# A New Cost Efficient and Low Latency Handoff in Wireless Networks

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## ABSTRACT
Presently, IEEE 802.11 based wireless local area networks (WLAN) have been widely deployed for business and personal applications. The main issue regarding wireless network technology is handoff or hand over management, especially in urban areas, due to the limited coverage of access points (APs) or base stations (BS). In this paper a new cost efficient and low latency handoff scheme is proposed where the number of access points (AP) is optimized in such a way that it fulfils both the criteria of low cost and low handoff latency. Here an efficient mathematical design utilizing the data's available from the base station is implemented which includes maximum number of active calls within a network, number of calls it can support and range of connectivity or coverage area. The simulations were performed in MATLAB 7.8 to judge the applicability of the model in practical field.

## General Terms
Mathematical Model, Wireless Communication.

## Keywords
Access Point (AP), Handover latency, Optimization, High and Low Load Network, Coverage Area.

## 1. INTRODUCTION
Handoff has become a plaguing factor in mobile communication system, especially in urban areas, owing to the limited coverage area of Access Points (AP). Whenever a mobile station (MS) moves from its current AP to a new AP it requires handoff. For successful implementation of seamless Voice over IP communications, the handoff latency should not exceed 50ms. But measurements indicate MAC layer handoff latencies in the range of 400ms which is completely unacceptable and thus must be reduced for wireless networking to fulfill its potential.

With the advent of real time applications, the latency and packet loss caused by mobility became an important issue in Mobile Networks. The most relevant topic of discussion is to reduce the IEEE 802.11 link-layer handoff latency. IEEE 802.11 MAC specification [1] defines two operation modes: ad hoc and infrastructure mode. In the ad hoc mode, two or more stations (STAs) recognize each other through beacons and hence establish a peer-to-peer relationship. In infrastructure mode, an AP provides network connectivity to its associated STAs to form a Basic Service Set (BSS). Multiple APs form an Extended Service Set (ESS) that constructs the same wireless networks.

### 1.1 Channel distribution
IEEE802.11b and IEEE802.11g operates in the 2.4GHz ISM band and use 11 of the maximum 14 channels available and are hence compatible due to use of same frequency channels. The channels (numbered 1to14) are spaced by 5MHz with a bandwidth of 22MHz, 11MHz above and below the centre of the channel. In addition there is a guard band of 1MHz at the base to accommodate out-of-band emissions below 2.4GHz. Thus a transmitter set at channel one transmits signal from 2.401GHz to 2.423GHz and so on to give the standard channel frequency distribution as shown in Figure1.

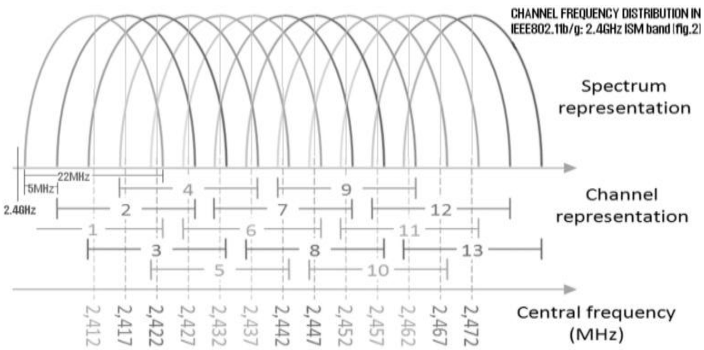


**Figure1. Channel distribution in IEEE802.11b**

It should be noted that due to overlapping of frequencies there can be significant interference between adjacent APs. Thus, in a well configured network, most of the APs will operate on the non-overlapping channels numbered 1, 6 and 11.

## 1.2 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. Three strategies have been proposed to detect the need for hand off [2]:

- **Mobile-controlled-handoff** (MCHO): The MS continuously monitors the signals of the surrounding base stations (BS) and initiates the hand off process when some handoff criteria are met.
- **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.
- **Mobile-assisted-handoff** (MAHO): The network asks the MS to measure the signal from the surrounding BSs. The network makes the handoff decision based on reports from the MS.

