# Signal to Interference Ratio Based Handoff Management for Next-Generation Wireless Systems

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***Abstract*—Next-generation wireless systems (NGWS) integrate different wireless networks, each of which is optimized for some specific services such as WLANs, WiMAX, General Packet Radio Service (GPRS) and Universal Mobile Telecommunications System (UMTS). The most important and challenging issue is seamless handoff management in NGWS to ensure the Quality of Service (QoS). In this paper, we propose a handoff management architecture using signal to interference ratio of the present and neighboring base stations. This handoff management scheme uses mobile's speed, handoff signaling delay information and also the size of the present and neighboring cell to enhance the handoff performance. In our proposed work we use the signal to interference ratio threshold values between present base station in which the mobile terminal is served and its neighboring stations. The simulation results show that our proposed mechanism supports mobility management in wireless IP networks and significantly enhances the handoff performance for both intra and intersystem handoffs reducing false handoff initiation and unnecessary call blocking probability.**

***Index Terms*- Next Generation Wireless Systems (NGWS), SIR (Signal to interference Ratio), MT (Mobile Terminal), Hand-off Latency, HMIP (Hierarchical Mobile IP).**

## I. Introduction

Next generation wireless networks is a convergence of different wireless communication systems such as Bluetooth for personal area, IEEE 802.11-based WLANs for local area, Universal Mobile Telecommunications System (UMTS) for wide area, and satellite networks for global networking. These networks are complementary to each other and, hence, their integration can realize unified next-generation wireless systems (NGWS). In the integrated NGWS, users are always connected to the best available networks and switch between different networks based on their service needs [1]. It is an important and challenging issue to support seamless mobility management in the NGWS. Mobility management contains two components: location management and handoff management [2]. One of the main issues with wireless mobility is the latency involved when a client moves out of the range of one BS and move into the range of a new BS, called a handoff. The overall handoff latency can cause loss of packets which is intolerable for the services such as voice over IP (VoIP) and Multimedia. The integrated architecture for NGWS (Fig. 1) consists of two different wireless systems, System A and System B. These two systems are integrated through the Internet backbone [1]. It may be noted that, in a real scenario, the integrated architecture may consist of many different wireless systems. Fig. 1 shows the architectural components of the hierarchical Mobile IP [4] protocol. In NGWS, two types of handoff scenarios may arise: horizontal handoff and vertical handoff [5], [6].

- Horizontal Handoff: Handoff between two BSs of the same system. Horizontal handoff can be further classified into
  - Link-Layer Handoff: Horizontal handoff between two BSs that are under the same foreign agent (FA), e.g., the handoff of a Mobile Terminal (MT) from BS10 to BS11 in Fig. 1.
  - Intra-system Handoff: Horizontal handoff between two BSs that belong to two different FAs and both the FAs belong to the same system and, hence, to same gateway foreign agent (GFA), e.g., the handoff of the MT from BS11 to BS12 in Fig. 1.
- Vertical Handoff (Intersystem Handoff): Handoff between two BSs that belong to two different

systems and, hence, to two different GFAs, e.g., the handoff of the MT from BS12 to BS20 in Fig. 1.

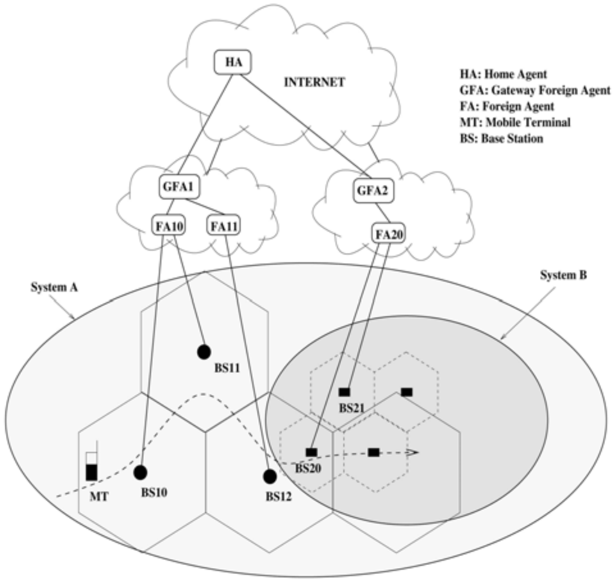


Fig1. Hand-off in the integrated NGWS architecture

Handoff can also be classified into two categories: Soft Handoff and Hard Handoff. In soft handoff the mobile can establish multiple connections with it neighboring cell before relinquishing connection with its old cell. The hard handoff term is used when the communication channel is released first and the new channel is acquired later from the neighboring cell.

