Indoor Positioning System Based on Wi-Fi

Abstract

Demand of technology is increasing throughout the globe and due to the location based service and security purpose; there has been high need of Indoor Positioning System based on Wi-Fi. Traditional Indoor Positioning Systems has been recognized to have number of gaps and problems that has overall impact on the performance and the desirable results. So, in the context of this research work, an innovative and high effective Indoor Positioning System based on Wi-Fi using the agent based communication mechanism has been presented.

In this research work the conceptual framework for the Indoor Positioning System has been utilized. However, there are number of different types of technologies that can be utilized for the position detection and in the context of this research Wi-Fi. The key components of the proposed solution are Indoor Map Construction Tool, Location Services, Map Service and Communication protocol. The communication protocol has been based on the agent based mechanism and verification and validation of the communication protocol has been conducted in the simulation environment.

Based on the simulation results, the proposed solution has been deployed in the real time environment. The parameters that have been improved through the utilization of proposed solution are accuracy, power consumption, data packet overhead and performances. The key recommendation has been presented to set future improvement in the context of Indoor Positioning System based on Wi-Fi.

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IoT	Internet of Thing
Wi-Fi	Wireless Fidelity
IEEE	Institute of Electrical and Electronics Engineers
SSID	Service set identifier
IR-UWB	Impulse-Radio Ultra-Wide Band Networks
BLE	Bluetooth Low Energy
IPS	Indoor Positioning System
GPS	Global Positioning System
AFSPC	Air Force Space Command
LoS	Line Of Sight
PSD	Position Sensitive Detector
API	Application Programmable Interface
MPS	Microsoft Provisioning System
RR	Route Request
TTL	Time-to-live
V&V	Verification and validation

Chapter 1

Introduction

Now-a-days, technology is quickly moving forward and it is examine that there are many organisations, business institutes, cooperated, large industrial sectors, small and medium size organisation etc. has embraced the information and communication innovation (ViFi: Virtual Fingerprinting WiFi-based Indoor Positioning via Multi-Wall Multi-Floor Propagation Model, 2016). Technology overall plays a critical role in streamlining business, functional and operational processes. However, with the progression of time it is analysed that technology and its sub components has highly improved and number of different types of key turn solution have being design, developed and implemented (An enhanced technique for indoor navigation system based on WIFI-RSSI, 2015). There are number of technology based solution available that helps in automation and streamlining of business, functional and operational processes supporting argument from (Autonomous smartphone-based WiFi positioning system by using access points localization and crowdsourcing, 2015).

(ViFi: Virtual Fingerprinting WiFi-based Indoor Positioning via Multi-Wall Multi-Floor Propagation Model, 2016) determined that there are distinct kinds of application that can be utilized for performing real time complex, critical and time consuming task and activities. To some extend it is also observed that the technology also helped in design and development of innovative solution that can be integrated in complex situation for example that technology can be utilized of for the forest fires detection, factory automation and many other area in which the human monitoring was overall quite impossible supporting argument from (A floor-map-aided WiFi/pseudo-odometry integration algorithm for an indoor positioning system, 2015). In today world technology is considered as the key player and today number of organisations or in different domain that technology deployment has being utilized to improve the performance. So to some extend the technology can be considered as a quality factor improving components for example it helps in automation of processes (WiFi-based indoor positioning, 2015).

With the progression of time there are distinct number of technologies that has being implemented and today the technology is rapid improving such as cloud computing

technology, Internet of Thing (IoT), wireless communication, wireless sensor network and many other (A robust indoor positioning system based on the procrustes analysis and weighted extreme learning machine, 2016). However, it is also observed that some time the key stakeholder finds it difficult to identify that which type or sort of technology they need to implement with the context of their requirement and specification as mentioned in (Evaluation of two WiFi positioning systems based on autonomous crowdsourcing of handheld devices for indoor navigation, 2016). In view of our study that there are number of programming and applications development organization throughout the globe and are involved in development of different types of solution (A robust indoor positioning system based on the procrustes analysis and weighted extreme learning machine, 2016). So, to extend it is quite complex to select the best fit technology and solution for the enterprise or the project in the technology need to be deployed.

Based on the existing researches (Indoor high precision three-dimensional positioning system based on visible light communication using modified genetic algorithm, 2018; Survey of wireless indoor positioning techniques and systems, 2007; Android application for WiFi based indoor position: System design and performance analysis, 2016) it is suggested that in order to select the best fit technology the proper investigation needs to be conducted. So that the key theme of can be extracted. According to our research work we will be focusing and analysing on the architecture and evolution of Indoor Positioning System (IPS). However, it is observed that through the utilization of the Indoor Positioning System (IPS) number of different technology can be deployed to overall achieve the objective or rethinking about finding the best possible technology for the solution. There are certain types of gaps that are also associated within the context of Indoor Positioning System (IPS) such as security, privacy and many others as mentioned in (Verification & validation of a multi agent meeting scheduling simulation model, 2014). So, it is observed that during the solution development the gap needs to be address so that the better outcome and the solution for the Indoor Positioning System (IPS) Based on Wi-Fi can be developed.

In the last couple of years that computer networking has highly improved and today almost 90% of the devices have being shifted from the traditional wired network to wireless network (Verification & validation of a multi agent meeting scheduling

simulation model, 2014). It is observed that there are certain benefits of the wireless technology but on the other hand it is observed that the problem of data security and privacy, distortion of received signals, power consumption and many other sort of problems exist (Enhanced WiFi ToF indoor positioning system with MEMS-based INS and pedometric information, 2014). It is observed that most of the homes, offices and buildings are equipped with the Wi-Fi route and in simple context it can be defined as that these Wi-Fi routes helps in establishing the user or its devices communication with the internet as mentioned in (Payless: A low cost network monitoring framework for software defined networks, 2014). As the technology is improving the speed and the performances of the wireless communication devices especially that mobile phone and wireless routes has also being improving as mentioned in (Autonomous smartphone-based WiFi positioning system by using access points localization and crowdsourcing, 2015).

Deep investigation need to be conducted in order to have better understanding that how the performance and the accuracy of the positioning system can be improved. The positioning is dependent upon number of different types of parameters such as accurate area, location etc. and if there is an need to find the right location or position of the object, user or devices as need analyse that through which device the user can be tracked. The Internet of Things (IoT) have being gaining much attention and in future that is a high probability that best and advance system can be formulated through the utilization of Internet of Things (IoT) and Cloud Computing technology. Still in this research the focus is laid on the context of internet of Things (IoT) as there are number of component and barriers that are still undergoing that processes.

1.1 Wi-Fi and Wireless Technology

The key theme of this research work is to design and development of Indoor Positioning System (IPS) based on Wi-Fi. It is analysed that the Wi-Fi is wireless local area networking with devices based on the IEEE 802.11 standards (Indoor Positioning System, 2015). Wi-Fi is considered as one of the most old devices in the family of wireless network technology and the concept of Wi-Fi has been introduced in September 1998 around about 20 years ago and still the technology is considered as one of the most active and utilized concept through the globe in 2018. However, it is

observed that the Wi-Fi is Compatible with Personal computers, gaming, mobile phones and many other technologies. However, on the other side today even the TV, LCD, AC have the concept of built-in Wi-Fi so that the can be connected within the context of internet. There is a high probability that due to the built in components of the Wi-Fi in number of physical devices will make it possible to set the communication and collaboration between the devices and the real them of the Internet of Things (IoT) can be simulated. In the next area the dialog inside the context of research objective that has been defined under the umbrella of Indoor Positioning System (IPS) Based on Wi-Fi is indicated. However, it is analysed that we will only be utilizing the secondary and experimental approach to identified that whether the objective has being achieved or not.

1.1.1 Problems/Drawbacks in WiFi

Wi-Fi is everywhere and built into everything. It's like oxygen for internet access, media streaming, gaming, and all types of networking. And it should just work all the time—right? If you've had an average experience with Wi-Fi on mobiles devices, laptops, game systems, and more, you know that while a solid Wi-Fi connection might be the norm, those times when it's *not* can leave you tearing your hair out.

For the most part Wi-Fi technology works quite well to keep your Mac, iPhone, and other devices connected; however, there are times when certain devices or setups may be plagued with Wi-Fi dropouts.

In this thesis, I look at a number of common scenarios that cause Wi-Fi problems and how to solve them, whether you're running your own network or trying to connect to someone else's using any platform.

a) Noise

The quality for any analog signal, be it electrical, optical, or radio, can be determined by comparing the desired signal level to the background noise level in the signal in what's known as a signal-to-noise ratio.

High noise levels can interfere with your network signal strength and cause areas of poor connectivity — or "dead zones" where there is no connectivity.

The quality and rate of a connection depends on the signal-to-noise ratio (SNR) that a receiving device detects. As described previously, attenuation or loss of signal strength happens easily. So, as the signal level goes down, the SNR goes down, and so does the transmission rate. A device that is “too far” from an access point may be able to see the network to which it wants to connect, but if the SNR is too low it will not be able to.

Another factor that affects the SNR is the noise floor, which can be defined as the ambient or background level of radio energy on a specific channel. This background energy can include modulated or encoded bits from nearby 802.11 transmitting radios or unmodulated energy coming from non-802.11 devices such as microwave ovens, Bluetooth devices, cordless phones, and so on. The higher the noise levels are, the lower the SNR will be.

The worst-case scenario is when you have a weak signal and high noise levels, this fatal combination will greatly lower your SNR. This, in turn, will cause performance and connectivity problems. Still, identifying SNR problems is very simple, you just need a tool that can measure both signal strength and noise. One thing to notice though, is that even though in the past most WiFi adapters could measure noise levels, there are not many of those anymore. Thus, you may need to acquire a dedicated troubleshooting tool that will provide this information. There are many WiFi troubleshooting or even surveying tools that can do this.

Strategies for decreasing noise level:

- Deselect all of your APs on the left sidebar and then re-select them one by one. Try to narrow down which APs are affected by high noise.

- Switch your network from the 2.4 GHz frequency band to 5 GHz. The 2.4 band tends to have a lot more noise. Both your APs and client devices will need to be capable of using the 5 GHz band. If you can’t ensure that, at least try to install double-frequency APs that cover both bands and inform users that connecting to the network at 5 GHz is preferable

- If switching to the 5 GHz band is not an option, try switching the affected APs to a different channel in the 2.4 GHz band.
- Check the environment and attempt to identify sources of noise. Turn them off one at a time (if possible) and use Discover Mode to quickly register changes in noise level in particular areas.
- Once you identify a source of noise, your choices are to move, replace or shield the source of noise, or to move the affected AP.

- Signal levels will attenuate more the further you get from the source of the signal, so try moving closer to your Wi-Fi router to see if the signal level increases.

- Many routers have an option for adjusting the Wi-Fi signal level, so consult your router manual to see about increasing this level. Not only will doing this increase your router's range, but it will also increase the quality of the signal and therefore increase your average connection speed (with the router, and not necessarily the internet).
- The signal from the router may be grounded by large metal devices between your computer and the router. Therefore, if your computer is situated in an area with obstructions between you and the router, then try moving to an area where you have a clear path to the router. Sometimes piping or electrical wiring in walls can be enough to ground and attenuate the signal being sent to your system.

- Improve the coverage of your WiFi network and make sure you have a signal strength that is at least 20 dBm higher than the noise floor. (For voice over WiFi deployments you want your signal strength to be 30 dBm higher.)

- Lower the noise floor on your environment by using channels with a low amount of WiFi traffic, and by removing non-WiFi devices that increase the noise floor on the WiFi channels you are using. On cases where the non-WiFi device generating the noise can’t be removed or disabled, you will need to reconfigure your access points so they won’t use the channels with a high noise floor.

Identifying and removing the source of noise might not be an easy task. In practice, the easiest solution is usually increasing the signal level rather than decreasing the noise level.[46]

b) Multipath effects:

Multipath is notoriously hard to identify with any degree of accuracy. The best we can do is evaluate symptoms and rely on gut instinct most of the time

Causes of multipath:

- Clients have issues only in a localized area.
- Area is complex, with large amounts of metal or other reflective, refractive, or scattering material.
- The data rate deteriorates quickly, with seemingly nothing changing. This is called excessive data rate shifting, and is bad for wireless network performance.

Solutions to over come Maltipath effect:

i) **Disable the higher data rates** (5.5, 11, 9, 12, 24, 36, 48, 54 Mbps).

Multipath is causing transmission errors, then the higher data rates may perform worse than lower data rates because of signal encoding, even if coverage and signal strength are excellent. Remember, signals encoded with lower data rates contain more error correction bits (coding-ratio). This is counter-intuitive unless you understand the fundamentals of the physical layer encoding mechanism.

Leaving only 1, 2 or 6 Mbps enabled helps the client and AP by maximizing error-correction capabilities and reducing the complexity of signal amplitude and phase shifting that must be recognized.

ii) Install 802.11n equipment

Newer 802.11n equipment handles multipath much better than legacy 11a/b/g equipment due to the benefits of MIMO and MRC (maximal ratio combining). Even if clients cannot be replaced, upgrading only the infrastructure should help communication improve.

iii) Install material that absorbs RF signals

If you can cover the metal or other reflective surfaces with material that will absorb the RF signals, rather than let them bounce around, then multipath should be reduced, improving network performance. This may be hard, if not impractical, to achieve since most environments that have multipath issues require those problem surfaces to operate in a specific fashion that prevents absorptive material from being installed. But it's worth a last-ditch effort!

C) Complex WiFi Algorithms

Traditional WiFi indoor positioning algorithm can be divided into three categories: Proximity algorithm, triangulation algorithm and scene analysis algorithm.

i) Proximity Algorithm

The proximity algorithm [6] helps to estimate the location of the target place using the proximity relationship between the target place and WiFi access points. When the mobile device at the target place receives WiFi signals from different WiFi access points, the location of WiFi access point with the strongest signal will be regarded as the location of the target place. The accuracy of this algorithm is determined by the distribution density and signal range of WiFi access points.

ii) Triangulation Algorithm

The triangulation algorithm [7] helps to estimate the location of the target place based on geometric properties of triangles. When the mobile device

at the target place receives the WiFi signals from one or more WiFi access points, the time of arrival (TOA), the angle of arrival (AOA) and the received signal strength (RSS) of WiFi signals will be used to calculate the distances between the target place and WiFi access points. With the locations of three or more WiFi access points, the target place can be estimated by triangulation.

iii) Scene Analysis Algorithm

The scene analysis algorithm [8] refers to the type of algorithm that first collects features (fingerprints) of a scene and then estimates the target place of an object by matching online measurements with the closest *a priori* location fingerprints. RSS-based location fingerprinting algorithm is commonly used in scene analysis. Also magnetic field and even the value of GPS signal indoors (its level) has been used as fingerprints [9,10].

The proximity algorithm is simple but not as accurate. It is generally used to support outdoor positioning. The triangulation algorithm requires the location of WiFi access points, thus limits the range of application. The scene analysis algorithm has the advantage of accuracy and it does not require the location of WiFi access points, and thus plays an increasingly important role in the indoor positioning field.

Although the above algorithms have made some breakthroughs, there are still some downsides.

- The lack of researches on WiFi signal features.
- Deficiency in the comprehensiveness in the offline stage discounts error of collection.
- Too much time and calculation during the online stage.

An Improved WiFi Indoor Positioning Algorithm

The proposed algorithm is based on the traditional fingerprinting algorithm [8] and also consists of two stages: the offline acquisition process and the online positioning process. However, the proposed algorithm managed to be more precise.

a) The offline acquisition process consists of three phases:

Phase 1: Collecting Indoor WiFi signal

This phase collects the WiFi signal based on a map of collecting points. The map of collecting points is formed by dividing the positioning home into a grid of equidistant points. Then, the original WiFi signal is collected by using a mobile device at the location of every single point.

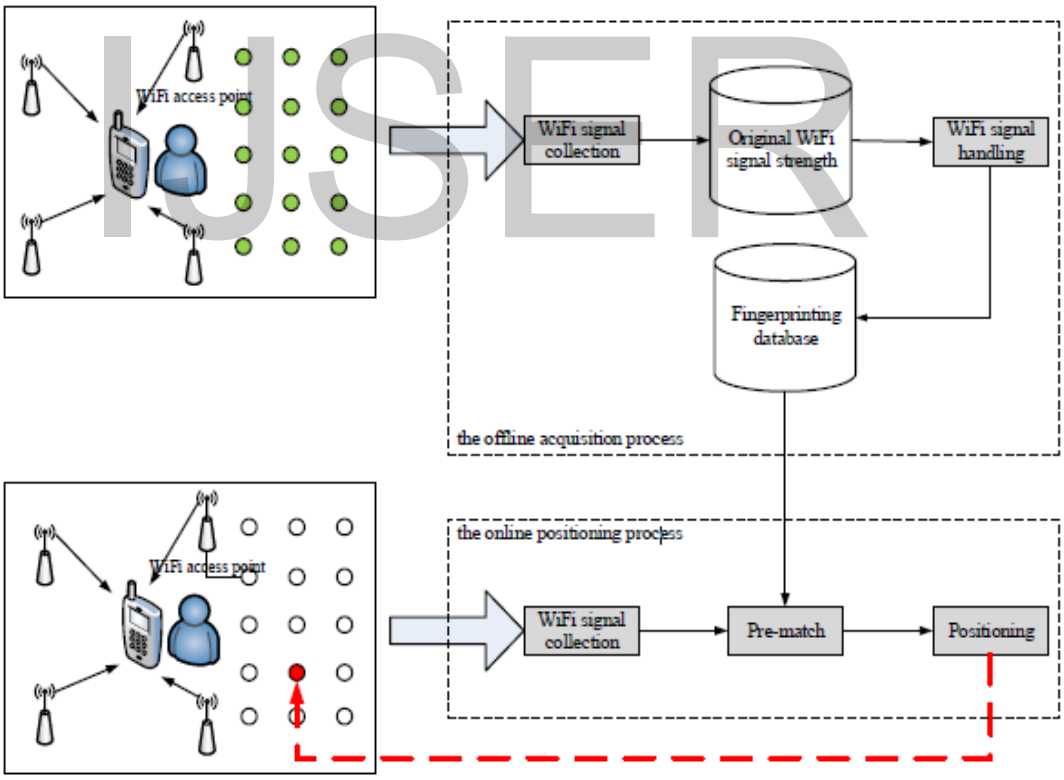


Figure 1.1 Methodology of proposed algorithm

Phase 2: Error handling of Indoor WiFi signal collecting

This phase processes the original WiFi signal by classifying the error when collecting. There are three types of errors: systematic error, gross error, and random error.