Two separate types of handoff approach are adopted i.e. hard & soft handoff depending upon the network criteria. Originally hard handoff is used where a station must break connection with the old AP before joining the new AP thus resulting in large handoff delays. However, in soft handoff the old connection is maintained until a new one is established thus significantly reducing packet loss. The handoff procedure consists of three logical phases which is depicted in Figure2.

The number of APS used varies with the density of users in a network and other parameters like coverage area. An optimal solution in placement of the network calls for looking through this issues and maintaining low handoff latency. In this paper an Optimal solution to the problem of number of APs required to be placed and the distance between them is dealt with in consideration to input parameters which includes Call density, call blocking probability, call termination rate and number of servers. To the best of knowledge this issue hasn't been answered in any manuscript. Overall the provided optimal solution reduces the cost of the network by maintaining good Quality of Service (QOS).

In section II the related work to this field are discussed and in section III the proposed mathematical model based optimization procedure is presented. This is followed by performance evaluation using simulations in MATLAB 7.8 in section IV. Section V provides an in-depth conclusion with provisions for further research in this field.

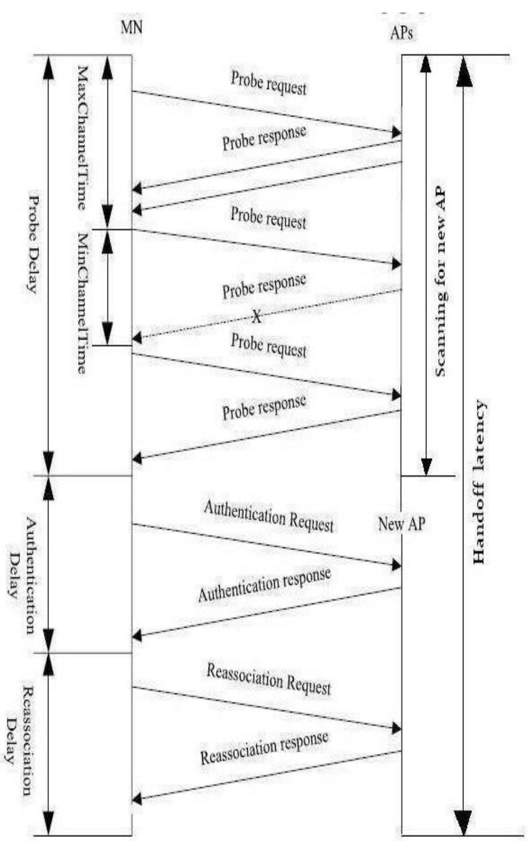


**Figure2. Stages in Handover in Wireless Network**

## 2. REALTED WORKS

A number of different methods have been proposed to reduce handoff latency in IEEE 802.11 wireless LANs. IEEE 802.11b based wireless and mobile networks [3], also called Wi-Fi commercially, are experiencing a very fast growth upsurge and are being widely deployed for providing variety of services as it is cheap, and allows anytime, anywhere access to network data. The new age applications require a seamless handover while the small coverage of individual APs has increased the number of handoffs taking place. Thus reducing the handoff latency has become a burning issue and much work has been done to achieve this. An overall review of handoff latency reduction methods are presented in [4]. Shin et al in [5] have introduced a selective scanning algorithm with the help of channel masking technique coupled with a caching mechanism to significantly reduce the handoff delay. However, it still scans excess APs even after the new AP may have already been found and thus leaves room for further improvements. Handoff, an inherent problem with wireless networks, particularly real time applications, has not been well addressed in IEEE 802.11, which takes a hard handoff approach [6]. In [7] the authors have introduced a novel caching process using neighbour graphs by pre-scanning neighbour APs to collect their respective channel information. The concept of neighbour graphs can be utilized in different ways and have become very popular in this field. In [8] a pre-authentication mechanism is introduced to facilitate seamless handover. [9] is a novel approach towards reducing handover latency in AP dense networks. In [10] a cross layer handoff management protocol scheme has been proposed which tried to enhance the handoff performance by analyzing the speed of the mobile node, handoff signaling delay, relative signal strength of old and new base station and their relation with handoff failure probability. A novel mobility management system is proposed in [11] for vertical handoff between WWAN and WLAN. The system integrates a connection manager (CM) that intelligently detects the changes in wireless network and a virtual connectivity manager (VCM) mantains connectivity using end-to-end priciple. Authors of [12] propose solutions towards enabling and