TALLINNA TEHNIKAÜLIKOOL
TALLINN UNIVERSITY OF TECHNOLOGY

Department of Electrical Power Engineering and Mechatronics

STORAGE YARD NAVIGATION SYSTEM FOR ASSET TRACKING

Laoplatsi tõstuki navigeerimissüsteem

MASTER THESIS

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Tallinn, 2017

AUTHOR'S DECLARATION

I declare that I have written this graduation thesis independently.

These materials have not been submitted for any academic degree.

All the works of other authors used in this thesis have been referenced.

The thesis was completed under Mart Tamre's supervision
….. January, 2017

Author: Ishan Sharma

Signature: …………

The thesis complies with the requirements for graduation theses.
"......." 2016

Supervisor: Professor Mart Tamre

Signature: ……….

Accepted for defence.
Chairman of the defence committee

"......."...................2016

Signature: …………..

TUT Department of Mechatronics

MASTER'S THESIS SHEET OF TASK'S

Student: Ishan Sharma, MAHM146463
Study program: MSc.
Specialty: Mechatronics
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THESIS TOPIC:
(In Estonian) Laoplatsi tõstuki navigeerimissüsteem

(In English) Forklift storage yard navigation system

Assignments to be completed and the schedule for their completion:

No.	**Description of the assignment**	**Completion week**
1.	In-depth study of the current situation, finding probable time consuming/wasting points, the current solution used on different levels, the economic factor bounding the large scale use of automated guide vehicles.	1 - 2
2.	Compilation of the initial finding in the thesis report, working on the loopholes found and methods to overcome the time and errors faced, compilation of the system to the current working forklifts.	2 - 4
3.	Working on the database handling, conceptual build up.	4 - 6
4.	Compiling and writing the report.	6 – December 2016
5.	Thesis report completion and changed recommended by the supervisor.	December 2016

Engineering and economic problems to be solved: The current problem faced by many handling units in a warehouse is the wastage of time in terms of material handling that comes in goes out, this handling includes the time wasted in searching for the items that are placed in the holding area. This time lost can cost a company a lot in long run.

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FOREWORD

First of all, I would like to express my sincere gratitude to my research principal supervisor Professor Mart Tamre at Tallinn University of Technology for his constant guidance and support throughout my master's candidature. I am immensely grateful for all the time and help he provided for the discussions of my work. Along with that, I would also like to thank my research co-supervisor/ consultant Maido Hiiemaa for reviewing my research progress from time to time and providing his fruitful insight during our discussions. I truly appreciate their efforts and guidance throughout the research.

My heartfelt thanks to all my friends who worked with me on various projects of forklifts for the last two years which helped me to choose the topic for my thesis.

At last but certainly not the least, I would like to express my deepest love and gratitude to my family who stood by me all the time with their support and encouragement to achieve the best results.

EESSÖNA

Kõigepealt ma sooviks avaldada siirast tänu oma lõputöö juhendajale professor Mart Tamrele Tallinna Tehnikaülikoolist oma pideva juhendamise eest, kes on olnud abiks ja toeks kogu magistriõppe jooksul. Ma olen väga tänulik kogu tema aja ja abi eest mida ta on pakkunud minu lõputöö kujunemisel. Lisaks sooviksin tänada oma kaasjuhendajat teadur Maido Hiimemaad, kes on pealt vaadanud ja juhendanud minu uurimistöö progressi ja andnud enda poolseid juhiseid erinevate probleemide lahendamiseks. Ma siiralt hindan nende pingutust ja abi kogu selle uurimistöö vältel.

Suur tänu kõigile minu sõpradele, kes aitasid mind mitmete projektide juures näiteks lao tõstukiga seotud projekt ja palju muud. Kõik see viimase kahe aasta jooksul on aidanud mul valida lõputöö teema.

Lõpuks sooviks ma avaldada suurimat tänu ja armastust oma perekonnale, kes seisid mu kõrval toe ja julgustusega sooritada parimad tulemused.

LIST OF ABBREVIATIONS AND ACRONYMS

RFID – Radio Frequency Identification

WPS – Wi-Fi based Positioning System

AGV – Automated Guided Vehicle

IPS – Indoor Positioning System

GPS – Global Positioning System

CDMA – Code Division Multiple Access

NFC – Near Field Communication

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1. INTRODUCTION

1.1 Motivation

“Material handling generates something like 80% of indirect labour cost in the plant.”
“Material handling may be responsible for one-third to one-half of the total cost of production in some plants.”
“An uninterrupted flow of materials through a plant can increase the productivity of existing men and equipment by 15%” [1]

Material handling and processing has been a critical branch of any goods producing organization. Storage yards and warehouses play a vital role in the chain of procurement and supply for any industry. They hold a vital key to store, lock and then dispatch the goods when a particular order has to be shipped out. They can prove to be very profitable unit of the entire system if managed properly, but it has been seen that if the material handling is not done properly and in required time then it turns into a bottleneck returning in as loss making part of the flow of the chain for the company.

The time factor plays a very critical role in determining whether material handling turns profitable or brings loss to the company. The time factor here is defined by the time taken to locate, retrieve and deliver the required entity from the warehouse to the delivery area or the shipping department. The time wasted in locating the required package to be delivered costs a lot in terms of money to the company over the year, which is discussed in this thesis report as well.

Nowadays, there is growing demand for a reliable method for assets tracking and its management to be able to use in a warehouse and storage yard. In any warehouse the most time consuming activity is sorting/picking of any package and is subjected to have the most recurring errors.

In the current technologically challenging world there is a high competition to come up with a new technology that has to be developed to decrease the time wastage and the recurring errors in asset management, for storage yards in particular.

This thesis research has the objective to compare and evaluate the current existing technologies used for indoor asset tracking, taking in consideration the various kinds of purpose that they are used for and the different environment that they work under. Further than just comparing the technologies to come up with a very effective and a reliable method to manage, track and dispatch the goods from the warehouse taking in consideration the initial cost, operating cost and effectiveness of the system.

1.2 Overview of the topic, tasks and previous research

Material handling has a vast history and importance in human existence, every ancient or modern work humans do have one aspect in common between them i.e., the time which is taken to complete the work.

Let us take example of any engineering wonder in the world, from the great Pyramids, sturdy Eiffel Tower to recent The Large Hadron Collider (LHC) which is the world's largest and most powerful particle collider, the largest, most complex experimental facility ever built by humans. They all took years to build, but as we go through the history, the size of what humans built became bigger and the respective time taken to build it became less. If we wish to construct these ancient wonders today they might take a few months to build. So what brings upon such a difference in the time taken? Answer is very simple: Materials Handling.

During the past few decades the focus on materials handling has risen drastically and varies from industry to industry. The importance of materials handling efficiency is much higher in the industries where we see a high ratio of holding and handling cost to the total processing cost such as warehouses which are used to hold the produced goods and then are dispatched further when the demand arises.

Thus, materials handling needs a lot of attention to make it a productive link in the chain of events in any industry. The biggest factor that we need to focus is the time taken in the materials handling, excessive time consumption is considered as the biggest fallout for any system. Time in itself is considered equivalent to money, which is discussed in details further.

Tasks in the thesis report consist of explanation of the chosen method for mapping and tracking of materials in a warehouse using RFID (Radio Frequency Identification) technology in comparison to different methods such as WPS (Wi-Fi based positioning system), Bluetooth, Grid tracking, Long range sensors etc.

Each of the above system has its own advantages and disadvantages above each other, and on comparison over different aspects a conceptual RFID tracking system is presented which serves the purpose required.

All the above mentioned tracking systems were investigated, the performance of the tracking systems in a controlled environment like a warehouse or a storage yard configuration in consideration the various aspects of results that were needed, along with it the basic acquisition of the sensor information for an antenna based sensor tag for the reliability and working distance measurements.

In this study, the main features of a RFID based tracking system that can be used inside a storage facility including the set-up, configuration based on the test environment are simulated and the results of this model are discussed further. To verify the validity of the mentioned system, a basic RFID field test with various conditions were done using passive RFID tags and a cellphone with RFID sensor acting as a reader.

2. LITERATURE REVIEW

2.1 Materials Handling

Materials handling is defined as movement of material of any form (raw, finished, packaged, solid, liquid, gas, light and heavy) from one location to another location either in a restricted path by manual or mechanical aids. The movement may be horizontal, vertical or maybe a combination of both. [1]

Any type of industry whether big or small, of any king from service sector or production plant there is one common thing that they all ponder upon *i.e.*, materials handling and movement of material in and out of the working environment. Thus material handling directly affects the productivity and efficiency of any plant. Inventory costs are the costs that are related to the storing, maintaining and then dispatching the inventory over a certain period of time. Assessing inventory costs is therefore essential and has repercussions on the finances of the company as well as on its management. It helps the companies determine how much profit can be made, how inventory costs can be reduced, where changes can be made etc. It is commonly calculated that the carrying costs alone represent roughly 25% of the inventory value in hand. [2]

One notable reference is the calculation of the total inventory cost can be classified into:

- Cost of money: 6 – 12%
- Warehouse expenses: 2 – 5%
- Physical handling expenses: 2 – 5%
- Clerical and flow control: 3 – 6%
- Taxes: 2 – 6%
- Insurance: 1 – 2%
- Obsolescence: 6 – 12%
- Deterioration: 3 – 6%

This can be simply deduced as, in most favorable conditions a warehouse would spend roughly 25% of the total inventory carrying cost in just handling it. [4]

In our study we mainly focus on the reduction of handling expenses and the flow control which accounts for 5 – 11% of the inventory costs. Furthermore an additional cost adds up as inbound logistics costs which is related to transportation and reception (unloading and inspecting). Those costs are variable. Then, the supplier's shipping cost is dependent on the total volume needed, thus producing sometimes strong variations on the cost per unit of order for the handling unit. [3]

Of everything discussed a question arise, why do we need better materials handling and what are the advantages of it.
There are various advantages of good materials handling system, some of the important advantages are listed as:

- Reduction in flow movement and indirect labor cost.
- Reduced costs of transportation.
- Better use of floor space and facilities.
- Less fatigue to the workers.
- Reduction in bottlenecks.
- Greater flexibility.
- Improvement in the safety and reduction in accidents.
- Less backtracking of inventory, etc.

2.2 Major principles

Major principles in the material handling are categorized into three types in our study:

i. Reduction in time.
ii. Reduction in handling.
iii. Equipment design and implementation.

2.2.1 Reduction in time

As we all know that time is money, any time lost during any stage in production or handling will not help any organization to achieve its targets and every effort should be put in to save the time utilization in each step. For this very purpose it is very important to analyze and deduce where the idle time (non-productive) is. In our case, the time under consideration is principally in three main categories namely:

- Waiting time.
- Loading and un-loading time.
- Travel time.

Waiting time in our case is considered to be the time that is utilized in recalling where a particular asset is placed in the warehouse. This time is the biggest bottleneck in the supply chain as there are thousands of assets and the time wasted in figuring out where the demanded asset is located in the warehouse which is at times a hit and trial method, and tends to be the cause of major held ups.

Loading and un-loading time here is the time that taken by an operator to load the required asset and then further un-load it to the dispatching area. We consider this time to be perfectly managed in our study and is not covered.

Travel time is the time lost in traveling from one point to another point in or outside the storage facility. This time can be reduced by using the tracking system to plan the shortest and the quickest path to locate the asset and thus send it to the dispatching area. Ideally, asset flow should be a smooth transition from point A to point B, and should be handled only once.

Thus in a warehouse or storage yard it is critical to consider the layout and flow to minimize the waste movement and time utilization. In reality, the travel distance inside the facility and the waiting time adds up to unnecessary costs throughout the course of a year.

According to the Peerless Research Group's 2015 State of Warehouse/DC Equipment Survey [5], Bar code scanners (65%), labels (56%) are the top of the list technologies used in the warehouse and distribution centers, and none of these provide a solid system to reduce the above mentioned issues.

The same study suggests that the coming technologies that are planned to provide a better solution include smart phones or tablets (62%), RFID readers (25%) and tags (22%), and voice technology (13%).

According to results of the findings, one in ten user currently uses an AGV (Automated Guided Vehicles) for tasks including transportation (41%), storage (38%), bin picking (23%), truck loading (20%) and unloading (14%), and order fulfillment (20%). About 18% use robotics for functions like palletizing (42%), pick and place or part transfer (36%), packing/packaging (36%), de-palletizing (19%), and unpacking (12%).

2.2.2 Reduction in handling

Handling of material should be done in such a way that it should minimize the number of times an asset is handled. Reduction of handling directly reduces the time cycle for one cycle. It can be mainly done by the means of:

- Proper containerization.
- Minimizing backtracking.
- Layout improvement.

Proper containerization directly indicates to the way assets are contained in the particular facility, instead of random selection of placement the placement should be carried out in a proper manner based on either type, size, dispatch date etc. This in return reduces the handling time for the material.

Backtracking any asset in the storage yard is the major issue that any facility faces. Backtracking means either the method to track back the asset or to return a particular asset back to the holding are due to many reasons including wrong asset selection.

Layout improvement is one method to reduce the handling, but it is a method that has to be taken during the planning of the warehouse/ storage yard but improves a lot in terms of handling and time saving for a warehouse.

2.2.3 Equipment design and implementation

Equipment design and implementation consists of the designing and implementation of the equipments either used for the handling or tracking of the assets in the warehouse along with the implementation to which they are put to. Many a times these equipments are either not used to the potential or are used in a way that they don't serve the purpose that they are meant to and the extent that they should be utilized.

A proper design and implementation is the key to having a smooth running and functioning of any warehouse because any potential flaw in the design can have long term impact.

There are a lot of different kind of equipments currently in use including manual labor, forklifts and AGV's, all of which have their own advantages and disadvantages and is discussed further ahead.

3. INDOOR POSITIONING SYSTEM (IPS)

An indoor positioning system is the method of localization/positioning of a person/object in an indoor environment by identifying the orientation and direction of a person/object to provide the correct location of the person/object in concern without navigational errors.

There are various ways to determine the position of a person/object in an indoor environment using radio waves, magnetic fields, acoustic signals, or by using other sensory information collected by various devices. There are various commercial system available in the market, but none of them follow or uses any standard for an IPS system since there are no standards yet thus signifying the relative newness of this field of research.

All the technologies used in IPS, be it a passive technology or active technology, they have different methods but for any kind of measurement or localization/positioning they share a common mathematical principle needed to unambiguously find a location; trilateration. With trilateration method the compensation for unpredictable errors reduces drastically, making the overall localization/positioning much accurate.

The conventional Global Positioning System (GPS) is not suitable when it comes to localization/positioning indoors due to the reason of attenuation and scattering caused by the building material and the multiple reflections due to the various objects/walls cause multi-path propagation of waves which arises the issue of uncontrollable errors.

Despite a lot of various technologies available in IPS, most of them are too coarse to be used as a reliable method to determine the orientation or direction of a person/object.

