UHYPERLINK: AN ORGANIZED METHOD TO COLLECT, MANAGE AND STORE OBJECT HYPERLINKS USING RFID

by

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I dedicate this thesis to my beloved wife who has inspired me to follow my dreams.

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ABSTRACT

Advancements in ubiquitous computing are allowing users to search and add information to the web for surrounding objects from any location at any time. With more and more information being added to the web, it is becoming hard for users to find the information about an object that surrounds the user at a given context. Current web based search engines are putting local organizations and local objects at a disadvantage in many cases. In recent years, a new era of object hyperlink has evolved which connects physical objects to web based content via graphical machine readable tags or automatic identification technology such as Radio Frequency Identification (RFID). Users can view the obtained information on the mobile device. However, users today may choose to process the obtained information on more than one computing device based on the activity or task that they are performing. The learning curve for transferring the obtained information to different devices is an addition to the information overload problem.

In this thesis, a user centered Radio Frequency Identification (RFID) based object hyperlink solution is proposed. First goal of this thesis is to provide users with the ability to easily collect information from any given object hyperlink location. UHyperlink is designed to provide users an ability to store object hyperlinks from different organizations to a central repository where users can analyze and recapitulate the collected information. UHyperlink is also designed to provide users with more than one object hyperlink where relevant links are presented to the user based on context and user request, reducing the information overload problem. From the experimental setup and evaluation of this thesis, it can be said that it is a novel and interactive approach to object hyperlink which provides users with different results based on user requirement.

LIST OF ABBREVIATIONS USED

RFID	Radio Frequency Identification
NFC	Near Field Communication
QR	Quick Response
URL	Uniform Resource Locator
I/O	Input / Output
RF	Radio Frequency
MP3	Motion Picture Experts Group version 3
USB	Universal Serial Bus
ISO	International Organization for Standardization
KHz	Kilo Hertz
MHz	Mega Hertz
GHz	Giga Hertz
UHF	Ultra High Frequency
EPC	Electronic Product Code
TID	Tag Identification
ATA	Air Transport Association
HCCB	High Capacity Color Barcode
GPS	Global Positioning System
SMS	Short Message Service
MoVIS	Mobile Visitor Information System

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CHAPTER 1 INTRODUCTION

Text is one of the oldest and primary sources of communication and information gathering. Traditionally, text was written and interpreted in a linear fashion. With advancements in printing technology and user adaptation, hypertext became popular. Studies indicate that an average reader can read various parts of the linear text in a non-linear fashion and synthesize them in a related fashion, from which they can create a meaningful summary [1]. The term "hyper" indicates that user may or may not choose to read the content in a linear fashion [1].

The benefits of hypertext really became visible to computing and digital information processing with the evolution of World Wide Web. As computing hardware and software became more capable of processing multiple data formats, the term "hyperlink" as the clickable links became popular [3]. The term hyperlink is often interpreted as a link which leads users from one form of web content to another document or a web based object [3]. However, it is not necessary that hyperlink is limited to two web based objects.

The term object hyperlinking can be defined as a link between a physical object or location and a web based object. The concept of association of a physical object and digital object has been there since a long time. Barcode and other machine readable data input methods were popular for inventory and object tracking since a long time now [5]. However, the computational hardware and software was not evolved to process hypertext that can relate to other objects on the web. With advancements in mobile devices; the notion of associating user readable text on mobile device via machine readable data input methods started becoming a reality. Hence, object hyperlinking methods of graphical tags and Near Field Communication (NFC) have become popular.

Graphical tags are similar to a barcode system, where it is made up from a machine readable data format image. Quick Response (QR) code, Datamatrix, Semacodes, SPARQCode, High Capacity Color Barcode, and barcodes are considered as types of graphical tags [13]. Among all, QR codes are becoming popular for object hyperlinking [14].

Near Field Communication (NFC) can be identified as a subset of Radio Frequency Identification (RFID) technology. A typical RFID system contains tag, reader, middleware and a server [50]. RFID technology can be divided as active and passive. When an RFID tag has an antenna and it is powered by the reader's electromagnetic waves, it is considered a passive tag. If the tag contains a battery to respond to the reader, then it is considered as an active tag [11]. The major reason behind RFID popularity is no requirement for line of sight, and that is why the prediction about "Internet of things" is becoming a reality [10, 11]. The "Internet of things" mainly describes a situation where all the physical objects are tagged with RFID, Sensor network or other forms of input output device; where they are connected seamlessly to the web or other form of digital information processing system [51].

With advancements in web technologies and "Internet of things", information on the internet is growing. After the introduction of web 2.0, users are uploading more content on the internet than ever before [8]. Therefore, an average user has to spend more time on the internet when it comes to researching on a particular topic due to wide variety of content, and locating the content that is useful to the user [7]. Hence, the task of information retrieval is becoming more and more challenging everyday [6, 7]. "92% of Internet users say the Internet is a good place to go for getting everyday information" [7]. Unlike a database search, information retrieval for everyday information is geared towards a goal which is achieved via researching various results. With Web 3.0 or "Semantic Web", major web based search engine providers are trying to provide user with a personalized content [8]. The reason to go to towards personalized search is because it is hard to produce search results as a generic result [7]. For example, it is hard for the search engine to balance the results for the search term "local restaurant" where one request is by an 18 year old and another by a 65 year old person. Personalized content may or may not be related to user's surroundings. However, in most cases users are looking for information which may be related to their surrounded area based on the given context [9]. This is one of the reasons behind object hyperlinking evolution and popularity.

Object hyperlinking provides users with local and global information from the objects that surrounds them at the given time. Hence, it is cutting down the effort for the user to find information about a particular local or global entity without relying on web based search providers. An average user is limited to a geographical location and user goals are limited to the environment around the user. If the objects around the user contain the relevant information then users can pick the information where relevancy depends on the user's task. This way, user is not limited to web based search provider algorithm results. Users are turning towards object hyperlinking because web based search usually put less traffic, less linked and limited keyword local organization websites at a disadvantage when users are interested in finding a local entity. Traditional systems were confined in stationary execution environment. Therefore, the context was not as dynamic as it is seen today. As computing devices are becoming more and more portable, users can carry them to different places for different activities. Users are also surrounded by embedded and other user's mobile devices. Low cost of hardware, software and increasing competition has made user expectation higher [31, 32, 52]. It has made object hyperlinking one of the new ways of personalized information gathering.

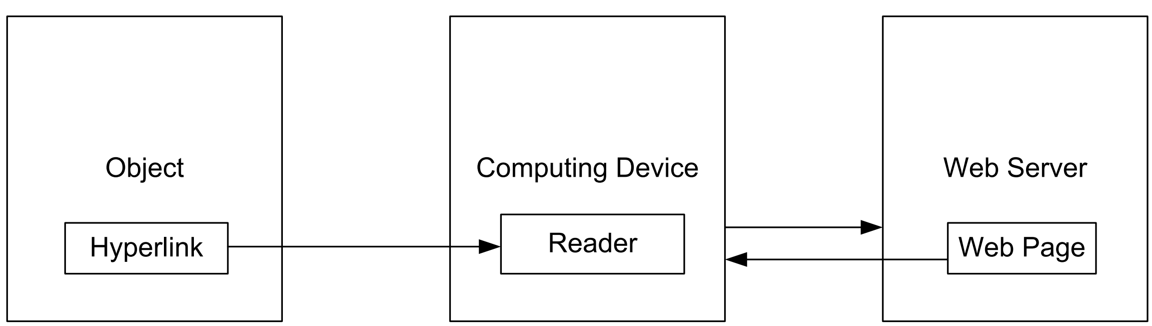

Figure 1.1 Components of an Object Hyperlink System

As shown in Figure 1.1, an object hyperlink system has six main components; object on which the tag is placed, tag, reader, computing device with I/O, internet service provider, and the web container containing information. Object can be of any solid physical form on which a tag can be placed. Here, tag and reader technology can be QR code, NFC or other suitable technology. Traditionally, computing device is a smartphone which has hardware and software capability to interact with input processing datatype. Internet service provider can be a wireless service provider for the mobile device. Web based object such as webpage, which contains the text that is associated with the object or user in some form. The association of webpage, object and subject is dependent upon tasks, time, location and user activity. In proper terms, we can say it as context history [31]. More details about context aware computing are covered in the background study section.

In this thesis, a user centered object hyperlink approach is proposed. The term UHyperlink is a combination of terms User centered and Object Hyperlink, where User and Hyperlink are the key aspects.

The rest of the thesis is as follows. Chapter 2 contains background study for the understanding of the current projects and problems that this thesis is trying to solve. Proposed solution is described in Chapter 3. Analysis and comparison with other projects can be found in Chapter 4. Chapter 5 contains concluding remarks, summary and future work.

CHAPTER 2 BACKGROUND

2.1 CONTEXT AWARE COMPUTING

Since object hyperlinking is associated with computing at different locations, time and contexts, it is necessary to understand the fundamentals of context aware computing. Two users at the same location can interpret and manipulate any given object in a different format to reach either same or different goal. Context can be divided as user context, physical context, computing context, and time context [30, 31]. Hence, it is necessary to understand scope, relation, abstraction and separation [9]. Software requirement for any application starts with scope. Therefore, scope decides how many context possibilities need to be taken into account. Perception toward everything is based on relation between the given object and surrounding objects. Abstraction and separation can be defined as a method of applying the given object based on location, activity, surrounding objects and time [9]. Guanling Chen and David Kotz defined context as "the set of environmental states and settings that either determines an application's behavior or in which an application event occurs and is interesting to the user" [31]. Term "set of environmental states" is the key to defining context mathematically. Since an environment contains Users (U), Process (P), Location (L), Time (T), Device (D), Information (I) and Services (S); context must carry them. Therefore, it can be defined as C (Context) is a set which contains [52]:

$$C = \{U, P, L, T, D, I, S\}$$

It is important to understand that all the values in this set are interconnected to each other. This interconnection can be described as relevance R. Probability of relation between all the elements in the set can be describe as Relevance Factors (RF).

$$R = C \times RF$$

In this equation, C is a context and RF is relevance factors [52]. Cross product of given two sets can have many combinations and possibilities in the real world. The step between context and context aware computing can be context awareness. Albrecht Schmidt defines context awareness as "The knowledge about the user's and IT device's state, including surroundings, situation, and, to a lesser extent, location" [9].

It is a common misconception that context aware computing is mainly related to ubiquitous computing. Even for applications with restrictive scope, such as an operating system for an airplane; context is “dynamic”. Pilot in command, knowledge of the pilot, time and state of aircraft define a different context for the operating system. This means that a context aware application should be adaptive [32]. A classic example of adaptability is video games where difficulty level changes as the user has more skill. Since the video game is keeping up with the user's skill, users are always interested in finding out “what if” possibilities at the next skill level. Expanding on this, we cannot see context aware application as a one-to-one relation between user and application. It should be seen as one-to-many relations [32]. Many other devices and physical variables are associated with the user and the device. On the other hand, several context dimensions are also related to each other. To some extent it is possible to relate and classify these dimensions.

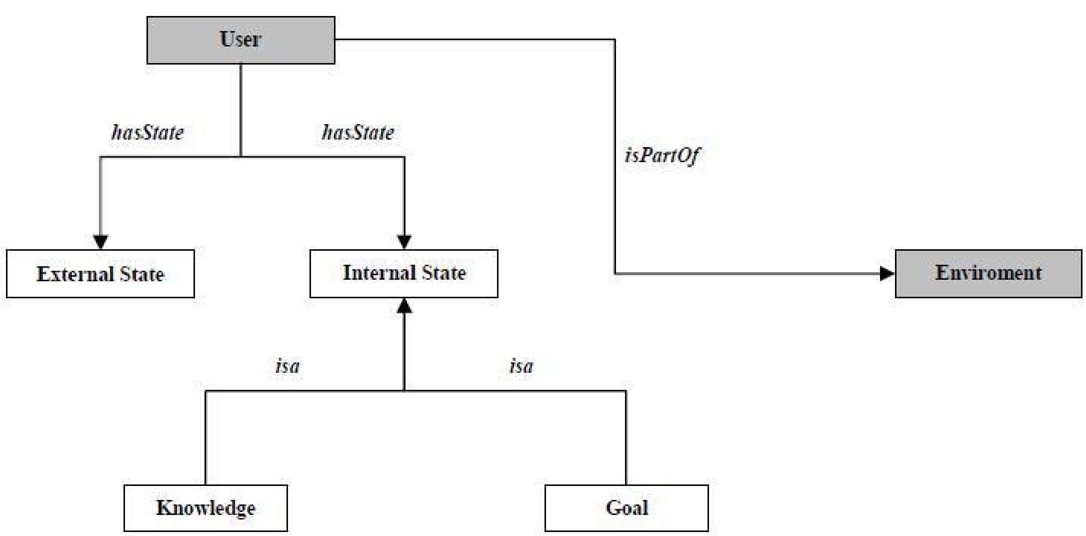

Figure 2.1 Associating User, Goal and Location into One Picture [32]

Figure 2.1 shows how user's goal is associated with other elements in general. Knowledge changes as user is progressing towards the goal. The external state changes based on the environment the user is in. Figure 2.1 only shows a small ontology for context elements and relationships between elements. An environment is the key element which has many variables which are shown in Figure 2.2.

