IJCES International Journal of Computer Engineering Science , Volume1 Issue2, November 2011
ISSN : 2250:3439
https://sites.google.com/site/ijcesjournal
http://www.ijces.com/

Analysis of Handoff Schemes in Wireless Mobile Network

Alagu S[#1] and Meyyappan T*[2]

[#1] *Faculty, Department of Information Technology*
Rai Business School, Chennai, TamilNadu, India

sivaalagu@hotmail.com

[*2] *Associate Professor, Department of Computer Science and Engineering*
Alagappa University, Karaikudi, TamilNadu, India

meyslotus@yahoo.com

Abstract. This paper analyses the different traffic schemes for handoff handling and call blocking attempts. As traffic in mobile cellular networks increases, Handoffs will become an increasingly important issue and as cell sizes shrink to accommodate an increasingly large demand of services, newer more efficient handoff schemes need to be used. In this paper the author analyses the various Handoff schemes for multiple traffic system and simulates an ATM based wireless Personal Communication Network to implement the non-preemptive Measurement Based Prioritization Scheme (MBPS).
Keywords: Handoff, Threshold, Deterioration, Tethered, Channel, Hysteresis.

INTRODUCTION

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, timeslot, spreading code or combination of them) associated with the current connection while a call is in progress [1]. It is often initiated either by crossing a cell boundary or by deterioration in the quality of the signal in the current channel. Poorly designed handoff schemes tend to generate very heavy signaling traffic and thereby a dramatic decrease in quality of service (QOS). The reason why handoffs are critical in cellular communication systems is that neighboring cells are always using a disjoint subset of frequency bands, so negotiations must take place between the mobile station (MS), the current serving base station (BS) and the next potential BS. Other issues like Decision making and priority strategies during overloading may also influence the overall performance [2].

Existing Work

The existing works in the related area are discussed in Section 2 & 3. In these sections the earlier research work on different Handoff schemes are discussed, which covers the different traffic model to handle handoff and new call attempt.

Proposed approach

The objectives of this research work is to analyze the different schemes in traffic model and to simulate an ATM based wireless personnel communication network and generate Constant Bit Rate traffic for it. Also the author implements MBPS – Measurement Based Prioritization Scheme for handling handoff failure in the above said ATM based wireless personnel communication network. The proposed work is discussed from section 4 to section 6. The results for the same are depicted in section 7.

HANDOFF INITIATION

Handoff is the mechanism that transfers an ongoing call from one cell to another as a user moves through the coverage area of a cellular system. The handover process is initiated by the issuing of handover request. The power received by the MS from BS of neighboring cell exceeds the power received from the BS of the current cell by a certain amount [3]. This is a fixed value called the handover threshold. For successful handover, a channel must be granted to handover request before the power received by the MS reaches the receiver's threshold. The handover area is the area where the ratio of received power levels from the current and the target BS's is between the handover and the receiver threshold. Each handoff requires network resources to reroute the call to the new base station. Minimizing the expected number of handoffs minimizes the switching load. Another concern is delay. If the handoff does not occur quickly, the quality of service [QoS] may degrade below an acceptable level. Minimizing delay also minimizes co-channel interference. During handoff there is brief service interruption. As the frequency of these interruptions increases the perceived QoS is reduced. The chance of dropping a call due to factors such as the availability of channels increases with the number of handoffs attempts. As the rate of handoff increases, handoff algorithms need to be enhanced so that the perceived QoS does not degrade and the cost to cellular infrastructure does not increase.

Numerous studies have been done to determine the shape as well as the length of the averaging window and the older measurements may be unreliable. Fig.1 shows a MS moving from one BS (BS_1) to another BS (BS_2). The mean signal strength of BS_1 decreases as the MS moves away from it. Similarly, the mean signal strength of BS_2 increases as the MS approaches it [4][17].