Cellular systems deploy smaller cells in order to achieve high system capacity due to the limited spectrum. The frequency band is divided into smaller bands and those bands are reused in non interfering cells [1-3].Our cellular model consists of *cells* that are geographical areas associated with each of which is a single *base station.* Each cell has a certain fixed number of radio communication channels which it can assign to calls in progress within that cell. A mobile unit normally communicates over one of these radio channels with the base station in a cell in which it is located. The individual cells tile the entire geographical area of interest. This tiling is not exact, however, in that neighboring cells overlap to form regions called *handover regions.* During the time interval the mobile traverses the handover region between the two cells during which the mobile can still communicate with its old cell. Such a call is aborted only if it could not be assigned a channel until the time it has crossed this handover region. When a mobile is in such a region and moving from one cell to another, it needs to relinquish its channel in its old cell and acquire a new channel in the new cell, before it has crossed over completely. A request from a call in progress that has just entered the cell's area is not immediately rejected. Instead, it is en-queued in the hope that it can be assigned a channel at some later time. If, due to unavailability of channel in the new cell, it is unable to do so, the call in progress is aborted, and a *handover failure* is said to have occurred. Different handoff techniques are proposed so far and two of the most important metrics for evaluating a handoff technique are forced termination probability and call blocking probability. The forced termination probability is the probability of dropping an active call due to handoff failure and the call blocking probability is probability of blocking a new call request. The aim of a handoff procedure is to decrease forced termination probability while not increasing call blocking probability significantly. This leads us to the need of reducing handoff latency and to efficiently start handoff procedure without increasing false handoff initiation probability and also decreasing handoff failure probability as much as possible. Handoff can cause jittering in the connection which interrupts the stream of data being sent to the client. Total handoff procedure and associated delays are described below (Fig 2)

### *A. Handoff Process:*

The handoff process involves three steps:

1. Discovery – This is when the MS scans the network by looking for the beacon messages that each access point broadcasts. Also, the MS can build a priority list of BSs, depending on its signal strength.
2. Re-authentication – Using the priority list built during discovery, the MS synchronizes itself with the best BS in its list. It involves having authorization credentials and state information sent from the original AP to the new one.
3. Re-association- The MS then associate with the newly authenticated BS.