supporting all types of mobility in heterogeneous networks. The proposed approach does not support real time applications by the network mobility functionality. This keeps the application unaware of network mobility and works as a back up for real time applications. Handoff using received signal strength (RSS) of BS has been proposed also to reduce handoff latency in NGWS. In [13], the authors proposed a handoff algorithm in which the received pilot signal strength is typically averaged to diminish the undesirable effect of the fast fading component. Unfortunately, the averaging process can substantially alter the characteristics of path loss and shadowing components, causing increased handoff delay. In [14], a handoff algorithm using multi-level thresholds is proposed. The performance results obtained, shows that an 8-level threshold algorithm operates better than a single threshold algorithm in terms of forced termination and call blocking probabilities. In [15] signal to interference ratio between old base-station and neighboring base-stations are calculated to make the handoff initiation decision for next generation wireless system or 4G networks. In [16], a handoff algorithm using multi-level thresholds is proposed. The performance results obtained, shows that an 8-level threshold algorithm operates better than a single threshold algorithm in terms of forced termination and call blocking probabilities. In research paper [17] a handoff management technique has been proposed where a curve fitting equation is implemented to the trajectory of MS by statistical regression method and the most potential AP is chosen according to the direction of the curve. In research paper [18 an efficient distance measurement technique where the distances between MS and the neighbor APs are measured and the nearest one is chosen as the best AP is proposed. In paper [19] authors proposed an angular displacement measurement technique where the cell segmenting had been done and each of the neighbor APs are assigned to each segment.

Other than handover delay reduction or handover management, research is yet to be done on the field of cost reduction in wireless networks. In literature no such paper exists to have dealt with the solution f this problem.

## 3. PROPOSED METHOD

Networks used for wireless and mobile communication use access points (AP) or base station (BS) to provide all time connectivity between the servers. Call density, call blocking probability, call termination rate and number of servers are deciding parameters to design a cost efficient low latency wireless network. An efficient network design calls for efficient installation of AP in a desired coverage region. In the proposed method following parameters are used:

$P_b$ = Call Blocking Probability of an AP

$S_i$ = The coverage region defined in terms of topology for an AP $i$ .

$C_{i,t}$ = Te number of active calls with an AP $i$ .at an hour interval $t$ .

$N_i$ =The minimum number of subscriber that can be supported by an AP $i$ .

$D_{i,j}$ = An arbitrary distance parameter which traces out the distance between the two APs $i$ .and $j$ .for the various values of parameters stated above.

### 3.1 Circular cell coverage area*:*

Due to fading of signal strength (*fast fading* due to scattering from interfering objects & s*low fading* due to long term spatial and variations, inversely proportional to the square of the distance) it is consider that each base station services a circular area (depending on the height of the antenna and power of its signal) beyond which signal strength becomes lower than usable levels. But for the presence of obstacles (like buildings, mountains) an exact circular cell area cannot be obtained. For this reason here topological concept is used which helps to consider the coverage area as a circle of radius $S_i$ for the $i^{th}$ AP, as shown in Figure 3.

