DEVELOPMENT OF A RFID BASED INVENTORY MANAGEMENT SYSTEM

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Zahid Hasan Chowdhury

Dedicated
To
All my well wisher

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List of Abbreviations

RFID	Radio Frequency Identification
IMS	Inventory Management System
OOP	Object Oriented Programming
EIN	Electronic Identification Number
UPC	Universal Product Code
RF	Radio Frequency
EAS	Electronic Article Surveillance
BAP	Battery Assisted Passive
FCC	Federal Communications Commission
EPC	Electronic Product Code
RO	Read Only
RW	Read Write
WORM	Write Once Read Many
RSSI	Received Strength Signal Indicator
LF	Low Frequency
HF	High Frequency
UHF	Ultra High Frequency
ISO	International Organization for Standardization
ISM	Industrial, Scientific and Medical
VB.NET	Visual Basic.Net
MySQL	My Structured Query Language
GUI	Graphical User Interface
ADO.NET	ActiveX Data Objects.Net
DBMS	Database Management System
ERD	Entity Relationship Diagram
OOAD	Object Oriented Analysis & Design
UML	Unified Modeling Language

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Abstract

Radio Frequency Identification (RFID) is a new generation of Auto Identification and Data collection technology which helps to automate business processes and allows identification of large number of tagged objects like assets, using radio waves. RFID based Inventory Management System (IMS) would allow fast transaction flow for the inventory and will prove immediate and long term benefits to inventory in traceability and security. The proposed system is based on Low Frequency Midrange RFID readers supported with antennas at transaction sections, and items containing RFID-transponders which are able to electronically store information that can be read or written even without the physical contact with the help of radio medium. The inventories across the globe started to use RFID to speed up the self check in or out processes, to control the theft and to ease the inventory control. Moreover, RFID could have a positive impact on the inventory control processes of the organization by either streamlining or formalizing them and facilitate the electronic storage of information captured in real-time, relating to the movement of stock and the amount of stock held, providing visibility to members of the organization. This project presents the experiments conducted to set up an RFID based IMS. Therefore, this system can play a vital role in removing the ongoing difficulties & irregularities in the inventory management in Bangladesh.

Chapter 1
Introduction

1.1 Overview

The project titled "RFID Based Inventory Management System" is an Inventory Management Software for monitoring and controlling the transactions in an inventory. This project is concerned with developing an Inventory Management System using Object Oriented Programming (OOP) [1], which mainly focuses on basic operations in an inventory like adding new user, member, items & updating information, searching items and items issued & returned from the members and facilitating the management system. In this system the Inventory Management becomes more efficient & easier to handle with its reliable system components.

Inventory Management System is used to keep records of items and manage items of any particular organization. By adopting RFID in middle or bigger sized inventories, the client's self-service efficiency can be greatly improved and the staff's work time can be effectively reduced. The barcode technology is slowly getting replaced by the RFID technology. It provides more intelligent inventory management which in turn means better service quality for the members.

The proposed system will consist of Passive RFID tag, a Low Frequency (LF) Midrange RFID reader with a user - friendly computer software. In this work, a system has been developed to keep records & track of items in IICT which are issued to any member. The developed scheme keeps records of items, users, members & vendors information. The RFID Reader will be placed in the room of inventory controller. In this system an RFID tag will be placed into the body of every asset which is registered in the system by physically attaching the tag. The reader will be interfaced with computerized database where the Electronic Identification Number (EIN) will be stored and used as key of information for tracking any tagged item entering or leaving from particular locations. If a registered member wants to borrow any item then the acting user would search his/her desired item information and by placing the tag within the range of the reader and then will assign or allocate that item

for the member. The database will be maintained about the Member who is taking the item and which item he/she is taking and that database will be updated when the item is returned. Moreover, different records regarding items location and members can also be viewed. As a result, the tracking of items becomes easier.

RFID technology is being implemented in a number of industries. Examples include vehicle & personnel access control, automotive anti-theft systems, product & asset tracking, animal identification, supply chain automation, waste management etc. In the warehouse & retail supply chain, goods come in and leave. Only occasionally they are returned. In inventories, items are taken out & returned many times. Thus the same RFID tag is re-used many times. In Bangladesh most of the organizations require and use a number of assets for different purposes. It is very difficult to maintain this large number of assets that are spread & used by different branch or site offices every day. It needs man power & hours to maintain these assets. Some of these organizations already use desktop based software & others use web based software with limited functionalities. So they require a complete low cost system. They can use this inventory management software to maintain & collect information within their network (intranet).

1.2 Motivation

Radio Frequency Identification (RFID) is a new promising wireless technology for automated data capturing [2]. It has the ability of identifying, locating, tracking and monitoring people & objects. RFID is one of the fastest growing and most beneficial technologies being adopted by business today and the benefits brings to the inventory are obvious. RFID is already being used in supply chain management, logistics, transportation, security, personnel identification, hospital management, airport luggage control, building access etc. In this project the RFID has been proposed for developing RFID based computerized management system for the inventory of an organization. In the traditional inventory management system the assets are identified manually primarily on paper based communications. The reliance on paperwork and data entry depends on the staff's efficiency. The more the assets become, the less accurate and effective are these management practices. Later on Universal Product

Code (UPC) or barcodes have been used to overcome this situation. RFID tags are now in the market for the replacement of barcodes having a number of important advantages over the older barcode technology. RFID tags do not have to be visible to be detected or scanned. It can be read even when it is embedded in an item. For instance a tagged item could be inside a box and yet still be scanned. RFID systems allow scanning from further distances than Barcode scanning. Therefore it is necessary to develop a RFID based new system instead of barcode reader to ease the problem of the conventional inventory management system and to eliminate paperwork and manual processing.

1.3 Objective with Specific Aims & Possible Outcome

The aim of this project is to develop a RFID based asset tracking and management system to provide real time audit and traceability of assets. To fulfill the aim the project will focus on following objectives:

- To develop a Graphical User Interface (GUI) for interfacing the RFID reader with computer.
- To develop a database for Asset Management System.
- To test the system extensively and to use for real time asset management.

1.4 Scopes

Some scopes of this software are given below:

1. Any particular organization which has assets can use this software to keep records of assets & to manage assets.
2. Any user can have access the software within a network (intranet).
3. Any user will be able to know about Items Issue & Return information.
4. A user will be able to log in into the system using given password.
5. After signing in a general user will be able to
    - Change the password.
    - Add, View, Edit & Delete Items Issue information.
    - Add, View, Edit & Delete Items Receive information.
    - Track all allocated items information with reliable Search options.
    - Verify Member's Fine information.
    - View & Print Reports with specific Search options.
6. An administrator will be able to log in into the system using given password.
7. After signing in an administrator will be able to
    - Change the password.
    - Add, View, Edit & Delete Items Category information.
    - Add, View, Edit & Delete Items information.
    - Add, View, Edit & Delete Items Issue information.
    - Add, View, Edit & Delete Items Receive information.
    - Add, View, Edit & Delete User's information.
    - Add, View, Edit & Delete Vendor's information.
    - Add, View, Edit & Delete Member's information.
    - Track all allocated items information with reliable Search options.
    - Verify Member's Fine information.
    - View & Print all Reports with specific Search options.

Chapter 2
An Overview of RFID Technology

2.1 Introduction to RFID

RFID (Radio Frequency Identification) [3] is used in all areas of automatic data capture allowing contactless identification of objects or person using RF electromagnetic fields to transfer data from a tag attached to an object, for the purposes of automatic identification, locating and tracking. They can similarly be embedded in identification badges to provide hands-free access to secure areas or implanted beneath the skin of pets, such as cats and dogs, so they can be returned to their owners if they are lost.

RFID is a technology where information can be read from and/or written to a microchip without contact might be using HF magnetic induction or UHF transmission and reflection. Both HF and UHF techniques have the same function, interfacing between a reader & an information storage device by means of antennas, but they are quite different in operation.

RFID, which is a “no touch technology”, can be used in surveillance, detection of counterfeiting, computation, tracking & checking for objects in various fields of industry such as manufacturing, construction & health care. With applications ranging from secure internet payment systems to industrial automation & access control, RFID technology solutions are receiving much attention in the research & development departments of large corporations. RFID is a major growth in auto ID, allowing emergency vehicles to safely trip traffic signals & providing the technology behind contactless smart cards, "auto piloting" cars, and production automation.

An RFID system has a few major components, a reader with an antenna, a tag & a database, often a Personal Computer with connection to a larger network. The tag is placed on the object that is to be identified, contains the suitable information. The reader has a number of different responsibilities like powering the tag, identify the tag, read & sometimes write data to the tag. The reader also communicates with the database in which the information from the tags will be processed.

Typical RFID system use inductive coupling between the card and the reader. Both of them have coils which interacting with each other (magnetic coupling). This interaction makes it possible to transfer power to the card (through alternating magnetic field or pulses) and transfer information (modulating the magnetic field). Typical this kind of inductively coupled systems operate at 125-kHz to 13.56-MHz frequency range. ISO frequencies of 125 kHz and 13.56 MHz are generally used.

2.2 Fundamental Components in an RFID System

An RFID system largely consists of Tags (transponder), Readers (transceiver) and Middleware (Host Computer).

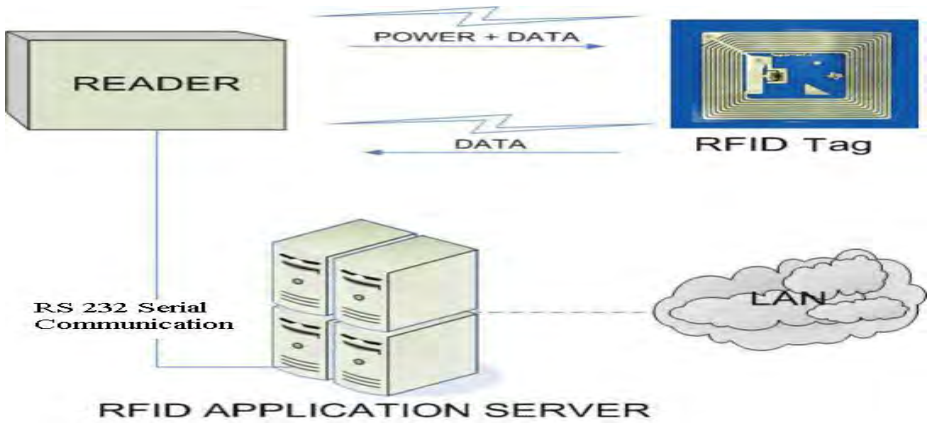

Figure 1: The Basic Building Blocks of an RFID System.

2.2.1 RFID Tag

An RFID tag is a device that stores certain unique information. The tag also known as the transponder, from the term's **trans**mitter and res**ponder**, holds the data that is transmitted between the tag and the reader. A tag consists of an Integrated Circuit (IC) with memory (for storing and processing information, modulating and demodulating a radio-frequency (RF) signal, collecting DC power from the incident reader signal, and other specialized functions) and an antenna for receiving and transmitting the signal. When the object that is tagged comes in a reader's interrogation zone (reading zone) and the reader sends out a radio wave to the tag then the tag powers up and the data from its memory is retrieved and transmitted to the reader, in some cases new

information is sent from the reader to the tag. The reader sends the information to a database that processes the data from the tag in a suitable way. Because RFID is using radio waves, it is not necessary to have a *line of sight* between the reader's antenna and the tag.

The distance between the transponder and reader depends on which coupling and frequency that are used. It is possible to achieve distances from a few centimeters up to 100 meters. The speed which the data can be transferred between tag and reader is also depending on which frequency that is used; lower frequencies can not transfer data as fast as the higher frequencies, due to the higher clock frequency allowed in the higher frequencies. This means that if it is necessary to read many tags at the same time a higher frequency is preferred.

A key classification of RFID tags is the source of power. However, there are some disadvantages of using power for the tag's circuitry. The tag's life span depends on the battery; it stops working when the battery dies. Active RFID tags are also larger and more expensive than passive RFID tags. This is particularly important in environments that may have special requirements and different tracking needs, such as health care facilities and hospitals that might be tracking large and expensive assets with active RFID tags, but smaller, less-expensive or disposable inventory items with passive or semi-passive tag technologies.

2.2.1.1 Tag Formats

Tags come in many shapes and sizes. The reading range of the different tags are depending on which frequency that are used and the power level that are transmitted from the reader. The tags also differ in memory capacity and temperature survivability. Almost all tags are encapsulated for durability against shock, moist, dirt and chemicals, but there are also cheaper tags without encapsulation.

Figure 2: Tag and Sensor Overview

The size of a tag depends primarily on two things, whether the tag have a battery or not and the size and shape of the antenna. The size and shape of the antenna depends on which frequency that is used.

2.2.1.1.1 1-bit Transponder

The simplest of all tags is the 1-bit transponder. The 1-bit transponder is used in Electronic Article Surveillance (EAS). The 1-bit tag can only represent two states 1 and 0, which means that the system only has two states as well, tag in readers interrogation zone or no tag in readers interrogation zone, there are no identification done. Despite of the 1-bit transponder limitations they are very widespread and its main application is anti-theft systems in shops.

2.2.1.1.2 Glass Housing

A glass tag is encapsulated in glass. The glass tag is mostly used for animal identification. The tag gets inserted under the skin of the animal and can later be read, or written, from the outside. These tags use the lower frequencies so the electromagnetic wave can penetrate the animal's tissue.

2.2.1.1.3 Disks and Coins

A very common construction is the so-called disk (coin), a tag in round injection molded housing with a diameter ranging from a few millimeters to several centimeters.