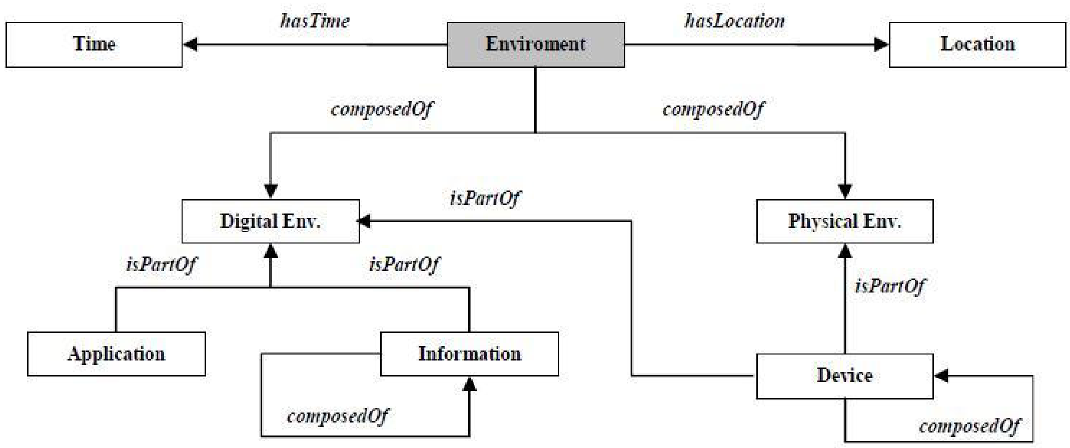

Figure 2.2 Context Dimensions [32]

As shown in the Figure 2.2, context has a major effect based on location change and what time factors are associated with it. Based on location and time user may have access to certain computing devices. In addition, other low level contexts are also important. Starting with orientation as an example, iPad or iPhone adjusts the display when held vertically or horizontally based on device position. Network bandwidth at every location becomes important in order to communicate with nearby objects or central infrastructure. Most easy context tracking is time. Most of the computing devices are equipped with timestamp capability to collect context history for training [31]. Based on the physical environment and device available, user is limited to what digital environment is available and what information is available from that application. This information in turn affects user's knowledge and goal in the long run.

One of the main challenges for context aware applications is diversity of systems. Ensuring the accuracy of location, identity, and establishing secret communication are key factors that depend on centralized or distributed architecture. There is still a debate of centralized and distributed architecture which is slowing down the problem solving the context aware computing. Balancing the benefits from both systems can be challenging. Other factors such as adaptability based on activity, and identity based on context history needs a lot of improvement. Since device availability and user application usage behavior are dependent on location and time, it is necessary to understand what types of devices are used by users and what device is used at what context.

2.2 ISSUE OF MULTIPLE DEVICES

Lower cost of hardware and advancements in ubiquitous computing is allowing an average user to have multiple devices. These devices may include desktop computer, laptop, MP3 player, smartphone, e-Reader, digital camera and other devices which can synchronize with computers. With multiple devices, an average user is able to accomplish the tasks more efficiently. A user task can vary from a simple task to a collection of multiple simple tasks to reach a long term goal [2]. Multiple tasks can form an activity which may span multiple computing devices [15]. Accomplishing an activity via multiple devices provides convenience of using the device based on location and context. However, it has created a new problem of information management across multiple devices. With different devices running different software compatibility, information flow from one device to another device is becoming important for users to manage the information. New smartphones and tablet computing devices are trying to consolidate features like MP3 player, digital camera and internet surfing. However, users still use specialized devices for better quality results because generic devices do not provide the goal satisfaction that specialized devices are capable of [15].

Studies show that users have one personal computer, one work computer, MP 3 player, digital camera, USB storage devices or tablet computing device [15]. Combining generic and specialized devices, an average computer savvy user today owns about 5.96 computing devices. These devices include devices that can connect to a computer to transfer data. To understand the relation with context, it is necessary understand how and where these devices are used.

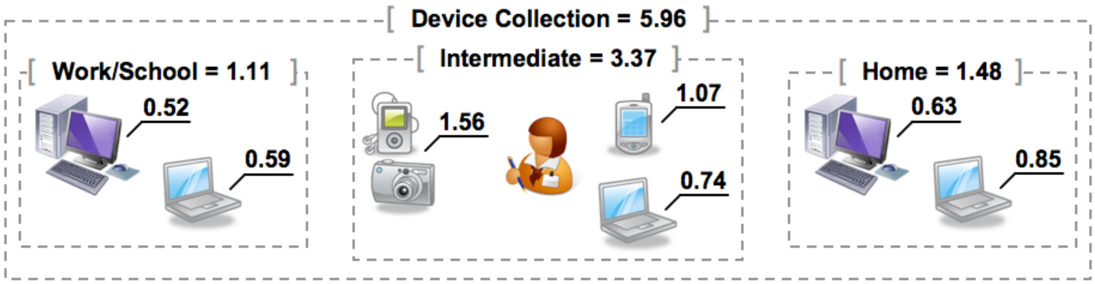

Figure 2.3 Device Distribution and Usage Summary [15]

Figure 2.3 shows the distribution of devices and usage summary based on the survey. At the time of the study, tablet computing devices were not popular but it is clear that users do prefer to work more on the laptop. The survey revealed many reasons as to why laptop was more popular. One of the reasons was that participants had hard time transferring information from their smartphones to their computers. Even though smartphone was capable of performing computation and other functions, users preferred to chose the devices based on what activity and what task they wished to perform. To summarize, it was the ability of laptops to seamlessly integrate with different location and environments. Laptops had the ability to complete all types of tasks with a bigger screen and easier data input format [15].

There are many alternatives available to overcome the issue of transferring the information from one device to another. Portable media, email and web based services are some of the popular ones that users use on a daily basis [15]. Issue with portable media is that it may or may not be available at the location where user wants to transfer the data from one device to another. E-mail is one of the popular solutions that an average user uses to manage and transfer information from one device to another. Another study claims that many users experience an email overload as tracking and finding email is harder as number of emails increase [2]. Hence, managing a task via email is not a long term solution. Transferring information via web based applications has a disadvantage of privacy issues. Nevertheless, growing popularity of Google Documents and other cloud based services show that most users do not carry sensitive information and are willing to sacrifice a part of their online privacy [53, 54, 55].

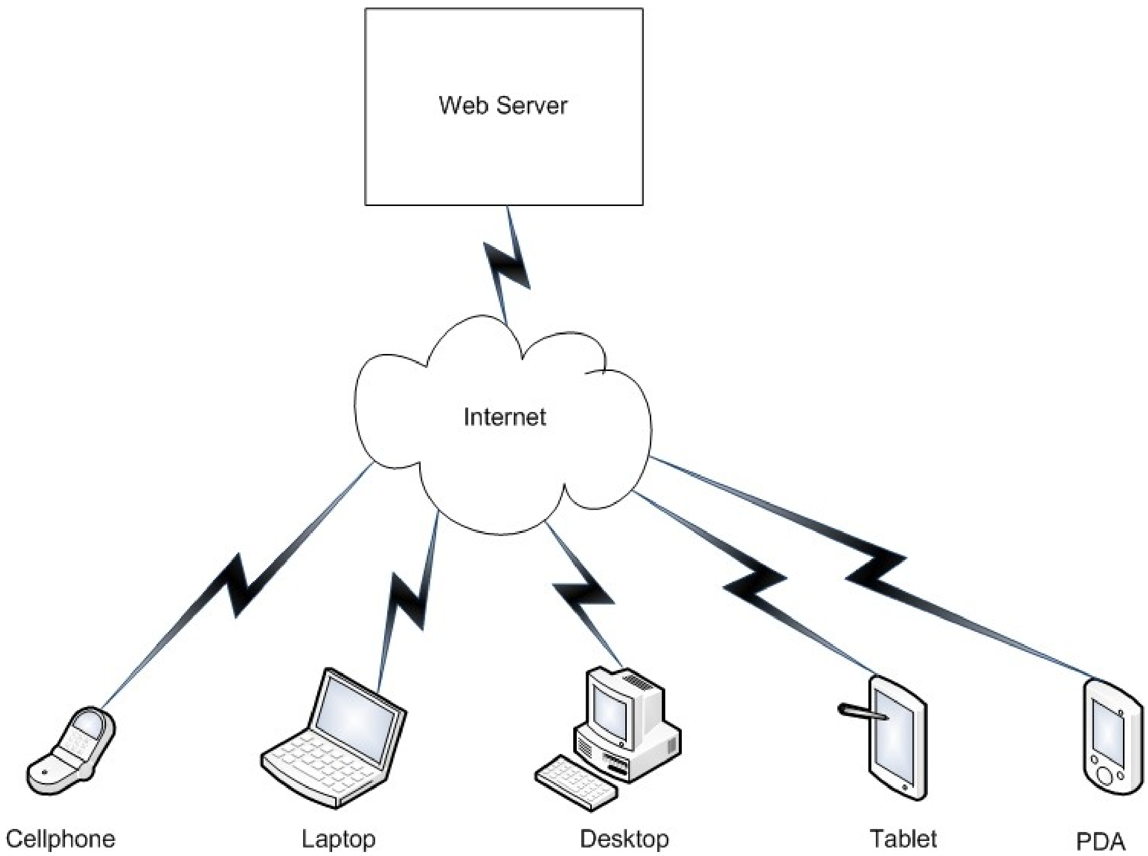

Figure 2.4 Web Based Application Reachability to all Devices and Tasks

With web based application, it is possible for the user to seamlessly perform the activity from one device to another. Hence, it is one of the ideal formats for object hyperlinking.

2.3 TECHNOLOGY OVERVIEW

There are many input methods available for computing devices today. One of the basic blocks of object hyperlinking requires an automated data input to the mobile or any form of computing device. Since this thesis is focusing on Radio Frequency Identification (RFID) technology, section 2.3.1 focuses on RFID and then other graphical tags technologies such as Quick Response (QR) code, Datamatrix, Semacodes, SPARQCode, High Capacity Color Barcode, and barcodes are discussed.

2.3.1 RFID

Radio Frequency Identification (RFID) technology dates back to 1935 [63]. During Second World War, Germans realized that when an aircraft was rolled; it created a certain pattern on the radar. This was used to identify host objects and it was one of the first passive forms of RFID system where waves reflected in a pattern which identified objects. On the other side, British air force implemented Identify Friend or Foe (IFF) system where aircrafts were tagged with a signal emitting device which identified their objects. It was one of the early forms of active RFID systems that we see today. Around 1973, the commercial and industrial RFID that we see today came into shape [64].

Similar to any other technology, RFID has standards that divide the types of technologies. In North America, Auto-ID Center has identified different standards for RFID. In Europe, Asia Pacific and other parts of the world, International Organization for Standardization (ISO) defines the RFID standards [27]. Before understanding the standards, it is necessary to understand the frequency distribution. Frequencies decide tag and readers's read / write distance and other configurations for standards. Starting with passive tags, RFID Low Frequency (LF) tags operate at 125 kHz. The most popular NFC operates at High Frequency (HF) of 13.56 MHz. Popular inventory management tracking tags work at Ultra High Frequency (UHF) of 860-960MHz. Active tags work at Ultra High Frequency of 433 MHz and 2.45 GHz Microwave frequency respectively [12].

Auto-ID Center has divided the active and passive technology into different class and generations based on release. Read only passive tags are Class 0. The tags on which you can write once and then read unlimited times are under Class 1. The most popular type of multiple reads and writes tags are under Class 1 Generation 2. Unlimited write type passive tags come under Class 2. Class 3 contains semi passive tags which is a balance of active and passive. A semi passive tag has a battery but it is used only based on conditions specified. Class 3 type tags are still under research and are not as popular as other two types. Active tags are considered class 4 tags. Readers of both types come under class 5 [65].

Figure 2.5 Passive RFID Tags

A general RFID tag mainly contains an Antenna and the Chip as shown in Figure 2.6. The chip mainly contains RF module, Logic Circuits and Memory. RF module contains Power Regulator, Rectifier, Voltage Reference and Backscattering where Rectifier generates power and backscattering is the generation of reply message. Logic circuits include Clock Extraction and Demodulator. Clock Extraction extracts time from reader and demodulator converts data symbols from reader. Memory is different based on tag type, manufacturer and capacity [66].

