact by scanning an RFID tag through their mobile phone, the tag in question can simply be holding an advertisement or a coupon or it trigger a Bluetooth pairing through NFC. Following chapters will address the user of RFID and NFC in more detail.

Chapter 4

RFID/NFC on Mobile Phones

4 RFID/NFC on Mobile Phones

Whilst RFID is establishing itself across a range of business sectors it is likely that it's most significant impact will come through being combined with mobile phones. Mobile phones are often described as a disruptive technology in that they have overturned the dominance of traditional fixed phone service. The incorporation of RFID and NFC onto mobile phone has similar possibilities in terms micro payments, digital distribution strategies, and interaction with everyday objects which is likely to radically alter existing consumer practices. In this chapter introduces RFID and NFC in relation to mobile phones and provide details of the associated standards and software development tools and environments.

Whilst much of the focus on RFID has come through asset tracking, another area that has greatly benefited from RFID is micro payments and pre-paid access services for mass transit systems which has seen huge take up in places such as Japan and Korea which has no-doubt fuelled the integration of RFID into the mobile phone feature set. RFID as a technology covers a range of possible operating frequencies which in turn affects the nature of the operation of the application of the technology. The particular operating range for mobile phones is generally 13.5 MHz which limits the range to approximately 3 cm or touch as shown in Figure 4.1.

Any discussion of RFID on mobile phones is incomplete without also discussing Near Field Communications (NFC) which is an interface and protocol built on top of RFID and is targeted in particular at consumer electronic devices, providing them with a secure means of communicating without having to exert any intellectual effort in configuring the network (ECMA 2004). Thus NFC takes RFID beyond the traditional use case scenario of interacting with tags to allow the communication between devices. To connect two devices together, one simply brings them very close together, a few centimetres, or make them touch. The NFC protocol then automatically configures them for communication in a peer-to-peer network. Once the configuration data has been exchanged using NFC the devices can be set up to continue communication over a longer range technology such as 802.11 or Bluetooth. The other advantage with NFC comes in terms of power saving, and it achieves this by having an Active Mode (AM) and Passive Mode (PM) for communication. In AM both devices generate an RF field over which they can transmit data. In PM, only one device generates the RF field, the other device uses load modulation to transfer the data. This is an ideal scenario for mobile phones as it would allow them to interact with other devices such as laptops whilst minimising battery consumption. The data rates available are relatively low, 106, 212, or 424 kbits/s, although for the applications envisaged this should be more than sufficient (ECMA 2004). The unique combination of NFC technology and mobile phones enables creation of innovative services and applications. NFC enabled mobile phones are not only equipped with a NFC reader/writer but also have a contactless card built in to them. Presence of NFC capabilities on a mobile phone provides some unique advantages to mobile users which not only helps encourage creation of new and innovative services but also increases market penetration of NFC services.

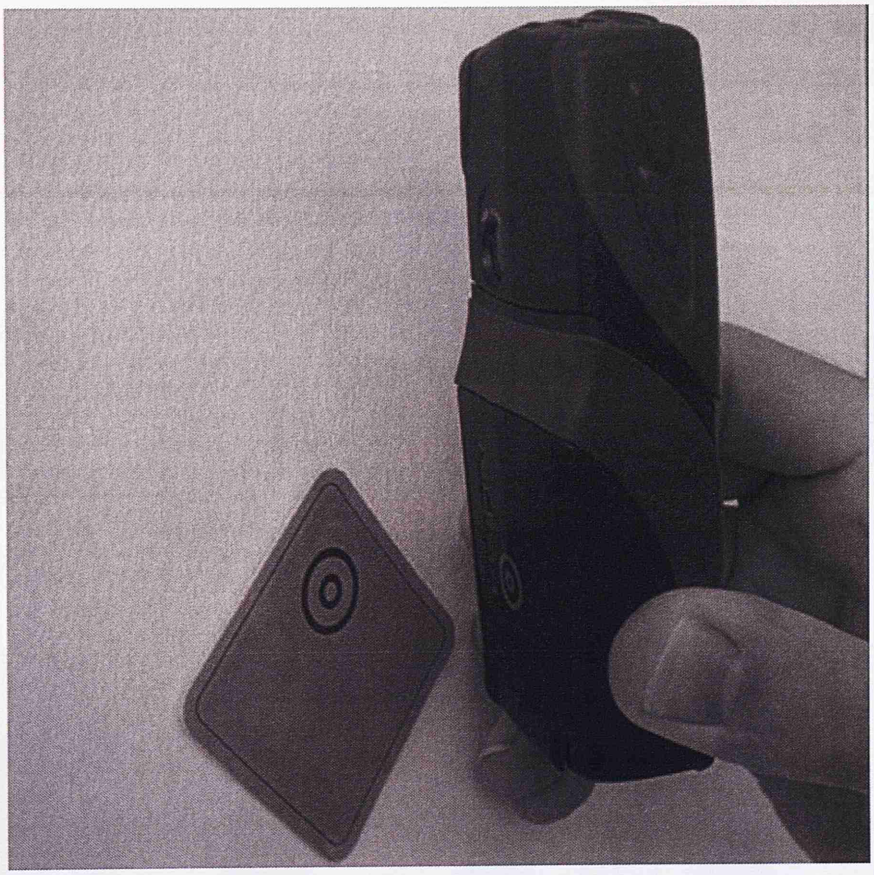

Figure 4.1: Phone Interfacing with RFID Tag

Nokia was the first to combine mobile phones with RFID/NFC when it introduced clip-on RFID shells for the 5140 (Nokia 2003) and NFC for 3320 (Nokia 2004) and 5140i (Nokia 2005) Series 40 phones called Nokia Xpress-on Mobile RFID/NFC Kits (Nokia 2004). The RFID/NFC shells can be accessed via J2ME applications running on the phone to trigger defined actions within the application. At the Consumer Electronics Conference in Las Vegas in January of 2007 Nokia demonstrated the 6131 NFC phone (Nokia 2007) with in-built NFC capabilities and support for NFC specifications. Nokia 6131 NFC was released in the 2nd quarter of 2007. Following the success of 6131 NFC mobile phone Nokia have recently released yet another NFC enabled mobile phone the 6212 Classic (Nokia 2008). Unlike its predecessors; which had the RFID antenna location either at the top of the device or as an express shell behind the battery; which required the RFID antenna to be near the NFC/RFID tag the 6212 Classic has a radical antenna design which does not require precision instead bring any part of the phone near an NFC/RFID tag will be enough to create sufficient field to read or write the data to the NFC/RFID. An important recent development for NFC on mobile, as reported widely in the press on 20th July 2010 was Nokia's executive VP for markets Anssi Vanjoki statement that: “every Nokia smart phone running Symbian OS built from 2011 on will be equipped with NFC technology” which should do much reinvigorate interest in this technology”.

Figure 4.2: NFC Devices

4.1 NFC specifications

It has already been highlighted that NFC is already on its way to becoming a part of everyday life and in order to achieve successful consumer adoption of this technology companies involved need to work together closely and applications need to be interoperable. In 2004 the NFC Forum (NFC Forum 2004) was formed with its main objective to promote the use of NFC technology in consumer devices and services, provide an extensive framework for interoperable applications by developing standards based specifications and ensure that products and devices claiming to be NFC compliant conform to the forum specifications.

A major step towards the goals of NFC Forum was in 2006 when it announced the first five NFC specifications.

- NFC Data Exchange Format
- NFC Record Type Definition
    - NFC Uniform Resource Identifier Service Record Type Definition
    - NFC Text Record Type Definition
    - NFC Smart Poster Record Type Specification

Further, tag formats based upon ISO14443 Type A, ISO 14443 Type B and ISO 18092 were also announced and a NFC Forum compliant device must support these. Since then NFC forum has added several new specifications and additions to existing specifications. These specifications include

- NFC Forum Type Tag Technical Specification
- Reference Application Technical Specification
- Protocol Technical Specification
- Device Internal Technical Specification
- NFC Generic Control Record Type Definition Technical Specification

The technology architecture of NFC is based upon three different modes of operation i.e. peer to peer, read-write and card emulation as shown in Figure 4.3.

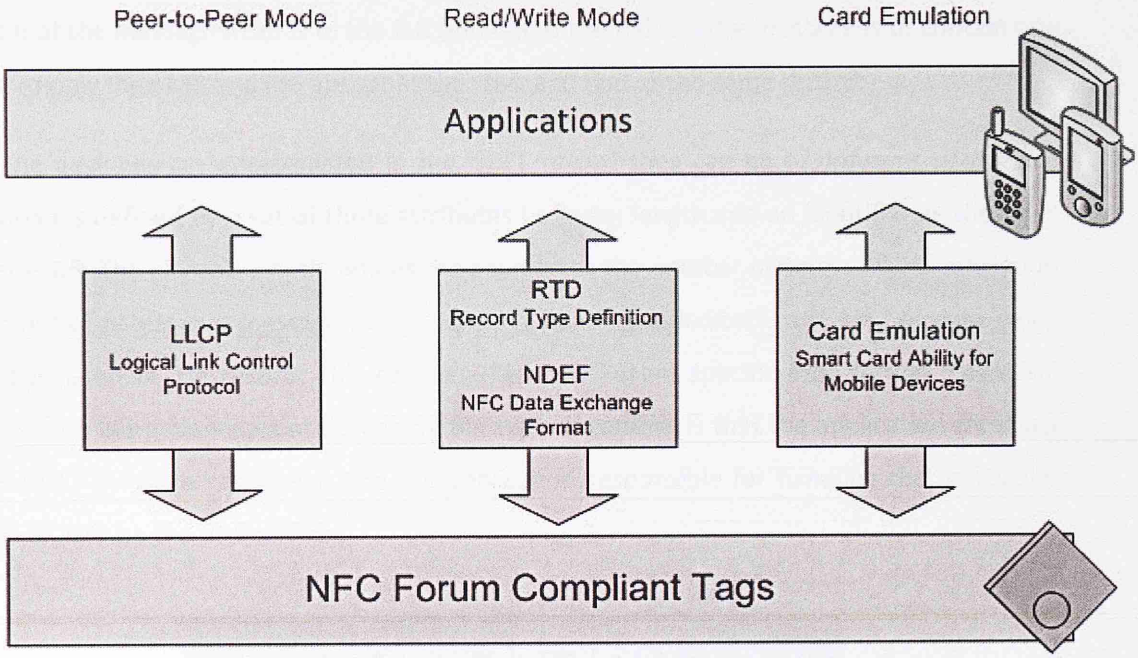

Figure 4.3: NFC Modes

4.1.1 NFC Data Exchange Format Specification

The main objective of NFC Data Exchange Format (NDEF) specification (NFC Forum 2006) is to build a common data format for NFC devices and tags. It does not define any record types as it focuses on data structure of the message to exchange information, record types are defined in separate specifications as listed earlier and they are discussed briefly in the sections below. NDEF is a lightweight binary message format designed to assemble single or multiple application defined payloads into a single message for information exchange between NFC Forum Devices or NFC Forum Device and NFC Forum supported tags. An NDEF message consists of one or more NDEF records which hold the payloads. Figure 4.4 shows the anatomy of a NDEF message (NFC Forum 2006).

NDEF Message					
R_1 MB = 1	.....	.....	....	......	R_n ME = 1

Figure 4.4: Structure of NDEF Message

The first record in NDEF message contains the Message Begin (MB) flag and the last record contains the Message End (ME) flag. In figure it can be seen that first record (index 1) has the

MB flag set whilst last record of the message (index n) has the ME flag set which also points out that the message head is to the left and tail to the right. If the message is to contain one record only then MB and ME are set at the start and end of the same record.

As the payloads are encapsulated in the NDEF record they can be of different sizes. Each payload is defined by a set of three attributes i.e. type, length and an identifier as shown in Figure 4.5. The payload length defines the payload as the number of octets where maximum number of octets in a message being 232-1. Payload Type indicates the kind of data being encapsulated in the record. This can be URIs, NFC Forum specific type format, or MIME types. The key advantages of describing the type of content is that the application receiving this NDEF message can direct it to the application responsible for handling that particular type of data on the user device.

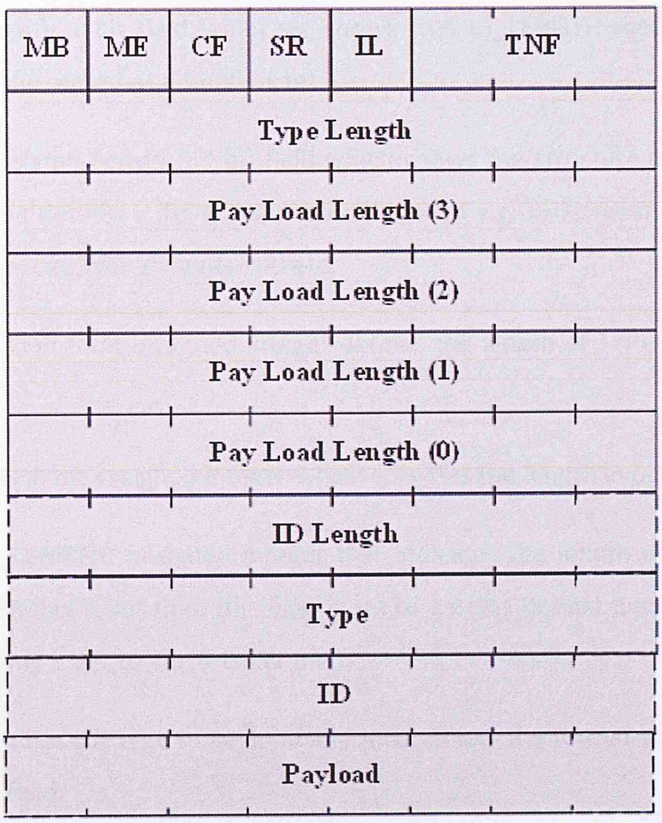

Figure 4.5: Structure of a NDEF record (NFC Forum 2006)

Since an NDEF message can comprise of multiple records so payload type of first record should generally dictate the payload type not only for itself but also for the records that follow. It is important to keep in mind that the specification does not define any model for handling of the data based upon type; in fact the processing of data is totally left up to the user application involved in the NFC information exchange. Third payload attribute, payload identifier, is optional and allows the application to identify the payload encapsulated in the record. This is crucial in supporting URI based links. Similar to payload handling the specification leaves the linking mechanism definition to the application.

- **MB:** MB Flag (1 bit field) shows the start of a NDEF message when set
- **ME:** ME flag (1 bit field) show the end of a NDEF message when set
- **CF** (Chunk Flag): 1 bit field which identifies chunked payload
- **SR** (Short Record): 1 bit field which indicates a short record when set, it indicates that the payload size is within the limits of payload fields i.e. between 0 – 255 octets.
- **IL** (ID_Length): 1 bit field when set shows that ID_LENGTH filed is present in the header of the record as a single octet.
- **TNF** (Type Name Format): 3 bit field which shows the structure of TYPE field. NDEF specification defines a list of values for this field e.g. 0x01 means NFC Forum well-known type, 0x03 for absolute URI etc.
- **TYPE_LENGTH**: 8 bit unsigned integer defines the length of TYPE filed in number of octets
- **ID_LENGTH**: 8 bit unsigned integer which specifies the length in octets for ID field
- **PAYLOAD_LENGTH**: unsigned integer that indicates the length of PAYLOAD field in octets. If SR flag is set then this filed is set to 1 octet (8 bits) but if SR flag is not set then this field is set to 4 octets (32 bits).
- **TYPE**: identifies the type of payload and must follow the format defined by the value set in TNF field.
- **ID**: contains an identifier in the form of a URI reference which can absolute or relative

NDEF specification leaves security and internationalization up to implementations. Since the specification supports definition of data types it is up to the application to consider the implications of accepting different data types.

4.1.2 NFC Record Type Definition

The NDEF specification discussed earlier defines a common data format for NFC Forum devices but it does not define any record types in detail. Different record types are defined in separate specifications. The RTD specification (NFC Forum 2006) provides guidelines for the specification of well-known types for inclusion in NDEF messages being exchanged. Each NDEF record contains a record type string which holds the name of the record type referred to as Record Type Name (RTN). RTNs can be specified in several different ways, these can be MIME types, URIs or NFC Forum well-known type names etc.

NFC Forum Well Known Type

Well-known type is designed to create primitives for certain common types. It is mainly used when there is no equivalent URI or MIME type available for a certain payload. It is identified within an NDEF message by setting the TNF field of a record to 0x01. A well-known type is a URN with a namespace identifier (NID) "nfc". There are two kinds of NFC Forum well-known types; NFC Forum global type and NFC Forum local type. The earlier is solely managed by NFC Forum; other parties are not allowed to define them. The latter is available for use within the perspective of another record.

NFC Forum External Type

This is meant for the organizations who wish to assign a name space to be used for their own purposes. External type is similar to well-known type however NSS part is put into another namespace i.e. "ext". The external type must be formed by taking the domain name of the organization issuing the external type.

4.1.3 NFC Text Record Type Definition

As the name suggests Text Record Type defines a NFC well-known type for plain text (NFC Forum 2006). It has been created as plain text field which can be used on its own as a solitary record in a NDEF message or in combination with another record type to provide extra description for the content. The specification does raise some security concerns for this record type. These are mainly due to the actual nature of this particular record type. For instance the text on a tag can be over written and the user can be tricked into doing something else than actually desired. In order to avoid this, the specification recommends the usage of this record type to be for information purposes only.

4.1.4 NFC Forum URI Record Type Definition

NFC URI Record Type Definition (NFC Forum 2006) is used to specify a record to be used with NDEF to retrieve a URI stored in a NFC-forum compliant tag. This specification provides a means to store URIs inside other NFC elements such as Smart Poster (NFC Forum 2006). The speciation defines URI service with data model and specifies simple Smart Poster examples. Smart Poster RTD can be considered as an extension to URI RTD. URI is NFC well-known type and is represented as "U" (0x55). Figure 4.6 shows the structure of a URI record (NFC Forum 2006).

Name	Offset	Size	Value	Description
ID Code	0	1 Byte	URI ID Code	ID code of URI
URI	1	N	UTF-8 String	URI

Figure 4.6: Structure of URI Record

The URI identifier codes are available in the specification, some examples of which are 0x04 for https:// and 0x03 for http:// etc. If the URI identifier is set as 0x04 and the URI filed value is www.mobileradicals.com then the communicating device will receive the URI as https://www.mobileradicals.com. Using Figure 4.7 let us see how a URI will be stored in the record structure provided previously.

Offset	Content	Description
0	0xD1	SR =1, TNF=0x01, MB=1, ME=1
1	0x01	Length of record type
2	0x13	Size of payload
3	0x55	NFC well known record type URI (U)
4	0x01	URI Identifier (http://www.)
5	0x6D 0x6f 0x62 0x69 0x6C 0x65 0x72 0x61 0x64 0x69 0x63 0x61 0x6C 0x73 0x2E 0x63 0x6f 0x6D	String "mobileradicals.com" in UTF 8

Figure 4.7: Example URL as URI record type

This figure shows a valid URI record type for URL http://www.mobileradicals.com. The NDEF record in this table shows that it is a Short Record (SR). Type Name Format is NFC well known type, and since we are not going to use multiple records within this NDEF message so MB and ME have been set in the same record. This is followed by length of record and payload respectively. Then we declare the record type which is NFC well know type URI followed by the identifier for URI. Finally we include the string for the URI.

4.1.5 NFC Smart Poster Record Type Definition

The Smart Poster record type (NFC Forum 2006) is a NFC forum well-known record type (well-known type "Sp"). URI RTD defines a way to store and communicate URIs but there is no functionality to add metadata to those URIs. Smart Poster provides a way to add this meta data to the URIs, for example, consider a poster advertising a new console game; by adding a NFC tag with Smart Poster record we can transform this simple object into a smart object. When users touch the poster with their mobile device (phone or PDA) they will be provided with URI to the advert for the game to be seen on their device along with some text based information for this clip, this information can be the size of clip, total running time, where to buy the game, promotional offers, etc.

Smart Posters are in fact one the key use cases of NFC and is often seen in one way or the other in different documents about NFC, press releases etc. Smart Poster records can also contain certain actions embedded in them as part of the record which can trigger actions on the user device e.g. launch browser to access the URI etc. Smart Poster payload is an NDEF message which can consist of multiple NDEF records (SR=0). Depending upon the content being stored the Smart Poster can have none, one or more of the following components.

Title Record

This is an optional record representing the service. This record can be used more than once if the Smart Poster is required to support different languages but it is critical not to make duplicate entries for languages being included in the record. This record is an instance of Text RTD.

URI Record

Since Smart Poster record provides an extension to URI record by adding metadata for the URI, it forms the core of the Smart Poster record and must not be repeated (one URI per smart poster record).

Action Record

This record is optional and can be used to trigger actions for the URI record e.g. action can be to launch the browser or simply save the URI as a bookmark for later on. Although this record is optional but not including it can leave the handling of URI to the device and that can result in a different user experience from device to device. It is a good practice to include this record so that appropriate application can be launched to handle the URI.

Icon Record

This record is optional and can be used to hold one or more MIME type image records so that the device reading the Smart Poster record can include one of those images (depending upon its capabilities) in the URI display.

Size Record

This record is optional as well and can be used to indicate the size of the content. This can be especially helpful to decide in advance if a device has lesser capabilities to handle that particular object. Using a good combination of size and type records the mobile device can decide whether it can handle the object being referenced or not.

Type Record

This record is used to declare the type of the external object being referenced through the URI provided in the URI record. This record is optional and as mentioned before when used in combination with size record can help determine if the mobile device is able to handle this external object or not.

4.1.6 NFC Generic Control Record Type Definition

NFC Generic Control Record Type (NFC Forum 2008) specification defines how to activate a specific application on request from another NFC Forum device or NFC Forum tag through NFC communication. A MIME type record in an NDEF message can provide access to an associated function but this association is purely defined by the associated device and can vary from device to device especially if the same MIME type is shared by more than one function. This is not only helpful if the target application or function is not covered by any other NFC Forum MIME type records but also if the source NFC Forum device clearly requests a particular application or function on the target device.

Access to an application or a related function in a NFC device is provided through MIME type associations. It is a common occurrence to have multiple applications to share the same MIME types. If this is the case the target device chooses one of those applications to process the request. The target device determines and controls the association between MIME types and applications however this can produce unexpected results for the source device. Generic Control resolves this problem by allowing the source device to request a specific application on the target device to handle the request.

Content of the Generic Control payload is expressed as NDEF message(s). The content consists of a configuration byte and several NDEF messages as sub-records. Structure of Generic Control record is as follows.

Configuration Byte: Used to specify multiple profiles to help determine how the payload is going to be handled.

Target Record: Identifies a function to handle the data contained within. It contains an instance of Text RTD or a URI RTD. It is the responsibility of the destination device to translate the sub records contained within. If the destination device is unable to translate these sub records the destination device should simply ignore this Generic Control record since it contains a Target record that cannot be resolved.

Action Record: Specifies the action for the function as identified by the target record. This specification defines that a Generic Control record must not contain more than one Action record but it is not compulsory to have at least one Action record present. If the Action record is not present the default action of the target function will be applied which is at the function's discretion. If the Target record cannot be resolved by the destination device the specification states that the Generic Record should simply be ignored.

Data Record: Identifies the data to be processed by the function identified by the target record. A Data record may contain any type of data.

NFC Forum defines the well-known type for the Generic Control Record as *"Gc"*. The first byte of Gc is always a configuration byte as seen from table 4.1. The rest of the payload comprises of Target record, Action record and Data record. The NFC Generic Control RTD does not impose any restrictions on the order of the records following the configuration byte. However it is recommended that a Target record precedes the Action record and Data record follows the Action record.

<table>
<tr><td rowspan="2">GC</td><td rowspan="2">Config Byte</td><td>"t"</td><td>Target Identifier</td><td>"a"</td><td>Action Flag Byte</td><td>Action Identifier</td><td>"d"</td><td>Data</td></tr>
<tr><td>Type Name</td><td>Payload</td><td>Type Name</td><td colspan="2">Payload</td><td>Type Name</td><td>Payload</td></tr>
<tr><td>Type Name</td><td colspan="8">Payload</td></tr>
</table>

Table 4.1: Structure of a Generic Control Record

Handling of Generic Control records is illustrated in figure 4.8. Once the record type has been correctly identified the record data is passed on to a record dispatcher. It is the record dispatcher's responsibility to determine the suitable handler for the record. Once the handler has resolved the association between data and application the application launcher starts the associated application and the data is passed on to the application. In terms of security the specification passes the responsibility to the destination device. For example prompting the user about security issues that may arise due to execution of actions described in the Generic Control record. Privacy concerns however are distributed to both source and destination device since Generic Control records transports data without taking privacy into consideration. The destination device is responsible for any privacy issues that may arise due to execution of action listed in the Generic Control records however the source device is responsible for any privacy issues that may be caused by transferring information through Generic Control records (NFC Forum 2008).

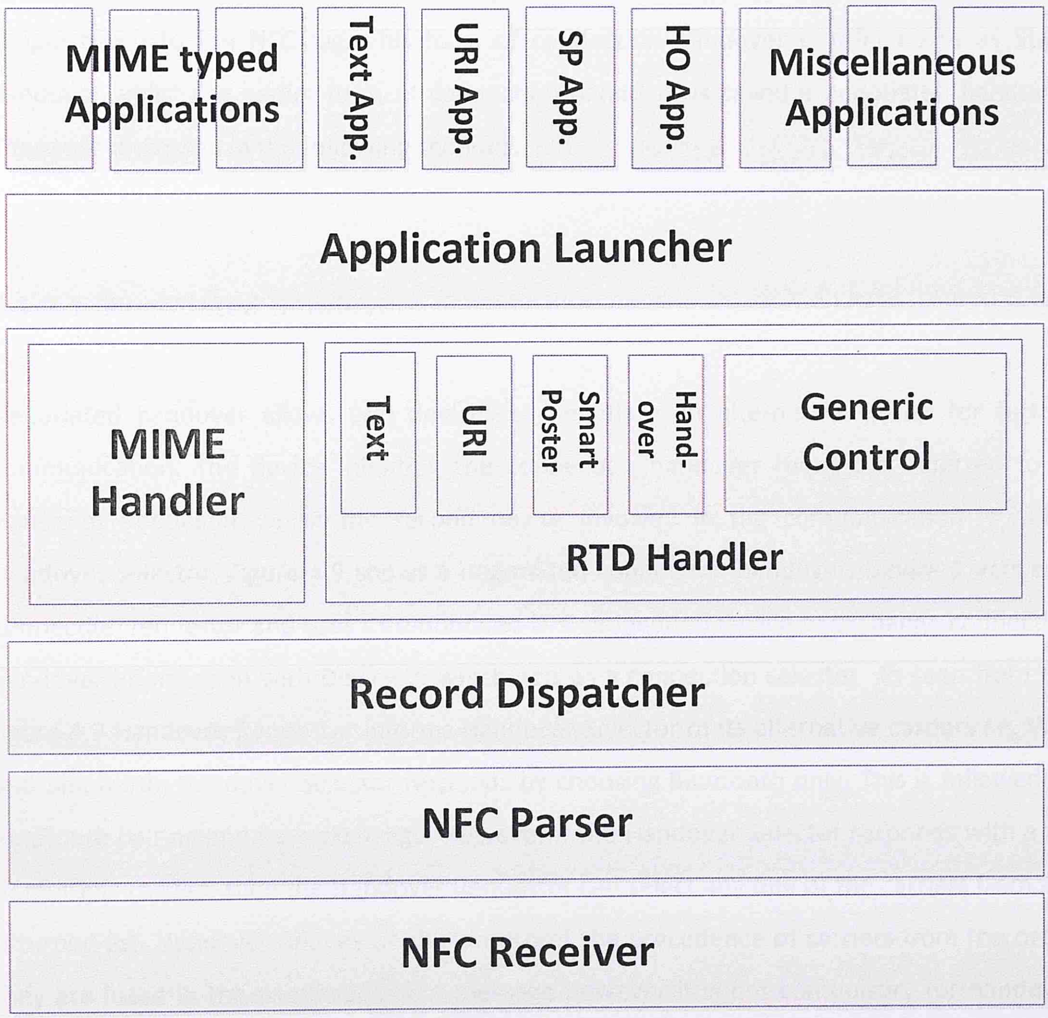

Figure 4.8: NFC Generic Record Handling

4.1.7 Connection Handover Technical Specification

Connection Handover Specification (NFC Forum 2008) defines how to NFC enabled devices can communicate with each other to establish a connection over another high speed medium such as WiFi or Bluetooth. A simple one touch setup of two NFC enabled devices completes the connection handover. During initial negotiation if matching capabilities are revealed about the two communicating devices then the connection can be switched to another common medium. All information required for setup of the new connection is exchanged between devices via NDEF messages. This specification also defines another form of connection where an NFC device needs to establish or acquire a high speed connection for example logging on to a public Wi-Fi system or communicating with a bank ATM etc. In this case the connection information for the other device is actually stored on a NFC tag. Device needing to establish the connection simply reads the connection credentials through a simple touch to the NFC tag. This form of connection handover is referred to as Static handover whilst the earlier form of connection handover is called a negotiated handover. These are discussed in the following sections.

