



## Performance Analysis of Handoff in CDMA Cellular System

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### ABSTRACT

Handoff mechanism is extremely important in cellular network because of the cellular architecture employed to maximize spectrum utilization. This unique feature has driven the rapid growth in the mobile network industry, changing it from a new technology into a massive industry within less than two decades. Handoff is the essential functionality for dealing with the mobility of the mobile users. This paper shows the soft handoff effects on the uplink direction of IS-95 CDMA networks is carried out, leading to optimize soft handoff for capacity under perfect power control approach. In practical systems, there is a nonzero handoff completion delay and soft handoff provides the required robustness to delays, although it comes at the expense of additional network resources. Thus, there is a tradeoff between the extent of soft handoff required and the handoff execution delay. This paper presents an analytical framework to study this tradeoff and also discuss simulation results simulated with the help of Matlab. For this, handoff dropping probability is minimized up to 0.1%.

### Indexing terms/Keywords

CDMA, Handoff, DCA, FCA

### Academic Discipline And Sub-Disciplines

Electronics and Communication Engineering

### SUBJECT CLASSIFICATION

Wireless Communication

### TYPE (METHOD/APPROACH)

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## 1. INTRODUCTION

CDMA is an attractive proposition for increasing cellular system capacity in dense urban areas, due to its many inherent benefits like the ability to mitigate multipath fading and interference, universal frequency reuse, soft handoff capability, and the ability to exploit voice activity detection.

CDMA employs what is known as a wideband spread spectrum technology to carry digitized voice and data transmissions. As each voice is digitized at the mobile phone, it is assigned a unique digital code known as a Walsh code. This code assigned as a pseudorandom noise code that's generated by the digital radio. At this point, the voice transmission has been encoded. This code is then transmitted to the base station, where the voice is decoded, and regular call processing is completed. This process is analogous to each mobile speaking a different language and the base station interpreting its own separate code.[1],[2]

### 1.1 Power control in CDMA

Power control is a necessary element in all-mobile systems because of the battery life problem and safety reasons, but in CDMA systems, power control is essential because of the interference limited nature of CDMA. In GSM slow (frequency approximately 2 Hz) power control is employed. In IS-95 fast power control with 800 Hz is supported in the uplink, but in the downlink, a relatively slow (approximately 50 Hz) power control loop controls the transmission power. The reasons for using power control are different in the uplink and downlink.[7]

CDMA base stations control the power of all mobiles for interference reduction purposes. All mobile signals must arrive at the base station at the same power level so that the signals can be properly coded. Power control is a required operational parameter of CDMA digital system operations. For example, if a mobile station that is right next to the base station is transmitting at very high power, and a mobile station 10 mile (16Km) away from the base station is transmitting at very low power, the power of the mobile next to the base station is throttled down to a given level while the power of the mobile 16Km away from the base station is raised to a given level.

Power control is necessary to maintain system capacity. Proper control of power in CDMA system results in reducing power costs at the BS, as well as increased battery life in the mobile phone system.[3]

## 2. HAND OFF

Mobility is the most important feature of a wireless cellular communication system. Usually, continuous service is achieved by supporting handoff (or handover) from one cell to another. Handoff is the process of changing the channel (frequency, time slot, spreading code, or combination of them) associated with the current connection while a call is in progress. It is often initiated either by crossing a cell boundary or by deterioration in quality of the signal in the current channel.

### 2.1 Types of handoff

Handoffs are broadly classified into two categories: hard and soft handoffs.

#### 2.1.1 Hard handoff

A hard handoff is essentially a "break before make" connection. Under the control of the MSC, the BS hands off the MS's call to another cell and then drop the call.

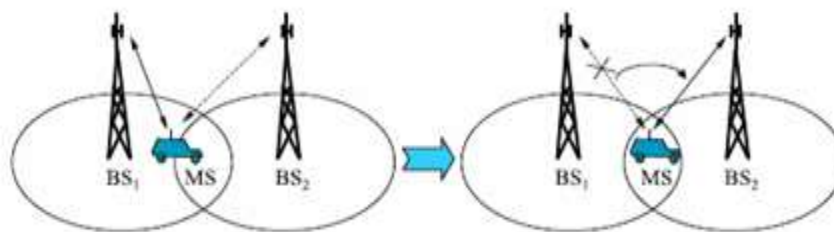
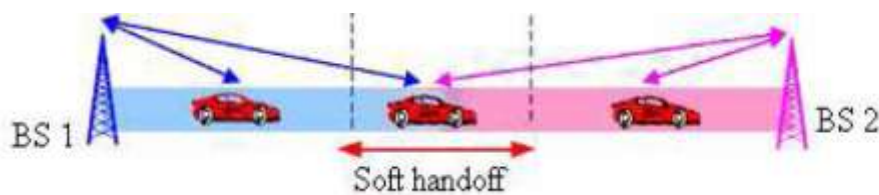


