EESM 698H
Spring 2011

Handoff Latency and Delay Minimisation in Wireless Networks

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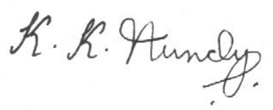
ACKNOWLEDGEMENTS

This project report has been prepared in partial fulfillment of my Master of Science in Telecommunications curriculum under the guidance of Prof. Vincent K.N. Lau. For successful completion of this project and report, I am extremely thankful to my instructor, without whose kind help this project would not have come to fruition.

I would also like to thank Prof. M.K.Naskar and Mr. D. Sarrdar of Jadavpur University, Prof. A. Chandra of NIT Durgapur, and Prof. K.B.Letaief & Prof. R.Cheng of HKUST for their guidance in the field of telecommunications in general and handoff management in particular.

For this report I owe my gratitude to the colossal storehouse of information known as the Internet and also to certain papers & books by several authors on the topic of wireless handoffs. Also, I am grateful to my universities, NIT Durgapur and the Hong Kong University of Science and Technology, for the academic background they have offered me, without which I could neither attempt the project nor be able to complete it.



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Chapter 1 - Abstract

For wireless networks with mobile stations dependent on a central master controller (base station/access point), an important aspect of reliable service is in the maintenance of reliable and good radio link quality between the mobile station and the fixed controller. For this to suitably happen, we must be able to switch control from one base station to another at the cell boundary to maintain the quality and existence of the call. A major bottleneck in ubiquitous, always best service occurs at handoff, with several instances of false handoff initiations resulting in network congestion and sub-par utilisation, and of handoff failures, due to inordinate delay in completion of handoff, resulting in termination of old connection before the new one is established. In this project we discuss current methods used to mitigate the problems of handoff latency and false handoffs, and suggest possible improvisation and modifications on curent and predicted technologies that can offer better handoff performance.

In this report we present techniques for reducing hand-off latency in several kinds of networks, including Next Generation Wireless Networks (NGWS) and Wi-Fi Networks(IEEE 802.11).

Chapter 2 – Introduction

Wireless networks have become an inalienable part of human life today. With nearly every individual owning multiple device that makes use of wireless communication networks, they have practically moved to ubiquity. Under the circumstances, it is often found that new devices can either join a framework or backbone wirelessly, acting as what can loosely be called a client server structure, or develop an ad-hoc network, with a direct connection between two or more equivalent nodes.

Handoff is a complicated process, and if improperly executed, may result in severe data loss, drop in effective channel capacity, and even cause the connection to be dropped. Thus handoff management is a primary design parameter in any such network that requires it. This has under it's purview nearly all familiar wireless LAN, MAN and WAN networks like GSM, CDMA, IEEE 802.11(Wi-Fi), Wi-Max, etc.

There is a need for reduced handoff time in wireless networks , 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.

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.

Chapter 3 - Preliminaries and Definitions

3.1 Handoff

"As a mobile instrument proceeds from one cell to another during the course of a call, a central controller automatically reroutes the call from the old cell to the new cell without a noticeable interruption in the signal reception. This process is known as handoff. "- Britannica[1].

A better description[2] would be , *"In cellular telecommunications, the term handover or handoff refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another."*

As we can see the terms handoff and handover can be used interchangeably and mean the same, the latter being in more common use in European literature.

3.2 Soft Handoff

In this report we will be considering only soft handoffs, where the connection with the new base station is attempted before the connection with the old base station is terminated, rather than immediately terminating the connection between a Mobile Station(MS) and a Base Station (BS). In the course of handoff, a new connection is established first between the MS and a new BS, while keeping the old connection between the MS and the old station. Only after the new connection can stably transmit data, the old connection is released. Thus, Soft Handoff[3] is a "make before break" mechanism. This mechanism helps ensure the service continuity, which is however at the cost of more capacity resource consumption during the handoff (as two connections are established simultaneously).

The difference between soft handoffs and hard handoffs(break before make) can be more clearly understood from Fig 3.1.

