ADAPTIVE RSS BASED INDOOR POSITIONING SYSTEM USING RFID AND WIRELESS TECHNOLOGY

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***Abstract**: Recently, a number of empirical models have been introduced in the literature of Indoor Positioning System (IPS). Hence, position awareness is necessary for communication of reference nodes in the wireless sensor network. IPS can be very useful in navigating the indoor living commodities, tracking objects in any inside location such as malls, colleges, schools, hospitals etc. While for outdoor navigation we use Global Positioning System (GPS), Global Navigation Satellite System (GNSS), cellular network etc. Due to the problems with signal generation from satellites or cellular towers they can't be used for navigation in indoor environments. The widely used technology for Indoor Positioning environment is based on Wi-Fi which consists of two categories namely Trilateration technique and Location Fingerprint technique (LF). The performance metrics of trilateration technique and LF with respect to noise and environmental changes results to inaccuracy. Particularly in indoor environment Radio Frequency Identification (RFID) has proved its potential for locating objects. The RFID-based and RSS-based localization approaches estimates the RFID tag's location by calculating the variation in the signal power as the distance varies of the tag-reader. In RSS, the strength of the received signal indicates the distance of the signal travelled by assuming that the transmission strength of the signal and its channel i.e. environment is known earlier.*

Key words: *Indoor Positioning System (IPS); Received Signal Strength (RSS); Radio Frequency Identification (RFID); Network Simulator*

I. INTRODUCTION

The widespread deployment wireless technologies have attracted the researcher's interest for developing the position of objects. Global Positioning Satellite Systems (GNNS) also named as Global Positioning System (GPS) [1] [2], Global Orbiting Navigation Satellite System (GLONASS) [3] and GALILEO [4] are the outdoor positioning system having some infeasible solutions. Indoor Positioning systems [5] are used to navigate the objects wirelessly inside the building and also can be used to provide tracking or monitoring services. Indoor environment provides large number of applications which can be used in factories, warehouse, shopping malls, hospitals and colleges. Wireless technology is the best technique for indoor positioning system hence IEEE 802.11 standard protocol is used by wireless radio signal for navigating the objects in Indoor positioning system. The Wireless signals are widely used for communication and they are not directly proportional to the distance from Wi-Fi Access Points (Wi-Fi Aps).

A) Received Signal Strength (RSS)

RSS is a measurement of the energy available in a received radio signal. In Existing Radio Based Measurement technique RSS has been used widely in Indoor Positioning System. RSS determines the nature and characteristics of location fingerprints. The circuit voltage is measured between transmitters and receiving device which varies due to path interfaces and it is measured by received signal strength indicator (RSSI) [6] [7]. The distance measure is estimated by receiving node from the source node by determining the energy of received signal strength. It uses the path-loss factor to convert RSS into the distance measure and works on the principle that the signal power decreases if distance between nodes increases. According to the IEEE 802.11 standard system RSS is the corresponding received signal strength in a wireless environment. We can initiate a reliable power-distance relationship for number of applications, including object localization.

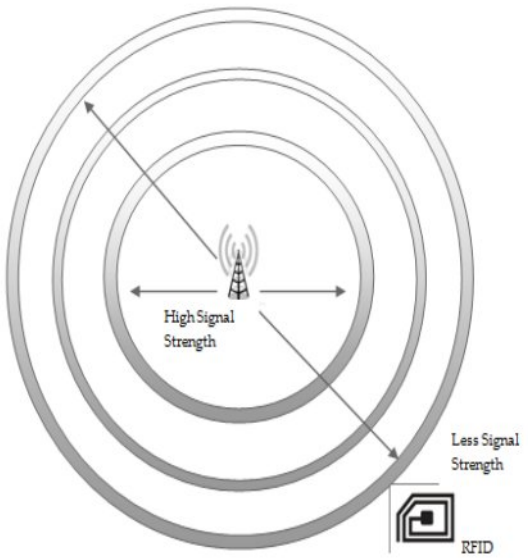

Figure 1: Signal Strength Framework

B) Radio Frequency Identification (RFID)

