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# Hybrid Approach Based Smart Antenna System for Increasing the Accuracy of Multiple User Indoor Localization

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**Abstract**— GPS is commonly used for navigation. Location estimation in indoor environment is not possible using GPS because GPS signals cannot work in indoor environment. There is a huge impact of multipath parameters like shadowing, reflection, refraction, diffraction phenomena in indoor localization which which leads to inaccurate localization and have an impact on the position estimation. Different methods available for localization are: TDOA, TOA, AOA, Location Finger Printing, GPS and RSSI. In all these approaches that are being considered the localization depends either on distance or on angle or on time only. In this paper a hybrid approach which is combination of RSSI and AOA is used to estimate the location of user in indoor environment using smart antenna system. This system combines the results obtained for AOA and RSSI to estimate the location of users. In, this technique the mode of the RSSI value is calculated and beamscan algorithm is used to know the location of the user. The results of this technique are tested and calculated with the help of hardware in indoor environment. Thus, this paper calculates the location of multiple users and also helps them in navigating in indoor environment.

**Index Terms**— AOA, beamscan, hybrid approach, indoor environment, location estimation, mode, RSSI, smart antenna.

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## 1 Introduction

Indoor localization means finding the location of users in indoor environment. Indoor positioning is useful in places like hospitals, warehouses, malls, tunnels, for building floor plan in college campuses etc. It is also essential for the various scenarios when the GLONASS/GPS signals are denied. Nowadays, vulnerability of the satellite signals in cluttered/closed environments creates an ever-increasing concern for users[1]. To address this issue a technique is proposed which measures the value of the Received Signal Strength Intensity (RSSI) and AOA and computes the exact location of the users. The significant advantage of proposed approach is that there is no necessity to use any special hardware.

THE SMART antenna (SA) is an emerging technology that is effective in improving the performance of wireless systems. The ability to reconfigure some of their parameters such as the radiation pattern and the polarization have a positive impact in terms of reliability and network capacity[2]. Smart antenna is a multiple antenna array consisting of multiple antenna components is used to increase the efficiency of wireless communication systems. It works on the principle of diversity effect at the transmitter and receiver of the wireless communication system. Diversity effect decreases the error while transmitting the data and also it increases the data transmission rate between the communicating wireless devices. The number of array elements are more in case of smart antennas which is the main difference between the normal antenna system and the smart antenna system[3]. Signal characteristics of the target area is obtained with the help of large number of access point equipped with single single antenna that gives enough information about the received signal strength value.

There are various location estimation solutions available that depends on one specific type of observation, i.e. either on range information only, or on angle information only. Different methods available for localization are: TDOA, TOA, AOA, Location Finger Printing, GPS and RSSI. The TDOA approach, results in inaccurate localization due to multipath propagation. Alternatively, in TOA, the estimated location varies with the LOS (line of sight) and NLOS (non line of sight) case. RSS based estimation is less costly as it requires less hardware also it gives accurate results in non line of sight path as compared to other technique but error occurs in it due to multipath propagation. Angle of arrival technique provides accurate results for line of sight but its accuracy decreases in case of non line of sight path.

The mean RSSI value fluctuates with the impact of outliers therefore in order to overcome this, mode of the RSSI value is calculated instead of mean. These calculated mode values are then adaptively filtered to improve the accuracy of the localization. The values for RSSI and AOA are combined using hybrid approach and the localization of the user is done in indoor environment.

The rest of the paper is organized as follows. In section II, related work i.e. RSSI and AOA methods available for the indoor localization is described. In section III methodology for indoor localization is explained. In section IV circuit diagram of the implemented hardware is described. In section V the methodology and algorithms of RSSI and AOA are described. Finally a new hybrid approach which is combination of RSSI and AOA is explained. In section VI the hardware results obtained are displayed with the help of snapshots. Section VII result analysis is done based on the obtained values. In section VIII concludes the topic followed by the references .

