Performance Evaluation of User Class Based Call Admission Control Techniques in Next Generation Wireless Networks

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***Abstract*— The users in the next generation wireless networks will be offered with abundant services by the network operators. The objective of the network operators would be to enhance revenue by accommodating maximum number of users, while at the same time they need to ensure that the users are given with the quality of service promised. Call admission control is the process of accepting or rejecting the call in the system and has a direct control on the number of users in the system. The design of call admission controller will be of utmost importance to the network operators as increase in the number of users in the system will increase the revenue generated. In this paper, the working of five different user class based models for call admission control are explained and evaluated. The simulation results for system call blocking probability versus utilization rate of different models are presented.**

Keywords-Partitioning; Queuing; Threshold; Reservation; Differential Access.

I. Introduction

The network operators in the Next Generation Wireless Networks (NGWN) come up with wide array of services to their users thus increasing the customer base of the network operators. The users in NGWN demand for Quality of Service (QoS) requirements of varied types, as they may not be willing to use all the services provided by the network operator. Hence, user differentiation plays a vital role in NGWN and providing QoS guarantee to users in NGWN will become a challenging problem [1]. In this paper, we categorize the users into three classes namely, ClassP, ClassG and ClassS representing platinum class users, gold class users and silver class users, respectively.

Accepting a user call or rejecting a call is totally determined by Call Admission Control (CAC) and hence, the number of users in the system is also directly controlled by CAC [2]. CAC is a prominent radio resource management technique that plays influential role in ensuring the desired QoS to the users and applications in NGWN [3][4]. General metrics used for CAC is Call Blocking Probability (CBP), call dropping probability and call rejection percentage [5]. This paper uses CBP as an appropriate parameter for evaluating the user class based CAC models.

The paper is organized as follows: Section II surveys the related work. Section III provides the intricacies of partition, queuing, threshold, reservation and differential access techniques for admission control. The simulation results are presented in Section IV. Insight to further research and conclusion are provided in Section V.

II. Related Work

Wide spectrum of CAC mechanisms are proposed in literature to guarantee QoS, primarily focusing on the application types, such as real time and non real time applications. The majority of work related to CAC, as reported by surveys on CAC [5] - [9] is carried out under two major headings namely, number of users based CAC and interference based CAC. However, few works of CAC based on type of users are also reported.

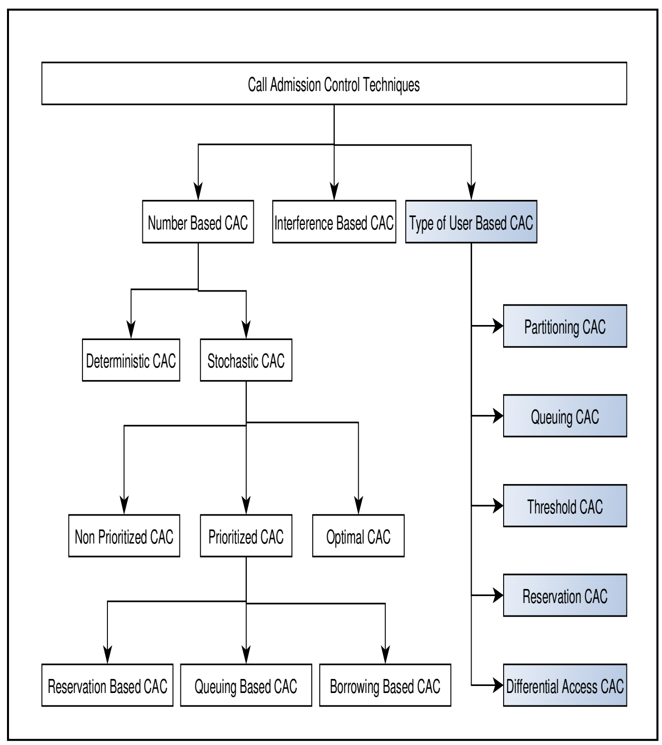

Figure 1. Classification of CAC Techniques.

