Original Article

Localized Positioning Systems using Trilateration Algorithm

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Abstract

We are impacted by Internet connectivity and connect to the outside world using the global positioning system (GPS). We can use GPS to locate a person in a fully connected area which makes it possible to identify his location but in cases where the Global Positioning System (GPS) is not available there is no alternative to communicate to the other user specially when they are in critical situations. The work shows an effective local positioning technique using the trilaterationalgorithm which not only identifies the location of the user but also tries to analyze the locateddata through different evaluated mechanism such as packet delivery ratio, Inter arrival time and packet loss. The entire local positioning system uses the anchor nodes and Receiver Signal Strength Indicator (RSSI) values of its own Wi-Fi network to locate the user in unfavorable situations where he/she may not have chosen to be. Simulations in mat lab tool were taken for single cases of single channel node position and multiple node position. However, when we test for multiple node positions, the error or delay is greater in comparison. The hardware demonstration shows the positioning scenarios by taking anchor positioning of the nearby network in terms of coordinates i.e. ‘x’,’y’, ‘z’ and measures the signal strength of its locations and pageant the distance from the measured coordinates.

Keywords: Trilateration, Packet Delivery Ratio, Intern arrival Time and Packet Loss.

INTRODUCTION

The Global Positioning System (GPS) is an essential component of our daily lives. We utilize it to meet our needs, whether they be for locating ourselvesin unknown locations or to meetdestinations andlocating ourselves in remote areas where there are network problems. Numerous navigational technologies, including Bluetooth, Ultra Wide Band (UWB), Xbee, Radio Frequency Identification (RFID), and Infrared Light, have been developed to increase human accessibility to these navigational findings. Different technologies can be employed to implement these listed technologies. UWB and Wi-Fi can deliver superior positional information of a user's or individual's location and don't require a large set up for identification of locational information, Bluetooth and RFID are primarily utilized for shorter distance communications. However, in order to access the information of every user, massive network-based navigation requires a planned design of nodes and network accessibility.

The science of moving a person from one location to another is referred to as “Navigation”. When people are trying to avoid a particular circumstance in a large apartment such as a shopping mall, or as a mine operator in an underground environment, indoor celestial navigation is helpful where the user is cut off from the outside world orin event of an emergency or any unpleasant circumstance that arises while they are working. When we list some of the circumstances such as inadequate ventilation, risks of significant rock fall, and hazardous gaseous atmosphere that could result in death the requirement for navigations is of prior importance’s to overcome these natural situations these situations may be difficult to overcome specially when GPS signals fail to locate the persons trapped. In order to group these conditions, radio frequency (RF) signals may be used to locate objects in some of the world's most remote locations. It is however necessary to measure the strength of these RF signals using a distance formula, with the tagged object or users in those locations evaluating the signal's strengthand measuring location's distance from a known point using the distance formula using trilateration algorithm. In comparison to other methods, like the grid search approach [1] and the dead reckoning method [2], trilateration gave us the most effective solution. We can tag anchor on the XY and Z plane using the trilateration method, and also use it to find a user along the z axis. Through 2D and 3D trilateration, allows us to determine the user's location the method adopted is different and complicated for 3D. The work proposed is based on 2D trilateration along the X, Y, and Z coordinates.

RELATED WORK

The implementation of the Asynchronous protocol is done in the reference work [1], which compares the grid search algorithm, which is a high complexity system which takes too much time in comparison to the other approaches. The proposed method uses the Asynchronous protocol for the position of the object and concept of shrinking circles, which basically identify the location of the object by using Anchors nodes and compute the cords of the coordinates by the xy coordinates, which is known as the time of departure(ToD), which gives the real time of departure of the signal, which is known as the grid search method, the receiver may be susceptible to disturbances from the environment .While trying to receive this signal, there may be some propagation delay or time for the signal to reach the anchors, which is known as the time of flight (ToF), which measures the distance between the two anchors. The receiver will respond with the Time of Arrival, which is represented as (ToA). The grid search algorithm and the suggested method combined the result in a time reduction, a narrowing of the search area, with improvement of 80%, and a good precision of 1 meter or less in theimplemented search range is improved by 5 times demonstrating a reduction in calculation time of approximately to 6 times.