RFID [35-38] is automated data collection technology which uses radio frequency waves to transfer data between a reader and a movable object to identify, navigate etc. Its networks are comprised of RFID tags, readers and servers All the RFID tags make use of radio frequency energy for communication with the readers. RFID tag is the data carrier also called as transponder or just the tag. Tags are of two types namely Passive tags and Active tags. Passive tags makes use of radio frequency from the RFID reader for transmitting their signal and they generally have their data into the tag permanently when they are made, still some can be rewritten. Active tags have battery power on-board for transmitting their data signal over the long distance. RFID reader sends radio waves of between 1cm and 30m or more, depending upon the radio frequency used and its performance. If the tag enters the given electromagnetic area, the activated signal is detected by it i.e. released from the reader. Then the reader decrypts the data present in the integrated circuit of the tag and communicates them with the server. Active RFID is suitable for dense environments.

II. REVIEW OF LITERATURE

For the literature review, the first indoor positioning system based on Wi-Fi signal strength named RADAR was developed by Microsoft Research's laboratory using Location fingerprint technique [8]. Template matching algorithm was used for comparing the real time user RSSI with already surveyed RSSI database system to locate the user's position. Indoor positioning systems [5] developed in recent years doesn't only uses Wi-Fi signal but also makes use of infrared technology to indicate the location. One such system was developed by AT&T Cambridge which used diffuse IR technology based system, which is nothing but a network sensors working along with the IR code every 15 seconds and then uses the information based on triangulation theory. However, the shortcoming of IR technology such as short-range transmission and line-of-sight (LOS) does not allow the IR technology to be used in huge and complex regions. The next proposed system known as LANDMARC [24] indoor location sensing and uses active Radio Frequency Identification (RFID) by a popularly known system Spot ON RFID [25] sensing in the year 2013 [9]. This system comprises of RFID tags, RFID readers and the signal communication between the tags and readers. The basis of this system is the radio signal strength information from respective tags to reader and then uses the classifier algorithm to identify the user's position. Another system developed in the year 2013 by MIT Laboratory for Computer Science known as The Cricket Location Support System used radio frequency (RF) and the ultra-sonic technology based on Time-of-Flight (TOF) [10] in order to measure the time difference of pulses signal collection between RF and ultrasonic, thus providing the users location information. The drawback of the Cricket Location Support system was high cost that made it unaffordable to maximum users. The Chinese researcher developed another Indoor Positioning System in the year 2013, XIHE based on mobile communication networking using Turbo Code OFDM technique [11] based on Time-of-Flight (TOF) technology that can provide services to both indoor and outdoor services along with the integration signal of BeiDou satellite navigation system. The Wi-Fi based trilateration technique [12] [13] [14] uses mathematical geometrical properties of triangles for tracking the user's location. The trilateration technique can be divided into three categories such as angulations, Lateration and RSSI-based in order to calculate the distance from multiple Wi-Fi Aps with mobile devices. With reference to study of literature [15] showed the Angle of Arrival (AOA) technique that help locate the user's position by measuring the angles that is corresponding to multiple Wi-Fi Aps. Though, the relationship between distance and the accuracy is inversely proportional to each other i.e. as the distance increases, accuracy will start degrading. In Lateration techniques [15], the signal of arrival (TOA) and Round-trip time of flight (RTOF) are used to evaluate the location of the user by time difference. In TOA method [5] the multipath reactions in Indoor localization is reduced thus proving to be more accurate but difficult to implement as compared to RTOF.

