Channel Partitioning with Queuing Model for User Class based Call Admission Control in Next Generation Wireless Networks

Mahesh G
Department of IS&E,
Ac.I.T, Bangalore,
Karnataka, INDIA.

Gowrishankar
Department of CS&E,
B.M.S.C.E, Bangalore,
Karnataka, INDIA.

RameshBabu H S
Department of IS&E,
Ac.I.T, Bangalore,
Karnataka, INDIA.

ABSTRACT
Users in Next Generation Wireless Networks (NGWN) will have varied Quality of Service (QoS) requirements as the network operators are expected to offer plethora of services. The main objective of the network operators is to guarantee the agreed upon QoS to the users, at the same time maximize the revenue earned by having more number of users in the system. Call Admission Control (CAC) has a direct control on the number of users in the system and is a challenging problem in NGWN taking into account the limited number of channels available in the system. Designing a CAC framework with users' varying QoS requirements is therefore an important aspect for NGWN. This paper proposes a channel partitioning with queuing model for CAC in NGWN by taking into account the varying QoS needs of the users. The main idea behind the model is that a small amount of delay to the users is much better than not providing service at all. The simulation results for the Call Blocking Probability (CBP) of different user classes are presented.

Keywords
Call Admission Control, Quality of Service, Next Generation Wireless Networks, User Class, Partitioning, Queuing, Call Blocking Probability.

1. INTRODUCTION
The NGWN are envisioned to be heterogeneous in nature and introduction of QoS to this heterogeneous network environment is a challenging problem. The NGWN 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]. Users act independently and unknowingly on the services provided by the network without considering the current network traffic conditions. Hence, system overload situations are unavoidable. In NGWN the situation will become worse as users are allowed to use more bandwidth and transmit large volumes of data. 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 [2]. CAC directly controls the number of users in the system [3]. CAC plays a significant role in providing the desired QoS in NGWN. CAC is one of the Radio Resource Management (RRM) techniques that plays influential role in ensuring the desired QoS to the users and applications in NGWN [4, 5]. 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. Network's QoS includes packet level QoS and connection level QoS [6]. Packet level QoS is measured in terms of delay, jitter or loss rate. Connection level QoS is measured in terms of CBP, call dropping probability and call rejection percentage. In this paper we focus on connection level QoS and consider CBP as an appropriate parameter.

The paper proposes a channel partitioning with queuing model for CAC in NGWN by considering the varying QoS needs of users and is organized as follows. In Section 2, the details of channel partitioning with queuing system model is presented. The expressions for CBP of different user classes for infinite and finite queue sizes are derived in Section 3 and Section 4 respectively. The simulation results are presented in Section 5. The paper concludes with Section 6.

2. CHANNEL PARTITIONING WITH QUEUING 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 next is ClassG. 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 greater than P_2 and P_2 is 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 and queuing 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 admits the user call request only if there are free channels available for that particular user class else the user call requests is queued. The admission controller does this process without disturbing the QoS of the existing user calls in the system. The main idea in this model is to minimize the denial of service at any point of time. Delaying the service by a small time is considered better than not providing service at all. 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 class is not empty then the released channel is assigned to the user call in front of the queue. 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.

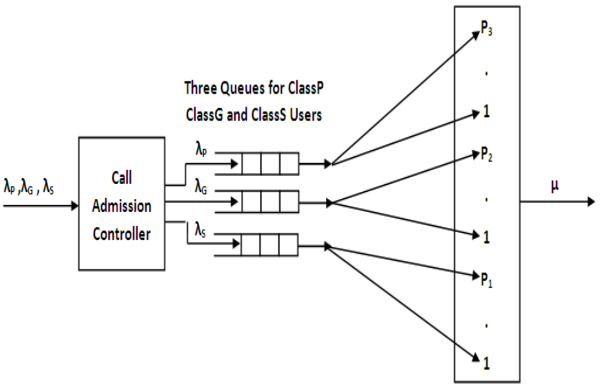

Figure 1: Channel Partitioning with Queuing System Model for User Class based CAC

3. ANALYSIS OF CBP FOR INFINITE QUEUE SIZE

Assuming the queue size to be infinite 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.

The state balance equations for Figure 2 are

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

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

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

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

$\lambda_S P(\mathrm{P}_1 - 1) = \mathrm{P}_1 \mu P(\mathrm{P}_1)$

$\lambda_S P(\mathrm{P}_1) = \mathrm{P}_1 \mu P(\mathrm{P}_1 + 1)$

$\lambda_S P(\mathrm{P}_1 + 1) = \mathrm{P}_1 \mu P(\mathrm{P}_1 + 2)$

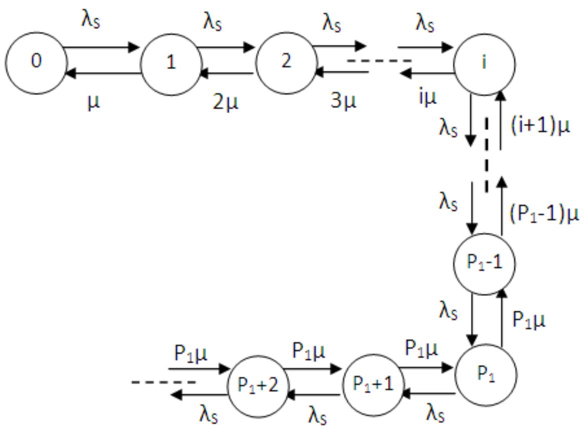

Figure 2: Markov Model for Silver Class Users of the System with Infinite Queue Size