In the reference paper [2], they suggested a local positioning system to locate underground miners with anoperating conditions challenging to find them in an emergency situation using the localization mechanism is demonstrated. It uses Receiver Signal Strength Indicator (RSSI), which is carried out without the assistance of a GPS or cellular signal, and concentrates on extending battery life. The implementation of this article comprises of RSSI and Time of Travel correction, which are data acquired in real time which is tainted by external disturbances. This signalis smoothed using the RSSI where the oscillations are eliminated using the Gauss-Newton technique to estimate the coordinates and find the miners from their underground locations. The dynamic node, static node, and localization technique to estimate the coordinates using the 2D approach make up the suggested Localizations algorithm implemented in this article. Testing was carried out in a 100-acre mining region where workers were engaged in digging and using a 433Mhz Wi-Fi. The weighted RSSI correction, smoothing, PLSR regression, and Gauss-Newton localization technique are the five steps used by the static nodes, which are assisted by four nodes based on the signal strength. The 61 dynamic nodes' positions were tracked, and a calculation of the maximum inaccuracy yielded a value of approximately 7.4435m.

SYSTEM DESIGN

The following four main construct blocks were used in this work's implementation of the localization scheme to set up communication between the local positional system where we placerespective anchors to carry out the communication. Estimating the coordinates in a set of the trilateration uses the weighted RSSI correction, RSSI smoothing approach, partial Least Square Regression (PLSR)-based distance estimation, and Gauss-Newton algorithm. Fig1 illustrates the setup's full overall structure. Real-time data collected from the four nodes, each of which is positioned in a specific area is received as the RSSI, will be used to complete the communication scenario. The RSSI value varies randomly, causingenvironmental, topographical factors, or signal absorption caused by structures, obstructions, and environmental factors. A weighted average-based self-corrections scheme is used in the examination of the coordinate scheme to deal with the unpredictability in the data collection used to calculate the RSSI value.

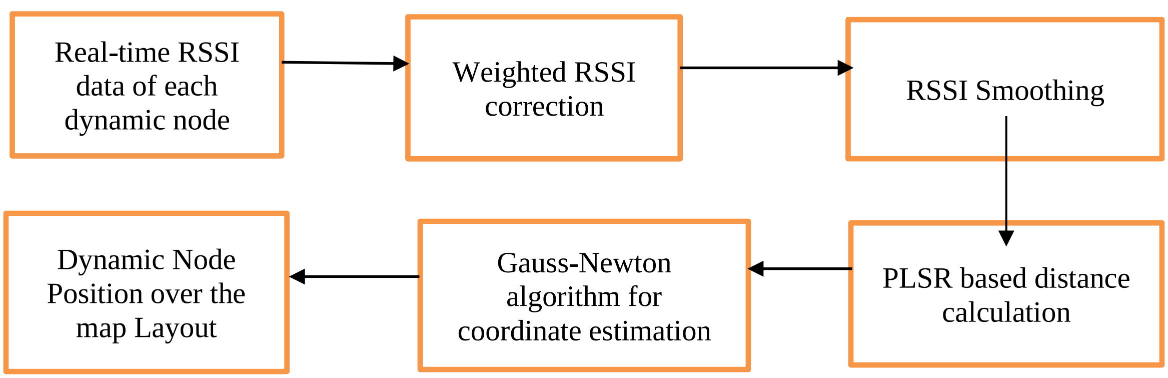

Fig 1 shows the suggested method's localization plan.

Weighted RSSI Correction: Because the data were obtained using RSSI samples, they may contain some uncertainty and localization mistakes which are likely to occur when the data's location are estimated. For the RSSI improvement, the real-time statistics of the data, a Gaussian weighted model is projected in the study. There are further approaches been used, such as average correction and mean-median mode correction techniques were the mean andvariance of the RSSI samples are two characteristics that are closely related to the weighed correction procedure.