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## 2 RELATED WORK

Most of the location estimation solutions available depends on one specific type of observation, i.e. either on range information only, or on angle information only or on time only. RSSI technique is based on the propagation model. It gives information on how the radio signal strength decreases as it travels over an indoor environment. Based on the RSSI value obtained at all the AP's the location of the user i.e. the distance of the mobile user from the AP is calculated. RSSI values are calculated using the combination of different antenna elements present in the multiple antenna array[1].

Due to such an operation the change in the mean and deviation value present at the particular AP occurring because of the multipath parameters present in indoor environment gets reduced. Also it outperforms the single antenna architecture in terms of accuracy, cost and number of AP's that will be required for indoor localization. A single AP equipped with smart antenna could obtain enough RSSI values to accurately locate the users in indoor environment. The accuracy of the system is increased from 1.34% to 92.4%.The error variance is reduced by 96% as compared to traditional location finger printing method[1].

AOA technique is used to calculate the expected error profile, for different room dimensions and different number of intelligent nodes based on chosen angular measurement errors. A localization error of 95.17 cm is observed for beamscan. but the difficulty arising in this approach is how to select the correct angle out of the two solutions[2].

RSSI technique to provide the scenario for multiple users recognition has been done. It is possible to recognize and distinct upto 3 users with reasonable precision but accuracy of the system decreases with increase in number of users[3].

RSSI technique can be used with four different approaches i.e mean, mode, mean +filtering, mode+filtering. RSSI technique is dependent on the type of antennae used at the transmitter and receiver end and also on the orientation of the antenna with respect to the target space. RSSI value changes if either of the nodes move away from the line of sight. Radio signals have an impact of outliers i.e they suffer from fading and multi-path reflection. It also gets affected by electromagnetic noise generated by any device used in the experimental region. A comparative study of all the four methods shows that conventional mean technique is sensitive to outliers. So, mean is not a good measure due to RSSI fluctuations. Rather mode of the RSSI values of a particular location is a better option. Mode filter technique achieves a 64.86% less error over mean technique distance estimation between transmitter and receiver. It has a 21.33% lower error in location estimation[4].

The model becomes more accurate when a low pass filter is used on the final RSSI values of particular locations. RSSI technique can also be used alongwith adaptive filtering. As RSSI based location estimating techniques do not require any additional hardware they are widely popular.RSSI measurements collected in indoor environments are impacted due to scattering, shadowing, reflection, diffraction, electromagnetic noise. RSSI measurements have large positioning errors due to this impact of multipath parameters which is not acceptable for indoor environments. Thus the RSSI measurements collected at indoor environment using Zigbee modules improve the location estimation by adaptively filtering the obtained values[5].

## 3 METHODOLOGY FOR INDOORLOCALIZATION

The following model to be constructed aims to determine the location of multiple users in an indoor environment. The model consists of two steps hardware part and the software part which is used for the localization of user in an indoor environment. Firstly, we describe a circuit diagram which is constructed according to the aim of the model which mainly consists of Zigbee, microcontroller, lcd display, and related circuits. The second stage of programming is further divided into two steps first step is of RSSI and second step consist of AOA which is used to localize the users. The corresponding algorithms in the respective mode will be described and related results are obtained. Thus, we describe the plan of project work as shown in Figure 1.

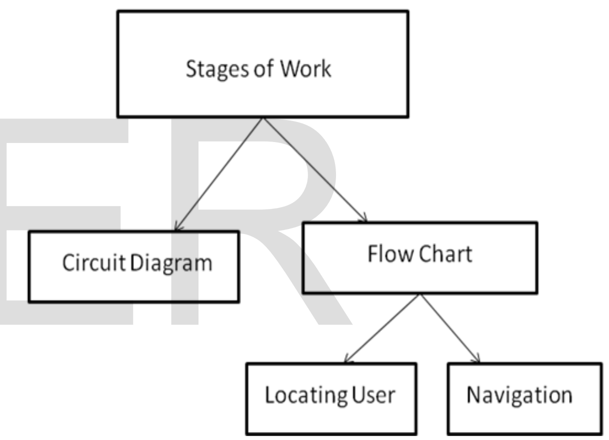


Figure 1. Stages of the work

## 4 CIRCUIT DIAGRAM

The system consists of set of Zigbee, microcontroller, LCD display, keys. The circuit diagram is constructed as per the block diagram. Figure 2 and 3 shows the following circuit diagram of the system.