3.1 Trilateration

In terms of geometry, trilateration is the process of determining an absolute or relative location of a person/object/point by measuring the distances using the geometry of circles, triangles (for 2-dimentional trilateration) or spheres (for 3-dimentional trilateration).

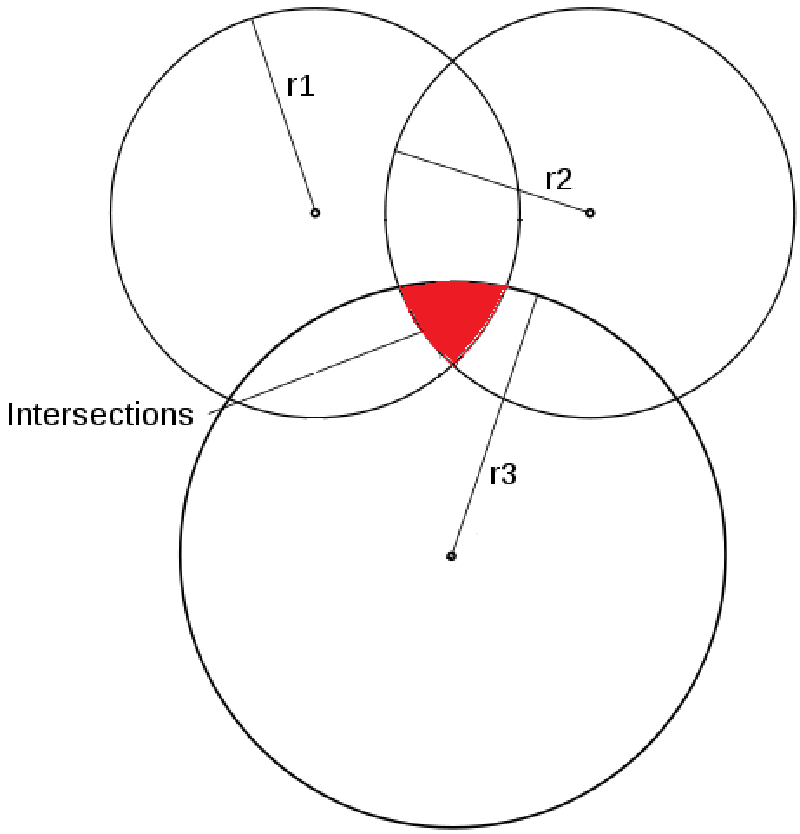


Figure 1- Geometry of two-dimensional trilateration.

In two-dimensional trilateration, the centers and the radii of the circles provide the information to determine the location. It is possible to determine the position using two circles but with the inclusion of the third circle it narrows down the position to a unique one (as shown in *Figure 1*), thus increasing the reliability, just like two points are enough to determine a line but three points always give a unique line.

The distance from the mobile target to the measuring unit is directly proportional to the propagation time. In order to enable 2-D positioning, TOA measurements must be made with respect to signals from at least three reference points, as shown in *Figure 1* [6].

A straightforward approach uses a geometric method to compute the intersection points of the circles of TOA. The position of the target can also be computed by minimizing the sum of squares of a nonlinear cost function, i.e., least-squares algorithm [6], [7].

It assumes that the mobile terminal, located at (x_o, y_o), transmits a signal at time (t_o), the N base stations located at $(x_1, y_1), (x_2, y_2), \ldots., (x_N, y_N)$ receive the signal at time$t_1, t_2, \ldots., t_N$. As a performance measure, the cost function can be formed by

$$F(x) = \sum_{i=1}^{N} a_i^2 f_i^2 (x) \ldots (1)$$

Where a_i can be chosen to reflect the reliability of the signal received at the measuring unit i, and $f_i(x)$ is given below:

$$f_i(x) = c\,(t_i - t) - \sqrt{(x_i - x)^2 + (y_i - y)^2} \ldots (2)$$

Where c is the speed of light, and $x = (x, y, t)^T$. The function is formed for each measuring unit, $i = 1, \ldots\ldots, N$ and $f_i(x)$ could be made zero with the proper choice of the variables(x, y, t). The location can be estimated by minimizing the function$F(x)$.

3.2 Various IPS systems

Having determining the importance of requirement of an IPS over GPS in terms of localization/positioning any object/person in an indoor environment we have to put some light on various approaches to designing a wireless geolocation system. There can be two basic approaches to develop a wireless geolocation system, first is to develop a signaling system and infrastructure to be used for location mapping using wireless applications, the second and the easy approach is to use an already existing wireless network infrastructure to locate a person/object. Both the approaches have their own advantages and disadvantages, but the second approach has a bigger advantage as that it helps in avoiding expensive and time-consuming (research) deployment of the infrastructure.

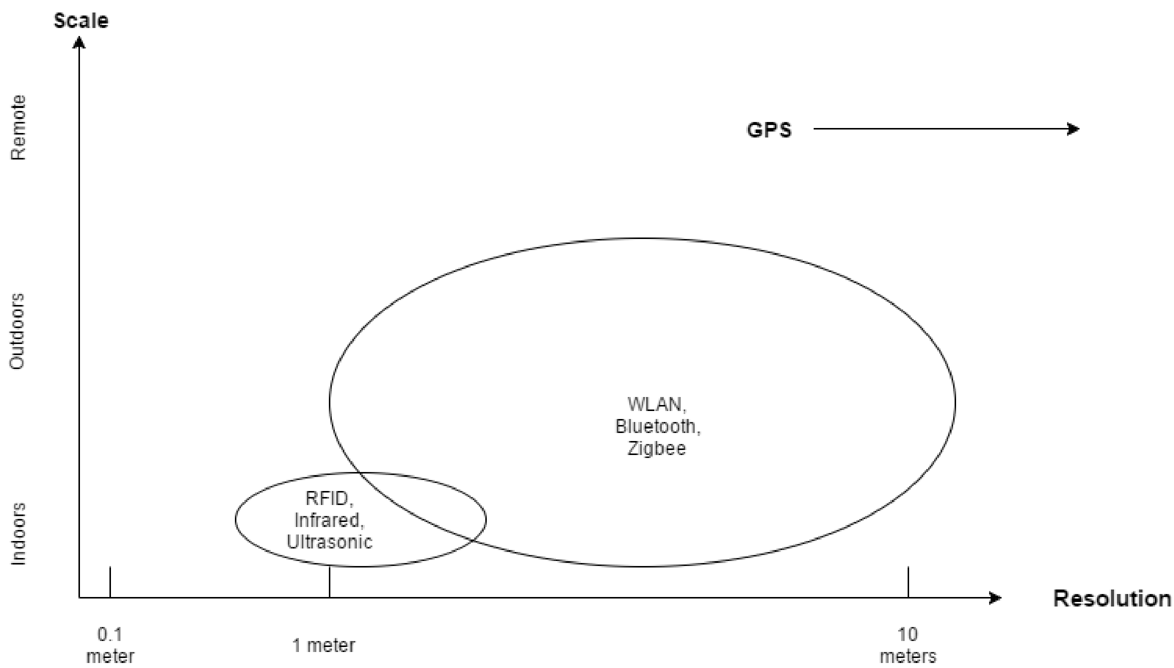


Figure 2- Current wireless positioning systems and their fields.

There are several types of wireless technologies used for indoor localization/positioning, some of them which we discuss further are depicted above in *Figure 2* according to their range and classification based on a field of use.

In the next section we shall discuss the various types of technologies mentioned above in the *Figure 2*.

3.2.1 GPS based

Global poisoning system (GPS) is used widely worldwide and is one of most successful positioning system in outdoor environment. Using GPS for outdoor position localization and information about the position along with the direction for guiding has been on a very high note since a few years and has become a very essential part of GPS application.

While as like many technologies GPS comes with a lot of drawbacks as well, the biggest and most prominent being the incapability of using GPS in closed environment. The signal strength weakens and it is practically impossible to use GPS for the same purpose indoors, as it serves no real use while navigating within buildings.

Though there have been recent progress in terms of making GPS work in the closed environment, Locata Corporation has invented a new positioning technology named Locata [8], for precision positioning with works in indoor and outside environment. The "Locata technology" consists of a time-synchronized pseudo lite transceiver called a LocataLite. A network of LocataLites forms a LocataNet, which transmits GPS-like signals that allow single-point positioning using carrier-phase measurements for a mobile device (a Locata). [16]

3.2.2 Cellular based

Over the year a lot of different kind of systems have used global system of Code Division Multiple Access (CDMA) and mobile (GSM), mobile cellular network to estimate the location of the device or clients outdoor. It has been seen generally that the accuracy varies a lot with such kind of positioning and is generally low (in the range around 50 to 200 meters).

Even the accuracy depends upon the cell size which has been seen to be much more accurate when used in a densely covered areas like cities and urban places, and much lower in rural places. [9]

In terms of using this technology as IPS, it must be noted that it is only possible if the building is covered by several base stations or can also be done by having one base station which has a very strong RSS received by the clients inside the building. The system that is used to do indoor localization uses the concept of *wide signal – strength fingerprint*. It analyses the 6 strongest signals from the reading of up to 29 GSM channels, and most of these channels are strong enough to get detected by the station but are too weak to be used as a mode of communication. Higher accuracy can be achieved with introduction of more channels, and can be accurate enough to differentiate between different floors of the building along with a floor accuracy as low as 2.5 meters.

3.2.3 Wi-Fi-based IPS

Wi-Fi based positioning method uses a few different ways namely Cell Identity (Cell-ID), Angle of Arrival (AOA), Time of Arrival (TOA), Time Difference of Arrival (TDOA), and signal strength aspects. All these systems use triangulation method to estimate the position of the required object, as shown below in *Figure 3*.

Over the past few years, many researchers have experimented with indoor positioning systems using wireless networks, the commercially available Wi-Fi based systems consists of a manager, a client and a server. The server serves a purpose of responding to the calculated position based on manager's positioning model. The usual accuracy for Wi-Fi based positioning varies between 1 to 3 meters depending upon the area. [16]

The biggest disadvantage with the Wi-Fi network must always exist as a part of the communication infrastructure, otherwise it will always need an expensive and time consuming development. Along with it the other issue that arises with Wi-Fi based IPS is the development cost in its designing. Given the fact that most of the IPS are designed to track small quantities of items, Wi-Fi based IPS doesn't give a cost effective solution for large quantities of items.

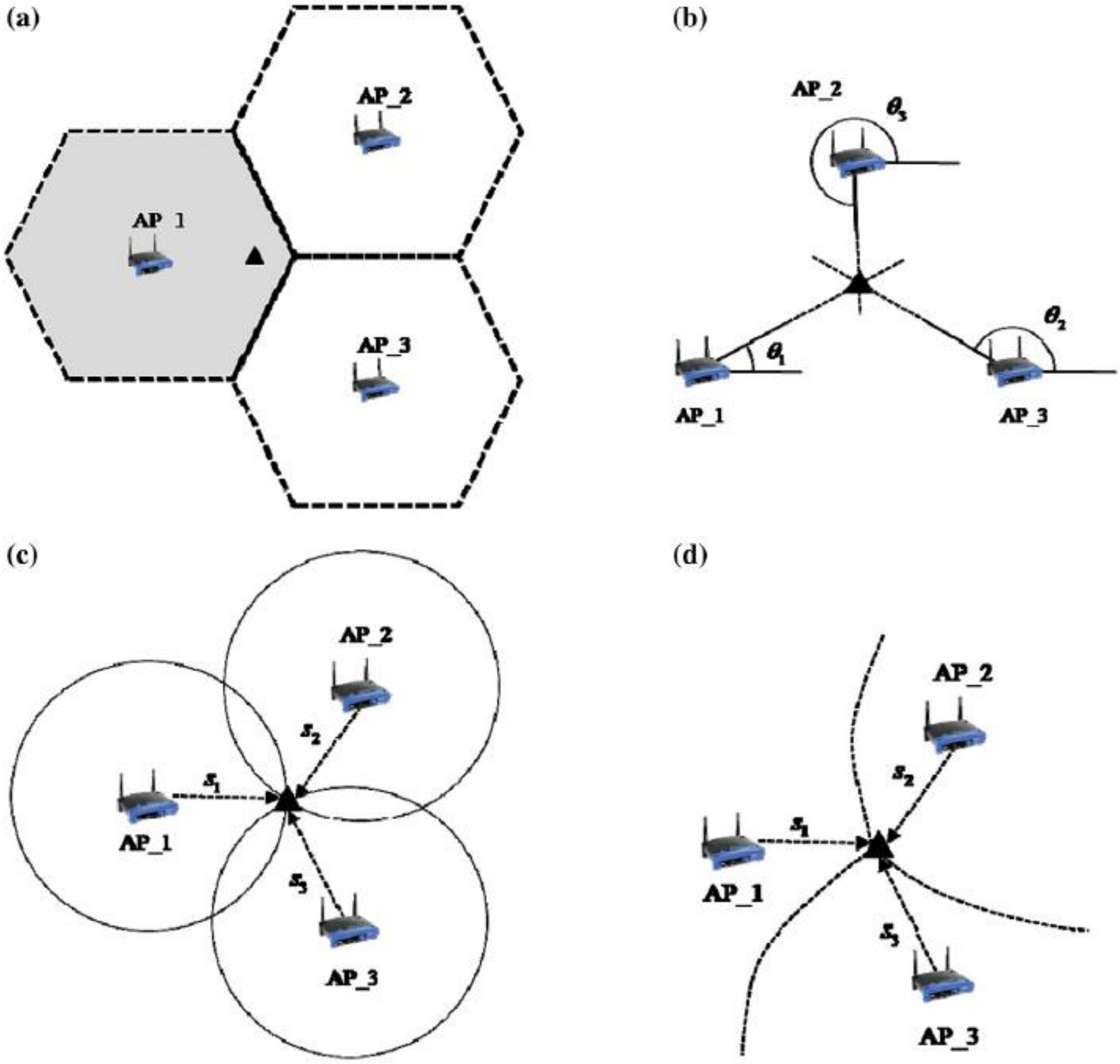


Figure 3: Various types of Wi-Fi based techniques. (a) Cell-ID, (b) AOA, (c) TOA, (d) TDOA

3.2.4 Bluetooth based IPS

The Bluetooth based IPS presents a technology which is well suited as an application which can be used in the indoor area for position localization. The position estimation in the mobile terminal without the need of changes in the already fixed installed network topology in the area.

Bluetooth based system is also based on the triangulation methods using the received signal's strength from the surrounding Bluetooth access points. For the precise location one must consider the interdependence between the signal strength that is received and the distance.