Phase 3: Constructing the database of location fingerprints

The database of location fingerprints mainly contains the following information: the average value of original WiFi signal strength, the standard deviation of original WiFi signal strength, and the average value of processed WiFi signal strength.

b) The online positioning process consists of four phases:

Phase 1: Pre-matching location fingerprints

This phase is used to reduce the number of possible fingerprints, so as to shorten the time for positioning.

Phase 2: Improved Euclidean distance positioning

After pre-match, the improved Euclidean distance is used to get an intermediate positioning result (X1, Y1). As for the improved traditional Euclidean distance positioning, this work chooses possible Kd fingerprints and uses their location to estimate a result (X1, Y1). The improved Euclidean distance values of these fingerprints are the smallest ones in all possible fingerprints.

Phase 3: Improved joint probability positioning

After phase 2, the improved joint probability is used to get an intermediate positioning result (X2, Y2). In the improved joint probability positioning, this work chooses the possible Kp fingerprints and uses their location to estimate a result (X2, Y2). The improved joint probability values of these fingerprints are the largest ones in all possible fingerprints

Phase 4: Weighted fusion positioning

This phase uses (X1, Y1) and (X2, Y2) to calculate the final result by the weighted fusion method (,) XY

D) WiFi Interference

Access points of the 802.11b/g/n variety will operate in some capacity on the 2.4GHz spectrum, a frequency that is unlicensed and free to use for any wireless connection. This is where WiFi interference comes into play. As so many household items offer wireless capability, the 2.4GHz spectrum has become congested with competing signals from nearby devices. With 2.4GHz only offering 14 channels, and only three of those not overlapping in some way, the technology is not specifically designed to combat interference.

The list of items that may cause WiFi interference is surprisingly long as the 2.4Ghz space is unlicensed and free to use for any wireless connection. Interference can be caused not only by other nearby wireless networks but also any 2.4GHz operating devices and even high voltage devices that generate electromagnetic interference for any nearby networks. Please see the list below for more details.

Types Of Interference

- **Nearby Wireless Networks**

Your neighbours likely all have wireless networks and any that operate on the same frequency will be causing interference and disrupting the performance of your local network.

- **Cordless Phones**

Many cordless phones operate on the same 2.4GHz space that is the host to most WiFi networks. If your network performance drops whenever your cordless phone is in use, consider switching to phones that operate on a different frequency, such as 900MHz or 1.9GHz DECT 6.0.

- **Baby Monitors**

Just like cordless phones, most baby monitors operate on 2.4GHz and, given the constant connection between the monitor and the receiver, a baby monitor can affect the performance of your network.

- **Microwaves**

Older or poorly-shielded microwaves cause a great deal of electromagnetic interference at the 2.4GHz space, causing transmission problems for many wireless devices. Newer and modern microwaves are properly shielded and should not present any considerable problems to your network.

- **Wireless Security Equipment**

Wireless cameras and motion sensors operate just like baby monitors and will congest 2.4GHz networks. The latest generation of this type of equipment has the ability to connect to your access point (cameras and sensors are WiFi-ready) and will operate as a client and not congest your local network.

- **Radios**

Radios and police scanners operate on a wide range of frequencies and can cause interference to any other nearby radio device. Proximity is likely the deciding factor in radio interference so don't have your access point located directly next to (or on) a radio transmitting device.

- **Monitors, TVs and Screens**

Monitors and TV's, especially those that are not properly shielded, can cause interference for 2.4GHz networks (specifically channels 11-14). Don't place your access point directly next to (or on) a TV, monitor, or screen.

- **High-Voltage Household Appliances**

High voltage or high-draw household items like laundry machines and air conditioning units cause electromagnetic interference. If you notice degraded network performance while operating a household appliance then your access point may be too close, or the appliance may not offer proper electromagnetic shielding.

Environmental Factors:

Apart from specific local devices causing radio interference on the same frequencies as your access point, there are environmental factors that can inhibit or disrupt the functioning of your home WiFi network. These factors include:

a) Housing Construction

- **Brick, stone, and concrete walls** - While not usually capable of blocking a WiFi signal, heavy stone, concrete, and brick will limit the effectiveness of a wireless signal.
- **Floors** - Having a wireless signal from a different floor will definitely impact WiFi signal. In addition tiling, carpeting and hardwood flooring may cause Wi-Fi interference.

- **Walls and Wall Construction** - interior walls are generally **not** a large hindrance to WIFI signals when there is no insulation, metal ducting, metal pipes, and steel studs are being used.
- **Metal** - The metal in walls or ceilings can have a dramatic effect on the range of a wireless network. This is why an access point may offer the best connection to devices on the same floor of your home. Floors and ceilings often have metal, wiring, conduits, ducting, and thermal shielding that can disrupt the radio signals that form your wireless network.
- **Lead paint** - While uncommon, lead paint acts as a very effective shield for radio signals and can diminish or block a local WiFi network.

b) Home Appliances

- **Additional Electronics** - Wires and other large electronic devices like Televisions can physically block WiFi signals.
- **Large Appliances** - fridges, stoves, washers, and dryers can all block a WiFi signal.
- **Large Furniture** - Heavy furniture such as bookshelves, mirrors, and fish tanks can all block WiFi signals.

Have a look at the list of physical obstacles in table 1-1 and what effect they may have on the wireless signal.[47]

Table 1-1

Type of Barrier	Interference Level
Wood	Low
Plaster	Low
Synthetic Material	Low
Glass	Low
Water	Medium
Bricks	Medium
Marble	Medium
Concrete	High
Metal	High
Mirror	Very High

Solution Of WiFi Interference

While most of the interference experienced by your home network may be unavoidable (neighbour's networks, domicile construction, etc.), there are some possible remedies of which to be aware when planning for the addition of other wireless devices, or attempting to improve the performance of your home network:

1. Use a dual band (simultaneous) 2.4 and 5GHz router. The 5GHz range is still a newer frequency so it is less used in many congested areas. Look for wireless routers marked as 802.11n. For best results, upgrade your entire network to 802.11ac, which operates exclusively on 5GHz and should bypass most local interference.
2. Allow your modem/router to automatically manage channels to switch away from congested frequencies. While forcing your access point onto a fixed channel can be quite effective in some situations, any modern access point has the ability to automatically move to a different channel if the current channel is experiencing too much interference.

3. Line of sight works best for signal strength. Don't put your 802.11b/g/n access point on the floor, this wastes half of its 360 degree field of range
4. 802.11n is not a guaranteed solution, as this standard relies on sending multiple signals (using both 2.4 and 5GHz) which can perform poorly in heavily congested areas.
5. Use WiFi devices whenever possible. Some home wireless devices like baby monitors and security equipment use their own point-to-point connections and can cause a great deal of interference to other local wireless networks. By using WiFi devices, all clients connect to the signal and network provided by your access point.[48]

1.2 Research Objective

Behind every research that are certain types of objective and goal. However, it is observed that before the execution of any sort of research these goals must be clearly defined. In the context of Indoor Positioning System (IPS) Based on Wi-Fi the following are the key goals that are indicated as below and there is a high probability that if all these goals are simulated that key objective or the theme of the Indoor Positioning System (IPS) Based on Wi-Fi will be achieved:

1. Design and development of Indoor Positioning System (IPS) based on the Multi-Listing approach. This approach will be utilizing the Wi-Fi hotspot and Wi-Fi rigid nodes for the detection of the location. The design of the approach is presented in Figure 3.2 Communication Protocl
2. Development of simulation environment to perform verification and validation of Indoor Positioning System (IPS) based on the Multi-Listing approach,
3. Analysing the strength and weakness of existing system and how the Multi-Listing approach integrated in the context of Indoor Positioning System (IPS) can help in better outcome,
4. Providing the in-depth description about the application areas of an Indoor Positioning System (IPS) using Wi-Fi and how the existing proposed solution can be linked with the android applications,

5. Design and development of the communication protocol for simulating the data packet of Indoor Positioning System (IPS) based on Wi-Fi need to be performed.

Development of the simulation environment that has the functionality to execute the Wi-Fi hotspot and Wi-Fi fixed nodes required processing time and in-depth understanding that how the Wi-Fi hotspot and Wi-Fi fixed nodes are simulated. In the above section the key objective have being achieved in the context of this research Indoor Positioning System (IPS) Based on Wi-Fi. In the next section the research question that has being answered in this research have being presented.

1.3 Research Question

Below are the main research question that are advised in the context of Indoor Positioning System (IPS) Based on Wi-Fi and through the execution of this research these research questions has been answered:

1. What are the key gaps and challenges that exist within the context of Indoor Positioning System (IPS) Based on Wi-Fi and how these key research gaps and issues can be addressed?
2. How the simulation environment has been developed and what are the key parameters that are considered during the design, development and implementation of the simulation environment for Indoor Positioning System (IPS) based in Wi-Fi?
3. Identify and analyse the key research methodology such as waterfall, agile, Microsoft operation framework or many other that will be utilized in the context of this research that is conducted for the design and development of Indoor Positioning System (IPS) based on Wi-Fi?

In the above point all the key research questions have been presented and these research questions have being answer through the proposed solution development and analysing the researches that are conducted in the context of Indoor Positioning System (IPS) Based on Wi-Fi.

1.4 Problem Statement

The real-time applications or system pose different sort of challenges and problems that directly or indirectly impact the development of the project if that are not properly conducted as indicated it (Fusion of WiFi, smartphone sensors and landmarks using the Kalman filter for indoor localization, 2015). It is examine that performance is always considered as centre piece of attention and within the passage of time the organisation demand for adopting of latest technology for example most of the organisation are shifting their infrastructure from traditional setup to cloud computing platforms. There are different types of benefits that can be obtained by help of information and communication technology and due to these benefits the deployment of technology is increasing such as process automation, business process streamlining, improving the functional process and many other.

Positioning system is utilized to locate people or objects inside building and there a number of positioning system application that has evolved are design and utilized for location detection. But still the technology selection for the positioning and location system is always defined and considered as the key challenge as there are different types of technologies exist and can be integrated in IPS..

During the analysis (ViFi: Virtual Fingerprinting WiFi-based Indoor Positioning via Multi-Wall Multi-Floor Propagation Model, 2016; A novel method for constructing a WiFi positioning system with efficient manpower, 2015) there are differetn sort of problem Bluetooth and IR-UWB such as have different sort of problems including delay response, system performances, poor performance, accuracy error, Service set identifier (SSID) , fault tolerance and many more (An enhanced technique for indoor navigation system based on WIFI-RSSI, 2015).

In this research work, the focus is laid on the addressing of these problems and issues through the integration of multilisting approach that will be simulated using component of hotspot and Wi-Fi fixed nodes. There is a high probability that through the utilization of this research there is a probability that more efficient and effective positioning system on Wi-Fi can be developed. In this research work we are developing the communication protocol to overall increase the accuracy rate of the position. Verification and validation of proposed solution will be tested in real-time

scenario and there is a high probability that better outcome can be achieved if hybrid approach is integrated.

1.5 Thesis Organisation

In the chapter one of this researches that discussion within the context of the basic theme of the design and development of IPS based on Wi-Fi has been presented. In this chapter the detailed discussion within the context of research objective, problem that will be addressed in the context of this research and the research question has being presented. In the chapter two the detail discussion within the context of literature review that has being conducted in the research and specially that technologies that are can be utilized has also being discussed.

In this chapter the focus is laid on highlighting and identification the key gaps that exist within the research. In chapter three that system design and architecture within the context of IPS based on Wi-Fi. In this chapter the system components are identified and analysed that connectivity between these system components. In chapter four the verification and validation about the proposed solution and its discussion is presented. In this research has focus on the utilization of the experimental approach and based on that experiment approach number of different parameters and their results has being measured. In the last chapter the discussion within the context of conclusion, recommendation and future research is presented.

Chapter 2

Literature Review

Wireless communications or wireless connectivity is a type of data communication mechanism that is performed and delivered wirelessly (Fusion of WiFi, smartphone sensors and landmarks using the Kalman filter for indoor localization, 2015). Through the utilization of the wireless connectivity and the data and information can be transferred with the involvement of the wired network. It is analysed that in the recent years the wireless communication has being gain much attention and today most of the computing and electronic devices are equipped with Wi-Fi (WiFi-based indoor positioning, 2015). In this chapter we will be focusing on the context of the existing solution and will be analysing the key gaps that existing under the umbrella of Wi-Fi.

It is analysed that there are different sort of reason due to which the wireless technology has gain much attention and one of the key reason it easy to install, speed and many other feature that are currently not provided by the traditional wired networks supporting argument from (Evaluation of two WiFi positioning systems based on autonomous crowdsourcing of handheld devices for indoor navigation, 2016). However, based on the existing researches (An inexpensive bluetooth-based indoor positioning hack, 2006; Application of an improved K nearest neighbor algorithm in WiFi indoor positioning, 2015) that the wireless communication network is always surrounded by different types of data security and privacy challenges including Middle Attack, Misconfiguration, Denial of Service Attack, Eavesdropping and many other. So, in the context of this chapter we will be analysing that how the current researches have being working in area of positioning system and how the performance of these researches can be improved.

It is analysed that there are number of researches (An inexpensive bluetooth-based indoor positioning hack, 2006; Application of an improved K nearest neighbor algorithm in WiFi indoor positioning, 2015) that are conducted in the context of wireless technology and communication. However, it is analysed that most of the researches have provides that proposed solution within the context of positioning system and also highlighted the gaps focusing on the context of poor communication, lack of communication protocol, synchronization between devices and many other.

However, there is a high probability that better results can be design and developed if these gaps within the presented approach can be conducted and that solution is based on the Wi-Fi technology.

Within the advancement in the information and communication technology it is analysed that there are number of real time application in which these technology are utilized (Autonomous smartphone-based WiFi positioning system by using access points localization and crowdsourcing, 2015). For example wireless sensor network is utilized for forest fires detection, industrial automation and many other areas support argument from (Evaluation of two WiFi positioning systems based on autonomous crowdsourcing of handheld devices for indoor navigation, 2016). But still most of the researches indicated that the key outcome or the results that are required are not obtained. (Graph-based data fusion of pedometer and WiFi measurements for mobile indoor positioning, 2014) in the research work has indicated that there are number of forest fire detection system that are deployed in the real time environment or have being testing in simulation environment has failed due to the lack of network performance or the maintains issues. So, there could be different types of reason due to which the proposed solution can be failed. One of the key reason due to which the communication based or wireless communication solution faced are due to the lack of communication protocol as mentioned in (Graph-based data fusion of pedometer and WiFi measurements for mobile indoor positioning, 2014).

Communication protocol and its implementation in the context of wireless communication is defined as the key gap. In research work we will be considering the problem within the context of communication protocol (A novel method for constructing a WiFi positioning system with efficient manpower, 2015). However, we will be emphasis on utilising the intelligent communication based protocol so that the key results can be extracted as mentioned in (Verification & Validation of a Multi Agent Meeting Scheduling Simulation Model, 2015). It is analysed that integration the technology for real-time monitoring is a complex and critical task as mentioned in [6]. Positioning system is utilized to locate people or objects inside building and within the passage of time there are number of Positioning application that are design and utilized for example BLE Beacon Wi-farer, indoor-atlas etc. However, it is investigated that IPS system utilized radio waves, magnetic fields, acoustic signals, or other sensory information for allocating the object or person inside the building [7].

However, there are certain concern and problems that are associated within the context of these solutions and the theme that we will be emphasis on the development of communication protocol solution.

There are different Technologies based on different Techniques.

2.1 Indoor Localization Technologies

2.1.1 WiFi

Wi-Fi is widely used all over the world and is one of the most common local area networking techniques today. Wi-Fi is to be applied in a local network by setting up wireless Access Points (AP) providing devices to connect to the network wirelessly. This provides the possibility to move around the device in the local area while being connected to the AP. This means that wherever the device appears in the local area it can communicate with the AP. The AP is usually part of a network that is connected to the Internet, which provides the device with the possibility of communicating with devices of different local area networks. Wi-Fi emerged as the marketing branding name of the latest wireless local area network (WLAN), which was based on the Institute of Electrical and Electronics Engineers IEEE 802.11 standard.

IEEE 802.11 operates under different protocols with various frequencies: 2.4GHz, 3.6GHz, 5GHz and 60GHz; all providing different range and speed of communication. The IEEE 802.11 was first developed in 1997, later on providing the protocols, “a” in 1999, “b” in 1999, “g” in 2003, “n” in 2009 and “ac” in 2013; they all induce further opportunities [42].

