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PROJECT REPORT
EIGHTH SEMESTER

Minimisation of Handoff latency and False handoff initiation in 4G - NGWS and 802.11 WLAN networks.

Report prepared by

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CONTENTS

Page No.

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LIST OF FIGURES

INTRODUCTION

This report presents a method of reducing hand off delay and minimising handoff failure probability using available technology, without compromising bandwidth efficiency considerably, by altering and streamlining the functionality and task division of the contemporary handoff technique. This would result in fewer call failures and in congestion-free networks.

In this report we present techniques for reducing hand-off latency in both Next Generation Wireless Networks (NGWS) and Wi-Fi Networks(IEEE 802.11).

For NGWS :

There is a need for reduced handoff time in Next Generation Wireless Networks (NGWS), since lower handoff periods would result in higher data efficiency and fewer handoff failures. This would cause fewer data packet losses resulting in higher QoS, which is a primary facet of NGWS networks. Moreover, 4G networks integrate certain microcellular networks, like IEEE 802.11, which requires quicker handoff because number of handoffs become exponentially higher and cell size dramatically drops with respect to macrocellular networks. Also effectively, the time spent in handoff cannot be used for useful data transfer. In this report, we propose a mechanism to reduce handoff latency time and produce a handoff mechanism with failure probability tending to zero.

For Wi-Fi :

IEEE 802.11 is a set of standards carrying out wireless local area network (WLAN) computer communication in the 2.4, 3.6 and 5 GHz frequency bands. They are created and maintained by the IEEE LAN/MAN Standards Committee (IEEE 802).

The 802.11 family includes over-the-air modulation techniques that use the same basic protocol. The most popular are those defined by the 802.11b and 802.11g protocols, which are amendments to the original standard. 802.11-1997 was the first wireless networking standard, but 802.11b was the first widely accepted one, followed by 802.11g and 802.11n. Security was originally purposefully weak due to export requirements of some governments, and was later enhanced via the 802.11i amendment after governmental and legislative changes. 802.11n is a new multi-streaming modulation technique. Other standards in the family (c–f, h, j) are service amendments and extensions or corrections to the previous specifications.

802.11b and 802.11g use the 2.4 GHz ISM band, operating in the United States under Part 15 of the US Federal Communications Commission Rules and Regulations. Because of this choice of frequency band, 802.11b and g equipment may occasionally suffer interference from microwave ovens, cordless telephones and Bluetooth devices. Both 802.11 and Bluetooth control their interference and susceptibility to interference by using spread spectrum modulation. Bluetooth uses a frequency hopping spread spectrum signaling method (FHSS), while 802.11b and 802.11g use the direct sequence spread spectrum signaling (DSSS) and orthogonal frequency division multiplexing (OFDM) methods, respectively. 802.11a uses the5 GHz U-NII band, which, for much of the world, offers at least 19 non-overlapping channels rather than the 3 offered in the 2.4 GHz ISM frequency band. Better or worse performance with higher or lower frequencies (channels) may be realized, depending on the environment.

The used segment of the radio frequency spectrum varies between countries. In the US, 802.11a and 802.11g devices may be operated without a license, as allowed in Part 15 of the FCC Rules and Regulations. Frequencies used by channels one through six (802.11b) fall within the 2.4 GHz amateur radio band. Licensed amateur radio operators may operate 802.11b/g devices under Part 97 of the FCC Rules and Regulations, allowing increased power output but not commercial content or encryption.

HANDOFF AND HANDOFF RELATED ISSUES IN IEEE 802.11 NETWORKS.

In cellular telecommunications, the term handoff or handover refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another. In satellite communications it is the process of transferring satellite control responsibility from one earth station to another without loss or interruption of service. The American English term for transferring a cellular call is handoff, which is most commonly used within some American organizations such as 3GPP2 and in American originated technologies such ascdma-2000. The British English term is handover, which is used within international and European organisations such as ITU-T, IETF, ETSI and 3GPP, and standardised within European originated standards such as GSM and UMTS. The term handover is more common than handoff in academic research publications and literature, while handoff is slightly more common within the IEEE and ANSI organisations.

- A hard handoff is one in which the channel in the source cell is released and only then the channel in the target cell is engaged. Thus the connection to the source is broken before the connection to the target is made—for this reason such handoffs are also known as *break-before-make*. Hard handoffs are intended to be instantaneous in order to minimize the disruption to the call. A hard handoff is perceived by network engineers as an event during the call.

- A soft handoff is one in which the channel in the source cell is retained and used for a while in parallel with the channel in the target cell. In this case the connection to the target is established before the connection to the source is broken, hence this handoff is called *make-before-break*. The interval, during which the two connections are used in parallel, may be brief or substantial. For this reason the soft handoff is perceived by network engineers as a state of the call, rather than a brief event. A soft handoff may involve using connections to more than two cells, e.g. connections to three, four or more cells can be maintained by one phone at the same time. When a call is in a state of soft handoff the signal of the best of all used channels can be utilised for the call at a given moment or all the signals can be combined to produce a clearer copy of the signal. The latter is more advantageous, and when such combining is performed both in the downlink (forward link) and the uplink (reverse link) the handoff is termed as *softer*. Softer handoffs are possible when the cells involved in the handoff have a single cell site .

LITERATURE SURVEY (Previous Work)

According to Shantidev Mohanty[1][4] during any handoff between two base stations efficient intra-and inter system handoff protocols should have limited handoff latency,low packet loss and limited handoff failure to support seamless roaming.Using speed and handoff signaling delay information the performance of existing handoff management protocols can be enhanced.Dr Mohanty presented a cross layer mobility model where the data link layer and the network layer could be used for speed and handoff signaling delay estimation.He called it Cross Layer Handoff Management Protocol.