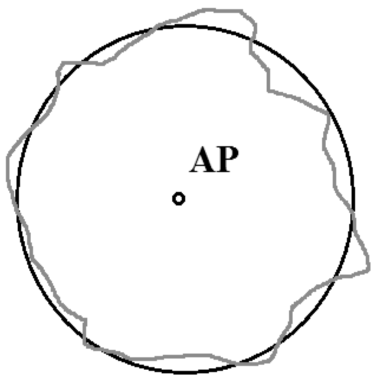


**Figure3. The actual and assumed coverage area of an AP**

## 3.2 Optimization of AP

For providing an all time connectivity if the number of active calls exceed the maximum achievable load of the AP then the overlapping coverage areas are required to sustain the requirement of the subscribers. A typical diagram for a low load and high load network considering the coverage area of each AP to be the same (i.e. smooth terrain) are shown in Figure4 and Figure5 respectively. Here a seven cell cluster is considered (i.e. number of cells $i^2 + j^2 + i \times j$, where $i = 2, j = 1$) and carried on this convention for rest of the papers.

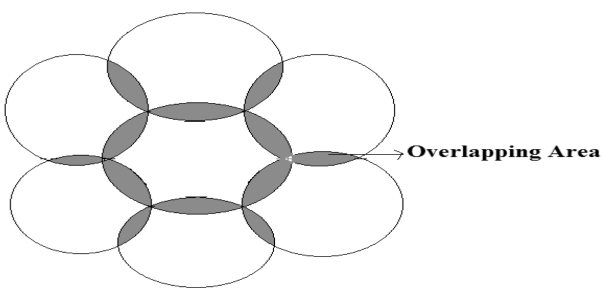


**Figure4. Overlapping coverage region for low load networks**

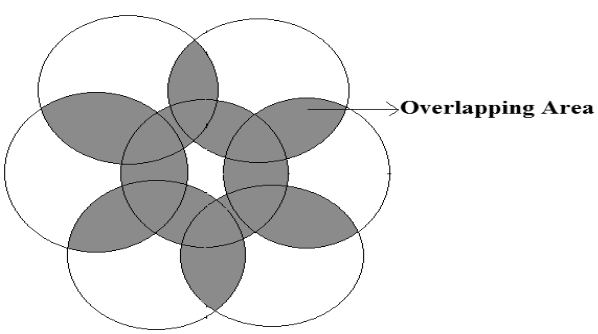


**Figure5. Overlapping coverage region for high load networks**

## 3.3 Placement of optimized AP for Cost effectiveness and low latency

The cost effectiveness and low latency through a mathematical approach is explained in this section. In this section the exact position of APs will be determined for which it could provide a low latency handoff scheme in communication network along with network cost optimization. In order to determine the placement of an AP in a network the parameter $D_{i,j}$ is used depending upon the mathematical derivations which will be stated afterwards.

In designing the wireless communication network, the prime constraint is the handover distance. To satisfy this constraint a minimum distance of overlapping coverage area between two APs must exist for efficient handover of subscriber connection in the network which in turn provides low latency. Let the minimum perpendicular distance of overlap between two APs be α, as shown in Figure6.

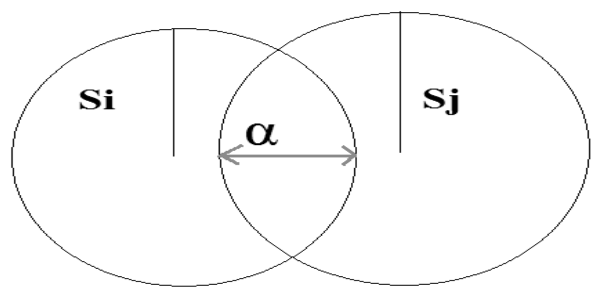


**Figure6. Perpendicular Distance of overlap between two AP**

The maximum separation that may occur between two APs $AP_i$ and $AP_j$ with radius $S_i$ and $S_j$ is $S_i + S_j - \alpha$ .The call blocking probability of $AP_i$ is defined mathematically as,

$$Pb_i = \{(C_{i,t})_{\max imum} - N_i\} / N_i$$

And that is for $AP_j$ is defined as,

$$Pb_j = \{(C_{j,t})_{\max imum} - N_j\} / N_j$$

As, $0 \leq Pb_i, Pb_j \leq 1$

Therefore, $Pb_i \times Pb_j \leq (Pb_i, Pb_j)$

So by increasing the overlapping region or in other words decreasing the distance between two APs a network design can be achieved with improved quality of service. We have defined a variable μ (user defined matrix) which guides the distance between two APs in terms of the blocking probability.

