A Threshold Model to Realize user Class based Call Admission Control in Next Generation Wireless Networks

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***Abstract*—With the rapid change and advancement in the communication technology users are in need of various services over wireless networks. To meet this demanding requirements network operators are going to offer various services to the users. Each network operator wants to maximize the revenue by increasing the number of users without compromising the promised quality of service. The number of users served by the system is directly controlled by the call admission control and it plays a vital role in the system, forcing its design in the system to be of utmost importance. This paper proposes a threshold based model with user differentiation in next generation wireless networks for call admission control. The expressions for call blocking probability of different classes of users are derived and the results are presented.**

Keywords—call admission control; threshold; user differentiation; call blocking probability; user class;

I. INTRODUCTION

The network operators of the Next Generation Wireless Networks (NGWN) will have wide array of services to their users to increase the customer base. Each individual users may not be willing to use all the services provided by network operators hence, the users of the NGWN not only demands for quality of service (QoS), but may demand for only specific service/s from the array of available services [1]. In this paper, we categorize the users into three classes viz. ClassP, ClassG and ClassS representing platinum class users, gold class users and silver class users respectively.

Accepting or rejecting a user call is totally determined by Call Admission Control (CAC) and hence the number of users of the system is directly controlled by CAC [2]. CAC is a best technique for effective management of radio resource and plays vital role in meeting quality of service (QoS) requirements to the users [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 the proposed CAC model.

A threshold model for CAC in NGWN is proposed by considering the changing QoS needs of the user classes. The paper is organized as follows: Section II surveys the related work. Section III provides the intricacies of threshold model. 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. Majority of the work related to CAC as reported by surveys on CAC [5 - 9] is carried out under two major headings viz. number of users based CAC and interference based CAC. However, few works of CAC based on type of users are also reported.

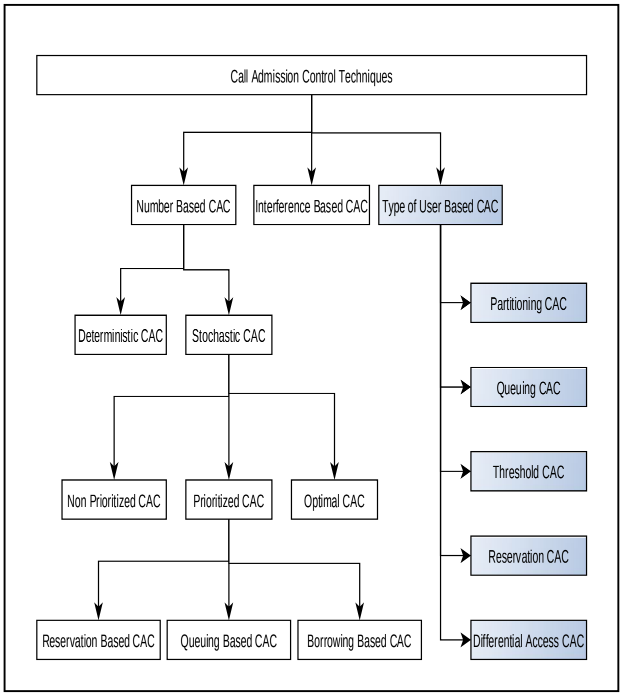

Fig. 1. Classification of CAC Techniques.

In [10] a QoS framework based on traffic class and user satisfaction is proposed by the authors. A user based bandwidth allocation technique for WiMAX named Differentiated Bandwidth Allocation Mechanism (DBAM) is proposed in [11]. A graded priority based admission control algorithm for LTE and WiMAX is proposed in [12]. In [13] a user classification based CAC technique for LTE Advanced networks is proposed. A QoS framework that allows an operator to provide class based connection admissions is proposed in [14]. In [15] a pricing approach that introduces three classes of user profiles platinum, gold and silver is proposed. A method and apparatus for adjustable QoS based admission control and scheduling in WLANs is proposed in [16].