Pal et al. [10] have proposed a QoS framework based on traffic class and user satisfaction. Kumar et al. [11] have proposed a user based bandwidth allocation technique for WiMAX named Differentiated Bandwidth Allocation Mechanism (DBAM). Algur et al. [12] have proposed a graded priority based admission control algorithm for LTE and WiMAX. AlQahtani [13] has proposed a user classification based CAC technique for LTE Advanced networks. Hosein [14] has proposed a QoS framework that allows an operator to provide class based connection admissions. Ozianyi et al. [15] have proposed a pricing approach that introduces three classes of user profiles platinum, gold and silver. Abraham et al. [16] have proposed a method and apparatus for adjustable QoS based admission control and scheduling in WLANs. Mahesh et al. [17] - [20] have proposed Partition Model (PM), Partition with Queuing Model (PQM), Reservation Model (RM) and Differential Access Model (DAM) for user class based CAC. A new classification of CAC techniques by adding "type of user" as an additional vertical to the existing classification is as shown in Figure 1. In this paper, the details of PM, PQM, RM and DAM are provided. The Threshold Model (TM) for user class based CAC is proposed and performance evaluation of PM, PQM, RM, DAM and TM is done.

III. User Class Based CAC Models

In this paper, we consider five user class based admission control models for performance evaluation namely, PM, PQM, TM, RM and DAM. For all the five models, three classes of users are considered namely, ClassP (Platinum Class Users), ClassG (Gold Class Users) and ClassS (Silver Class Users). This classification is done based on users varying QoS requirement and their willingness to pay the extra cost for the opted priority class of service. It is assumed that the ClassP user calls are of highest priority, ClassS user calls are of lowest priority and ClassG user calls are in between ClassP and ClassS. The arrival rates of ClassS, ClassG and ClassP user calls are denoted by λ_S, λ_G, and λ_P, respectively and are assumed to follow Poisson process. The mean service time of calls for all classes of users is assumed to follow a negative exponential distribution with a mean rate of $1/\mu$. The total number of virtual channels in the system is assumed to be equal to N.

A. Partition Model

The channel partition model is proposed in [17]. In this model, the entire set of N channels is divided and grouped into three disjoint sets P_1, P_2 and P_3. The first set of channels P_1 is to be used only by ClassS user calls, the second set of channels P_2 is to be used only by ClassG user calls and the third set of channels P_3 is to be used by only ClassP user calls. It is assumed that the number of channels in the third set P_3 is very much greater than the other two sets P_1 and P_2. Also, the number of channels in the second set P_2 is very much greater than the first set P_1.

Upon arrival of a call, the admission controller will first determine the class of call and based on availability of channels for the arrived calls' class, the call gets accepted or rejected. If the arrived call is of ClassP and if there are no free channels available between 1 to P_3, then the ClassP call gets rejected. The ClassP call gets accepted only if there are any free channels available between 1 to P_3. Similarly, ClassG and ClassS call gets accepted only if there are free channels available between 1 to P_2 and 1 to P_1, respectively, else the calls get rejected.

In [17], the expressions for call blocking probability for all the three classes of users namely ClassS, ClassG and ClassP are derived for partition model. The expressions for call blocking probability of ClassS, ClassG and ClassP users are denoted by B_{PS}, B_{PG} and B_{PP}. (1), (2) and (3) represents the CBP of ClassS, ClassG and ClassP users, respectively.

$$B_{PS} = \frac{\frac{1}{P_1!}\left(\frac{\lambda_S}{\mu}\right)^{P_1}}{\sum_{j=0}^{P_1}\frac{1}{j!}\left(\frac{\lambda_S}{\mu}\right)^{j}} \tag{1}$$

$$B_{PG} = \frac{\frac{1}{P_2!}\left(\frac{\lambda_G}{\mu}\right)^{P_2}}{\sum_{j=0}^{P_2}\frac{1}{j!}\left(\frac{\lambda_G}{\mu}\right)^{j}} \tag{2}$$

$$B_{PP} = \frac{\frac{1}{P_3!}\left(\frac{\lambda_P}{\mu}\right)^{P_3}}{\sum_{j=0}^{P_3}\frac{1}{j!}\left(\frac{\lambda_P}{\mu}\right)^{j}} \tag{3}$$

B. Partition With Queuing Model

The channel partition with queuing model is proposed in [18]. In this model, the entire set of N channels is divided into three disjoint groups P_1, P_2 and P_3. The first set of channels P_1 is to be used only by ClassS user calls, the second set of channels P_2 is to be used only by ClassG user calls and the third set of channels P_3 is to be used by only ClassP user calls. It is assumed that the number of channels in the third set P_3 is very much greater than the other two sets P_1 and P_2. Also, the number of channels in the second set P_2 is very much greater than the first set P_1.

The model is built with an idea that a small amount of delay in providing the service is better than not providing the service at all and the major objective is to minimize the denial service to all classes of users. Hence, in this model, if a class of users finds that all channels belonging to its class are occupied, then instead of dropping the call they are queued in appropriate queue class. When a channel of a particular class is released and if the queue of that particular

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class is not empty then the released channel is assigned to the user call in front of the queue.