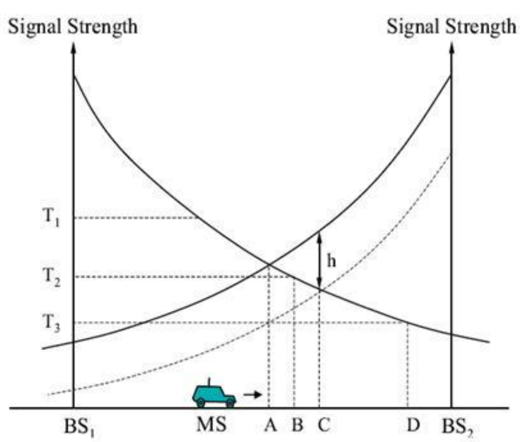


Fig. 1. Signal strength and hysteresis between two adjacent BSs for potential handoff [17].

Relative Signal Strength

This method selects the strongest received BS at all times. The decision is based on a mean measurement of the received signal [5]. In Fig.1, the handoff would occur at position A. This method is observed to provoke too many unnecessary handoffs, even when the signal of the current BS is still at an acceptable level.

Relative Signal Strength with Threshold

This method allows a MS to handle handoff only if the current signal is sufficiently weak (less than threshold) and the other is the stronger of the two. The effect of the threshold depends on its relative value as compared to the signal strengths of the two BSs at the point at which they are equal. If the threshold is higher than this value, say T_1 in Fig.1, this scheme performs exactly like the relative signal strength scheme, so the handoff occurs at position A. If the threshold is lower than this value, say, T_2 in Fig.1, the

MS would delay handoff until the current signal level crosses the threshold at position B. In the case of T_3, the delay is so long that the MS drifts too far into the new cell. This reduces the quality of the communication link from BS_1 and may result in a dropped call [5].

Relative Signal Strength with Hysteresis

This scheme allows the MS to handle handoff only if the new BS is sufficiently stronger (by hysteresis margin h in figure 1) than the current one. In this case the handoff would occur at point C. This technique prevents the Ping-Pong effect, the repeated handoff between two BSs caused by rapid fluctuations in the received signal strengths from both BSs [6].

Relative Signal Strength with Hysteresis and Threshold

This scheme hands a MS over to a new BS only if the current signal level drops below a threshold and the target BS is stronger than the current one by a given hysteresis margin. In Figure 1, the handoff would occur at point D if the threshold is T_3.

HANDOFF SCHEMES

In urban mobile cellular systems, especially when the cell size becomes relatively small, the handoff procedure has a significant impact on system performance. Blocking probability of originating calls and the forced termination probability of ongoing calls are the primary criteria for indicating performance. In this section several existing traffic models and handoff schemes are discussed.

Traffic Model

In a mobile cellular radio system it is important to establish a traffic model before analyzing the performance of the system. Several traffic models have been established based on different assumptions about user mobility.

- **Hong and Rappaport's Traffic Model**

This scheme proposes a traffic model for a hexagonal cell (approximated by a circle) [7]. They assume that the vehicles are spread evenly over the service area; thus the location of a vehicle when a call is initiated by the user is uniformly distributed in the cell. They also assume that the vehicle initiating a call moves from the current location in any direction with equal probability and that this direction does not change while the vehicle remains in the cell.

From these assumptions they showed that the arrival rate of handoff calls is

$$\lambda_H = \frac{P_h (1-B_o)}{1-P_{hh} (1-P'_f)} \lambda_o$$

Where

P_h = the probability that the new call that is not blocked would require at least one handoff

P_{hh} = the probability that a call that has already been handed off successfully would require another handoff

B_o = the blocking probability of originating calls

P'_f = the probability of handoff failure

λ_o = the arrival rate of originating calls in a cell

The probability density function (pdf) of channel holding time T in a cell is derived as

$F_T(t) = \mu_{ce}^{\mu ct} + ((e^{\mu ct}) / (1+\gamma c)) [f_{Tn}(t) + \gamma c f_{Th}(t)]-((\mu ce^{\mu ct})/(1+\gamma c))[F_{Tn}(t)+\gamma c F_{Th}(t)]$

where

$f_{Tn}(t)$ = the pdf of the random variable T_n as the dwell time in the cell for an originated call