The RSSI-based technology using the attenuation of the released signal strength defined by propagation loss equation [7] is used to calculate the range between transmitter and receiver. It can also be used with mobile rescue robots as database is not needed, leads to low-affordable cost and no switching position problem. Jeffrey Vander Step Proposed stochastic framework for RSS-based localization that incorporates the RSS measurement uncertainty into the location estimation algorithm statistics of the beacon distances but because to its high cost it is unaffordable by most of the users. Moreover, the Location fingerprint technique [16] [17] uses the pre surveyed RSSI values. The LF technique is dependent on the sample location coordinates for generating radio frequency map called Fingerprint Map for labelling databases and then classifies the same by the use of template matching algorithms. Examples include the K-Nearest Neighbour (K-NN) algorithm; it is the deterministic process that is used in the RADAR system implemented by Microsoft Researcher's laboratory. The selection of nearest K-neighbours surrounded around the mobile units was proposed by Microsoft Company to evaluate the user's position by calculating Euclidean distance between the real-time RSSI values and location fingerprint database. The

Support Vector Regression [18] (SVR) and Artificial Neural network are used in unknown properties transfer system function or in non-linear function system. For e.g. The Zigbee wireless sensor network by ANN proposed by Rey-Chue Hwang et al. [19] to locate the higher accuracy position even when the strength of the received signal is unstable. It was also found that the accuracy level of polar form was better than the rectangular form. Because of the computational complexity ANN is not much used in Indoor Positioning System, the LF technique are easy to implement and shows to be more robust in of stable infrastructure as noise gets added to the survey map. Another proposed technique by W. Xiao et al. has a combinational effect of the inertial measurement unit (IMU) consisting of 9 degrees of freedom, along with LF technique which is used by Kalman filter. Hattori K. et. Al [20] has proposed the hybrid data Wi-Fi and built in camera on smart phone to track the position; this can lower the ambiguity in real time environment. Furthermore, Peer pong Torteeka, YANG Dongkaiand XIU Chundi proposed a novel approach to combine the benefits of Wi-Fi trilateration technique using RSSI-based and Location fingerprint based on Extended Kalman Filter [21] (EKF). The combination of these two methods lead to improved positioning accuracy, the system has more robustness in the unstable environment and the continuous approximate positioning.

Different antennas have been used for RF based localization systems depending upon the technologies used recently and signals being processed. The framework of the localization system, assembled by reference units, has mainly combined with directional antenna radiation patterns. Lkhagva Chuang has proposed RFID system that helps to locate an object and can also track the movement of a target object in real time.

III. TECHNOLOGICAL REVIEW

Indoor Localization systems can be divided as token or token-less systems, depending upon whether the mobile device carries any device that is used for localization system. In this section, we describe the most used localization techniques for token systems. These localization techniques are divided as RSS Scene Analysis, Triangulation and Proximity.

1) Triangulation

This technique uses the mathematical geometric properties to assess the targeted object. Lateration and angulations are the two derivations of this technique. Range measurement or Lateration approximates the location of the mobile node depending on the distances from multiple referenced nodes. The distances is obtained, by computing the measured RSS or it is obtained from the signal generation TOF, mainly divided as time difference of arrival (TDoA), Time of Arrival (TOA) and round-trip TOF (RToF). Other source of triangulation is angulations, known as Direction of Arrival (DoA) or Angle of Arrival (AoA).

1.1) Time of Arrival (ToA)

This technique obtains the distance value between the two referenced nodes by computing the one-way propagation time between the nodes, with a pre surveyed signal speed. The distance of the area in between the devices can be calculated by using: distance = signal Speed (Arrival Time – Send Time) where Arrival Time is the time of signal arrival at the receiver and Send Time is the time when the signal is sent and signal Speed is the speed of the generated signal. The calculated distances of the area between the devices along with the referenced units allow us to calculate the localization of mobile units. The localization can be approximated as the intercepted point of spheres centred on reference units and radius of approximated distances of mobile units. Accurate synchronization of all the networks devices is required in order to gain precise position estimation.

