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Fast Handoff Implementation by using Curve Fitting Equation With Help of GPS

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Abstract

Due to rapid growth in IEEE 802.11 based Wireless Local Area Networks (WLAN), handoff has become a burning issue. A mobile station (MS) requires handoff when it travels out of the coverage area of its current access point (AP) and tries to associate with another AP. But handoff delays provide a serious barrier for such services to be made available to mobile platforms. Throughout the last few years there has been plenty of research aimed towards reducing the handoff delay incurred in the various levels of wireless communication. In this paper we propose a method using the GPS(Global Positioning System) to determine the positions of the MS at different instants of time and then by fitting a trend equation to the motion of the MS to determine the potential AP(s) where the MS has maximum probability of travelling in the future. This will result in a reduction of number of APs to be scanned as well as handoff latency will be reduced to a great extent.

Keywords: *IEEE 802.11, Handoff latency, GPS (Global Positioning System), Regression, Neighbor APs.*

1. Introduction

IEEE 802.11 based wireless local area network (WLAN) are widely used in domestic and official purpose due to its flexibility of wireless access. However, WLANs are restricted in their diameters to campus, buildings or even a single room. Due to the limited coverage areas of different APs a MS has to experience handoff from one AP to another frequently.

1.1 Handoff

When a MS moves out of reach of its current AP it must be reconnected to a new AP to continue its operation. The search for a new AP and subsequent registration under it constitute the handoff process which takes enough time (called handoff latency) to interfere with proper functioning of many applications.

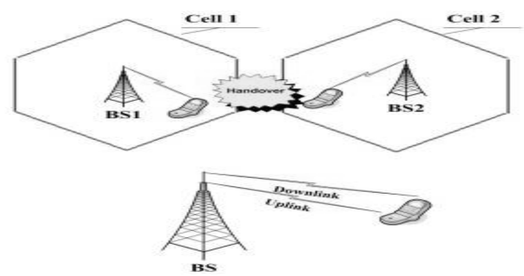

Figure 1. Handoff process

For successful implementation of seamless Voice over IP communications, the handoff latency should not exceed 50ms.It has been observed that in practical situations handoff takes approximately 200-300 ms to which scanning delay contributes almost 90%.This is not acceptable and thus the handoff latency should be minimized.

Three strategies have been proposed to detect the need for hand off[1]:

*1)mobile-controlled-handoff (MCHO):*The mobile station(MS) continuously monitors the signals of the surrounding base stations(BS)and initiates the hand off process when some handoff criteria are met.

2)network-controlled-handoff (NCHO):The surrounding BSs measure the signal from the MS and the network initiates the handoff process when some handoff criteria are met.

*3)mobile-assisted-handoff (MAHO):*The network asks the MS to measure the signal from the surrounding BSs.the network make the handoff decision based on reports from the MS.

Handoff can be of many types:

Hard Handoff: In this process radio link with old AP is broken before connection with new AP. This in turn results in prolonged handoff latency which is known as link switching delay.

Soft Handoff: This mechanism is employed nowadays. Here connection with old AP is maintained until radio link with new AP is established. This results in reduced handoff time in comparison to hard handoff as shown in figure 2.

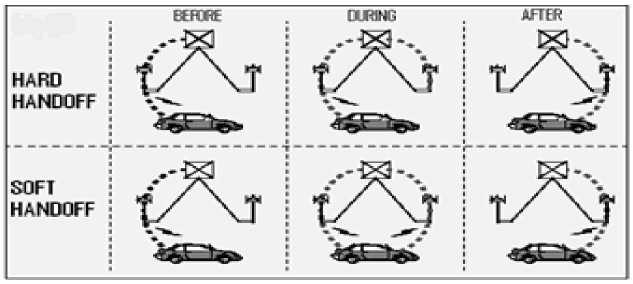

Figure 2. Hard & soft handoff

In NGWS(next generation wireless system),two types of handoff scenarios arise: horizontal handoff, vertical handoff[2][3].