Wi-Fi is a half-duplex system, meaning that it supports communication of both directions but not at the same time. It works by encoding data on a radio wave (carrier), which is then applied to a frequency by broadcasting it. The radio waves are then received and decoded back into readable data. In order to send data on a radio frequency one of two ways of modulating the radio signals must be applied, either by amplitude modulation (AM) or by frequency modulation (FM).

Pros and cons of indoor positioning using wifi

Pros:

- indoor positioning works without GPS
- existing WiFi infrastructure can be used

- enabled WiFi is sufficient
- there is a back channel to the client
- large range (up to 150m)
- detects floor level

Cons:

- relatively inaccurate (5-15m) compared to BLE/RFID
- WiFi client based positioning is not possible with iOS devices – but BLE can be used as an alternative
- application required

2.1.2 Bluetooth

Bluetooth is a widely used wireless communication technology, it has become very popular in homes with, for example, wireless speakers using this technology to receive music from a device. The technology is primarily designed for communication over short distances and its original application was to act as a cable replacement protocol in wireless keyboards, wireless headsets etc. Its short distance low power characteristics makes Bluetooth very suitable in communication between small wireless devices.

Figure2.1 shows an illustration of two Bluetooth devices communicating wirelessly.

Fig. 2.1 shows an illustration of two Bluetooth devices communicating wirelessly. Bluetooth unites a set of protocols that devices can use in order to communicate, which is roughly illustrated in Fig. 3. The technology operates in the 2.4 GHz frequency band. This frequency band is called Industrial, Scientific and medical(ISM) and is used by several other technologies. To minimize interference Bluetooth uses a technique called normal frequency hopping. Normal frequency hopping is to avoid

interference by changing the carrier among several frequency channels at high speed in a random sequence [43].

2.1.3 BLE

Bluetooth Low Energy, also known as Bluetooth Smart, evolved from the classic Bluetooth technology aimed to offer significantly lower energy consumption than its predecessor and is specifically designed to be applied in wearable technology, internet of things and beacons. BLE was merged into Bluetooth version 4.0 in 2010 [43].

Beacons are BLE devices with the ability to broadcast short messages to nearby Bluetooth devices. Beacons are usually designed to take full advantage of the low energy consumption characteristics of BLE, small discrete devices that melt into the environment and with very long battery life. Beacons are specifically designed for various location based applications such as indoor positioning and location aware marketing applications [44].

Pros and cons of indoor positioning using bluetooth

Pros:

- cost-effective, unremarkable hardware
- low energy consumption
- flexible integration into the existing infrastructure (battery-powered or power supply via lamps and the domestic electrical system)
- works where other positioning techniques do not have a signal
- compatible with iOS and Android
- high accuracy compared to WiFi (up to 1m)

Cons:

- additional hardware
- app is required for client based solutions
- relatively small range (up to 30m)

2.1.4 Ultra Wide Band (UWB)

Ultra-wideband radio is a technology with high-bandwidth communication capabilities over short distances. UWB is a very lowenergy technology that is used in applications where high bit-rate at short range is required and, due to its power

characteristics, can also be used at medium-to-long ranges where only low bit-rate is required. UWB uses short pulses over a large frequency spectrum to send data. This property have been proven to be useful for high-precision ranging applications. The use of a large frequency spectrum also means that UWB is less vulnerable to reflections when going through obstacles than technologies using smaller bandwidth [45].

2.1.5 Visible Light Communication

VLC can be used as a positioning technology, mainly for inside areas. Special LED and fluorescent lamps send out indiscernibly flickering light which can be detected by a smartphone camera or a separate photo detector, which is for example attached to a shopping basket. This enables for example indoor navigation (via app) and tracking (analysis of motion profiles via app). In the future, VLC could also be used for wireless internet connection.

Technically it works like that: Each lamp has its own ID which it compiles into pulsing light and sends to smartphones in the reception range. The app can access a map in which the lamps and their IDs are located. The incidence angle helps refine the position. Additional hardware such as beacons can fill in, where light doesn't advance.

Pros & cons of visible light communication

Pros:

- lamps are extensively and homogenously available in buildings
- beacons can complement positioning
- signals can easily be limited
- modern LED are energy efficient
- the positioning technology is not dependent on batteries
- VLC is precise (less than 1 meter) and has a high range (up to 8 meters)
- no disturbing, eye-catching, costly hardware
- works cross-platform

Cons:

- draws on the reserves of the smartphone battery
- low flexibility when installing lamps
- most suitable for indoor installations
- high costs when modern lamps are already installed
- back channel and tracking only possible with special hardware/app

2.1.6 Radio-frequency identification (RFID)

RFID is a form of wireless communication that uses radio waves to identify objects. Passive RFID technology works only in the proximity of specialized RFID readers (infsoft Locator Node, functioning as a power source for RFID tags), providing a 'point-in-time' location.

Pros & cons of RFID

Pros:

- high accuracy
- low latency times with position updates up to 100 times/second,
- almost no interferences

Co*ns*:

- higher cost and shorter battery life time then bluetooth

2.1.7 Zigbee

Zigbee is built upon the IEEE 802.15.4 standard that is concerned with the physical and MAC layers for low cost, low data rate and energy efficient personal area networks. Zigbee defines the higher levels of the protocol stack and is basically used in wireless sensor networks. The Network Layer in Zigbee is responsible for multihop routing and network organization while the application layer is responsible for distributed communication and development of application. While Zigbee is favorable for localization of sensors in WSN, it is not readily available on majority of the user devices, hence it is not favorable for indoor localization of users.

Pros and Cons Of Zigbee

Pros:

- Setting up the network is very simple and easy.
- It does not have central controller and loads are distributed evenly across the network.
- It is easy to monitor and control home appliances from remote.
- It will take the place of existing Infrared technology based devices. This will save cost of battery replacement as zigbee uses lithium battery which lasts long.
- The network is scalable and it is easy to add/remote zigbee end device to the network.

Cons:

- It requires knowledge of the system for the owner to operate zigbee compliant devices.
- It is not secure like wifi based secured system.
- Replacement cost will be high when any problem occurs in zigbee compliant home appliances.
- Like other wireless systems, zigbee based communication is prone to attack from unauthorized people.
- The coverage is limited and hence can not be used as outdoor wireless communication system. It can be used in indoor wireless applications.

2.1.8 Acoustic Signal

The acoustic signal-based localization technology leverages the ubiquitous microphone sensors in smart-phones to capture acoustic signals emitted by sound sources/RNs and estimate the user location with respect to the RNs. The traditional method used for acoustic-based localization has been the transmission of modulated acoustic signals, containing time stamps or other time related information, which are used by the microphone sensors for ToF estimation. In other works, the subtle phase and frequency shift of the Doppler effects experienced in the received acoustic signal

by a moving phone have been also used to estimate the relative position and velocity of the phone. Although acoustic based systems have been shown to achieve high localization accuracy, due to the smart-phone microphone limitations (sampling rate/anti-aliasing filter), only audible band acoustic signals (<20KHz) can provide accurate estimations. For this reason, the transmission power should be low enough not to cause sound pollution (i.e., the acoustic signal should be imperceptible to human ear) and advanced signal processing algorithms are needed to improve the low power signal detection at the receiver. Moreover, the need of extra infrastructure (i.e., acoustic sources/reference nodes) and the high update rate (which impacts the device battery), make the acoustic signal not a very popular technology for localization.

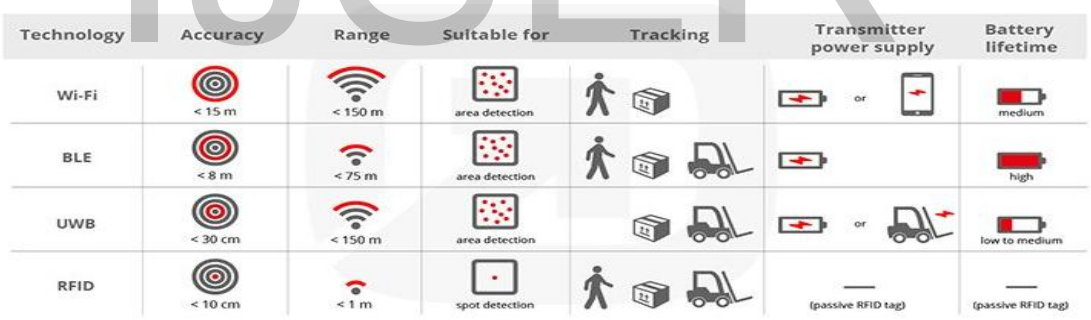
Pros and Cons of Acoustic Signal

Pros:

- Can be used for proprietary applications,
  can provide high accuracy.

Cons:

- Affected by sound pollution, requires
  extra anchor points or hardware



Comparison of different technologies for server-based indoor positioning

2.2 Indoor LocalizationTechniques

2.2.1 Received Signal Strength Indicator (RSSI)

The received signal strength (RSS) based approach is one of the simplest and widely used approaches for indoor localization [31]–[35]. The RSS is the actual signal power strength received at the receiver, usually measured in decibel-milliwatts (dBm) or

milliWatts (mW). The RSS can be used to estimate the distance between a transmitter (Tx) and a receiver (Rx) device; the higher the RSS value the smaller the distance between Tx and Rx. The absolute distance can be estimated using a number of different signal propagation models given that the transmission power or the power at a reference point is known. RSSI (which is often confused with RSS) is the RSS indicator, a relative measurement of the RSS that has arbitrary units and is mostly defined by each chip vendor. For instance, the Atheros WiFi chipset uses RSSI values between 0 and 60, while Cisco uses a range between 0 and 100 in fig 2.2

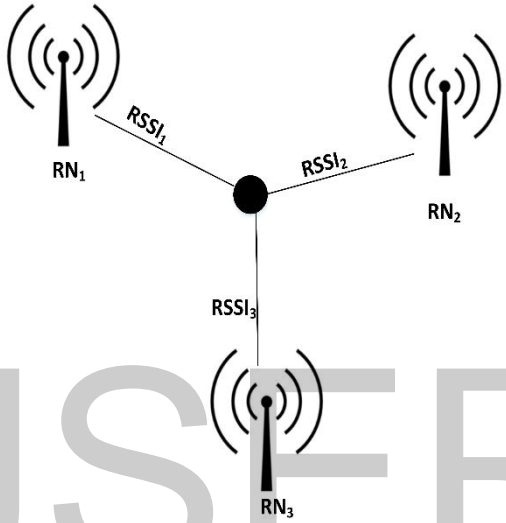


Fig. 2.2 RSSI based localization

Using the RSSI and a simple path-loss propagation model [36], the distance d between Tx and Rx can be estimated from (1) as RSSI = □10n log10(d) + A; (1)
where n is the path loss exponent (which varies from 2 in free space to 4 in indoor environments) and A is the RSSI value at a reference distance from the receiver.
at a reference distance from the receiver. RSS based localization, in the DBL case, requires trilateration or N-point lateration, i.e., the RSS at the device is used to estimate the absolute distance between the user device and at least three reference points; then basic geometry/trigonometry is applied for the user device to obtain its location relative to the reference points as shown in Figure 1. In a similar manner, in the MBL case, the RSS at the reference points is used to obtain the position of the user device. In the latter case, a central controller or ad-hoc communication between anchor points is needed for the total RSS collection and processing. On the other hand, RSS based proximity based services (such as sending marketing alerts to a user when in the vicinity of a retail store), require a single reference node to create a

geofence 3 and estimate the proximity of the user to the anchor node using the path loss estimated distance from the reference point. While the RSS based approach is simple and cost efficient, it suffers from poor localization accuracy (especially in non-lineof- sight conditions) due to additional signal attenuation resulting from transmission through walls and other big obstacles and severe RSS fluctuation due to multipath fading and indoor noise [31], [37]. Different filters or averaging mechanisms can be used to mitigate these effects. However, it is unlikely to obtain high localization accuracy without the use of complex algorithms.

2.2.2 Channel State Information (CSI)

In many wireless systems, such as IEEE 802.11 and UWB, the coherence bandwidth of the wireless channel is smaller 3A virtual fence around any Point of Interest than the bandwidth of the signal which makes the channel frequency selective (i.e., different frequencies exhibit different amplitude and phase behavior). Moreover, in multiple antennae transceivers, the channel frequency responses for each antennae pairs may significantly vary (depending on the antennae distance and signal wavelength). While RSS has been widely used due to its simplicity and low hardware requirements, it merely provides an estimate of the average amplitude over the whole signal bandwidth and the accumulated signal over all antennae. These make RSS susceptible to multipath effects and interference and causes high variability over time.

On the other hand, the Channel Impulse Response (CIR) or its Fourier pair, i.e., the Channel Frequency Response (CFR), which is normally delivered to upper layers as channel state information (CSI), has higher granularity than the RSS as it can capture both the amplitude and phase responses of the channel in different frequencies and between separate transmitter-receiver antennae pairs [31]. In general, the CSI is a complex quantity and can be written in a polar form as H(f) = jH(f)jej\H(f); (2) where, jH(fi)j is the amplitude (or magnitude) response and \H(fi) is the phase response of the frequency fi of the channel. Nowadays, many IEEE 802.11 NICs cards can provide subcarrier-level channel measurements for Orthogonal Frequency Division Multiplexing (OFDM) systems which can be translated into richer multipath information, more stable measurements and higher localization accuracy.

2.2.2 Fingerprinting

Fingerprinting is a commonly used estimation method today. It has the potential to estimate the position of a mobile device very accurately. The idea of this approach is to let certain signal properties or sensor measurements identify a certain location. Different signal properties and their corresponding locations are stored in a database effectively creating a map of the radio properties at different locations. The locations that make up the radio map are often referred to as reference points. The location of a mobile device is determined by matching detected signal properties with the reference points stored in the database. Besides the accuracy this approach also has the advantage of not relying on the placement of APs. In fact, the location of APs can be unknown and a fingerprinting approach would still work. A fingerprinting typically consists of two phases, the offline phase where the signal properties in the environment are measured and the radio map is built. The second, the online phase, is when a user location is determined by collected data that is matched with the radio map in the database. Various technologies can be used when deploying a fingerprint based indoor positioning system. In fact, the technologies do not necessarily need to be based on radio signals. An example is magnetic anomalies, which can be used to create fingerprints of an area, resulting in a magnetic map that in combination with magnetic sensors can be used in a way similar to a radio map. In this case magnetic properties can be measured at different locations and a certain location can be identified by the mobile device by measuring magnitude and magnetic strength in z-axis.

Offline Phase

The offline phase can also be referred to as the calibration phase. This phase include certain procedures required to set up a fingerprint based positioning system, it involves collecting data, creating the radio map and creating the database. This is done by first dividing the indoor area into sub-areas, where each sub-area is represented by a reference point. This is done by applying a grid, as presented in Fig. 2.5, and a coordinate system to the indoor area providing the possibility of referring to a certain point of the indoor map. This grid will represent the radio map.

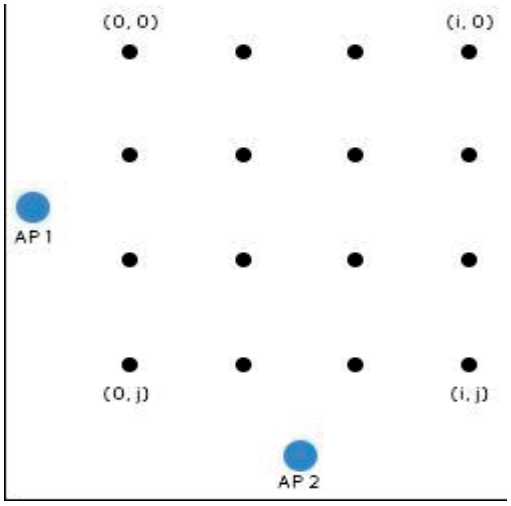


Figure 2.5 shows a radio map with reference point. Each reference point is represented by a set of coordinates.

After creating a radio map, a unique identification is provided at every reference point. This id is represented in terms of APs names or ids together with corresponding RSS. The theory is that broadcasted signals from the APs can take multiple paths all providing different combinations of various distances; obstacles such as walls, windows, roofs, floors, interior design; and phenomenon's like interference, etc. This large amount of combinations provides each reference point with a rather unique identification. This identification is often referred to as a fingerprint, hence the name fingerprinting. The identification is created by measuring the RSS from surrounding APs and is performed at every single reference point of the radio map as seen in Fig. 2.4. Since the RSS varies over time due to smaller environmental changes like people changing their positions, this is taken into consideration by taking multiple samples during the measuring, or by filtering the signal in some other way, in order to get a more approximate fingerprint. These fingerprints are embedded in a vector that is stored in a database together with its corresponding coordinate.

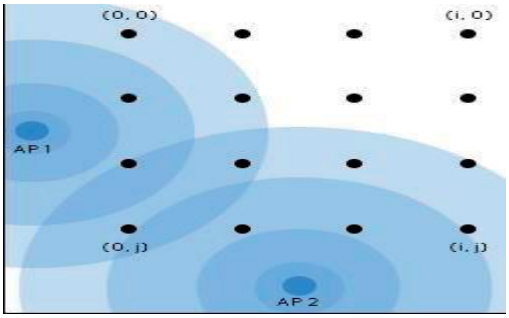


Figure 2.4 shows the radio map with reference points at which different combination transmitted signals appears origin from different access points.

Online Phase

The online phase consists of the user sending and receiving data to and from the server. When the user is entering the radio map, the device should start collecting RSS from surrounding APs. This collected vector of name/ids together with RSSs is then sent to the server and matched towards the fingerprints in the database. Wi-Fi is the most commonly used technique for generating a radio map. Bluetooth and LTE signals can be used as well as LTE signal strengths tend to vary at different locations within a building. To achieve a more accurate radio map a combination of technologies can be used. More technologies means more parameters that will contribute to the uniqueness of a reference point.