To reduce disturbances in the received RSSI samples, RSSI smoothing is used to retrieve the signal that is undisturbed. This method mainly involves calculating the signal strength from a client device for various access points, integrating the information with a proliferation model to calculate the separation between user devices and anchor nodes, and then comparing the results. The predicted device of the client position and the actual location of the entrance point are evaluated using a trilateration process.

A further development of the linear regression technique that depends on the variable as well as the predictor variable and dynamic node's Euclidian distance, has been taken into consideration. Because the final amplitude is lowered as a result of the mathematical processes employed in the RSSI correction scheme, PLSR is utilized to determine a linear regression model in order to compare the Euclidian distance and original distance of the accessible dynamic and static nodes.

Gauss-Newton algorithm: This algorithm is primarily utilized for coordinate estimationwhich essentially is an iterative technique to estimate the various dependent variables of the given target samples, it is one of the iterative techniques to resolve various nonlinear issues. To access single point optimizations, it is the computational model that fits it the bestapproach in order to access the improved coordinate of the dynamic node for the 2D Layer, the work implements the Euclidian distance from the suggested PLSR model in the block diagram. The Implementation calculate the readings based on the insights learned from the RSSI values. The Gauss Newton approximations, which are the best fit technique, will be utilized to estimate the coordinates using the 2D coordinates because the localization models take into account the Least RSSI value. Since the work uses four anchors as the accessing points, we can consider one of them to be the origin node and the other nodes to be the accessing nodes for the x- and y-coordinates of the quadrant.

Hardware Demonstration

To Validate the work the coordinates are considered as ‘XY’,’YZ’ and ‘ZX’, these are being pointed out as the anchor position in the three coordinates which are represented as ‘X’,’Y’ and ‘Z’ coordinates which creates situation where the needed signal strength of the target locationis to be identify, the said coordinates iscreated in a particular scenario where it searches for the available Wi-Fi networks from at least three networks. The demonstration was done on original Arduino MKR with 1010 board which collects the signal from these minimum 3 AP pointes and provides the signal strength from the target locations, a single search illustrations made from the kit is been shown in the below fig 3. In the illustration the Wi-Fi networks are kept at points ‘E’,‘I’,’K’ and ‘J’which acts as access points from the target node ‘C’ .The distance to these access points are represented as d_1^2, d_2^2 and d_3^2 which are measured for RSSI of each access point kept at ‘C’ and is represented as

EI= x – axis =xdmin (1)

EK = y – axis =ydmin (2)

EJ = z – axis = z dmin (3)

Now the coordinates of the x, y, and z are calculated by the formula

x coordinates = $d_3^2-d^2-x_{dmin}^2/ 2x\ dmin$ (4)

y coordinates = $d_2^2-d^2-y_{dmin}^2/ 2y\ dmin$ (5)

z coordinates = $d_1^2-d^2-z_{dmin}^2/ 2z\ dmin$ (6)

The distance from these points are calculated by equation 7

$d = x^2+ y^2+ z^2$ (7)