$f_{Th}(t)$ = the pdf of the random variable T_h as the dwell time in the cell for a handed-off call

$F_{Tn}(t)$ = the cumulative distribution function (cdf) of the time T_n

$F_{Th}(t)$ = the cdf of the time T_h

$1/\mu c$ = the average call duration

$\gamma c = P_h (1-B_o) / [1-P_{hh}(1-P'_f)]$

- **El-Dolil et al.'s Traffic Model**

An extension of Hong and Rappaport's Traffic model to the case of highway microcellular radio network has been done by El-Dolol et al. [8]. The highway is segmented into microcells with small BSs radiating cigar-shaped mobile radio signals along the highway. With these assumptions they showed the arrival rate of handoff calls is

$\lambda_H = (R_{cj} – R_{sh})P_{hi} + R_{sh}P_{hh}$

where

P_{hi} = the probability that a MS needs a handoff in cell i

R_{cj} = the average rate of total calls carried in cell j

R_{sh} = the rate of successful handoffs

The pdf of channel holding time T in a cell is derived as

$f_T(t) = ((\mu_c + \mu_{ni})/(1+G))e^{(\mu c+\mu ni)t} + ((\mu_c+\mu_h)/(1+G))e^{(\mu c+\mu h)t}$

where

$1/\mu_{ni}$ = the average channel holding time in cell i for a originating call

$1/\mu_h$ = the average channel holding time for a handoff call

G = the radio of the offered rate of handoff requests to that of originating calls

- **Steele and Nofal's Traffic model**

Steele and Nofal [9] studied a traffic model based on city street microcells, catering to pedestrians making calls while walking along a street. From their assumptions, they showed that the arrival rate of handoff call is

$\lambda_H = \Sigma^6_{m=1}[\lambda_o(1-B_o)P_h\beta+\lambda_h(1-P'_f)P_{hh}\beta]$

where

β = the fraction of handoff calls to the current cell from the adjacent cells

$\lambda_h = 3\ \lambda_o(1-B_o)\ P_h\beta$

P_h = the probability that the new call that is not blocked would require at least one handoff

The average channel holding time T in a cell is

$\_ \quad (1+\alpha_1)(1-\gamma) \qquad \gamma\ (1+\alpha_2) \qquad \alpha_1(1-\gamma) + \gamma\alpha_2$

T = -------------- + ------------ + --------------------

$\mu_w+\mu_c$ $\mu_o+\mu_c$ $\mu_d+\mu_c$

where

$1/\mu_w$ = the average walking time of a pedestrian from the onset of the call until he reaches the boundary of the cell

$1/\mu_d$ = the average delay time the pedestrian spends waiting at the intersection to cross the road

$1/\mu_o$ = the average walking time of a pedestrian in the new cell

$\alpha_1 = \mu_w P_{delay}/(\mu_d - \mu_w)$

$\alpha_2 = \mu_o P_{delay}/(\mu_d - \mu_o)$

$P_{delay} = P_{cross}P_d$, the proportion of pedestrians leaving the cell by crossing the road

P_d = the probability that a pedestrian would be delayed when he crosses the road

$\gamma = \lambda_H(1-P'_f) / [\lambda_H(1-P'_f) + (\lambda_o(1-B_o)]$

ASYNCHRONOUS TRANSFER MODE (ATM)

The bandwidth requirements for data traffic within commercial organizations have been increasing steadily for some time, both in the local area networks and in wide area networks. Workstations have been used to introduce multimedia applications to the desktop, including components of voice, video and image, besides growing amount of data. This development requires networks of greater bandwidth than commonly present today with the capability of handling multiservice traffic on the same network.