2.2.1.1.4 Smart Labels

Smart Label also called *Smart Tag*. Like bar codes, these labels are able to easily applied, unobtrusive, quick to read, cheap & disposable. On a label the antenna is printed, etched or punched on a thin paper/polyester substrate with a chip. They are very flexible and can easily be attached to any products. They are less resistant to environmental conditions than the encapsulated tag but much cheaper. The labels provide low-cost benefits in open systems. When a label is involved in an open system it is attached to the product somewhere in the supply chain but never removed, so when it reaches the consumer it will never be reused. The labels can also be printed with all existing formats and layouts of text, barcodes and graphics. These printers also write information to the tags. The benefits that smart labels offer over bar coding systems are beginning to outweigh the shortcomings and the costs of implementing smart labels solutions, making smart labels a cost-effective technology.

2.2.1.1.5 Smart Cards

Smart card, or contactless smart card, often looks like a normal credit card. There are three types of smart cards; close-coupling smart card, proximity-coupling smart card and vicinity coupling smart card. The close-coupling smart cards have extremely short reading range and are often used for payment in public transportation like buses, planes subways. Proximity coupling smart cards have a reading range of a few centimeters, they are often used for large public gatherings that requires access control like sport events or concerts. Vicinity-coupling smart cards are designed to have a reading range up to a half meter or so, they are used as controlled access cards in office buildings. [4]

2.2.1.2 Special Purpose Tags

2.2.1.2.1 Sensor Tags

A sensor tag is not only designed to read or write from its memory, it can also perform simple tasks like measure air pressure, temperature or the presence of bacterial agents. A sensing device is packed together with the tag to record whatever it was designed to monitor. The challenge is when you would like a passive sensor tag. This means that the sensor only has power when the tag is in a reader's interrogation zone. That means that the sensor only can record the conditions for a very brief period of time and with a very limited power. Sensor tags are mostly active.

2.2.1.2.2 Chipless Tags

A chipless tag is, as it sounds, a tag without a chip. They are therefore passive and most of the technologies involve the idea of encoding unique patterns on the surface of the tag that reflects the radio waves.

2.2.1.2.3 Encrypted Tags

The encrypted tag is used whenever you are looking for a secure system like payment systems, ticketing or when you store company sensitive data on the tags like process flow.

2.2.1.3 Tag Types

RFID tags can be Passive, Active or Battery Assisted Passive. Since tags have individual serial numbers, the RFID system design can discriminate several tags that might be within the range of the RFID reader and read them simultaneously.

2.2.1.3.1 Passive RFID Tag

A passive tag does not have a battery; they use the energy that the electromagnetic wave from the reader induces in the antenna to power up the chip and to transmit the data back to the reader. Passive tags reflect energy from the reader or receive and temporarily store the energy in order to generate the tag response to the reader. A passive tag is cheaper and smaller because it has no battery. Instead, the tag uses the radio energy transmitted by the reader as its energy source. The interrogator must be close for RF field to be strong enough to transfer sufficient power to the tag.

Rely entirely on the reader as their power source. These tags are may read up to 30 feet away depending on the type of material to which they are attached and have lower production costs. Accordingly, they can be attached to the merchandise that is less costly, higher volume or disposable. These tags may be manufactured to be disposable, along with the items on which they are placed. A recent breed of passive tags have incorporated electronic elements to store and save the energy received from the reader in a fashion similar to how rechargeable batteries work. Tags may then use the power from this source to transmit data in longer range of up to 50 feet.

Passive RFID systems are composed of three components: an interrogator (reader), a passive tag and a host computer. The tag is composed of an antenna coil and a silicon chip that includes basic modulation circuitry and non-volatile memory. The tag is energized by a time-varying electromagnetic radio frequency (RF) wave that is transmitted by the reader. This RF signal is called a carrier signal. When the RF field passes through an antenna coil, there is an AC voltage generated across the coil. This voltage is rectified to supply power to the tag. The information stored in the tag is transmitted back to the reader. This is often called backscattering. By detecting the backscattering signal, the information stored in the tag can be fully identified. Passive RFID devices also use a serial bus, but the power, clock, and data are all in the same signal. Instead of wires, this signal is carried through wireless means.

2.2.1.3.2 Active RFID Tag

Active RFID tags have their own internal power source, which is used to power the integrated circuits and periodically transmits its ID signal. It allows very low-level signals to be received and can still generate high-level signal to be transmitted back to the reader. Active RFID tags carry battery or some other power, which provides a smarter function; can send more information than simple ID code, or has a longer range than interrogator-powered versions. These tags are reserved for more costly items that are read over greater distances. They broadcast high frequencies from 850 to 950 MHz and ISM 2.4 GHz band that can be read from 100 feet or more away. Additional batteries can boost a tag's range to over 300 feet (100 meters).

The active tag lies in sleep-mode until it gets a wake-up signal from the reader. As soon as the tag gets the wake-up signal the data carrier gets into operating mode. After the completion of the data transaction, the tag gets into sleep-mode again. They have therefore much longer reading range than a passive tag. On the other hand because they have a battery, they have finite lifetime.

Active tags, due to their onboard power supply, also transmit at higher power levels than passive tags, allowing them to be more effective in "RF challenged" environments like water (including humans/cattle, which are mostly water), metal (shipping containers, vehicles), or at longer distances, generating strong responses from weak requests (as opposed to passive tags, which work the other way around). Typical applications of Active RFID Solutions:

- Personnel/Vehicle Access Control
- Parking Lot Management
- Fleet Monitoring
- Inventory Management
- Container & Pallet Tracking
- Manufacturing Line Management
- Skids and Bins Tracking
- Body Temperatures of Patients & Babies Monitoring
- Conference Personnel Tracking
- Temperature/Humidity/Sunshine Monitoring
- Personnel Tracking at Mining & Oil Rig
- Personnel & Asset Tracking in Hospital
- Prison Inmate Tracking
- Tourist Group Tracking

2.2.1.3.3 Semi-Passive RFID Tag

A semi-active, or semi-passive depending on the manufacture, also has an onboard battery. These tags are sometimes called Battery Assisted Passive (BAP). Semi-passive RFID uses an internal power source to monitor environmental conditions, but requires RF energy transferred from the reader/interrogator similar to passive tags to power a tag response. Semi-passive tags differ from passive in that semi-passive tags possess an internal power source (battery) for the tag's circuitry which allows the tag to complete other functions such as monitoring of environmental conditions (temperature, shock) and which may extend the tag signal range. Like the active tags, semi-passive tags are also reserved for costly items that are read over greater distances -- broadcast high frequencies from 850 to 950 MHz that can be read 100 feet (30.5 meters) or more away. If it is necessary to read the tags from even farther away, additional batteries can boost a tag's range to over 300 feet (100 meters).

This version is just a passive reflector with a binary function. It either passively reflects, triggering response or just sits there and does not respond at all. Semi-passive tags do not transmit a beacon, but rather only transmit their data once interrogated by a reader. Due to the onboard power source, semi-passive tags much like active tags can contain on-board processor for customized applications and sensor integration. Semi-passive tags are ideal for rapid development of customized RFID tags, since they do not require FCC certification.

2.2.1.4 Tag Memory

Tags can be differentiated on the basis of Memory type. Transponders with memory functions range from simple RO tags to tags with intelligent crypto logical functions. There are tags available with memory ranges between a few bytes up to around 4 MB of memory. It depends on what type of tag, passive or active, you choose to use and what standard you will follow. There are many companies those following the Electronic Product Code (EPC) standard which allows 96 bits of memory.

2.2.1.4.1 RO

A Read Only (RO) tag has a pre-programmed serial number written on its memory. The serial number is incorporated during chip manufacturing. The user can not alter this serial number or write new data to the tag. When the tag enters a reader's interrogation zone it will instantly start to send out its unique identification number and it will do so continuously until it is out of the reading zone. The data communication is unidirectional; data transmission from the reader to the tag is not possible. When using RO tags you need to connect the serial number of the tag with which product it involves with appropriate software.

2.2.1.4.2 RW

RW tags are often called *Smart Tags*. With a Read Write (RW) tag you can write new information to the tag or write over existing information. It is only possible to write information to the tag when it is in a reader's interrogation zone. You can of course also read information from the tag.

RW tags usually have a pre-programmed serial number that can not be written over. But unlike the RO tags an RW tag also have a memory space where the user can put his own information. An RW tag has limited write cycles depending on which type of memory it is using.

2.2.1.4.3 WORM

A Write Once Read Many (WORM) is a tag which is something between an RO and an RW. You can, which the name indicates, write to the tag one time and read it as many as you like. When you have written to the tag the data on the tag becomes locked and you can only read from it. WORM tags can have additional data (like another serial number) added once, but they cannot be overwritten.

2.2.2 RFID Reader

An RFID system uses tags, or labels attached to the objects to be identified. Two-way radio transmitter-receivers called interrogators or readers send a signal to the tag and read its response. It creates a read zone between tags and readers. Below the reader 'zaps' the chip with a radio wave, the chip replies with its EPC.

Figure 3: Passive RFID Tag's response by the Reader's RF signal.

The reader connects with the tag and the host computer. The reader receives the tag's information and sends it through standard interface to the host computer. The tags emit identifiable radio waves and the readers receive this information through their internal antennas. The range of the read zone depends on the reader's power and the frequency used to communicate as well as the tag used. Lower-frequency tags can be read from shorter distances and higher-frequency tags from longer distances.

The readers generally transmit their observations to a computer system running RFID software or RFID middleware. When the tagged item moves in or passes by the electromagnetic fields, the chips in that tag are stimulated by radio waves. The chip is powered up and then broadcasts its data. Even though most tags operate similarly, their applications differ depending on the location of reader and the types of readers used. There are three basic kinds of RFID reader installations: hand-held, fixed reader installed in area, and fixed reader installed at chokepoint.

2.2.2.1 Hand-held Reader

A handheld reader is a small, lightweight device that is used to find tagged items quickly and conveniently. Users can grip the hand-held reader easily and carry this while users look for specific things that they want in large and complicated areas. The user can determine how far away the desired tagged items are located through measure and display of the Received Strength Signal Indicator (RSSI).

2.2.2.2 Fixed Reader Installed in Area

A fixed reader is installed on a stationary point like a wall or a ceiling to read movement, location or internal data of objects in the area. The reader collects the information continuously. Depending on the reader size (especially its antenna), the range & accuracy is greater than hand-held readers. In the other words, the antenna size of the tag & reader is important for range considerations because a bigger antenna can collect & broadcast more energy. So, fixed readers are used mainly with active RFID tags.

2.2.2.3 Fixed Reader Installed at Chokepoint

A fixed reader at a chokepoint is the most common application of RFID. The operating principle of the reader is to read a signal whenever the tagged objects arrive or depart. Thus, users are able to see the flow of assets with ease. Moreover, it is efficient because all objects have to flow through the chokepoint. Fixed readers installed at chokepoints are used mainly with passive RFID tags.

2.2.3 Middleware

Middleware is the software loaded on the RFID host computer to integrate various data received from several readers. This means that middleware connects two disparate applications, reader & host computer, allowing these to pass information between them. Through middleware, users can get data from the reader for displaying on the host computer such as Electronic Product Code (EPC) number, sales, date, inventory and directions in the movement of hardware (tags and readers).

2.3 Reader Antenna

An antenna is connected to a reader (transceiver) and the antenna sends out the reader's signals. Basically, the reader tells the antennas how to generate the proper RF field. This field can cover an area from a few centimeters up to 30 meter or more. How large that area can be is depending on the power output & the frequency. When an RFID tag moves into the antenna's radio field, it becomes activated. After the activation it sends back the information that is programmed into its memory. Through its array of antennas, the reader receives the tag's signal and decodes the signal. The decoded signal is then sent to the software system. A reader can also transmit special signals to a tag, for example telling a tag to come alive, synchronizing a tag with the reader or interrogating all or part of the tag's content. Antennas can act continuously or on demand. The continuously active system is used when tags are present regularly or for multiple tag reading in the antenna's detection field. This detection field can be activated only when needed by a sensor of some kind and is called the on-demand method.

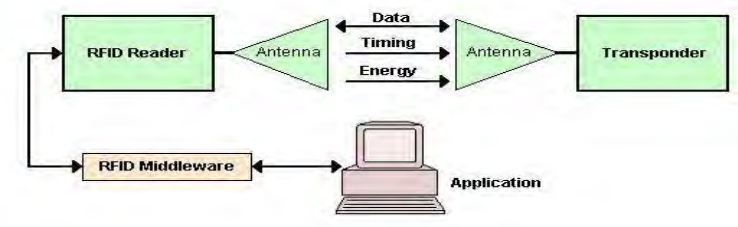

Figure 4: RFID Antenna's function.

Normally one to four antennas can be attached to one reader. There are some readers where up to eight antennas can be attached. The reason for that is the need of free sight when using frequencies in the UHF band to read on metal. With, for example, four antennas connected to a reader it is possible to cover a larger reading area from four directions. This is very useful, especially if the tagged items have different orientations in the reading area. An antenna gate can, for example, be used in a doorway or in the process line. It is important to choose the right type of antenna to an RFID system. Preferably the antenna should be a compromise between a very sharp tune, i.e. maximum performance without detuning, and a very flat tune that is less affected by detuning.

2.4 RFID Standards

Development of RFID in industry, standardization for RFID becomes more important. The purpose of RFID is convenient & rapid application, but if it is not easy to interact with different locations or items, it will not serve its purpose. Thus, two types of standards are considered here: Data standards and Technology standards.

Data standards can provide unified data through the EPC. The EPC is a unique code number which has same structure in every tag. This code, which was invented by MIT Auto-ID Center, is divided into 4 portions. The 2 digit header number identifies the length, type, structure, version & generation of the EPC. EPC manager number means the company contained in the production of the manufacturer. With 28 bits, the EPC manager is able to cover as many as 228 companies. Object class represents the stock keeping unit (SKU) when applied to retail products. A serial number is used to identify each product; it can share about 68 billion items. So the EPC will not be repeated for different items.