We propose a new classification to CAC techniques as shown in Fig. 1 by adding "type of user" as an additional vertical to the existing classification. Based on type of user, in [17] Partition Model for user class based CAC is proposed, in [18] Partition with Queuing Model for user class based CAC is proposed, in [19] Reservation Model for user class based CAC is proposed and in [20] Differential Access Model for user class based CAC is proposed. In this paper, a Threshold Model for user class based CAC is proposed.

III. THRESHOLD MODEL (TM)

The N channels are partitioned into two groups P_1 and P_2 which are disjoint. High priority ClassP users do not have any restrictions and can access any of the N channels. ClassS users are allowed to access channels in the group P_1 as long as it does not cross the threshold T_S and ClassG users are allowed to access channels in the group P_2 as long as it does not cross the threshold T_G. Also the number of channels in the group P_2 is very much greater than that in group P_1 to ensure that ClassG have greater priority than ClassS. In this model as the high priority user class is allocated with channels without any thresholds, the probability of user call rejection / blocking for ClassP user calls is much lower when compared to the other two classes. The CAC system model with threshold for three classes of users is as shown in Fig. 2.

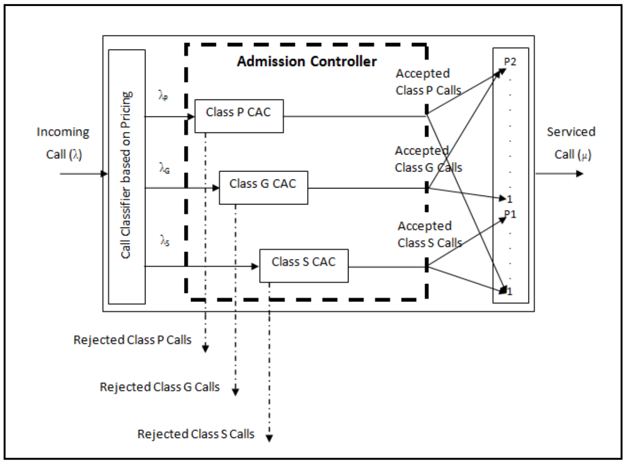

Fig. 2. TM for User Class based CAC.

The behavior of the system in Fig. 2 can be modeled as two independent Markov process. The corresponding state transition diagrams are as shown in Fig. 3 and Fig. 4.

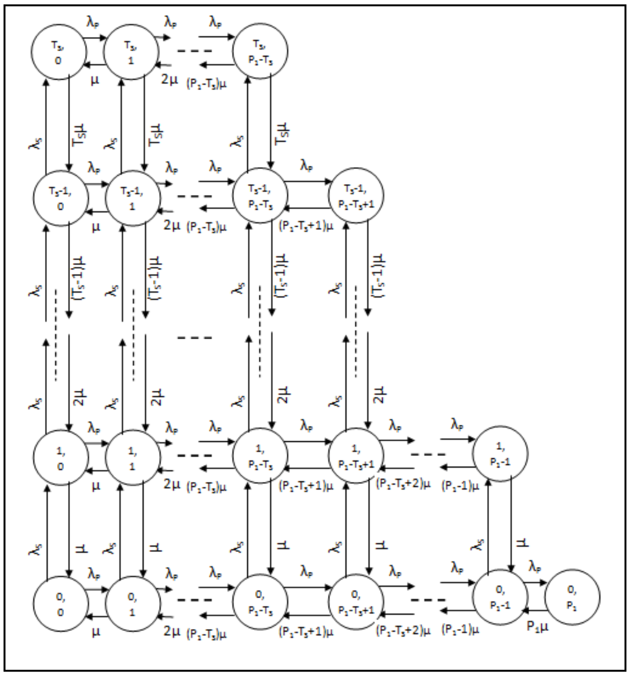

Fig. 3. Markov Chain for ClassS & ClassP Users with Threshold T_S.

