Channel Reservation Model for User Class Based Admission Control in Next Generation Wireless Networks

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Abstract

The Next Generation Wireless Networks (NGWN) are expected to offer abundant services to its users. Guaranteeing the agreed upon Quality of Service (QoS), while trying to maximize the revenue of the network operators by having more number of users in the system is a challenging problem. Call Admission Control (CAC) directly controls the number of users in the system and hence utmost care must be taken in the design of an effective CAC framework. This paper proposes a channel reservation model for CAC in NGWN based on the users' QoS needs and the simulation results for call blocking probability of different user classes are presented.

Keywords: *call admission control, user class, quality of service, next generation wireless networks, reservation model.*

1. Introduction

The network operators in NGWN are envisioned to provide plethora of services to the users. In the next few years the capability of the current generation wireless networks are about to be tested for the greater magnitude of services provided by the operators in addition to the increase in number of users. Providing QoS guarantee in NGWN is thus a challenging problem [1]. CAC directly controls the number of users in the system [2]. It is one of the radio resource management techniques that plays influential role in ensuring the desired QoS to the users and applications in NGWN [3, 4]. It is the set of actions taken by the network during a call setup inorder to determine if a request for bandwidth is accepted or rejected.

QoS provisioning becomes a real challenge when network operators try to raise their profits while meeting users varied QoS requirements by maximizing the number of connected users [5]. Hence from the network operator's point of view user differentiation is becoming increasingly important. An important aspect of providing differentiated services in NGWN is to design an effective CAC framework [6].

Network's QoS includes packet level QoS and connection level QoS [7]. Packet level QoS is measured in terms of delay, jitter or loss rate. Connection level QoS is measured in terms of call blocking probability, call dropping probability and call rejection percentage. In this paper we focus on connection level QoS and consider call blocking probability as an appropriate parameter.

The paper proposes a channel reservation model for CAC in NGWN by considering the varying QoS needs of the user classes and is organized as follows. In Section 2, the details of channel reservation system model is presented. The mathematical expressions for call blocking probability of different user classes are derived in Section 3. The simulation results are presented in Section 4. The paper concludes with Section 5.

2. Channel Reservation Model

From both the network operators and users point of view user differentiation is becoming a very important agenda in NGWN and hence users need to be categorized into different classes based on their QoS requirements. In this model the user calls are categorized as Platinum, Gold and Silver user calls denoted by three classes viz. ClassP, ClassG and ClassS. Platinum users are of highest priority, Gold users have an intermediate priority and Silver users have the lowest priority. Users with higher priority are subject to increased subscription rates in return for prioritized network access and QoS.

The call arrival rates of ClassP, ClassG and ClassS user classes are denoted by λP, λG, and λS respectively. The call arrival of all user classes is assumed to follow a Poisson process. The mean service time of calls for all user classes is assumed to follow negative exponential distribution with a mean rate of 1/μ. The total number of virtual channels in the system is assumed to be N.

In this model out of the N virtual channels some channels are exclusively reserved for high priority users. Out of N channels R_1 channels are reserved for ClassP users, the remaining channels available is $C_2 = N – R_1$. Out of C_2 channels, R_2 channels are reserved for ClassG users (also can be used by ClassP users), the remaining channels available is $C_1 = C_2 – R_2$. The C1 number of channels is shared among all the three user classes. The CAC system model with channel reservation for three classes of users is as shown Figure 1.

