

Minimization of Handoff Latency by Distance Measurement Method

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Abstract

Now a day, 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. Quality of service (QoS) demanding applications like Voice over IP (VoIP) and multimedia require seamless handover. But handoff delay (time required to perform hand off) provides a serious barrier for such services to be made available to mobile platforms. Throughout the last few years so many researches had been done to reduce the hand off delay. Here we propose a new scanning method in which we determine the distance of nearest access points from the mobile node to bypass the main processes involved in increasing Medium Access Control (MAC) layer handoff latency.

Keywords: *AP (Access Point), GPS (Global Positioning System), handoff latency, IEEE 802.11, MS (Mobile Station).*

1. Introduction

For successful implementation of seamless Voice over IP communications, the handoff latency induced when a mobile station(MS) moves over to a new AP 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.

1.1 IEEE802.11x Architecture

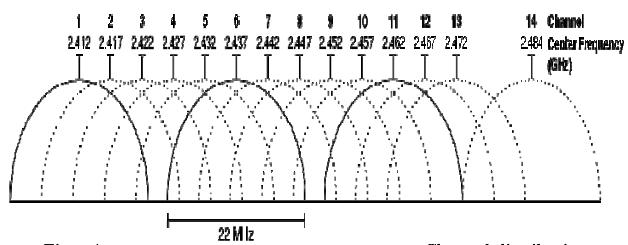
The stations are the basic component of a wireless network and may be anything from laptops to mobiles to other handheld devices that contain Medium Access Control (MAC), physical layer (PHY) and a connection to the wireless media.

The IEEE802.11x WLANs operate in two modes, namely:
i) *Ad-hoc***:** Here STAs recognize each other by establishing a peer-to-peer communication between them.

ii*) Infrastructure***:** Here APs (Access Point) controls all data transfer between the STAs under it. The AP along with the associated STAs form a BSS (Basic Service Set) and a collection of APs (connected to a main server) forms an Extended Service Set (ESS).

Besides, there exists a unique label called Service Set Identifier (SSID) which characterizes all APs and STAs attempting to become a part of a specific WLAN and thus distinguishes one WLAN from another. The wirelesses STAs use this SSID to maintain connectivity with the APs.

1.2 Channel distribution



Figur.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 figure (1).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.

1.3 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[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 & soft handoff: Originally hard handoff was 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 as shown in figure (2):

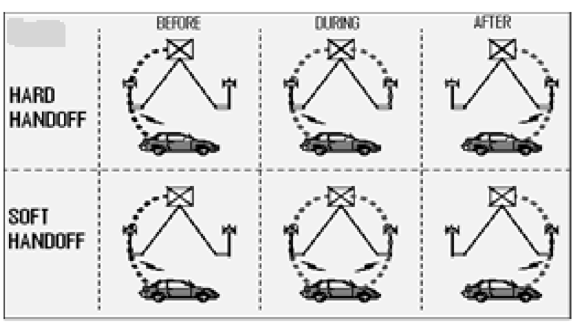


Figure 2 hard and soft handoff.

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 .

1.4 Handoff process:

The handoff procedure consists of three logical phases where all communication between the mobile station undergoing handoff and the APs concerned is controlled by the use of IEEE802.11 management frames as shown below in figure(3).

Scanning: When a mobile station is moving away from its current AP, it initiates the handoff process when the received signal strength and the signal-to-noise-ratio have decreased significantly. The STA now begins MAC layer scanning to find new APs. It can either opt for a passive scan (where it listens for beacon frames periodically sent out by APs) or chose a faster active scanning mechanism wherein it regularly sends out probe request frames and waits for responses for T_{MIN} (min Channel Time) and continues scanning until T_{MAX} (max Channel Time) if at least one response has been heard within T_{MIN}. Thus, $n*T_{MIN} \leq$ *time to scan n channels* $\leq n*T_{MAX}$. The information gathered is then processed so that the STA can decide which AP to join next. The total time required until this point constitutes 90% of the handoff delay.