When using the technology indoors, boundary conditions like reflections, wall damping doesn't allow the use of free field propagation. Thus, there is the requirement of use of approximations of the RSSI. [15]

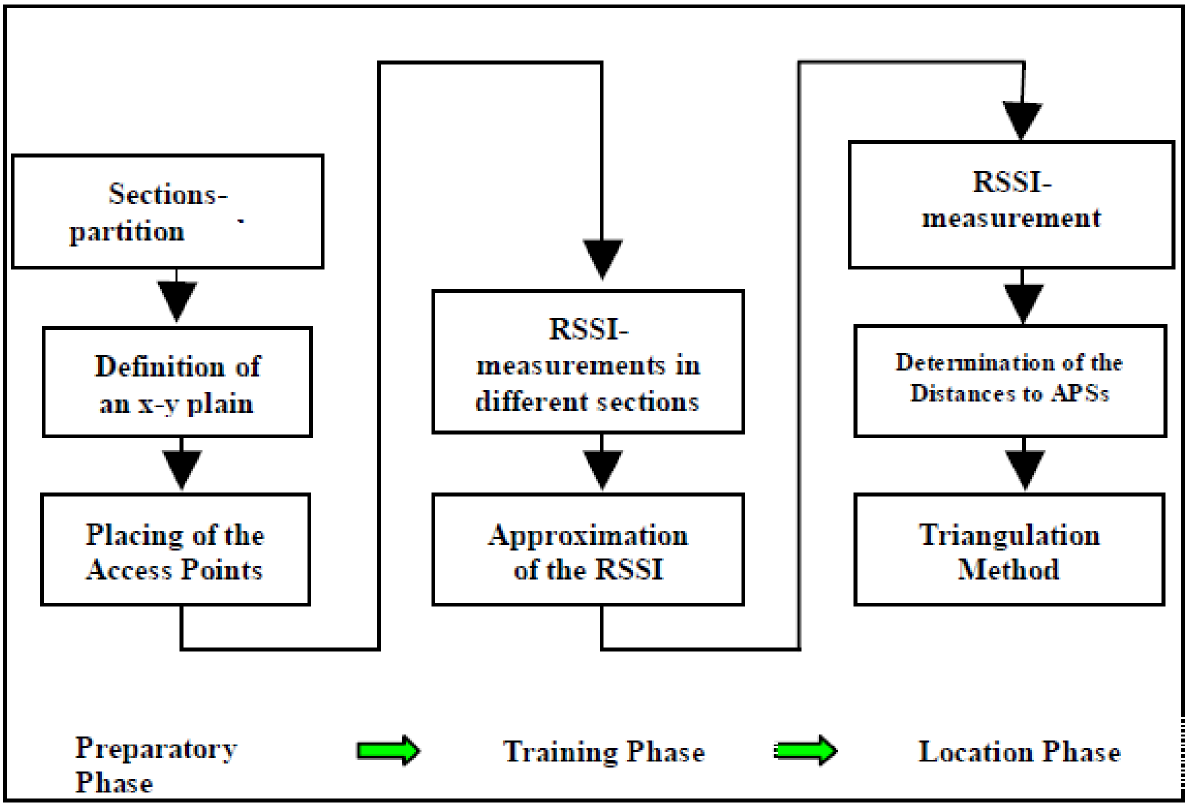


Figure 4: Structure of Bluetooth based IPS

Bluetooth operates in the 2.4 GHz ISM band, as compared to WLAN it has a lower bit rate of around 1 Mbps along with having a lower range around 10 – 12 meters. Ease of Bluetooth come with a fact that most of the personal computing devices such as cellphones, PDAs already have Bluetooth in them, furthermore Bluetooth technology is a lighter technology to use as compared to WLAN.

The usual accuracy of Bluetooth based IPS systems is around 2 meter with a reliability of approximately 95% with a delay of 15 – 30 seconds.

4. RADIO FREQUENCY IDENTIFICATION (RFID) AS IPS

Indoor positioning systems (IPS) locate the objects in the closed structures where Global Positioning System devices generally fail to work like stores, offices and buildings. Most widely available IPS systems use optical tracking, wireless concepts or ultrasound technology to serve the purpose. To enhance the ability of RFID technology being viable indoors with low cost has seen it been recognized as the next promising technology in serving the positioning purpose.

The concept presented here is based on the fact that it has to be used in a warehouse thus the forklifts would carry an RFID reader module, which would read the passive read-only tags installed in the pathway, the entire concept with details is explained in the next few chapters.

Compared to the conventional active technology method which are very high cost solutions, the study also features the feasibility of using passive RFID tags for indoor positioning at a lower cost and to locate the object to provide the real time information on position. Along with it, it also shows the readability of the passive RFID tags, and its performance being satisfactory to provide the required results. [10]

RFID technology is a very effective and efficient non-contact, automatic identification technology that uses the basis of radio signals to track, identify and sort various kinds of objects like people, goods and assets through a network of radio enables scanning device over a distance of several meters (depending upon the RFID tag).

RFID technology has been around since 1970's but until recently it has been too expensive to be used on a large scale as a localization method. Originally they were used for the tracking of large objects like livestock, airline luggage and railroad cars that were shipped over a long distance. They were then called inductively coupled RFID tags, and were a complex system of coils, antenna and glass.

At basic level all kinds of RFID tags available work on the same principle and the way:

- Data is stored in the RFID tag's microchip and it wait to be read.
- When the RFID reader comes in the proximity of the tag, the tag's antenna receives electromagnetic energy from the reader's antenna.
- Depending on being an active or a passive tag the power generated from the internal battery or the power harvested from the reader's electromagnetic field, the tag sends the radio waves back to the reader.
- The radio waves received by the reader from the tag's radio waves, it interprets the frequencies as meaningful data.

Every RFID system can be broken down on the frequency band that they operate on, whether it is low, high or ultra-high frequency. The frequency refers to the size of the radio that is used to communicate between each of the RFID system components. Hence the RFID systems are able to operate in low frequency (LF), high frequency (HF) and ultra-high frequency (UHF) bands. The radio waves are able to behave differently in each of these frequencies – and there are pros and cons of each frequency band.

Depending on the type of energy the tag uses RFID can be divided into three basic categories:

- Active RFID
- Passive RFID
- Battery-Assisted Passive (BAP)

The comparison table between these types is listed below:

	Active RFID	**Passive RFID**	**Battery-Assisted Passive (BAP)**
Tag power source	Internal to tag	Energy transfer from the reader via RAF	Tag uses internal power source to power on, and energy transferred from the reader via RD to backscatter
Availability of Tag Power	Continuous	Only within field of reader	Only within field of reader
Required Signal Strength from Reader to Tag	Very low	Very high (must power the tag)	Moderate (does not need to power tag, but must power backscatter)
Available Signal Strength from Tag to Reader	High	Very low	Moderate
Communication Range	Long range (100 m or more)	Short range (up to 10 m)	Moderate range (up to 100m)
Sensor Capability	Ability to continuously monitor and record sensor input	Ability to read and transfer sensor values only when tag is powered by reader	Ability to read and transfer sensor values only when tag receives RF signal from reader

As per the comparison above stated and the practicality of the usage to solve our purpose we choose to use a passive RFID tag. Passive RFID tags work on the principle that when radio waves from the reader are introduced in the field, the coiled antenna present in the tag forms a magnetic field. The tag powers itself from it by energizing the circuit. This energy enables the tag to send the information across to the RFID reader.

The functioning diagram of a passive RFID tag is shown below:

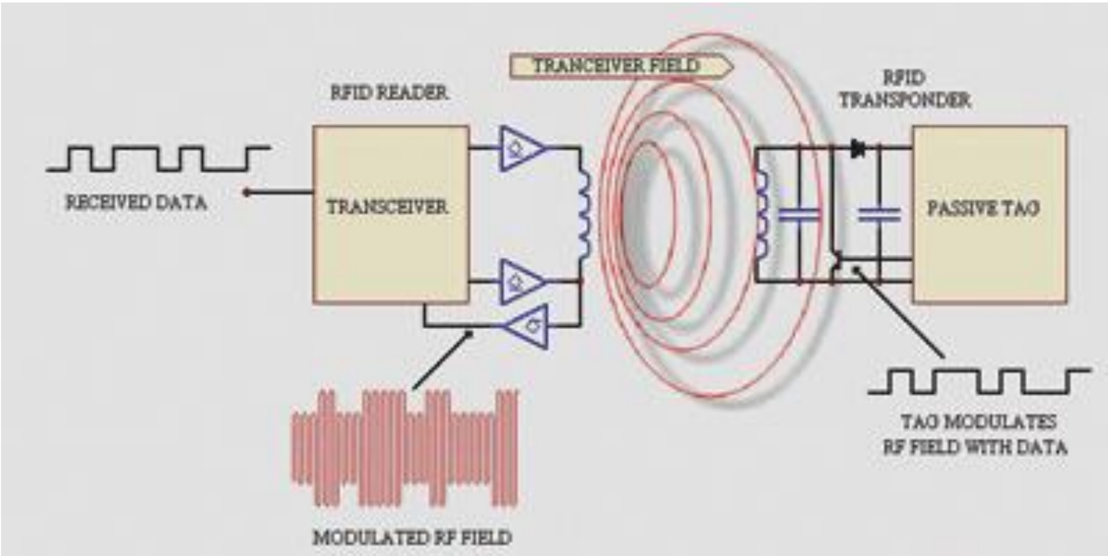


Figure 5: Passive RFID working concept

Figure 6 below illustrates the architect of the proposed RFID based indoor positioning system. The entire system basically consists of the passive RFID tags, a smartphone/PDA for the purpose of RFID reader in form of NFC and act as a processing module alone with a RFID reader which can be connected to the PDA/smartphone if in the case needed. The passive RFID tags are set up as fixed data tags in the working environment. The simple setup helps in reducing any additional information source, signal strength or the direction of the tag. The backend information can be handled easily by the mobile application (explained in the next chapter) thus saving the use of a server or control center.

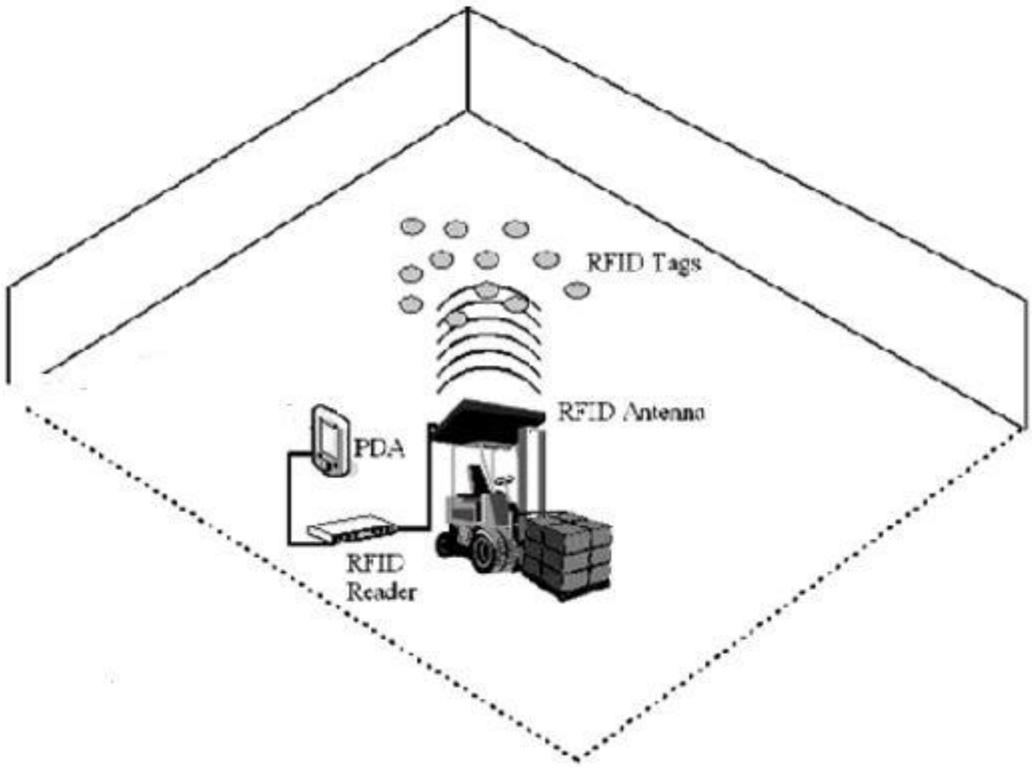


Figure 6: Architecture of the RFID based indoor positioning system [13]

The passive RFID tags used in for the study are a NXP MIFARE Ultralight (Ultralight C) – NTAG213 model [11], which have a memory size of 137 bytes, writable and can be made into a read-only tag if required.

These tags can hold the location memory of the position that they are set to along with the possibility of adding the additional information required as per the need.

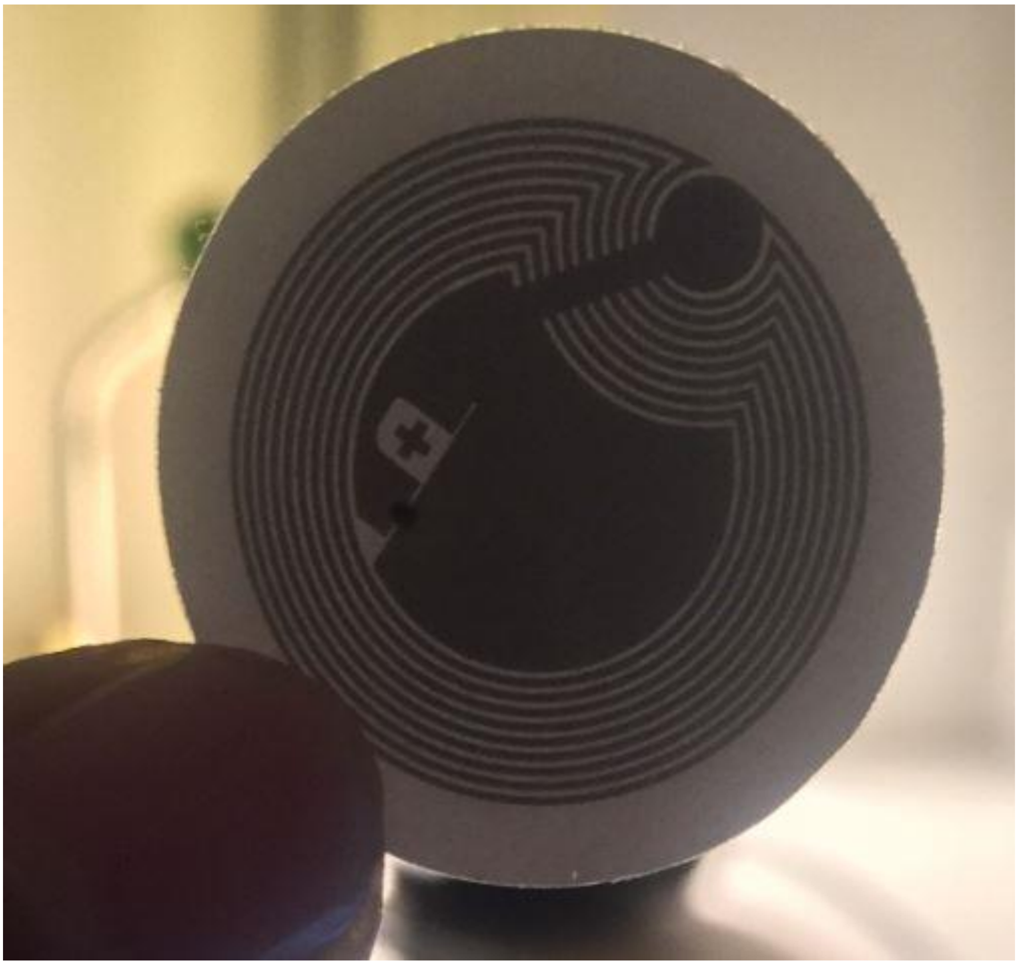


Figure 7: NXP MIFARE Ultralight (Ultralight C) – NTAG213 model RFID tag

The working concept of the architecture above mentioned is provided when the location of a certain object is determined by the detection of the RFID tag present on the ground. The location of each RFID tag is already known to the system and can be utilized for locating the required object. The system uses RFID technology stand alone to determine the required position without the need of any other additional information or source. [12]

The setup for the system requires one fixed RFID reader (if in case required) connected to the smartphone/PDA which is mounted on the forklift, a series of passive RFID tags are installed on the ground in the fixed projection at determined intervals that the forklifts follows. The distance between the tags can be determined on the factors of the total floor area of the warehouse along with the accuracy of the measurement that is needed to be achieved, the more densely populated area with RFID tags increases the reading accuracy of the system.