For optimizing the overlapping region between two AP $i$ and $j$ is defined by $\alpha_{i,j}$ as,

$$\alpha_{i,j} = \mu_{i,j} \times Pb_i \times Pb_j$$

The above equation stands as follows on putting the respective values,

$$\mu \times [\{(C_{i,j})_{\max imum} - N_i\} / N_i] \times [\{(C_{j,t})_{\max imum} - N_j\} / N_j]$$

Now $\mu_{i,j}$ is the optimization factor which guides the over lapping region between two APs. It is evident that the minimum value which µ can attain is,

$$\mu_{\min} = \alpha_{\min} / (Pb_i \times Pb_j)$$

But for such case lower connectivity is ensured in the network. For optimizing µ we define an arbitrary variable P which gives the blocking value based on the blocking probability of the whole network. For n number of APs in a network with separation as found in above equation for $\alpha_{i,j}$ and the for the overlapping area in AP1 and AP2 as shown in Figure6, the variable P can be defined as,

$$P = \sum_{i=1}^{n} Pb_i + \sum_{i=1, j=1}^{n} (Pb_i \times Pb_j) + \sum_{i=1, j=1, k=1}^{n} (Pb_i \times Pb_j \times Pb_k) + .....$$

In the above equation, 1st term defines the blocking probability of region of $i^{th}$ AP without any overlapping region. 2nd term defines the overlapping region of $AP_i$ and $AP_j$. 3rd term defines the overlapping region of $AP_i$, $AP_j$ and $AP_k$ and the rest of the terms are defined in a similar way. So, for particular optimization matrix $\mu$ the common coverage distance matrix $\alpha$ is derived from which the distance separation matrix $D$ is calculated. It may be noted here that for the APs which have no direct connection between them i.e. no overlapping region, the value of $\mu_{i,j}$ will be zero.

The cost effectiveness can be determined by the number of APs required to be deployed in the network following the data calculated from the above procedure. For a network where N numbers of APs are present the total cost is given by the equation

$$C = N \times X$$

Where $X$ is the cost of setting up one AP.

The number of AP required for a particular area can be determined by the spacing factor $D_{i,j}$. In the simulation section the variability of P and C with different values of $\mu_{i,j}$ and the optimized value is shown i.e. the value for which the minimum possible value of P and C are obtained (with tradeoffs), is taken as the design parameter. So, for a defined set of blocking probability, maximum load and network area to be covered the optimized number of AP and the cost of the network can be determined.

## 4. SIMULATION RESULT

In this section a design is done to show the applicability of the model proposed in the previous section. For justifying the practicability of the method in real models an artificial environment is created where the method is implemented. The network traffic is considered to be Poisson both in respect to arrival and density of callers in an area. As µ is a user defined matrix let it be an arbitrary matrix defined as below (this is just demonstrated as an example and this kind of scenario may be bizarre to this context),

$$\mu = \begin{bmatrix} a & a+1 & a+2 \\ a+1 & a+3 & a+4 \\ a+2 & a+4 & a+5 \end{bmatrix}$$

The parameter 'a' is a variable on which the optimization factor depends. To find the optimized value the variable 'a' is varied to calculate the optimal solution to the above matrix µ. The plot for various values of 'a' with network cost C and blocking probability are shown in Figure 7 and 8 which are done with values for the defined parameters in section 3 generated by Poisson distribution function which adds to the real time based simulation for the method. The number of active calls with an AP at an hour interval $C_{i,t}$ was taken to be 12 and minimum number of subscriber that can be supported by an AP was taken as 15.