The **Asynchronous Transfer Mode (ATM)** is being developed as a high speed networking technique for public networks capable of supporting many classes of traffic. Asynchronous Transfer Mode (ATM) has been accepted universally as the transfer mode of choice for Broadband Integrated Services Digital Networks (B-ISDN) [10].

ATM is a high-speed, packet switching technique that uses short fixed length packets called cells. Fixed length cells simplify the design of an ATM switch at the high switching speeds involved. The selection of a short fixed length cell reduces the delay and most significantly the jitter (variance of delay) for delay-sensitive services such as voice and video. ATM is capable of supporting a wide range of traffic types such as voice, video, image and various data traffic.

Quality of Service (QoS)

ATM networks are thought to transmit data with varying characteristics. Different applications need various qualities of service. Some applications like telephony may be very sensitive to delay, but rather insensitive to loss, whereas others like compressed video are quite sensitive to loss.

The ATM Forum specified several QoS categories:

CBR (Constant Bit Rate)
VBR (Variable Bit Rate)
ABR (Available Bit Rate)
UBR (Unspecified Bit Rate)

Constant Bit Rate (CBR)

During a connection setup CBR reserves a constant amount of bandwidth. This service is conceived to support applications such as voice, video and circuit emulation, which requires small delay variations (jitter). The source is allowed to send as the negotiated rate any time and for any duration. It may temporarily send at a lower rate as well.

Variable Bit Rate (VBR)
VBR negotiates the Peak Cell Rate (PCR), the Sustainable Cell Rate (SCR) and the Maximum Burst Size (MBS). VBR sources are burst. Typical VBR sources are compressed voice and video. These applications require small delay variations (jitter).

Available Bit Rate (ABR) and Unspecified Bit Rate (UBR)
ABR and UBR services should efficiently use the remaining bandwidth, which is dynamically changing in time because of VBR service. Both are supposed to transfer data without tight constraints on end-to-end delay and delay variation. Typical applications are computer communications, such as file transfers and e-mail.

UBR service provides no feedback mechanism. If the network is congested, UBR cells may be lost.

An ABR source gets feedback from the network. The network provides information about the available bandwidth and the state of congestion. The source's transmission rate is adjusted in function of this feedback information. This more efficient use of bandwidth alleviates congestion and cell loss. For ABR service, a guaranteed minimum bandwidth (MCR) is negotiated during the connection setup negotiations.

Wireless ATM

In recent years there has been an increasing trend towards personal computers and workstations becoming "portable" and "mobile". These ever-increasing groups of mobile users have been demanding access to network services similar to their "tethered" counterparts. The desire to provide universal connectivity for these portable and mobile computers and communication devices is fueling a growing interest in wireless packet networks. At the same time, wire line communication networks have been undergoing a revolutionary change themselves with the introduction of Asynchronous Transfer Mode (ATM) based Broadband Integrated Services Digital Network (B-ISDN) which can provide QoS guarantee [18]. Given these rapid advancements, the communication networks of today are employing wireless media in the local area and utilizing wire line physical media in the metropolitan and wide area environment.

To support multimedia applications in wireless systems, it is necessary to construct a wireless networking infrastructure that can support QoS guarantees essential to provide broadband services. Since ATM is the standard for wire line broadband networks, it has generally been agreed that broadband services are best provided to wireless users by exploiting ATM in wireless systems. However, since the characteristics of the wireless communication channels (e.g., high bit error rate and user mobility) are significantly different from those of wire line channels, solutions that are designed for wire line networks cannot be expected to work for wireless environments.

PERSONAL COMMUNICATION NETWORK (PCN)

Personal Communication Network (PCN) is an emerging wireless network that promises many new services. With the availability of the interface cards, mobile users are no longer required to be confined within a static network premise to get network access. Mobile users may move from one place to another and yet maintain transparent network access through wireless links. Information exchanged between users, may be bi-directional, which includes but not limited to voice, data and image, irrespective of location and time while permitting users to be mobile.