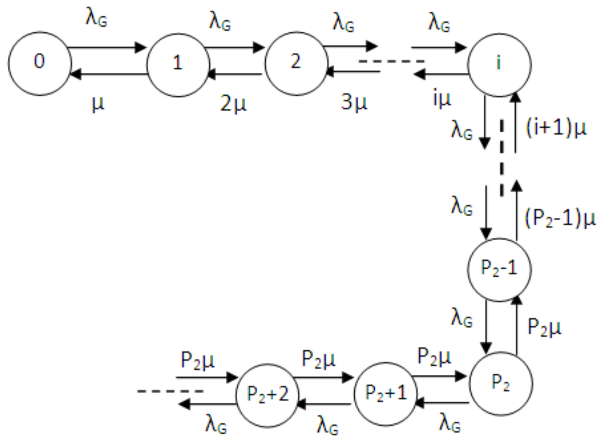

Figure 3: Markov Model for Gold Class Users of the System with Infinite Queue Size

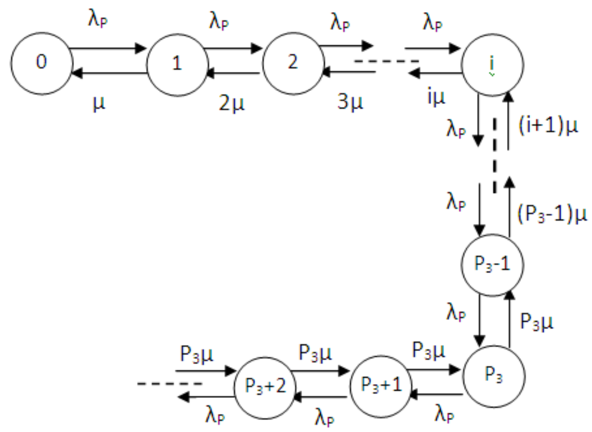

Figure 4: Markov Model for Platinum Class Users of the System with Infinite Queue Size

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

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

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

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

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

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

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

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

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

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

$$P(i)=\begin{cases}\frac{1}{i!}\left(\frac{\lambda_S}{\mu}\right)^i P(0) & i<P_1\\ \frac{i}{P_1!P_1^{i-P_1}}\left(\frac{\lambda_S}{\mu}\right)^i P(0) & i\geq P_1\end{cases} \quad (1)$$

With the normalization constraint we have,

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

$$P(0)=\left[\sum_{k=0}^{P_1-1}\frac{(P_1\rho)^k}{k!}+\frac{(P_1\rho)^{P_1}}{P_1!}\frac{1}{1-\rho}\right]^{-1} \quad (2)$$

Where $\rho=\frac{\lambda_S}{P_1\mu}$

The probability that a call of silver user class will be blocked denoted by $B_{S\infty}$ is written using the ErlangC formula

$$B_{S\infty}=\sum_{k=P_1}^{\infty}P(k)=\frac{P(P_1)}{1-\rho}$$

$$=\frac{(P_1\rho)^{P_1}}{P_1!(1-\rho)}*\frac{1}{\sum_{k=0}^{P_1-1}\frac{(P_1\rho)^k}{k!}+\frac{(P_1\rho)^{P_1}}{P_1!}\frac{1}{1-\rho}} \quad (3)$$

Similarly from Figure 3 and Figure 4, the CBP of gold and platinum user class denoted by $B_{G\infty}$ and $B_{P\infty}$ can be written as

$$B_{G\infty}=\sum_{k=P_2}^{\infty}P(k)=\frac{P(P_2)}{1-\rho}$$

$$=\frac{(P_2\rho)^{P_2}}{P_2!(1-\rho)}*\frac{1}{\sum_{k=0}^{P_2-1}\frac{(P_2\rho)^k}{k!}+\frac{(P_2\rho)^{P_2}}{P_2!}\frac{1}{1-\rho}} \quad (5)$$

Where $\rho=\frac{\lambda_G}{P_2\mu}$

$$B_{P\infty}=\sum_{k=P_3}^{\infty}P(k)=\frac{P(P_3)}{1-\rho}$$

$$=\frac{(P_3\rho)^{P_3}}{P_3!(1-\rho)}*\frac{1}{\sum_{k=0}^{P_3-1}\frac{(P_3\rho)^k}{k!}+\frac{(P_3\rho)^{P_3}}{P_3!}\frac{1}{1-\rho}} \quad (6)$$

Where $\rho=\frac{\lambda_P}{P_3\mu}$

4. ANALYSIS OF CBP FOR FINITE QUEUE SIZE

Assuming the queue size to be finite Q_S, Q_G and Q_P for ClassS, ClassG and ClassP users respectively, 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 5, Figure 6 and Figure 7.

