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Channel partitioning model for user class based call admission control in next generation wireless networks

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ABSTRACT

The Next Generation Wireless Networks (NGWN) are heterogeneous in nature and Call Admission Control (CAC) in NGWN is a challenging problem. User differentiation is becoming increasingly important to the service providers as Quality of Service (QoS) requirements vary amongst users. The number of users in the network is directly controlled by CAC and hence must be carefully designed to guarantee the varying QoS needs of users. This paper proposes a channel partitioning model for CAC in NGWN by taking into account the users QoS needs and the simulation results for the call blocking probability of different user classes is presented.

1. Introduction

The NGWN are envisioned to be heterogeneous in nature and are expected to provide better speed, higher bandwidth and low cost services supporting a variety of applications including web transfer, file transfer, email, sms, real time audio/video applications, streaming applications and gaming [1]. CAC is one of the radio resource management techniques that plays influential role in ensuring the desired QoS to the users and applications in NGWN [2, 3]. CAC accepts a new call request only if there are enough free resources to meet its QoS requirements without violating the QoS of already accepted calls, thereby preventing network congestion and service degradation for already active users. A good call admission control algorithm must maximize channel utilization in a fair manner to all calls and minimize the dropping probability of active calls, blocking probability of new calls and reduction of the QoS for the active calls [4]. User differentiation is becoming increasingly important to the service providers as QoS requirements vary amongst users. An important aspect of providing differentiated services in NGWN is to design an effective CAC framework [5].

QoS support can occur at the packet, transaction, circuit, user, and network levels [6-8]. Most of the existing research on CAC has focused on an abstract representation of the network in which only call level QoS parameters namely call blocking probability, call dropping probability and call rejection percentage are considered. In this paper we assume that the total bandwidth is channelized and the focus is on call level QoS. Channels could be frequencies or timeslots depending on the radio technology used. In particular we consider the call blocking probability as an appropriate parameter.

The paper proposes a channel partitioning 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 partitioning system model is presented. The expressions for call blocking probability of different user classes are derived in Section 3. The simulation results are put forth in Section 4. The paper concludes with Section 5.

2. Channel Partitioning Model

Based on varying QoS requirement of users, the user calls are categorized into three different classes namely ClassP, ClassG and ClassS representing Platinum, Gold and Silver user classes respectively. Calls of ClassP users are of highest priority then ClassG comes in priority order. ClassS user calls are given lowest priority. Users with higher priority are subject to increased subscription rates in return for prioritized network access and QoS.

λ_P, λ_G, and λ_S are the call arrival rates of ClassP, ClassG and ClassS user classes 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 $1/\mu$. N is the total number of virtual channels in the system.

In this model the N virtual channels are partitioned into three disjoint groups P_1, P_2 and P_3. P_1 channels are for ClassS, P_2 channels are for ClassG and P_3 channels are for ClassP. The priority constraint followed is P_3 is very much greater than P_2 and P_2 is very much greater than P_1 i.e. $P_3 >> P_2 >> P_1$ where $P_1 + P_2 + P_3 = N$. The CAC system model with channel partitioned into three disjoint groups for three classes of users is as shown in Figure 1.

The admission controller keeps track of the number of free channels available for all the three user classes. When a user call of a particular class requests for a channel, the admission controller accepts the user call request only if there are free channels available for that particular user class else rejects the user call requests. The admission controller does this process of accepting / rejecting user call requests without disturbing the

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QoS of the existing user calls in the system. In this model as the partition for high priority user class (Platinum user class) contains more number of channels as compared to other classes of users, the probability of user call rejection / blocking for ClassP user calls is much lower when compared to the other two classes.

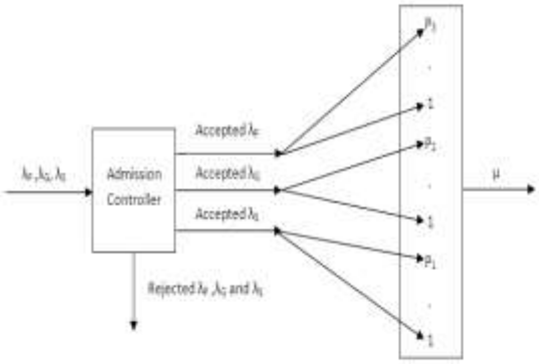

Figure1: Channel Partitioning System Model for User Class based CAC

3. Analysis of Call Blocking Probability

The behavior of the system in Figure 1 can be modeled as three independent Markov process. The corresponding state transition diagrams are as shown in Figure 2, Figure 3 and Figure 4.