In a PCN, the covered geographical area is typically partitioned into a set of microcells. Each microcell has a base station to exchange radio signals with wireless mobile terminals. Due to the limited range of wireless transceivers, mobile users can communicate only with the base stations that reside within the same microcell at any instance. The number of handoffs during a call will increase as the cell radii decrease, thus affecting the quality of service [11]. As a result of the increase in processing load due to demand for service and fast handoffs to mitigate the propagation effect, a high speed backbone network for the PCN to connect base stations is required. The ATM technology, which is been accepted as a predominant switching technology, is suited to be an infrastructure to interconnect the base stations of the PCN.

Thus the given geographical area is partitioned into a set of disjoint clusters, each of which consists of a set of microcells. Each microcell has a base station to serve the mobile terminals within the cell. An ATM switch is allocated within each cluster and each of the base stations in this cluster is connected to one of the ports of this ATM switch. The ATM switch offers the services of establishing / releasing channels for the mobile terminals in the cluster. Two neighboring clusters can be interconnected via the associated ATM switches. The links between the ATM switches are called **Backbone Links,** and the links between an ATM switch and base stations are called **Local Links.** Each base station has a given number of radio channels for calls generated within its cell [19].

Mobile hosts engaging in a call or data transfer within the same cluster will consume two local channels, one for each local link, between the base stations and the associated switch and one radio channel [19]. For intercluster communication, backbone links will be allocated in addition to the local links and radio channel, and the channels occupied will depend on the communicating path being assigned.

SIMULATION OF ALGORITHM IN ATM BASED WIRELESS PCN NETWORK

The author analyses the ATM based wireless PCN network based on the schemes discussed in section III and simulates the same using a non-preemptive Channel allocation algorithm called Measurement Based Prioritization Scheme (MBPS) [12].

Performance metrics for Handovers [20]:

Call blocking probability – The probability that a new call attempt is blocked.
Handoff blocking probability – The probability that a handoff attempt is blocked.
Handoff probability – The probability that while communicating with a particular cell, an ongoing call requires a handoff before the call terminates. This metric translates into the average number of handoffs per cell.
Call dropping probability – The probability that a call terminates due to handoff failure. This metric can be derived directly from the handoff blocking probability and the handoff probability.
Rate of handoff – The number of handoff per unit time.
Duration of interruption – The length of time during handoff for which the mobile terminal is in communication with neither base station.

Measurement Based Prioritization scheme without Guard channels

In MBPS, if all channels of a cell are occupied, calls originating within that cell are simply blocked and the handover requests to that cell are queued as per their priority [13][14][15][16][21]. MBPS is a non-preemptive dynamic priority discipline. The handover area can be viewed as regions marked by different ranges of values of power ratio, corresponding to the priority levels such that the highest priority belongs to the MS whose power level is closest to the receiver threshold. On the other end, MS that has just issued a handover request has the least priority. Obviously the last comes joins the end of the queue. A queued MS gains higher priority as its power ratio decreases from the handover threshold to the receiver threshold. The MS's waiting for channels in the handover queue are sorted continuously according to their priorities. When a channel is released, it is granted to the MS with the highest priority. MBPS is designed as a handover protection method, which a cellular communication network can utilize along with any channel allocation strategy. The queuing can be performed at the BS or the Mobile Switching Center (MSC) depending on the intelligence distribution between these cellular network components [13]. The basic idea is that originating calls are not assigned channels until the queued handover requests are served. (Refer Fig.2) In MBPS, new calls are served only when a channel is available and no handover request exists in the queue. Probability of forced termination, P_f, is the probability that an originating call is eventually not completed because of an unsuccessful handover attempt. P_f, therefore gives the percentage of handover requests that are not served because the power received by the MS from the current BS approaches the receiver threshold before a channel is granted. The objective is to minimize the time spent by MS in higher priority, corresponding to the poorer signal reception, by favoring those MS's that received the lowest power level from their current BS in channel assignment.