- *Horizontal Handoff:* When the handoff occurs between two BSs of the same system it is termed as horizontal handoff. It can be further classified into two:
- *Link layer handoff* : Horizontal handoff between two BSs that are under the same foreign agent(FA).
- *Intra system handoff* : Horizontal handoff between two BSs that belong to two different FAs and both FAs belong to the same gateway foreign agent (GFA) and hence to the same system.
- *Vertical Handoff* : When the handoff occurs between two BSs that belong to two different GFAs and hence to two different systems it is termed as vertical handoff as shown in figure 3.

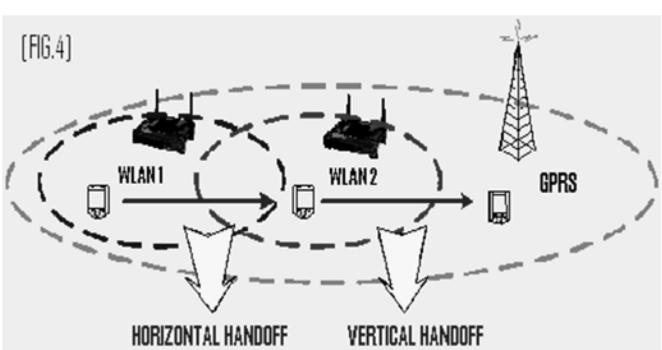

Figure 3. Horizontal & vertical handoff

1.2 Handoff Mechanism

The handoff process is composed of the following three stages:

Scanning: The scanning process constitutes the bulk (almost 90%) of the total handoff time [4]. As the MS starts moving away from the AP the *Signal-to-Noise-Ratio* (SNR) starts decreasing and this phenomenon triggers the initiation of handoff. The MS has to establish a radio link with a potential AP before the connectivity with the current AP is detached. This is accomplished by means of a MAC(Medium Access Control) layer function called *scanning*.

Authentication: After scanning, The MS sends authentication frames to inform the AP (selected by the scanning process) of its identity. The AP then responds by sending an authentication response frame indicating approval or rejection

Re-association: It is the process by which association transfer takes place from one AP to another. This process follows the authentication process depending on the authentication response sent by the AP.

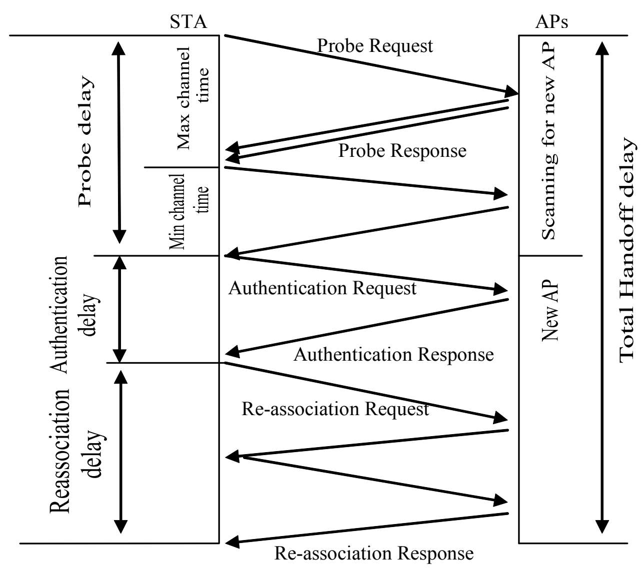

Figure 4. The handoff process

1.1 Global Positioning System

The *Global Positioning System* (GPS) is a space based global navigation satellite system which is used in map making, land surveying, navigation, geocaching and in

other fields. A GPS receiver is able to calculate its position by precisely timing the signals sent by the GPS satellites. The receiver uses the received messages from the satellites to determine the transit time of each message and calculates the distance to each satellite. These distances are then utilized to compute the position of the receiver. For normal operation a minimum of four satellites are necessary. Using the messages received from the satellites the receiver is able to calculate the times sent and the satellite positions corresponding to these points.
Each MS is equipped with a GPS receiver which is used to determine the positions of the MS at different instants of time. This will provide knowledge about the MS's movement within 1 to 2 meter precision.