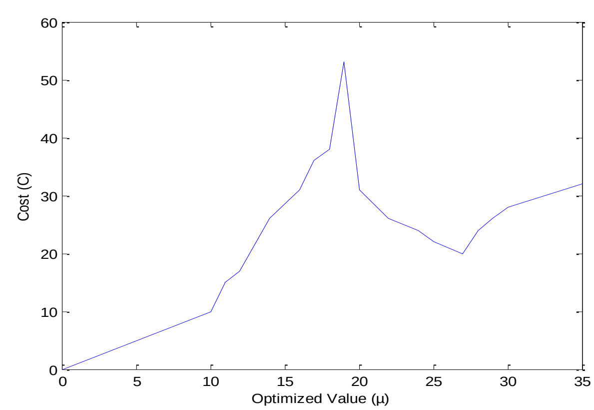


**Figure7. Plot of the cost (C) with varying optimization factor**

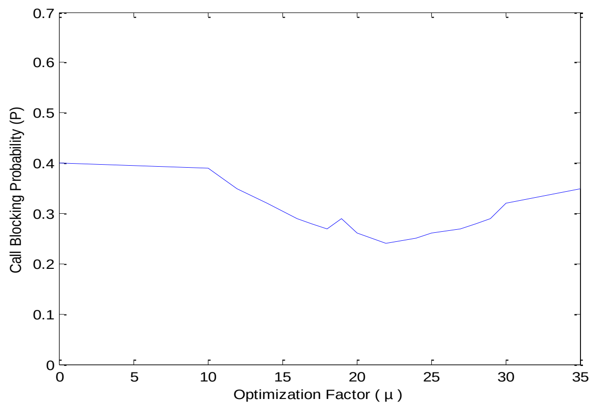


**Figure8. Plot of the blocking probability with varying optimization factor**

From Figure 7 and 8, the minimum value of P and C is obtained at μ = 23 for the hypothetical network designed. For different networks the value of the above parameters will change and according to those parameters different optimized value of μ can be obtained.

## 5. CONCLUSION

The optimization technique discussed above guarantees a low cost adaptive wireless network with optimal blocking probability and number of APS required to design the network i.e. it acts as an efficient design tool. Here the optimization factor is defined in terms of the common area of coverage between two APS. Optimization can also be done in reference to signal strength with more complex situations where dynamic nodes are deployed. Future research prospect following this work can be designing an efficient optimization factor in respect to these situations and parameters.

## 6. REFERENCES

[1] Hye-Soo Kim, Sang Hee Park, Chun-Su Park, Jae Won Kim and Sung-Jea Ko. “Selective Channel Scanning for Fast Handoff in Wireless LAN using Neighbor Graph”, July 2004.

[2] Hongqiang Zhai, Xiang Chen, and Yuguang Fang. “How well can the IEEE 802.11 wireless lan support quality of service?” IEEE Transactions on Wireless Communications, 4(6):3084-3094, December 2005.

[3] STEMM, M. and KATZ, R. H., "Vertical handoffs in wireless overlay networks," ACM/*Springer Journal of Mobile Networks and Applications*(MONET), vol. 3, no. 4, pp. 335-350, 1998.

[4] Jaeyoung Choi *Student Member, IEEE*, Taekyoung Kwon & Yanghee Choi, *Senior Member IEEE,* Sangheon Pack *Member*, , *IEEE,*Fast Handoff Support in IEEE 802.11 Wireless Networks.

[5] Arunesh Mishra, Minho Shin & William Arbaugh, An Empirical Analysis of the IEEE 802.11 MAC Layer Handoff Process. [Anshuman Singh Rawat & Henning Schulzrinne Reducing MAC Layer Handoff Latency in IEEE 802.11 Wireless LANs.

[6] Sangho Shin, Andrea G. Forte, Context Caching using Neighbor Graphs for Fast Handoffs in a Wireless Network.

[7] S. Park and Y. Choi Pre-authenticated fast handoff in a public wireless LAN based on IEEE802.1x mode IFIP TC6 Personal Wireless Communications. Singapore, October 2002.