2.2.3 Angle of Arrival (AoA)

Angle of Arrival (AoA) based approaches use antennae arrays [22] (at the receiver side) to estimate the angle at which the transmitted signal impinges on the receiver by exploiting and calculating the time difference of arrival at individual elements of the antennae array. The main advantage of AoA is that the device/user location can be estimated with as low as two monitors in a 2D environment, or three monitors in a 3D environment respectively. Although AoA can provide accurate estimation when the transmitter-receiver distance is small, it requires more complex hardware and careful calibration compared to RSS techniques, while its accuracy deteriorates with increase in the transmitter-receiver distance where a slight error in the angle of arrival calculation is translated into a huge error in the actual location estimation [21]. Moreover, due to multipath effects in indoor environments the AoA in terms of line of sight (LOS) is often hard to obtain. Figure 2.5 shows how AoA can be used to estimate the user location (as the angles at which the signals are received by the antenna array can help locate the user device.).

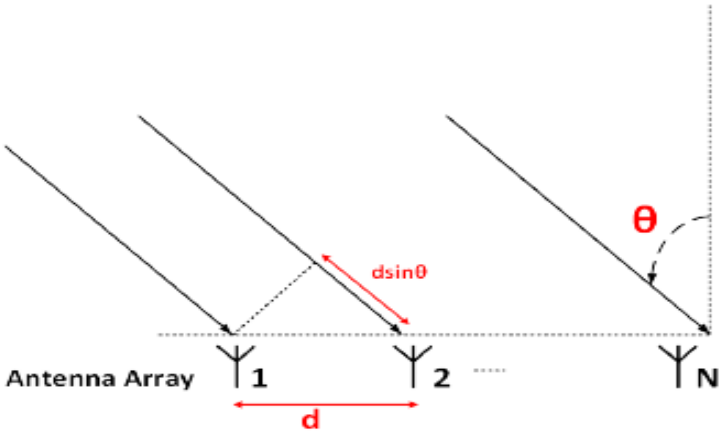


Figure 2.5 AoA based localization

2.2.4 Time of Flight (ToF)

Time of Flight (ToF) or Time of Arrival (ToA) exploits the signal propagation time to calculate the distance between the transmitter Tx and the receiver Rx [40]. The ToF value multiplied by the speed of light c = 3 _ 108 m/sec provides the physical distance between Tx and Rx. In Figure 3, the ToF from three different reference nodes is used to estimate the distances between the reference nodes and the device. Basic geometry can be used to calculate the location of the device with respect to the access points. Similar to the RSS, the ToF values can be used in both the DBL and MBL scenarios. ToF requires strict synchronization between transmitters and receivers and, in many cases, timestamps to be transmitted with the signal (depending on the underlying communication protocol). The key factors that affect ToF estimation accuracy are the signal bandwidth and the sampling rate. Low sampling

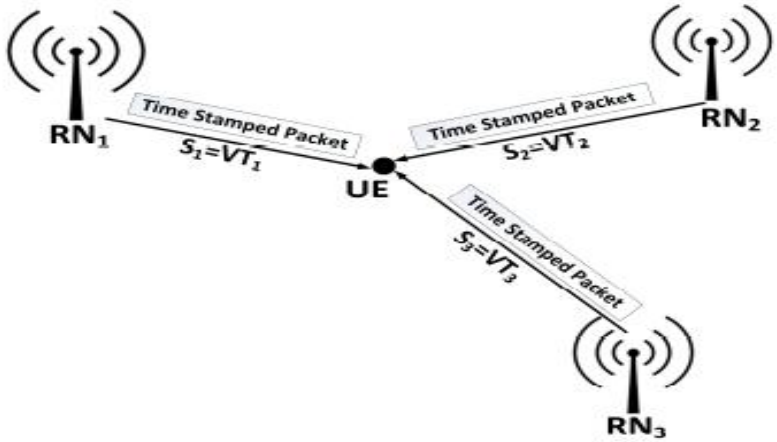


Figure 2.6 ToF based user equipment (UE) Localization

rate (in time) reduces the ToF resolution since the signal may arrive between the sampled intervals. Frequency domain superresolution techniques are commonly used to obtain the ToF with high resolution from the channel frequency response. In multipath indoor environments, the larger the bandwidth, the higher the resolution of ToF estimation. Although large bandwidth and super-resolution techniques can improve the performance of ToF, still they cannot eliminate significant localization errors when the direct line of sight path between the transmitter and receiver is not available. This is because the obstacles deflect the emitted signals, which then traverse through a longer path causing an increase in the time taken for the signal to propagate from Tx to Rx. Let t1 be the time when Tx i sends a message to the Rx j that receives it at t2 where t2 = t1 + tp (tp is the time taken by the signal to traverse from Tx to Rx) [40]. So the distance between the I and j can be calculated using Equation (5) Dij = (t2 □ t1) _ v (5)
where v is the signal velocity.

2.2.5 Time Difference of Arrival (TDoA)

Time Difference of Arrival (TDoA) exploits the difference in signals propagation times from different transmitters, measured at the receiver. This is different from the ToF technique, where the absolute signal propagation time is used. The TDoA measurements (TD(i;j) - from transmitters i and j) are converted into physical distance values LD(i;j) = c _ TD(i;j), where c is the speed of light. The receiver is now located on the hyperboloid given by Eq.(6)

$$L_{D(i,j)} = \sqrt{(X_i - x)^2 + (Y_i - y)^2 + (Z_i - z)^2} - \sqrt{(X_j - x)^2 + (Y_j - y)^2 + (Z_j - z)^2},$$

where (Xi; Yi;Zi) are the coordinates of the transmitter/ reference node i and (x; y; z) are the coordinates of the receiver/user. The TDoA from at least three transmitters is needed to calculate the exact location of the receiver as the intersection of the three (or more) hyperboloids. The system of hyperbola equations can be solved either through linear regression [15] or by linearizing the equation using Taylorseries expansion. Figure 2.7 shows how four different RNs can be used to obtain the 2D location of any target. Figure shows the hyperbolas formed as a result of the measurements obtained from the RNs to obtain the user location (black dot). The

TDoA estimation accuracy depends (similar to the ToF techniques) on the signal bandwidth, sampling rate at the receiver and the existence of direct line of sight between the transmitters and the receiver. Strict synchronization is also required, but unlike ToF techniques where synchronization is
needed between the transmitter and the receiver, in the TDoA case only synchronization between the transmitters is required.

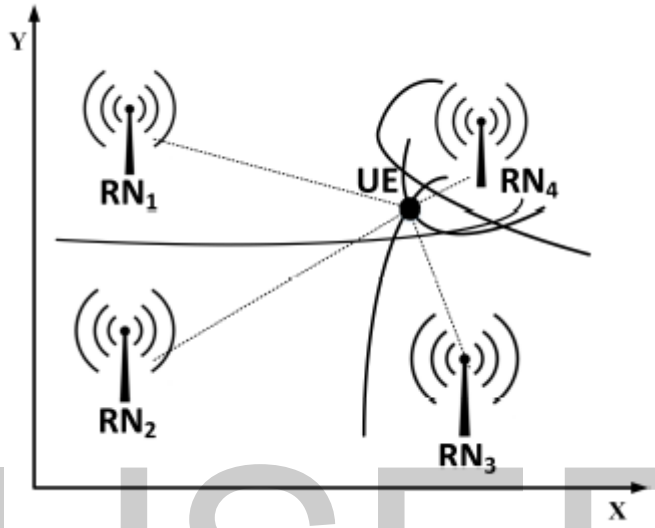


Figure 2.7 TDoA based Localization and proximity detection

2.2.6 Phase of Arrival (PoA)

PoA based approaches use the phase or phase difference of carrier signal to estimate the distance between the transmitter and the receiver. A common assumption for determining the phase of signal at receiver side is that the signals transmitted from the anchor nodes (in DBL), or user device (in MBL) are of pure sinusoidal form having same frequency and zero phase offset. There are a number of techniques available to estimate the range or distance between the Tx and Rx using PoA. One technique is to assume that there exists a finite transit delay Di between the Tx and Rx, which can be expressed as a fraction of the signal wavelength. As seen in Figure 2.8, the incident signals arrive with a phase difference at different antenna in the antenna array, which can be used to obtain the use location. A detailed discussion on PoA-based range estimation is beyond the scope of the paper. Therefore interested readers are referred to [41], [42]. Following range estimation, algorithms used for ToF can be used to estimate user location. If the phase difference between two signals transmitted from

different anchor points is used to estimate the distance, TDoA based algorithms can be used for localization. PoA can be used in conjunction with RSSI, ToF, TDoA to improve the localization accuracy and enhance the performance of the system. The problem with PoA based approach is that it requires line-ofsight for high accuracy, which is rarely the case in indoor environments.

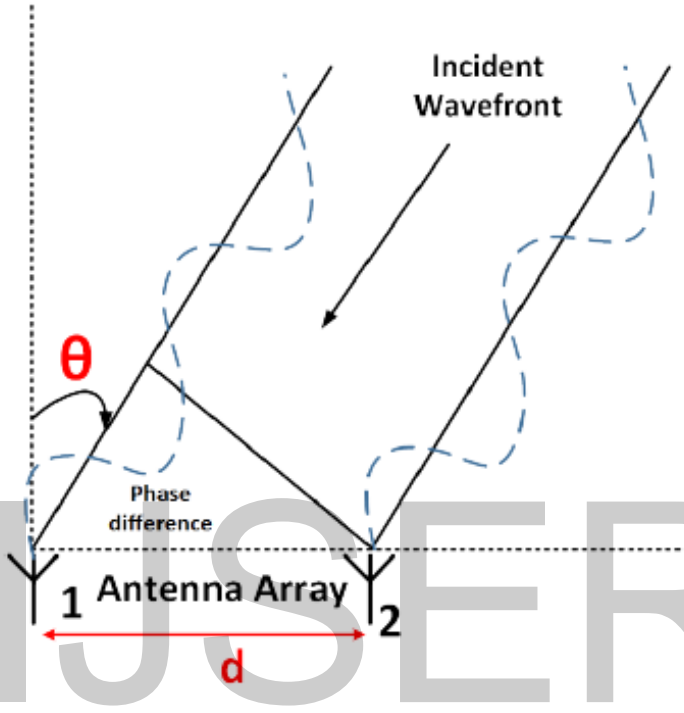


Figure 2.8 PoA based Localization

Advantages and Disadvantages of Techniques of Localization are in Table 2.1

Table 2.1 Advantages & Disadvantages Of Different Localization Techniques

Technique	Advantages	Disadvantages
RSSI	Easy to implement, cost efficient, can be used with a number of technologies	Prone to multipath fading and environmental noise, lower localization accuracy, can require fingerprinting
CSI	More robust to multipath and indoor noise,	It is not easily available on off-the-shelf NICs
AoA	Can provide high localization accuracy, does not require any fingerprinting	Might require directional antennas and complex hardware, requires comparatively complex algorithms and performance deteriorates with increase in distance between the transmitter and receiver
ToF	Provides high localization accuracy, does not require any fingerprinting	Requires time synchronization between the transmitters and receivers, might require time stamps and multiple antennas at the transmitter and receiver. Line of Sight is mandatory for accurate performance
TDoA	Does not require any fingerprinting, does not require clock synchronization among the device and RN	Requires clock synchronization among the RNs, might require time stamps, requires larger bandwidth
PoA	Can be used in conjunction with RSS, ToA, TDoA to improve the overall localization accuracy	Degraded performance in the absence of line of sight
Fingerprinting	Fairly easy to use	New fingerprints are required even when there is a minor variation in the space

2.1 Indoor Positioning System (IPS)

There are different sort of definition that are presented within the context of IPS System. In simple context that IPS is defined as "a system that is utilized to locate objects or people" (Radio map recovery and noise reduction method for green WiFi indoor positioning system based on inexact augmented lagrange multiplier algorithm, 2015). The location detection or sharing is not a simple process and in order share the location there is always a need of radio waves, magnetic fields, acoustic signals or many other different types and categories of waves. However, in the context of this research we will be using the radio waves that are emitted by the help of wireless route.

(VLC-based indoor positioning system with tracking capability using Kalman and particle filters, 2014) in the research has indicated different technologies has being presented to improve the performance and efficacy of the Indoor Positioning System (IPS). It is analysed that the technology that is utilized for IPSes is Wi-Fi access points, magnetic positioning, and dead reckoning as mentioned in (A survey of indoor positioning systems for wireless personal networks, 2009). It is observed that through the utilization of this mechanism the locate mobile devices can be integrated and the better results or outcome can be executed as indicated in (Radio map recovery and noise reduction method for green WiFi indoor positioning system based on inexact augmented lagrange multiplier algorithm, 2015).

There are different categories of technology that are utilized in the scenario of Indoor Positioning System. However, current most of the IPS system are equipped with Non-radio technologies and due to the utilization of Non-radio technologies that performance and efficacy is always considered as the key question as mentioned in (Compass: A probabilistic indoor positioning system based on 802.11 and digital compasses, 2006). It is also examine that the proposed technology is quite expensive and most of the stakeholder still doesn't prefer to deploy these sort of solution within the context of build on position detection.

The security is considered as one of the main barrier and there is a high probability that if the security module is integrated better results can be executed as mentioned in

(A systems thinking framework for knowledge management, 2001). In the context of this research work we will also be analysing and will be integrating the hash code for the implementation of proposed solution. The discussion within the context of hash code is presented in section 1.4.

2.2 GPS System

Global Positioning System is defined as one of the common and universal known system that is utilized for the position location. However, as the mobile application use is increasing the most of the mobile system or phone the GPS system has being deployed as mentioned in (Information and communication technology and the social inclusion of refugees, 2016). This system is executed by help of AFSPC and the key country that lies of origin is United States. However, in the leading world of information and communication technology the need of the GPS use have being increasing. However, it is the initial phase the key concept for which the GPS is utilizing is Military (Payless: A low cost network monitoring framework for software defined networks, 2014). However, as the technology and the application demand has being increasing that GPS have being utilized in number of application as today in the external environment it is considered as the key operator for the execution of location based services.

(Towards an efficient, intelligent, opportunistic smartphone indoor positioning system, 2015) conducted that research work and identify and analysed that how the GPS system application can be executed and can also be linked within the context of Location based services. It is observed that for the communication protocol has been improved and the User-satellite geometry has being extended so that the location based application can be improved. However, the solution works on the simple principles and through the global navigation satellite system the GPS receive share the position information with the user. However, based on that position the locations are identified and that user knows about the food and hotel that are near the location.

All the information and data exchange in the network are executed through the GPS location. However the expected solution has being approved in the simulation environment. During the analysis it is also observed that not all the hotel can be identified in the location and this is due to the weak connectivity. Based on the

analysis it has been example that most of the application are utilizing the google or Bing Maps (Performance metrics and auditing framework using application kernels for high-performance computer systems, 2013). (VLC-based indoor positioning system with tracking capability using Kalman and particle filters, 2014) in the research work has indicated that collaboration has been set within the context of google maps and GPS that directly help set in execution of project. The protocol of the location based service has being working efficient but to some extend the GPS positing was not accurate and due to this the key objective of the location was unable to achieve.

According to our analysis in the context of Indoor Positioning System (IPS) based on Wi-Fi it have been analysed that accuracy is unable to be achieved and during the execution of this project or research theme that accuracy need to be considered. In this research we will be sorting out this problem and we will be focusing on developing the protocol that will help in share the accurate position. (Geng, et al., 2014) in the research work has indicated that accuracy of solution can be shared within the context of the around about 20 meter and the same principles have being applied in the perspective of Google maps. It is also observed that if the proper and better algorithms that are develop the accuracy can be improved.

It is analysed that there are different types of researches (A floor-map-aided WiFi/pseudo-odometry integration algorithm for an indoor positioning system, 2015; Compass: A probabilistic indoor positioning system based on 802.11 and digital compasses, 2006; Radio map recovery and noise reduction method for green WiFi indoor positioning system based on inexact augmented lagrange multiplier algorithm, 2015) that have indicated that GPS system has number of advantages such as it helps in improving the improve military navigation, Neighborhood Search, Weather and Traffic Alerts and many other. Today, it is analysed that the GPS system have not being utilized for the complex operations but it is also being observed that the GPS system has also being simulated and utilized by the basic consumers. (Wi-Fi fingerprint-based indoor positioning: Recent advances and comparisons, 2016) in the research has indicated that there are different types of concept that can be utilized to extend the solution and today the GPS is considered as one of the main application for the execution of location based services.

It can be summarized that due the analysis we will be focusing on the context of analysing and identifying the proposed solution. It is also observed that the GPS technology and the location based services can also be integrated as the part of the Indoor Positioning System (IPS) based on Wi-Fi. There is a high liklihood that better result can be achived. (A systems thinking framework for knowledge management, 2001) indicated that if the analysis or modifications are conducted on the two key principles including accuracy and system trouble that key outcome can be executed. In the next sub section the detail discussion within the context of comparison and summary of the research discussed in this section is presented.