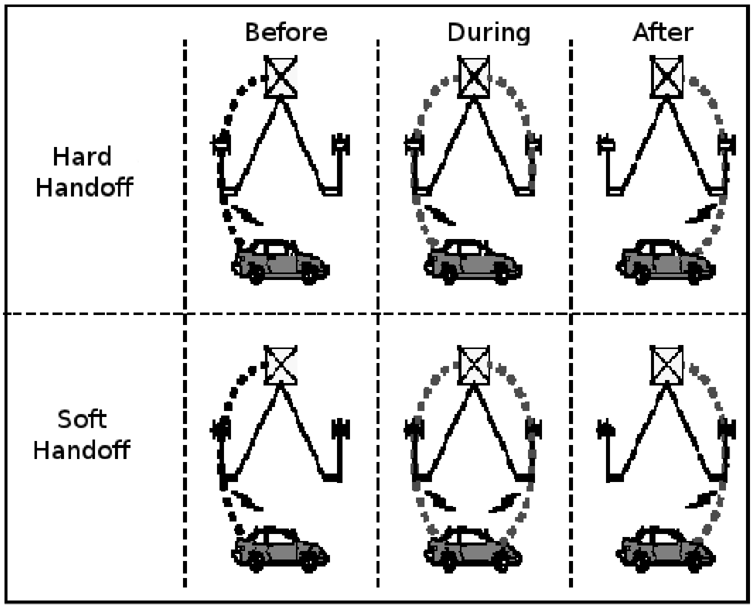

Fig 3.1 Soft and Hard Handoff

3.3 NGWS

Next Generation Wireless System (NGWS)[4][5] consists of different wireless architectures ranging from cellular wireless networks to satellite networks. It is basically a network which follows the always best principle, in form of a heterogeneous network which incorporates networks of various sizes and properties using multiple wireless communication standards to create a network always accessing the best link (optimal throughput, delay and reliability) for communication.

3.4 IEEE 802.11

IEEE 802.11 is a set of standards for Wireless Local Area Networks(WLAN) as specified by the IEEE LAN/MAN Standards Committee. It is colloquially referred to as Wi-fi.

The 802.11 family consists of various over-the-air modulation techniques which use the same basic protocol. The latest release of the specifications is 802.11n, which incorporates enhancements for increased throughput.

The base current version of the standard is IEEE 802.11-2007[6].

Wi-fi is technically a more general de-facto standard based on the IEEE 802.11, and is specified by the Wi-fi Alliance.

Fig 3.2 Logo of the Wi-Fi Alliance

3.5 GPS

GPS or Global Positioning System is a space based location determination standard using satellites. Originally developed by the US military in 1973, currently, it is open for use by everyone, who can receive position(latitude and longitude) data, as well as time information, using a receiver unit. Similar global navigation satellite systems include the Russian GLObal NAvigation Satellite System (GLONASS), opened for civilian use in 2007. Planned alternatives are Compass Navigation system (China), and Galileo positioning system (EU).

Several mobile devices, notably “smartphones”, have started to incorporate GPS receiver units, thereby opening up the possibilty of it's use in telecommunication equipment.

Chapter 4 – Background and literature survey

Considerable work in handoff delay minimisation has been done by Mohanty *et al.*[5][7][8], Tekinay[9], Mollini and several others in various types of networks, mostly in IS-95, WCDMA, WI-Fi, Wi-Max and LTE systems.

According to Shantidev Mohanty[7][8] 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.

4.1 Cross Layer Mobility

One of the older examples of using information from multiple layers[8], stated that, using speed and handoff signaling delay information the performance of existing handoff management protocols can be enhanced. Mohanty *et.al.*[7] 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. It was called Cross Layer Handoff Management Protocol.

4.2 Velocity and Received Signal Strength Estimation

Narsimhan & Cox shows us a simple technique to estimate the speed of the mobile station[10], using Doppler Shift and show that location within the cell be estimated using Received Signal Strength(RSS)[11], to determine the suitable point where handoff should start. They propose that when combined with an estimation of the Doppler shift of the signal received, cell boundaries and time required for handoff can be derived to a reasonable extent[10] [11].

Nundy *et.al.*[12] discusses how to reduce false handoff initiation in low latency networks, using speed and signal strength information, which in turn will help reduce handoff delay and resultant overhead.

4.3 Location Information and GPS

Sarrdar *et al.*[13] suggested a pre-scanning of adjoining cells to detect available channels, using GPS based location information. This resulted in faster handoff, and lower handoff failures without putting any appreciable load on the base station or the network.

Also, in an early implementation, a patent[14] discusses the use of location determination for handoff in mobile systems.

Dutta *et.al.*[15] shows an efficient mechanism for GPS assisted handoffs in real time communication systems. It provides a new methodology that can provide faster IP address discovery using GPS coordinates of the mobile station.

Celebi & Arslan[16], apply GPS information in cognitive networks for more efficient signalling and handoff.

We see other examples of location assisted handoff in the works of Cortes-Rodriguez *et al.*[17] and Raith[18], among others.

4.4 Network Graphs

Network mapping and graphs have been used to estimate handoff initiation and associated signalling for a long time. In recent times, several techniques have been suggested or implemented that utilise both such graphs and location data, to form a more efficient handoff scheduling mechanism. This approach is even more helpful in microcellular and ad-hoc type networks, where the nature of such maps is dynamic and needs to be varied in real time, thus making node location even more pertinent.

In a recent unpublished work[19], we see a modification of the neighbour graph technique[20] to schedule handoff more efficiently in 802.11 type networks, by looking up the location of the nearest access point, so that channel allocation and preregistration can be finished before the handoff actually starts, thus reducing handoff delay significantly.

