A Model For Balancing Grade Of Service For Originating And Handoff Calls In Wireless Asynchronous Transfer Mode Networks

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***Abstract*—One of the major problems in the design of a cellular-based multimedia wireless system like the WATM network is to balance the two contradicting interests of the service provider and mobile users. While efficient system utilization is the main goal of the service provider, the mobile users want high quality of service (QoS). The call dropping probability and call blocking probability are the two most important connection-level QoS parameters in any wireless cellular-based multimedia system. The former represents the probability that a handoff call is dropped if no channel is available in the new or target cell while the later represents the probability that a new call is blocked due to unavailability of channels in the originating cell. In this work, a handoff scheme, which not only recognizes the effect of mobility on the user terminal but also protects the new calls in order to improve channel utilization of the cellular network, is proposed. The proposed scheme is modeled as M/M/C/C queueing system. The system model defined by one dimensional Markov chain is used to derive the analytical expressions for the QoS parameters. Lastly, these performance metrics are computed in MATLAB environment and validated against the modified model.**

Keywords*— *Handoff dropping probability, Wireless ATM, New call blocking probability, guard channel, Markov chain, Quality of Service (QoS).

1. INTRODUCTION

The Asynchronous Transfer Mode (ATM) is a data transport technology that supports a single high speed integrated broadband communication involving voice, video and data [1]. In this high speed packet-based scheme, information is transmitted in small packets called cells over transmission links at a bit rate of about 155 Mbits/second or about 600 Mbits/second. Each ATM cell comprises of 53 bytes of information of which 5 bytes is the header and 48 bytes is the payload. A cursory look at the history of wireless networks shows that all the current popular wired networks have their own wireless extensions [2]. Examples include the Public Switched Telephone Network (PSTN) which has Global System for Mobile communications (GSM) and the Local Area Network (LAN) with Wireless LAN as its extension. Therefore, in order for ATM to compete effectively with these technologies, it must have wireless extension. Otherwise, it cannot compete in the rapidly growing wireless communications. If wireless extension is added to ATM, efficient mobility management is needed to provide the necessary QoS constraints in the network. Mobility management consists of two components: location management and handoff management. While location management tracks and locates the mobile station (MS) for successful information delivery, handoff on the other hand is the mechanism by which a mobile station (MS) keeps its connection active when it migrates from the coverage area of one network attachment point to another. It does so by changing the current channel in the current cell into a new channel when the MS moves into a new cell. In order to accommodate the increased demand for wireless services, smaller cells (micro- and even pico-cells) are being deployed to satisfy this demand. It is therefore expected that handoffs will occur more frequently than in the present macro-cellular environment. For these reasons, a handoff scheme that can handle the increased signaling load without jeopardizing the existing QoS is needed.

Many of the current researches on mobile systems are primarily concerned with the protection of the connection continuity of handoff calls at the expense of new calls. This is because; it is more annoying to experience forced termination of handoff calls than blocking of new calls. Due to scarcity of wireless channels, it is very challenging to provide the required QoS while achieving high bandwidth utilization. A handoff scheme which is poorly designed tends to generate very heavy signaling load and this leads to reduction of network resources utilization. Therefore in designing a good handoff scheme, a compromise must be reached so that the blocking probability of new calls should be maintained within a reasonable level. This is what the handoff scheme in this paper tries to address as it puts into consideration the mobility of the MS and also admits new calls within the segment reserved for handoff calls with acceptability probability [3]. This is to ensure high bandwidth utilization.

1.1 Reasons for handoff

There are different reasons that give rise to handoff in wireless networks. A change in channel (timeslot) in the same cell (intra-BTS handoff) may be caused by signal strength of the serving base station (BS) going below a certain threshold value. Unbearable interference which causes reduction in Signal to Noise Ratio (SNR) in the timeslot, high bit error rate (BER) which is the percentage of bits that have errors relative to the total number of bits received in a network transmission also trigger handoff in cellular based wireless networks [4]. Also due to the increasing demand for wireless services, the available channels within the cells become insufficient to support the growing number of users. \and to increase the system capacity, techniques such as cell splitting and sectoring may be implemented. The use of microcells improves cellular system capacity. However, innate to microcells concept is the increase in frequency of handoffs as the cell size is greatly reduced. Also the speed of the MS also affects the rate of handoff. When the MS moves fast, time for handoff is usually shorter and hence the handoff scheme should be
capable to deal with this requirement.