Fig 2.1. Hard handoff between MS and BSs

In a hard handoff, the link to the prior BS is terminated before or as the user is transferred to the new cell's BS; the MS is linked to no more than one BS at any given time. Hard handoff is primarily used in FDMA and TDMA, where different frequency ranges are used in adjacent channels in order to minimize channel interference. So when the MS moves from one BS to another BS, it becomes impossible for it to communicate with both BSs (since different frequencies are used). Figure 2.1 illustrates hard handoff between the MS and the BSs.[8]

#### 2.1.2 Soft handoff

"Soft" call handoffs are different from "hard" call handoffs in that a soft handoff allows both the original cell and new cells to temporarily service a call during the handoff transition. The handoff transition is from the original cell carrying the call to one or more new cells and the final new cell.



**Fig 2.2. Soft handoff between MS and BSs**

With soft handoff, the call is actually carried by two or more cells simultaneously. The CDMA based soft handoff system provides a “make-before break” switching function with relation to call handoff. Not only does soft handoff greatly minimize the probability of a dropped call, but it also makes the handoff virtually undetectable to the user.[8]

### 2.1.2.1 Soft handoff operations

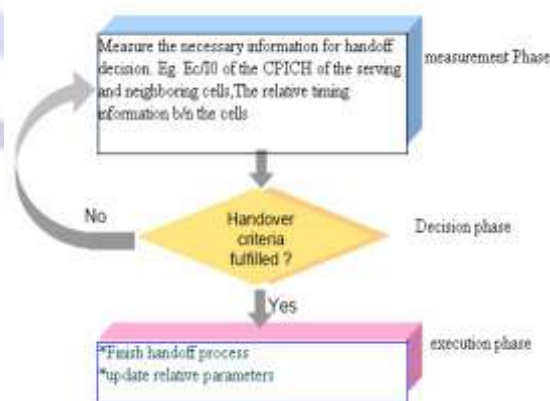
The sequence of events in soft handoff is as follows:

- (i). After a mobile call is initiated, the mobile station continues to scan the neighboring cells to determine if the signal from another cell becomes stronger than that of the original cell.
- (ii). When this happens, the mobile station knows that the call has entered a new cell’s coverage area and that a handoff can be initiated.
- (iii). The mobile station transmits a control message to the mobile telephone switching Office (MTSO), which states that the mobile is receiving a stronger signal from the new cell site, and the mobile identifies that new cell site.
- (iv). The MTSO initiates the handoff by establishing a link to the mobile station through the new cell while maintaining the old link.
- (v). While the mobile station is located in the transition region between the two cell sites, the call is supported by the communication through both cells. This eliminates the ping-pong effect of repeated requests to hand the call back and forth between two cell sites.
- (vi). The original cell site will discontinue handling the call only when the mobile station is finally established in the new cell.[9]

### 2.1.2.2 Handoff measurements and procedures

The handoff procedure can be divided into three phases: measurement, decision and execution phases.

*In the handoff measurement phase*, the necessary information needed to make the handoff decision is measured. Typical downlink measurements performed by the mobile are the  $E_c/I_0$  of the Common Pilot Channel (CPICH) of its serving cell and neighboring cells. For certain types of handoff, other measurements are needed as well. For example, in a wide band CDMA, the relative timing information between the cells needs to be measured in order to adjust the transmission timing in soft handoff to allow coherent combining in the Rake receiver. Otherwise, the transmissions from the different BSs would be difficult to combine and especially the power control operation in soft handoff would suffer additional delay.



**Fig 2.3. Handoff Procedures**

In the handoff decision phase, the measurement results are compared against the predefined thresholds and then it is decided whether to initiate the handoff or not. Different handoff algorithms have different trigger conditions.