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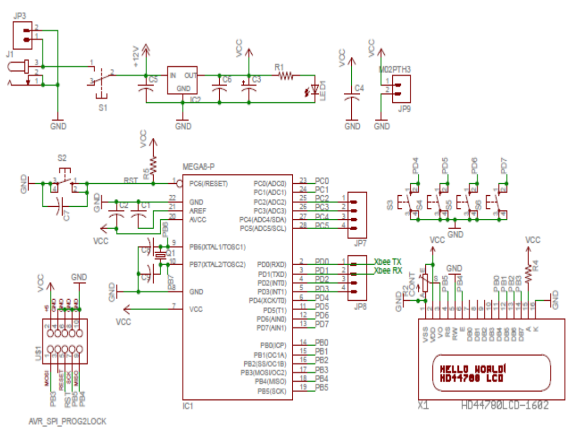


Figure 2. Circuit Diagram for User Device

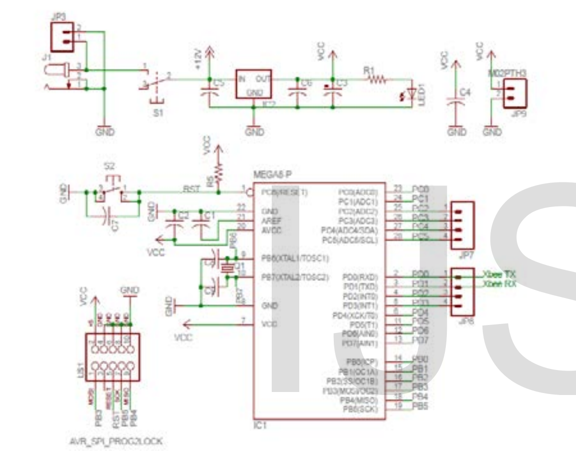


Figure 3. Circuit Diagram for Access Point

Zigbee are the devices used as an antenna for knowing the RSSI value and also to calculate the angle of arrival of signal from the user device. These signal values so obtained will be used to map them into there corresponding coordinates. These coordinates will further be mapped into the distance value. The four access points will be located at four corners of the room. The mobile nodes will be moving in the indoor area whose location will be calculated. The ZigBee XBee excels in very low-power scenarios, when configured as an End Device, this module has the lowest current draw of any Digi RF product. It has range of 40 m indoor environment. Transmit power of 3dbm, with 250 kbps data rate and operates at 2.4 GHZ ISM band.

The microcontroller will be programmed accordingly with corresponding pins to get the location of user. Here two controls will be given for to enable locating user mode and navigating mode. The microcontroller will switch the modes accordingly and store the data in its memory. All the operations within the microcontroller are performed at high speed and quite simply. As the ATmega8 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture, it is well suited for our application. By executing powerful instructions in a single clock cycle, the ATmega8 achieves throughputs approaching 16 MIPS per 16 MHz. The port B pins i.e. pin $B_0$ to $B_3$ is connected to LCD pins $D_4$ to $D_7$. Port D pins $D_0$ and $D_1$ are connected to $T_x$ and $R_x$ pin of Zigbee. Pin $D_4$ to $D_7$ are connected to keys which are used to switch between different functions.

A liquid-crystal display (LCD) is a flat panel display device which can be helpful for electronic visual display, or video display that uses the properties of liquid crystals by modulating light. Here we use the LCD that is 16 characters wide with 2 rows. The position of the user will be displayed accordingly in order to localize the user in indoor environment.