Chapter 5 – Overview of Current Methods

As mentioned in the introduction, for a best case scenario, handoff techniques require to be started at an optimum time, as late as possible, but never too late.

Also, the handoff algorithm should, for it's own usage, use up as little of the resources as is feasible for acceptable performance.

In most currently deployed solutions, one of the above comes at a very unpleasant lack of the other. Thus, a wasteful tradeoff is executed, resulting in a sub-optimal handoff performance.

At the current rate of growth of wirelessly connected devices, where we move to Everything over IP (EoIP), conservative estimated suggest a trillion connected devices by 2050, compared to around 4-5 billion now. Just we can see that there will be nearly no scope for bandwidth wastage, and further optimization has to occur.

Here, we shall investigate the performance of some of the current production and prototype algorithms for handoff, and discuss their shortcomings and advantages. We shall also analyse the benefit that can be obtained if algorithmic modifications and novel solutions suggested by academia and industry, if incorporated into current or new systems can improve their handoff performance considerably. We shall give special emphasis to methods that use location information of some sort as part of the handoff management.

5.1 Standard Handoff mechanisms in IEEE 802.11

First, as a point of easy reference to the suggested modifications, we mention the typical algorithms that are currently under use in common networks, in the following order : Wi-fi and LTE.

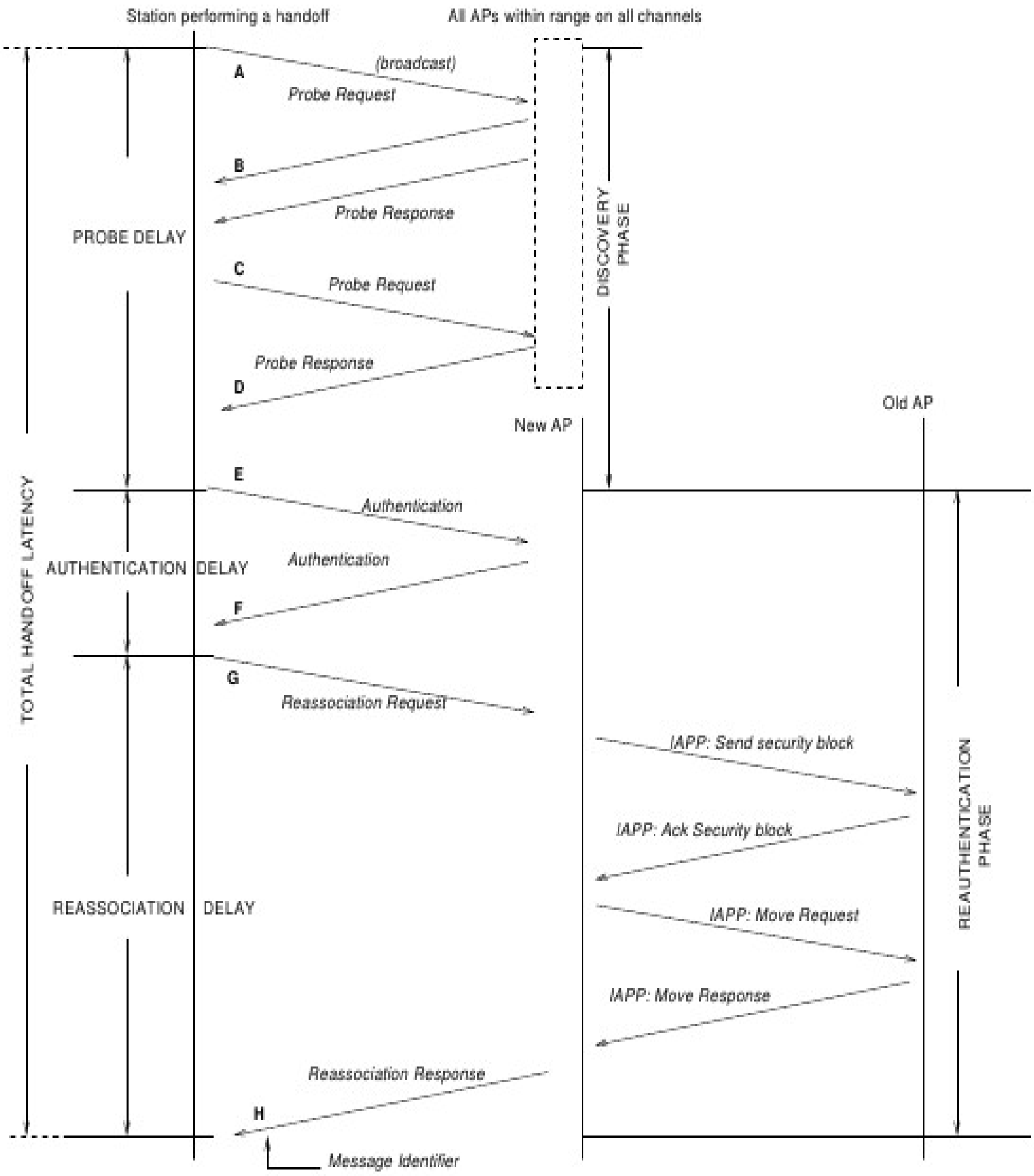

Fig 5.1 The typical IEEE 802.11 Handoff procedure [21]