where

x dmin = max dimension along x axis

y dmin = max dimension along y axis

z dmin = max dimension along z axis

The graphical representation represents the equations shown in fig.2

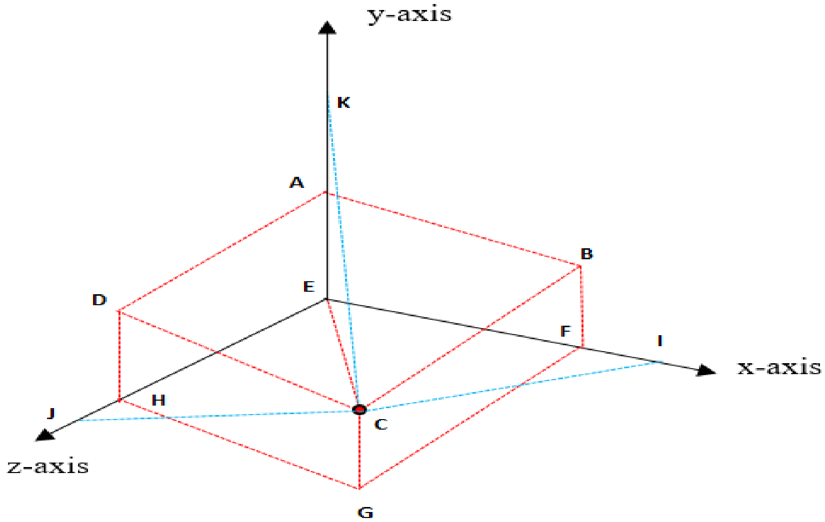

Fig.2 Illustrations using anchor positions to identity the RSSI for a particular target location

```
07:57:23.899 -> Scanning network - Access Points available ...
07:57:28.589 -> Scanned Output - Number of Access Points (AP) in a Network :9
07:57:28.589 -> AP:0:Ryan Signal: -14dBm, X: 0 Y: 0.07
07:57:28.589 -> AP:1:MRP-ACT Signal: -67dBm, Y: 0 Z: 1.11
07:57:28.589 -> AP:2:jothikumar_act Signal: -77dBm, Z: 0 X: 1.85
07:57:28.589 -> AP:3:ARUNNULVI_2.4GHz Signal: -78dBm,
07:57:28.589 -> AP:4:AJNetwork Signal: -86dBm,
07:57:28.636 -> AP:5:ACT102605199310 Signal: -86dBm,
07:57:28.636 -> AP:6:Jaswanth Signal: -88dBm,
07:57:28.636 -> AP:7:Diya Signal: -89dBm,
07:57:28.636 -> AP:8:BSNL Signal: -95dBm,
07:57:28.636 ->  Distance: 21.54 dBm
```

Fig 3: Sample output of the RSSI from the wifianchor positions obtain on the Arduino MKR with 1010 board

The illustrations shown in fig 3 is the snapshot of the scanned wifi networks collected from the Arduino MKR with 1010 board. The idea is to create the illustrations shown in fig 2 in order to located the I,J,K points and convert the coordinates to the distance given in equation (7).

SYSTEM IMPLEMENTATION

In [4], the Received Signal Strength Indicator (RSSI) for target localization is taken into consideration along with the result comparisons to4 Anchor nodes plotted on a trilateration algorithm where each point in the image is projected into a 3D space.

Position Estimation Algorithm using Trilateration model:

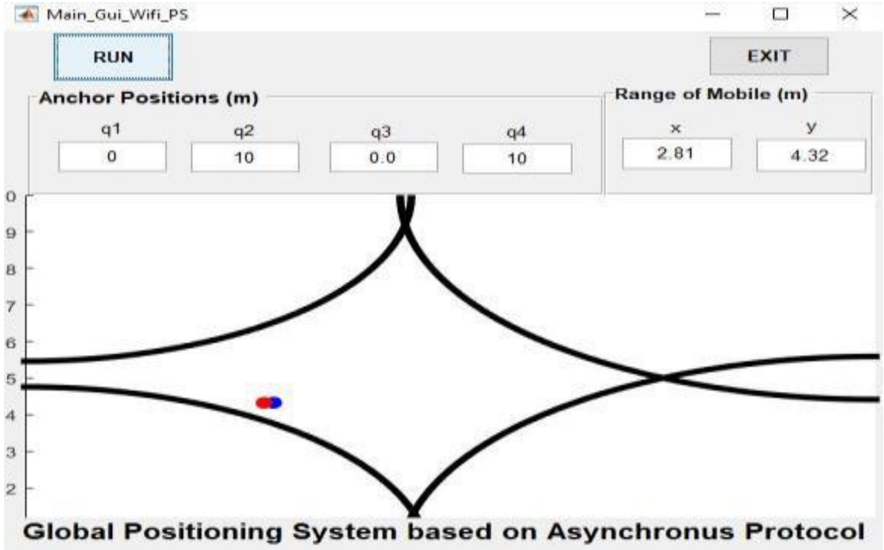

Fig 4 Node plots of the Positions

Let's take a look at the four Nodes or Anchors that are plotted on the GUI in fig 4, where the user's location has been tracked, Wi-Fi is configured alongside the mobile network and is given with an estimated rangeof ‘x’,‘y’ and ‘z’ coordinates where the signal from the transmitter and receiver is being observed and plotted. The range is fairly small, and the position may be tracked, as shown. This procedure can also be used to track the distance between numerous nodes or channels. The work proposed specifies values for the RSSI when comparing with distance formula. The distance calculation below can be used to approximate the actual position based on the estimated distances.