Authentication: Authentication is necessary to associate the link with the new AP. Authentication must either immediately proceed to association or must immediately follow a channel scan cycle. In pre-authentication schemes, the MS authenticates with the new AP immediately after the scan cycle finishes. IEEE 802.11 defines two subtypes of authentication service: 'Open System' which is a null authentication algorithm and 'Shared Key' which is a four-way authentication mechanism. If Inter Access Point Protocol (IAPP) is used, only null authentication frames need to be exchanged in the re-authentication phase. Exchanging null authentication frames takes about 1-2 ms.

Re-Association: Re-association is a process for transferring associations from old AP to new one. Once the STA has been authenticated with the new AP, re-association can be started. Previous works has shown re-association delay to be around 1-2 ms. The range of scanning delay is given by:-
N × Tmin _ Tscan _ N × Tmax
Where N is the total number of channels according to the spectrum released by a country, Tmin is Min Channel Time,Tscan is the total measured scanning delay, and Tmax is Max Channel Time. Here we focus on reducing the scanning delay by minimizing the total number of scans performed.

ISSN (Online): 1694-0814
www.IJCSI.org

In section II we take you through the various works that have already been done to achieve this and in section III We introduce a new method using the instantaneous distance to the neighboring APs 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. Finally, we provide an extensive list of references that has helped us tremendously in our work.

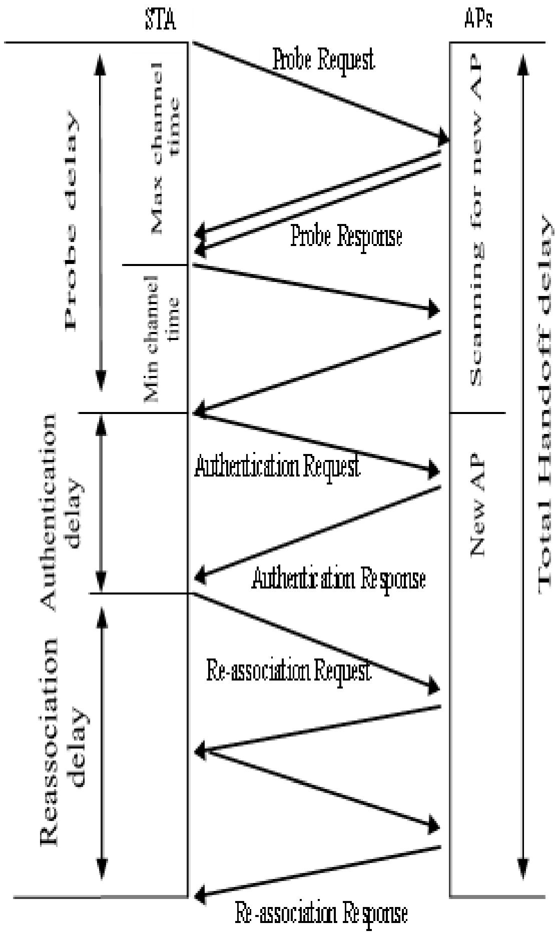


Figure.3 Handoff procedure.

2. Related Works

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. See [1] for an overall review of popular methods suggested.

Shin et al in [3] 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.
In [4] the authors have introduced a novel caching process using neighbor graphs by pre-scanning neighbor APs to collect their respective channel information. The concept of neighbor graphs can be utilized in different ways and have become very popular in this field. In [5] a pre-authentication mechanism is introduced to facilitate seamless handover. [6] is a novel approach towards reducing handover latency in AP dense networks.

Besides, much progress has been made in introducing GPS aided handoffs; vide [7] to [10]. In our work also we look at another such position dependant solution with a view to minimize overhead signaling problems. This is necessary since extensive pre-scanning is unacceptable in high traffic AP dense networks.