5.2 Standard Handoff mechanisms in LTE networks

Fig 5.2 shows the basic structure of call handoff [22] when the control plane is already established, and there will only be a change in the user plane. Thus there will be no change in the Serving Gateway(SGW). The handoff taking into consideration the SGW change, called the X2 handover, is a more general case.

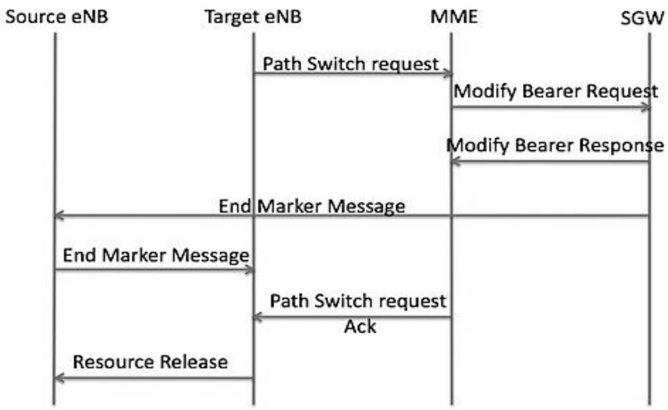

Fig 5.2 . Handoff flow in LTE without SGW change [23]

