# Interfacing RFID and Web 2.0 Technologies to Improve Inventory Management in South African Enterprises

**A dissertation submitted by**

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# DECLARATION

I, Sizakele Untonette Mathaba, declare that this work has not been submitted in any form to any tertiary institution for degree or diploma purposes. The existing knowledge used in this thesis is acknowledged and a list of references is given.

Signature:

Date:

# DEDICATION

I dedicate this work to my mother Phumzile Mathaba, for her unconditional support and encouragement during this journey; to all my sisters and my brother Bongani for being there to share my joy and hardships on this journey and finally, to my sons for understanding that Mom has to study and be away all the time.

# ACKNOWLEDGEMENTS

I would like to acknowledge my God for His love towards me and His blessings: without Him, I would not be here.

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# ABSTRACT

Cost-effective inventory management includes balancing the cost of inventory with its profit. Most business owners fail to recognise the value of the cost of carrying inventory, which includes not only the direct costs of storage, insurance and taxes, but also the cost of having money tied up in inventory. Running inventory using paper-based systems, Excel files and traditional enterprise software is a costly and resource-intensive approach that may not even address the appropriate issues for most businesses.

It is with this in mind that this research proposes an architecture which appropriates the advantages of the Radio Frequency Identification (RFID) and Web 2.0 social media tools (specifically Twitter) to enhance management of inventory. RFID promotes the communication between things/objects through sensors. However, Web 2.0 tools such as twitter, promote communication amongst people through their cell phones or computers. The collaboration of these two technologies could improve inventory management.

A comprehensive literature survey was conducted on inventory management functionalities. RFID and Web 2.0 technologies were then mapped to the identified inventory management functionalities. As a result, the architecture of a system that fully integrates the technical advantages of RFID and Web 2.0 tools such as Twitter for loss prevention, and an enabler for locating misplaced stock and for sending notifications of stock level on the shelves, amongst other applications, was proposed and developed. The architecture focused on enterprises in developing regions of Africa and South Africa in particular. RFID technology adoption is becoming a viable option in the South African retail sector.

The inventory management prototype was developed and evaluated. The inventory management system demonstrated how to detect misplaced products and low stock levels, and how to send notifications via Twitter to update inventory managers using the RFID and Twitter technologies.

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ***Ajax*** | *Asynchronous JavaScript and Xml* |
| ***CSS*** | *Cascading Style Sheet* |
| ***DHTML*** | *Dynamic Hypertext Markup Language* |
| ***DNS*** | *Domain Name Service* |
| ***DOM*** | *Document Object Model* |
| ***DSS*** | *Decision Support System* |
| ***EDI*** | *Electronic Data Transfer* |
| ***EPC*** | *Electronic Product Code* |
| ***EOQ*** | *Economic Order Quantity* |
| ***GPS*** | *Global Positioning System* |
| ***HTTP*** | *Hypertext Transfer Protocol* |
| ***ICASA*** | *Independent Communications Authority of South Africa* |
| ***IM*** | *Instant Messaging* |
| ***IMS*** | *Inventory Management System* |
| ***IoT*** | *Internet of Things* |
| ***IPCS*** | *Intelligent Product Cross Selling System* |
| ***IT*** | *Information Technology* |
| ***ICASA*** | *Independent Communications Authority of South Africa* |
| ***JEE*** | *Java Enterprise Edition* |
| ***JMS*** | *Java Messaging Service* |
| ***KHz*** | *Kilohertz* |
| ***MHz*** | *Megahertz* |
| ***NFC*** | *Near Field Communication* |

| | |
|---|---|
| ***ONS*** | *Object Naming System* |
| ***PHP*** | *Hypertext Preprocessor* |
| ***PI*** | *Perpetual Inventory* |
| ***POS*** | *Point of Sale* |
| ***QR*** | *Quick Response* |
| ***RA*** | *Resource Adaptor* |
| ***REST*** | *Representational State Transfer* |
| ***RF*** | *Radio Frequency* |
| ***RFDC*** | *Radio Frequency Data Communication* |
| ***RFID*** | *Radio Frequency Identification* |
| ***RIA*** | *Rich Internet Applications* |
| ***SaaS*** | *Software as a Service* |
| ***SCM*** | *Supply Chain Management* |
| ***SDS*** | *Smart Dressing System* |
| ***SLEE*** | *Service Logic Execution Environment* |
| ***SOA*** | *Service Oriented Architecture* |
| ***SOAP*** | *Simple Object Access Protocol* |
| ***SUP*** | *Suspected Unapproved Parts* |
| ***UI*** | *User Interface* |
| ***UML*** | *Unified Modeling Language* |
| ***UPC*** | *Universal Product Code* |
| ***USB*** | *Universal Serial Bus* |
| ***VoIP*** | *Voice over Internet Protocol* |
| ***XHTML*** | *Extensible Hypertext Markup language* |

| | |
|---|---|
| ***XML*** | *Extensible Markup Language* |
| ***XMPP*** | *Extensible Messaging and Presence Protocol* |
| ***XSLT*** | *Extensible Stylesheet Language Transformation* |

# CHAPTER ONE
# INTRODUCTION

## 1.1 Overview

Proper management of inventory remains a vital requirement for many enterprises, in order for the business not only to grow, but to achieve consistently increasing profit margins. Poor management of inventory leads to the loss of sales, resulting in business failure. Unfortunately, not all enterprises practise proper management of inventory. Business enterprises face hurdles such as misplacement of products, counterfeited products and inappropriate or laborious approaches to stock replenishment on shelves. According to (Xin, 2009), stock shortages are estimated at 30%, affecting retail sales by a margin of 5% to 18%.

Inventory management is comprised of a number of control processes, as illustrated in Figure 1.1. The phrases ‘inventory management’ and ‘inventory control’ are often used interchangeably. However, inventory control entails critical procedures which need to be managed appropriately.

The inventory control processes in the retail industry are based on information regarding received goods/stock, and involve the counting of stock, validations, and issuing of invoices. These processes also involve using serial numbers of goods when checking damaged and expired products. Another process in inventory management is the movement of goods within or between locations, and this involves the transfer of stock from warehouses to shelves at wholesale or retail locations. It may also involve the shipping of goods to other destinations. Inventory control may also require assessment of the value and status of stock for the purposes of stock replenishment on shelves. This involves ordering products that are running low or following up on order requests that have been sent to suppliers (see Heavner 2009, Hornak 1994, & Wild 2002).

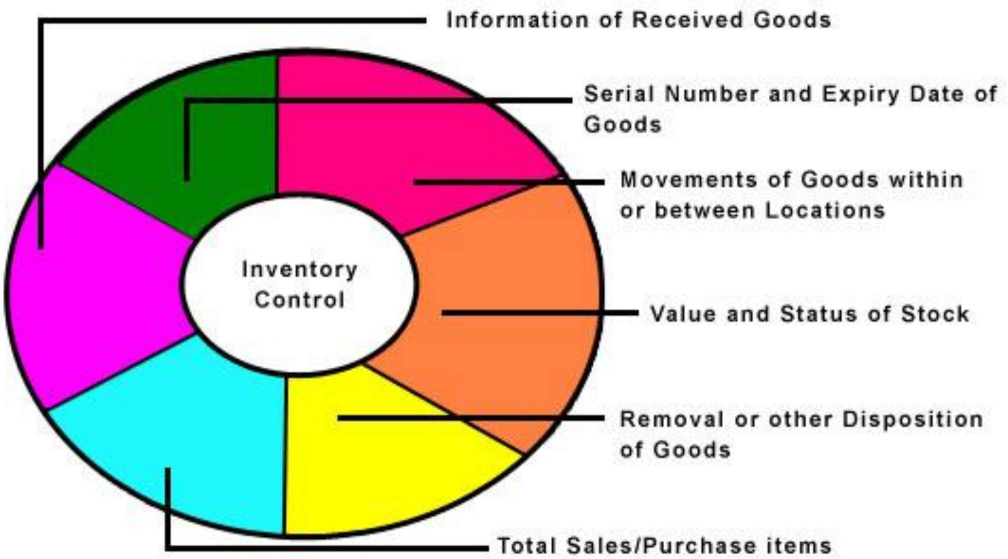



**Figure 1.1** Inventory control in a retail industry (adapted from: Intermec Technologies Magazine, 2007)

Removal and disposal of unwanted goods from the inventory is also part of inventory management. This may be because the product is no longer fit for consumption or because it has been damaged. Inventory systems also record total sales of products on a daily basis. Information gathered from a combination of these activities can be used to determine the profit or the loss made by a business. Sales analysis is an important process in inventory management systems: it is used to identify the stock which needs to be ordered.

Poor inventory management is costly and it can result in decreased profit according to (Cakici et al., 2010). This necessitates the use of appropriate technology for achieving optimum inventory control. Barcode printers, labels and scanners, mobile computers and inventory software are important components of the inventory control system. Radio Frequency Identification (RFID) application is potentially the most powerful technology for managing inventory because of its ability to reduce the time it takes for inventory control, thereby providing enterprises with real-time knowledge regarding the products on the shelves, as stated by (Baudin, 2005, Wei, 2009, Chande et al., 2005, and Delen et al., 2007).

RFID is a core component in Internet of Things (IoT) technology. RFID enables communication by sensors and product scanning in real time with the possibility of eliminating the problem of counterfeiting, as well as streamlining the present time-consuming mode of stock replenishment, (Goyal, 2009). Similarly, product misplacement on shelves can also be eliminated. The process of using RFID is usually possible without any human intervention, or requiring at most only one employee who can perform inventories daily in less than two hours. In traditional inventory management, a typical inventory cycle takes two to three days and is only performed two to three times in a year. Clearly, this technology allows for a tremendous improvement in productivity.

These improvements allow RFID users to take immediate advantage of the inventory data which has been gathered, thereby enabling instant decisions regarding stock availability. Data gathered through real-time inventory is used not only to improve the customer experience and increase sales, but also to streamline operations and reduce overall costs.

Moreover, Web 2.0 technologies promote communication via mobile phones or desktop computers. Web 2.0 technologies include wikis, blogs, mashups and various social networks (such as Facebook), according to (Yap et al., 2008) and (O'Reilly, 2007). When the technologies of RFID and Web 2.0 are used in conjunction with one another, they can improve management of inventory. This study considers the combined advantages of IoT technology or RFID and Web 2.0 tools, such as Twitter, in order to enhance inventory management, by keeping managers of inventory informed about the status of inventory by means of their mobile phones. Mobile phones are the most commonly used and most economically viable mode of communication, as opposed to the desktop computer. According to (Siorpaes, 2006), "The interaction between mobile devices and physical objects in the real world is gaining more and more attention as it provides a natural and intuitive way to request services associated with real world objects" .

## 1.2 Background

### 1.2.1 Inventory Technologies in South African Enterprises

Information technology (IT) provides value to the firm by increasing internal and external coordinating efficiency, and firms that do not make use of IT maybe at a competitive disadvantage. However, technological changes are not always strategically beneficial, and will not guarantee the success of the business in all cases; in fact, they may even lower the competitive advantage. IT alone has not produced sustainable performance advantages in the retail industry, as explained by (Powell, 1999, Wild, 2002). Large retailers use sophisticated inventory management technologies, including electronic data transfer to and from suppliers, to increase operational efficiencies and improve services. Information technology is a tremendous driving force in inventory management. However, large percentages of retailers in developing economies still use scanners to log the receipt of goods, and point of sale (POS) scanning to record purchases for accounting, marketing, and inventory management purposes, and for taking physical inventories (Powell, 1997).

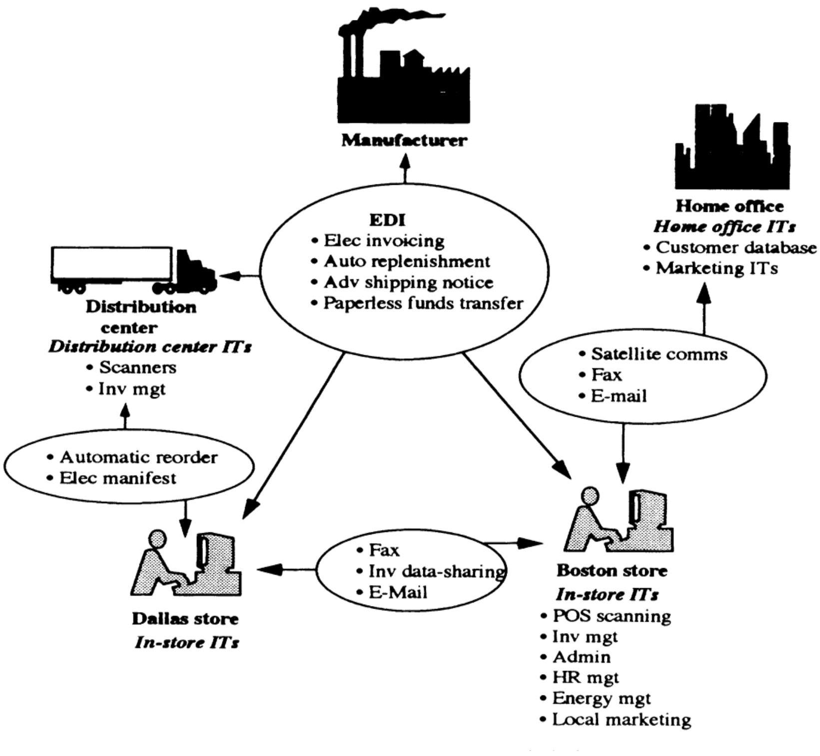



**Figure 1.2** IT linkages in a retail industry (adapted from Powell, 1997)

Figure 1.2 describes technologies that are applied today within the retail industry of South Africa. Such technologies will slowly fade as new technologies emerge. For example, Walmart announced that all its suppliers must deliver RFID technology-enabled products by the year 2007 (Chen 2008, Sarac et al. 2010, Chen et al. 2010).

### 1.2.2 Web 2.0 in the Enterprise (Enterprise 2.0)

(McAfee, 2006) first used the term Web 2.0 in connection with its application within an organisation as a tool for the enhancement of effectiveness and productivity. Most of the organisations and industry verticals noticed excessive growth over the web related to social as well as community sites such as YouTube, Myspace, and all the other Web 2.0-related sites. Many enterprises have observed the move of big web companies such as Google, Amazon, Yahoo and eBay towards social and community features, and noted the demand and interest this has created amongst consumers. As a result, most enterprises are ardently considering the construction of portals in online communities and businesses for their own organisations. With such socially-inclined solutions, Web 2.0 tools are moving into business enterprises in order to make a difference (Fuchs-Kittowski et al., 2009).

Organisations are interested in implementing Web 2.0 tools in two main areas. These are: within the business itself to advance competency and production, and in interactions between the organisation and its customers, to improve revenue and customer satisfaction. The use of Web 2.0 within organisations is called Enterprise 2.0 and is likely to be the first area where Web 2.0 will be used by organisations. Enterprises are using Web 2.0 technology mainly to communicate with customers (advertising), business partners and potential employees, allowing these parties to achieve the goal of true real-time collaboration. This can increase output and also provides enterprises with a mechanism to promote their products easily. The creation of online communities, blogs, and wikis that initiate conversations and promote the sharing of knowledge is proving to be particularly interesting to enterprises. Enterprises are already using Web 2.0 technologies inside the organisation for communication with employees and customers, and for marketing. This enables analysts, decision makers, and consumers to control their own user experiences with less guidance from IT specialists, and thus makes for a more insightful and competent work environment, according to (Fernandez et al., 2008). The benefits of this include improved worker productivity, increased morale, and greater user satisfaction. Web 2.0 tools can also play a major role in inventory management in enterprises.

### 1.2.3 RFID in the Enterprise

RFID technology has been around for years and it has been used in many industries including the retail industry, the food industry, livestock management, and supply chain management. RFID is becoming more innovative and exciting area in enterprises and is receiving much attention. Figure 1.3 illustrates the benefits of using RFID in enterprises.

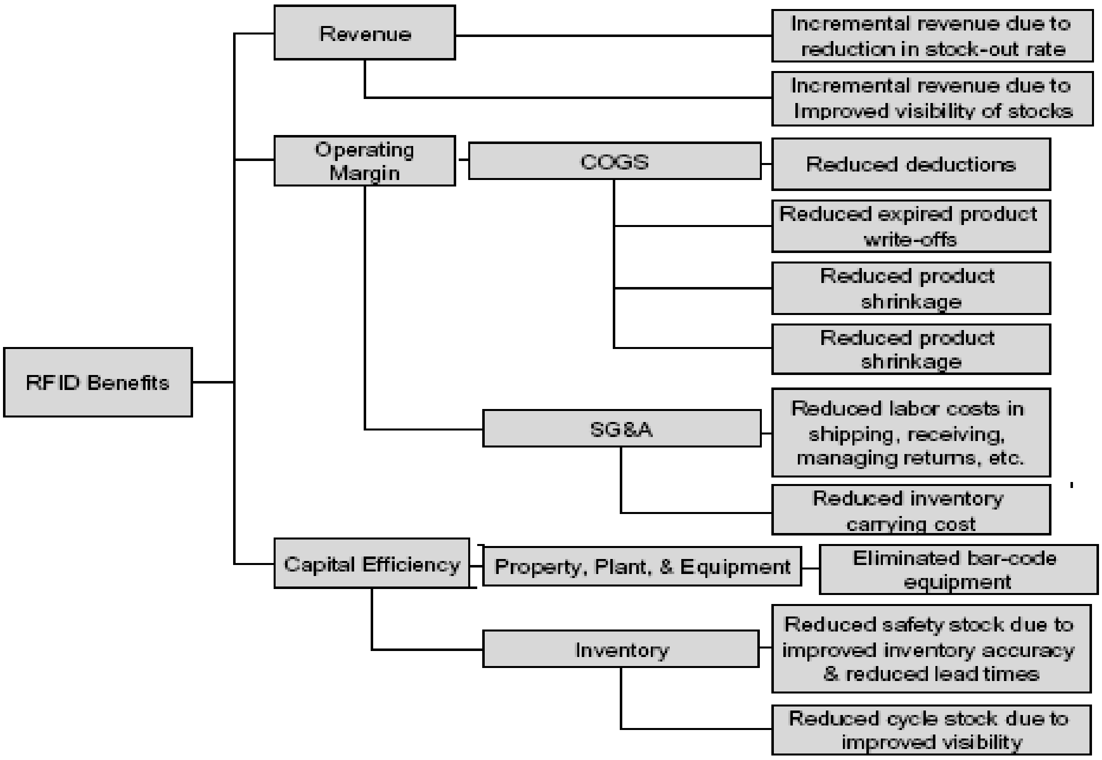



**Figure 1.3** Benefits of RFID technologies in enterprise (adapted from Sarac et al., 2010)

The major push started when the giant retailer Walmart announced that all its suppliers must supply RFID-enabled shipments in 2005. RFID technology in a retail industry provides real-time replenishment of products, and it does not require human intervention or line-of-sight to function (Chen et al., 2010, Sarac et al., 2010). RFID technology is able to keep track of and trace the location of products more precisely than other methods in current use, thereby potentially reducing losses. Walmart stores which were RFID-enabled were 63% more efficient in replenishing out-of-stock items, which resulted in a 16% drop in out-of-stock problems (Dane et al., 2010).

## 1.3 Problem Statement

It is vital that inventory management systems allow managers to receive real-time information regarding inventory. RFID technology provides the relevant information concerning the products available on shelves. It also helps to give information about expiry dates, misplaced or damaged items, etc. Most existing RFID systems are connected so as to transmit information to a personal computer system. As a result, the full advantages provided by RFID cannot be utilised, since one cannot update inventory managers on the data related to their inventories by means of their mobile phones. Receiving notifications over a social network (e.g. tweets) about the state of inventory will further result in optimum inventory management. Twitter can assist in sending inventory status information received over RFID technology to managers in real time. RFID technology does not require any human intervention; as a result Twitter can be an enabler to bridge the information gap between the RFID technology and managers. This can help members of management to attain accurate and up-to-date information for immediate decision making. This saves time and labour, thereby assisting management to make informed decisions, anywhere and anytime, quickly and cheaply.

Enterprises can accurately ascertain which products are top sellers and which are slow movers. Using RFID technology, managers of enterprises can obtain accurate analysis of employee performance as well (Myers, 2010). The massive potential of RFID technology needs intensive investigation in the context of small- and medium-sized retail enterprises in developing economies such as South Africa. Consequently, this research proposes that RFID technology and Web 2.0 technology are used for inventory management, by means of integration with mobile phones and social networks. Utilisation of the two technologies will bridge the digital division between inventory managers of businesses in developing and developed economies.

## 1.4 Rationale of the Study

South Africa is aware of RFID and is gradually utilising this technology in various areas like healthcare and mining. RFID vendors are becoming specialised in providing specific applications and tailoring their offerings to particular industries. There are several reasons for the demand for RFID in South Africa. Most urgently, there is a need to reduce theft, to quell product counterfeiting and to eradicate fraud.RFID technology has greater potential for keeping track of the location of products than any other currently prevalent and/or viable technologies. It offers the possibility of a reduction in losses and increased efficiency. The South African Government supports RFID projects and complies with the international policies associated with the application of RFID when importing goods such as beef products, and this has influenced the adoption of RFID in South Africa (Frost & Sullivan, 2008).The relatively slow adoption of RFID in South Africa presents diverse opportunities for retailers. The most vital advantage is the availability of abundant opportunities that have not yet been exploited.

Projects aiming to roll out RFID applications in different African countries are also on the rise. According to the study conducted by (Marsh, 2011), RFID can be used in South Africa for spot timing. Supply chain, asset management and mining are amongst the areas expected to show an increase in the demand for RFID applications, and implementation in these areas is progressing rapidly. However, despite the numerous opportunities for RFID applications, there are also factors hindering its expansion. The most remarkable is the high cost of installing the application: most enterprises in South Africa are small- to medium-sized businesses that do not manufacture or sell products in massive quantities. RFID is costly for such businesses to implement. Consequently, many sectors continue to use alternative solutions such as bar codes (Brown & Russell, 2007).

The slow rate of RFID adoption is hindering the developmental process. Acceptance of RFID applications requires good infrastructure standards, especially in the industries of power and telecommunications. This is why the demand for RFID is negatively affected in many countries or regions that face infrastructural complications. However, despite diverse technological challenges, the cost of RFID tags is dropping consistently and significantly as its manufacturing advances. It is expected that this will lead to advances in the manufacturing of low-cost RFID. The continued drop in prices will be a key factor in creating a greater demand for RFID in South Africa. Cheaper tags will lead to a decrease in demand for the more expensive RFID devices currently in use. This will make it possible for enterprises of all sizes to adopt RFID.

Apart from price considerations, interoperability of RFID devices is another challenge. Participants in the market need to collaborate in order to resolve interoperability issues and other concerns that have an effect on the use of RFID applications, such as agreeing to a common approach to the industry principles (Frost & Sullivan, 2008).

The study conducted by (Upfold & Liu, 2010) states that South African retail enterprises are aware of RFID technology and its advantages, but there are hindering factors such as poor tag read rates, inaccuracy and non-compliance with global standards. However, RFID in South Africa has become well-established in some niche applications such as access control, i.e. biometrics and tollgates (Brown & Russell, 2007). South African regulator, the Independent Communications Authority of South Africa (ICASA), permitted suitable Electronic Product Code (EPC) RFID frequencies in 2010. This shows that major deployments are yet to take place. However, the cost of the tags has been too high for retail organisations to see the advantages of using this type of real-time tracking. This will eventually change as time goes by (Franz-Kamissoko, 2009). With this in mind, researchers are motivated to conduct research into improving the quality of applications and the general performance of the RFID technology in order to prepare for a more robust future for the technology. This study sees this as a motivation to investigate the possibilities in the domain of RFID technology to implement novel applications for porting inventory information on social networks.

## 1.5 Research Question

How can RFID and Web 2.0 technologies (specifically Twitter) be utilised to improve inventory management systems in Retail Enterprises?

## 1.6 Research Goal and Objectives

### 1.6.1 Goal

The aim of this research is to develop enhanced software architecture for inventory management and to improve on traditional approaches. The goal is to develop a system that can fully integrate the technical advantages of Radio Frequency Identification (RFID) with Web 2.0 tools on social media platforms such as Twitter.

### 1.6.2 Objectives

**i)** To review relevant literature in relation to management of modernised inventory systems with emphasis on RFID and Web 2.0 technologies

**ii)** To determine from analysis of existing systems that have adopted the RFID technologies and how RFID impacts management of inventory

**iii)** To explore knowledge gained in Objective (ii) to design an innovative architecture for managing inventory using RFID and Web 2.0 technologies

**iv)** To create a prototype of the developed architecture using the most appropriate tools and evaluate the performance of the prototype.

## 1.7 Research Methodology

### 1.7.1 Literature survey

A comprehensive literature survey on the management of inventory, RFID and Web 2.0 technologies was conducted. The literature surveyed included journal articles, conference papers, White papers, and online sources to identify past and on-going research that is relevant to RFID and Web 2.0 technologies for the enhancement of inventory management in retail enterprises.

### 1.7.2 Model design

Scholarly literature on RFID and Web 2.0 management of inventory architecture was identified. RFID and Web 2.0 were further investigated in depth, in order to identify useful criteria for determining RFID-compatible functionality. This was used to propose architecture for management of inventory that utilises existing RFID and Web 2.0 application systems.