2. Literature Review

Many researchers have proposed various types of handoff schemes. The schemes can broadly be classified into non-priority and priority schemes. When no priority is accorded to new or handoff calls, the probabilities of blocking a new call and handoff probability are equal. This is referred to as non-priority scheme (NPS). In other words, the NPS does not differentiate new calls from handoff calls [5]. Priority Schemes (PSs) give high preference to handoff calls and a low preference to new calls. The PS is very suitable for the wireless cellular networks. [6] proposed a multiple-threshold bandwidth reservation scheme combined with a call admission control algorithm. This proposed bandwidth reservation scheme is an enhanced guard channel scheme called the Multimedia Guard Channel (MGC). It is modelled as M/M/C/C queuing system and three Quality of Service (QoS) metrics are computed and compared with the Complete Sharing (CS) scheme. The simulation results show that this scheme surpasses the complete Sharing scheme in terms of call blocking probability, call dropping probability and bandwidth utilization. In most literatures for prioritized handoff schemes, a single queue for handoff call is always considered for the whole cell in a microcellular networks. However, [7] modified [8] to propose a new model for optimization of handoff procedure. In this model, there is a separate queue for each transceiver (TRX) of the same cell in line with the recommendation of Nokia for operators that use multilayer cellular architectures in their networks. [9] proposed a non-disruptive handoff protocol with dynamic channel reservation for wireless ATM networks. This scheme under high traffic reduced average waiting time during handoff. This scheme reduced forced
termination due to handoff failure.

3. Architecture of Wireless ATM Network

Figure 1 shows the architecture of wireless ATM network adopted by [10]. It is cluster arrangement where a group of cells form a cluster. Each cluster accesses the fixed ATM network through the Mobile Enhance switch (MES). Radio links are reserved between each cluster and the MES for intra-cluster handoff while there is reserved radio links between two MES inter-cluster handoff. The ATM-based clustered networks may employ statistical multiplexing and statistical bandwidth assignment. Since statistical bandwidth assignment can be mapped into per call equivalent bandwidth assignment [9], the concept of guard channel can be directly applied to set aside reserved channel for handoff calls in WATM network. This is the assumption made in the use of this proposed handoff scheme for wireless ATM network.

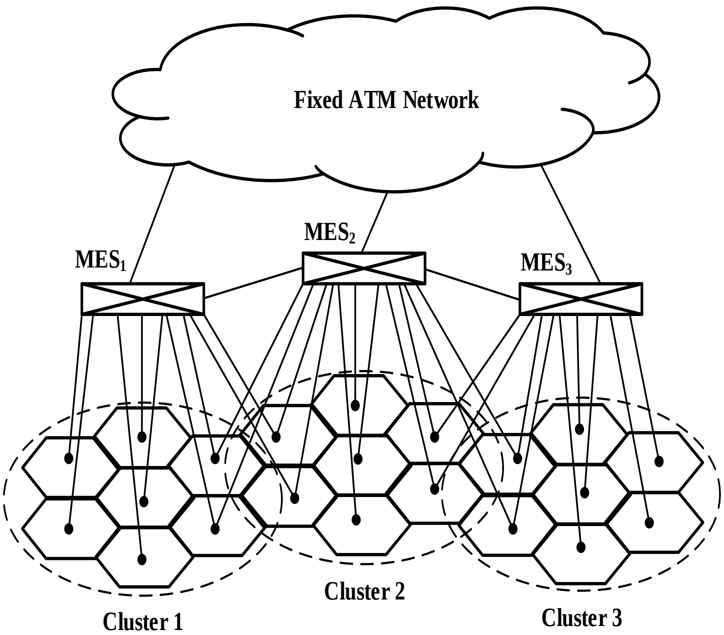

Figure 1: Wireless ATM Architecture [10]