The speed estimation unit in this Protocol uses an algorithm called VEPSD(Velocity Estimation Using Power Spectral Density of the received envelope).The Cross Layer handoff Management Protocol is explained using the following flowchart:

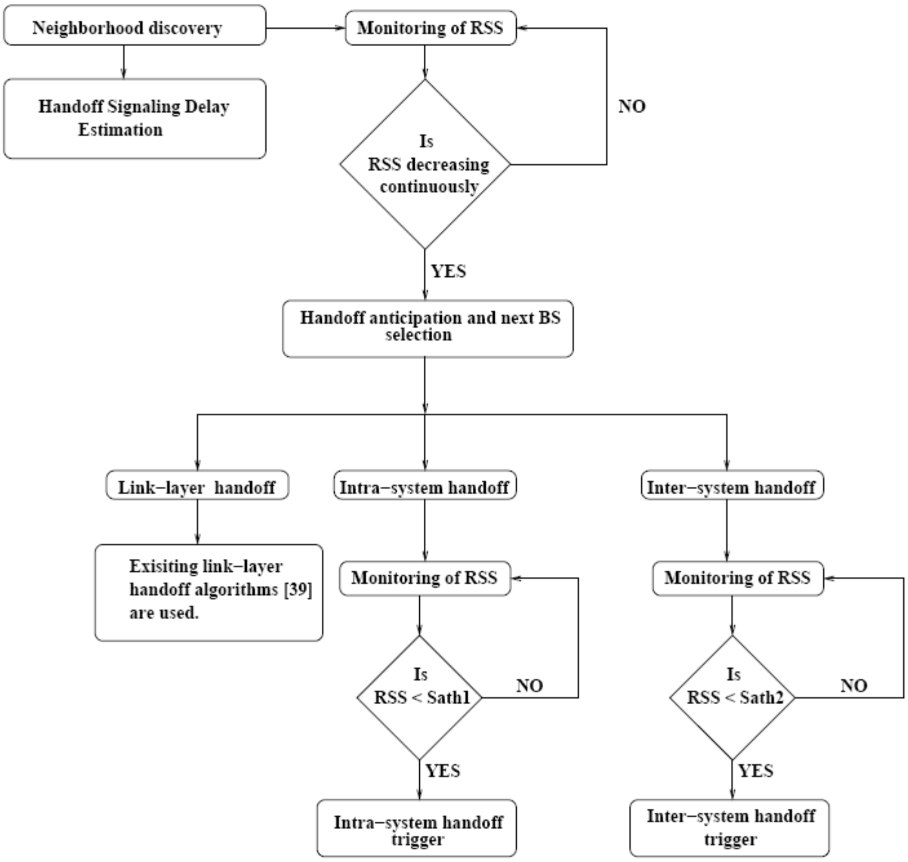

Figure 1. Velocity Estimation Using Power Spectral Density

Performance analysis and simulation results show that cross layer mobility management protocols significantly enhance the performance of both intra and intersystem handoffs.It also significantly reduces the cost associated with false handoff initiation because it achieves lower false handoff initiation probability.

According to Narsimhan and Cox [2][3] the method uses the local stationarity of the received signal to expand the signal in a basis of smooth local exponential functions. The coefficients of the expansion provide an estimate of the time-varying Doppler power spectrum. The time-varying spectrum and a two-element antenna array are used to estimate and track the variable mobile speed and the average received power. This estimation method is extended to the case of an unknown, arbitrary orientation of the antennas at the mobile station. Using three antennas, this estimator is shown to yield performance comparable to the method using two antennas oriented along the mobile velocity. The best basis estimator has been shown to perform significantly better than an extended adaptive averaging method.The above technique is used to detect the corner effect present in urban cellular systems. A corner is detected if the average received power changes by a significant amount within a short distance. Simulations demonstrate that this method detects corners with small delay and, hence, is useful in reducing handoff delay and the call dropping rate.

In the context of wireless local area networks Hye-Soo Kim, Sang-Hee Park, Chun-Su Park, Jae-Won Kim, and Sung-Jea Ko[9][11][13] have suggested selective channel scanning for faster handoff. According to IEEE 802.11, an STA has to scan all channels in scanning. This paper, based on the neighbor graph (NG), introduces a selective channel scanning method with unicast for fast handoff in which an STA scans only channels selected by the NG. Experimental results show that the proposed method reduce the scanning delay drastically.Traditional handoff techniques use broadcast signals for channel and access point scanning.This makes it a longer process because all the channels are scanned.In this selective channel scanning method a neighbour graph is used for scanning.It is composed of 3 subparts,a neighbour graph server,a neighbour graph client which is the mobile station and a monitor which checks the necessity of handoff and sends the necessary impulse for transfer of neighbour graph information to the client from the server.The broadcast message is replaced by a unicast signal which is transmitted selectively to access points chosen by the neighbour graph.This reduces the scanningdelay which comprises nearly ninety percent of the total handoff latency time.The neighbour graph server sends the information to the neighbour graph client and the client responds by storing the neighbour graph server information in its device driver.This can be demonstrated by the following flow diagram

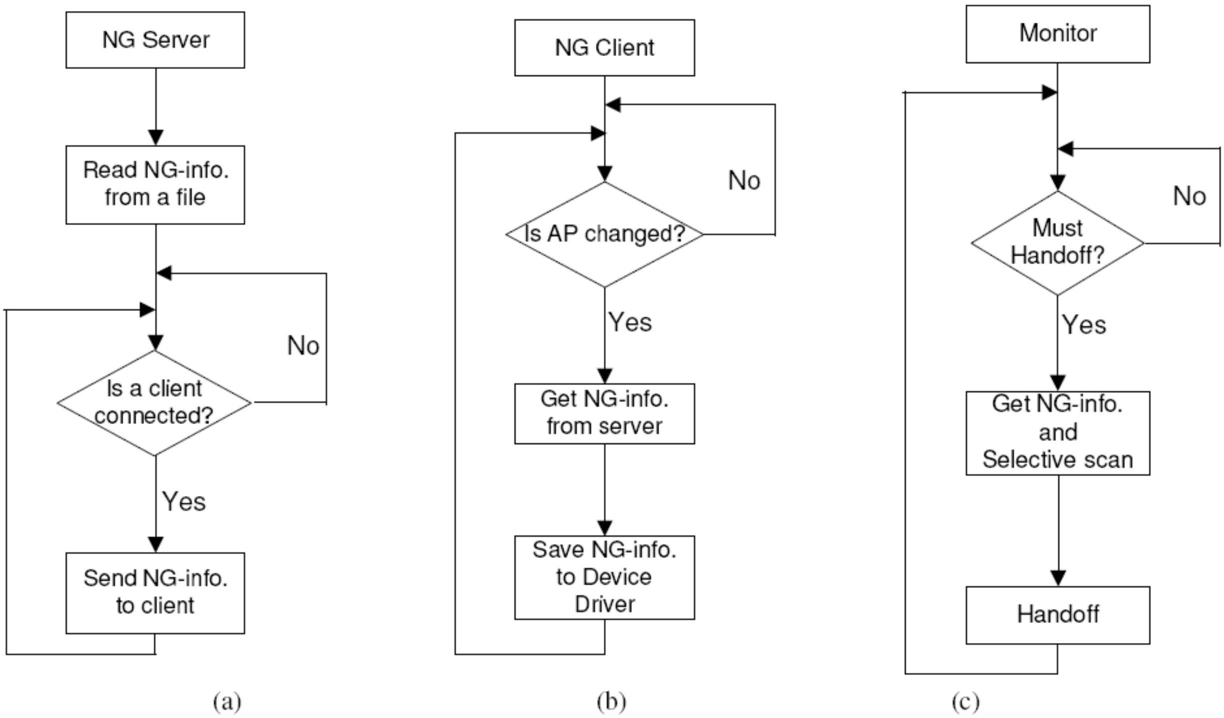

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Figure 2. Neighbour Graph flow diagram

EXPERIMENTAL PROCEDURE

(For NGWS)

METHOD

Proposed methods in the literature have used velocity and position information using layer (2+3) of the mobile station ([1] and [3]), for both contemporary and NGWS networks. Here we use a simple approach based on the proposed technologies to reduce handoff failure rate by dividing the handoff procedure into two major subparts:

1) A General Part, which is same for all mobile stations, and
2) A Specific part, which is for each individual mobile station.