## 5.METHODOLOGY AND ALGORITHM

The working of proposed hybrid approach which is combination of RSSI and AOA is described along with Figure 4 as follows:
There are two steps of operation:

### 5.1 LOCATING THE USER:

The four AP are located at four corners of the room. These access points are the Zigbee devices. These devices measures the received signal strength value at all the access points. Depending upon the angle of arrival of these values and the RSSI values it first calculates the mode of all the received RSSI values these values are then adaptively filtered and the new multiplying factor is obtained from RSSI and AOA of all the four AP's. Then based on this value its location is estimated from the database available at the access point in form of (x, y) coordinate. Thus the location of the user is estimated using this hybrid approach. An algorithm is described for locating the users in indoor environment as follows:

1. Start
2. Scan the access point nodes for RSSI value.
3. Calculate the RSSI values obtained at the array elements.
4. Calculate the mean and mode of the obtained RSSI values.
5. Calculate the AOA value for the particular obtained RSSI value.
6. Map the RSSI and AOA value so obtained into the (x, y, θ) coordinates.
7. As per the obtained coordinates map it into distance values.
8. Compare the results obtained for mode and mean of RSSI.
9. Display the results of distance for mode and mean from the nearest access point node.
10. Mode value gives the exact user location as compared to mean value.
11. Stop.
12. End of locating user mode.

Locating user mode will consists of three sub stages cal-

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culating the RSSI value its mode, mean and AOA. The following algorithm explains this stage of getting the mode of RSSI value.

In the first sub stage of this algorithm the user location is calculated based on the mean of RSSI value. Mean value of received RSSI is calculated by calculating the average of all the values and the average so obtained is used to calculate the coordinates of user and also the distance of user. Its algorithm is described as follows:

1. Start.
2. Initialize the Zigbee modules.
3. Calculate the received RSSI values at array elements
4. if(modeFlag == 1)
5. {max_val = 0;for(int i = 0;i<5;i++)
6. {max_val += mode_vals[i];}
7. max_val /= 5;
8. node_rssi[node_count-1] = max_val;
9. distance[node_count1]=(int)pow(10.0,((A+max_val)/(10.0*n)));
10. Stop.

The formula used for calculating the mode of all the obtained RSSI values is:

$$Mean= \{RSSI[0]+ RSSI[1]+ RSSI[2]+ RSSI[3]+ RSSI[4]+ RSSI[5]\}/ 5 \quad (1)$$

$$RSSI = -(10*n*\log10(d) + A) \quad (2)$$

Where
RSSI being the value received (dBm)
n being the path-loss exponent is 2.7 for indoor environment
d be the distance
A being the RSSI value which is at a reference distance of 1 meter is 45

The second sub stage calculates the location of user based on the mode of these received RSSI values. Mode is calculated based on the frequency of occurrence of the RSSI values. If all the RSSI values obtained are different then the one which is the high RSSI value will be considered as the mode of RSSI value otherwise the one having highest frequency of occurrence is considered to be the RSSI value. This stage is explained as follows with the algorithm.

1. Start.
2. Initialize the Zigbee modules.
3. Calculate the received RSSI values at array elements.
4. if(modeFlag == 0)
5. Then max_count = 0;max_val = 0;
6. Loop for(count1=0;count1<5;count1++)
7. {val1 = mode_vals[count1];curr_count =0;
8. Loop for(count2=0;count2<5;count2++)
9. {if(val1 == mode_vals[count2])
10. Then{curr_count++}
11. if(curr_count > max_count)
12. {max_count = curr_count; max_val = val1;}}}
13. node_rssi[node_count-1] = max_val;
14. distance[node_count1]=(int)pow(10.0,((A+max_val)/(10.0*n)));
15. Stop

The formula used for calculating the mode of obtained RSSI value is:

All the obtained RSSI values are arranged in the ascending order, then the frequency of occurrence of these numbers is checked and the value for which this frequency count is high will be considered as the mode of RSSI value. In case if all the values obtained have the same frequency of occurrence then the one with the larger value of RSSI is considered to be the mode value.

$$Mode = L+[(f_1-f_0)/2f_1-f_0-f_2]*h \quad (3)$$

where

**L** is the lower class limit of the modal class
$\mathbf{f_1}$ is the frequency of the modal class
$\mathbf{f_0}$ is the frequency of the class before the modal class in the frequency table
$\mathbf{f_2}$ is the frequency of the class after the modal class in the frequency table
**h** is the class interval of the modal class

The third sub stage calculates the location of user based on the mode of these received RSSI values and AOA.

For calculating the AOA of these received signals beamscan algorithm is used. Beamscan scans all the received signals based on these received signals from different access point the intersection of all these beams is calculated and based on there intersection users coordinates are determined then based on the value so obtained of these coordinates it is mapped into the angle. This stage is explained as follows with the algorithm.

1. Start.
2. Initialize the Zigbee module.
3. Calculate the mode of the received RSSI value.
4. diff_rssi[1]=abs(node_rssi[1]-rssi_arr[c][1]);
5. diff_rssi[2]=abs(node_rssi[2]- rssi_arr[c][2]);
6. diff_rssi[3]=abs(node_rssi[3]- rssi_arr[c][3]);
7. sum=diff_rssi[0]+diff_rssi[1]+diff_rssi[2]+diff_rssi[3];
8. if(sum < min_val)
9. Then{min_val = sum;min_index = c;
10. Loop for(int c = 0;c < 4;c++)
11. {if(node_rssi[c] < min_val)
12. {min_val = node_rssi[c];
13. min_node = c}}
14. double diff_x = abs(nodes_val[min_node][0]-rssi_loc[min_index][0]);
15. double diff_y = abs(nodes_val[min_node][1]-rssi_loc[min_index][1]);
16. double AOA = (atan(diff_y/diff_x)*180)/3.14;
17. Stop.

The formula used for calculating the AOA is given below, where (x, y) coordinates are obtained by scanning all the incoming beams of the 4 nodes. The intersection of all these four beams gives the coordinates of the user based on

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there RSSI value and these obtained coordinates are then mapped into the angle by using the formula given below:

$$AOA = \{\tan^{-1}(y/x)*180\}/3.14 \quad (4)$$

In the locating user mode, for accurate localization of user the results obtained are compared for both mode value as well as for mean but it is found that mode gives the exact location of user rather than mean.

## 5.2 NAVIGATION:

In second step if user wants to move from its current location to new location which is its destination location then user needs to pass the query to the nearest access point node depending upon the query the AP which is nearer to that particular destination location will pass the information to the user and will assist him in navigating in the indoor environment.

1. Start
2. Check for query at all the access point .
3. If there is any query for knowing the distance of some destination node from user go to step 4 else go to step 7.
4. Access point maps the destination location from its corresponding present location into the distance.
5. Passes the route information to user who has queried.
6. Go to step 2.
7. Stop.
8. End of navigating mode.

## 6. HARDWARE RESULT

The hardware considered consists of four user devices whose location has to be calculated in the indoor environment. The user module consist of the Zigbee, microcontroller, LCD display. Four Access point which calculates the location of user are placed at the four corners of the room. The access point node consists of the Zigbee, microcontroller, power supply. Here, the various sub stages of locating user mode are shown in the following figures.

### 6.1 LOCATING THE USER:

The first stage consist of localization of user in indoor environment based on mean RSSI value it is shown in Figure 5.