4. Model Description

We consider a cellular system where each cell consists of a total of S channels. C of these channel are the common channels which can be accessed by both new calls and handoff calls while the remaining channels are reserved for handoff calls. However, new calls can also access the reserved channels with acceptability probability, ϒ which depends on the network traffic condition. In the event of all the resources (channels) being occupied on the arrival of new call, this call is automatically lost while the handoff calls are queued up in a queue facility of length N. Handoff calls are only lost when the queue spaces are fully occupied. In cases where there are several handoff requests in the queue, they can be served either by the use of First-In-First-Out (FIFO) queuing principle or by a Measured-Based Priority scheme (MBPS). The order of service in this case is determined by the power level that the mobile station receives from the new base station. The mobile station with the lowest signal level or the poorest quality of service is served first [11]. The arrival rate of new calls is $\lambda_n$and the arrival rate of the handoff calls is λ_h. Both are assumed to be poison process. If a handoff call possesses poor signal quality, it will not be admitted into the network. This is why the arrival rate of the handoff is qualified by a signal strength factor α, whose value ranges from 0 to 1.0. ϒ is the acceptability probability with which new calls can access the reserved channels. The essence of this is to ensure that when the rate of arrival of handoff calls is very low, more new calls are admitted in the reserved channels. Its value is from 0 to 1. Another important feature of this scheme is the mobility factor β. Mobility is very important physical characteristic of the mobile cellular network. The idea here is that a stationary MS is assumed to have a mobility factor of 0, while an MS approaching a target base with an appreciable speed is assumed to have very high mobility factor. Figure 2 shows the system model while figure 3 is the state transition diagram.

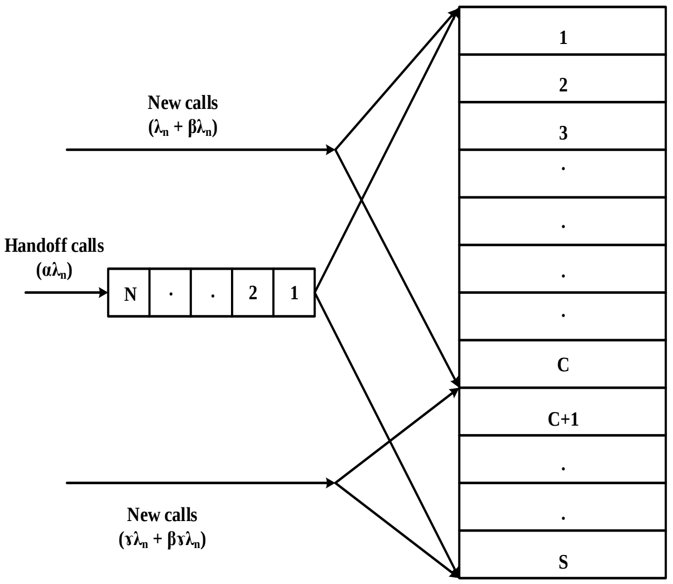

Figure 2: The System Model

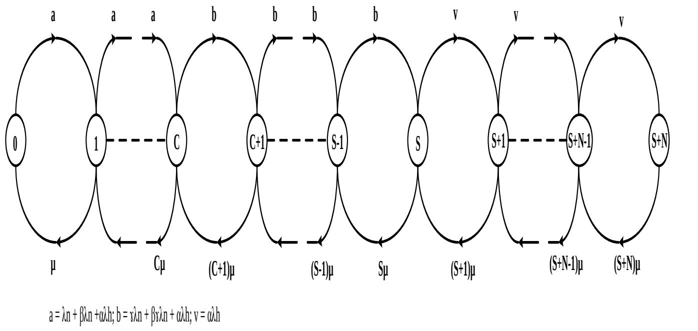

Figure 3: The State Transition Diagram

The steady state transition probability of the model is illustrated in equation (1).