In [18], the expressions for call blocking probability for all the three classes of users namely ClassS, ClassG and ClassP are derived for partition with queuing model. The expressions for call blocking probability of ClassS, ClassG and ClassP users are denoted by B_{QS}, B_{QG} and B_{QP}. (4), (5) and (6) represents the CBP of ClassS, ClassG and ClassP users, respectively. In (4), (5) and (6), Q_S, Q_G and Q_P represents the queue size for ClassS, ClassG and ClassP, respectively.

$$B_{QS} = \frac{(P_1\rho_S)^{P_1}\rho_S^{Q_S}}{P_1!} * \frac{1}{\sum_{k=0}^{P_1-1}\frac{(P_1\rho_S)^k}{k!} + \frac{(P_1\rho_S)^{P_1}}{P_1!}\left(\frac{1-\rho_S^{Q_S+1}}{1-\rho_S}\right)} \tag{4}$$

$$B_{QG} = \frac{(P_2\rho_G)^{P_2}\rho_G^{Q_G}}{P_2!} * \frac{1}{\sum_{k=0}^{P_2-1}\frac{(P_2\rho_G)^k}{k!} + \frac{(P_2\rho_G)^{P_2}}{P_2!}\left(\frac{1-\rho_G^{Q_G+1}}{1-\rho_G}\right)} \tag{5}$$

$$B_{QP} = \frac{(P_3\rho_P)^{P_3}\rho_P^{Q_P}}{P_3!} * \frac{1}{\sum_{k=0}^{P_3-1}\frac{(P_3\rho_P)^k}{k!} + \frac{(P_3\rho_P)^{P_1}}{P_3!}\left(\frac{1-\rho_P^{Q_P+1}}{1-\rho_P}\right)} \tag{6}$$

C. Threshold Model

In this model, the entire set of N channels is divided into two disjoint groups, P_1 and P_2. The first set of channels P_1 is to be used by ClassS and ClassP user calls and the second set of channels P_2 is to be used by ClassG and ClassP user calls. It is assumed that the number of channels in the second set P_2 is much greater than the number of channels in the first set P_1. T_S and T_G are the thresholds for ClassS and ClassG, respectively.

Upon arrival of a call, the admission controller will first determine the class of call and based on availability of channels for the arrived calls' class, the call gets accepted or rejected. If the arrived call is of ClassP and if there are no free channels available between 1 to P_1 and 1 to P_2, then the ClassP call gets rejected. The ClassP call gets accepted as long as there are any free channels available in the system. A ClassG user call gets accepted only if there are free channels available between 1 to P_2 and its utilization threshold is less than T_G else it gets rejected. Similarly, a ClassS user call gets accepted only if there are free channels available between 1 to P_1 and its utilization threshold is less than T_S else it gets rejected.

The expressions for call blocking probability of ClassS, ClassG and ClassP users are denoted by B_{TS}, B_{TG} and B_{TP}. (7), (8) and (9) represents the CBP of ClassS, ClassG and ClassP users, respectively.

$$B_{TS} = \frac{\sum_{b=0}^{P_1-T_S}\frac{1}{T_S!}\left(\frac{\lambda_S}{\mu}\right)^{T_S} * \frac{1}{b!}\left(\frac{\lambda_P}{\mu}\right)^{b} + \sum_{a=0}^{T_S-1}\frac{1}{a!}\left(\frac{\lambda_S}{\mu}\right)^{a}\frac{1}{(P_1-a)!}\left(\frac{\lambda_P}{\mu}\right)^{P_1-a}}{\sum_{a=0}^{T_S}\frac{1}{a!}\left(\frac{\lambda_S}{\mu}\right)^{a}\sum_{b=0}^{P_1-a}\frac{1}{b!}\left(\frac{\lambda_P}{\mu}\right)^{b}} \tag{7}$$

$$B_{TG} = \frac{\sum_{d=0}^{P_2-T_G}\frac{1}{T_G!}\left(\frac{\lambda_G}{\mu}\right)^{T_G} * \frac{1}{d!}\left(\frac{\lambda_P}{\mu}\right)^{d} + \sum_{c=0}^{T_G-1}\frac{1}{c!}\left(\frac{\lambda_G}{\mu}\right)^{c}\frac{1}{(P_2-c)!}\left(\frac{\lambda_P}{\mu}\right)^{P_2-c}}{\sum_{c=0}^{T_G}\frac{1}{c!}\left(\frac{\lambda_G}{\mu}\right)^{c}\sum_{d=0}^{P_2-c}\frac{1}{d!}\left(\frac{\lambda_P}{\mu}\right)^{d}} \tag{8}$$