*In the execution phase*, the handoff process is completed and the relative parameters are changed according to the different types of handoff. For example, in the execution phase of the soft handoff, the mobile enters or leaves the soft





handoff state, a new BS is added or released, the active set is updated and the power of each channel involved in soft handoff is adjusted.[5],[6]

### 3. CHANNEL ASSIGNMENT STRATEGIES

Channel assignment schemes attempt to achieve a high degree of spectrum utilization for a given grade of service with the least number of database lookups and the simplest algorithm employed in both the MS and the network. Some trade-offs occur when trying to accomplish the following goals:

- (i) Service quality
- (ii) Implementation complexity of the channel assignment algorithm
- (iii) Number of database
- (iv) Spectrum utilization

Handoff requests and initial access requests compete for radio resources. At a busy BS, call attempts that fail because there are no available channels called blocked calls. Handoff requests for existing calls that must be turned down because there is no available channel are called forced terminations. It is generally believed that forced terminations are less desirable than blocked call attempts. Note that the successful handoff process is intimately tied to the radio technology of the channel assignment process, which may be dynamic channel assignment (DCA) or fixed channel assignment (FCA).

To reduce forced termination and to promote call completion, four channel assignment schemes have been proposed. These are the non-prioritized scheme, the reserved channel scheme, the queuing priority scheme, and the sub-rating scheme.

#### 3.1 Non-prioritized scheme and reserved channel scheme

The non-prioritized scheme (NPS), the BS handles a handoff call in exactly the same manner as a new call; that is, the handoff call is blocked immediately if no channel is available.[4]

The reserved channel scheme (RCS) is similar to NPS except that a number of channels or transceivers in each BS are reserved for handoffs. In other words, the channels are divided into two groups: The normal channels, which serve both new calls and handoff calls, and the reserved channels, which only serve handoffs calls.

#### 3.2 Queuing priority scheme (QPS)

The queuing Priority scheme (QPS) is based on the fact that adjacent cells in a PCS network overlap. Thus, there is considerable area where a call can be handled by either BS of the adjacent cells, called the handoff area. The time that an MS spends in the overlapped area is referred to as the degradation interval. The channel assignment for a QPS new call is the same as that for NPS. If a channel in the new cell is available for the handoff, the handoff actually occurs. If no channel is released, the BS first checks if the waiting queue is empty. If not, the released channel is assigned to a handoff call in the queue. The next handoff to be served is selected based on the queuing policy. Two scheduling policies for the QPS waiting queue have been considered. In the FIFO scheme, the next handoff call is selected on a first-in-first-out basis. The measured based priority scheme (MBPS) uses a non pre-emptive dynamic priority policy. The power level that the MS receives from the BS of the new cell defines the priorities. The network dynamically monitors the power levels of the handoff calls in the waiting queue. We may view a handoff call as having a higher priority if its degradation interval is closer to expiration. The candidate selected by the network will be the radio link with the lowest received signal strength and the poorest quality, as measured by the MS. This implies the existence of a mechanism for the MS to relay this information to the network over the failing radio link between the MS and the old BS. A released channel is assigned to the handoff call with the highest priority in the waiting queue.

#### 3.3 Sub-rating scheme

The sub-rating scheme (SRS) creates a new channel on a blocked BS for a handoff call by sharing resource or sub-rating an existing call if no channel is available in the new BS. Sub rating means an occupied full-rate channel is temporarily divided into two channels at half the original rate: one to serve the existing call and the other to serve the handoff request. When occupied channels are released, the sub rated channels are immediately switched back to full-rate channels. Studies have indicated that under certain conditions, these handoff schemes can significantly reduce the probability of forced termination as well as the probability of call incompleteness (new call blocking plus handoff call forced termination).[4]

### 4. CAPACITY RESERVATION AND COST MOBILITY

In capacity reservation scheme, priority is given to handoff requests by reserving  $\eta_0$  channels exclusively for handoff calls among the total  $\eta$  channels in a cell. The remaining  $\eta - \eta_0$  channels are shared by both new calls and handoff requests. The new call is blocked if the number of available channels in the cell is less than or equal to  $\eta_0$ . A handoff request is blocked if no channel is available in the target cell.