Measurement Based Prioritization scheme with Guard Channels

The only difference here should be noted that the employment of guard channels has the effect of reducing the number of handover requests to be queued. However if started with congested cell whose channels are already occupied, the number of guard channels, if any, will not have an impact on the waiting time distributions of the arriving handover requests[13] [14][15][16][21].

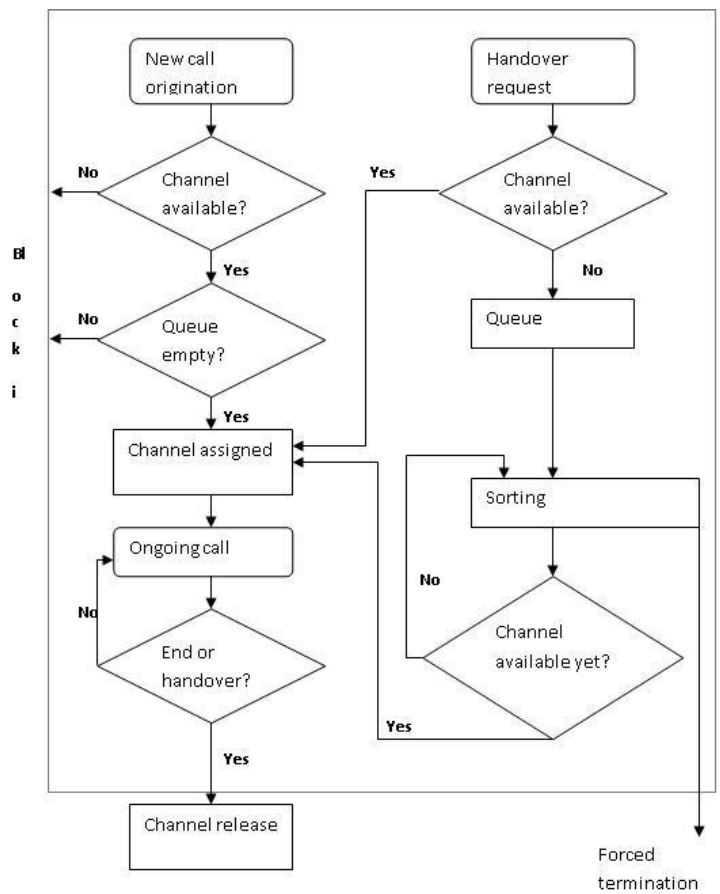


Fig. 2. Call Flow Diagram for the Measurement Based Prioritization Scheme [21].

Simulation Parameters

busy_channels : Number of channels occupied by calls.

next_event_type : Type of next event New call, New handover, Channel release.

total_calls : Number of calls generated in or handed to the cell.

new_success : New calls which have been assigned channels by the BS.

ho_success **:** Handovers which have been assigned channels by the BS

ho_fail **:** Handovers which have not been assigned channels.

blocked **:** New calls which have not been allocated channels.

incell_success **:** New incell call or handover which have been assigned channels.

incell_blocked **:** New incell call or handover which have not been assigned channels.

incluster_success : New incluster call or handover which have been assigned channels.

incluster_blocked : New incluster call or handover which have not been assigned channels.

outcluster_success: New outcluster call or handover which have been assigned channels

outcluster_blocked: New outcluster call or handover which have not been assigned channels.

call_type **:** Type of call; Incell, Incluster, Outcluster

BTS_index **:** Index of Base Station whose event will occur.

Capacity **:** Load which a backbone link can handle.

next_call **:** Time at which next new call will be generated.

next_event_time : Time at which next event will occur.

next_handover **:** Time at which next new handover will be generated.

ho_delay **:** Time for which a handover is stored in the handover queue.

niat **:** Mean inter arrival time. Time difference between successive calls

hmiat **:**Handoff Mean inter arrival time. Time difference between successive handover.

RESULTS

The results for the three switch ATM network and the six switch ATM network have been computed. The result comprises of comparison between the Measurement Based Prioritization Scheme (**MBPS)** and MBPS using Guard Channels (**GMBPS)** for call blocking, handoff failures and throughput. Initial starting parameters are listed below.