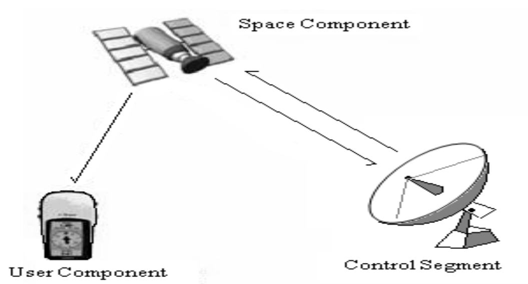

Figure5. Components of GPS

In section II we take you through the various works that have already been done to achieve successful handoff and in section III we introduce a new method using the statistical regression over the movement of MS by which we intend to reduce the handoff delay to the range of a few milliseconds. This is followed by performance evaluation of our proposed technique using simulations in section IV after which in section V we propose a few areas in which further improvement can be made.

2. Related works

A number of different schemes have been proposed to reduce handoff latency in IEEE 802.11 wireless LANs. Authors of [8] aimed at reducing the authentication process which contributes very little to the handoff time.
In [5] authors present a useful method using a neighbor graph and a non overlap graph. This concept was used to reduce total number of channels to be scanned and the waiting time on each channel. However the complexity of implementation of the algorithm was a major setback. In [6] a channel mask scheme was introduced where a selective scanning algorithm was proposed along with a caching mechanism. In [7] authors propose selective scanning algorithm using neighbor graphs. This method requires changes in the network infrastructure and use of IAPP. Moreover, these processes involve channel scanning of all neighboring APs and do not consider the position or velocity of MS to select potential APs. Hence these methods are more power consuming and are less effective for reducing handoff.

3. Proposed Works

Here we propose a method depending upon statistical regression to minimize the handoff delay. We will select the potential APs where the MS has maximum probability of travelling when it moves out of the coverage area of its present AP. Thus we will minimize handoff delay by Scanning only the potential APs for available channels. . We implement our method with the help of GPS. We present the method in the following four sections:

3.1 Definition of Parameters

In an idealized model we approximate the overlapping circular cell areas by hexagonal cells that cover the entire service region with the AP being located at the centre of the hexagon. For the sake of simplicity we consider that a particular hexagonal cell is surrounded by six similar cells (7 cell cluster). Considering the entire cell area as a two dimensional plane, we define two mutually perpendicular coordinate axes namely the X and Y axes with the AP as the origin. Now let us consider the motion of a MS in a particular cell. The position namely the X and Y coordinates of a MS can be obtained via a GPS.
As shown in the figure.6 we divide the cell into two regions:
(a) REGION 1(white region): This denotes the core region where the GPS is used to monitor the position of the MS.
(b) REGION 2(grey region): This denotes the region where the signal strength received by the MS falls below a threshold value and the MS starts the scanning process to initiate handoff.

3.2 Handoff Initiation

As long as the MS is travelling in region 1 no handoff is required. Here we note the (x, y) coordinates of the MS via the GPS. Let the initial position(at time $t=t_o$ sec) of the MS be denoted by (x_o, y_o) with respect to the origin. This process is repeated after a fixed time interval of T sec. When the MS leaves region 1 and enters region 2 the scanning of MS's position by the GPS is stopped. Handoff process has to be initiated. Here we propose a statistical method of regression to determine the potential APs where the MS has maximum chance of moving. During handoff it will scan only the channels of those APs.