2.2.2 IEEE 802.16 standards and Technology

The industry name of the IEEE 802.16 standards is "WiMAX." WiMAX is the wireless technology which mainly functions in the radio spectrum of "10-66 in the Line of Sight (LOS) and 2-11 GHz in the Non-LOS (WiMAX forum)". It is a point to multi point technology. WiMAX is developing broadband wireless entrance technology that conveys a "carrier-class, high speed" at a comparative lower-cost than the other cellular facilities or services while giving long distances as covered than WiFi. The purpose of designing WiMAX was to provide "cost-effective technology" with a theoretic data rate of "70Mbps over a wide area up to 50km in the NLOS", control of great quality voice, records and video services (Westech Communications Inc, 2005). LOS is required by the WiMAX for higher rate of frequencies. The WiMAX has compatibility benefit as compared to other wireless technologies which includes asynchronous transfer mode (ATM), Internet Protocol (IP) etc. WiMAX is categorized as a "wireless metropolitan area network" (WMAN). The 802.16 standard was designed after the failures of security that subjected down the development of "IEEE 802.11 wireless networks". The IEEE 802.16 Working Group is developed for a robust mechanism incorporated Data over Cable Service Interface Specification (DOCSIS) a solution to the last mile cable problem. Since the security was considered as main priority in the development of IEEE 802.16. On the other hand, the Working Group was very busy in the development of several mechanisms in order to defend theft of service and unapproved or unauthorized information, alteration and disclosure. Table 1 shows Comparison of Wireless Network Technology

Wireless Protocol	Data Rates	Airwaves
Bluetooth	1mbps	Unlicensed
WiFi-a WiFi-b WiFi-g WiFi-n	54Mbps 11Mbps 54Mbps 100mbps	Unlicensed
GPRS	115kbps	licensed
EDGE	384kbps	licensed
HSPDA	2mps	licensed
WiMAX	8-10Mbps	licensed
VSAT	512 kbps	licensed

Table 1 Comparison of Wireless Network Technology

2.3 Comparison and Summary

In the above segment that detail discussion within the context of the existing literature that is carried out in context of Indoor Positioning System Based On Wi-Fi is presented and the key problems, issues, challenges and gaps that exist within the context of these system have also being discussed. Through the detail analysis of the existing solution we are able to identify that in which are the improvement can be made or what is the key problem that need to be resolved in the initial phase.

Through the analysis of the existing research It is analysed that Hugh demand of real time and monitoring application exist in today market that can be utilized in commercial systems or for the domestic purpose as well. According to our analysis based on the existing researches [8, 9] it is investigated that current in market there is still a lack of standard IPS system and the communication protocol mechanism that can provide a client or key stakeholder flexibility. In this research (Indoor Positioning System Based On Wi-Fi) the detail discussion will be carried out within the context of Indoor Positioning System using the concept or approach of Wi-Fi. It has being analysed the Indoor Positioning System works in the similar as GPS works. However, key difference is that IPS system is utilized for in-door and on the other side the GPS

is utilized for out-door tracking. It is observed that both of these system have different types of advance and disadvantages IPS system have the connectivity problem. However, the GPS system doesn't have any sort of these problems and mostly in number of mobile application the GPS systems are deployed.

It is analysed that there are different sort of mechanism that can be utilized to track or locate objects for Indoor Positioning System. In this research work we will be considering the mechanism of Wi-Fi. We will be analysing and identifying the existing approaches that can be utilized for locate objects through integration of Wi-Fi access points. Based on the existing researches it is analysed that there are different researches [10, 11, 2] that has being using the Wi-Fi technology for Locating and tracking and performing many other related task within the context of Indoor Positioning System.

In recent years the location based service (LBS) demand are dynamically increasing and it is analysed that due to the lack of LoS (Line Of Sight) in context of in-door monitoring the accurate results can't be obtained that overall has cause the barriers for different sort of location based services/application. It has being identified that instead of utilizing the Global Positioning Systems (GPS) for location identification we will be focusing on hybrid approach. The approach will be working on the Wi-Fi context but Wi-Fi hotspot and Wi-Fi fixed nodes will be utilized for the Indoor Positioning System. Hybrid approach is considered as one of the most innovative in this research as we will be key component including Wi-Fi hotspot and Wi-Fi fixed nodes. In the next chapter the discussion within the context of Indoor Positioning System Based on Wi-Fi is presented.

Chapter 3

System Design and Implementation

System design and implementation is always consider as the time consuming challenge and it is analysed that with the entry of time other techniques and tools such as fingerprinting location, topology-based and viterbi-like algorithm, propagation models and many other have being developed to streamline the business and functional processes related in context of development of proposed solution (WIFI-Based Indoor Positioning System with Twice Clustering and Multi-user Topology Approximation Algorithm, 2016). Position detection is a complex process and there is always a need of connectivity in order to ensure that the right and accurate position has being shared supporting argument from (Geng, et al., 2014). It is observed that the Position Sensitive Detector (PSD) and much other similar kind of devices have being developed to share the position as mentioned in (Geng, et al., 2014).

However the working principle of the position sensitive device is based on the isotropic sensors and discrete sensors. If the right methodology and system architecture is design and developer there is a high liklihood that the major objective and goals that are associated within the context of Indoor Positioning System (IPS) Based on Wi-Fi can be achieved. It is also analysed that there is a high chance that if the proper deployment is made the key objective can be achieved. Most of the Indoor Positioning System (IPS) simulate their task through the utilization of IEEE 802.11 wireless network.

In this chapter, the detail discussion within the context of the expected solution that is design and development for Indoor Positioning System (IPS) (IPS) based on Wi-Fi has being presented. The proposed solution or the conceptual framework that has being presented in this context is to analyse that the key objective that have being set can be achieved. According to our analysis based on existing researches it is analysed that different types and categories of components need to be integrated so that the key results and the system architecture can be developed. There is a high liklihood that the key novelty of the research will also be presented in the context of this chapter and analysing the how the gaps that exist within the context of the Indoor Positioning System (IPS) based on Wi-Fi can be resolved through the presentation of the

conceptual framework. In the next section the system design of the Indoor Positioning System (IPS) based on Wi-Fi is presented.

3.1 System Architecture

Developing the System Architecture is always treated as the complicated challenge as there are distinct types of parameters that are linked within the context of system architecture (Radio map recovery and noise reduction method for green WiFi indoor positioning system based on inexact augmented lagrange multiplier algorithm, 2015). It is observed that the system design is defined as "is the conceptual model that defines the structure, behavior, and more views of a system" (Algorithms of fire seat detection, modeling their dynamics and observation of forest fires via communication technologies, 2015). As the technology is improving it is analysed that there are number of different types of parameters that can be utilized under the umbrella of System Architecture. Most of the researches has identified and analysed that system architecture and conceptual framework is a same concept as mentioned in the context of (An Analysis of the Optimal Placement of Beacon in Bluetooth-INS Indoor Localization, 2018). In this section the detail discussion in context of system architecture is presented.

The block diagram figure 3.1 of the system architecture is presented and in this architecture data and information will be collected about the position from the external environment. Each of the devices that are utilized for the location detected will be equipped with the sensor. All the information that is executes from the sensor will be stored in the data collection server. However we will not be deploying the real time server it is will be small application that will be linked within the context of google maps or Bing. All the data and information the will be collected form the external environment will be stored in the raw data. So that later on it can be utilized for the process.

Data collection server will be linked within his indoor map construction tool and on the other side it will be linked within the location services. It is observed that in the standard operating system that IEEE protocols are utilized. In the context of this application we will be utilizing the Multi listing technique as proposed by (WIFI-Based Indoor Positioning System with Twice Clustering and Multi-user Topology

Approximation Algorithm, 2016) and later on discussed in detail in the context of chapter 3.

3.1.1 Indoor Map Construction Tool

There are several components that can be linked in the context of indoor map construction tool. Floor planning tool, POI editor, Survey Planning Tool and many other are linked in the context of indoor map construction tool and it is analysed that there are serval benefits that can be obtained through the utilization for Indoor map construction tool. For indoor map construction tool all the tools has been purchase from the integration and the tools have the quantity to be associated within the context of other line of business application. All the sub component of the indoor map construction tool will not be mapped in the context of the application. All the application are linked in the context of data collection server.

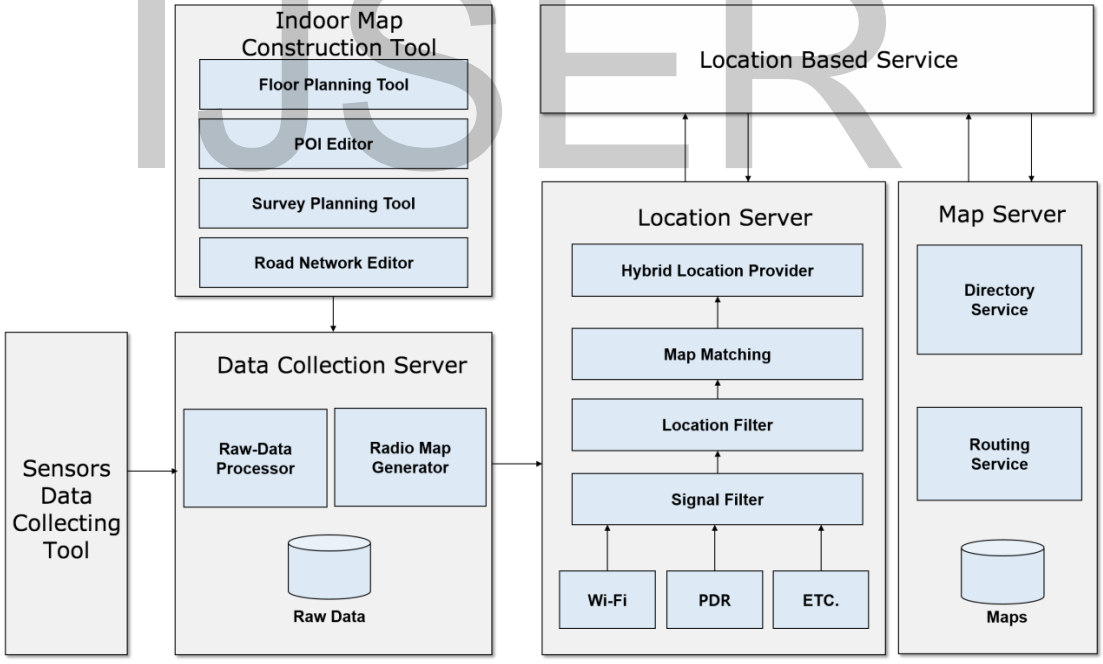


Figure 3.3 Proposed Architecture

3.1.2 Location Server

In the context of the expected solution we have integrated two server applications and on the other side with the data collection server and location server has been lined

with each other. The location server will also be containing different types of location services and the Wi-Fi will be utilized. All the position information in the context of the location server will be obtained from the Wi-Fi in the scenario of Indoor Positioning System (IPS).

The Wi-Fi will be receiving the signal and will be filtering them through the utilization of signal filter. The location filter will also be applied to identify and analyse the location. However, once the location filter is completed the map matching and the hybrid location provide will be analysing the results. It is can be concluded that the expected solution has the capacity to achieved the research objective that has been set for Design and development of Indoor Positioning System (IPS) based on the hybrid approach. This approach will be utilizing the Wi-Fi hotspot and Wi-Fi fixed nodes for the detection of the location.

3.1.3 Map Server

Map server is defined as the last module of the Indoor Positioning System (IPS) based on Wi-Fi and it is analysed that through the utilization of proposed solution some of the customization will be performed. There are two module that will be considered in the context directory service and routing services. We will be using the google maps so that the key results and the outcome can be obtained. However, instead of deploying the map server will be considering the google API.

In the next section the methodology has been presented.

3.2 Methodology

Selection of the right methodology or best fit methodology is considered as critical processes and there is a high liklihood that if the right methodology or best fit methodology is selected better results and the research objective can be obtained as mentioned in (An inexpensive bluetooth-based indoor positioning hack, 2006). However, in this section the detail discussion within the context of research methodology has been presented. If the proposed analyses are conducted there is a high probability that the best fit methodology for the Indoor Positioning System (IPS) based on Wi-Fi can be extracted.

With the entry of time there are distinct sort of research methodology based on the concept of qualitative and quantitative such as Microsoft solution Framework, Agile, Waterfall, Proprietary, MPS etc. that are presented and can be utilized in context of technology solution development. Most of the programming and application development companies that are involved in the design, development and implementation of customized methodology that has been based on that agile concept. According to our analysis based on the existing research of Indoor Positioning System (IPS) based on Wi-Fi it is considered as one of the complex and critical challenge to select the methodology that can let the key stakeholder to carry out the key activities and achieve the required objective.

However, in this research we will be utilizing Microsoft software framework and the framework is divided into five key phases including Envisioning, Arranging, Developing, balancing out and conveying. There are distinct sort of key turns solutions that are linked within the context to support technology are simulated by help of MSF Foundational Principles According to out analysis there is a high probability that utilization of Microsoft software framework will overall help in achieving the research objective related within the context of Indoor Positioning System (IPS) based on Wi-Fi. It is observed that all the transformation process of Indoor Positioning System (IPS) based on Wi-Fi will be mapped on the Microsoft software framework. Through the integration of Microsoft software framework the proposed solution and the development will be conducted within specific resources, timeframe and cost. It can be summary there Microsoft Solution Framework has the capacity of the fully execution the solution of Indoor Positioning System (IPS) based on Wi-Fi so, according to our analysis it is indicated that we will be considering these solution. In the following figure 3.2 we indicated that how the android will be linked with the system through the utilization of android application.

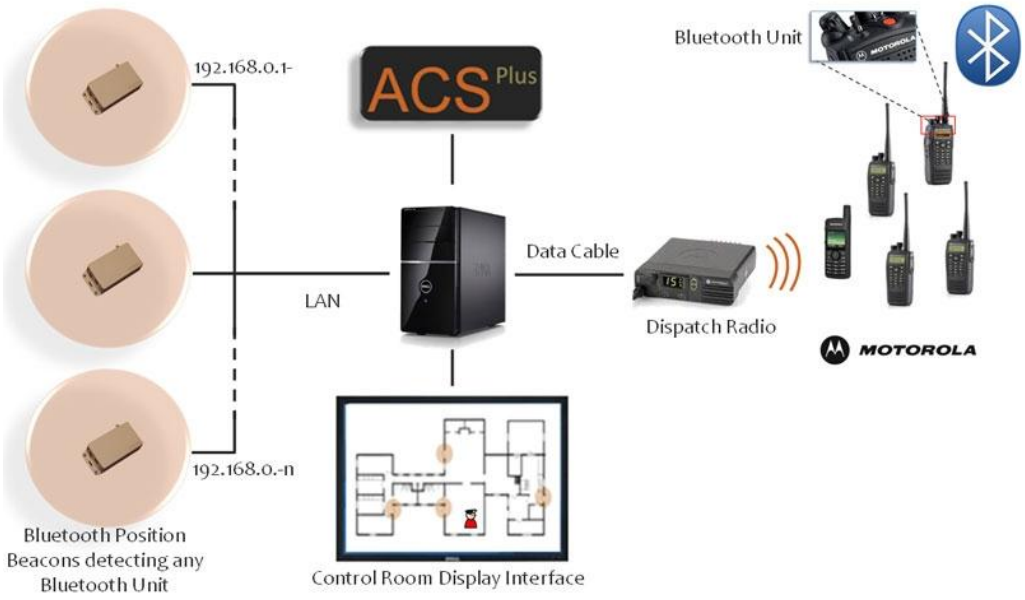


Figure 3.4 IPS Android Linkage

3.3 Challenges

3.3.1 Software Development Methodology

Software Development Methodology play an important role in the design, development and planning of the information technology solution. In the sub section the software development methodology has been discussed.

3.3.2 Agile Methodology

Agile methodology is one of the common software development methodologies which have been utilized in number of software and application development solutions. The Agile methodology has been integrated with the cloud computing solution as well. The Abhishek Jain (Analytical Study of Agile Methodology with Cloud Computing, 2011) conducted a research in which the in depth analyses of the Agile Management, development methods and its benefits with cloud computing have been conducted. It have been analysed that agile is a light weight methodology and the methodology around by number of software development companies around the world. Agile development processes optimize the opportunity provided by cloud computing by doing software releases iteratively and getting user feedback more frequently.

It have been analysed that the agile methodology can provided number of benefit to the companies and processes linked in the software and application development. The research also suggested number of improvement which should be made in the agile methodology to make it more efficient and effective so that it can be integrated with cloud computing technology. In figure 3.3, the main focus of research was to perform the analytical study of agile methodology with cloud computing.