4.1.7.1 Negotiated Handover

Negotiated handover allows two devices to negotiate an alternative carrier for further communication. The device initiating the connection handover request is referred to as Handover Requestor whilst the second device involved in the communication is called Handover Selector. Figure 4.9 shows a negotiated connection handover. Device 1 acts as a connection requestor and uses its embedded NFC embedded device to exchange connection handover information with Device 2; which acts as a connection selector. As seen from the figure 4.9 Handover Requestor informs Handover Selector of its alternative carriers i.e. WiFi and Bluetooth. Handover Selector responds by choosing Bluetooth only. This is followed by Bluetooth pairing and data exchange. However if the Handover Selector responds with a list of multiple carriers then the Handover Requestor can select any one of the carriers from the returned list. Handover Requestor shall interpret the precedence of carriers from the order they are listed in the handover select message however it is not compulsory for handover requestor to honour the precedence.

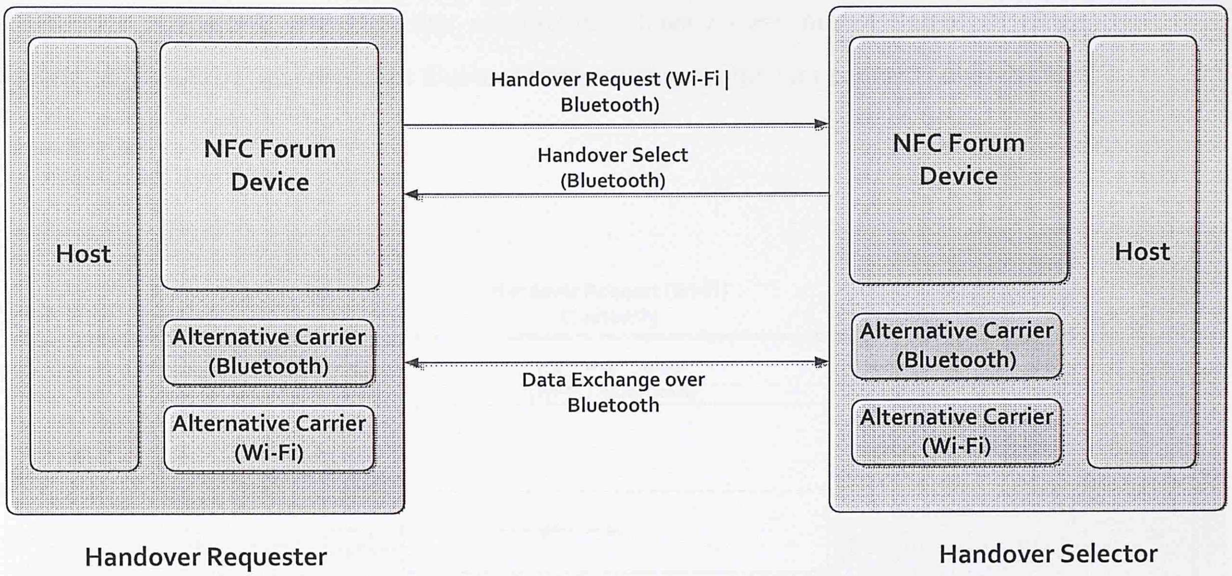

Figure 4.9: Negotiated handover

Figure 4.10 shows multiple carriers and handover selector i.e. WiFi and Bluetooth. Handover requestor chooses Bluetooth as a carrier ignoring handover selector's preference of WiFi.

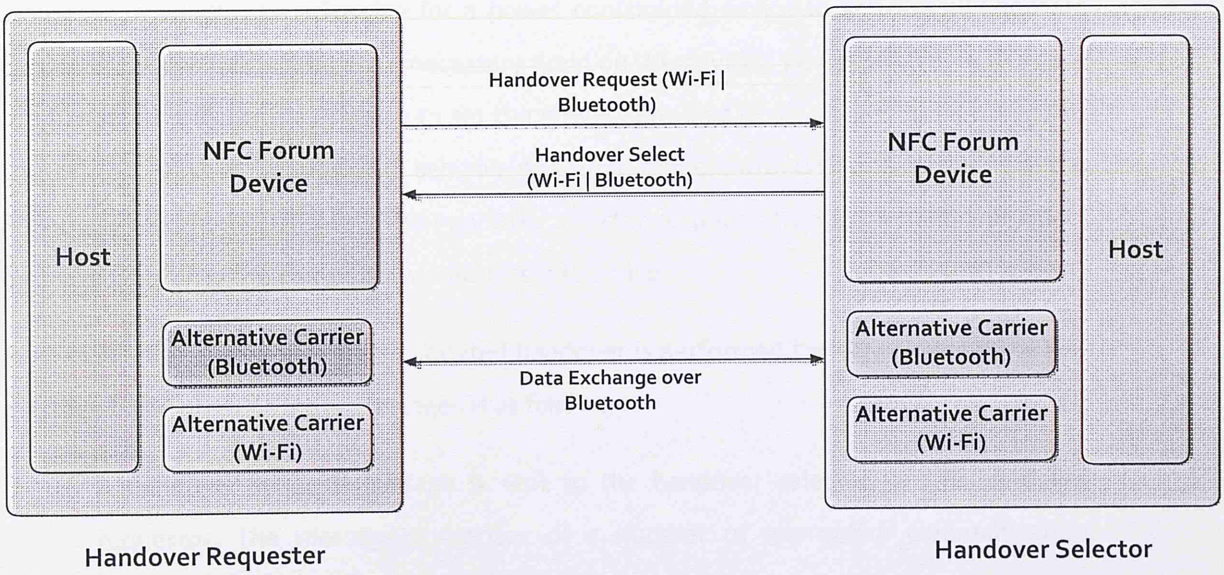

Figure 4.10: Negotiated handover with multiple selections

In certain cases the handover requestor can again choose not to honour the handover selector's carrier preferences. A similar scenario is show in figure 4.11 where handover selector has responded with a list of two carriers i.e. Bluetooth and Wi-Fi. Handover requestor first attempts to connect over Bluetooth by honouring the handover selector's preference but fails as the handover selector may have moved out of Bluetooth range. Following the failure to connect via Bluetooth the handover requestor connects over Wi-Fi.

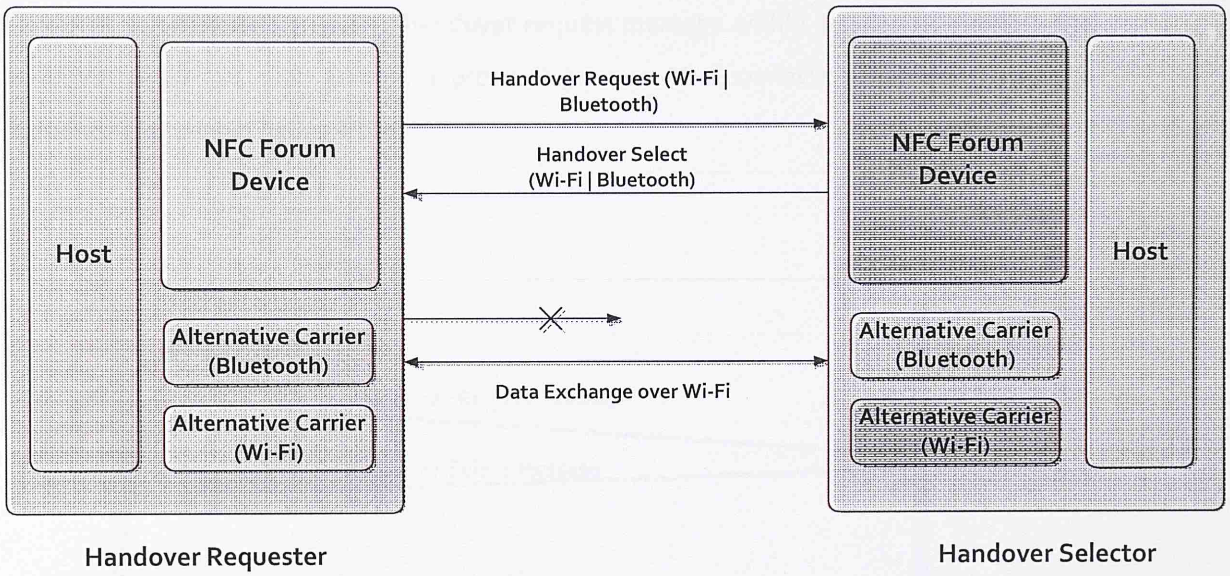

Figure 4.11: Handover selection with Multiple Selections

This specification also defines cases where a handover selector is a device with limited power resources. It will not be advisable for a power constrained device to activate all alternate carrier circuits as this will be an unnecessary drain on the device's power source. In this case the handover selector may choose to set the power state flag of all carriers to inactive. This triggers the handover requestor to send a subsequent request with only one carrier from the previously returned carrier list. The handover selector responds through a handover select message which has the carrier power status set to active.

In all cases discussed above the negotiated handover is performed through exchange of two messages. The order of these messages is as follows;

1. A handover request message is sent to the handover selector by the handover requestor. The message comprises of a number of alternative communication carriers that are available to the handover requestor.
2. The handover selector device performs a comparison on the list received from the handover requestor against its own communication capabilities. Handover selector sends a message to the handover requestor containing a list of carriers common to both of them.

If an empty list is returned to the handover requestor the handover has failed. Alternately the handover has completed and the connection establishment depends upon the carrier(s) selected. The handover select message must include information within in regards to how a connection can be established to the alternate carrier. The specification also defines that the handover selector shall answer a handover request message within 1 second otherwise the handover requestor shall assume a processing error. The connection handover message sequence is shown in figure 4.12.

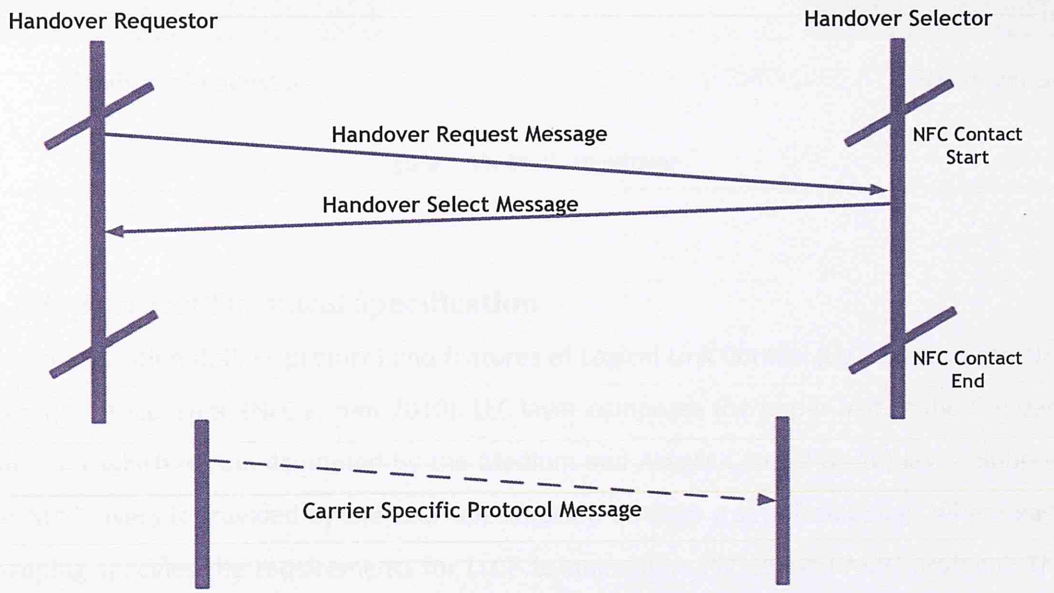

Figure 4.12: Connection Handover Message Sequence

4.1.7.2 Static Handover

Static handover is used when handover selector device is not a NFC Forum device but a NFC Forum tag. NFC Forum tags cannot receive and handle a handover request message nor can they respond with a handover select message. Instead the NFC Forum tag holds a handover select record and additional information records regarding the alternate carrier. Since the information stored on the NFC Forum tag is static it is impossible to adapt to any other requirements that a handover requestor may provide. A static handover is show in figure 4.13.

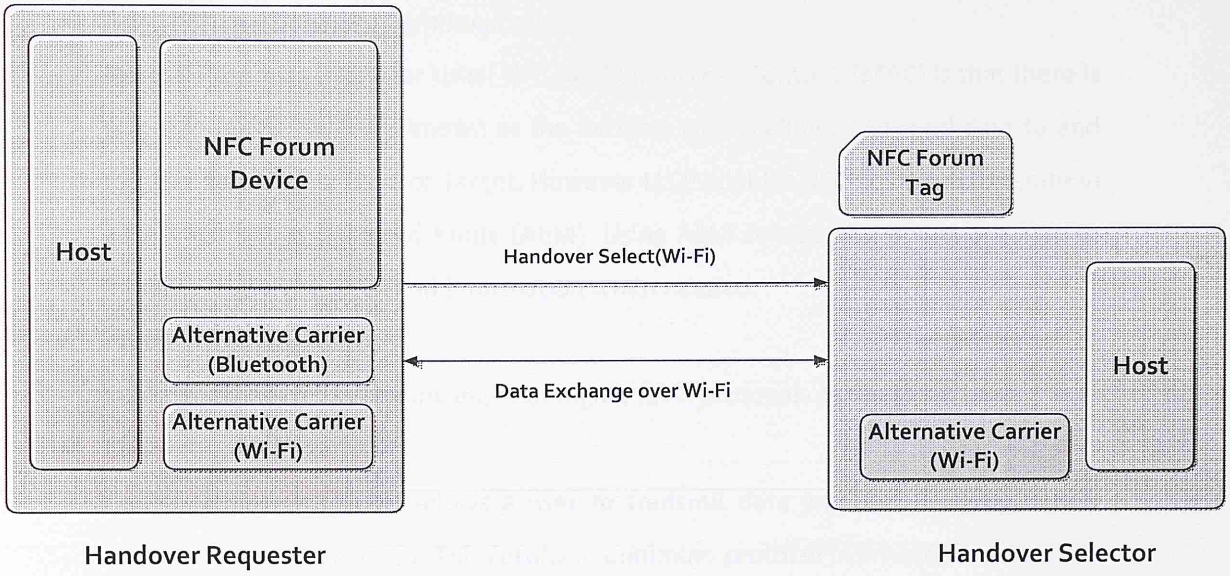

Figure 4.13: Static Handover

4.1.8 Protocol Technical Specification

This specification defines protocol and features of Logical Link Control (LLC) layer of the NFC Forum protocol suite (NFC Forum 2010). LLC layer composes the upper half of the OSI data link layer which is complemented by the Medium and Access Control (MAC) layer. Support for MAC layers is provided by the LLCP specification through a set of mappings where each mapping specifies the requirements for LLCP to one externally defined MAC protocol. The specification defines two service types, connectionless and connection-oriented, organized into three link service classes: connectionless service only; connection-oriented service only; and both connectionless and connection-oriented service.

4.1.8.1 Features

The Logical Link Control Protocol (LLCP) specification defines the technical means to transfer information units between two NFC Forum Devices. It is a compact protocol based upon the IEEE 802.2 which was designed to support small data transfer applications such as small file transfers or network protocols such as OBEX or TCP/IP. An overview of the features defined by the LLCP specification is given below.

- *Link Activation*

  LLCP specification defines how two NFC devices within communication range can recognize LLCP implementations that are compatible and carry out link establishment, connection supervision and link deactivation.

- *Asynchronous Balanced Communication*

  Normal Response mode for usual NFC Medium Access Controls (MAC) is that there is only one master which is known as the Initiator who is allowed to send data to and request data from a slave or Target. However LLCP enables NFC devices to operate in an Asynchronous Balanced Mode (ABM). Using ABM service end points are able to initialize, supervise and send information when needed.

- *Protocol Multiplexing*

  LLCP can facilitate several instances of higher level protocols at the same time.

- *Connectionless Transport*

  Connectionless transport allows a user to transmit data without any preparatory steps for connection setup. This results in minimum protocol overhead however it is unacknowledged transmission.

- *Connection Oriented Transport*

  Connection oriented transport provides sequenced and guaranteed data transmission and requires initial connection setup.

4.1.8.2 LLCP Components

LLCP comprises of logical components as listed below and shown in figure 4.14 (NFC Forum 2010).

- *MAC Mapping*

  Integrates an existing RF protocol (ISO 18092) into LLCP architecture.

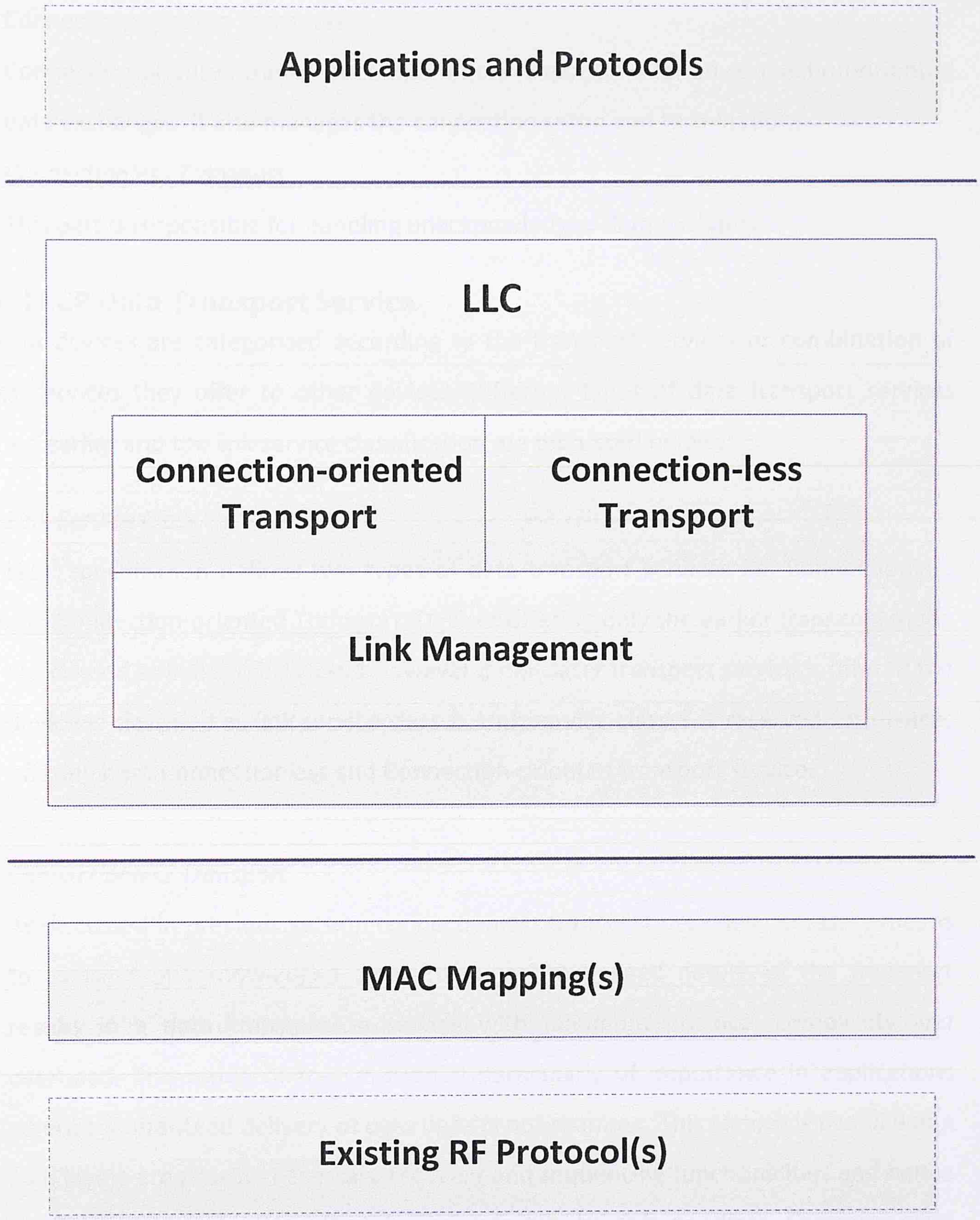

Figure 4.14: Logical Components

- *Link Management*

  This component is responsible for serialising all LLC Protocol Data Unit (PDU) exchanges for both connection-less and connection-oriented data transmission. It also aggregates and disaggregates small PDUs. Asynchronous balanced mode communication and supervision of link status are also guaranteed by this component.

- *Connection-oriented Transport*

  Connection-oriented transport component is responsible for all connection-oriented data exchanges. It also manages the connection setup and termination.

- *Connectionless Transport*

  This part is responsible for handling unacknowledged data exchanges.

4.1.8.3 LLCP Data Transport Service

NFC Forum devices are categorised according to the transport services or combination of transport services they offer to other devices. Different types of data transport services mentioned earlier and the link service classification are discussed below.

- *Link Service Class*

  LLCP specification defines two types of data transport services i.e. Connectionless and Connection-oriented Transport. Devices offering only the earlier transport mode are classed as link service class 1 however if only later transport service is offered the device is classified as link service class 2. Link service class 3 is reserved for devices offering both Connectionless and Connection-oriented transport service.

- *Connectionless Transport*

  As discussed in previous section connectionless transport provides necessary means to transmit unacknowledged data. The unacknowledged nature of the transport results in a data transmission service with minimum protocol complexity and overhead. This mode of transmission is particularly of importance in applications where a guaranteed delivery of data units is not required. This service is useful when high layers are provide necessary recovery and sequencing functionalities and hence duplicating these functionalities in the data link layer is needless. Connectionless transport does not require any setup prior to connection formation or connection termination therefore providing spontaneous data exchange between two devices without any additional overheads both in terms of time and protocols.

- *Connection-oriented Transport*
- Unlike connectionless transport connection-oriented transport provides a sequenced and guaranteed delivery of data units. Before any data can be exchanged a data link connection is established between two NFC Forum devices. Once a data link has been established the PDUs are transferred from one LLC to the other acknowledged

by PDUs in the opposite direction. The acknowledgment is only sent by an LLC after the PDU has been dispatched to the service user.

4.2 Developing NFC Applications on Mobile Phones

When the first commercial RFID/NFC handsets were launched in the market (Nokia 5140i and Nokia 3220) the NFC specifications had not been fully normalised. Developing NFC applications required developing for a certain brand and model of phone using proprietary development toolkits. Most significant development solution was delivered by Nokia called Field Force Solution (Nearfield and Nokia Field Force 2004). Key benefit of this solution was the fact that it was targeted at mobile phones with embedded RFID/NFC reader/writers. The solution not only contained a software development toolkit providing a Java API but also a server for networked interactions named the Local Interaction (LI) server. LI server was a real time web service that allowed capturing of data, management reporting and communication with the devices in the field. Architecture overview of the Nokia Field Force Solution is shown in figure 4.15.

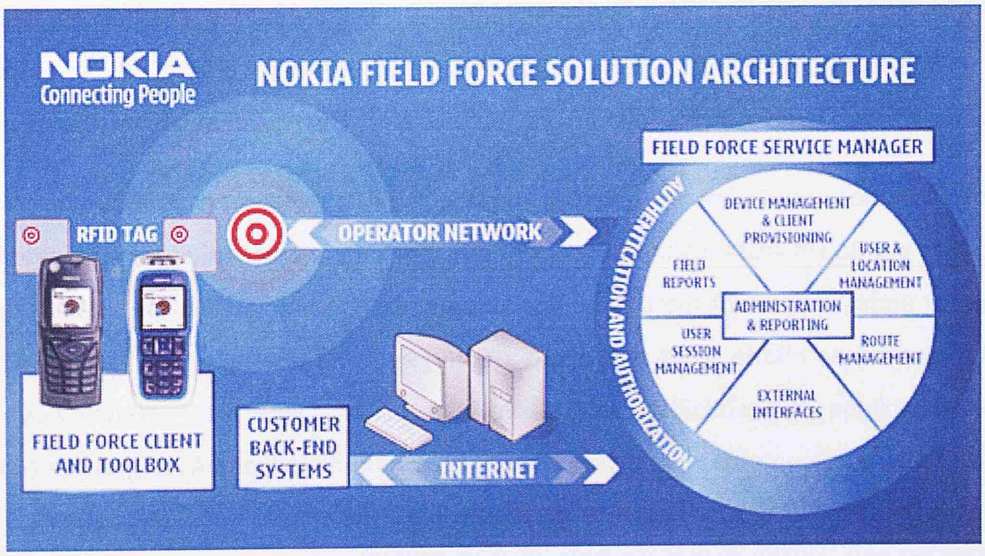

Figure 4.15: Nokia Field Force Solution Architecture

With the release of JSR-257, the contactless communications API for J2ME a standard way to develop NFC enabled applications was formed. JSR-257 complies to NFC Forum specifications and not only provides API for NFC enablement but also for other contactless ways of communication such as QR codes. JSR-257 is discussed in more detail in the following section.

4.2.1 Overview of JSR-257

The Contactless Communication API, or JSR-257 (SUN Microsystems 2006), allows applications to access information on contactless targets, such as RFID tags and visual codes such as QR codes and Semacodes (Rashid, Bamford, Coulton, Edwards and Scheible 2006). The 2D barcodes are similar to RFID tags in that they contain data often in the form of a URL. However, they hold much smaller amounts of information than the newer RFID tags and they are generally slower and more difficult to read (Rashid, Bamford, Coulton, Edwards and Scheible 2006).

The primary objective of JSR-257 is to provide easy access to various contactless targets and transfer information to or from them. Before we provide details of programming RFID/NFC applications we shall first consider the mandatory and optional parts of the API, which are divided into five packages as shown in Figure 4.16 (SUN Microsystems 2006).