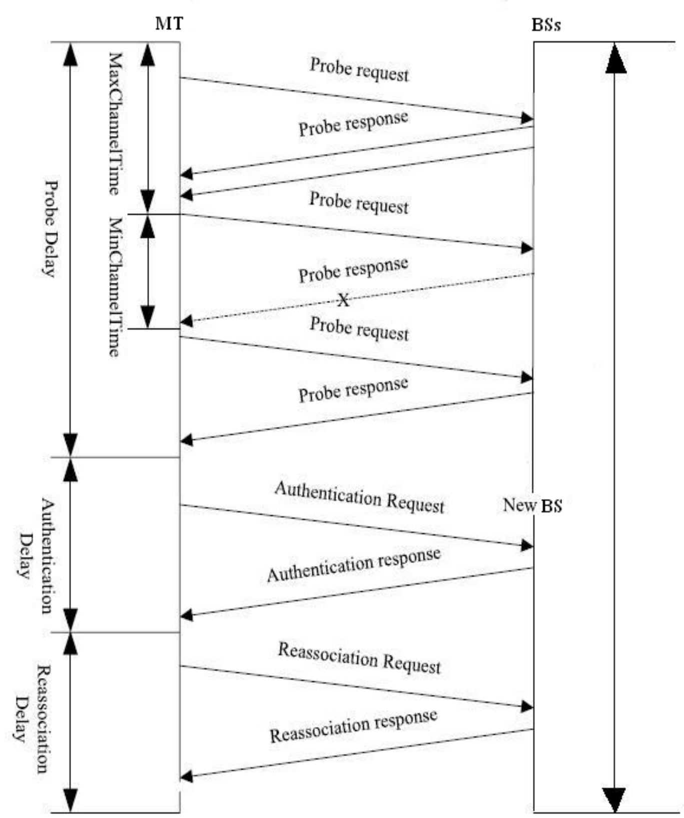


Fig 2 Handoff procedure

### *B. Handoff Delays:*

The three steps required for a successful handoff introduce latency issues. These issues are as follows:

• Probe Delay – This is the amount of time, the MS takes to complete a scan of available networks and to build its priority list. It is required to send somewhere between 3 to 11 messages in order to complete this task.
• Authentication Delay – This is the amount of time it takes for the MS to re-authenticate to the AP it chose from its priority list. Depending on the type of authentication, either 2 or 4 packets need to be exchanged.
• Reassociation Delay – This is the amount of time it takes for the MS to signal the AP that the handoff is complete. It is required that a minimum of 2 packets be exchanged.

## II. RELATED WORK

Recently different cross layer approaches has been proposed to enhance the performance of handover in next generation heterogeneous wireless networks. Some proposed new algorithms or new protocols. For QoS demanding applications like VoIP and multimedia seamless handoff in mobility support has become a great issue in NGWS.

Handoff using received signal strength (RSS) of BS has been proposed previously. Using dynamic threshold value of RSS for handoff management for MTs of different velocities has been described in [7].

In [8], 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 [9] and [10], an improved threshold-based method is introduced and compared with the basic initiation techniques such as maximum power handoff (MPH or RSS), RSS with hysteresis, RSS with threshold, and combinations of hysteresis and threshold based methods in a ten-cell structure. Work has also been done for a SIR based handoff initiation protocol in [11].

In [12], 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.

Handoff delay is mainly looked after on the MAC layer and higher layers in present scenario [13]. Handoff delay mainly occurs due to averaging and hysteresis in the physical layer. Both hysteresis and averaging delays have been calculated analytically in [14]. Optimal handoff delay has been analyzed in [15].

In case of GSM, combined relative and absolute signal strength measurements based hard handover algorithm (CSS) is used in [16]. Timer based algorithm is used in case of CDMA based system. A hysteresis plus timer based algorithm has been proposed for 2 BS model in [17] and [18].

Local averaging is employed other than conventional exponential averaging in [19] to get better performance.

## III. PROPOSED WORK

In this paper we attempt to develop a handoff algorithm that reduces false handoff initiation which creates unnecessary traffic load, by considering different value of signal to interference ratio (SIR) threshold of different sized cells and different velocity of MT.

In this section we assume that two base stations, the primary BS and the secondary BS antennas are transmitting a signal and both of the signals are received by a MT currently under BS1, the primary BS in figure 3.

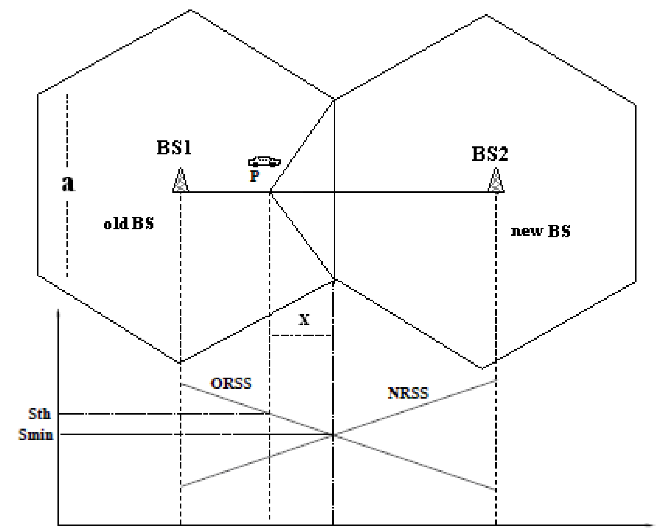


Fig 3

$SIR_{th}$ is the threshold value of Signal to Interference Ratio (SIR) to initiate Hierarchical Mobile IP(HMIP) handover process. Therefore, when the SIR of the BS1 drops below $SIR_{th}$, the HMIP registration is initiated for MT's handover to the new BS (BS2). We are considering the scenario where the mobile terminal (MT) is moving with a velocity v away from BS1 towards BS2.