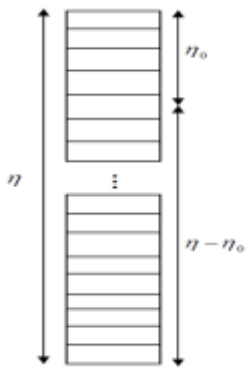
Both new calls and handoff calls can be assumed to arrive as independent Poisson processes with mean rates  $\lambda_N$  and  $\lambda_H$  respectively. Calls have a lifetime in the cell, that is, they are terminated or leave the cell within a time interval that is



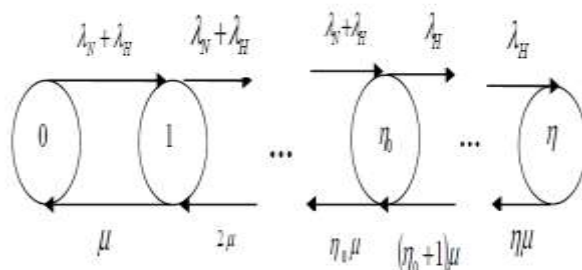
exponentially distributed with average  $1/\mu$ . So we determine the blocking and dropping probabilities as a function of the traffic load when 50% of the total calls arriving at the cell are handoffs and a total of  $\eta$  channels are available.

Denote the total number of calls in progress in the cell at time  $t$  by  $N(t)$ . Note that whenever a call has arrived and is assigned a channel, it is no longer of any consequence to the number of calls in the cell, whether this call originally was handed off to the cell, or if it was a new call arriving at that cell. Due to the memory-less properties of the Poisson arrivals and the exponential distribution of the call lifetime in the cell,  $N(t)$  will be a Birth-Death Markov chain with the state-transition diagram in figure 4.2.

We proceed to derive the stationary state probabilities



**Fig 4.1. Capacity reservation model for handoff call**



**Fig 4.2 State diagram of Markov process**

by means of the flow cut equations:

$$(\lambda_N + \lambda_H) P_{k-1} = k \mu P_k \quad 1 \leq k \leq \eta_0$$

$$\lambda_H P_{k-1} = k \mu P_k \quad \eta_0 < k \leq \eta$$

Iteratively solving these equations yields

$$P_k = P_0 \frac{(\lambda_N + \lambda_H)^k}{\mu^k k!} \quad \text{for } k \leq \eta_0 \quad \text{else } P_k = P_0 \frac{(\lambda_H + \lambda_N)^{\eta_0} (\lambda_H)^{k-\eta_0}}{\mu^k k!} \quad \text{for } \eta_0 < k \leq \eta$$

using the fact that all  $P_k$  add up to unity, we can solve for  $P_0$ . Using the notation

$$\rho_{tot} = \frac{\lambda_N + \lambda_H}{\mu} \quad \text{and } \rho_H = \frac{\lambda_H}{\mu} \quad \text{we get:}$$

$$P_k = \frac{\frac{(\rho_{tot})^k}{k!}}{\sum_{j=0}^{\eta_0} \frac{(\rho_{tot})^j}{j!} + \sum_{j=\eta_0+1}^{\eta} \frac{(\rho_{tot})^{\eta_0} (\rho_H)^{j-\eta_0}}{j!}} \quad \text{for } k \leq \eta_0$$

$$\text{Else } P_k = \frac{\frac{(\rho_{tot})^k (\rho_H)^{k-\eta_0}}{k!}}{\sum_{j=0}^{\eta_0} \frac{(\rho_{tot})^j}{j!} + \sum_{j=\eta_0+1}^{\eta} \frac{(\rho_{tot})^{\eta_0} (\rho_H)^{j-\eta_0}}{j!}} \quad \text{if } k > \eta_0 \leq \eta$$

now deriving the blocking and handoff dropping probabilities yields

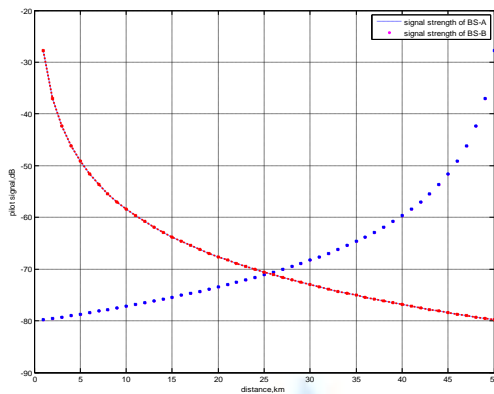
$$P_{block} = \sum_{k=\eta_0}^{\eta} P_k \quad \text{and } P_{drop} = P_{\eta}$$