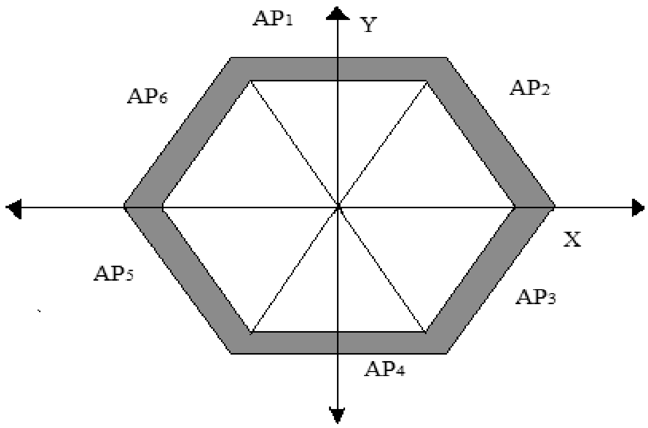

Figure 6.The hexagonal cell

Table1. Angle division

UPPER LIMIT OF θ	LOWER LIMIT OF θ	AP TO BE SCANNED(VIDE FIG.6)
0^0	*60^0*	*AP2*
60^0	*120^0*	*AP1*
120^0	*180^0*	*AP6*
180^0	*240^0*	*AP5*
240^0	*300^0*	*AP4*
300^0	*360^0*	*AP3*

3.3 Selection of Potential AP by Regression Method

We employ the *method of least squares* to fit curves for the motion of the MS. Let the equation of motion of the MS along the Y-direction be denoted by $y=a_0+a_1t$.We are now faced with the problem of choosing the values of the variables a_0 and a_1. The sum of the squares of the deviations of the data points with those obtained from the proposed curve is given by,

$$S=\sum (y_i-a_0-a_1t_i)^2$$

The method of least squares states that S should be minimum with respect to a_0 and a_1. This metric has many desirable characteristics:

Errors of opposite sign are not cancelled.

It weighs large errors more than small errors.

To minimize S we take the partial derivative of S with respect to a_0 and a_1 and set these to zero. Thus,

$$\partial S/\partial a_0 =\sum 2(y_i - a_0 - a_1t_i)(-1) = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$\partial S/\partial a_1 =\sum 2(y_i - a_0 - a_1t_i)(-t_i) = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Solving the above equations we obtain estimates for a_0 and a_1.

$$a_0=[\sum y_i\sum t_i^2-\sum t_i\sum yit_i]/[n\sum t_i^2-(\sum t_i)^2] \quad \ldots\ldots\ldots\ldots\ldots\ldots..(3)$$

$$a_1= [n\sum y_i\, t_i - \sum y_i\sum t_i]/[n\sum t_i^2-(\sum t_i)^2] \quad \ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

Similarly by the least squares method it is possible to fit a regression line for the equation of motion of the MS along the X direction. Let the regression equation along y axes be denoted by $x=b_0 + b_1t$ where b_0 and b_1 are estimated by the above mentioned method.

Now, with the regression equations it will be possible to predict the position of the MS outside the present cell. Let the MS enters region 2 of the present cell at time $t=t^/$ sec. Before the handoff process starts the regression lines are computed. We evaluate the probabilistic (x, y) coordinates of the MS at time $t= (t^/ + T^/)$ sec by putting $t= (t^/ + T^/)$ sec in the two regression equations for the x and y coordinates. If the predicted MS's position still falls within the present AP then the probabilistic position is calculated at time $t= (t^/ + 2T^/)$ sec and the process continues. Here $T^/$ is a fixed time interval after which probabilistic positions are computed and should be appropriately chosen depending on the cell size. The first position of the MS which falls outside the current cell area as indicated by the regression equations is denoted by $(x^/, y^/)$. The AP within which this point falls can be evaluated by knowing the angle this point makes with the coordinate axes.