3. Proposed Works

3.1 The Hexagonal Cell Structure

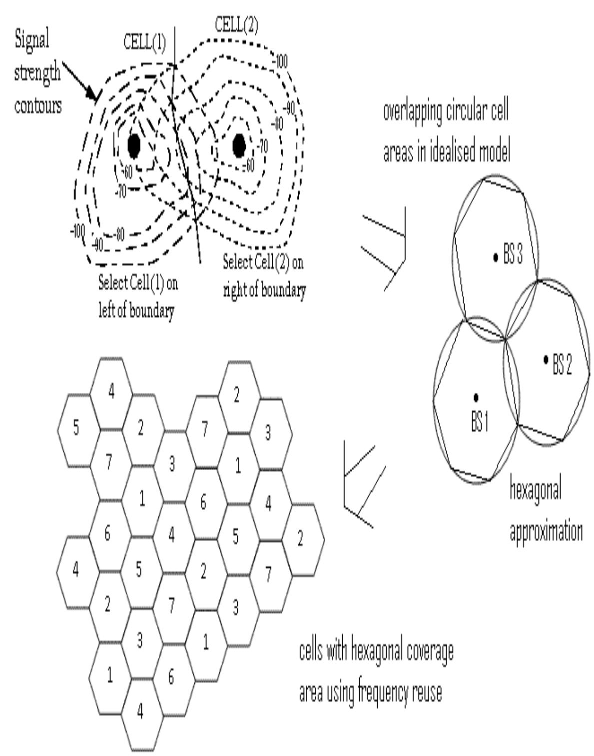


Figure.4 Hexagonal cell structure

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) we 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. In an idealized model we approximate the overlapping circular cell areas by hexagonal cells that cover the entire service region through frequency reuse concept where every cell marked similarly can use the same frequencies being out of range from each others' signal strength figure (4).

3.2 Signal Strength vs. Distance Measurements

The signal strength being primarily a function of distance, and the geometry of the coverage area being known, we can think of some new criteria for the selection of the most suitable AP in terms of best signal strength. In most cases, the best AP is the one which is nearest to the STA. And since from the geometry of the situation we already know the distances to the neighboring APs we can bypass channel scanning and signal strength measurements. Also refer to [6] for more on nearest APs having better signal strengths due to their advantage in competing for the wireless channel. Thus we can use a new algorithm to connect to the nearest AP and save scanning time.

3.3 Distance to AP Measurements

We utilize this hexagonal cell concept to realize a new caching mechanism that will minimize the handoff delay. Here we define a polar coordinate system with respect to the current AP and measure the position of the MS in terms of r and θ as shown in figure (5) by means of GPS or sensor networks or any other localization techniques. Knowledge of (r,θ) provides the formula for the instantaneous distances R_i to the neighboring APs as follows:

$$R_i=\sqrt{r^2 + D^2 - 2rD\cos\{\tfrac{(2i-1)\,\pi}{6} - \theta\}} \qquad (1)$$

We can now update (r,θ) in regular intervals and with its help calculate the distance to APs and maintain a cache as shown (here we store the APs in reference to some keys or IDs, e.g. the MAC addresses of the respective APs).

AP	KEY	distance
1	mac1	
2	mac2	
3	mac3	
....	....	

Once the MS enters the handoff region it continuously checks the cache. The moment it detects that an AP is nearer to the current AP and that distance is less than R then it concludes that it is moving into a new AP and thus initiates a handoff. This bypasses the elaborate scanning processes since from distance measurements we directly get the best AP to connect.

Upon failure the MS can look for 2nd nearest option and thus initiates a handoff. If that too fails then we can go for some traditional good selective scanning techniques. From the algorithm figure (7), we can see that scanning is required only if a cache miss occurs; every time we have a cache hit, no scanning is required.

The region within the incircle and the circumcircle of the individual APs are known as handoff region. The region within them covers a distance R*(1-0.5√3) which is sufficient to complete the handoff for normal cell size R and MS velocity. A cache hit usually takes 5ms to connect to a new AP. But a cache miss tends to induce a *back off delay* (of up to 15ms) that may be reduced by setting a timer to connect to the next best entry after a 7ms wait. Thus a single miss would cause a delay of about 11ms while a double miss would imply a latency of 12ms plus some scanning time of about 30-40ms. In this way a cache miss would not significantly affect the handoff delay.