$$P_j = \begin{cases} \sum_{j=1}^{C} \left[\frac{\lambda_n+\beta\lambda_n+\alpha\lambda_h}{\mu}\right]^j \frac{P_0}{j!} & 1 \le j \le C \\ \sum_{j=C+1}^{S} \frac{1}{\prod_{i=1}^{S} C+1} \left[\frac{\gamma\lambda_n+\beta\gamma\lambda_n+\alpha\lambda_h}{\mu}\right]^S \left[\frac{\lambda_n+\beta\lambda_n+\alpha\lambda_h}{\mu}\right]^C \frac{P_0}{C!} & C+1 \le j \le S \\ \left[\frac{(\alpha\lambda_h)^N}{\prod_{i=1}^{N}(S\mu+i\mu_d)}\right] \frac{1}{\prod_{j=1}^{S} C+j} \left[\frac{\gamma\lambda_n+\beta\gamma\lambda_n+\alpha\lambda_h}{\mu}\right]^S \left[\frac{\lambda_n+\beta\lambda_n+\alpha\lambda_h}{\mu}\right]^C \frac{P_0}{C!} & S+1 \le j \le N \end{cases} \quad 1$$

The new call blocking probability and the handoff blocking are given by equation (2) and equation (3) respectively.

$$P_{B1} = P_c + P_S$$
$$= \sum_{j=1}^{C} \left[\frac{\lambda_n+\beta\lambda_n+\alpha\lambda_h}{\mu}\right]^j \frac{P_0}{j!}$$
$$+ \sum_{j=C+1}^{S} \frac{1}{\prod_{i=1}^{S} C+1} \left[\frac{\gamma\lambda_n+\beta\gamma\lambda_n+\alpha\lambda_h}{\mu}\right]^S \left[\frac{\lambda_n+\beta\lambda_n+\alpha\lambda_h}{\mu}\right]^C \frac{P_0}{C!}$$
(2)

$$P_{F1} = P_C + P_S + P_{S+N}$$
$$= \sum_{j=1}^{C} \left[\frac{\lambda_n+\beta\lambda_n+\alpha\lambda_h}{\mu}\right]^j \frac{P_0}{j!}$$
$$+ \sum_{j=C+1}^{S} \frac{1}{\prod_{i=1}^{S} C+1} \left[\frac{\gamma\lambda_n+\beta\gamma\lambda_n+\alpha\lambda_h}{\mu}\right]^S \left[\frac{\lambda_n+\beta\lambda_n+\alpha\lambda_h}{\mu}\right]^C \frac{P_0}{C!}$$
$$+ \left[\frac{(\alpha\lambda_h)^N}{\prod_{i=1}^{N}(S\mu+i\mu_d)}\right] \frac{1}{\prod_{i=1}^{S} C+j} \left[\frac{\gamma\lambda_n+\beta\gamma\lambda_n+\alpha\lambda_h}{\mu}\right]^S \left[\frac{\lambda_n+\beta\lambda_n+\alpha\lambda_h}{\mu}\right]^C \frac{P_0}{C!} \quad (3)$$

where,

$$P_0 = \left[\begin{array}{c} 1 + \sum_{j=1}^{C} \left[\frac{\lambda_n + \beta\lambda_n + \alpha\lambda_h}{\mu}\right]^j \frac{1}{j!} + \\ \sum_{j=C+1}^{S} \frac{1}{\prod_{i=1}^{S} C+1} \left[\frac{\gamma\lambda_n + \beta\gamma\lambda_n + \alpha\lambda_h}{\mu}\right]^S \left[\frac{\lambda_n + \beta\lambda_n + \alpha\lambda_h}{\mu}\right]^C \frac{1}{C!} + \\ \left[\frac{(\alpha\lambda_h)^N}{\prod_{i=1}^{N}(S\mu + i\mu_d)}\right] * \\ \frac{1}{\prod_{i=1}^{S} C+i} \left[\frac{\gamma\lambda_n + \beta\gamma\lambda_n + \alpha\lambda_h}{\mu}\right]^S \left[\frac{\lambda_n + \beta\lambda_n + \alpha\lambda_h}{\mu}\right]^C \frac{1}{C!} \end{array} \right]^{-1}$$

5. Comparative Analysis

In this section, the performance of the proposed scheme (model 2) is compared with the MAHO scheme (model 1) [3]. The following hypothetical data used by [3] are used in the comparative analysis:

$\lambda_n =$ 0.6 packets/second; $\lambda_h =$ 0.6 packets/second; Signal strength factor α = 0.6. With good signal strength this parameter approaches unity.

Acceptability factor ϒ= 0.6.