Defining the relative mobility  $a$  as  $a = \lambda_H / (\lambda_N + \lambda_H)$  and grade of service (GOS) as  $GOS = P_{block} + \alpha P_{drop}$ ,  $\alpha > 1$  is balancing factor for some different values of  $a$ . GOS is a measure of the ability of a user to access a trunked system during the busiest hour. The busy hour is based upon the customer demand at the busiest hour during a week, month, or year.[6]

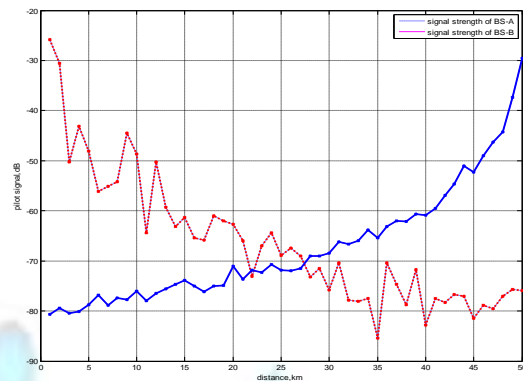


## 5. SIMULATION RESULTS AND DESCRIPTION

The performance parameters measured in this work is pilot signal measurement for handoff decision, call-blocking probability,  $P_b$ , handoff dropping probability,  $P_d$ , and Grade of service (GoS). In our simulation results in IS-95 CDMA,

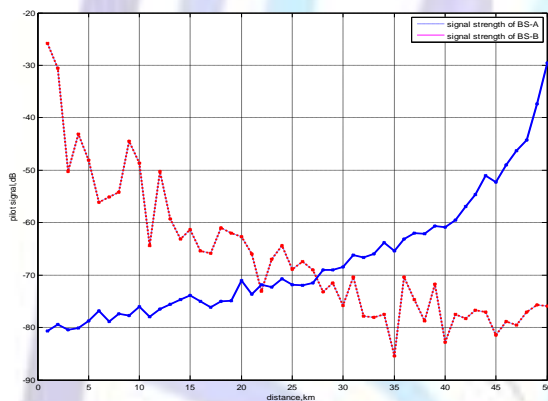


**Fig 5.1. Received power at Base stations A and B without noises**

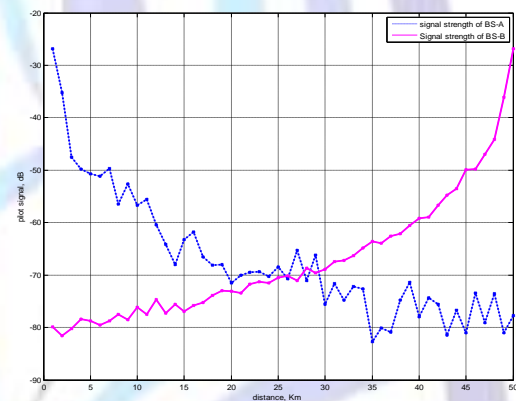


**Fig 5.2. Received power at Base stations A and B with noises**

figures 5.1 and 5.2 shows variation of received signal strength of the mobile from both base stations when no noise and noise were present in the system respectively, i.e., received power at B without noise, received power at A with Gaussian noise 3 dB and received power at B with Gaussian noise 5 dB.