Consider "X" as a matrix storing the positions of each access point and ‘d’ as the distances from each access point. Consider "real1" as the "x" coordinate of the known position and "real2" as the "y" coordinate of the known position. "min X" is the dataset's least X coordinate; "max X" is its maximum; and "min Y" is its minimum Y coordinate; and "max Y" is its maximum. Since installed Wi-Fi access points are typically deployed in random locations, connecting to at least one Wi-Fi access point which is all that is required for anchor nodes. We provide the subsequences of the localization approach with a followingstep:

1. Place the WiFi Access Points and Anchor Nodes;
2. Each anchor node's real signal strength is processed by the WIFI access point and stored as a dataset;
3. The mean signal strength of each anchor node is calculated from the recorded dataset;
4. The blind node measures each anchor node's signal intensity, reads the dataset data, and increases RSSI;
5. The median filter sharpens the corrected RSSI, which corrects RSSI and then converted to distance using the Free Space Path Loss propagation model;
6. The least squares algorithm is used to evaluate the position of the blind node.

Pseudo Code for the proposed work

1.tbl = table (X, d) to create a lookup table;

2. Establish the weights. weights = d. (-1); equals 1 over the square of the distance d = d 2.

3. Apply Transpose of weights

weights = transpose(weights);

4. Middle approximate coordinates of the dataset

beta0 = [(max_X - min_X)/2, (max_Y - min_Y)/2];

5. In Matlab, define the Trilateration model.

modelfun = @(b,X)(abs(b(1)-X(:,1)).^2+abs(b(2)- X(:,2)).^2).^(1/2);

6.Adapt the model to the data.

7. mdl = fitnlm(tbl,modelfun,beta0, 'Weights', weights);

8. approximate location

b = mdl. Coefficients{1:2,{'Estimate'}};

Distance estimate Algorithm using Free Space Path Loss propagation model

1. Based on the observed Wi-Fi RSS, calculate the distance between the Wi-Fi Access Point and the unknown point using the Free Space Path Loss propagation model.

2. The estimated distances vector between the unknown position and the Access Points is produced from observed Wi-Fi RSS Input vector (associated to an access point).

aN = 27.55;

bConst = 20;

Ci = 2400;

result = (aN - (bConst * log10(Ci)) + abs(RSSI)) / bConst;

3. Use The Power of the Square of the Input to Get the Outcome.

d = Sum(result)^2;

4. Consider the distance "d" as transposed as

d = transpose(d);

RESULTS AND DISCUSSION OF THE OBTAIN PLOT

The received signal strength indicator measures the device's ability to pick up signals from an anchor or access point and displays the signal strength. The various values have used to measure signal intensity arein dBm, absolute value is used to describe power levels in mill watts. The plot from the connected Anchor position (AP)is simulated on the Mat lab tool 2016a, where AP1 represents the sent signal and AP2 represents the received signal, in the analysis acquired. We can see from fig5 that the plots are for one channel, the distance between the transmitter and the receiver is roughly as small as it can be, and the packet delivery ratio is almost 100%. When there is no instant between the nodes.