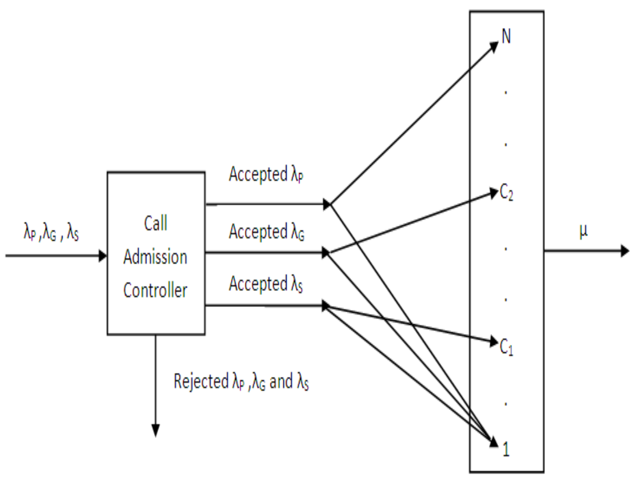

Figure 1: Channel Reservation System Model for User Class based CAC

The call admission controller keeps track of number channels used in the system based on which it accepts/rejects a user call belonging to a particular user class. As long as the number of channels used in the system is less than or equal to C_1 calls from all classes of users are accepted into the system. When the number of channels used becomes greater than C_1 only ClassG and ClassP user calls are accepted into the system with a constraint that the number of channels used is less than or equal to C_2. When the number of channels used become greater than C_2 only ClassP user calls are accepted into the system. Hence exclusive channel reservation for high priority user calls ensures that the probability of user call rejection / blocking for high priority user calls is much lower than low priority user calls.

3. Analysis of Call Blocking Probability

The behavior of the system in Figure 1 can be modeled using a Markov process with (N+1) states where each state is labeled by an integer from 0 to N. The state transition diagram is as shown in Figure 2. The following notations are used,

- $\lambda_1 = \lambda_P + \lambda_G + \lambda_S$ is the overall call arrival rate of the system.
- $\lambda_2 = \lambda_P + \lambda_G$ is the combined call arrival rate of ClassP and ClassG user classes.
- $\lambda_3 = \lambda_P$ is the call arrival rate of ClassP traffic.
- B_P, B_G, and B_S are the call blocking probabilities of ClassP, ClassG, and ClassS users respectively.

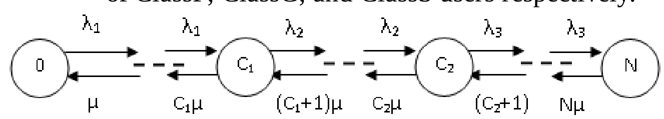

Figure 2: Markov Chain for Channel Reservation Model

The state balance equations for Figure 2 are

$$0 = -\lambda_1 P(0) + \mu P(1)$$

$$0 = -(\lambda_1 + i\mu)P(i) + \lambda_1 P(i-1) + (i+1)\mu P(i+1) \qquad 1 \le i \le C_1-1$$

$$0 = -(\lambda_2 + i\mu)P(i) + \lambda_1 P(i-1) + (i+1)\mu P(i+1) \qquad i = C_1$$

$$0 = -(\lambda_2 + i\mu)P(i) + \lambda_2 P(i-1) + (i+1)\mu P(i+1) \qquad C_1+1 \le i \le C_2-1$$

$$0 = -(\lambda_3 + i\mu)P(i) + \lambda_2 P(i-1) + (i+1)\mu P(i+1) \qquad i = C_2$$

$$0 = -(\lambda_3 + i\mu)P(i) + \lambda_3 P(i-1) + (i+1)\mu P(i+1) \qquad C_2+1 \le i \le N-1$$

$$0 = N\mu P(N) + \lambda_3 P(N-1)$$

The steady state probability of the system being in state 'i' is

$$P(i) = \begin{cases} \dfrac{\left(\frac{\lambda_1}{\mu}\right)^{i}}{i!} P(0) & 0 \le i \le C_1 \\ \dfrac{\left(\frac{\lambda_1}{\mu}\right)^{c_1}\left(\frac{\lambda_2}{\mu}\right)^{i-c_1}}{i!} P(0) & C_1+1 \le i \le C_2 \\ \dfrac{\left(\frac{\lambda_1}{\mu}\right)^{c_1}\left(\frac{\lambda_2}{\mu}\right)^{c_2}\left(\frac{\lambda_3}{\mu}\right)^{i-(c_1+c_2)}}{i!} P(0) & C_2+1 \le i \le C_1 \end{cases} \qquad (1)$$