Figure 5: Electronic Product Code (EPC)

Technology standards, that are different to EPC data structure, are associated with air interface (frequency) between RFID tags & readers. There are several standards such as the following: ISO 15693 (Smart Labels), ISO 14443 (Contactless payments) & ISO 11784 (Livestock), but the ISO 18000 standards family is used most widely. [5]

•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

Even though these various standards exist, one RFID tag does not enable interoperability with the reader of different manufacturers. However, ISO 18000-6 A/B (UHF) tried to communicate with RFID hardware by different manufacturers & 2nd generations by EPC global and ISO 18000-6 C (Passive UHF) have agreed to interoperate their data. The unification of technology standards will improve the utility of RFID.

2.5 RFID Frequencies

Just as TV broadcasts in VHF or UHF band, similarly RFID systems also use different bands for communication. Because of RFID systems generate & radiate electromagnetic waves, they are justifiably classified as radio systems. The function of other radio services must under no circumstances be disrupted or impaired by the operation of RFID systems. So understanding the relation between RFID & frequency can provide better knowledge about the application of RFID. RFID systems generally operate at three different frequencies. These are low frequency (LF), high frequency (HF) & ultra high frequency (UHF). There are advantages & disadvantages to all of these frequencies.

LF	HF	UHF	Microwave
Access control	Supply chain	Supply chain	
Livestock Tracking	Ticketing	Logistics	Emerging technologies
Race timing	Wireless commerce	Warehousing	Asset tracking
Auto immobilizers	Product authentication	Pallet tracking	
Wireless commerce		Asset tracking	

Table 1: Different Applications by Different Frequencies in RFID.

Low frequency (LF) is generally referred to as frequency in the range of about 30 - 300 KHz. RFID mainly uses 125 - 134 KHz frequencies. The typical read range of a LF RFID tag is typically less than 0.5 meters or 1.5 feet & transfers small data at rates of less than 1 kbps. LF RFID tags are less sensitive to interference so they generally perform better in harsh environments, on metal surfaces & in the presence of liquids.

High Frequency (HF) is 3 - 30 MHz. HF systems typically operate at a frequency of 13.56 MHz. They have a higher read speed & higher read range than LF RFID systems. The read range for HF RFID is typically 1 meter or 3 feet. HF can transfer data approx. 25 kbps. Like LF, this frequency passes through water, but also metal.

Ultra high frequency (UHF) is 300 MHz - 3 GHz. UHF RFID systems typically operate at a frequency of 868 MHz - Europe, 902 - 928 MHz - USA. They have a higher read speed & a higher read range than HF RFID systems. The read range for UHF RFID is typically 3 meters or 9.5 feet and transfers 1 kbps, but it cannot penetrate both water and metal.

As typical *Microwave frequency* is 2.45 GHz, it can read long distance & transmit data at high rates. Microwave frequency is used for toll booths on a highway. Because of these differing characteristics, the application is also different for each frequency range.

Band	Regulations	Range	Data Speed	Remarks	Approximate tag cost in volume (2006) US $
120–150 kHz (LF)	Unregulated	10 cm	Low	Animal identification, factory data collection	$1 US
13.56 MHz (HF)	ISM Band worldwide	1 m	Low to moderate	Smart cards	$0.50
433 MHz (UHF)	Short Range Devices	1–100 m	Moderate	Defense applications, with active tags	$5
868-870 MHz (Europe) 902-928 MHz (North America) UHF	ISM Band	1–2 m	Moderate to high	EAN, various standards	$0.15 (passive tags)
2450-5800 MHz (Microwave)	ISM Band	1–2 m	High	802.11 WLAN, Bluetooth standards	$25 (active tags)
3.1–10 GHz (Microwave)	Ultra Wide Band	Up to 200 m	High	Requires semi-active or active tags	$5 projected

Table 2: RFID Frequency Bands.

2.6 Interfaces between Reader and Software

Data exchange between the control unit and the software is performed by an RS232 or RS485 interface. Other interfaced used are Bluetooth, Ethernet (TCP/IP), WLAN and Zig Bee.

2.7 RFID vs. Barcode

RFID is expanding its use to industry, education and the others more widely. However, RFID tags will not replace every barcode, but RFID obviously has distinct advantages over the barcode.

• RFID tags are more difficult to counterfeit because each chip has a unique serial number, while barcode can be duplicated easily because they are printed on paper.

• Barcodes should scan products one by one, but RFID tags can scan items from far away automatically without human intervention.

• RFID does not rely on line-of-sight.

• RFID tags can store more data than barcodes do.

• RFID tags can read and write as well as revising.

• RFID tags are not affected by harsh environments, while barcodes are.

2.8 Limitations of Reader and Tag Communications

Due to the science of radio frequency is analogue, as that RF susceptible to degradation caused by interference from spurious RF sources and environmental conditions. The following examples can cause interference:

- Liquid, for example water.
- Metal, foil, or other metallic objects.
- High humidity.
- Extreme temperatures. Very cold or very hot.
- Motors and engines.
- Cordless phones.
- Wireless devices, such as cell phones and Personal Digital Assistants (PDA).
- Wireless computer or communication network.

How much these conditions affect a given RFID system's performance depends on the operating frequency. One of the most significant roles in the success of an RFID deployment is the capability to address interference issues. Because of that, it is critically important to extensive trials and pilots to enable optimal placement and installation of the individual RFID components. RF engineers are making great progress in designing systems to push the RF physics to overcome some of these limitations. At the same time, many of the inconsistencies and inaccuracies also can be addressed with sophisticated software solutions that implement error correction, fault tolerance and redundancy.

Chapter 3

Development Process of the System

3.1 Outline of Methodology

The project consists of the following Stages:

1. Feasibility Study
2. System Study Stage
    I. Requirement Gathering
    II. Specification
    III. Planning
3. Design Stage
4. Coding Stage
5. Testing Stage
6. Operational Mode
7. Modification Stage

This process followed the "Rapid Prototype Software Life Cycle Model". The brief overview of the process is depicted below.

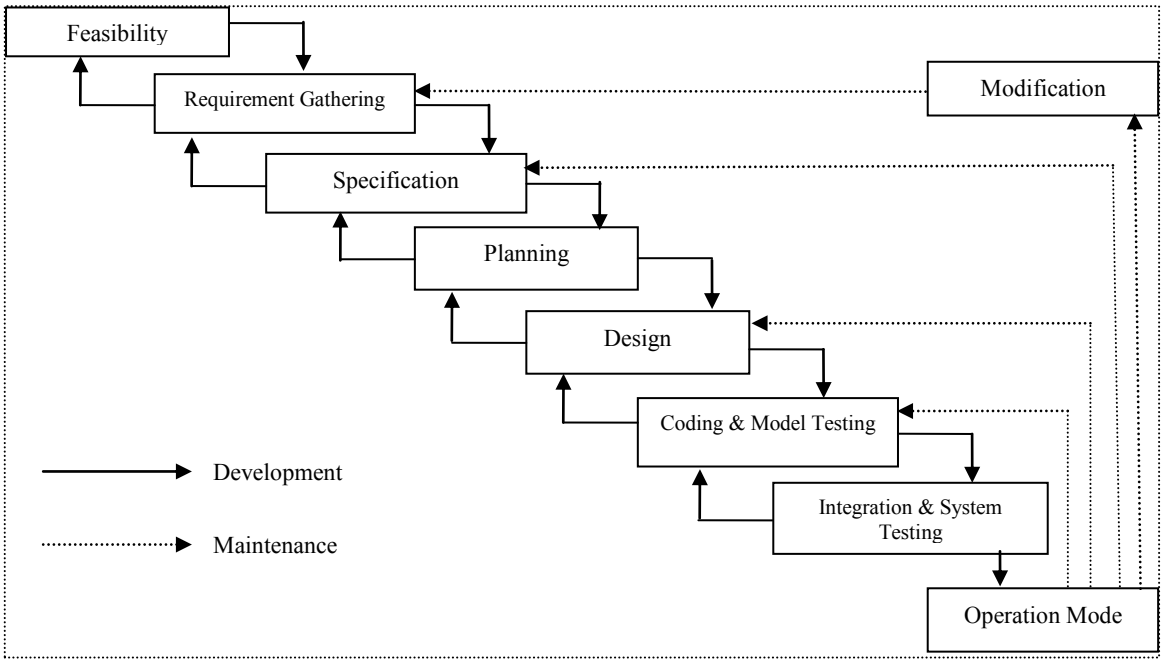

Figure 6: Rapid Prototype Software Life Cycle Model.

3.2 Feasibility Study

A project feasibility study is an exercise that involves documenting each of the potential solutions to a particular business problem or opportunity. The purpose of a project feasibility study is to clarify the wanted outcome of the project. It is important to understand what the project will deliver. If a project is seen to be feasible from the results of the study, the project can be continued to the next stage.

For an organization without any software it is very difficult to maintain these large numbers of asset that are spread & used by different branch or site offices every day. Some of these organizations already use desktop based software & others use web-based software with limited functionalities. Some organizations maintain a section for asset management. So, a complete low cost system will be financially feasible. The system will reduce maintenance cost. The system will save user's time and give proper information when she/he wants.

3.3 Requirement Gathering, Specification & Planning

Requirement Gathering, specification & planning are essential parts of any project and project management. During this process, different similar software is analyzed and hardware requirements are also studied & specified in this phase. Different types of idea about the development are written up. The requirement process is completed when the specifications for the new software product are written in a formal document called the requirements specification document. In planning phase, a plan is made to develop this software with requirement specification document.

3.3.1 Identify User

Identifying the Administrator and the General users of software is very important. The different types of users of the software are as follows:

1. Admin User (Administrator)
2. General User

3.3.1.1 Admin User (Administrator)

System administrator can do anything on the software. System administrator is responsible for updating and maintaining the database & codes of the software. The administrators could view/insert/edit/delete item, category, user, vendor and member's information. She/he could also able to view/insert/edit/delete items issue & receive from the members and verify member's fine information.

3.3.1.2 General User

A general user is a responsible person appointed by the organization, who could view/insert/edit/delete items issue & receive from the members and change his/her own password. She/he could also able to verify member's fine information.

3.3.2 Identify Member

Members are faculties, employees and students of the organization. To use this service, a member should have registered by the user. Then she/he could borrow her/his desired items from the inventory system.

3.3.3 Analysis of Main Features

The Inventory Management System software is designed to manage its fleet of items more effectively & efficiently. An administrator can monitor items distribution, retrieve any item's historical information using this software. Some key features of Inventory Management System are discussed next.

Allocation Process

Any member can demand for an item. A user can allocate that item by select the specific item by using the RFID reader & member ID. Users also add the allocated days of issued item and the delay fee per day information which would be reasonable. Users can see the inventory stock of item allocation.

Control Information

The administrators can control different information such as users, issued days, fines information etc. General users can only view limited information.

Sending to Issue Location

Users can select the specific item by using the RFID reader and add the information regarding sending of it to specific location according to member's need. Users can also insert the information about the allocated days of issued items and the delay fee per day.

Return from Issue Location

Users can select the specific item by using the RFID reader and verify the information regarding item issue including fine and update the information of its new location where it would be.

Search Records

Users have power to search previous information from database by ID, name, address, date or location. Users can search and select different records related to user, member, item, category, vendor information.

Print Option

Users can print inventory stock report which contains the information about item, location and issue status. Users can print member's fine report which contains the allocation information about member, item, issued by, date, date, fine, location etc. Nevertheless admin users have specific search options where they can print the information about user, member, item, category and vendor. Users can keep hard copies of allocation records through print option.

3.3.4 Software Architecture

The developed Inventory Management System works within a network (Intranet). The architecture for the system contains two necessary components: [6]

- The Data & Data Server
- The Client Application & Client.

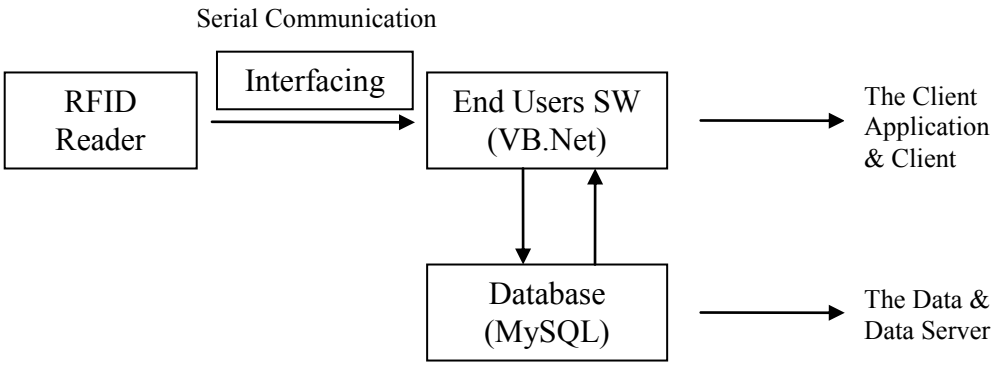

Figure 7: Overall System of IMS using RFID System.

3.3.5 Software Interfaces

In this project the following tools software are used:

Software: VB.NET

Version No.: 2008 (VB 9.0)
Source: Microsoft Corporation
Purpose:

Microsoft Visual Studio 2008 is sets of tools that are simple, fun, and easy to learn. They enable developers of all skill levels—hobbyists, students, experienced, and casual developers—to create cool, fun applications.

Definition of the Interface:

VB.NET is an object-oriented computer programming language that can be viewed as an evolution of the classic Visual Basic (VB), which is implemented on the .NET Framework.

Software: MySQL Community Server

Version No.: 5.5
Source: MySQL
Purpose: Required as Database Server.