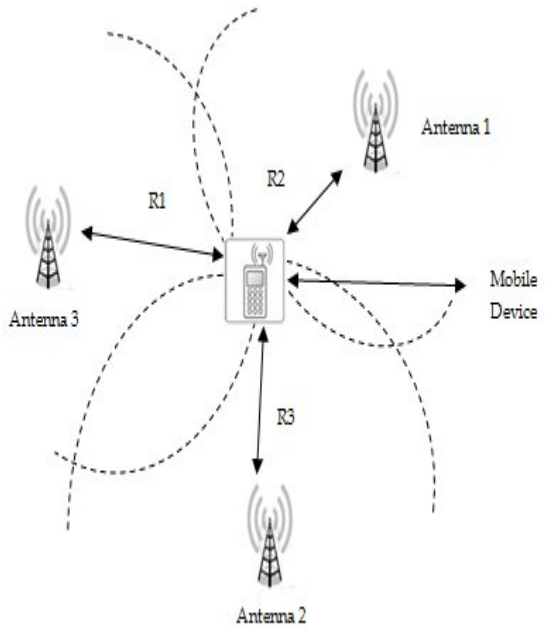

Figure 2: ToA

1.2) Time Difference of Arrival (TDoA)

Following two approaches are used to determine the associated position of the units:

- *A difference in the propagation time of a broadcast signal within single or more referenced units.*

- *Difference in the propagation time of number of signals from a single source unit and three or more reference units.*

The time value that increases the cross-correlation behaviour is referred by TDoA. The estimated distance to the mobile node unit by TDoA technique is represented by hyperboloid behaviour [39]. Depending upon the closed TDoA pairs and the interception of two the hyperboloids gives us the estimated location of the mobile units. This technique of TDoA do not require synchronization of the mobile devices in the network, instead an extra hardware for providing higher accuracy is needed.

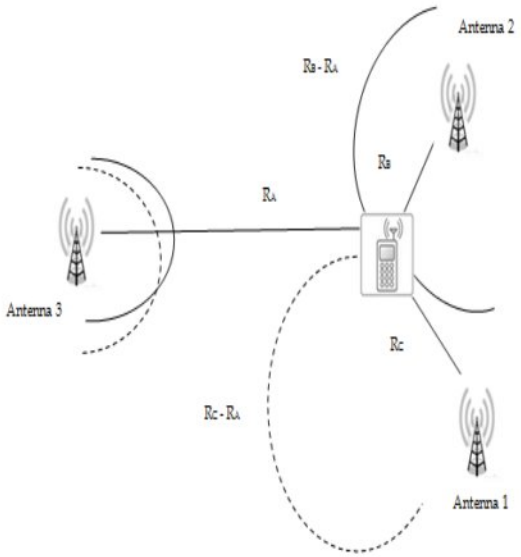

Figure 3: TDoA

1.3) Round Trip Time of Flight (RToF)

RToF or ToA two-ways ranging, calculates the complete trip ToF of the propagated signal in between the sender nodes and the receiver nodes. These systems technique are similar to those of RADAR systems, instead the receiver node executes signal processing rather than simply reflecting the signals. When properly synchronized, this RToF technique is for passive RFID technology where the readers can energize the passive RFID tags, "responders" and measure the RToF.

1.4) Received Signal Strength Indicator (RSSI)

The RSSI are used to assess the distance between the mobile nodes or units based on signal attenuation. The advantage of using this system is its simple implementation and low cost because the wireless system receivers are integrated commonly with RSS measurement adequacy, which was already used for purposes like transmit energy control and also automatic gain control.

In indoor environments it becomes challenging to detect the Line-of-Sight (LOS) in between the units, RSSI is affected by shadowing, antenna type and even multipath fading, making it difficult to propose mathematical model of the channel that matches the real propagation, thereby resulting in inappropriate estimations. When the low cost becomes the priority, these RSSI based systems are best solution to be used. The conversion of RSSI into distance can be done by the interference of three circumferences centred on the associated units.

1.5) Angle of Arrival (AoA)

Another derivation trigulation technique is angulations also referred as Direction of Arrival (DoA) or even Angle of Arrival (AoA). The approximation of the unit localization calculating angles associated to number of reference point is performed. Various Antenna or directive arrays are used to approximate the AoA. The benefit of AoA technique is that if the orientation of the mobile unit is known, then only two values of non collinear reference nodes are needed for 2D localization, moreover there is no demand for synchronizing the time between the units [40]. The disadvantage of using AoA technique is its complex and large hardware requirements.