RSSI from Transmitting and Receiving signal

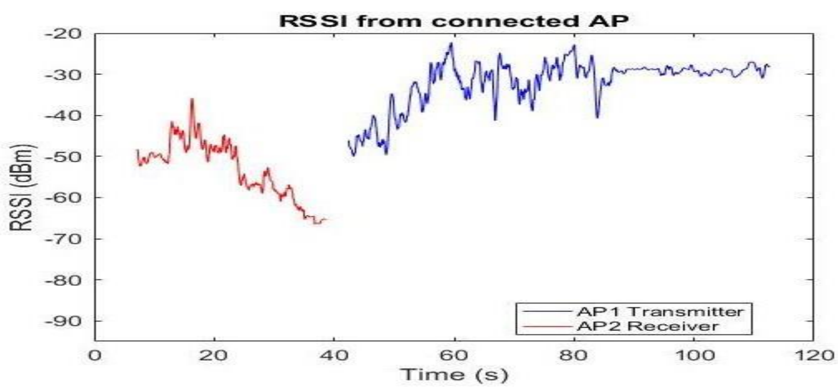

Fig.5 RSSI from Transmitting and Receiving signal

The work has resulted from the anchor nodes which are been considered as nodes on the code where APis shown as blue in the graph represents the transmitted RSSI signal and the red represents the received RSSI signal, there are path losses from the signal due to the disturbances occurred due to the interferences which are considered as 'Vo' in the code. The demonstration has been shown for the communication between single channel.

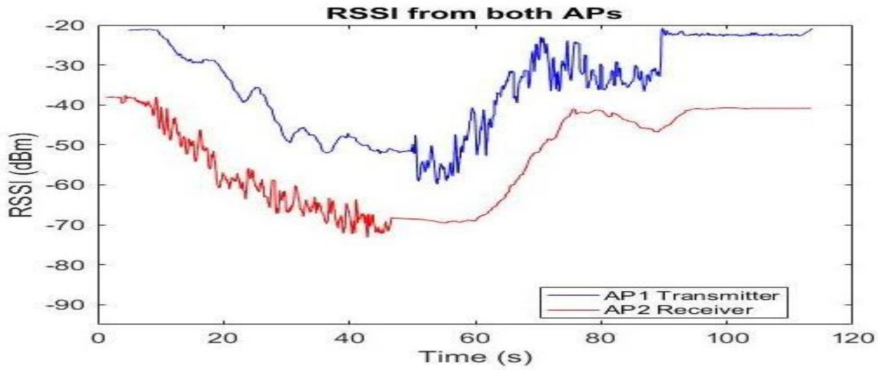

Fig.6 RSSI from Transmitter and Receiver for differentchannel

When we consider for multiple channels then the graphs are displayed as shown above where the path of reception and transmission of signal looks almost similar and along the line. The values measured for both the illustrations are in dBm.

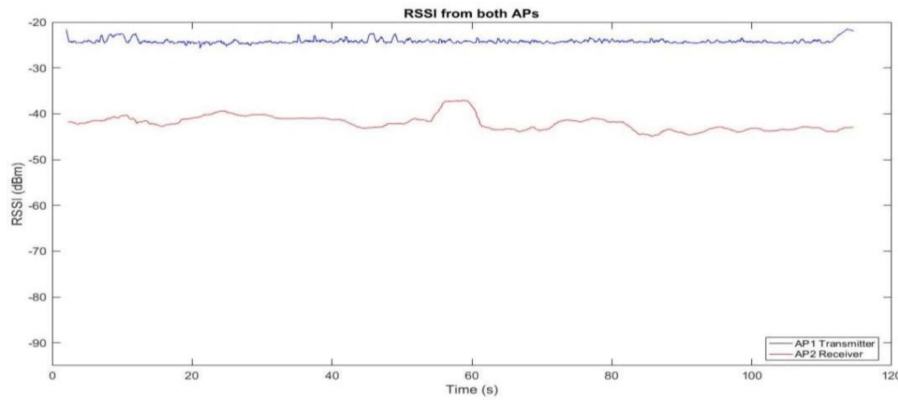

Fig. 7 RSSI from Transmitter and Receiver for different channel for further analyses

The above plot shows the transmitter signal, which has an RSSI range for the transmitter access point from -50 dBm to -22 dBm and the Receiver access point signal with an RSSI ranging from -68 dBm to -36 dBm. According to this plot, the transmitting signal's RSSI will decrease until it reaches the receiver.The transmitter should be placed so that the receiver has an RSSI of -40 dBm level in order to achieve a system accuracy of (96-100%)%. The two scenario shows the loss between 40 and 60% for the samples.