Only javax.microedition.contactless is the mandatory package whilst the rest are optional and can therefore be left unimplemented. A reference implementation must provide a list of target types it supports and it is this list of targets that dictates the packages that must be implemented. If a target type is listed in supported target types an implementation must be provided. All the targets supported by this API implementation are defined in the TargetType class. To aid understanding shall briefly consider the functionality provided by each package.

Javax.microedition.contactless: This package provides functionality common to all contactless targets supported by this API. The DiscoveryManager Class sits on top of this API and is the starting point of contactless communication. In order for an application to receive notifications about targets in close vicinity an application must obtain an instance of the DiscoveryManager class which in return provides the notifications to application about contactless targets. An application can then use sub packages to communicate with different targets depending upon their type. Connections to contactless targets are built on top of Generic Connection Framework (GCF). Each target defines a new protocol to GCF, although only the visual code protocol is visible and all RFID related protocols are hidden due to the nature of communication involved.

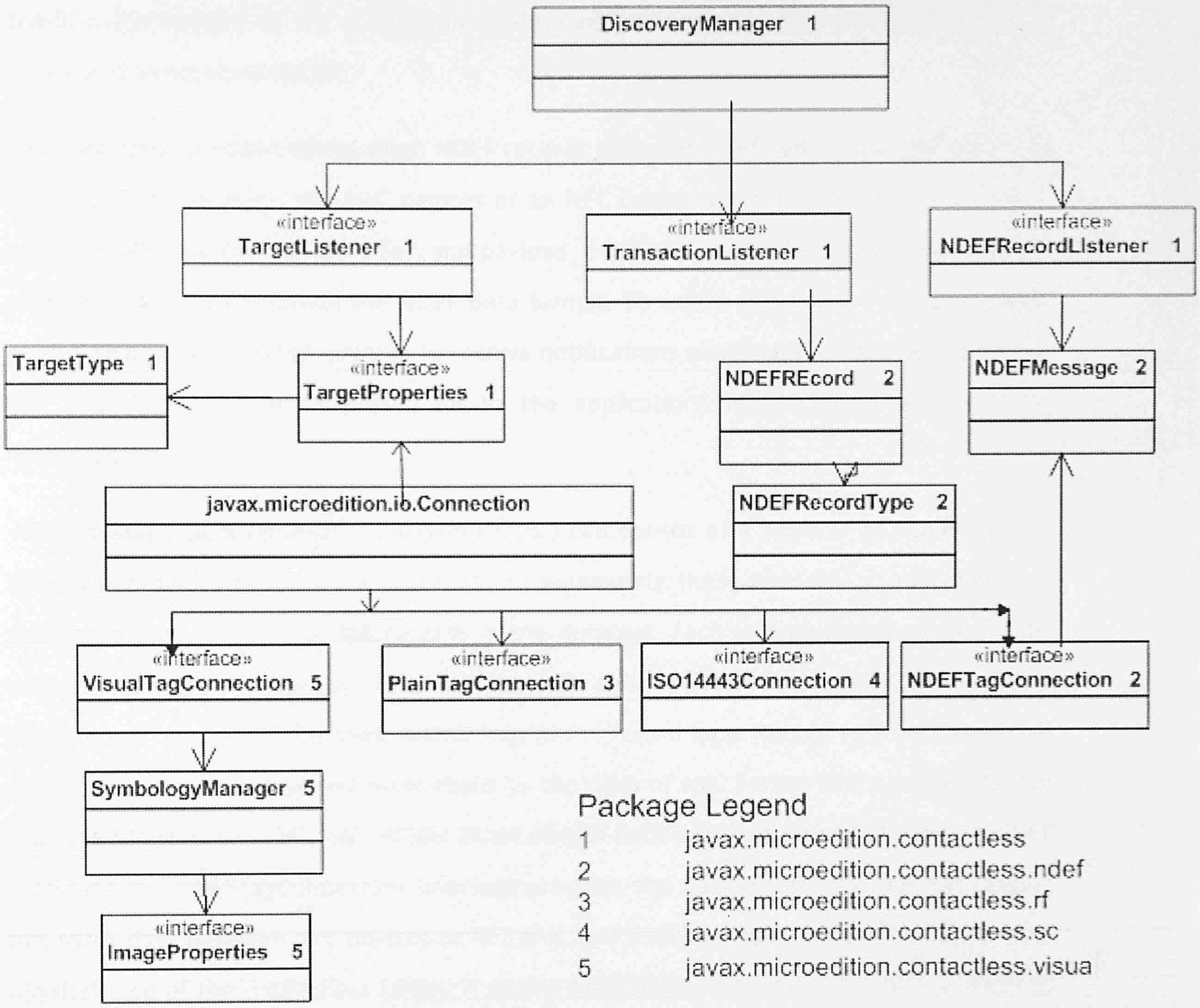

Figure 4.16: Overview of JSR 257 Reference Specification

The TargetListener interface provides notifications back to DiscoveryManager instance once a target is discovered by the device hardware. In essence a Java Virtual Machine (JVM) must provide a TargetListener for each TargetType obtained by calling getSupportedTargetTypes() function of DiscoveryManager class. Only one TargetListener can be registered at a time as RFID hardware can only handle one physical connection and failing to do so will result in a registration failure and an exception will be thrown.

Class TargetType provides all the contactless targets supported by the API whilst the TargetProperties interface provides the properties common to all supported contactless targets. Since the API can support card emulation mode, the interface TransactionListener provides information to the application relating activity between secure elements on the device and an external reader.

Javax.microedition.contactless.ndef: NDEF records have been defined by the NFC Forum to exchange data between two NFC devices or an NFC device and a tag. Since these records contain type, type format, identifier, and payload, a connection can be established with any physical target that supports the NDEF data format. To utilize this feature the application must register with an NDEF Listener to receive notifications about tags, or devices, detected. The data from the tag is passed on to the applications registered to receive NDEF notifications.

NDEFMessage class represents messages which can consist of a number of NDEF records. This class provides necessary functionality to manipulate these records i.e. add, delete or update data payload within the records in the message. Each individual record within the message is represented by the NDEFRecord class stored in a byte array. Class NDEFRecordType stores the name and format of the record type. Record types are stored as constants within the class and must abide by the rules of NFC Forum RTD's and RFC's. For example MIME types, URL, etc. Whilst other classes handle definition and storage of NDEF messages the NDEFTagConnection interface provides the basic connection for exchanging this NDEF data between NFC devices or NFC tag. This interface does not concern itself with physical type of the contactless target; it simply reads and writes the data. The protocol to do achieve this read and write process is extended from GCF.

Javax.microedition.contactless.rf: Although this API implementation aims to use NDEF records as standard, it also provides access to physical RF targets that do not support NDEF. This package contains one interface; PlainTagConnection; which encloses functionality to detect RFID tags. This is done to enable comprehensive support for various types of RFID tags since it would be undesirable have an API to support all different types of tags.

Javax.microedition.contactless.sc: This package is responsible for communication with external smart cards. Although JSR-177 covers communication with smart cards, through an APDU connection, JSR-257 defines an ISO14443 connection interface to access smart cards. Unlike and APDU connection, an ISO4443connection can read both resident and external smart cards and provides access at a much lower level.

Javax.microedition.contactless.visual: This package provides support for visual tag targets which are detected as contactless targets. This package contains classes and interfaces to read information stored on the visual codes.

Chapter 5

RFID/NFC based Implied Location Tracking in Mixed Reality Games

5 RFID/NFC based Implied Location Tracking in Mixed Reality Games

Some of the work presented in this chapter was originally published by the author in ACM Computers in Entertainment, ACM Inc. New York, Volume 4 Number 4, October 2006 , Proceedings of IEEE International Conference on Consumer Electronics, Las Vegas USA, 2006 and International Journal of Computer Games Technology Volume 2008, Hindawi Publishing Cooperation.

5.1 Introduction

Mixed reality is the merging of real and virtual worlds to produce a new environment where physical and digital objects can co-exist and interact. RFID is often hailed as one of the enabling technologies that will bring about this vision. RFID tags, a simple microchip and antenna, interact with radio waves from a receiver to transfer the information held on the microchip to the receiver. RFID tags are classified as either active or passive, with active tags having their own transmitter and associated power supply, while passive tags reflect energy sent from the receiver. Active RFID tags can be read from a range of 20 to 100m; passive RFID tags range from a few centimeters to around 5m (depending on the operating frequency range). With over five billion users (International Telecommunications Union 2010) and the emergence of standardized operating systems (Coulton, Rashid, Edwards and Thompson 2005), it is widely forecast that the mobile phone will become the dominant computing device for the majority of the world's population. This is no doubt why mobile games are the subject of much debate within the games industry, particularly as revenues from mobile gaming is expected to surpass $5.6 billion which is 19% growth from 2009 and is expected to reach $11.4 billion by 2014 (Nguyen 2010). Industry analysts are predicting that the mobile may become the dominant force in games. However, recent reports by Glu Mobile in the UK and NPD in the US indicate that the mobile gamer demographic is very different from the traditional console and PC gamer. This means that the games industry has a tremendous opportunity for creating new gaming genres that will take advantage of the unique nature of the mobile phone and the broad range of users who possess them. One such opportunity is that of mixed-reality games; where players can interact with objects that are either fixed or mobile, which is a practical possibility with the emergence of mobile phones with in-built RFID readers. It was predicted in 2005 that as many as 50% of all phones will incorporate RFID by 2009 (RFID Journal 2004) but this never materialized however Nokia have recently announced that most of their handsets will incorporate NFC by 2011 (NFC

News 2010). Nokia have further revealed plans to include NFC in the forthcoming MeeGo operating system (Clark 2010) hence this is a practical long-term solution that will cover both high and low- end phone models.

RFID is not the only means of interacting with objects. Alternative approaches include the utilization of other short- range communications such as Bluetooth or WiFi. However, these techniques require a power supply for the object, and so are impractical for wide-scale implementation. Therefore, in the short to medium term, for phone/object interaction, we must consider passive RFID or the various forms of two-dimensional barcodes such as QR codes as the best solutions, as neither requires a power supply. All of the two-dimensional barcode systems use a phone with an on-board camera to either decode the code on the phone or through interaction with an online database. RFID and its associated technology of near field communications (NFC) (ECMA 2004) offer an alternative approach:

- that provides faster read times, as the tags can be accessed at rates between 106, 212, or 424 kbits/s, whereas the two-dimensional barcodes require image capture and processing, which we found typically takes a few seconds;
- provides RFID tags that can be written to as well as read from;
- provides a simpler reading method, as the phone and the tag have merely to be placed in close proximity (less than 3cm), whereas the barcodes require the user to take a picture. In fact, the phone and RFID tags used in this project provide round target icons to make positioning intuitive; and
- that is more robust, as errors are more likely to occur when scanning a barcode due to irregular camera orientation.

Mixed-reality games on mobile phones are not new, and a number of them have been reported (Rashid, Bamford, Coulton, Edwards and Scheible 2006), although as yet none have used RFID, and only ConQwest (semacode.org) has used two-dimensional barcodes. The work described here does not compare RFID technology against two- dimensional barcodes, as the majority of the findings would merely confirm the technical analysis previously discussed.

Instead, we seek to identify what RFID mixed-reality mobile phone games have to offer in terms of user experience and gameplay. Therefore, the objectives of this project were to create a readily deployable game in which we can ascertain the following:

- if the use of physical objects enhances the user experience;

- whether RFID produces effective user interaction with those objects;
- the effectiveness of RFID as an implied location- positioning scheme when the game players are moving quickly; and
- how tactics develop over subsequent participation in the game.

In the following sections a novel mixed reality version of the classic video game Pac-Man, called PACLAN is presented, in which human players use the Alexandra Park accommodation complex at Lancaster University as the game maze (Rashid, Bamford, Coulton and Edwards 2006).

5.2 PACLAN System Overview

This section provides an overview of PACLAN game play and system implementation.

5.2.1 Gameplay

PAC-LAN is a novel version of the video game Pacman, in which human players use the Alexandra Park accommodation complex at Lancaster University as the game maze. The player who takes the role of the main PAC-LAN character collects game pills (using a Nokia 5140 mobile phone equipped with a Nokia Xpress-on™ RFID reader shell), in the form of yellow plastic discs fitted with stick-on RFID tags. These tags are placed around the maze as shown in Figure 5.1.

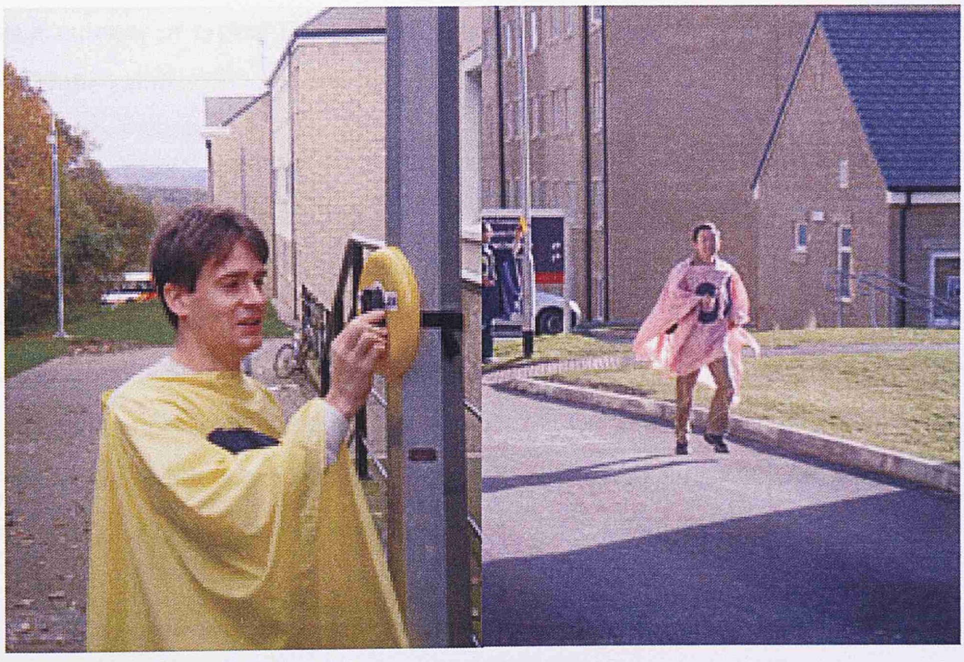

Figure 5.1: PAC-LAN player tagging a pill with his phone and a Ghost (Mr. Pink) in full flow

Four other players take the role of the "ghosts" who attempt to hunt down the PAC-LAN player. The mobile phone game client is implemented on the J2ME platform which is connected to a central server using a GPRS connection. The server relays to the PAC-LAN character his/her current position along with position of all ghosts based on the pills collected. The game pills are used by the ghosts to obtain the PAC-LAN characters last known position and to reset their kill timer which, if expired, will prevent them from "killing" PAC-LAN. In this way the ghosts must regularly interact with the server which is then able to relay their position to the PAC-LAN.

PAC-LAN sees a display with his own position highlighted by a red square around his animated icon, while the ghosts see both a white square highlighting their animated icon and the red flashing square around PAC-LAN. These character highlights were added after pre-trials revealed that players found it difficult to quickly identify important information.

The ghosts can kill the PAC-LAN character by detecting him/her via an RFID tag fitted to their costume (assuming their kill timer has not run out). Once PAC-LAN is killed, the game is over and the points for the game are determined by calculating the number of game pills collected and time taken to do so. When PAC-LAN tags one of the red power pills, indicated by all ghost icons changing to white on the screen, he/she is then able to kill the ghosts, and thus gain extra points, using the same RFID detection process. Dead ghosts must return to the central point of the game maze where they can be reactivated into the game. Figure 5.2 shows a number of typical screens that the PAC-LAN character will experience during the course of the game.

Figure 5.3 highlights a simple game scenario for a ghost player where he/she enters the game after a controlled delay. The ghost player then attempts to kill PAC-LAN, but his kill timer has expired and he/she then falls victim to PAC-LAN who has subsequently obtained a power pill. The game's scoring mechanism is simple for all participants. The PAC-LAN character obtains 50 points for a normal pill; 150 points for a power pill; 1000 points for collecting all the pills; and 500 points for a ghost kill. The ghosts obtain 30 points per pill (this is linked to the length of the kill timer) and 1000 points for killing PAC-LAN. All players lose 1 point per second to ensure they keep tagging.

Figure 5.2: PAC-LAN phone user interface.

Figure 5.3: Ghost (Mr. Orange) phone user interface.

5.2.2 Design Decisions

This section highlights significant design decisions made during the development of the game and the rationale for each. These are important as they explain the choices made and will aid the reader to better understand this game.

Why Pacman?

Pacman was used as the basis for this game design for a number of reasons:

- it is widely recognized, with simple but compelling game play. Therefore, players can quickly ascertain the game's overall concept without the need for a complex and lengthy explanation of the rules;
- the virtual game maze premise transfers readily to a physical location; and

- the Pacman character (PAC-LAN) interacts with game elements (the game pills) which can be considered as physical objects at specific locations. This type of interaction is one of the principal elements we wish to investigate. This is not the first time Pacman has inspired the development of a location-based game. The most famous other example is probably Pac-Manhattan (PacManhattan 2004). However, Pac-Manhattan differs significantly from PAC-LAN in that:
  - it does not incorporate actual physical objects;
  - it uses mobile phones simply to provide a voice link (effectively a walkie-talkie arrangement);
  - the developers chose not to implement a means of estimating location because the game was played around the streets of Manhattan, which would have acted as urban canyons for systems such as GPS; and
  - the gameplay of each player was controlled by a human central operator.

It was specifically chosen to avoid incorporating voice calls or SMS, and hence human game controllers, as the intention was to keep the gameplay as fast as possible and more akin to the arcade classic. Although human controllers introduce interesting aspects of trust and acceptance, as explored by games such as Uncle Roy All Around You (Magerkurth, Cheok, Mandryk and Nilsen 2005) but on the other hand there would be a greater possibility for the emergence of spontaneous tactics without a controller.

The other significant implementation has been Human Pacman (Cheok, Goh, Liu, Farbiz, Fong, Teo, Li and Yang 2004), which uses an innovative combination of virtual reality goggles, GPS receivers, and portable computers with Bluetooth and WiFi access to recreate the game. This differs from PACLAN in that

- it is played over a much smaller area, approximately 70 meters squared, compared to 300 meters squared;
- only one real object is used for interaction;
- the game is played at a slower pace due to the large amounts of equipment being carried; and
- each player is controlled by a human central operator.

Obviously this is a highly specialized and expensive technology; in November 2004, its creator, Dr. Adrian Cheok, predicted that "Within two years we'll be able to see full commercial Pacman-type games on mobile phones."

With the commercial technology presented in this chapter this became a reality in less than a year, with an equipment outlay of less than $1500. Hence, the system can be tested with large numbers of people, without concern over equipment costs or the practicalities of running while wearing virtual reality goggles. NFC is available on more mobile phones at present as compared to when PAC-LAN was created when only two commercially available mobile phones had NFC/RFID capabilities.

Why Alexandra Park?

Alexandra Park has a number of physical attributes that make it particularly desirable for this type of game. The most obvious can be viewed in Figure 5.4, in that it exhibits a maze-like structure of tall buildings spread over an area of approximately 300 m2. This means there is sufficient space to allow players to extend the gameplay over a reasonable length of time and avoid the situation where players can be sighted from a long distance.

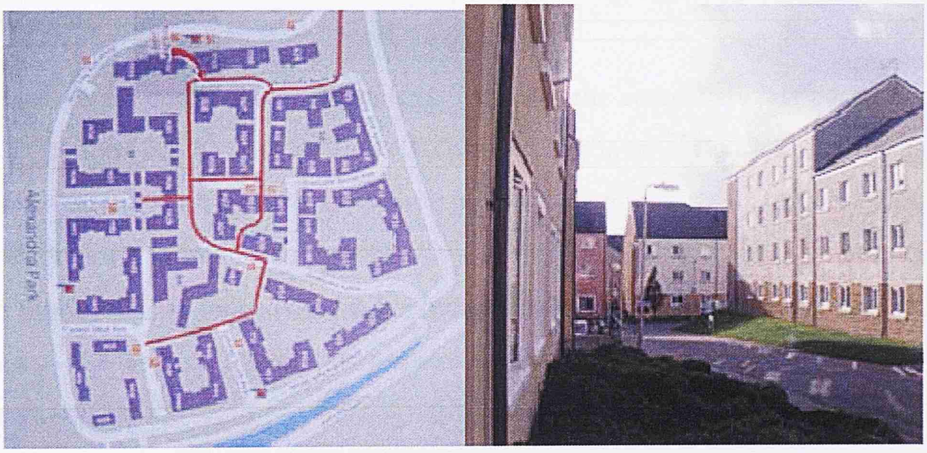

Figure 5.4: Campus map and typical buildings

Additionally, the area is entirely pedestrian with wide pathways, which means that our desire to keep the game action as fast as possible would not place the contestants in danger from vehicles or produce too much interference to the general populous. As our game includes a large number of people, safety is a serious issue that we feel all designers of location-based games should consider seriously; especially when children are among the game players.

Why this Mobile Phone Model?

Although this model phone, with limited display size (128 x 128 pixels) would not be many developers first choice in terms of features, it was the only one that incorporated an RFID shell at the time of development. However, during testing it was found that the small form factor and rubberized case made it easier to run with and much more resilient when dropped. In fact, these features are why it is a very popular model among people engaged in outdoor activities who may well represent a more likely target audience than traditional video game players. Further, due to the current trend for "retro" phones with limited features, developers cannot assume that everyone will carry an elaborate "smart" phone.

Why use RFID to Provide Location?

Many location technologies have varying degrees of accuracy (Rashid, Coulton and Edwards 2008), and RFID is effectively independent of terrain. In our case, a GPS survey of the site revealed that the buildings created a large number of urban canyons, as highlighted in Figure 5.4, where the signal was lost resulting in reacquisition times that were sometimes as long as 60 seconds. It also allowed us to place some of the pill locations undercover, which would be impossible with GPS.

Why Use Plastic Discs?

The discs were a cheap and effective way of keeping the action very fast-paced, in that the RFID tag location can be seen easily by the players, as shown in Figure 5.5. In the game, the discs were generally attached to lamp posts by a Velcro strap at about 1.5m from the base to make them easily visible and accessible. At a couple of points around the maze, we had to attach them to a low fence (< 0.5 m), although it did not appear to cause the players any problems. The discs thus served as physical anchors situating the virtual game in the real environment.

Figure 5.5: Normal yellow game pill and red power pill.

Why Use GPRS?

There are a number of reasons for choosing GPRS over other wireless technologies such as WiFi. First, it does not require the installation of additional infrastructure to support a game; second, as Figure 5.6 shows, the coverage of the game maze is excellent, never dropping below 70%. Third, it is specifically designed to be resilient to Doppler shift and frequency selective fading, which, if a player is running, can significantly degrade communication performance.

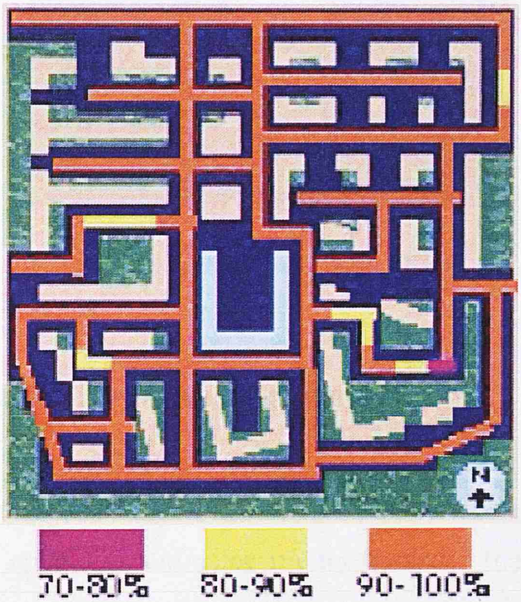

Figure 5.6: GPRS coverage over the game maze.

Why Use an RFID Tag as the Kill Mechanism?

The original idea was to use Bluetooth as the 'kill' method, to allow the player to kill the opponent once they were in range without the necessity for physical contact, which we felt could cause problems. However, an RFID tag on a foam disk attached to the characters' costumes by Velcro, as shown in Figure 5.7, which worked well during gameplay.

Figure 5.7: Ghost (MR. Blue) kill tag.

5.3 PACLAN System Implementation

The system architecture consists of a central server communicating via a GPRS to the PAC-LAN and ghost client applications running on the phones. The client applications are programmed in J2ME and utilize the contactless communications API. Once a particular RFID tag has been scanned (indicated by an audible alert), the tag ID is sent to the central server. While the application is communicating, a red communications icon is displayed to the user, instead of the compass symbol on the game maze as shown on Figure 5.8.

The server uses PHP to process the tag information, depending upon its type; and, depending on the game logic, updates the database running on MySQL. The server then returns the current location of all the ghosts and PAC-LAN to the client device. Figure 5.9 shows the average round-trip time for the server to respond to the application, based on all the tag locations.

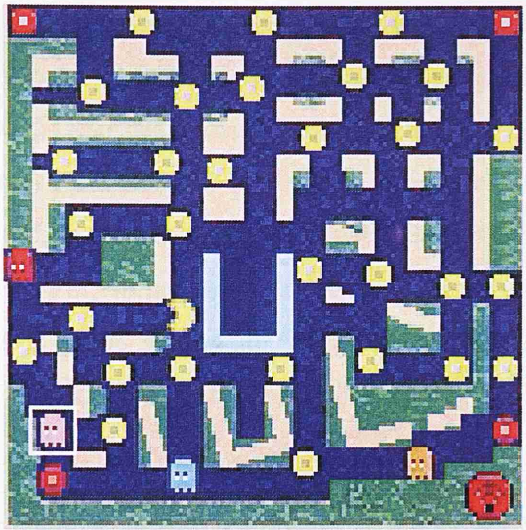

Figure 5.8: Update verification icon on Mr. Pink's phone screen.

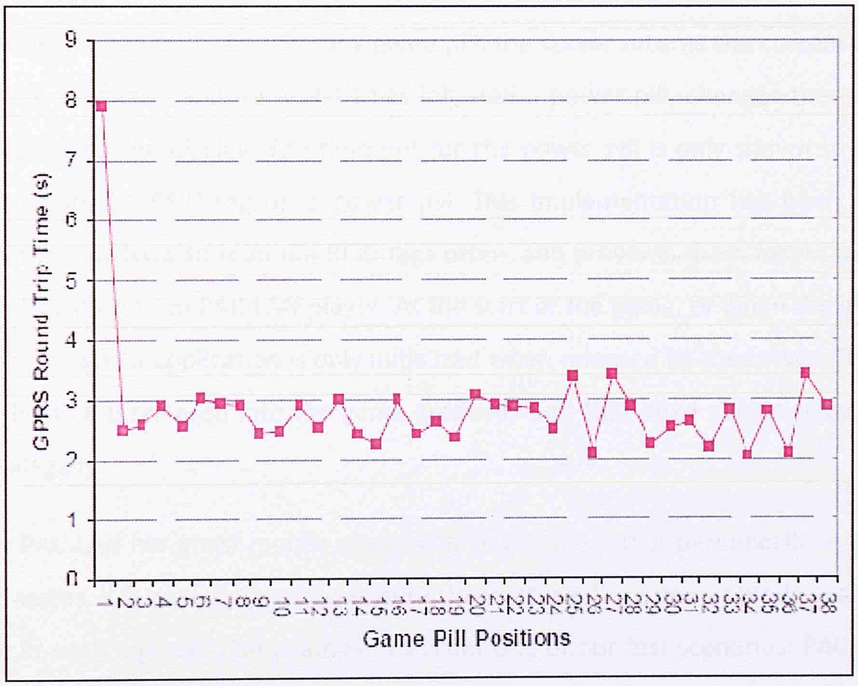

Figure 5.9: Average GPRS round-trip communication.