2) RSS Scene Analysis

In this technique of localization the approximation of the mobile unit position is carried out by matching the online scene collected features i.e. fingerprints with nearest fingerprint already saved in the database. This technique can be implemented in two phases: offline and online. During performing in online phase, the observed RSS values are utilized by the localization fingerprinting algorithms to find out mobile units position. While in offline phase, the coordinates of the position and respective RSS values from close associated units is collected. The major difficulty of using RSS Scene Analysis technique is long consumption of time, that should be updated every time the environment changes, also the computational cost is extensively high and requires high memory space to store network information.

3) Proximity

The symbolic related localization information is provided by the proximity method. If number of associated units is detected, then the mobile position is related to the unit with the strongest signal. Whereas, if the mobile node is detected by a single reference unit then the mobile's position is associated with it. This procedure is widely used in localization systems based on IR, RFID and even cell identification.

Various wireless positioning system technologies

Some of the existing and most popular used technologies for wireless positioning system are shown in the FIG. 4.

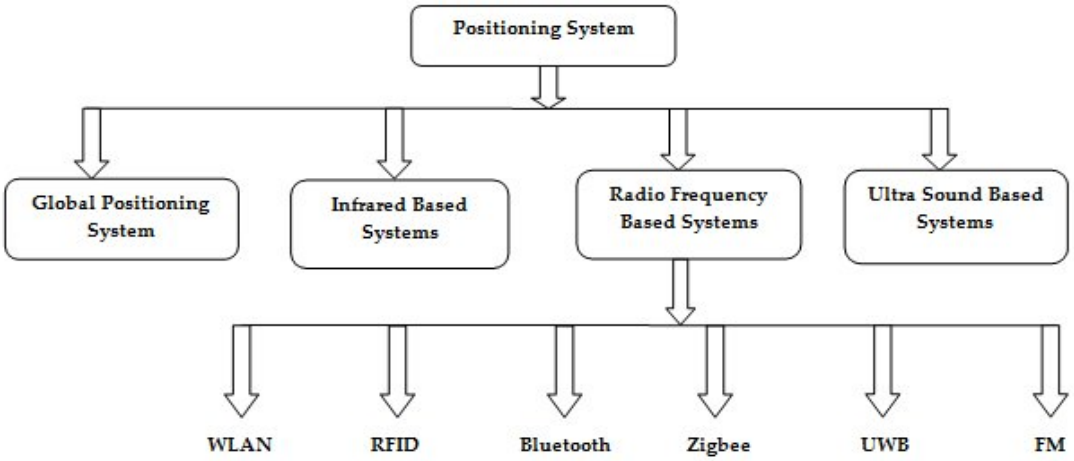

Figure 4: Wireless Positioning Technologies

1) Global Positioning System (GPS)

GPS [1] [2] is most widely used system to locale the object and to perform tracking in the outdoor environment. However, GPS do not work in the indoor environment because of the obstacles present in the Line of Sight (LOS) between the recipient and the satellite, due to which the signal waves is spread and disrupted because of the obstacles. Hence, GPS can't be used well in the indoor positioning system tracking.

2) Infrared Radiation (IR)

IR [22] [23] is the most common positioning system that use wireless technology positioning system. IR makes use of its spectral region for detection or navigation of objects or people. IR is available in most of the wireless and wired gadgets like TV, laptops, computers, mobile phones etc. Advantages of using IR is its lightweight, small size, and ease of carrying, whereas the disadvantages of using IR based IPS is that it's less secured and does not maintain privacy. IR signals have some difficulties for location determination, as obstruction from sunlight and fluorescent light. Moreover, the hardware system is expensive and has high maintenance cost.

3) Radio Frequency: The Technologies based on Radio frequency are widely used in location position system because of some advantages such as emitted radio signals can get through various obstacles including building, walls, human bodies and windows. This results in larger area coverage and requires less hardware as compared with other systems available for location positioning.

RADAR [8] developed by Microsoft Research was the first Radio Frequency based technique for navigating the location and user position.