### 1.7.3 Prototyping

This prototype is a testing-out prototype as it is not the first attempt made in this area. RFID tags, readers and Arduino were used to identify products during the inventory. Knowledge of the platform Beachcomber (Butgereit and Coetzee 2011), which is designed to communicate things via XMPP (Extensible Messaging and Presence Protocol), HTTP and Quick Response (QR) codes to humans via e-mail and Twitter, was also used. The Beachcomber information was merged with RFID technologies to come up with the proposed system.

## 1.8 Organisation of the Thesis

Chapter 1 describes the overall work, which includes the introduction and the rationale of the study, problem statement, objectives of the study and the methodology that was used. Chapter 2 presents RFID in literature, explaining RFID research trends within the domain of the investigation. It also identifies a gap in the literature. Chapter 3 is the related technology review on inventory management, the application of RFID in inventory management and the use of Web 2.0 tools as a communication medium. It also explains how these technologies can improve inventory management.

Chapter 4 presents the model development or architecture for inventory management using RFID in combination with Web 2.0 tools for communication. Chapter 5 illustrates the design and implementation of the proposed architecture. It also presents the results of how the proposed architecture worked. Chapter 6 presents the conclusions of this study. It also presents the benefits of this research. Finally, it points out the drawbacks of the work that could be improved upon by future researchers dealing with this topic.

## 1.9 Publications Arising from this Work

Mathaba S., Dlodlo N., Smith A. and Adigun M. (2011). "The use of RFID and Web 2.0 Technologies to Improve Inventory Management in South African Enterprises". In *The Electronic Journal of Information Systems Evaluation,* Vol. 14(2) p.p.228-241. Available at www.ejise.com.

Mathaba S., Dlodlo N., Williams Q. and Adigun M. (2011). "The use of RFID and Web 2.0 Technologies to Improve Inventory Management in South African Enterprises". In *Proceedings of the 2nd International Conference on Information Management and Evaluation,* p. 300.

Mathaba S., Dlodlo N., Smith A., Makitla I., Sibiya G. and Adigun M. (2012). "Interfacing internet of things technologies of RFID, XMPP and Twitter to reduce inaccuracies in inventory management". IST Africa, Dar es Salaam, Tanzania.

# CHAPTER TWO
# RFID IN THE LITERATURE

## 2.1 Introduction

The continuous critical work involved in inventory management has resulted in new technologies being invented which will make inventory management processes easier. These processes include identifying misplaced stock, counting the stock on shelves, and identifying expired products on shelves. These tasks are quite difficult to manage by means of human observation. This has resulted in the ever-increasing adoption of RFID technologies in retail industries and other sectors, due to their ability to minimise the possibility for human error (Dane et al., 2010). This chapter will review the use of Internet of Things and RFID technology in inventory management for locating misplaced stock, checking stock levels and identifying misplaced stock both in the pre-web technology and web technology eras. The chapter also presents a review of current state-of-the-art applications of IoT and Web 2.0 technology in inventory management. The gap in literature which this research aims to fill is identified in the course of the discussion of the background to the work.

## 2.2 Application of RF Technology for Real-time Data Collection in the Pre-Web Technology Era

(Yao & Carlson,1999) discuss the impact of real-time data communication on inventory management. The authors evaluate barcoding, scanning and two-way radio frequency (RF) transmission methods of real-time data collection. Their paper emphasises that activities of suppliers, sales and distribution personnel and customers are performed with greater confidence and result in improved profitability due to the increased inventory accuracy and timeliness of real-time data. The article, which reported on the work of (Eckles, 1992), was entitled “Move data fast with RF data communication.” (Hornak , 1994) is the author of another historic work on the use of automatic identification of inventory items. The work of (Yao & Carlson, 1999) further represents RF technology options for mobile workers. (Forger, 1995) also discusses how radio frequency data communications (RFDC) and software resulted in a 40% cut in order turnaround time in a study reported in *Modern Materials Handling* in March 1995.

These studies reveal that RF technology had an impact on transmitting real-time data before the explosion of the internet. Over the years real-time data access of inventory systems has been made more possible with advancement in internet and web technologies. The following section discusses how advances in RF and web technologies are currently being used to enhance real-time inventory management.

## 2.3 Current State of Research in Application of RFID-IoT and Web Technologies to Inventory Management

The study of (Lancioni, 2003) reveals that “Internet usage within supply chains is maturing as evidenced by enhanced and increased productivity, reduced costs and increased profit for participating firms.” ( Cosmin et al., 2012) proposed the use of RFID technology to automate shelf replenishment decisions in retail store operations. They constructed and tested “an inventory control policy based on RFID data with case-level tagging.” The RFID hardware model in their work is “capable of detecting bidirectional product movements between a store's backroom and the sales floor.” The contribution of the work is threefold. Firstly, records of “detection errors caused by imperfect RFID read rates were taken.” Secondly, the research proposed and evaluated a “simple heuristic extension to avoid some of the inherent downsides of fully automatic inventory control.” Thirdly, a comparison was performed between their proposed policies and traditional schemes under the categories of stochastic demand, lost sales, and shrinkage. The research found that RFID-based policies have the potential to improve cost efficiency and service levels.

(Wong et al.,2012) used a combination of RFID technology and product cross-selling systems to perform “cross- and up-selling” for the retail industry. They developed two systems, namely the Smart Dressing System (SDS) enabled by RFID technologies, and Intelligent Product Cross Selling System (IPCS). According to the researchers “the SDS demonstrates a research endeavour in which, unlike the previous studies focusing on transactional data, customers’ in-store data can be collected using RFID-enabled

SDS and used for promoting or cross-selling new products to the customers effectively and efficiently." Their IPCS integrates a rule-based expert system and a fuzzy screening technique. It is a simulated scheme for handling the "difficulty of processing linguistic and categorical information" for "fashion designers to recommend appropriate fashion product items for cross-selling effectively." Their proposed systems were evaluated to execute the selling strategies more effectively. The proposed solution improved sales performance in the fashion retail industry.

(Matta et al., 2012) examined the stages hypothesis of the process of technology adoption by management personnel of organisations in the supply chain sector. The hypothesised stages in the investigation are: Initiation, Experimentation, and Implementation. Antecedent factors, such as top management support, external pressure, and organisation size, which may influence those various stages, were examined in the research. By analysing responses collected from top management representatives of 210 supply chain organisations to their organisations' engagement with Radio Frequency Identification (RFID) technologies, this research found that these stages are true for RFID technologies. Over 80% of organisations, who had reached the Implementation stage of adoption, had gone through the Initiation and Experimentation stages as well. This shows that organisations seem to progress sequentially through the Initiation, Experimentation, and Implementation stages. Furthermore, the data from the research showed that the antecedent factors exerted varying levels of influence during the three stages. "Top management support strongly influenced all three stages: external pressure influenced the Initiation and Implementation stages, and organizational size influenced Experimentation and Implementation stages."

(Bakker et al., 2012) reviewed the advances made in the field of inventory control of perishable items (deteriorating inventory) from 2001 to 2012. The researchers used the classification of (Goyal & Giri, 2001) based on shelf-life characteristics and demand characteristics. "Contributions are highlighted by discussing main system characteristics, including price discounts, back ordering or lost sales, single or multiple items, one or two warehouses, single or multi-echelon, average cost or discounted cash flow, and payment delay." The study shows that RFID facilitates integration down the supply chain, resulting in great opportunities for inventory control of perishables.

## 2.4 Related Work

The work of (Chande et al., 2005) relates to the optimisation problem in inventory management and pricing. They developed a discrete time framework and an efficient algorithm and proposed an architecture application of RFID technology in the problem domain. (Li et al, 2006) discuss the technology behind RFID systems, identify the applications of RFID in various industries, and discuss the technical challenges of RFID implementation and the corresponding strategies to overcome those challenges. The authors “identified research that addresses the technical issues of RFID implementation” at that point in time.

Research in the combined use of IoT and Web technologies is still very much in its infancy. (Brown & Russell, 2007) conducted an exploratory investigation into RFID adoption in South African retail organisations and identified factors that have an impact on the adoption status. The findings showed that in 2005 many retailers had not yet adopted RFID or even conducted pilot studies, but intended to do so in the future. The situation has not changed much at the time of conducting this research.

(Delen et al., 2007) conducted a case study using RFID data collected by a major retailer for shipment by one of its major suppliers. (Chao et al, 2007) shed light on RFID trends and contributions through a historical review and bibliometric analysis. From the analysis of the study’s findings, supply chain management (SCM), health industry and privacy issues emerge as the major trends in RFID. The contributions of the RFID industry and forecasts of technological trends were also analysed. The study concluded that RFID will be more ubiquitously assimilated into our daily lives in the near future.

(Pedroso et al., 2009) provide a framework for RFID technology adoption considering company size and five dimensions of analysis: RFID applications, expected benefits, business drivers or motivations, barriers and inhibitors, and organisational factors. The authors found that many companies have been developing RFID initiatives in order to identify potential applications and map benefits associated with their implementation. The survey highlights the importance of business drivers in the RFID implementation stage, and shows that companies who implement RFID should begin by focusing on a few specific applications. However, they discovered a weak association between expected benefits and business challenges in connection with what was then the current level of RFID technology adoption in Brazil, where the research was conducted. A similar survey in South Africa by (Brown & Russell, 2007) shows a grimmer result. Up-to-date empirical results have not been validated to reach this conclusion as of yet, but there is ample evidence based on observation.

(Visich et al., 2009) investigated the actual benefits of RFID on supply chain performance by means of gathering empirical evidence. The study discovered that an automating effect on operational processes is the main benefit of RFID. This is closely followed by positive effects on the amount of information available during managerial processes. The RFID implementation had not reached transformational level in either operational or managerial processes at the time of conducting the research. It is doubtful whether the situation is any different today, especially in the context of this research. RFID has an automating effect on operational processes through inventory control and efficiency improvements. An informational effect for managerial processes is observed in improved decision quality, production control and the effectiveness of retail sales and promotions coordination. In addition, a three-stage model was proposed by the authors to explain the effects of RFID on the supply chain.

## 2.5 Summary

The study of background literature on inventory management shows that little has been written regarding the notification of inventory managers using the web as a platform. Alarm systems are currently used to detect errors and system failures. In addition to this, social networking tools like Twitter can be used to send notifications about inventory, allowing easy access to data and instant notification anywhere, anytime (Mathaba et al., 2011, 2012). Web 2.0 technologies allow for ease of use and integration with other applications; they use light programming models and HTTP communication protocol. The RFID technology integrated with Twitter can provide an online platform for inventory monitoring. Chapter 3 will focus on the literature on these technologies and their applications in enterprises.

# CHAPTER THREE
# RELATED TECHNOLOGY REVIEW

## 3.1 Overview

The previous chapter defined the goal of this study, but there are concepts which need to be explained in detail. These include inventory management, Internet of Things (IoT), the Beachcomber model, and Web 2.0 technologies and applications. This chapter explains all the fundamental concepts used in this study, as well as their background.

## 3.2 Inventory Management Systems

Inventory is the most visible and tangible aspect in a business. Inventory refers to the stock necessary to do business, and the management of said stock. "In an inventory system, a data may include inventory levels, quantity of orders picked in certain time frame or locating products in transit" (Hamid & Hong , 2008). Inventory management is vital in retail for effective and efficient supply chain processes. These processes include forecasting, stock replenishment, ordering, hardware and software control and effective utilisation of stock information. Figure 3.1 shows all the activities required for an inventory repository database. Inventory management regulation also comprises recognition and monitoring of information services, which use hardware and software assets. It has three major areas: acquisition, redeployment and termination.

- **i)** **Acquisition:** The main task of the acquisitions department is to help personnel in procurement processes. It ensures proper validations are performed and financial procedures are followed properly. In acquisitions, purchases and orders are acquired, and once added to shelves, the master inventory record is updated. The inventory records are used to calculate resale and placement of new products.
- **ii)** **Redeployment:** Redeployment entails procedures carried out to ensure that products reach their destination and that they do so within budget. When the products are delivered to another location, the system is updated to

indicate that the stock has been removed from the previous owner and transferred to the new owner.

**iii)** **Termination:** Termination is mainly the completion of the inventory management process. Data wiping is performed on the database at this stage. This process need to be certified first to avoid losing critical data.

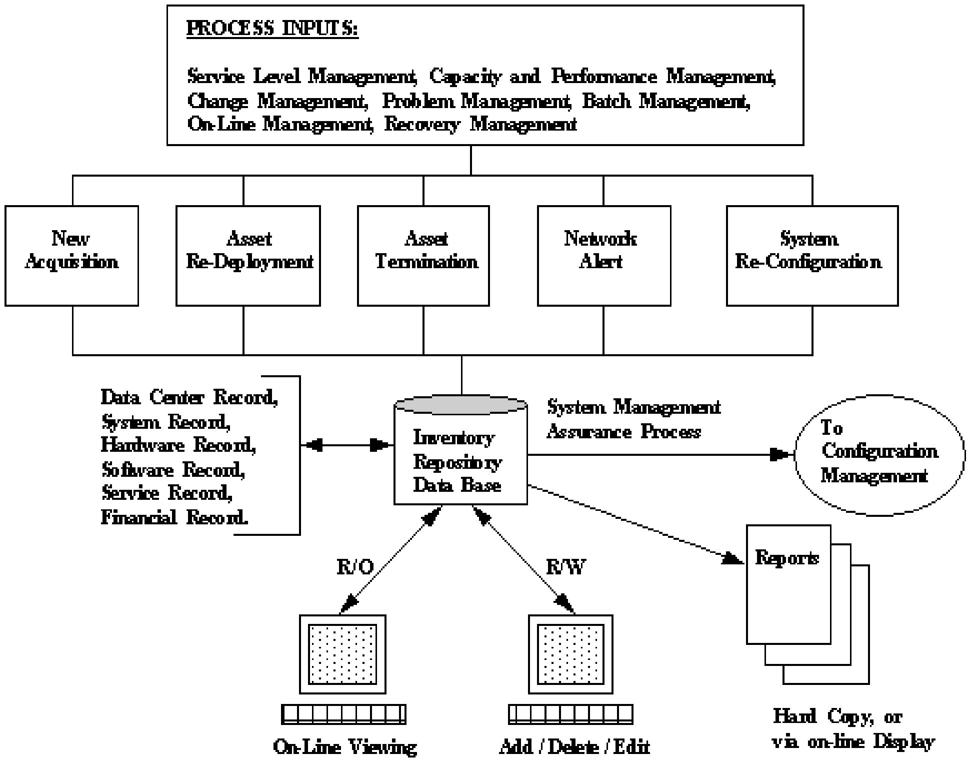



**Figure 3.1** Inventory management process (Bronack , 2012)

The aforementioned processes, if not painstakingly carried out, can lead to inventory inaccuracy. Inventory inaccuracy is a major problem if overlooked. Inventory systems need to have accurate inventory records of stock on hand and stock to be ordered. However, most small retailers find it difficult to know how many products they have in the store. The actual inventories or Perpetual inventory (PI) in the store and inventory records are not always up to date. Perpetual inventory is the keeping of book inventory in parallel with the stock on hand within specified time intervals; stock on hand and the inventory book are integrated to check the inventory to be ordered and inventory on hand. PI records show the actual inventory in the store.

The inventory management systems are able to calculate PI based on the stock that is present (on hand), but this information is not always accurate and thus the ordering process might be based on incorrect information. Traditionally, to reduce these errors would require more human labour in the form of physical counts, resulting in increased labour costs. Yet the accuracy of the counts still cannot be guaranteed. The basic PI inaccuracy can result in either overstated or understated inventory. An overstated PI occurs when an inventory system shows more inventory than is actually available in the store. An understated PI happens when the system shows fewer items than there are available. These items are called 'hidden inventory'. These PI inaccuracies result in too much, or too little stock being ordered. The result is excess cost, reduced profit, and poor inventory control (Goyal et al., 2009). Inventory control systems are used to eliminate or reduce these errors to the barest minimum.

The following are types of inventory control systems:

- **a) Visual control** – examining inventory visually. This type of inventory control is mostly used in small businesses for slow-moving stock.
- **b) Tickler control** – products are physically counted on a daily basis in small portions or by segments.
- **c) Click sheet control** – records the item immediately as it is taken or used.
- **d) Stub control** – a part of the price ticket of the item sold is retained. The inventory manager uses the stub to record all items sold and which ones to order.
- **e) Point-of-sale terminals** – transmits information on each product as it is sold. The inventory manager receives printouts on a regular basis for review and decision making.
- **f) Offline point of sale** – transmits information directly to the supplier system. The supplier uses this information to ship stock to the buyer (Hedrick et al., 2008).

Inventory management systems have a number of interfacing functional areas that interact to achieve the overall goal of the process. Figure 3.2 is a graphic representation of the functional areas that interface with inventory management systems as explained by (Bronack, 2012).

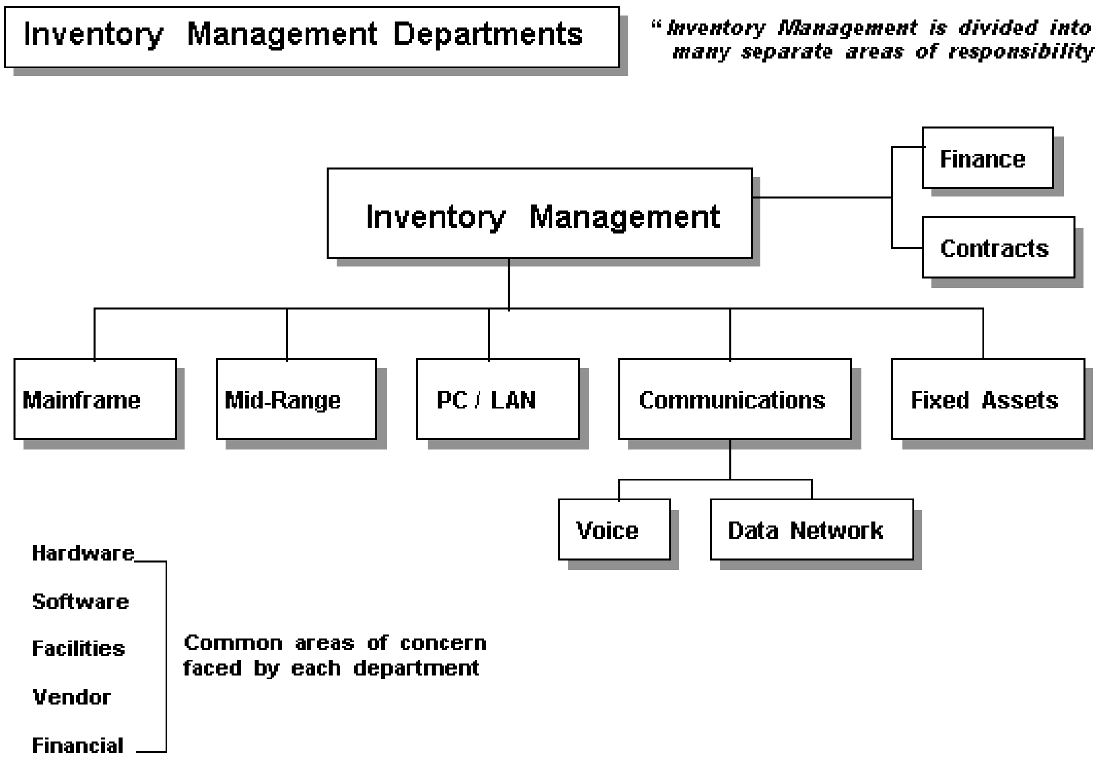



**Figure 3.2** Inventory management departments (Bronack, 2012)

The inventory management system utilises different departments' information, networks and systems from all over the enterprise. Product information of a financial and technical nature must be available in the inventory system for the finance/ contract management department. All assets in the enterprise must be documented in the inventory system for easy recovery management, and recovery procedures must be preserved as vital assets.

## 3.3 Internet of Things Application and Technologies

The Internet of Things (IoT) is defined as the worldwide interconnections of objects or things, which are uniquely distinguishable, by means of established communication protocols. It is a universal networking substructure with its own identifying and configuring capabilities, using interoperable protocols by which virtual things flawlessly amalgamate in information networks (de Saint-Exupery 2009, Prasad & Reichert, 2011). These objects communicate with each other using intelligent communicating mechanisms such as RFID tags, sensors, and actuators (Atzori et. al, 2010). These tools intelligently enable locating, identifying, tracking, and monitoring of objects over the internet. IoT is a three layer system. These layers are (1) the sensing layer, (2) the network layer, and (3) the application layer. The sensing layer consists of readers and cipher labels, which are generally RFID tags, RFID readers, global positioning systems (GPS), cameras, near field communicators, machine-to-machine terminals and sensor network gateways.

The network layer is the integration of communication networks and the internet. It supports intelligent processing of massive amounts of information, incorporates network management, transports data, connects cloud computing platforms, and supports expert systems. The network layer is the infrastructure that can assist the IoT to become a worldwide service.

The application layer is known as the input and output control terminal. It is a set of intelligent application solutions that combine the IoT technology and industry field technology. The main responsibility of the application layer is the social sharing of information and ensuring the security of information (Ning et.al, 2006).

### 3.3.1 Components of Internet of Things

The Internet of Things links any objects to the Internet, exchanges information and communicates using technologies such as RFIDs, near field communication (NFC), electromagnetic sensors, GPS and laser scanning, etc. These tools intelligently enable location, identification, tracking and monitoring of objects over the network. IoT is viewed as the third trend in the global IT industry, after the emergence of computers and the internet. The IoT is also defined as a real physical world network connection, whereas the internet is a virtual information-sharing network. RFID and other sensor networks are the fundamental components of Internet of Things, according to the (European Commission, 2008) and (FossoWamba et.al, 2008) Figure 3.3 provides an overview of IoT within a communication framework.

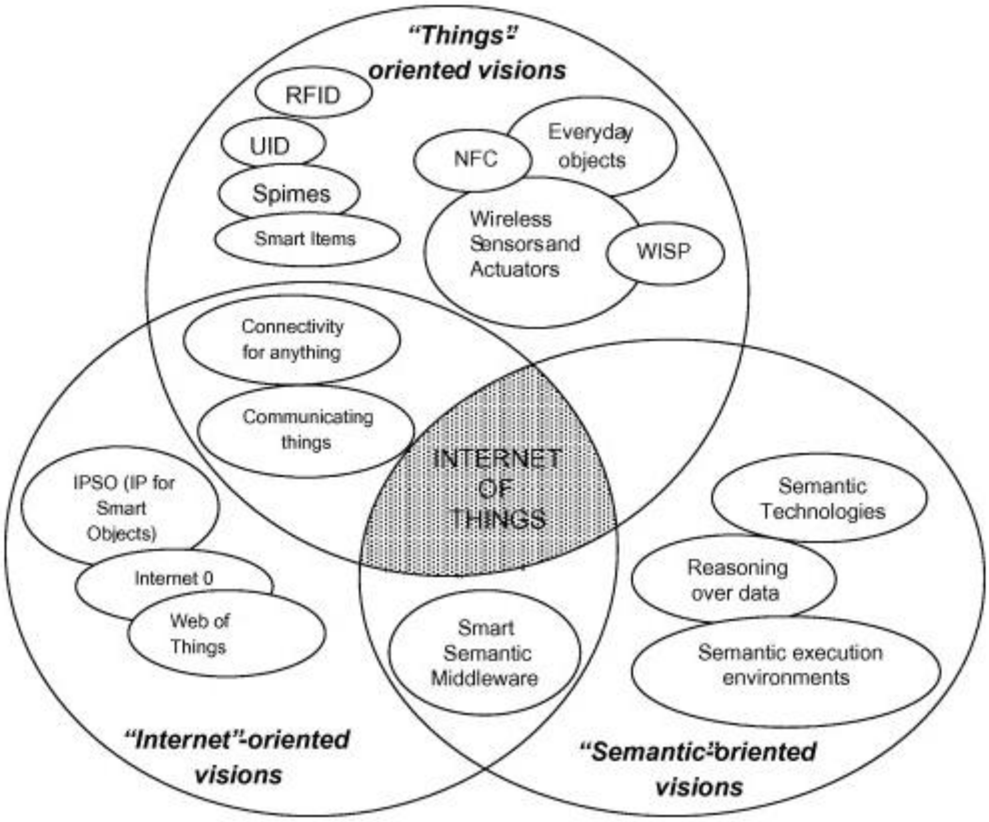



**Figure 3.3** IoT communication and connection (adapted from Atzori et. al, 2010)

3.3.2 IoT application areas

This section reviews the areas of application of IoT including retail, logistics, retail warehouse management, the food industry, ubiquitous intelligent devices, aerospace and aviation, the medical and health sector, independent living, and the oil and gas industry.

**i. Retail**

The Internet of Things' first large-scale application is in the retail industry, to replace barcodes. Retailers will have incorporated identification procedures at the point of manufacture, from supplier to storage, on shop shelves, and at cashiers and checkout. The consumers will benefit from this kind of technology because it will eliminate long checkout queues, and product history is available to consumers who wish to enquire about the product. According to (Hellstrom , 2009) and (Lee et.al, 2008) manufacturers can easily obtain sales statistics from the retailers and can produce items accordingly, thus reducing underproduction and overproduction. Nevertheless, these IoT technologies raise security concerns for consumers once they have left the shop with the tagged products. There is on-going research on how to deactivate or remove the identification devices once the consumers exit the shop so that they can be recycled (this is not covered in this research).