It is to be noted that the time consumed to predict the MS's position outside the present cell area is quite small and can be neglected for practical purposes. The angle θ that the point $(x^/, y^/)$ makes with the X axis is given by $\theta = \tan^{-1} (y^/ / x^/)$. The value of θ can be used to determine the potential AP which has to be scanned.

3.4 Error Estimation

Although we have opted for the best fit yet there will be some amount of error, however small, which has to be taken into consideration. For the error estimation we propose the following method.

Let us first concentrate on the regression line of x on t. Let α denote the maximum magnitude of the deviation of the data points from the predicted values obtained from the equation $x=a_0 + a_1t$. Hence

$\alpha = \max (I\, x_i - a_0 - a_1t_i I)$ for i =0, 1, 2 ...……. n

Similarly let β denote the maximum magnitude of the deviation of the data points from the predicted values obtained from the equation $y=b_0 + b_1t$. Hence

$\beta = \max (I\, y_i - b_0 - b_1t_i I)$ for i =0, 1, 2 ………… n

Thus we may assume the maximum variation that can take place in the y coordinate of a predicted value obtained from the equation $y=a_0 + a_1t$ to be α. Thus the y coordinate of the MS may vary between $y^/-\alpha$ and $y^/+ \alpha$. Similarly this variation takes the value of β for motion along x axis. Thus considering error measures the MS has the probability of being located in the rectangle as shown in the following figure with maximum probability being located at the centre (x', y'). From the above discussion it is clear that the coordinates of the vertices of the rectangle ABCD are A $(x'-\alpha, y'+\beta)$, B $(x'+\alpha, y'+\beta)$, C $(x'+\alpha, y'-\beta)$ and D $(x'-\alpha, y'-\beta)$. However, our concern is variation of θ. Clearly considering such error measures minimum value of θ will result when the MS is located at C and maximum value will result when the MS is located at vertex A.

Thus $\theta_{min}= \tan^{-1}(y'-\beta/x'+\alpha)$

and $\theta_{max}= \tan^{-1}(y'+\beta/x'-\alpha)$.

Thus we effectively have a range of values of θ with the most probable value being $\tan^{-1}(y'/x')$. For good fitting the values of α and β will be quite small in comparison to x' and y' and hence in most cases the range of values of θ will be small enough to yield 1 AP or at the most 2 APs for scanning purposes.