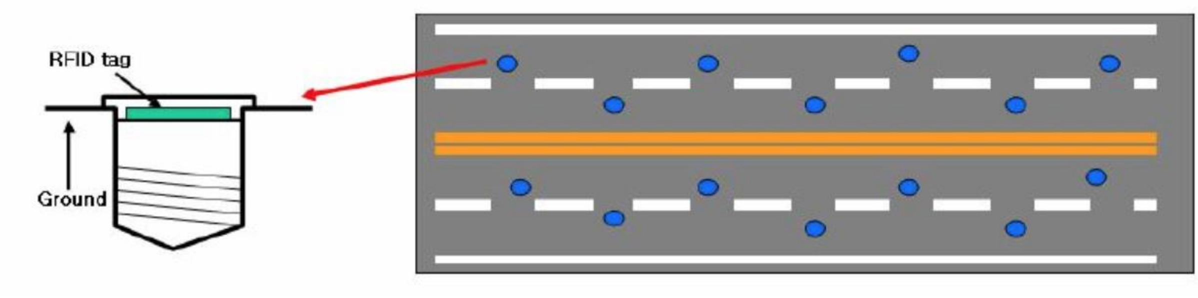


Figure 8: Model of RFID tags in ground

To localize any RFID tag on the ground to the overall reference frame that we create for the entire floor need an estimation, and the significant advantage of the RFID tag is the non-contact and non-directional nature additionally the ability of being more scalable, ability to re-write the information on them, more reliable and the ease of multiple tag detection at once. The one thing about the RFID tags that works particularly well in our case is that its performance is rarely every affected by any external noises like ambient light. Also another experimental advantage of the tags was seen to be that they could work with the introduction of dirt, wear (as they were covered with a film), and moisture only reducing the performance (detection distance) by a very marginal value.

According to some of the basic experiments conducted the detection distance of the tag was from a distance at least 6 cm when the tags were laid on the floor. The detection distance can be increased with the use of a tag with a bigger antenna.

The flowchart below signifies the flow of communication in when a forklift has to reach to a goal destination using the RFID tag sensors.

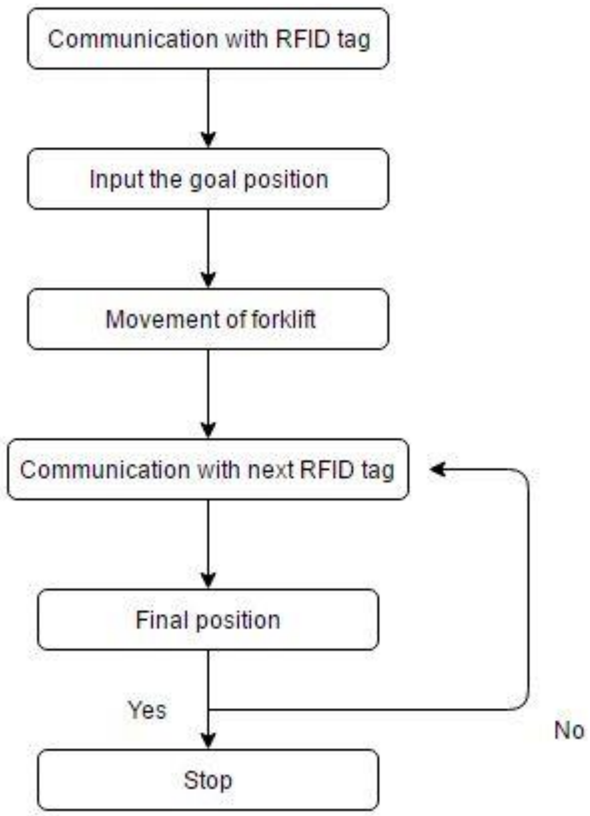


Figure 9: Communication flow between Forklift and RFID tag to reach a marked point

5. SOLUTION ONE: CREATING MOBILE APPLICATION

Mobile applications have been a great in terms of next generation technology for various customer based needs. For serving the purpose here as IPS for the warehouse a mobile based application has been created. Mobile phone applications have been a very reliable and are easy to create and de-bug in case if the application gets affected by a bug.

Here in the chapter it has been explained about creating a mobile based application (Android Operating System) using Near Field Communication (NFC) feature which is widely available on Android operating system based phones. NFC technology is relatively simple to operate, it is evolved from RFID. A NFC chip operates as one end of the wireless link wherein on the other end we have a RFID tag (in our case) completing the communication and sending the required data from one end to the other, as explained in the previous chapter. We can widely see the use of NFC technology in the mobile based payment between smartphones. There can be various more possibilities to use NFC like paperless tickets, access controls and even wireless car keys.

There are various kinds of NFC/RFID tags that can be read using the application from simple sticker tags to the complex cards with integrated cryptographic security hardware.

In the next section I have explained how to build android application which I have named NFC Tool. It guides and helps anyone to build and access the application to use it as indoor positioning system. The used codes are also available at the end of this report, but the basic build up and codes are explained ahead.

5.1 NFC Tool

NFC Tool is an android based application which is free to download from the Google Play Store which was made to read RFID tags and communicate using NFC technology, but we use it in a different way to solve our purpose, I have explained a bit on how to create the application using Android Studio and the codes that can be used to make the application are also available in the Appendix.

As the name suggests, NFC tool application will use the NFC technology already present in most of the Android based smartphones/tablets. The various tools that will be added in the application will include the options to read the RFID tag, protect the RFID tag information, set a location point information in the RFID tag, link to the navigation application.

The flow in which the system works has been shown below:

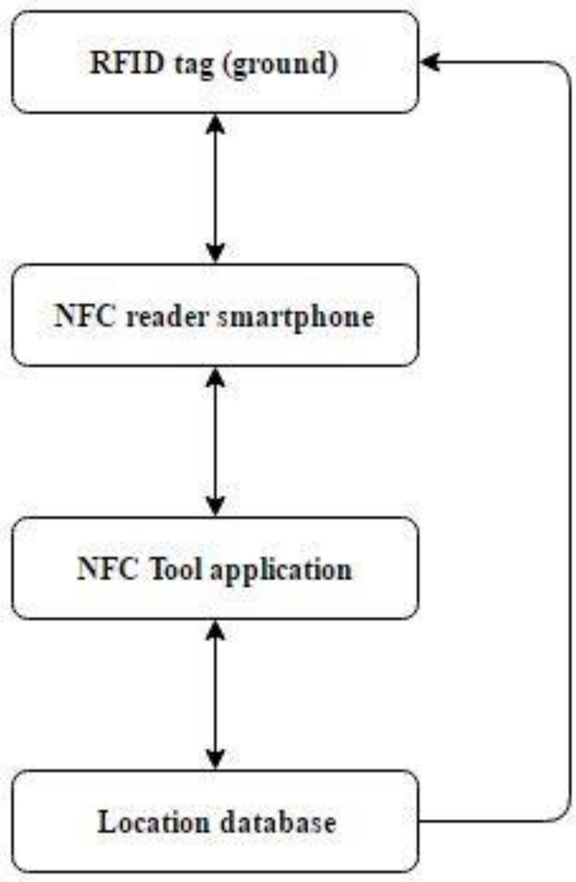


Figure 10: Application flowchart

To get started we need to download Android Studio, I will be using Android Studio version 2.2.2.0 for Apple MacBook to develop the application. The software is free to download and use, which can be downloaded from: https://developer.android.com/studio/index.html

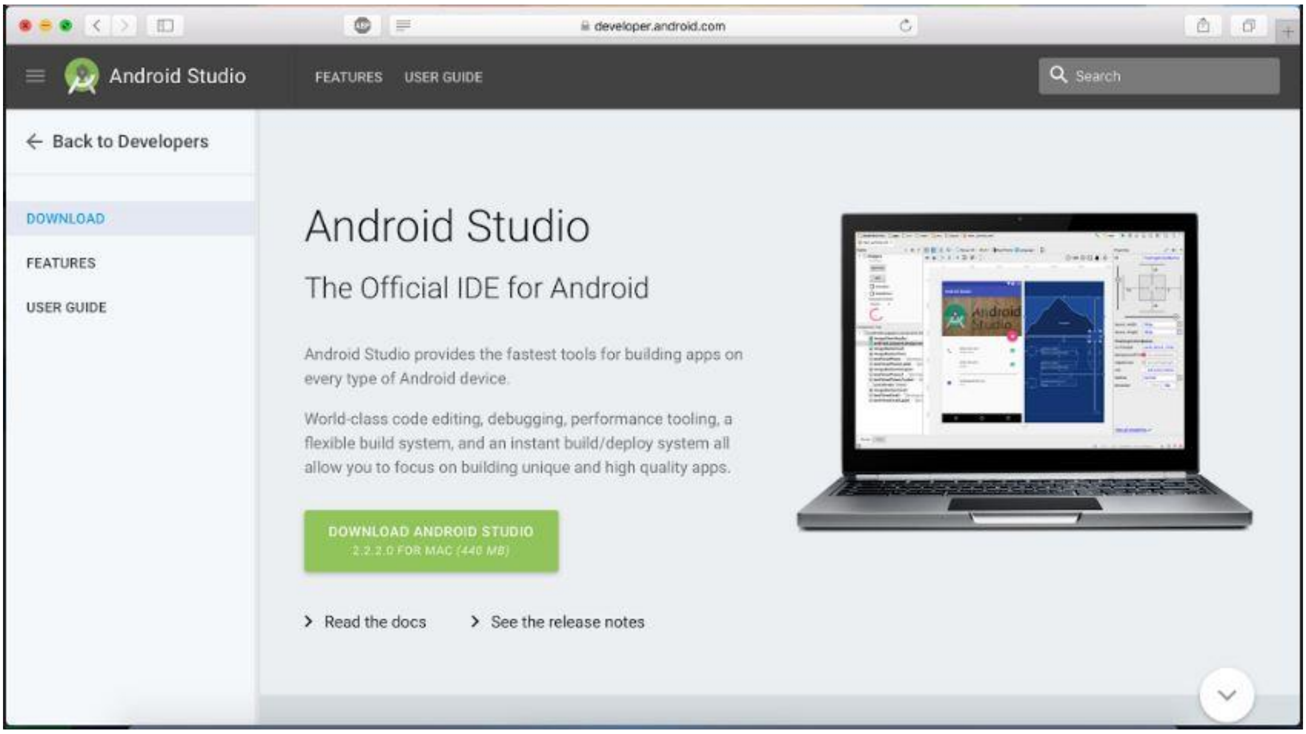


Figure 11: Android Studio download

It must be noted that once we download and install the Android Studio, we also must have Java installed on the computer because we would use Java programming to make the application. We have to make sure that we have Java Development kit 7.0 or higher (I have used Java Development kit 8.0 which is also free license product.

In *Figure 7* below we can see the start-up screen for Android Studio, in which we can choose between various different options to start, edit or import an Android project. Before we start building up the code and configure the application we can also go onto check the SDK (Software Development Kit) manager to check the compatible version of operating system that the application can run on as shown in *Figure 8* and *Figure 9.*