**ii. Logistics**

Logistics improve the efficiency of processes, and automated warehouses where orders can be checked in and out from suppliers quickly and simply will allow easy asset management and proactive planning. Manufacturers can easily manage market demands and thus production and transportation, (Qin et.al, 2008).

In general, the operation in warehouse management remains manual, with data being captured by keyboards, voice entry or by means of barcodes. This also includes the use of human-machine interface, and IoT has RFID sensors as well as RFID actuators that lead to ease of warehouse operations. Automated data entry/capture results in accurate information collection and therefore informed decisions can be made, as stated by (Nath, 2006, Curtain et. al, 2007, and Oh & Park, 2008).

**iii. Food industry**

In the food industry, food safety is very important, and thus traceable identification is necessary to assist consumers in verifying the quality and the origin of the product. Traceability also provides feedback to the managers so that they can assess their sales and plan ahead.

**iv. Ubiquitous intelligent devices**

IoT makes it possible for any object to exchange information virtually and work in conjunction with other objects in order to increase quality of life, e.g. smart homes with smart objects like kettles, washing machines, fridges, heaters, etc. communicating with their owners to report their statuses (Atzori, 2011, Hribernik, 2011). Smart metering is one popular application in measuring energy consumption at homes and notifying energy providers automatically (see Figure 3.4).

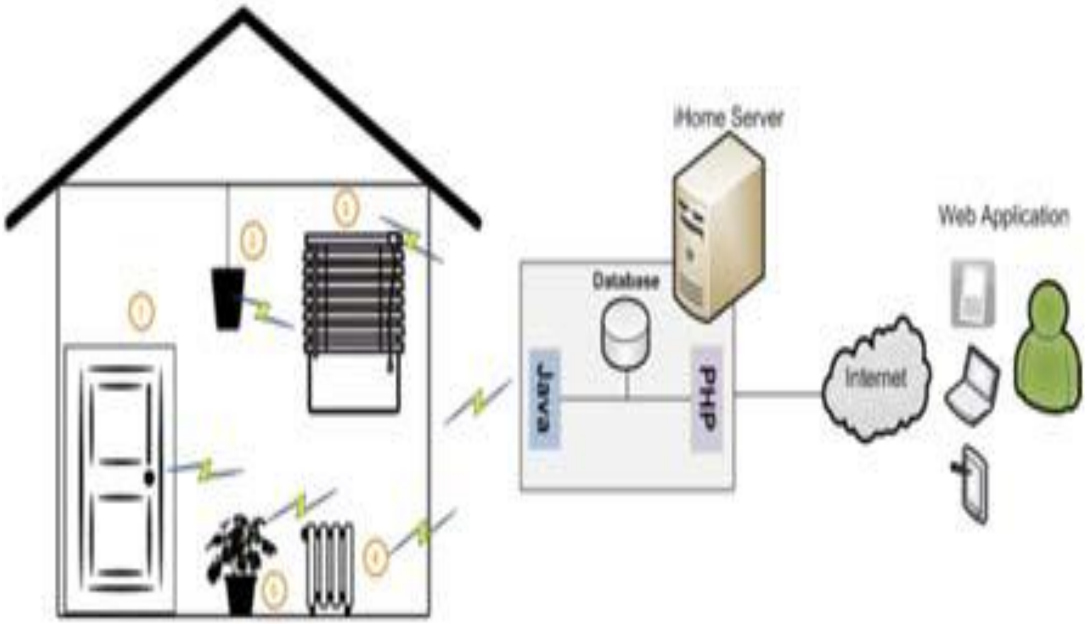



**Figure 3.4** Intelligent home (adapted from Hribernik , 2011)

**v. Aerospace and aviation**

IoT improves the safety and security of products by preventing counterfeiting. In the aviation industry the safety of aircraft is critical, but the industry faces the problem of suspected unapproved parts (SUP). SUP refers to aircraft parts that do not comply with acceptable quality standards for use in aircrafts, which puts aircrafts at risk of accidents. The use of IoT technologies like RFID reduces this problem because the origin of the parts can easily be authenticated from the supplier central database.

**vi. Medical and health sector**

In the medical sector, IoT has major role to play. RFID sensor-enabled phones can be used to monitor medicine parameters and medicine delivery. Patients' medications cannot be compromised (i.e. counterfeited). Patients in homes for the aged can be monitored and reminded to take their medication on time.

**vii. Independent living**

IoT promotes independent living, which is very useful for the elderly. Using ambient sensors, daily routines can be monitored and emergency alerts can be sent when suspicious behaviour or alarming circumstances arise. The monitoring of people may raise privacy concerns though, despite security benefits.

#### viii. Warehouse management in retail

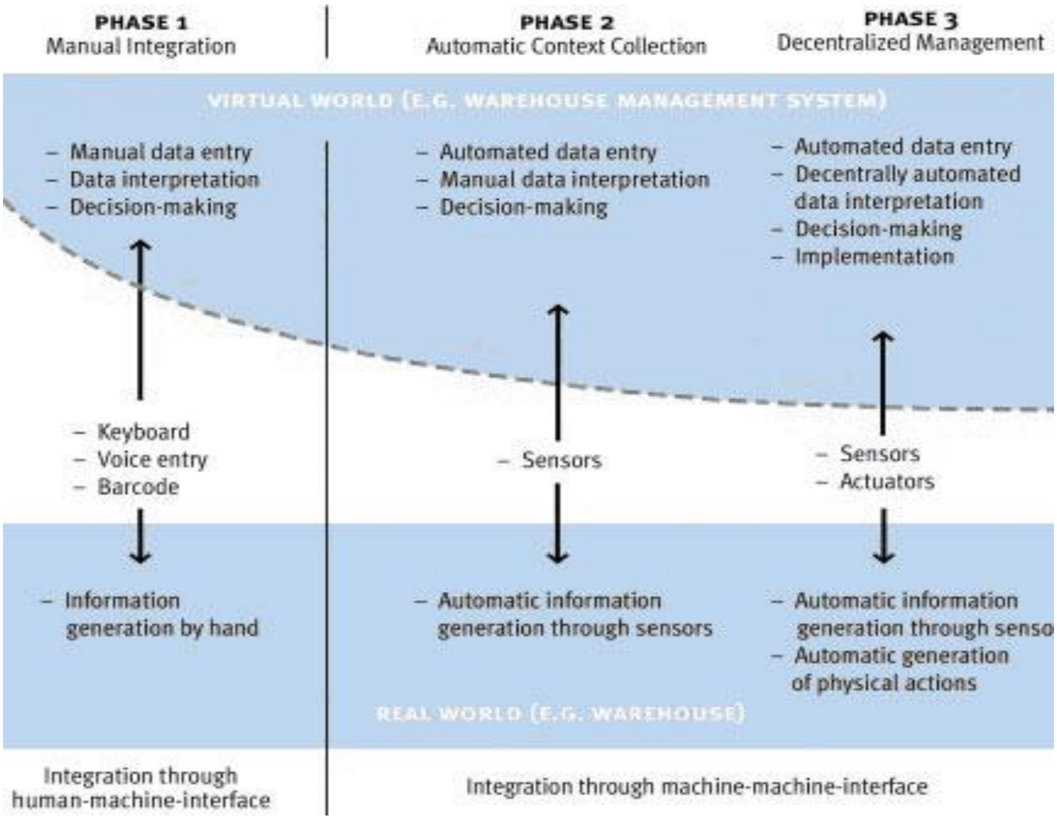



**Figure 3.5** IoT in warehouse management (adapted from Fleisch , 2010).

Traditionally, operations in warehouse management were processed manually, information captured through keyboard, voice entry and barcodes. Technologies such as RFID promote communication without any sort of human intervention in warehouse management,( Baudin , 2005 , Tan, 2008 and Han & Wenling, 2010). The example in Figure 3.5 shows IoT technologies being used in warehouse processes.

#### ix. Oil and gas industry

IoT technologies enable the monitoring of hazardous petroleum substances and the safety of personnel working in dangerous environments. Oil containers can be equipped to send periodic updates on their pressure, temperature and their state of repair to plant managers. This can assist in reducing oil leakages which result in unexpected explosions.

## 3.4 The Scientific Structure of IoT

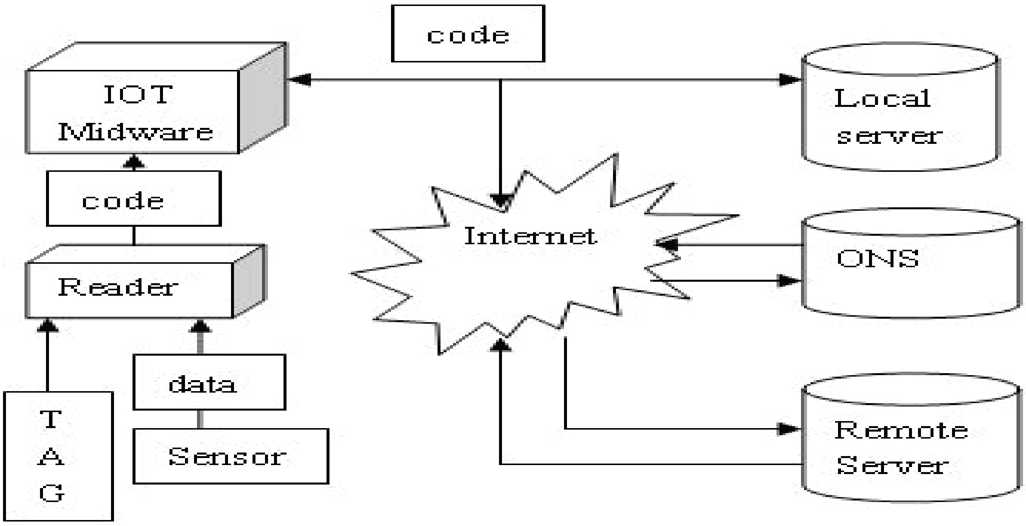



**Figure 3.4** Illustration of Internet of Things (adapted from Shen , 2010)

Figure 3.6 illustrates how the IoT functions. RFID technology comprises tags attached to an object, where each tag holds product data such as expiry date, price, temperature, etc. Sensors can be embedded inside the tagged object, which can then be accessed and decoded by tag readers. The role of IoT middleware is to filter unnecessary data and then send code to the respective local server. Data for the object remains available on the internet by means of a remote server. The Object Naming Service (ONS) acts like a Domain Name Service (DNS) and notes the data stored on servers (Hada & Mitsugi, 2011, Shen, 2010).

In IoT technology, objects are autonomous entities; social platform can enable interaction between the objects. Moreover, these technologies interact with their environments and then send or exchange data sensed in the environment, reacting autonomously towards the real physical world. This is influenced by running procedures that can trigger reactions and thereby can create services without the need for direct human intervention. Interfaces noted for services consequently facilitate communications with smart objects in the Internet, query and update the status of information related to them, and noting the privacy and security issues (de Saint-Exupery, 2009, Ma, 2011, Kosmatos et .al, 2011).

## 3.5 Radio Frequency Identifiers

Radio Frequency Identification is defined as wireless automatic data for the purpose of identification of objects which have been fitted with the technology (Dane et .al, 2010). RFID technology is a development from World War II that was used to assist aircraft in the identification of fellow commanders and aircraft on the ground (Niederman et. al, 2007). RFID tags are categorised into two types, namely active and passive, depending on the source of electrical power. Active RFID tags have their own power source, such as an on-board battery. Passive RFID tags attain power from an external reader. The readers of RFID can be active or passive, depending on the tag that they are reading (Intermec Technologies, 2007).

### 3.5.1 Active tags

Active tags have own power sources. They generally send a stronger signal, and thereby the readers can attain adequate access. However, having an on-board power source makes them expensive and comparatively big, so active RFID function well when used for large objects that are tracked from lengthy distances. Low-power related to active tags are larger than playing cards' deck. Active tags remain inactive until they are within the receiver range or can transmit a particular signal. As active tags have their on-board power source, they can function at higher frequencies, i.e. 2.45 GHz, 455 MHz or 5.8 GHz, relying to the reading range and the demands of the memory. Readers can converse with active RFID tags from 20-100 meters away (Intermec Technologies, 2007).

### 3.5.2 Passive tags

Passive tags are more economical and can cost as little as 20 cents/piece. Manufacturers are continually advancing the technology used in production in an effort to reduce the cost of these products, so that they will be affordable to a larger market (Abraham, 2002). As passive tags are inexpensive, they can be the starting point in the process of expanding the implementation of RFID, particularly in the less affluent regions of a developing country like South Africa. Apart from the low cost, passive tags are generally smaller than their active counterparts. Current antenna technology can be installed in a tag that is 75% smaller than the original passive tags. If the tag is larger, the range that can be read will also be larger. In the current scenario, passive RFID tags have almost 2 kilobits of memory. However, they are required to hold much complex data (such as identification and historical data).

RFID technology is improving continuously. Eventually data storage capabilities will increase to the point where inexpensive RFID tags will both hold and transmit adequate data (Weinstein, 2005). Table 3.1 illustrates differences between passive tags and active tags.

**Table 3.1** Passive tags versus active tags (adapted from White et. al, 2007)

| **Passive Tags** | **Active Tags** |
|---|---|
| Shorter reading range | Longer reading range |
| No power source required | Battery powered (limited lifespan) |
| Sensitive to intrusion | Less sensitive to intrusion |
| Data transmission rate is lower | Data transmission rate is higher |
| Fewer tags can be read at once | Many tags can be read simultaneously |
| RFID reader must point at the tag | No precise aiming is required to read tags |
| Cheaper | More expensive |

Passive tag readers can transmit signals continuously or can transmit only when needed. As a tag moves across the range of the reader, it accepts electromagnetic signals attained from reader via the antenna of the tag, by keeping energy from the signal within the on-board capacitor: this is known as inductive coupling. As the capacitor attains sufficient charge, it offers power to the tags' RFID circuitry, transmitting modulated signals to the reader. The return signal contains data which is stored within the tag. Low-frequency tags (>100 MHz) send data through the energy released from the capacitor towards tag coils at strengths that vary over time, which affects the radio frequency created by the tag. The reader perceives these varying waves and uses these variances to demodulate code (Weinstein 2005). In higher-frequency tags (<100 MHz), the tag transmits the signal by means of backscatter, in which the tag's circuit adjusts the resistance of the tag's antenna. This change in resistance creates the transmission of Radio Frequency (RF) waves, which the reader can accept and demodulate. Passive tags usually work at frequencies of 128 KHz, 13.6 MHz, 915 MHz, or 2.45 GHz, and have read ranges of only a few inches up to 30 feet. Frequency selection depends on the system's environment, the kind of material the signals have to pass through, and the system's essential read range. RFID tags can be enclosed in numerous materials. Plastics are the most common material used for RFID tags: they are used to produce identification cards for building entrances, credit cards, or bus fare cards (Weinstein, 2005, Intermec Technologies, 2007).

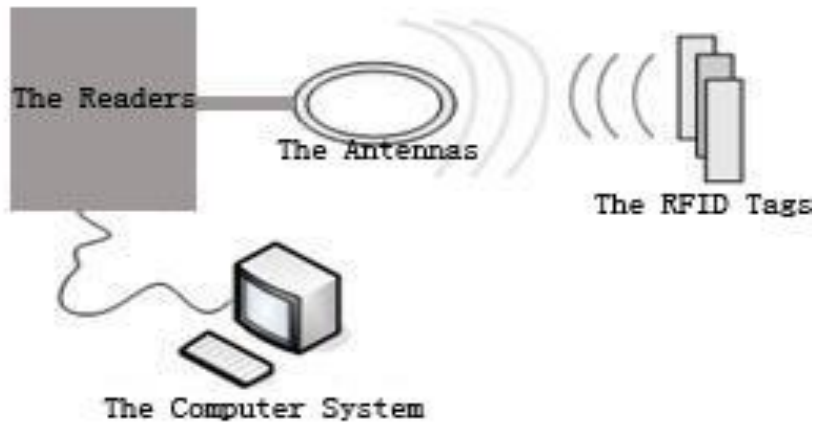



**Figure 3.5** RFID system components (adapted from Yan & Huang, 2008)

Figure 3.7 represents the RFID components and illustrates how these components work in any given environment. Tags which are usually very small in size are attached to almost any object and they send out signals which are received by the reader through an antenna, which is an enabler for tags and readers to transmit information. The information is sent to a back-end computer system for processing.

## 3.6 Beachcomber Model

Beachcomber is a platform developed to enable easy communication between objects and humans. Beachcomber can receive RFID tag information that has been transmitted using the XMPP protocol, and convert that information into a readable format for the user. When using Beachcomber, communication can either be synchronous or asynchronous. It enables Things to communicate using a number of technologies such as XMPP, HTTP, Mxit, Twitter, Java Messaging Service (JMS), Quick Response (QR) Codes and POP3. All these technological tools are deployed as Resource Adaptors below the Mobicents platform. According to (Butgereit & Coetzee, 2011), “Beachcomber is defined as a service building block running under Mobicents in JEE (Java Enterprise Edition) environment”. The Beachcomber controller provides the interface between business service and protocols. Figure 3.8 illustrates Beachcomber and its protocols.

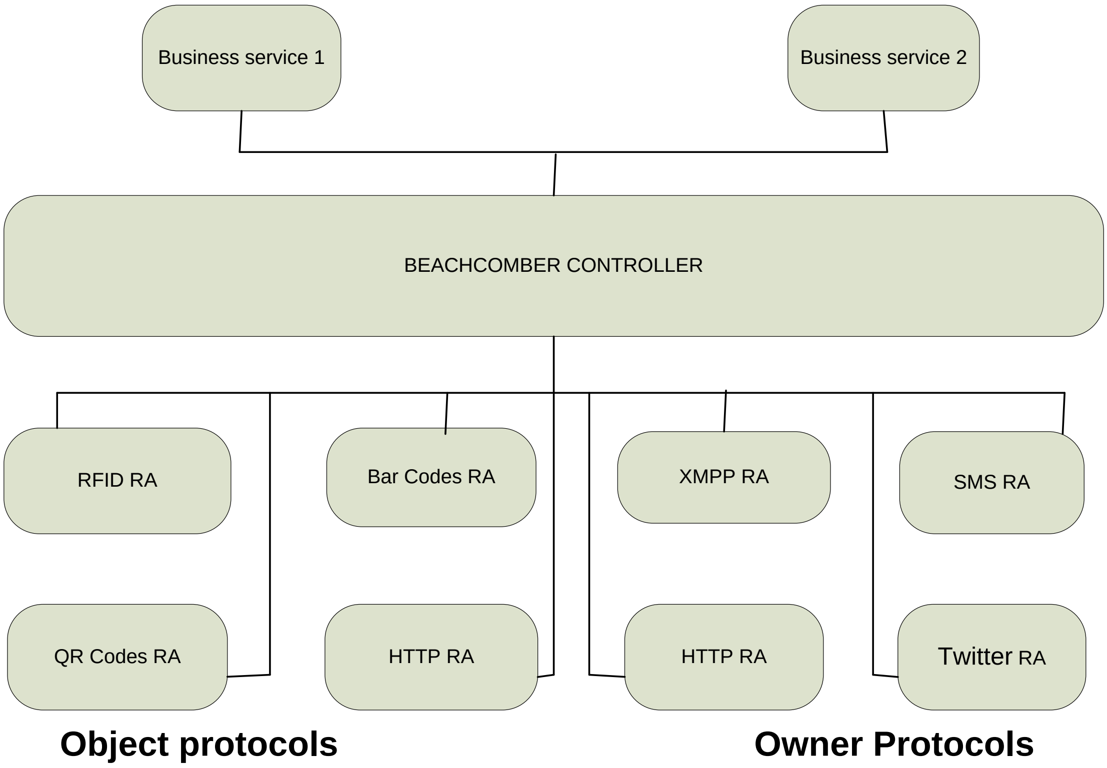



**Figure 3.6** Beachcomber model (adapted from Butgereit & Coetzee 2011)

Beachcomber enables humans to communicate using applications/protocols such as email, XMPP, and Twitter. Beachcomber links things to their human owners (Butgereit & Coetzee 2011). Messages are sent to Beachcomber and are received by appropriate resource adaptors which then convert the message format and forward it to a routing module and finally to a business service, namely Twitter. This study proposes to take advantage of Beachcomber protocols, i.e. Twitter and HTTP, to enhance the communication process in inventory management. Beachcomber can receive RFID tag information that has been transmitted using the HTTP protocol, and convert that information into a readable format for the user. When using Beachcomber, communication can either be synchronous or asynchronous. In this study, synchronous communication is supported due to the nature of the business service environment.

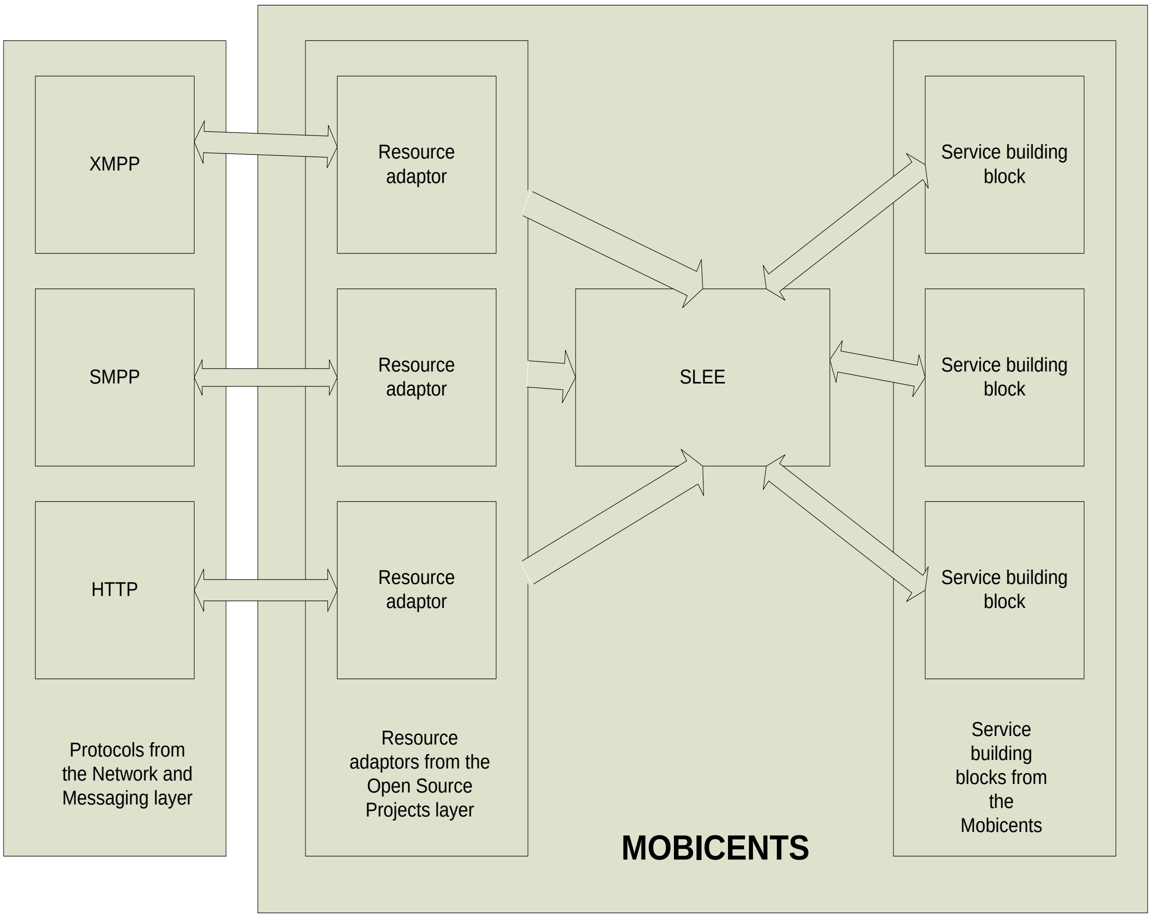



**Figure 3.7** Illustration of communication in Mobicents environment (adapted from Dlodlo & Tolmay, 2011)

### 3.6.1 Mobicents

Mobicents is an open source communication platform; it provides the runtime environment for services and applications like video/voice and messaging over the range of communication network protocols. Mobicents enables the joining of web enterprises and communication applications. Mobicents is comprised of service building blocks, resource adaptors and the Service Logic Execution Environment (SLEE) which is the event engine (Dlodlo & Tolmay, 2011). Figure 3.9 is an illustration of Mobicents and its method of communication.

### 3.6.2 Resource adaptors and Service building blocks

Resource adaptors enable information to go through to the business service or end user. Service building blocks handle the routing of information in various resource adaptors and business services.

## 3.7 Web 2.0

The Web 2.0 idea arose during the brainstorming session conference between O'Reilly and Dougherty in 2007 as illustrated in Figure 3.10. It was defined as "visualization of Web 2.0 as a set of principles and practices that tie together a veritable solar system of sites that demonstrate some or all of those principles at varying distance from that core". Web 2.0 encourages people to meet virtually, share opinions, interests or simply listen and observe (O'Reilly 2007).

Web 2.0 technologies outline the beginning of the subsequent creation of web-based applications. They allow web applications to be created that are more operationally rich and quicker to respond than the usual static pages of traditional web technologies. They also enable content to be produced and shared in real time, with end users commonly able to add content to applications themselves (O'Reilly 2007, Al-Tameem 2008, Shi et.al, 2010). This implies that Web 2.0 technologies support open communications and provide users with the freedom to share their suggestions and opinions.