Definition of the Interface:

MySQL is the world's most popular open source database software. With superior speed, reliability and ease of use, MySQL has become the preferred choice of corporate IT Managers because it eliminates the major problems associated with downtime, maintenance, administration and support. [7]

Connector/NET: MySQL Connector .NET

Version No.: 6.5.4
Source: MySQL
Purpose: ADO.NET Driver for MySQL.

Definition of the Interface:

MySQL Connector/Net is an open-source .NET data provider for MySQL. Connector/Net is a fully managed ADO.NET driver for MySQL written in 100% pure C# and does not utilize the MySQL client library. One managed-code, external library is required (SharpZipLib) for compression of the data stream between the driver & MySQL. (This used to be known as ByteFX.Data.) Connector/Net lets you easily develop .NET applications that require secure, high-performance data connectivity with MySQL. It implements the required ADO.NET interfaces and integrates into ADO.NET-aware tools. Connector/Net includes full support for the features provided by MySQL Server up to and including MySQL Server version 5.5.

SQLyog: MySQL GUI

Version No.: 9.6.1
Edition: Community Edition
Source: Webyog, Inc.
Purpose: MySQL Front-end, MySQL Monitoring Tool.

Definition of the Interface:

SQLyog - MySQL GUI is the most powerful MySQL manager and admin tool, combining the features of MySQL Administrator, phpMyAdmin and other MySQL Front Ends and MySQL GUI tools.

Crystal Reports: Crystal Reports Basic for Visual Studio 2008

Version No.: 2008
Source: Microsoft Corporation
Purpose: To generate & display interactive reports.

Definition of the Interface:

Crystal Reports is a business intelligence application used to design and create powerful, user-friendly & dynamic reports from a wide range of data sources. Crystal Reports allows users to graphically design data connection(s) & report layout. In the Database Expert, users can select & link tables from a wide variety of data sources, including Microsoft Excel spreadsheets, Oracle databases, Business Objects Enterprise business views & local file system information.

3.3.6 Hardware Interfaces

This system is developed for the organizations which have their own network. So, there is no need of extra computer or internet connection. Printer is necessary for printing the documents generated from the system.

RFID Kit: Series 2000 Reader System

Model No. : S2000 Micro Reader RI-STU-MRD1

Source: Texas Instruments Incorporated

Purpose:

The easy-to-use plug and play Low Frequency Midrange Reader Evaluation Kit gives you the opportunity to explore the capabilities of Texas Instruments' 134.2 kHz Radio Frequency Identification (RFID) technology TIRIS™. RFID creates an automatic way to collect information about a product, place, time or transaction quickly, easily and without human error. It provides a contactless data link, without need for line of sight or concerns about harsh or dirty environments that restrict other auto ID technologies such as bar codes. [8]

Definition of the Interface:

Protocol Frame PC to Micro-Reader:

In order to select the "Read Mode" of the Micro-Reader we have to follow this frame to communicate with the RFID Tags in the middleware.

Start	Length	Cmd 1	Cmd 2	Data	BCC

Table 3: Protocol Frame PC to Micro-Reader.

Byte	Contents (Hexadecimal Value)
0	Start Mark (SOH, 01hex)
1	Length
2	Command Field (1)
3	Command Field (2) (optional)
4(3)	Data Field (1)
.	
.	
N+3(2)	Data Field (N)
N+4(3)	BCC

Note: The total number of bytes sent within a protocol frame (including Start Mark and BCC) is limited to 41 bytes.

Start Mark

The 'Start-Mark' signifies the beginning of a message. It is represented by the ASCII character SOH (Start Of Header, 01_{hex}).

Length

The 'Length' byte indicates the length, in bytes, of the following Command and Data Fields.

Command Field

The 'Command Field(s)' defines the mode in which the Micro-reader operates and determines the operation that is to be carried out in the transponder. Depending on the setting of the relevant bits, the corresponding information specified in the Data Fields will be sent to the transponder or not. Thus all functions of each particular transponder type can be executed.

Command Field (1)

Bit	Use	Setting	Comment
0/1	Mode/Cmd	00 (MSB,LSB)	Perform single command (E.g.: single read, program, lock)
		01	Read in continuous Normal Mode
		10	Read in continuous Line Mode
		11	Send Micro-reader S/W version
2	FBCC Calculation	1/0	If set, Micro-reader calculates FBCC of the MPT protocol
3	Power Burst I	1/0	If set, needs to be determined in Data Field
4	Power Pause Duration	1/0	If set, needs to be determined in Data Field
5	Power Burst II	1/0	If set, needs to be determined in Data Field
6	Data	1/0	If set, needs to be determined in Data Field
7	Cmd Expansion Field	1/0	If set, Command Field (2) follows

Table 4: Command Field (1) of Protocol Frame PC to Micro-Reader.

If bit 2 (FBCC calculation) and bit 6 (Data) are set, the Micro-reader automatically calculates a two byte BCC over the data to be sent to the transponder and adds it to the protocol. When bits 2 and 6 are set the PC must not send the 2 byte FBCC to the Micro-reader.

Bit 4 (Power Pause Duration) is for future use and must not be set when addressing standard TIRIS transponders.
If bit 5 (Power Burst II, for example: for programming and locking) is set, the Microreader automatically operates in single mode. Thus the user is enabled to validate the programming or lock response before a further cycle is started.

Command Field (2)

Bit	Use	Setting	Comment
0	Special Write Timing	1/0	If set, needs to be determined in Data Field
1	Wireless Synchronization	1/0	If set, wireless synchronization is used
2	DBCC calculation	1/0	If set, Micro-reader calculates DBCC of the R/W and MPT write data
3-7	Reserved		

Table 5: Command Field (2) of Protocol Frame PC to Micro-Reader.

If Command Field (2) is not present, standard TIRIS write timings are used and wireless synchronization is switched on/off according to the status of input line WLSC.

Note: The settings specified in Command Field (1) and (2) are only valid during the execution of the current command.

Data Field

The presence of the relevant data field depends on the setting of the bits in the Command Field. If the relevant bit (E.g.: Command bit 3 “Power Burst I”) is set to “1”, then Data Field 1 is present defining the Power Burst length. If the relevant bit in the Command Field is set to “ 0 ” the consequent Data Field is omitted, this results in the following data field being moved forward (decremented) by one.

Data Field	Use	Range (dec)	Comment
1	Power Burst I	1..255 ms	If bit 3 of Command Field(1) is set
2	Power Pause Duration	1..255 ms	If bit 4 of Command Field(1) is set
3	Power Burst II	1..255 ms	If bit 5 of Command Field(1) is set
4/5	toffLow (LSByte/MSByte)	28..2044 ms	If bit 0 of Command Field(2) is set
6/7	tonLow (LSByte/MSByte)	28..2044 ms	If bit 0 of Command Field(2) is set
8/9	toffHigh (LSByte/MSByte)	28..2044 ms	If bit 0 of Command Field(2) is set
10/11	tonHigh (LSByte/MSByte)	28..2044 ms	If bit 0 of Command Field(2) is set
12	# of Data Fields that follow	See *	If bit 6 of Command Field(1) is set
13..	Data Fields	LSByte first	

Table 6: Data Field of Protocol Frame PC to Micro-Reader.

* The number of Data Fields must not cause an infringement of the total number of bytes allowed within a protocol frame.

BCC

The 'BCC' field is a one-byte value of the Longitudinal Redundancy Check calculation (Xor'ed bytes) for the preceding message. The calculation is performed on the whole message excluding the Start-Mark.

3.3.7 Security Requirements

Most IT departments have security requirements for applications. The requirements are often written as checklists.

- Requires password & have options to change password.
- Database servers should be physically secured.
- Login ID & Password will be checked before starting the system.
- Use a secured password for the MySQL Server administrator.

3.4 Design

The design phase describes how the software is constructed so that it fulfils the specifications agreed upon in the requirements specification document. It explains required features & operation in detail, including database design, software design, screen layouts & other documentation. When the design is completed it is recorded in the design specification document. There are different types of design to develop this software like ERD, UML etc. design stage is described in details in Chapter 4.

3.5 Coding & Model Testing

In this stage, the designs are translated into code. The software is divided into separate units called modules, in order to handle the complexity of the programming process. All rules & regulations of programming language are maintained properly. Computer programs are written using VB.Net 2008.

3.6 Integration & System Testing

During this stage, the individual modules of the software product are combined to form the integrated software product. A special testing environment is created to check for errors, bugs & interoperability.

3.7 Operational Mode

At this stage, the checked software is ready for use. If required, the modification stage will modify & enhance the system according to the difficulty.

3.8 Modification & Maintenance

After the system is in operation, various changes are made in order to fix bugs, to add new functionality, to port the software to new platforms, or to adapt the software to new technologies during the modification & maintenance phase of the system. Although it may seem that the development of the software is finished after its delivery, this is far from true. Even a successful software product need to be developed or modified to meet the changing needs of the clients.

Chapter 4
System Design

4.1 Introduction

The software system design describes the desired software features in detail, including database design (ERD), software design (UML is produced here), screen layouts & other documents. In system design, the software's overall structure is defined with a full data dictionary. These design elements are intended to describe the software in detail that helps to develop the software with minimal additional input.

4.2 Database Design

A database is a collection of information, organized in such a way that a computer program can quickly select desired pieces of data. The computer program used to manage & query a database is known as a database management system (DBMS) [9]. Databases are designed to offer an organized mechanism for storing, managing & retrieving information. This includes detailed specification of data elements, data types, indexing options & other parameters residing in the DBMS data dictionary. Many models & languages are used for design of the database. To design the database the Entity-Relationship (ER) Diagram is used.

4.3 E-R Diagram

Entity-Relationship (ER) Diagram is a graphical representation of entities & their relationship to each other, typically used in computing in regard to the organization of data within databases or information systems. There are three basic elements in E-R diagram.

- **Entities** (tables) are the elements about which one seeks information. Rectangular boxes are commonly used to represent entities.
- **Attributes** are the data one collect about the entities. Ovals are used to represent attributes.
- **Relationships** provide the structure needed to draw information from multiple entities. Diamonds are normally used to represent relationships.

4.3.1 E-R Diagram of Inventory Management System

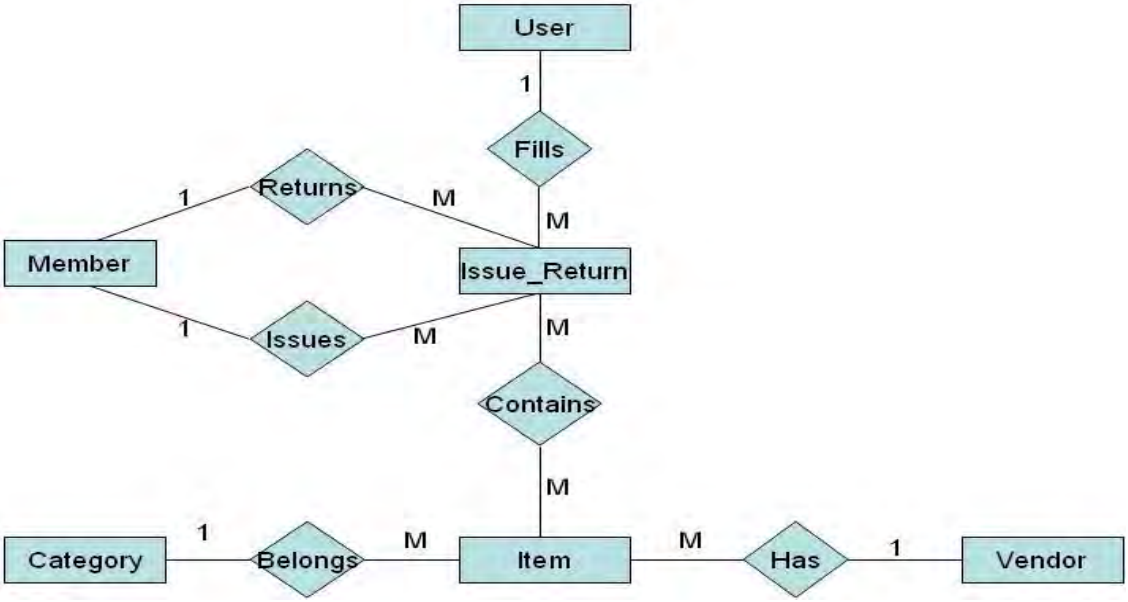

Figure 8: E-R diagram of Inventory Management System.

Figure 8 shows entire an E-R diagram. The entities are given in detail in the later figures. The descriptions of these entities are given next.

1. User Information: The name of this entity set is **User**. Due lack of space, this entity set will be displayed in figure 9.

2. Member Information: The name of this entity set is **Member**. Due lack of space, this entity set will be displayed in figure 10.

3. Vendor Information: The name of this entity set is **Vendor**. Due lack of space, this entity set will be displayed in figure 11.

4. Item Information: The name of this entity set is **Item**. Due lack of space, this entity set will be displayed in figure 12.

5. Item Category Information: The name of this entity set is **Category**. Due lack of space, this entity set will be displayed in figure 13.

6. Issue_Return Information: The name of this entity set is **Issue_Return**. Due lack of space, this entity set will be displayed in figure 14.

4.3.2 E-R Diagram of User Information Table

Figure 9 shows the entire E-R diagram of User Information. Admin users can add/view/edit/delete User Information in this table.