$\beta =$ Mobility factor: To be varied between 0.1 and 1.5 to investigate the effect of this mobility factor on the handoff dropping probability. A mobile terminal

moving at very low speed is assumed to have low value of mobility factor; N=20 (Queue length); S=12 (fixed Base station capacity);
C= 8 (common channels)
μ = call service rate within the BS : varied from 0.1-0.9 packets/second. $\mu_d = 1$ (service rate in the queue facility).

The two most important Quality of Service (QoS) parameters namely, the new call blocking probability (NBP) and the handoff dropping probability (HDP) are used in the comparison.

6. RESULTS AND DISCUSSIONS

It can be seen from figures 3 and 4 that at mobility factor β=0, the handoff off dropping probability and the new call blocking probability of the proposed scheme and MAHO scheme take exactly the same curve and decreases rapidly with increase in service rate and drop to zero at service rate μ=0.45 packets/second. As the mobility factor β takes the value 0.5 packets/second, 1.0 packets/second and 1.5 packets/second, the handoff dropping probabilities at these values increase. The percentage increase at these values of β relative to β=0 are 49.05%, 97.97% and 146.56% respectively. The mobility factor which has been neglected in the MAHO has been seen to increase the handoff dropping probability in mobile cellular network. Therefore this factor should not be neglected as mobility is a very important physical characteristic of mobile cellular system.

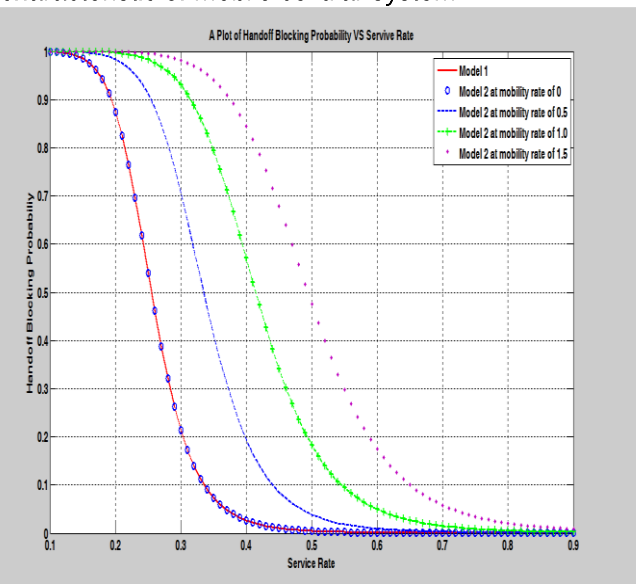

Fig. 3: Handoff Dropping Probability Vs Service Rate (μ)

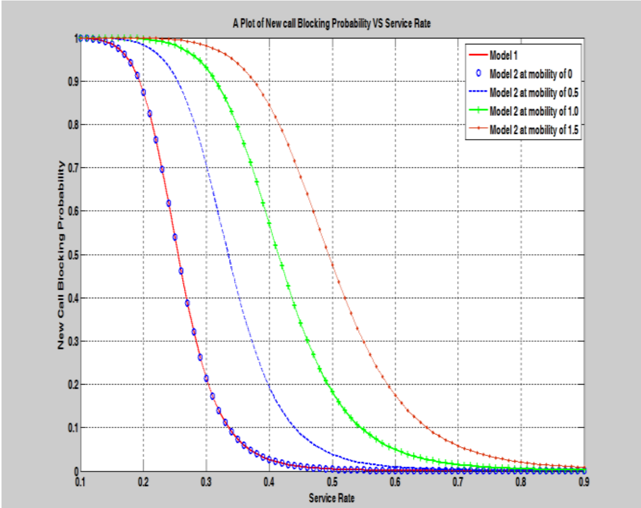

Fig. 4: New Call Probability Vs Service Rate (μ)