According to (O'Reilly, 2007), Web 2.0 features "the Web as a platform, harnessing collective intelligence, and data as the next Intel inside." Other features are the "end of the software release cycle, lightweight programming models, software above the level of a single device and rich user experience" (Shang et. al, 2009) and (Wu et. al, 2010).

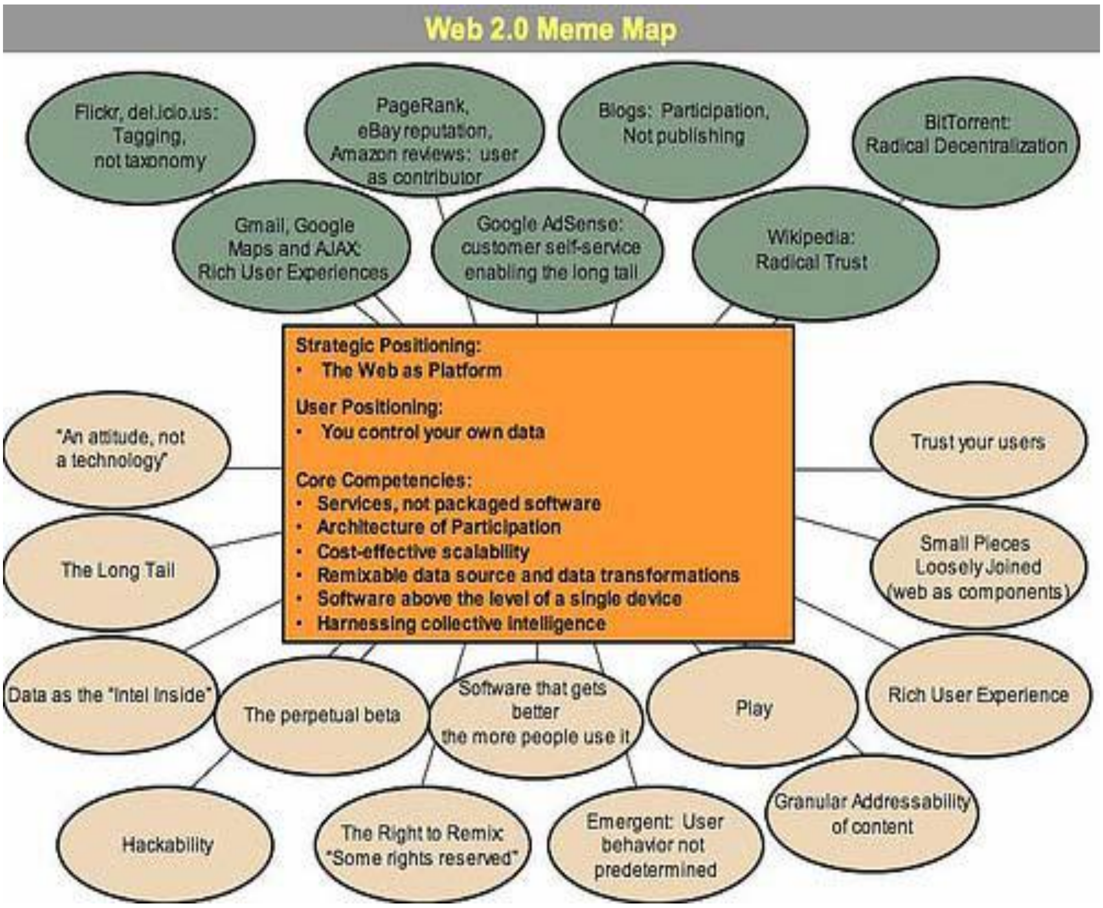



**Figure 3.8** Web 2.0 architecture (adapted from O'Reilly, 2007)

### 3.7.1 The Web as a platform

Web 2.0 tools use the web as a platform, in which a massive collection of interconnected devices offer a dynamic level of rich and explorative experience for users. Web 2.0 uses lightweight programming models for the developer and a quick, flexible deployment method for the supplier. It sees the internet from the user's, the developer's, and the supplier's perspectives, allowing each individual a new and creative utilisation of the internet (Yap et.al, 2008).

The web service system supports all connected systems, which includes Web 2.0. The service-based system employs the approach of separation of concerns through the employment of loose coupling or message passing. Loose coupling enables functionality to be produced as a service and delivered over the network; i.e. in the

Web 2.0 world, updates on inventory can be provided by a blog engine and be sent as a service to the end user (management team) or blogger over the internet. This delivery of software utilisation over the internet is generally called Software as a Service (SaaS) and it is an enabler for the majority of Web 2.0 systems at present (O'Reilly, 2007 and Omar et.al, 2007).

Software as a Service is a software distribution model where applications delivered by a vendor or service provider are made available to consumers over a network, normally over the internet, according to (Choudhary, 2007). SaaS is progressively becoming a more prevalent delivery model as fundamental technologies that sustain web services and Service Oriented Architecture (SOA) are becoming more established, and innovative developments are taking place, (Turner et.al, 2003). For example, recently the broadband service has become more accessible to enable more user access countrywide (Schroth & Janner, 2007, Omar et.al, 2007). The SaaS model enables easier management, automatic updates and patch management, consistency (i.e. same version of software for all users), easier alliance and worldwide openness.

Simple Object Access Protocol or SOAP-based web services are normally implementations of SOA, though there are non-web service implementations of SOA that offer related benefits. The protocol autonomy of SOA implies that diverse users can correspond with the service in different ways, according to (Kryvinska et.al, 2009).

As far as the internet as a platform is concerned, it has to offer significant platform fundamentals such as device autonomy, a friendly user interface, a familiar programming interface, and a software or service deployment and administration method, as stated by (Choudhary, 2007).

### 3.7.2 Rich user experience

The significance of rich and immersive user experience was noted in the computing world long ago at the introduction of Windows, which has been the centre of browser-based applications for years. JavaScript and Dynamic Hypertext Markup Language (DHTML) were introduced as lightweight programming models for providing client-side programmability and enriching user experience in what are called Rich Internet Applications (RIA).

The combination of technologies used to offer these rich and dynamic browser-based systems is known as Ajax (Asynchronous JavaScript and XML). It integrates several technologies in powerful new ways to provide RIA functionality:

**i)** Standards-based presentation by means of XHTML (Extensible Hypertext Markup Language) and CSS (Cascading Style Sheet)

**ii)** DOM (Document Object Model) by means of vigorous and interactive web platforms

**iii)** XML (Extensible Markup Language) and XSLT (Extensible Stylesheet Language Transformation) manipulation and information exchange

**iv)** Asynchronous data retrieval using XML HttpRequest

**v)** JavaScript as the programming metaphor

Ajax is generally a key module for Web 2.0 applications. It enables the creation of rich and dynamic web applications similar to Windows-based applications. Ajax-based applications can now work while disconnected from the internet and consequently can provide offline operations similar to Outlook in Windows (O'Reilly, 2007).

There are technologies other than Ajax which are increasing the value of the user experience in the area of communications, such as voice and video instant messaging (IM) which are frequently used in Web 2.0 applications to provide instantaneous communications. There are many agents and delivery options available for IM systems. Voice over Internet Protocol (VoIP) systems enable voice and teleconference communication over the Internet as part of the user experience.

The elasticity delivered by these technologies alters the user interface (UI) beyond a dynamic UI to a complete interactive audio-visual experience, with new, powerful ways for people to interact with systems and one another.

The provision of users with a single user experience for the majority of their requirements increases efficiency, reduces training expenses, and motivates deeper implementation and usage. It encompasses access to information and applications irrespective of being connected or disconnected, or whether the user is equipped with a mobile phone, laptop, thin client or a smart client. Ajax and graphics subsystems such as Silverlight provide the rich user experience that clients are beginning to expect.

Web 2.0 supports lightweight programming models which provide a necessary change from the bottlenecks and constraints associated with IT-based systems.

### 3.7.3 Lightweight programming models

In Web 2.0, the programming models and concepts differ from those used in the enterprise. Though they are services-based and underpinned with the concept of message passing, they use Representational State Transfer (REST) protocols, and focus on simplicity and ease of use.

"Web 2.0 programming is based on separation of concerns using a loosely coupled, message-passing-based model on top of an Internet-based, standard set of communications protocols (HTTP) which is often called RESTful programming. It entails the acts of syndication and composition where services are delivered exclusively to knowledge of their use. This is different from a usual tightly coupled, transactional and object-oriented system. It has a different set of benefits, such as flexibility and speed of implementation, and challenges, such as integrity and management" (O'Reilly, 2007). The languages used in Web 2.0, like Perl, Python, and Ruby frameworks, are simple and dynamic and thus provide a low blockade to entry, re-use and high productivity.

### 3.7.4 End of software release cycles and deployment

The perception following Web 2.0 was of a new balance between the controls, managerial ease of centralised systems, and elasticity and user empowerment of distributed systems. Web applications are by nature centrally deployed. Software as a Service (SaaS) builds on this concept to provide the idea of software and service delivery over the internet, according to (Choudhary, 2007). Web 2.0 builds on top of SaaS to offer social and content services over a SaaS system. This usage of SaaS by Web 2.0 provides all the eminent SaaS advantages of simple deployment, minimised management and administration, and continual updates. The underlying usage of the internet as a platform in Web 2.0 enables simplicity, quick and flexible delivery of applications and data throughout the enterprise, and eradicates predetermined and inflexible IT upgrading cycles. It also enables a new level of organisational support and responsiveness for the user (Shwind et. al, 2010).

## 3.8 Web 2.0 in the Enterprise

Enterprise 2.0 refers to the use of Web 2.0 technologies in the enterprise. Below are some characteristics of Enterprise 2.0.

### 3.8.1 Read/Write Web

Documents and data are essential to any business and Web 2.0 is a service-based system. It allows data and document establishment, alteration and substitutions with reduced complexity and improved simplicity of use, according to (Al-Tameen et.al, 2008). The provision of facts, content regulation, and alliance systems, which can support the rich content format and social techniques of Web 2.0, is vital for the use of the read/write web in the enterprise (Yap et.al, 2008).

### 3.8.2 Collaborative Web

Large enterprises with many employees, partners, suppliers and customers can attest to the significance of the knowledge residing in employees' minds and in the databases and vague documents found across the organisation. Efforts to gather information into knowledge management systems have been made since for centuries with varying levels of success, but the use of Web 2.0 technologies such as blogs, wikis, and enterprise searches for individuals and data may reduce the hassles of knowledge management and offer a new platform to collaborate on amalgamated and innovative tasks. In conclusion, one can motivate that Web 2.0 tools like Twitter, which is an online social blogging service that allows people to share short textual messages with others (Boyd et. al, 2010), can be an enabler for immediate knowledge notification and knowledge management throughout the inventory management process.

## 3.9 Barcode Technology

Barcode technology is a well-established and widely-used technology in retail environments. It is coupled with Universal Product Code (UPC) to identify products. Table 3.2 states the differences between RFID and Barcode technology in order to define the benefits of RFID technology.

**Table 3.2** Barcode versus RFID technologies

| **Barcode Technology** | **RFID Technology** |
|---|---|
| Read individually (one by one) | Can read multiple tags simultaneously |
| Requires line of sight | Tags can be read without line of sight |
| Not possible to update/modify | Can be overwritten with new information |
| Manual tracking (prone to errors) | Automatic tracking |
| Identify type of item | Identify items specifically |
| Not possible to read if dirty / broken | Copes with harsh /dusty environments |

(White et. al, 2007) conducted a study to compare the performance and reliability of these two technologies. The findings stated that the time taken to read/scan a certain amount of products when using RFID was 9.669 seconds, whereas in barcode scanning it took 24.479 seconds to read the same amount of products. The standard deviation was 3.0134 for RFID and 3.6858 for barcodes.

The result reported in (White et.al, 2007) shows that RFID technology is more consistent and much faster than barcode technology. This also shows that RFID can bring computable operational benefits, like higher throughput, productivity, etc. However, the RFID technology did have drawbacks, mainly due to poor reading of tags (Upfold & Liu, 2010, Dane et .al, 2010, White et. al, 2007). Sometimes the tag may be broken or movement of reader wheels is prevented. Figure 3.11 shows the errors occurring in RFID scanning while Figure 3.12 shows the errors occurring in barcode scanning. There were nine misread tags (where N = 200) during the RFID scanning, compared to barcode scanning, where there were 45 missing labels and 24 unreadable (damaged) labels for the same number of items.

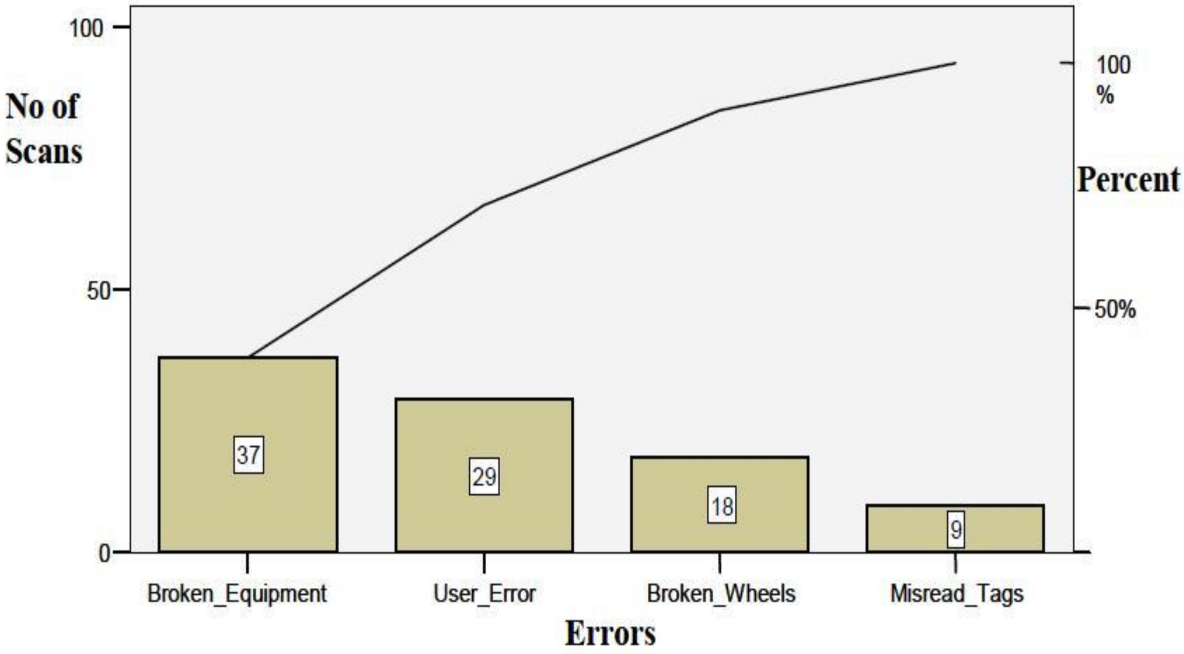



**Figure 3.9** Errors in RFID technology (adapted from White et .al, 2007)

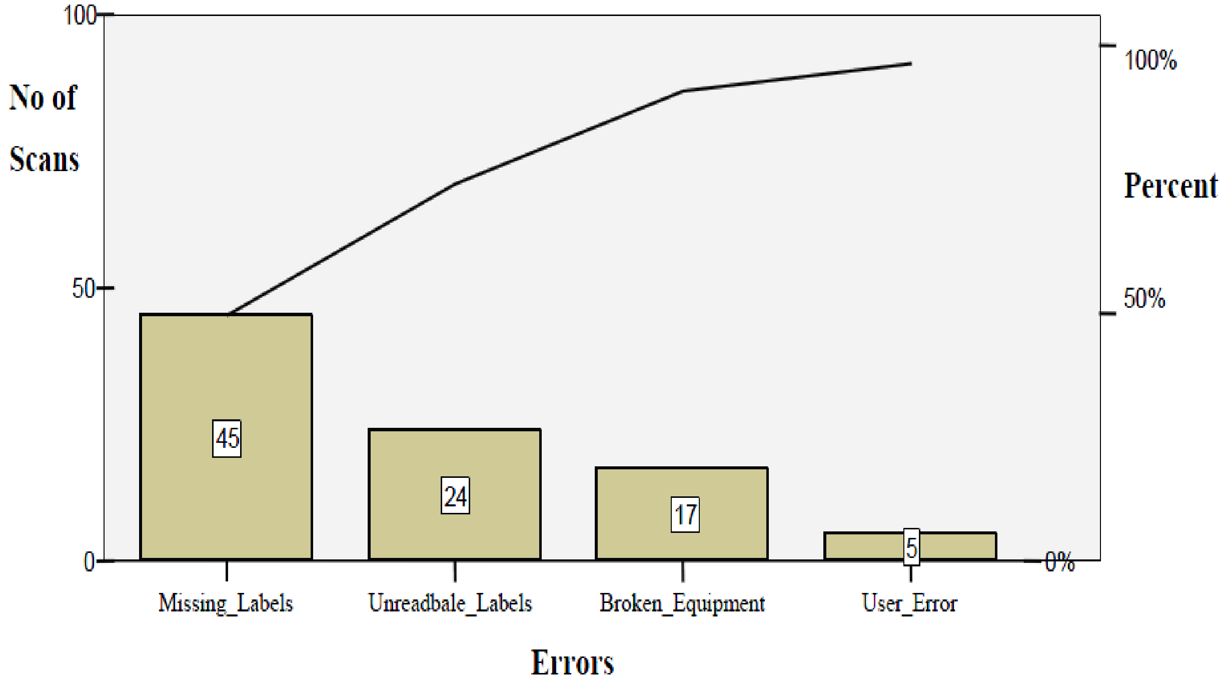



**Figure 3.10** Errors in barcode technology (adapted from White et al. 2007)

The high rate of unreadable labels and missing labels in barcode technology is due to the fact that barcodes can easily be torn; and once torn, dirty or wet, can no longer be read. This happens frequently at retail till points, where the cashier tries several times to read a barcode unsuccessfully; he/she has no choice but to enter the code manually, which is time consuming.

RFID is not a mature technology in South Africa; hence the 29 user errors, whereas for barcodes there were only 5 user errors. Users' errors will decrease rapidly as the technology becomes more widely available and users gain expertise. Furthermore, RFID technology does not require human intervention once the system is running smoothly.

## 3.10 RFID Benefits in Retail

The collection of data regarding required stock and disposal of unwanted items is important when determining the stock to be ordered. RFID technology has been around for years: its first large scale application in enterprises was to replace barcodes. Smart systems that have capabilities of self-configuring, self-monitoring, and self-recovering are useful to large retailers when it comes to the management of large and rapidly-growing processes (Haller et. al, 2009, Haller & Magerkurth, 2011). The main barriers are the cost of this technology, a lack of standardisation; poor read rates on metal products and liquid products, and security concerns in the retail sector (Upfold & Liu, 2010). However, Walmart RFID-enabled stores successfully reduced out-of-stocks by 63%. The understated PI inaccuracy was reduced by 13% (Dane et. al, 2010). This shows that RFID technologies can play a major role in retail enterprises. Figure 3.13 illustrates the areas where RFID can influence the retail industry and illustrates the automated applications of RFID in inventory management.

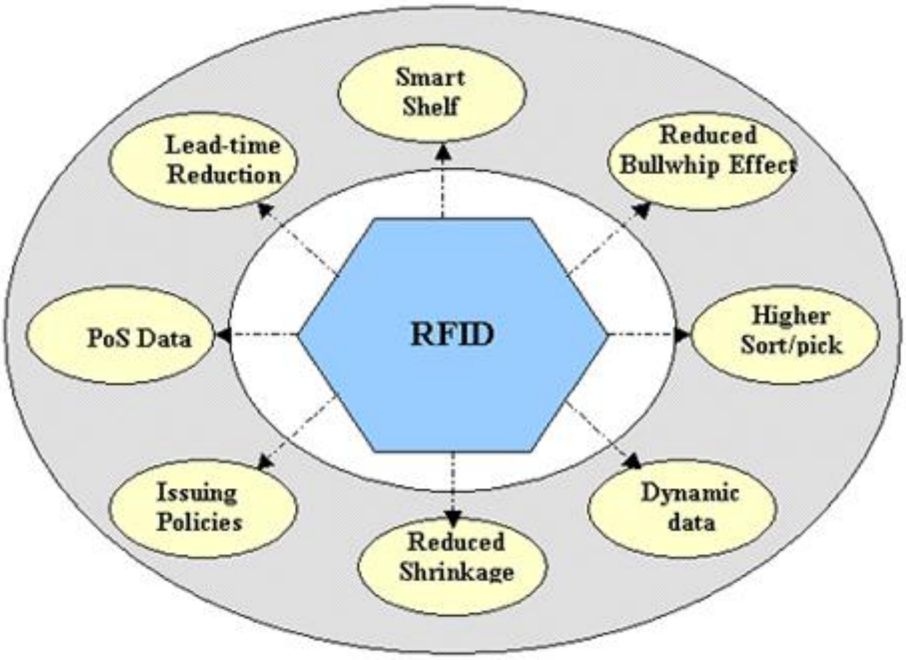



**Figure 3.11** RFID in inventory management (adapted from DMDirect , 2010)

**i) Automatic non-line-of-sight scanning**

The most attractive offering of RFID technology is that, unlike barcode technology, line-of-sight is not required for reading RFID tags. Multiple products can be read within a short period of time, thus reducing the time involved in counting stock. This capability assists in the mechanisation of various management processes involved in supply chain management, which remain highly exhaustive due to monitoring and counting incoming stock and keeping inventory up to date. Enterprises employing RFID technology are accurately informed of stock levels on shelves. This reduces inventory costs and the frequency of out-of-stock situations (Michael & McCathie, 2005). The result is that the retailer has access to accurate information required for the decision-making process (Huber & Michael, 2007).

**ii) Shelf replenishment**

Shelf replenishment is a critical, time-consuming process in inventory. Poor management can lead to out-of-stock situations that can result in losses in sales. Shelf replenishment involves locating stock and keeping track of the stock on shelves and at the warehouse. Item-level tagging using RFID technology reduces the laborious task of inventory taking (Michael & McCathie, 2005, Zang, 2011). Shelf replenishment, which is the most laborious task in the inventory management process, is performed more accurately when using RFID technology, and the inventory manager can receive all updates on inventory via Twitter anywhere and at any time via the internet (Mathaba et. al, 2011). The result is that errors due to human fallibility are significantly reduced and information is used effectively.

**iii) RFID and misplaced products**

Another significant advantage provided by RFID and not provided by barcode, is the ability to allocate misplaced and lost products. RFID tracks and traces products across the supply chain, which reduces product shrinkage**.** Timely information about location and also the condition of a product worldwide is what motivated retailers like Walmart to adopt it to enhance inventory processes (Glidden et. al, 2004, Weining et.al, 2010).

**iv) Cost savings**

RFID technology application and implementation looks expensive and complicated, and this has proved to be a barrier to its adoption. However, its automation of processes results in human labour reduction, increased security, and improved inventory processes, all of which reduce costs massively and increase accuracy and sales.

**v) Labour reduction**

RFID technology automates the most critical and laborious tasks of inventory control activity. This means that less labour is required. According to (Michael & McCathie 2005), RFID technology can reduce the time taken to process incoming stock by 60-93%, reduce labour cost by 36% and ease validation of shipping of stock by 90%. RFID technology may also enhance current inventory systems, and it can uniquely identify products without human intervention.

**vi) Counterfeit products**

Counterfeiting is the presentation of fake products as real products.Counterfeiting not only leads to dissatisfied consumers; it negatively affects the reputation of the retailer, and it also affects the country's economy. It causes losses for product inventors, job losses in factories, and lower tax revenues. It has a negative impact on research and development, and consumer safety. With RFID, customers are offered a platform by means of which they can query the authenticity of a product they purchase in real time (Huber & Michael, 2007).

#### vii) Effective information usability and mobility

The above sections have revealed that the integration of IoT technologies enhances the information flow of critical data in inventory processes and analysis. The information generated is automatically saved on the central product database inside the organisation. However, the effective utilisation of mobility is an added advantage which should be exploited. The automated notification is normally sent or saved on the standalone database; as a result the inventory manager cannot move outside the product database room when waiting for inventory notifications and alarms. The easy access of information anywhere, anytime could allow inventory managers to make informed decisions irrespective of their location.

## 3.11 The Role of Social Networks

Social networks support human interaction. For example, users post status updates on Facebook and Twitter for their friends and acquaintances to see and to comment on should they choose to do so. Social networks play an important role in personal relationships. They make relationships more dynamic and manageable over long distances by means of instant messaging (Kranz et .al, 2010). Groups, forums, and discussions can be created easily over the network. However, social networking is not only limited to personal relationships. Social networks are used for business purposes such as marketing, brand testing, and business collaboration.

The emergence of the IoT addresses another human need as it allows the objects people own to do things by themselves without the need for human intervention. In IoT processes, networked objects exchange data with one another to perform their tasks through sensors and actuators. However, the information exchanged in the IoT is not visible to humans and thus there is a missing connection between humans and their possessions, (Mathaba et.al, 2011, Kranz, 2010, Butgereit & Van Rooyen, 2011). For the purposes of this research, Beachcomber has been used to notify users of their objects' statuses.