[8] Jin Teng, Changqing Xu, Weijia Jia, Dong Xuan, D-scan: Enabling Fast and Smooth Handoffs in AP-dense802.11 Wireless Networks.

[9] Chien-Chao Tseng, K-H Chi, M-D Hsieh & H-H Chang, Location-based Fast Handoff for 802.11 Networks. IEEE COMMUNICATIONS LETTERS, VOL9, NO 4 April 2005.

[10] S.Mohanty and I.F. Akyildiz,’A Cross-Layer(Layer 2+3) Handoff Management Protocol for Next-Generation Wireless Systems’,IEEE Transactions On Mobile Computing,Vol-5,No-10 OCT 2006.

[11] Q. Zhang, C. Guo, Z. Guo and W. Zhu, Wireless and Networking Group, Microsoft Research Asia,” Efficient Mobility Management for Vertical Handoff between WWAN and WLAN’’ IEEE,communications Magazine,2003.

[12] I.F. Akyildiz, J. Xie, and S. Mohanty, “A Survey on Mobility Management in Next Generation All-IP Based Wireless Systems,” IEEE Wireless Comm., vol. 11, no. 4, pp. 16-28, Aug. 2004.

[13] I.F. Akyildiz, S. Mohanty, and J. Xie, “A Ubiquitous Mobile Communication Architecture for Next Generation Heterogeneous Wireless Systems,” IEEE Radio Comm. Magazine, vol. 43, no. 6, pp. S29-S36, June 2005.

[14] Brannstorm, R. Kodikara, E.R. Ahlund, C. Zaslavsky, A Mobility Management for multiple diverse applications in heterogeneous wireless networks, Consumer Communications and Networking Conference, 2006. CCNC 2006. 3rd IEEE.

[15] K. Ayyappan and P. Dananjayan, RSS Measurement for Vertical Handoff in Heterogeneous Network, Journal of Theoritical and Applied Information Technology, pp.989-984, 2008.

[16] Leu, A. E, Mark, B. L., "Local Averaging for Fast Handoffs in Cellular Networks" *IEEE Transactions On Wireless Communications*, Vol. 6, No.3, March 2007, pp. 866 - 874.

[17] Debabrata Sarddar, Shubhajeet Chatterjee, Ramesh Jana, Shaik Sahil Babu, Hari Narayan Khan, Utpal Biswas and M.K.Naskar, “Fast Handoff Implementation by using Curve Fitting Equation With Help of GPS”, International Journal of Computer Science issues (IJCSI) Vol. 08, Issue 03, pp. 535-542, No. 1, May 2011, ISSN (Online): 1694-0814.

[18] Debabrata Sarddar, Shubhajeet Chatterjee, Ramesh Jana, Shaik Sahil Babu, Hari Narayan Khan, Utpal Biswas and

M.K.Naskar, " Minimization of Handoff Latency by Distance Measurement Method", International Journal of Computer Science issues (IJCSI) Vol. 08, Issue 02, pp. 283-289, March 2011, ISSN(Online): 1694-0814.

[19] Debabrata Sarddar, Joydeep Banerjee, Tapas Jana,Souvik Kumar Saha, Utpal Biswas and M. K. Naskar, "Minimization of Handoff Latency by Angular Displacement Method Using GPS Based Map", International Journal of Computer Science Issues (IJCSI), Vol. 7, Issue 3, No 7, pp. 29-37, May 2010 ISSN (online): 1694-0784. ISSN (print): 1694-0814.

[20] Debabrata Sarddar, Shubhajeet Chatterjee, Ramesh Jana, Hari Narayan Khan, Shaik Sahil Babu, Hari Narayan Khan, Utpal Biswas and M.K.Naskar, "Minimization of Handoff Latency by Vector Analysis Method", International Journal of Computer Science issues (IJCSI) Vol. 08, Issue 03, pp. 570-576, No. 1, May 2011, ISSN (Online): 1694-0814.

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