It was found that this delay averaged approximately 2.7s, which we found more than sufficient to avoid interfering with the gameplay. Note that the first reading always takes longer (around 8s), irrespective of position, as the server connection is initiated; but this has no effect on the game-play.

The way the client software on the phones handles the tag information and communicates with the server differs between the ghosts and PAC-LAN. In Figure 5.10 highlights the application flow-diagram for the PAC-LAN client software.

The application uses J2ME's persistent storage functionality to maintain information about tags as they are scanned during the course of a particular game. If a tag has already been scanned, that is, a game pill that has already been collected, the application first alerts the PAC-LAN player and then checks with the server for any updates on player positions. If the tag has not been used before, its information is checked in the record store to find out its type (game pill, power pill, or kill pill) and the actions necessary are then taken, such as updating points, initializing timers, and so on. For newly scanned tags, the unique ID, along with timer information, is sent to the central server over GPRS. This is represented by dotted lines in Figure 5.10.

There are several differences between the software architecture of the ghost and PAC-LAN client. One of the major ones is the way RFID tag data is handled. The ghost application sends the tag ID to the server to obtain updates on the state of the game and then reinitializes its kill timer. In the case of a game pill, the server returns the current location of the PAC-LAN character, and if PAC-LAN has initiated a power pill, changes the color of the PAC-LAN sprite on the display. The time out for the power pill is only shown to the ghosts when they read the RFID tag on a power pill. This implementation has been devised to ensure that ghosts have to read the RFID tags often, and prevents them from trying to hide their actual location from PAC-LAN player. At the start of the game, or when the ghosts have been killed, the ghost application is only initialized when released by the server. This ensures that the ghosts are released into the game gradually and that dead ghosts cannot re-enter the game illegally.

As neither PAC-LAN nor ghost mobile clients connect to the server periodically to check their activation status, it is essential that we ensure that status information is made available from the server at each tag read. For example, consider one of our test scenarios: PAC-LAN kills a ghost (Mr. Orange) this information is sent to the server immediately, but will not be available to the ghost client (Mr. Orange) until he reads the next tag, which could result in the ghost then being able to kill PAC-LAN. This problem was overcome by sending the status of all players (dead or alive) along with position updates. Therefore, in this test scenario, PAC-LAN is credited with killing a ghost (Mr.Orange) and the server updates this information in the database along with Mr. Orange's new position to spawn point.

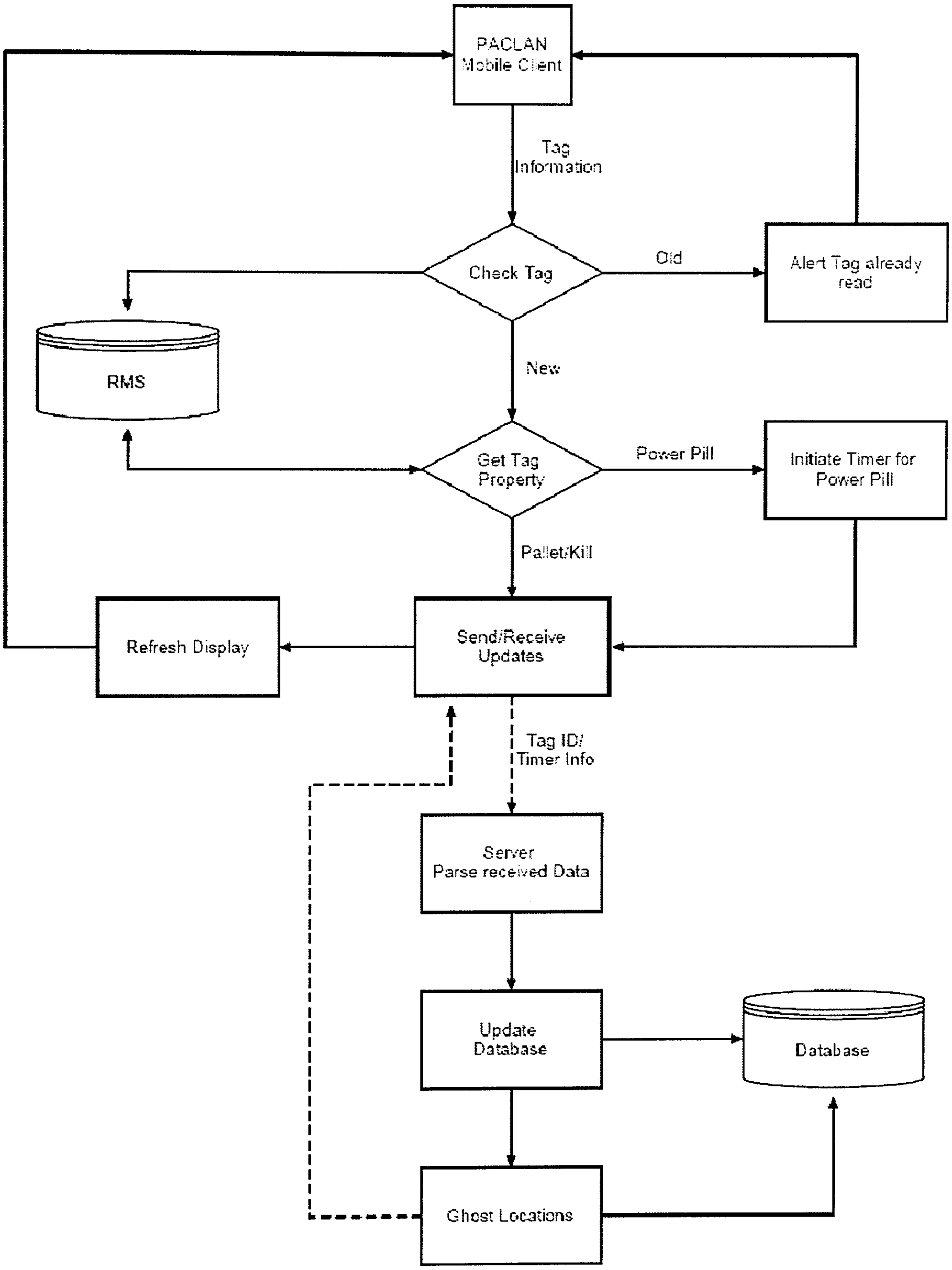

Figure 5.10: PAC-LAN mobile client.

When Mr. Orange reads the next tag the ghost mobile client recognizes that Mr. Orange is dead and locks his/her display until spawn tag is touched. The other ghosts in the game simply see that Mr. Orange is at the spawn points, which implies that he/she has been killed.

Having discussed the mobile clients, let us turn our attention to the server. Although most of the scenarios are straightforward tag updates to the database and the provision of information is through a query from the clients, there is one particular scenario that requires the server to control the execution of mobile applications, that is, handling a kill by PAC-LAN or a ghost; illustrated in Figure 5.11.

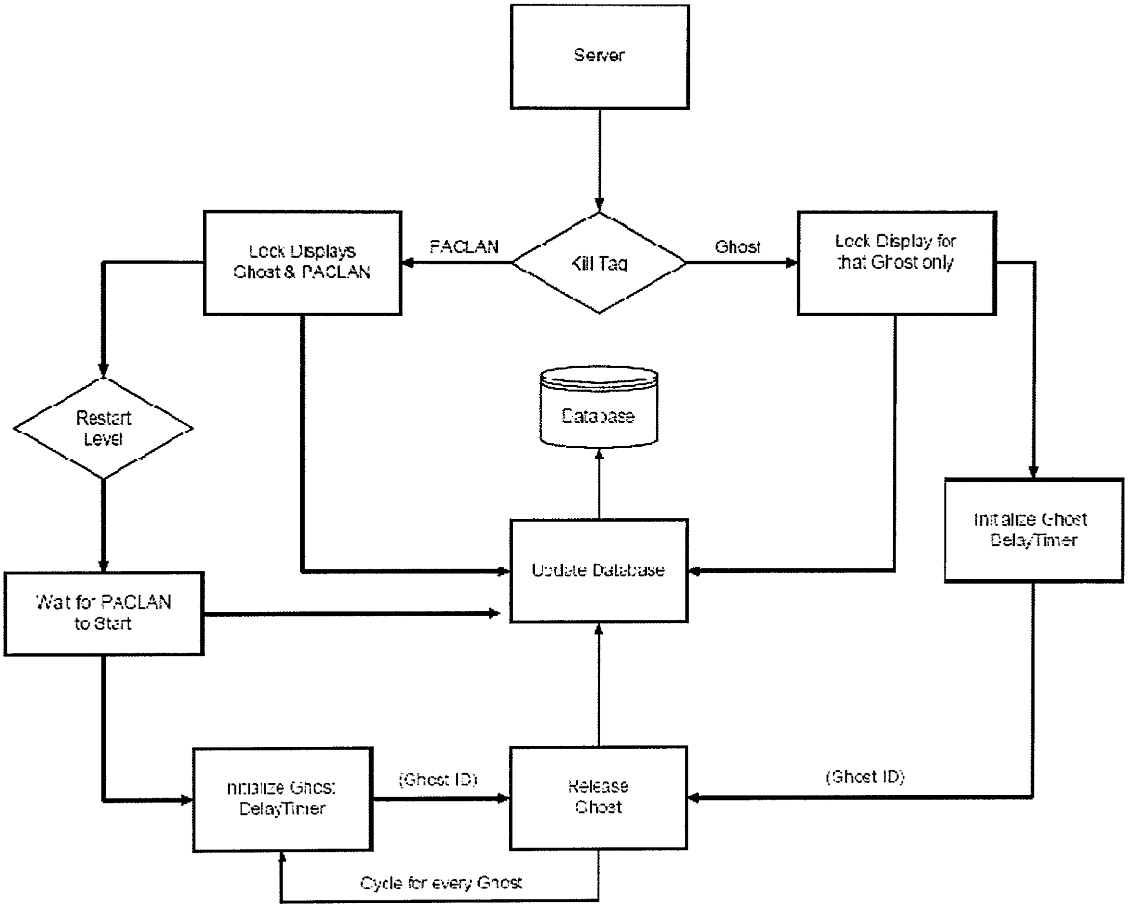

Figure 5.11: Server "kill" handling.

Once the server receives the tag information, it parses the data to check which client has scored the kill and the identity of the "victim." If PAC-LAN has been killed, the server updates the database with a display lock on all ghosts and PAC-LAN clients; the players must then return to the central maze point and the game can restart. The server initializes the level restart once PAC-LAN reads a random tag. Once PAC-LAN has joined the game, the server releases the ghosts at specific intervals. In the alternative scenario, where PAC-LAN kills one of the ghosts, the server updates the database, and once again this information is passed onto other ghosts when they connect to the server. The "dead" ghost player must return to the central maze point where he/she can join the game, after an enforced delay by the server, by reading the central maze tag.

5.4 User Experience

This section presents the feedback collected from 8 games of PAC-LAN played by 45 players (5 per game), taken after their first experience of the game. The average time for the games was 26 minutes, and in all cases the games ended with the PAC-LAN player being killed; there was an average of 1.5 ghost kills per game. The players were students from Lancaster University who answered an advert distributed via the university email system. The player groups were selected by the research team, who took care to select groups from the various faculties across the campus to ensure we did not have a technophile-biased sample. Of the 45 players, 7 were female; the players were aged between 18 and 24, except for 6 males aged between 25 and 35. As no discernable difference was evident in the experience of the PAC-LAN players to the ghost players, the following tables and statistics were taken from questionnaires completed by all 45 players. Of the players, 93% expressed no knowledge of RFID prior to playing the game, although at the end the same proportion expressed a willingness to use an RFID-enabled mobile phone to access other services, which is encouraging for the proponents of this technology. One of the surprising results was the mobile games-playing habits of the players shown in Figure 5.12. The graph indicates that the highest proportion of people play a mobile game almost daily, although 70% of people who played games only played preinstalled games. This is likely due to the fact that all the players were students in the predominantly 18-24 age group, which might account for the bias.

Table 5.1 provides the feedback concerning the UI of the application's relation to reading RFID tags, sounds, vibrations, visual alerts, and overall usability. A scale of 1 to 5 was used, with 1 being difficult and 5 being easy for tag reading and overall usability; and 1 being not useful and 5 being very useful for the rest.

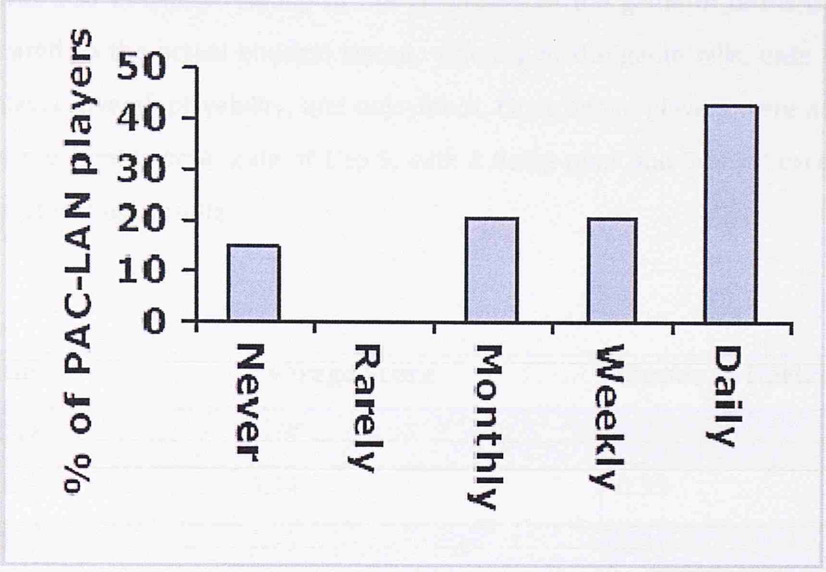

Figure 5.12: Frequency playing mobile games.

UI Feature	Average Score	Standard Deviation
Reading RFID Tags	3.71	1.14
Sounds	4.07	1.14
Vibrations	4.29	0.83
Visual Alerts	3.69	0.93
Overall Usability	4.21	0.80

Table 5.1: User Feedback on Interface Design

From this, it can be seen that in general the application was seen as easy to use, although the RFID reading and visual alerts were perceived slightly less favorably. Having interviewed a number of players after these findings the general perception was that at first they had difficulty aligning the phone correctly with the tag for RFID reading, so that more guidance at the start of the game would have helped. In respect of the visual alerts, players felt the sound and vibrations worked best when running. This is useful observation, as few location-based games have made extensive use of sound or vibration.

Feedback was also obtained relating to the playability of the game in terms of the phone map, compared to the actual physical layout, visibility of the game pills, ease of killing an opposing player, overall playability, and enjoyment. Once again, players were asked to rate each of these elements on a scale of 1 to 5, with 1 being poor and 5 being excellent. Table 5.2 encapsulates these results.

Game Feature	Average Score	Standard Deviation
Maze Layout	4.29	0.73
Pill Visibility	4.14	0.53
Ease of Kill	3.71	0.91
Overall Playability	4.21	0.58
Overall Enjoyment	4.36	0.63

Table 5.2: User Feedback on Game Playability

As one of the objectives was to see if physical objects enhanced game-play, it is encouraging to note that pills were scored highly and the game map seen as very effective. In terms of playability and enjoyment, the game fulfilled all the expectations of the developer, and indeed the majority of players expressed a great desire to play again. It was particularly good to see that the kill mechanism seemed to strike a good compromise between being too hard and too easy, as a compromise had to be achieved from the original design due to the capabilities of the phone model.

By analyzing the logged date at the server helps identify tactics that became apparent during gameplay. The first concerned PAC-LAN players who deliberately went long periods without tagging a pill, despite losing a point for every second they went without doing so. This occurred on a couple of occasions, which did not seem to prolong the game much above the average. In both cases the PAC-LAN character failed to get close to the two highest scorers, who, interestingly, were players who tagged most regularly. This phenomenon was not as noticeable in the ghost players who generally tagged regularly, as they had to keep their kill timer charged; those who didn't invariably finished with a negative score.

It was also considered to make the points' deduction for the PAC-LAN player exponential, based on the time between tags, but it was delayed until more players had been exposed to multiple games. The second tactic is related to whether the ghosts appeared to act as a group or were truly independent. Some ghosts quickly grasped the concept of adjusting their movements in relation to the other ghosts as well as to the PAC-LAN character, enabling the ghosts to cut off his/her means of escape. When they came into close proximity to each other, we often observed ghosts either calling directions to each other to try and catch the PAC-LAN character in a pincer movement, or warning each other that the PAC-LAN character had a power pill. These kinds of ghosts most often achieved a kill, while those who became fixated on the PAC-LAN character were more likely to be killed, as they often failed to spot that the PAC-LAN character was approaching a power pill. We considered developing an enhancement that will adapt the monitor/spectator application to create a ghost master who will be able to send messages to the individual ghosts to instigate a greater degree of collaborative play. The intention was to make the ghost master "invisible" to the PAC-LAN player, in that he does not wear a costume or knows the players prior to the game. The textual descriptions would be created in such a way that the ghost master has to have an understanding of the game maze. The descriptions could vary from the straightforward, such as giving a building number, to something less direct like "having a pint." From the latter description, the ghost master has to infer that the player is near to one of the college bars in Alexandra Park.

Further improvements could be to dynamically change the allocated points, or provide special "power moves" (a power move allows a ghost to kill PAC-LAN, even if he/she has a power pill) or provide a longer kill time to the ghosts as the game progresses. The changes can be deduced from the real-time data received at the server to ascertain the effectiveness of the time the ghosts have spent in the game. To see how this can be obtained consider Figure 5.13, which shows a space-time plot (Coulton, Bamford, Cheverst and Rashid 2008) for data obtained during a trial and shows PAC-LAN being hunted down by a ghost.

From this space-time analysis, this particular ghost, despite a delayed start, was often very close to PAC-LAN, and therefore very active in the game. This can be measured dynamically within the game by performing a real-time cumulative correlation calculation between the path of the PAC-LAN player and each ghost. At some point in the game, the server can trigger a power move for the most active ghost. The points or power move benefits will not only encourage ghosts to be more active in the game, but could also result in more collaborative play, e.g., two ghosts lure PAC-LAN into an area where a third ghost is hiding with a power move.

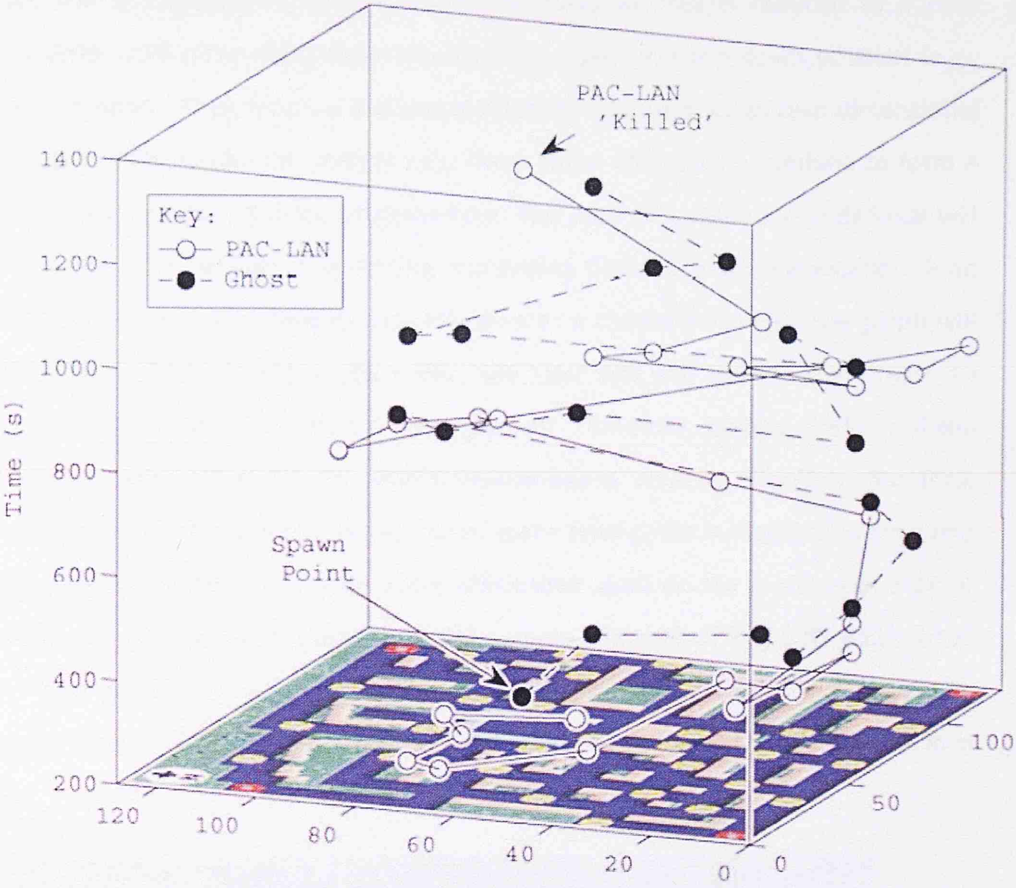

Figure 5.13: Space-time analysis of PAC-LAN and ghost during a game.

Overall, it was concluded from the user experiences that the game is a great success, perceived as fun to play and easy to use. The following are quotes taken from the feedback questionnaires, given at the end of each game.

- "A unique experience! Great Fun!"
- "Very good idea and very good fun (but exhausting!)"
- "This is a very simple game but effective and enjoyable to play. It seems well thought out and would be popular with gamers and non-gamers. Top game!!"
- "Amazing game! Would definitely play again!"
- "Thanks for the chance to play. Enjoyed it and got very tired!"

5.5 Analyzing Player Behavior

In order to further understand the player behaviors in a mixed reality game this section looks at the use of space time paths. A space-time path illustrates how a person navigates their way through the spatial-temporal environment. The physical area is reduced to a two-dimensional plane with these dimensions representing a person's top-down position (e.g., longitude and latitude). Their location and destination are represented as zero-dimensional points. Time is represented by the vertical axis. These three dimensions combine to form a world representing a specific portion of space-time. The path of a stationary individual will appear as a vertical line between the starting and ending times at a specific location. If an individual moves between two geographical locations at a constant velocity, the graph will show a line with a fixed trajectory which joins the start and end points. The slower an individual travels, the greater the line's vertical gradient. Therefore, vertical gradient of the plot is inversely proportional to the user's ground-based velocity (Coulton, Bamford, Cheverst and Rashid 2008). To illustrate the use of space-time paths in location-based game analysis, this section considers a specific game which took place on the morning of 10th of February 2006, rather than try to encompass the numerous games of PAC-LAN which have been played thus far (Rashid, Bamford, Coulton, Edwards and Scheible 2006). The players, in this case, were five males from Lancaster University between the ages of 22 and 27 shown in Figure 5.14.

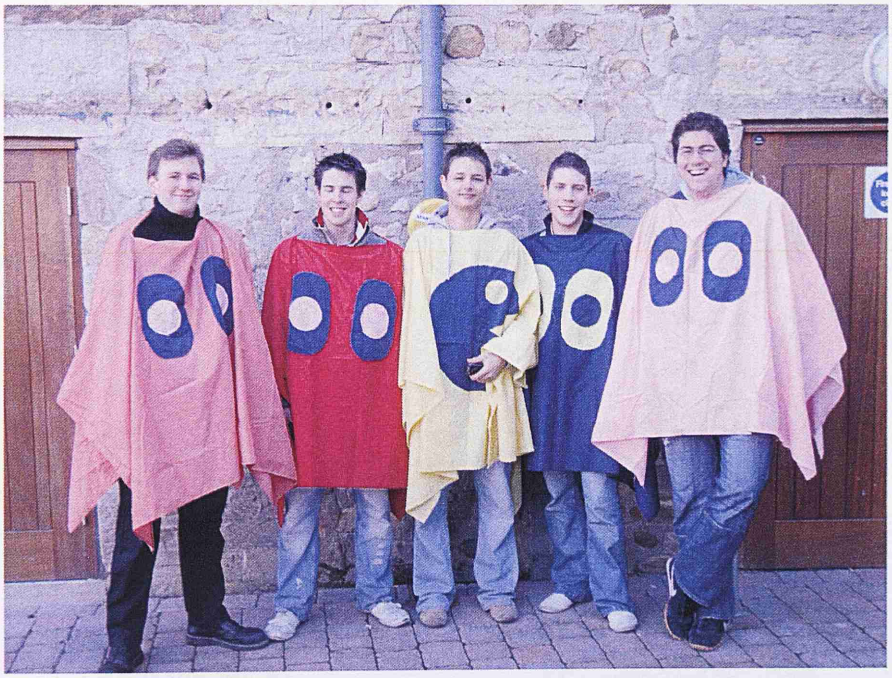

Figure 5.14: PAC-LAN trial team for 10th of February.

None of the players had previous experience of the game nor had any of them used an RFID-enabled mobile phone. Furthermore, only Mr. Pink was familiar with the game's real-world environment (he lived in the accommodation area which forms the game's maze). The game in question was shorter than average at 16 minutes and 30 seconds (the average game duration was 26 minutes), although the action was fairly typical of a first play experience.

In terms of mapping the game a Java class that uses the JBDC connector library to link the database of our game server to Matlab (Coulton, Bamford, Cheverst and Rashid 2008). This method not only provides a quick and easy method for producing the space-time paths, but also allows us to generate them in real time as the game progresses. Once the paths are generated, Matlab allows us to manipulate them in 3D space, as shown in Figure 5.15, which is useful for extracting detail and allows various combinations of players to be selected. In all the Figures used for the game analysis of PACLAN, we have not represented the axes of the spatial plane in meters or degrees and minutes but rather in terms of the pixels as they would appear on the phone screen map. For example, the actual game maze area is approximately 350 meters squared and the mobile phone map of this maze is represented as a 128×128 pixel bitmap. Therefore, each pixel edge represents a length of approximately 2.74meters.