Number of Radio Channels = 30 per cell.

Number of Local Link Channels = 30 per cell.

Average time for a new call = 60 sec.

Average time for a handover call= 30 sec.

Maximum handover queue time = 10 sec.

Capacity of Backbone Links = 50 calls.

Number of Reserved Radio channels for GMBPS = 5

Number of Reserved Backbone Links for GMBPS = 5

Formulas Involved

Call Blocking = Total number of calls blocked **/** Total number of calls processed

Handoff failures = Total number of handovers not assigned channels **/** Total number of calls processed.

Throughput **= (**TSC + TSH) / Total number of calls processed

Where,

TSC = Total number of calls that have been assigned channels and backbone links.

TSH=Total number of handovers that have been assigned channels and backbone links.

Results of the Simulation

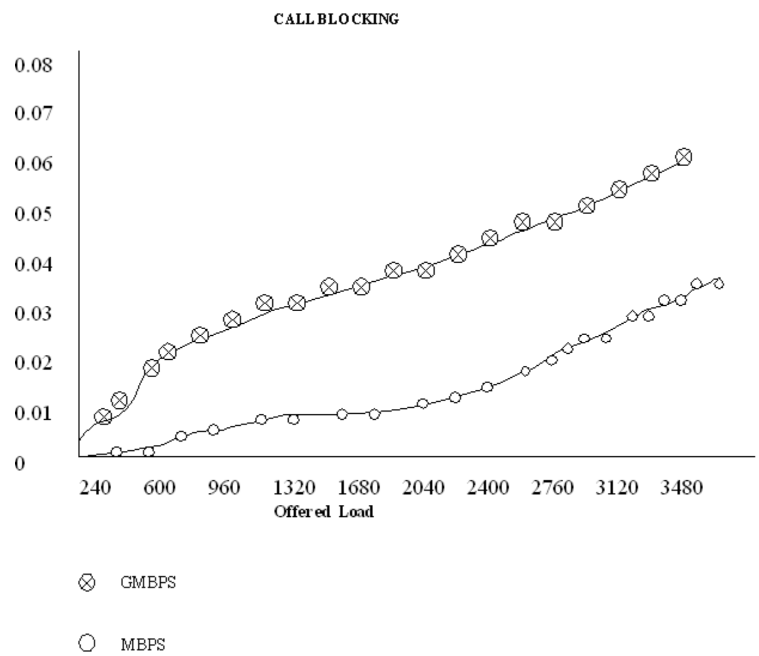
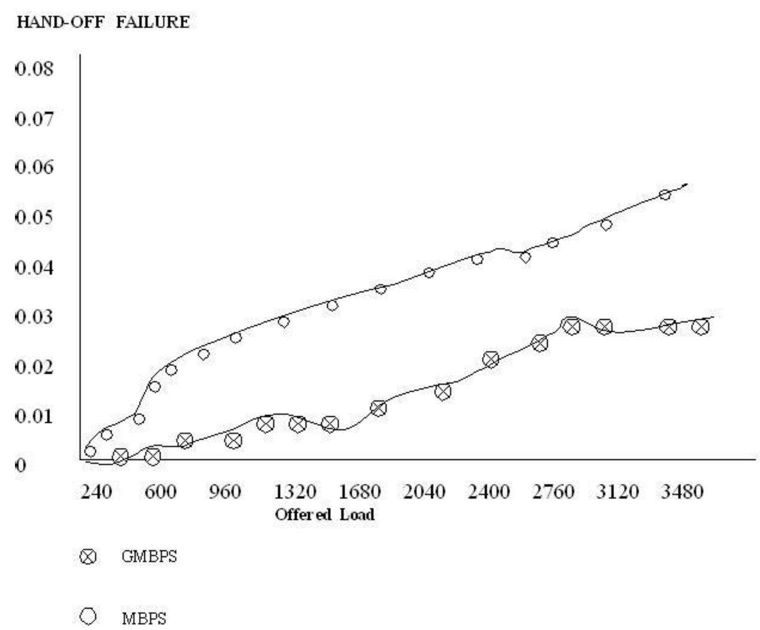


Fig. 3. (a) Graph showing the comparison of Guarded Scheme and Non Guarded Scheme for Call Blocking in the three switch ATM network.