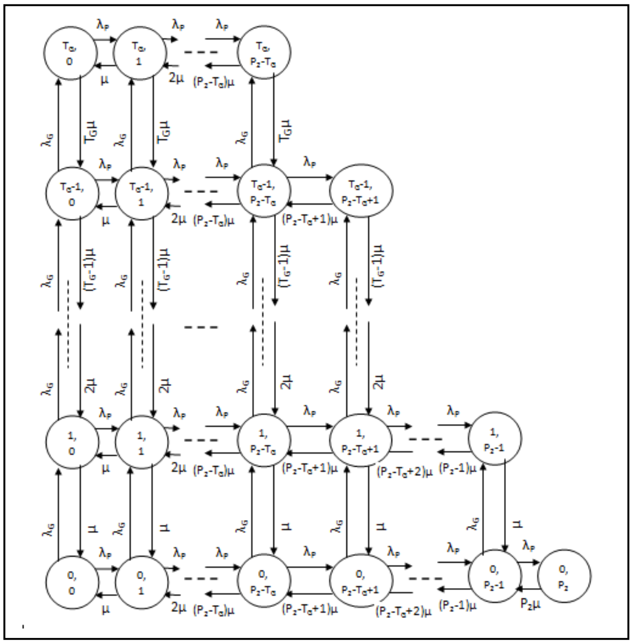

Fig. 4. Markov Chain for ClassG & ClassP Users with Threshold T_G.

The probability of platinum class user getting blocked is denoted by P_{P1}, is the sum of probability of being in states, $(0, P_1)$ $(0, P_1-1)$. . . . (T_S-1, P_1-T_S+1) and (T_S, P_1-T_S).

$$\mathrm{P}_{P1}=\frac{\sum_{a=0}^{T_S}\frac{1}{a!}\left(\frac{\lambda_{\mathrm{S}}}{\mu}\right)^{\mathrm{a}}\frac{1}{(P_1-a)!}\left(\frac{\lambda_{\mathrm{P}}}{\mu}\right)^{P_1-a}}{\sum_{a=0}^{T_S}\frac{1}{a!}\left(\frac{\lambda_{\mathrm{S}}}{\mu}\right)^{\mathrm{a}}\sum_{b=0}^{P_1-a}\frac{1}{b!}\left(\frac{\lambda_{\mathrm{P}}}{\mu}\right)^{\mathrm{b}}} \tag{1}$$

The probability of silver class user getting blocked is denoted by P_S, is the sum of probability of being in states, (T_S, 0) (T_S, 1) . . . (T_S, P_1-T_S) and (0, P_1) (1, P_1-1). . . .(T_S-1, P_1-T_S+1).

$$P_S=\frac{\sum_{b=0}^{P_1-T_S}\frac{1}{T_S!}\left(\frac{\lambda_{\mathrm{S}}}{\mu}\right)^{T_S}*\frac{1}{b!}\left(\frac{\lambda_{\mathrm{P}}}{\mu}\right)^{b}+\sum_{a=0}^{T_S-1}\frac{1}{a!}\left(\frac{\lambda_{\mathrm{S}}}{\mu}\right)^{a}\frac{1}{(P_1-a)!}\left(\frac{\lambda_{\mathrm{P}}}{\mu}\right)^{P_1-a}}{\sum_{a=0}^{T_S}\frac{1}{a!}\left(\frac{\lambda_{\mathrm{S}}}{\mu}\right)^{\mathrm{a}}\sum_{b=0}^{P_1-a}\frac{1}{b!}\left(\frac{\lambda_{\mathrm{P}}}{\mu}\right)^{\mathrm{b}}} \tag{2}$$

The probability of platinum class user getting blocked is denoted by $\mathrm{P}_{\mathrm{P}2}$, is the sum of probability of being in states, (0, P_2) (0, P_2-1). . . . . .(T_G-1, P_2-T_G+1) and (T_G, P_2-T_G).

$$\mathrm{P}_{P2}=\frac{\sum_{c=0}^{T_G}\frac{1}{c!}\left(\frac{\lambda_{\mathrm{G}}}{\mu}\right)^{\mathrm{c}}\frac{1}{(P_2-c)!}\left(\frac{\lambda_{\mathrm{P}}}{\mu}\right)^{P_2-c}}{\sum_{c=0}^{T_G}\frac{1}{c!}\left(\frac{\lambda_{\mathrm{G}}}{\mu}\right)^{\mathrm{c}}\sum_{d=0}^{P_2-c}\frac{1}{d!}\left(\frac{\lambda_{\mathrm{P}}}{\mu}\right)^{\mathrm{d}}} \tag{3}$$