The general part includes sections like probability of movement to a certain New Base Station (NBS), based on location region. This can be saved in a tabular form as it is constant for all mobile stations. The specific part contains International Mobile Subscriber Identity(IMSI), authentication, etc. This part is considered the effective handoff delay in the scenario in discussion.

A. Basic cell patterns

Here for simplicity, we consider an intrasystem handoff in a homogenous honeycomb network.

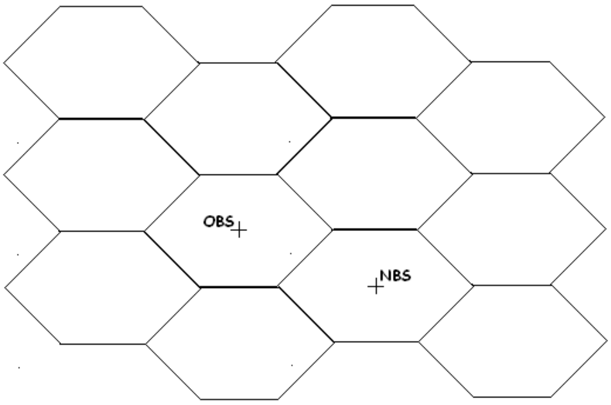

Figure 3. Honeycomb Homogenous network.

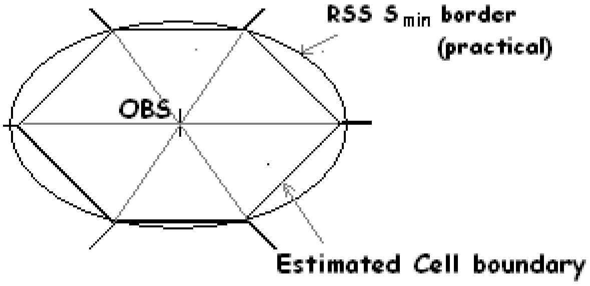

Figure 4. One Cell

For an intrasystem handoff we know the time required to perform the handoff. Let us consider it as τ_1. We may get the velocity and position of the mobile station using Doppler effect and signal strength(RSS), from [2] and [3],. If we know the velocity, the total time delay for handoff and the cell size for RSS Threshold value, we can calculate the position from which we can optimally begin handoff.

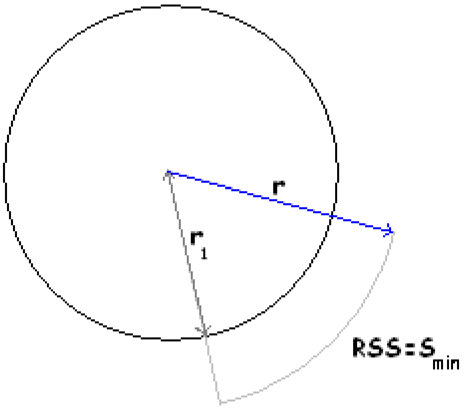

Figure 5. Radial distances from OBS for circular cell

If radial velocity of Mobile Station (MS) = v and effective radius of cell = r, then let us assume we need to begin the handoff at a distance of r_1 from the OBS using circular cell. Therefore, $\frac{r-r_1}{v}=t_d$ is the time taken to traverse from given position to boundary.

For maximum efficiency, $t_d \rightarrow \tau_1$.

For zero failure probability, $t_d >> \tau_1$.

However, considering that MS is moving at constant radial speed,we can say that handoff failure probability is zero for $t_d = \tau_1 + \Delta t$, where Δt is a tiny amount of time. With higher data efficiency (low latency) or low velocity, r_1 approaches higher value, with limiting case (ideal) being $r_1 = r$, when latency time is reduced to zero. In a hexagonal honeycomb we can estimate from the position the new base station to which MS has the highest probability of moving to. For each 60° section there is a 1:1 correspondence of new base stations.

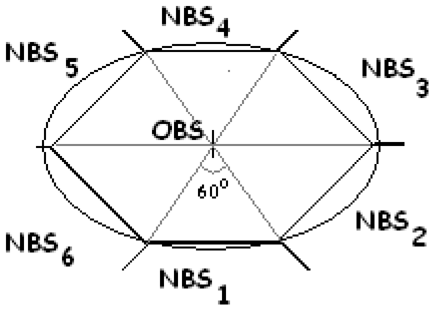

Figure 6. 1:1 NBS correspondence per 60° division

So we can proceed with parts of handoff like checking for channel availability without actually waiting for the detection of NBS from MS. Although this results in higher bandwidth cost, it causes moving of major handoff data to preregistration period,causing fewer data packet losses during actual handoff, resulting in reduced failure probability.

B. Bandwidth Offset

This approach however has a shortcoming. Due to considering only position and not direction of travel, false handoff probability is higher than usual. However there is a provision for low latency. This results in increase in r_1. This in turn reduces area of concern. This negates the previous effect to a certain degree as from lower area of concern, probability of moving to other new base stations is low thus reducing false handoff.