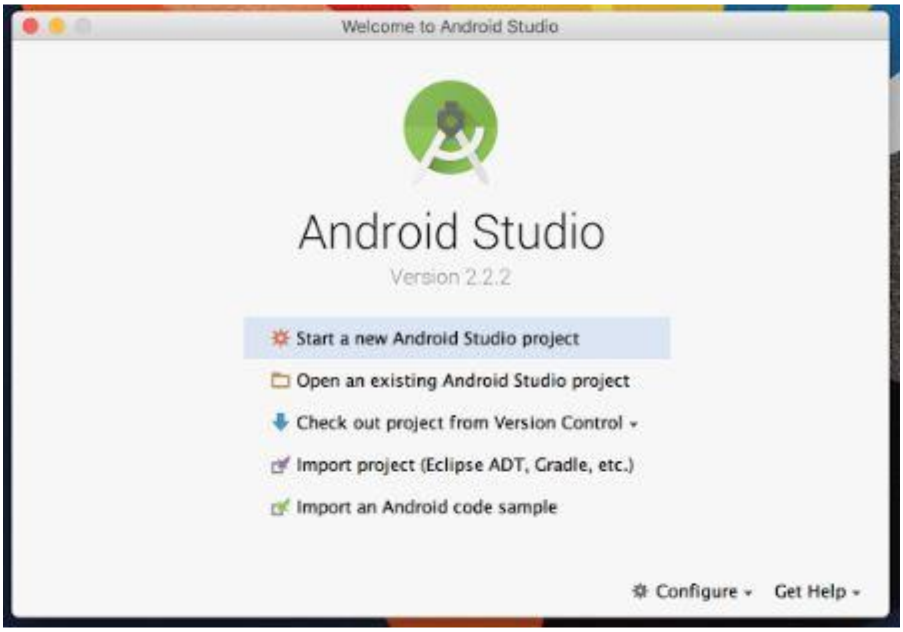


Figure 12: Android Studio start-up

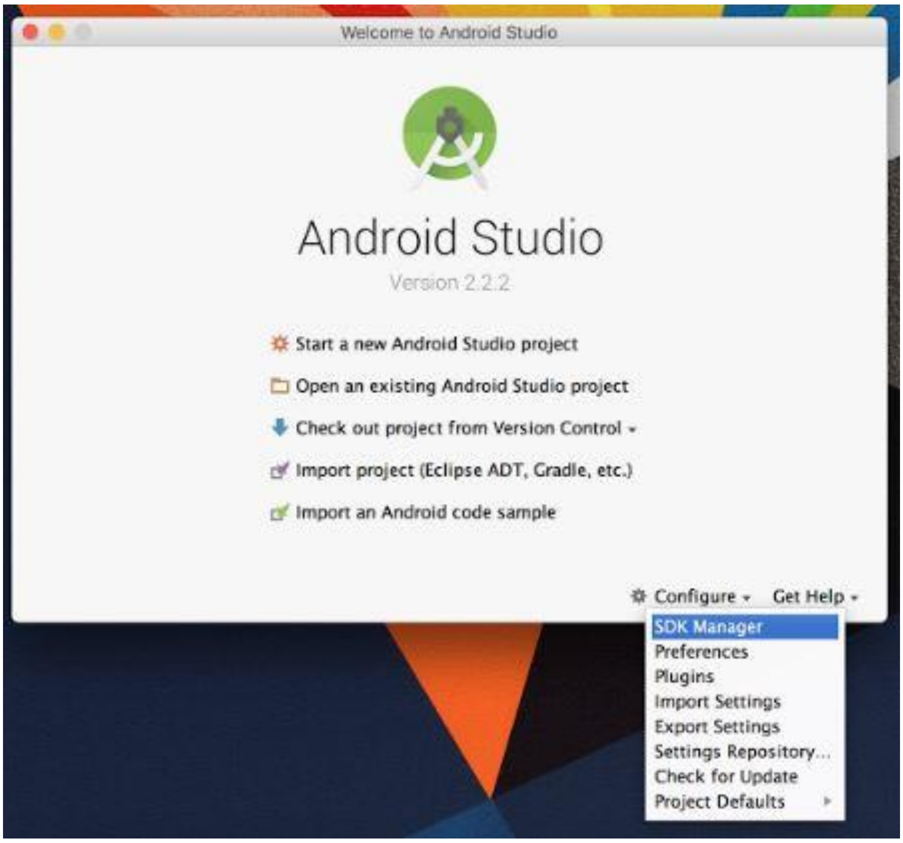
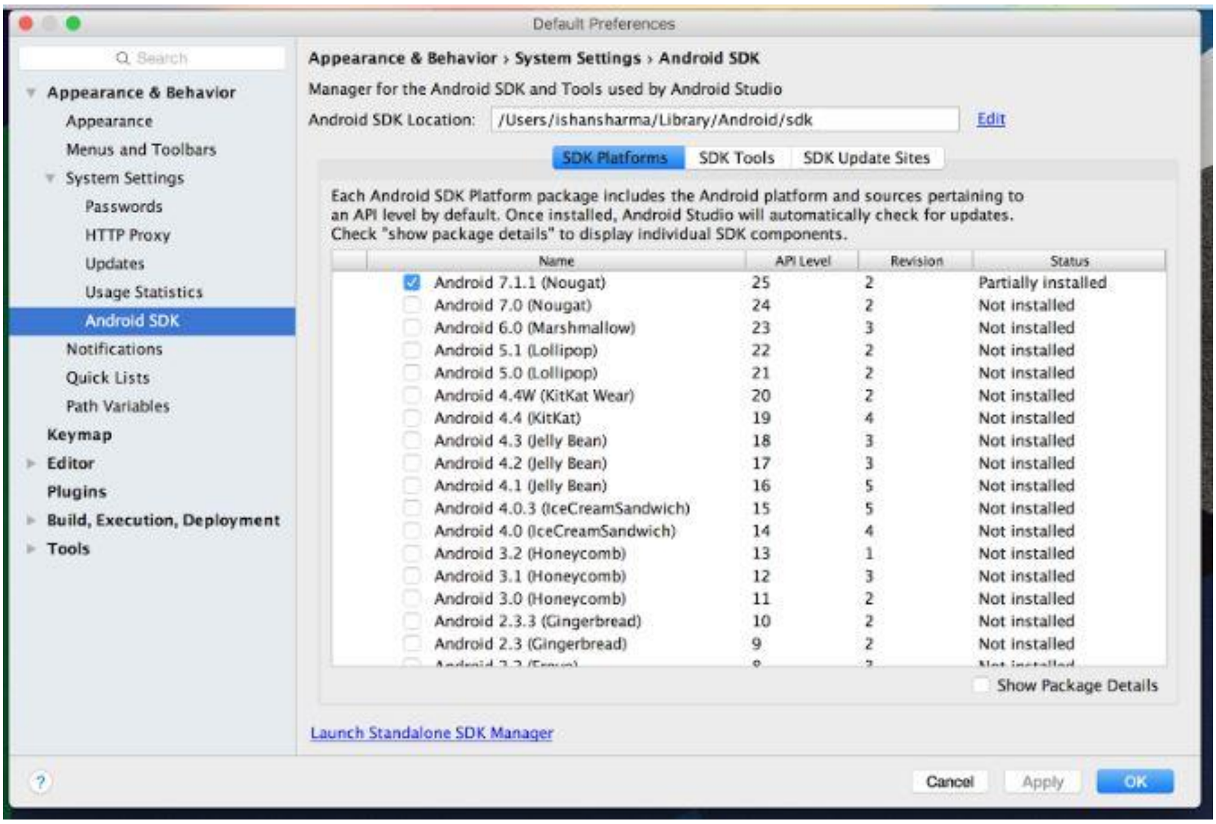


Figure 13: Android Studio configure manager



Name	API Level	Revision	Status
Android 7.1.1 (Nougat)	25	2	Partially installed
Android 7.0 (Nougat)	24	2	Not installed
Android 6.0 (Marshmallow)	23	3	Not installed
Android 5.1 (Lollipop)	22	2	Not installed
Android 5.0 (Lollipop)	21	2	Not installed
Android 4.4W (KitKat Wear)	20	2	Not installed
Android 4.4 (KitKat)	19	4	Not installed
Android 4.3 (Jelly Bean)	18	3	Not installed
Android 4.2 (Jelly Bean)	17	3	Not installed
Android 4.1 (Jelly Bean)	16	5	Not installed
Android 4.0.3 (IceCreamSandwich)	15	5	Not installed
Android 4.0 (IceCreamSandwich)	14	4	Not installed
Android 3.2 (Honeycomb)	13	1	Not installed
Android 3.1 (Honeycomb)	12	3	Not installed
Android 3.0 (Honeycomb)	11	2	Not installed
Android 2.3.3 (Gingerbread)	10	2	Not installed
Android 2.3 (Gingerbread)	9	2	Not installed

Figure 14: Android manager SDK configuration

As we can see above in *Figure 9*, the initial setting is for the application to work on Android 7.1.1 (Nougat) version which supports 97.4% of all Android smartphones/tablets in use currently as shown below in *Figure 10*. But it is recommended to install a few older versions as well as some devices may face compatibility issues. It also gives option to build the application for Android based watches and Televisions which in our cases will remain unchecked.

Figure 15: Compatibility search

To start building the application, as in *Figure 7* click on to start a new android project.

Once we start building the project, we need to declare the Application name, Company domain and project location. As shown in *Figure 11*, I named the application as NFC Tool, since it is an application owned by me I named the domain as ishansharma.

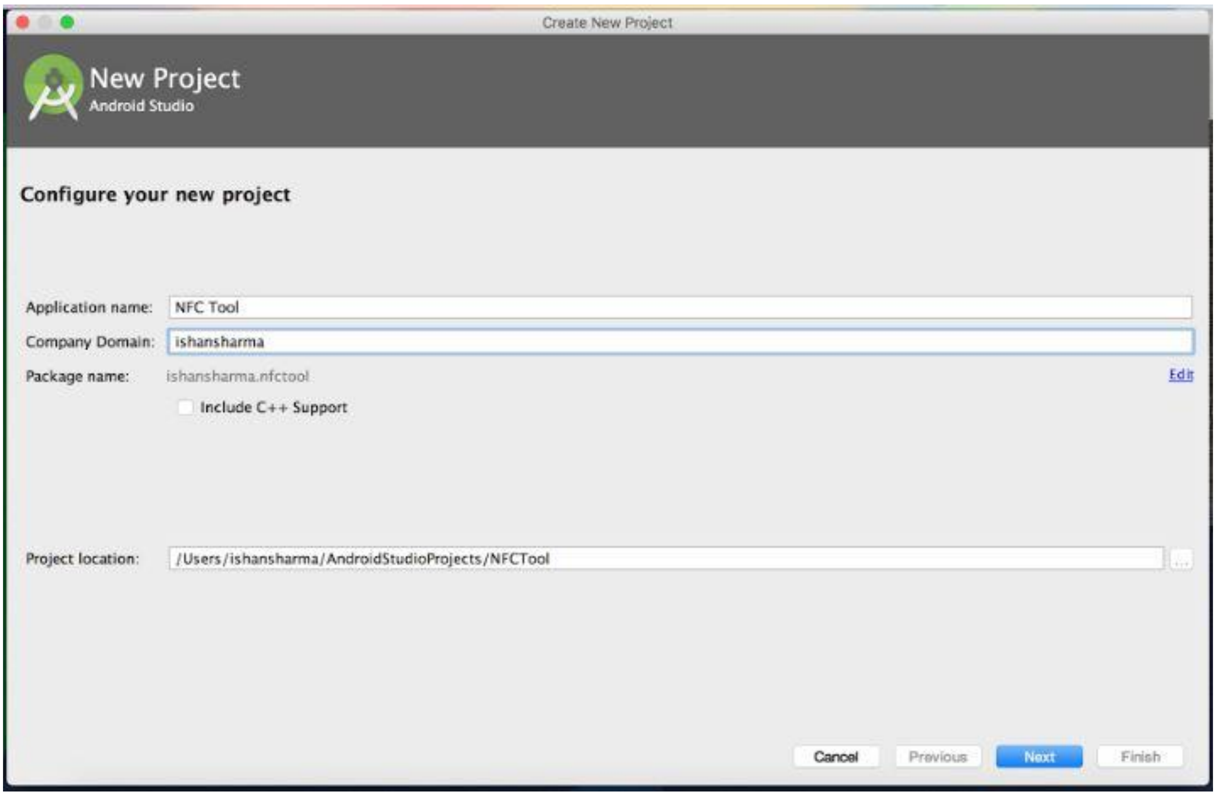


Figure 16: Project configuration

Next we need to choose the kind of activity the application would be for the phone. The software allows a variety of application type, but we chose it to be a Basic Activity as we would configure it according to our needs, as shown in *Figure 12*. Basic activity gives an advantage of referencing existing codes and bits to the Java programming.

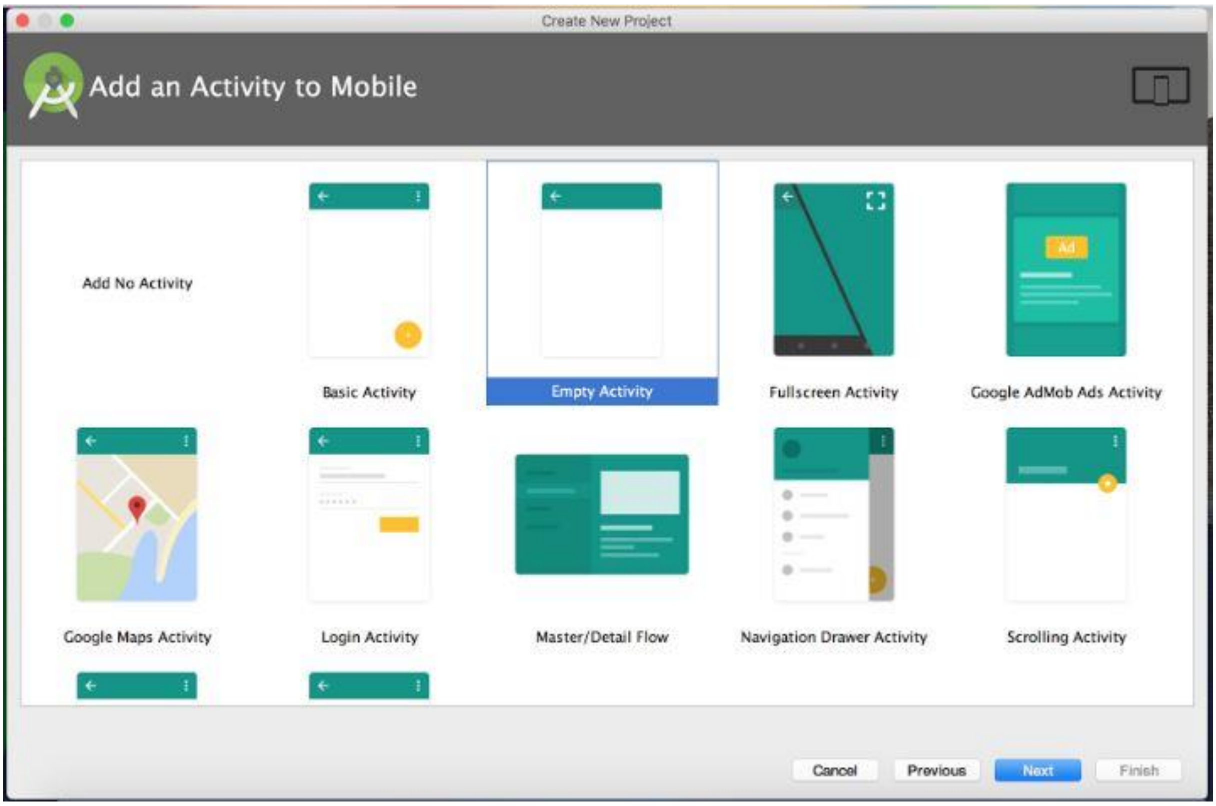


Figure 17: Application activity selection

Upon selecting the Basic activity, Android Studio creates a new basic activity with an application bar where we can give the Activity name, Layout name and the title of the activity, as shown in *Figure 13*. We leave the settings unchanged to finish building basic steps to set up the application which then gives us the platform to work on Java, XML files and along with it create a user interface for the activity. Android Studio takes a few minutes to set up and build the application editing mode.

