DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

USING MOBILE TECHNOLOGY IN WAREHOUSE MANAGEMENT SYSTEM

by

Fady FAYYAD

November, 2015

İZMİR

USING MOBILE TECHNOLOGY IN WAREHOUSE MANAGEMENT SYSTEM

A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of Dokuz Eylül University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Computer Engineering Program

by

Fady FAYYAD

November, 2015

İZMİR

M.Sc. THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"USING MOBILE TECHNOLOGY IN WAREHOUSE MANAGEMENT SYSTEM"** completed by **FADY FAYYAD** under supervision of **DR. ÖZLEM ÖZTÜRK** and we certify that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Dr. Özlem ÖZTÜRK

Supervisor

Dr. Derya BİRANT

(Jury member)

Dr. Özgür Tamer

(Jury member)

Prof. Dr. Ayşe OKUR

Director

Graduate school of Natural and Applied Sciences

ACKNOWLEDGMENTS

I would like to express my gratitude to my supervisor Dr. Özlem ÖZTÜRK who's experienced, understandable, and patient for her help, suggestions and excellent guidance. I would also like to express my gratitude to all the academic staff of computer engineering department who gave me valuable courses specially Dr. Derya BİRANT, Dr. Adil ALPKOÇAK, Dr. Kökten Ulaş BİRANT, Dr. Malik Kemal ŞİŞ and Dr. Melda DUMAN.

Also, my deepest gratitude goes to my family specially my parents for their unlimited love and unconditional support throughout my life and studies. You made my life the most unique and magic. None of this would have been possible without the love and patience of you. Your carefree childhood that you provided to me has made me who I am now!

Fady FAYYAD

USING MOBILE TECHNOLOGY IN WAREHOUSE MANAGEMENT SYSTEM

ABSTRACT

Since its invention during the Second World War to identify fighter jets in the sky, Radio Frequency Identification (RFID) is used. Recent discovery of its application in several areas has revolutionized its use. Inventory control or tracking in warehouse and wholesalers is one of the application areas among many. It is widely used in such tracking businesses to increase the accuracy of inventory data, to facilitate decision support and data analytics, to increase efficiency of inventory management and minimize theft of inventory items. However, thousands of small sized retailers around the world are not benefiting from the RFID technology in use in all sectors because of high installation costs due to for example the expensive of the RFID readers.

In this work, we propose use of a low cost Ultra High Frequency (UHF) reader connected to android devices to be used in stock/warehouse management systems. It is an efficient and low cost implementation of RFID inventory tracking management system. The study has found the use of UHF readers' plugin instead of traditional RFID readers highly decreases the cost of the installation. The research concludes that implementation of such a system empowers small sized retailers to increase efficiency in their inventory tracking systems, increase customer satisfaction, minimize theft and loss of inventory items, and increase accuracy of inventory management.

Keywords: Mobile, RFID technology, inventory management, supply chain management, warehouse management, android

STOK YÖNETİMİ SİSTEMİ İÇİNDE MOBİLE TEKNOLOJİ KULLANIMI

ÖZ

Radyo Frekansı ile Tanımlama (RFID) teknolojisi ilk olarak İkinci Dünya Savaşı esnasında savaş uçaklarının tespiti için kullanılmıştı. Bu uygulamanın son keşifleri çeşitli alanlarda kullanımında devrim yaratmıştır. Depo kontrolu ve envanter takibi birçok uygulama alanlarından birkaçıdir. Bu teknoloji envanterlerin doğruluğunu ve hassasiyetini arttırmak, karar desteği sağlamak ve veri analatığını kolaylaştırmak, envanter yönetimi verimliliğini arttırmak ve stok kaybı ve hırsızlığını en aza indirmek için kullanılmaktadır. Ancak, RFID okuyucularının maliyeti ve sistemin kurulum maliyetleri yüksek olduğu için, dünyada binlerce küçük ve orta ölçekli perakendeciler bu RFID teknolojisini kullanamamaktadır.

Bu çalışmamızda, düşük maliyetli Ultra High Frequency (UHF) okuyucusunun android cihazlar üzerinde kullanımını sunuyoruz. RFID teknolojisini kullanan daha etkili ve daha avantajlı bir stok kontrolü ve envanter yönetimi uygulamasını ileri sürüyoruz. Bu çalışmada normal RFID okuyucusu yerine UHF'in eklentisinin kullanılmasının daha uygun olduğu tespit edildi. Böylece sistemin kurulum masrafından kaçınılmış olur. Araştırma, böyle bir sistemin uygulanması ile küçük çaplı perakendeciler için stok takibi sisteminde verimliliği ve müşteri memnuniyetini arttırmak, hırsızlık ve stoktaki ürünlerin kaybını en aza indirmek, ve envanter yönetimi doğruluğunu ve hassasiyetini arttırmak amaçlıdır.

Anahtar Kelimeler: Mobil, RFID teknolojisi, envanter yönetimi, tedarik zinciri yönetimi, depo yönetimi, android

CONTENTS

LIST OF FIGURES

Pages

LIST OF TABLES

Pages

CHAPTER ONE

INTRODUCTION

1.1 Background

Radio Frequency Identification (RFID) is a wireless automatic identification technology that communicates data by radio waves. RFID tag “also known as transponder” is comparable to barcode; however, unlike barcode, RFID tag does not need a line of sight for an RFID reader “also known as interrogator” to detect. Data is encoded in a chip, which is integrated with an antenna and packaged into a finished tag. RFID tags may be passive that requires installation within close proximity to a reader, or active in which the RFID tag contains a small battery to allow continuous monitoring. RFID technologies offer different options such as memory sizes and forms, and can be read from anywhere within range of the reader. Different from Barcode that does not have a multi reading at the same time capability, data storage, and reading from distance capability. Simply Barcode is a technology to read the printed barcode that acts a serial or identification code by scanner. Most products carry a simple barcode known as the UPC (Universal Product Code) it is a line of vertical stripes with a set of numbers printed underneath it.

Nowadays, the application of RFID technologies in inventory management systems is not widely used because of its costs. Like most electronic parts, RFID unit costs dropped dramatically within past years, but still high when compared with other technologies used in inventory management like barcode technology. However, RFID technology is still in use. For example, Tetaş AŞ, a Turkish company, has installed RFID in its distribution center in Tekbes near Izmir – the largest with a surface area of 8,500 m^2. RFID ensures that the precise storage location can be called up for any article at any time – fully automated and error-free. For this purpose, the products delivered by the manufacturers are first stacked on pallets by Tetaş. Each of these storage pallets is equipped with an RFID transponder to identify the goods henceforth (Siemens AG, 2008).

A few companies have also introduced RFID mirrors, usually used in fitting rooms of fashion boutiques. When a potential costumer wear an RFID tagged piece of clothing, the mirror will display additional information such as size, brand, material and other matching clothes. The mirror may also provide option to the customer to request a different size of the same clothing. The RFID mirror not only attempts persuade a customer to purchase an item but also provides an engaging experience for the customer to stay longer (Ong, 2008).

1.2 Motivation

This project proposes a mobile RFID system using android application installed on mobile device with backend web application with a database to automate inventory counting and tracking and thus reducing the cost of deploying RFID readers in inventories. The RFID readers are implemented on a mobile device working with android operating system with an Ultra High Frequency (UHF) plugin working as antenna.

The main contributions of this thesis are making RFID technology affordable, make normal android powered mobile devices multi-functional, easies inventory management and increase profit through automation to optimize economic order quantity and reorder points.

1.3 Organization

This study is organized as follows. Chapter 2 summarizes a literature review about inventories and warehousing principles, a brief description about RFID, and the difference between RFID technologies and other related technologies like NFC and BARCODE technologies. Chapter 3 deeply describes RFID systems and its components and how its work, and the applications of it. Chapter 4 describes the architecture of the developed system, the hardware and software components, and the dataflow. Chapters 5 discuss the evaluation of the system. Finally Chapter 6 concludes with the contributions of this thesis and a brief description of future work to follow.

CHAPTER TWO
LITERATURE REVIEW

2.1 Inventory Management Definition and History

Inventory management is a process. The process consists of observing and controlling of the sales, ordering, storage of quantities and tracks product’s (items) movements inside a business. A business's inventory is one of its major assets and represents an investment that is tied up until the item is sold or used in the production. It also costs money to store, track and insure inventory. Inventories that are mismanaged can create significant financial problems for a business, either due to an inventory overloading or an inventory shortage.

2.1.1 Inventory Management

“Inventory” and “‘stock” are often used to relate to the same thing (Wild, 2002); yet when inventory management is mentioned, there is however a slight difference between inventory and stock. Stock is usually an amount of goods that is being kept at a specific place (in a warehouse for example), sometimes referred to as inventory. Conversely, inventory management is primarily about specifying the size and placement of stocked goods. Inventory management is necessary at different locations within an organization or within multiple locations of a supply chain, to protect the production from running out of materials or goods. The scope of inventory management is broader than stock. Basically inventory management can be defined as the “management of materials in motion and at rest” (Coyle et al., 2003). The following activities all fall within the range of inventory management (Wikipedia, 2009): control of lead times, carrying costs of inventory, asset management, inventory forecasting, inventory valuation, inventory visibility, future inventory price forecasting, physical inventory, available physical space for inventory, quality management, replenishment, returns and defective goods and demand forecasting. Inventory management basically serves two main goals (Reid & Sanders, 2007). First of all good inventory management is responsible for the availability of goods. It is important for running operations that the required materials are present in the right quantities, quality and at the right time in order to deliver a specific level of service. The second goal is to achieve this service level against optimal costs. Not all items can be held in stock against every cost for example and therefore choices have to be made.

2.1.2 Inventory Management History

In the earliest days of merchants, shop keeping, and purchasing, the people tried to look at how much sales are performed at the end of the day, and then then they tried to forecast the expected sales that will happen at the future.

After the Industrial Revolution, efficiency and mass production became the main goals of businesses, along with an improved customer experience at the point of sale. A team at Harvard University designed the first modern check-out system in the early 1930s. It used punch cards that are coupled with catalog items. A computer would read the punch cards and pass the information to the storeroom, which would then bring the item up front to the waiting customer. Because of the automated system, the machines could also generate billing records and manage inventory. The system proved to be too expensive to use, but a version of it is still in use today in some stores, where merchants place cards with product information on the aisle for customers to select and bring to the checkout line. This usually applies to items that are expensive or large and to controlled items, such as medicines (Crosby, n.d).

Merchants knew they needed a better system, and researchers created the forerunner of the modern bar-coding system in the late 1940s and early 1950s. It used ultraviolet light-sensitive ink and a reader to mark items for sale. Again, the system was too cumbersome and lacked the computing power needed to make it work. Technology had yet to catch up with their ideas (Crosby, n.d).

The Universal Product Code (UPC) was adopted by the grocery industry in April 1973 as the standard barcode for all grocers, though it was not introduced at retailing locations until 1974 (Cavanaugh, Coelho, Bellaire, & Pleten, 2008).

This helped drive down costs for inventory management because retailers in the United States and Canada didn’t have to purchase multiple barcode readers to scan competing barcodes. There was now one primary barcode for grocers and other retailers to buy one type of reader for.

In the early 1980s, personal computers began to be popular (Polsson, 2003). This further pushed down the cost of barcodes and readers. It also allowed the first versions of inventory management software to be put into place. One of the biggest hurdles in selling readers and barcodes to retailers was the fact that they didn’t have a place to store the information they scanned. As computers became more common and affordable, this hurdle had been overcome. Once barcodes and inventory management programs started spreading through grocery stores, inventory management by hand became less practical. Writing inventory data by hand on paper was replaced by scanning products and inputting information into a computer by hand.

During the mid to late 1990s, retailers began implementing modern inventory management systems, made possible in large part by advances in computer and software technology. The systems work in a circular process, from purchase tracking to inventory monitoring to re-ordering and back around again (Crosby, n.d).

Starting in the early 2000s, inventory management software progressed to the point where business people no longer needed to input data by hand but could instantly update their database with barcode readers.

Also, the existence of cloud based business software and their increasing adoption by businesses mark a new era for inventory management software. Now they usually allow integrations with other business backend processes, like accounting and online sales.

2.2 Challenges of Inventory Management

Inaccuracy problem in inventory management systems have been identified in many different areas such as manufacturing and distribution (Wight, 1995). Investment and real estate trading as in (Yacine, 2006), governmental foundations according to (Laudon, 1986), phone and utility companies (Redman, 1992) and (Knight, 1992) has suffered a lot from inaccuracy problem. So, it is one of the biggest challenges in inventory management systems.

The way of managing inventories has rarely differentiated between the computerized inventory management and the physical inventory management. The two way have the same and the main concern, it is how to observed demand and the inventory levels, and how to determine the order dates and economic order quantities.

2.3 How to Solve Inaccuracy Problem in Inventory Management Process

To resolve the inaccuracy in inventory management process, different methods can be used. A lot of investigations in (Uckun et al., 2008), (Kang and Gershwin, 2004), (Sahin, 2004) and (DeHoratius et al., 2008) agreed that the inaccuracy of inventory management may be happened because of lack of tracking process of the inventory. So, RFID technology may help in tracking items through the supply chain as well as solving the inaccuracy in inventory management problem. The technology may also help to eliminate the reasons of inventory inaccuracy such as unidentified loss.

2.4 RFID Technology Definition and History

Before we proceed further, it would be interesting to have insights into RFID technology a little more to understand the ins and outs of this technology. It would be beneficial to know the components used by RFID technology so that it would be easier to understand how this technology works.

2.4.1 RFID Technology Definition

"Radio Frequency Identification (RFID) is a generic term used for technologies that use radio waves to automatically identify people or objects." RFID, can be used in identification, detection, tracking, computation, detection of fraud, and checking for objects in various fields of industry such as inventorying, manufacturing, construction, and health care.

2.4.2 RFID Technology History

RFID has taken many years to mature to the point where it is sufficiently affordable and reliable for widespread use. In 1845, Michael Faraday identified the field of electromagnetism about the relationship between light and radio waves in 1845, after that the revolution of electromagnetic aspects started. Radio Frequency Identification (RFID) technology is one of these technologies that had been developed and expanded (Encyclopaedia Britannica, 2004). The first device employing RFID technology was developed by Leo Theremin, radio wave decoder. Soviet government used it for recognition and exploration in 1940s in World War II. Tied with it, tags technology (transponder) was originated from a discrimination system used to distinguish friendly and enemy aircraft. Friendly aircraft sent out a signal while passing near to another friendly forces or aircraft, depending on that signal, the system could be able to identify whether the aircraft is friendly or not. Tracking technology is advancing and being used in everyday life more frequently. When customers order any product online (by internet or phone), they wonder where their package is: is it invoiced, checked to shipping, is it shipped, on which shipping stage is it, or when it will be delivered. Customers can check their orders by using internet or phone, entering the tracking number, and find the relevant information about their order. RFID is currently one of the most accurate and dedicated tracking technologies in the world. RFID started to be commonly used since the beginning of 2000's. When it became affordable, companies started to integrate RFID technology as a product identification technology and started to raise RFID technology in the supply chains market.

2.5 Alternative Tracking Technologies for Inventory Management

The most widely used tracking technologies are Barcode, RFID and NFC. RFID and Barcode are two of the most popular automatic identification technologies used in several businesses around the world. Barcode needs line of sight to read while RFID does not. RFID uses chip called tags which could be passive or active. RFID can write and/or read from the tags. Due to high price of RFID reader, its use and application is limited to large warehouses and wholesalers. Use of RFID is not limited to wholesalers or retailers only; but it is also used in fitting rooms of fashion boutiques as well.

The **Barcode** can best be described as an "optical Morse code." Series of black bars and white spaces of varying widths are printed on labels to uniquely identify items. The bar code labels are read with a scanner, which measures reflected light and interprets the code into numbers and letters that are passed on to a computer. So it is a technology used in tracking and controlling stocks and inventories.

Near field communication (NFC) is the set of protocols that enable electronic devices to establish radio communication with each other by touching the devices together, or bringing them into proximity to a distance of typically 10cm or less. So it is also a technology used in tracking.

2.6 SWOT Analysis

A SWOT analysis (alternatively SWOT matrix) is a structured planning method used to evaluate the strengths, weaknesses, opportunities and threats involved in a project or in a business venture. A SWOT analysis can be carried out for a product, place, industry or person. The researcher used this analysis method to evaluate the three available alternatives of tracking technologies. These technologies are RFID, Barcode, and NFC (Near Field Communication).

2.6.1 Barcodes

- Strengths

1. Bar codes are comparatively cheaper and widely used especially in low price products wherein the technologies like RFID and Machine to Machine (M2M) are out of question due to the low profit margins (Wani, 2012).
2. Barcodes are at a mature stage and have been adopted widely in most of the industries around the globe.

- Weaknesses

1. Bar Codes have a limited amount of information flow capability which includes the information about the manufacturer and product description (Schuster, Allen and Brock, 2007).
2. Bar codes require line of sight to be read (Schuster, Allen and Brock, 2007).
3. Bar codes can only be read individually (Schuster, Allen and Brock, 2007).
4. Bar codes cannot be read if they become dirty or damaged
5. Bar codes must be visible for scanning
6. Bar codes can only provide limited information
7. There is no possibility to update the information in Bar codes
8. Bar codes can be scanned one at a time
9. Bar codes require human interference (Schuster, Allen and Brock, 2007).
10. Manual tracking is required for item identification resulting in human errors.

- Opportunities

1. Bar codes have an opportunity to expand especially in the low cost products where other technologies may fail to be implemented.

- Threats

1. As stated by Mr. George J. Laurer in The New York Times, a veteran engineer at IBM (1970) and team leader responsible for invention of bar codes, “bar code is challenged by newer and much more sophisticated competitors. Radio frequency identification, or RFID, is one such technology” (Shih, 2009).
2. Customers especially in Business to Business (B2B) are demanding more features and information which bar codes fail to provide due to the technology limitations as a result of which the suppliers and organizations’ prefer other technologies that can fulfill the demands of their clients.

2.6.2 RFID

- Strengths

1. RFID tags can be read or updated without line of sight (Tsipoulanidis, 2012)
2. Multiple RFID tags can be read simultaneously (Tsipoulanidis, 2012).
3. RFID tags can even function under harsh and dirty environments
4. RFID tags are thin and can be printed on a label
5. RFID tags can be read even when packed inside an object.
6. RFID tags are capable of identifying a specific item or product
7. Mostly importantly the electronic information can be over written repeatedly in case of RFID tags (Tsipoulanidis, 2012)
8. RFID tags can be tracked automatically with almost no human intervention which results in eliminating the human error (Tsipoulanidis, 2012).

- Weaknesses

1. “RFID tags are application specific and no one tag fits all” (Wireless Technology Advisor, 2012).
2. Customer privacy issues.

- Opportunities

1. Decreasing costs of RFID
2. “Low initial setup costs and risk by building in stages” (Wireless Technology Advisor, 2012)
3. RFID can be left unattended.

- Threats

1. Possibility of becoming outdated due to rapid changes in the technology.

2.6.3 NFC (Near Field Communication)

- Strength

1. Ability to run on mobile devices and expected to continue to grow (Jandebeur et al., 2013).
2. Available in a lot of mobile devices.
3. As smartphones have become ubiquitous, it is useful that NFC can so easily be added to them (Alliance, 2007).
4. NFC technology enables users to make mobile transactions, exchange digital content easily and to connect their Smartphones just by touching them (Bodhani, 2011).
5. NFC also is compatible with other standard technologies for contactless services, such as with smartcard readers ((Jandebeur et al., 2013).

- Weakness

1. NFC requires some power, which is likely to reduce the life of the phone’s battery.
2. The antenna and other parts are small but they do take up some space and may require redesigning older models of phone, which can be expensive.

3. Security problems of the cell phones it may be infected with viruses and hacked.

- Opportunities

1. Easy to integrate with mobile applications.
2. No need for plugin device.

- Threats

1. So slowly in reading the tags and it may unread some of its.

2.6.4 Results

As far as the measurement of the three technologies on the basis of SWOT analysis is concerned it becomes evident that the bar codes are used on a large scale in most of the industries all over the world however, at the same time have certain limitations more importantly on the amount of information that they can provide. Also the flexibility in terms of updates etc. is not possible in bar codes.

NFC technology has limitations that make it impossible to use in inventory tracking and seems that barcode technology is more useful. RFID in this case evidently shows confidence in terms of maturity, tag costs, rewritable features and information carried. However it cannot be ruled out that it will take time for RFID tags on products to completely replace Barcodes. Both systems will function in parallel and complement one another.

Regarding the discussion above, it is evident why RFID technology is emerging fast in the current market trends and is considered as a technology which has a potential to replace the bar coding technology due to its wide scope features which also include data generation and data transfer.

2.7 Challenges of RFID Systems

2.7.1 Technical

RFID systems face a lot of technical challenges. The main challenge is simply getting RFID systems to work in real-world environments. Systems that work perfectly in a laboratory may face many problems when they are used in a real-world system.

2.7.2 Economic

Another main challenge is that RFID systems are still expensive; especially when the RFID readers are considered, the UHF readers' costs are too high. At this price levels, many firms may only afford a small number of readers in loading bays. "Smart shelves" that incorporate readers throughout a retail or warehouse environment would be prohibitively expensive for most applications. As the market grows, RFID prices will also decrease and it will be more economical, especially as more investments are made into back-end architectures.

2.7.3 Security and Privacy

Security and privacy of RFID systems is one of the important issues. Many of applications tags don't contain sensitive information. For example the tags on railway cars contain the same information painted on the side of the cars themselves. However, as more consumer applications are developed, security, and especially privacy, will become important issues. Recently, a lot of studies discussed RFID security and privacy issues. Gildas Avoine maintains a comprehensive bibliography of RFID security and privacy papers (Albrecht, and McIntyre, 2005). Ari Juels offers a survey of RFID security and privacy issues in (Juels, 2006).

The main security and privacy issues may be listed as following:

- Eavesdropping
- Forgery
- Denial of Service
- Viruses

2.8 Summary

Inventory management basically comes to serve two main objectives. It's important for running operations that the required materials are present in the right quantities, quality and at the right time in order to deliver a specific level of service. The second goal is to achieve this service level against optimal costs. Inventory is one of the assets in a company. It needs overseeing and control. Mismanagement results in an inventory glut or an inventory shortage. The term inventory and stock is used exchangeability. However, when it comes to inventory management it is slightly different. Stock is the amount of goods in a specific place while inventory management is the size and placement of stoked goods. Its scope is wider.

Introduced as Universal Product Code (UPC) in the grocery industry as a standard barcode in April 1973, it has helped to drive down costs of inventory management. Introduction of personal computers also contributed to its wide use. The start of the year millennium, revolutionized inventory management to the point where reading barcode by the reader and inputting instantly to update their database started.

Inaccuracy is chronic problem in inventory management systems. The inaccuracy of inventory management may be because of lack of tracking process. Thus RFID technology may be a solution in tracking items in supply chain. RFID faces technical, economic and security and privacy challenges.

CHAPTER THREE

RADIO FREQUENCY IDENTIFICATION (RFID) SYSTEMS

3.1 Fundamental Components of RFID Systems

There are three basic components of an RFID system as shown in the Figure 3.1 below:

1. A tag (transponder), which is composed of a semiconductor chip, an antenna, and sometimes a battery.
2. A reader (read/write device), which is composed of an antenna, an RF electronics module, and a control electronics module.
3. A Middleware (controller and Database) which most often is computer running particular software.

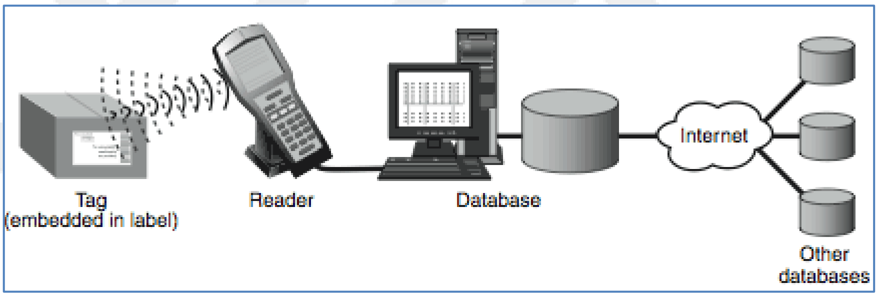


Figure 3.1 RFID solution architecture

3.1.1 RFID Tag (Transponder)

RFID (Radio Frequency Identification) tag is similar to barcodes; it is attached to item and contains the unique ID of the item (Karmakar, 2010), it is a device that stores and transmits certain unique information to a reader in a contactless manner using radio waves. Tags are either active or passive. Active tags transmit information to receiving stations and passive tags are read by scanners as they move through the chain.

The main concept of RFID technique is to attach radio frequency identification (RFID) tag to an object placed outside of a package. The most common tags mainly consist of two main parts, the integrated circuit (IC) chip and the antenna (Ton et al., 2009). There are two possibilities, one is that the tag emits a signal regularly or it gets activated to transmit required information as and when a known signal is received from another source (Schuster, Allen and Brock, 2007). In other words, the two types of RFID are those with power supply from a battery and those without a battery. Figure 3.2 below shows general RFID tag.