The probability of gold class user getting blocked is denoted by P_G, is the sum of probability of being in states, (T_G, 0) (T_G, 1) . . . . . . (T_G, P_2-T_G) and (0, P_2) (1, P_2-1). . . . .(T_G-1, P_2-T_G+1).

$$\mathrm{P}_G=\frac{\sum_{d=0}^{P_2-T_G}\frac{1}{T_G!}\left(\frac{\lambda_{\mathrm{G}}}{\mu}\right)^{T_G}*\frac{1}{d!}\left(\frac{\lambda_{\mathrm{P}}}{\mu}\right)^{d}+\sum_{c=0}^{T_G-1}\frac{1}{c!}\left(\frac{\lambda_{\mathrm{G}}}{\mu}\right)^{c}\frac{1}{(P_2-c)!}\left(\frac{\lambda_{\mathrm{P}}}{\mu}\right)^{P_2-c}}{\sum_{c=0}^{T_G}\frac{1}{c!}\left(\frac{\lambda_{\mathrm{G}}}{\mu}\right)^{\mathrm{c}}\sum_{d=0}^{P_2-c}\frac{1}{d!}\left(\frac{\lambda_{\mathrm{P}}}{\mu}\right)^{\mathrm{d}}} \tag{4}$$

The blocking probability of platinum class users denoted by P_P is given by

$$\mathrm{P}_P=\left[\frac{\sum_{a=0}^{T_S}\frac{1}{a!}\left(\frac{\lambda_{\mathrm{S}}}{\mu}\right)^{\mathrm{a}}\frac{1}{(P_1-a)!}\left(\frac{\lambda_{\mathrm{P}}}{\mu}\right)^{P_1-a}}{\sum_{a=0}^{T_S}\frac{1}{a!}\left(\frac{\lambda_{\mathrm{S}}}{\mu}\right)^{\mathrm{a}}\sum_{b=0}^{P_1-a}\frac{1}{b!}\left(\frac{\lambda_{\mathrm{P}}}{\mu}\right)^{\mathrm{b}}}*\frac{\sum_{c=0}^{T_G}\frac{1}{c!}\left(\frac{\lambda_{\mathrm{G}}}{\mu}\right)^{\mathrm{c}}\frac{1}{(P_2-c)!}\left(\frac{\lambda_{\mathrm{P}}}{\mu}\right)^{P_2-c}}{\sum_{c=0}^{T_G}\frac{1}{c!}\left(\frac{\lambda_{\mathrm{G}}}{\mu}\right)^{\mathrm{c}}\sum_{d=0}^{P_2-c}\frac{1}{d!}\left(\frac{\lambda_{\mathrm{P}}}{\mu}\right)^{\mathrm{d}}}\right] \tag{5}$$

IV. RESULTS

The TM is simulated using matlab. The utilization rate for all classes of users is varied during simulation. Logarithmic scale bar graphs are used to interpret the results obtained. The bars in the graph represent the CBP of different class of users. It is to be noted that smaller the size of the bar, larger is the value and vice versa. Fig. 5 is the graph of utilization rate versus CBP for all the three classes of users for N= 90 with T_S=18 and T_G=27. The graph clearly depicts that for all user classes the CBP increases with increase in utilization rate. The simulation results show positive trend and clearly indicates that high priority user classes exhibit very low CBP when compared to low priority user classes. Also for all classes of users CBP decreases with increase in the number of channels as shown in Fig. 6, Fig. 7 and Fig. 8.

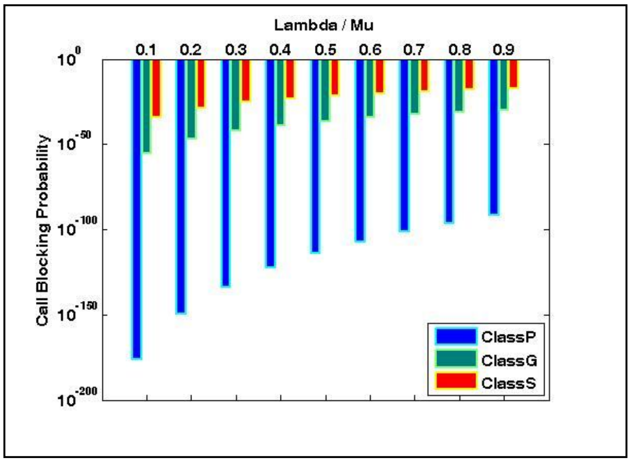

Fig. 5. CBP of ClassP Vs ClassG Vs ClassS for TM.