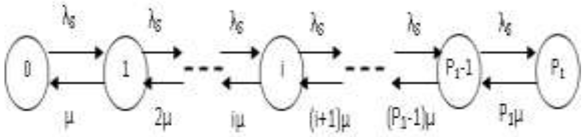

Figure2: Markov Chain for Silver Class Users of the System

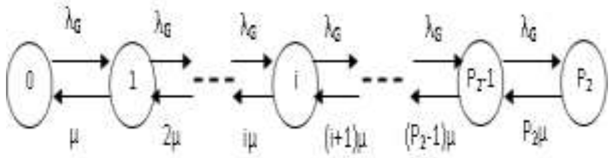

Figure 3: Markov Chain for Gold Class Users of the System

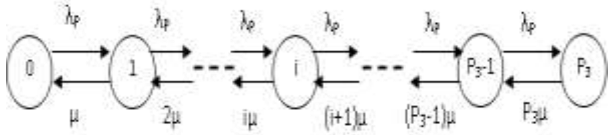

Figure4: Markov Chain for Platinum Class Users of the System

The state balance equations for Figure 2 are

$$\lambda_S P(0) = \mu P(1)$$

$$\lambda_S P(1) = 2\mu P(2)$$

$$\lambda_S P(i-1) = i\mu P(i)$$

$$\lambda_S P(i) = (i+1)\mu P(i+1)$$

$$\lambda_S P(P_1 - 1) = P_1 \mu P(P_1)$$

The state equilibrium equation is

$$P(i) = \frac{\lambda s}{i\mu} P(i-1) \tag{1}$$

Expressing all the state probabilities in terms of P(0) we get,

$$P(0) = P(0)$$

$$P(1) = \frac{\lambda s}{\mu} P(0)$$

$$P(2) = \frac{\lambda s}{2\mu} P(1) = \frac{1}{2}\left(\frac{\lambda s}{\mu}\right)^2 P(0)$$

$$P(i) = \frac{1}{i}\left(\frac{\lambda s}{\mu}\right) P(i-1) = \frac{1}{i!}\left(\frac{\lambda s}{\mu}\right)^i P(0)$$

$$P(P_1) = \frac{1}{P_1}\left(\frac{\lambda s}{\mu}\right) P(P_1 - 1) = \frac{1}{P_1!}\left(\frac{\lambda s}{\mu}\right)^{P_1} P(0)$$

With the normalization constraint we have,

$$1 = \sum_{j=0}^{P_1} P(j)$$

$$= P(0)\left[1 + \frac{\lambda s}{\mu} + \frac{1}{2!}\left(\frac{\lambda s}{\mu}\right)^2 + \ldots\ldots \frac{1}{i!}\left(\frac{\lambda s}{\mu}\right)^i + \ldots\ldots \frac{1}{P_1!}\left(\frac{\lambda s}{\mu}\right)^{P_1}\right]$$

$$P(0) = \frac{1}{\sum_{j=0}^{P_1} \frac{1}{j!}\left(\frac{\lambda_s}{\mu}\right)^j} \tag{2}$$

Therefore, the steady state probability of the system being in state ‘i' is given by

$$P(i) = \frac{\frac{1}{i!}\left(\frac{\lambda s}{\mu}\right)^i}{\sum_{j=0}^{P_1} \frac{1}{j!}\left(\frac{\lambda_s}{\mu}\right)^j} \qquad 0 \le i \le P_1 \tag{3}$$

The probability that a call of silver user class will be blocked denoted by B_S is written using the ErlangB formula

$$B_S = P(P_1) = \frac{\frac{1}{P_1!}\left(\frac{\lambda s}{\mu}\right)^{P_1}}{\sum_{j=0}^{P_1} \frac{1}{j!}\left(\frac{\lambda_s}{\mu}\right)^j} \tag{4}$$

Similarly from Figure 3 and Figure 4, the call blocking probability of gold and platinum user class denoted by B_G and B_P can be written as

$$B_G = P(P_2) = \frac{\frac{1}{P_2!}\left(\frac{\lambda_G}{\mu}\right)^{P_2}}{\sum_{j=0}^{P_2} \frac{1}{j!}\left(\frac{\lambda_G}{\mu}\right)^j} \tag{5}$$

$$B_P = P(P_3) = \frac{\frac{1}{P_3!}\left(\frac{\lambda_P}{\mu}\right)^{P_3}}{\sum_{j=0}^{P_3} \frac{1}{j!}\left(\frac{\lambda_P}{\mu}\right)^j} \tag{6}$$

4. Simulation Results

The channel partitioning model is simulated using matlab. It is assumed that the total number of virtual channels available in the system is 30. This is partitioned into three disjoint classes in the ratio of 1:2:3 i.e. partition 1consisting of 5 channels is for ClassS users, partition 2 consisting of 10 channels is for ClassG users and partition 3 consisting of 15 channels is for ClassP users. It is assumed that the arrival rate of all class of users is 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 5 is the graph of utilization rate versus call blocking probability for all the three classes of users. The graph clearly indicates that as the utilization rate increases the call blocking probability also increases for all the three class of users. Also the call blocking probability of high priority user class is very low when compared to that of low priority user classes.

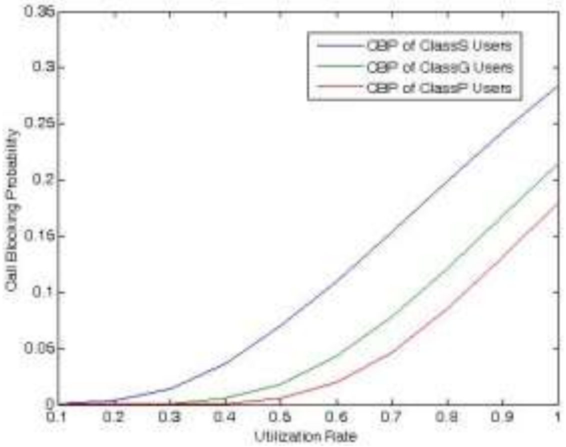

Figure 5: Utilization Rate VS Call Blocking Probability of all User Classes

5. Conclusion

In this paper, we have proposed channel partitioning model for user class based CAC in NGWN. Equations for call blocking probability are derived for all class of users. Equations (4) to (6) represent the call blocking probability of ClassS, ClassG and ClassP users respectively. The model is simulated using matlab and the simulation results are as shown in 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.

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