3.1) RFID: The next recognizable technology used in positioning system was RFID [24] [25] for approximating the objects and persons. RFID initiates a one way wireless communication by use of noncontact and automatic identification technique that uses radio signals, puts the RFID tags on persons and objects. Wide variety of applications makes use of RFID such as automobile assemble industry, robotics industry, warehouse management area, even including persons.

3.2) Bluetooth: Bluetooth [26] [27] is a wireless protocol used in wireless personal area networks i.e. WPANs. Maximum of the Wi-Fi authorized devices namely laptop, mobile phones etc. has Bluetooth enabled in it. The Bluetooth works with 2.4 GHz of bandwidth. The use of Bluetooth for exchange of information is very safe, small in size, requires less cost as well as low power consumption. Every Bluetooth tag is comprised with its unique Bluetooth identification (ID), which is used for approximating the Bluetooth Tag. Because of numerous advantages of Bluetooth, researchers developed localization systems which are based on Bluetooth. Due to some limitations of using Bluetooth in localization system is that the localization latency increases as it runs the device discovery procedure, thus resulting into more power consumption. Hence, in real time application Bluetooth has an unsuitable latency.

3.3) Ultra wideband (UBW) : *UBW* [28] [29] is another radio based technology useful for short range, high bandwidth communication. higher accuracy is

achievable by using UBW in localizations systems as compared to the traditional wireless localization techniques the structure of UBW.

Table1: Comparison of common positioning techniques

System	Positioning Method	Working Range	Proposition for Localization	Declaration
GPS	Good positioning in Outdoor Environment & Poor in Indoor Environment	6m-10m	TOA	GPS is satellite based Positioning system and Computation Speed I Low
Infrared	Good in Indoor Positioning	1m-2m	Proximity, TOA	Infrared has short range Detection
Wi-Fi	It can be used as Indoor or Outdoor Positioning	1m-5m	Proximity, TOA, TDOA, Fingerprinting	Having accessible network from nearly and convenient location. Initial deployment is expensive. Speed is low according to the other wireless networks.
Bluetooth	Used in Indoor Positioning	2m-5m	RSSI Fingerprinting & RSSI theoretical propagation model	Do not require clear LOS between Bluetooth devices and only allows short range communications between devices.
RFID	Used in Indoor Positioning	3m-4m	Proximity, TOA, RSSI theoretical propagation model	Response time is high and does not need to line of sight with the receiver to be read. RFID is the real time location system and manual Programming is done for RFID
Zigbee	Used in Indoor Positioning	3m-5m	RSSI Fingerprinting & RSSI theoretical propagation	Zigbee has Low data transmission rates.
Ultrasound	Used in Indoor Positioning	3cm-1cm	TOA, AOA	Ultrasound is environmental sensitive.
FM	Used in Indoor Positioning	2m-4m	RSSI Fingerprint	It covers large area due to strong signals.

consists of radio wave generator and receivers which captures the emitted radio wave signals. The hardware of UBW is expensive and maintenance cost is high.

3.4) The FM radio based system

FM Radio based System [30] if very popular and most used throughout especially found most in houses and cars. It uses the FDMA [31] Frequency-division multiple access technique which splits the bands into number of frequency channels that are used by stations. It is the recent indoor positioning system work carried based on FM radio based system.

3.5) The Zigbee

The Zigbee technology is emerging standard useful for short and medium range communications because of its number of advantages. This technology is used in application which requires less power consumption but does not acquire huge throughput of data. The Zigbee covers 3m-5m of range in indoor environments. The distances of the area between two Zigbee nodes are calculated by RSSI values. Zigbee can interference a wide number of signal types using same frequency and can disturb the radio based communication as it works in the unlicensed ISM bands. Hu et al. [32] proposed an algorithm for indoor localization based on Zigbee. Further, Fernandez et al. [33] deployed an algorithm that improves the position estimation in an IPS depending on RSSI values.