$$B_{TP} = \left[\frac{\sum_{a=0}^{T_S}\frac{1}{a!}\left(\frac{\lambda_S}{\mu}\right)^{a}\frac{1}{(P_1-a)!}\left(\frac{\lambda_P}{\mu}\right)^{P_1-a}}{\sum_{a=0}^{T_S}\frac{1}{a!}\left(\frac{\lambda_S}{\mu}\right)^{a}\sum_{b=0}^{P_1-a}\frac{1}{b!}\left(\frac{\lambda_P}{\mu}\right)^{b}} * \frac{\sum_{c=0}^{T_G}\frac{1}{c!}\left(\frac{\lambda_G}{\mu}\right)^{c}\frac{1}{(P_2-c)!}\left(\frac{\lambda_P}{\mu}\right)^{P_2-c}}{\sum_{c=0}^{T_G}\frac{1}{c!}\left(\frac{\lambda_G}{\mu}\right)^{c}\sum_{d=0}^{P_2-c}\frac{1}{d!}\left(\frac{\lambda_P}{\mu}\right)^{d}}\right] \tag{9}$$

D. Reservation Model

The reservation model is proposed in [19]. In this model, exclusive reservation of channels is done for high priority users. ClassP users have an exclusive reservation of R_1 channels out of the N channels. Amongst the remaining C_2=N–R_1channels, ClassP and ClassG users have prioritized access to R_2 channels. The remaining channels $C_1=C_2-R_2$ can be used by all the three classes of users.

Upon arrival of a call, the admission controller will first determine the class of call and based on availability of channels for the arrived calls' class, the call gets accepted or rejected. If the arrived call is of ClassP and if there are no free channels available in the system, then the ClassP call gets rejected. The ClassP call gets accepted as long as there are any free channels available in the system. A ClassG user call gets accepted only if there are free channels available between 1 to C_2 else it gets rejected. Similarly, A ClassS user call gets accepted only if there are free channels available between 1 to C_1 else it gets rejected.

In [19], the expressions for call blocking probability for all the three classes of users namely ClassS, ClassG and ClassP are derived for reservation model. The expressions for call blocking probability of ClassS, ClassG and ClassP users are denoted by B_{RS}, B_{RG} and B_{RP}. (10), (11) and (12) represents the CBP of ClassS, ClassG and ClassP users, respectively.

$$B_{RS} = \frac{\sum_{i=c1}^{c2}\frac{1}{i!}\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{i-c1} + \sum_{i=c2+1}^{N}\frac{1}{i!}\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{c2}\left(\frac{\lambda_3}{\mu}\right)^{i-c2}}{\sum_{i=0}^{c1}\frac{1}{i!}\left(\frac{\lambda_1}{\mu}\right)^{i} + \sum_{i=c1+1}^{c2}\frac{1}{i!}\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{i-c1} + \sum_{i=c2+1}^{N}\frac{1}{i!}\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{c2}\left(\frac{\lambda_3}{\mu}\right)^{i-c2}} \tag{10}$$

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$$B_{RG} = \frac{\sum_{i=c2}^{N} \frac{1}{i!}\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{c2}\left(\frac{\lambda_3}{\mu}\right)^{i-c2}}{\sum_{i=0}^{c1} \frac{1}{i!}\left(\frac{\lambda_1}{\mu}\right)^{i} + \sum_{i=c1+1}^{c2} \frac{1}{i!}\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{i-c1} + \sum_{i=c2+1}^{N} \frac{1}{i!}\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{c2}\left(\frac{\lambda_3}{\mu}\right)^{i-c2}} \tag{11}$$

$$B_{RP} = \frac{\frac{1}{N!}\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{c2}\left(\frac{\lambda_3}{\mu}\right)^{N-c2}}{\sum_{i=0}^{c1} \frac{1}{i!}\left(\frac{\lambda_1}{\mu}\right)^{i} + \sum_{i=c1+1}^{c2} \frac{1}{i!}\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{i-c1} + \sum_{i=c2+1}^{N} \frac{1}{i!}\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{c2}\left(\frac{\lambda_3}{\mu}\right)^{i-c2}} \tag{12}$$

E. Differential Access Model

The differential access model is proposed in [20]. In this model, priority to users is given by allocating more number of channels for high priority user calls. It is assumed that ClassP user calls require 3 channels, ClassG user calls require 2 channels and ClassS user call requires 1 channel. BP, BG, and BS are the call blocking probabilities of ClassP, ClassG and ClassS users, respectively. When a user call requests for channels, the admission controller accepts the user call request if and only if there are free channels available to accommodate that particular user class (3 channels for ClassP, 2 channels for ClassG and 1 channel for ClassS) else rejects the user call requests.