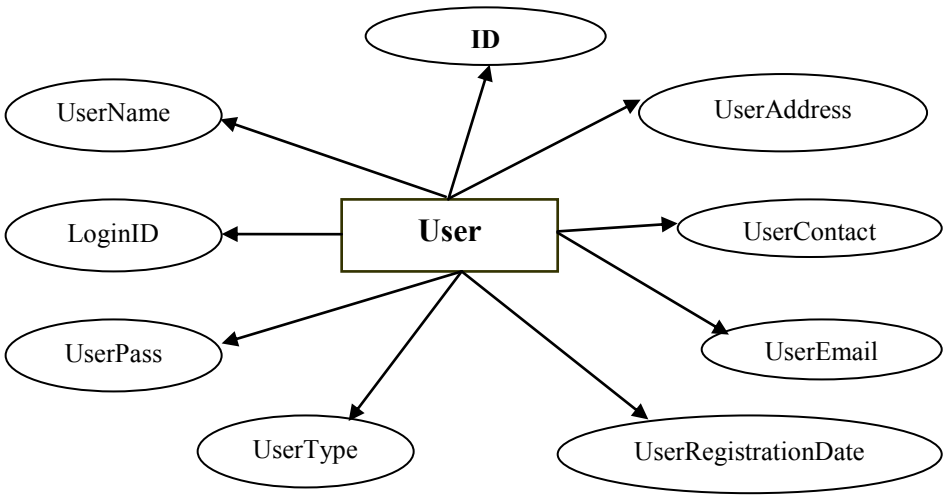

Figure 9: E-R Diagram of User Information Table.

4.3.3 E-R Diagram of Member Information Table

Figure 10 shows the entire E-R diagram of Member Information. Admin users can add/view/edit/delete Member Information in this table.

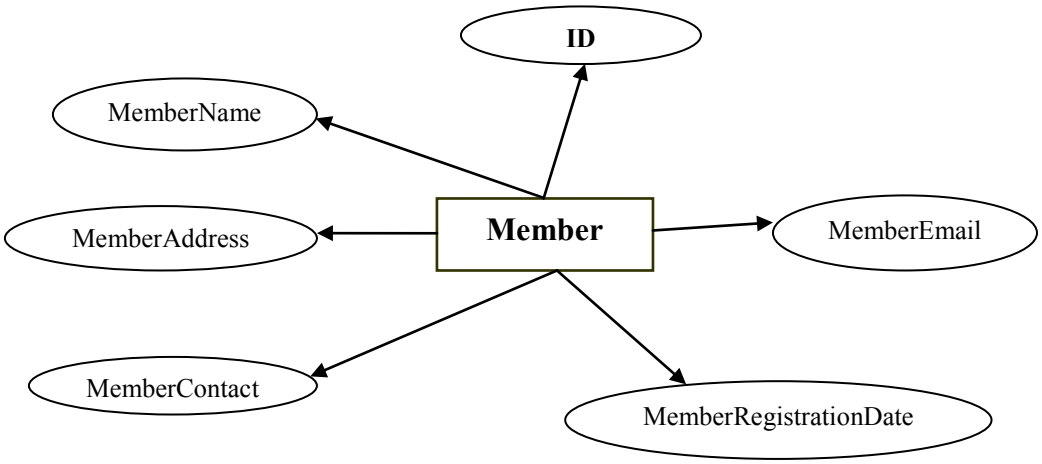

Figure 10: E-R Diagram of Member Information Table.

4.3.4 E-R Diagram of Vendor Information Table

Figure 11 shows the entire E-R diagram of Vendor Information. Admin users can add/view/edit/delete Vendor Information in this table.

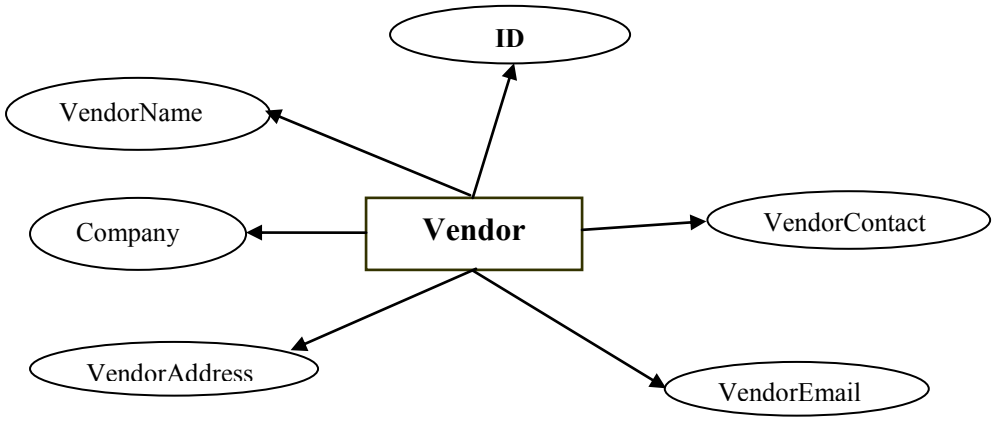

Figure 11: E-R Diagram of Vendor Information Table.

4.3.5 E-R Diagram of Item Information Table

Figure 12 shows the entire E-R diagram of Item Information. Admin users can add/view/edit/delete Item Information in this table. Issue Status & Item Location will be updated from Issue_Return table. General user can only view Item Information in this table.

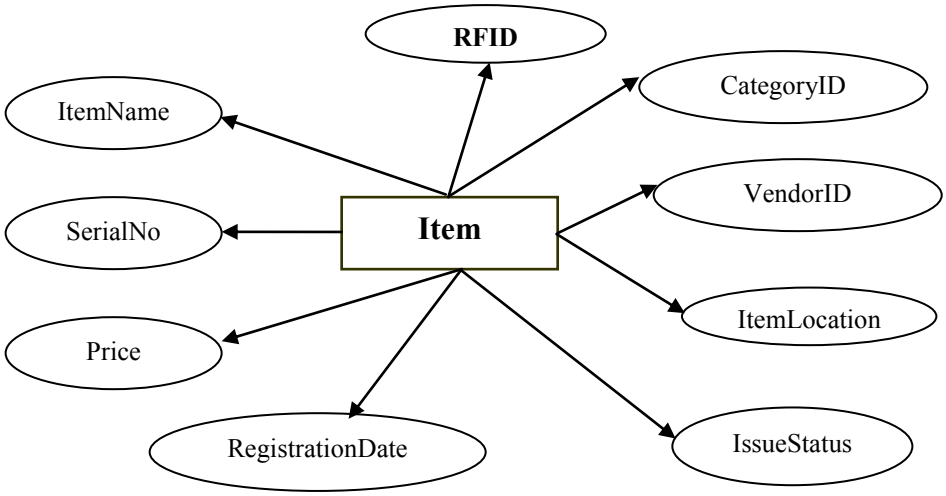

Figure 12: E-R Diagram of Item Information Table.

4.3.6 E-R Diagram of Item Category Information Table

Figure 13 shows the entire E-R diagram of Item Category Information. Admin users can add/view/edit/delete Item Category Information in this table.

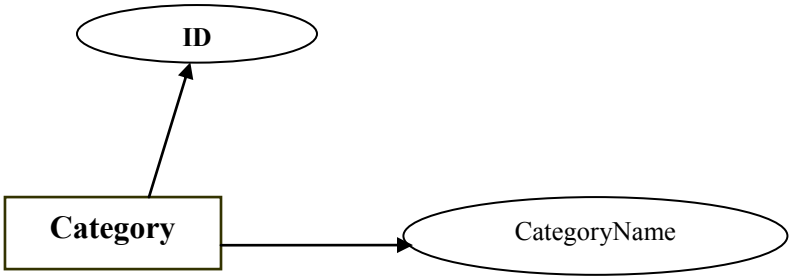

Figure 13: E-R Diagram of Item Category Information Table.

4.3.7 E-R Diagram of Issue_Return Information Table

Figure 14 shows the entire E-R diagram of Item Issue & Return Information. Admin users can add/view/edit/delete Item Issue & Return Information in this table. Admin user can also add Issued Days & Delay Fee for the Issued Item & verify fine. General user can also do the same in this table.

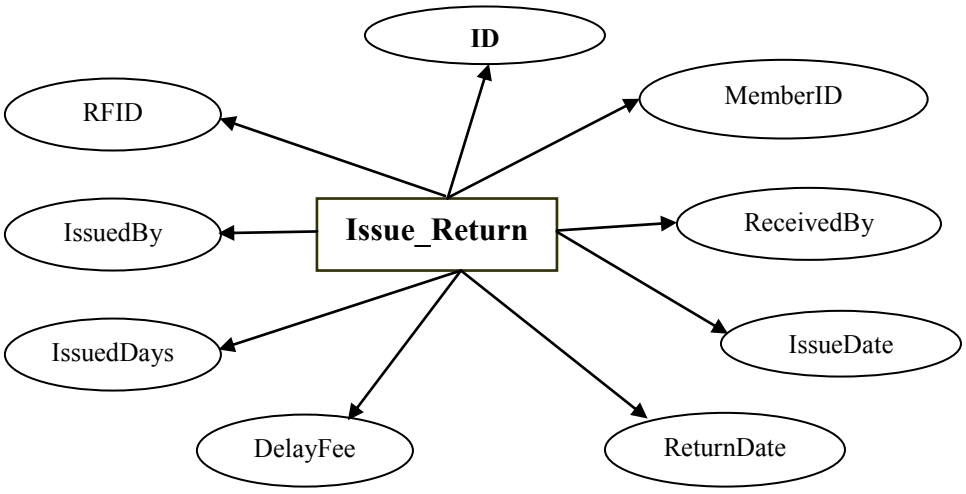

Figure 14: E-R Diagram of Issue_Return Information Table.

4.4 Data Dictionary

Data Dictionary describes the table format (fields, data types, data length, primary, foreign keys etc.) which is used in database design. The following tables are used in database design.

Table: User Information

Fields	Domains	Constraints	Description
ID	Integer (11)	Not null	Auto Increment
UserName	Varchar (50)	Not null	Name of User
LoginID	Varchar (15)	Not null	Unique Key
UserPass	Varchar (15)	Not null	Password of User
UserType	Varchar (11)	Not null	Unique Key
UserAddress	Varchar (300)		Address of User
UserContact	Integer (15)		User's Contact No.
UserEmail	Varchar (50)		Email of User
UserRegistrationDate	Datetime		User's Registration Date

Table 7: User Information.

Table: Member Information

Fields	Domains	Constraints	Description
ID	Integer (11)	Not null	Auto Increment
MemberName	Varchar (50)	Not null	Name of Member
MemberAddress	Varchar (300)		Address of Member
MemberContact	Integer (15)		Member's Contact No.
MemberEmail	Varchar (50)		Email of Member
MemberRegistrationDate	Datetime		Member's Registration Date

Table 8: Member Information.

Table: Vendor Information

Fields	Domains	Constraints	Description
ID	Integer (11)	Not null	Auto Increment
VendorName	Varchar (50)	Not null	Name of Vendor
Company	Varchar (50)	Not null	Unique Key
VendorAddress	Varchar (300)		Address of Vendor
VendorContact	Integer (15)		Vendor's Contact No.
VendorEmail	Varchar (50)		Email of Vendor

Table 9: Vendor Information.

Table: Item Category Information

Fields	Domains	Constraints	Description
ID	Integer (11)	Not null	Auto Increment
CategoryName	Varchar (50)	Not null	Name of Item Category

Table 10: Item Category Information.

Table: Item Information

Fields	Domains	Constraints	Description
RFID	Varchar (16)	Not null	Unique Key*
CategoryID	Integer (11)	Not null	Foreign Key
VendorID	Integer (11)	Not null	Foreign Key
ItemName	Varchar (50)	Not null	Name of Item
SerialNo	Varchar (15)		Serial No. of Item
Price	Decimal		Price of Item
RegistrationDate	Datetime		Inventory Date of Item
ItemLocation	Varchar (100)		Location of Item
IssueStatus	Integer (11)	Not null	Issue Status of Item

* The EPC will be generated from RFID tags.

Table 11: Item Information.

Table: Issue_Return Information

Fields	Domains	Constraints	Description
ID	Integer (11)	Not null	Auto Increment
RFID	Varchar (16)	Not null	Foreign Key
MemberID	Integer (11)	Not null	Foreign Key
IssuedBy	Integer (11)	Not null	Foreign Key
IssueDate	Date	Not null	Issue Date of Item
IssuedDays	Integer (11)	Not null	Issued Days for Item Issue
DelayFee	Integer (11)	Not null	Delay Fee for Item Issue
ReceivedBy	Integer (11)		Foreign Key
ReturnDate	Date		Return Date of Issued Item

Table 12: Issue_Return Information.

4.5 Software Design

Software Design is a process of problem solving & planning for a software solution. Object-Oriented Analysis and Design (OOAD) are implemented during the software design. Each object represents some entity of interest in the system being modeled & is characterized by its class, its state (data elements) & its behavior. Various models can be created to show the static structure, dynamic behavior & run-time deployment of these collaborating objects. There are a number of different notations for representing these models such as the Unified Modeling Language (UML). Different diagrams are used to help visualizing the whole development process.

4.5.1 Unified Modelling Language (UML) Diagram

UML [10] is graphical notation system for Object-Oriented analysis & design. UML is the industry standard language for the specification, visualization, construction & documentation of the components of software systems as well as for business modeling. UML helps to simplify the process of software design, making a model for construction with a number of different views. One of the great merits of UML is the way it helps open up the development process which is called use cases. These serve to identify principal roles (actors) in the system, boundaries, actions & so on. UML Use Case Diagram can be used to describe the functions of a system in a horizontal way.

4.5.1.1 Use Case Diagram

A use case diagram in the UML is a type of behavioral diagram defined by & created from a Use case analysis. It is a set of scenarios that describes an interaction between a user & a system. The two main components of a use case diagram are use cases & actors. It can be shown by the figure 15.