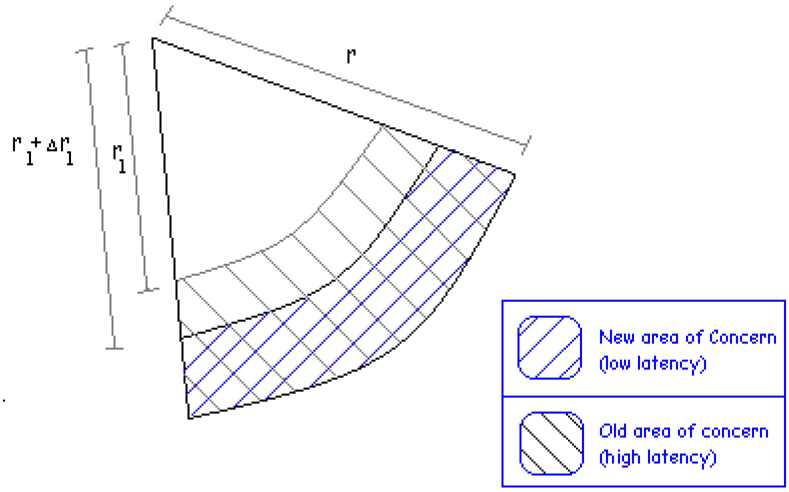

Figure 7. Old and new latency regions

C. Overlapping factor

We see from the following figure that the 60° divisions remains same for similar honeycomb patterns, even if the cells overlap partially, as long as there is some semblance of uniformity (Fig. 6). Consequently, the 1:1 correspondence is still maintained in this case, between each 60° sector and the neighbouring NBSs.

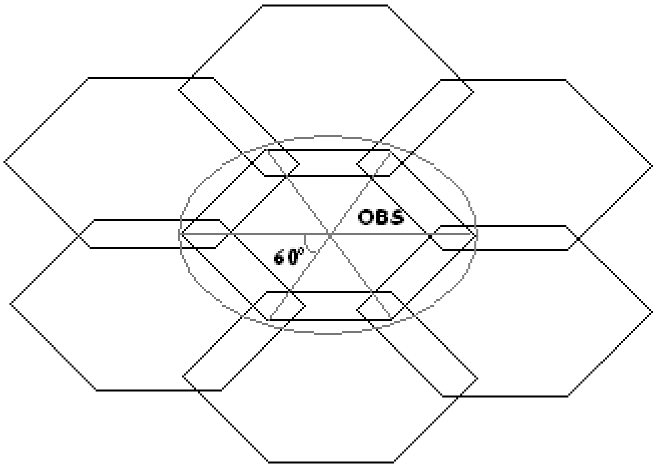

Figure 8. Overlapping cells

D. Unequal Cells

For cells of unequal size, the logic remains unchanged (Fig.7). Only the aforementioned value of 60° changes according to the cell topography.

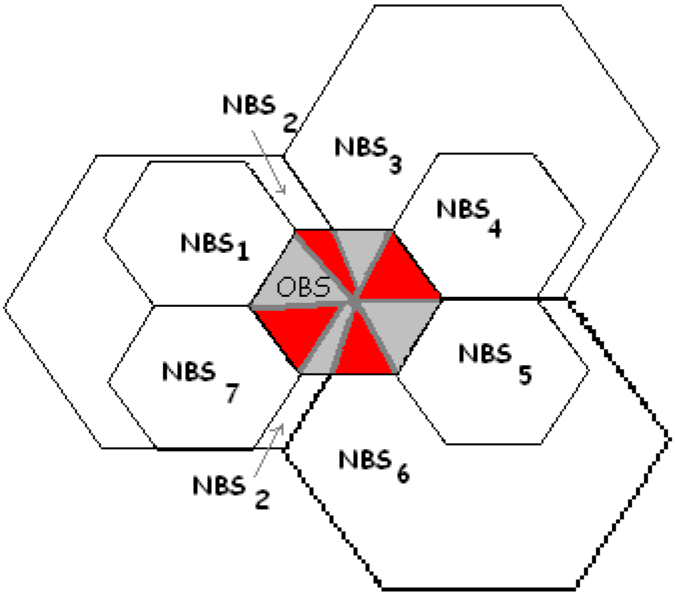

Figure 9. Unequal cells

EXPERIMENTAL PROCEDURE

(For Wi-Fi)

METHOD

The complete handoff procedure can be divided into three distinct logical phases: scanning, authentication, and reassociation.In the first phase, an STA scans for APs by either sending *ProbeRequest* messages (Active Scanning) or by listening for *Beacon* messages (Passive Scanning). After scanning all channels, an AP is selected by the STA using the Received Signal Strength Indication (RSSI), link quality, and etc., and the selected AP exchanges IEEE 802.11 authentication messages with the STA. Finally, if the AP authenticates the STA, the STA sends *Reassociation Request* message to the new AP.In this phase, the old AP and new exchanges messages defined in IAPP. The delay incurred during these exchanges is referred as the L2 handoff delay, that consists of probe delay,authentication delay, and reassociation delay.