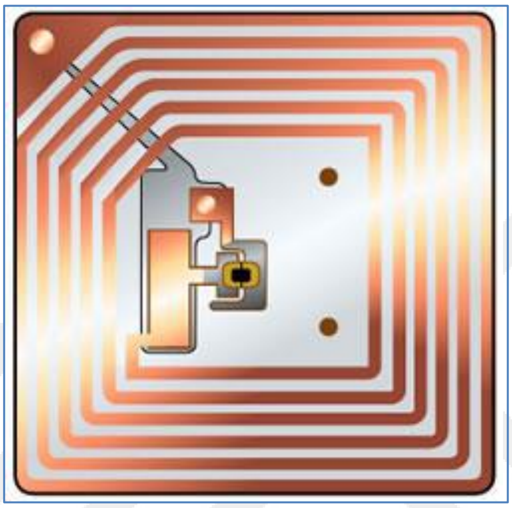


Figure 3.2 RFID tag

3.1.1.1 Active Tag

Active RFID tags have their own power source built in on the board; it may be a battery or other sources of power, such as solar energy for performing specialized tasks. Also, an active tag uses its built-in power supply to transmit its data to a reader. It does not need the power that is released by the reader for data transmission. The built-in electronics can contain microprocessors, sensors, and input/output ports powered by the built-in power source as in (Lahiri, 2005).

There are some disadvantages of these types of tags such as signal interference, expense and battery life according to (Schuster et al., 2007). Signal interference could happen since these tags transmit distant signals, and there are greater chances of frequency interference with other waves like radio, transformers or cellular phones. The reader in this case fails to recognize the signal of the certain tag. Figure 3.3 shows active tag process.

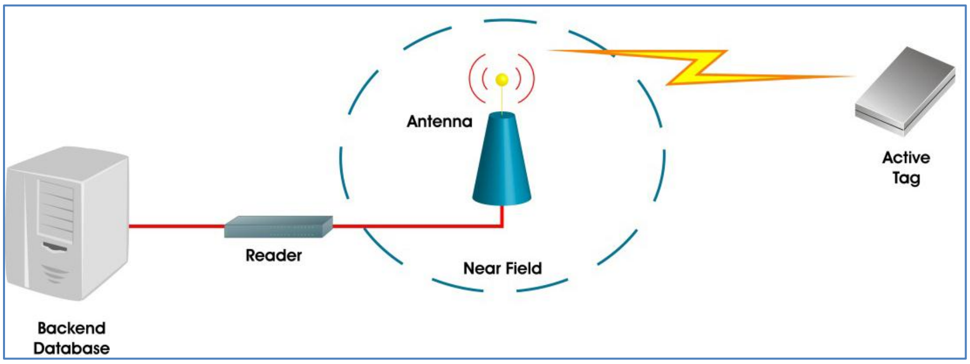


Figure 3.3 Active tag process (Passive and active tag processes, 2007)

The small batteries that could be used in RFID tags are expensive. So, the active tags are generally used for expensive objects because of their high cost. The Figure 3.4 below depicts an active tag.

Figure 3.4 Active tag

3.1.1.2 Passive Tag

This type of tags doesn't have an on board power supply, it works just when it receive a signal emitted from the reader by converting the coming waves to power and use this power to send the response with the information to the reader as stated in (Lahiri, 2005). Passive tag process is shown in Figure 3.5.

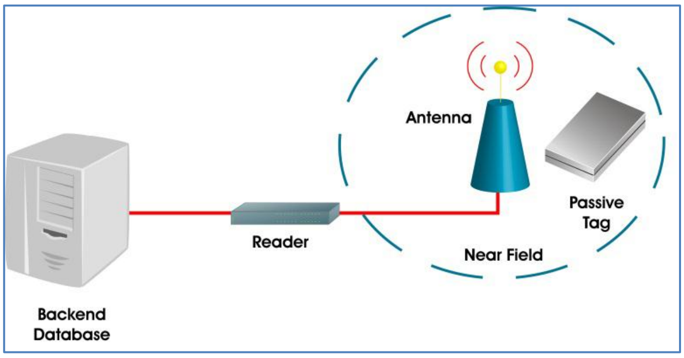


Figure 3.5 Passive tag processes (Passive and active tag processes, 2007)

It contains three kinds of circuits, named antenna, rectifier and Manchester encoder (RFID chip). This mean that some passive tags have the ability of data processing but other do not have this ability.

The main advantage of passive tags over active tags is the lower cost per unit and it gives the opportunity to use passive tags in wider areas and applications over active tags. As a result of low cost, passive tags will challenge the bar codes in supply chain management and inventory management applications.

Passive tags are designed to operate at low energy levels and stores little information which could be the IDs or serial numbers. This information is stored on a server or internet or other private network so it makes passive tags technique efficient and effective (Schuster et al., 2007).

3.1.1.3 Semi Active Tag

Semi active tags contains on board power source (such as battery) and electronics for performing specialized tasks. The on board power source is to supply energy to the tag for its operations, however for transmitting its data, the semi active tag uses the headers emitted power (Lahiri, 2005). The battery is charged every time the semi active tag enters the EM field of the reader. However this type of tags is not widely used in industrial applications but maybe in the future.

3.1.1.4 *Comparison of Different Tags*

Comparison between different tags types are shown in the Table 3.1 below (Schuster et al., 2007). It compares the tags based on different parameters.

Table 3.1 Comparison of different tags

	Active tag	**Passive tag**	**Semi active tag**
Power source	Battery	Induction from EM waves coming from reader	Both battery and induction
Read distance	Up to 30 meters	3-7 meters	Up to 30 meters
Proximately information	Poor	Good	Poor
Frequency collision	High	Medium	High
Information storage	32 KB or more. Read/Write	2 KB read only	32 KB or more. Read/Write
Cost	High	Low	Medium
Physical size	Larger than passive since it contains battery	Smaller than active (no battery)	Same to active
Life	Short operational life (need battery replacement)	Long operational life since no battery	Same to passive
Applications	Good for tracking high cost goods and for security applications	Good for tracking low cost goods and supply chain tracking	Good for all applications

3.1.2 RFID Reader

It is also called interrogator, it has the corresponding task as barcode reader. The main goal of RFID reader (Clampitt, 2006) (Sweeney, 2010) is to connect with the tag and the host computer (server) and transfer the data from the tag to the host computer. The biggest different between barcode reader and RFID reader are that the barcode reader only can read one item at a time and visual connection is required, but RFID reader can read multiple items at a time in the reading zone. The reader produce UHF waves and receives the reflexed tag’s information and sends it through standard interface to the host computer. It creates a reading zone between tags and readers; the reading zone depends on the power of both reader and tag and also depends on the frequency used to communicate.

The tags reflex the identifiable radio waves and the readers receive this information through their internal antennas. Lower-frequency tags can be read from shorter distances and higher-frequency tags from longer distances. Figure 3.6 below summarizes the interaction between reader and tag.

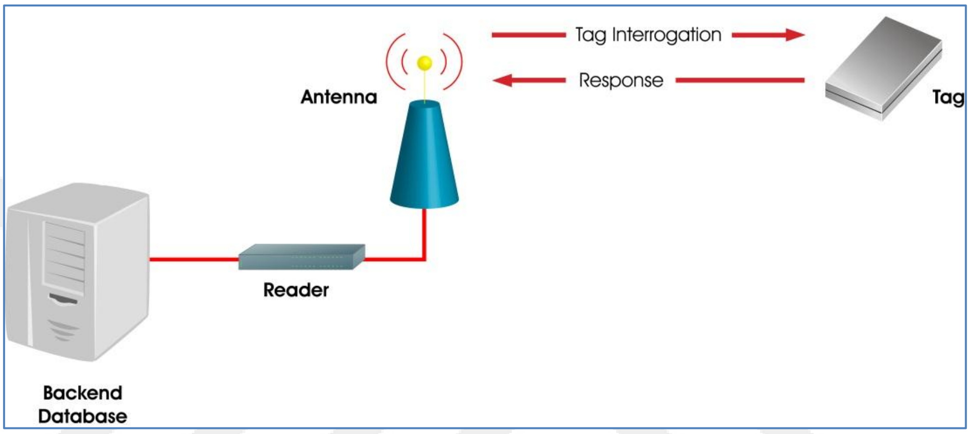


Figure 3.6 The interaction between the reader and RFID tag (The interaction between the reader and RFID tag, 2007)

3.1.3 RFID Middleware

RFID middleware is also called a backend. It is very important element of RFID system. It is software to integrate received data from several readers (Clampitt, 2006).

Middleware connects the host computer, and the readers. It allows them to transfer data between each other. It also works as a device monitor to ensure the readers are functioning correctly, securely, and with up to date instructions. Figure 3.7 below shows typical RFID components.

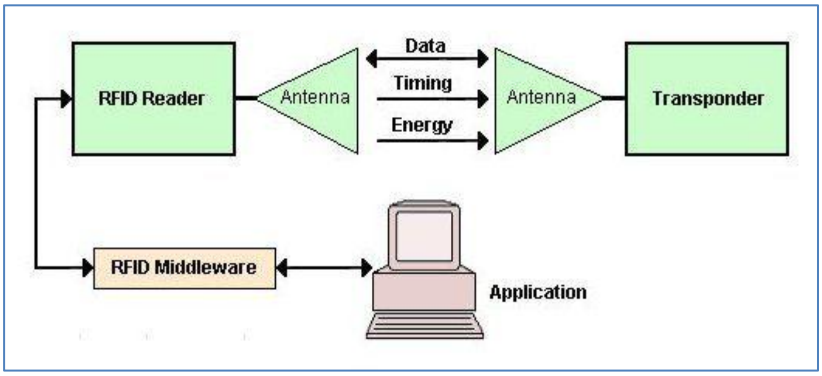


Figure 3.7 Typical RFID system components

3.2 RFID Frequencies

There are four main frequencies used in RFID tags to transmit data to the RFID reader. These frequencies as listed below (lin, 2009)

- Low frequency (LF).
- High frequency (HF).
- Ultra high frequency (UHF).
- Microwave frequency (MF).

Table 3.2 shows the radio frequency ranges of RFID systems and their corresponding properties (Tajima 2007).

Table 3.2 Radio frequency ranges of RFID systems and the corresponding properties

Frequencies	**Low frequencies 120-140kHz**	**High frequencies 13.56 MHz**	**Ultra high frequencies 860-950 MHz**	**Microwave frequencies 2.45 GHz**
Operating range	Up to 1 meter	Up to 1 meters	Up to 3 meters	4-12 meters
Tag type	Passive	Mainly passive	Active and passive	Active and passive
Tag size	Larger	Different sizes	Smaller	Smaller
Data storage	Smaller	Up to 4KByte	Larger	Larger
Data transfer rate	Slow	Medium	Fast	Fastest

Table 3.2 Radio frequency ranges of RFID systems and the corresponding properties (continue)

Ability to read near metal or wet surfaces	**Best**	**Better**	**Worse**	**Worse**
Tag cost	**High**	**Lower than LF tags**	**Lowest**	**High**
Advantages	Simple and robust technology Lots of shapes and sizes Insensitive to disturbances Good penetration Works best around metal and liquid	Good anti-collision Large assortment relatively transponder Common worldwide standards Longer read range than LF (low frequency) tags Lower tag costs than LF tags	Good anti-collision Fast speed Long read range Cheap price Good standards	Good anti-collision Very fast data transfer rates Very long transmit ranges Commonly used in active and semi-active modes
Disadvantages	Limited anti collision Slow data transfer	Unable to read through liquid Poor performance around metal	Incompatibility issues related to regional regulations Susceptible to interference from liquid and metal	Poor performance around liquid and metal
Examples of Usage	Animal identification Industrial automation Access control	Payment and loyalty cards Access control Various item level tracking applications such as for books, luggage, Garments, etc. Smart shelf People identification and monitoring	Supply chain and logistics such as: inventory control, warehouse management, asset tracking	Access control Electronic toll collection Industrial automation

3.3 RFID Standards

Since the RFID systems quickly grew in industry and became widely used in a lot of fields, standardization of RFID technology becomes a must. There are two types of standards related to RFID systems: Data standards and Technology standards (Jung et al, 2007).

3.3.1 Data Standards

As shown in the following Figure 3.8, data standard provides a unified data structure by the electronic product code (EPC). The EPC is a unique code, invented by MIT Auto-ID Center, and all tags have the same structure of the EPC. This EPC code is divided to four partitions (Sweeney, 2010) (Ward et al, 2006):

- Header (28 bits) to identify the length, structure, type, version and generation of EPC.
- EPC manager (28 bits) to identify the sub company of division, it can cover 228 company or division.
- Object class (24 bits) to identify the stock keeping unit (SKU).
- Serial number (36 bits) to identify each product or item and it can covers 68 billion items.

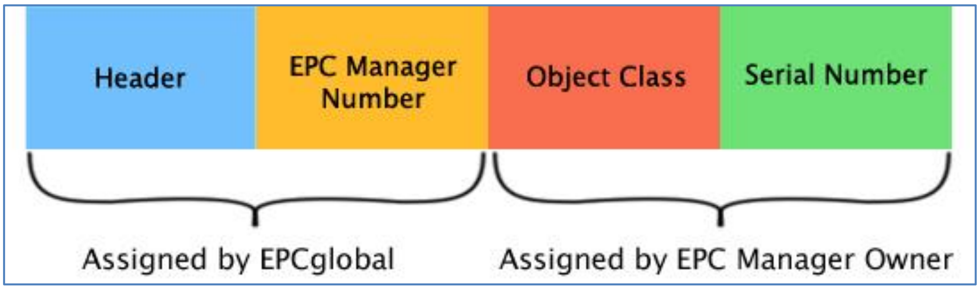


Figure 3.8 Data standards

3.3.2 Technology Standards

There are several standards related to air interface (frequency) between RFID readers and RFID tags such as the following (Clampitt, 2006). Table 3.3 shows ISO/IEC identification card standards (Sweeney, 2010).

- ISO 15693 (Smart Labels)
- ISO 14443 (Contactless payments)
- ISO 10536
- ISO 11784 (Livestock)
- ISO 18000 standards (most widely used).
    - ISO 18000-2 (LF) : under 135 KHz
    - ISO 18000-3 (HF) : 13.56 MHz
    - ISO 18000-4 (Microwave) : 2.45 GHz
    - ISO 18000-7 : 433 MHz

Table 3.3 ISO/IEC identification card standards

Standard	**Type of ID card**	**What does each part cover?**
ISO/IEC 15693 Contactless integrated circuit(s) cards — Vicinity cards		Part 1: Physical characteristics Part 2: Air interface and initialization Part 3: Anti-collision and transmission protocol
ISO/IEC 14443 Identification cards — Proximity integrated circuit(s) cards	Smart identification cards with a longer range (up to 1 meter), using RFID at 13.56 MHz	Part 1: Physical characteristics Part 2: Air interface Part 3: Initialization and anti-collision Part 4: Transmission protocol
ISO/IEC 10536 Identification cards — contactless integrated circuit(s) cards	Smart identification cards, using RFID at 13.56 MHz	Part 1: Physical characteristics Part 2: Dimensions and location of coupling areas Part 3: Electronic signals and reset procedures Part 4: Answer to reset and transmission protocols

3.4 Potential Applications of RFID Technology

A detailed overview of the potential applications of RFID technology in different industries is demonstrated in Table 3.4.

Table 3.4 Applications of RFID in different industries

Manufacturing	A major tire manufacturer inserted RFID tags into its tires. The tags store a unique number for each tire, which is associated with the car's vehicle identification number.
Pharmaceuticals	Pharmaceutical companies have embedded RFID chips in drug containers to track and avert the theft of highly controlled drugs, such as OxyContin.
Airlines	Continental Airlines uses RFID tags to track passenger bags, while Delta Airlines is tagging customer bags with RFID technology to reduce the number of lost bags and make it easier to route bags if customers change their flight plans.
Restaurants	A premier coffee chain is considering using RFID chips and readers to enable its suppliers to make after-hour deliveries to stores, which avoids the disruption of staff members during work hours.
Toll Roads	Many tolls roads in the United States use RFID technology to collect fees without the need for toll booth personnel.
Retail	ExxonMobil uses RFID technology for its "SpeedPass," which instantly collects payment on gas stations from a tag on a driver's keychain, while Wal-Mart is requesting that all their suppliers apply RFID tags to all cartons of goods delivered.
Seaports	Three seaport operators in the United States, which account for 70 percent of the world's port operations, agreed to deploy RFID tags to track daily arriving containers.
Government	The U.S. Department of Defense is planning to use RFID technology to trace military supply shipments.
Corporate & Municipal	Australia placed RFID tags in employee uniforms to aid in deterring theft. The same idea would work well in a corporate environment to help control desktop computers, networking equipment, and personal digital assistants or handheld computers.
Credit Card	Visa is combining smart cards and RFID chips so people can conduct transactions without having to use cash or coins.
Banks	The European Central Bank is considering embedding RFID chips in Euro notes to combat counterfeiters and money-launderers. This also would enable banks to count large amounts of cash in seconds.
People Tracking	The United Nations uses RFID technology to track the movements of its personnel.

3.5 Summary

There are three basic components of an RFID system. RFID tag is similar to barcode, but it stores and transmits certain unique information to the reader. It comes as passive which are read by scanners and active which transmit information to the receiving stations. Battery life, expense and signal interferences are the three demerits of an active tag. Lower cost per unit of passive tags over active one gives greater advantage to the passive one and even challenging barcode in supply chain management and inventory control applications.

RFID readers connect with the tag and the host computer to transfer the data from the tag to the host computer. It produces the UHF waves and receives the reflexed tag's information and sends it through standard interface to the host computer. The frequency strength of tags determines their power of responding to the readers distances. RFID middleware is its backend, software to integrate received data from various readers. In addition to connecting to the host computer and the readers to pass data, it also service as monitoring device.

RFID tags come having four main frequencies bands. The low, high, ultra-high and microwave frequencies. Their frequency range determines the behavior such as operating range, data storage, data transfer rate and cost. They also have both merits and demerits. The growth of RFID and widespread use has prompted the industry for standardizing it. It has therefore data standards and technology standards. The potential application areas of RFID technology are manufacturing, pharmaceuticals, airlines, restaurants, tall roads, retail, seaports, government, corporate and municipal, banks and people tracking.

CHAPTER FOUR

DESIGN AND IMPLEMENTATION OF THE SYSTEM

4.1 System Installation Requirements

The implementation of the solution requires both hardware and software. The following components are required for the RFID system installation.

- Web Server (apache, MySQL).
- Client PC's.
- Fixed RFID Readers.
- Android Mobile Devices.
- UHF reader plugin.
- RFID Tags.

4.2 System Architecture

System architecture is a concept model that shows the structure of the system and how the system's components interact between each other. It describes and presents the system using diagrams that shows the whole structure of the system. Figure 4.1 describes the architecture proposed as a solution to the problems stated in the abstract of this work. The apps on android devices communicate in a duplex way with the API. The audio cable is used to connect and let the UHF reader to communicate to the apps through the API. The UHF reader sends signal to the RFID tags, captures the data and send it to the apps.

Figure 4.1 RFID system architecture

4.2.1 Application and API

The application is written for Android (Java). It can,

- Find tags, read tags, referred to as inventory which is the most frequent operation. An application can look for one specific tag, a set of tags, or all tags.
- Write a new EPC to a tag.

The API layer communicates with the UHF reader to perform various operations, and transmit data back to the application. While inventory is being run, the API tracks which tags have been found and time of discovery. This functionality is common to almost all RFID applications; having it in the API makes RFID applications quicker and simpler to write. The API layer also manages connection status, and makes it easy for applications to gracefully handle the UHF reader being connected and disconnected. In addition, the API layer also provides information about the UHF reader and the UHF reader's capabilities. Under the hood, the API layer implements a communications stack to talk with the UHF reader (connections, bits, bytes, packets and so on). This stack is highly optimized to provide robust performance over the audio port connection. The API is provided as a static library that gets linked into and distributed as part of your application.

4.2.2 Audio Cable Connection

The UHF reader is connected to the android device via the audio port, a quick and universal connection. The audio port is used only for communication and the UHF reader does not draw any power from the smartphone, but only from its built-in battery.

4.2.3 UHF Reader Plugin

The UHF reader device executes the RFID functionality and communicates with the API layer in the device. Figure 4.2 shows UHF reader plugin and android logo.

Figure 4.2 Android and UHF reader

4.2.4 Tags

Any standard EPC Class1 Gen2 tags will work with the developed system. These tags vary in size; as a general rule, the larger the tag, the farther away it can be read. Each tag has an ID called the EPC code or just the EPC.

4.2.5 Android Interface

Android interface is a mobile application installed on devices supporting android operating system and captures tag’s identification number (EPC) and sends it to the server. Some of RFID android application interfaces are shown in following:

Figure 4.3 Android application login page

Figure 4.4 Android application main page

Figure 4.5 Scan tag page

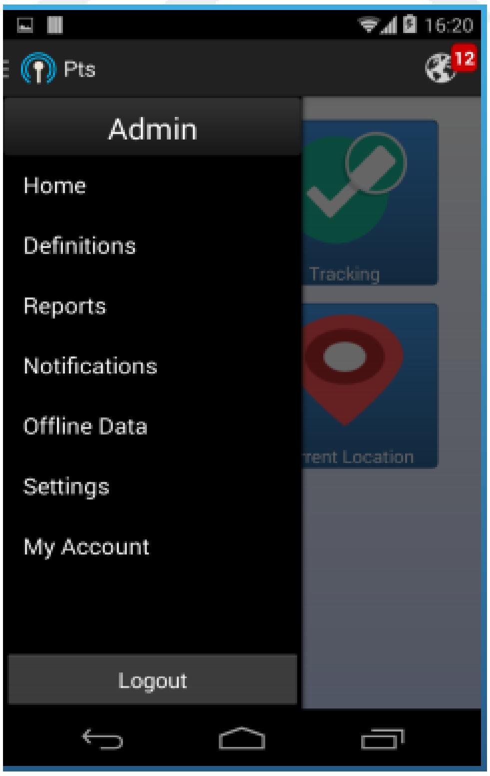


Figure 4.6 Main menu of android application

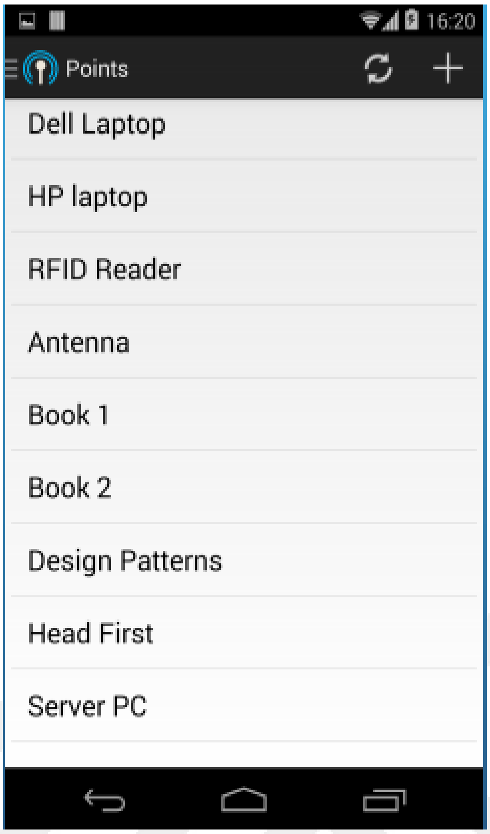


Figure 4.7 Point report in Android application

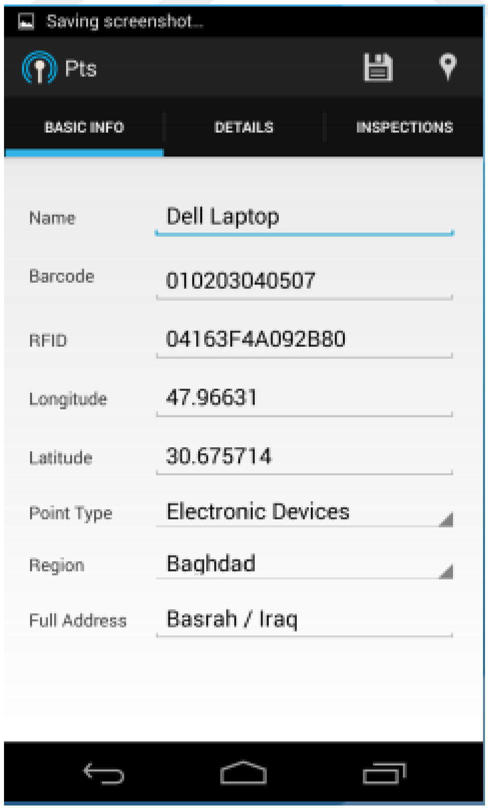


Figure 4.8 Point details in Android application

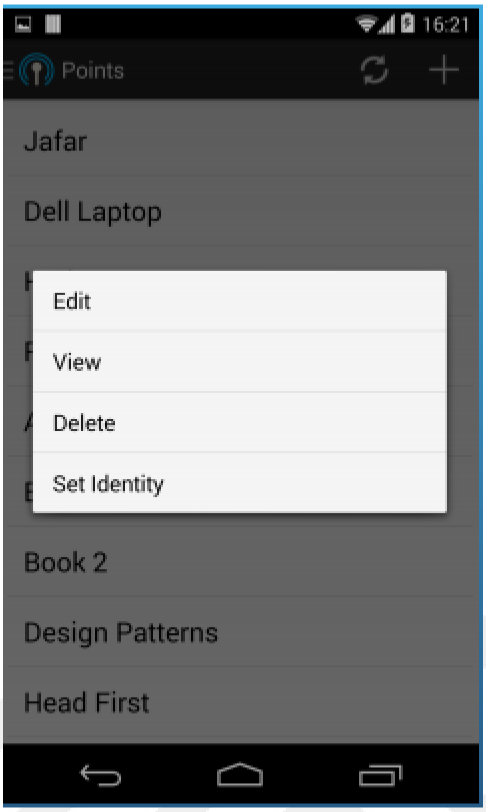


Figure 4.9 Modifying the point details in Android application

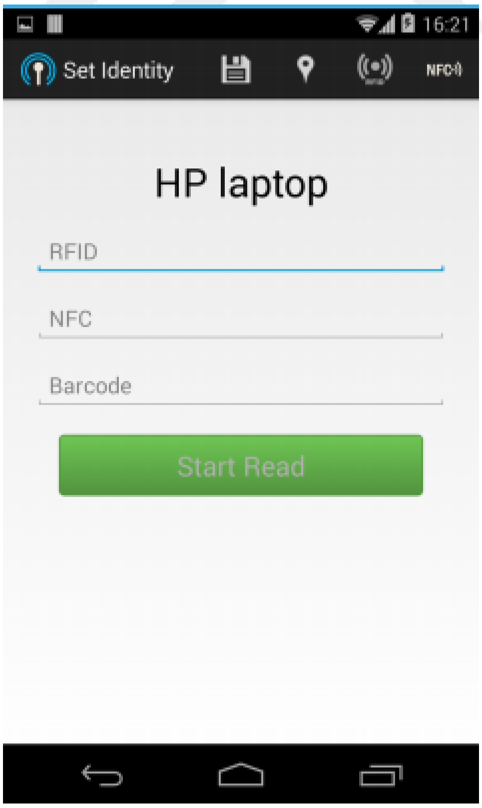


Figure 4.10 Set identity to the point in Android application

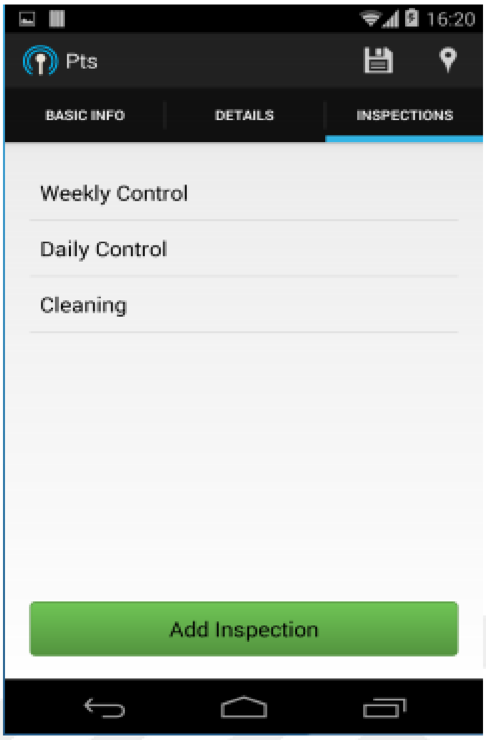


Figure 4.11 Inspections in Android application

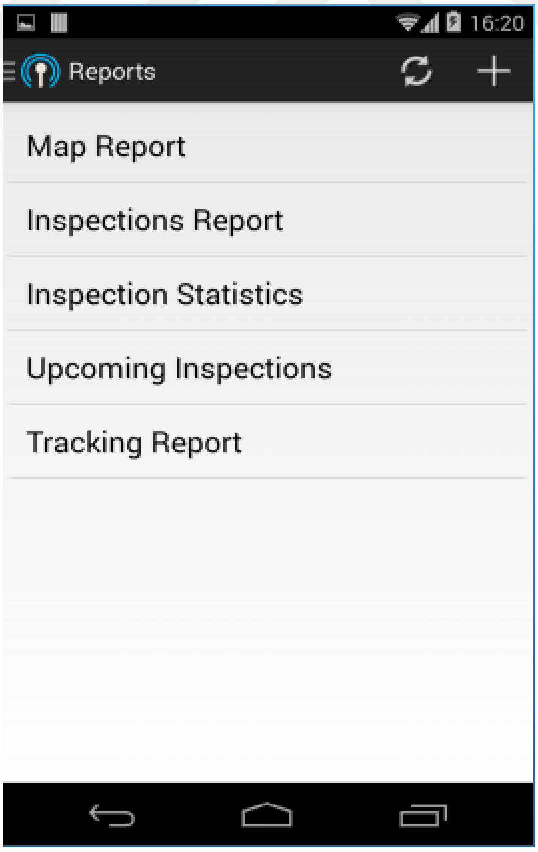


Figure 4.12 Reports list in Android application

4.2.6 Database Design

The purpose of this application is to enhance inventory management and increase accuracy of inventory control. This needs tracking of each item's data; which calls for the use of database to manage such data. We used the MySQL database management system to handle the data because it is freely available and can efficiently solve our data tracking challenges.

4.2.6.1 Entity Relationship Diagram

Figure 4.4 below shows the ER-diagram design of the system, having 15 numbers of tables and their relationship.

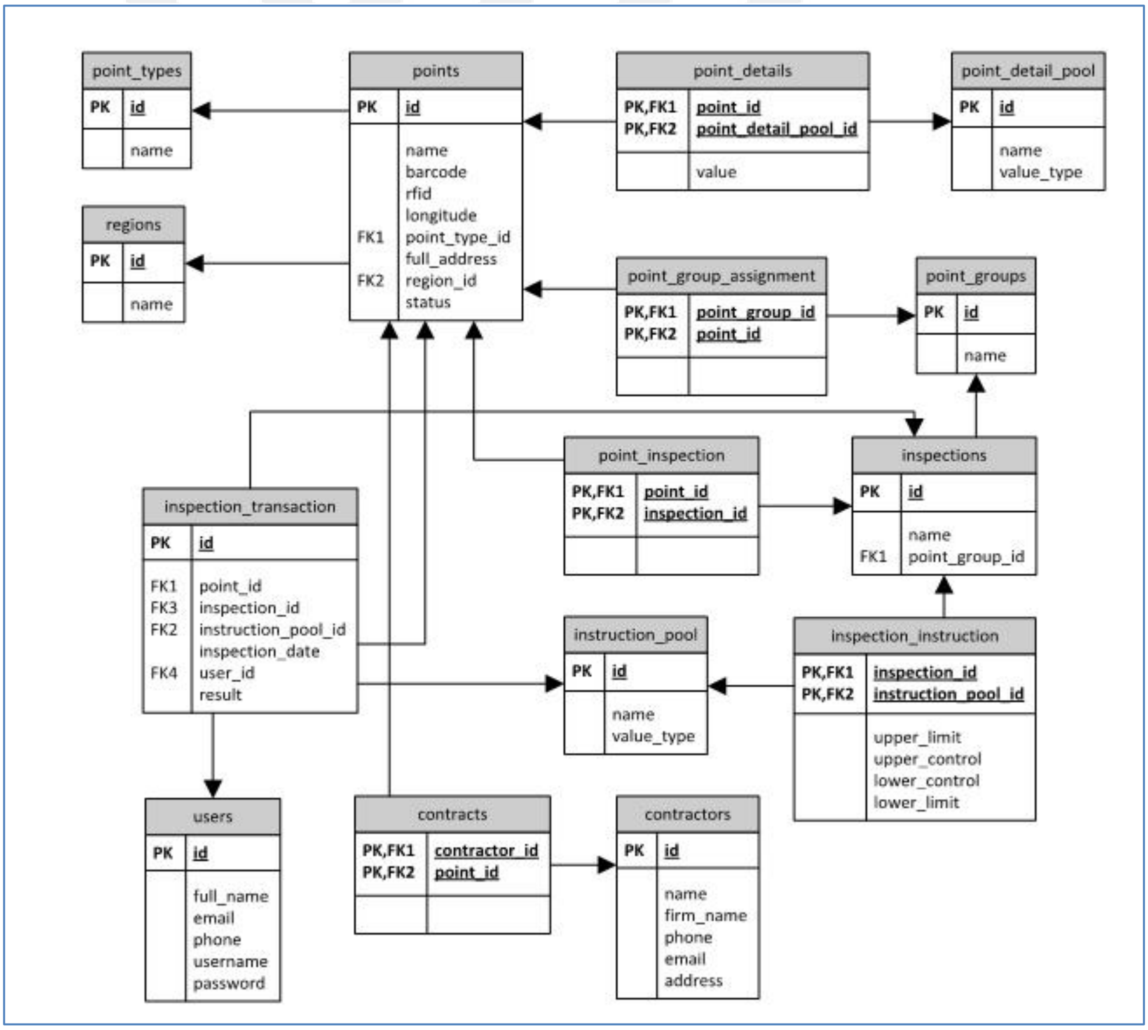


Figure 4.13 Database ER diagram

4.2.6.2 SQL Join Statements

At this section the researcher shows some of the SQL join statements that he used in implementing the database.

```
-- View: inspection_transaction_view
CREATE VIEW `inspection_transactions_view` AS
   (select
      `it`.`id` AS `id`,
      `p`.`name` AS `point_name`,
      `p`.`point_type_id` AS `point_type_id`,
      `p`.`region_id` AS `region_id`,
      `i`.`name` AS `inspection_name`,
      `ip`.`name` AS `instruction_pool_name`,
      `it`.`inspection_date` AS `inspection_date`,
            case when `ip`.`value_type` = 2 then
                  (case when `it`.`result` = 1 then 'Checked' else
'Unchecked' end)
            else `it`.`result` end AS `result`,
      `it`.`comment` AS `comment`,
         `u`.`full_name` AS `user_full_name`
   from      ((((`inspection_transactions` `it`
      left join `points` `p` ON ((`it`.`point_id` = `p`.`id`)))
      left join `inspections` `i` ON ((`it`.`inspection_id` = `i`.`id`)))
      left join `instruction_pool` `ip` ON ((`it`.`instruction_pool_id` =
`ip`.`id`)))
      left join `users` `u` ON ((`it`.`user_id` = `u`.`id`))));

-- View: last_inspections_view
CREATE VIEW `last_inspections_view` AS
   select max(`it`.`point_id`) AS `point_id`, `p`.`name` AS `point_name`,
      max(`it`.`inspection_id`) AS `inspection_id`,`i`.`name` AS
`inspection_name`,
```

```
        max(`it`.`inspection_date`) AS `inspection_date`
    from        ((`inspection_transactions` `it`
        left join `points` `p` ON ((`it`.`point_id` = `p`.`id`)))
        left join `inspections` `i` ON ((`it`.`inspection_id` = `i`.`id`)))
    group by `it`.`point_id` , `it`.`inspection_id`
    order by `it`.`id` desc;

-- View `tracking_transactions_view`
CREATE VIEW `tracking_transactions_view` AS
    select
        `t`.`id` AS `id`,
        `t`.`caption` AS `caption`,
        `tt`.`point_id` AS `point_id`,
        `tt`.`result` AS `result`,
        get_tracking_result_name(`tt`.`result`) AS `result_name`,
        `tt`.`transaction_date` AS `transaction_date`,
        `p`.`name` AS `point_name`,
        `p`.`point_type_id` AS `point_type_id`,
        `pt`.`name` AS `point_type_name`,
        `tt`.`room_id` AS `room_id`,
        `r`.`department_id` AS `department_id`,
        `d`.`building_id` AS `building_id`,
        concat(`r`.`name`,'-',`d`.`name`,'-',`b`.`name`) AS `location`,
            `u`.`id` AS `user_id`,
            `u`.`full_name` AS `user_full_name`
    from        `trackings` `t`
        join `tracking_transactions` `tt` ON `tt`.`tracking_id` = `t`.`id`
        left join `points` `p` ON `tt`.`point_id` = `p`.`id`
        left join `point_types` `pt` ON `p`.`point_type_id` = `pt`.`id`
        left join `rooms` `r` ON `tt`.`room_id` = `r`.`id`
        left join `departments` `d` ON `r`.`department_id` = `d`.`id`
        left join `buildings` `b` ON `d`.`building_id` = `b`.`id`
        left join `users` `u` ON `tt`.`user_id` = `u`.`id`;
```

4.2.7 Web Based Backend

By using web based back-end the user can define new point, locations, inspections, users, contractors and companies. By means of backend, one can also generate reports like point list report, map report, inspection report, inspection companies, inspection statistics, tracking reports and debit history reports. The features of the web based backend listed as following:

4.2.7.1 Home

Login Page: this page used to open a session and access the content of the system.

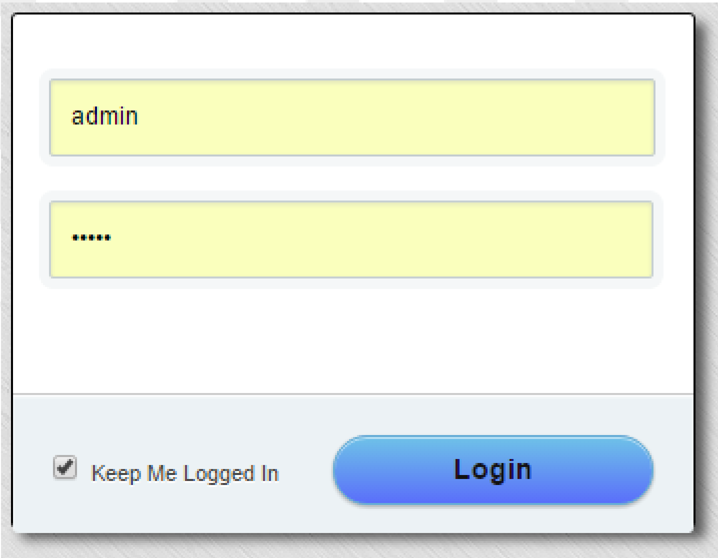


Figure 4.14 Login page to web based backend

The Home Page: This part contains a graphical report that shows the item statistics by region.

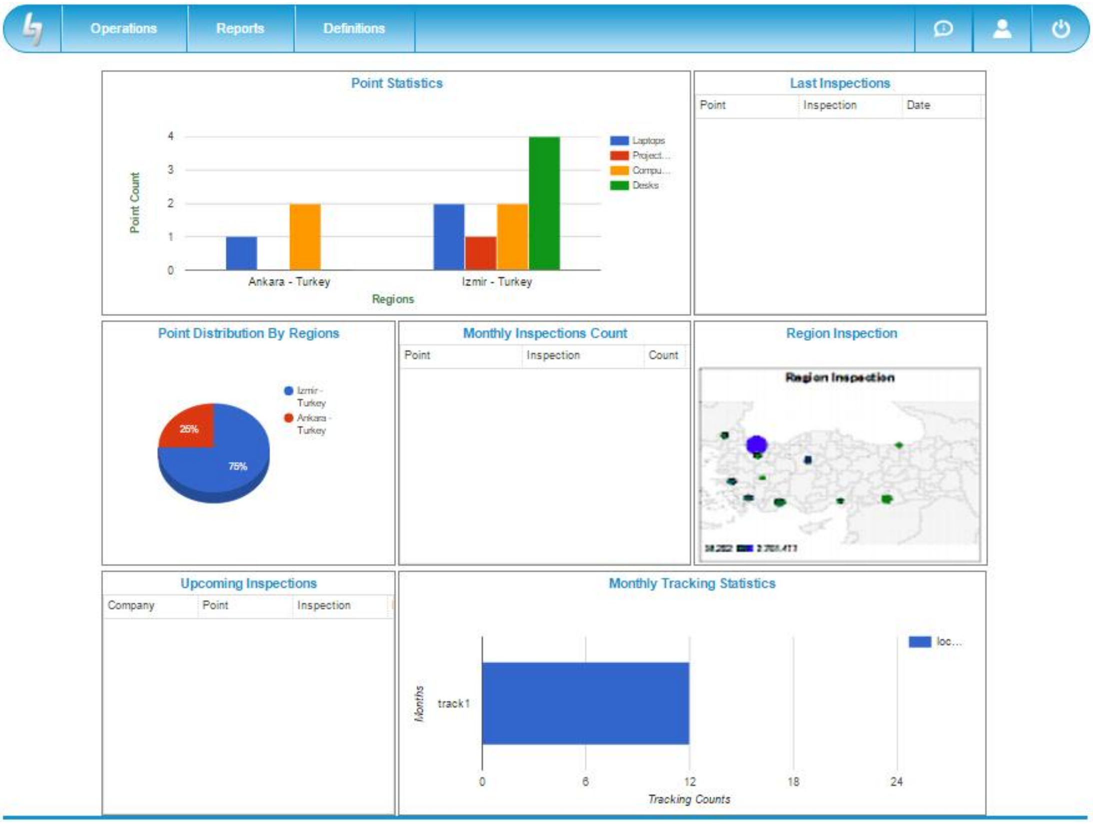


Figure 4.15 Front page of web based backend

4.2.7.2 Definitions

Contains the following:

Add or edit items, locations, inspections and users to the system by the following forms:

Points, Point Types, Point Details and Point Groups. Inspections and Instructions. Regions, Buildings, Department, Room and Floor. Users and Contractors.

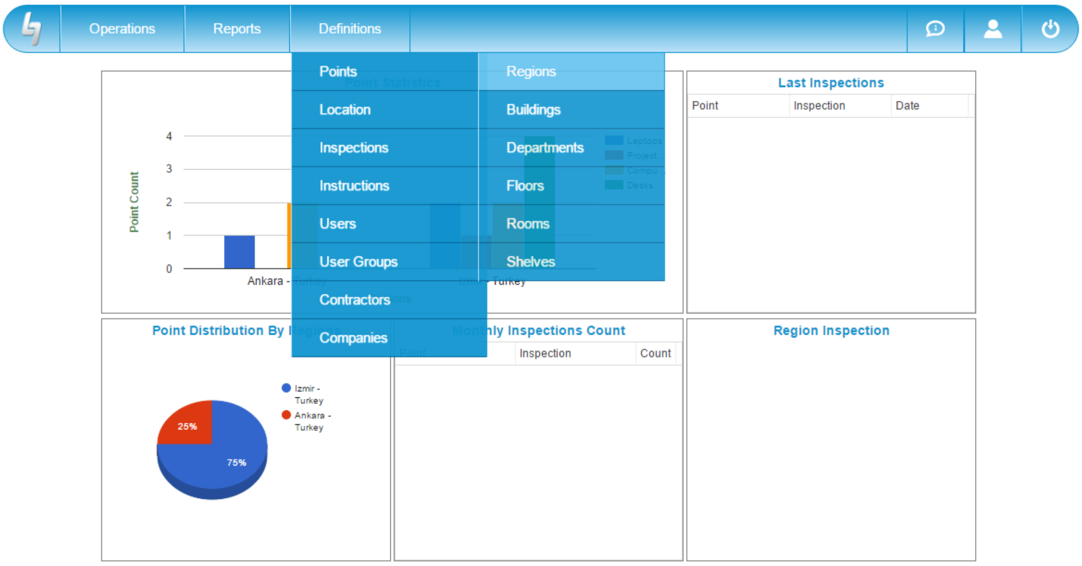
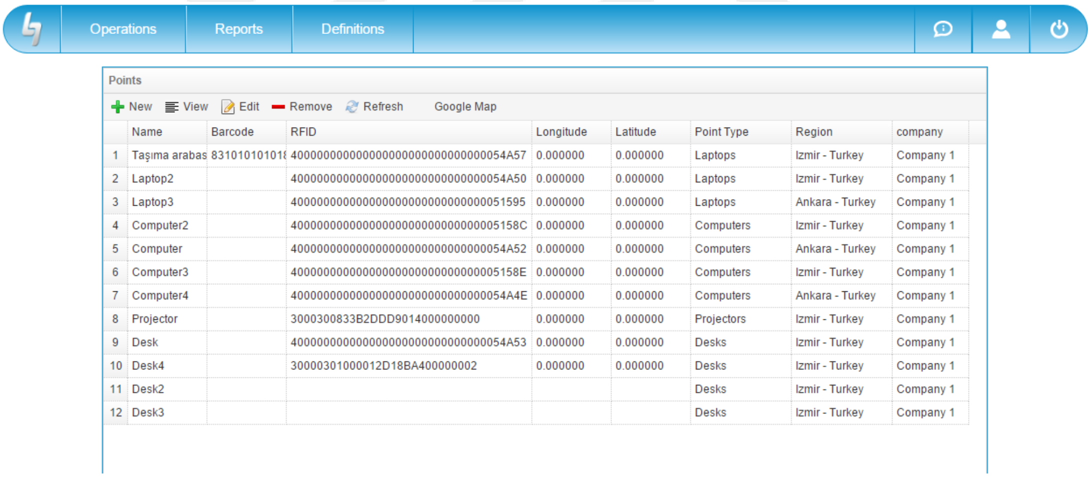


Figure 4.16 Web based application definition menu

Point List: define and modify points.



	Name	Barcode	RFID	Longitude	Latitude	Point Type	Region	company
1	Taşıma arabas	83101010101ȩ	4000000000000000000000000000000054A57	0.000000	0.000000	Laptops	Izmir - Turkey	Company 1
2	Laptop2		4000000000000000000000000000000054A50	0.000000	0.000000	Laptops	Izmir - Turkey	Company 1
3	Laptop3		4000000000000000000000000000000051595	0.000000	0.000000	Laptops	Ankara - Turkey	Company 1
4	Computer2		400000000000000000000000000000005158C	0.000000	0.000000	Computers	Izmir - Turkey	Company 1
5	Computer		4000000000000000000000000000000054A52	0.000000	0.000000	Computers	Ankara - Turkey	Company 1
6	Computer3		400000000000000000000000000000005158E	0.000000	0.000000	Computers	Izmir - Turkey	Company 1
7	Computer4		4000000000000000000000000000000054A4E	0.000000	0.000000	Computers	Ankara - Turkey	Company 1
8	Projector		3000300833B2DDD9014000000000	0.000000	0.000000	Projectors	Izmir - Turkey	Company 1
9	Desk		4000000000000000000000000000000054A53	0.000000	0.000000	Desks	Izmir - Turkey	Company 1
10	Desk4		30000301000012D18BA400000002	0.000000	0.000000	Desks	Izmir - Turkey	Company 1
11	Desk2					Desks	Izmir - Turkey	Company 1
12	Desk3					Desks	Izmir - Turkey	Company 1

Figure 4.17 Add or edit points

Edit Point: edit the information of the specific point.