In [20], the expressions for call blocking probability for all the three classes of users namely ClassS, ClassG and ClassP are derived for differential model. The expressions for call blocking probability of ClassS, ClassG and ClassP users are denoted by B_{DS}, B_{DG} and B_{DP}. (13), (14) and (15) represents the CBP of ClassS, ClassG and ClassP users, respectively.

$$B_{DS} = \frac{\lambda}{3\mu}\left(P(n-1)+P(n-2)+P(n-3)\right) \tag{13}$$

$$B_{DG} = \frac{\lambda}{3\mu}\left(P(n-2)+P(n-3)+P(n-4)\right) \tag{14}$$

$$B_{DP} = \frac{\lambda}{3\mu}\left(P(n-3)+P(n-4)+P(n-5)\right) \tag{15}$$

IV. RESULTS

In this section, we present the numerical results and compare the system call blocking probability of different models. Logarithmic scale bar graphs are used to interpret the results obtained. The bars in the graph represent the system CBP. It is to be noted that smaller the size of the bar, larger is the value and vice versa.

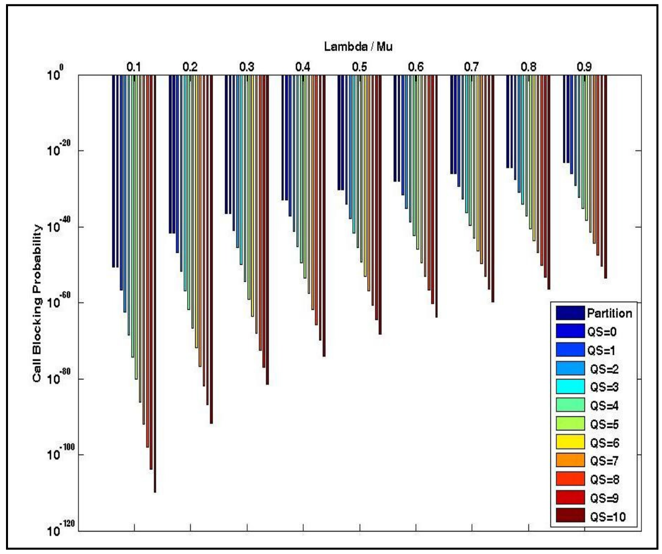

Figure 2. PM versus PQM (Ratio 2:3:5 and N=30)

It is assumed that the total number of virtual channels available in the system is 30. Figure 2 shows the graph of system CBP versus utilization rate of partition model and partition with queuing model for partition ratio 2:3:5, N=30 and queue size ranging from 0 to 10.

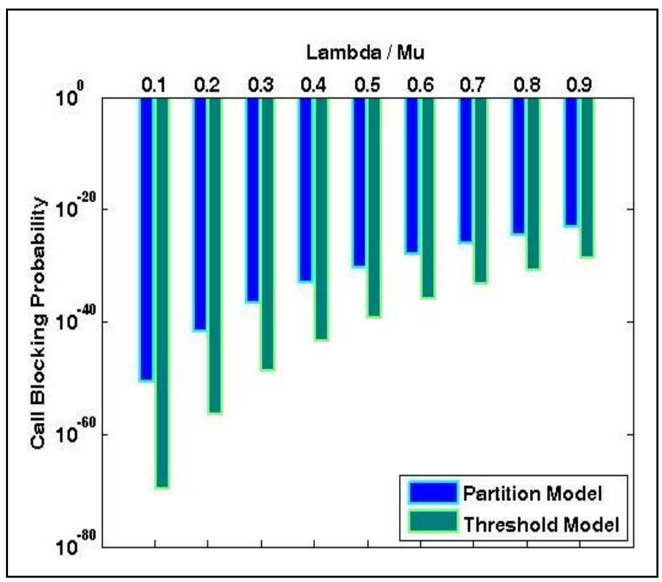

Figure 3. PM versus TM (Ratio 2:3:5, T_S=6, T_G=9 and N=30)

It can be seen that when queue size is zero, partition model and partition with queuing behave alike i.e., their CBP is same. Also, it is observed that with increase in queue size, the CBP decreases. Figure 3 shows the graph of system CBP versus utilization rate of partition model and threshold model

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for N= 30. It can be seen that threshold model exhibits lower CBP when compared to partition model in all cases.