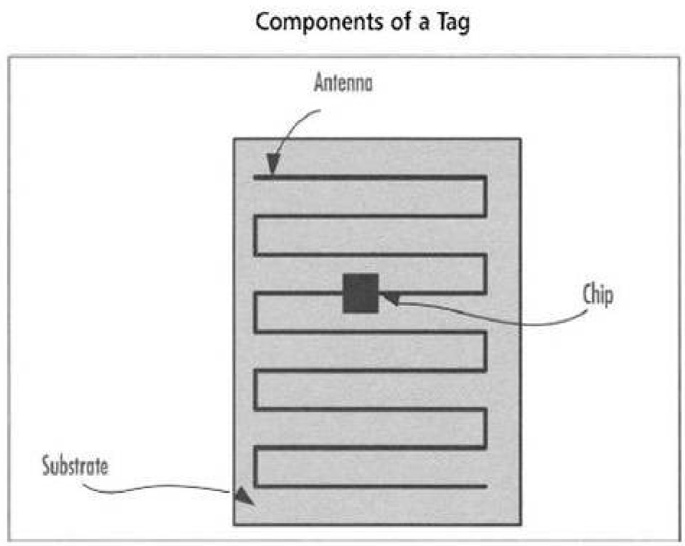

Figure 2.6 A Typical RFID Tag [66]

A typical Electronic Product Code (EPC) Class 1 Gen 2 tag of 2048 bits with 96 bit scheme divides this memory into 96, 224, and 1728 bits. First 96 bits include header, EPC Manager, Object Class, and Serial Number. Next 224 bits include Status Control, Information about read only cells, and Kill command processing data. 1728 bits can be open for user or it can be divided into four sub parts as per ISO 18000-6 standard [12]. It may include user data, TID and reserved bits where TID is the unique ID given by the user. ISO 18000-6 standard is one of the compatible standards with Auto-ID EPC Class 1 Gen 2 standards [66, 12].

For the implementation and discussion of this thesis, High Frequency 13.56 MHz was used. Conversely, the thesis implementation and design allows any of the RFID technology to be used but the NFC 13.56 MHz was chosen based on device availability.

2.3.2 OTHER TECHNOLOGIES

Other data input technologies include Quick Response (QR) code, Datamatrix, Semacodes, SPARQCode, High Capacity Color Barcode, and barcodes. Although many of these technologies are considered a sub category under barcode, QR code has gained more popularity when it comes to text based object hyperlink technology. QR code was originally invented by Toyota for a quick information decoding [60]. Figure 2.7 shows an example of QR code.

Figure 2.7 QR Code Pointing to http://www.cs.dal.ca/

Data Matrix 2 dimensional barcodes look very similar to QR codes and major applications of use include Air Transport Association (ATA) and Electronic Industries Alliance (EIA) for small electronic parts [67]. The benefit of Datamatrix is that compare to QR code they can be decoded with different contrast ratios. Semacode is a sub version of Data Matrix technology [68]. SPARQCode is a sub version from QR code, optimized for mobile devices [69]. High Capacity Color Barcode (HCCB) is a term given by Microsoft for color coded 2 dimensional barcodes [70]. Due to the colors involved, it can store more data compare to other black and white barcode technologies.

For the scope of this thesis, QR code can also be used. Yet, RFID is chosen due to benefits of no requirement of line of sight and ruggedness factors.

2.4 CURRENT METHODS OF OBJECT HYPERLINKING

Evolution of object hyperlinking has been done in many areas via different technologies. For the scope of this thesis, this section will look at the subset of RFID based object hyperlinking technologies that have played a role in hypertext information collection. Yet, it is necessary to understand where the origins of this technology came from. In 2001 when global positioning system (GPS) was not a widely accepted technology, Hewlett Packard started a project named Websign. This project was trying to introduce the concept of a smart city where it was termed as "CoolTown" [4]. The research in that paper was trying to solve the problem of a visitor to a new location. Essentially the physical location had different cellular towers, which located the wireless device in the range. If the device was websign enabled, then it would contact the web server and relay the information related to that location to the wireless device [4]. This project can be considered one of the earlier forms of object hyperlinking that we see today. Since it was mainly targeting for location based user behavior; advancement in GPS and other location based technologies have taken over the original concept for user surrounded place detection.

In 2004, a project named yellow arrow started in New York [56]. When smartphones were not popular, Short Message Service (SMS) was one of the popular methods of text based wireless communication. Yellow arrow utilized the SMS technology to exchange text based information to users. A big yellow colored arrow indicates to users that there is more information than what you can see in physical context. The core concept of yellow arrow lies in the idea of sharing stories, memory, crazy experiences and information about famous landmarks. The arrow contains a telephone number and a yellow arrow code. When the code is sent to the given number, users receive the associated story that is related to the place where the arrow was placed. Began as an art project, the concept has reached 35 countries and 380 cities worldwide [52]. After the smartphone revolution, users have the ability to browse the web and receive emails on the mobile device which has declined the use of SMS [58].

Introduction of smartphones also created different streams in object hyperlinking via different data input and output methods. RFID and QR code were two of the many technologies that are used for object hyperlinking. While this thesis will look at some of QR code projects, the major focus will be on RFID based object hyperlinking projects.

2.4.1 RFID OBJECT HYPERLINKING

In May of 1999, the research paper by Want et al. with the title "Bridging Physical and Virtual Worlds with Electronic Tags" was one of the first to consider an interaction between a user and a physical object [72]. The research discussed about presense of RFID on different types of objects such as documents with an RFID seal, books, photographs, watch and business cards. The idea of utilizing information in the tag and using them when needed was in the inception phase at this point. Due to limited computational hardware and software available at that point, the research did not gained much attention for next few years. By 2005, advancements in hardware and software in mobile devices was enabling handheld devices to have different forms of input and output. Enrico Rukzio et. al. proposed a framework for mobile interactions with physical world [37]. This research shows that a user can not only interact with other users with mobile device but options have expanded to other objects. Other objects may include physical objects such as text documents, image based output formats, public display, smart environments and other electronic devices. The research looked into various ways of interacting with physical objects via a mobile device. Unlike the yellow arrow, this was one of the beginning approaches to having an input datatype based hyperlink system for mobile devices. The research describes a concept called PhysicalWorldConnector which interacted with various input technologies. These technologies include audio, visual, user input, location, Bluetooth and RFID. One of the disadvantages with this approach is that users require an RFID or camera enabled device with the appropriate software to process the data input in a particular format.

Research by P. Välkkynen et.al. in 2006 shows the evidence that the emerging technology of object hyperlinking has many challenges as to user acceptance [36]. Since object hyperlink is a link which is part of the environment and acts as an ambient intelligence object, it is necessary to visualize the link to users in order to gain popularity. Since an average user was only aware of web based clickable links, mobile device based input and output object hyperlink was something that needed to be conveyed to the users. The main issues discussed in the research are about ambient intelligence challenges of communicating to the user about the existence of a link, the precise location of the link, the supported selection methods, and the action of the link. The research concluded with some of the formats that can be used as a visual sign to indicate that an object hyperlink exists at a given location.

During the same time period, the research paper by P. Välkkynen was one of the first versions of RFID based object hyperlinking systems [35]. The project Hovering was one of the initial versions of modern RFID object hyperlink that is popular today. The objective of Hovering project was to identify the usability benefits of getting information through hovering the reader as a form of collecting and using the information. The prototype was based on a Nokia RFID enabled mobile device and object hyperlink that would display different types of content possible through a RFID enabled business card. Types of content from the RFID tag included options such as calling the user or a website link. At that time a detailed study for user acceptance was still on the agenda. While user required an NFC enabled phone, it also required installing additional software for operating some of the features. Storing the collected information for future reference was also not an option which limited the user information collection.

In 2007, J. Schwieren and G. Vossen proposed Mobile Visitor Information System (MoVIS) prototype from the physical hyperlink research [3]. MoVIS was designed for Museums, were users can utilize RFID tags to obtain the information about collected artifacts and objects. MoVIS was one of the first prototypes that fulfilled the meaning of object hyperlink where museum objects had a link that had more content related to it, which user can read and analyze upon. This research proved the usability and expandability of the object hyperliking with RFID and laid out one of the first successful commercial architecture for the subject matter. The drawbacks of this design were that it was limited to a small domain and it required special hardware. The handheld devices were distributed to the visitors while entering the museum and when scanned, it displayed the information via a local repository. User was limited to local content available and the option to search at other web based resources was not available. Content transfer to different computing device and storing the content for future use was not an option.

Another research from T. Herting and G. Broll evaluated user acceptance for physical hyperlinks [38]. The study conducted in this research proved that users would prefer an object or physical hyperlink when it is available. This research proved that users are interested in gathering information from physical locations. The study looked at Presentation of Information, Physical Hyperlinks, Tagging, Broadcasting, Tag Emulation and 2-Way Interaction. It is important to note that study also evaluated users emulating tag via their device for making credit card payments. Users liked having the mobile device emulate the tag because it saved time but there was a raising concern about using the technology for financial transactions. The study also proved that even though some users seem confused with the operation of technology or interaction format, majority of users were keen about using the technology in general when the visual sign and presentation of information was properly formatted.

While above mentioned study proved growing concerns with using RFID tags for financial transactions, MasterCard successfully implemented RFID NFC technology to deploy RFID tag based payment system [40]. Other organizations such as Dairy Queen also introduced a points collection system via an RFID enabled card system where users can collect points based on the amount spent and obtaining rewards [39]. Since 2007, T Money has been very popular in Korea where mobile accessory contain an RFID tag which can be used to pay at various locations [46]. From the above mentioned three cases and other research, it can be concluded that users do have developed trust in the RFID systems even for financial transactions. On the other hand, none of the above and other RFID based financial tags or cards are used for hypertext use or to distribute and collect user content choice preferences.

Despite the fact that users were accepting RFID technology for various purposes, users were also accumulating various computing devices due to cheaper cost of hardware and software. The issue of multiple devices for users started to appear for users in computer and computer related professions. Around 2007, one of the interesting approaches was made with RFID to solve the problem. Smartphones generally allow synchronization to users' computer. Project ShifD allows users to synchronize user generated content between their regular mobile phone and website via either SMS or website, based on the device configuration [43]. ShifD uses RFID to detect if the phone is in the range of the computer and provides user an option that which content needs to be shifted. While this project utilizes text and RFID, this project has the main goal of inter device connectivity and does utilize object hyperlinking or other forms of incoming content from other users or organizations.

Around the same time period as ShifD, RFID awareness started to make an impression for end users. RFID was popular for tracking inventory systems and for business use since many years but advancements in software and cheaper RFID hardware allowed researchers and organizations to apply it to end user based applications. RFID wrist bands also started becoming popular for tracking user activity within a theme park, hospital or a cruise ship where user activity scope is limited to certain geographic location [47, 48, 49]. This has made user tracking possible for RFID deployments. Hospital and cruise ship solutions were mainly targeting user activity tracking and may not be seen as an object hyperlink as there is no content involved. Yet, the method proved that users are willing to keep RFID tags and it is a convenient option for users to utilize tap without a learning curve or investment in any device. The Coca-Cola project in a theme park allowed users to tap their wristbands to a facebook like RFID reader which updated the like count on the organization's facebook page for tracking ride popularity. Similarly to other projects, there is no text content flow involved other than the facebook like which can be seen as a partial object hyperlink system. In Mobile World Congress 2010 conference, an RFID based object hyperlink was implemented where users are given an RFID card which they can tap at various booths and an email was sent to the user with relevant information [33]. The disadvantage with this solution was that it is limited to the trade show as users would return the RFID card and it cannot be use anywhere else. They were able to track that user collected information from which readers but there was no user tracking involved that after the email is sent what content was actually useful to user. Also, it would be hard for users to locate that email and content after a certain period of time, if the user is using email on a daily basis [2]. Very similar approach has been used at other events to collect user based data and to personalize user content choices [59]. Nevertheless, other approaches do not send the information to users but they collect user behavior by tap history, social networking, personalized greeting and other customizations. This has been termed as "Activating the space" [59].

Recently, a study from Google has shown that users are looking for local information that is reachable by users on a daily basis. "Google Hotpot" uses RFID enabled smartphone to track local organizations via tagging them with RFID [34]. This allows users to rate their favorite places and other recommendations and reviews to be shared via mobile device or other computing devices. The solution also has a mobile app for users who do not have the RFID reader built into their mobile device and uses an alternative way of accessing information. The project is still being experimented in various areas of United States to evaluate the usability and popularity. While Android is one of Google’s main mobile device software platform, Android does provide capability to connect to external sources of RFID readers and tag emulators [44]. Nevertheless, this functionality is limited to certain hardware such as Samsung Nexus S smartphone which is a joint project with Google [45]. On the other hand, Microsoft surface has also introduced RFID content transfer compatibility which recognizes RFID enabled devices and displayed the content when that object is placed on the surface screen [59].

From ShifD to Google Hotpot, it showed that there have been developments on the ad hoc projects side in recent years. On the research side, there have been some developments in the past three years. Due to the popularity of various technologies, a research architecture named BIT was inspired from “Internet of Things”. BIT aimed to utilize the internet of things framework to identify 2D barcode and NFC objects and provide user with a single point of interaction on a mobile device [73]. One of the recent studies in Finland about public displays utilized object hyperlink technology by implementing RFID reader in the public display and tags assigned to the users. When a user approached the public display, RFID scan would identify the user and a WiFi or Bluetooth connection can be established via the app on the mobile device to interact with the display to get news, bus routes and current information. However, information was limited to mobile device interaction only. Hyperlinks to external websites were prohibited to ensure that larger display was replicated on the mobile device [74]. As discussed earlier, content management between different devices was also becoming an issue. Similar to ShifD project, a research in Germany proposed an NFC based content transfer solution to ensure a seamless transition of task application migration from one device to another device [75]. The proposed architecture used a migration server which kept track of application state and transferred the state to another device via a web server. It used NFC technology to detect the location of the user and if a bigger display computing device such as a desktop or laptop was available then mobile application can be transferred to that machine upon user’s wish by taping the RFID tag enabled smartphone. However, migration server does not manage any information collection such as object hyperlink or web based URL collection.