During its motion the MT anticipates a handoff with a neighboring BS when it finds the SIR decreasing in a constant manner. Then it needs to perform HMIP registration with the corresponding BS or the FA (Foreign agent) serving the BS. The existing HMIP protocols propose to initiate the handoff process when the SIR from the serving BS drops below $SIR_{th}$ .

It is not efficient at all to use same value of $SIR_{th}$ for inter and intra system handoff because the latencies of inter and intersystem handoff is different. In intersystem handoff the MT takes much greater time than intra-system handoff.

It is also inefficient to use same $SIR_{th}$ value if the cell size differs (fig4) from one another because handoff initiation takes place a lot earlier than needed in smaller cell. In this case false handoff initiation probability may be increased causing greater traffic load.

In our approach we want to use five parameters: speed of the MT, SIR, latency of handoff, size of the cell the MT is served at present and size of the cell with which the MT is attempting to initiate handoff. We define threshold of SIR, based on latency, speed, size of the cells, hence the threshold will be dynamic depending on the situations.

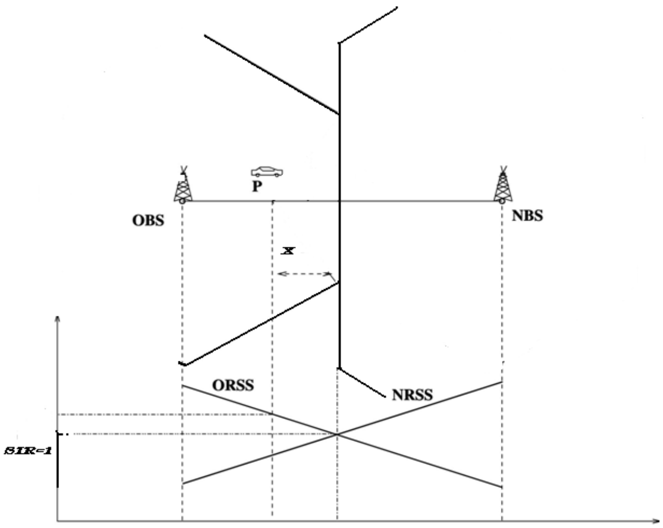


Fig 4

Let us assume that during the course of MT's motion it is at a distance x from the cell boundary of its serving BS as shown in figure5. We assume that at this point the SIR drops below $SIR_{th}$ value and the MT will start HMIP registration with the BS of the neighboring cell. Let r1 be the distance of the BS from the cell boundary of the cell the MT is presently situated and r2 be the new cell size (Fig 5).

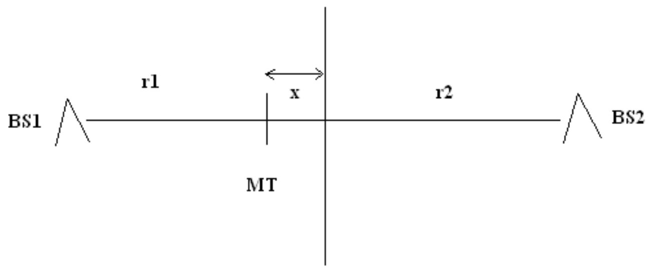


Fig 5

Here we consider cells to be hexagonal. The signal from the secondary station (BS2 in fig 3) causes interference with the signal from the signal from the primary base station (BS1 in fig 3). We take SIR as the ratio of signal strength of the primary BS to that of the secondary BS. So as the MT moves toward s the cell boundary it decreases and it increases if the MT moves closer to the primary BS. We want to use this ratio to define a threshold, so that when the SIR drops below this threshold value handoff is initiated.

We consider that the receiver and transmitter antennas have the same gain and the system loss factor is the same for all the BSs.