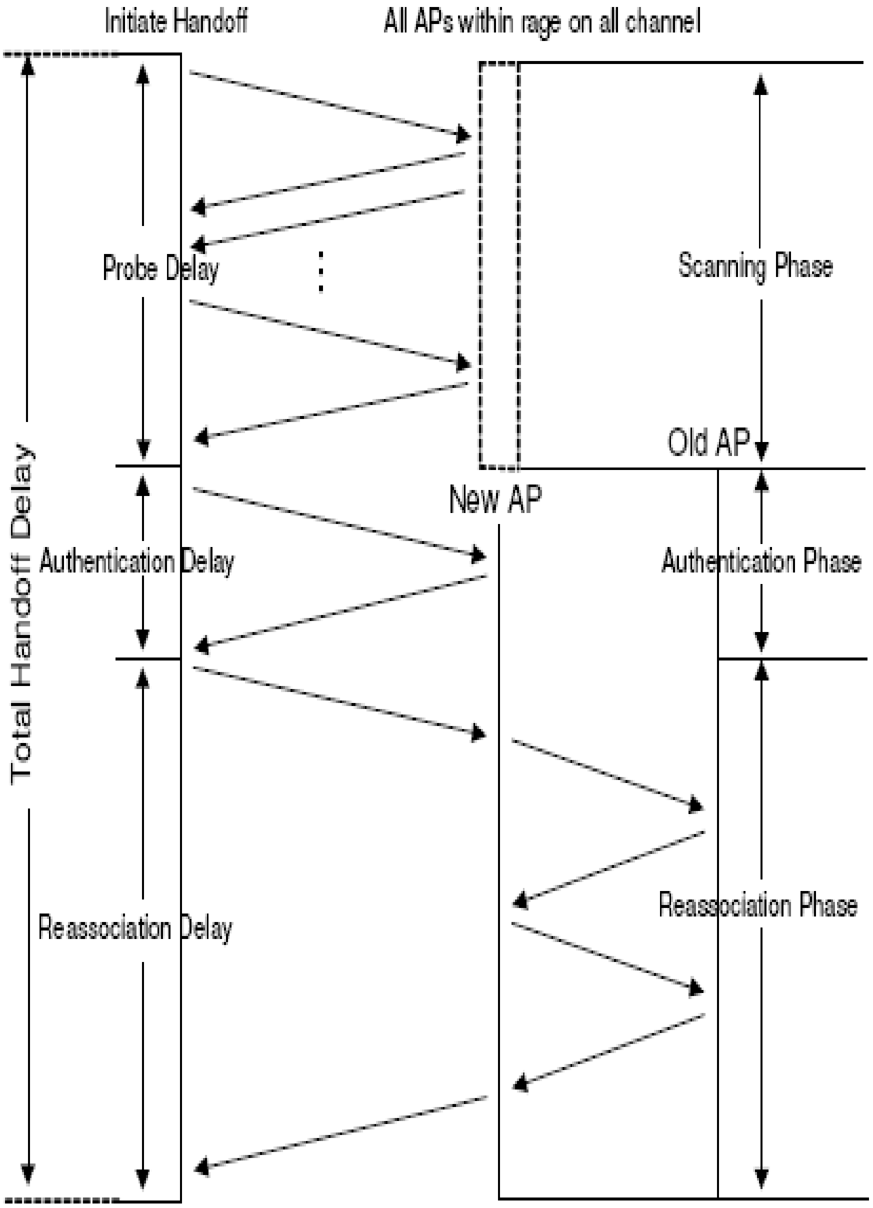

Fig 10. IEEE 802.11 Handoff procedure

PASSIVE AND ACTIVE SCANNING MODES

An STA operates in either a passive scanning mode or an active scanning mode. To become a member of a particular ESS using the passive scanning, an STA scans for *Beacon* message containing the ESS's Service Set Identifier (SSID) whether the *Beacon* message comes from an Infrastructure BSS or Independent Basic Service Set (IBSS). To actively scan, after contending to access the medium, the STA sends a *Probe Request* message with the desired SSID and broadcast BSSID, then starts a *Probe Timer*. If the STA has not received a *Probe Response* message before the *Probe Timer* reaches *Min Channel- Time*, then the STA scans the next channel. Otherwise, the STA has to wait until the *Probe Timer* reaches *Max Channel- Time*, then scans the next channel. During active scanning, the bound of scanning delay can be calculated as:

$N \ X \ T_b <= t <= N \ X \ T_t$

where N is the total number of channels which can used in a country, T_b is *MinChannelTime*, T_t is *MaxChannelTime*, and t is the total measured scanning delay. Our work focuses on the reduction of the active scanning delay time.It is so because the scanning delay or probe delay makes up for nearly ninety percent of the total handoff latency delay.Minimisation of this scanning delay can thus improve performance during handoff drastically.

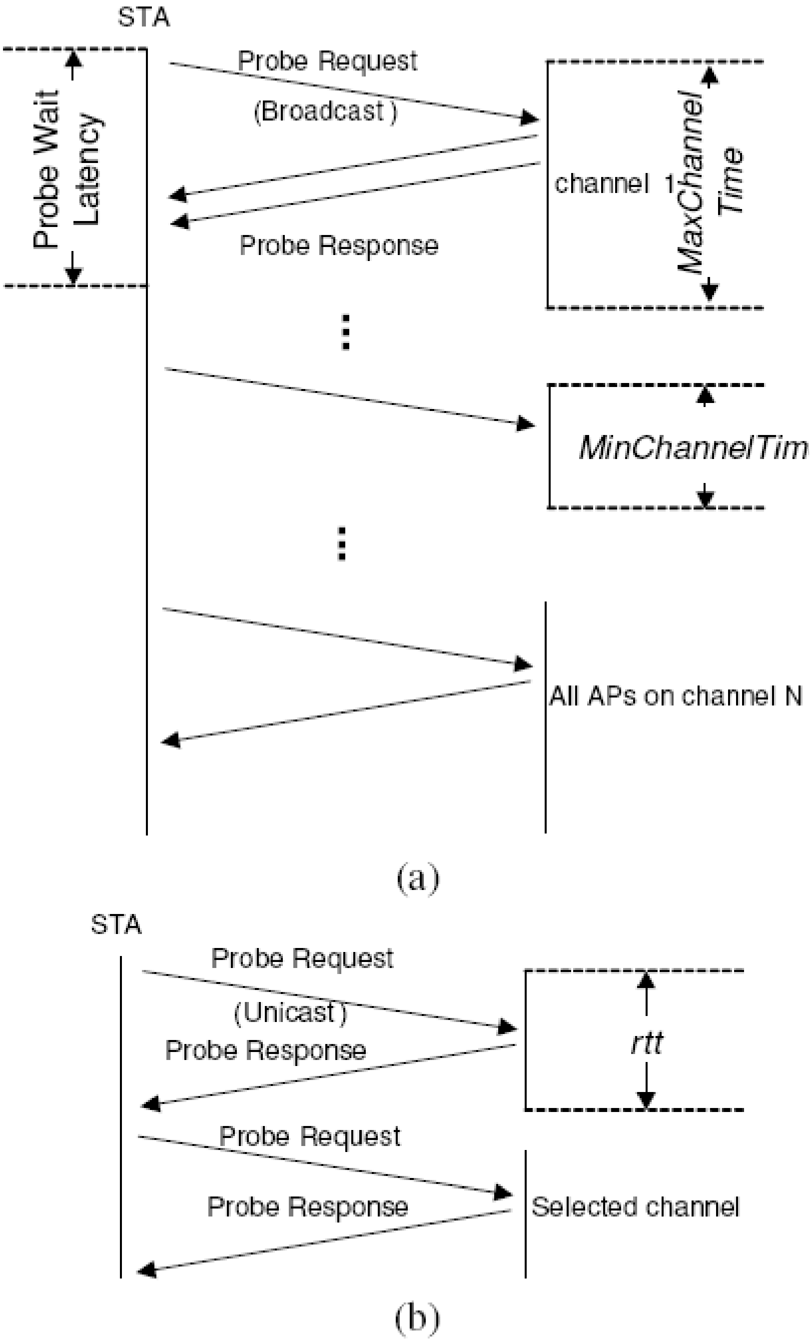

Fig 11. Active scanning

MODIFICATIONS

Before introducing our proposed method, we briefly review the NG (Neighbour Graph). The NG is an undirected graph with each edge representing a mobility path between APs. Therefore, given an edge, the neighbors of an edge represent the set of potential next APs.

The undirected graph representing the NG is defined as

$G = (V,E);$

$V = (ap_1; ap_{2 \ldots\ldots,}\ ap_i);$

$e = (ap_i; ap_j);$

$N(ap_i) =\{ap_{ik} : ap_{ik} \in V, (ap_i;ap_{ik}) \in E\};$

where G is the data structure of NG, V is the set containing all APs, E is the set which consists of edge (e), and N is the neighbor APs of a AP. The NG can be automatically generated.It uses *Reassociation Request* message from an STA that contains the BSSID of the old AP. In this method, the NG is created by following algorithm by using management message of IEEE 802.11.