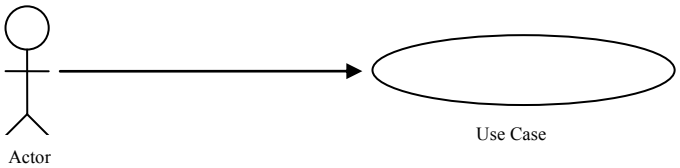

Figure 15: Use Case Diagram.

An actor represents a person, organization or external system that will interact with this system. The symbols of actors are drawn as stick figures. A use case is an external view of the system that represents some actions the user might perform in order to complete a task & is drawn as a horizontal ellipse. Lines are used to represent the relationships between these elements.

4.5.1.1.1 Use Case Diagram of General User

Figure 16 shows the use case diagram of General user. General user can log in his/her account and can insert, update and delete item issue or return information for the member. She/he can also logout from the account.

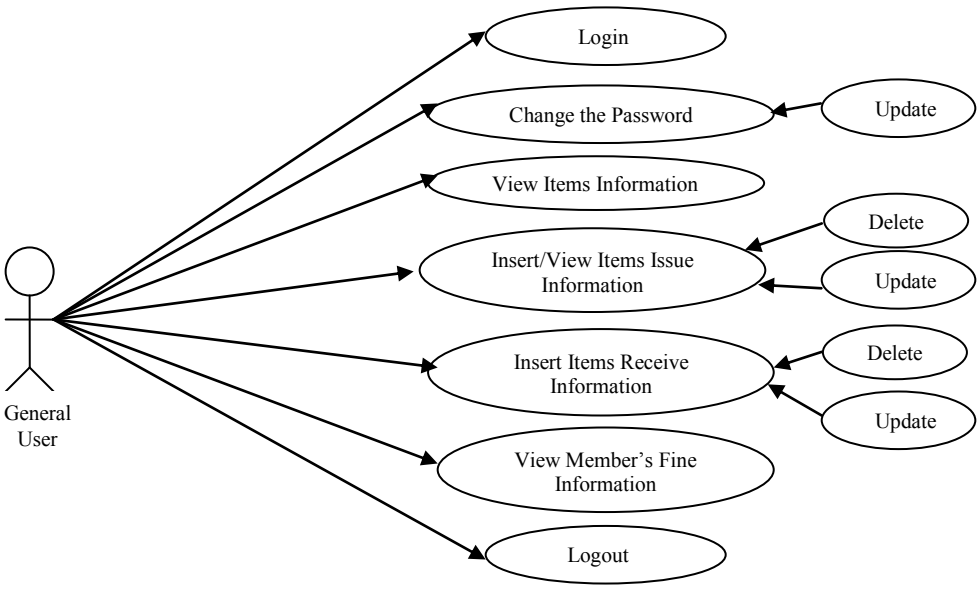

Figure 16: Use Case Diagram of General User.

4.5.1.1.2 Use Case Diagram of Admin User (Administrator)

Figure 17 shows the use case diagram of Admin User (Administrator). Admin can log in his/her account and can insert, update and delete the required information for the system. She/he can also logout from the account.

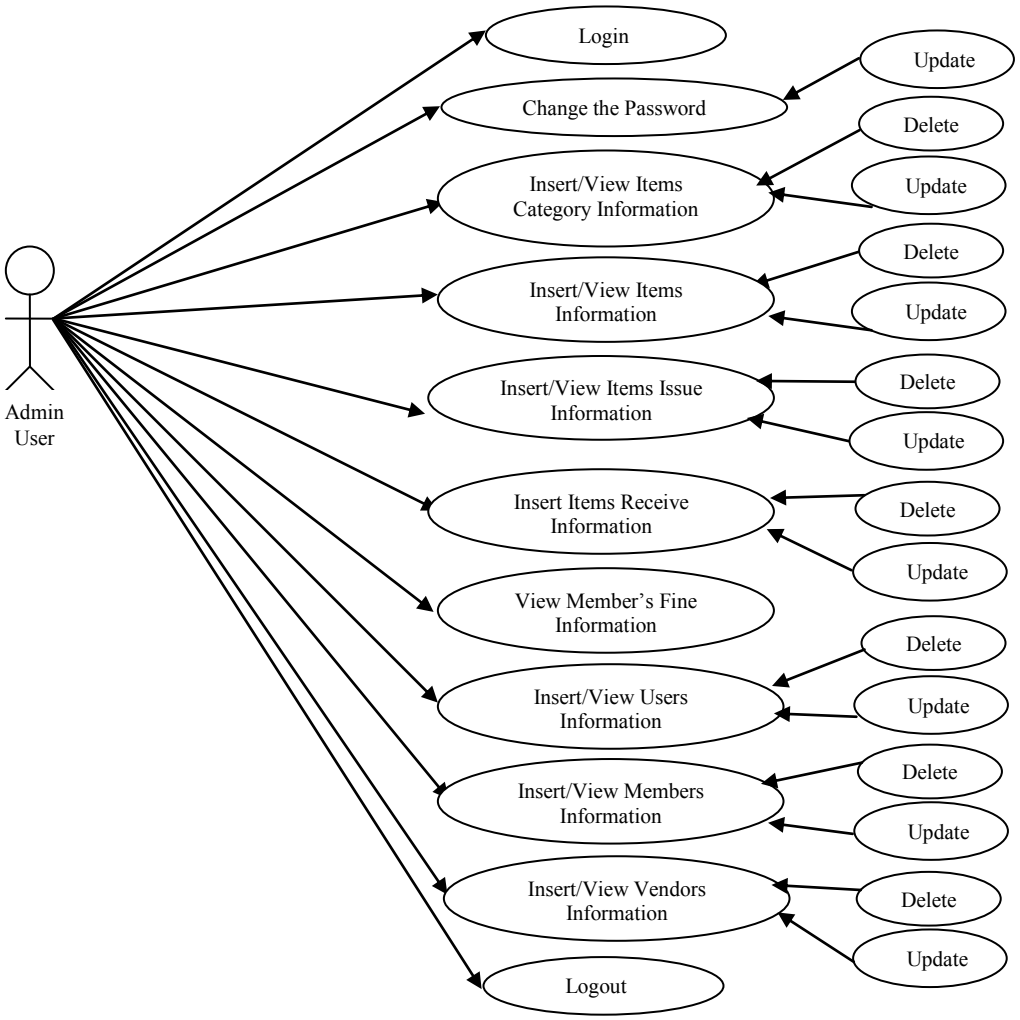

Figure 17: Use Case Diagram of Admin User.

4.5.1.2 Class Diagram

In software engineering, a class diagram in the Unified Modeling Language (UML) is a type of static structure diagram that describes the structure of a system by showing the system's classes, their attributes, operations (or methods), and the relationships among the classes. The class diagram is the main building block of object oriented modeling. It is used both for general conceptual modeling of the systematic of the application, and for detailed modeling translating the models into programming code. Class diagrams can also be used for data modeling. The classes in a class diagram represent both the main objects, interactions in the application and the classes to be programmed.

In the design of a system, a number of classes are identified and grouped together in a class diagram which helps to determine the static relations between those objects. With detailed modeling, the classes of the conceptual design are often split into a number of subclasses. In order to further describe the behavior of systems, these class diagrams can be complemented by state diagram or UML state machine.

4.5.1.2.1 UML Class Symbol

In the diagram, classes are represented with rectangle boxes which contain three parts:

- The top section of the rectangle is the ***name*** of the class
- The middle section is the ***attributes*** of the class
- The bottom section lists the ***methods*** or operations of the class (methods define the behavior of objects of the class). Methods are not always shown as far as they are standard.

4.5.1.2.2 Domain Model Class Diagram

A domain model in problem solving and software engineering is a conceptual model of all the topics related to a specific problem. It describes the various entities, their attributes, roles, and relationships, plus the constraints that govern the problem domain. The domain model is created in order to represent the vocabulary and key concepts of the problem domain. The domain model also identifies the relationships among all the entities within the scope of the problem domain, and commonly identifies their attributes. A domain model that encapsulates methods within the entities is more properly associated with object oriented models. The domain model provides a structural view of the domain that can be complemented by other dynamic views, such as use case models. It can add precision and focus to discussion among the business team as well as between the technical & business teams. Some key terms of domain model class diagram are given below:

- Unified Modelling Language (UML) diagram.
- *de facto* standard for models used with object-oriented system development.
- Domain model class diagram is a model to show classes of objects.
    - Models things in the users' work domain.
    - Used to define requirements for OO.
- No methods shown in domain model.
    - Domain classes are not software classes.
- Very similar to Entities in ERD.
    - UML and domain model can be used in place of ERD in traditional approach.

4.5.1.2.3 Domain Model Class Diagram of IMS

Figure 18 shows the domain model class diagram of IMS. Here shows all the classes and their attributes of the system. The associations among the classes are also denoted here.

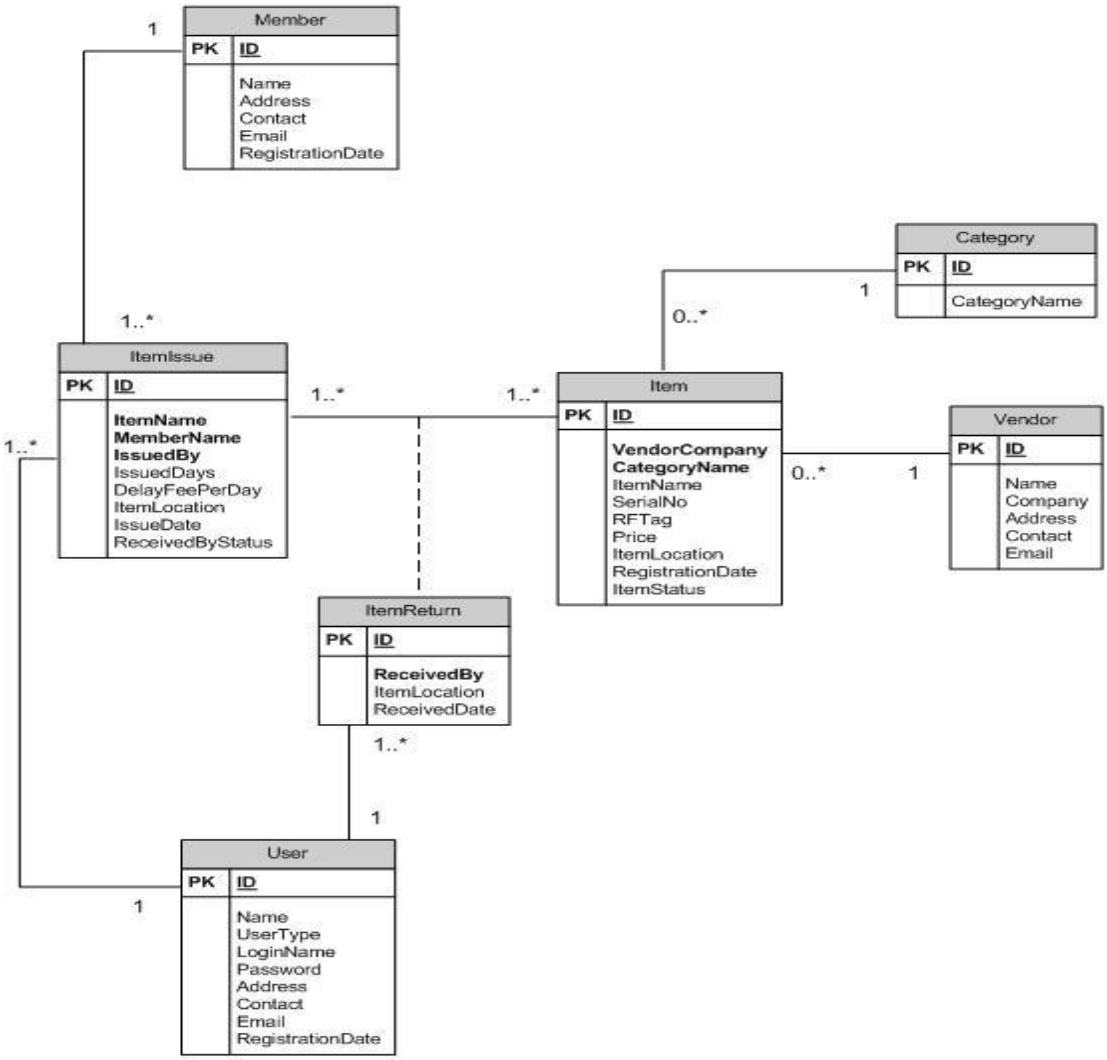

Figure 18: Domain Model Class Diagram of IMS.

4.5.1.3 Activity Diagram

An activity diagram illustrates the dynamic nature of a system by modeling the flow of control from activity. An activity represents an operation of some classes in the system that results in a change in the state of the system. Typically, activity diagrams are used to model workflow or business process and internal operation. Activity diagrams can show activities that are conditional or parallel.

4.5.1.3.1 Activity Diagram of Inventory Management System

Figure 19 shows the activity diagram of IMS. In this case, both Admin User (Administrator) & General User can issue or return items for the member after signing in the system. Admin can also updating user, member, item category, item and vendor's information. The users would log-out from the system after finished their works.