From the above study, it is observed that RFID based interaction is gaining popularity but convincing all users to have RFID enabled smartphone devices is a greater challenge. Mobile RFID reader may have a log of which tags are scanned by the reader but an average tag does not have information about the reader which performed the scanning on it. Therefore, either users or organization has a record of what tag was scanned where but both entities does not have all the records of what content was actually useful to which user. RFID tags, cards and other forms of RFID tags are becoming popular for financial transactions but there is no hypertext or text based information that is collected, stored and managed by users which can be referred in future.

2.4.2 OTHER PROJECTS

One of the reasons behind RFID not being used for text based information collection is popularity of other technologies. QR code is one of the top most used object hyper-linking framework which also follows the theory of having the QR code application on the mobile device and converting the information to a link [14]. Studies show that an average user has anywhere from 14 to 40 apps on the smartphone [16]. With hundreds and thousands of apps to choose from, users do have a burden to choose the right QR app that suits them [19].

Even though there are many applications of object hyperlinking using QR code, the application by Tesco was one of the most successful approaches to using the technology [61]. Since QR code scanning requires the user to stop at the location, start the app, adjust the lighting and scan the code; it was deployed at subway stations and users can scan the QR code while waiting for the next train. This project allowed users to complete a shopping task while on the way to office or home. Conversely, most of the QR code deployments are not as successful as Tesco or other implementations. It is because even though QR code is becoming popular, still a large number of users are not aware of the technology due to its complex look [17, 18]. In addition, based on the requirement of line of sight, lighting and QR code reader mode or app type; there are multiple issues reported of not being able to read the QR code [42]. When a user has to stop, start the app, adjust, and scan; user expects to have some useful information available right away that will benefit the user for the effort [19]. However, disappointments like not being able to read the code may result in lack of interest when it comes to scanning the code again [42]. Most organizations are using QR codes for a fancy look or a website link from which users are not gaining any useful content. Getting only the web URL or basic info from a scan is also a factor in declining user interest for the technology [19]. Studies also show that 2D barcodes are becoming popular for inverted use such as having the user show QR code for airline boarding [20,21]. Hence, we can summarize that users may want to carry the code but users are not interested in knowing more about the technology and downloading the software for it.

Other than airline boarding, one of the recent researches at MIT involved a research named PalimPost [62]. It was one of the first applications of inverted hypertext object hyperlink. Here, inverted means that user has the code and the personal computer or the computer at the given location is the scanner. In this method, user has a post it or a piece of paper on which the QR code is printed. User can open the documents and links that need to be bookmarked and scan the QR code. This action associates the code and the links or documents. Scanning the code again in future opens the bookmarked documents or links. Despite of many benefits, one of the major drawbacks include user has to manage of all the codes scanned so far on paper. Losing a code may mean losing those bookmarks. In addition, issues of line of sight and other general limitations of QR code apply as well.

In addition to above issues, the organization or individual who is applying all the tags may wish to know the number of scans on either QR code or the RFID tag. Current QR code systems do not allow easy tracking of scans. There are organizations that provide tracking at a certain cost and the user needs to generate all codes with that organization [24].

CHAPTER 3 PROPOSED ARCHITECTURE

Before going into details of the proposed architecture, it is necessary to understand the difference between targeted search and a goal oriented search. To understand it in simple terms, it can be compared with a database query and an information retrieval search. For example, when a user is specifying a query in a database for a book with a particular title; user knows what exact information is needed. On the other hand, when user is using web based information retrieval or web search for a given topic; user knows the goal but specifics for reaching that goal is not clear yet. Similarly, object hyperlink can be used for two purposes. First scenario is where a user has the object and knows what information or action can be found by going to the web based link. Second scenario is where user may or may not have the object but user knows what information is needed, yet details about the object needs more research.

The main problem with most of the past and existing systems is that a tag is providing only one link. If the user knows what exact information is needed, and the URL on the object hyperlink can help user reach the target; then it is a successful solution. On the other hand, in most of the cases where user knows what information is needed; a web based link browsing may not be required as user may get the same information from surrounding media or text description. When only one link is provided in an object hyperlink tag, users with a targeted search may not find the correct result from the given link as context will change relevancy factor parameters.

From the background study, it can also be concluded that despite of multiple devices and all in one feature smartphones, users still use laptop and desktop to accomplish their goals. Small tasks such as finding weather or an address is easier on a smartphone but activities such as finding a vacation package which comprise of multiple tasks require laptop or desktop as they require more time to research and there could be a variable time break between two tasks. Hence, having a link on the smartphone is not useful when a user needs to refer it after a given time period on a computer. Time is a major factor in context change. Any acquired URL through an object hyperlink may be used in a different context at a different time. Designing an all in one context requires calculation of many possibilities which is not an efficient solution. Instead, it is resourceful to monitor user activity for a given object hyperlink and calculate the context based on the history. Some of the existing solutions do monitor user activity but user does not have a full record of what content was acquired by object hyperlinks in the past. In addition, users have to acquire, learn and apply a synchronization method if they wish to transfer the content to other devices. Therefore, it can be summarized that a solution that does not require user to spend much time and resources to collect information and yet allowing different context possibilities and information management will allow users to utilize full potential of object hyperlinking.

3.1 ARCHITECTURE OVERVIEW

The proposed solution has three foundation concepts. First and the foremost concept is that instead of the object having the tag, tag is assigned to the subject. Object is assigned a tag reader. Second is that the obtained hyperlink is sent and stored on the web instead of the user's device which allows user to access from any device without any synchronization. The last one is that the obtained hyperlink can retrieve related links from the information provider as well as on the web.

Starting with the first concept where a tag is assigned to a user instead of an object, it is necessary to understand that RFID was chosen over graphical tags due to various shapes and sizes, ruggedness and no requirement of line of sight. This way RFID allows user to choose a tag that fits user needs. Even though this can be achieved by any RFID technology, this thesis is targeting the solution based on Near Field Communication (NFC) frequency. Using any long range RFID frequency will need access control complications to filter the user willingness to collect information or user may receive unwanted data. NFC allows users to tap the tag on the reader and specify the willingness. After a user specifies willingness to collect information, an RFID reader collects user's tag ID then sends reader location, tag ID and object information to the web. A web based UHyperlink solution will store the object information and reader location in the tag ID's container. User can log in via any device by providing tag ID and the authentication mechanism. User is displayed the object information divided by location category where options of retrieving more information from the reader location or web based search options are given. Figure 3.1 shows above described the basic concept structure.

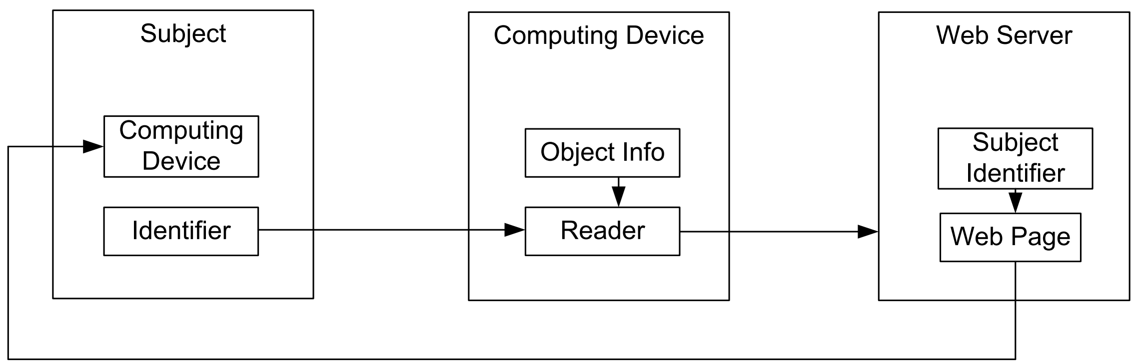

Figure 3.1 Foundation Concept

Comparing figure 3.1 with 1.1, the major difference is that in figure 1.1, object is residing at a given location where in figure 3.1 computing device or reader is residing at a given location. Object may or may not be there with the reader but object is associated with the location where reader is placed. To expand, we can elaborate the components of figure 3.1 as shown below in figure 3.2.

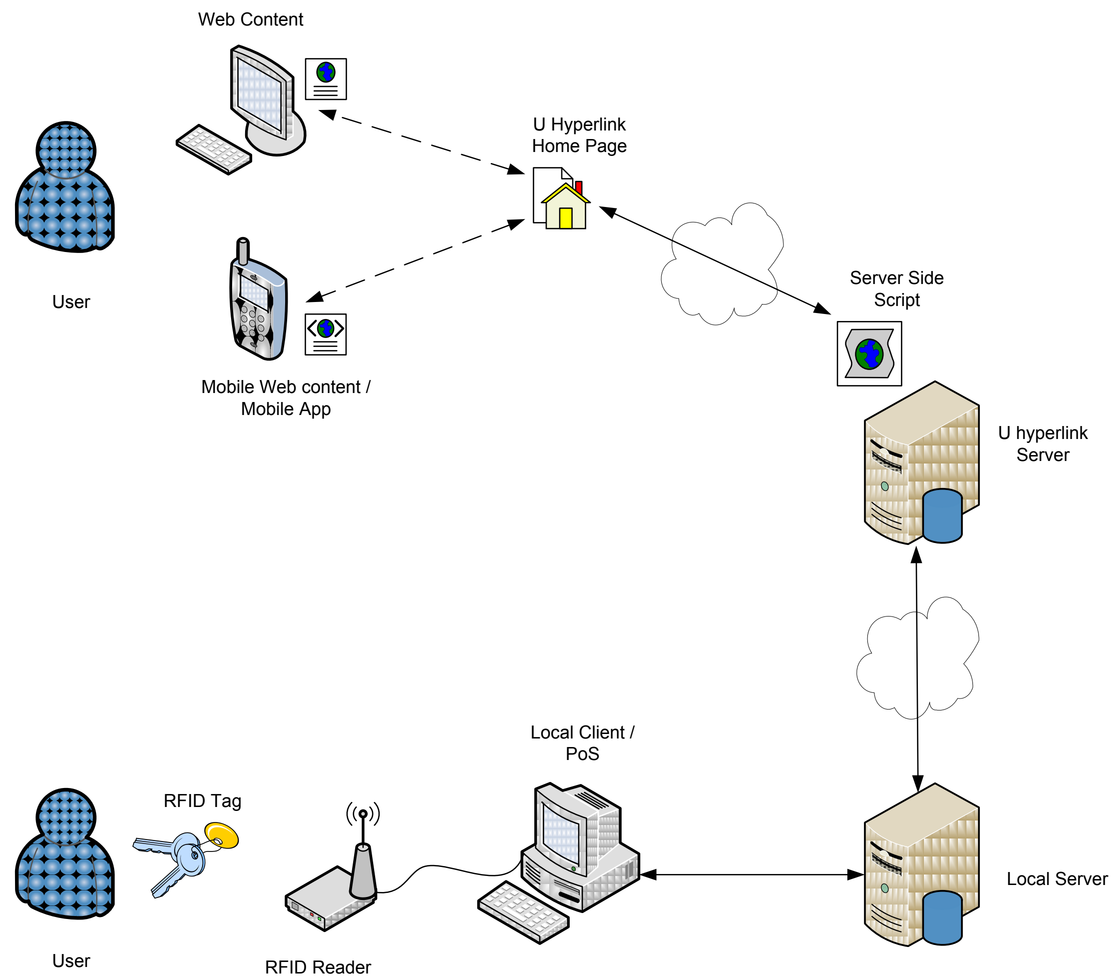

Figure 3.2 UHyperlink Architecture and Components

Starting from the bottom left, user has the RFID tag as a keychain, which is scanned by an RFID reader. User can choose any shape and size of the RFID tag and register it with the UHyperlink system. Next component is the RFID reader fitted on the location from where user would like to obtain information from. Local client computer is the machine which processes the RFID data. Local server maintains the object information and it may maintain user history, transaction history and other statistics. It is important to note that local client and local server is a logical separation and they can be in a one physical machine or may be divided into two or more separate entities based on data load. UHyperlink server is the central repository where all user accounts are created and all locations send the object related information to. When a user accesses the UHyperlink account via one of the computing devices, the server side script processes the information and displays to the user based on the request.

Before looking at the flows, there are some assumptions that need to be taken into consideration. First, all RFID tags have to be registered with the system. When registering the tag, users may or may not choose to specify their personal information. The proposed solution only requires tag ID, username and password from the user. Second, all RFID reader and local computers are also registered with the system and configured to communicate with UHyperlink server. Since this thesis is focusing more on object hyperlink content flow in relation to users, third assumption is that communication is secured by any suitable algorithm based on usage. Proposed solution is not enforcing the collection of any user, organization specific confidential or financial information by design. Therefore, security threats are minimal. From a software security perspective, an MD 5 for message integrety check and a firewall to prevent Denial of Service (DoS) attack should suffice.