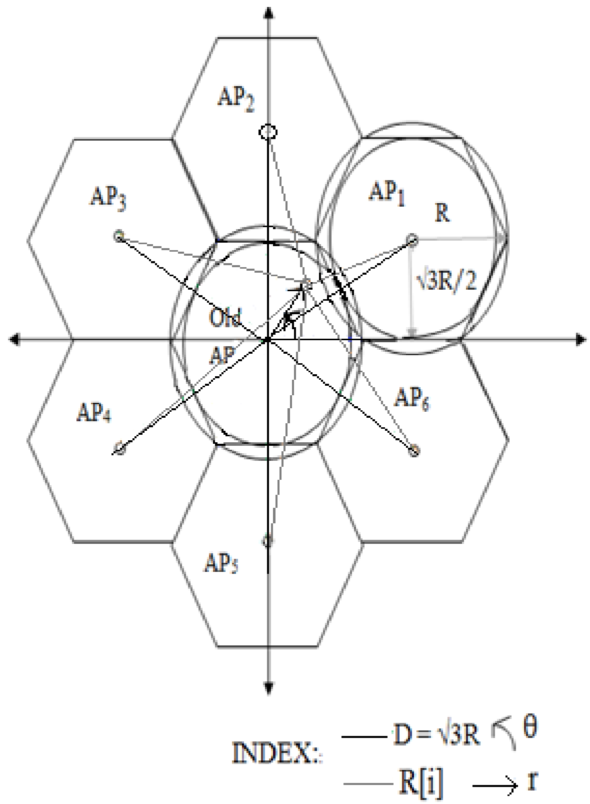


Figure .5 Cell cluster

{*Here i is the number of the AP as found proceeding anticlockwise with the one on the +ve x-axis taken as 1, and D is the distance between the current and its neighboring access points.}

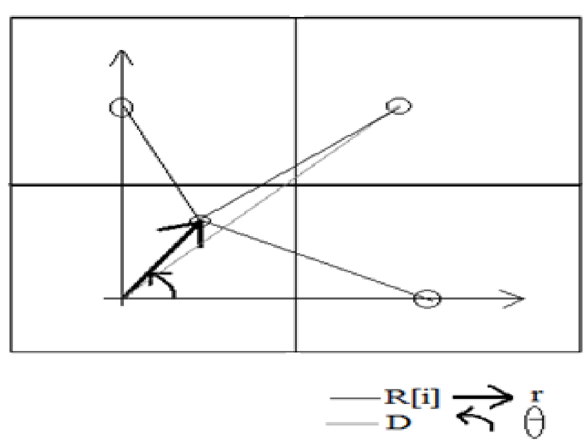


Figure.6 Handoff in square cell

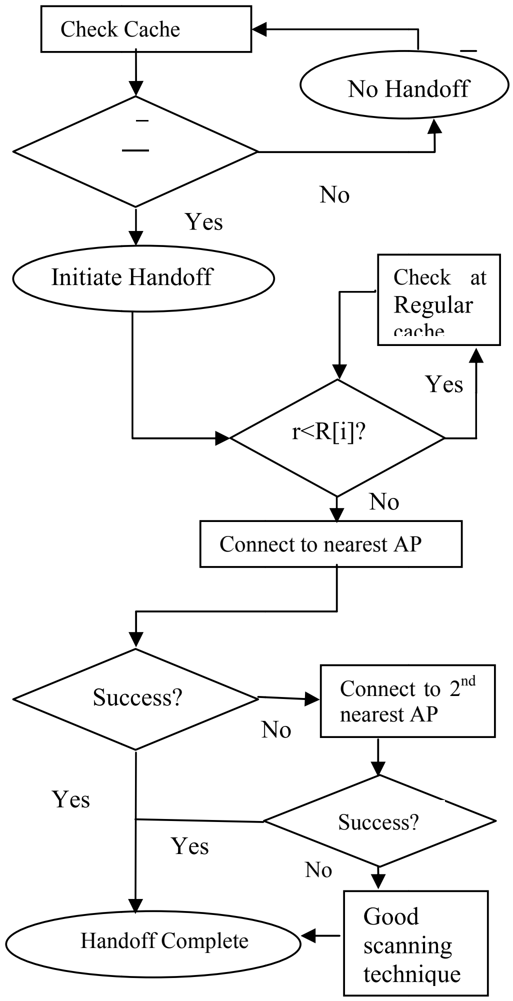


Figure.7 Handoff Algorithm

Note here that we do not consider time to calculate the distance to APs because it is very small compared to the other time values involved. To further hasten the process we can look to pre-authenticate with the 2 best options so that we now effectively reduce the handoff time to little over the re-association time.