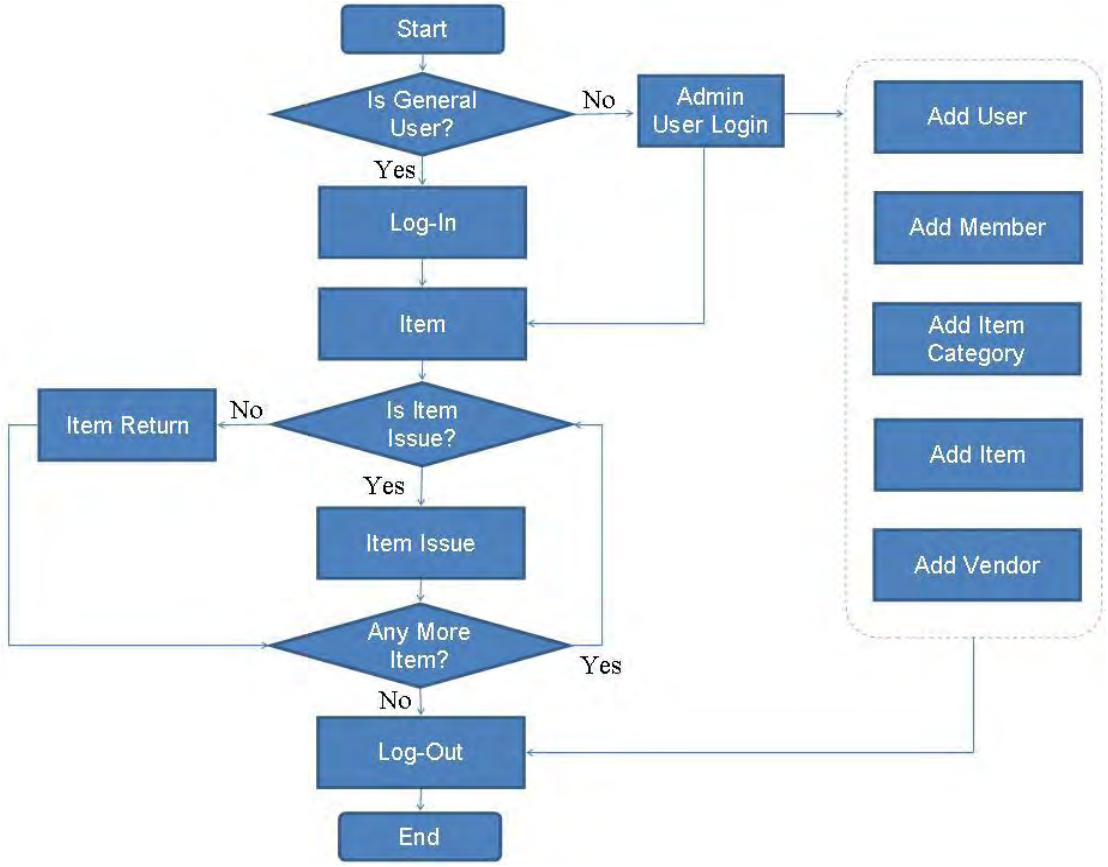

Figure 19: Activity Diagram of IMS.

Chapter 5

Functionalities of the RFID System

5.1 Hardware Aspects

A User can do different works by using the RFID reader, which is interfaced with RS 232 serial communication. When an RFID tag is placed within the range of the RFID reader's antenna then the following works will be done.

5.1.1 Item Registration Aspect

Administrators can register different Items by using the RFID reader. Here depicted an inventory Item's RFID tag is being registered by a User when it is placed within the range of the RFID reader's antenna.

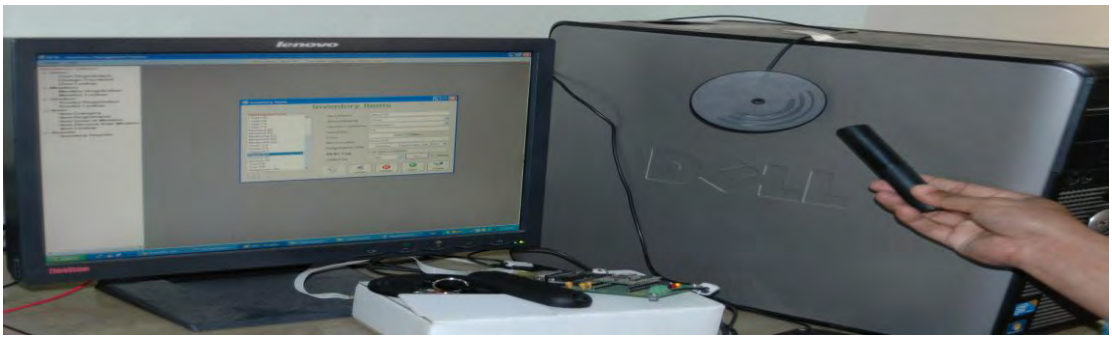

Figure 20: Item Registration Aspect.

5.1.2 Item Issue Aspect

Both Admin User (Administrator) and General User can Issue on demanded Items by using the RFID reader to the members. Here depicted an Item's RFID tag is being Issued to a member when it is placed within the range of the RFID reader's antenna.

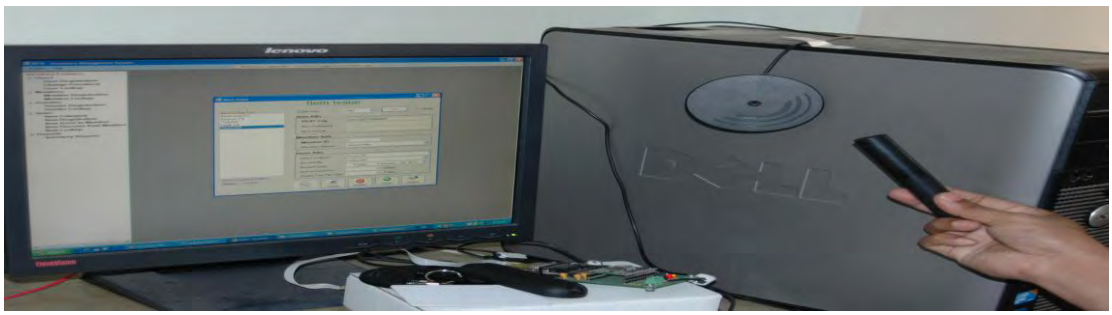

Figure 21: Item Issue Aspect.

5.1.3 Item Return Aspect

Both Admin User (Administrator) and General User can Receive Items by using the RFID reader from the members & verify member's fine information. Here depicted an Issued Item's RFID tag is being Returned from that member when it is placed within the range of the RFID reader's antenna.

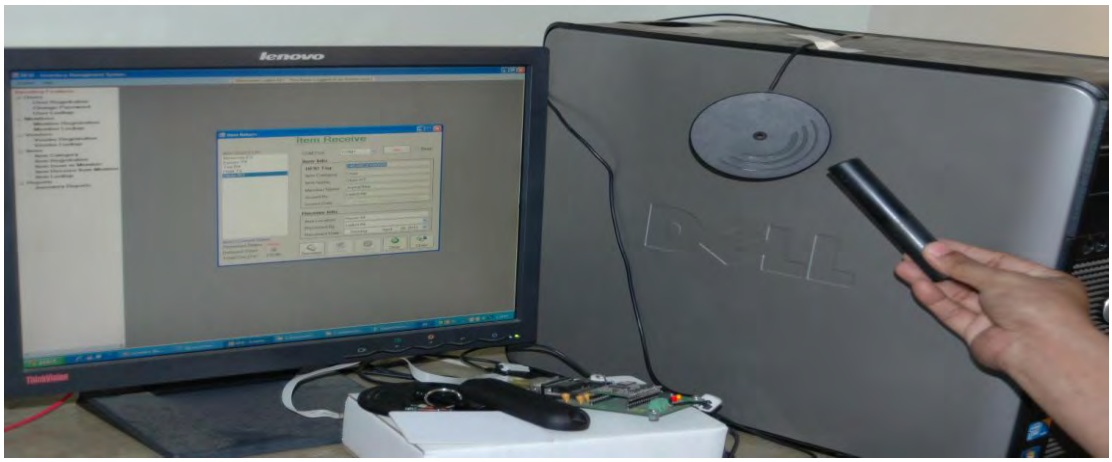

Figure 22: Item Return Aspect.

5.2 Software Features

The developed Inventory Management System has different essential features codes. Screen shot of the main features are explained below.

5.2.1 Login Form

Both Admin User (Administrator) and General User can access the system for their role privilege with their own Login ID & Password those given to them when his/her account would be created.

Figure 23: Login Form.

5.2.2 Inventory Main Form

It contains the tree view of all the system's features and the menu. Administrators can do anything on the software whereas General Users can have access limited features. Both Users after done their role privilege they can also logout from the system.

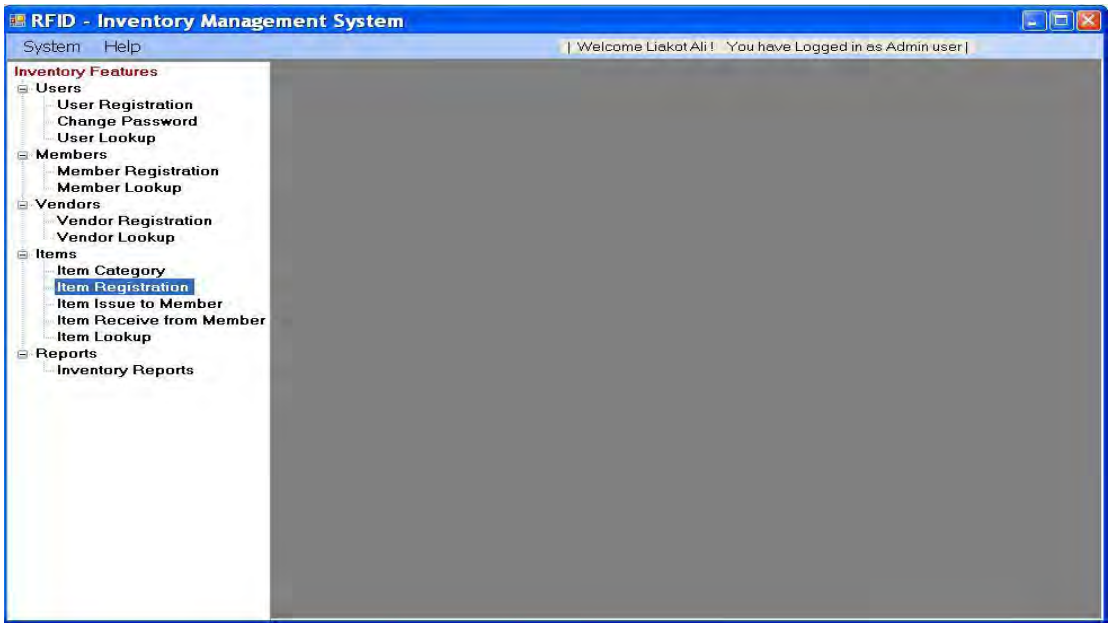

Figure 24: Inventory Main Form.

5.2.3 User Registration Form

Administrators can create different User in this form. She/he will also able to go **User Lookup** form and search and pick selected User information in here which could very helpful for editing.

Figure 25: User Registration Form.

5.2.4 Change Password Form

Both Admin User (Administrator) and General User can change his/her own password if they wish.

Figure 26: Change Password Form.

5.2.5 User Lookup Form

Administrators can view different User information with specific searching in this form. Users can also print the selected information in here.

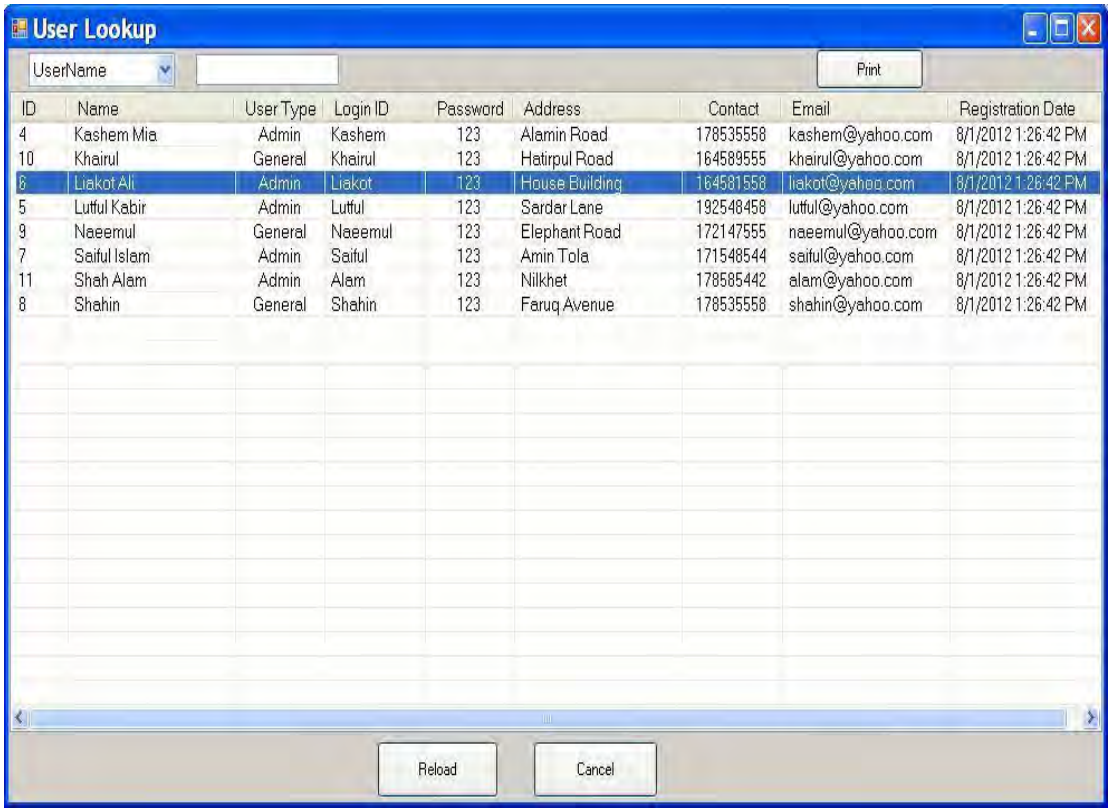

Figure 27: User Lookup Form.

5.2.6 Member Registration Form

Administrators can create different Member in this form. She/he will also able to go **Member Lookup** form and search and pick selected Member information in here which could very helpful for editing.