In the proposed architecture, local server and local client are the components that may be configured differently by different organizations. Therefore, the proposed architecture can be configured in two ways depending upon organization local server specification or information need. First and the primary way is where local server owned by the organization is capable of sending new or related information when user is requesting more information. Secondary configuration is where orgnization sends all the information in one transaction.

3.1.1 CONFIGURATION A

When a user is in a given geographic location, the location will have RFID reader fitted on the premises. Upon user's wish, user will tap the RFID card to the RFID reader and tag ID will be transmitted to the local machine via RFID reader. Local machine will send the tag id, reader id and location information to the local server where it will analyze that what information should be sent to the user based on time, RFID reader's location, context and user history. More local server processing for personalized content will benefit the UHyperlink solution but it is out of the scope of this thesis at this point. Local server will send the related links to the UHyperlink server along with search criteria keywords. If the user wishes to search for the object related information on a configured search engine, then the received keywords will be used. Once the information is received by UHyperlink, it will store the information in relation to the tag id of the user. The steps so far are shown in figure 3.3 below.

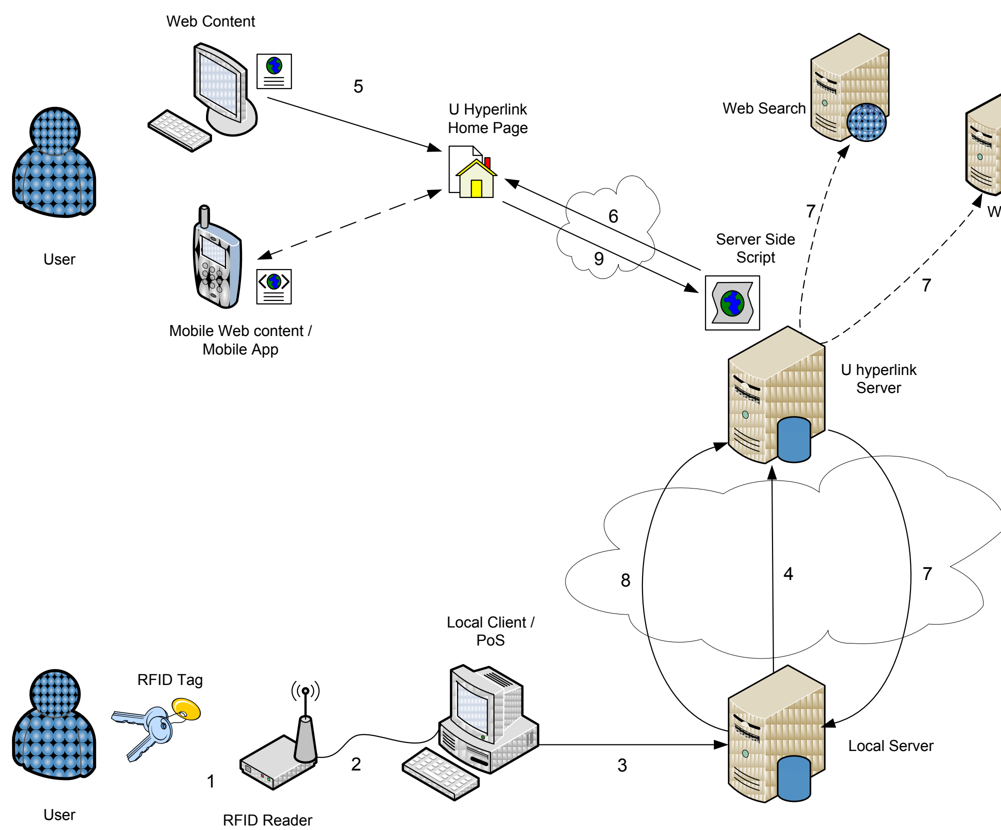

Figure 3.3 Configuration for Dynamic Local Server

The data flow so far can be seen from step 1 to step 4 in Figure 3.3. In the next step, when the user logs onto the UHyperlink server; UHyperlink will analyze which links were recently collected by the user and it will categorize the results and display it to the user. At this point user has three options, which includes going to the collected URLs, requesting more information about a particular URL from the object hyperlink originator organization or using the search keywords to look for further information on the web. Hence step number 7 has three possibilities as shown with solid and dotted lines. Assuming the user requests more information from the content originator, the web server will contact the local server with tag ID of the user and the URL for which more information is requested. Local server has the choice to match original link sent time, user transaction history, object database, current time and relation of the URL with user parameters to generate dynamic content that can match the user needs at the given time. This also allows local server to know what topic information is being requested by the user and may help in imporving that content if demand is high. Once more information is sent back to UHyperlink, it will be displayed to the user based on category, location and original link parameters. At this point, user has two options of going to the URL or searching more information over the internet. If the user chooses to search from the web based search provider at this point or at step 7, UHyperlink retrieves the keywords sent by the hyperlink originator and searches the web provider(s) for the results. Once the results are retrieved, they are displayed to the user as first best results in local and general category. Within each category, user is given the option to expand the number of results to view and analyze.

The basic fundamental for this approach is to have an interactive experience with the user, through which user can obtain related information from the hyperlink originator organization. On the other side, originator organizations can keep track of what information is useful to the users and modify the content accordingly. In addition, this approach allows collecting not only multiple URLs and text based information but it allows both originator and the user to generate or use the information dynamically. Dynamically generated information can not only be tailored for the user but it can also be targeted to a particular context if needed. Another major thing to note is that current object hyperlinking is focusing one object and one hyperlink, where this approach is focusing on multiple objects and multiple links. Hence, it is helping the user in performing an activity which may contain multiple tasks where conventional approach is helping the user perform one task within an activity.

There are multiple advantages of this approach. To begin with, most object hyperlink content generator wish to not only promote the information to users but also find out what users are looking for. This approach allows content generator to convey the information, collect user data as well as reply to user based on context and user specific needs which conventional approach is missing. Based on the algorithm used by content originator, user request and response can be improved which gives more control on both sides. Next is reduction of user information overload by reducing web search possibilities. As discussed earlier, web search is based on keywords and number of hits for that keyword related content which makes it harder for user to find local information. By providing proper search keywords to users, object hyperlink originator and end user both can point to a common web object related to the object in context. This reduces information overload from the web search aspect. Combining all the advantages, user has more options within a limited scope which gives user more control of the object hyperlink information that is collected.

3.1.2 CONFIGURATION B

Proposed architecture's configuration A covers most of the aspects of the proposed approach. However, configuration B provides a backup of the same approach with minor modifications. Since local server or object hyperlink originator is out of the scope of this approach, configuration B covers the scenario when local server does not have the ability to process incoming requests and provide an instant response.

In a given geographic location, the premises will have RFID reader fitted on where user can interact with the reader. When a user will tap the RFID card to the RFID reader; tag

ID will be transmitted to the local machine via RFID reader. Local machine will send the tag id, reader id and location information to the local server where it will analyze that what information should be sent to the user based on time, RFID reader's location, context and user history. In this case, local server may have pre-formatted data to send to all users without any processing. Since the server will not be taking incoming future requests, local server will send the base links to the user along with potential related links and search criteria keywords if the user wishes to search for the object related information on different search engines.

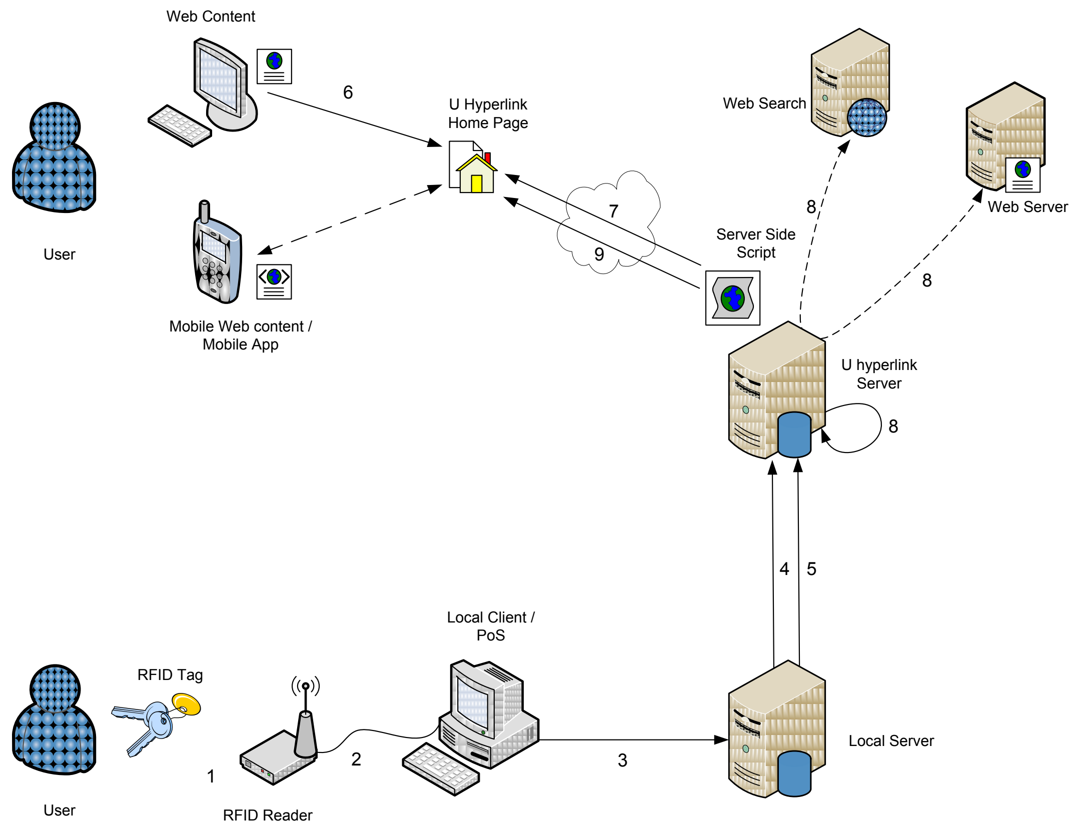

Figure 3.4 Configuration for Static Local Server

In figure 3.4, step 4 is sending the base links and keywords to UHyperlink server and step 5 is sending potential related links. This can be accomplished in one step but it is separated for logical understanding. Difference between base links and potential related links is explained as part of step 8. Once the information is received by UHyperlink, it will store the information in relation to the tag id of the user.

In the next step, when the user logs onto the UHyperlink server; UHyperlink will analyze which base links were recently collected by the user and it will categorize the results and display it to the user. At this point in step 8, user has three options; going to the collected link, performing a web search or requesting more information from hyperlink originator. Assuming the user requests more information from the originator, the potential related links are provided to the user. The main difference between base links to the potentially related links is that base links are the ones marked by originator to show to the user as mandatory where potential related links are shown to the user only upon request. Once the related links are displayed, then user has the option to either visit the URLs or perform a web based search. Web based search is similar to architecture A where the keyword is given to the web based search provider and based on that results are filtered as first most related local result in local and global search category. User can choose to view more of the local, global or both results.

Other than communication effectiveness, configuration B can be seen as an extension to configuration A in the scenarios where location or organization does not have a need to process incoming requests. Small organizations where local machine and local server are combined in one machine with limited amout of data to be sent to UHyperlink can be configured with this approach to facilitate users without getting into complexities of implementing an algorithm to dynamically process incoming requests.

3.1.3 PROPOSED STORAGE DESIGN

It is essential to store the incoming object hyperlinks and user click history in a centralized managed repository. Figure 3.5 shows the entity relationship diagram for the proposed UHyperlink storage.

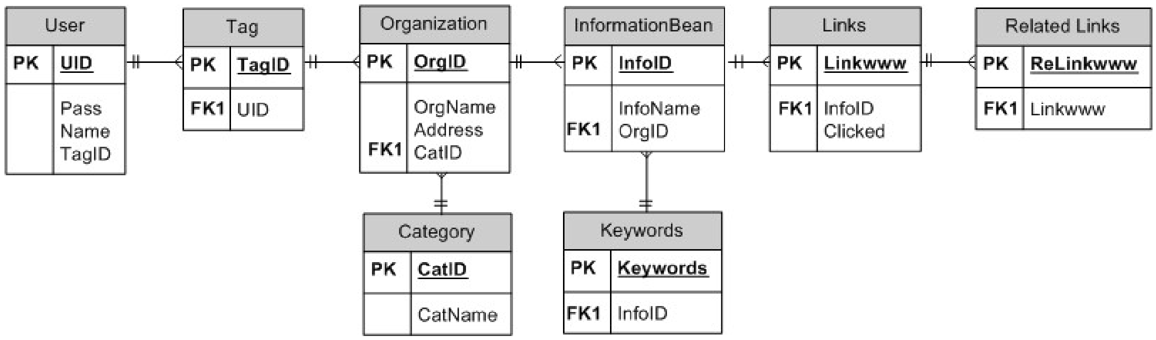

Figure 3.5 Proposed Entity Relationship Diagram for UHyperlink

A user can have one or more tags. Based on the convenience, user can have RFID tag in a keychain, wallet or stuck on a phone and use it as per convenience. Therefore a one to many relationship exists from user to the tag. One tag can be scanned at more than one organization. Since it is necessary to categorize the results for the user, one category can have many organizations under it which requires a one to many relationship for category and organization. One organization can be part of more than one category but it may create link repeat for same organization under different categories for the user. That is why organization to category many to many is not considered. One organization can have many objects which are grouped based on different criteria. One link can point to a group of objects which can be seen as an "information bean". One information bean can have many links associated with it. Similarly, one information bean can have many keywords associated with it which makes one to many relationship from information bean to links and keywords. One link can have many related links associated to it based on context.