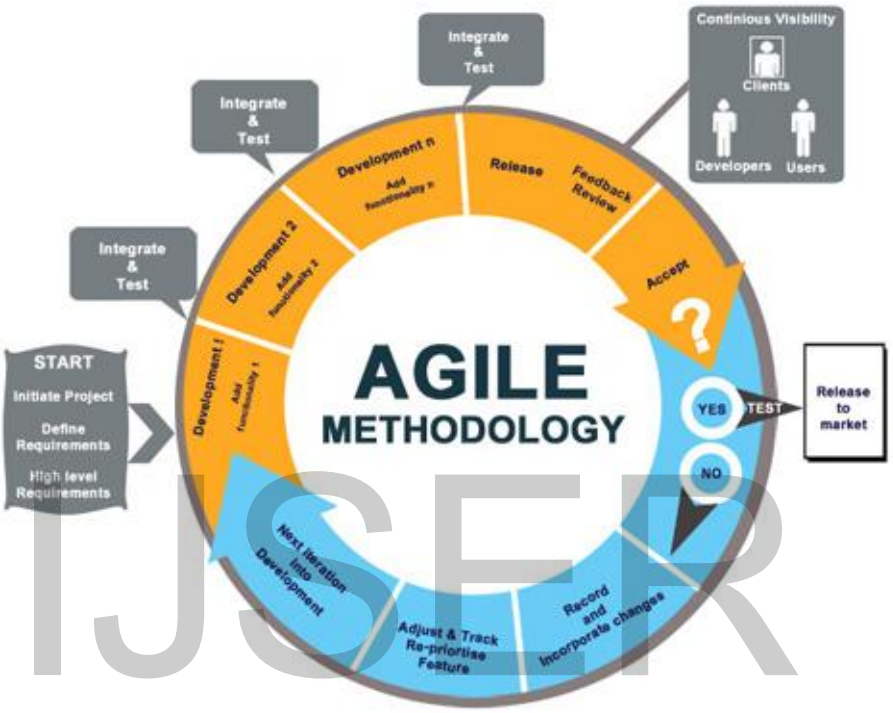


Figure 3.3 Agile Methodology (Highsmith, 2002 p. 49)

3.3.3 DMAIC Methodology

DMAIC is an improvement cycle based on the methodology of Six Sigma methodology. DMAIC Methodology can be utilized for managing the cloud computing solution. It can be utilized for optimizing and improving the business and functional processes. DMAIC is a core tool for the Six Sigma methodology. The reductions of defect rates in the development have utilized the DMAIC Methodology. The main phases of the DMAIC Methodology approaches include “Design, Measure, Analyse, Improve and Control” (Implementing Six Sigma via TQM improvement: an empirical study in Taiwan, 2008).

A large number of the research studies have been presented in the software and application development (DM make up water reduction in thermal power plants using Six Sigma DMAIC methodology, 2008), (A view of cloud computing, 2010). All the

phases have helped in the overall reduction of defect rates in the software development. There are number of dynamic strategies which are involved in the Six Sigma methodology. This continue help in the evaluation and transformation by industry leaders especially software and application development companies (Integrating Human-Computer Interaction Development into SDLC: A Methodology., 2004).

3.3 Simulation Tools

Proposed solution will be tested and executed in the simulation environment and the real time parameters will be mapped on the nodes deployed in simulation environment the detail of the simulation environment is presented in chapter 4. NETLOGO and JAVA language will be use for the developed of proposed solution. It is analysed based on the existing researches (ViFi: Virtual Fingerprinting WiFi-based Indoor Positioning via Multi-Wall Multi-Floor Propagation Model, 2016; A novel method for constructing a WiFi positioning system with efficient manpower, 2015; Survey of wireless indoor positioning techniques and systems, 2007) that most of existing solutions or scenario developed for wireless network use NETLOGO as a tools for executing of their technique and algorithm. So, it can be concluded that as most of the scenario of proposed solution is linked with the category of communication the testing of data packet and its flow will be performed using the behaviour model that is developed in JAVA.

3.4 Communication Protocol

Accuracy in the context of the Indoor Positioning System (IPS) is considered as the key element and based on the existing researches (Towards a crowdsourced radio map for indoor positioning system, 2017) it is analysed that the efficiency can be upgrated through the integration of communication protocol. It is observed that most of the existing system that are based on the Indoor Positioning System (IPS) are utilizing the standard protocol such as and due to the utilization of the standard protocol that accuracy of the solution are affected in the context of real time environment. According to our analysis based on the existing researches it is quite complex to conduct design and develop a protocol from the starch as it is considered as one of the

time consuming and critical process as mentioned in (Compass: A probabilistic indoor positioning system based on 802.11 and digital compasses, 2006). During the investigation we have being considering different types of protocols that can be integrated in the concept of Indoor Positioning System (IPS) based on Wi-Fi.

Through the deep analysis of the mechanism it has being decided that instead of using the traditional communication and protocol development technology we will be focusing and will be analysing on working on the intelligence communication protocol. In the recent years that multi agent based system has gain attention and these systems are utilized in number of real time application for sort out the complex and time consuming problem. During the analysis we considered different types of communication protocol and module that are based existing researches that the protocol that are utilized of the communication and collaboration within the context of Indoor Positioning System (IPS) based on Wi-Fi can be integrated within the perspective of setting intelligence communication protocol. According to our analysis this is considered as one of the key and core section of this research work of Indoor Positioning System (IPS) based on Wi-Fi. In this area the detail discussion within the context of communication protocol that is presented for Indoor Positioning System (IPS) based on Wi-Fi is presented.

During the design and development of the protocol that are distinct types and aspect of parameters that we need to considered (Algorithms of fire seat detection, modeling their dynamics and observation of forest fires via communication technologies, 2015). However, through the deep analysis and the deep investigation of the agent based system we considered multi-listing technique that can be integrated for the Indoor Positioning System (IPS) based on Wi-Fi. There are number of research and the key solution such as wireless sensor network, artificial intelligent and for carrying out the data packet and setting communication and collaboration in many real time applications. However, there are different reason or justification due to which it has being decided that the Multi-listing technique will be utilized an the existing gaps that have been highlighted in the context of proposed solution can easily be addressed.

The proposed solution in figure 3.4 will be simulated for the Indoor Positioning System (IPS) based on Wi-Fi and there would be two processes that will be controlled and managed by the communication protocol as mentioned in (A mobile indoor

positioning system based on iBeacon technology, 2015). We will be focusing on the context of both the process and will be analyzing that how these processes can be linked within the context of Indoor Positioning System (IPS) based on Wi-Fi. One of the key goal of this research is to set the synchronization between all the position packets that has being retrieved from the environment and have been detected.

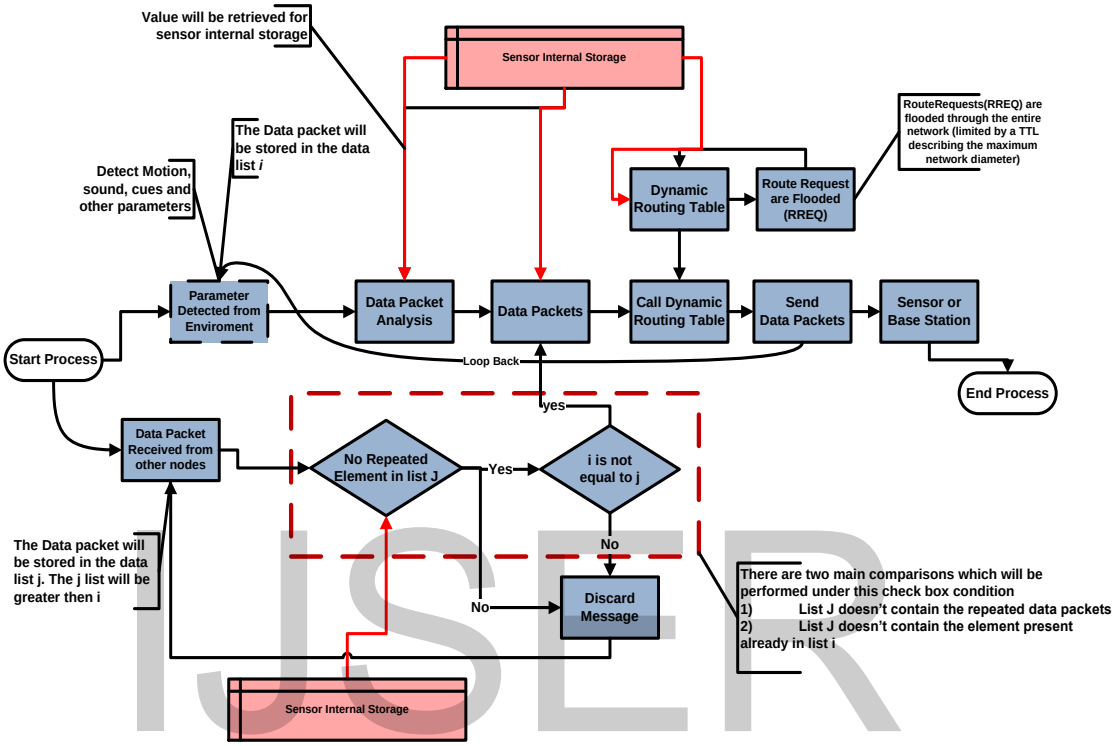


Figure 3.4 Communciation Protocl

There are two processes that are linked within the context of expected solution and during the development of the communication protocol that key concept is to identify that accurate position, decrease data packet overhead, increasing the transaction speed, air time delay and many other parameters. It is analyzed that with the in order to extract the required outcome we have utilizing using the proposed communication multi listing mechanism that has based on the multi Listing technique adopted from (Verification & validation of a multi agent meeting scheduling simulation model, 2014). To some extend the similar sort of mechanism is utilized in the context for agent based communication. In the context of this research we are not working on the traditional algorithm. We have planned and have utilized that intelligent mechanism. It is observed that the proposed communication protocol will be executed through the Wi-Fi fixed and the similar algorithm can be implemented in mobile Wi-Fi Nodes.

3.4.1 Communication Protocol Module – I

One the user or devices share the position the process one starts and the data packets are formulated. These data packets contain the key information about the position. However, one of the positions of the object or devices is identified that location within the context of index calculation are performance. In the indexing calculations the longitude and latitude focusing on the context that the exact location can be calculated. However, after the calculation there are serval modifications that are made in the context of data packet and the accuracy of the location is improved.

In order to share the location with the specific user or devices that is always a need of analyzing the neighbor nodes. However, in the context of this research we will not be using any sort of control packets and ACK packets that are utilized in the perspective of the traditional solution. In this research we have planned to utilize that simple flooding that that is utilized in number of wireless sensor network or many other techniques. There are number of routing mechanism that can be integrated in the context of Indoor Positioning System (IPS) based on Wi-Fi. It is analyzed that simple flooding technique is utilized for sending and establishing the routing table.

It can be examine in the proposed solution that Route Request (RR) is flooded and through the execution of the route request better results and outcome can be obtained. However, some of the delay has been reported in the context of network formulation as we have also integrated the Hash code and function with each Route Request (RR) packet so that the security to some extend can also be ensured. It was overall a simple process but it order to ensure the performance we will has integrated that Time-to-live (TTL) so that if the packet validity can be ensured. Once all the data packet formulation is completed it is analyzed that the key goal that is associated within the context of route formulation can achieve.

In the last phase once all the routing process is completed the data packet is shared with the specific location. Same process has being utilized for the agent based communication and has being implemented in the context of proposed solution is utilized in the Indoor Positioning System (IPS) based on Wi-Fi. Through the utilization of this process that better communication can be performed and more outcomes can be extracted.

3.4.2 Communication Protocol Module – II

It is complex to transfer the message directly to the base station or to the required node. So we will be utilizing the communication protocol and in this section we will be discussing the process two of the proposed communication protocol. We are utilizing the flooding technique and during the flooding technique the repeated messages may be received at the Wi-Fi devices or Wi-Fi nodes. So, in order to remove the repeated data packets messages there are two key checks that has been implemented in the context of proposed solution.

The Wi-Fi will also be receiving the data packets and all the data packets that we will be processes will be investigated first. As it is can be analyzed in the above figure 3.2 there are two check lists. The checking process will be analyzing that whether the data packets are repeated or not. However, in this process the internal storage has also being set so that that the repeated data packets can be detected and the packets can be discarded. However, once the analysis process based on the multi listing technique is completed that data packet are shared or transmitted according to the process one. Based on our understanding from (Payless: A low cost network monitoring framework for software defined networks, 2014; Overview of current indoor positioning systems, 2009) that the technique is quite efficient and for the testing purpose and analyzing the gaps that proposed solution has being integrated in the simulation environment and the detail discussion has been performed in the chapter of system evaluation.

In the above section the detail discussion within the context of communication modules has been discussed. However, we will be analyzing the communication module in the context of Indoor Positioning System (IPS) based on Wi-Fi. There is a high liklihood that proper analysis need to be conducted before integration of any sort of solution. It is concluded that the design and development of the communication protocol for simulating the data packet of Indoor Positioning System (IPS) based on Wi-Fi need to be performed. There is a high liklihood that better outcome can be obtained and the objective that we have defined in order to achieve the outcome has also be extracted.

In the next chapter 4 the detail discussion in context of system evaluation for the proposed solution has being conducted.

Chapter 4

System Evaluation

Verification and validation of proposed solution or system is defined one of the critical challenge as mentioned in (Compass: A probabilistic indoor positioning system based on 802.11 and digital compasses, 2006). However, it is examine that before the selection of any sort of testing the best fit tools and techniques must be selected.

Based on the previous studies (Fusion of WiFi, smartphone sensors and landmarks using the Kalman filter for indoor localization, 2015; A mobile indoor positioning system based on iBeacon technology, 2015) whenever the key turn solution are developed or design most of the stakeholder prefers to utilize the simulation environment as the simulation environment helps in saving the cost and the duration. There is a probability that if simulation testing is not conducted and the solution or approach is direclty deployed in real-time environment there is a probability that better results would not be achieved. (ViFi: Virtual Fingerprinting WiFi-based Indoor Positioning via Multi-Wall Multi-Floor Propagation Model, 2016) indicated that failure of project in real-time environment the overall cost, resources and time frame will be impacted.

Simulation and testing is defined as the core objective or theme of this research and according to our analysis presentation of proposed approach is not a complex tasks. There is always a need of testing so that it can be investigated that the solution fit best according to the requirement and specific.

Developing and selecting the simulation tools is critical challenge and through the utilization of the existing approach and deep analysis of the existing literature the goal related to the simulation tools selection has been achieved.

4.1 Simulation Environment

There are different types of scenario and components that need to be simulated and tested in the context of proposed solution. The key emphasis or gaps that will be addressing in this solution are communication protocol and there is a high probability

that if communication gaps in the proposed solution are developed better results and outcome in the context can be achieved. As already discussed we utilized NetLogo and Java classes for the simulation of the proposed solution based on Wi-Fi. The simulation environment is presented in the figure 4.5

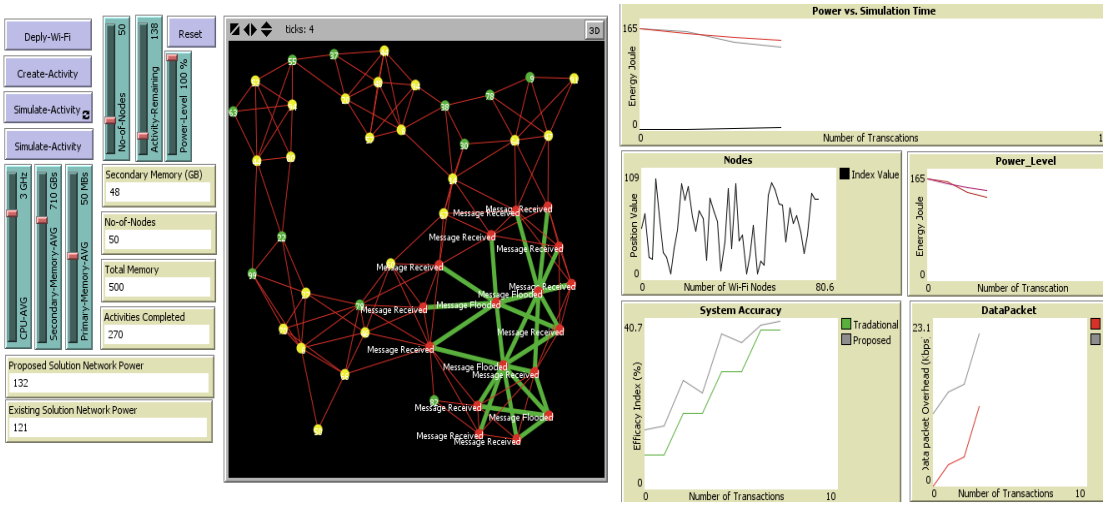


Figure 4.5 Simulation Environment

4.1.1 Deployment of Nodes and Patch Settings

In the initial section the simulation area in the context of the simulation environment has been selection. However, in order to conduct that simulation we have selected patch around 41 x 41 area on which the Wi-Fi hotspot and Wi-Fi fixed nodes will be simulated. The area selection and the nodes deployment is presented in the figure 4.2

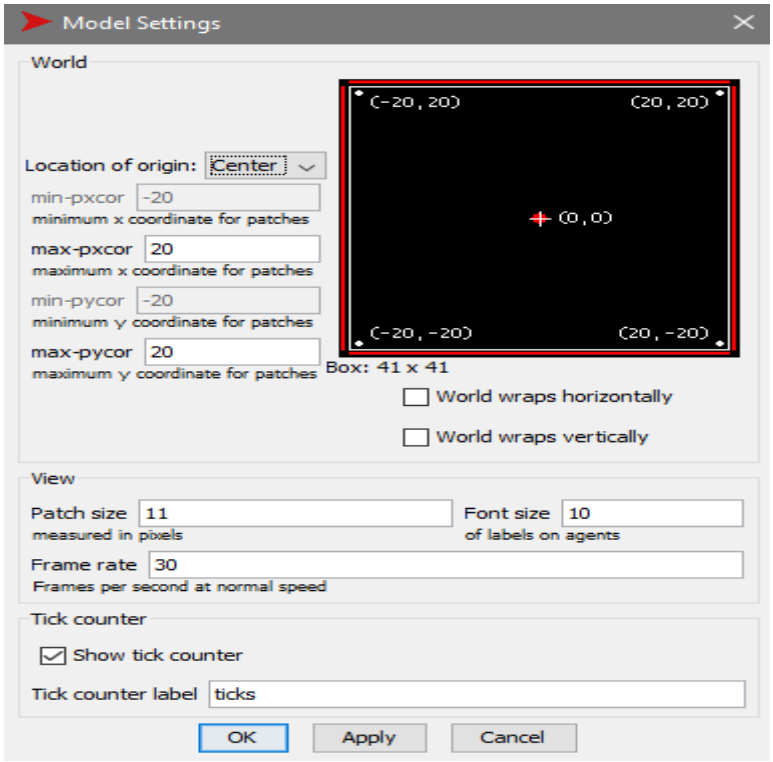


Figure Error! No text of specified style in document.**.6 Environment Setting**

In the figure 4.6 we have considered the environment setting and it is analyzed that different patches according to the pxcor coordination's has been set.