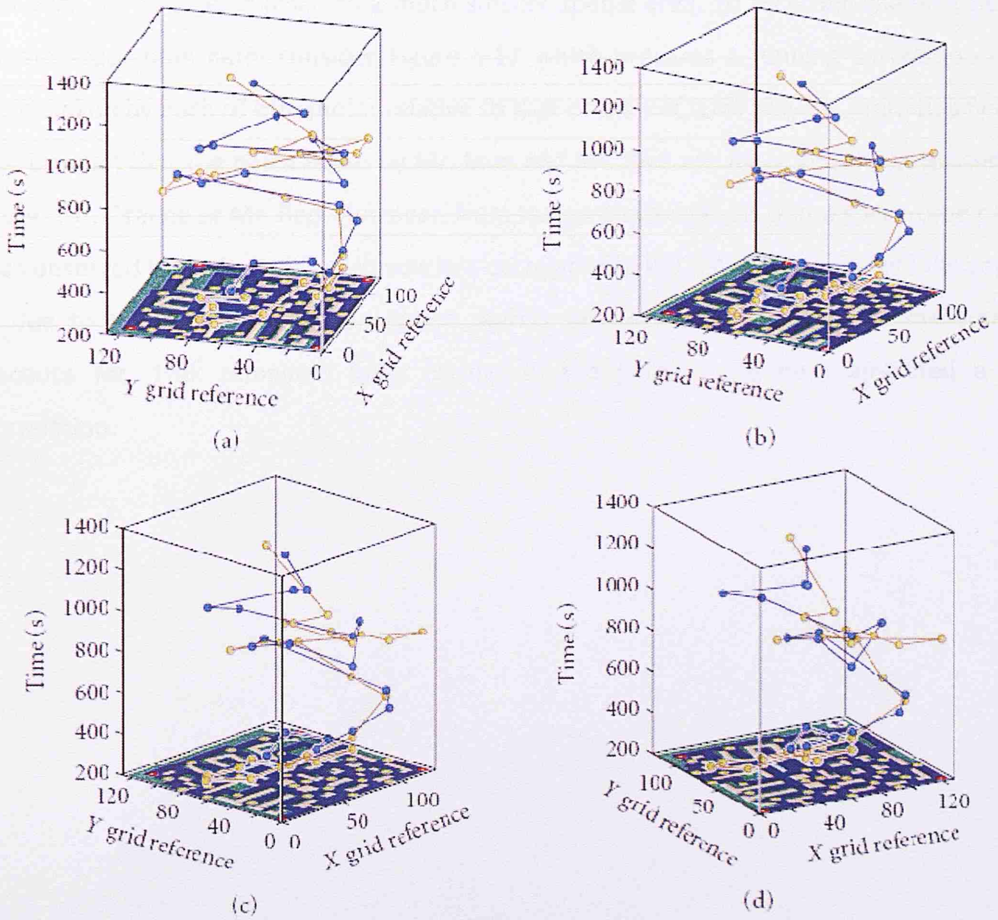

Figure 5.15: Rotating space-time paths for PAC-LAN and Mr. Blue.

Figure 5.15 illustrates that at the start of the game, the path taken by Mr. Blue bears relatively little correlation to that of PAC-LAN but as the game progresses it can clearly be observed that Mr. Blue starts to track the movements of PACLAN.

Figure 5.16, shows the space-time paths of all four Ghosts together with that of PAC-LAN. It is worth noting that unlike other location-based implementations of Pac-Man, such as Human Pac-Man (Cheok, Goh, Liu, Farbiz, Fong, Teo, Li and Yang 2004) or Pac-Manhattan (PacManhattan 2004), there are no online controllers and each player acts on his/her own initiative within the game (Rashid, Bamford, Coulton, Edwards and Scheible 2006).

From this, it can see those space-time paths of Mr. Blue appear to closely correlate with PAC-LAN, whilst Mr. Orange's path is similar but with greater divergence at more points. Conversely, Mr. Red generally appears to have run around fairly aimlessly, as Mr. Pink does although he confined himself to a much smaller spatial area. To ascertain the effectiveness of the space-time path, consider Figure 5.17 which presents a running correlation of the paths taken by each of the Ghosts relative to that of the PAC-LAN players. From this figure, it can be seen that the paths taken by Mr. Blue and Mr. Pink are more closely correlated than either Mr. Orange or Mr. Red. However, from the previous analysis of the space-time paths it was observed that Mr. Pink's path was less correlated to PAC-LAN. This apparent discrepancy is due to the fact that the correlation merely provides a simple distance measure and because Mr. Pink remained fairly central in the game maze he maintained a good correlation.

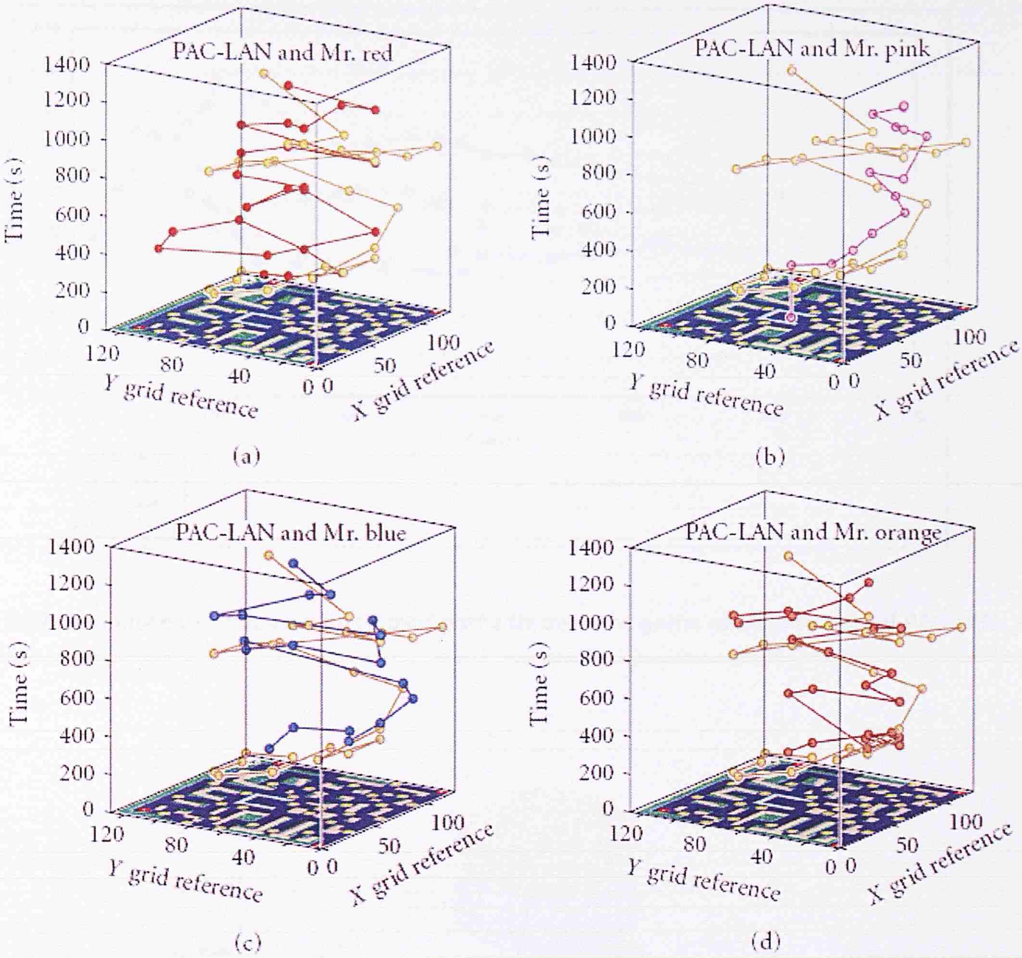

Figure 5.16: Space-time paths of PAC-LAN compared to each of the four Ghosts.

This actual player activity can best be illustrated through Figure 5.18 which shows each player's movement as a circle whose radius is the mean displacement centered on his/her average position to give some sense of how adventurous each player was during the game. Whilst this gives a view of general activity it does not provide the detail of the space-time path (Coulton, Bamford, Cheverst and Rashid 2008).

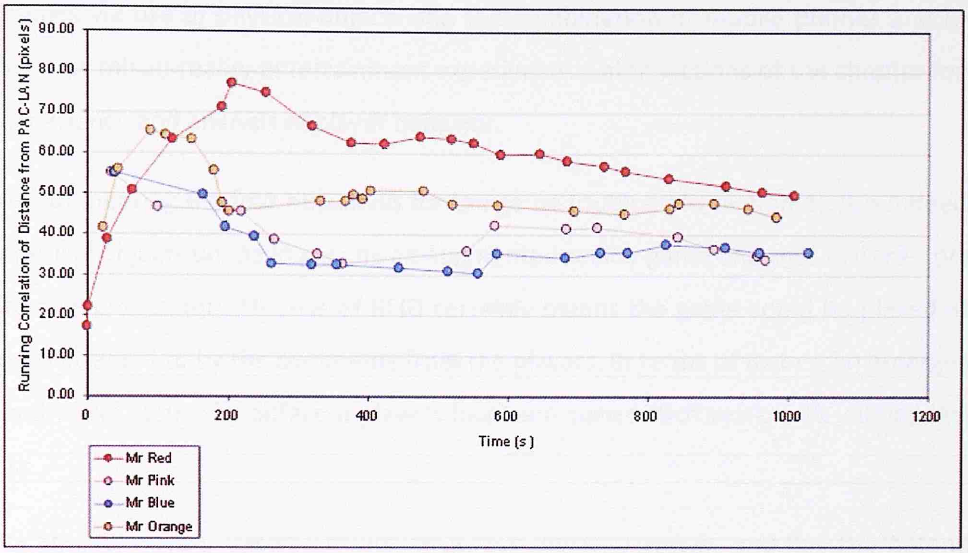

Figure 5.17: Running correlation of the Ghosts' paths through the game relative to that of PAC-LAN.

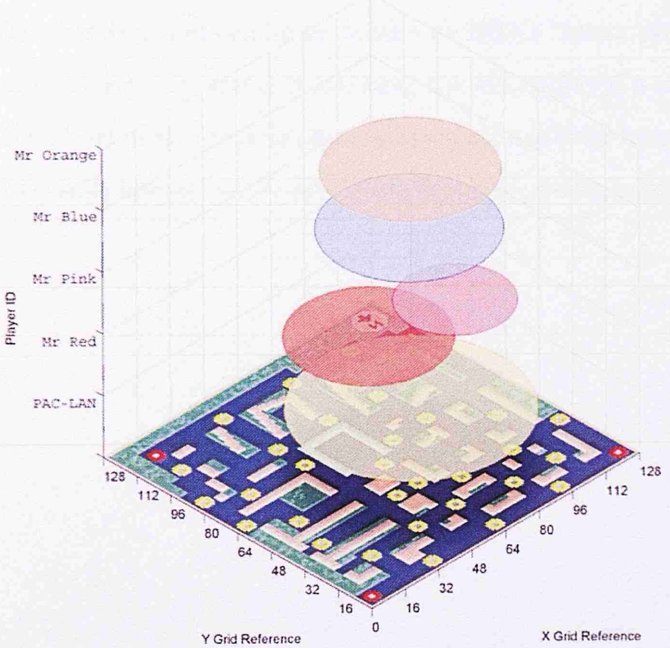

Figure 5.18: Players' mean displacement from their averaged position

5.6 Summary

This chapter presents the details of a novel location and object enhanced mixed-reality version of the Namco arcade classic, Pacman. In particular, the chapter presents a comparison of the game to other mixed-reality versions of Pacman; the rationale behind specific design choices made during game design and its subsequent implementation; and an analysis of the experiences of people who have played the game. The system highlights the possibilities via use of physical objects and the combination of mobile phones and RFID of yielding new mixed-reality entertainment experiences. Later sections of the chapter focus on user experience and analysis of player behavior.

In terms of meeting the four objectives for the game (outlined in section 2), it is indeed seen that physical objects do aid in playing an augmented reality game and that RFID can produce an effective interaction. The use of RFID certainly means the game could be played at high speed, as attested to by the comments from the players. In terms of tactics, an emergence of new and novel tactics by different players has been seen which work with varying levels of success.

RFID is already having significant impact on the business sector, and has the potential to make an equally significant impact on the consumer market. Frequent consumer use can be seen with successful adoption of Oyster and Barclaycard contactless technology. A small number of examples of RFID games can be seen, such as SEGA's "Major War," but they have all been based on a static location scenario and have not incorporated a mobile phone. The synergy of the RFID and NFC with a mobile phone will enable a greater level of innovation, as it will allow users to readily interact with real objects in real locations, outside the traditional games arcade.

Chapter 6

RFID/NFC based Implied Location Tracking in Mobile Social Software

6 RFID/NFC based Implied Location Tracking in Mobile Social Software

Part of the work presented in this chapter was originally published by the author in ACM SIGCHI International Conference on Advances in Computer Entertainment Technology, Hollywood, USA, 14-16 June 2006. and 2nd International Conference on Pervasive Computing Technologies for Healthcare 2008, Tampere, Finland 30 Jan – 1 Feb 2008.

6.1 Introduction

Social networking applications have become one of the most widely used services on the World Wide Web e.g. Facebook (Facebook 2010), Orkut (Orkut 2010), MySpace (MySpace 2010), Twitter (Twitter 2010) etc. Mobile Social Applications (MoSoSo) build on the social networking application experience by allowing social interaction between connected mobile users. Some MoSoSo applications are simply an extension of internet social networking applications on to mobile devices e.g. Facebook and YouTube (YouTube 2010). Other MoSoSo applications lay emphasis on data sharing rather than communication i.e. Foursquare (Foursquare 2010), Gowalla (Gowalla 2010) and MyTown. These applications generally take advantage of the inherent nature of terminals they run on i.e. Mobile Phones. Mobile phones are always connected and with location provisioning readily available mobile social applications provide an extra dimension to their users by adding location and time to the social interactions. Further enhancements can be achieved by incorporating data from other sensors (if present on the device) resulting in context recognition. MoSoSo application development, growth and adoption have been rapid and were designed for consumption on the move whilst making use of the user location. MoSoSo applications are highly personal due to their content which is mostly user generated. MoSoSo applications consider location as an implicit form of user data whilst content generated by users is considered as explicit user data. This data can be kept personal by a MoSoSo however the real value for MoSoSo comes from the ability to share this information with others within the user's social network or the entire social network.

Sharing of user data not only leads to a plethora of privacy and security concerns but it also leads to social phenomenon like collaboration, association, self-expression, competition, creativity and relationship. These social phenomenons define the scope of MoSoSo applications. It has been argued that MoSoSo should be designed to support social capital which is directly related to development; both economic and social. This is not so straight forward to accomplish as aspects of social capital differ from one definition to the other mainly because there has been a broader agreement on what social capital does whilst there has never been an agreement on definition of social capital e.g. “relationships, and norms that shape the quality and quantity of a society’s social interactions” (World Bank 2010) or “the rules, norms, obligations, reciprocity and trust embedded in social relations, social structures and society’s institutional arrangements which enable members to achieve their individual and community objectives.” or “those tangible substances that count for most in the daily lives of people” (Hanifan 1920). This complexity has been captured better by Ruuskanen (Ruuskanen 2001) who presents a conceptualization of social capital where sources, mechanisms and outcomes are three discrete components. He points out that trust and communication mediate social capital, taking input as activity for individuals, communities or society (micro, meso and macro level) produces cooperation and trust. On the other hand unequal access to social capital may have negative consequences such as exclusion or restrictions (Portes 1998). Lugano extends Ruuskanen’s (Ruuskanen 2001) conceptual model and defines three dimensions for MoSoSo design (Lugano 2008) as shown in figure below.

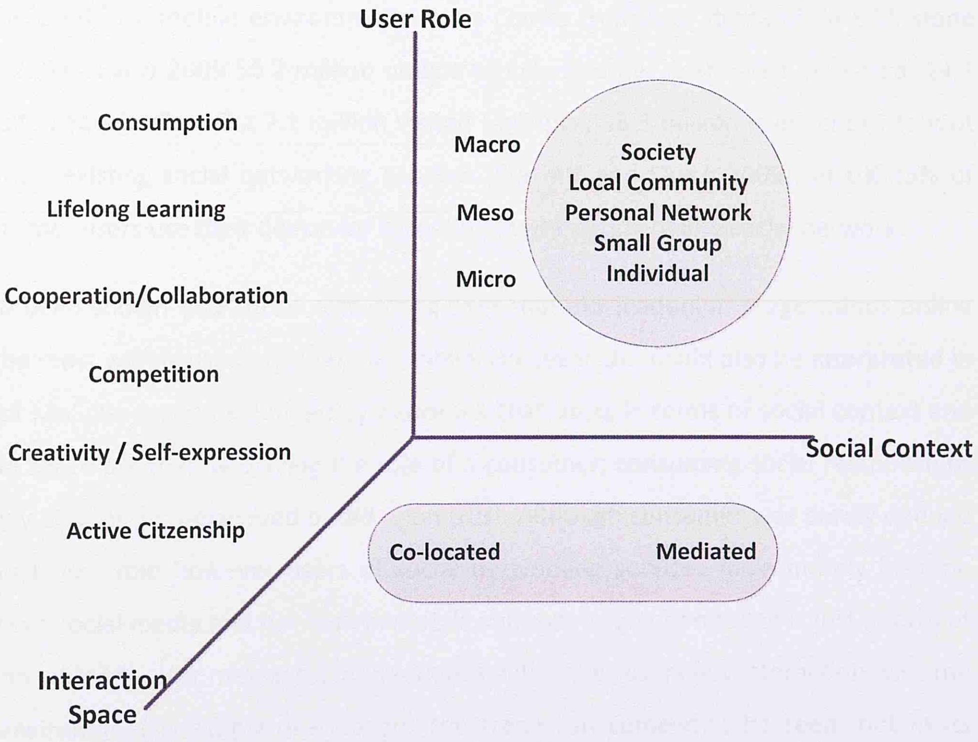

Figure 6.1: Scope of MoSoSo

Questions need to be asked about Lugano’s approach i.e. what is the definition and scope of each dimension? The model shown in figure 6.1 defines user role as how people present themselves to others in their daily life e.g. a user can be a boss at work, father at home, consumer whilst shopping and friend in a social context. User role can change depending upon the situation the user is subjected to. Each role has distinct goals and tasks that need to be undertaken to achieve that goal. For example worker role may involve collaboration, competition or even creativity which may not be needed whilst his role is that of a consumer. So it can be argued that MoSoSo should provide features to support a user's various roles. Let us look at another dimension of MoSoSo i.e. social context which is complex to model as compared to the other two dimensions. Social context will greatly depend upon relationship, trust and intensity of relationship etc. Interaction can be classed at a micro, meso and macro level but in terms of social context and interaction space they can be classed as mediated or co-located. For a mobile environment interaction can be divided into three classes (Marti 2002) i.e. interaction between person and medium, interaction between person and co-located people, interaction between person and two or more people (mediated).

Taking a look at some of the existing mobile social applications it becomes evident that although they try to support the social capital but the most widely used social networking applications today on the mobile devices are mere extensions to their online version. Their need to be used in a mobile environment simply comes from user demand. In USA alone from July 2008 to July 2009 56.2 million unique mobile internet users were reported, 14.7 million visited Facebook whilst 7.1 million visited MySapce, 18.3 million users chose to visit several other existing social networking services (Stewart and Quick 2009). In UK 23% of mobile internet users use their device for accessing their existing online social network.

It has also been shown that social networking sites that our leaders in usage trends online are also the most widely used ones on the mobile. However this could also be interpreted in the light of MoSoSo scope as defined by figure 6.1 that users in terms of social context and interaction space are merely playing the role of a consumer; consuming social relationships that already exist or are developed based upon trust. Although consumer was purely defined as a distinct user role however users of social networking services have merely become consumers of social media and network in mobile context. Interaction space is just a form of information added to user messages, interaction is with other users but interaction with the physical environment is simply overlooked. The trend can somewhat be seen; not in its entirety; if a review is taken of social applications which were designed and targeted for mobile environment from the start. For example Nokia Sensor (Nokia Sensor 2005) and Mobiluck (Mobiluck 2005) allowed social interaction amongst co-located users.

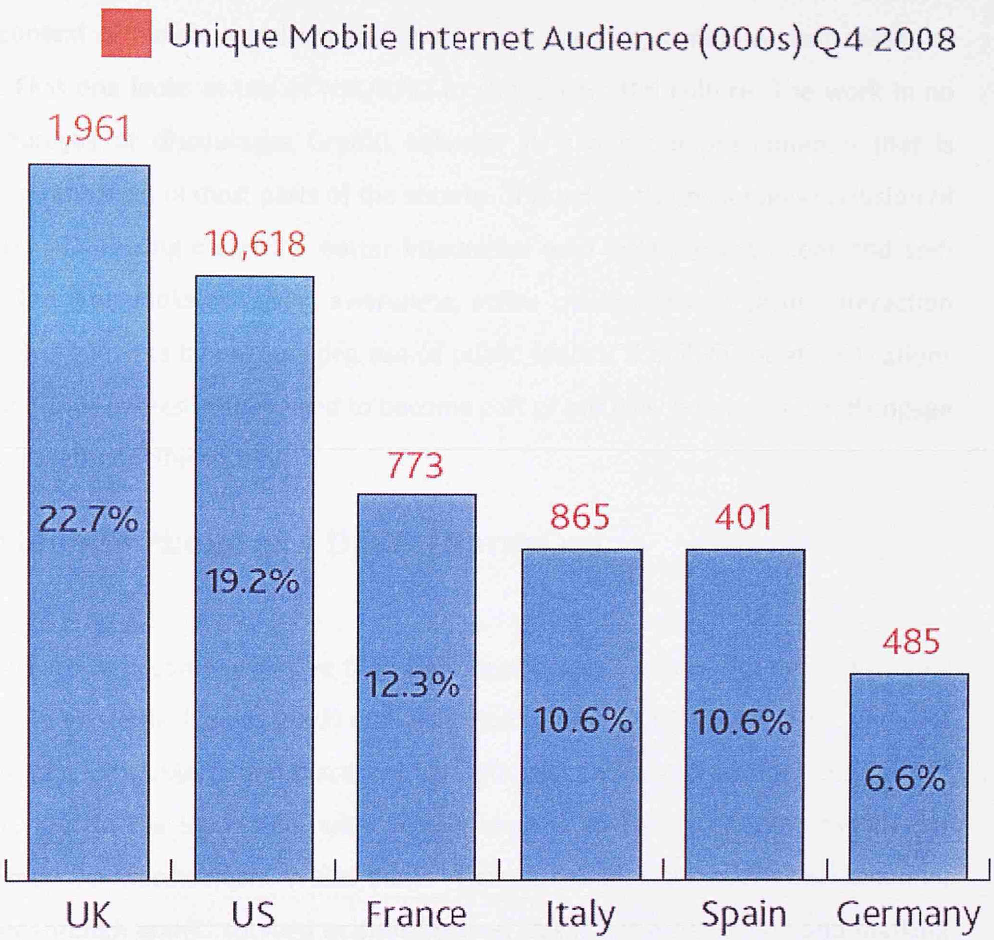

Figure 6.2: Social networks have the greatest mobile web reach in the UK and USA (Nielsen 2009)

An alternate version of this was the "toothing" phenomenon where users simply send messages/images to other Bluetooth enabled phones that are set as visible. In this case interaction space is the active Bluetooth range but user role is again limited to consumption of who is around rather than whom and what is around. Some MoSoSo rectify this situation (Loopt 2010), which allow users to discover what is around, where are user's friends currently located, what social events are available in the vicinity. This is where mobile location based services meets mobile social networking.

But question still remains do these address the issue of social capital? Yes but what about the concerns regarding social exclusion for those lacking social capital? Users are consuming location based information in a social context but their interaction with physical space is still limited. It is merely what is around a user rather than you are here. Perhaps symbiosis between user, device and environment needs to be reached, including those who are excluded and perhaps breaking new ground in terms of mobile social applications and address the issues around active citizenship, creativity, self-expression and raising awareness from daily activities. This chapter explores these issues by utilising NFC/RFID on mobile phones in context of mobile social applications. Two distinct application or test cases are considered. First one looks at use of NFC/RFID to support Graffiti culture. The work in no means encourages or discourages Graffiti however it is a social phenomenon that is considered as vandalism in most parts of the society. This indirectly encourages exclusion of certain users, suppressing creativity, better interaction with urban environment and self-expression. The later looks at raising awareness, active citizenship and better interaction with urban environments by encouraging use of public spaces. If mobile social applications are to become truly pervasive they need to become part of our daily fabric of life and engage users from all sectors of the society.

6.2 The Mobile Phone as a Digital SprayCan

If applications are to become pervasive then they must become part of our everyday fabric of our lives and existence (Paulos 2003) and will often require us to provide users with the ability to interact with objects and places within both real and virtual worlds. One trait of human behaviour in the interaction with objects appears to be an inherent passion for leaving our mark on these objects. Whilst this is often perceived as a modern phenomenon, most notably through graffiti sprayed in public places, this is not a new trend and marking our surroundings is evident from ancient times most notably cave paintings. Modern spraycan graffiti divides opinion; some view it as blight on the landscape, while others view it as an art form. As a consequence this has led to very polarized approaches of how authorities should deal with its perpetrators. Some authorities and communities take a very hard line by treating all graffiti art as vandalism; the Berkeley Police Department of California even go as far as to issue guidelines on their website to enable parents to spot if their children are likely to be engaged in graffiti, whilst others have tried to incorporate it into the mainstream with the acceptance and exhibition of the work of artists such as the Keith Haring (Hager 1984) or Banksy. In either case, judging by its continued proliferation, neither approach appears to be providing a solution acceptable to both the authorities/communities and the perpetrators.

The work discussed here draws inspiration from the book 'Banksy Wall and Piece' by of one of the most innovative graffiti artists of the current era (Banksy 2005), which states:

'Imagine a city where graffiti wasn't illegal, a city where everybody could draw wherever they liked. Where every street was awash with a million colours and little phrases. Where standing

at a bus stop was never boring. A city that felt like a living breathing thing which belonged to everybody not just estate agents and barons of big business. Imagine a city like that and stop leaning against that wall – its wet.'

Whilst the work presented here does not advocate the implementation of this graffiti utopia, and given Australia's banning of the PlayStation 2 game "Marc Ecko's Getting Up: Contents Under Pressure" for allegedly promoting graffiti this would appear unwise. There are aspects of this vision which could produce a system that may offer benefits to both sides of the debate and produce a richer urban landscape. To this end we do explore a system utilizing the already pervasive consumer device, the mobile phone, coupled with the emerging pervasive technology of RFID.

To enable an understanding of the design of the system, which is described in sections to follow, let us first explore the nature of modern graffiti and more particularly the practice of 'tagging' (the act of writing graffiti tags most commonly using spray paint). This is followed by describing a means of using RFID/NFC technology to create a system that could well address the social needs of the perpetrators whilst minimizing the physical impact on the environment in which they operate.

6.2.1 Tagging

As with any cultural phenomenon there is some dispute over where tagging began, whilst many cite 'Julio 204' who began writing his tag (tag is the most basic form of modern graffiti art representing the writer's signature. It is normally in the form of a moniker or nickname of four to six letters in length) in New York during the late 1960s closely followed by his contemporary 'Taki 183' they essentially popularized what first began in Philadelphia by 'Cornbread' and 'Top Cat' (Dennant 1997). However, it was an Interview with Taki 183 in the New York Times in 1971 that seemed to spawn a whole generation of writers (perpetrators of graffiti refer to themselves as writers rather than artists underlying the importance of text within these images) who gave rise to what is now one of the images synonymous with New York, the graffiti-strewn subway car. As the abundance of tagging grew, partially fuelled by the emergence of the Hip-Hop, a whole new sub-culture formed with writers forming alliances or 'crews' (crews differed from the gang cultures that also emerged at this time as they spanned ethnic and social divides (George 2001)) engaged in particular styles of graffiti and producing increasingly complex designs. New members of a crew are often sought out by the more experienced writers to whom they then pass their knowledge about techniques and style. The actual crew style differentiates one crew from another and often crews compete against each other through their expertise in implementing their style. Within this competition there are certain 'rules of engagement' in that it is considered unacceptable to write over another writer's tag or 'bite' (effectively graffiti writing plagiarism) another writer's style (Mailer, Kurlansky and Naar 1974). An individual writer's skill is shown through the evolution of the simple tags through to 'throw-ups' (a throw-up is larger than a basic tag and normally more elaborate lettering styles. A throw-up using one colour for the outline and another for the centre is known as a fill-in) and 'pieces' (elaborate large scale painting not only of a writers tag but possibly including caricatures or statements, sometimes also known as 'burners') which raises their position within the graffiti hierarchy. A later metamorphism of the tag was the stamp, which is a pre-tagged sticker and as we shall see has parallels to the mobile system discussed here.