## 3.12 Summary

The review of literature has helped to provide detailed definitions and explanations of core concepts involved in the work. IoT technologies enable wireless communication of objects autonomously. IoT technologies include RFID, actuators, GPS, etc. Beachcomber enables bearer agnostic communication between objects and their owners via a number of protocols including the Web 2.0 tool Twitter. Web 2.0 technologies are emerging in enterprises and making vital contributions in collaboration and information-sharing and advertising. They also provide rich internet applications for users.

# CHAPTER FOUR
# MODEL DESIGN AND DEVELOPMENT

## 4.1 Introduction

Internet of Things is a complex and wide area of study, which consists of autonomous entities, as in the case of RFID-enabled products in a retail establishment. The retail environment is a very busy one, due to unpacking of stock, tagging prices, etc. Some retailers close their shops to load stock onto shelves.

This section shows the prototype and design of the proposed architecture for managing inventory. This approach integrates technical advantages related to RFID with Web 2.0 tools such as Twitter, for the prevention of loss and counterfeiting, locating misplaced stock and ensuring continuous stock availability.

This chapter introduces the technologies which will be used in the design of the proposed system. These technologies include Beachcomber, Arduino, Ethernet Http, RFID reader/tags and Twitter. The chapter will wrap up with a discussion about how this model can enhance inventory management in retail enterprises.

The literature revealed that Internet of Things is an autonomous environment, i.e. smart objects exchange information autonomously. This study also revealed that there is an information flow gap in inventory processes when using IoT technologies; as a result inventory management needs to be enhanced. In order to address this problem, as stated in Chapter 1, the model is developed. The main task to be addressed by this model is to enable bearer agnostic communication between humans, objects and business services. The Beachcomber model provides synchronous communication between objects and their owners.

Furthermore, the literature reviewed in Chapter 3 showed that RFID caused some errors in reading tags. This may lead to poor analysis of results in retail. Therefore, the proposed prototype firstly investigated the possibility of reducing reading errors by using product delimiters. Using product delimiters allows all shelves to be recognised and categorised by product, thereby enhancing visibility of products. The information about all the stock available will be captured and saved in the database. The monitoring will then be supervised.

For design clarity, the following scenario was considered for inventory management in retail industry.

*Mr Bongani is the inventory manager of XXZ Retailers. He was having a meeting on 24 February 2012 with his stakeholders. Mr Bongani was still in his meeting with the stakeholders when he received the stock update tweet that said: a) sugar stock was running low in the shop, b) some tea packets were misplaced in the milk products zone, and c) some items in stock needed to be removed from the shelves as they had expired. Mr Bongani then conducted sales analysis to discover the inventory status before corrective action was taken. He quickly sent an email to place orders for sugar with ABC suppliers. He then instructed the stock packers to move the misplaced items into the correct position. Finally, he told them to remove the expired items from the shelves. The manager continued with his meeting, knowing that everything was under control. This provided the manager the platform to monitor and manage inventory anywhere and at any time.*

This clearly illustrates the challenge faced by inventory managers to keep everything in the shop up to date, and the need for remote inventory monitoring. From this scenario, one can outline the significant requirements of inventory management systems in the retail environment.

## 4.2 Functional Requirements

a) **Automated stock capturing and counting:** Stock control is laborious and prone to human error and thus accurate automated/real-time stock capturing and counting is required. RFID readers and tags must work properly to capture product data.
b) **Automated check-ups for damaged products:** Alerts on expired/damaged goods to be removed from the shelves are generated to protect consumers and the reputation of the retailer.

c) **Awareness of stock levels on shelves:** IMS sends alerts about product shortages on time, to notify inventory managers so that they can make necessary decisions.

d) **Awareness of misplaced stock:** IMS identifies locations and quantities of misplaced stock.

## 4.3 Non-Functional Requirements

a) **System scalability:** In this environment, where thousands of products need to be tracked and analysed, the system needs to be capable of storing the product information regardless of the size of the enterprise.

b) **Response time:** It is necessary for inventory managers to receive inventory updates in real time with no delays. The time it takes for a manager to receive updates must be less than a minute.

c) **System trustworthiness:** This is vital. The IMS must provide reliable information to the user, with no delays that could jeopardise inventory management.

d) **System backup:** The system backup must always be up to date, as inventory analysis may require annual reports to determine the growth of the business and/or reports in case of system failure.

The overall functional requirements of the proposed architecture must be met in order to ensure the reliability of the system. Figure 4.1 shows communication in the Beachcomber model for the proposed architecture.

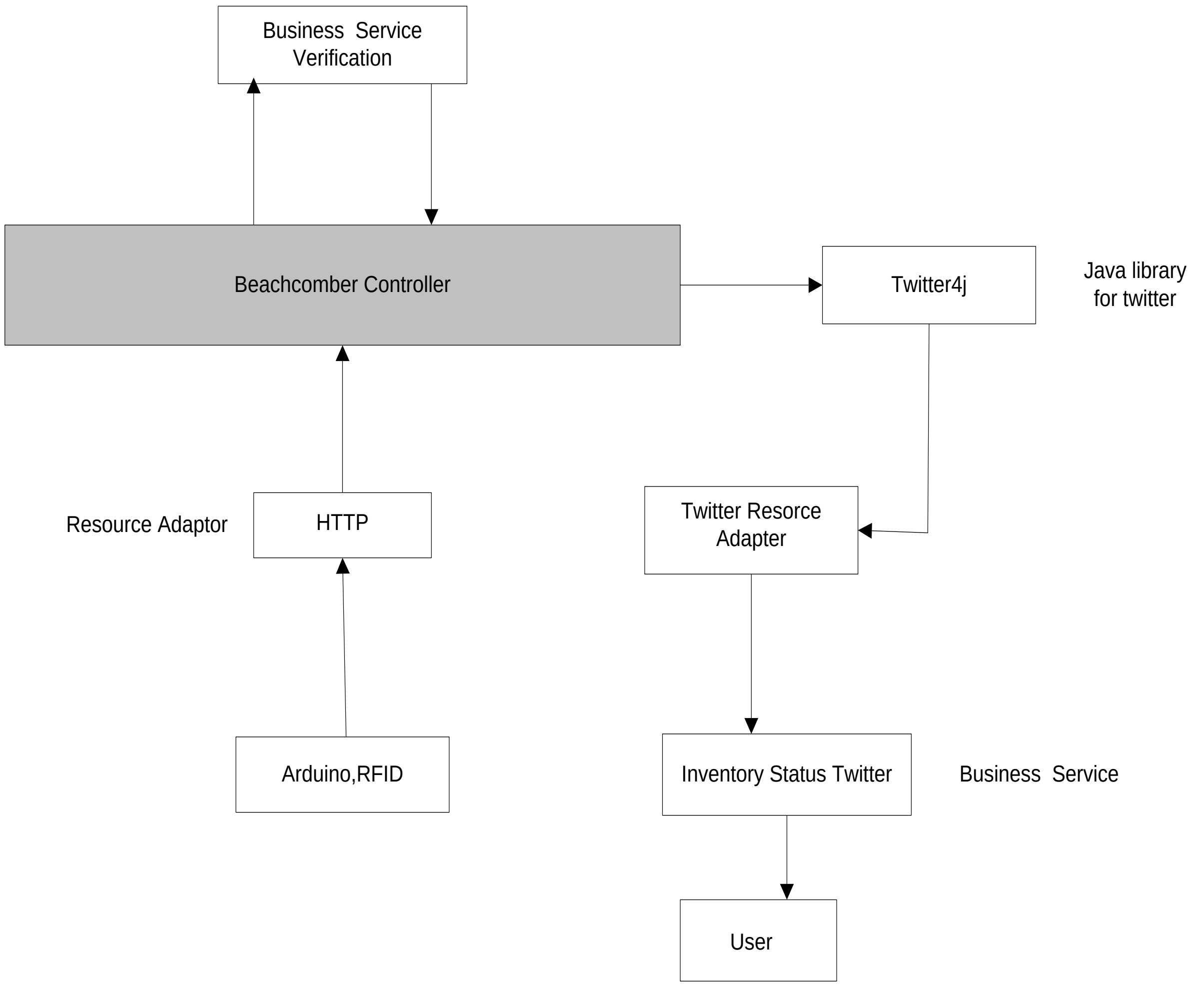



**Figure 4.1** Twitter and Beachcomber interface using Mobicents

The HTTP in this case is the resource adaptor which sends information to the Beachcomber controller on *http//:146.64.28.16:8080/beachcombservlet /inventory?msg=()*. The Beachcomber controllers will route the information to the intended business service. The service building block routes the information to the intended resource adaptor, which is Twitter. The Twitter account must be created and its details must be saved in the service building block for the routing of messages.

## 4.4 Components of the Architecture

### i) Arduino board

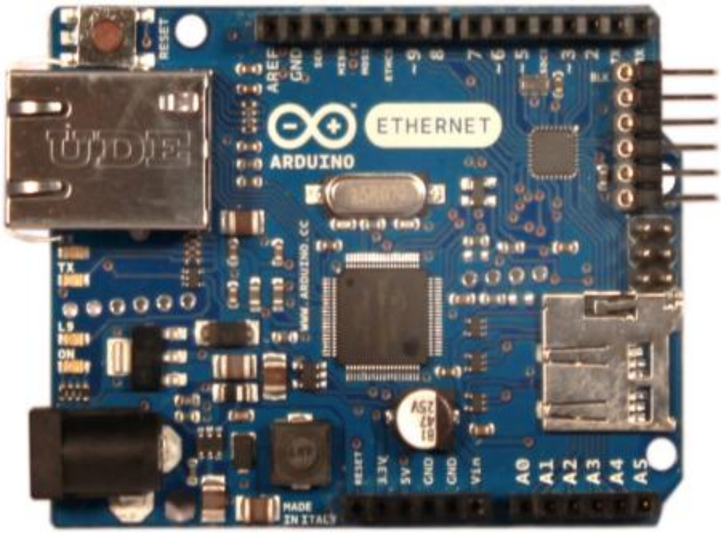



**Figure 4.2** Arduino board

Arduino is an open-source platform for electronic hardware and software; it is a flexible prototyping platform for users who wish to create interactive objects and environments. Arduino, illustrated in Figure 4.2, is capable of sensing the environment and receiving input from a variety of sensors (Arduino.com 2011). Arduino hardware consists of a board, Atmal AVR Processor, and built-in I/O support to enable programming incorporation into other software.

Another important aspect of Arduino is the way connectors are deployed, allowing a variety of interchangeable modules/shields to be connected in the processor. Arduino projects can stand alone or can be connected to software running on a computer and can interface easily via USB if programming is needed (Dlodlo & Smith 2011).

In our proposed model, the Arduino will communicate with the software running on a computer. The data will be transferred via Ethernet cable. The Arduino works as a buffer; it has ID stack and time stack and limited memory. It has a URL used to retrieve information from its memory for display on the web browser: normally this is called screen scrapping. The data on the screen is then extracted for processing. In this study, the Arduino URL is - *http:// 172.19.2.4.* The HTTP request will be sent to this URL to retrieve data.

**ii) Ethernet cable**

The normal RJ-45 Ethernet network cable will be used. It is the most widely used cable in local area networks. In this study, it will enable HTTP request and response for inventory status data in the browser.

**iii) RFID reader and tags**

RFID passive tags will be used; they will be attached to the products. The readers will scan information from the tags.

**iv) Twitter page**

The Twitter account must be created: this is where the inventory manager will receive tweets on inventory. The account information is stored in the Beachcomber database.

## 4.5 Proposed Inventory Architecture

The study proposes a monitoring system for inventory management enterprises to enhance visibility and effective use of information for immediate decision making. The proposed model addresses the issue of unobserved, misplaced or expired products on shop shelves, and the issue of late stock replenishment which can lead to lost sales. The use of Twitter plays a major role in notifying the inventory manager of inventory changes which require immediate attention. Figure 4.3 illustrates the proposed architecture for monitoring inventory.

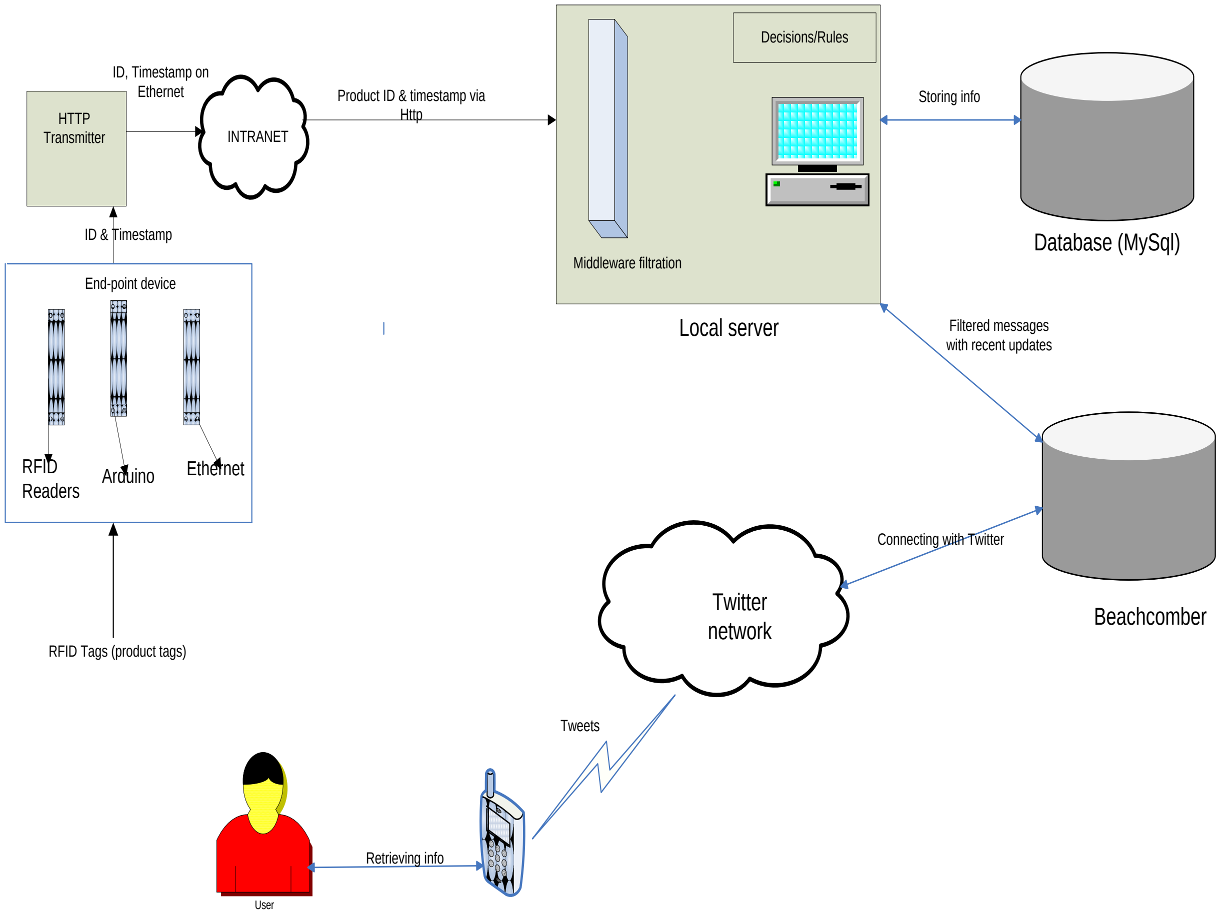



**Figure 4.3** HTTP and RFID for inventory control

In this inventory management architecture, the RFID-enabled reader device reads RFID-tagged products and the data is buffered to Arduino. Arduino allocates a time to the RFID product tags. The timestamp is the number of milliseconds that have elapsed since the exact time when the product was read. The data is sent with product ID and timestamp via HTTP over the internet to the web browser (http:// 172.19.2.4). The data is extracted from the browser and sent to the database. The database will then be updated for changes in inventory.

The changes to the inventory are sent to Beachcomber via HTTP on *(http:// 146.64.28.16:8080beacomber/inventory?msg= ())*. The URL links the database to the Beachcomber server. The Beachcomber controller will then connect to resource adaptors which route information to the intended business service, which is Twitter. The messages regarding inventory will be displayed on a Twitter page.

Figure 4.3 illustrates the envisaged architecture which includes RFID, HTTP, Twitter, Arduino and Beachcomber. When completely implemented, the system keeps the retailer informed of inventory process activities using Twitter. The end-point device is made up of three boards – the RFID reader, the Arduino and the Ethernet device (for HTTP transmission). The reader device is an RFID tag reader. The reader is mounted in a fixed position. It reads RFID tags on products as the shelf rotates and sends data as HTTP messages to the Arduino buffer.

In the system, the RFID-enabled shelf shown in Figure 4.4 rotates for the RFID-reader to access the product information. Products are placed on the shelf according to product zones, e.g. a sugar zone for sugar, a milk zone for milk, etc. Each product zone has ‘zone start’ and ‘zone end’ tags. One cannot read the product ID before coming to its product zone. In the database, all the product information messages are collected and sorted according to timestamp.

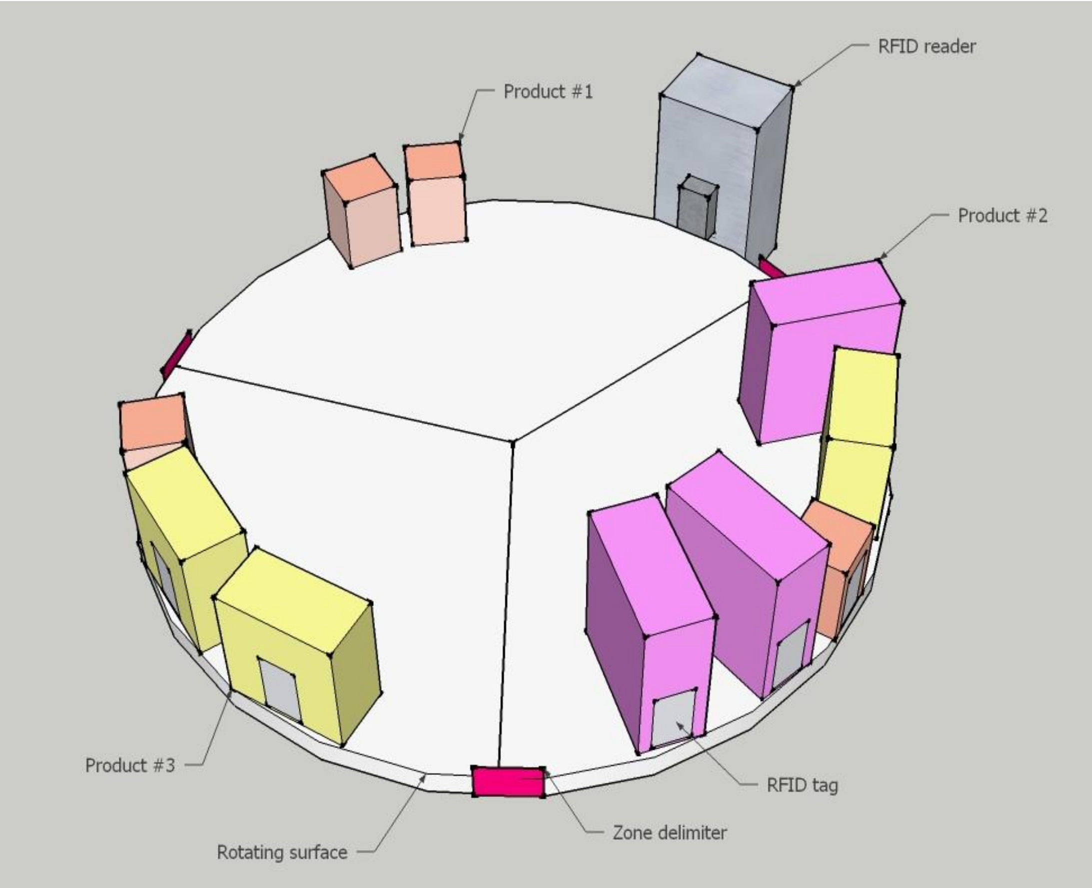



**Figure 4.4** RFID-enabled shelves

The database interprets the meaning of each particular tag. For example, zone ID 000-00-AF-11 could be an identifier for the bread zone. The RFID-reader knows the zone a product is in at any point in time by communicating with the database in the local server, which contains information on the identities of the product zone delimiters. It sends the zone ID and timestamp to the database and advises it to retrieve the zone name for the zone ID. The database returns zone ID and checks whether the product zone ID of the product is the same as the current zone ID. If not, then the product is identified as misplaced.

An example of the data structures for the zones and products follows:

**ZONES**

Zone ID: 0000-00-AF-011 [ RFID tag of the zone delimiter]

Zone Name: Bread

**PRODUCTS**

Product ID**:** 000-00-AR-BB-001 [RFID of the product]

Zone ID**:** 0000-00-AF-011

Product Name**:** Bread

The Arduino, which works with the RFID reader in the end-point device, stores the RFID-tagged products on the product shelves and provides the time at which the products were read. The product information, that is, the product ID and timestamp, is sent via HTTP protocol to the server that hosts the decision support system. The decision support system receives the product information in the form of HTTP messages. It forwards the HTTP notifications to Beachcomber. Beachcomber forwards the HTTP inventory notifications to Twitter in the form of tweets.

The following pseudo code describes the process in more detail:

```
While (there are still zones to scan)

   {Get zone_ID and set as current Current_zone};

      While (the next element IS NOT a zone delimiter)

{Do get product_zone_ID};

End while

// checking for expired products first

Get product_expiry_ date;

If (product_expiry_date < now())
   Then

             send product_expiry_notification};

// if not expired

             Else
                       if
```

```
                (Product_zone is same as current_zone);
                Then

                  Product is on correct shelf ;
                  Increment_product_count};

                Else
                        If  Product misplaced ; then
                        Send notification;
                        End if
             End if
  End if

// counting level of stock

For all Product zones:
Loop
   If (product= inzone_count + outOfZone_Count);
     Then

Send low stock notification

If (product_ total<= threshold);

Send low stock notification

End if
   End if
        End for
```

The following can be said about the current technology:

- **i)** RFID technology sometimes experiences poor read rates and poor accuracy (Upfold & Lui, 2010).
- **ii)** On the smart shelf, for inventory control, the products need to be scanned first and the information stored in the database. In the laboratory experimental system, the shelf simulation consists of a round wooden table top mounted with an RFID reader and zone delimiters. RFID tags are used as zone delimiters and

mounted onto the table to categorise products and the RFID reader scans tags mounted onto products. This can reduce poor read rates.

**iii)** The reader rotates at certain intervals to read the inventory status. When the table rotates, the RFID reader detects all the delimiters and products in sequence. The system then retrieves information from the database and sorts the products according to their zones. If any products are found in a wrong zone, an 'event' is triggered. The system then sends a message to Twitter. A similar event is triggered when the product level on a shelf has reduced to a level at which more products need to be ordered. The user can view the updates on Twitter.

## 4.6 Summary

The architecture presented in this chapter shows how RFID serves as a replacement for the barcode scanners which are normally used to track products and shipments in similar ways. This architecture fully integrates the technical advantages of RFID and Web 2.0 to provide feedback on the process to the inventory manager. RFID system consists of three fundamental components. The first component is the RFID tag, which is attached to an asset or product in the inventory. The tag contains information about the particular asset or product. The next component is the RFID reader, which communicates with the RFID tags. The last component is the backend system, which links the RFID readers to a centralised database/server. The centralised database will store all the information about the products, such as price, for each RFID-tagged item. Beachcomber plays a major role in sending notifications regarding inventory changes to update the inventory manager. A unique feature of the architecture is the Twitter network by means of which the inventory manager can access inventory information on his/her mobile phone. In this proposed architecture for inventory management, the passive tags were used due to their low cost. The product zone delimiters are proposed to reduce inaccuracy when reading products. The next chapter explains the results of the implementation.

# CHAPTER FIVE
# MODEL IMPLEMENTATION AND EXPERIMENTATION

## 5.1 Introduction

In the previous chapter, the proposed inventory architecture and the implementation hardware and software were presented and explained in detail. The aim of the study is the enhancement of inventory monitoring and the efficient use of information regarding the inventory processes in real time. In this chapter the implementation design is described in Unified Modelling Language (UML) diagrams which include a use case diagram, an activity diagram and a sequence diagram. The results from the prototype that was implemented are shown and discussed in detail.

## 5.2 Inventory Management Implementation Design

This section describes the elementary design of the proposed system. It includes all the functionalities and processes and mechanisms which contribute to the inventory manager receiving updates about the inventory. The UML diagrams are briefly explained for the purposes of clarification.

### 5.2.1 Use case diagram

Use case diagrams illustrate clearly the sequence and the interaction between the actors in the system. Figure 5.1 shows the use case diagram for this study. There are two actors in the system: end-point device and inventory manager. The main actor which initiates action is the end-point device which includes the RFID reader, RFID tag and Arduino board and software. The inventory manager is the end user who retrieves information at the end of the process.