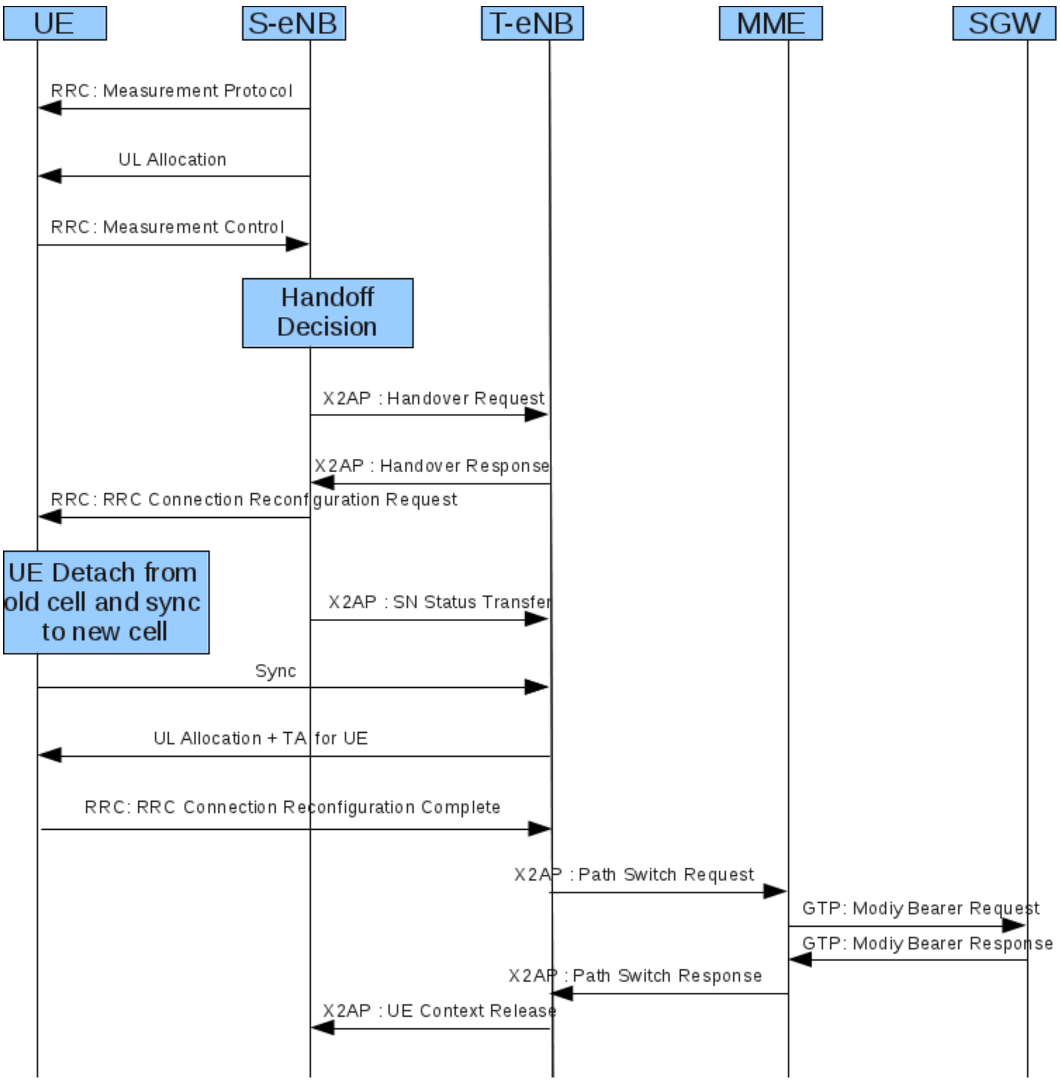

Fig 5.3 LTE X2 Based Handover [23]

Fig 5.3 shows a more complete handoff mechanism, where X2 is the interface between two eNB's and X2-AP is the protocols used for communication over it. Handoff takes place when the eNB detects that UE can no longer be served by it because of the power constraints.

Chapter 6 – Suggested improvements

As is seen in Chapter 4, handoff mangement has been rigorously investigated. In this chapter two possible improvements are suggested to the handoff mechanism, assuming location data is available.

6.1 Modified Neighbour Graph Technique for *IEEE 802.11*

First we show the neighbour graph method[20] flow diagram in Fig. 6.1.

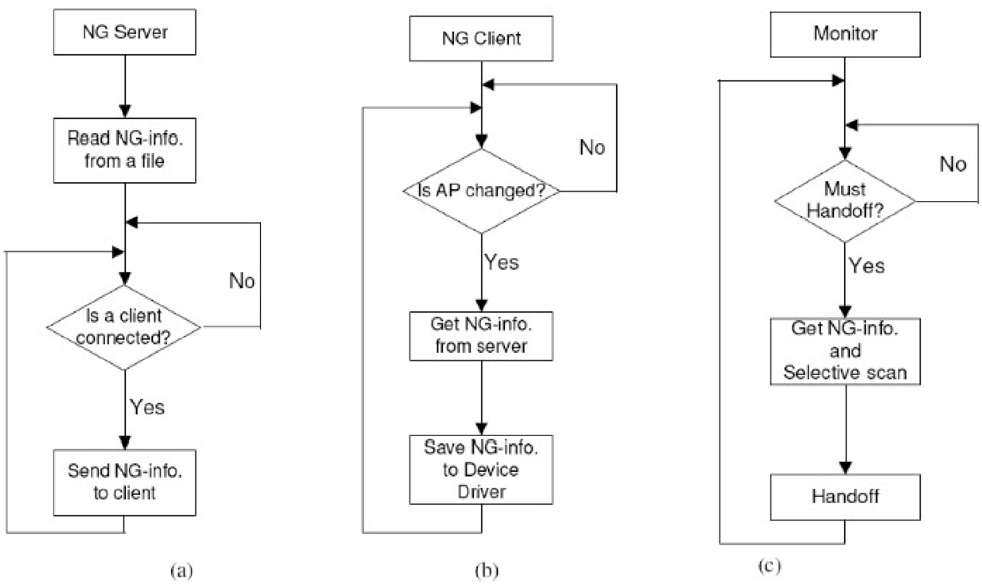

Fig 6.1 Neighbour Graph flow diagram

Thus we see that for the neighbour graph to be correctly generated, we need to actively scan for all the adjoining access points. For a homogenous honeycomb network, this figure is 6 cells/ APs. If location information and cell map is available, we can reduce the number of scans to be made significantly. Two cases of MS position are considered, which can be generalised to represent signal state in all cellular systems, at any positions.

Case A, with radial velocity of MS towards one of the corners of the hexagonal cell.

Case B, with radial velocity of MS towards one of the flat edges of the hexagonal cell.