In the figure 4.7 the node deployment of (Wi-Fi hotspot and Wi-Fi fixed nodes) has been presented.

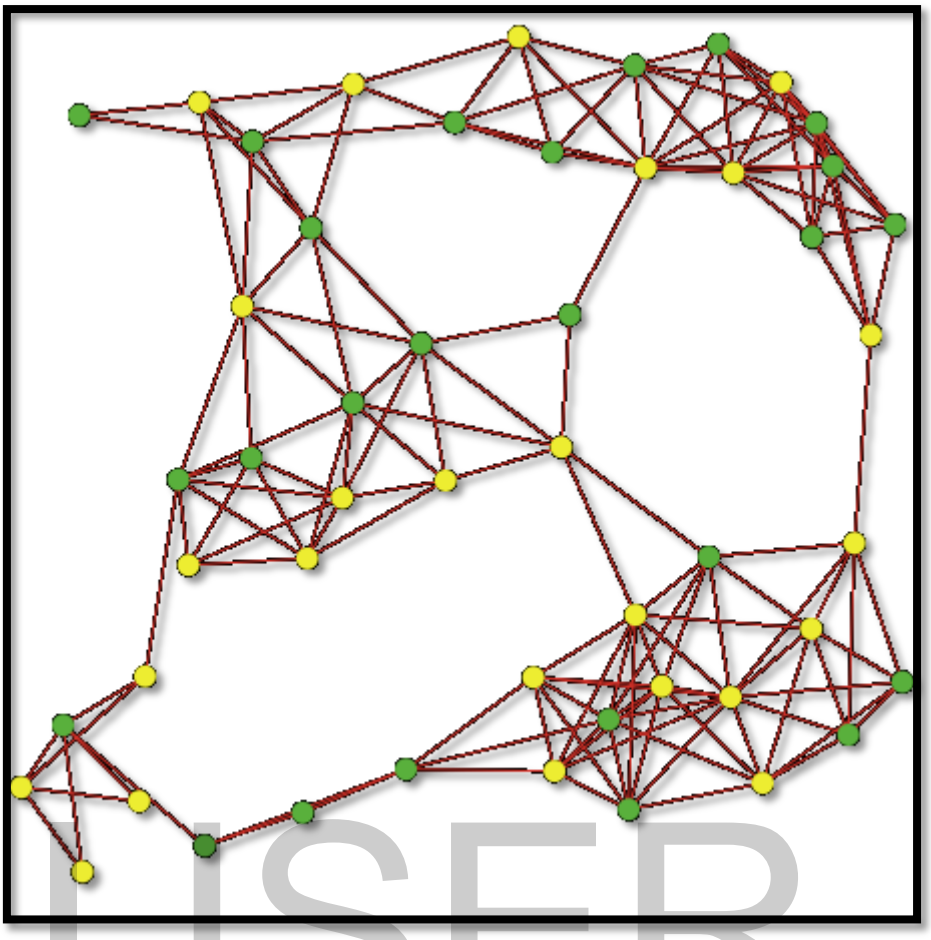


Figure Error! No text of specified style in document..**7 Nodes Deployment**

4.1.2 Parameter and Variables

In order to manage the Wi-Fi nodes there are different types of parameters that has been selected and have been programmed in the simulation environment. It is observed that there is a high liklihood that if the nodes are variable and can be changed according to the scenario. It is analysed that some extend better testing can be performed that will help in better outcome. In the figure 4.8 the key parameters that have been considered in the simulation environment of Indoor Positioning System (IPS) based on Wi-Fi has been presented.

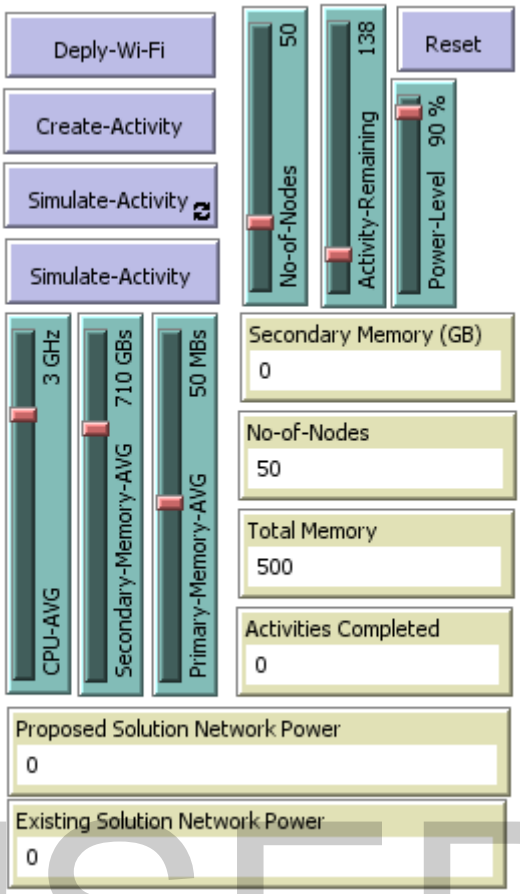


Figure Error! No text of specified style in document.**.8 Simulation Parameters**

4.1.3 Monitors Settings

We deployed the monitors so that the continuous monitoring of the key parameters such as power, activity, total memory, secondary memory and many other parameters that we have set in context of Indoor Positioning System (IPS) based on Wi-Fi. Figure 4.9 the monitors have been presented.

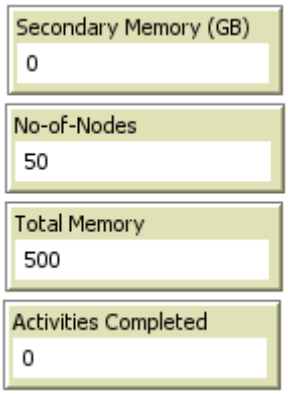


Figure Error! No text of specified style in document.**.9 Monitors**

Through the utilization of the monitoring the continuous analysis of the parameters can be performed by the help of these monitors.

4.1.4 Deployment of Behavior Space

In order to conduct that testing of the proposed solution and to execute different types of the experiment that behavior space is utilized. Figure 4.10 represent the module that will be utilized for conducting the experiment.

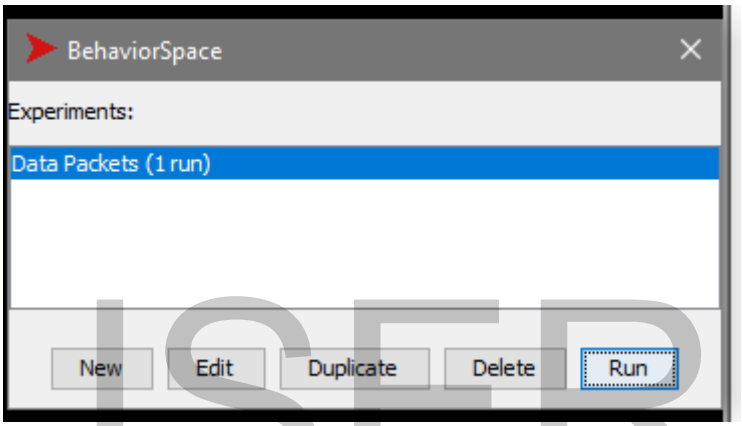


Figure Error! No text of specified style in document.**.10 BehaviorSpace**

There are also other experiment that has been conducted through the Behavior Space of that the right results and outcome in the context of proposed solution can be extracted.

In the above step the detail discussion of the deployment of the simulation environment has been presented. It is analysed that if the simulation environment is properly deployed better location can be performed. However, as indicated that better results can be extracted if the deep analysis of proposed solution are simulated. In the next section the experimental approach within the context of Indoor Positioning System (IPS) based on Wi-Fi and there is a high probability that experiment results will overall ensure that the proposed solution can be simulated in real time environment or in which areas that improvement is required.

4.2 Experimental Approach

Experimental approach is defined as "is a systematic and scientific approach to research in which the researcher manipulates one or more variables, and controls and measures any change in other variables" (A mobile indoor positioning system based on iBeacon technology, 2015). There are different sort of parameters that needs to be considered in the context of experiment. However, through the utilization of communication protocol it would be analysed (A systems thinking framework for knowledge management, 2001) that better results would be able to achieve. All the key experiments are conducted in the context of simulation environment and it is observed that as we are utilizing the NetLogo so we have being using the behaviour space for the execution of experiment as mentioned in (Radio map recovery and noise reduction method for green WiFi indoor positioning system based on inexact augmented lagrange multiplier algorithm, 2015).

The following are the key experiment that are considered and have being executed within the context of Indoor Positioning System based on Wi-Fi. There is a high probability that if these experiments are properly conducted that key goals, objectives and other parameters that are linked within the context of Indoor Positioning System based on Wi-Fi can be extracted.

1. Nodes Power Analysis,
2. Data Packet Overhead,
3. Performance and Results Accuracy.

4.2.1 Nodes Power Analysis

Power is considered as one of the key parameter in the context of wireless technology or wireless communication as mentioned in (Development of a polymer optical fiber pH sensor for on-body monitoring application, 2014). There is different researches (Payless: A low cost network monitoring framework for software defined networks, 2014; Development of a polymer optical fiber pH sensor for on-body monitoring application, 2014; Algorithms of fire seat detection, modeling their dynamics and observation of forest fires via communication technologies, 2015)that have been conducted to identify and analyse that how the power or energy efficiency of the protocol can be ensured. This experiment is conducted to measure the power and

energy efficient of proposed solution that is considered in this research. However, based on the understanding if proposed solution has the capacity to provide better outcome in term of power utilizing it can be indicated that solution would be able to deployed in real time environment. The solution is tested in simulation environment and the results are presented in table 4-1.

Table 4-1 Power Analysis

No of Transections	Proposed Solution Power in watt	Traditional solution Power in watt
1	140 w	140 w
2	140 w	124 w
3	133 w	112 w
4	131 w	106 w
5	125 w	88 w
6	118 w	87 w
7	112 w	68 w
8	108 w	64 w
9	101 w	59 w
10	100 w	48 w
11	96 w	29 w
12	89 w	18 w
13	84 w	14 w
14	76 w	11 w
15	68 w	-3 w
16	68 w	-3 w
17	68 w	-7 w
18	63 w	-14 w
19	55 w	-20 w
20	49 w	-27 w
21	44 w	-54 w

For the results it is extracted the proposed solution that is utilized in the technique of multi-listing performs better as compared to traditional solution. In this research that dataset of the traditional solution is extracted from (Indoor high precision three-dimensional positioning system based on visible light communication using modified genetic algorithm, 2018). So, based on the simulation results the proposed solution is high effective and efficient as compared to traditional solution. So that according to the context of proposed communication solution it can be deployed in the real time environment. In the next section the discussion within the context of the Data Packet Overhead has been conducted. The results are presented in figure 4.11

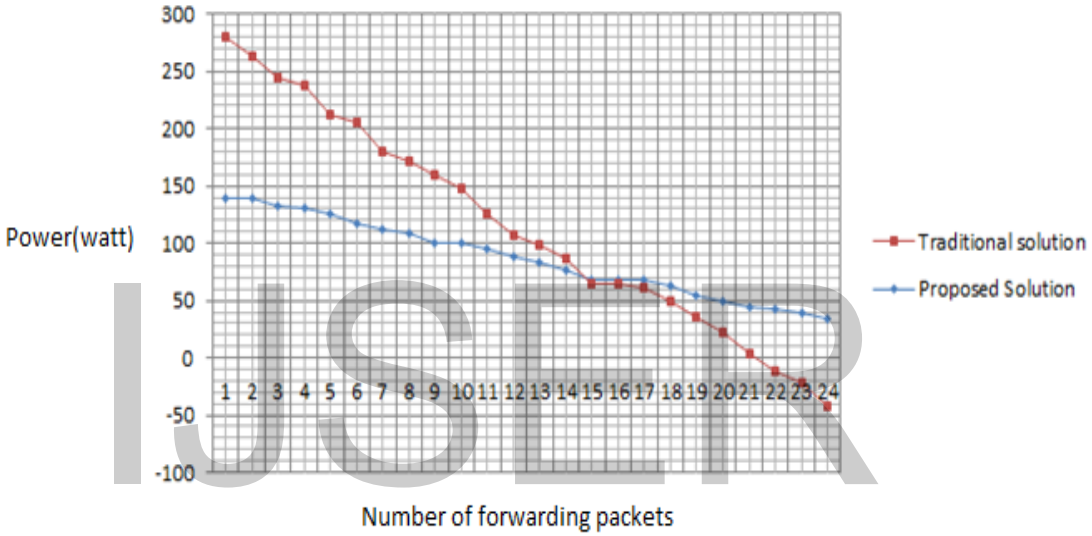


Figure 4.11 Power Level Analysis

4.2.2 Data Packet Overhead

Network transaction are always surrounded by different sort of challenges and one of the key challenges that has been reported by number of researchers (WIFI-Based Indoor Positioning System with Twice Clustering and Multi-user Topology Approximation Algorithm, 2016) are the data packet overhead. Due to flooding technique that is simulated in the network the overall data size and the data size packet keep on increasing supporting argument from (Design of indoor positioning system based on WiFi signal intensity characteristic, 2015). However, in the context of the proposed solution we have also indicated

the discard mechanism and that to some extent that data packet overall size can be minimized.

This experiment (Data Packet Overhead) has been conducted to measure the data packet overhead size of the proposed solution that has been design and development for Indoor Positioning System based on Wi-Fi. It is concluded in our research work IPS that if the data packet overall size is less there is a high probability that better results can be executed. The solution is tested in simulation environment and the results are presented in figure 4-2.

Table 4-2 Data Packet

No of Data Packets	Proposed Solution Data Packet Overhead in (kbps)	Traditional Solution Data Packet Overhead in (kbps)
1	0 kbps	10 kbps
2	7 kbps	17 kbps
3	11 kbps	21 kbps
4	18 kbps	28 kbps
5	18 kbps	28 kbps
6	22 kbps	32 kbps
7	29 kbps	39 kbps
8	38 kbps	48 kbps
9	42 kbps	52 kbps
10	50 kbps	60 kbps
11	56 kbps	66 kbps
12	56 kbps	66 kbps
13	56 kbps	66 kbps
14	65 kbps	75 kbps
15	71 kbps	81 kbps
16	75 kbps	85 kbps
17	82 kbps	92 kbps
18	89 kbps	99 kbps
19	91 kbps	101 kbps
20	98 kbps	108 kbps
21	103 kbps	113 kbps

The experiment is performed in the simulation environment and extracted results indicated that proposed solution overall has less data packet overhead as compared to the traditional solution. The dataset of the traditional solution has been adopted from (Detection of Cyber-attacks to indoor real time localization systems for autonomous robots, 2018) and observed that proposed solution was able to provide the better outcome as compared to that traditional solution.

The results are presented in fig 4.12

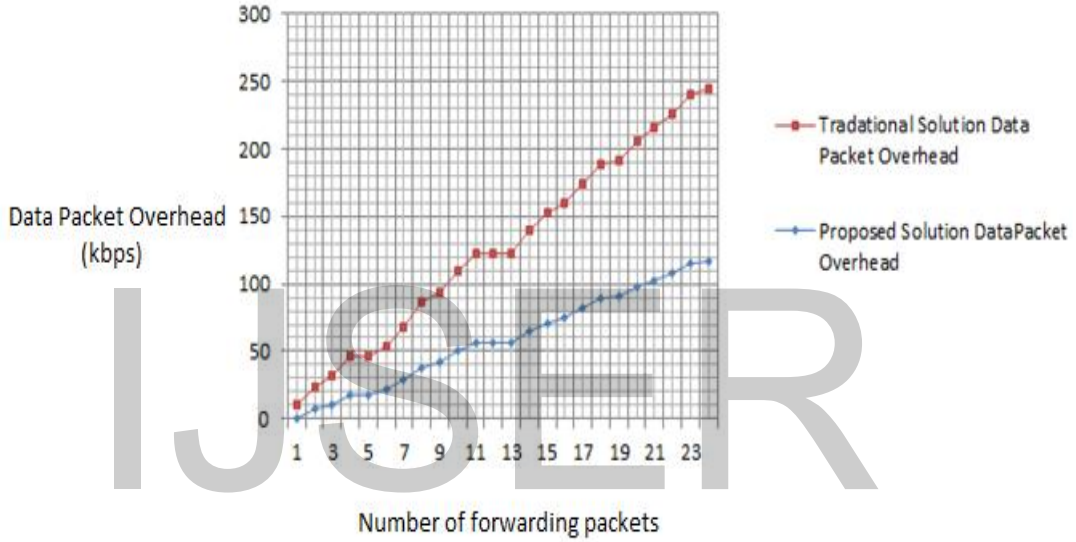


Figure 4.12 Data Packet Overhead

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4.2.3 Performance and Position Accuracy

Performance and Position Accuracy are defined as the key function of this research as the key theme of this research is to design, develop and implement an Indoor Positioning System based on Wi-Fi and to extent we have also planned to improve the performance that through the integration of the multi listing technique on which the proposed solution have been implemented. As already discussed that this is the key theme and there is a high probability that if the performance and position accuracy is improved that proposed solution by sort out some parameter can be deployed in the real time environment.