It appears that for many engaged in tagging it is a way of gaining recognition and a sense of belonging both in their local landscape and amongst their peers (Ley and Cybriwsk.R 1974) and has little to do with gaining a thrill from engaging unlawful acts as Banksy observes (Banksy 2005)

'Graffiti writers are not real villains. I'm always reminded of this by real villains who consider the idea of breaking in someplace, not stealing anything and then leaving a painting of your name in four foot high letters as the most retarded thing that they have ever heard of.'

Many sociologists would agree and advocate that tagging should not be simply dismissed as an act of vandalism, but as a reflection of the society that produced them. This view is perhaps endorsed by the fact that despite the large amounts of resources expended on preventing tagging it continues to flourish. With the birth of the internet we have seen graffiti evolve its communities through sites such 'Art Crimes The Writing on the Wall' (Graffiti.org 2010) and WataRush (Watarush 2010) although for many it does not satisfy a desire for the belonging to a physical space (Dennant 1997) and is why a more innovative solution could be achieved through ubiquitous computing.

6.2.2 Mobile Graffiti System

The system described here is not the first to propose mobile digital graffiti. Siemens have described a system were users can save virtual post-its (Garner, Rashid, Coulton and Edwards 2006) in the form of SMS messages, in a virtual world at a physical location defined by a latitude and longitude obtained from a GPS enabled mobile phone. Although this system could be used for graffiti it only exists in the virtual world and as such would require users to permanently monitor their position with GPS switched on their phone which would place a high power burden on the device. A conceptually similar development is the Place-Its project developed by (Sohn, Li, Lee, Smith, Scott and Griswold 2005) which uses a location-aware system on a mobile device to leave messages for people depending upon their position in the physical space.

A system once operated in the UK called TagandScan (Garner, Rashid, Coulton and Edwards 2006) allowed users to tag physical locations with information or pictures through a Java application operating on their mobile phone which connects to a central server. The actual location was identified by GSM cell-id and is therefore highly variable in its accuracy. The Grafedia project (Grafedia 2010) allows users to access rich media content on their mobile phone by entering a word, written by hand onto physical surfaces e.g. walls, appended with the suffix @grafedia.com. Whilst this system offers a new experience to the writers it appears to offer no benefit to the authorities/communities concerned with graffiti as the physical defacement is still taking place.

The system proposed here, known as 'Mobile SprayCan or Mobspray', addresses the limitations of the two systems previously described and is akin to stamps only in that we use stick-on 13.5 MHz RFID tags rather than traditional stickers. However, unlike stamps, the RFID tags are not a repository for the actual writers tag but represent a physical location where digital writers can 'get-up' (get-up or getting-up is the term used by graffiti writers for the physical act of writing their tag at a particular location) their mobtag (to avoid confusion between RFID tags and graffiti tags the term 'mobtag' was coined to describe the images created in this project) using the application on their mobile phone. The particular RFID tags being used are Mifare Ultralight (Mifare.net 2010) with a memory area of 64 bytes only. The Ultralight tag's memory is divided into pages of 4 bytes, giving it a total of 16 pages. The first 16 bytes of an Ultralight tag contain the unique identifier of the tag, one-time programmable area (OTP), lock bytes and checksum bytes. The rest of the memory is assigned for user data which amount to 48 bytes (pages 4-15). The 48 bytes of tag memory is comprised as follows:

- 15 bytes for tag location as a text string
- 25 bytes holding 5 writer tag names each 5 characters

Ultralight tags support both MifareUL features and NFC Transfer Interface Packet (NTIP) records for data transfer 'to and from' the tag. NTIP has record types, and by knowing the types, an application can understand the binary structure of the record. The particular type of NTIP record is defined by fully qualified name (FQN) which can then be used to auto launch a midlet once a tag is touched. Mobspray uses MifareUL features to read and write data as the RFID shells made available for this project did not support target or NTIP record type definition while registering for auto launch. MifareUL uses either a logical or physical structure to access the memory on an Ultralight tag with the logical addressing range being 0-47 and physical range being 0-63. The contents of a typical mobspray tag are shown in figure 6.3.

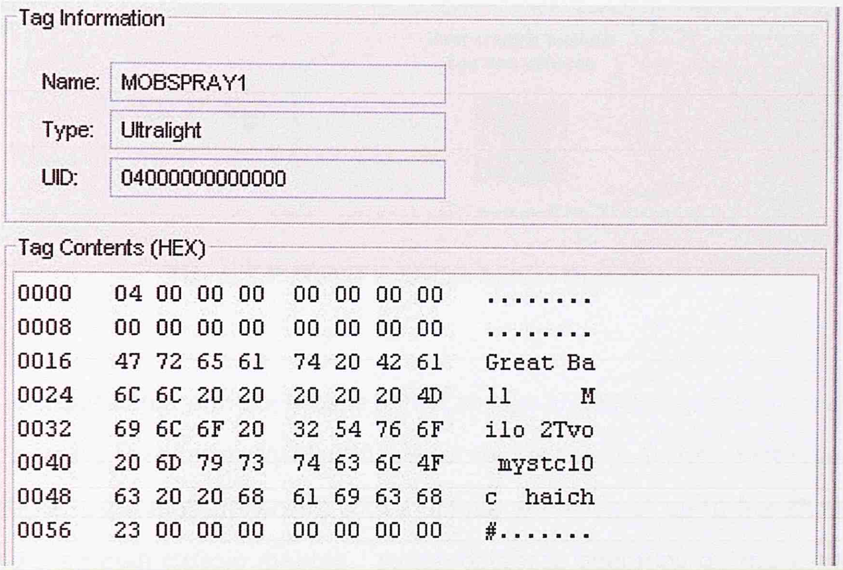

Figure 6.3: Mobspray Tag Content (HEX)

Figure 6.4: Mobile SprayCan Site Marker

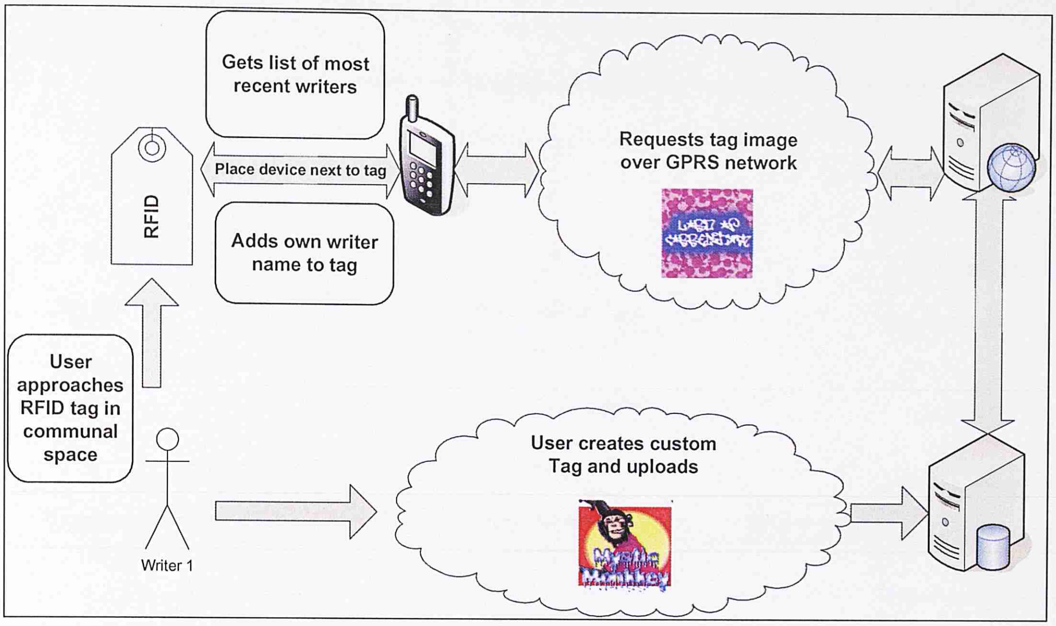

Figure 6.5: Mobile SprayCan System Operation

Mobspray uses postcards with the Mobile SprayCan logo and RFID tags attached, as shown in Figure 6.4, to make tag sites easily identifiable for the test crew. Writers first register on the project website, www.mobspray.com, with a unique tag name of up to five characters and then upload their own custom mobtag to the database operating on this central server. Writers' are then able to use their own mobtags, or view other writers' mobtags, by accessing this database using a GPRS connection initiated by the J2ME application on the phone when an RFID tag is read as shown in Figure 6.5. Once a writer reads an RFID tag, the client application, shown in figure 6.6, displays the contents of the RFID tag which consists of a tag location string and the names of last writers to have visited that particular RFID tag.

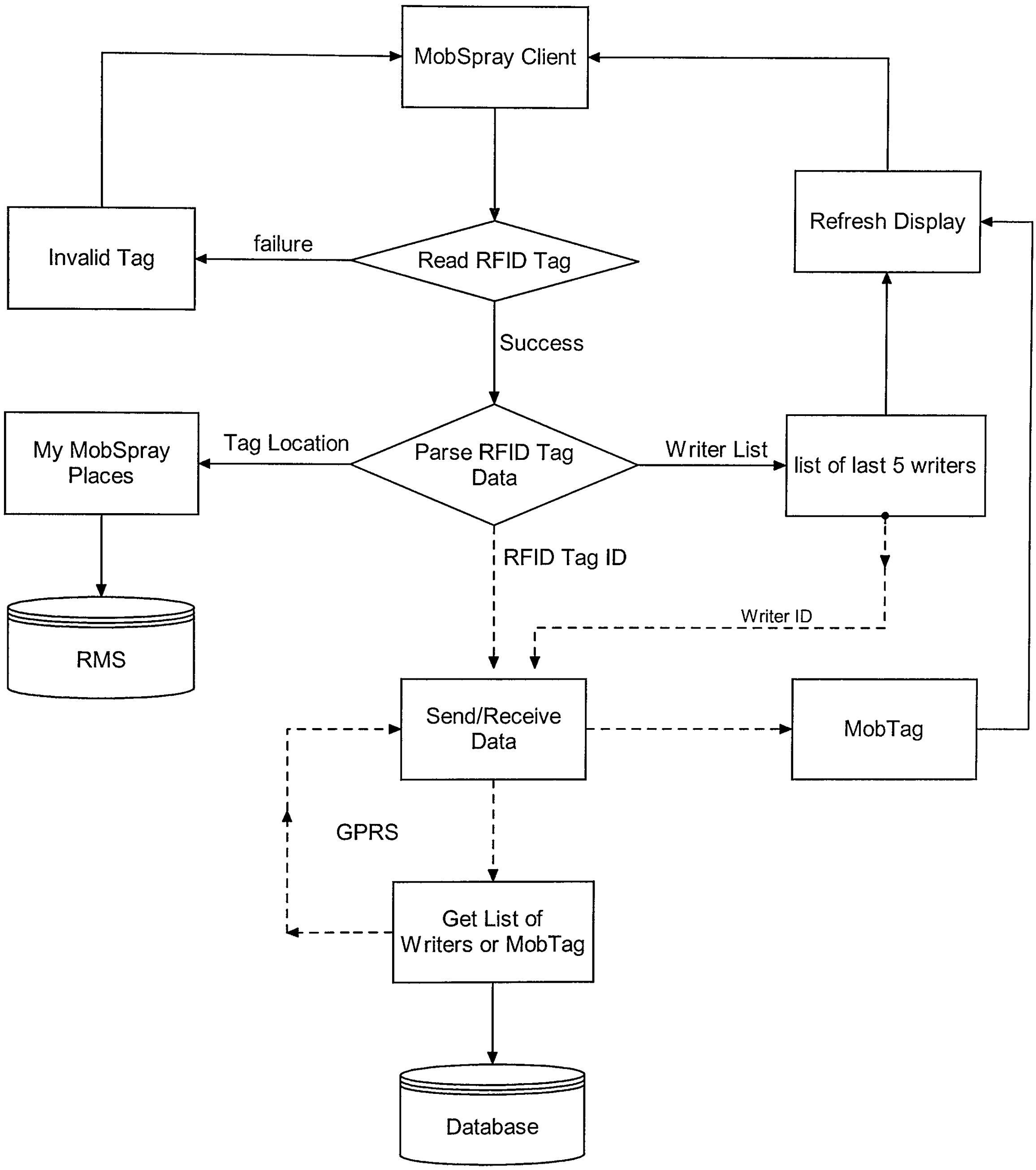

Figure 6.6: Mobile SprayCan J2ME client reading RFID tag

The application then connects to the database which returns the time and date at which those writers tagged that location. The writer can then choose to view any of the writer's mobtag images or place their own mobtag at that location and these details are stored within the database. If the user chooses to write his tag, the application creates a new list of the last 5 writers by dropping the last writer from the previous list and shifting the remaining by one position. This list is then written on the RFID tag. The writing event triggers an update on the database as shown in Figure 6.7.

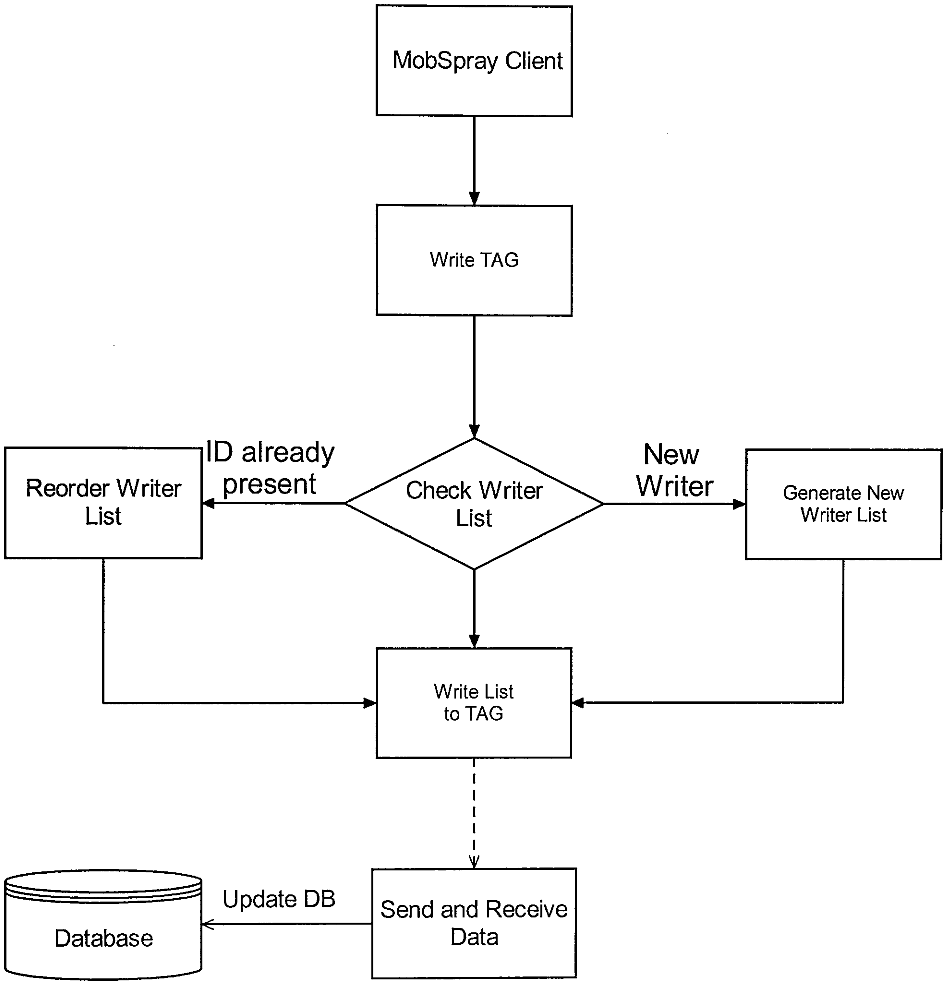

Figure 6.7: Mobile SprayCan J2ME client writing RFID tag

It would be possible to achieve the same functionality without storing any data on RFID tags, with writers' interactions and the tag location stored server-side. However, the design outlined was chosen in order to demonstrate the potential for future systems where tag storage is not as severely constrained and also because of graffiti's inherent nature of physical interaction with a particular location. Figure 6 shows the actual screenshots of the application highlighting the reading and writing functions outlined earlier in figure 4 and 5 respectively.

The application starts by prompting the user with a visual alert to touch the tag. A successful read results in the name of the location and then a list of last 5 writers who wrote to that tag. The writers are displayed as a selectable list on the mobile phone and the current writer can then select from the list to view the mobtags by initiating a connection to the server over GPRS. The current writer can write his/her mobtag to the location at any time after the initial tag read. To avoid entry errors into the system the application checks before every write if the user is attempting to write at the location he initiated the read action upon. This is done by checking the unique identifier of the RFID tag before initiating write process against the identifier obtained by the RFID read process earlier on.

Figure 6.8: Mobspray Application Screenshots

The images for this particular system are 128x128 pixels, 16 bit colour. This mobtag size was chosen to match the maximum resolution on the test mobile devices. In Figure 6.9 we show the six tags of our test crew.

Figure 6.9: Mobspray Crew mobtags (monkE, LOC, Nboy, Milo, 2Tvo, haich)

6.2.3 Writers Experience

Whether it is the work of an individual or a group, the context of Graffiti is always social in nature. A piece of writing or a tag can represent social disintegration or group dynamics; it can just be a representation of an individual's creativity or motivation; it can emerge through boredom or revenge; but what is common to all these is a social relationship, mutual encouragement, competition, anonymity amongst peers and socialization. Mobspray attempts to retain this social relationship through a website that links the tags to a map of the local area which marks all Mobspray sites together with a history of mobtags submitted by different writers. The sense of competition is kept alive by displaying the latest mobtag as a site marker on the map. Writers can choose to keep their identities anonymous or just be known within a certain group of peers. This, in author's view, not only keeps the essence of graffiti but also creates a whole new breed of community where members interact in both physical and virtual worlds whilst interacting physically with their environment. Figure 6.10 shows a screenshot of an interactive map of Lancaster University where the authors are testing the system. Visitors hover over the image and each mobspray site shows the last tag submitted to it.

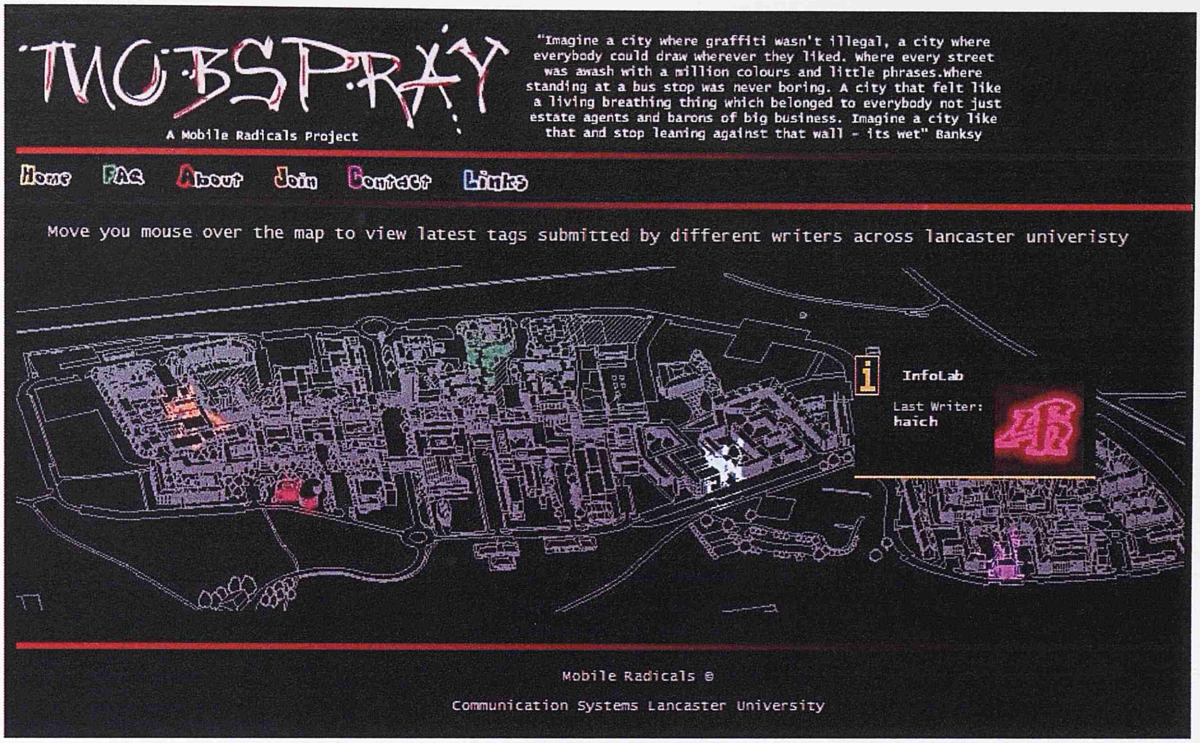

Figure 6.10: Interactive map from Mobspray website

Although, only a small proportion of the test crew of writers had a specific interest in graffiti, their experiences do highlight some interesting experiences of utilizing this technology and produce aspects akin to the tagging behaviour of 'real' writing crews and indeed behaviour often associated with gaming.

Firstly, as the website was linked to the mobtags a competitive aspect of tagging did emerge as writers tried to get their tag on as many locations as possible which is referred to as bombing amongst conventional writers. There is an obvious ludic parallel of trying to win the game and indeed a game based around this premise could prove popular.

Secondly, the mobtags started out as very simple one colour signatures in the majority of cases but a competitive element emerged where the mobtags became much more elaborate in a similar vein to traditional spraycan tags as discussed in section two. This is also akin to the ludic desire of identifying yourself as an experienced player rather than a novice.

Finally, the storage of a list of the last writers to tag a particular location gave a sense of community and belonging to a space which appears an important attribute for most writers.

In terms of the tagging process, it was perceived to be extremely easy and most of the crew commented that the act of actually touching the object you wished to communicate with seemed very obvious and natural. The major criticism was related to not having the ability to create the mobtags using the mobile phone directly which was a limitation of the devices themselves and is something we would address with a future evolution.

6.2.4 Limitations and Future Improvements

The system as described above is limited due to relatively low resolution images, constrained by network bandwidth, device display limitations and the storage capability of low-cost RFID tags. However, the system can be extended in several appealing ways. The natural progression is to enable the system to support rich media, including sound, video and hyperlinks in a similar vein to the Grafedia project (Grafedia 2010). With modern mobile devices now equipped with an array of multimedia capabilities including sound recording, up to two cameras capable of taking full motion video and the ability to store such creations on capacious flash memory, the opportunity for an innovative application co-existing in real and online worlds is clear. Such a development would enable tagging to evolve into something akin to performance art, with writers creating short videos for the consumption by their peers or others in the locality.

Improvements in the HCI present in mobile devices will make the development of street art on much easier. Already we see the market success of phones with touch screen to aid user input; it is conceivable artistically complex works could be produced on-device for display on a system described herein. Further, use of 3D sensors on mobile phones could allow writers to create virtual art pieces by moving the mobile phone in the same way as an actual spraycan.

Viewing of mobtags on a constrained mobile phone makes it unlikely that Mobile SprayCan would replace or even reduce graffiti in a given area and indeed it would need trials within a real writing community to truly ascertain its applicability and acceptability. However, by utilizing NFC access points the system could be extended to allow mobtags to be downloaded from phones and then projected onto walls or displayed on large screens, as shown in Figure 6.11.

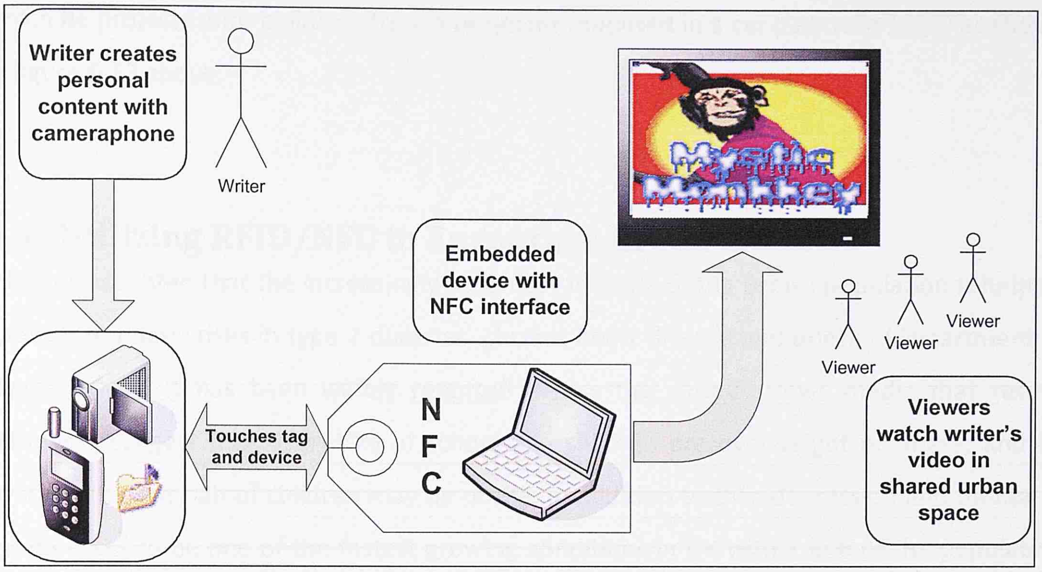

Figure 6.11: Mobile SprayCan Utilising NFC Sensors and Smartphones

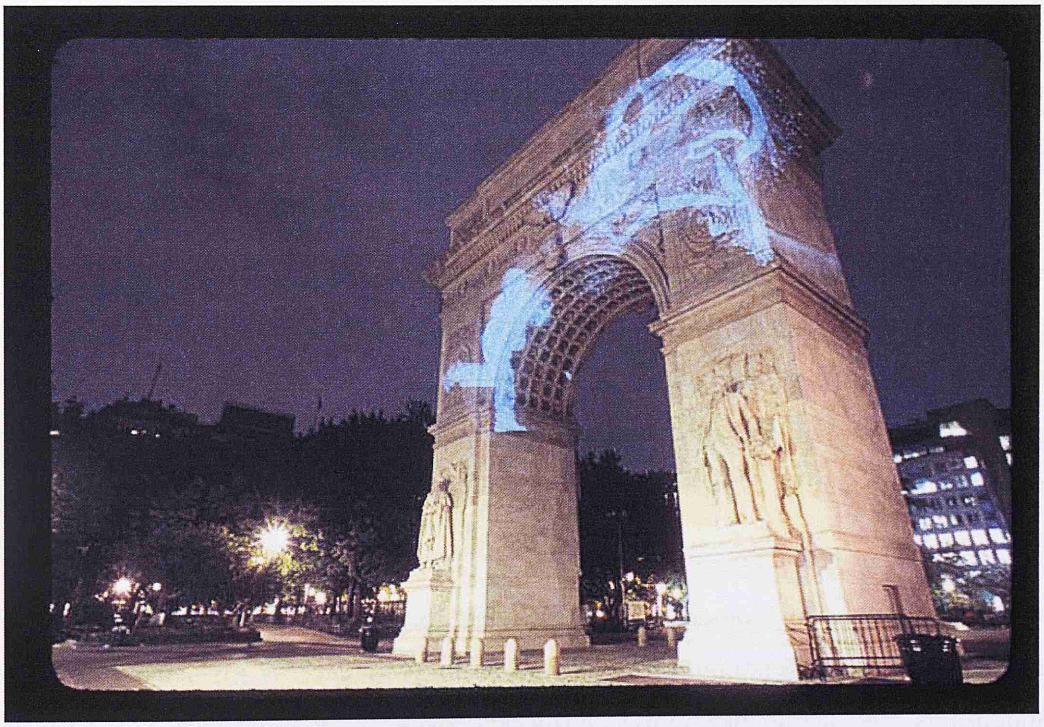

Figure 6.12: Graffiti images projected onto buildings in New York: an example of the Graffiti Analysis project by Fi5e (Garner, Rashid, Coulton and Edwards 2006)

Here, a writer's creations could be viewed by a large number of urban dwellers, reflecting the effects of traditional graffiti with a number of drawbacks removed. Projecting graffiti onto buildings has already been seen in New York through the work of the writer Fi5e, who has captured the motion from real writers creating their tags and produced small movies which he projects onto buildings from a projector mounted in a car (Sannella 1994) as shown in figure 6.12 above.