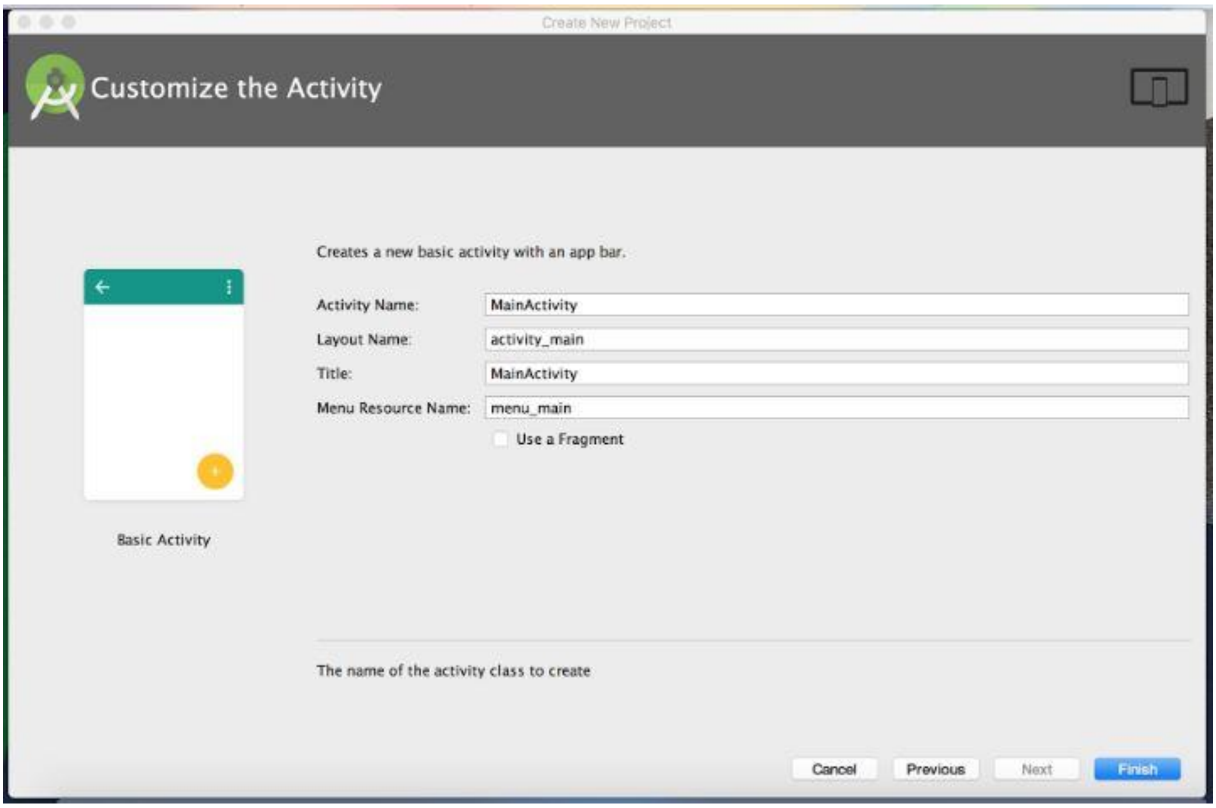


Figure 18: Activity customization

Once we finish the basic build-up of the application in terms of setting it up, we are then we get the access to the main application build-up screen where we can work on the Java script, XML and the visual representation of the application.

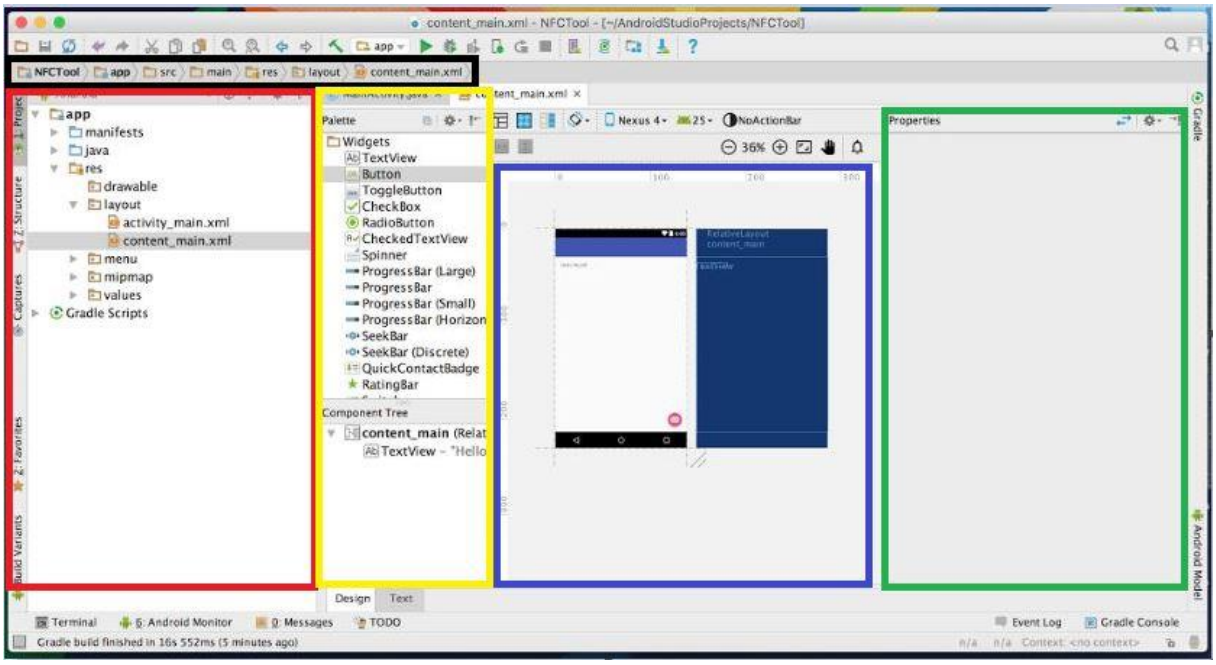


Figure 19: Application development mode

In *Figure 14*, is the application development screenshot with highlighted areas that define different windows or work area needed for application development. The black highlighted area defines the root directory in which we are currently working, for the above case being NFCTool > app > src > main > res > layout > content_main.xml; area highlighted in red being the project window; yellow being the Pallet and Component tree; blue the visual of the application and green being the property window where we define widget action.

When the application is launched it searches for the list of defined activities to work on, which is the tree under the column called Manifest. The application will look all of the activities and look for properties called launcher now, launcher is applications starting point. Once the launcher runs, it moves to the main activity where all other activities get defined. The main project heading are manifest, Java (where all the java scripts are added), and layout (where the app design is defined).

5.1.1 Getting NFC started

To get access to the NFC hardware on the device we need to add a permission first and foremost in the manifest. If NFC is not started when the application starts the application holds no use and will not serve out purpose.

To start the NFC in the device we need to add the following code in the manifest:

```
<uses-permission android:name="android.permission.NFC" />

<uses-feature
    android:name="android.hardware.nfc"
    android:required="true" />
```

Along with it we need to add Java file in the MainActivity to make sure that the device that we are using for the application supports NFC, or else it warns the user about the device being a non-supportive. The Java file is mentioned in the Appendix.

The further files for coding are also mentioned in the Appendix and are available separately as well.

The next step after making the application is to link it with another application NFC Tasks which is also available free to use on Google's Play Store as well. Upon installation this application automatically connects itself to NFCTools application and then allows us to write data on the RFID tags, this data includes naming the tag and as well as adding co-ordinates in a location tab of the application. Adding location data to the tab makes it possible for the tag to have its position determined with the help of any map based application.

This location data is all saved in the passive RFID tag which can be used to solve the purpose of asset tracking.

6. SOLUTION TWO: RFID READER via USB

This solution for the problem uses a basic connection of Arduino along with a RFID reader which allows the user to use a simple end user to detect the RFID Tag and thus the location.

We need the system to process and save the data from and to the database for the cycle to run. The idea that goes into this includes a central database (location and tag number) which the microcontroller uses to process the information from. Each RFID tag has a unique code to it, this unique identity acts as the main location plotter. In the database which is created during the set-up of the system, each tag number is linked to the particular location in the warehouse which acts as the unique location identity for it.

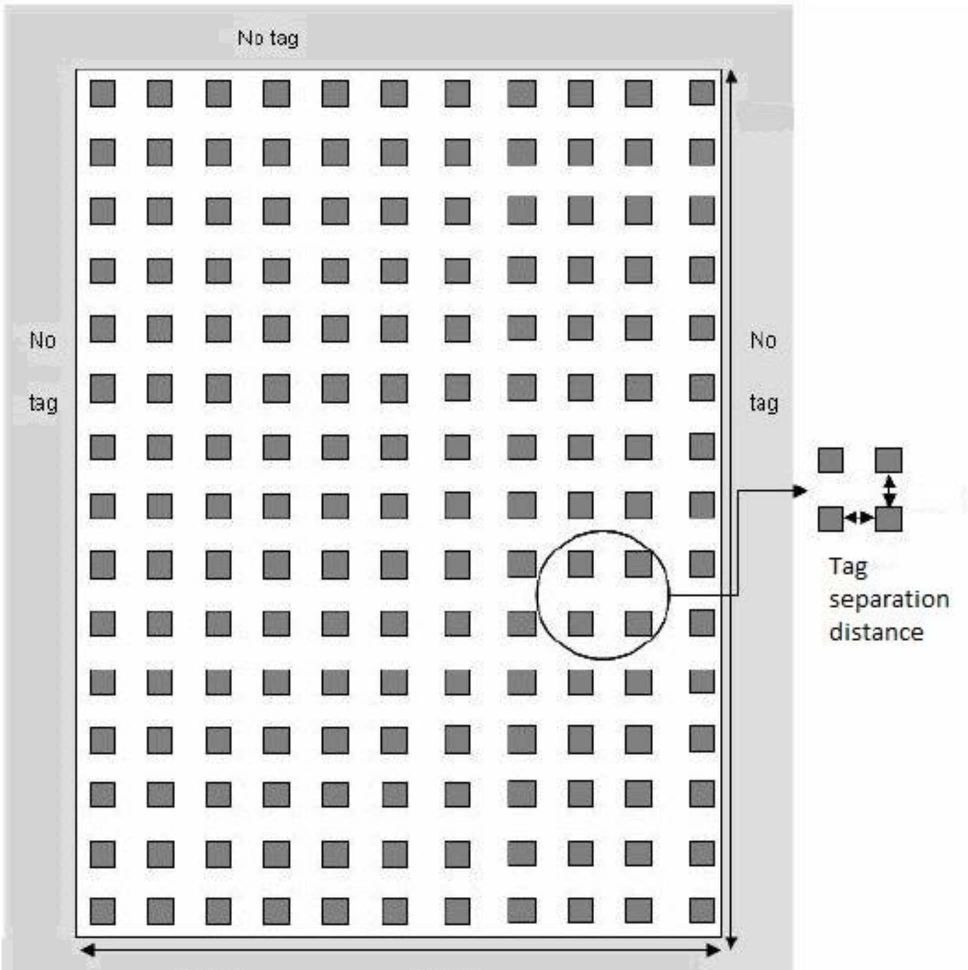


Figure 20: Floor placement of RFID tags

In the above figure we define the position of the RFID tags on the floor of the warehouse, the tag separation distance depends on the size of the warehouse and the accuracy required for the system. The number of tags is directly proportional to the accuracy achievable for the system.

6.1 Arduino to RFID reader connection

The RFID reader that we are using for the system is RDM 125 kHz card mini module which is designed to read RFID tags from 125 kHz compatible read, read and write or read-only cards. This is a very widely used reader which can we used for various purposes in homes, offices for security, personal identification, access control and in our case make a useable IPS system.

Some of the important features of the model we used (RFR101A1M) are:

- Small outline design, which allows us to mount it to the forklift easily.
- Decoding time of less 100ms.
- Effective reading distance of 50mm.
- Support external antenna which helps us to increase the effective reading distance as well.
- Very low cost (12 USD)

Technical details of the reader are:

- Power supply: 5V DC (±5%)
- Current: < 50 mA
- Operating range: > 50 mm (depending upon card/ tag size)
- Working temperature: -10 ℃ to +70 ℃
- Storage temperature: -20 ℃ to +80 ℃
- Size: 38.5 mm × 19mm × 9mm

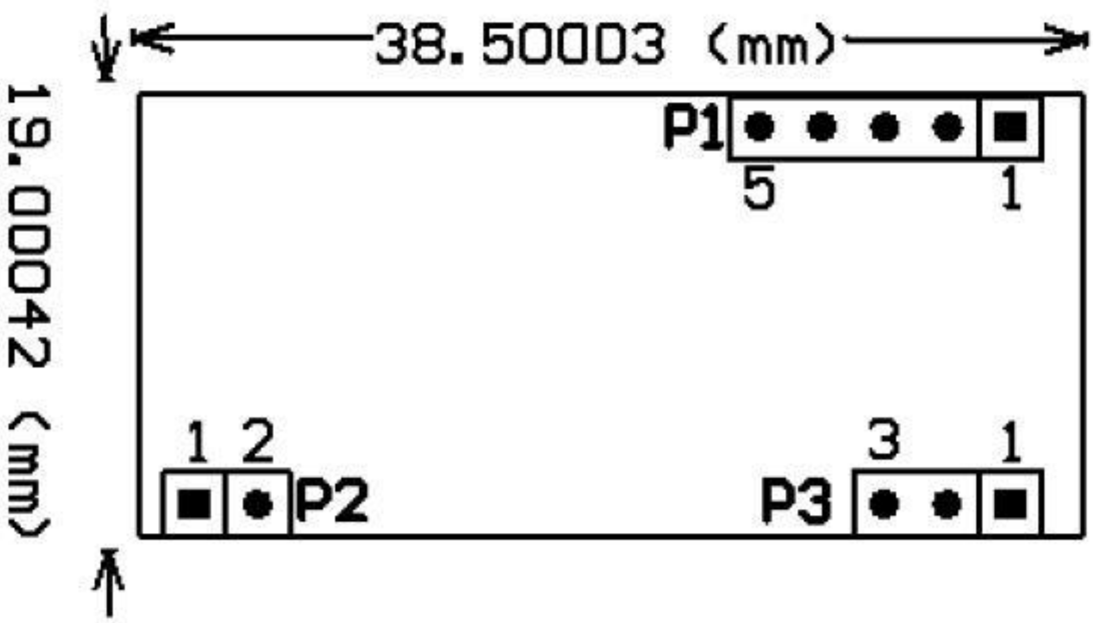


Figure 21: Size and pin layout of RFID reader

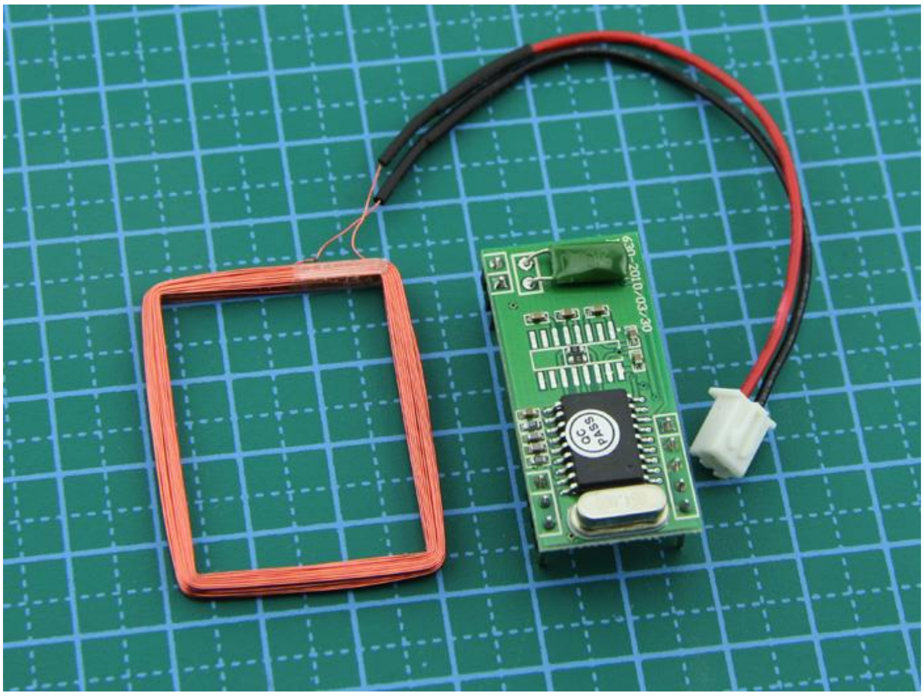


Figure 22: RFR101A1M RFID reader along with antenna

The final connections about the system can be seen below in *Figure23.*

Since we are applying the use of Arduino, we shall know the basic of using the microcontroller as well as the basic hardware configuration that goes along with it. Arduino is one of the most widely used microcontroller by hobbyists to make projects because of being very easy to program and being open source, meaning that all the design files that Arduino uses are public and anyone can use it for their use. Arduino in itself has digital pin headers that are series of plastic lines with holes which gives the access to the chip below. These pins are numbered from 0 to 13 along with a GND (ground).