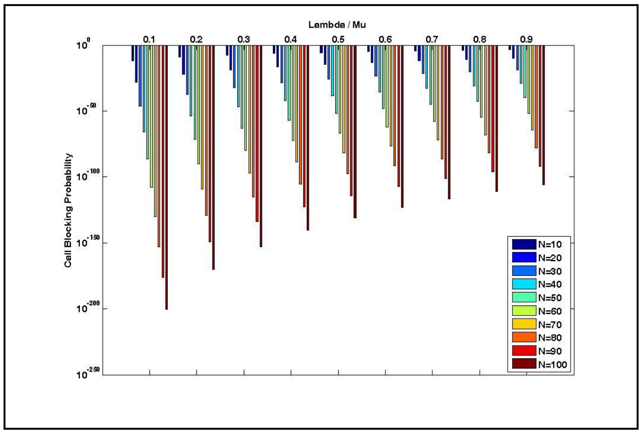

Fig. 6. CBP of ClassP Users for TM.

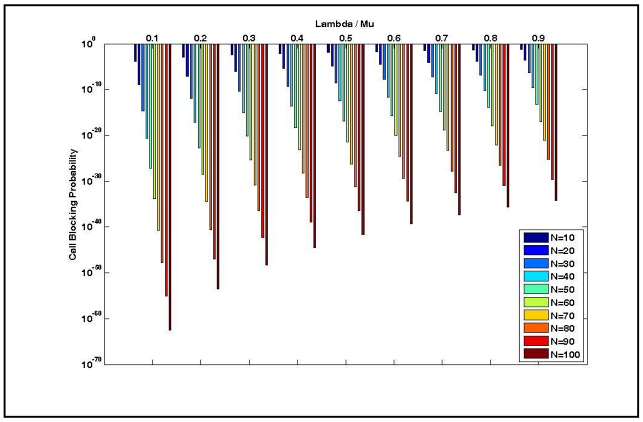

Fig. 7. CBP of ClassG Users for TM.

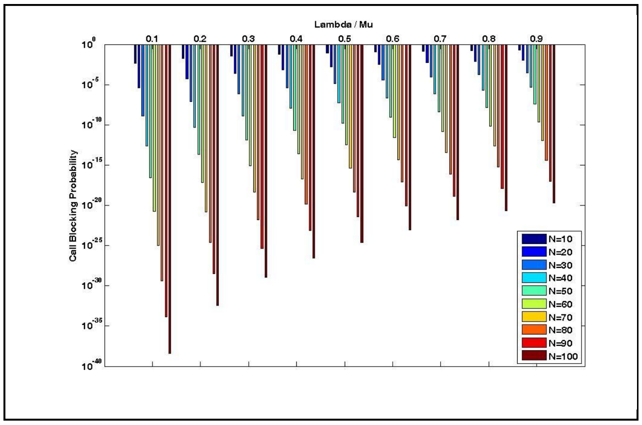

Fig. 8. CBP of ClassS Users for TM.

The simulation study was conducted for varied number of channels in the system; however the same observations were reported.

V. CONCLUSION

In this paper TM for user class based CAC in NGWN is proposed. Importantly, CBP equations are derived for all class of users. Equations (2), (4) and (5) represent the CBP of ClassS, ClassG and ClassP users respectively. The model is simulated using matlab and the simulation results are depicted in Figure 5, Figure 6, Figure 7 and Figure 8. The simulation results are in positive trend and clearly indicate that that high priority user classes have very low CBP when compared to low priority user classes. 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 proposed model TM is 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 model is envisioned to realize optimal resource utilization, greater user flexibility and satisfaction.

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