IJCES International Journal of Computer Engineering Science , Volume1 Issue2, November 2011
ISSN : 2250:3439
https://sites.google.com/site/ijcesjournal
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Fig. 3.(b) Graph showing the comparison of Guarded and non-Guarded schemes for Handoff Failures in the three switch ATM network

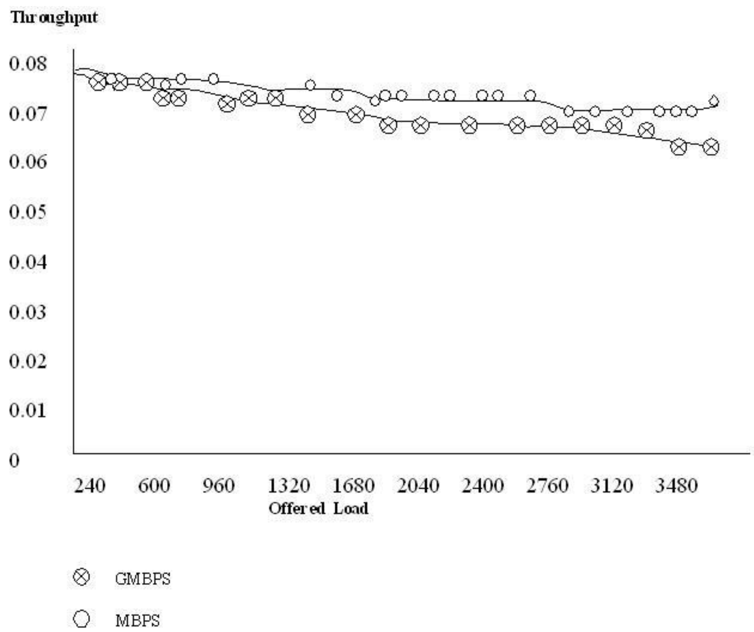

Fig. 3.(c) Graph showing the comparison of Guarded and Non Guarded schemes for Throughput in the three switch ATM network

Discussion

1. From fig 3. (a) – (c) it can be seen that with the increase in load offered to the network the call blocking and handoff failure increase exponentially and hence the throughput decreases for any scheme used.
2. Since reducing handoff failure is the main concern for any cellular network, many schemes have been proposed which reduce handoffs but at the cost of increasing call blocking.
3. As can be seen from fig 3. (a), call blocking is high in Guarded Measurement Based Prioritization Scheme (GMBPS).
4. From 3. (b), it can clearly been seen that the probability of handoff failure is greatly reduced for the GMBPS scheme when compared to the MBPS. The improvement without using guard channels is between 30 – 40% and with guard channel is about 5%.
5. The use of guard channels greatly improves handoff failures by almost 75% in the case of MBPS scheme, which is at the cost of 30% increase in call blocking. Hence overall throughput of the network improves greatly when guard channels are used.
6. As can be seen from fig 3. (c) The throughput of GMBPS is better than MBPS.

CONCLUSION

This research focuses on the problem of handoffs in a mobile cellular environment. After studying the currently used schemes, it is clear that there is some room for improvement. Using simulation of two types of networks it is shown that an allocation of separate channel for handover requests (Guard Channel) shows considerable improvement. The three commonly used performance metrics for a cellular network showed improvement when the MBPS scheme is used. The use of guard channels does improve handoff failures but also causes call blocking to increase. Hence there is a trade-off.

Hence the author conclude that, as network topology becomes more and more complicated and the offered load to the network increases it is very necessary to use a priority based handoff scheme such as MBPS which would reduce handoff failures without increasing call blocking.

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