6.3 Utilizing RFID/NFC to Encourage Green Exercise

It is well accepted that the increasingly sedentary lifestyle of the British population is helping fuel the dramatic rises in type 2 diabetes, chronic heart disease and obesity (Department of Health 2004). It has been widely reported across the various News media that recent estimates suggest that over 40% of school age children are overweight or obese, and by 2010 more than half of children may be obese. In addition to this, depression and mental ill health is set to be one of the fastest growing conditions in UK with 1 in 6 of the population suffering from a neurotic disorder (Department of Health 2004). Whilst the overall reasons for this are complex there are simple things we can all do to improve this situation. A report on the impact of physical activity and its relationship to health by the Chief Medical Officer in 2004 (Department of Health 2004) concluded that:

> *"The minimum amount of regular physical activity needed to improve peoples' health and reduce disease risk is 30 minutes of moderate intensity physical activity on at least 5 days a week."*

The report also highlights that less than half of the British population manages to do this even though something as simple as brisk walking can achieve this end. Walking is known to have considerable benefits not only in combating the serious diseases highlighted but improving peoples general sense of social well-being and is the most natural and convenient form of moderate intensity physical activity that is common to all, except for the most seriously frail or disabled individuals.

To improve the levels of activity of the population a number of projects have been developed such as the Walking for Health Initiative (WHI) from the British Heart Foundation and Natural England, which was originally conceived by Dr William Bird in 1994, and supports a number of projects such as Green Exercise (Walking for Health 2007). Green Exercise encompasses any physical activity out of doors but with an emphasis on accessible, regular and moderate activities that people can build into their daily lives. Green Exercise might be walking, cycling or, in the case of children, unstructured outdoor play activities. For the more adventurous it could be climbing, kiting or orienteering. For others the focus could be on nature or the environment, such as conservation activities, bird watching, gardening or wild camping. The factor uniting all these activities is that they can encourage people to be more active, more frequently, close to home and in the outdoors.

An important element of encouraging walking is the need to provide feedback as it is known (Whitehead 1993) to aid both the level and continued engagement in activity. Additionally, many people may have difficulties making sure that their activity is in fact moderate and not just light and it is important for individuals to not only be aware of their overall amount of exercise but also its intensity (Maitland, Sherwood, Barkhuus, Anderson, Hall, Brown, Chalmers and Muller 2006). The obvious solution is some form of exercise diary to record activity but these are heavily reliant on the users remembering what activities they undertook, how long the activity lasted, and possibly the distance travelled. This requirement would likely be perceived as particularly burdensome if required on a daily basis and is not well suited to recording activities integrated into normal daily activity such as walking. One possible solution is that of pedometers, which have shown to have success (Merom, Rissel, Phongsavan, Smith, Van Kemenade, Brown and Bauman 2007) but as it is for such a specific purpose it requires a conscious effort on users to remember to carry it around and would normally still require the user to record the details for further analysis.

In this project a system was created, originally conceived by Intelligent Health, which combines elements from a number of technologies and services to support and encourage walking as part of daily activity. These are; Mobile phones; RFID in the form of NFC; A redeemable points accumulation scheme.

Mobile phones are the most pervasive technology on the planet and given the importance of the phone it seems an obvious choice for aiding the recoding of activity levels. The use of mobile phones to track activity is not a new concept as a number of phone manufacturers have embedded pedometer functionality (generally implemented through accelerometers) with simple on-board activity logs into some of their devices, for example the Nokia 5140 (Nokia 2003) and Nokia 5500 (Nokia 2006). Although pedometers have proved effective for encouraging and recording activity this functionality is unlikely to widespread inclusion of phones for some time if ever. A system designed to record activity automatically to the web was developed that tracked activity by monitoring cell IDs (Maitland, Sherwood, Barkhuus, Anderson, Hall, Brown, Chalmers and Muller 2006) and although this met with some success its accuracy was limited in rural environments as it required consistent network coverage and was computationally intensive (Maitland, Sherwood, Barkhuus, Anderson, Hall, Brown, Chalmers and Muller 2006) and thus likely to cause significant battery drain. Ideally a phone based system should be; capable of being operated across a wide range of devices; easy to operate; capable of being used in a wide variety of scenarios and we shall return to these criteria when we have discussed the remaining components of the proposed system.

The choice of RFID, and in particular an associated technology NFC, may not be immediately obvious as RFID is often primarily associated with asset tracking. However, it is also finding application as a ticket replacement mechanism on public transport such as the Oyster in London. Oyster is a RFID `smartcard` which can store £90 of pay as you go credit plus a travel card or annual bus pass and can be used on the Tube, buses, Dockland Light Railway, trams and some national rail services in London. In a recent press release Lambeth Council state that by March 2007 over 10 million Oyster cards had been issued and more than 80% of all journeys on services run by Transport for London used the Oyster card. NFC is an interface and protocol built on top of RFID and is targeted in particular at consumer electronic devices, providing them with a secure means of communicating without having to exert any intellectual effort in configuring the network (ECMA 2004). The final element of the system is related to creating motivational forces to encourage continued engagement. Previous research into motivational perspectives for engaging in physical activity (King, Friedman, Marcus, Castro, Forsyth, Napolitano and Pinto 2002) has highlighted the importance of intrinsic over extrinsic motivational forces. Whereas extrinsic motivation originates outside of the person, for example social influence brought to bear through a counselling relationship such as a trainer or a prize; intrinsic motivational forces involve phenomena that originate within the individual. The intrinsic motivational perspective is based on people's needs to be self-determining and competent, and is believed to be crucial to long term behaviour change (King, Friedman, Marcus, Castro, Forsyth, Napolitano and Pinto 2002).

The proposed scheme is designed to facilitate both extrinsic and intrinsic motivational forces in that intrinsic behaviour is facilitated by allowing the user to see the recorded levels of activity in terms of calories used and extrinsic motivation is facilitated by a mechanism similar to those employed by banks and credit card companies whereby redeemable the points are accumulated for a prescribed activity in this case physical. In the long term it is envisaged that these points could be redeemed within the local parks and shops. Having defined the basic elements of the system the following section provides more detailed system design.

6.3.1 Credx System Design

The system described here is known as Credx and works by implying the location of a user (Rashid, Bamford, Coulton, Edwards and Scheible 2006) at a given time which is triggered when a user scans his/her NFC tag. Credx users are given NFC tags whose Unique Identifier (UID) is used as basis of monitoring their activity within the system. Mobile phones equipped with NFC readers are placed at different locations with distance between each location known and this is linked to known calorie data for healthy adults undertaking various physical activities such as walking, running and cycling.

A single scan at any location is not sufficient to imply the path taken by the user they must therefore scan their NFC tag at two distinct locations. Since the distance and calorie count is known between these two locations and the users can register a particular activity which means that a detailed description of activity can be provided to user listing the time taken to travel, calories consumed and speed to support intrinsic motivation.

The extrinsic motivation is achieved by rewarding the user with Credx points for each scan they make during their trip. This encourages the user to scan more often although only scans that form a valid journey or trip contribute to Credx points gained by the user. Each scan is time stamped which plays a vital role in identifying valid trips from those that are invalid.

Figure 6.13 shows a simple usage scenario which consists of three access points (in this case mobile phones equipped with NFC readers). The example shows two users, each one starting their trip at Location L1. User 1 starts his trip by scanning his tag at L1 and ends it at L3 in T2-T1 seconds whilst user 2 starts the journey at L1 but ends at L2 whilst going through L3.

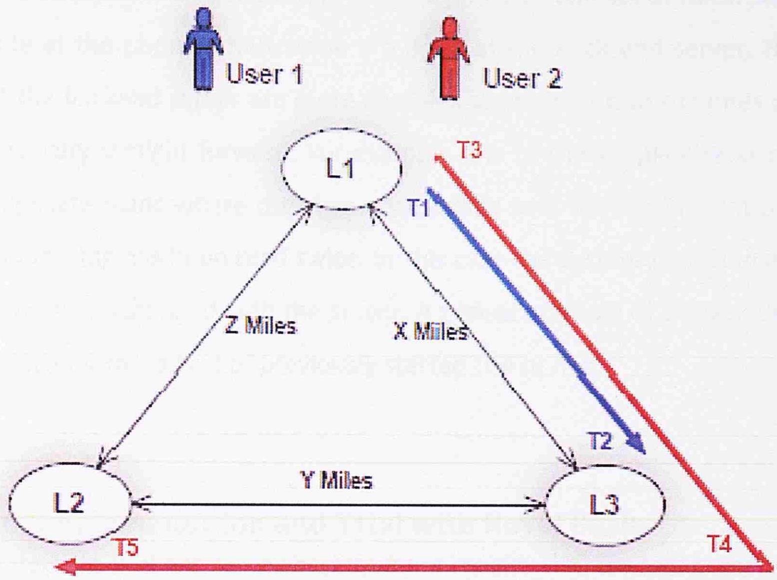

Figure 6.13:

Table 1 below shows the distance covered and points accumulated by each user in the earlier scenario.

	Distance	Scans	Points
User 1	X	2	2
User 2	x+z	3	3+1

Table 6.1: Distance covered and points accumulation

Although User 2 has made 3 scans only during his trip he is still awarded with 4 (3+1) points in total. This is done to further motivate the user to increase their daily walking distance. Three points are awarded for number of scans done and since User 2 is continuing his journey beyond points L3 an additional point is awarded as an added bonus to encourage the user. So the trip taken by User 2 will be reported as L1 – L3, L3 - L2.

In order to achieve the scalability and ease of implementation at various locations parent child architecture was chosen for the selection of locations where NFC readers are placed. A parent location represents a park or a busy shopping mall. A child location will then be various key points within a parent location. Each of parent and child locations is given unique identifiers within the system to link a child location to a parent location and uniquely distinguish one parent or child location from another. NFC readers, with a unique reader identifier, are then assigned to a child location.

Each scan is time stamped and checked for validity against certain set of rules. Some of these checks are made at the phone whilst some are done at the back end server. However the checks done at the backend server are more complex as compared to the ones done on the phone which are very straight forward. For example one of the simple checks done on the phone is for duplicate scans where user has accidentally held the tag in front of the phone for too long and the tag has been read twice. In this case the second scan is marked as void and no information is exchanged with the server. A typical example of a check on server will be to see if that scan forms a part of previously started trip or not.

6.3.2 System Implementation and Trial with Royal Parks

The Credx architecture is client server based where mobile NFC readers communicate with the backend server via GPRS as shown in Figure 6.14. At the heart of the system is the central database which holds user, location and NFC scanning data. NFC readers located at various locations send the UID of the NFC tag along with the unique location identifier and timing details to the server. This information is processed by the server and stored in the database.

The Royal Parks (The Royal Parks 2010) is the organization responsible for managing the 5,000 acres of historic parkland across eight major sites in the heart of London which are: Bushy Park, The Green Park, Greenwich Park, Hyde Park, Kensington Gardens, The Regent's Park, Richmond Park and St James's Park. Millions of Londoners and tourists visit the Royal Parks for free each year and they provide opportunities for a simple walk or a picnic, sports, organized activities/events etc. and thus presents an ideal locale for trialling this project.

During the first trial phase nine key locations were identified within Hyde Park shown in figure 3 which is in the heart of London. The key criteria being the fact that they are on a path way within the park and within the walking distance of the nearest London Underground station. These locations are shown on figure 6.15. Each of these locations was equipped with a NFC phone having a unique identifier within the system.

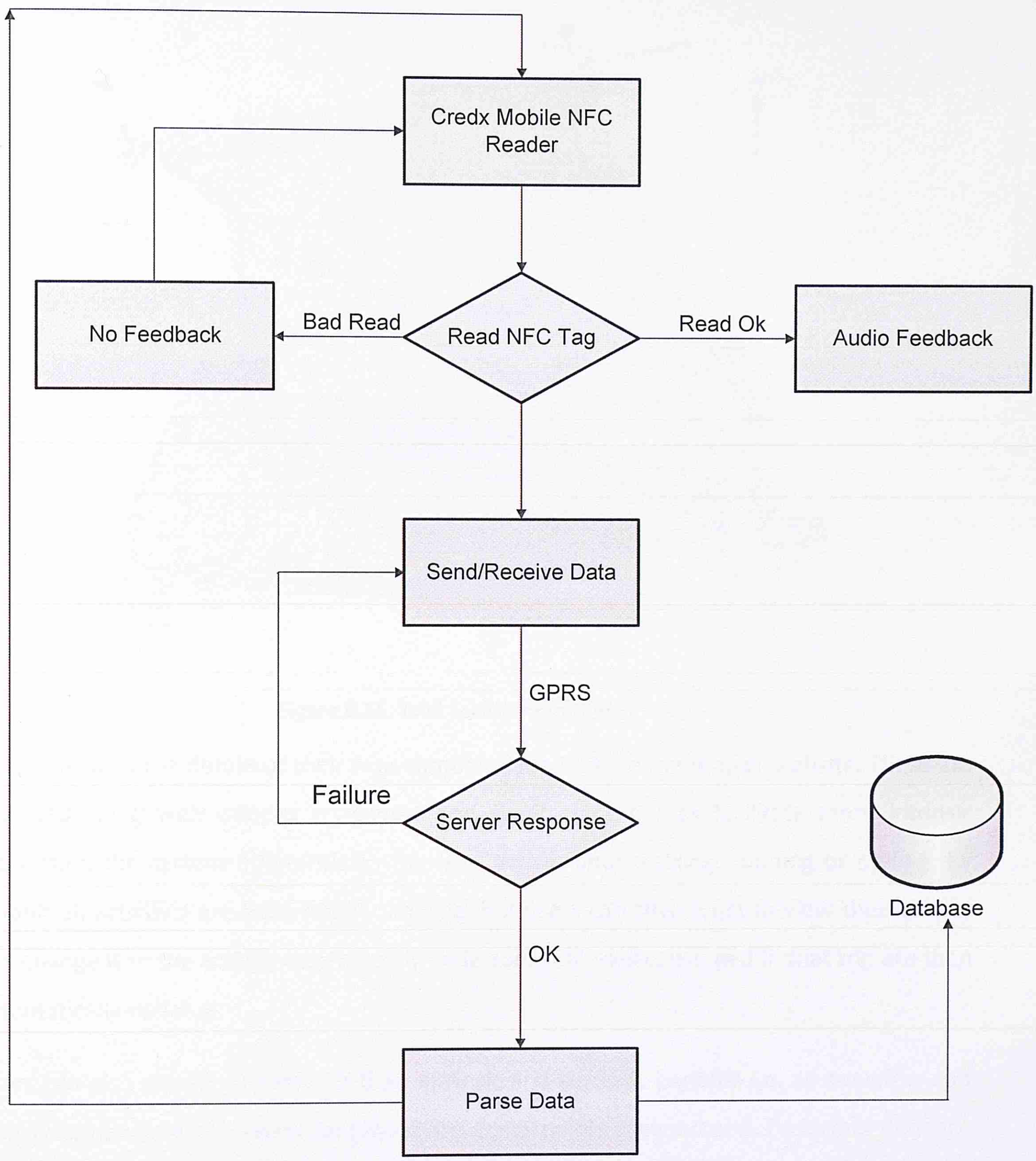

Figure 6.14: Credx System Design

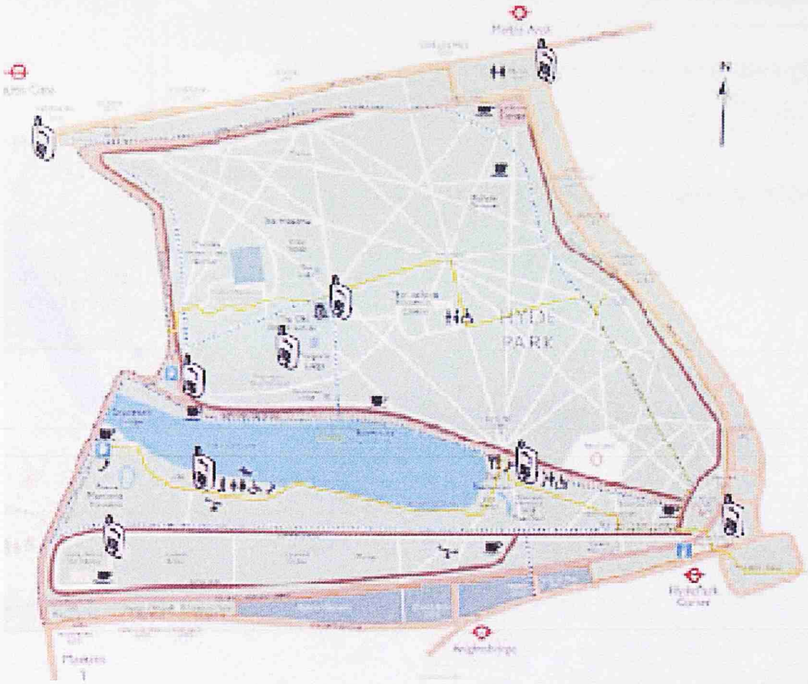

Figure 6.15: Trial Locations in Hyde Park

Users can view the details of their trips through Hyde Park on the project website. These are reported along with calories consumed and speed. In order to facilitate more intrinsic motivation the system differentiates the user activity into walking, running or cycling. By default all activities are reported as 'walking' but users can then login to view their results and change it to the activity they actually undertook. Calories consumed in that trip are then automatically updated.

Users can also see an overview of their intrinsic and extrinsic benefits i.e. an overview and weekly comparison of calories consumed and Credx points accumulated. To further enhance intrinsic motivation users can view their calorie consumption through a range of graphical representations. They can either select a certain time frame or select a weekly comparison which compares the current week's calorie consumption to that of the last 2 weeks as shown in figure 6.16.

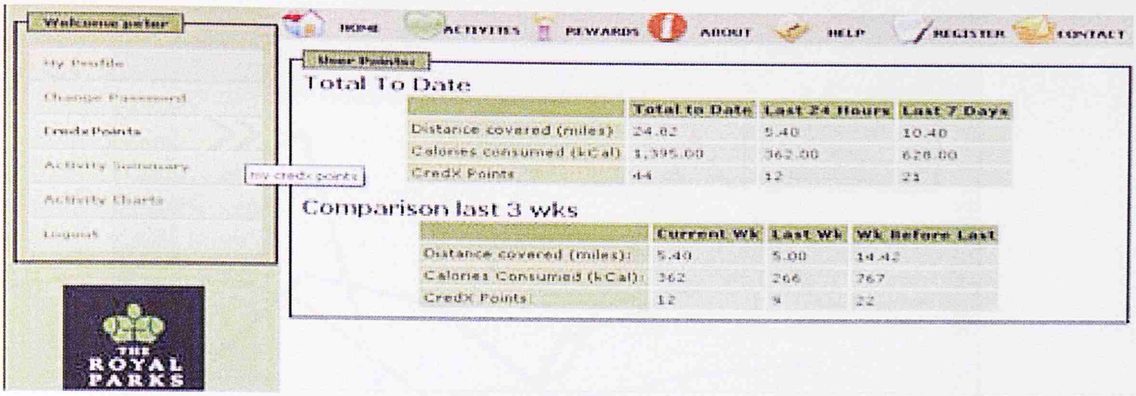

Figure 6.16: User Calorie Consumption Table Overview

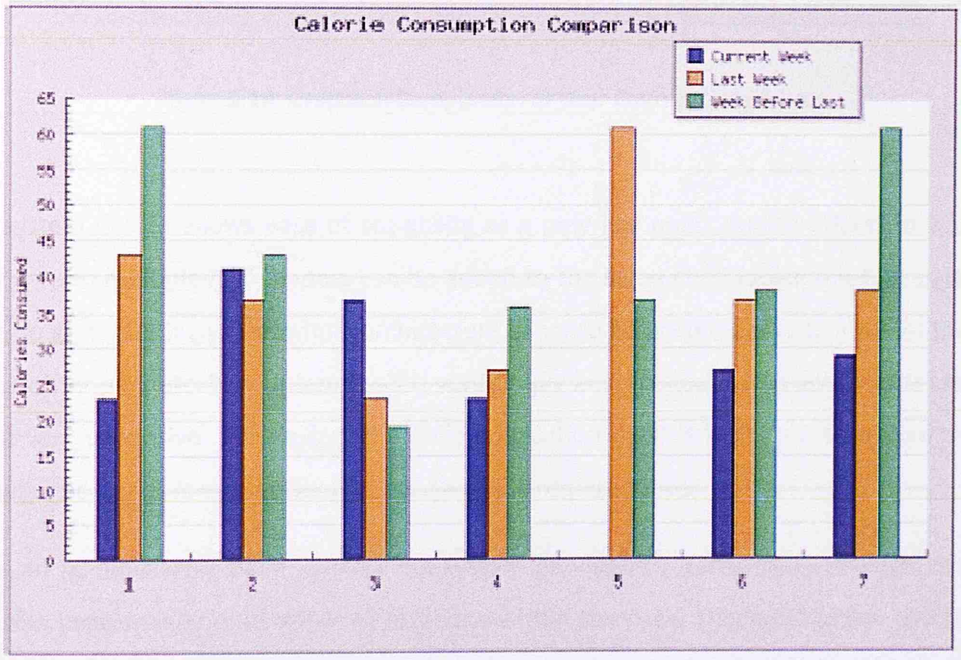

Figure 6.17: Graphical Comparison of User Calorie Comparison

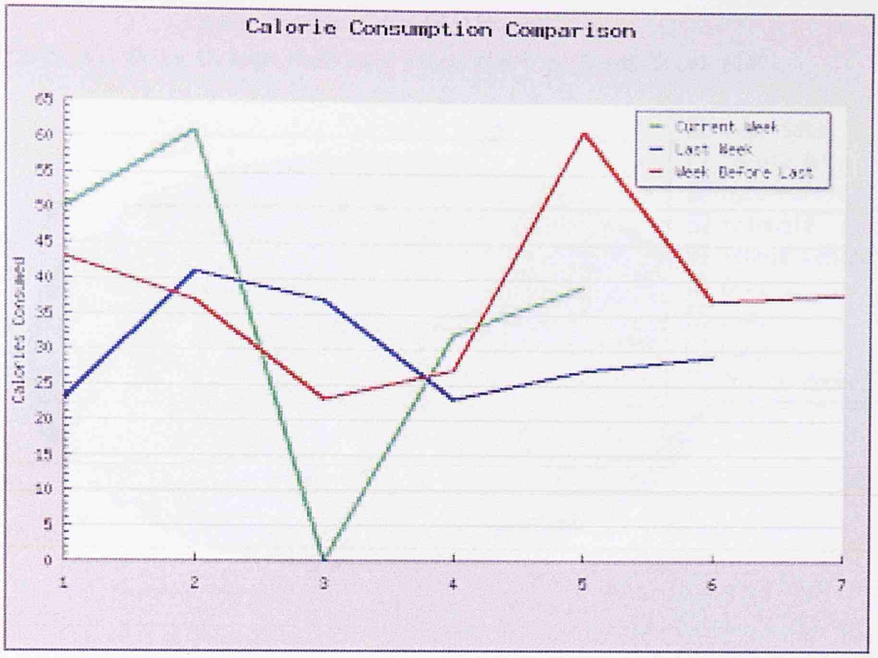

Figure 6.18: Graphical Comparison of User Calorie Comparison

The system design allows ease of scalability as a new key point can be added to a parent location and multiple NFC readers can be added to the same child location if that particular location gets very busy. The whole architecture can also be ported easily to another location e.g. another park etc. The system itself is very simple and economical as equipment involved is not very expensive. The design of mobile application itself is kept to a bare minimum to conserve power as longer battery life is one of the requirements.

From an administrator point of view the system provides overall activity through the park and also provides usage of different locations within the park. This information can further be used by parks to provide other services at those locations. Use of Hyde Park by Credx test users during the trial period is shown in figure 6.19 below.

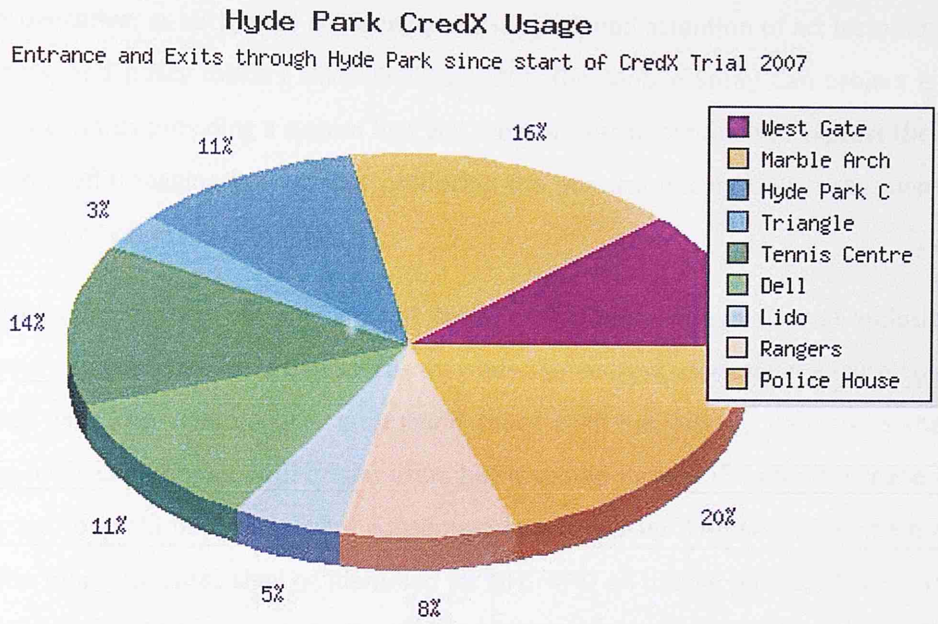

Figure 6.19: Monitoring Use of Urban Spaces through Credx

From a user point of view the combination of intrinsic and extrinsic motivation encourage the user to increase their physical activity in their daily routine. A clear comparison was seen with two different users in the trial. One user had many incomplete trips (trips where user scanned one tag only) and this was done at the start and end of the working day. This points out that the user has not changed his/her daily routine whilst in the other case many complete trips were seen which highlighted that instead of taking the shortest path that particular user is undertaking extra physical activity to obtain that second scan hence consuming more calories and gaining points.

6.4 Summary

As stated before if we are to truly attain an environment of pervasive computing technology then we must utilize technologies available to all sectors of our society and provide systems that will engage groups whose activities are out of the mainstream. Graffiti is a cross cultural phenomenon that is part of every single society. Within the variable contexts of their production, graffiti allows personalized and de-personalized space, the construction of landscapes of identity, the ability to make public space into private space, and act as a promoter of ethnic unity as well as diversity. Graffiti can be understood as concrete manifestations of personal and communal ideologies which are visually striking, insistent, and provocative; as such, they are worthy of the continued attention of art historians, social scientists, and policy makers alike (Phillips 1996). The Mobile Spray Can project is but an attempt towards providing a system that will allow writers to continue to express themselves through graffiti tagging but without producing the physical impact that many members of the community find objectionable.