Besides the obvious low handoff delays involved we can speak of greater flexibility in our approach in that it is not fixed to hexagonal cells only. Suppose we are using 4 APs in a large conference hall ABCD with coverage areas as shown in figure (6). Then we can approximate the network by square cell areas and then implement our algorithm by finding R[i] as a function of D[i] from the cell geometries as follows:

$$R_i = \sqrt{r^2 + R^2 - 2rR\cos\{\tfrac{(i-1)\pi}{4} - \theta\}} \qquad \text{for odd } i$$

$$R_i = \sqrt{r^2 + R^2 - \sqrt{8}rR\cos\{\tfrac{(i-1)\pi}{4} - \theta\}} \qquad \text{for even } i$$

{*applying same sign convention}

It may be noted here that while distance measurements have already been utilized in some areas such measurements have largely come out through processing information gathered through scanning whereas here we are able to get the required data through simple computation which obviously takes much less time and also reduces the excess signaling that eats up bandwidth space during pre-scanning. Now let us simulate the proposed model and see if it actually works out.

4. Simulation Results

First let us take a look at how our distance measurements work. In the following figure we show how the distance to neighboring APs figure (8) are updated as the MS is on the move.

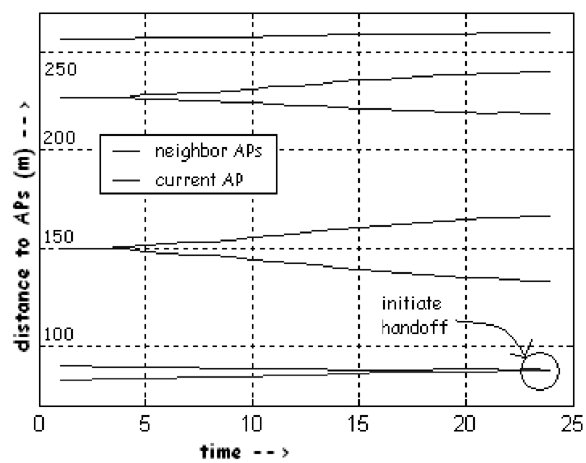


Figure.8 Distance between MS and APs

The moment the distance to the current AP becomes greater than that form a neighbor AP a handoff process is initiated to connect with the latter. The actual path followed by the MS is shown here figure (9) (AP coverage areas have been taken as 100m).

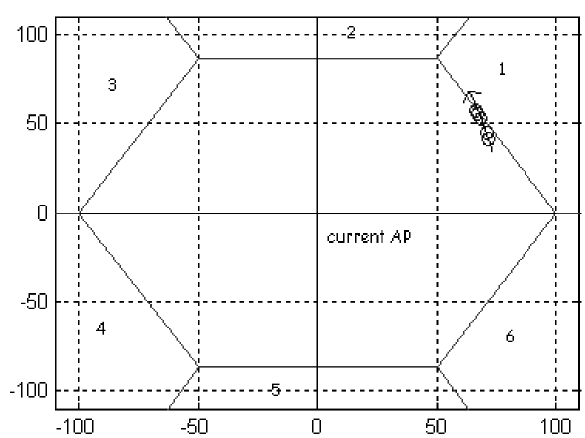


Figure.9 Path of movement of MS

Now that the new AP has been identified the algorithm is executed as mentioned before. The simulations show how the nearest AP is not always the next AP and how the latency is increased considerably when a cache hit does not occur. Moreover, the proportion of hits is not constant.

This may be due to a variety of factors. Difference in traffic levels can determine the ease with which new connections may be made while the approximation that the nearest AP is the best AP is likely to be valid to different extents in different networks. We show three such scenarios below.

Here we have assumed cache hit and miss times as mentioned in the previous section in accordance with [3]. Seamless handoffs require a latency of less than 50ms. The simulation results figure (10,11and 12) show the average values of 6.47ms, 7.65ms and 9.7ms which is a significant improvement.