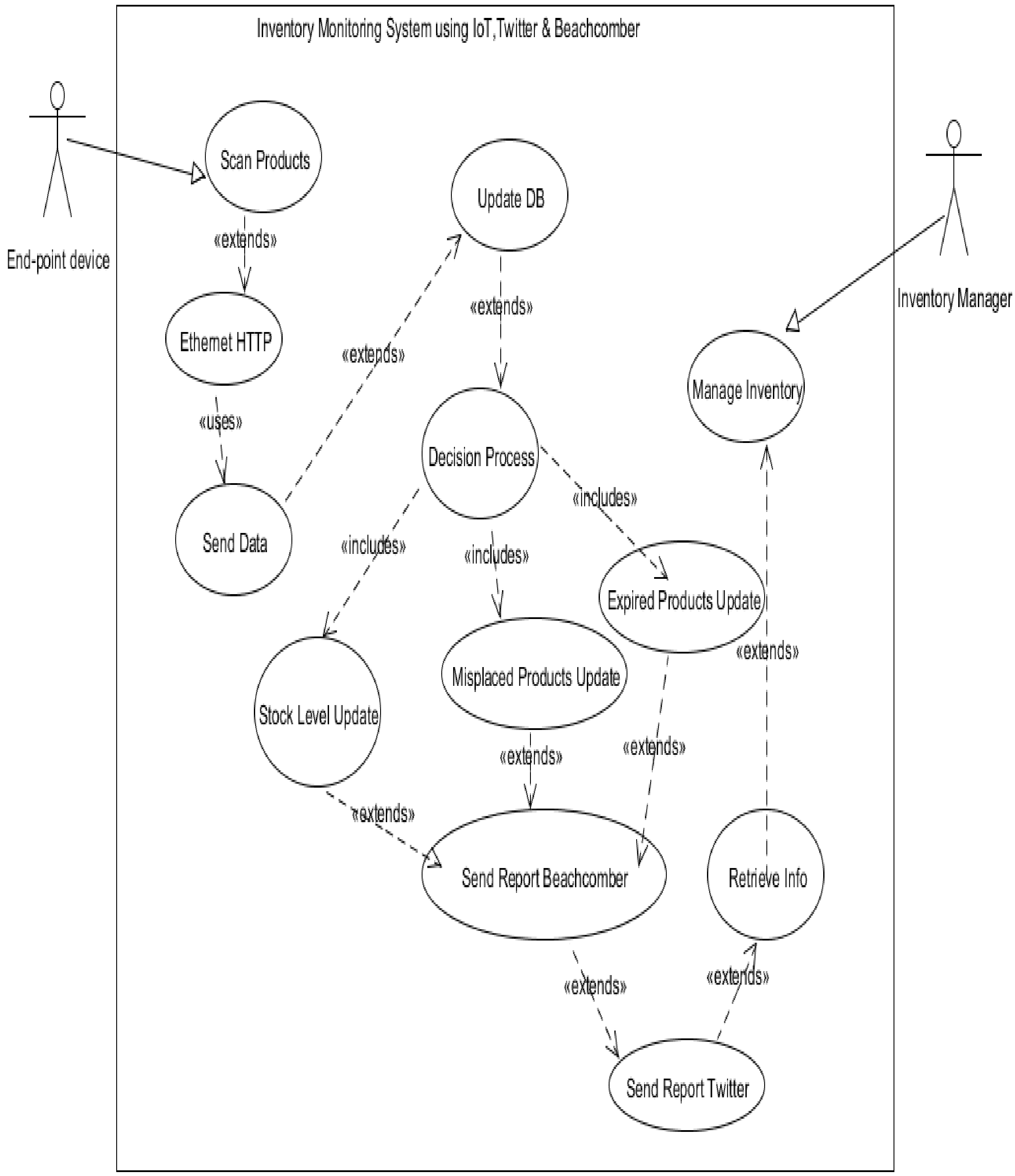



**Figure 5.1** Use case diagram for the inventory monitoring system

#### i) End-point device

The end-point device is the hardware and software which is responsible for reading data. It uses Ethernet via HTTP to send data to the database.

#### ii) Decision support system (DSS)

The DSS involves three separate actions: counting and identifying the stock levels on shelves, tracking misplaced stock, and identifying expired products to be removed from shelves. DSS processes include all necessary tasks related to inventory; the system relays the information to Beachcomber to send notification to the inventory manager.

#### iii) Inventory manager

The inventory manager is at the receiving end of the data. She/he is a person retrieving inventory updates from the system. He/she may receive updates on his/her mobile phone or any device connected to the internet.

### 5.2.2 Activity Diagram

The activity diagram shows the sequential flow of activities in the system. It also shows activities that occur concurrently. In the proposed inventory monitoring system, the first activity is performed by the end-node device which scans the products as illustrated in Figure 5.2.

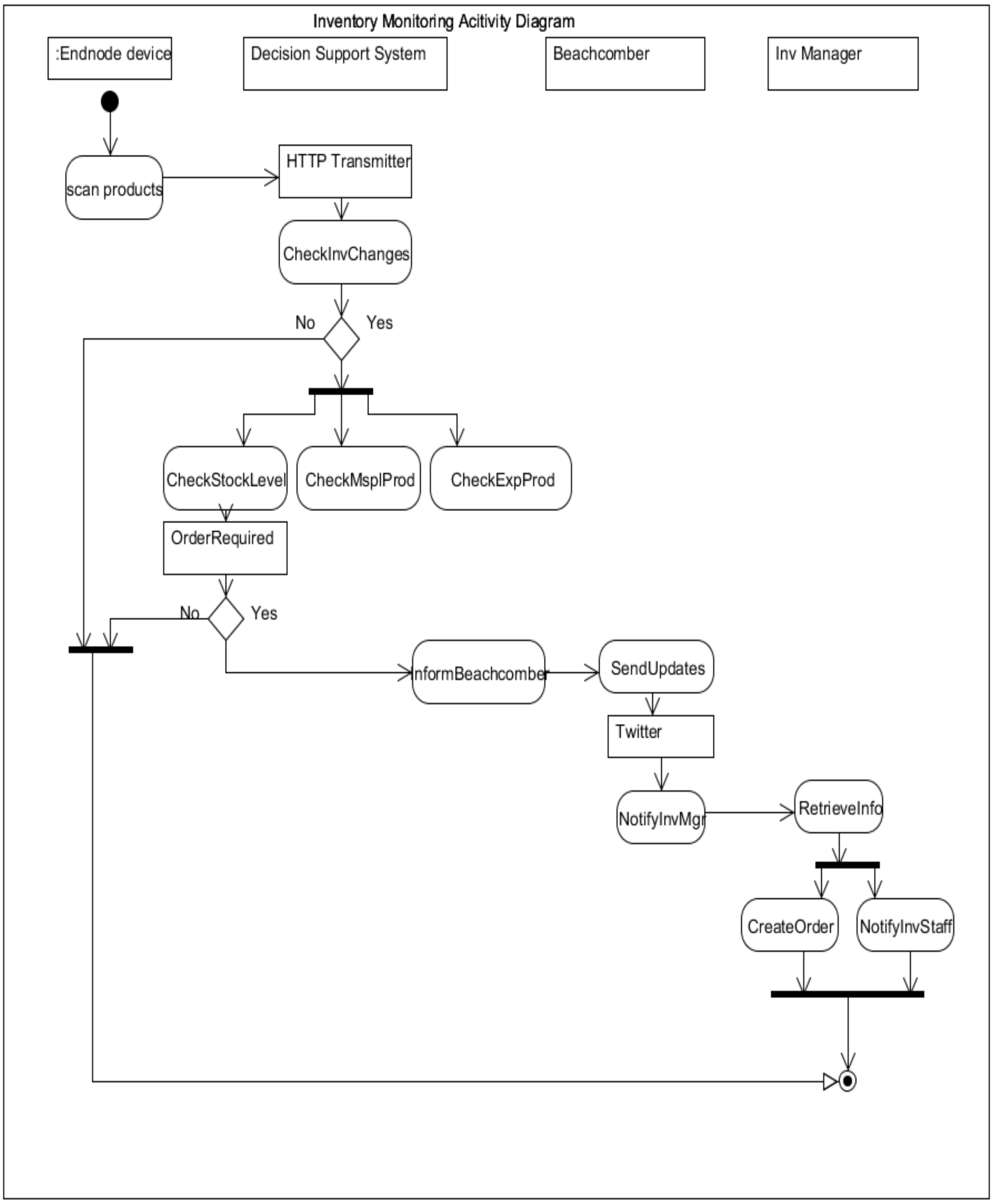



**Figure 5.2** Activity diagram for inventory monitoring

The next activity is performed by the DSS which checks the inventory status to establish whether there are critical changes that need to be attended to immediately. Once checked, three concurrent activities are performed, which are: check stock level, check misplaced products and check expired products (Figure 5.2). If the stock level is low, or there are misplaced products or expired products on shelves, a message is sent to Beachcomber.

Beachcomber will perform its task which is to send a message to the Twitter account. Beachcomber activity takes place via certain protocols which run in Mobicents, which are service building blocks. Those protocols are resource adaptors and business service verifiers.

The inventory manger can perform many tasks after receiving the inventory update on Twitter. He can place orders, instruct inventory packers to remove misplaced stock on the wrong shelves and remove damaged/expired stock from the shelves, make sales analysis reports, etc.

### 5.2.3 Sequence diagram

Sequence diagrams show the order in which processes occur and how they interact with one other. It shows the time at which each entity starts to perform its task in a system. The initial process is started by the end-point device which sends data to the database and thus to DSS as shown in Figure 5.3.

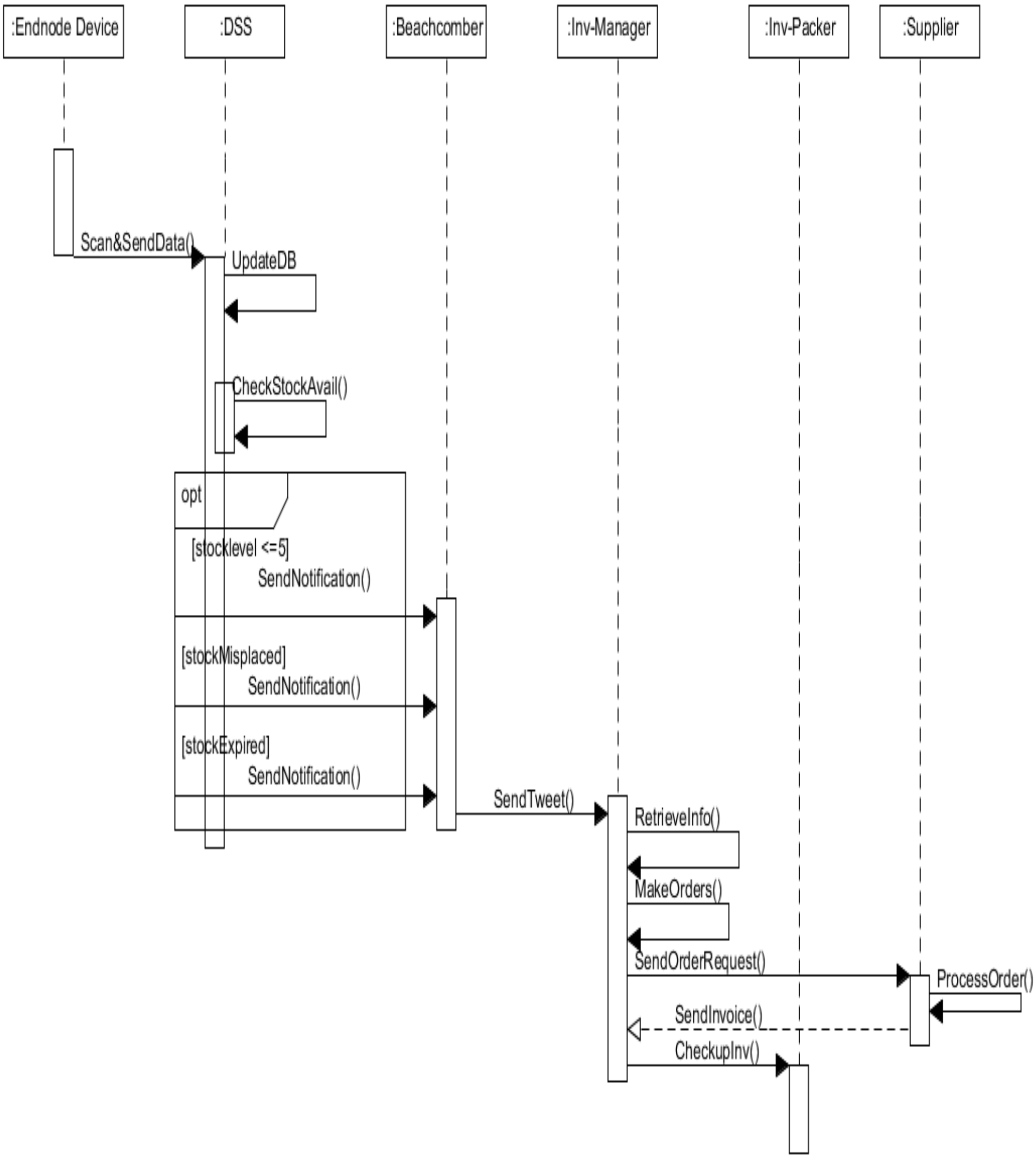



**Figure 5.3** Sequence diagram for inventory monitoring activities

The DSS has a number of tasks to perform and an options combination fragment named [opt]. The fragment combination [opt] in a system states that if a certain condition does not occur, the sequence will not occur. Likewise, in the proposed system, if DSS did not detect any changes in the inventory stock, the sequence would not continue. These options are:

i) **Check the stock level** – If stock is still available, no sequence will occur. If stock level is low, the sequence continues.

ii) **Check misplaced products** – If there are no changes on the shelves and all stock is in the correct place, the sequence does not take place.

iii) **Check expired products** – If there are no expired products, the sequence will cease.

The sequence diagram in Figure 5.3 clearly illustrates all the tasks performed by each object after DSS has updated the database to track changes.

## 5.3 Inventory Management Implementation

In the previous section, the implementation model was explained in detail. This section presents the results of the experiment when the system was tested.

### 5.3.1 Scanning of products

The products are are placed on a table so that they can be read by the RFID reader. The Lazy Suzan hardware rotates the table at specific time intervals. The hardware is programmed to rotate at certain intervals in order to keep track of inventory status during the day, so as to make necessary arrangements in time should more stock be required. Figure 5.4 shows the interface that displays the status of the stock after it has been read. The first scan keeps the inventory records as they are before any changes occur.

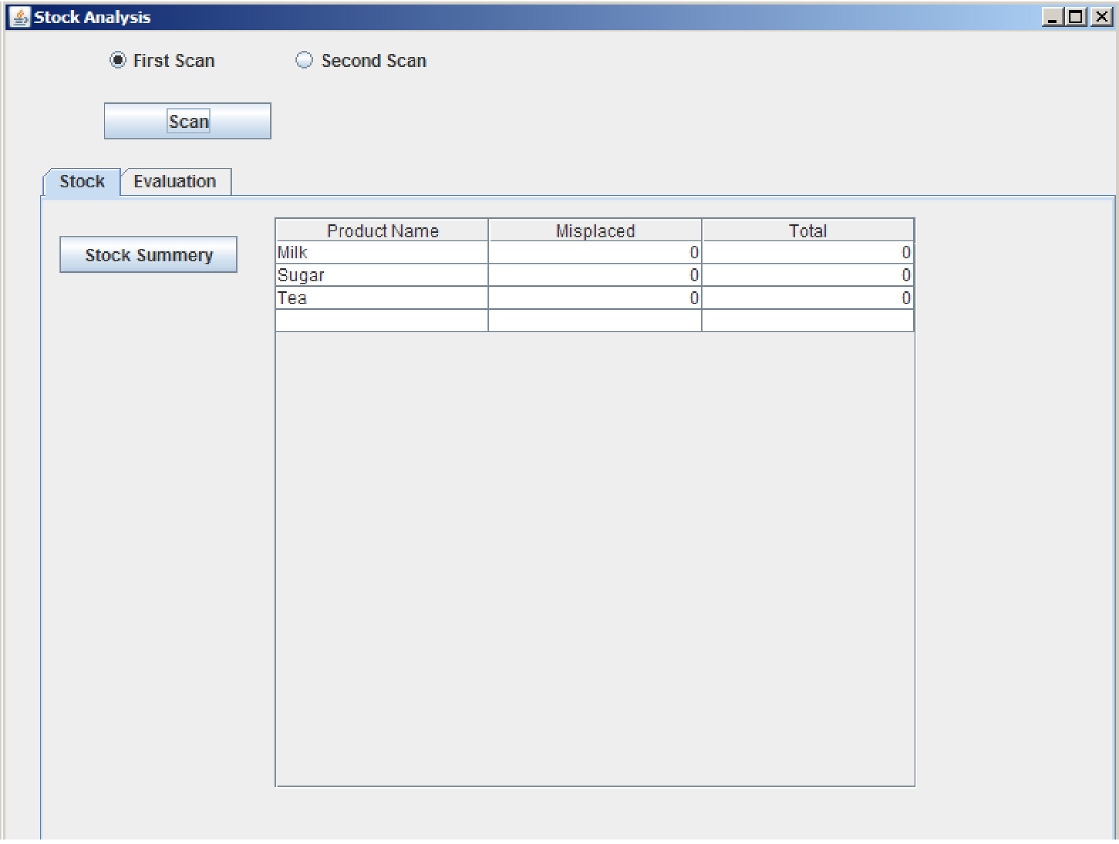


**Figure 5.4** Product scan interface

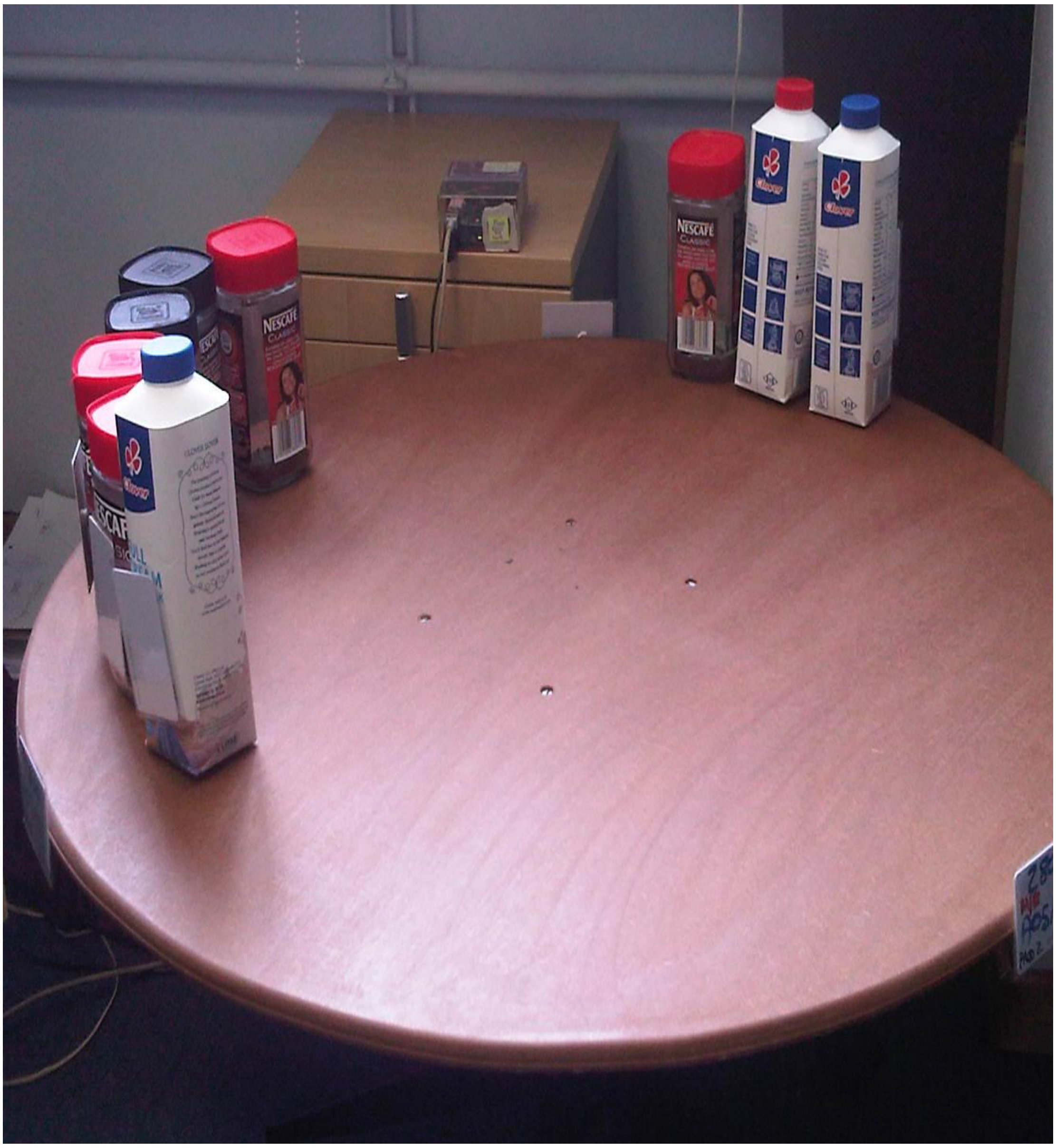


**Figure 5.5** Rotating store table simulation

Figure 5.5 shows the table with products placed on its surface. The table rotates and passes by the reader, which scans the products. The reader is connected to an Ethernet cable and a power cable.

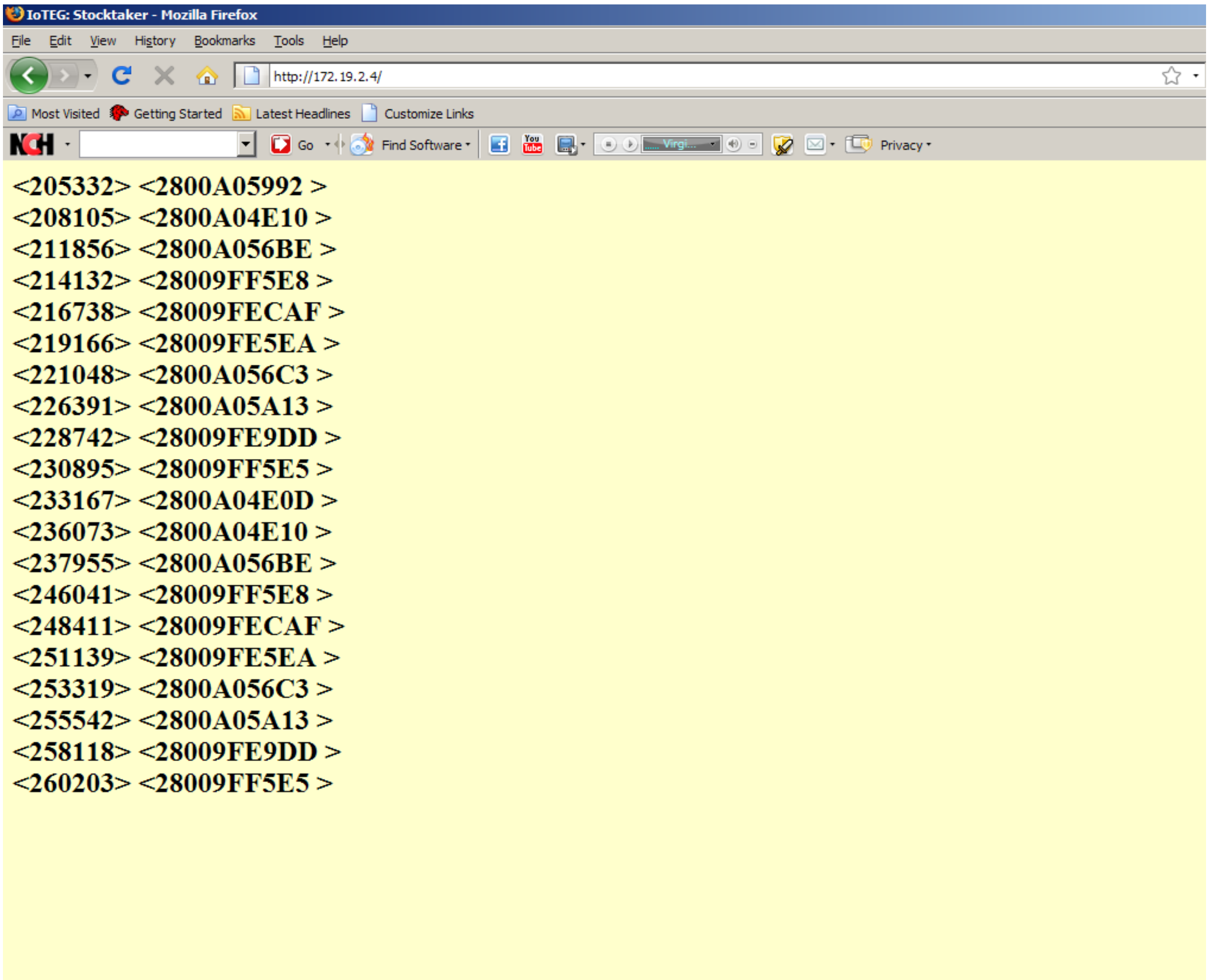
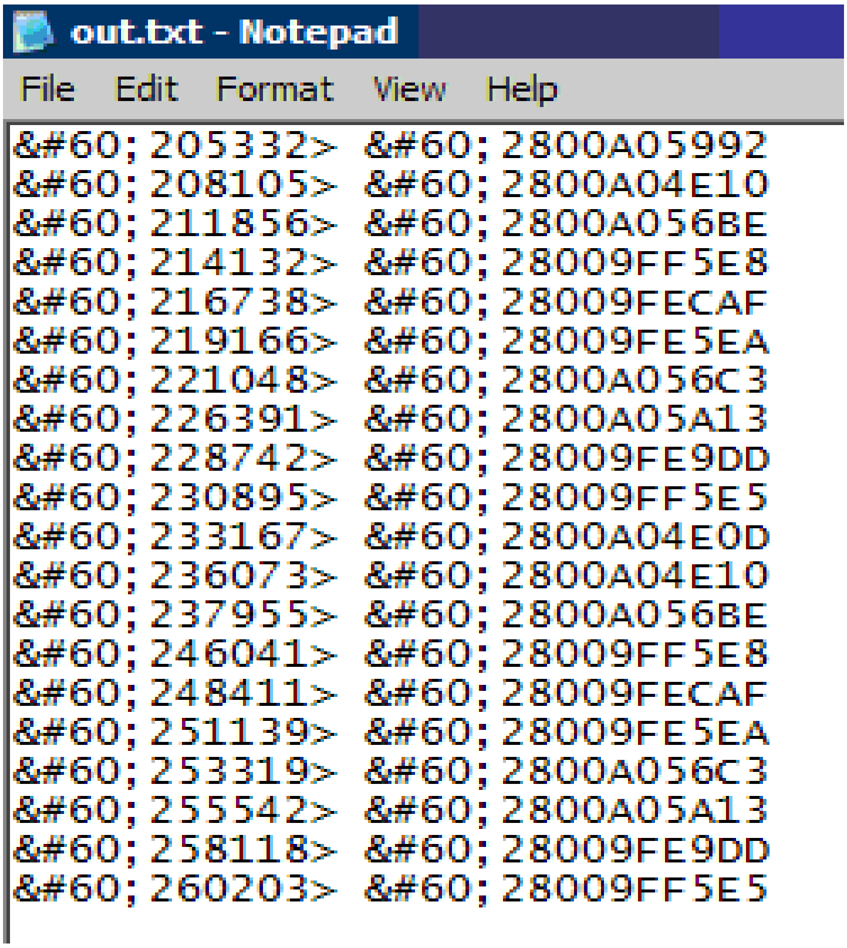



**Figure 5.6** Record of total stock in the inventory

### 5.3.2 Data on the Web browser

The data captured by RFID reader appears on the web browser as discussed in the previous section. It is sent via HTTP. This data has an Arduino timestamp on the left and the product ID on the right. The data is then extracted from the web browser and sent to the database for processing.