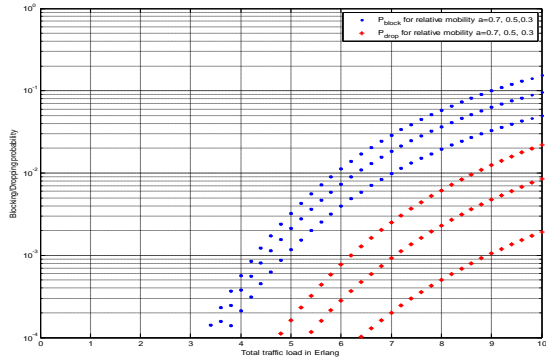


**Fig 5.3. Received power at Base stations A and B with noises**

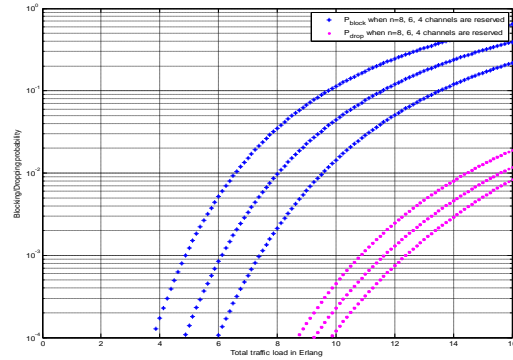


**Fig 5.4. Received power at Base stations A and B with equal Gaussian noises of 3 dB.**

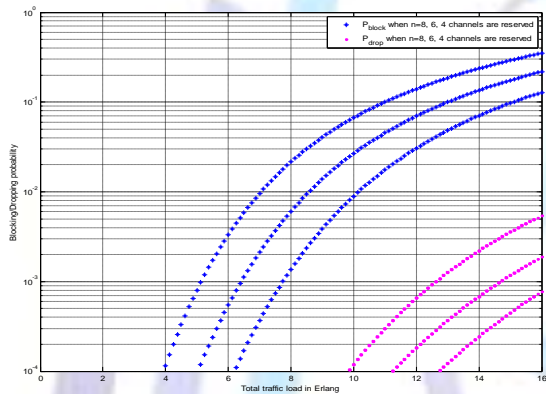
Okumura-Hata is an empiric model for how the signal strength between a base station and a terminal is attenuated as a function of distance, carrier frequency, base station antenna height and mobile antenna height. To analyze a slightly more realistic cellular environment two Gaussian noise sequences were introduced. By introducing a hysteresis margin, it is clearly seen that number of handoffs decrease (Figure 5.4 has a hysteresis margin of -5 dB). But in figure 5.3 shows that handoffs taking place at different points than taking place at one place). However excess hysteresis margin will cause an initiation delay. If the delay persists for longer intervals of time the call will be dropped due to deteriorating signal conditions. Clearly, there exists a tradeoff between hysteresis and initiation delay.



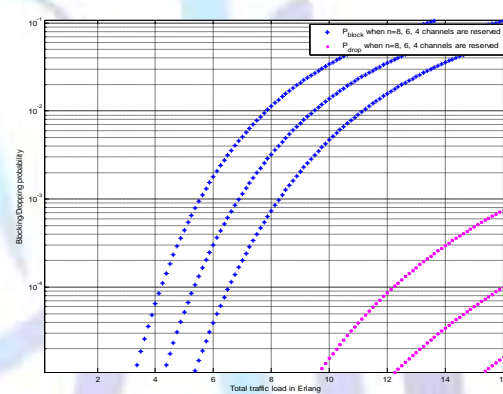
**Fig 5.5. Blocking and handoff dropping probability as a function of total traffic load when 3 channels out of  $\eta$  channels are reserved.**



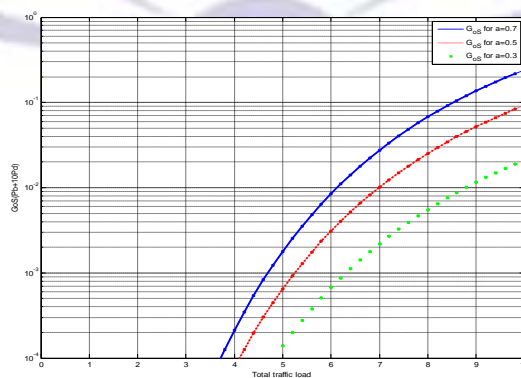
**Fig 5.6. Blocking and handoff dropping probability as a function of traffic load of a total of  $\eta$  out of a total of  $\eta$  channels are reserved for relative mobility  $a=0.7$**



**Fig 5.7. Blocking and Handoff dropping probability as a function of total traffic load when  $\eta_0$  out of a total of  $\eta$  channels are reserved for relative mobility  $a= 0.5$**



**Fig 5.8. Blocking and Handoff dropping probability as a function of total traffic load when  $\eta_0$  out of a total of  $\eta$  channels are reserved for relative mobility  $a=0.4$**



**Fig 5.9. GoS as a function of total traffic load when 3 out of a total of  $\eta$  channels are reserved for handoff traffic for different relative motilities .**





## 6. CONCLUSION

In this paper, the simulation observations do show the decrease in the number of unnecessary handoffs on incorporation of an optimum hysteresis margin and also gives an insight of the tradeoffs involved in introducing an optimum hysteresis margin and the associated initiation delays. The simulation results also show that new call blocking and handoff call dropping probability with a variation of traffic load. The unnecessary handoffs (the continuous movement of mobiles around a cell corner) attempts per call and the forced termination probability are minimized. Handoff call dropping probability is decreased to a minimum and reasonable value. The dropping probability measured in percentage is about 0.1% as indicated in the simulation result waveform.

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