To reduce the scanning time, we must reduce the values of T_b (*MinChannelTime*), T_t (*MaxChannelTime*), or N. Among three values, T_b and T_t can not be reduced because of physical restriction. And because the frequency ranges are subject to the geographic-specific regulatory authorities, N is fixed in each country. However, the channels which are occupied by APs are not same in all Basic Service Areas(BSAs) or Extended Service Areas (ESAs). Thus, if we know the used channels in each site, STAs do not need to scan all channels allowed in the country. Therefore, we propose using an NG to select the channels to be scanned. The above NG proposed uses the topological information on APs. But our algorithm needs to use not only topological information but also channels of APs. Thus, we modify the data structure of NG defined above as follows:

$G' = (V';E);$

$V' = \{v_i : v_i = (ap_i, \text{channel}); v_i \text{€} V\};$

$e = (ap_i , ap_j);$

$N(ap_i) = \{ap_{ik} : ap_{ik} \text{€} V', (ap_i;ap_{ik}) \text{€} E\};$

where G' is the modified NG, and V' is the set which consists of APs and their channels.

In order to scan channels, after transmitting *Probe Request* message whose destination is all APs, STAs must wait for *MinChannelTime* or *MaxChannelTime* because an STA does not know how many APs would response to *Probe Request* message. However, if using unicast instead of broadcast, *Probe Request* message is sent to the potential APs selected by NG. And on receiving *Probe Response* message, STAs can transmit other *Probe Request* messages without waiting for *MaxChannelTime* or *MinChannelTime*. Thus, if using the proposed scanning algorithm, scanning delay can be expected as $t = N_0 X \ r_{tt} + \alpha$; where N_0 is the number of the potential APs, r_{tt} is the round trip time, and α is the message processing time. Compared to the previous scenario, we can know that the scanning delay is reduced through the proposed algorithm.

For handoff in modern cellular systems we consider hexagonal honeycomb cells where from the service area each home base station has a probability of moving to six adjoining new base stations (NBS) on the six sides of the regular hexagonal boundaries.

It has been found experimentally that each adjoining NBS takes atleast 3ms to probe. This takes the total probe time to (3 x 6)=18ms.However by accessing the cross layer mobility information we can get an estimate of the RSS and velocity of propagation of the mobile station.We can subdivide this analysis into two cases.

Case I

According to Narsimhan and Cox we can only consider radial velocity for Received Signal Strength velocity estimation using Doppler effect.If the mobile station moves along one of the edges of the hexagonal honeycomb cell then the probability of moving to an adjoining new base station gets reduced from six to two as with radial velocity in a low latency wireless network movement into any other new base station

(NBS) other than these two is geometrically impossible.This drastically reduces the probe delay minimum channel time from (6 x 3) = 18ms to (2 x 3) = 6ms.

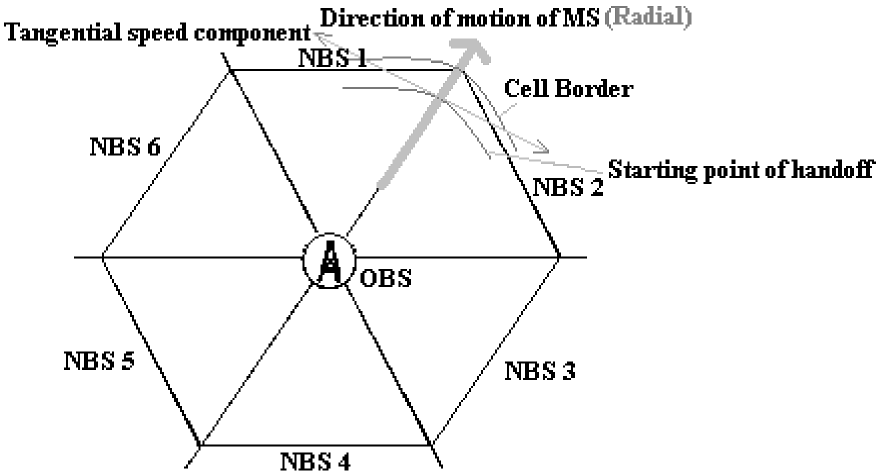

Fig 12. Tangential movement for 2 NBS

Thus, we see from the figure that for linear displacement, in this scenario, movement is possible only on 2 New Base Stations.

Case II

If the mobile station does not move along the edge of a hexagonal honeycomb radially then for a low latency wireless area network it can move into only 3 adjoining cells by using the same logic as above.In this scenario the minimum probe time reduces to (3 x 3)=9ms.

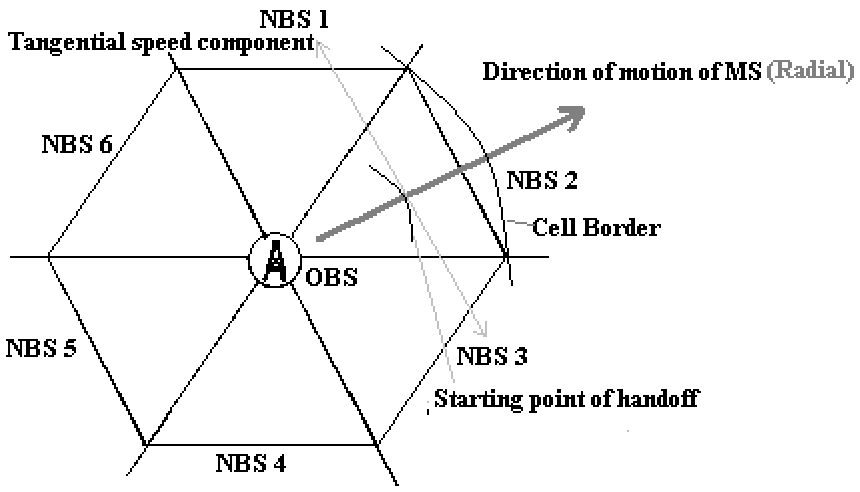

Fig 13. Tangential movement for 3 NBS

Thus we see that in both cases the probe delay time is reduced by (18 - 9) = 9ms and in the other situation it is reduced by (18 - 6) = 12ms by using selective scanning technique.

RESULTS AND DISCUSSIONS

MATHEMATICAL ANALYSIS

Considering radial velocity is outward, which is obvious because, otherwise, there is no requirement of handoff, we get a 180° band which is our region of concern for calculation of false handoff initiation linear invariant velocity estimation.