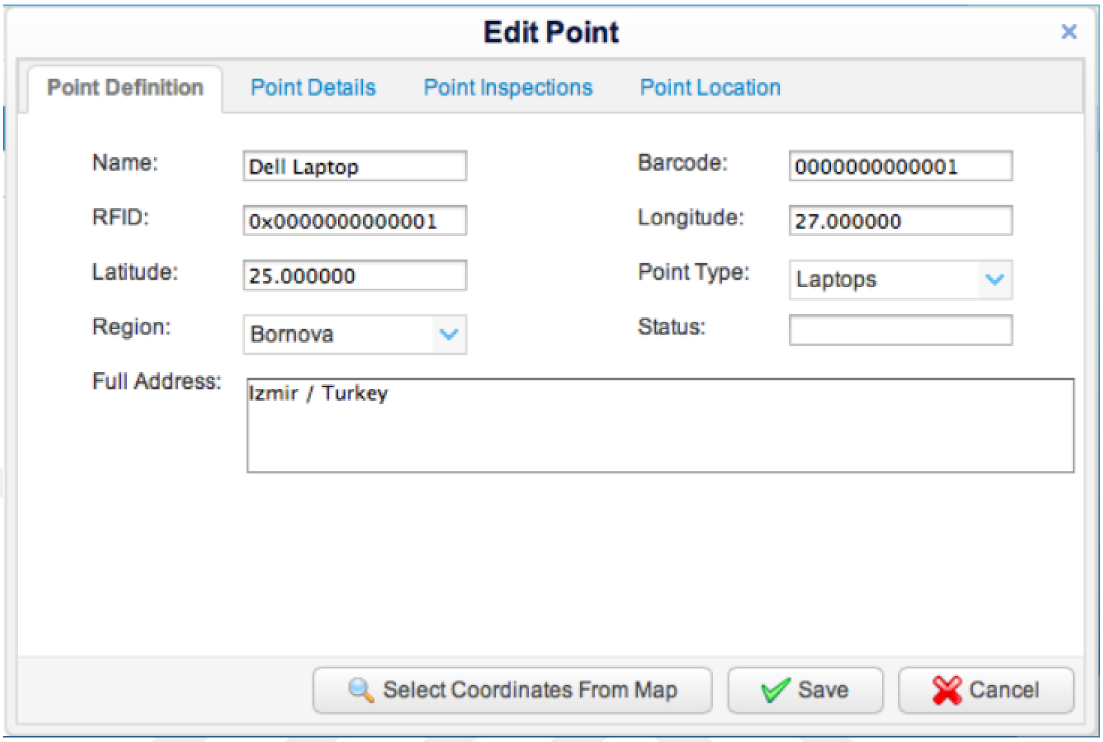


Figure 4.18 Edit point definition basic info from web based backend

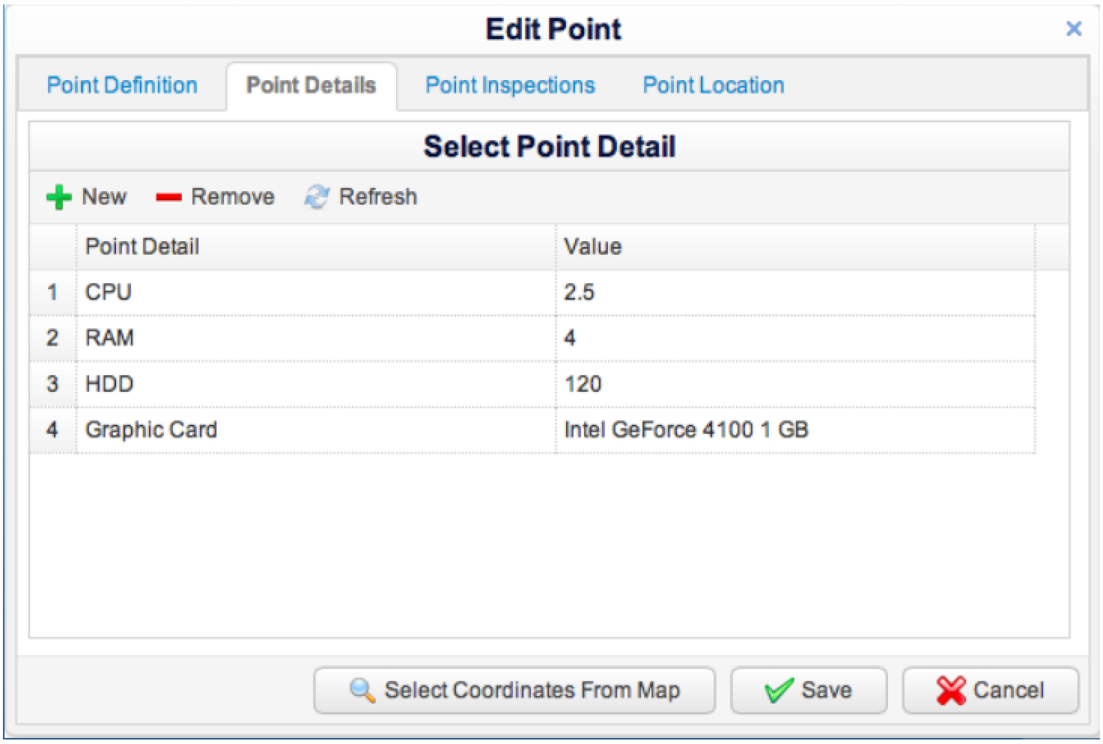


Figure 4.19 Edit point details info from web based backend

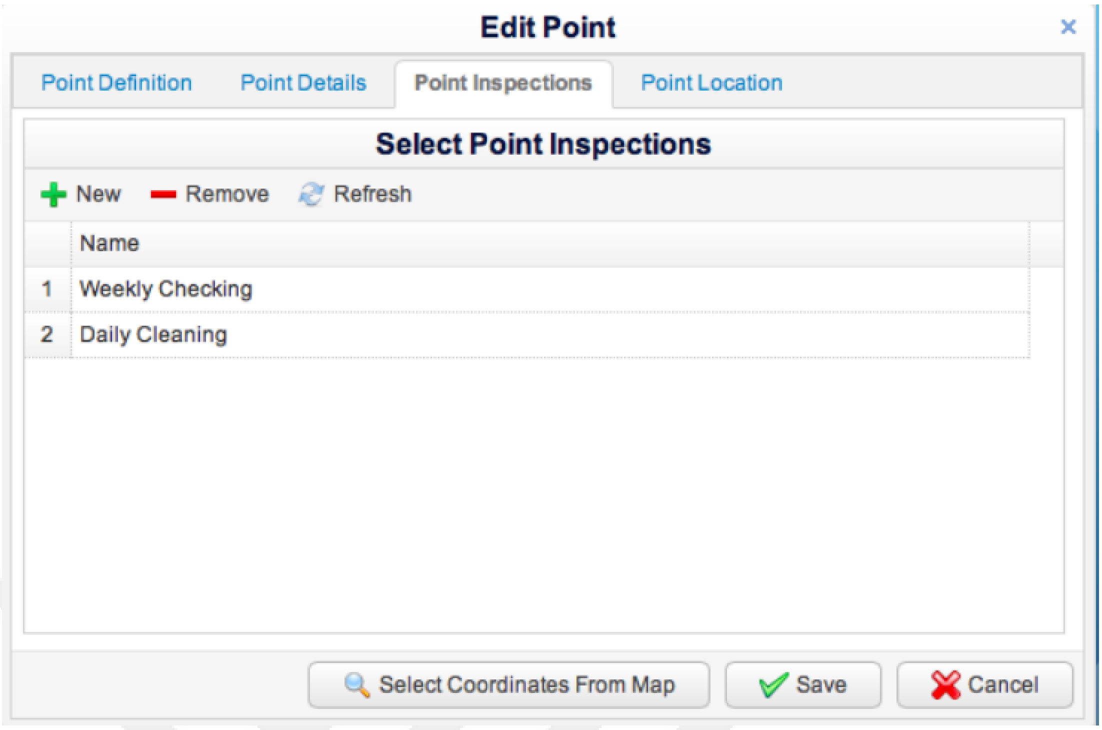


Figure 4.20 Edit point inspections info from web based backend

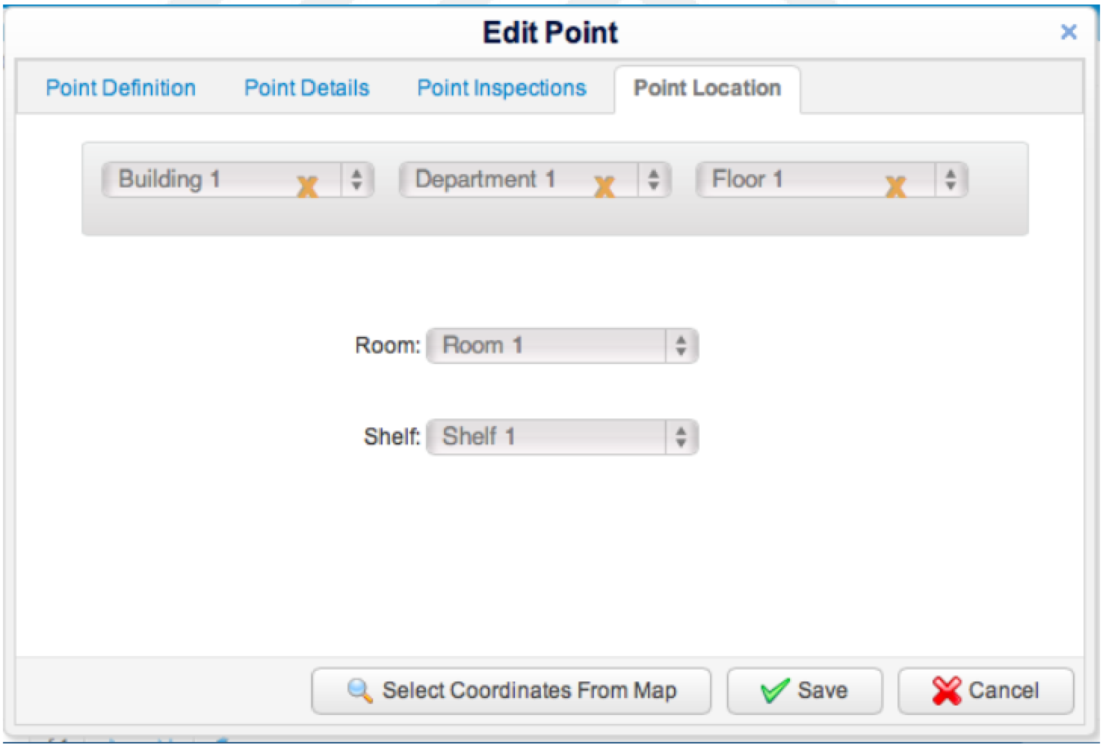


Figure 4.21 Edit point location info from web based backend

Point Detail Pool.

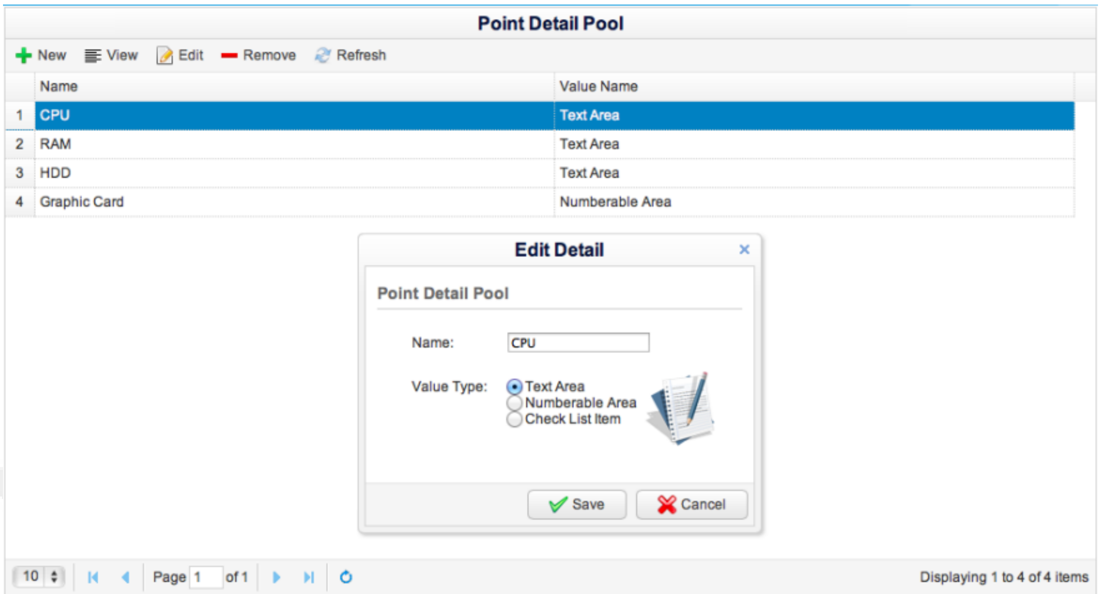


Figure 4.22 Point details pool

Defining user.

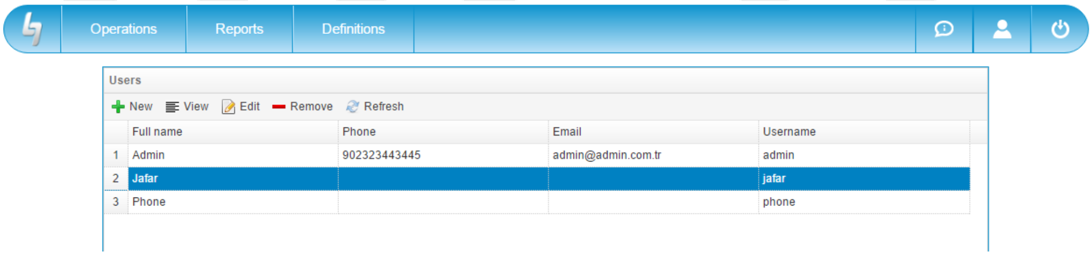


Figure 4.23 Add, view, define or remove user from web based backend

Defining user group.

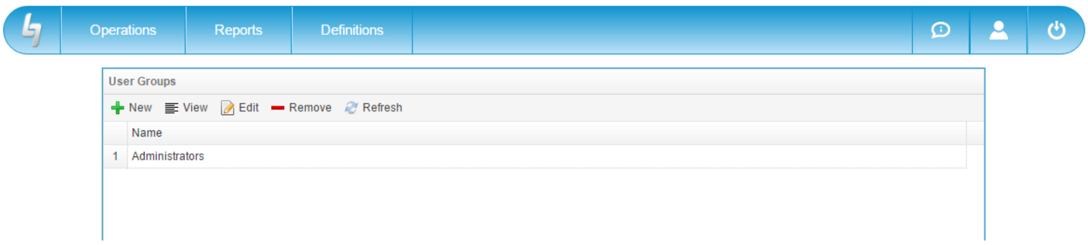


Figure 4.24 Add, view, define or remove user group from web based backend

Defining companies.

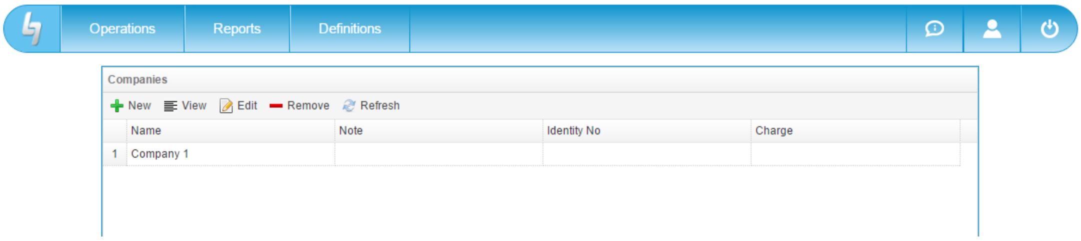


Figure 4.25 Add, view, define or remove company from web based backend

4.2.7.3 Operations

Contains Tracking List, Manual Inspection, Send Notification, Import Points, Settings, Integration forms.

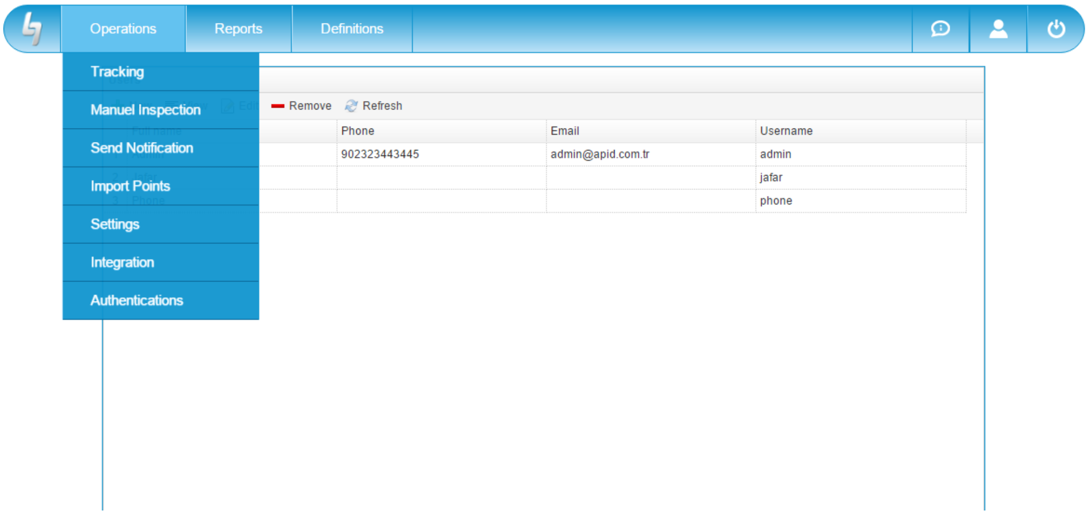


Figure 4.26 Operation menu in web based backend

Defining new tracking.

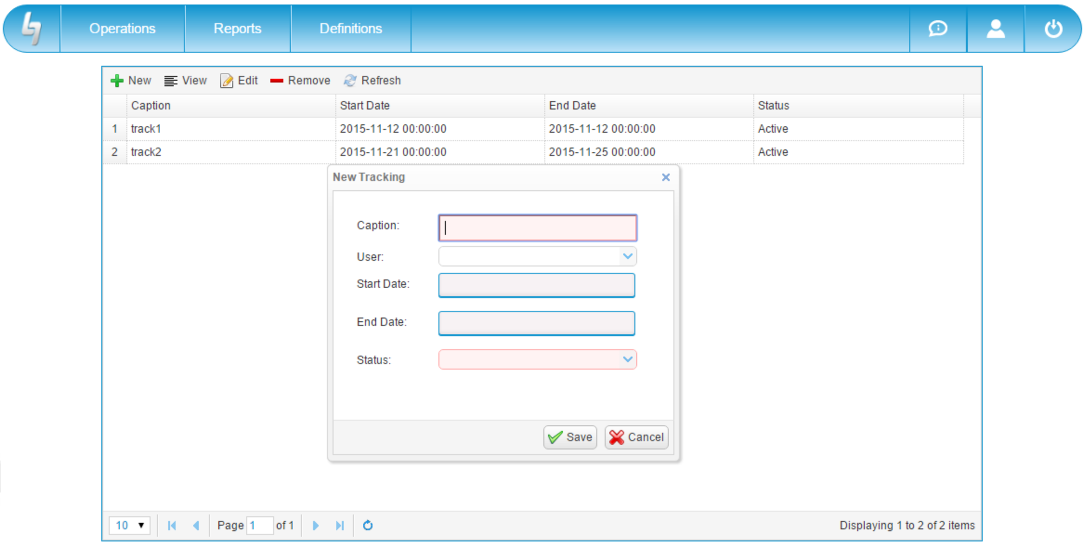


Figure 4.27 Add, view, define or remove trackings from web based backend

Tracking List.

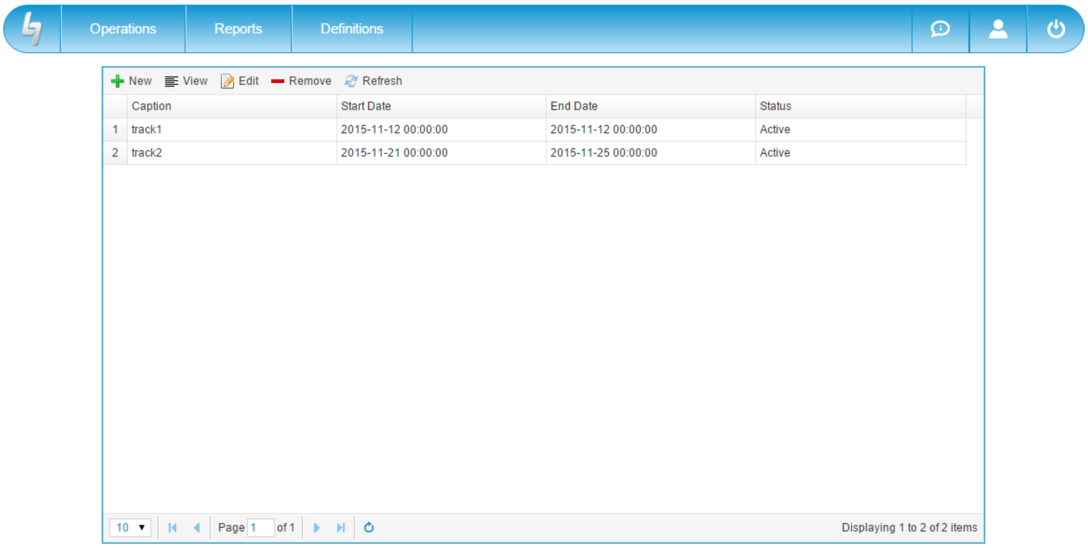


Figure 4.28 The tracking list

Manual Inspection.

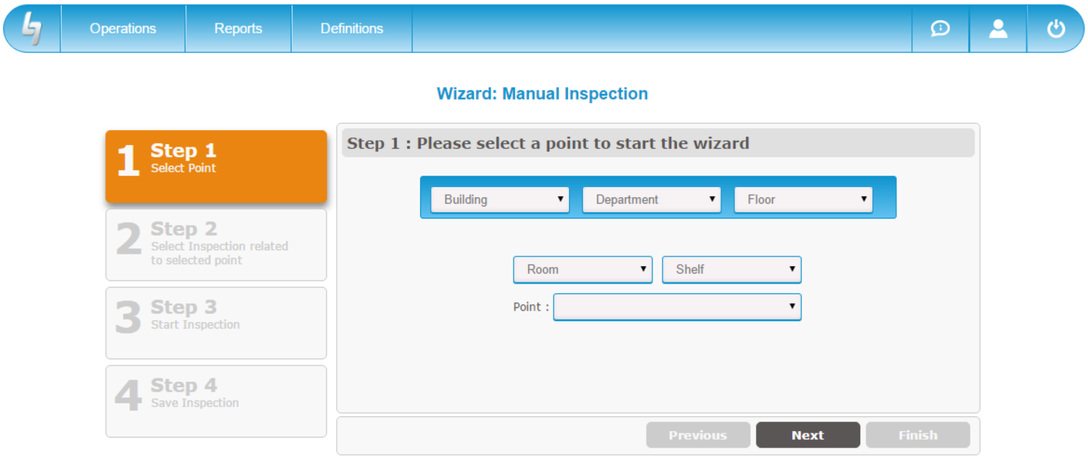


Figure 4.29 Manual inspection definition

Send Notification.

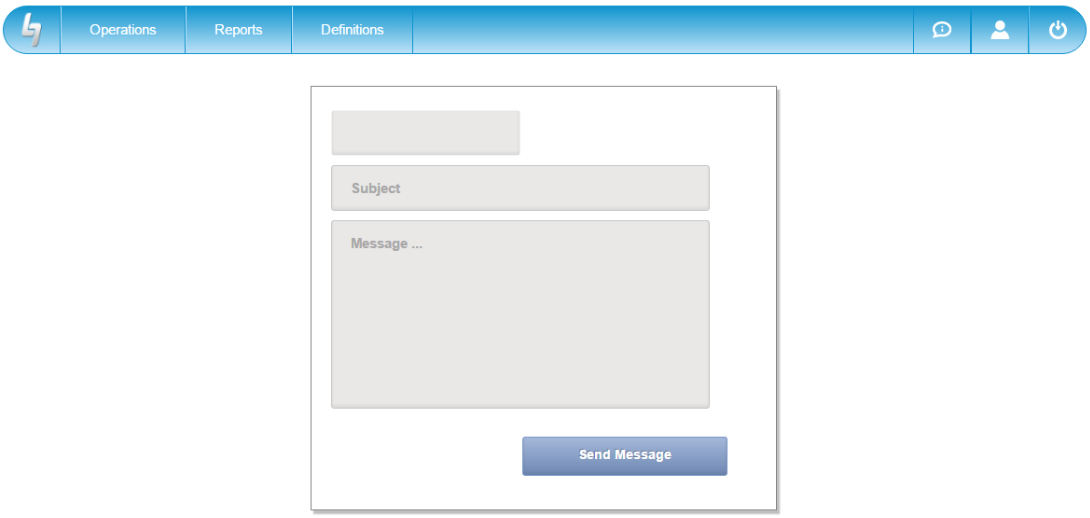


Figure 4.30 Sending a notification form.

Import Points.

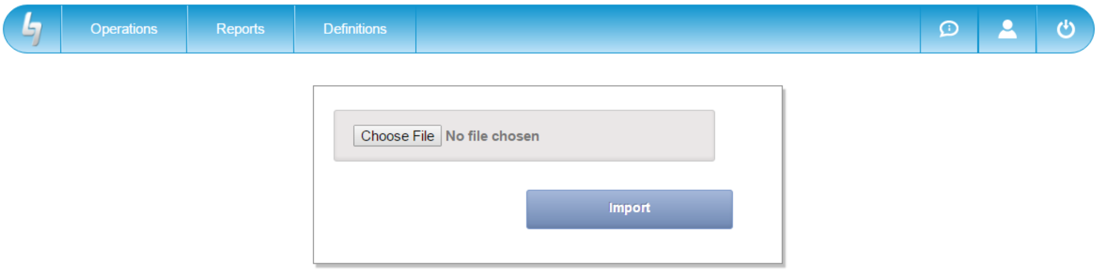


Figure 4.31 Import points to the system

Settings.

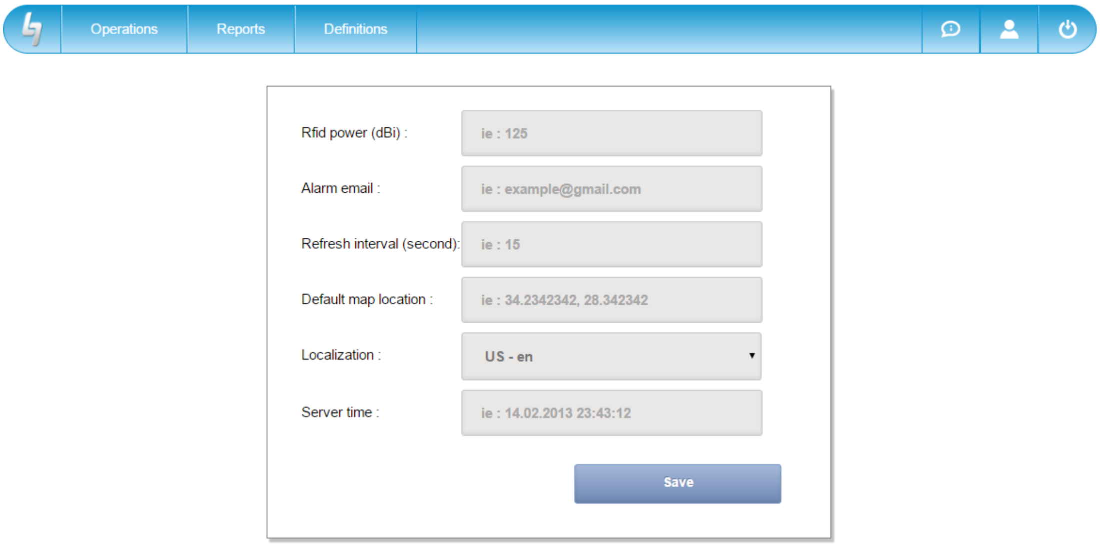


Figure 4.32 General sittings

Integration.