Where,

$$P(0) = \left[\sum_{i=0}^{c_1} \frac{\left(\frac{\lambda_1}{\mu}\right)^{i}}{i!} + \sum_{i=c_1+1}^{c_2} \frac{\left(\frac{\lambda_1}{\mu}\right)^{c_1}\left(\frac{\lambda_2}{\mu}\right)^{i-c_1}}{i!} + \sum_{i=c_2+1}^{N} \frac{\left(\frac{\lambda_1}{\mu}\right)^{c_1}\left(\frac{\lambda_2}{\mu}\right)^{c_2}\left(\frac{\lambda_3}{\mu}\right)^{i-(c_1+c_2)}}{i!} \right]^{-1}$$

The call blocking probability of platinum user calls (ClassP users) is the probability that all the N channels are occupied in the system and is given by

$$B_P = P(N)$$

$$= \frac{\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{c2}\left(\frac{\lambda_3}{\mu}\right)^{N-(c1+c2)} \Big/ N!}{\sum_{i=0}^{c1}\frac{\left(\frac{\lambda_1}{\mu}\right)^{i}}{i!} + \sum_{i=c1+1}^{c2}\frac{\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{i-c1}}{i!} + \sum_{i=c2+1}^{N}\frac{\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{c2}\left(\frac{\lambda_3}{\mu}\right)^{i-(c1+c2)}}{i!}} \quad (2)$$

The call blocking probability of gold user calls (ClassG users is the probability that more than C_2 channels are occupied in the system and is given by

$$B_G = \sum_{i=c2}^{N} P(i)$$

$$= \frac{\sum_{i=c2}^{N}\frac{\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{c2}\left(\frac{\lambda_3}{\mu}\right)^{i-(c1+c2)}}{i!}}{\sum_{i=0}^{c1}\frac{\left(\frac{\lambda_1}{\mu}\right)^{i}}{i!} + \sum_{i=c1+1}^{c2}\frac{\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{i-c1}}{i!} + \sum_{i=c2+1}^{N}\frac{\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{c2}\left(\frac{\lambda_3}{\mu}\right)^{i-(c1+c2)}}{i!}} \quad (3)$$

The call blocking probability of silver user calls (ClassS users) is the probability that more than C_1 channels are occupied in the system and is given by

$$B_S = \sum_{i=c1}^{N} P(i) = \sum_{i=c1}^{c2} P(i) + \sum_{i=c2}^{N} P(i)$$

$$= \frac{\sum_{i=c1}^{c2}\frac{\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{i-c1}}{i!} + \sum_{i=c2}^{N}\frac{\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{c2}\left(\frac{\lambda_3}{\mu}\right)^{i-(c1+c2)}}{i!}}{\sum_{i=0}^{c1}\frac{\left(\frac{\lambda_1}{\mu}\right)^{i}}{i!} + \sum_{i=c1+1}^{c2}\frac{\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{i-c1}}{i!} + \sum_{i=c2+1}^{N}\frac{\left(\frac{\lambda_1}{\mu}\right)^{c1}\left(\frac{\lambda_2}{\mu}\right)^{c2}\left(\frac{\lambda_3}{\mu}\right)^{i-(c1+c2)}}{i!}} \quad (4)$$

4. Simulation Results

The channel reservation model is simulated using Matlab. Simulation study is made by assuming the total number of virtual channels in the system as 30. This is divided into three sets consisting of 5, 10 and 15 channels making the values of C_1=5 and C_2=15. The first 5 channels are shared by all the classes of users. When the number of channels used in the system exceeds 5, only ClassG and ClassP users are allowed. When the number of channels used in the system exceeds 15, only ClassP users are allowed. The arrival rate of all class of users is assumed to be the same i.e. $\lambda_P = \lambda_G = \lambda_S = \lambda$ and the service rate of all class of users is μ. The utilization rate is given by λ/μ. The simulations were carried out by varying the utilization rate for all classes of users. Figure 3 is the graph of utilization rate versus call blocking probability for low priority silver class users. Figure 4 is the graph of utilization rate versus call blocking probability for gold class users. Figure 5 is the graph of utilization rate versus call blocking probability for high priority platinum class users. It is observed that as the utilization rate increases the call blocking probability also increases for all the three class of users and in addition the call blocking probability of high priority user class is very low when compared to that of low priority user classes.