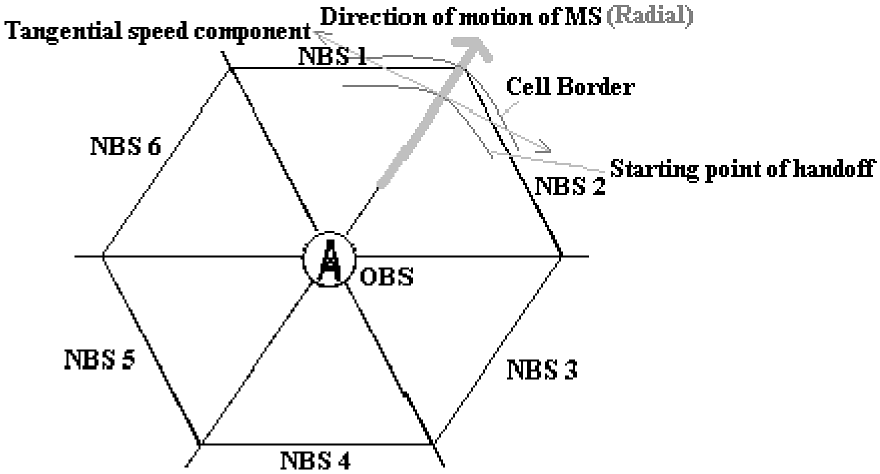

Fig 6.2 Case A with 2 adjoining NBS

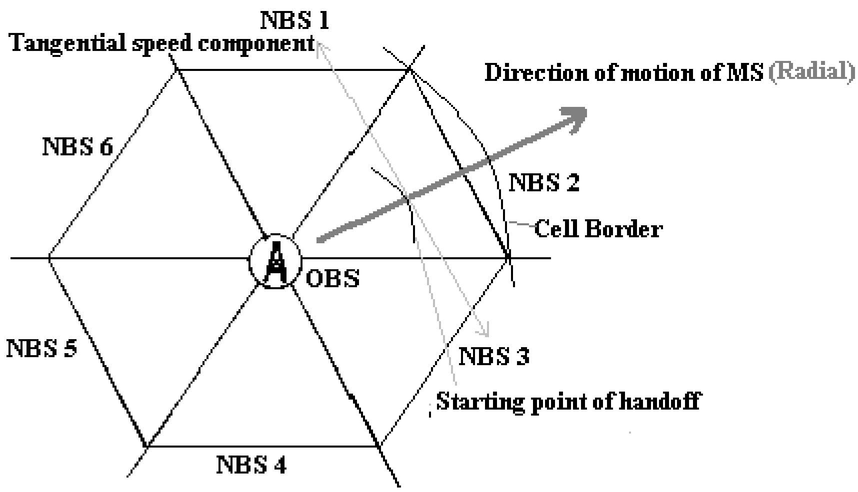

Fig 6.3 Case B with 3 adjoining NBS

6.2 Pre-Selective Scanning with GPS *in IEEE 802.11*

As we can see in Fig. 5.1, handoff delay in 802.11 networks consists of probe delay,authentication delay and reassociation delay.

We are proposing a scheme named “Pre-Selective Scanning with GPS” to reduce the scanning(probe) delay which is 90 percent of the whole handoff delay.

Our scheme has the advantage of selective scanning. There are 14 channels used to be scanned. But only first 11 channels of them are used by IEEE 802.11b. But 1,6,11 number channels are not overlapping; therefore most of APs are likely to operate on these three channels. We also use pre-scanning mechanism where we can complete the scanning phase almost before handoff such that scanning delay will not be included in handoff delay.

In this way, we can reduce handoff delay drastically. We also use GPS to calculate the distance between the Mobile Node (MN) and the best AP in the old AP's neighbourhood area when the MN moves within old base station's cell. We describe our proposed work in flowchart form in Fig 6.4

Taking,

n *= no of times cache is updated with neighbour graph,* ***N****=no.of potential channels.*

Let us assume, actual call time before handoff needed is ***t***. So $N=\frac{t}{T_s}$. If our scheme is applied, then one time will come when ***n*** will be just less than 1, in that time the value of ***n*** will be:

$$n=N-0.005\times[(200\times(N-1))]$$

And the scanning delay will be

$$S_d=T_s-t+.005\times T_s\times[(200\times(\frac{t}{T_s}-1))]$$

To simulate our proposed algorithm, we have found a formula to find scanning delay as function of actual call time before handover. So at every interval of time $\frac{T_s}{100}$, minimum change of n may be 0, and maximum change of ***n*** is 0.1.

So, $$Avg.\,change\,of\,n=\frac{(0+.01+.02+.03+.04+.05+.06+.07+.08+.09+0.1)}{11}=.05$$

So at every interval of time $\frac{T_s}{100}$, n can be changed by 0.05 on average.

For choosing the value of T_s we can have different combination of values.

Pre scanning scheme	Value of T_s *(in ms)*	Reference
Basic active scan	332.00	[24]
Fast active scan	32.36	[25]
Basic selective scan	129.00	[26]
Fast selective scan	3.00	[27]