Figure 28: Member Registration Form.

5.2.7 Member Lookup Form

Administrators can view different Member information with specific searching in this form. Users can also print the selected information in here.

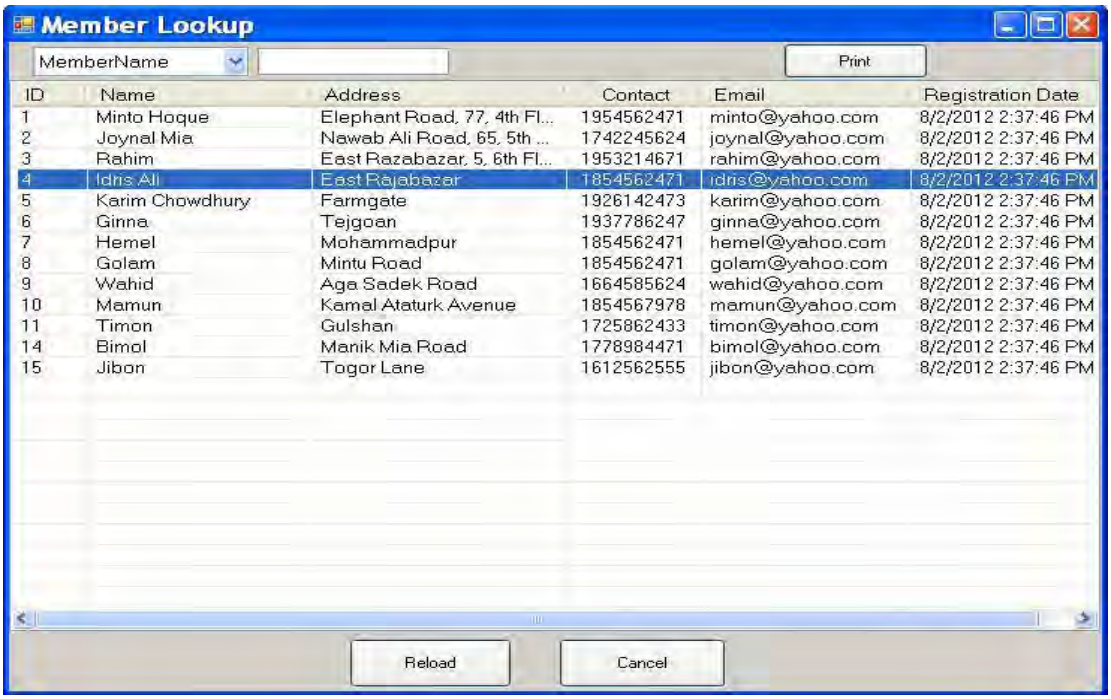

Figure 29: Member Lookup Form.

5.2.8 Vendor Registration Form

Administrators can register different Vendor in this form. She/he will also able to go **Vendor Lookup** form and search and pick selected Vendor information in here which could very helpful for editing.

Figure 30: Vendor Registration Form.

5.2.9 Vendor Lookup Form

Administrators can view different Vendor information with specific searching in this form. Users can also print the selected information in here.

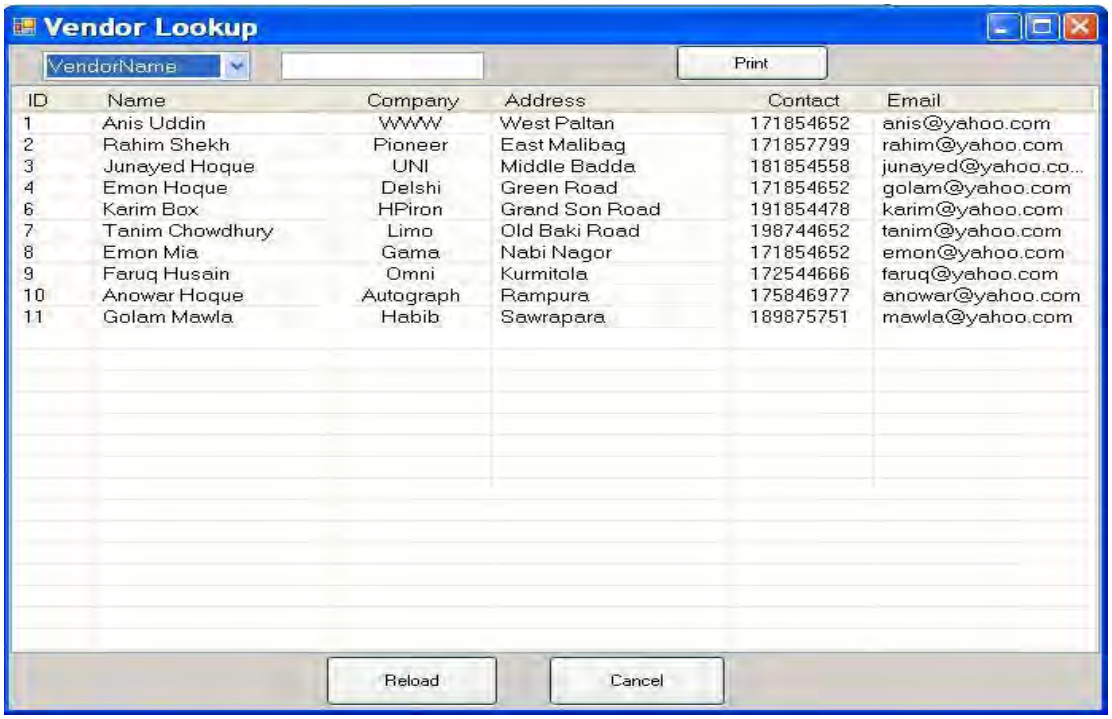

Figure 31: Vendor Lookup Form.

5.2.10 Item Category Form

Administrators can create different Item Category in this form.

Figure 32: Item Category Form.

5.2.11 Item Registration Form

Administrators can register different Items by using the RFID reader in this form. She/he will also able to go **Item Lookup** form and search and pick selected Item information in here which could very helpful for editing.

Figure 33: Item Registration Form.

5.2.12 Item Issue Form

Both Admin User (Administrator) and General User can Issue on demanded Items by using the RFID reader to the members in this form. When the User Issued any Item then its current status will be showed **Issued** and if any Item has received from the Issue list then the status will be showed **Received**. Users can also add *Item Issued Days & Delay Fee per Day* information for the Issued Item in here according to the system's law. Item's Issue Location would be updated from here.

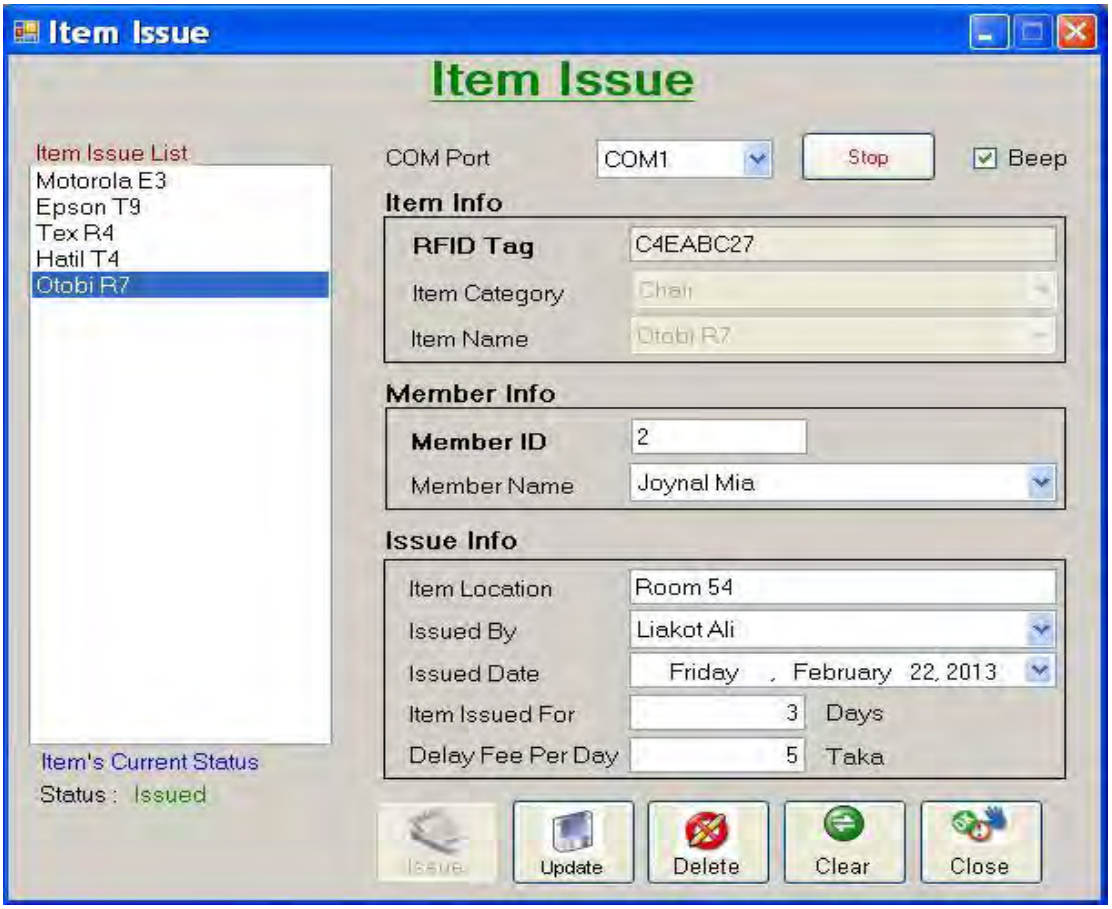

Figure 34: Item Issue Form.

5.2.13 Item Return Form

Both Admin User (Administrator) and General User can Receive Items by using the RFID reader from the members & verify member's fine information in this form. When the User Received any Item then its current status will be showed **Received** and if any Item would not received yet from the Issued list then the status will be showed **None**. Item's Return Location would be updated from here also.

Figure 35: Item Return Form.

5.2.14 Item Lookup Form

Both Admin User (Administrator) and General User can view different Items information with specific searching in this form. Users can also print the selected information in here. Users could distinguish easily which Items are Issued or Vacant from the *Issue Status* column.

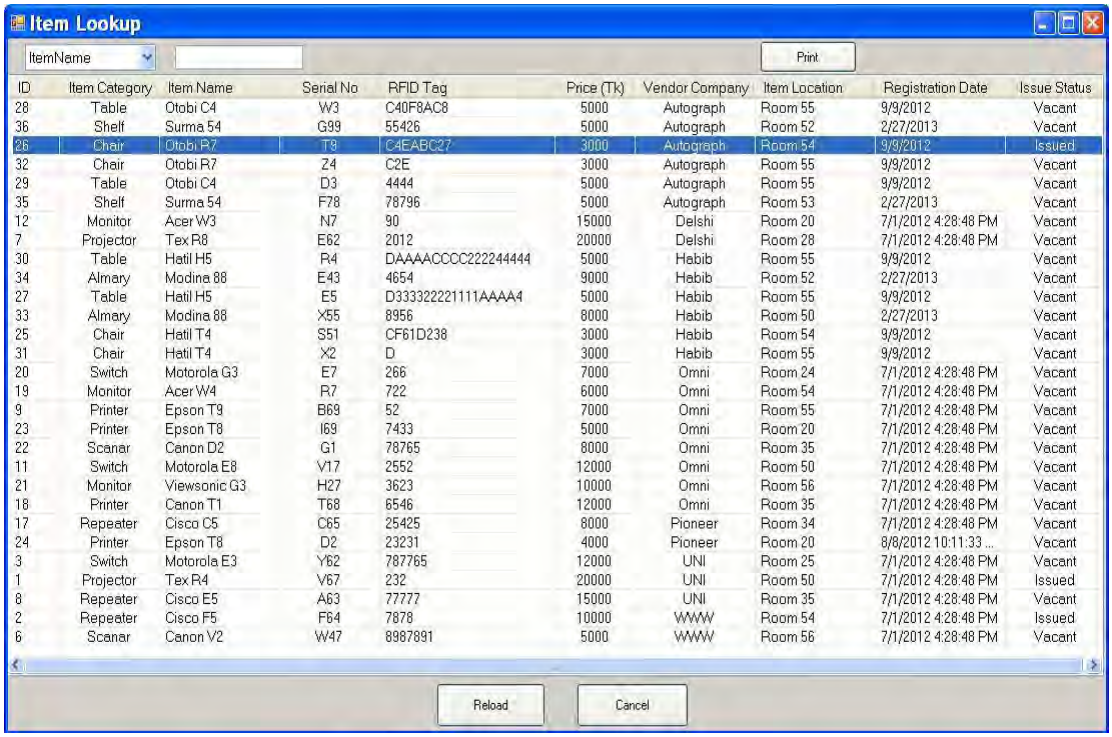

Figure 36: Item Lookup Form.

5.2.15 Inventory Reports Form

Both Admin User (Administrator) and General User can view or print current Stock information, Stock summary & Fine information of the Members in this Report form.

Figure 37: Inventory Reports Form.

Chapter 6
Conclusion

6.1 Conclusion

RFID technology is now being used in a lot of useful applications. In this project it has been shown the use of RFID technology in inventory management. RFID reader Educational Kit and tags have been used to develop the proposed prototype system. A GUI has been developed to interface with the RFID reader and tags. The GUI is user friendly and it has the facility to add, view or delete new inventory items. Different types of reports can also be generated from the GUI. Experimental result proves the proper functionality of the complete system. Research and development work can be carried out to improve the developed prototype system to a commercial product.

6.2 Future Works

In the current system Low Frequency RFID reader has been used. In the future version a high frequency RFID reader can be used to read the tag easily in a flexible manner.

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