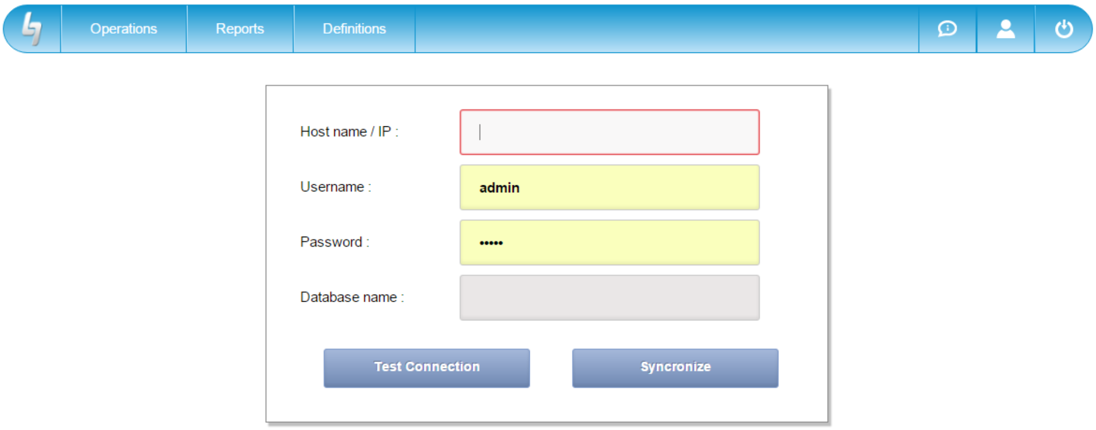


Figure 4.33 Integrating the systems database with another

User Group Authentications to add, delete, or modify system users groups.

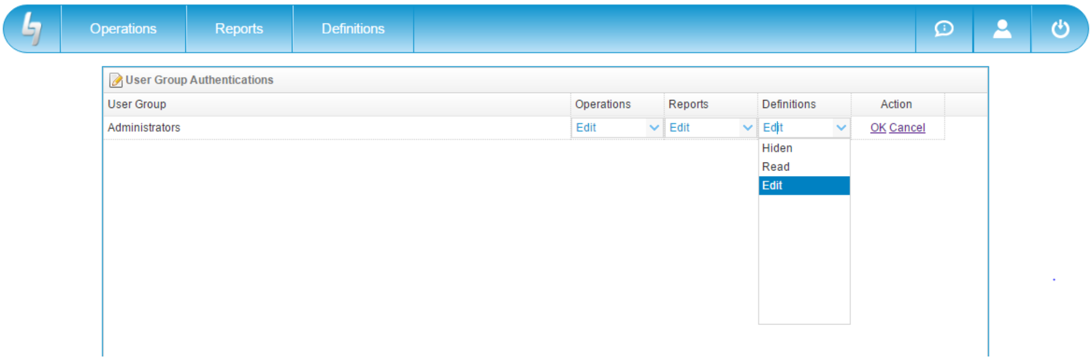


Figure 4.34 Add, view, define or remove system users groups

4.2.7.4 Reports

The system provides many reports to make the system easy to use and easy to retrieve the data. For instance, there is a view point item list as shown in Figure 4.7. This report is to view the items list that is entered into the database manually by web user interface. Figure 4.8, shows points locations on the Map. Figure 4.9 demonstrates the records of the items whether it is tracked or not.

The provided reports is Point List Report, Map Report, Tracking Report, Advanced Tracking Report, Tracking Filtered Report, and Tracking Differences Report.

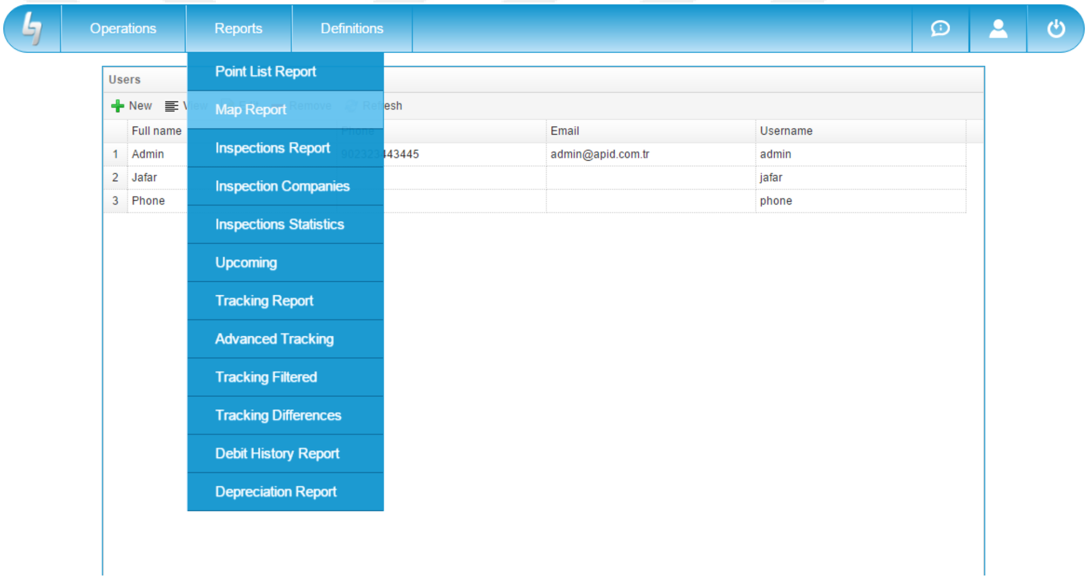


Figure 4.35 Report menu in web based backend

Point List Report.

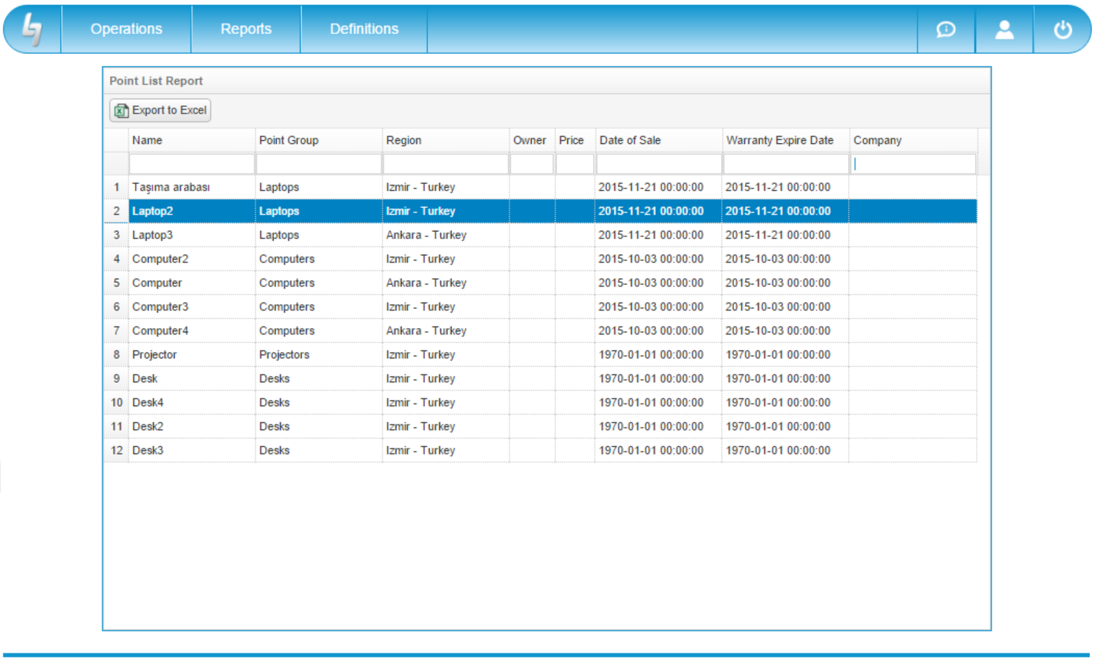


Figure 4.36 Items view list report

Map Report.

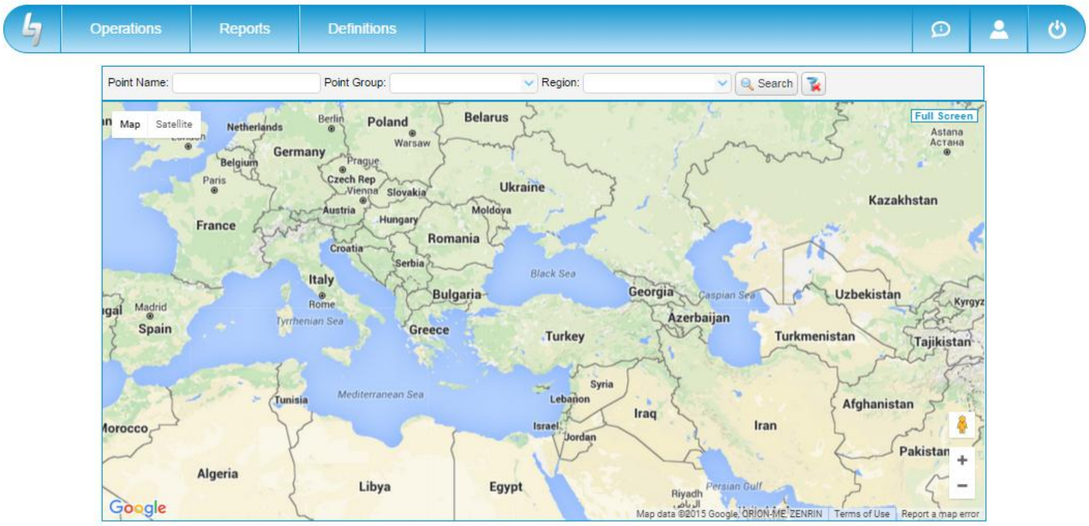


Figure 4.37 Points locations report

Tracking Report.

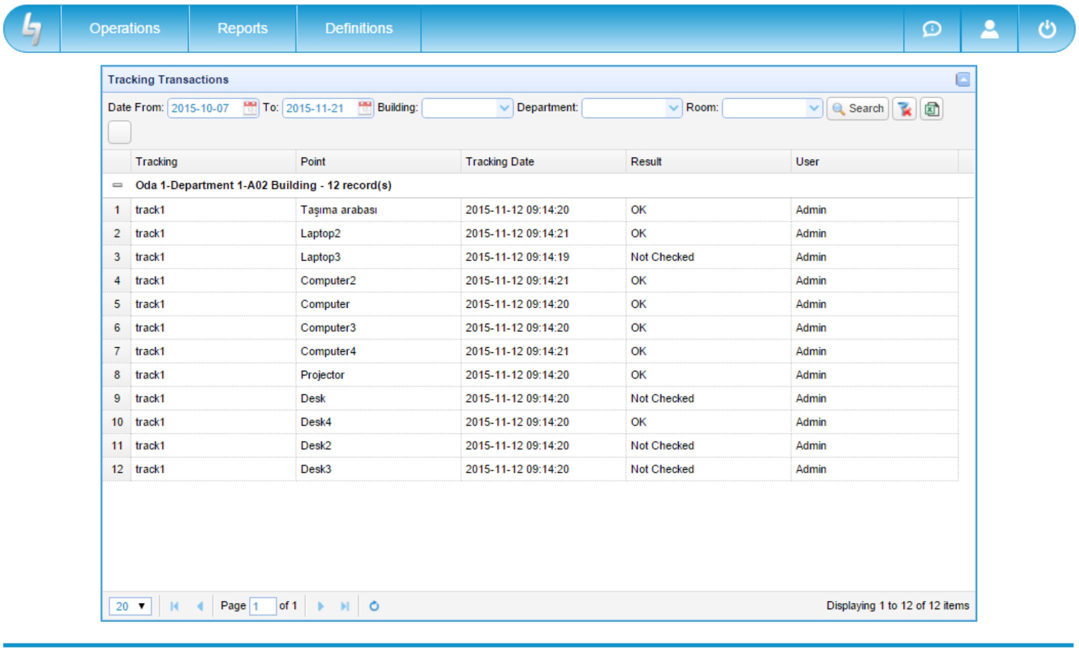


Figure 4.38 The tracking status of the items report

Advanced Tracking Report.

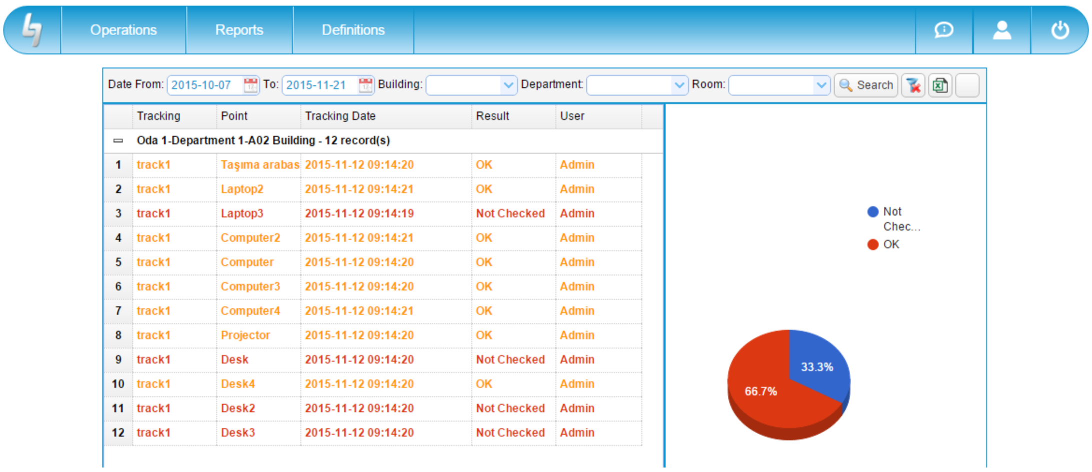
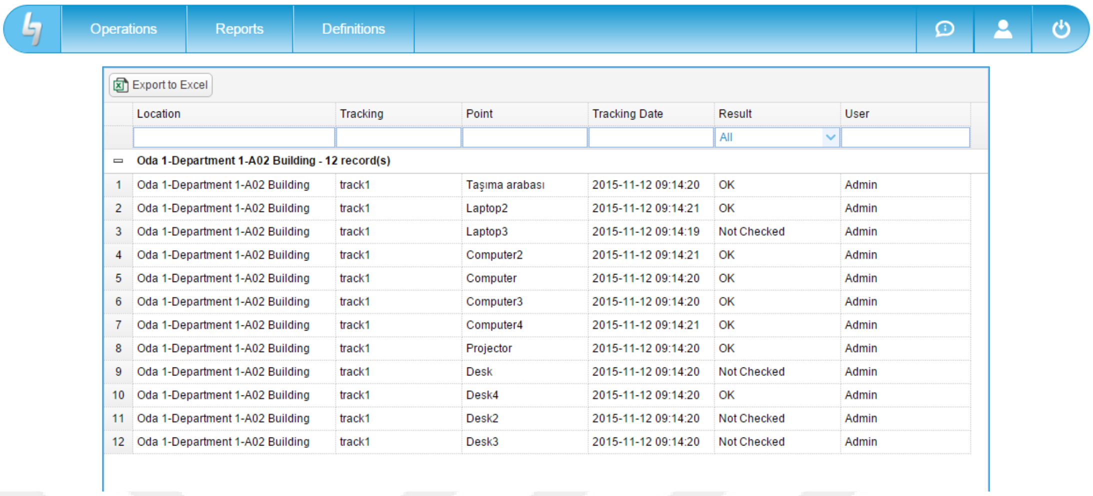


Figure 4.39 Colored tracking report with graph

Tracking Filtered Report.



	Location	Tracking	Point	Tracking Date	Result	User
					All	
	Oda 1-Department 1-A02 Building - 12 record(s)					
1	Oda 1-Department 1-A02 Building	track1	Taşıma arabası	2015-11-12 09:14:20	OK	Admin
2	Oda 1-Department 1-A02 Building	track1	Laptop2	2015-11-12 09:14:21	OK	Admin
3	Oda 1-Department 1-A02 Building	track1	Laptop3	2015-11-12 09:14:19	Not Checked	Admin
4	Oda 1-Department 1-A02 Building	track1	Computer2	2015-11-12 09:14:21	OK	Admin
5	Oda 1-Department 1-A02 Building	track1	Computer	2015-11-12 09:14:20	OK	Admin
6	Oda 1-Department 1-A02 Building	track1	Computer3	2015-11-12 09:14:20	OK	Admin
7	Oda 1-Department 1-A02 Building	track1	Computer4	2015-11-12 09:14:21	OK	Admin
8	Oda 1-Department 1-A02 Building	track1	Projector	2015-11-12 09:14:20	OK	Admin
9	Oda 1-Department 1-A02 Building	track1	Desk	2015-11-12 09:14:20	Not Checked	Admin
10	Oda 1-Department 1-A02 Building	track1	Desk4	2015-11-12 09:14:20	OK	Admin
11	Oda 1-Department 1-A02 Building	track1	Desk2	2015-11-12 09:14:20	Not Checked	Admin
12	Oda 1-Department 1-A02 Building	track1	Desk3	2015-11-12 09:14:20	Not Checked	Admin

Figure 4.40 Report to filter the records automatically

4.3 Figures and Diagrams

At this section we will show illustration diagrams and figures about the system we developed like architecture internal independences directories diagrams, UML Diagrams, architecture graph directory structure diagram, cluster call diagrams, and code volume distribution diagrams.

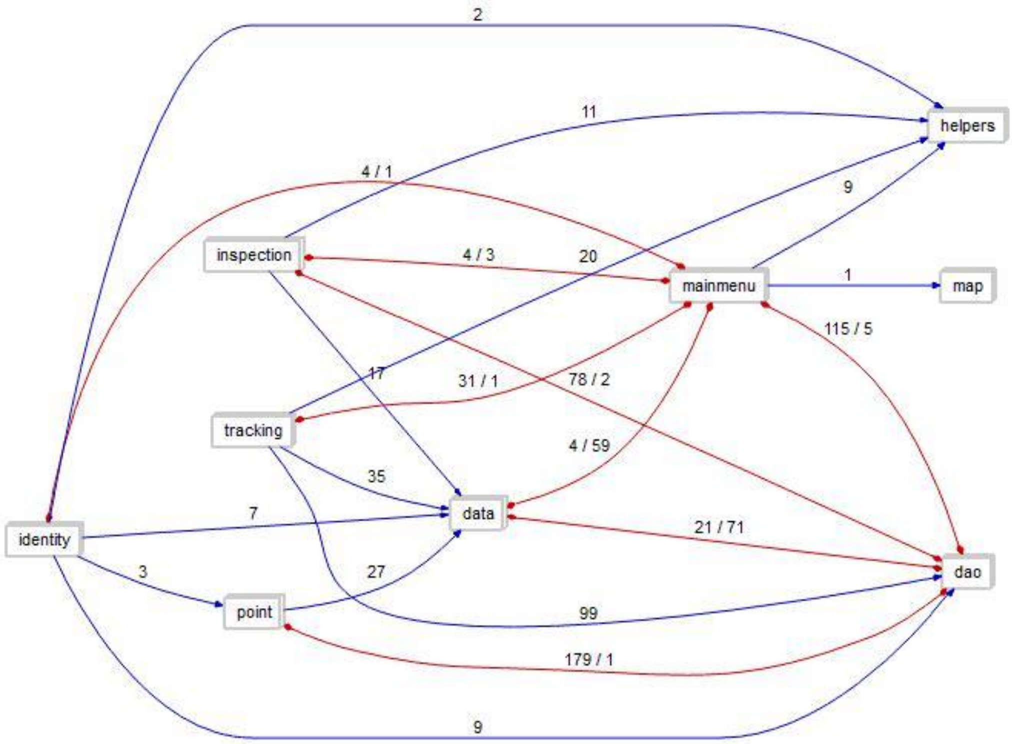


Figure 4.41 Architecture internal independences directories diagram (mobile)

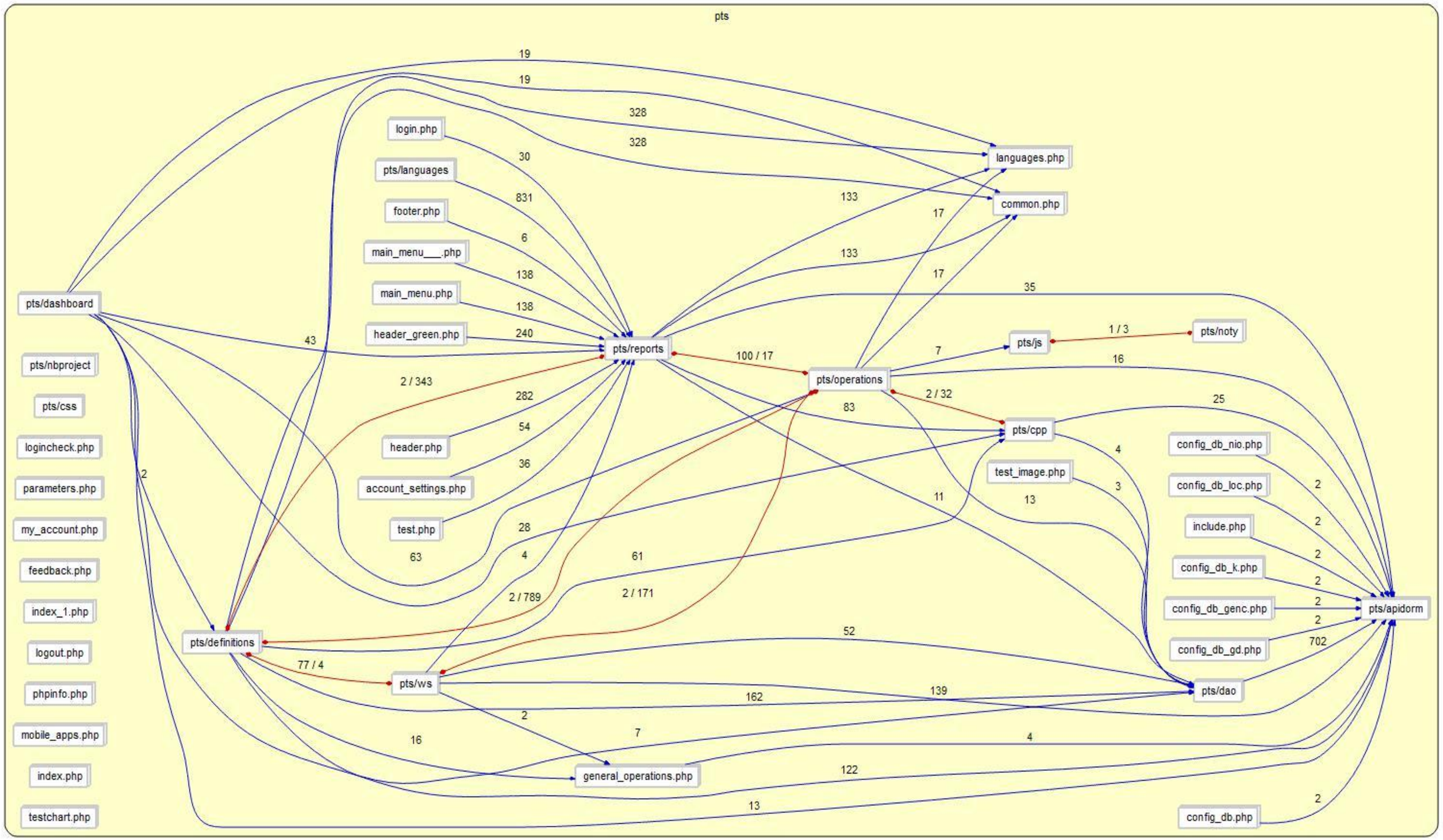


Figure 4.42 Architecture internal independences directories diagram (web)

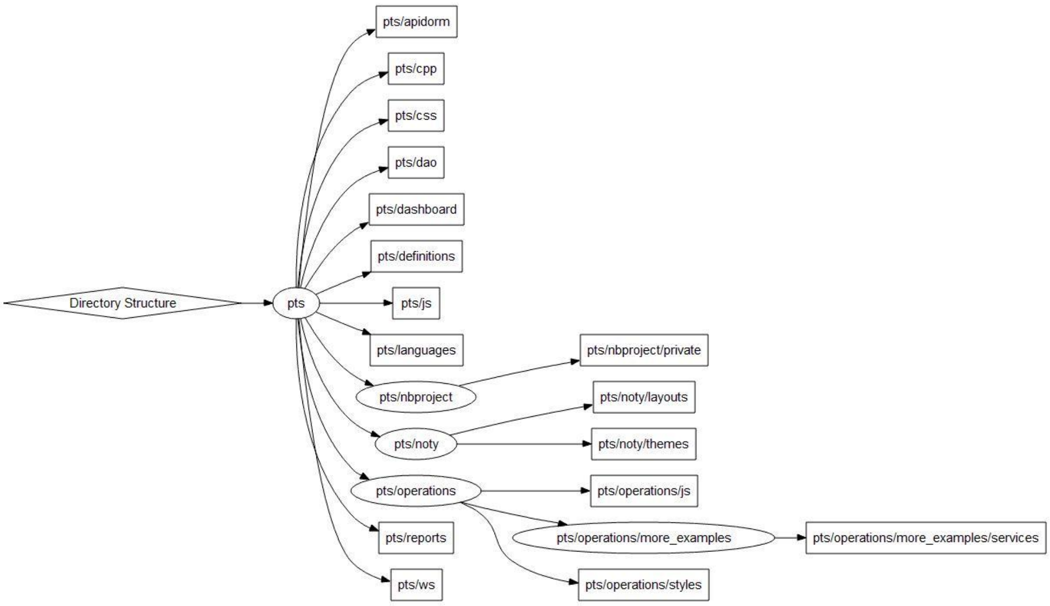


Figure 4.43 Architecture graph directory structure (web)

The Unified Modeling Language (UML) is a general-purpose, developmental, modeling language in the field of software engineering that is intended to provide a standard way to visualize the design of a system.