This experiment covered two key component including Performance as shown in figure 4.13 and Position Accuracy as shown in figure 4.15 and through the experiment we are able to extract the requirement outcome there is a high probability that proposed solution that is design and development for Indoor Positioning System based on Wi-Fi can be simulated for the real time environment. If the key results are not obtained there is no user of deploying the proposed solution in the real time environment. So, according to our analysis to some extend it can also be obtained that we will be supporting the argument that we have rained in this research through the utilization of proposed solution.

There are different types of parameters that are linked within the context of proposed solution and each parameter has been closely monitored through the integration of the information and communication system. The following are the results that have been obtained through the extraction of the proposed solution in the real time environment.

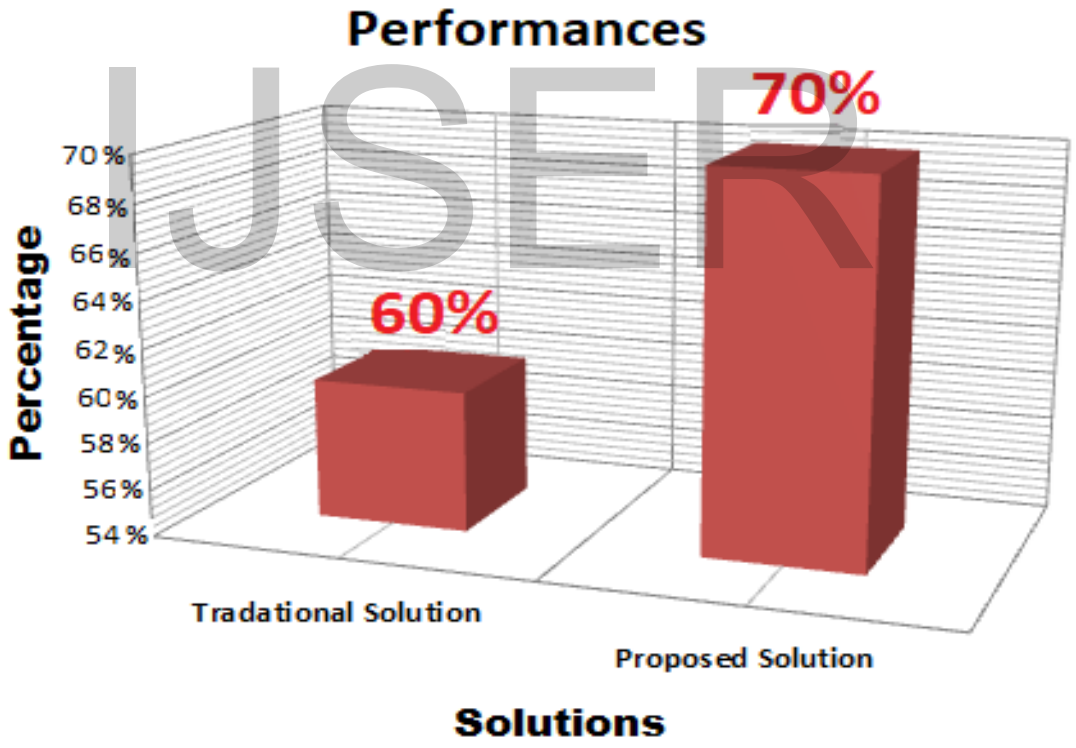

Figure 4.13 System Performances

Performance is defined as one of the key parameter and in the proposed solution that we have presented in this research is more efficient and effective as compared to the existing solution. There are different types of parameters that has been conducted in the context of this research and based on the parameter that we consider in this

research are data packet overhead, network lifetime, system response and many other. However, through summarize these results the specific set of performance and position accuracy has been obtained.

4.2.4 Overall System Performances

System performance is always considered as the centre of attention and it is analysed that with the passage of time there are number of parameters that have been considered in the context of performance as mentioned in (Said, Haider, Charan, & Hassan, 2015). However, in this context of experiment we have overall reviewed the system performances and all the results that have been extracted from the simulation environment.

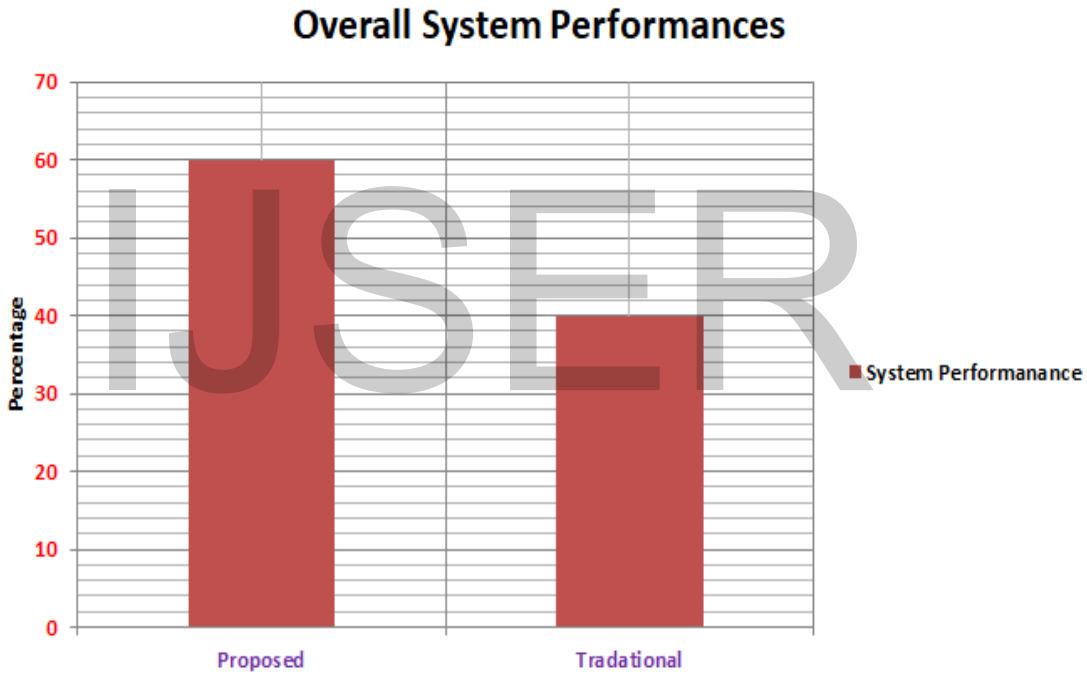

Figure 4.14 System Performance Analysis

According to our analysis it is analysed that system performance is directly dependent upon number of parameters. In the context of the simulation environment we have conducted the detail discussion that actually how the better results and outcome can be obtained. However, I think that agent based multi listing technique has played an important role in overall improving the system performances.

It is observed that in the context of this research we have conducted different sort of experiment and based on that results it is observed that in figure 4.14 overall the system performance is satisfactory but on the other side it is also observed that much

room for the improvement exist. It is analysed that based on these research results the proposed communication technique based on the simulation environment can be integrated in the context of real time environment.

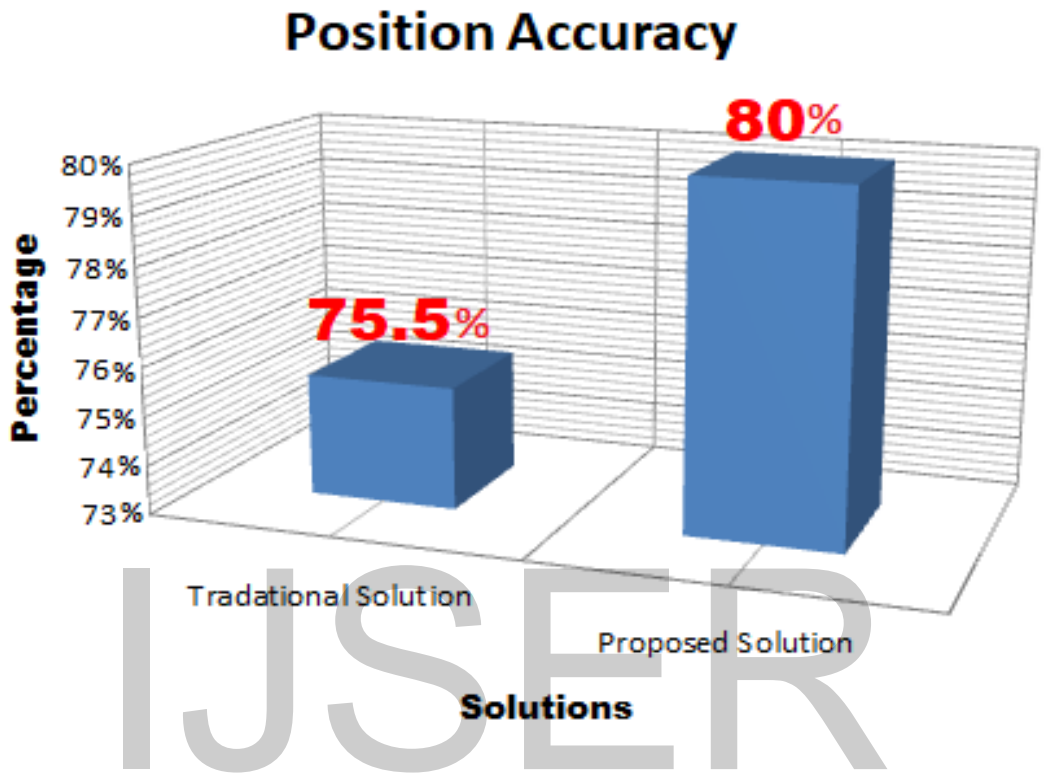

Figure 4.15 Position Accuracy

Chapter 5

Conclusion, Recommendation and Future Work

Demand of information and communication technology is dynamically increasing throughout the globe. It is observed that there are number of processes that are shifting throughout the information and communication technology as it is observed that technology provide number of benefits. There is a high probability that better results can be extracted if technology deployment is properly conducted. In this research the detail discussion within the context of Indoor Positioning System (IPS) based on Wi-Fi have been performed. According to our analysis it is observed that it was really a complex challenge but in order to ensure the system accuracy we considered the hybrid approach for Indoor Positioning System (IPS) based on Wi-Fi.

It is past it is observed that there are number of researches that are conducted within the context of Indoor Positioning System (IPS) based on Wi-Fi. During the analysis it is observed that there are number of researches that are using different types of technology that are utilized within the context of Indoor Positioning System (IPS). On the other side it is also observed that as the demand of location based services are increasing the positioning system demands are also increasing. To some extend it can be analysed that positioning system are directly proportional to the location based services. It is observed that we have considered two key system and technology that are most considered in the context of positing system including IPS and GPS system. However, each system has several advantages and disadvantages. In the context of this research we have being focusing on design and development of hybrid approach for Indoor Positioning System (IPS) based on Wi-Fi. The key objective of this

research is to design and development of Indoor Positioning System (IPS) based on the hybrid approach. This approach will be utilizing the Wi-Fi hotspot and Wi-Fi fixed nodes for the detection of the location.

In the context of wireless communication there is always a need of communication protocol and based on the existing researches it is observed that if the communication protocol is better and efficient the better results and outcome can be achieved. It is observed that for the hybrid approach we have presented that agent based multi listing technique and based on that analysis we have implemented the Indoor Positioning System (IPS) based on Wi-Fi. In the context of the proposed solution we have implemented two processes that have the capacity to perform the task of communication and collaboration. Through the integration of the communication protocol the accurate position can be detected and the better results can also be obtained.

During the development and planning of the key turn solution there is always a need of research methodology or project development lifecycle. So, the key tasks and activities can be carried out in context of development, planning etc. There are different types of researches that are conducted within the context of research methodology. However, for the simulation and solution development of Indoor Positioning System (IPS) based on Wi-Fi we have utilized the concept of Microsoft Solution Framework. All the simulation environment and it tasks that are linked within the context of the Indoor Positioning System (IPS) based on Wi-Fi has being mapped according to the Indoor Positioning System (IPS). Due to the selection of right methodology the research work of Indoor Positioning System (IPS) has been completed within specific time framework, budget and resources. However, the time framework of the project was six month and as it is a software type of project so we have not considered any type of budget and the resources.

During the development of the theme there are different types of research objectives and goals that have been set within the context of Indoor Positioning System (IPS) based on Wi-Fi. However, based on the system architecture and conceptual framework it is analysed that the key objective has been achieved. We have successfully design and development the Indoor Positioning System (IPS) based on the hybrid approach. However, it is observed that we have equipped the sensor of

position analyse with the GPS and have set it connectivity within the Wi-Fi. This approach will be utilizing the Wi-Fi hotspot and Wi-Fi fixed nodes for the detection of the location through the integration of the sensor and the agent based communication technique.

Testing is always defined as one of the key problem and objective of this research is also to develop of simulation environment to perform verification and validation (V&V) of Indoor Positioning System (IPS) based on the hybrid approach and through the utilization of NetLogo the key objective has been achieved. In the context of NetLogo and programming language Java we have successful implemented the simulation environment and different types of experiment through the utilization of the behaviour model have been conducted. Based on the simulation results it is analysed that with some modification the proposed solution can be implemented in the real time environment.

In the context of this research we have also provided the in-depth description about the application areas of an Indoor Positioning System (IPS) using Wi-Fi and how the existing proposed solution can be linked with the android applications. Through the deep analysis of the mobile based application has not been considered but still in general term these application have been discussed. We design and develop a communication protocol for simulating the data packet of Indoor Positioning System (IPS) based on Wi-Fi need to be performed. In the end according to our analysis the key objective has been achieved and in the next section some modification has been presented so that more improve in future can be made in context of Indoor Positioning System (IPS) based on Wi-Fi.

5.1 Recommendation

The following are the key recommendation within the context of the Indoor Positioning System (IPS) based on Wi-Fi.

There is a high probability that if these recommendation are simulated in the case of Indoor Positioning System (IPS) based on Wi-Fi better results and outcome can be obtained:

1. **Communication and Collaboration:**

a. Communication and Collaboration is always considered as the centre of attention and it is observed that if the communication and collaboration is properly developer there is a high probability that better results and decision making can be performed.
b. It is analysed from the existing researches that in most of the real time application such as Indoor Positioning System (IPS) the proper Communication and Collaboration is not developer. In the context of this research it is suggested that the proper Communication and Collaboration must be set of that the key objective and gaols can be obtained.
c. According to our analysis based on the existing researches it is observed that it is necessary to develop the communication and collaboration between the key stakeholders so that the better results and decision making can be perform.

2. Intelligent Variables:

a. During the position sharing not just longitude and latitude need to be shared but it is also suggested that key parameters such as floor etc. information can also be shared. There is a high probability that if the intelligent variables are shared that better finding of the object can be performed. So, in the context of Indoor Positioning System (IPS) based on Wi-Fi it the intelligent variables must be integrated.
b. This is not a simple scenario and there is a need of multi agent system or artificial intelligence tools so that the Intelligent Variables can be integrated.

3. Data Security and Privacy:

a. Security is defined as one of the key problem in the context of proposed solution (Indoor Positioning System (IPS) based on Wi-Fi). Hash functionality have been provided in the context of communication protocol to secure the data and information. However, still it is suggested that more efficient and efficient security communication protocol need to be implemented.
b. Security is considered as one of the main barrier and there is a high probability that if the security module is integrated better results can be executed. So, it is suggest that the third party solution need to be

integrated in order to ensure the security. In the next section the impact of the recommendation has being presented and there is a high probability that if the impact if properly calculation the recommendation priority can also be set.

5.2 Impact of Recommendation

Impact of the recommendation that are suggested for Indoor Positioning System (IPS) based on Wi-Fi are presented in table 5.1

Table 5.1 Impact of Recommendation

	Parameter	Description	Impact
1	Communication and Collaboration	Communication and Collaboration is always considered as the centre of attention and if the communication and collaboration is properly developer there is a high probability that better results and decision making can be performed. It is analysed from the existing researches that in most of the real time application such as Indoor Positioning System the proper Communication and Collaboration is not developer. In the context of this research it is suggested that the proper Communication and Collaboration must be set of that the key objective and gaols can be obtained.	High
2	Intelligent Variables	During the position sharing not just longitude and latitude need to be shared but it is also suggested that key parameters such as floor etc. information can also be shared. It is observed that there is a high probability that if the Intelligent Variables are shared that better finding of the object can be performed. So, in the context of Indoor Positioning System based on Wi-Fi the intelligent variables must be integrated. This is not a simple scenario and there is a need of multi agent system or artificial intelligence tools so that the Intelligent Variables can be integrated.	Low
3	Data Security and Privacy	Security is defined as one of the key problem in the context of proposed solution (Indoor Positioning System based on Wi-Fi). Hash functionality have been provided in the context of communication protocol to secure the data and	High

		information. However, still it is suggested that more efficient and efficient security communication protocol need to be implemented.	

Based on the above analysis the recommendation analysis has been set.

Table 5. 2Priority

	Parameter	Priority
1	Communication and Collaboration	1st
2	Data Security and Privacy	1st
3	Intelligent Variables	2nd

In the above section the key recommendation within the context of Indoor Positioning System (IPS) based on Wi-Fi has been provided. In the next section the future work is presented.

5.3 Future Work

As already discussed that high demand of position system exists. However, in the future we will be working on the context of the Indoor Positioning System (IPS) and instead of Wi-Fi we will be working and focusing on the context of using the internet of things (IoT) for setting the communication and collaboration. It can also be predicated that better results can be extracted if the internet of Things (IoT) are linked within the context of Indoor Positioning System (IPS).

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