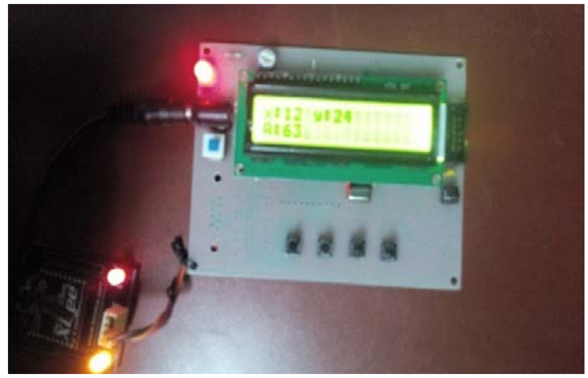
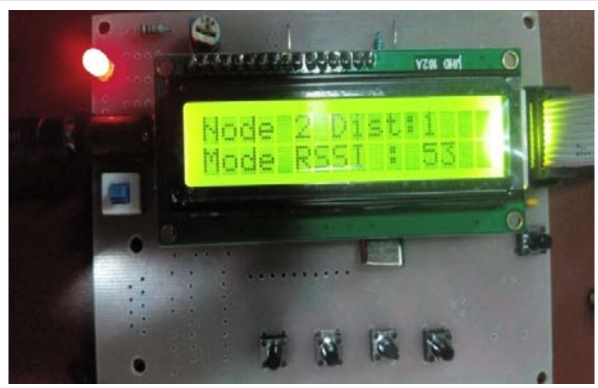



Figure 5.Locating the user based on Mean RSSI value

The second stage consist of localization of user in indoor environment based on mode RSSI value it is shown in Figure6.

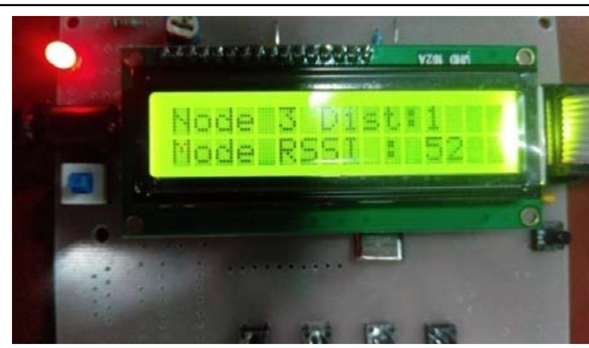



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Figure 6. Locating the user based on Mode RSSI value

The third stage consist of localization of user in indoor environment based on mode RSSI and AOA value it is shown in Figure 7.


Figure 7. Locating the user based on Mode RSSI and AOA value

TABLE 1
RSSI VALUES FOR ARRAY ELEMENTS

| Array Element No. | Node1 | Node 2 | Node 3 | Node4 |
|---|---|---|---|---|
| 0 | 55 | 53 | 52 | 76 |
| 1 | 54 | 54 | 52 | 72 |
| 2 | 54 | 53 | 52 | 59 |
| 3 | 54 | 53 | 53 | 57 |
| 4 | 52 | 58 | 59 | 59 |

TABLE 3
LOCATION OF USER IN INDOOR ENVIRONMENT

| | |
|---|---|
| (x, y) coordinates of user based on Mean | (36,24) |
| (x, y) coordinates of user based on Mode | (36,36) |
| AOA and distance based on Mean | 45°, 1 m |
| AOA and distance based on Mode | 33°, 2 m |

### 6.2 NAVIGATION:

In navigating mode the query is asked to the user to which destination the user intends to go to. Based on these query user replies with its intended destination. The user is replied with the destination distance from its current position.



Figure.8. Navigating Mode

## 7 RESULT ANALYSIS

From above tables, the data in the locating and user mode mode is obtained. The location of user is tested by placing the user modules at different distances and it was found that the accuracy of the system is 100% when mode of RSSI and AOA is used while this accuracy is less when mean value of RSSI is used it is 97.15%. As mean value averages the obtained RSSI value so it does not gives accurate results as compared to mode technique. The obtained RSSI value are also calculated theoretically and it is found to be the same as that obtained in our hardware results. The following table compares the theoretically and actually obtained results.