The first scan records the data about the product in a .txt file. The data in the .txt file is the data which has been scanned, as displayed in Figure 5.6 above. It is the record of the initial stock in the shop.



```
out.txt - Notepad
File Edit Format View Help
&#60;205332> &#60;2800A05992
&#60;208105> &#60;2800A04E10
&#60;211856> &#60;2800A056BE
&#60;214132> &#60;28009FF5E8
&#60;216738> &#60;28009FECAF
&#60;219166> &#60;28009FE5EA
&#60;221048> &#60;2800A056C3
&#60;226391> &#60;2800A05A13
&#60;228742> &#60;28009FE9DD
&#60;230895> &#60;28009FF5E5
&#60;233167> &#60;2800A04E0D
&#60;236073> &#60;2800A04E10
&#60;237955> &#60;2800A056BE
&#60;246041> &#60;28009FF5E8
&#60;248411> &#60;28009FECAF
&#60;251139> &#60;28009FE5EA
&#60;253319> &#60;2800A056C3
&#60;255542> &#60;2800A05A13
&#60;258118> &#60;28009FE9DD
&#60;260203> &#60;28009FF5E5
```

**Figure 5.7** Total stock saved on the database

### 5.3.3 Inventory initialisation

Figure 5.7 shows the temporary .txt database used to save product data and track the changes. The .txt file type was used for quick loading of data over the web. Furthermore, it is easy to use and data cannot be erased or deleted once it is saved. It is also suitably efficient for the purposes of this study as inventory needs to be updated frequently.

The second scan updates from this .txt file to track changes in the inventory. The inventory record on the database does not change, unless the inventory manager is loading new stock, in which case new inventory records are created.

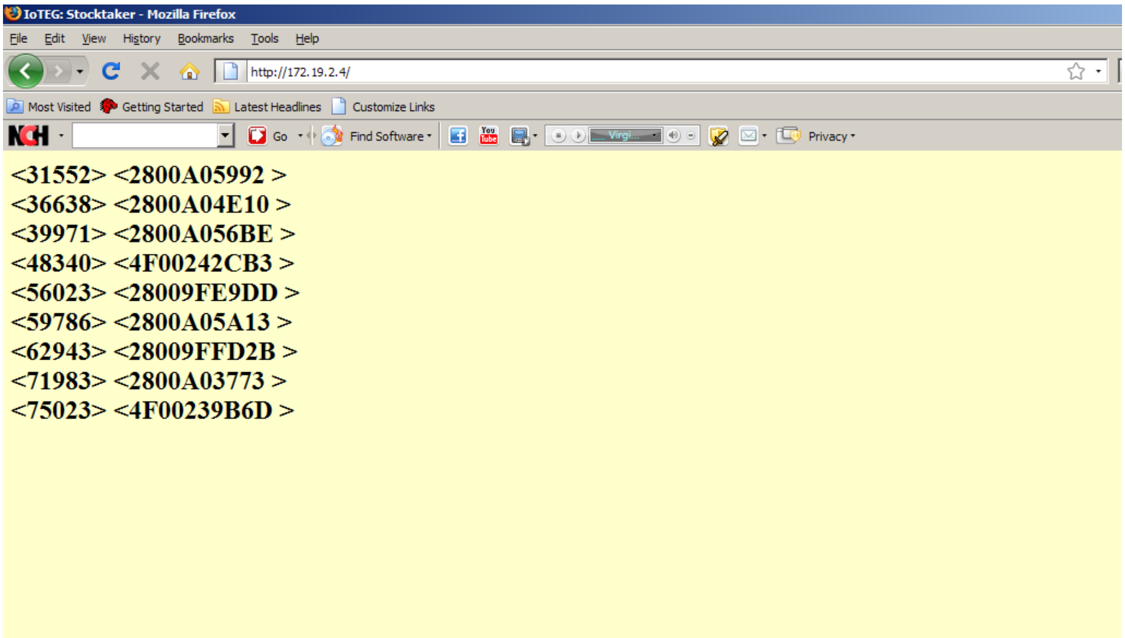



**Figure 5.8** Changes in inventory

### 5.3.4 Database update for changes (2nd scan)

The 2nd scan tracks changes in the inventory. Figure 5.8 displays the changes in the inventory. It shows scans for some products that were misplaced, and stock that is low. For testing purposes, items were swapped around to illustrate misplaced products. To test the stock level, some items were not scanned. In Figure 5.8, only 6 items were scanned and 3 delimiters were used to categorise them according to their zones.

The system updates the inventory record on the database to track changes and send notifications to the Twitter page. Figure 5.8 shows some results displayed on the second scan. In the tea zone, 4 items are on the shelf and 1 item, which is milk, has been misplaced. In the milk zone, only 1 item is available which means milk stock is low, and replenishment is required. The misplaced item also needs to be replaced.

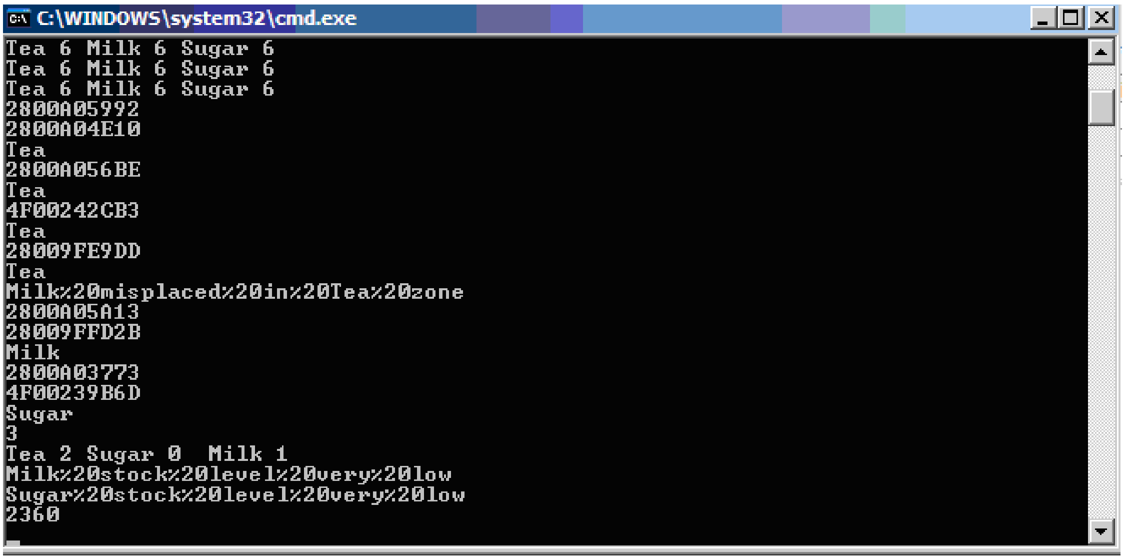



**Figure 5.9** The second scan product count

In Figure 5.9, the system counts all the products and detects products that are not in the correct zone, as well as stock levels. Only one unit of milk is on the correct shelf, and another one is misplaced in the tea zone. Therefore the milk total is 2. Sugar stock is low: only one item is available and it is not misplaced. The total tea stock is at 3 units.

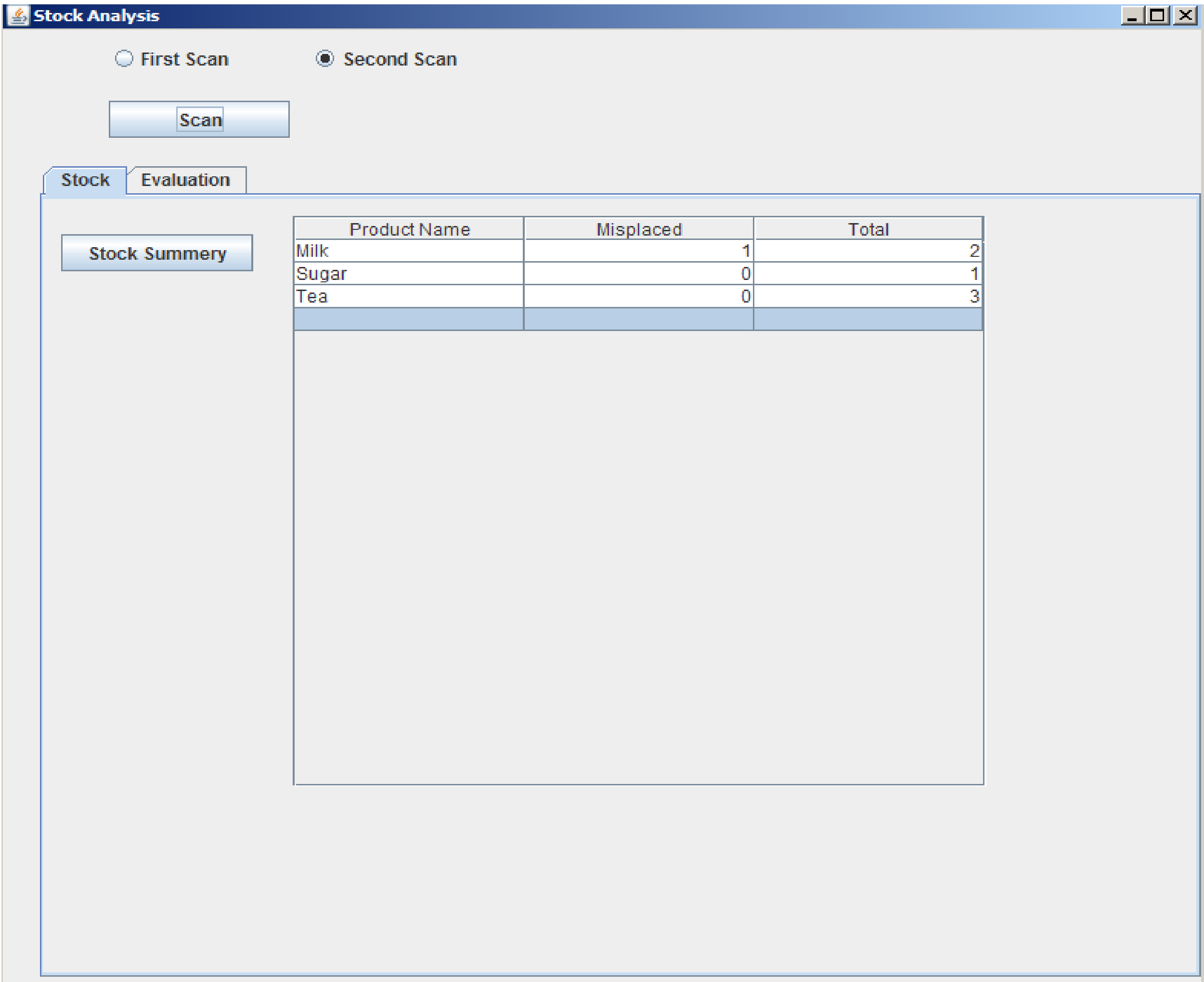



**Figure 5.10** The product summary table

The product summary interface must display product items in detail, the counts of misplaced items, and the stock on hand, as shown in Figure 5.10.

### 5.3.5 Notifications on Twitter

Figure 5.11 shows the notifications appearing on Twitter to update the inventory manager.

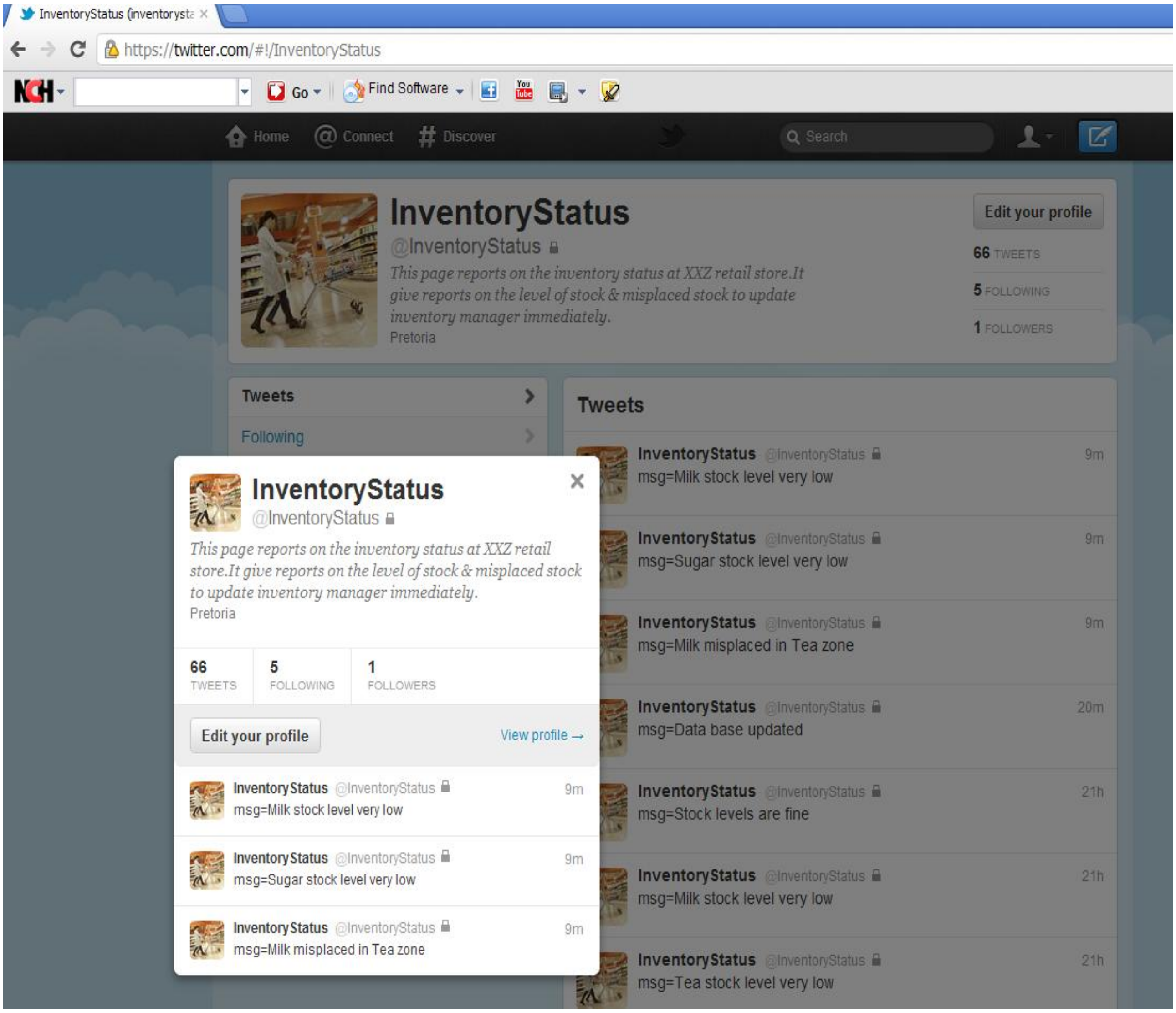



**Figure 5.11** Inventory status tweets

The inventory tweets alert the inventory manager of milk stock and sugar stock running low on shelves and milk which is misplaced in the tea zone. These notifications feed into Twitter in real time.

## 5.4 Prototype Evaluation

### 5.4.1 Software performance evaluation

The evaluation of the proposed system used scalability versus time to measure the performance when a certain number of RFID tags were read. The Arduino time is measured in nanoseconds, and 20 items were scanned in 4 seconds.

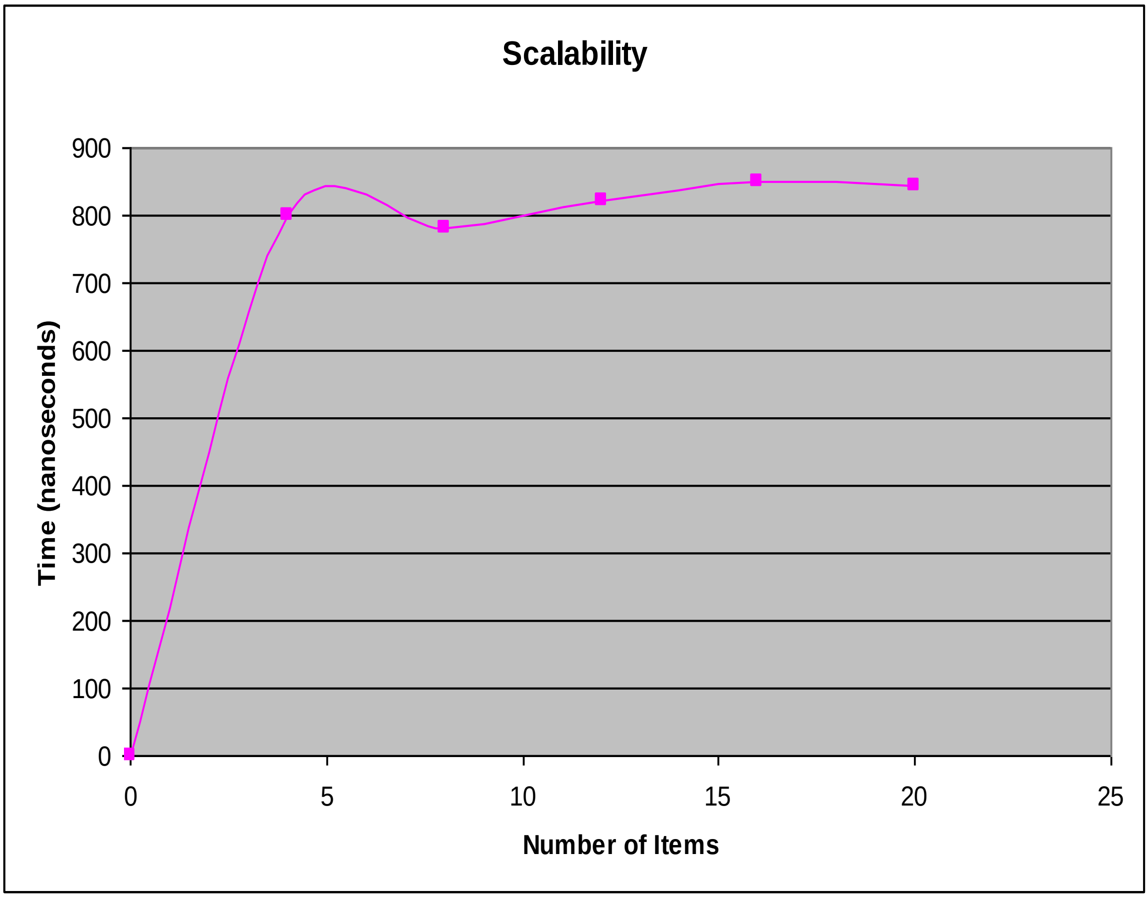



**Figure 5.12** Scalability for reading items

The results in Figure 5.12 indicated that as the number of tags read increases, time taken increases as well. However, when 4 tags were scanned, it took longer than was expected. This shows that the system scalability rate may not be proportionate to time.

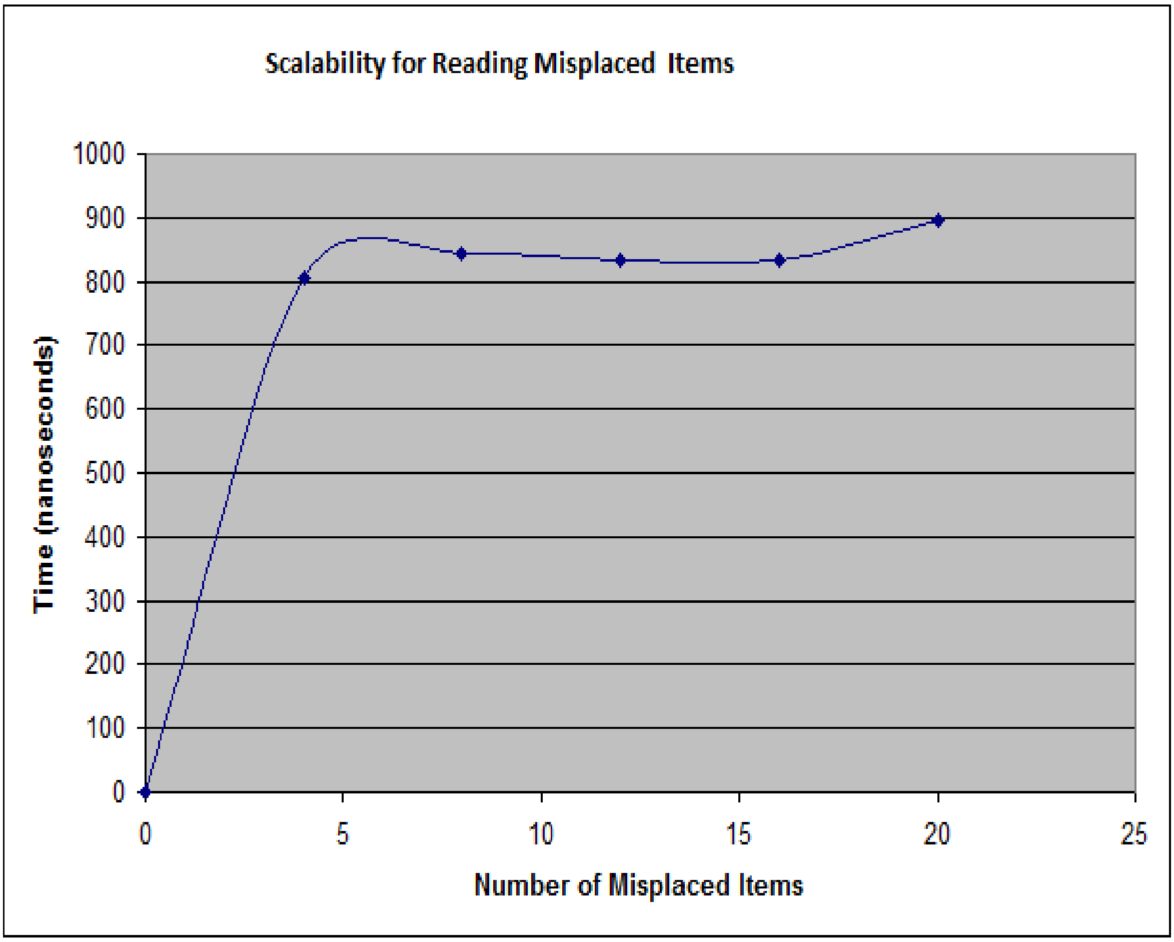



**Figure 5.13** Scalability for reading misplaced items

Figure 5.13 shows the scalability when a number of items were misplaced and the time taken to detect those items and send notifications to Twitter. The system was quicker to identify the first 4 items which were misplaced. Time taken was longer to identify all the misplaced items. However, the time is in nanoseconds, which resulted in quicker feeds to Twitter.

### 5.4.2 Comparison with existing studies

A good number of applications of IoT technology in supply chain and inventory management exist. The work of (Lancioni et. al, 2003) reveals that the integration of the internet into supply chain management applications has increased and has moved away from the indiscriminate application of novel internet technologies towards becoming a focused endeavour with precise expectations and measurable goals.( Myers , 2010) analysed a variation spike in time spent on work during the same time block by employees of a paint manufacturing company using RFID for data collection at various points of the production stages. The graphical results generated from the time spent at each RFID point were informative. They revealed unproductive employees who were responsible for reducing quality of production as a result of hurrying to complete certain processes.