The free space model predicts that the received power decays as a function of distance rose to some power, i.e. a power law function. The received signal power of a receiver at a distance d from a transmitter antenna is given by the Friis free space equation

$$P_r=P_tG_tG_r(\lambda)^2/((4\pi d)^2L) \qquad (1)$$

Here $P_t$ =the transmitted power

$G_t$=the transmitter antenna gain

$G_r$=the receiver antenna gain

$\lambda$=wavelength of radiation in meters

L is the system loss factor and it is not related with propagation.

Now

$$SIR=P_{rcell1}/P_{rcell2} \qquad (2)$$

So from equation (1) we get that

$$SIR=P_{tcell1}\,(r2+x)^2/P_{tcell2}(r1-x)^2 \qquad (3)$$

Now $P_t$ is not same for all the BSs and it depends on the cell size of the corresponding BS.

At the boundary of the two cells the received signal strength will be same for both the BSs as shown in figure4. Hence at the boundary (r1 distance from BS1, r2 distance from BS2) of the two cells

$$P_{rcell1}=P_{rcell2} \qquad (4)$$

From equation (1) and (4) we get that

$$P_{tcell1}/P_{tcell2}= (r1/r2)^2 \qquad (5)$$

Here we have taken all the assumptions we made earlier.

From equation (3) and (5) we get that

$$SIR= (r1/r2)^2((r2+x)/(r1-x))^2 \qquad (6)$$

Now we know that handoff failure probability is 0 for t>=T and hence x>=vT

Where T is the latency of handoff or signaling delay and v is velocity of the undergoing handoff and t is the time the MN takes to move out of the coverage area of BS.

It is proposed in [7] that probability of false handoff initiation

$$P_f=1- \arctan(a/2x)/\pi$$

This shows that probability of false handoff initiation decreases as x decreases. Hence we have chosen t=T and x=vT to make probability of false handoff initiation as small as possible keeping handoff failure probability zero.

So the threshold of SIR is given by

$$SIR_{th}= (r1/r2)^2((r2+vT)/(r1-vT))^2$$

Actually, if the same value of $SIR_{th}$ is used for different MT speeds for different size of cells then that will increase handoff failure probability and false handoff initiation. Our aim here is to use an adaptive value of $SIR_{th}$ depending on the MT's speed, size of the cells concerned and handoff latency so that handoff failure probability is as less as possible and also to ensure that there is no unnecessary load of traffic by increasing number of false handoff initiation.

We design a architecture with adaptive $SIR_{th}$ for handoff management as shown in figure6.

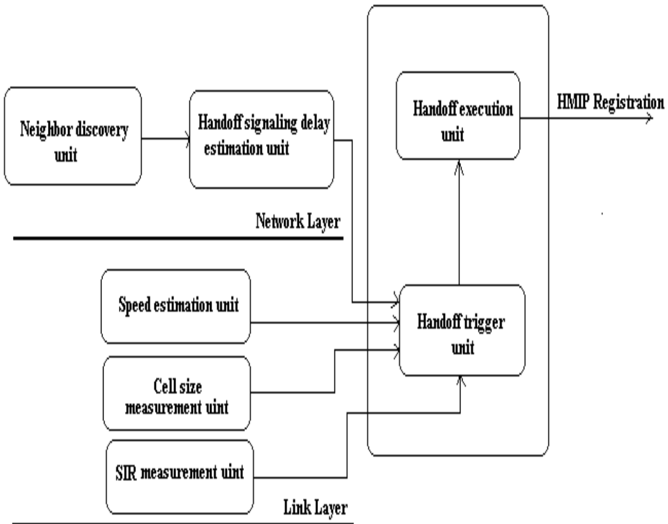


Fig 6. Proposed handoff management architecture.

The *Neighbor discovery unit* assists the MT to learn about the neighboring BSs.

The *Handoff signaling delay estimation unit* helps in estimating the time needed for handoff execution.

The *Speed estimation unit* determines the speed of the MT.

The *Cell size measurement* unit measures the size of the present cell and the neighboring unit and helps in determining the $SIR_{th}$ for handoff. The cell size is measured by using the signal strength of both the BSs at some definite distance intervals and hence measuring the distance of the boundary of the two cells from their respective BSs.