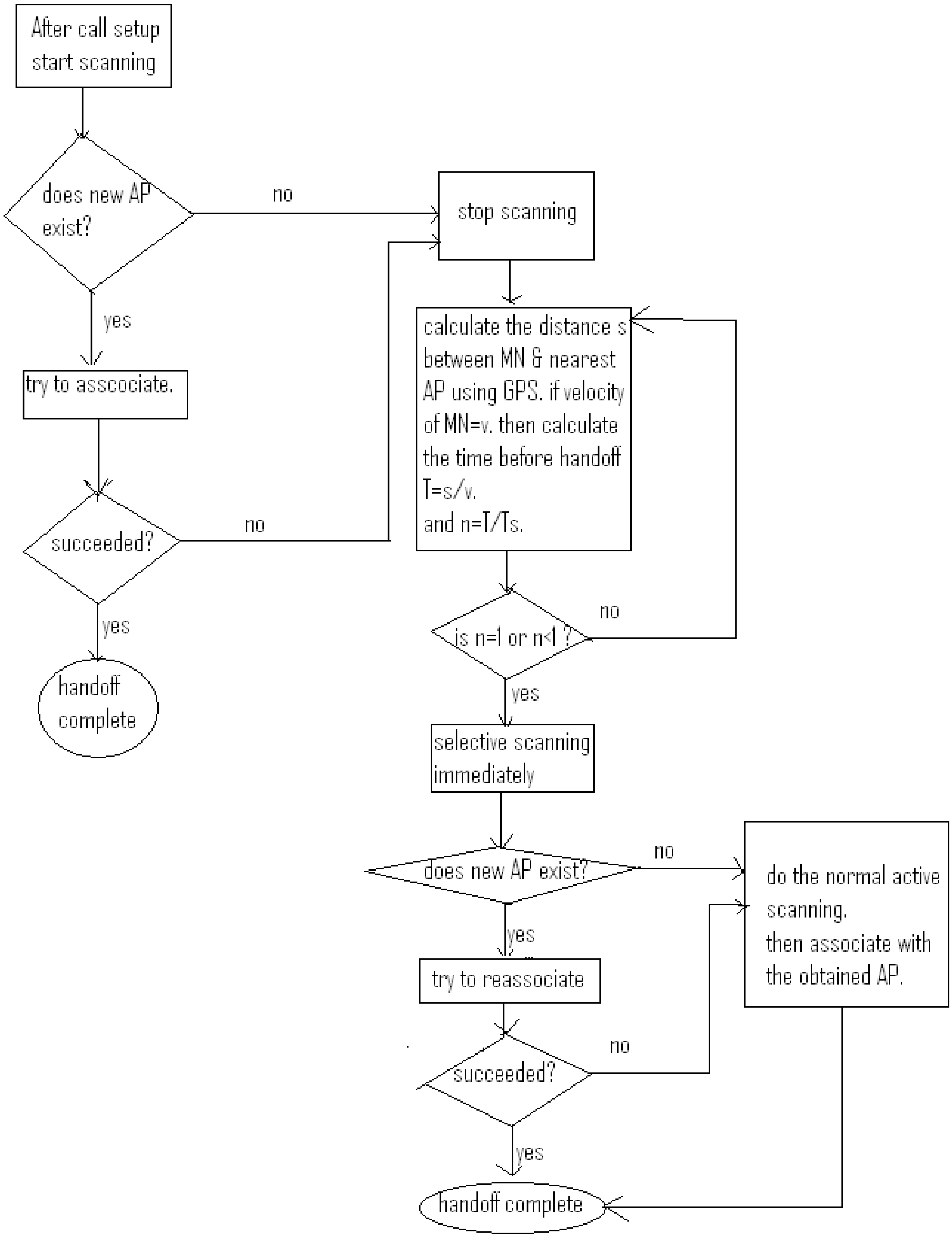

Fig 6.4 Pre-Selective Scanning Algorithm

Chapter 7 - Results & Discussion

7.1 Modified Neighbour Graph Technique

It has been found experimentally that each adjoining NBS takes atleast 3ms to probe. This takes the total probe time to $(3 \times 6) = 18\,ms$. However by accessing the cross layer mobility information we can get an estimate of the RSS[11] and velocity[10] of propagation of the mobile station.

According to *Narsimhan & Cox*[10] [11], 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 **[Case A]**, 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 $(6 \times 3) = 18\text{ms}$ to $(2 \times 3) = 6\,ms$.

Similarly, for **Case B,** 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 $(3 \times 3) = 9\,ms$.

Thus we see that in both cases the probe delay time is reduced by $(18 - 9) = 9\,ms$ and in the other situation it is reduced by $(18 - 6) = 12\,ms$ by using selective scanning technique in Neighbour Graph method. Hence probe delay, which constitutes typically 90% of the total delay can be reduced by upto 67%, thus greatly improving handoff performance.

7.2 Pre-Selective Scanning with GPS

So, from Fig 7.1 to 7.4, we can realize that the effective delays are lesser than the previous value because of pre-scanning. The simulation results indicate that the average delays for basic active scanning, fast active scanning, basic selective scanning and selective scanning using cache are largely minimised. So if we use our proposed pre-scanning mechanism, handoff delay can be reduced to a great extent.