There are 6 analog pin headers in Arduino board marked from 0 to 6, it also consists of a reset button which enables the microcontroller to end the program and run it from the beginning without deleting the files thus enabling to give the user a soft reboot button.

Since it is an open source program it can be used very easily and can be found for free for download. The program called integrated development environment and (IDE). For installing Arduino, go to Browser >> Arduino Home page i.e. arduino.cc > go to downloads >> select operating system (Arduino is available for all operating systems, we test it on Windows OS and MacOS).

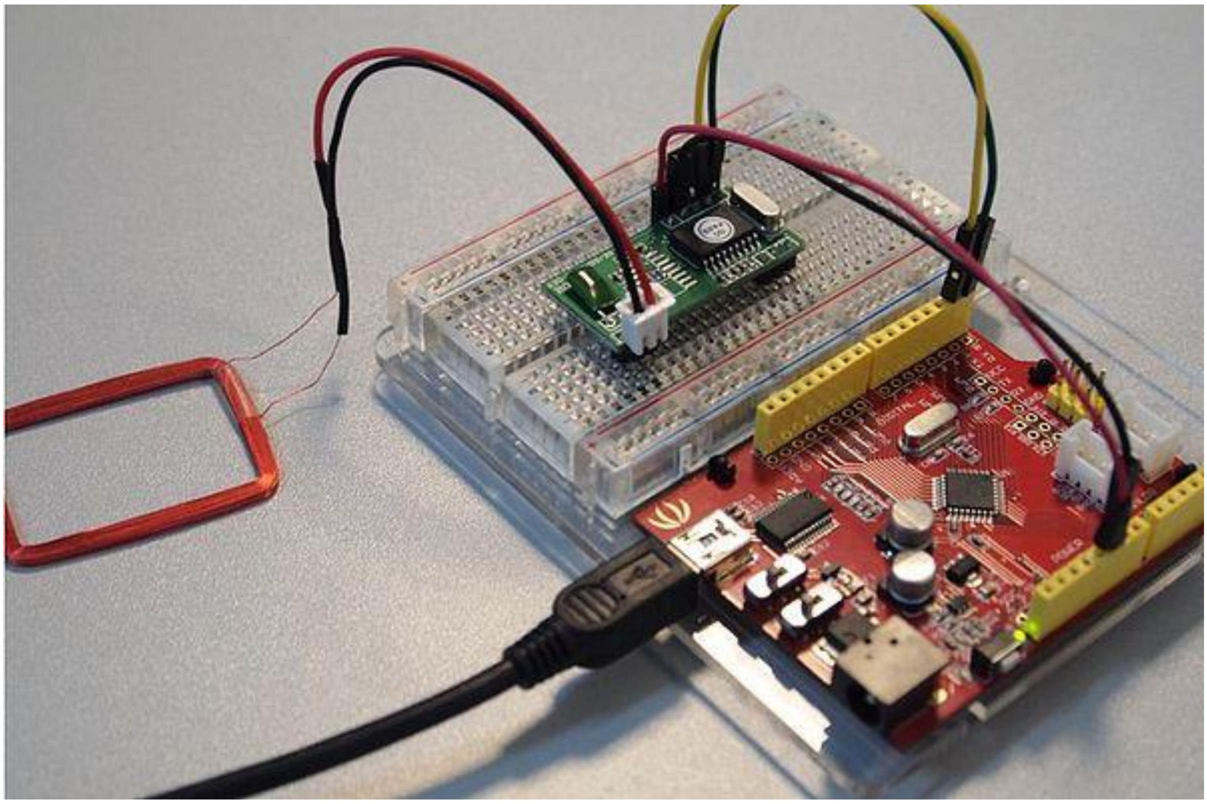


Figure 23: Arduino and RFID Reader connection

Before setting up the microcontroller via. USB, I would like to explain how the structure of the system work with a help of a flowchart depicted in the Figure below.

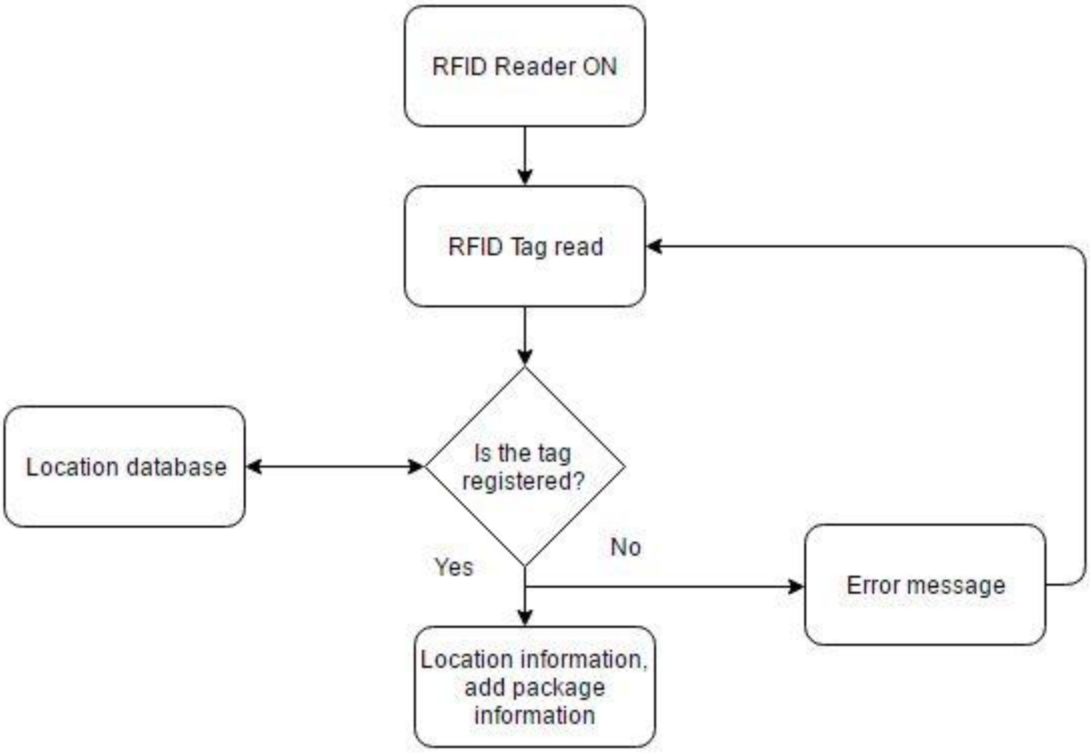


Figure 24: RFID via USB flow structure

When the RDIF reader is on, it activates the passive RFID tag which should upon activation share the tag information which includes its location as well as any package data that it might be registered with.

If in case there is any package information it can be read and edited to remove it if needed, if a new package is to be registered to any location point the same information is added to the database which is accessible to all units or forklifts. If there is a case wherein the tag is read by the RFID reader and there is no location information for it, an error message informs for the same thus helping in bringing the accuracy up. All the location information can be password protected to make sure that there is no repeated location points in the system by error.

For setting up the whole system, we connect the microcontroller, the antenna and the reader in the following way:

- RFID reader is connected to the breadboard.
- Further connections are needed on RFID sensor: PIN 1 to Tx
- PIN 2 to Rx
- PIN 3 to NC
- PIN 4 to GND
- PIN 5 to VCC (+5V)

Along with it, Tx from RFID board goes to the digital PIN 2 on Arduino board.
This setup lets us work for using the RFID reader connected to the antenna.

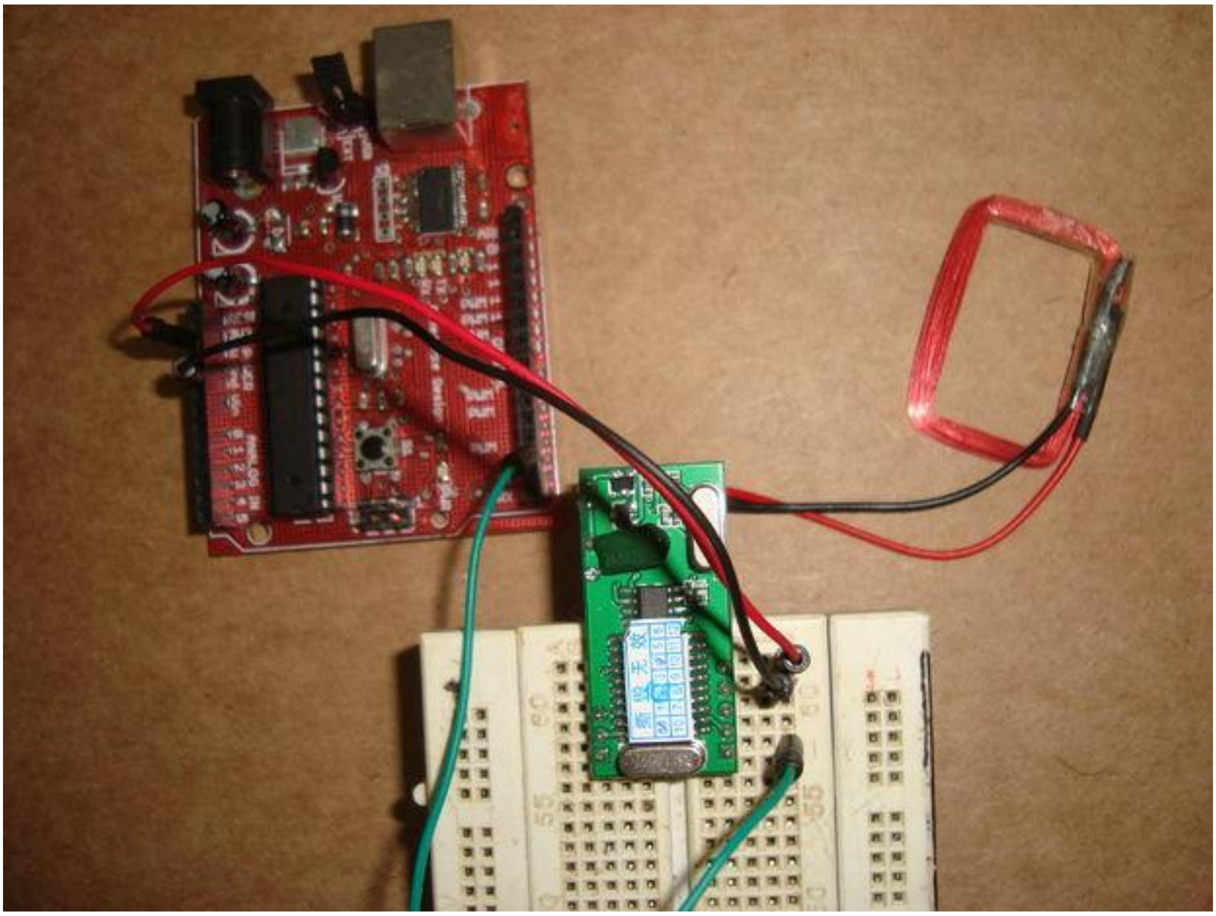


Figure 25: Setup of the system with Arduino, RFID reader and antenna

The connections can also be explained as, we simply insert the RFID reader main board into the breadboard as shown in *Figure 24*. Using jumper wires we connect the pins from RFID board to Arduino 5V and GND as per the list above. The RFID antenna coil connects to the top two-right pins (they can be connected either way). Lastly we need to connect jumper wire from the bottom-pin on the RFID reader board to the Arduino digital pin 2.

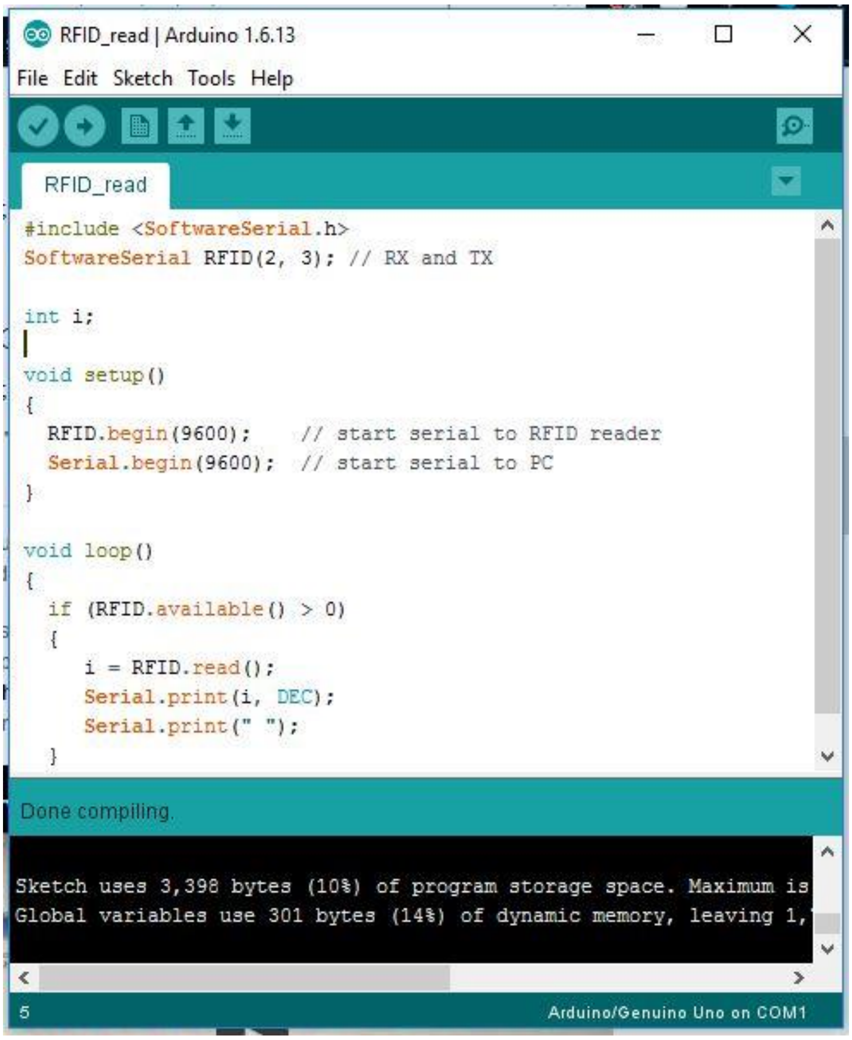


Figure 26: Arduino sketch for setting up RFID reader

We will use SoftwareSerial in the Arduino sketch because if we connect the data line from the RFID reader board to the RX pin on the Arduino board then we would have to remove the pins when we update the sketch at any point of time during coding, thus this becomes a convenient step.