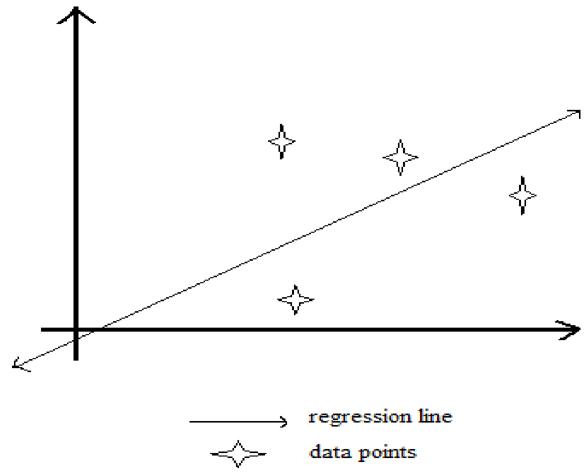

Figure.7A. Illustration of the error estimation

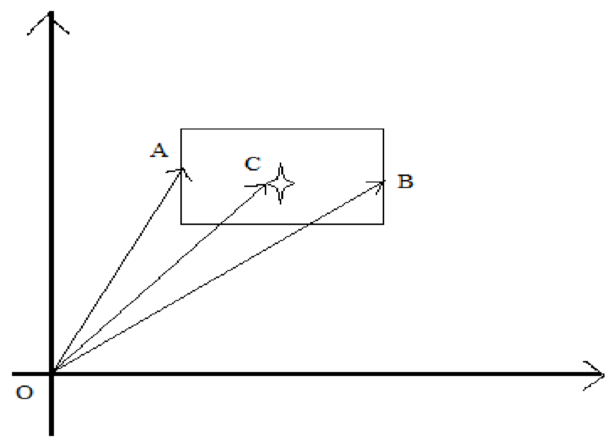

Figure.7B Illustration of the error estimation

3.5 Scanning and Pre-authentication

All necessary information like MAC(Medium Access Control) addresses and operating channels of the neighbor APs are downloaded by the MS from the server data. Selective channel scanning with the help of uncast instead of broadcast efficiently reduces the handoff delay to a great extent. Moreover, the MS has to wait for only the ‘round trip time’ (rtt) for scanning each channel instead of the Min Channel Time or the Max Channel Time. When the MS responds to handoff, according to the proposed algorithm, it first looks for the potential AP and then scans the channels of that AP. As proposed in [9], the expected scanning delay using selective scanning is,

$$t = N \times \Gamma + \omega$$

where‘t’ is the scanning delay, ‘N’ is the number of channels scanned, ‘Γ’ is the round trip time and ‘ω’ is the message processing time. ‘Γ’ is the summation of the time taken for the Probe Request to be sent to the selected AP’s and for the Probe Response to be received, which has been estimated to be around 3-7 ms. By pre-authentication during the scanning phase the factor ω would also be greatly reduced and would consist only of the re-association time. This mechanism can be implemented as proposed in [10].

4. Simulation Results

Simulations of a sample run of our experiment have been presented here. We consider the handover for a MS from the cell in which its call originates. The coverage region of the AP is taken as regular hexagon of length 100m approx. The handoff region starts at a radial distance of 90m from the AP. The mobility pattern of the MS has been presented in Fig.8 which was tracked by GPS at an interval of 5 s.

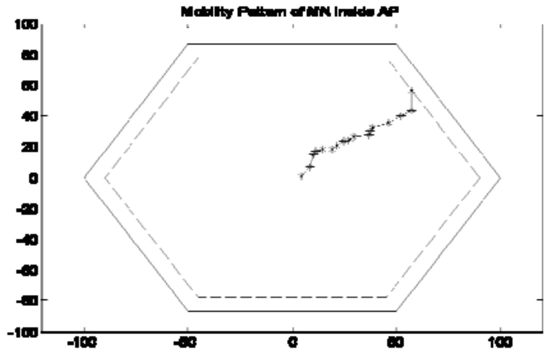

Figure.8

On entering the handoff region GPS was turned off. Regression lines for X and Y axes were computed. The equations in this case turned out to be
$x = 4.583159 + 0.532045\ t$ and
$y = 7.017031 + 0.399405\ t$

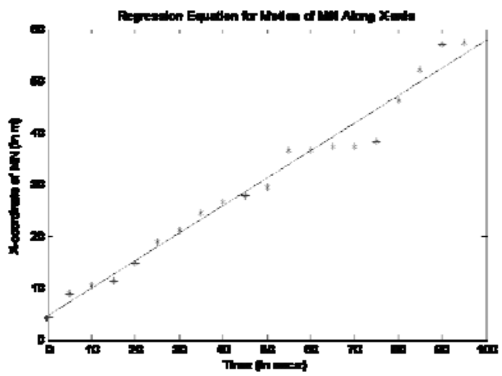

Figure.9

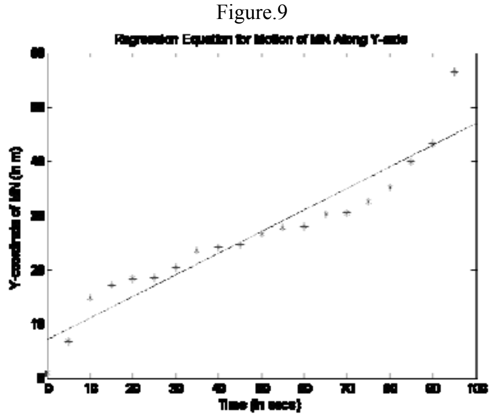

Figure 10

Hence the parameters computed were
$x' = 71.089$ m, $y' = 56.943$ m and $\theta = 38.695$ (degree)
The deviations of predicted from actual positions of MS obtained by GPS were plotted for both axis.