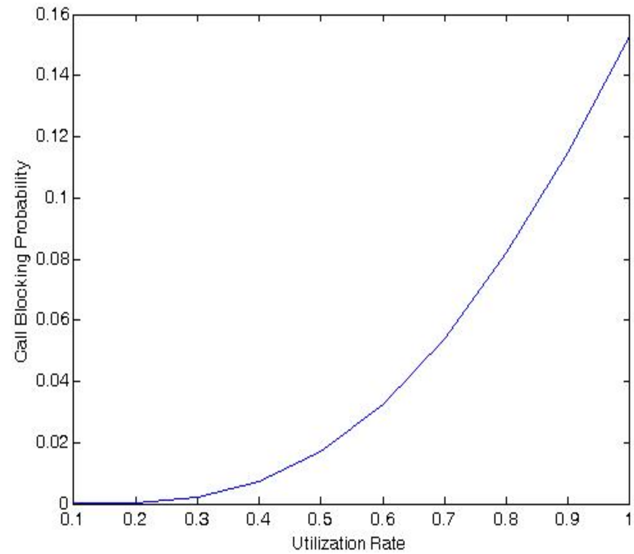

Figure 3: Utilization Rate VS Call Blocking Probability for ClassS Users

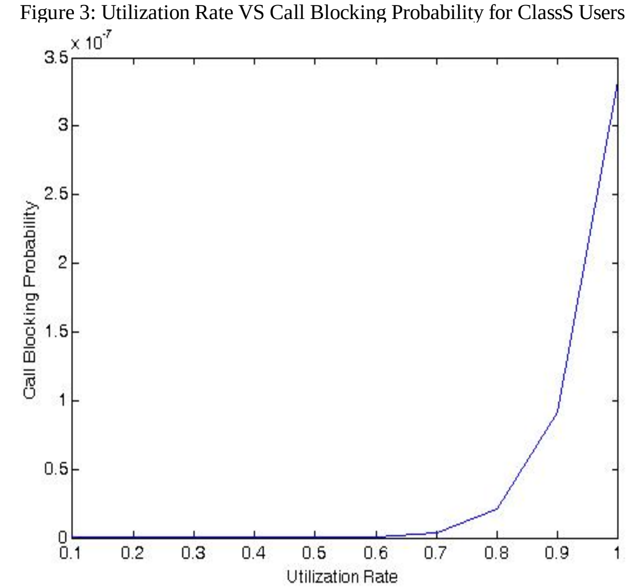

Figure 4: Utilization Rate VS Call Blocking Probability for ClassG Users

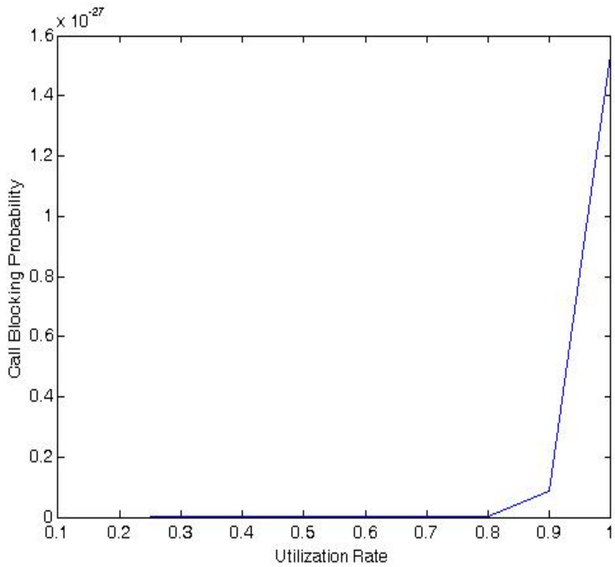

Figure 5: Utilization Rate VS Call Blocking Probability for ClassP Users

5. Conclusion

In this paper, we have proposed channel reservation model for user class based CAC in NGWN. Equations for call blocking probability are derived for all class of users. Equations (2) to (4) represent the call blocking probability of ClassP, ClassG and ClassS users respectively. The model is simulated using matlab and the simulation results are as shown in Figure 3, Figure 4 and Figure 5. The simulation results are optimistic and clearly indicate that high priority user classes have very low call blocking probability when compared to low priority user classes because of exclusive channel reservation of high priority users. In the view of high priority users and network service providers the proposed model brings in user delightness and more revenue respectively.

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