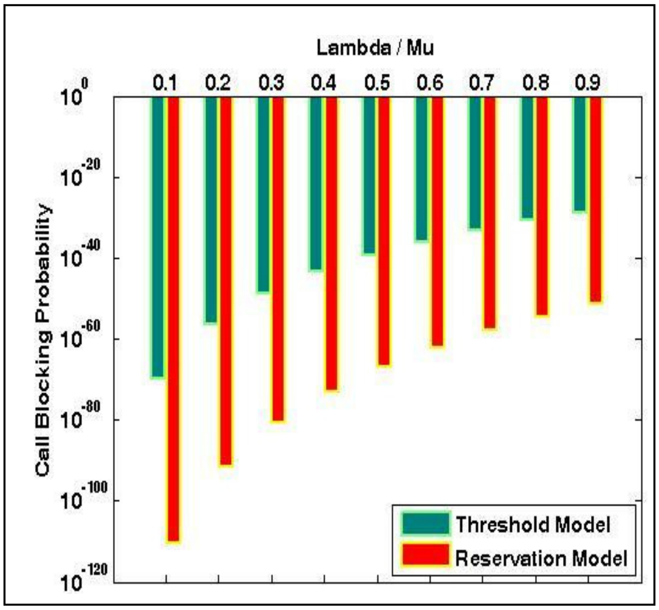

Figure 4. TM versus RM (Ratio 2:3:5, R_1=6, R_2=15 and N=30)

Figure 4 shows the graph of system CBP versus utilization rate of threshold model and reservation model for N= 30. It can be seen that reservation model exhibits lower CBP when compared to threshold model in all cases.

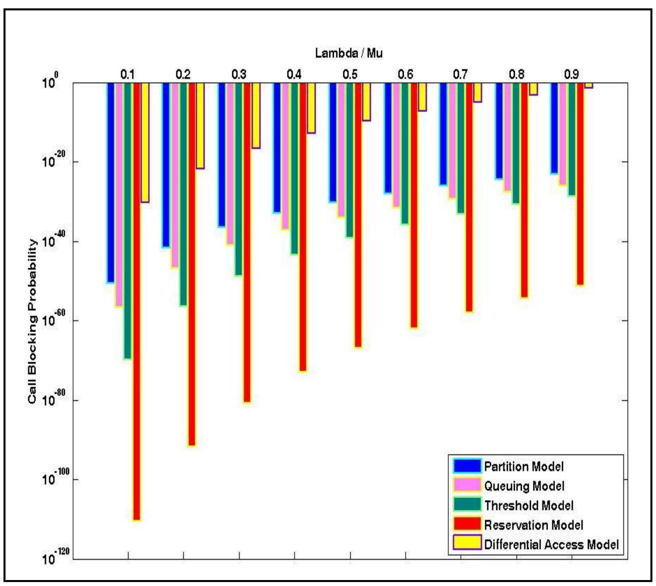

Figure 5. CBP of all 5 Models (N=30)

Figure 5 shows the graph of system CBP versus utilization rate of all the five models for N= 30 and partitioning ratios 2:3:5. It can be seen that reservation model exhibits the lowest CBP in all cases when compared to all other models.

The simulation study was conducted by considering different partition ratios with varied number of channels in the system; however the same observations were reported.

V. CONCLUSION

In this paper, we have evaluated performance of five different models for user class based CAC in NGWN. The models are simulated using Matlab and the simulation results are as shown in Figure 2 to Figure 5. The results clearly indicate that reservation model outperforms other models interms of CBP. Second in line is the threshold model, followed by partition with queuing model, partition model and finally differential access model. The CBP of partition with queuing improves with increase in queue size. The reason for differential access model to have greater CBP is that it allocates more than one channel for prioritized users and hence will be able to accommodate less number of users in the system. The pricing plays important role in commercialization of any experimental studies. NGWN is no exception and it has to primarily address pricing factor. Models of this nature are very essential to realize an optimal pricing model. The models evaluated in this paper are expected to bring delight to users and optimal revenue to service providers - ‘a win-win scenario’. Future work is to integrate pricing strategies of various players with the proposed CAC models. The proposed models are envisioned to realize optimal resource utilization, greater user flexibility and satisfaction.

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