3.2 PROTOTYPE

The motivation behind designing a prototype was to create a baseline which can help identify and improve design flows. It can also be used for comparison for any future work. For the prototype design, RFID reader, tag and two computers were used. It is important to note that to develop prototype of UHyperlink, we have combined the local machine and local server into a single box.

Figure 3.6 Testbed Setup

Figure 3.6 shows the hardware setup for UHyperlink testbed. The desktop machine on the left is a Sony Vaio desktop and the laptop machine on the right is a HP Pavillion laptop. Starting from the bottom left is an RFID reader and tags that were used in the experiment. The desktop machine on the left was used as the host machine where RFID reader is connected. Desktop machine had logical components of local machine and local server. It was wirelessly connected to HP laptop via a WiFi connection. HP laptop had logical components of UHyperlink server and user's local machine. CD in the center was the software provided by the RFID reader manufacturer.

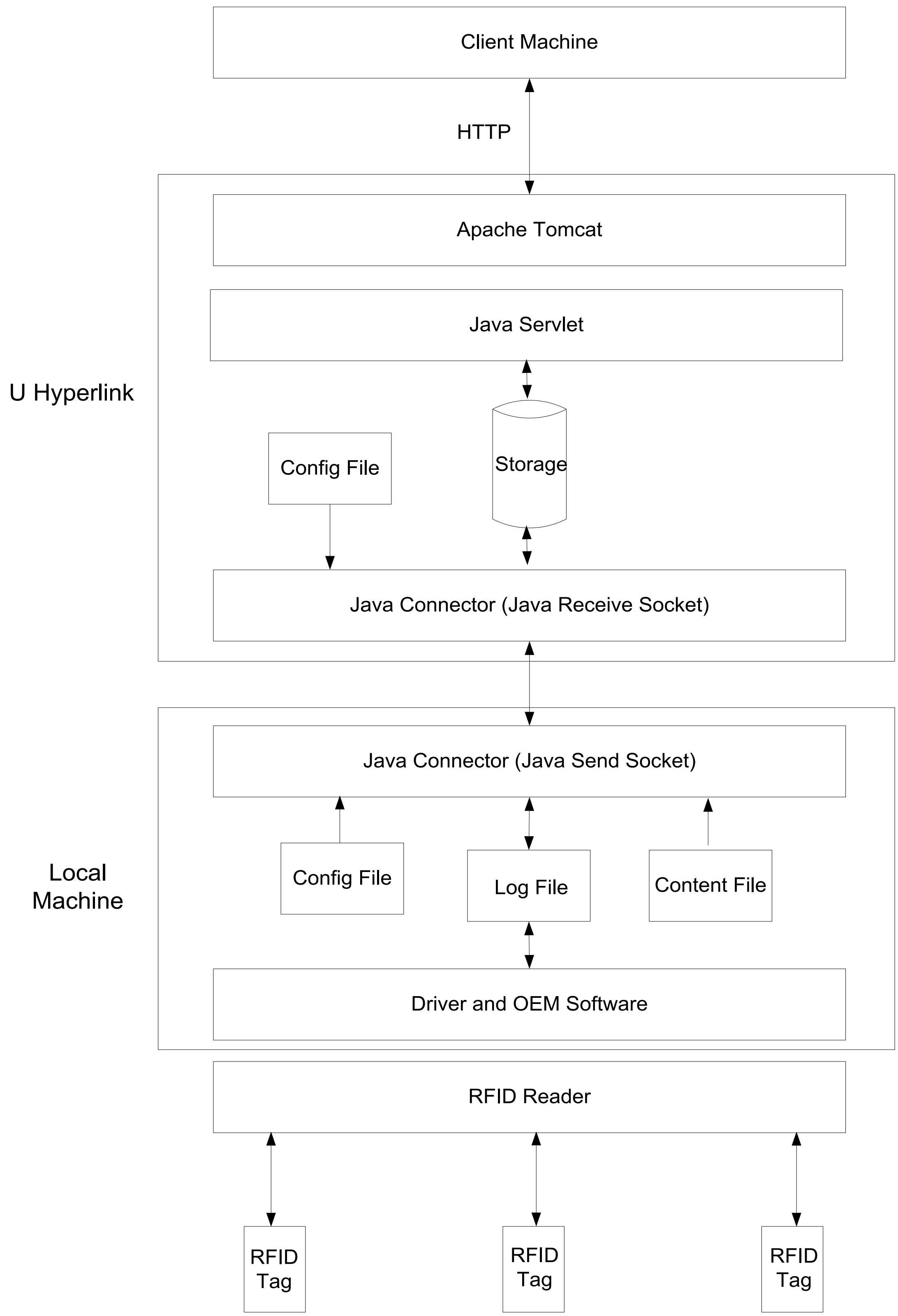

Figure 3.7 Implementation Architecture

Figure 3.6 shows the implementation components. Going bottom up, High Frequency (HF) 13.56 MHz passive tags of different shapes and sizes were tested. Primarily the keychain type tags were used due to a convenient design and ruggedness factor. For the RFID reader, Deister Electronic made RDL 5 High Frequency (HF) 13.56 MHz reader was used. Communication with RFID reader was done via RDemo application software and driver.

Figure 3.8 RDL 5 Reader

Host machine or local machine was a Sony Vaio desktop computer with Windows Vista Home Premium 64 bit OS. RDemo software was configured in a way to write the tag reads to a log file at any given location.

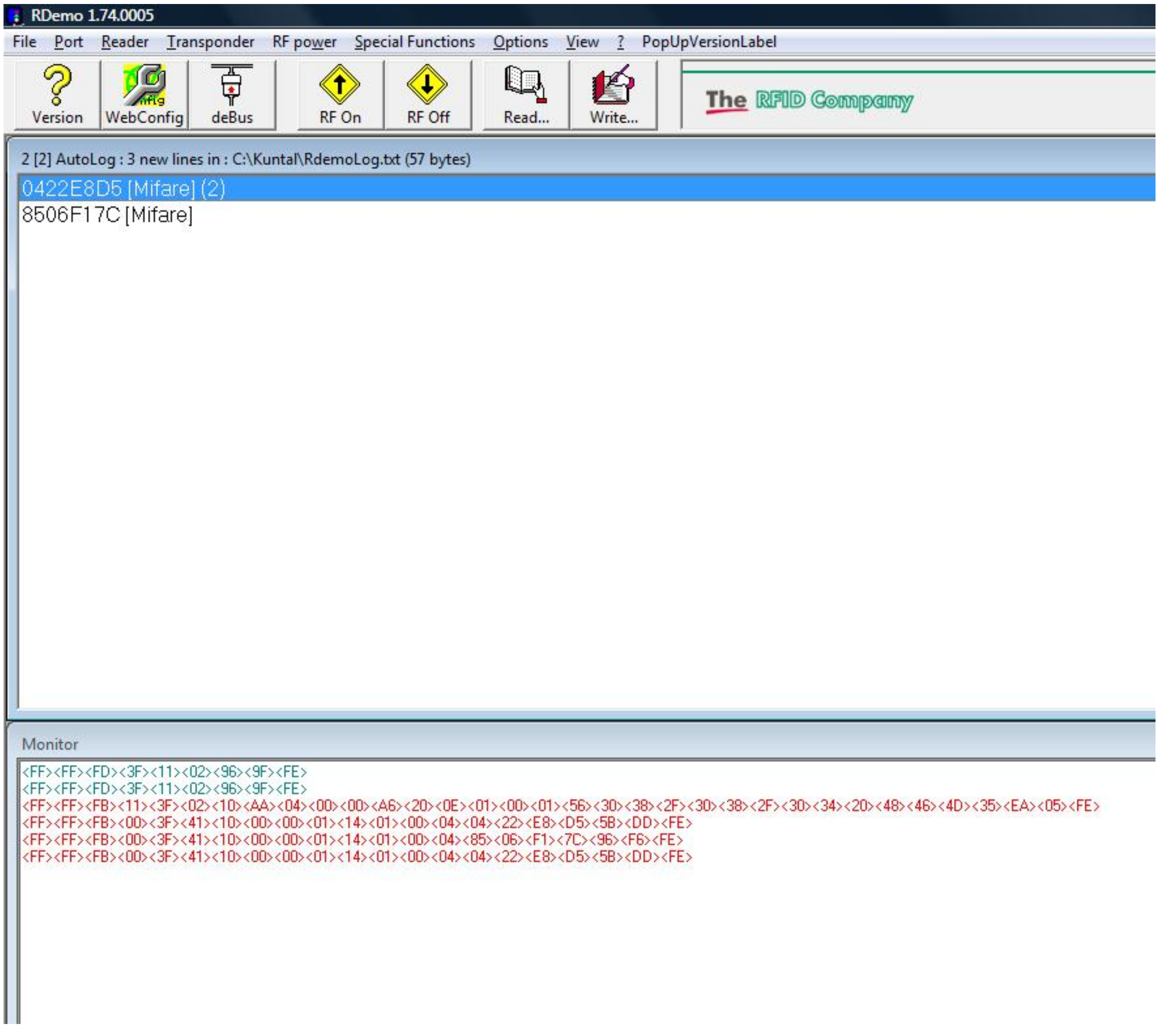

Figure 3.9 RDemo Software

The java send connector application was developed with java version 1.6 and NetBeans IDE version 6.9.1. For configuration file, there are three paths that needed to be specified. First the location of RDemo read log file where a thread is checking for new read after a variable interval. Java connector at the local machine required a configuration parameter file where UHyperlink IP address, UHyperlink port number, and local machine outgoing port number needed to be specified so that it does not conflict with any other application or firewall. Last was the content file where the links, related links and keywords are stored. A database can be used for the same but for the prototype purpose a file was sufficient. Another important thing to note was that configuration B was implemented as the local server was assumed to have no incoming processing requests.

Moving upwards in Figure 3.6, java send connector consists of 4 classes. Object and functions of class named getContent.java is responsible for retrieving information from the given file locations and return the content in a send ready format. Object of communicate.java is the thread that opens the local computer port receives incoming messages from UHyperlink. It should be noted that port number and receive functionality for communicate.java is not utilized as configuration B was implemented but it can be utilized in future if an algorithm needs to be implemented for any incoming requests. RFIDScanner.java is the class which initiates the thread to check the RDemo log file and if there is a new read entry then it sends the new entry to the UHyperlink server by opening an instance of the communicate object. Last and the main class is PoS.java which contains the main function and starts the RFIDScanner object which starts the thread. PoS stands for "Point of Sale" assuming that RFID reader will be placed at the billing section of any given organization. However, RFID reader can be placed at any place where object hyperlink originator wants.

It is important to note that by dividing send connector and RFID reader program, many compatibility issues with UHyperlink can be solved. Send connector just needs an RFID read log file. RFID software and RFID hardware are independent as per organization need. On the other side, depending upon hardware and software platform, only send connector piece needs to be developed. By having UHyperlink receive connector as a generic receiver and multiple send connectors which convert the message from various system types and software configurations to UHyperlink understandable format; many compatibility issues are addressed. By multiple send connectors, it means that depending upon software platform a different send connector can be used. For example, UHyprlink server is a windows server and local server is a UNIX platform deployment; then a send connector developed for UNIX system will need to be used. For the proof of concept local server was Microsoft Windows platform dependent so Microsoft Windows send connector was used. When deploying the prototype for a different platform based local server, a different send connector may need to be developed. However, only one send connector for each platform is required as configuration file can be expanded with more variables to specify environment settings and reducing the need for more customized development.