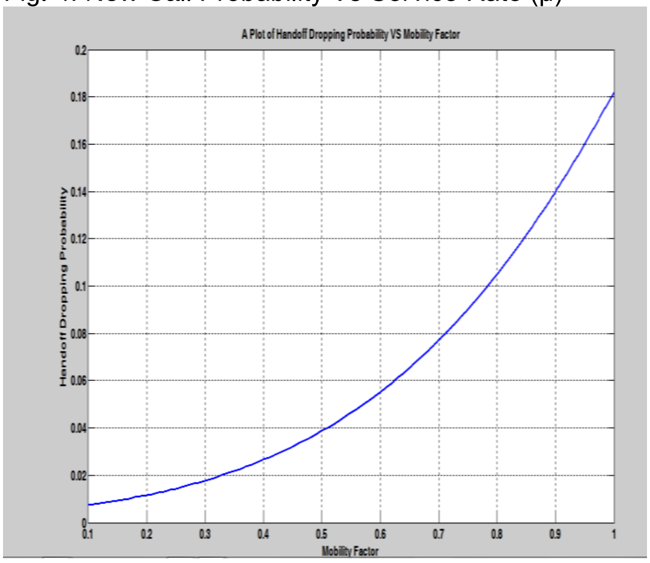

Fig 5: Handoff Dropping Probability Vs Mobility factor

7. CONCLUSIONS

Handoff model that balances the QoS for new calls and handoff calls in a wireless ATM network is presented in this paper. The paper considered the importance of mobility of the mobile station in the evaluation of new call blocking and handoff dropping probabilities which are the two most important connection-level QoS parameters of any wireless cellular network. The performance of this scheme is evaluated and compared with the MAHO scheme [3] as they share common features. The QoS metrics are computed in a MATLAB environment. The handoff dropping probability of the new scheme depreciates as the mobility factor is increased. Because the MAHO scheme neglected mobility factor which is a very important physical characteristic of a mobile wireless cellular network, it appears to have better handoff dropping probability.

REFERENCES

1. Jamila Bhar et al, "International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering; Vol 1; No:2, pp 134-139, 2007.

2. Chrysotomos Chrysostomou, "A Survey of Wireless ATM Handover Issues", Accessed from Internet on March 24, 2015: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.4.7966&rep=rep1&type=pdf.

3. V. Goswami and P.K. Swain, "A MAHO Based Prioritized Handoff Queueing Scheme in Cellular Networks'', 2011 IEEE Third International Conference on Advanced Computing, Department of Computer Technology, MIT, Anna University Chennai, India, 14-16th December, 2011.

4. Marc Kahabha, Pocket Guide for Fundamentals and GSM Testing. Publisher: Wandel & Goltermann GmbH & Co Elektronische Meûtechnik,P. O. Box 12 62 D-72795 Eningen u.A.Germany.

5. D.U. Onyishi et al, "A Comparative Study of Prioritized Handoff Schemes with Guard Channels in wireless Networks", Nigerian Journal of Technology, Volume 34, Number 3, July, 2015.

6. Nadal H. Nasser and Sghaier Guizani, "Analysis of Cell-based Call Admission Control Scheme for QoS Support in Multimeia Wireless Networks". Computer Communications and Networks, Proceedings of 16th IEEE ICCCN 2007, Honolulu, HI, 13th-16th August, 2007,pp 1250-1255.

7. S.Louvros et al, "Handoff Multiple Queue Model in Microcellular Networks", Computer Communications (Elsevier), Volume 30, Number 2, pp 396-403, 2007.

8. D. Hong and S.S. Rappaport, "Traffic Model and Performance Analysis for Cellular Mobile Radio Telephone Systems with Prioritized and Non-Prioritized Handoff Procedures," IEEE Trans. on Vehicular Technology, August 1986, vol. VT- 35, no. 3,pp 77-92.

9. Parag Jain and S.G Gupta, "Hybrid mixed handover for call blocking probability analysis in wireless ATM netwok", Journal of Engineering and Computer Innovations Vol. 2(4), pp 68-77, April 2011.

10. Jamal Elbergali and Neco Ventura, "Performance Evaluation of a New Fast Inter-Cluster Handoff Scheme in Wireless ATM Networks", IEEE Global Conference on Telecommunications Taipei, Taiwan, November 17-21,2002, Vol 1, PP 876-880.

11. Chenn-Jung H. et al, "A Ratioed Channel Assignment Scheme for Initial and Handoff Calls in Mobile Cellular Systems", *Elsevier Computer Communications* 24, 2001, pages 308-318.