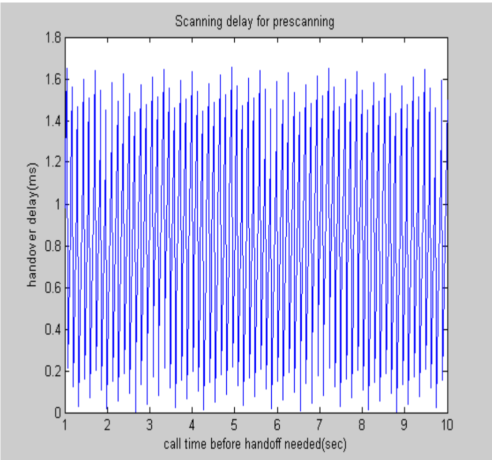

Fig 7.1 Scanning delay (basic active scan) (T_s = 332 *ms*)

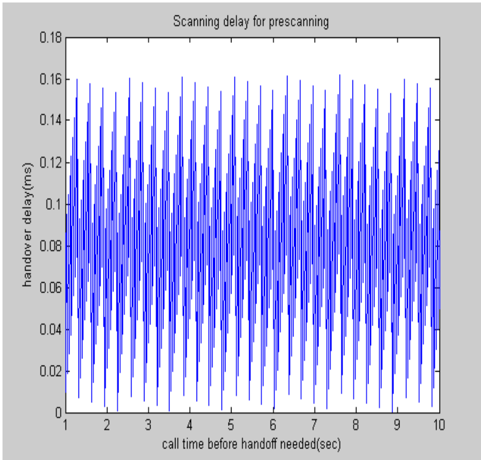

Fig 7.2 Scanning delay (fast active scan) (T_s = 32.36 *ms*)

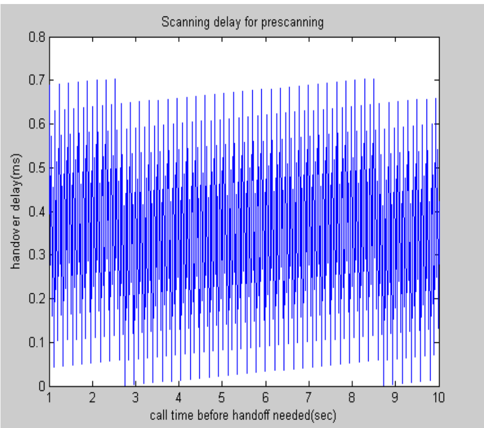

Fig 7.3 Scanning delay (basic selective scanning) (T_s = 141 *ms*)

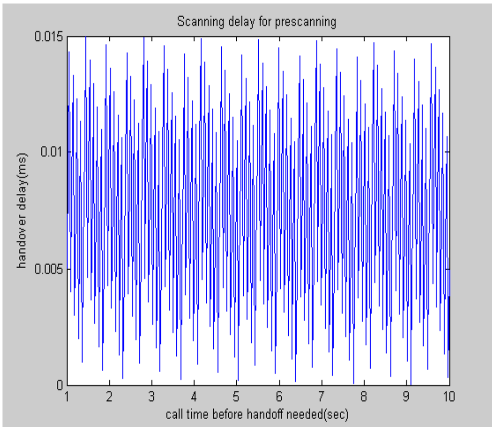

Fig 7.4 Scanning delay(selective scanning) using cache (T_s = 3 *ms*)

Pre scanning scheme	T_s ***(in ms) with normal scan***	**Effective value of delay after pre-scanning *(in ms)***
Basic active scan	332.00	0.825
Fast active scan	32.36	0.08
Basic selective scan	129.00	0.35
Fast selective scan	3.00	0.0075

So, we see a marked improvement in handoff delay minimisation.

Chapter 8 – Conclusion and Future Scope

We can see that because of it's inherent role in the way cellular communication systems function, handoff management is a primary area of study in the design of all such telecommunication networks and systems.

The utilisation of location information has been broadly discussed and available literature, some of which is discussed here, makes us expect better performance in terms of minimisation of handoff delay, hand off failure and false handoff initiation.

This, however, comes at the price of complexity, poorer battery performance (GPS and velocity estimation techniques are power guzzlers), and lack of reliability.

The last point arises from the issue of GPS being under an unilateral military administration, thus causing reasonable lack of independent calibration, fine tuning and technical support. Also, it works only in an outdoor low-cloud environment, with errors that can go upto 50 m, thus rendering them unsuitable for heterogeneous and microcellular networks. Also the current unavailability of GPS receivers or similar equipment universally results in our being unable to deploy it within the standard. The aforementioned environmental limitations also suggest that location information may not be available at all times even in mobile stations equipped with relevant hardware and software.

So we can say that while the availability of location information improves the efficiency of the handoff mechanism, a lot of work remains to be done to ensure its universal availability. This leaves scope for a lot of future research and study, for development of reliable, accessible and uniform acquisition of such relevant information.

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