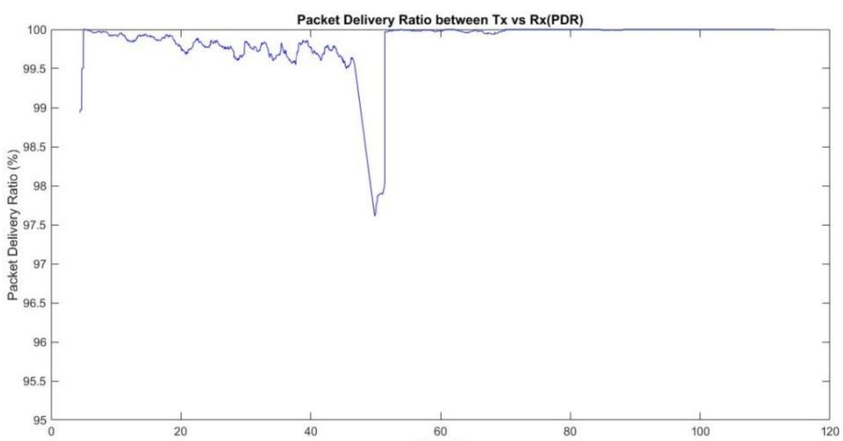

Fig. 8 Packet delivery Ratio of the proposed system on Matlab Simulation for Scenario 1

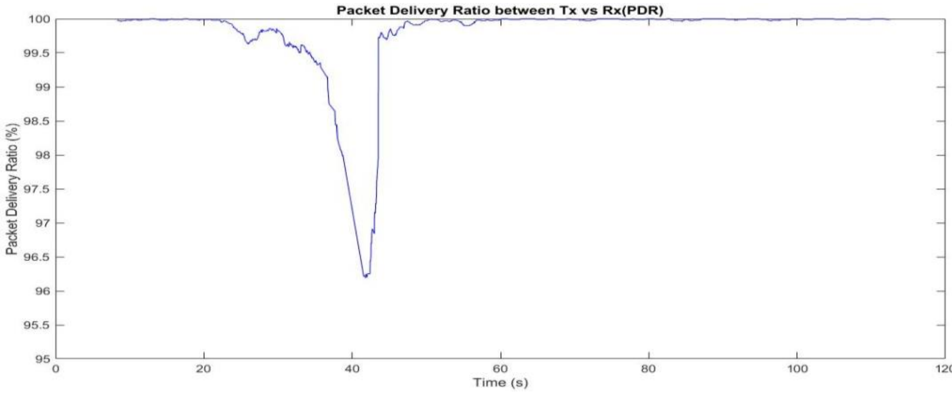

Fig.7 Packet delivery Ratio of the proposed system on Matlab Simulation for Scenario 2

The Packet delivery ratio [11] represents the total number of packet received to the total number of packet sent. In this case there arepacket almost representing 100 % in the initial cases but as the time interval increases from the range close to 40ms there is a packet loss by a very less margin we can say by 3 to 4 % which is a small number.To have extended the iteration for more values we consider the second case with the observation that the error was more wider at the initial time interval of 40ms which can be seen in fig 7. So we conclude the error will increase in the graph which narrates the real time scenario.