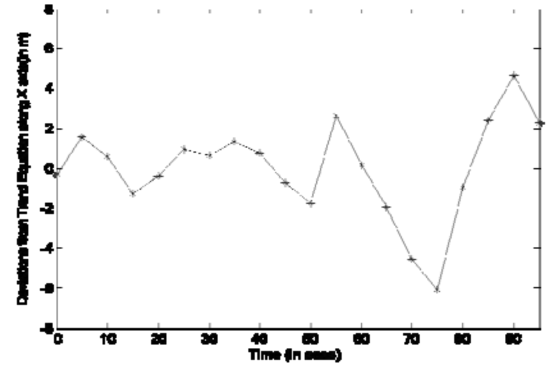

Figure.11

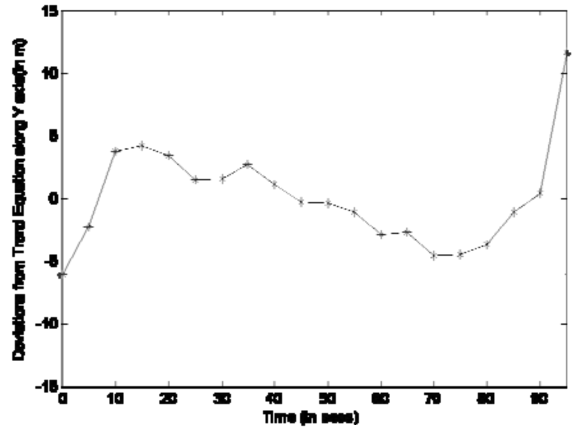

Figure.12

Hence, $\alpha = 6.086$ m
and $\beta = 11.579$ m
Thus, $\theta_{min}= \tan^{-1}(y'-\beta/x'+\alpha)= 30.447$(degree)
and $\theta_{max}= \tan^{-1}(y'+ \beta/x'-\alpha)= 46.510$(degree)
This indicates that the MS is moving towards AP2 as the expected range of angle lies between 0 and 60 degrees.
We made 100 such sample runs by varying various parameters like mobility range and velocity of MS, cell coverage area, etc. In 89% of the cases one potential AP was selected while in 9% cases two potential APs were selected. The remaining 2% constituted cases where potential APs selected by the proposed algorithm resulted in association failure leading to an efficient full scanning of the channels of other APs (approx 30-40 ms). Taking the 'round trip time' (rtt) as 3 msec the average handoff latency measured was 6.563 msec which is a drastic improvement in comparison to earlier proposed methods. The graph of this simulation is plotted in Fig.12, which shows the various handoff delay times in the Y-axis in msec, for each experiment, which is shown in the X-axis.
The success of our simulation clearly depicts the applicability of our proposed algorithm.

5. Conclusion

Our proposed method aims at reducing handoff time by reducing the number of APs to be scanned which is accomplished by fitting a trend equation to the motion of the MS. This in turn reduces the number of channels to be scanned which brilliantly reduces the handoff delay as is clear from the simulation presented in the above section. In the proposed algorithm a linear trend equation has been fitted because it is the most common and trustworthy fit. However higher order polynomials may also be used for fitting and best fit may be chosen by comparing the norm of the residuals.

However the proposed algorithm may prove erroneous if the motion of the MS is too much random to be used for prediction purposes. Future works in this field may include research on more refined algorithms regarding curve fitting and prediction. Error estimation method may also be improved. It is worth mentioning here that although the proposed work has been presented considering honeycomb structures yet our algorithm would work in a similar manner for other cell structures and neighbor AP locations. Minor changes would be introduced depending on the network topology.

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