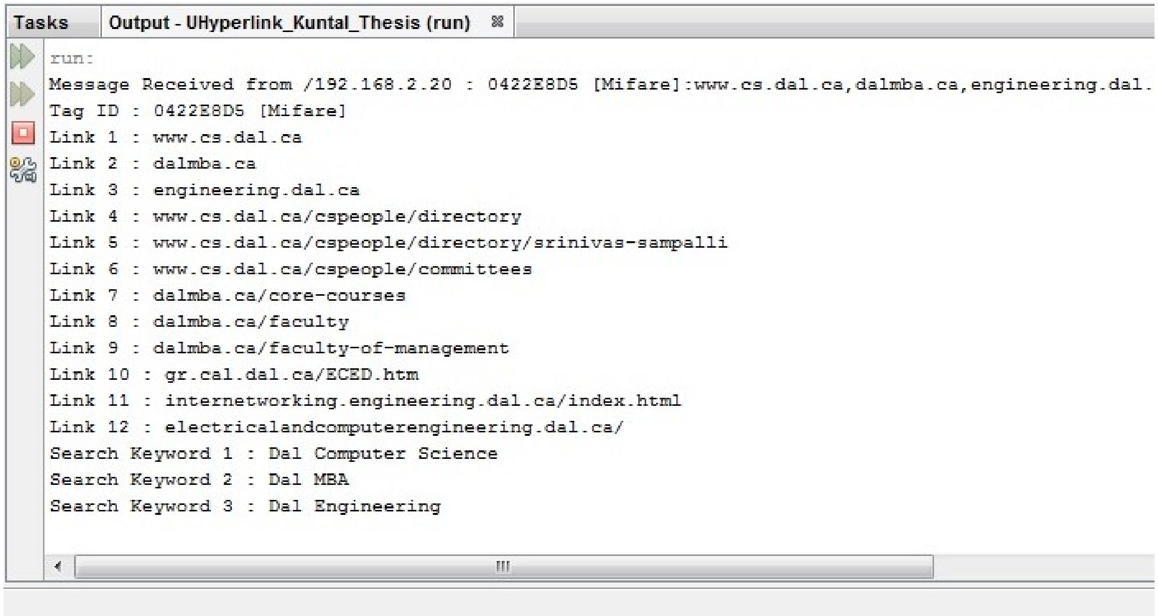

Figure 3.10 Java Receive Connector Receive, Divide and Store

For the UHyperlink machine, an HP Pavillion g6 laptop with Windows 7 64 bit OS was used. Java development was made on NetBeans IDE 7.1 with the java version of 1.6. Similar to the send connector, receive connector has a communicate.java class which creates an object with a thread that opens a port for listening to incoming data packets from local server system. Figure 3.10 shows the information breakdown when information is received. Once the information is received, the data is divided as base links, potential related links and keywords. Once divided by the communicate object, it is passed on to FileManager.java class object where the information is stored into different containers. For the prototype, different text files were used for storage instead of database because prototype was built to identify user experience and scalability was a second priority. Another future expansion class ClickScanner.java on UHyperlink was developed for scanning and sending URL click information to the hyperlink originator if needed. The main class for receive connector was UHyperlink.java which initiated communication object and thread.

For the web interface part, Eclipse Java EE IDE Indigo Service Release 1 version with the same java 1.6 version was used. In the Eclipse EE Dynamic Web Project, Apache Tomcat 7 was used as the web server. After the login page the user was redirected to tagId.html.

Here tagId.html redirected itself to tagId.java which read through the storage medium and displayed the user homepage for his tagId. The name tagId was given because of the prototype assumption that one user will use only one tag. Other java classes are divided into two parts. Capture java classes are used to capture the user click and display the related links for the link that was clicked. Web classes are used to read the related keyword from storage and provide the search result from Google™. To plug in the search keywords, retrieve, and sort the results; Google Custom Search API was used [71].

After a user scans a tag at the organization and logs onto UHyperlink server via login page, the account home screen will show the links collected so far.

Figure 3.11 User Account Links

In this case, a scenario where user has collected three links from a location is simulated. User has four options. Starting from the left, clicking on the link will take the user to the URL in a new tab. Clicking delete will remove the link from the listings. Upon clicking more will provide the user with related links as shown in Figure 3.12.

Figure 3.12 Revealing Potential Related Links

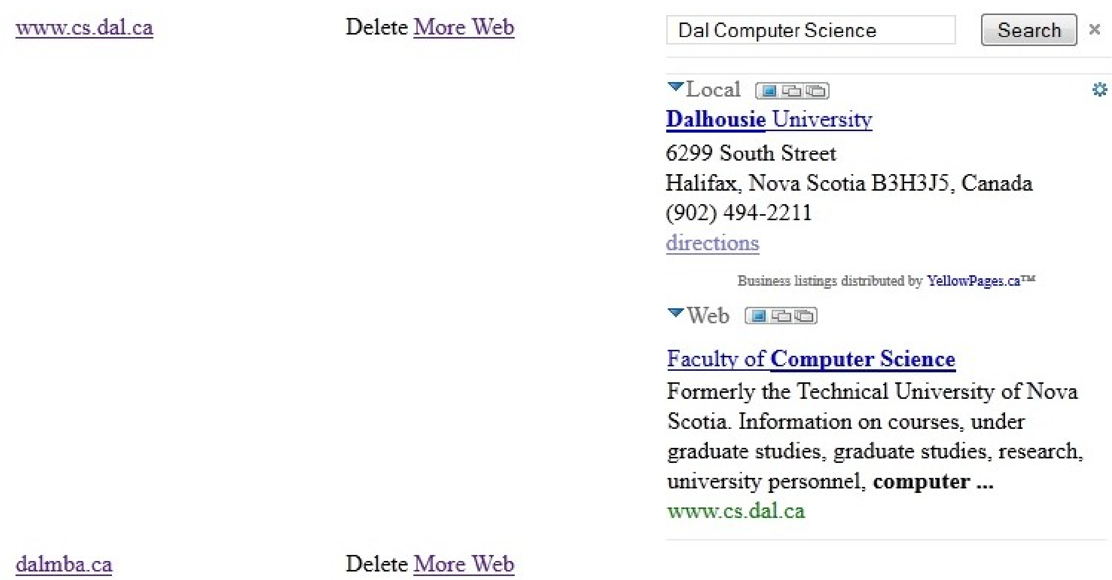

Figure 3.13 Web Search Results Based on the Keyword

In Figure 3.13, the screenshot shows the top results for the given keyword in local and general search category. If the search result is not relevant to what the user is looking for, clicking more will provide the full set of results.

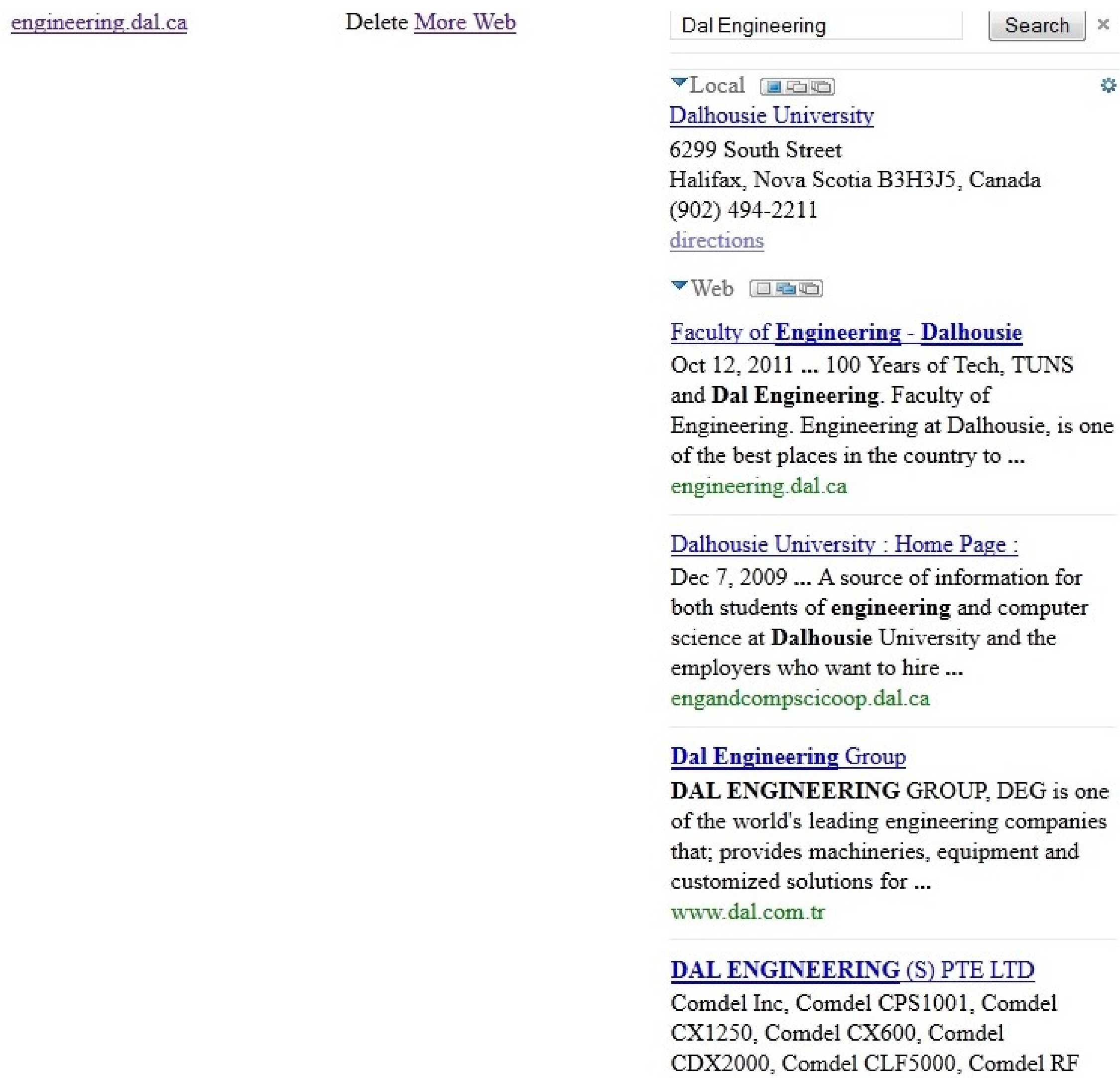

Figure 3.14 Choosing More Results in Global Search Category

As shown in Figure 3.14, there are three modes to see the results. First is one result, second is some results and third is all results. This gives user a control of how many results needs to be reviewed.

CHAPTER 4 ANALYSIS

Object Hyperlinking allows users to collect information from various physical locations or objects. In the conventional approach, this information is coming from an object and it is stored on the mobile device. After the information is collected by a user, if a user needs to view it on a bigger screen then the data needs to be transferred to a different device via mobile device specific technology. After looking at the website on a computer, user may wish to search about the collected topic, object or location via web based search engine. Furthermore, task of collecting information, transferring to a computer and searching on the internet can be seen as part of a bigger task; which may comprise of multiple small tasks. All the projects discussed in the background study section are trying to solve different parts of this bigger task individually.

Table 1 Comparison of Proposed Architecture with other Systems

	Collect Info	**Store**	**Organize**	**Web Interface**	**Device Independent**	**NFC Enabled Device Not Required**
MoVIS	Y	N	N	N	N	N
A Framework for Mobile Interactions with the Physical World	Y	N	N	N	N	N
Hovering	Y	Y	N	N	N	N
Credit Card and Air Miles	N	N	N	Y	Y	Y

	Collect Info	Store	Organize	Web Interface	Device Independent	NFC Enabled Device Not Required
ShifD	N	N	Y	Y	Y	Y
Mobile World Congress Conference	Y	Y	N	N	Y	Y
Google Hotpot	Y	Y	N	Y	N	N
Coca Cola Project	N	Y	N	Y	Y	Y
BIT project	Y	Y	N	N	N	N
UBI Oulu Public Display	Y	Y	N	N	N	Y
Migration Server	N	N	N	Y	Y	Y
UHyperlink	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**

Table 1 shows the comparison of features of UHyperlink system with past and existing object hyperlinking systems that are described in the background study section. Mobile interactions, MoVIS, and Hovering are providing users with targeted information from objects such as storing phone number to a mobile device from a business card or viewing information about a particular object. In the next wave, RFID was not used for text based transactions so it is not considered an object hyperlink but it is worth noticing that the contribution of that technology was to visualize a device independent user. By the time, ShifD and projects similar to ShifD proposed solutions to synchronize information between many devices via a web based solution and proved that web based synchronization is one of the most convenient solutions for users. Solutions like Mobile World Congress came up with solutions that did not required users to have a specific device, collect information and research on the gathered content at a later point on a laptop as a different location and time. Yet, it lacked organization. Google Hotpot solution seems to lack device independency for the object hyperlink solution. Recent projects like Coca Cola theme park campaign may be considered object hyperlink to some extent but that is still just a counter and not performing any text based interaction with user. Bit project allows users to scan all types of tags form a signle application using web based services and internet of things framework but yet it is limited to mobile devices. Public Displayes project allows users to have only an RFID tag but still it is limited to mobile devices and no external hyperlink reference is allowed. Finally, migration server search is proposing a framework to seamlessly transfer application state to different device via NFC technology but it can not be considered an object hyperlink solution.

The proposed solution is suggesting location based multiple link and keyword collection in a centralized web based storage for users to manage the collected object hyperlinks. Proposed solution is allowing users to collect information at a lower effort and perform two post collection tasks at a single point. Hence, Table 1 concludes that UHyperlink has contributed towards solving all the problems in a single framework.