The *SIR measurement unit* measures the SIR of the present base station and the neighboring base station.

The *Handoff trigger unit* collects information from the Handoff signaling delay estimation unit, Speed estimation unit, SIR measurement unit and Cell size measurement unit to determine the time to start handoff procedures.

Finally the *Handoff execution unit* initiates the HMIP registration process at the time calculated by Handoff trigger unit.

*Speed Estimation*:

The speed is estimated using the algorithm VEPSD (velocity estimation using the power spectral density of the received signal envelope) proposed in [20]. The maximum Doppler frequency ($f_m$) is related to speed of light in free space (c), carrier frequency of the received signal ($f_c$) and speed of mobile user through

$$v=(c/f_c)\, f_m \qquad (7)$$

it estimates $f_m$ using the slope of the power spectral density (PSD) of the received signal envelope. The slope of the PSD of received signal has maxima at frequencies $f_c \pm f_m$ in mobile environments. VEPSD detects the maximum value of received signal envelope's PSD that corresponds to the highest frequency component $f_c+f_m$ to estimate $f_m$.

## IV. SIMULATION RESULT

To evaluate our proposed mechanism for handoff we simulate the mechanism for three cases i.e. handoff between 1.macro-cell to macro-cell, 2.macro-cell to micro-cell and 3.microcell to micro-cell. We simulate the work taking three values of signaling delays 500ms, 1s and 2s. For first case, we consider a macro-cellular system with a cell size of a= 1 km and the maximum value of mobile terminal's speed in a macro-cell is 100 km/h. Fig 7 shows the relation between SIR threshold and different speed values of the MT when the MT moves into a macro-cell from its macro-cellular base station.

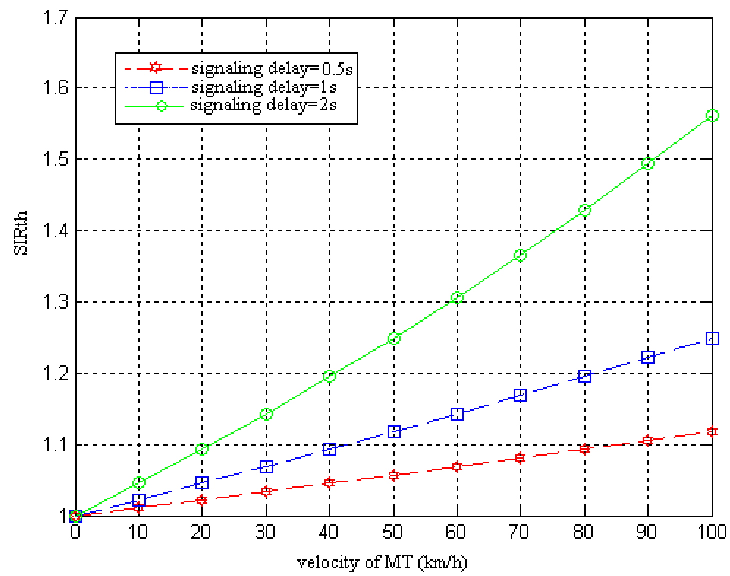


Fig 7

For second case we consider a macro-cellular and a microcellular system with a cell size of a= 1 km and a= 500m respectively. The maximum speed of the mobile terminal is 100 km/h. Fig 8 shows the relation between SIR threshold and different speed values of the MT when the MT moves into a microcell from its macro-cellular system.