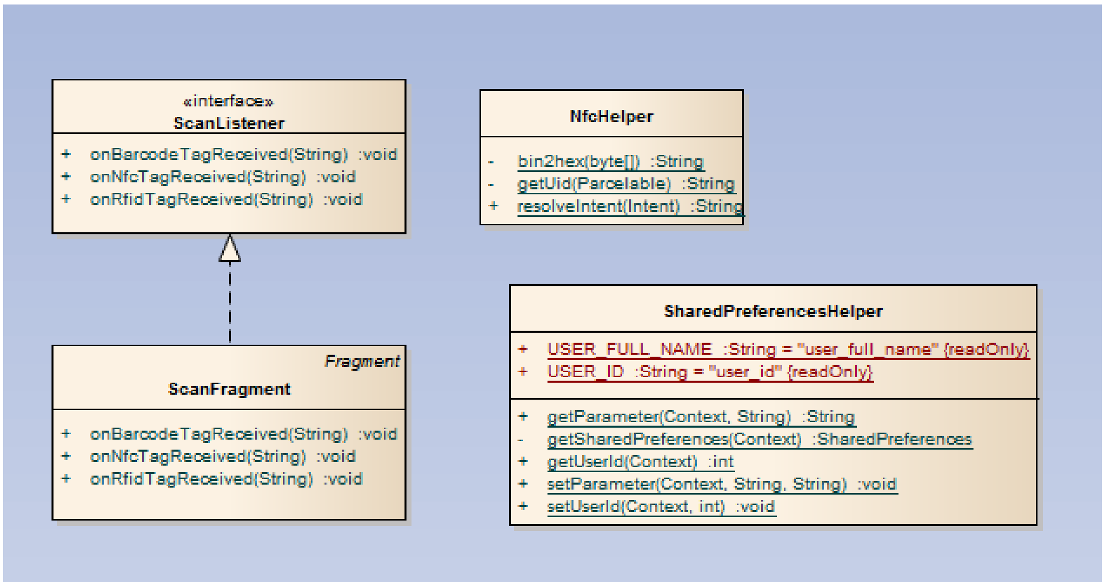


Figure 4.44 Helper deployment model

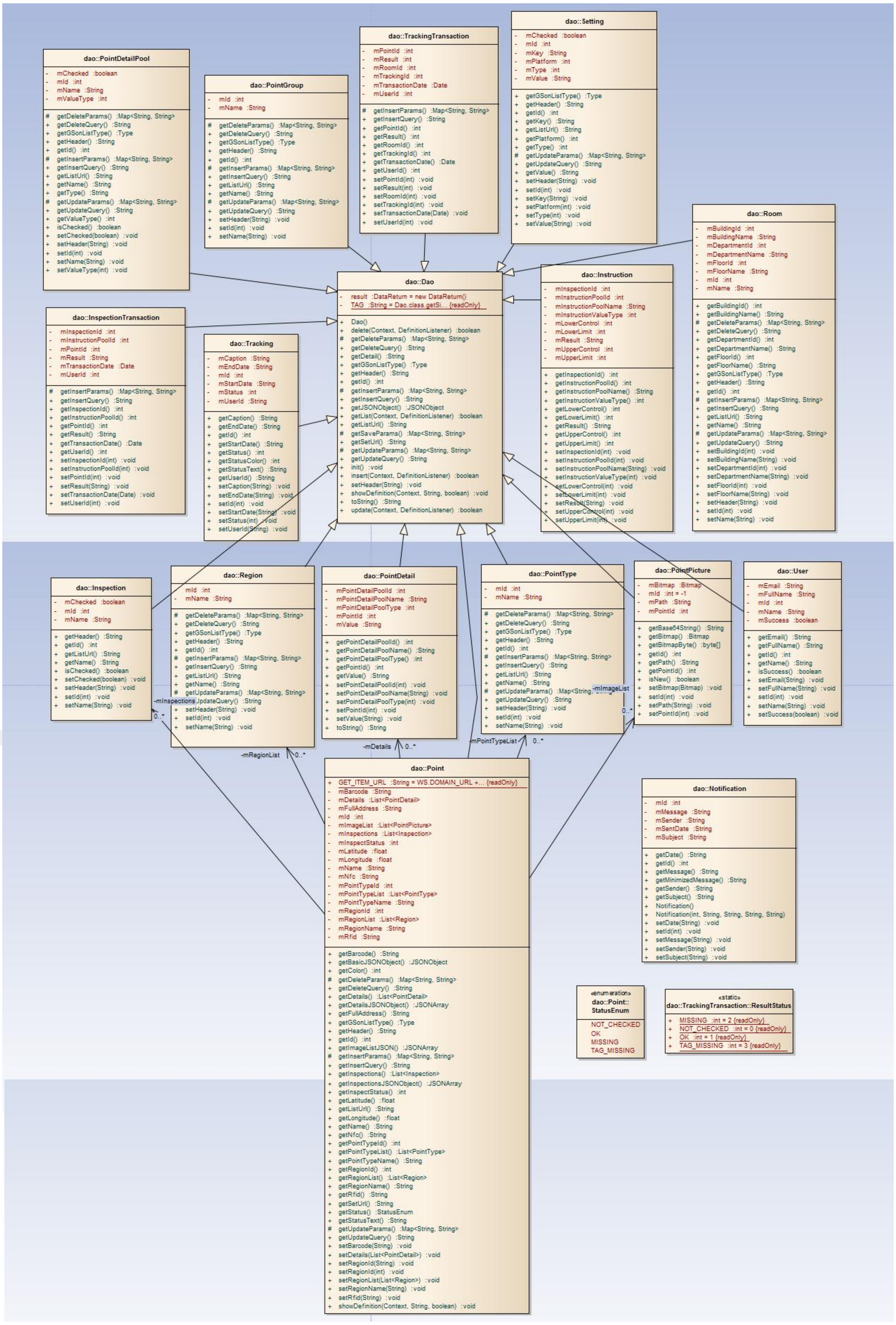


Figure 4.45 Dao deployment model

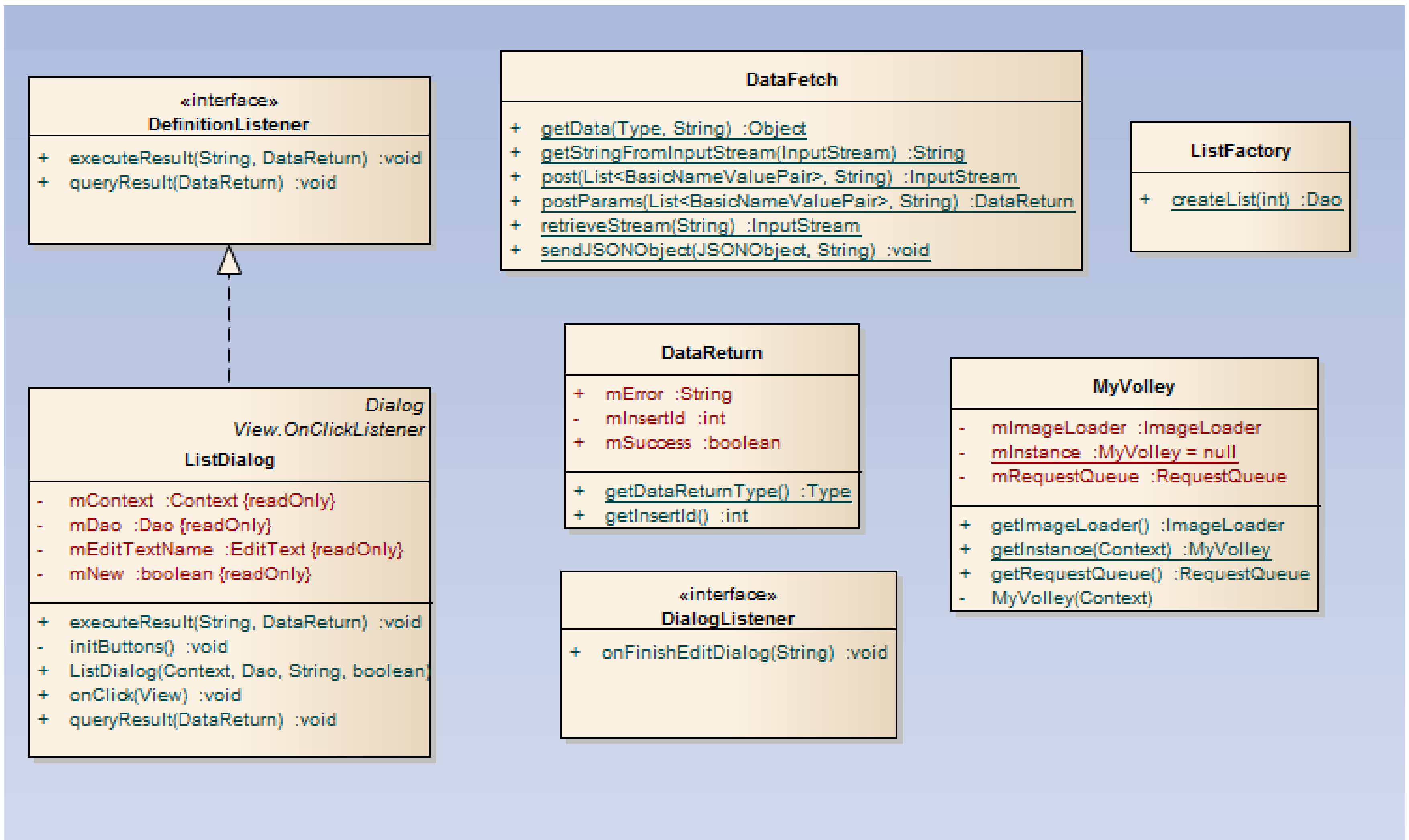


Figure 4.46 Data deployment model

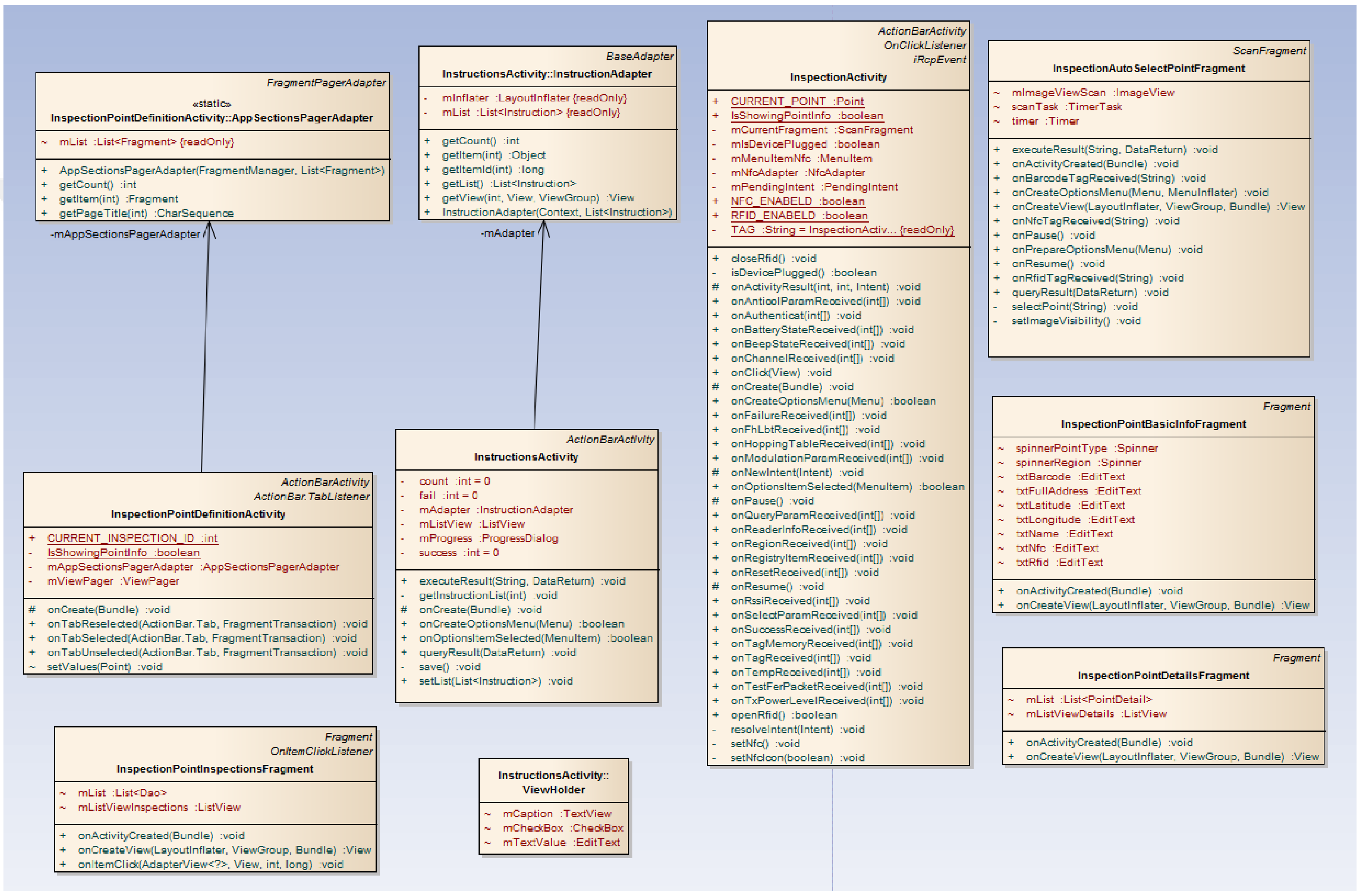


Figure 4.47 Inspections deployment model

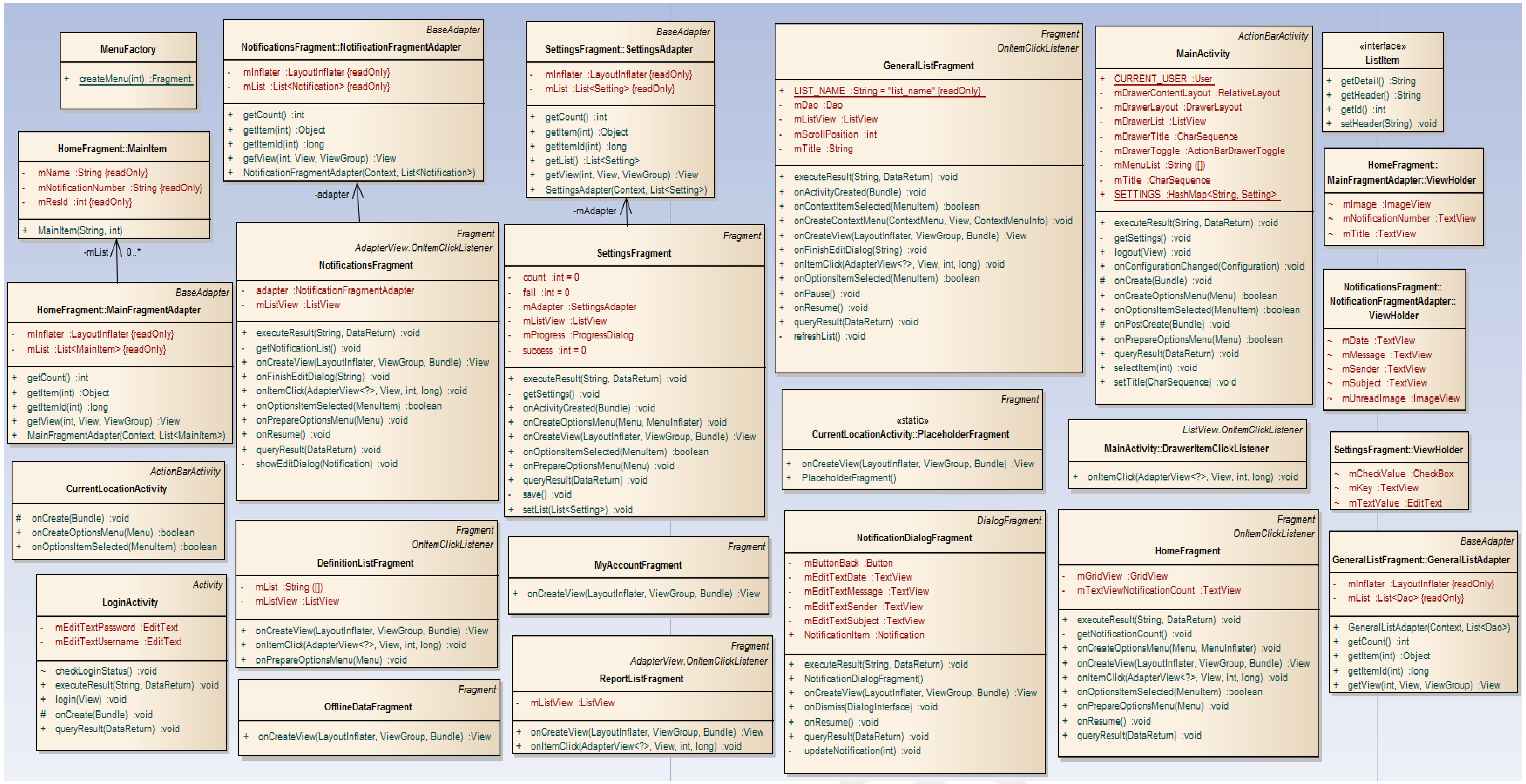


Figure 4.48 Main menu deployment model

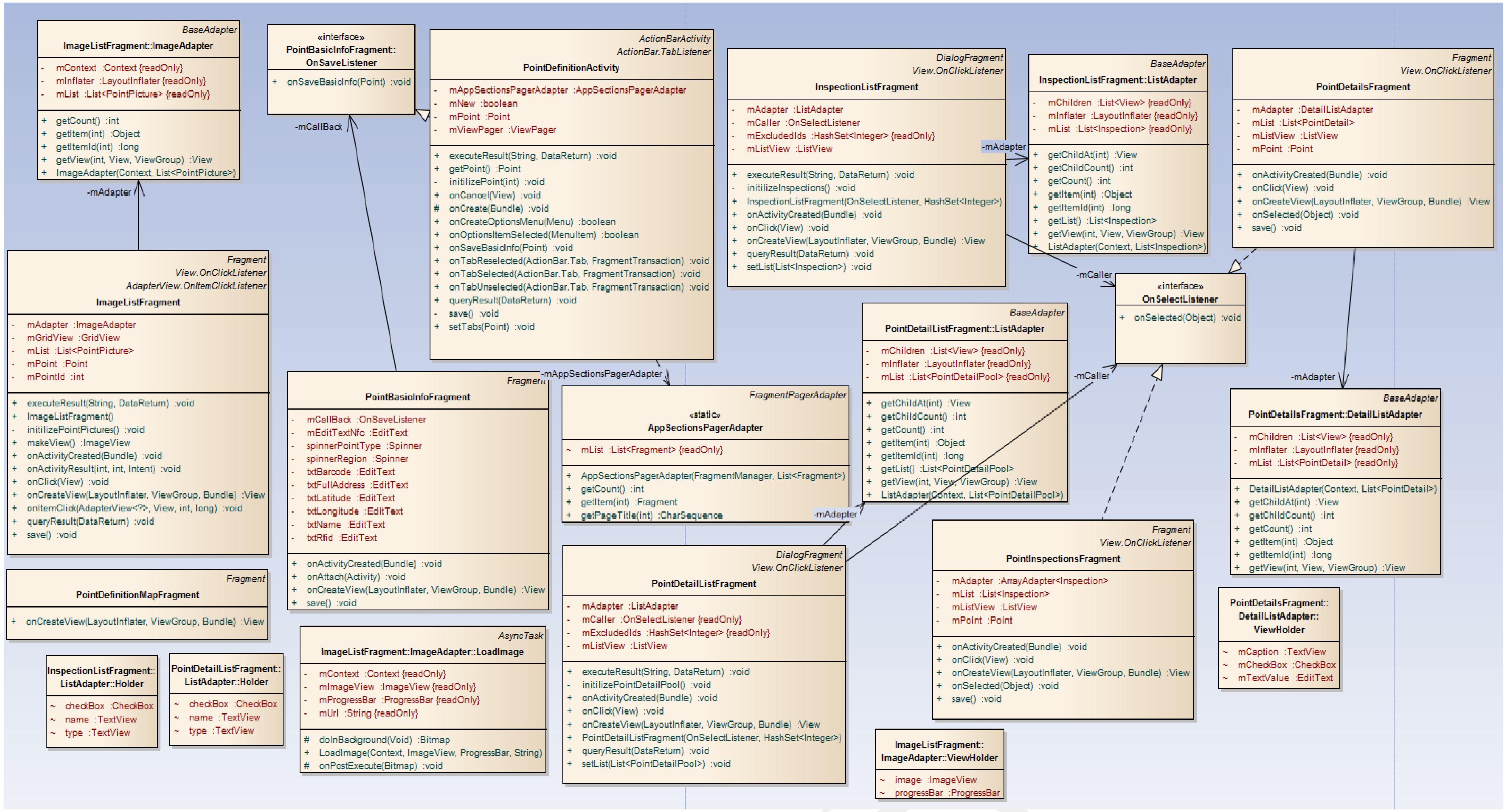


Figure 4.49 Point deployment model

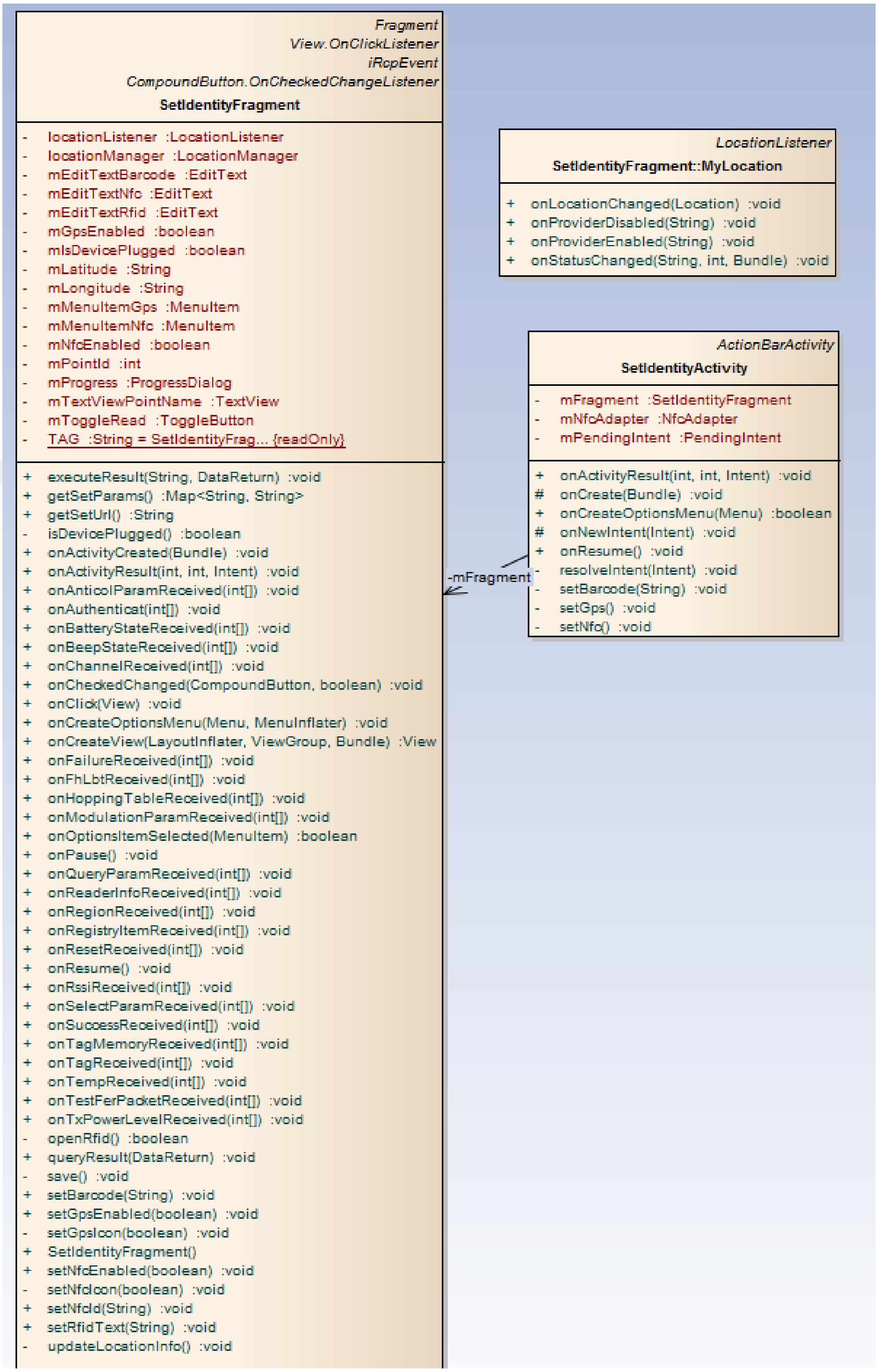


Figure 4.50 Identity deployment model

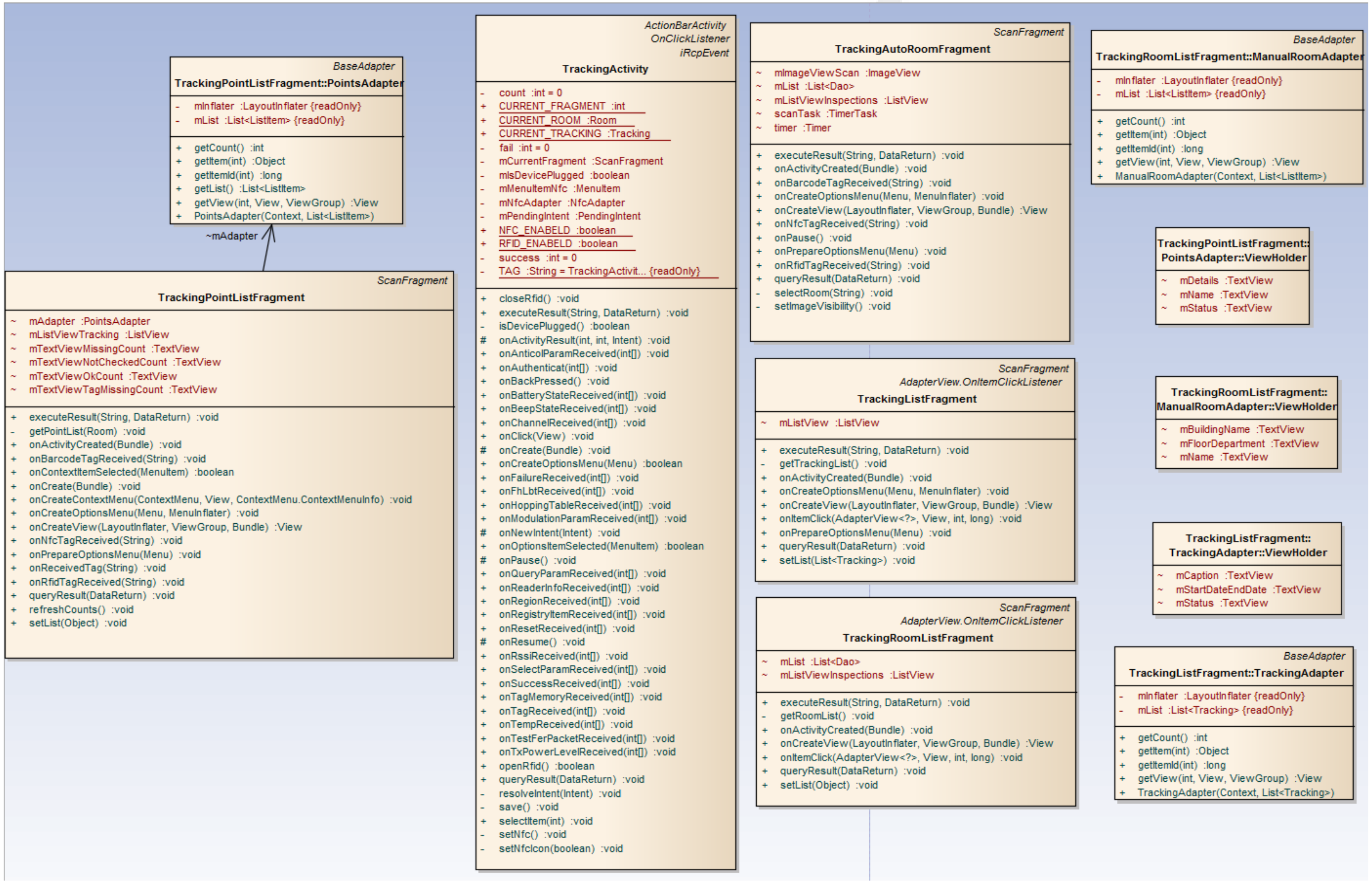


Figure 4.51 Tracking deployment model

4.4 Implementation

Implementation of the solution proposed for the problems stated and the design specifications discussed above are presented as follows. The project implementation is done as web-based for both pc and android devices. RFID transmitter is a plugin plugged into audio jack of android powered mobile devices. It comes with java DLL as a driver for android mobile devices. Then we implemented android application as per the specification and manipulated incoming data transmitted to the android through the plugin. Some features of android such as scanning, adding new points, showing items, defining items with new points and perform tracking events are used. Web based application for PC is implemented by using PHP and MySQL as a backend and HTML, JavaScript and CSS as frontend. Java and MySQL is used as the backend of the android application.

4.5 Summary

The applications on the android devices communicate in a duplex way with the API. The audio cable is used to connect and let the UHF reader to communicate to the application through the API. The UHF reader sends signal to the RFID tags, captures the data and sends it to the applications. For the purpose of storing the data captured and manipulating later, a data storage called MySQL database management is used. The application is developed by using PHP and MySQL for the web based to be used on the computer; Java and MySQL for the android version. The front end of both the application has used HTML, JavaScript, and CSS.

The use of UHF plugin reader bought alone and the application developed for android powered devices provides almost the same services or functionality as the normal RFID reader sets produced by RFID companies. The prices of the complete set supplied by these companies are very expensive to be afforded by thousands of small sized retailers. The solutions proposed to the problem statement of the research is implemented and the researcher found that this UHF plugin and application developed are affordable to the majority of the retails; increasing their efficiency, inventory accuracy increment, reduced loss and/or theft, and make easy calculation of EOQ and RP.

CHAPTER FIVE
EVALUATION AND MEASUREMENTS

5.1 Evaluation

As stated earlier, RFID technologies are in use in big and medium sized warehouse and wholesalers. These companies have the capacity to afford expensive RFID readers to increase inventory accuracy, decrease loss of items, increase efficiency of operations, and make easy calculation of EOQ and RP. However, small sized retailers are incapable to afford this expense. As per the solution proposed we have implemented the proposed system's architecture. The following tabular information in Table 5.1 depicts comparison of the normal RFID reader and UHF reader in terms of price, installation cost and running cost. These parameters are not the only parameters used in the RFID systems, but they are the most important parameters where the difference lays and the focus of our solution to the problem stated.

Using RFID tagging for tracking offers several advantages over other methods mentioned in SWOT analysis for the following reasons:

- Tags can be read remotely, often at a distance of several meters.
- Several tags can be read at once.
- Tags can be given unique identification codes, so that individual products can be tracked.
- Certain types of tag can be overwritten, enabling information about items to be updated to prevent over-stocking or under-stocking a product or component.
- For stock security, by positioning tag-readers at points of high risk, such as exits, and causing them to trigger alarms.
- For quality control, particularly if you make or stock items with a limited shelf life.
- The cost associated with RFID tagging the researcher used is affordable.

Table 5.2 Comparison between RFID, NFC and Barcode readers' parameters

	RFID	NFC	Barcode
Line of sight	Not required	Required	Required
Number of items that can be scanned at same time	Multiple	One	One
Data storage	Up to several KB	Limited codes	Up to several KB
Reading speed	Very fast	Slow	Slow
Security	High, difficult to replicate	High, difficult to replicate	Low, easy to replicate
Visibility	Not must	Must be visible	Must be visible
Update data	Can be updated	Cannot be updated	Can be updated
Way of tracking	Automatically	manually	Manually
Durability	Can be used even when scratched / stained	Cannot be used even when scratched / stained	Can be used even when scratched / stained
Installation Cost	Very expensive	Less expensive	Cheap
Running Cost	Very Expensive	Less expensive	Cheap

Traditional RFID readers are sold in a complete set configured with all the parameters and software required for the system to function properly. The same UHF RFID reader's with all the other required components are very expensive and mostly small sized retailers cannot afford it. The use of UHF RFID reader with our android application and web-based apps is very cheap when compared with that of the complete set sold by RFID companies. In addition to the low price of the solution to the problem, the running cost in the case of normal RFID is more than that of the UHF plugin reader we used in this work. Normal RFID readers need its own host to keep track of the data locally with all the expenses of expert on the system, and may be software licenses. In the case of our solution, the business owners can rent the servers we are using so that when there is a bugs or software related problems, we can easily and quickly fix the problem timely. Even though there is cost related to rents and software licenses, these costs are very low when compared to the installation and running cost of normal RFID readers.

Introducing RFID technology to warehousing industry enhances and increases the speed, accuracy, and visibility of operational information updates for specific units of business. This study has examined a wide range of studies and research literature.

The researcher has concentrated on both explorative and indicative studies in an effort to understand the impact that the adoption of RFID technology will have on improving the performance of the inventory management and minimize the hardware costs of RFID technology by comparing the normal methods and tools used in inventory managements with RFID technology and the costs of varies technologies also.

5.2 Measurements

The researcher has done comparison RFID and alternative tracking technologies parameters. The following graphs shows details of these parameters, such as reading time per item, prices per reader, price of a tag, and reading range.

Reading time: The measurement graph, Figure 5.1, shows the time period that is needed for reading specific number of tags using Barcode, NFC, and RFID readers.

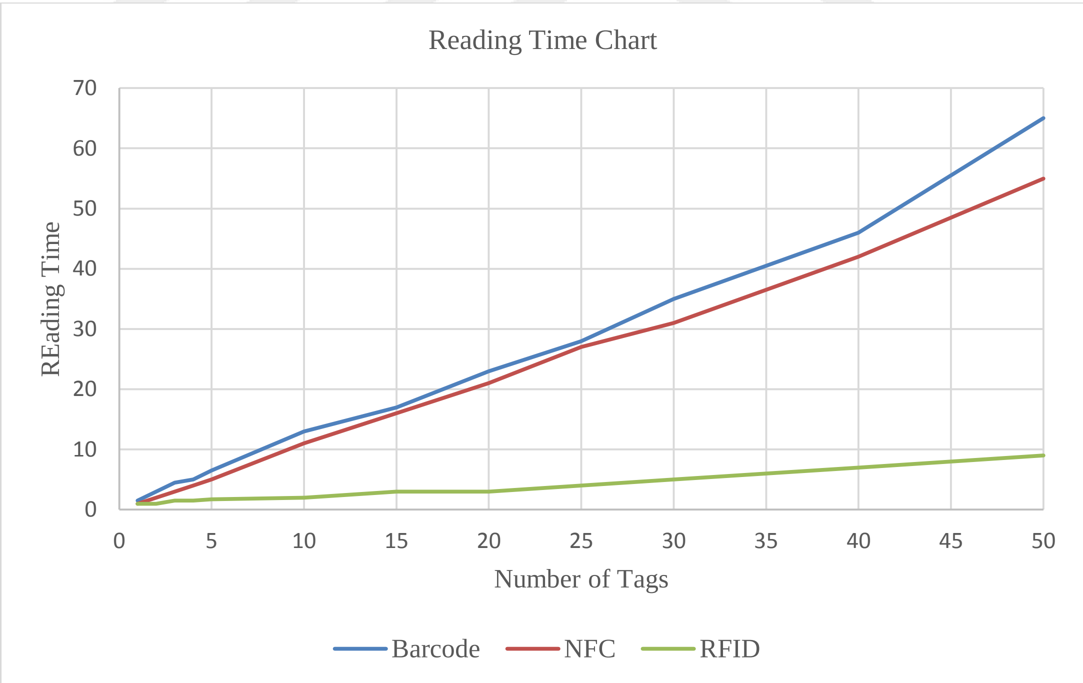


Figure 5.1 Reading Time Chart

Prices of readers of alternative technologies used in market. Figure 5.2 below shows prices of Barcode, NFC, and RFID readers' prices per reader in USD.

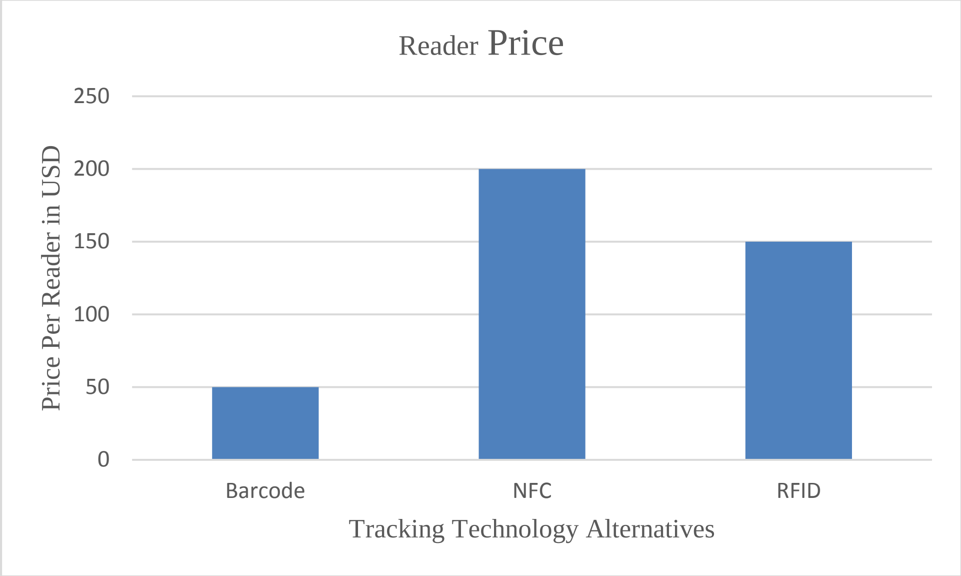


Figure 5.2 Reader Price

Prices of tags of alternative technologies used in market. Figure 5.3 shows prices per tag in USD. As shown on the graph, RFID tag price costs the highest and Barcode being the lowest.

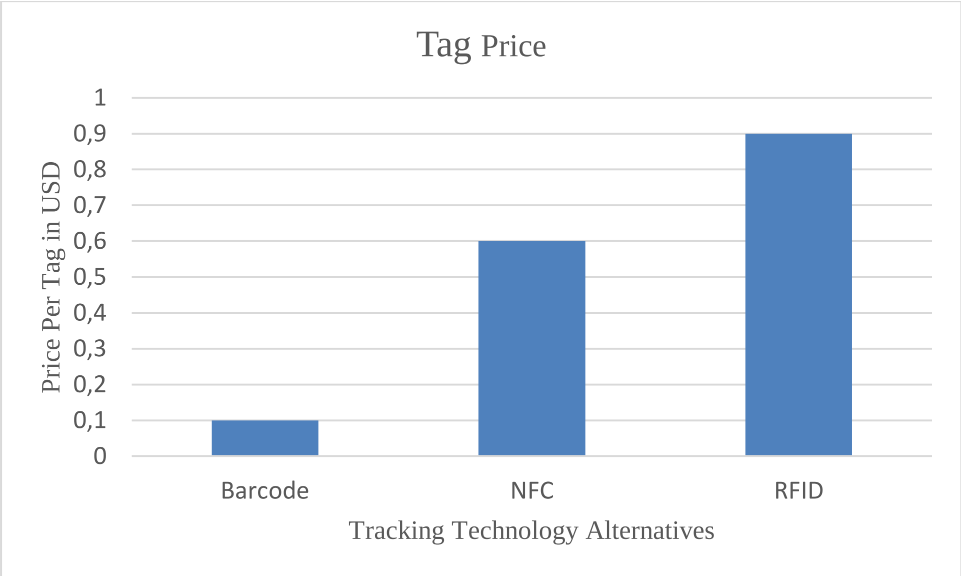


Figure 5.3 Tag Price

Comparison between UHF Readers regarding reading range and price is shown in Figure 5.4, it shows comparison of two parameters. The blue bars shows UHF readers' prices in USD, and the red line shows the reading range of the readers.