4) Ultrasound system

Ultrasound technique is dependent on the nature of bats and requires low bandwidth to work in comparison to the other signalling techniques. The signals of ultrasound can be used for position estimation of the tags emitted from the receiver. These signals can reflect most of the indoor obstacles but cannot penetrate the walls; its accuracy level is low (in cm) and is affected due to conflict from reflected ultrasound [34] signals propagated by sources such as collision of obstacle say metals.

IV. SIMULATION ENVIRONMENT

To establish the accurate behaviour of positioning system different types of wireless technologies has been used for indoor localization they are Bluetooth techniques, Infrared Techniques, Wireless Bluetooth Technique, Radio Frequency Identification and Ultra wideband Techniques. Among these techniques we have concluded that RFID can work more efficiently in indoor positioning. The network simulators that we can use to implement operations of positioning system are NS2, NS3, GloMoSim [41] [42], NETSIM (Network Based Environment for Modelling and Simulation) [44] and OPNET (Optimized Network Engineering Tools) [44].

- ***NS2 (Network Simulator version 2):*** NS2 is a distinct event simulator written in C++ language. OTcl is an interpreter shell used by NS2; it acts as an interface which allows the input files i.e. Tcl scripts to be executed.
- ***NS3 (Network Simulator version 3):*** This is another open-sourced distinct event simulator which is primarily developed for educational and research work.
- ***GloMoSim (Global Mobile Information System Simulator):*** This simulator is used for simulating large number of wireless network and it uses parallel distinct-event simulation which is dependent on Parsec.
- ***NETSIM (Network based environment for modelling and simulation):*** NETSIM is an application which behaves as the simulator for Cisco Systems networking software and hardware. Used by various users to learn the structure of Cisco IOS command.
- ***OPNET (Optimized Network Engineering Tools):*** OPNET is applicable as a simulator for heterogeneous networks along with various protocols. This tool is one of the broadly used tools.

For implementing the operations, one can develop RFID extension for Indoor Positioning using the Network Simulator 2 (NS2) developed at UC Berkeley. The primary goal of NS2 is to provide support for education and research in networking, as well as it allows one to design new protocols, comparing various protocols and evaluations of traffic. NS2 along with the RFID technology can be helpful in the positioning system in the area of setting nodes, links, queues and topology. NS2 can define agents and applications, also tracing is the important part of NS2 tool. Simulation of TCP, routing and multicast protocol over the wired and wireless networks can be well supported by NS2. It has networking Component object Simulation Event Scheduler, Libraries and also Network Setup Module Libraries. NS2 is the object oriented tcl script interpreter in which tcl scripts have to be written by user using network objects and plumbing functions in the library to check start and stop transmitting packets through scheduler. From Moravek [43] investigation NS2 has almost all the basic properties to support different localization techniques. In the ad-hoc wireless networks NS2 have suitable flexible modules which can help the researcher to work efficiently. The basic structure of NS2 is been shown in FIG.5. We are using NS2 network simulator for simulation purpose of 50 nodes as it is capable to fully utilize the CPU. If only one application is carried out simulation environment NS2 will prove to be useful, whereas if more than one application needs to be simulated the CPU utilization will be reduced.

New modules added to the NS2 contain mainly two classes that are MMSE class and Position Class which simplifies the evaluation of localization schemes. MMSE Class deals with the all mathematical operations mainly matrix functions which require shorter execution time and less computational time. Positioning Class includes the basic localization method in which multilateration technique has been used. In the simulated scenario we can consider simulation performed with (No. of nodes) specific sensor nodes, anchor nodes and the obstacles. For approximating the position first we have to create the nodes in the simulator by using set n0 [$ns node] and which we can further use for communication by creating links in between the nodes created with the command $ns duplex-link node1 node2 bandwidth delay queue-type. Each node in the Simulator can encounter its position by itself. Simulation parameter values can be used for creating the nodes. Simulation generates the text based results known as the trace files. These files record the information of every discrete event in the simulation. After setting the network, now we have to set up the protocols namely TCP and UDP with the nodes respectively. Then execute the NS2 code by using $ns run**,** then open terminal and execute the .tcl file with the command $ns filename.tcl. Nam in NS2 is an animation tool used to anticipate the ns simulation and the packet trace information. The nam trace file consist of the data about topology such as links, node connectivity, packet trace data, queues along with the packet trace information.