The only inconvenience that proposed architecture has is the ability to collect object specific information. The proposed architecture requires one reader representing multiple objects instead of just one. However, it cannot be concluded as a disadvantage because Internet of Things allows object specific information to be stored on the web but it requires an RFID enabled device being used by most users. Since it is a inflexible assumption for all users to have RFID enabled device, proposed solution is allowing users to not have RFID enabled device or a Smartphone and still collect information. Therefore, it can be seen as a trade off instead of inconvenience. Also it is important to note that the proposed solution is for a goal driven task and not for target driven task as explained in the beginning of section 3.

The proposed solution is bringing two parts. First is ease of collection and second is storage and manage. For collecting the information, conventional QR code approach requires user to have a combination of Smartphone, proper app, light, QR code size and focus factors in order to collect information. Assuming Smartphone and proper app are one time effort, loading the app and scanning the code in proper lighting is more time consuming than scanning an RFID tag. Again, registering the user is assumed to have a onetime effort similar to downloading an app. Therefore, it can be said that RFID user with tag is more efficient in terms of value and efficiency cost compare to conventional object hyperlink systems.

In any task that spans over a period of time, user may wish to browse or search through various sources. Currently, users have some data on mobile devices and rest on different computing devices based on device availability. UHyperlink is not only providing users with user's central storage repository but it is also providing users with an ability to request more information from object hyperlink originator as well as search helper tool in addition to conventional search engines. When users collect information from a location, UHyperlink displays collected link under the location name title which makes it easier for users to recall the related point. Hence, it can be said as location based information collection. This way, users can manage the collected links by the locations they have visited during a certain time. On the other side, when users request more information for a given link; UHyperlink contacts local server with user's ID to retrieve more information for the user chosen hyperlink. This way when UHyperlink contacts the local server, object hyperlink originator organization is able to gather the data about which links were actually clicked by the user. Aggregation of such data may be used in mining the content and object hyperlink originator can understand which content areas are more important for its users and content can be updated accordingly. In the configuration B, same can be achieved by a batch update to object hyperlink originator via pre-determined policies with user permission.

To understand the benefits of proposed architecture, it will be necessary to look at use cases. For looking at the applications of the proposed architecture, this thesis will take an example from medical, library management, auto, retail, travel, and real estate industries. In the proof of concept, each use case was sent 3 main links with 3 relevant links to each links making 12 links in total. In addition, one search string was sent with each main link making 3 search strings in total. For each experiment, each search string was used and first four results from global category were taken into consideration for relevant result criteria. In the web search feature of UHyperlink, user can view top first, top four or top eight results and go to further page. The number four was chosen assuming user will choose to view top four results. This thesis is using the formula of precision from general information retrieval definition [7]. However, it is important to note that unlike conventional search engine, this solution does not have a corpus so it is not possible to find total relevant documents and therefore only precision is calculated for the evaluation. Essentially, precision here is how many documents are actually relevant to user's need from the total number of retrieved documents.

$$\text{precision} = \frac{|\{\text{relevant documents}\} \cap \{\text{retrieved documents}\}|}{|\{\text{retrieved documents}\}|}$$

Use Case 1: Medical Industry

One of the basic blocks that connect an average user with medicine topics is the ability to search about a topic and find information that may help in identifying prevention, symptoms and other hygiene tips. Taking an example of swine flu outbreak, users may search conventional search engine for information. Without the help of subject matter expert, it may be hard to identify actual relevant results that apply to a given region. Conventional approach may allow a user to view a website for a particular medicine or a given object but it does not help user in finding information about general topics or concerns. The proposed architecture can be deployed at swine flu centres or medical clinics in the case of outbreak. Users can have their tag scanned and receive information that they can read as per time convenience. Links sent by organization are relevant for the user as they are sent by subject matter expert and keywords are also provided for users.

Use Case 2: Library

Modern library is a collection of thousands of books and digital content. An average user may search library website or library search to find out related books or content. However, sorting through many search results may be a daunting task when it comes to finding information about a particular area. Conventional object hyperlink may help user in finding more information about the book itself or the author. However, it is not helpful when it comes to finding information about books that are related to previous transactions or in related domain. Assuming proposed architecture in place at the library and local server's capability of sending information to UHyperlink account based on user's past transactions or current transaction will allow users to easily search for books that are related to the currently borrowed book. Library may also know which information pieces user need from time to time and that content can be improved.

Use Case 3: Auto Show Event

Attending an event can provide overwhelming information at once. It is often the case that a user can be very busy networking with other people at the event. Usually, it is after the event that a user has a chance to process the gathered information. For example, an Auto Show where user has to decide towards buying a car. For an average user, buying a car requires information search over a long period of time; including the event. Conventional object hyperlinking may not be helpful at the event as user is always in the task of engaging in conversation with other people and looking at cars at the event. This may not allow loading an app and browsing the website on the mobile device at the given location. Proposed infrastructure allows user to tap the RFID card at the readers fitted on the event booth and collect information that can be processed later. When users click more, organizations with booths may send the updated information and also know which users need more information in what direction. For organizations to find out what information needs to be sent to the user is the key object for entering an event and getting the word out.

Use Case 4: Retail Industry

Retail industry is always trying to reach customers in different ways and getting the attention of an average user can be a challenging task. Yet, there is a large user base which may prefer to shop from a certain organization or store. Users may like to monitor the new products for a particular organization after shopping from there. Conventional object hyperlink may allow them to view more description for a given product but it does not help in getting more updates for related products. Browsing through the website or portal can be time consuming task as browsing or searching will require sorting through many products. Proposed architecture for retail industry may allow users to be able to receive more information by contacting the organization at user's request. Retail stores may also customize their send links or products based on the past and current transaction with the user.

Use Case 5: Travel Industry

Planning a vacation can be seen as a bigger task as it involves many small tasks and information gathering. Visiting a travel agent office may require post information processing about the options available and options discussed. Doing a web based search may provide user with reviews and travel options after sorting through many pages. Conventional object hyperlink may point to the organization website but may not be helpful in decision making process. Proposed architecture may allow organizations to send appropriate information to user's UHyperlink account with review finding keywords and in future more information can be sent based on any updates. This way users can log on to UHyperlink account and review the information discussed when needed.

Use Case 6: Real Estate

Finding a place to live requires users to research on it for a period of time. After looking for a house to buy, finding more information on the internet requires searching for related information on a web portal like MLS®, which may contain general information. Conventional object hyperlink may allow users to go to a real estate agent's page with a given house but related information cannot be retrieved easily. Proposed architecture will allow users to obtain information from broker's office with related information about buying or selling a property. Depending on local server configuration, user may be sent with updates when user wants and reducing unwanted emails.

In all of the use cases mentioned above, user maintains the control of requesting the information which does not allow information overload like spam emails and junk information pushed to the user. Similar examples can be given for other industries as each industry application requires users to perform a knowledge driven task which can be assisted by the proposed solution.

For the six use cases, six experiments were made. As discussed earlier, the proof of concept sends 3 + (3x3) links and 3 search terms to the UHyperlink account. For each run, the 12 links are sent by subject matter expert so they are considered as relevant documents to the topic that user is looking for. To find overall precision, it has to combine with the search results. For each industry 3 search terms were used and average of them was taken and added to the base links. As discussed earlier, four results were considered for the experiment. Hence, precision for search was calculated based on relavant results out of 12 in each case. The search relavant documents percentage for medical, library, auto show, retail, travel and real estate is shown in Figure 4.1.

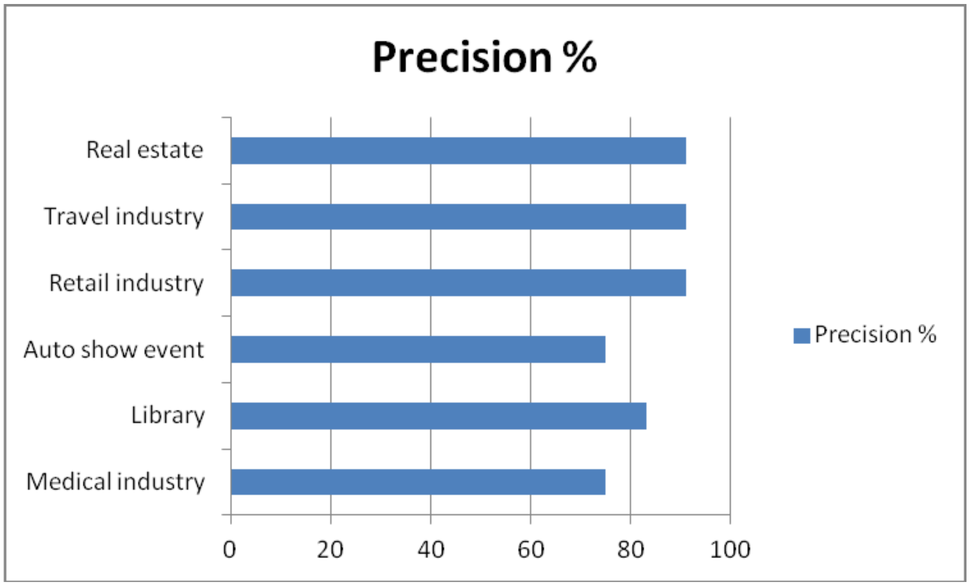

Figure 4.1 Search Result Precision

Hence, overall search engine result precision was 84 percent. These numbers were combined with base 12 links and overall Retrieved and Relavant set was generated. Table 2 shows the overall retrieved and relevant results.

Table 2 Test Results

	Retrieved	**Relevant**
Medical industry	24	21
Library	24	22
Auto show event	24	21
Retail industry	24	23
Travel industry	24	23
Real estate	24	23

From the results of Table 2, it can be said that overall precision of the proposed system in the experiment run was 92.36%. It is important to note that Precision is not related to the industry as subject matter expert input may vary based on implementation. Even though an average was taken from various search results, different search term may have diverse search results. Since keywords will be sent by subject matter expert or in hyperlink originator favour, average accuracy should be at least or more than the experiment. Figure 4.2 shows the accuracy for each industry use case experiment.

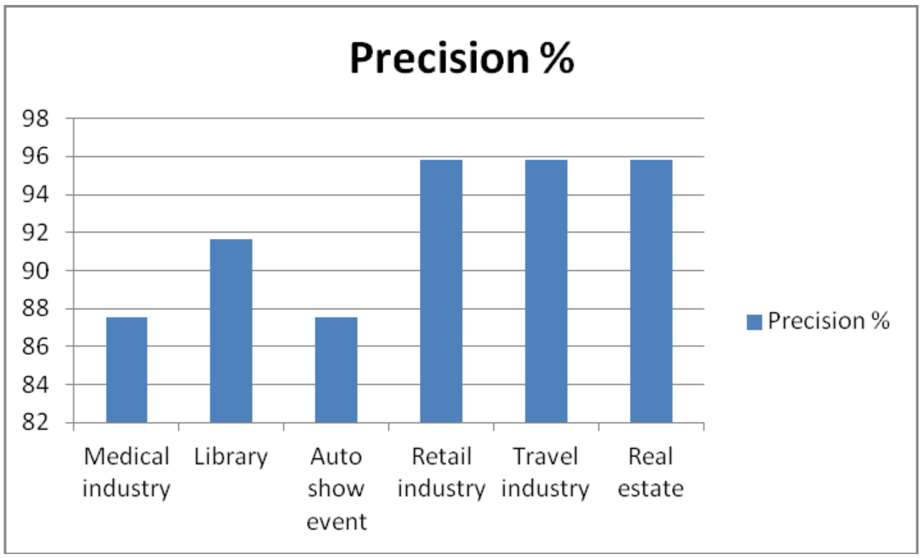

Figure 4.2 Overall Precision for Each Use Case

Due to the convenience of having only the tag to collect information and being able to see all the links at one place with device independency, it can be concluded that the proposed solution is a user centered approach. From the experiments, it is clear that user can find the appropriate information with less effort and device independency. Therefore, UHyperlink can be an effective solution to collect, store and manage object hyperlinks across many organizations and industries.

CHAPTER 5 CONCLUSION

Pervasive computing has allowed much advancement in many areas of computer science. Linking physical objects with web is not only allowing easier tracking of objects but interacting with objects can provide a better receptiveness towards day to day interaction. With more options and more content, users have the advantage of finding almost all information from the web. Object hyperlinks allow users to find targeted information easily.

From the analysis, it is clear that current methods of object hyperlinking are not an efficient solution for the users when they are already encumbered with lots of information to excavate through. The proposed architecture allows object hyperlink originators to not only convey information but it also allows them to track what information is useful to users and tailor the future content based on requests. On the other hand, proposed architecture allows users to congregate all of the collected links at one place and access it from any device at any place at any time.

The proposed architecture enables users to communicate back to object hyperlink originator as well as making the web based search easier for users to find the information related to the object hyperlink originator. Due to this feature, user can collect the object hyperlink once but it can be reused in future with updated content and in different contexts. Having user carry a tag is faster and easier for the user without requiring any learning curve. Even though currently developed prototype was very useful in evaluating the design of the proposed architecture; a further extension can be made by adding an algorithm on the local server side which will adapt itself to user requests. More intelligent algorithm to search web based search providers can also reduce false positives. Nevertheless, the above mentioned extensions may require a user study to evaluate the success.

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