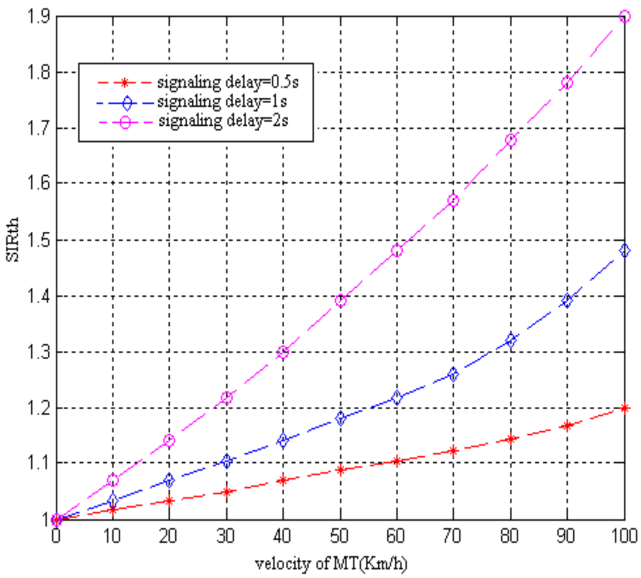


Fig 8

For last case we consider two micro-cellular system with a cell size of a= 200 m each. The maximum speed of the mobile terminal is 20 km/h in a micro-cellular system. Fig 9 shows the relation between SIR threshold and different speed values of the MT when the MT moves into a microcell from its old micro-cellular system.

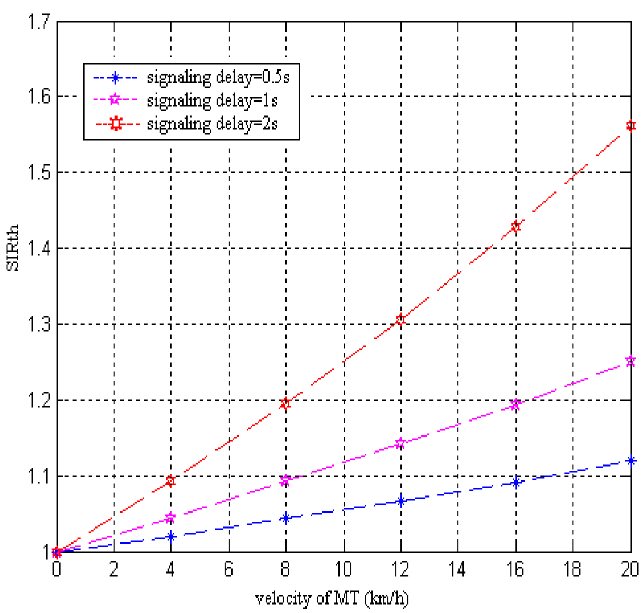


Fig9

The simulation results indicate that if a mobile terminal moves with a higher speed threshold value of SIR increases exponentialy. So whenever a MT moves with a higher speed towards its cell boundary it has to initiate HMIP registration earlier as compared to slow moving MT to achieve a successful handoff. SIR threshold also increases if signaling delay or handoff latency increases. It indicates that if the traffic load of a base station is large the MT in that cell has to initiate HMIP registration earlier than low traffic load network to reduce false handoff.

## V. CONCLUSION

In this work, we discuss the different types of handoff and the factors that determine the reliability of any handoff protocol. It is shown that the threshold value of SIR depends on the velocity of the MT and the latency of handoff. It is shown that how size of the present and neighboring cells determine the threshold of SIR in any handoff process. Through our analysis we see that adaptive value of $SIR_{th}$ depending on the cell size behaves better than using a fixed value of $SIR_{th}$ for different sizes of cell. Our proposed handoff management estimates mobile's speed and predicts the handoff signaling delay of possible handoffs and also the size of the present and the neighboring cell. Our protocol uses this information to calculate a dynamic value of SIR threshold ($SIR_{th}$) for handoff initiation. Using different values of $SIR_{th}$ for handoff between different sizes of cell reduces the false handoff initiation probability considerably and hence unnecessary traffic load which could lead to unnecessary call blocking.

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He is an author/co-author of the several published/accepted articles in WDM optical networking field that include "Adaptive Dynamic Wavelength Routing for WDM Optical Networks" [WOCN,2006], "A Heuristic Solution to SADM minimization for Static Traffic Grooming in WDM uni-directional Ring Networks" [Photonic Network Communication, 2006],"Genetic Evolutionary Approach for Static Traffic Grooming to SONET over WDM Optical Networks" [Computer Communication, Elsevier, 2007], and "Genetic Evolutionary Algorithm for Optimal Allocation of Wavelength Converters in WDM Optical Networks" [Photonic Network Communications,2008].