If MoSoSo are to truly not only support social capital but also avoid social exclusions and enhance enragement with urban spaces they need to address user role in an interconnected manner with interaction space. Interaction space shall not just be defined as the space where users can interact with others users but it should include the physical space itself. If users are to avoid becoming mere consumers of mashed up data served to them at their location more use cases shall be identified for NFC/RFID on mobile phones. A true symbiosis can be reached between user, device and environment creating a mixed reality world where enjoy and benefit from the best of both worlds.

Further, the work discussed in this also highlights the potential for mobile phones equipped with RFID/NFC capabilities enabling many other applications, such as games which have already been discussed in previous chapters. Combining these technologies takes advantage of the synergy between two pervasive computing domains, and indeed the ever-evolving feature sets on mobile phones paving the way for many innovative applications.

Chapter 7
Conclusions & Future Work

7 Conclusions and Future Work

7.1 Conclusions

Location plays an important role in current mobile applications and services. It has been cited that global market for LBS will reach $21.14 billion by 2015. The LBS industry has matured rapidly in recently through a mixture of consolidation, improved price/performance of the enabling technologies and compelling location applications (Zimmermann 2009). Proliferation of GPS enabled phones, lower pricing, emergence of mobile2.0 and new platforms like Google's Android and iOS (iPhone) from Apple have all helped in rapid growth of LBS market. Location information about mobile devices is already being employed by network operators and application vendors to provide a bespoke experience to end users resulting not only in increased profitability for application vendors and network operators but also places LBS as an integral asset for their future success. From a mobile advertising point of view location based advertising provides a much greater level of personalisation and customization for the end user and hence increasing the chances of a sale through advertisement consumption.

However current location based services and applications mostly rely on GPS or Cell id to locate a mobile device. As discussed in chapter 2 Cell id does not provide a greater level of accuracy that may be required by some services/applications. GPS on the other hand provides much greater accuracy in terms of locating a mobile device as compared to Cell id but suffers from the fact that it cannot be used to locate a user indoors. A much greater level of accuracy is required by applications and services operating indoors in big shopping malls or closed arenas e.g. location based advertisement or a promotion very close to point of sale, presence of social connections within close proximity, interaction with a physical landmark as part of a mixed reality game or interaction with a landmark for information retrieval etc. Looking at current application and services it becomes evident that these applications and services can provide a much superior user experience and level of interaction but they tend to settle for a much inferior user experience indoors due to inaccuracies in estimating location of a mobile user. Moreover looking at the ubiquitous nature of these applications and services indicates that they tend to fall short in achieving goals of a truly ubiquitous experience (Weiser 1994) i.e. focusing more on the task rather than on the computing aspect of it which integrates into fabric of life. Their level of interaction with environment is sparse despite using location information as their key operating component e.g. despite being played in the real world and based upon real world location data many games isolate the players from their environment in interest of scalability (Rashid, Mullins, Coulton and Edwards 2006) or mobile social applications becoming location aware but merely using location as an added piece of information rather than an integral part of the experience resulting in social exclusion at both individual and group level as they are simply serving the user based upon his/her social capital.

The work presented in this thesis aimed to look at utilisation of contactless communications as means of implying user's location to fill the gap left by current applications and services resulting in a much enhanced and bespoke user experience resulting in a symbiosis between user, device and environment. The thesis explores the utilisation of contactless communication through Bluetooth and NFC as implied location technologies across a range of applications and services through real world experimentation. In particular their effectiveness has been researched in relation to three areas considered to benefit most from location based information i.e. mobile advertising, mixed reality gaming and mobile social applications.

Chapter 3 looks at the use of Bluetooth as both an implied location technology and a short range contactless communication. Two usage scenarios are considered i.e. supermarket advertisements/promotions/coupons and use as a guide system. In both use cases explored users can simply opt. in and opt. out at any point, moreover there is no requirement for the user to download any application or subscribe to a particular location based service provided by the vendor or network operator or any other 3rd party. Users can choose to receive advertisements by simply switching on Bluetooth on their mobile phone making their device discoverable to other Bluetooth devices in the area. This action by the user is considered as their willingness to receive advertisements or promotional offers over Bluetooth however actual advertisement is only pushed to the user's device after they have explicitly chosen to do so hence users only receive information when they wish to do so as advertisements pushed to user's device await a confirmation from the end user. If the user wishes not to accept the incoming message it can be considered as their unwillingness to accept any advertisements and they may have left their Bluetooth radio on to communicate with other personal devices such as a Bluetooth headset.

Mixed reality game Pac-Lan discussed in Chapter 5 explores the use of NFC as an implied location technology and demonstrates that physical objects do aid in playing an augmented reality game. Pac-Lan also demonstrates that RFID can produce an effective interaction when used in a gaming context. The use of RFID certainly means the game could be played at high speed, as attested to by the comments from the players. In terms of tactics, an emergence of new and novel tactics by different players has been seen which work with varying levels of success. Furthermore use of NFC for mixed reality games will ensure that players interact with the real world space in which the game is being played rather than being immersed in the virtual world only.

The thesis explores the utilisation of contactless communication as an implied location technology in context of mobile advertising, mixed reality gaming and mobile social applications. Let us review the objectives of this thesis as set out in Chapter 1 in light of work presented in previous chapters.

Mobile Advertising

What implied location technologies will be useful for mobile advertising?

A short range contactless communication technology will form an ideal basis for this. Utilisation of contactless communication will in particular be valuable at point of sale. Since most of the shopping centres are indoors each individual vendor can have their own advertisements related to the products available within their shops. Moreover the potential customer is in close vicinity of the product which can have a profound impact for both short and long term goals.

What are the security and privacy concerns that may arise from use of such technologies?

The system proposed in chapter 3 is targeted towards personal devices such as mobile handsets which users wear almost everywhere and all the time. Users do not want to receive spam or receive information without their permission. End users being targeted with a lot of spam or being tricked into receiving information from other parties as part of accepting a message from a certain provider are major concerns. This seems to be very common with online signups or online voucher use etc. Policies and regulations need to be in place that would circumvent these potential problems. User trust in mobile advertising is far less as compared to other types of advertising and marketing. According to a survey (Nielsen 2009) only 21% users showed some degree of trust in advertisement received on mobile phones which is the lowest as compared to other advertising and marketing mediums. Degree of trust in various forms of advertisements is shown in figure 7.1.

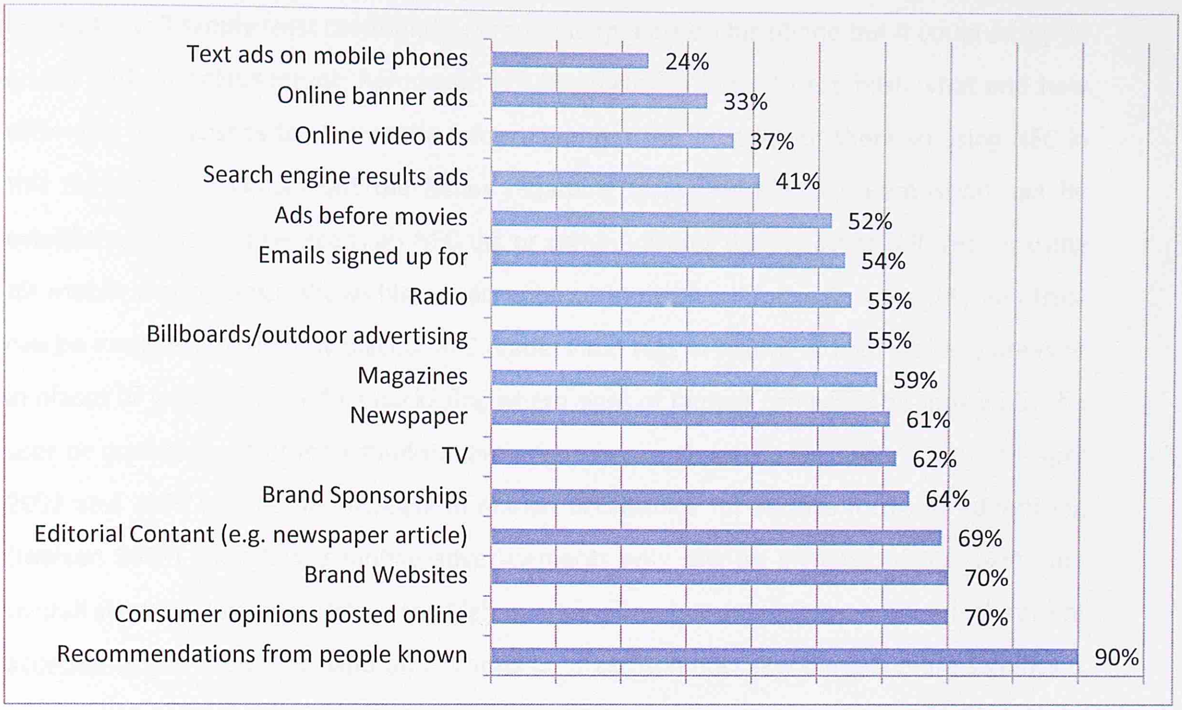

Figure 7.1: Degree of trust in the different forms of advertising in April 2009 (Nielsen 2009)

Trust in general with mobile marketing is low because consumers are often misled into contractual obligations by various mobile ringtones and application vendors. Users were misled when they downloaded a single ring tone for a set price but in fact by downloading that item they were signed up to a weekly subscription without their knowledge. Users' mobile account was charged via SMS and they only found out about the issue when they received itemised billing information. UK network providers took steps against this fraudulent behaviour by introducing a trusted payment service named PayForIt (Payforit 2006). PayForIt is run on behalf of the UK network providers by trusted intermediaries who have been carefully selected by the network providers. The scheme enforces strict regulations on how merchants conduct themselves before, during and after the sale. Similar approach will need to be taken if we are to exploit the true potential of location based advertisement which is very closely tied into product placement and point of sale.

What implied location technologies will be more useful in mobile marketing?

Although the system discussed in Chapter 3 utilises a permission based advertisement model and utilises Bluetooth which is a very common features on mobile devices now a days but as pointed out in the later sections of chapter 3 that what is the guarantee for the end user that the device about to connect to his mobile device over Bluetooth is actually who it claims to be. A user will simply trust the friendly name that appears on his phone but it could easily be a user with malicious intent. Permission is a key factor in order to establish what and how often the user wishes to receive the information but the trust in not there so using NFC in this scenario can circumvent the issues regarding trust and identity. Permission can be established when a user scans an NFC tag or communicates with another NFC reader using his mobile device which shows his/her acceptance to receive information. Identity and trust can be easily established by placing NFC readers and tags in secure or high visibility areas or in places or within the product packaging where signs of tamper can easily be spotted by the user or management of the establishment. A survey conducted over 2 years between April 2007 and 2009 studies the increase in market acceptance for various forms of advertising (Nielsen 2009). Text based mobile advertisements only saw an increase of 6% taking the overall share to 24% which given the high number of mobile subscribers is not a high rate of acceptance. On the other hand other forms of advertisements saw a much more significant increase as shown in the figure 7.2.

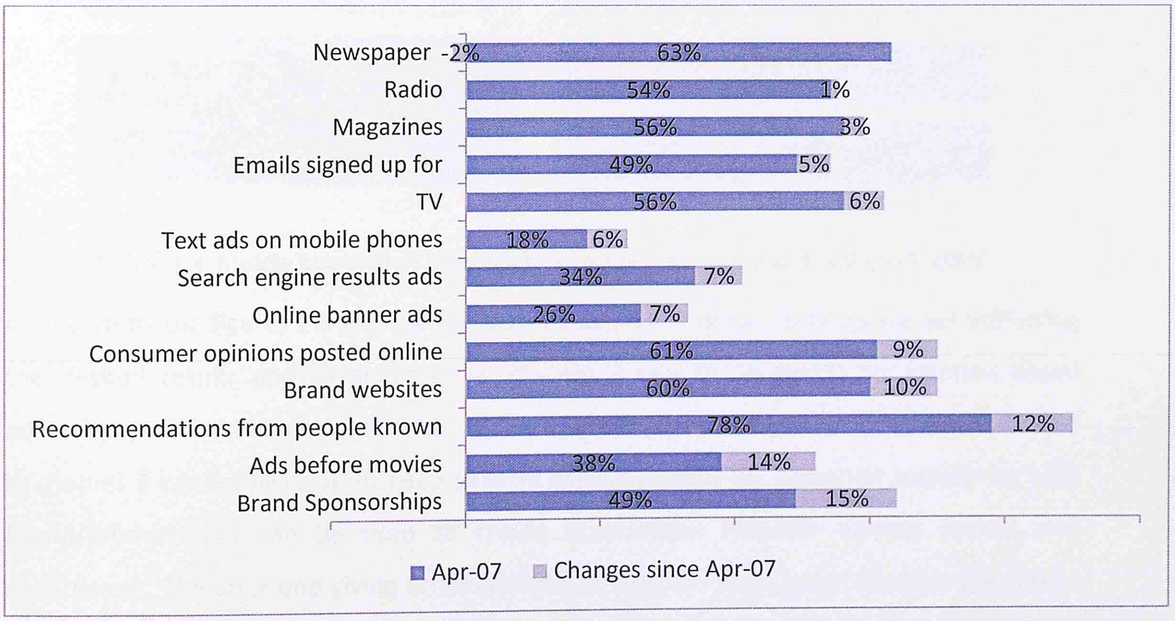

Figure 7.2: Forms of advertising ranked by changes in levels of trust from April 2007 to April 2009 (Nielsen 2009)

Analysts identify three key mobile marketing opportunities i.e.

- Drive Sales
- Enhance customer experience with brand or product
- Brand association with a desirable and successful product or experience

Figure 7.3 shows the mobile marketing activities that can be utilised to make the most of the above opportunities (Stewart and Quick 2009).

Figure 7.3: Mobile Marketing Opportunities and Activities (Stewart and Quick 2009)

As shown by the figures 7.1 and 7.2 text based ads on the mobile phones are not delivering the desired results and as discussed in chapter 3 use of Bluetooth for location based advertising will help achieve better results. It has been demonstrated that system discussed in chapter 3 can be successfully used to drive sales, enhance the customer experience with brand/product and can be used to create associations between various brands and experiences. The later one giving financial rewards that are twofold i.e. revenue generated by direct sales and revenue generated by ones successful brand or experience's association with a new or upcoming brand. However as discussed here and in chapter 3 there concerns regarding security and privacy that need to addressed carefully if Bluetooth is to be utilised in such a manner. In the light of the results achieved by the real world trials of the Bluetooth based systems the thesis proposes that NFC will be a better candidate to achieve mobile marketing success. Such a system is outlined in future work section.

Mixed Reality Gaming

Can implied location technologies be useful to improve the user interaction with the real world? Can their use produces effective user interaction with physical objects in the real world? Will use of physical objects enhance the user experience?

As demonstrated by the mixed reality game Pac-Lan, discussed in chapter 5, that use of implied location technologies significantly improve the user interaction with the real world and physical objects located within. Mixed reality games or even location based games tend to absorb the user in the game play occurring in virtual world. Although location plays an important part but interaction with real world and physical objects is often very limited. Moreover existing LBS games heavily rely of GPS or Cellid to locate the mobile device and cannot be played in doors. However the work discussed in this thesis has proven that NFC can be used both outdoors and indoors to not only locate the mobile devices but also to create innovative new game play experiences. Feedback obtained relating to the playability of the Pac-Lan in terms of the phone map, compared to the actual physical layout, visibility of the game pills (interaction with physical objects), ease of killing an opposing player (interaction with other players in both virtual and real world), overall playability and enjoyment (overall experience) showed a high level of acceptance as shown in table 5.2.

What is the effectiveness of an implied location positioning scheme when the game players are moving quickly and how tactics develop over subsequent participation in the game?

Generally people may assume that interacting with a physical object whilst being part of a fast paced mixed reality game will either compromise game play or location tracking (if physical artefacts are being used as part of an implied location scheme) but as seen by the results of various Pac-Lan trials that this is not the case. An important thing to keep in mind is that if the interaction with physical object takes too long to process it will surly compromise the experience and effectiveness of location data and its impact on the game. Keeping this in mind and reviewing the effectiveness of different types of contactless communication technologies discussed in previous chapters the thesis confirms that NFC will deliver a much better experience as compared to 2D barcodes. Some critics will argue that proliferation of NFC enabled handsets is much smaller as compared to phones with cameras which makes 2D barcodes a better choice but as seen by the work presented in this thesis that this is clearly not the case as capturing a 2D barcode and processing the code will take much longer as a player will have to focus and capture the 2D barcode and avoid any bad photo captures due to hands shaking or moving on the next task before the camera has finished processing the photo. On the other hand scanning an NFC tag is as simple as a tap and will work with same degree of efficiency for both fast and slow paced games. Moreover it has been demonstrated by work and results outlined in chapter 5 that new tactics do develop after subsequent participation which is akin to other forms of gaming where players gain experience and improve themselves whilst playing in the same virtual world.

Mobile Social Applications

Although mobile social applications are location and context aware they fail to overcome the phenomenon of social exclusion at both individual and group level, can implied location technologies be used to encourage social inclusion?

Mobile social applications are mostly an extension of their online counterparts or are designed simply to support social capital which can lead to social exclusion for those people or activities that do not have enough social capital. As seen by the Mobile Spray Can prototype, discussed in chapter 6, that if mobile social applications are to truly become ubiquitous they also need to engage and include users that do not have social capital or activities that out not main stream.

Can this result in a symbiosis between user, device and environment where the interaction space is not simply the space where interaction amongst users takes place but is an integral part of the experience and since mobile social applications are responsible for increase in data consumption on mobile devices can implied location technologies enhance the user experience?

If MoSoSo are to truly not only support social capital but also avoid social exclusions and enhance enragement with urban spaces they need to address user role in an interconnected manner with interaction space. Interaction space shall not just be defined as the space where users can interact with others users but it should include the physical space itself. If users are to avoid becoming mere consumers of mashed up data served to them at their location more use cases shall be identified for NFC/RFID on mobile phones. A true symbiosis can be reached between user, device and environment creating a mixed reality world where enjoy and benefit from the best of both worlds.

7.2 Future Work

The thesis has explored the utilisation of contactless communication technologies for utilisation in providing location based advertising to mobile users, mixed reality gaming and mobile social applications. In particular use of Bluetooth and NFC were explored, based upon the conclusions extracted from the work presented in this thesis following directions for future work are recommended.

7.2.1 Mobile Location Based Advertising/Marketing Utilising NFC

As discussed previously that NFC provides a much better alternative to Bluetooth for use as an implied location technology for indoor location based advertisement. Utilising NFC for such a scenario will be particularly useful in supermarkets or shopping centres or at airports or other points of sale. This thesis proposes following use cases

7.2.1.1 Utilising NFC to Complement Bluetooth

As pointed out in previous sections that there are certain security privacy and security concerns regarding use of Bluetooth for providing location based advertising to existing mobile users. These concerns mainly arise due to the ambiguity if the device claiming to be the source is actually who it claims to be. NFC can help circumvent this problem. As discussed in chapter 4 NFC now has specification that covers a negotiated connection handover to faster data bearer e.g. Bluetooth. In this scenario a NFC tag can be placed behind the glass near a secure or monitored area where no one can unlawfully gain access and tamper with the tag. When a user taps the surface of this display the NFC tag triggers a negotiated handover to a certified Bluetooth advertising provisioning system. Key benefits of utilising NFC triggered negotiated handover are

- Users can be sure that they are only going to be receiving information from a known, secure and regulated source.
- If users do not wish to receive advertisements but yet want to keep the Bluetooth on their devices switched on they can do so as connection handover only takes place after they have scanned the NFC tag.
- Since the work was carried out to provide location based advertising to mobile over Bluetooth there have been some implementations that use a similar approach. If the existing systems wish to utilise such an approach they can easily do so as utilising NFC based connection handover is not going to require any changes to the existing infrastructure.

- Merchants can be sure that they are only targeting users who actually want to receive the marketing information.

In order enhance the affectivity of the promotions or advertising it will be a good idea to place the NFC tag containing handover information next an electronic display. The display can show the advertisements or promotions relating to different products and also point out to the user that if they wish to receive more of the same they can simply tap their NFC enabled mobile phone next to the display. As seen from figure 7.1 55% of users have shown trust in advertisements shown on publically located electronic displays.

7.2.1.2 Collectively Utilising NFC and Social Capital

It has been pointed out previously in figure 7.1 that users have varying degree of trust in different forms of advertising and marketing. This trust amounts to a massive 90% when it comes to recommendations from friends and family. From a mobile marketing point of view in order to drive sales one must provide a certain level of information to support the purchase. If there is a high level of trust in recommendations from friends and other people known why not utilise that higher degree of trust and use that as the supporting information to support the purchase. In this scenario NFC tag will be placed within product packaging or inside the price label. Users can simply tap the product and within a few seconds recommendations or reviews from their social network are available to them. If reviews and recommendations from a user's social network are not available recommendations and reviews from other people who purchased the same item can be made available. There are some applications and services already available that utilise recommendations or reviews from other people or show competitive prices but they rely on either user entering the product model or taking the picture of the 2D barcode on the product. However to utilising the 2D barcode approach can be cumbersome for both users and merchants as merchants often need to reprint the 2D barcode and place it next to the product pricing label because for some products such as electronics the 2D bar code is often hidden behind the cover or under the product.

7.2.2 Educational Mixed Reality Games for Heritage Sites

In the light of the work presented in thesis regarding provision of location based information for tourists regarding various parts of an attraction and the conclusions extracted from the real world experimentation of interacting with physical objects via NFC in a mixed reality gaming context it is recommended that a combination of the two can be utilised to create exciting new educational games targeted at school visits to a museums or other heritage sites. Such mixed reality educational games can transform the visit to a museum into an exciting and learning adventure. It is proposed that NFC tags to be placed on the information planks next to each exhibit. Participants receive their instructions over Bluetooth as they are about to proceed into the museum turning their visit into a mixed reality time machine. They must follow the instructions received over Bluetooth when they enter various other parts of the museum whilst following the map on their phone and unravel the mysterious clues triggered when they interact with the information planks next to each exhibit. Participants attempt to solve all the clues going from one section to the other and interacting with the exhibits to be the first one to solve the mystery and in doing so grasp a lot of historical information about the exhibits but also about the time and era they belonged to. Since each NFC tag is uniquely identifiable museums can create new game maps by simply changing the order in which users will end up visiting those exhibitions upon solving a clue. Similarly museums can also create interactive challenges for other visitors whereby solving the mystery, based upon historical facts, results in prizes or discounts.

In short contactless communications and in particular NFC can be deployed in a wide range of scenarios creating a unique experience for the users.

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Appendix A
List of Publications

Appendix A: List of Publications

Journal Publications

Providing Location Based Information/Advertising for Existing Mobile Phones Users
Rashid O., Coulton P, and Edwards R."Providing location based information/advertising for existing mobile phone users", Journal of Personal and Ubiquitous Computing, Springer London, November 2006, pp 1-8.

PAC-LAN: Mixed Reality Gaming with Mobile Phones
Rashid O.,Bamford W.,Coulton P.,Edwards R, and Scheibel J. "PAC-LAN: Mixed reality gaming with RFID enabled mobile phones", ACM Computers in Entertainment,Vol 4, Issue 4, October, 2006.

Extending Cyberspace: Location Based Games using Cellular Phones
Rashid O., Mullins I., Coulton P. and Edwards R. ACM Computers in Entertainment, Vol. 4, Issue 1, January 2006.

Creating Entertainment Applications for Cellular Phones
Coulton P., Rashid O., Edwards R. and Thompson R. ACM Computers in Entertainment, Vol. 3, Issue 3, January 2005.

3-D Space Time Visualization of Player Behavior in Pervasive Location Based Games
Coulton, P.,Bamford, W., Cheverst, K., and Rashid, O., 3D Space-Time Visualization of Player Behaviour in Pervasive Location-Based Games," International Journal of Computer Games Technology, vol. 2008, Article ID 192153, 5 pages, 2008. doi:10.1155/2008/192153.

Book Chapters

Mobile Games: Challenges and Opportunities
Coulton, P., Bamford,W., Chehimi,F., Edwards, R.,Gilbertson,P.,and Rashid, O., Chapter in Advances in Computers Volume 69, Academic Press, June 2007, ISBN-13:978-0-12-373745-8.

Using In-built RFID/NFC, Cameras, and 3D Accelerometers as Mobile Phone Sensors
Coulton, P., Bamford,W., Chehimi,F.,Gilbertson,P.,and Rashid, O., Chapter in Mobile Phone Programming, Springer, 2007, ISBN 978-1-4020-5968-1.

RFID and NFC on Mobile Phones
Coulton P., Rashid O., and Edwards R., Chapter to appear in book, RFID Handbook: Applications. Technology, Security and Privacy, CRC Press to be published Sep. 2008.

Conference Proceedings

Experiencing 'Touch' in Mobile Mixed Reality Games

Coulton, P., Rashid, O., and Bamford, W., "Experiencing 'Touch' in Mobile Mixed Reality Games", Proceedings of The Fourth Annual International Conference in Computer Game Design and Technology, Liverpool, 15th – 16th November 2006.

Implications of IMS and SIP on the Evolution of Mobile Applications
Rashid O., Coulton P., and Edwards R. Tenth IEEE International Symposium on Consumer Electronics, St. Petersburg Russia, 2006.

Running with the PAC
Coulton P., Rashid O., Bamford W., and Edwards R. 1st World Conference for Fun 'n Games, June 26-28, 2006, Preston, UK.

The Mobile Phone as a Digital SprayCan
Garner P., Rashid O., Coulton P. and Edwards R. to appear at ACM SIGCHI International Conference On Advances In Computer Entertainment Technology, Hollywood, USA, 14-16 June 2006.

PAC-LAN: The Demo
Coulton P., Rashid O., and Bamford. W. Third International Workshop on Pervasive Gaming Applications - PerGames 2006, Dublin, Ireland, 7th May 2006.

Utilizing RFID for Mixed Reality Mobile Games
Rashid O., Coulton P., Edwards R., and Bamford. W. in Proceedings of IEEE International Conference on Consumer Electronics, January 2006.

Implementing Location Based Information/Advertising for Existing Mobile Phone Users in Indoor/Urban Environments
Rashid O., Coulton P., and Edwards R., in proceedings of IEEE Fourth International Conference on Mobile Business, Sydney Australia, July 2005.

Mobile Information Systems Providing Estimated Time of Arrival for Public Transport Users
Rashid O., Coulton P., Fisher A., Thompson R. and Edwards R., in Proceedings of IEEE VTC-Spring 2005, Stockholm, Sweden.

Symbian, J2ME and Brew: A Comparative Study of Mobile Application Development
Coulton P., Edwards R., and Rashid O., in proceedings of ASU/ IEEE International Conference on Information Technology, September 2004, Amman, Jordan.

A Comparative Study of Mobile Application Development in Symbian and J2ME using the Example of a Live Football Results Service Operating over GPRS
Rashid O., Thompson R., Coulton P., and Edwards R., in Proceedings of IEEE International Symposium on Consumer Electronics, September 1-3, 2004 Reading, UK.