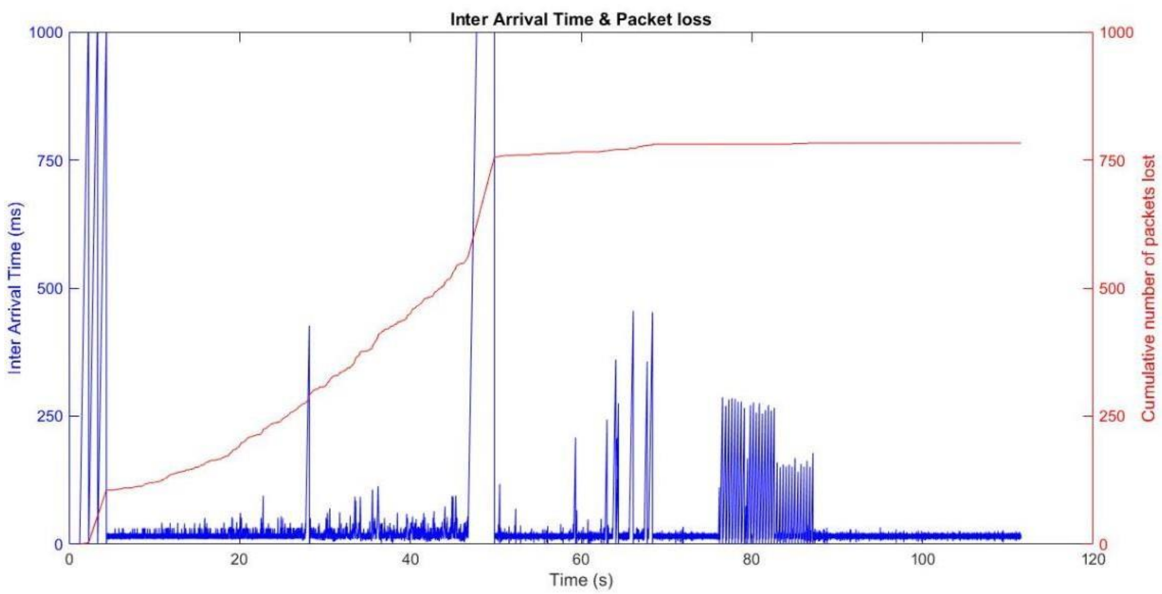

Fig.8 Cumulative Packet losses w.r.t. inter arrival time of Packets from Transmitter

This demonstrates that in the worst case, only (2-4%) of transmitting data is lost at the receiver, and (96-98%) successfully reaches the receiver. The greatest amount of data delivered from the transmitter to the receiver is 100%, and the least amount is (96-98%). Cumulative Packet losses w.r.t. inter arrival time of Packets from Transmitter are in millisecond showing a packet loss as the inter arrival and the packet loss are inversely proportional. In this case the number of intervals are significantly lesser in number of packet loss between transmitter and receiver.

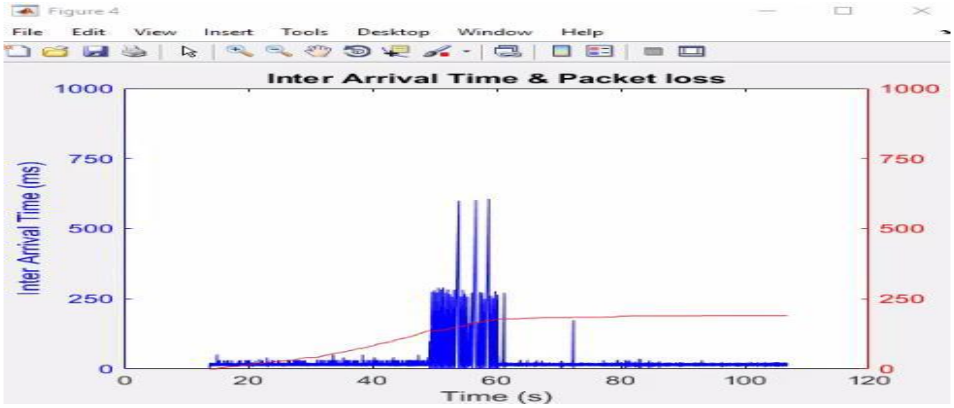

Fig.9 Inter Arrival Time & Packet Loss for A Single Channel

The above-mentioned data demonstrates the inter-arrival time between packets delivered andpacket loss at the receiver also rises accordingly. Theabove-mentioned plots advise us to keep the time interval for obtaining coordinates by each of the four different methods below 250–300 msec before combining them using other Methods to create a single coordinate system.

CONCLUSION

The work concludes with the demonstration of the inter arrival time and packet loss from the transmitter and the receiver variesconsidering the number of channels in the demonstration. The RSSI for a single and multiple channel systems are different which shows also some significant path loss at a particular time for multiple channel system.

FUTURE WORK

The idea behind the work illustrated is that the positioning system for one particular method has been shown with a significant illustration of Trilateration is one such method illustrated, there are other methods which can be shown such as the triangulation, proximity methods which can also show similar results but there are based on angle and time difference between nodes. In order to improve the accuracy of the signal strength we can use machine learning algorithm which can satisfy the requirement of the work to be carried out.

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