The Graphs analysis for the above table values is

TABLE 4
COMPARISON OF THEORETICAL AND PRACTICAL RESULT

| Type of Value | Node1 | Node 2 | Node 3 | Node4 |
|---|---|---|---|---|
| Mean | 54 | 55 | 54 | 65 |
| Mode | 54 | 53 | 52 | 59 |
| Theoretical value for Mean | 53.8 | 54.2 | 53.6 | 64.6 |
| Theoretical value for Mode | 54 | 53 | 54 | 59 |
| Accuracy for Mean | 99.7% | 96.3% | 97.2% | 95.4% |
| Accuracy for Mode | 100% | 100% | 100% | 100% |

shown with the help of figure9 and figure 10.

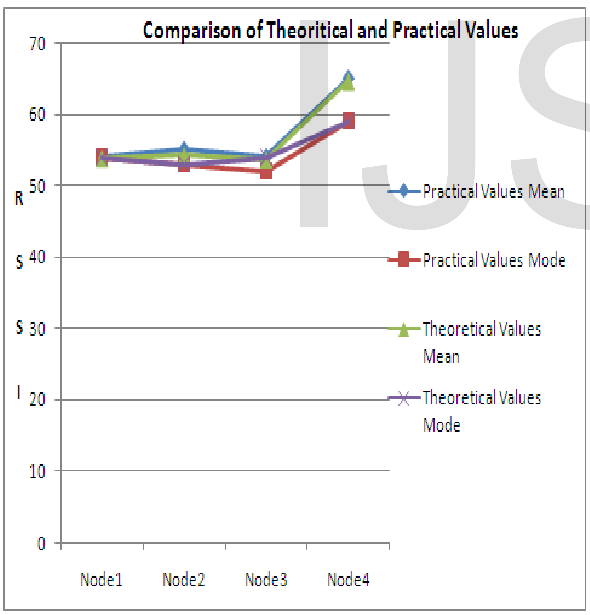


Figure 9. Comparison of Theoretical and practical values

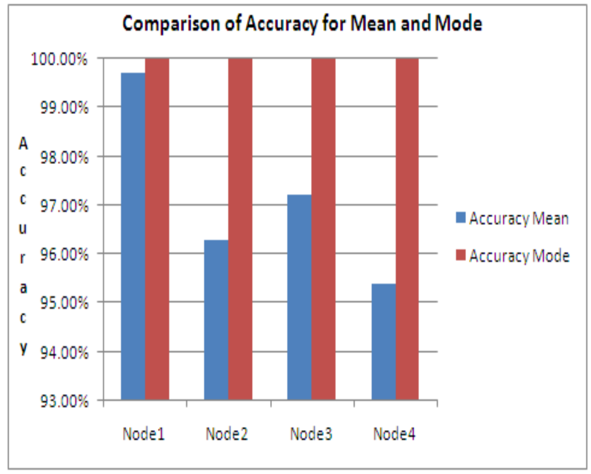


Figure 10. Comparison of Accuracy for Mean and Mode

The above graphs shows that the theoretical and practical values obtained for mean values are not same but in case of mode both the values obtained are same. The accuracy is 100% when the localization of users is done based on the Mode RSSI and AOA and it is 97.15% when Mean RSSI and AOA is used.

## 8. CONCLUSION

A smart antenna system for multiple user indoor localization and navigation using hybrid RSSI and AOA approach is proposed. Here, the multiple user localization is done using the received RSSI i.e. mode of RSSI value and based on AOA information for the user. The accuracy for the mode values of RSSI is compared with the mean RSSI values and it is found that 100% accurate results are obtained for mode RSSI and AOA. Thus the smart antenna system so developed provides the exact location of multiple users in indoor environment and also help them in navigating in indoor environment.

## 9 FUTURE SCOPE

This technique being developed can be used for indoor localization. Indoor localization is useful in places like industries, college campuses, shopping malls, hospitals etc. It is also helpful to civil engineers for building the floor plan of the building. This can also be used to guide the deaf people in public premises by integrating a voice guided system along with this smart antenna system.

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