Table 1: Cache memory

time point	r	r_1	r_2	r_3	r_4	r_5	r_6
1	83.00	90.00	149.86	226.22	256.00	226.22	149.86
2	83.30	89.70	149.57	226.26	256.30	226.64	150.15
3	83.90	89.14	148.09	225.73	256.89	228.05	151.60
4	84.05	89.07	146.62	224.85	257.01	229.11	153.07
5	84.35	88.88	145.43	224.26	257.27	230.09	154.25
6	85.05	88.49	143.01	223.13	257.87	232.10	156.65
7	85.60	88.26	141.18	222.26	258.31	223.63	158.48
8	86.25	88.09	139.02	221.21	258.79	235.39	160.63
9	86.80	88.05	137.14	220.27	259.18	236.89	162.50
10	86.90	88.41	135.63	219.23	259.12	237.84	164.02
11	87.35	88.34	134.51	218.74	259.45	238.80	165.14
12	88.10	88.02	133.31	218.44	260.06	240.02	166.33

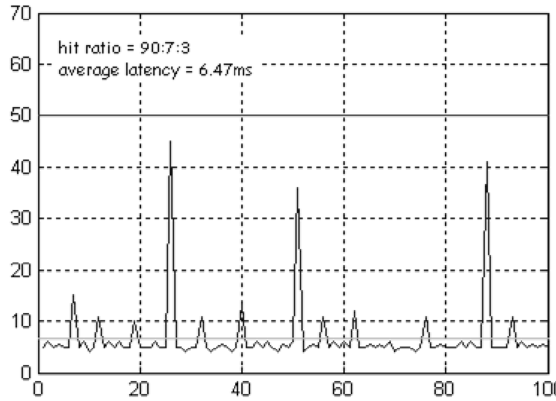


Figure.10

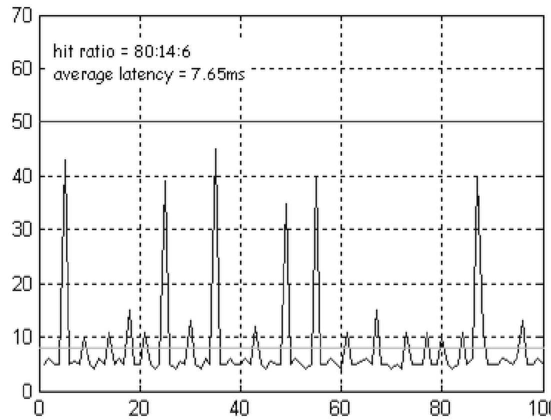


Figure.11

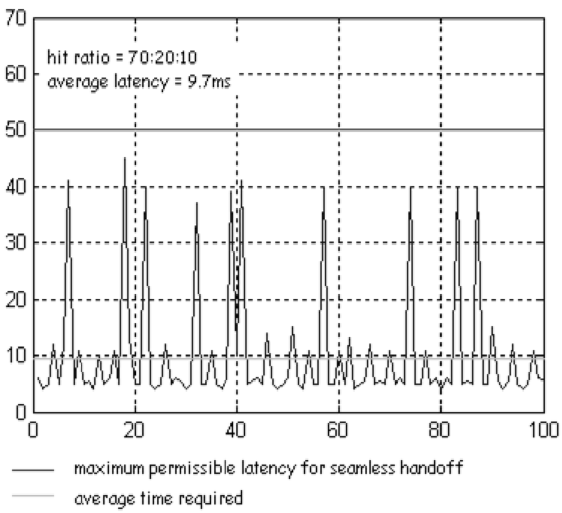


Figure.12

5. Conclusions

As we have already seen above, model simulations give favorable results for our new approach. Also the simplicity and flexibility of the proposed method point to diverse fields of implementation with the help of appropriate improvements and modifications.

For example, though we have been able to reduce handoff latencies we do not consider whether the handoff was at all necessary in the first place, i.e. ping-pong effects can significantly increase the number of false handoffs taking place.

Also, our approach may result in handoff failure in a very small number of cases when more than two distances from APs are involved, i.e. towards the vertices of the hexagonal cells.

Such limitations can be effectively eliminated using mobility measurements of the STA involved in handoff. Indeed this would not require significant changes to the actual scheme as we are already using GPS to get positional data. We intend to take up this matter in future studies. The real challenge as of now is to interpret the coverage areas of APs geometrically and incorporate that knowledge.

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