The code mentioned in Appendix 3 (as well as figure 25) can be used to start the RFID reader, and when the RFID tag is passed over the antenna the unique code of the tag gets displayed in the Arduino IDE serial monitor.

Besides that we also need to work on the RFID tag data that we receive i.e. we need to create some functions to retrieve the card data when it is brought close to the reader and then to place the same in an array and then compare the card data to against the existing data in the array (for example in our case, the location data) so that the system knows which place is the tag being read from. Using such functions we can make our own system and location database for the array to work on.

For the array to work on first of all we need to add the RFID tag ID's in the database using the code in Appendix 3 to read the ID's. Once we have the RFID tag ID's we can link the data related to the location of each tag with their unique ID. The code that we can use for the same has been explained in Appendix 4, with an example of location ID for three such tags.

In the sketch mentioned in Appendix 4, we have a few functions that are used for reading and comparing RFID tags. If we notice it, there are the allowed tag numbers (which have the location added to them) are listed at the top of the sketch, we can always add more of our own tags – as long as we add them to the list in the function checkmytags() which determines if the card being read is registered with a location or should give an invalid location prompt.

To get all the information we save the data in an excel sheet which also can serve the purpose of managing the package data. All the data (package ID and tag ID) are saved in the excel sheet which are further used when it is necessary. The data can be send to the sheets via different methods like adding Arduino code (using CreateWrite () function) or using simple software of data acquisition like PLX-DAQ.

The main aim behind using this is to use a simple method for our solution instead of using complicated technology.

CONCLUSION

In concluding the thesis report I would like to point out a few very important aspects that came into light during the study. The conclusion is summarized in four parts as follows:

- The principle of using RFID as Indoor Poisoning System: This passive RFID Indoor Positioning System is based on the measurement of the location that is pre-set in the RFID tag. The relation between the tag, its placement and the unique location entry helps in the determination of the position of an abject accurately.

- The trend in using RFID as Indoor Poisoning System: RFID has already been used to track goods in earlier times to being used for security and access control systems in recent times. There is trend of developing more use for this technology because of the ease of use and the wide application area this technology brings.

- Cost effectiveness of RFID as Indoor Poisoning System: Upon comparison of various tracking technologies and the maintenance cost each has it can be deduced that using RFID is a very cost-effective method. With low initial cost and at the same time low labor cost improves the use of RFID. If a large area of warehouse has to be covered it brings down the overall cost as well because of lowering of variable cost, i.e., passive RFID tags. Thus, this passive RFID Positioning System can be used to determine the location of an object at very low cost.

- Feasibility of RFID as Indoor Poisoning System: The conclusions of the thesis for using RFID is feasible to measure the position of the object effectively. The overall low cost and the almost zero running cost for implementing the system makes it very effective for industrial use in warehouses. Also, we use standard codes for the passive tags thus making it easy to implement, even any kind of supply chain industry can implement this as they can locate the objects without attaching tags to each object. Another factor that helps RFID is that it can withstand harsh conditions or change in the working environment.

KOKKUVÕTE

Selle lõputöö eesmärk on luua siseruumides töötav positsioneerimissüsteem mida saaks kasutada lao rakendustes. Esmalt uuriti olemasolevaid tehnoloogiaid ja nendega kaasnevaid probleeme. Eesmärgiks oli arendada selline süsteem, mis oleks lihtne ja kasulik tavalisele nutitelefoni/PDA-d kasutavale töötajale. Nutiseadmed muutuvad järjest paremaks ja lihtsamini kasutatavaks ning funktsionaalsusest tingitud puudused on viimaste aastate jooksul viidud minimaalseks.

Positsioneerimissüsteem laoruumidele, mis suudaks aidata leida pakke kiirelt ja efektiivselt ja mis oleks võimeline töötama siseruumides on vajalik vähendamaks ajalist kulu logistilistele operatsioonidele. Erinevad positsioneerimissüsteemid leivad rakendust igapäevaselt, säästavad raha, lisaks vähendavad vigu, mis tulenevad inimlikust eksimusest, mis omakorda suurendavad tööprotsesside aega. Mida rohkem erinevaid tehnoloogiaid ja süsteeme suudetakse panna omavahel koos töötama seda rohkem parendatakse kogu laosüsteemi usaldusväärsust.

Käesolevas lõputöös üritasime kasutada võimalikult vähe raadiolaineid emiteerivaid seadmeid. Selleks kasutame passiivseid asukoha markereid vähendamaks raadiolainete ja muude signaaliallikate peegeldusi laohoones. Süsteem koosneb järgmistest põhilistest osadest: RFID lugemisseade, RFID markerid mida on võimalik lugeda, kirjutada ja lukustada. Asukoha informatsioon kirjutatakse markeri mälualasse. Töstuk millele on külge pandud RFID lugemismoodul koos antenni ja mikrokontrolleriga navigeerib laohoones mööda kindlaksmääratud teid pidevalt kogudes ja uuendades asukohaandmeid. Asukohaandmed on kirjutatud markeritesse.

Paki andmed on lisatud andmebaasi koos RFID asukohainfoga, mis aitab leida pakki kui seda on vaja välja saata. Paki infot on võimalik kustutada selle väljasaatmisel, vabastades andmebaasi mahtu uuele infole. Andmebaasist on võimalik väga lihtsasti leida paki asukoht laohoones see säästab paki leidmiseks kuluvat aega võrreldes tavapäraste meetoditega.

Töös on kasutatud kahte lähenemist, üheks lahenduseks on kasutada Android põhist arendusplatvormi, kus luuakse rakendus asukoha leidmise jaoks, teise süsteem kirjeldus on eespool nimetatud. Kuigi on palju asju, mida on vaja edasi arendada on süsteemil potentsiaali. Majanduslikus mõttes on see üks odavamaid lahendusi mida saaks rakendada, minimaalse jooksva kuluga.

Kasutusmugavuse seisukohalt on võimalik rakendust mitmel viisil edasi arendada. Üheks võimalikuks edasiarenduseks on hääljuhtimise lisamine. See annab kasutajale võimaluse sihtpunkti valikuks kasutades käedvabad süsteemi. Teiseks võimalikuks lisaks on navigeerimine hääljuhiste põhjal, mis juhataks töötaja laohoones pakini. Need teeks töö kiiremaks ja efektiivsemaks.

SUMMARY

Indoor positioning system (IPS) for a warehouse which works a dual purpose of IPS along with a logistic entry to reduce the time taken to track the needed package is a need of the hour for warehouse logistic operations. Such kind of technology is gaining the implementation day by day because of the money saved in terms of time that occurs due to the misplacement or wrong retrieval of a package which increases the work cycle and handling time for the warehouse. With more technologies coming into work in sync with each other, there is a drastic decrease in the errors and increase in the reliability of the system.

This thesis work had a goal of making an indoor positioning system useful for average smartphone/PDA user for managing logistics in the warehouse by understanding the issues of the already existing technologies and their drawbacks in functionality. With the increase in the reliability over the few years and with the inclusion of smartphones along with it, the drawbacks of functionality has come down to a minimum.

In this thesis work we try to use as less possible radio signals to avoid backscattering of signals in the warehouse and other noises that gets induced thus we use passive RFID tags as location markers.

The system includes basic parts, i.e. RFID reader module, RFID tags with a capability of read, write and lock, Arduino microcontroller and a smartphone/PDA device. The location information is written on the tags and then they are locked to avoid any location errors that can occur while in use. The RFID reader module along with the antenna and the microcontroller are set-up on the forklift which continuously gets the location data as it passes over the preset path over the RFID tags.

The package data is added to the database along with the RFID location which helps in finding the preferred package when it is needed to be dispatched. Upon dispatch the package data can be deleted thus making room for new data to be fed in for the next package. From the database it is very easy to find the location of the package when it is needed to be collected for dispatching purpose, thus saving on the time wasted in finding the package in the warehouse.

The work is divided into two solutions, one that uses android development to create an application which serves the purpose of IPS and the other system which is explain above. This system has a lot of potential along with a lot to be done in future to improve its functionality. This system has a very good financial factor backing it up as it is one of the cheapest system to implement with almost zero running costs.

The application could be extended in several ways to further improve the user's experience. It could implement voice control, letting the user choose a destination by voice commands. Also, it could use audio feedback, telling the user where it is heading, what the next move is and when it has reached its destination.

FUTURE WORK AND IMPROVEMENTS

The future for such kind of application holds a wide scope in terms of precision and ease of use. First of all I would like to mention the possibility of having a better readable distance for the RFID tags. Currently the readable distance for the passive RFID tags is low and the reader should be within a very close proximity of the tag to be able to read the tag. With the help of better antennas and tags the distance can be increased.

Secondly, the other major factor that should be looked upon in near future should be the ability to communicate the different tags at once i.e. the ability to read multiple tags at once and using trilateration method to be able to make the precision of the system be better. Along with it the possibility to add the orientation of the vehicle which would provide the information about the direction of the movement of the vehicle enabling the different vehicles to interact with each other. The interaction of various vehicles would make it possible to have a smooth flow of traffic inside the storage yard thus helping in reducing the ideal time on floor.

Another improvement that we can add on is the use of RFID tag in form of nails instead of the ones using in the experiment which were stick on. Currently there are unique RFID tag nails available which are used for pallet tracking. The reason these nails are not effective in our case is that they are too fragile to be used on the concrete floor of the warehouse, they can be hammered into the wooden pallets but not to the floor. Another reason of it being non-effective is that the signal strength reduces due to the high density of concrete, it is only effective for less dense materials like wood.

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7. APPENDICES

Appendix 1

```
package net.example.android.NFCTool;

import android.app.Activity;
import android.nfc.NfcAdapter;
import android.os.Bundle;
import android.widget.TextView;
import android.widget.Toast;

/*

 Activity for reading data from an NFC Tag.

 */

public class MainActivity extends Activity {

    public static final String TAG = "NFCTool";

    private TextView mTextView;
    private NfcAdapter mNfcAdapter;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_main);

        mTextView = (TextView) findViewById(R.id.textView_explanation);

        mNfcAdapter = NfcAdapter.getDefaultAdapter(this);
```

```
        if (mNfcAdapter == null) {
            Toast.makeText(this, "This device doesn't support NFC.",
Toast.LENGTH_LONG).show();
            finish();
            return;

        }

        if (!mNfcAdapter.isEnabled()) {
            mTextView.setText("NFC is disabled.");
        } else {
            mTextView.setText(R.string.explanation);
        }

        handleIntent(getIntent());
    }

    private void handleIntent(Intent intent) {
        // TODO: handle Intent
    }
}
```

Appendix 3

```
#include <SoftwareSerial.h>
SoftwareSerial RFID(2, 3); // RX and TX

int i;

void setup()
{
  RFID.begin(9600);    // start serial to RFID reader
  Serial.begin(9600);  // start serial to PC
}

void loop()
{
  if (RFID.available() > 0)
  {
     i = RFID.read();
     Serial.print(i, DEC);
     Serial.print(" ");
  }
}
```

Appendix 4

```
#include <SoftwareSerial.h>
SoftwareSerial RFID(2, 3); // RX and TX

int data1 = 0;
int ok = -1;
int yes = 13;
int no = 12;

// use first sketch in Appendix 3 to get tag numbers
int tag1[14] = {2,52,48,48,48,56,54,66,49,52,70,51,56,3}; //hypothetical tag ID 1
int tag2[14] = {2,52,48,48,48,56,54,67,54,54,66,54,66,3}; //hypothetical tag ID 2
int newtag[14] = { 0,0,0,0,0,0,0,0,0,0,0,0,0,0}; // used for read comparisons

void setup()
{
  RFID.begin(9600);    // start serial to RFID reader
  Serial.begin(9600);  // start serial to PC
  pinMode(yes, OUTPUT); // for status LEDs
  pinMode(no, OUTPUT);
}

boolean comparetag(int aa[14], int bb[14])
{
  boolean ff = false;
  int fg = 0;
  for (int cc = 0 ; cc < 14 ; cc++)
  {
```

```
    if (aa[cc] == bb[cc])
    {
      fg++;
    }
  }
  if (fg == 14)
  {
    ff = true;
  }
  return ff;
}

void checkmytags() // compares each tag against the tag just read
{
  ok = 0; // this variable helps decision-making,
  // if it is 1 we have a match, zero is a read but no match,
  // -1 is no read attempt made
  if (comparetag(newtag, tag1) == true)
  {
    ok++;
  }
  if (comparetag(newtag, tag2) == true)
  {
    ok++;
  }
}

void readTags()
{
  ok = -1;

  if (RFID.available() > 0)
  {
    // read tag numbers
```

```
    delay(100); // needed to allow time for the data to come in from the serial buffer.

    for (int z = 0 ; z < 14 ; z++) // read the rest of the tag
    {
      data1 = RFID.read();
      newtag[z] = data1;
    }
    RFID.flush(); // stops multiple reads



    checkmytags();
  }

  // now do something based on tag type
  if (ok > 0) // if we had a match
  {
    Serial.println("Location A1"); // Hypothetical location that I used for a place and named it
A1 for the example
    digitalWrite(yes, HIGH);
    delay(1000);
    digitalWrite(yes, LOW);

    ok = -1;
  }
  else if (ok == 0) // if we didn't have a match for a location
  {
    Serial.println("Unknown location");  // In case if we do not find a location registered to that
tag, and should have a notification to tell about the unknown location
    digitalWrite(no, HIGH);
    delay(1000);
    digitalWrite(no, LOW);

    ok = -1;
  }
```

```
}

void loop()
{
  readTags();
}
```

Appendix 5

Technical specification sheet:

Key Specification

Frequency	125KHz
Baud Rate	9600 (TTL Electricity Level RS232 format)
interface	Weigang26 Or TTL Electricity Level RS232 format
Power supply	DC 5V (±5%)
Current	<50Ma
Operating range	>50mm(Depend on Card/Tag shape, manufacturer)
Expand I/O port	N/A
Indication light	N/A
Working temperature	-10℃~ +70℃
Storage temperature	-20℃~ +80℃
Max. humidity	Relative humidity 0 ~ 95%
Size	38.5mm ×19mm×9mm