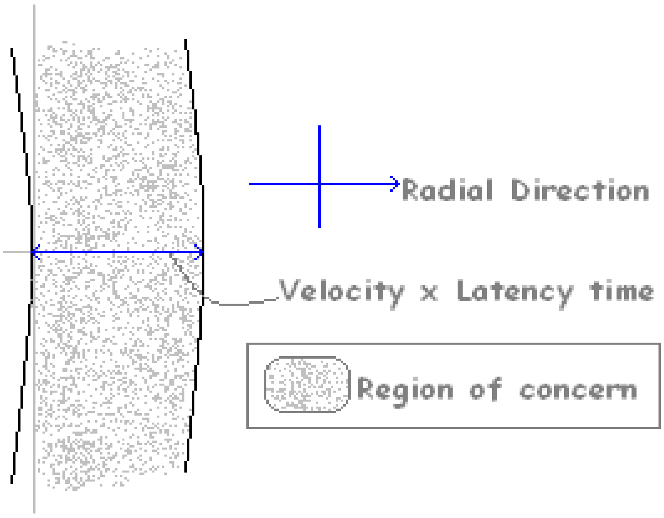

Figure 14. Region of Concern

A. Low latency microcellular

1. Radius of circular cell = 20 m
2. Latency time = 100 ms
3. Speed (Outward radial) = 18 km/h
4. Starting point of handoff (distance from OBS) = 19.5 m

5. Point beyond which false handoff cannot occur (for 60° region explained in section II(A)) = 17.32 m

Thus, Probability of false handoff (for 60° region explained insection 2.1) = 0%

B. Low latency macrocellular

1. Radius of circular cell = 1000 m
2. Latency time = 100 ms
3. Speed (Outward radial) = 36 km/h
4. Starting point of handoff (distance from OBS) = 999 m
5. Point beyond which false handoff cannot occur (for 60° region) = 867 m

Thus, Probability of false handoff (for 60° region) = 0%

C. High latency microcellular

1. Radius of circular cell = 20 m
2. Latency time = 1 s
3. Speed (Outward radial) = 18 km/h
4. Starting point of handoff (distance from OBS) = 15 m
5. Point beyond which false handoff cannot occur (for 60° region) = 17.32 m

Thus, Probability of false handoff (for 60° region) = $\frac{180^\circ - 153.9^\circ}{180^\circ} \times 100$ = 14.5%

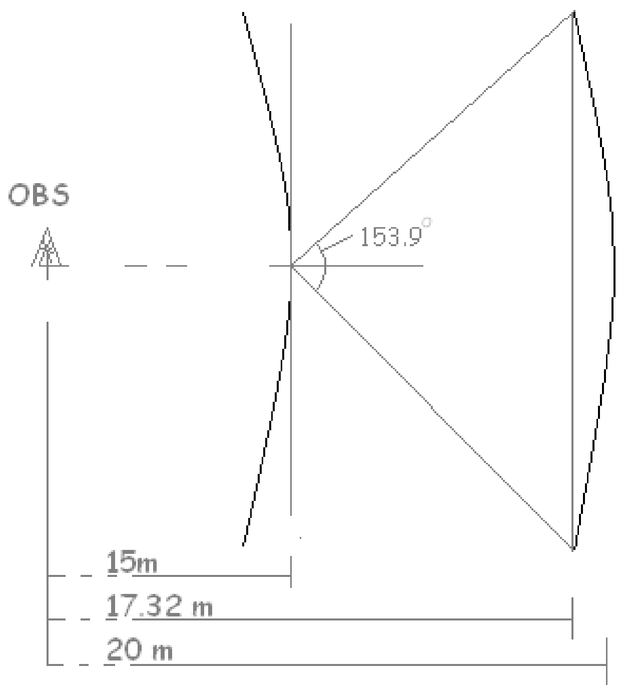

Figure 15. Geometric Representation of high latency microcellular

D. High latency macrocellular

1. Radius of circular cell = 1000 m
2. Latency time = 1 s
3. Speed (Outward radial) = 36 km/h
4. Starting point of handoff (distance from OBS) = 990 m
5. Point beyond which false handoff cannot occur (for 60° region) = 867 m

Thus, Probability of false handoff (for 60° region) = 0%

Hence, we can see that the problem of false handoff initiation discussed in II(B) is faced minimally (mostly in high latency microcellular networks). This, too, is not a major issue of concern, as we are considering here low latency networks.

Moreover, in microcellular networks, we generally do not see mobile stations moving at velocities as high as 18km/h. At a velocity of 9.65 km/h or below, the probability would be reduced to zero. So, the problem of II(B) is taken care of.

SIMULATION

For varied values of velocity and cell size, in both high and low latency networks, we see how the false handoff initiation probability varies in figures 10 to 13. As we can see above, the question of false hand off initiation arises only at very high velocities, more so for low latency networks. This is due to the reasons explained earlier in Section III. These speeds are rarely if ever reached and thus need not bother us. Moreover, the minor shortcomings of this near perfect behaviour, is offset by the fact that our procedure accounts for zero handoff failure probability in practically all scenarios.