As we see in Figure 5.4 the reading range of UHF plugin reader is 50 CM but the price is so affordable. So, it is appropriate for the medium and small sized firms.

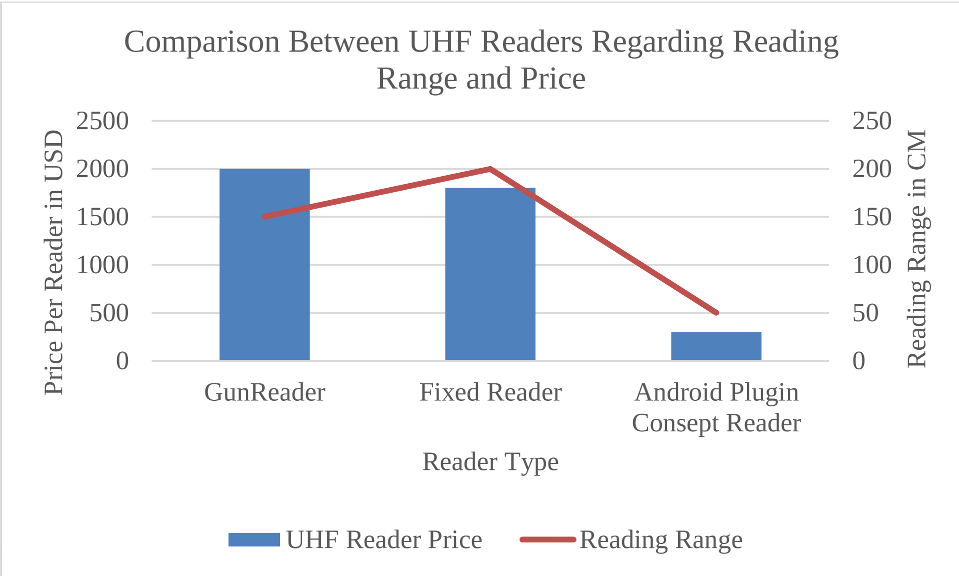


Figure 5.4 Comparison of UHF reader regarding reading range and Price

CHAPTER SIX
CONCLUSION AND FUTURE WORK

6.1 Conclusion

Several small and medium sized business ventures are not widely benefiting from RFID technology, that's because of the unaffordability of the technology for small and middle sized businesses, which can empower them to manage their inventories and track the assets. Lots of alternative technologies are in the market like barcode technology and NFC. After detailed analysis of the existing alternative technologies in the area of inventory management, and instead of waiting until the price of such technology decreases, we applied engineering skills; and created small, cheap and easily portable RFID reader. This RFID reader that we created by using existing technology and developing android based solution is affordable for small and medium sized businesses. It can be sold through subscription. We conclude that without creating a wheel, we can solve problems using existing technology.

6.2 Future Work

This study has focused to solve the problem mentioned in the abstract, high cost of installation of traditional RFID readers in small sized retailers. They are unable to benefit from the advantages it provides in terms of inventory tracking, which could increase inventory accuracy, increase customer satisfaction and decrease loss or theft to mention few. In future work, we will focus on case studies of companies that may use this mobile RFID technology and evaluate the business process inside its inventories; adapt the same system to medium sized retailers and warehouses, evaluate the performance of such devices with traditional fixed or mobile RFID readers.

Increasing the reading range of the RFID reader, and apply the technology to large companies.

REFERENCES

Albrecht, K., & McIntyre, L. (2005). *Spychips: How major corporations and government plan to track your every move with RFID*. Thomas Nelson Inc.

Alliance, S. C. (2007). Proximity mobile payments: Leveraging NFC and the contactless financial payments infrastructure. Retrieved October 07, 2015 from http://www.smartcardalliance.org/resources/lib/Proximity_Mobile_Payments_200709.pdf

Britannica, E., & Iacocca, L. (2004). *From the Encyclopædia Britannica*. Retrieved May 14, 2014 from http://epub.wu.ac.at/448/1/document.pdf.

Bodhani, A. (2011). *Smartphones pay the price*. Engineering & Technology Magazıne, Savoy Place, London.

Cavanaugh, T. M., Coelho, B., Bellaire, M. I., & Pleten, L. N. (2008). *Using RFIDs to minimize the implementation cost and risks in the Grocery Supply Chain*. Retrieved October 05, 2015 from http://re.vu/doc-download/ Cavanaugh / 264195/ work_ example- todd.m.. cavanaugh- rfidresearchpaper .265638.1370559520.pdf

Clampitt, H. (2010). *The RFID handbook.* Retrieved October 5, 2015 from http://www.rfidhandbook.blogspot.com.tr/

Coyle, J. J., Bardi, E. J., & Langley Jr, C. (2003). John (2002) The management of business logistics: a supply chain perspective. *South Western, a Division of Thomson Learning*.

DeHoratius, N., Mersereau, A. J., & Schrage, L. (2008). Retail inventory management when records are inaccurate. *Manufacturing & Service Operations Management*, *10*(2), 257-277.

Disadvantages of RFID Most Are Easy to Overcome. (2014). Retrieved May 13, 2015 from http://www.wireless-technology-advisor.com/disadvantages-of-rfid.html

Gerry, C. S. (2009). *Game changer in retailing, bar code is 35*. Retrieved January 06, 2015 from http://hhuc.us/2009/Game%20Changer%20in%20Retailing.pdf

Inventory management software. (2015). Retrieved May 22, 2015 from https://en.wikipedia.org/wiki/Inventory.

Jandebeur, J., Cho, J., Lee, S. E., & Schaeufele, A. (2013). SWOT analysis of near field communication technology. *In Proceedings of Academic and Business Institute International Conference.*

Juels, A. (2006). RFID security and privacy: a research survey. *Selected Areas in Communications, IEEE Journal*, *24*(2), 381-394.

Jung, H., Chen, F. F., & Jeong, B. (2007). *Trends in supply chain design and management: technologies and methodologies*. Springer Science & Business Media.

Kang, Y. K. (2004). *Information inaccuracy in inventory systems.* P.hD. Thesis, Massachusetts Institute of Technology, Cambridge, MA.

Karmakar, N. C. (Ed.). (2010). *Handbook of smart antennas for RFID systems*. New York: Wiley.

Knight, B. (1992). The data pollution problem. *Computerworld, 26*(39), 81-83.

Laudon, K. C. (1986). Data quality and due process in large interorganizational record systems. *Communications of the ACM*, *29*(1), 4-11.

Lin, L. C. (2009). An integrated framework for the development of radio frequency identification technology in the logistics and supply chain management. *Computers & Industrial Engineering*, 57(3), 832-842.

Ong, J. (2008). *Mobile RFID system for inventory automation.* Ph.D. Thesis, Massachusetts Institute of Technology, Cambridge, MA.

Passive and active tag processes (2007). Retrieved July 06, 2015 from http://www.intechopen.com/source/html/42622/media/image1.jpeg

Polsson, K. (2015). *Chronology of personal computers*. Retrieved October 5, 2015 from http://pctimeline.info/

Redman, T. C. (1992). *Data quality: management and technology*. Bantam Books, Inc.

Reid, R., & Sanders, N. R. (2007*). Operations management: an integrated approach (3rd edition).* New York: John Wiley & Sons.

Sahin, E. (2004). *A qualitative and quantitative analysis of the impact of the Auto ID technology on supply chains* P.hD. Thesis, Ecole Centrale Paris.

The interaction between the reader and RFID tag (2007). Retrieved July 06, 2015 from http://www.intechopen.com/source/html/42622/media/image2.jpeg

Lahiri, S. (2005). *RFID sourcebook*. USA: IBM Press.

Schuster, E. W., Allen, S. J., & Brock, D. L. (2007). *Global RFID: the value of the EPCglobal network for supply chain management*. Springer Science & Business Media.

Siemens A.G. (2008). *Turkish wholesale company uses RFID for warehouse and logistics management*. Retrieved July 05, 2015, from https://www.automation.siemens.com/simatic-sensors-static/ftp/Tetas_en.pdf.

Sweeney, P. J. (2010). *RFID for dummies*. New York: John Wiley & Sons.

Tajima, M. (2007). Strategic value of RFID in supply chain management.*Journal of Purchasing and Supply Management*, 13(4), 261-273.

Crosby, T., (n.d). *How inventory managements systems work*. Retrieved May 09, 2015 from http://money.howstuffworks.com/how-inventory-management-systems-work1.htm

Ton, Z., Dessain, V., & Stachowiak-Joulain, M. (2007). *RFID at the metro group*. Harvard Business School.

Tsipoulanidis, A. (2012). *International supply chain management*. Student Reader, MBA European Asian management. Berlin: IMB Institute of Management, HWR.

Uckun, C., Karaesmen, F., & Savaş, S. (2008). Investment in improved inventory accuracy in a decentralized supply chain. *International Journal of Production Economics*, 113(2), 546-566.

Wani, D. (2012). *MBA European Asian management*. Berlin: IMB Institute of Management, HWR.

Ward, M., Van Kranenburg, R., & Backhouse, G. (2006). *RFID: Frequency, standards, adoption and innovation*. JISC Technology and Standards Watch.

Waters, D. (2003). *Inventory control and management*. Retrieved May 22, 2015, from http://www.tbm.tudelft.nl/fileadmin/Faculteit /TBM/ Over_de_Faculteit/ Afdelingen/Afdeling_Infrastructure_Systems_and_Services/Sectie_Informatie_en

_Communicatie_Technologie/medewerkers/jan_van_den_berg/news/doc/GvHeck_THESIS_FINAL.pdf

Wight, O. (1995). *The executive's guide to successful MRP II (Vol. 6)*. New York: John Wiley & Sons.

Wild, T. (2007). *Best practice in inventory management*. Retrieved June 02, 2015, from http://www.tbm.tudelft.nl/fileadmin/Faculteit/TBM/Over_de_Faculteit/Afdelingen/Afdeling_Infrastructure_Systems_and_Services/Sectie_Informatie_en_Communicatie_Technologie/medewerkers/jan_van_den_berg/news/doc/2014-12-24-ThesisRoyFinal-Censored.pdf

Wireless Technology Advisor (2012). *Making wireless technology easy to understand*. Retrieved August 15, 2015 from http://www.wireless-technology-advisor.com/disadvantages-of-rfid.html.