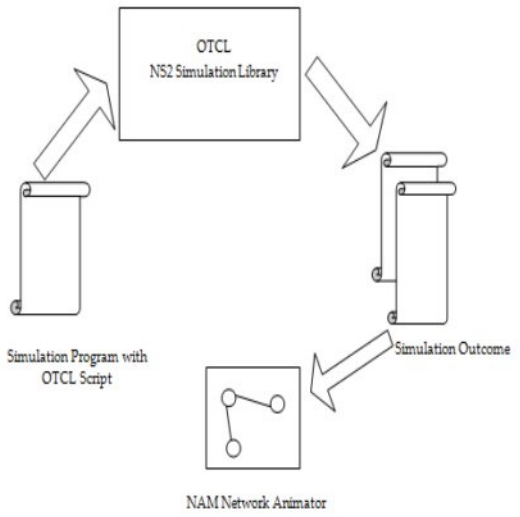

Figure 5: NS2 Structure

For implementation of another function such as AOA or TDOA, instead of RSS position class should be replaced by the new class. Creation of the new class will not change the localization algorithm and computation function of the localization system. Simulation structure of 50 nodes is shown in the FIG. 6.

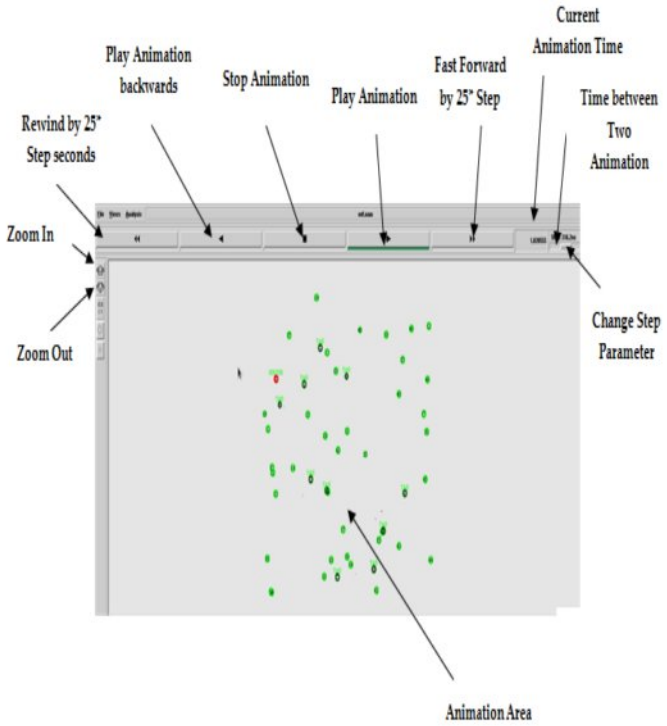

Figure 6: Simulation on NS2 for the 50 Nodes

V. CONCLUSION

This review paper surveys the existing wireless indoor positioning systems and their technologies. Different solutions for wireless indoor positioning, tracking and navigation are discussed along with number of trades off including precision/accuracy, robustness. In-spite of all the available approaches surveyed in this review paper, it is observed that the current solutions can't cope with the significant performance level that is required in the applications. The performance metrics required for various application environments are precision/accuracy, low cost hardware, availability and coverage. Among, the techniques discussed above, RFID have improved precision in indoor positioning system. The study of NS2 simulator for calculation of positioning operations is also included in this paper.

Future works on wireless indoor positioning systems are as follows:

- *In future we can propose an indoor positioning system based on RFID using RSS values to give better performance and it will be less effected by the interruption such as walls, windows etc.*

- *We can embed Directional Antenna with RFID based Indoor Positioning system to obtain precise solution in locating an object or person. The proposed system will be more robust as compare to already existing technology.*

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