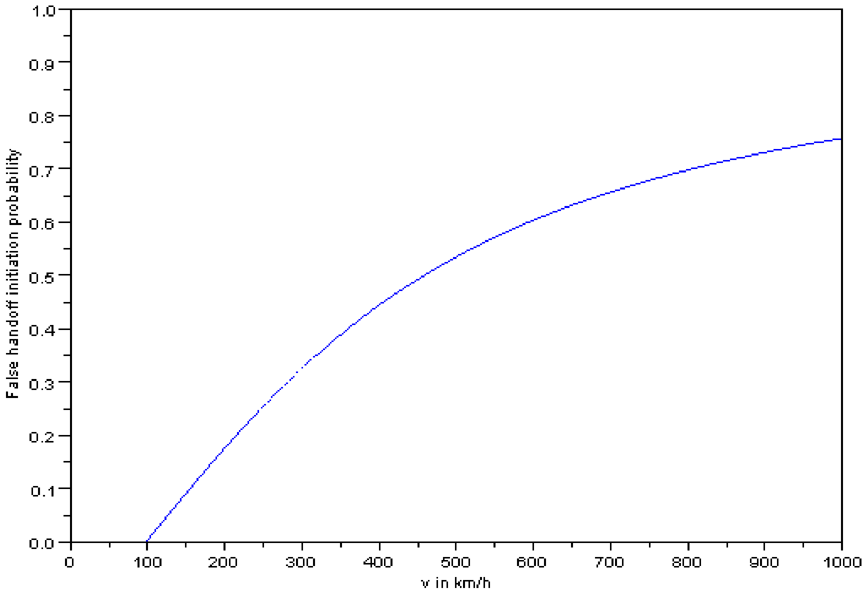

Figure 16. Low latency microcellular

Latency time = 100ms Radius of cell = 20m

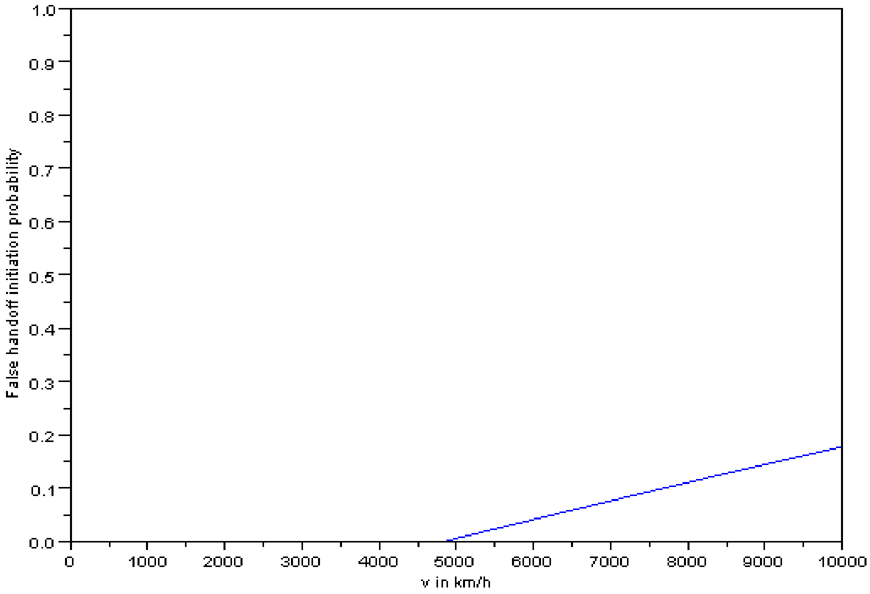

Figure 17. Low latency macrocellular

Latency time = 100ms Radius of cell = 1000m

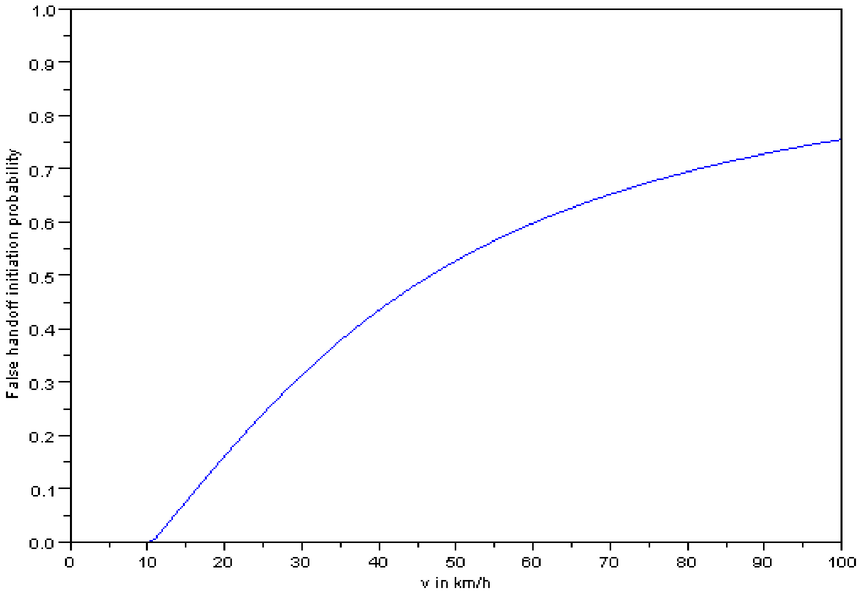

Figure 18. High latency microcellular

Latency time = 1s Radius of cell = 20m

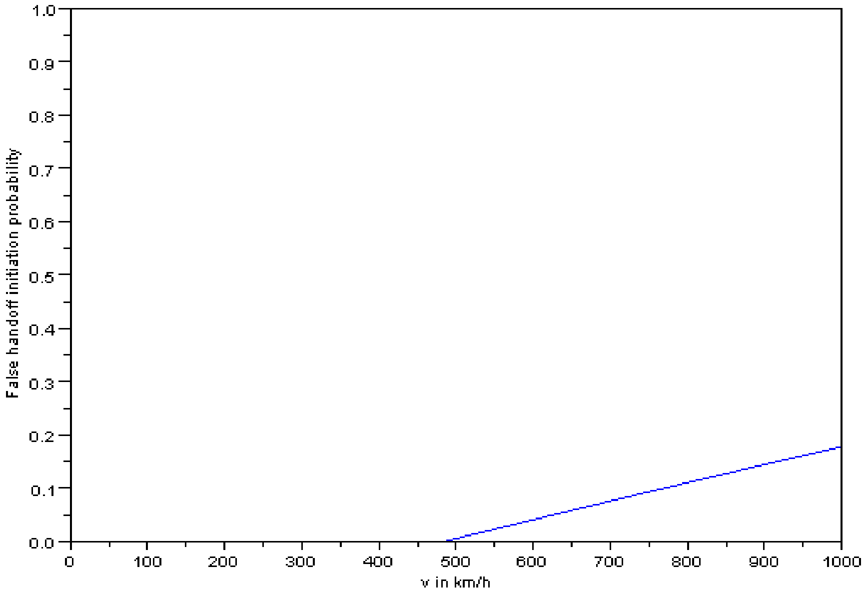

Figure 19. High latency macrocellular

Latency time = 1s Radius of cell = 1000m

CONCLUSION

For NGWS networks

Thus we can see that by suitably restructuring the functional divisions as explained above, we can reduce the latency period, albeit at a minimally higher bandwidth cost, for a short period, which would be offset by the lower network congestion due to lower latency. This would then result in speedier handoffs, lower handoff failure rates, and higher network efficiency. This behaviour would be present irrespective of the presence of overlap and heterogenous networks as explained above.

For 802.11 networks

Thus, as conclusion, we can comfortably say that, by introducing selective scanning of adjoining cells / access points, we can significantly reduce the time required to perform handoff in 802.11 networks. The selective scanning based on position, speed and direction of motion of the Mobile station, is based on a modified form of the neighbour graph scanning technique, which in itself is an efficient procedure. The modification that we suggest in this method further improves performace, by reducing probe delay by upto 67%, resulting in huge savings on bandwidth and data overhead.

This is especially important in the current age as Wi-Fi access points and devices become ubiquitous, and the speed of a mobile station is on the rise.

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