Existing research has not sufficiently addressed real-time shelf replenishment. Much emphasis has been laid on elimination or reduction of inventory inaccuracies occasioned by “theft, product misplacements, or transaction errors” (Rekik et.al, 2009). In order to address the problem of shelf replenishment, (Wong & McFarlane, 2007) provided a qualitative analysis of opportunities for improvement using RFID. The authors describe the push/pull traditional replenishment processes. They describe “an RFID-supported process characterized by automatic monitoring of stock levels and product movements as well as automatic compilation of pick lists on mobile devices” among other contributions. In order to show that RFID is not an error-free identification technology, (Cosmin et. al, 2012) account for detection errors caused by imperfect RFID read rates. They demonstrate that RFID performance is influenced by the physics of RF communications, the quality of hardware components, issues in the labelling and logistics processes, and other factors.

Existing research outputs have concentrated to a large extent on the use RFID or IoT in inventory management with little emphasis on the performance of software that communicates these real-time data (Chande et.al, 2005, Condea et. al, 2012, Eckles 1992, Harrington ,1994, Hellstrom & Wiberg 2010, Wong & McFarlane 2007, Li, et al. 2006, Yao & Carlson, 1999). Existing software solutions have concentrated on customised applications with little attention given to how to utilise existing Web solutions to enhance inventory management in the IoT (Forger 1995, Lancioni et.al, 2003, Wong, et. al, 2012). The social network platform is used by almost every mobile internet user today. It is much more user friendly and convenient now for an average user to receive and transmit content over social networking media such as Facebook, Twitter, YouTube etc. The proposed model in this research enhances existing studies by providing a novel application of RFID combined with social internet technologies to provide better real-time shelf information for stock replenishment (Mathaba et. al 2011). The work also evaluates the developed prototype application to determine the scalability of its performance in the event of increasing task loads. The scalability results (Figures 5.12 and 5.13) show that optimum utilisation of the prototype system requires a minimum of five items to be read. As a result of laboratory experimental constraints, only 20 items were used to test the system. The experiments show further that the performance of the system does not degrade when using the maximum number of items.

## 5.5 Summary

This chapter demonstrated the design and implementation of the enhanced inventory management system. The main objective of this study was to notify relevant personnel responsible for inventory management using IoT technology (RFID) and Web 2.0 tools (Twitter). The scalability of the system versus the number of products and the response time versus the number of misplaced products were measured. The work done in this research has also been compared with existing related work. Chapter 6 presents the conclusions of the study.

# CHAPTER SIX
# CONCLUSION AND FUTURE WORK

## 6.1 Introduction

This research proposed and prototyped a 'just in time' architecture for inventory control that utilises RFID and Web 2.0 technologies. The result of the prototype was evaluated in Chapter 5. The proposed inventory management system was able to provide timely information required by the inventory manager over a social network medium. The two tasks to notify inventory manager of misplaced stock and low stock levels on shelves were achieved. The Twitter notifications on inventory were received in real time. This chapter begins with a summary of the research work in Section 6.2. Section 6.3 presents the contribution of the work. The chapter closes with the limitations of the research and possibilities for future work in Section 6.4.

## 6.2 Summary

Radio Frequency Identification (RFID) technology is an integral part of Internet of Things (IoT). RFID combined with Web 2.0 technology can help enterprise owners in inventory management by monitoring stock validity, stock on shelves, misplaced stock, etc. The use of Web 2.0 tools could play a major role in keeping enterprise owners posted about the inventory without them being physically present, and helping them to make informed decisions. They are also informed about urgent matters which may need their attention immediately. Web 2.0 tools bridge the divide between objects and humans. As a result of this study, South African enterprises may be actively encouraged to promote the development procedures of RFID technology with Web 2.0 tools and the Internet of Things to improve the inventory management in their enterprises.

The proposed architecture was able to meet the requirements of checking the availability of stock, checking misplaced stock and sending a tweet containing the relevant data to the inventory manager. The following features are identified as possible functionalities that should be met in future implementation: identifying expired/ruined stock and identifying counterfeit products.

This study is a real and feasible business application in retail enterprises. Many tasks will need to be taken into consideration. This includes training of the staff, cost of the technology, and the complexity of the technology. The South African retail industry is aware of RFID technology, but is still sceptical and adopting a 'wait-and-see' approach (Upfold & Lui, 2010). The IoT technology has drawbacks though; for example, the cost of its adoption is a major concern for developing countries like South Africa, hence the unwillingness of retailers to adopt the technology.

## 6.3 Contribution

This research demonstrates the potential that the combination of existing technologies such as RFID and Web 2.0 has in supporting small enterprises in developing regions regarding enhanced inventory monitoring. Introducing the use of a social media network (Twitter) to enhance 'just in time' availability of information in inventory management is the novel contribution of this work. The 'just in time' model is one of the contemporary inventory control models. The architecture proposed in this work has presented a new approach to the 'just in time' model.

## 6.4 Limitations and Future Work

The prototype implemented was simulated in a single room environment, which gives an idea of what can happen in real world inventory scenarios using Twitter. However, when the system is implemented in real life, it is not certain that the system will scale as effectively as in this simulation. This is due to the immensity of the task involved in real life applications, which may not have been the case with the simulation. For instance, a sample of only 20 items was used in the simulation. The scalability of the system might be a challenge when one takes into consideration the huge amounts of data that need to be processed in a timely manner. Reading expiry dates and identifying counterfeited products is a potential challenge that can be addressed in future implementations.

Although RFID is a suitable technology for many applications, such as those described in this work, it does have limitations in certain areas. RFID is not the ideal identification technology where ferrous materials need to be tracked. This is because of the electro-magnetic shielding properties of such metals as well as the resultant de-tuning of the antenna circuits embedded in the tags. When used on such materials, the reader will not be able to receive data from the tag. When a passive tag is used in such circumstances, it would probably not be able to harvest sufficient energy from the reader to activate in any case, making use of RFID tags on ferrous materials a major problem. Volatile liquids are another application area not well suited to RFID because of the risk of explosion. The RFID technology is ineffective if used in certain conditions, i.e. transponders do not function well when tagged on iron objects or wet surfaces. This creates complications for manufacturing and other industries that use a variety of metallic objects (Dane et.al, 2010).

For these reasons this research can be extended to incorporate optical markers as replacements for RFID in certain applications. Optical markers include QR codes (SO/IEC 18004:2000, Information technology - Automatic identification and data capture techniques - Bar code symbology - QR Code, 2000) and fiducials, (Bencina et.al, 2005) such as those used in the reacTIVision system.

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# APPENDICES

**A1 - Inventory Management System source code**

```
public class StockTakingClient {
    private int numberScanned;
    private JTable stockSummery;

   public void firstRead(HttpEntity entity)throws Exception{
         if(entity!= null){
        InputStream instream =  entity.getContent();
        Reader reader = new InputStreamReader(instream);
        String line;
        BufferedReader breader = new BufferedReader(reader);

         FileWriter writer = new FileWriter("out.txt");
         BufferedWriter bwriter = new BufferedWriter(writer);
         String st = "";
         writer.write(st);
         int count = 0;
         while((line=breader.readLine())!=null){
             count++;
             if(line.startsWith("&")){
                 bwriter.append(line);
                 bwriter.newLine();
             }
         }
         numberScanned = count;
         bwriter.close();
         sendTweet("Data%20base%20updated");

      }
   }
```

```
public void secondRead(HttpEntity entity) throws Exception{
    //Read from file
    Vector recordedTea = new Vector();
    Vector recordedMilk = new Vector();
    Vector recordedSugar = new Vector();
    Vector columnNames = new Vector();
    String[] cols = {"Product Name","Misplaced","Stock level"};

    Vector<Vector> data = new Vector<Vector>();
    Vector row = new Vector();

    String zoneID = "";
    int productCount = 0;
    int milkCount = 0;
    int teaCount = 0;
    int sugarCount = 0;

    Map<String, String> map = new HashMap<String, String>();
     map.put("2800A05992"  ,  "Tea");
     map.put("2800A05A13"  ,  "Milk");
     map.put("2800A03773"  ,  "Sugar");

    String line;
    FileReader fileReader = new FileReader("out.txt");
    BufferedReader bReader = new BufferedReader(fileReader);
    while((line = bReader.readLine())!=null){
      if(map.containsKey(line.substring(line.lastIndexOf(";")+1))){
          zoneID = line.substring(line.lastIndexOf(";")+1);
          line = bReader.readLine();
       }

       if(zoneID.equals("2800A05992")){
           recordedTea.add(line.substring(line.lastIndexOf(";")+1));
       }
```

```
            if(zoneID.equals("2800A05A13")){
                recordedMilk.add(line.substring(line.lastIndexOf(";")+1));
            }
            if(zoneID.equals("2800A03773")){
                recordedSugar.add(line.substring(line.lastIndexOf(";")+1));
            }

           System.out.println("Tea   "+recordedTea.size()+"   Milk   "+recordedTea.size()+"
Sugar "+recordedTea.size());
        }



        InputStream instream =  entity.getContent();
        Reader reader = new InputStreamReader(instream);
        BufferedReader breader = new BufferedReader(reader);
        String line2;
        while((line2=breader.readLine())!=null){

            if(line2.startsWith("&")){
                String id = line2.substring(line2.lastIndexOf(";")+1);
                System.out.println(id);

                if(map.containsKey(id)){
                   zoneID = id;
                }
                else{

                    if(zoneID.equals("2800A05992")){
                        row.clear();
                        System.out.println("Tea");
                        if(recordedTea.contains(id)){
                            productCount++;
                            teaCount++;
                        }
```

```
    else{
        if(recordedSugar.contains(id)){
            sendTweet("Sugar%20misplaced%20in%20Tea%20zone");
            sugarCount++;
            productCount++;
        }
        if(recordedMilk.contains(id)){
            sendTweet("Milk%20misplaced%20in%20Tea%20zone");
            milkCount++;
            productCount++;
        }
    }

}
if(zoneID.equals("2800A05A13")){
    System.out.println("Milk");
    if(recordedMilk.contains(id)){
        productCount++;
        milkCount++;
    }
     else{
        if(recordedSugar.contains(id)){
            sendTweet("Sugar%20misplaced%20in%20Milk%20zone");
            sugarCount++;
            productCount++;
        }
        if(recordedTea.contains(id)){
            sendTweet("Tea%20misplaced%20in%20Milk%20zone");
            teaCount++;
            productCount++;
        }
    }

}
```

```
            if(zoneID.equals("2800A03773")){
                System.out.println("Sugar");
                if(recordedSugar.contains(id)){
                    productCount++;
                    sugarCount++;
                }
                else{
                    if(recordedTea.contains(id)){
                        sendTweet("Tea%20misplaced%20in%20Sugar%20zone");
                        teaCount++;
                        productCount++;
                    }
                    if(recordedMilk.contains(id)){
                        sendTweet("Milk%20misplaced%20in%20Sugar%20zone");
                        milkCount++;
                        productCount++;
                    }
                }
            }

        }
    }


}
System.out.println(productCount);
numberScanned = productCount;
System.out.println("Tea "+teaCount+" Sugar "+sugarCount+" Milk
"+milkCount);
if(teaCount<=1)
    sendTweet("Tea%20stock%20level%20very%20low");
if(milkCount<=1)
    sendTweet("Milk%20stock%20level%20very%20low");
if(sugarCount<=1)
    sendTweet("Sugar%20stock%20level%20very%20low");
```

```
    else {
        sendTweet("Stock%20levels%20are%20fine");
    }

    data.clear();
    row.clear();
    row.add("Tea");
    row.add("");
    row.add(teaCount);
    data.add(row);
    row.clear();
    row.add("Milk");
    row.add("");
    row.add(milkCount);
    data.add(row);
    row.clear();
    row.add("Sugar");
    row.add("");
    row.add(sugarCount);
    data.add(row);
    columnNames.clear();
    for(String n: cols){
        columnNames.add(n);
    }
    stockSummery = new JTable(data, columnNames);

}

 private void sendTweet(String message) {
     DefaultHttpClient client =  new DefaultHttpClient();
     String request = "/beachcomberservlet/inventory?msg="+message;
     try{
         //client.getParams().se
         HttpHost target = new HttpHost("146.64.28.16",8080,"http");
```

```
            HttpPost req = new HttpPost(request);
            client.execute(target, req);
            System.out.println(message);
        }catch(Exception e){
            e.printStackTrace();
        }

    }

    public int getNumberScanned() {
        return numberScanned;
    }

    public JTable getStockSummary() {
        return stockSummary;
    }

}
```

**A2 – Message transmission to Beachcomber source code**

```
public class MessageProcess {

    DBConnection dbCon = new DBConnection();
    private Map<String, String> map = new HashMap<String, String>();
    private static String currentZone="";
    private static int scancount = -1;
    private static Vector<String> recorded = new Vector<String>();

    public void process(Message message){

        firstScan(message);

    }

    private void updateScan (Message message){
        recorded.removeAllElements();
        String contents = message.getBody();
        String query;
        ResultSet result;
        //Vector<String> recordedProducts = new Vector<String>();
```

```
String rfid = contents.substring(0, contents.indexOf(' '));
rfid.trim();
if(currentZone.equals("2800A05992")){
   try {
      int productCount = 0;
      query = "select rfid from Product where Description = ' Product 1 '";
      result = dbCon.getResults(query);

      while(result.next()){
         recorded.add(result.getString(1));

      }
      while (result.next()) {
         if(!map.containsKey(rfid)&& recorded.contains(rfid)){
               productCount++;
               System.out.println("There are "+productCount+" Product 1");
         }
         if(map.containsKey(rfid)){
            return;

         }else{
            String tweet = "The product "+rfid+"is misplaced in Product 1 zone";
            System.out.println(tweet);
         }
      }
   } catch (SQLException ex) {
      Logger.getLogger(MessageProcess.class.getName()).log(Level.SEVERE,
null, ex);
      System.out.println(ex.getSQLState());
   }


}

  if(currentZone.equals("2800A05A13")){
   try {
      int productCount = 0;
      query = "select rfid from Product where Description = ' Product 2 '";
      result = dbCon.getResults(query);

      while(result.next()){
         recorded.add(result.getString(1));

      }
      while (result.next()) {
         if(!map.containsKey(rfid)&& recorded.contains(rfid)){
               productCount++;
               System.out.println("There are "+productCount+" Product 1");
         }
         if(map.containsKey(rfid)){
```

```
                return;

            }else{
                String tweet = "The product "+rfid+"is misplaced in Product 2 zone";
                System.out.println(tweet);
            }
          }
        } catch (SQLException ex) {
          Logger.getLogger(MessageProcess.class.getName()).log(Level.SEVERE,
null, ex);
        }


      }

        if(currentZone.equals("2800A03773")){
        try {
          int productCount = 0;
          query = "select rfid from Product where Description = ' Product 3 '";
          result = dbCon.getResults(query);

          while(result.next()){
            recorded.add(result.getString(1));

          }
          while (result.next()) {
            if(!map.containsKey(rfid)&&recorded.contains(rfid)){
                  productCount++;
                  System.out.println("There are "+productCount+" Product 1");
            }
            if(map.containsKey(rfid)){
                return;

            }else{
                String tweet = "The product "+rfid+"is misplaced in Product 3 zone";
                System.out.println(tweet);
            }
          }
        } catch (SQLException ex) {
          Logger.getLogger(MessageProcess.class.getName()).log(Level.SEVERE,
null, ex);
        }


      }

    }

    public void firstScan(Message message){
      map.put("2800A05992"  ,  "Product 1");
```

```
        map.put("2800A05A13"  ,  "Product 2");
        map.put("2800A03773"  ,  "Product 3");
        String query ;
        String contents = message.getBody();

        try {

                String rfid = contents.substring(0, contents.indexOf(' '));
                rfid.trim();

                if(map.containsKey(rfid)){

                    if(rfid.equals("2800A05992")){
                         currentZone = rfid;
                         scancount++;
                         if(scancount>0 ) //Calls the update scanner if it is not a first scan
                             updateScan(message);
                    }else{
                        currentZone=rfid;
                    }


                 }else{
                    if(scancount>0){
//checks if its a first scan before inserting data into the data base
                        updateScan(message);
                    } else{

                        String timestamp = contents.substring(contents.indexOf(' '));
                        query = ("insert into Product values ('"+ rfid +
"','"+map.get(currentZone)+"','"+timestamp +"')");
                        System.out.println(query);
                        dbCon.executeQuery(query);
                    }

              }

        } catch (Exception e) {
            System.out.print(e.getMessage());
        }


    }

    public void sendTweet(String message){
        System.out.println(message);
    }
}
```

**A3 – Scan Interface source code**

```
public class Main extends javax.swing.JFrame {
StockTakingClient stclient = new StockTakingClient();
/** Creates new form Main */
public Main() {
initComponents();
}

private void initComponents() {

jTabbedPane1 = new javax.swing.JTabbedPane();
jPanel1 = new javax.swing.JPanel();
stockSummeryButton = new javax.swing.JButton();
jScrollPane1 = new javax.swing.JScrollPane();
jTable1 = new javax.swing.JTable();
jPanel4 = new javax.swing.JPanel();
jButton20 = new javax.swing.JButton();
jButton21 = new javax.swing.JButton();
jRadioButton1 = new javax.swing.JRadioButton();
jRadioButton2 = new javax.swing.JRadioButton();
jButton7 = new javax.swing.JButton();

setDefaultCloseOperation(javax.swing.WindowConstants.EXIT_ON_CLOSE);
setTitle("Stock Analysis");

stockSummeryButton.setText("Stock Summery");
stockSummeryButton.addActionListener(new java.awt.event.ActionListener() {
public void actionPerformed(java.awt.event.ActionEvent evt) {
stockSummeryButtonActionPerformed(evt);
}
});

jTable1.setModel(new javax.swing.table.DefaultTableModel(
new Object [][] {
{"Milk", new Integer(0), new Integer(0)},
{"Sugar", new Integer(0), new Integer(0)},
{"Tea", new Integer(0), new Integer(0)},
{null, null, null}
},
new String [] {
"Product Name", "Misplaced", "Total"
}
) {
Class[] types = new Class [] {
java.lang.String.class, java.lang.Integer.class, java.lang.Integer.class
};

public Class getColumnClass(int columnIndex) {
return types [columnIndex];
```

```
}
});
jScrollPane1.setViewportView(jTable1);

javax.swing.GroupLayout jPanel1Layout = new javax.swing.GroupLayout(jPanel1);
jPanel1.setLayout(jPanel1Layout);
jPanel1Layout.setHorizontalGroup(
jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
.addGroup(javax.swing.GroupLayout.Alignment.TRAILING,
jPanel1Layout.createSequentialGroup()
.addContainerGap()
.addComponent(stockSummeryButton, javax.swing.GroupLayout.DEFAULT_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, Short.MAX_VALUE)
.addGap(26, 26, 26)
.addComponent(jScrollPane1, javax.swing.GroupLayout.PREFERRED_SIZE, 452,
javax.swing.GroupLayout.PREFERRED_SIZE)
.addGap(137, 137, 137))
);
jPanel1Layout.setVerticalGroup(
jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
.addGroup(jPanel1Layout.createSequentialGroup()
.addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.L
EADING)
.addGroup(jPanel1Layout.createSequentialGroup()
.addGap(25, 25, 25)
.addComponent(stockSummeryButton))
.addGroup(jPanel1Layout.createSequentialGroup()
.addContainerGap()
.addComponent(jScrollPane1, javax.swing.GroupLayout.PREFERRED_SIZE, 402,
javax.swing.GroupLayout.PREFERRED_SIZE)))
.addContainerGap(131, Short.MAX_VALUE))
);

jTabbedPane1.addTab("Stock", jPanel1);

jButton20.setText("Scalability");
jButton20.addActionListener(new java.awt.event.ActionListener() {
public void actionPerformed(java.awt.event.ActionEvent evt) {
jButton20ActionPerformed(evt);
}
});

jButton21.setText("jButton21");

javax.swing.GroupLayout jPanel4Layout = new javax.swing.GroupLayout(jPanel4);
jPanel4.setLayout(jPanel4Layout);
jPanel4Layout.setHorizontalGroup(
jPanel4Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
.addGroup(jPanel4Layout.createSequentialGroup()
.addGap(31, 31, 31)
```

```
.addGroup(jPanel4Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.T
RAILING)
.addComponent(jButton21)
.addComponent(jButton20))
.addContainerGap(635, Short.MAX_VALUE))
);
jPanel4Layout.setVerticalGroup(
jPanel4Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
.addGroup(jPanel4Layout.createSequentialGroup()
.addGap(55, 55, 55)
.addComponent(jButton20)
.addGap(41, 41, 41)
.addComponent(jButton21)
.addContainerGap(389, Short.MAX_VALUE))
);

jTabbedPane1.addTab("Evaluation", jPanel4);

jRadioButton1.setText("First Scan");
jRadioButton1.addActionListener(new java.awt.event.ActionListener() {
public void actionPerformed(java.awt.event.ActionEvent evt) {
jRadioButton1ActionPerformed(evt);
}
});

jRadioButton2.setText("Second Scan");
jRadioButton2.addActionListener(new java.awt.event.ActionListener() {
public void actionPerformed(java.awt.event.ActionEvent evt) {
jRadioButton2ActionPerformed(evt);
}
});

jButton7.setText("Scan");
jButton7.addActionListener(new java.awt.event.ActionListener() {
public void actionPerformed(java.awt.event.ActionEvent evt) {
jButton7ActionPerformed(evt);
}
});

javax.swing.GroupLayout layout = new javax.swing.GroupLayout(getContentPane());
getContentPane().setLayout(layout);
layout.setHorizontalGroup(
layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
.addGroup(layout.createSequentialGroup()
.addGap(69, 69, 69)
.addGroup(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADIN
G)
.addComponent(jButton7, javax.swing.GroupLayout.PREFERRED_SIZE, 118,
javax.swing.GroupLayout.PREFERRED_SIZE)
.addGroup(layout.createSequentialGroup()
```

```
.addComponent(jRadioButton1)
.addGap(49, 49, 49)
.addComponent(jRadioButton2)))
.addContainerGap(454, Short.MAX_VALUE))
.addGroup(javax.swing.GroupLayout.Alignment.TRAILING,
layout.createSequentialGroup()
.addGap(24, 24, 24)
.addComponent(jTabbedPane1, javax.swing.GroupLayout.DEFAULT_SIZE, 754,
Short.MAX_VALUE))
);
layout.setVerticalGroup(
layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
.addGroup(layout.createSequentialGroup()
.addContainerGap()
.addGroup(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELI
NE)
.addComponent(jRadioButton2)
.addComponent(jRadioButton1))
.addGap(18, 18, 18)
.addComponent(jButton7)
.addGap(18, 18, 18)
.addComponent(jTabbedPane1)
.addContainerGap())
);

pack();
}// </editor-fold>//GEN-END:initComponents

private void jButton7ActionPerformed(java.awt.event.ActionEvent evt) {//GEN-
FIRST:event_jButton7ActionPerformed

DefaultHttpClient client =  new DefaultHttpClient();
long elapsed = 0;
try{
HttpHost target = new HttpHost("172.19.2.4",80,"http");
HttpGet req = new HttpGet("/?req=yyyy1234mm12dd12hh08mm34ss00");
HttpResponse rsp = client.execute(target, req);
HttpEntity entity = rsp.getEntity();
long startTime = System.currentTimeMillis();
if(jRadioButton1.isSelected()==true){
stclient.firstRead(entity);
}
if(jRadioButton2.isSelected()==true){
stclient.secondRead(entity);
}else
if(jRadioButton1.isSelected()==false&&jRadioButton2.isSelected()==false){
System.exit(10);
}
long endTime = System.currentTimeMillis();
```

```java
elapsed = endTime - startTime;
System.out.println(elapsed);

}catch(Exception e){
e.printStackTrace();
}
FileWriter writer;
try {
writer = new FileWriter("data.txt");
BufferedWriter bwriter = new BufferedWriter(writer);
bwriter.append(elapsed+" "+stclient.getNumberScanned());
bwriter.newLine();
bwriter.close();
} catch (IOException ex) {
Logger.getLogger(Main.class.getName()).log(Level.SEVERE, null, ex);
}


private void jRadioButton1ActionPerformed(java.awt.event.ActionEvent evt)
}
private void jRadioButton2ActionPerformed(java.awt.event.ActionEvent evt)

private void jButton20ActionPerformed(java.awt.event.ActionEvent evt)

private void stockSummeryButtonActionPerformed(java.awt.event.ActionEvent evt)
jTable1 = stclient.getStockSummery();
jTable1.updateUI();

public static void main(String args[]) {
java.awt.EventQueue.invokeLater(new Runnable() {
public void run() {
new Main().setVisible(true);
}
});
}

private javax.swing.JButton jButton20;
private javax.swing.JButton jButton21;
private javax.swing.JButton jButton7;
private javax.swing.JPanel jPanel1;
private javax.swing.JPanel jPanel4;
private javax.swing.JRadioButton jRadioButton1;
private javax.swing.JRadioButton jRadioButton2;
private javax.swing.JScrollPane jScrollPane1;
private javax.swing.JTabbedPane jTabbedPane1;
private javax.swing.JTable jTable1;
private javax.swing.JButton stockSummeryButton;
// End of variables declaration//GEN-END:variables
}
```