Yacine, R., (2006). *The impact of the RFID technology in improving performance of inventory systems subject to inaccuracies. engineering sciences*. Retrieved July, 02, 2015, from https://tel.archives-ouvertes.fr/tel-00222915/document

APPENDICES

LIST OF ABBREVIATION

API: Application Programming Interface

B2B: Business to Business

CSS: Cascading Style Sheet

CM: Centimeter

EM: Electromagnetic

EOQ: Economic Order Quantity

EPC: Electronic Product Code

ER: Entity Relationship

HF: High Frequency

IC: Integrated Circuit

ISO: International Standard Organization

LF: Low Frequency

M2M: Machine to Machine

MF: Microwave Frequency

NFC: Near Field Communication

RF: Radio Frequency

RFID: Radio Frequency Identification

RP: Reorder Point

SKU: Stock Keeping Unit

SQL: Structured Query Language

SWOT: Strengths, Weaknesses, Opportunities, Threats analysis

UHF: Ultra High Frequency

UPC: Universal Product Code

UML: Unified Modeling Language

USD: United States Dollar

SQL Code of Tables

The following SQL script is the script for the database used in the web application of the thesis.

```
-- -----------------------------------------------------
-- Table `contract`
-- -----------------------------------------------------
CREATE TABLE IF NOT EXISTS `contracts` (
  `contractor_id` INT NOT NULL,
  `point_id` INT NOT NULL,
  PRIMARY KEY (`contractor_id` , `point_id`)
) ENGINE=InnoDB DEFAULT CHARACTER SET=utf8 COMMENT='this table shows which contructor has been assigned to each  /* comment truncated */ /*point.*/';

-- -----------------------------------------------------
-- Table `contractor`
-- -----------------------------------------------------

CREATE TABLE `contractors` (
  `id` INT NOT NULL AUTO_INCREMENT,
  `name` varchar(100) DEFAULT NULL,
  `firm_name` varchar(100) DEFAULT NULL,
  `phone` varchar(45) DEFAULT NULL,
  `email` varchar(45) DEFAULT NULL,
  `address` varchar(500) DEFAULT NULL,
  `user_id` INT(11) DEFAULT NULL,
  PRIMARY KEY (`id`)
) ENGINE=InnoDB DEFAULT CHARSET=utf8 COMMENT='this table holds all contructor, for example : in each point there might be more than one contructor. ie : Turksat, TTnet, Avea ';
```

```
-- -----------------------------------------------------
-- Table `inspection`
-- -----------------------------------------------------
CREATE TABLE `inspections` (
   `id` INT NOT NULL AUTO_INCREMENT,
   `name` varchar(100) DEFAULT NULL,
   `point_group_id` INT DEFAULT NULL,
   `frequency` INT DEFAULT NULL,
   `user_id` INT(11) DEFAULT NULL,
   PRIMARY KEY (`id`)
) ENGINE=InnoDB DEFAULT CHARSET=utf8 COMMENT='this table holds definition of each inspection, ie : how to  /* comment truncated */ /*clear a point place etc.        */';

-- -----------------------------------------------------
-- Table `point_inspection`
-- -----------------------------------------------------
CREATE TABLE `point_inspection` (
   `point_id` INT NOT NULL,
   `inspection_id` INT NOT NULL,
   PRIMARY KEY (`point_id` , `inspection_id`)
);

-- -----------------------------------------------------
-- Table `instruction_pool`
-- -----------------------------------------------------
CREATE TABLE `instruction_pool` (
   `id` INT NOT NULL AUTO_INCREMENT,
   `name` VARCHAR(500) NULL,
   `value_type` INT NULL,
   `user_id` INT DEFAULT NULL,
   PRIMARY KEY (`id`)
```

```
);

-- -----------------------------------------------------
-- Table `inspection_instruction`
-- -----------------------------------------------------

CREATE TABLE `inspection_instruction` (
    `inspection_id` int NOT NULL,
    `instruction_pool_id` int(11) NOT NULL,
    `upper_limit` float DEFAULT NULL,
    `upper_control` float DEFAULT NULL,
    `lower_control` float DEFAULT NULL,
    `lower_limit` float DEFAULT NULL,
    `user_id` INT(11) DEFAULT NULL,
    PRIMARY KEY (`inspection_id` , `instruction_pool_id`)
)  ENGINE=InnoDB DEFAULT CHARSET=utf8;

-- -----------------------------------------------------
-- Table `inspection_transactions`
-- -----------------------------------------------------
CREATE TABLE `inspection_transactions` (
  `id` int(11) NOT NULL AUTO_INCREMENT,
  `point_id` int(11) DEFAULT NULL,
  `inspection_id` int(11) DEFAULT NULL,
  `instruction_pool_id` int(11) DEFAULT NULL,
  `inspection_date` datetime DEFAULT NULL,
  `user_id` int(11) DEFAULT NULL,
  `result` varchar(255) DEFAULT NULL,
  `comment` varchar(255) DEFAULT NULL,
  PRIMARY KEY (`id`)
) ENGINE=InnoDB AUTO_INCREMENT=8 DEFAULT CHARSET=utf8;
```

```
-- -----------------------------------------------------
-- Table `point`
-- -----------------------------------------------------
CREATE TABLE IF NOT EXISTS `points` (
  `id` INT NOT NULL AUTO_INCREMENT,
  `name` VARCHAR(100) NULL DEFAULT NULL,
  `barcode` VARCHAR(45) NULL DEFAULT NULL,
  `rfid` VARCHAR(45) NULL DEFAULT NULL,
  `nfc` varchar(45) DEFAULT NULL,
  `longitude` FLOAT(10 , 6 ) NULL DEFAULT NULL COMMENT ' X ',
  `latitude` FLOAT(10 , 6 ) NULL DEFAULT NULL COMMENT ' Y ',
  `point_type_id` INT NULL DEFAULT NULL,
  `full_address` VARCHAR(500) NULL DEFAULT NULL,
  `region_id` INT NULL DEFAULT NULL,
  `room_id` INT NULL DEFAULT NULL,
  `shelf_id` INT NULL DEFAULT NULL,
  `status` INT NULL DEFAULT NULL COMMENT 'This field holds the data status as integer, 0 = passive 1 = active',
  `user_id` INT(11) DEFAULT NULL,
  PRIMARY KEY (`id`)
) ENGINE=InnoDB DEFAULT CHARACTER SET=utf8 COMMENT='This table is responsible of all point definitions.';

-- -----------------------------------------------------
-- Table `point_details`
-- -----------------------------------------------------
CREATE TABLE `point_details` (
  `point_id` INT NOT NULL,
  `point_detail_pool_id` INT NOT NULL,
  `value` VARCHAR(255) NULL,
  PRIMARY KEY (`point_id` , `point_detail_pool_id`)
) COMMENT='        ';
```

```
-- -----------------------------------------------------
-- Table `point_detail_pool`
-- -----------------------------------------------------
CREATE TABLE `point_detail_pool` (
   `id` INT NOT NULL AUTO_INCREMENT,
   `name` VARCHAR(255) NULL,
   `value_type` INT NULL,
   `user_id` INT(11) DEFAULT NULL,
   PRIMARY KEY (`id`)
);

-- -----------------------------------------------------
-- Table `point_group`
-- -----------------------------------------------------
CREATE TABLE `point_groups` (
   `id` INT NOT NULL AUTO_INCREMENT,
   `name` varchar(100) DEFAULT NULL,
   `user_id` INT DEFAULT NULL,
   PRIMARY KEY (`id`)
) ENGINE=InnoDB DEFAULT CHARSET=utf8 COMMENT='This table holds point groups, for example : electronic, mechanic';

-- -----------------------------------------------------
-- Table `point_group_assignment`
-- -----------------------------------------------------
CREATE TABLE IF NOT EXISTS `point_group_assignments` (
   `point_group_id` INT NOT NULL,
   `point_id` INT NOT NULL,
   PRIMARY KEY (`point_group_id` , `point_id`)
```

```
)  ENGINE=InnoDB DEFAULT CHARACTER SET=utf8 COMMENT='this table is responsible of point group and point assignmen /* comment truncated */ /*t. Because each point can be in different groups.*/';


-- -----------------------------------------------------
-- Table `point_type`
-- -----------------------------------------------------
CREATE TABLE `point_types` (
   `id` INT NOT NULL AUTO_INCREMENT,
   `name` varchar(100) DEFAULT NULL,
   `user_id` INT(11) DEFAULT NULL,
   PRIMARY KEY (`id`)
)  ENGINE=InnoDB DEFAULT CHARSET=utf8;

-- -----------------------------------------------------
-- Table `region`
-- -----------------------------------------------------
CREATE TABLE `regions` (
   `id` INT NOT NULL AUTO_INCREMENT,
   `name` varchar(100) DEFAULT NULL,
   `user_id` INT(11) DEFAULT NULL,
   PRIMARY KEY (`id`)
)  ENGINE=InnoDB AUTO_INCREMENT=2 DEFAULT CHARSET=utf8;

-- -----------------------------------------------------
-- Table `user`
-- -----------------------------------------------------
CREATE TABLE IF NOT EXISTS `users` (
   `id` INT NOT NULL AUTO_INCREMENT,
   `full_name` VARCHAR(100) NULL DEFAULT NULL,
   `email` VARCHAR(100) NULL DEFAULT NULL,
```

```
  `phone` VARCHAR(45) NULL DEFAULT NULL,
  `username` VARCHAR(45) NULL DEFAULT NULL,
  `password` VARCHAR(45) NULL DEFAULT NULL,
  `user_group_id` INT NOT NULL,
  PRIMARY KEY (`id`),
  UNIQUE INDEX `username_UNIQUE` (`username` ASC)
)  ENGINE=InnoDB AUTO_INCREMENT=2 DEFAULT CHARACTER SET=utf8
COMMENT='contains all users';

-- -----------------------------------------------------
-- Table `user_groups`
-- -----------------------------------------------------
CREATE TABLE `user_groups` (
  `id` INT NOT NULL AUTO_INCREMENT,
  `name` varchar(100) DEFAULT NULL,
  PRIMARY KEY (`id`)
)  ENGINE=InnoDB DEFAULT CHARSET=utf8;

-- -----------------------------------------------------
-- Table `authentications`
-- -----------------------------------------------------
CREATE TABLE IF NOT EXISTS `authentications` (
  `user_group_id` INT NOT NULL,
  `definitions` INT NOT NULL,
  `reports` INT NOT NULL,
  `operations` INT NOT NULL,
  `user_id` INT(11) DEFAULT NULL,
  PRIMARY KEY (`user_group_id`)
)  ENGINE=InnoDB CHARACTER SET=utf8 COMMENT='0:hiden 1:read 2:edit';

-- -----------------------------------------------------
-- Table `buildings`
```

```
-- -----------------------------------------------------
CREATE TABLE `buildings` (
   `id` INT NOT NULL AUTO_INCREMENT,
   `name` VARCHAR(255) NULL,
   `user_id` INT(11) DEFAULT NULL,
   PRIMARY KEY (`id`)
);

-- -----------------------------------------------------
-- Table `departments`
-- -----------------------------------------------------
CREATE TABLE `departments` (
   `id` INT NOT NULL AUTO_INCREMENT,
   `name` VARCHAR(255) NULL,
   `building_id` INT NULL DEFAULT NULL,
   `user_id` INT(11) DEFAULT NULL,
   PRIMARY KEY (`id`)
);

-- -----------------------------------------------------
-- Table `floors`
-- -----------------------------------------------------
CREATE TABLE `floors` (
   `id` INT NOT NULL AUTO_INCREMENT,
   `name` VARCHAR(255) NULL,
   `user_id` INT(11) DEFAULT NULL,
   PRIMARY KEY (`id`)
);

-- -----------------------------------------------------
-- Table `rooms`
-- -----------------------------------------------------
```

```
CREATE TABLE `rooms` (
  `id` INT NOT NULL AUTO_INCREMENT,
  `name` VARCHAR(255) NULL,
  `number` VARCHAR(45) NULL,
  `rfid` VARCHAR(45) NULL,
  `nfc` varchar(45) DEFAULT NULL,
  `floor_id` INT NULL DEFAULT NULL,
  `department_id` INT NULL DEFAULT NULL,
  `user_id` INT(11) DEFAULT NULL,
  PRIMARY KEY (`id`)
);

-- -----------------------------------------------------
-- Table `shelfs`
-- -----------------------------------------------------
CREATE TABLE `shelves` (
  `id` INT NOT NULL AUTO_INCREMENT,
  `name` VARCHAR(255) NULL,
  `room_id` INT NULL DEFAULT NULL,
  `user_id` INT(11) DEFAULT NULL,
  PRIMARY KEY (`id`)
);

-- -----------------------------------------------------
-- Table `trackings`
-- -----------------------------------------------------
CREATE TABLE `trackings` (
  `id` int(11) NOT NULL AUTO_INCREMENT,
  `caption` varchar(45) DEFAULT NULL,
  `user_id` int(11) DEFAULT NULL,
  `start_date` datetime DEFAULT NULL,
  `end_date` datetime DEFAULT NULL,
```

```
  `status` int(11) DEFAULT NULL COMMENT '0:inactive 1:active 2:started 3:finished',
  PRIMARY KEY (`id`)
) ENGINE=InnoDB DEFAULT CHARSET=utf8;

-- ----------------------------------------------------
-- Table `tracking_transactions`
-- ----------------------------------------------------
CREATE TABLE `tracking_transactions` (
  `tracking_id` int(11) NOT NULL DEFAULT '0',
  `user_id` int(11) DEFAULT NULL,
  `point_id` int(11) NOT NULL DEFAULT '0',
  `room_id` int(11) DEFAULT NULL,
  `transaction_date` datetime DEFAULT NULL,
  `result` int(11) DEFAULT NULL,
  PRIMARY KEY (`tracking_id`,`point_id`)
) ENGINE=InnoDB DEFAULT CHARSET=utf8;
-- ----------------------------------------------------
-- Table `notifications`
-- ----------------------------------------------------
CREATE TABLE `notifications` (
  `id` INT NOT NULL AUTO_INCREMENT,
  `sender_id` INT DEFAULT NULL,
  `subject` varchar(155) DEFAULT NULL,
  `message` TEXT,
  `sent_date` datetime DEFAULT NULL,
  PRIMARY KEY (`id`)
) ENGINE=MyISAM AUTO_INCREMENT=5 DEFAULT CHARSET=latin5;

-- ----------------------------------------------------
-- Table `notificaiton_details`
-- ----------------------------------------------------
```

```
CREATE TABLE `notification_details` (
  `notification_id` INT NOT NULL,
  `receiver_id` INT NOT NULL,
  `read_date` datetime DEFAULT NULL,
  `status` INT DEFAULT NULL COMMENT '0:unread, 1:read',
  PRIMARY KEY (`notification_id`, `receiver_id`));
-- -----------------------------------------------------
-- Table `pictures`
-- -----------------------------------------------------
CREATE TABLE `point_pictures` (
  `id` INT NOT NULL AUTO_INCREMENT,
  `caption` VARCHAR(45) NULL,
  `path` VARCHAR(500) NULL,
  `point_id` INT NULL,
  PRIMARY KEY (`id`));
-- -----------------------------------------------------
-- Table `inspection_pictures`
-- -----------------------------------------------------
CREATE TABLE `inspection_pictures` (
  `id` INT NOT NULL AUTO_INCREMENT,
  `caption` VARCHAR(45) NULL,
  `path` VARCHAR(500) NULL,
  `inspection_id` INT NULL,
  PRIMARY KEY (`id`));
-- -----------------------------------------------------
-- Table `settings`
-- -----------------------------------------------------
CREATE TABLE `settings` (
    `id` int(11) NOT NULL AUTO_INCREMENT,
    `key` varchar(45) DEFAULT NULL COMMENT 'the name of the parameter',
    `value` varchar(500) DEFAULT NULL COMMENT 'the value of the parameter',
```

```
  `platform` int(11) DEFAULT NULL COMMENT '0: all, 1 : web , 2 : mobile , 3 : service',
  `type` int(11) DEFAULT NULL COMMENT '0: text, 1: number, 2: boolean',
  `user_id` INT(11) DEFAULT NULL,
 PRIMARY KEY (`id`)
) ENGINE=MyISAM AUTO_INCREMENT=10 DEFAULT CHARSET=latin5;

-- ----------------------------------------------------
-- Auto insert `settings records`
-- ----------------------------------------------------
insert into settings values(2,'refresh_interval' , '10', 1,1,1);
insert into settings values(3,'defualt_map_location' , '34.234234,28.342342', 1,0,1);
insert into settings values(4,'localization' , 'US-en', 0,0,1);
insert into settings values(5,'server_time' , '', 0,0,1);
insert into settings values(6,'rfid_enable' , '0', 2,2,1);
insert into settings values(7,'nfc_enable' , '0', 2,2,1);
insert into settings values(8,'barcode_enable' , '0', 2,2,1);
insert into settings values(9,'rfid_power' , '30 dBi', 2,1,1);
```

SQL Code of Procedures and Functions

```
-- ----------------------------------------------------
-- PROCEDURE: get_inspection_transaction_count
-- ----------------------------------------------------
DELIMITER $$
CREATE PROCEDURE get_inspection_transaction_count(in start_date datetime,in end_date datetime,in regions VARCHAR(255),in point_types VARCHAR(255) )
BEGIN
 SET @query = CONCAT('
  select
    count(*) AS `inspection_count`,
    `p`.`id` AS `point_id`,
    `p`.`name` AS `point_name`,
```

```
        `p`.`region_id` AS `region_id`,
        `p`.`point_type_id` AS `point_type_id`,
        `i`.`id` AS `inspection_id`,
        `i`.`name` AS `inspection_name`
    from
        ((`inspection_transactions` `it`
        left join `points` `p` ON ((`p`.`id` = `it`.`point_id`)))
        left join `inspections` `i` ON ((`i`.`id` = `it`.`inspection_id`)))
    where `it`.`inspection_date` > ''' , start_date , ''' and `it`.`inspection_date` < ''' , end_date , ''' and `p`.`region_id` in (' , regions , ') and `p`.`point_type_id` in(' , point_types , ')
    group by `p`.`id` , `i`.`id`
    order by `inspection_count` desc');

  PREPARE stmt FROM @query;
  EXECUTE stmt;
  DEALLOCATE PREPARE stmt;
END;

-- --------------------------------------------------
-- FUNCTION: getValueName
-- --------------------------------------------------
DELIMITER $$
CREATE FUNCTION `getValueName`(value_type int) RETURNS varchar(45) CHARSET utf8
    DETERMINISTIC
BEGIN
        if (value_type = 0) then
                return 'Text Area';
        end if;
        if (value_type = 1) then
                return 'Numberable Area';
```

```
            end if;
            if (value_type = 2) then
                        return 'Check List Item';
            end if;
RETURN '';
END;
-- ----------------------------------------------------
-- PROCEDURE: getPointCounts
-- ----------------------------------------------------
DELIMITER $$
CREATE  PROCEDURE `getPointCounts`()
BEGIN
if((select count(*) from point_counts_view) != 0) then

SET @sql = NULL;
SELECT
  GROUP_CONCAT(DISTINCT
    CONCAT(
      'MAX(IF(point_type_name = ''',
      point_type_name,
      ''', point_count, 0)) AS ',
      '\"',point_type_name, '\"'
    )
  ) INTO @sql
FROM point_counts_view;
SET @sql = CONCAT('SELECT region_name, ', @sql, ' FROM point_counts_view
GROUP BY region_name');
PREPARE stmt FROM @sql;
EXECUTE stmt;
DEALLOCATE PREPARE stmt;
end if;
END;
```

```
-- ---------------------------------------------------
-- PROCEDURE: getTrackingResultName
-- ---------------------------------------------------
DELIMITER $$
CREATE FUNCTION `get_tracking_result_name`(value_type int) RETURNS
varchar(45) CHARSET utf8
   DETERMINISTIC
BEGIN
	if (value_type = 0) then
		return 'Not Checked';
	end if;
	if (value_type = 1) then
		return 'OK';
	end if;
	if (value_type = 2) then
		return 'Missing';
	end if;
if (value_type = 3) then
		return 'Tag is Missing';
	end if;
RETURN '';
END
```

SQL Code of Foreign Keys

```
-- ---------------------------------------------------
-- Foreign Key `shelves-room_id`
-- ---------------------------------------------------
ALTER TABLE shelves
ADD CONSTRAINT FK_room
FOREIGN KEY (room_id) REFERENCES rooms(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
```

```
-- -----------------------------------------------------
-- Foreign Key `rooms-floor_id`
-- -----------------------------------------------------
ALTER TABLE rooms
ADD CONSTRAINT FK_floor
FOREIGN KEY (floor_id) REFERENCES floors(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- -----------------------------------------------------
-- Foreign Key `rooms-department_id`
-- -----------------------------------------------------
ALTER TABLE rooms
ADD CONSTRAINT FK_department
FOREIGN KEY (department_id) REFERENCES departments(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- -----------------------------------------------------
-- Foreign Key `departments-building_id`
-- -----------------------------------------------------
ALTER TABLE departments
ADD CONSTRAINT FK_building_id
FOREIGN KEY (building_id) REFERENCES buildings(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- -----------------------------------------------------
-- Foreign Key `points-point_type_id`
-- -----------------------------------------------------
ALTER TABLE points
ADD CONSTRAINT FK_point_type
FOREIGN KEY (point_type_id) REFERENCES point_types(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
```

```
-- ----------------------------------------------------
-- Foreign Key `points-region_id`
-- ----------------------------------------------------
ALTER TABLE points
ADD CONSTRAINT FK_region
FOREIGN KEY (region_id) REFERENCES regions(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- ----------------------------------------------------
-- Foreign Key `points-shelf_id`
-- ----------------------------------------------------
ALTER TABLE points
ADD CONSTRAINT FK_point_shelf
FOREIGN KEY (shelf_id) REFERENCES shelves(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- ----------------------------------------------------
-- Foreign Key `points-room_id`
-- ----------------------------------------------------
ALTER TABLE points
ADD CONSTRAINT FK_point_room
FOREIGN KEY (room_id) REFERENCES rooms(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- ----------------------------------------------------
-- Foreign Key `inspections-point_group_id`
-- ----------------------------------------------------
ALTER TABLE inspections
ADD CONSTRAINT FK_point_group_id
FOREIGN KEY (point_group_id) REFERENCES point_groups(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
```

```
-- ----------------------------------------------------
-- Foreign Key `authentications-user_group_id`
-- ----------------------------------------------------
ALTER TABLE authentications
ADD CONSTRAINT FK_user_group_id
FOREIGN KEY (user_group_id) REFERENCES user_groups(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- ----------------------------------------------------
-- Foreign Key `users-user_group_id`
-- ----------------------------------------------------
ALTER TABLE users
ADD CONSTRAINT FK_user_group
FOREIGN KEY (user_group_id) REFERENCES user_groups(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- ----------------------------------------------------
-- Foreign Key `point_details-point_id`
-- ----------------------------------------------------
ALTER TABLE point_details
ADD CONSTRAINT FK_point_id
FOREIGN KEY (point_id) REFERENCES points(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- ----------------------------------------------------
-- Foreign Key `point_details-point_detail_pool_id`
-- ----------------------------------------------------
ALTER TABLE point_details
ADD CONSTRAINT FK_point_detail_pool_id
FOREIGN KEY (point_detail_pool_id) REFERENCES point_detail_pool(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
```

```
-- ----------------------------------------------------
-- Foreign Key `inspection_instruction-inspection_id`
-- ----------------------------------------------------
ALTER TABLE inspection_instruction
ADD CONSTRAINT FK_inspection_id
FOREIGN KEY (inspection_id) REFERENCES inspections(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- ----------------------------------------------------
-- Foreign Key `inspection_instruction-instruction_pool_id`
-- ----------------------------------------------------
ALTER TABLE inspection_instruction
ADD CONSTRAINT FK_instruction_pool_id
FOREIGN KEY (instruction_pool_id) REFERENCES instruction_pool(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- ----------------------------------------------------
-- Foreign Key `contracts-contractor_id`
-- ----------------------------------------------------
ALTER TABLE contracts
ADD CONSTRAINT FK_contractor_id
FOREIGN KEY (contractor_id) REFERENCES contractors(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- ----------------------------------------------------
-- Foreign Key `contracts-point_id`
-- ----------------------------------------------------
ALTER TABLE contracts
ADD CONSTRAINT FK_contract_point_id
FOREIGN KEY (point_id) REFERENCES points(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
```

```
-- ---------------------------------------------------
-- Foreign Key `point_inspection-point_id`
-- ---------------------------------------------------
ALTER TABLE point_inspection
ADD CONSTRAINT FK_point_inspection_point_id
FOREIGN KEY (point_id) REFERENCES points(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- ---------------------------------------------------
-- Foreign Key `point_inspection-inspection_id`
-- ---------------------------------------------------
ALTER TABLE point_inspection
ADD CONSTRAINT FK_point_inspection_inspection_id
FOREIGN KEY (inspection_id) REFERENCES inspections(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- ---------------------------------------------------
-- Foreign Key `point_pictures-point_id`
-- ---------------------------------------------------
ALTER TABLE point_pictures
ADD CONSTRAINT FK_pictures_point_id
FOREIGN KEY (point_id) REFERENCES points(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
-- ---------------------------------------------------
-- Foreign Key `inspection_pictures`
-- ---------------------------------------------------
ALTER TABLE inspection_pictures
ADD CONSTRAINT FK_inspection_picture
FOREIGN KEY (inspection_id) REFERENCES inspections(id)
ON UPDATE CASCADE
ON DELETE NO ACTION;
```