The state balance equations for Figure 5 are

$$\lambda_S P(0)=\mu P(1)$$
$$\lambda_S P(1)=2\mu P(2)$$
$$\lambda_S P(i-1)=i\mu P(i)$$
$$\lambda_S P(i)=(i+1)\mu P(i+1)$$
$$\lambda_S P(P_1-1)=P_1\mu P(P_1)$$
$$\lambda_S P(P_1)=P_1\mu P(P_1+1)$$
$$\lambda_S P(P_1+Q_S-1)=P_1\mu P(P_1+Q_S)$$

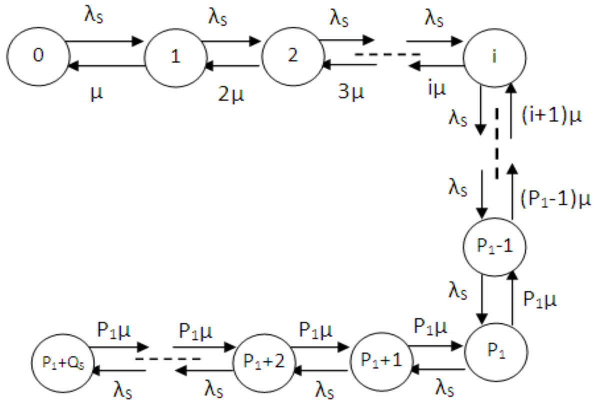

Figure 5: Markov Model for Silver Class Users of the System with Finite Queue Size

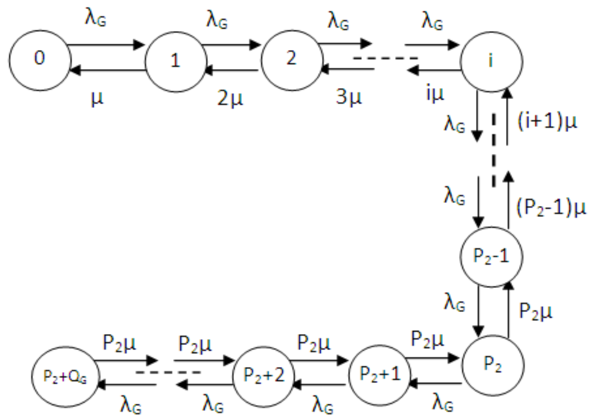

Figure 6: Markov Model for Gold Class Users of the System with Finite Queue Size

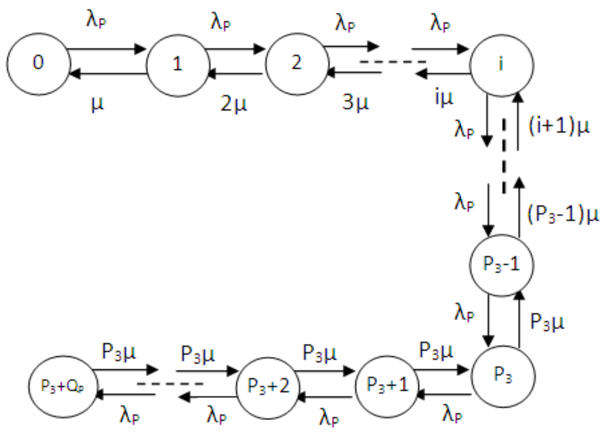

Figure 7: Markov Model for Platinum Class Users of the System with Finite Queue Size

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

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

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

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

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

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

$$P(P_1+1) = \frac{1}{P_1}\left(\frac{\lambda_S}{\mu}\right) P(P_1) = \frac{1}{P_1}\frac{1}{P_1!}\left(\frac{\lambda_S}{\mu}\right)^{P_1+1} P(0)$$

$$P(P_1+2) = \frac{1}{P_1}\left(\frac{\lambda_S}{\mu}\right) P(P_1+1) = \frac{1}{(P_1)^2}\frac{1}{P_1!}\left(\frac{\lambda_S}{\mu}\right)^{P_1+2} P(0)$$

$$P(P_1+Q_S) = \frac{1}{P_1}\left(\frac{\lambda_S}{\mu}\right) P(P_1+Q_S-1) = \frac{1}{(P_1)^{Q_S}}\frac{1}{P_1!}\left(\frac{\lambda_S}{\mu}\right)^{P_1+Q_S} P(0)$$

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

$$P(i) = \begin{cases} \frac{1}{i!}\left(\frac{\lambda_S}{\mu}\right)^i P(0) & i < P_1 \\ \frac{i}{P_1! P_1^{\,i-P_1}}\left(\frac{\lambda_S}{\mu}\right)^i P(0) & P_1 \le i \le P_1+Q_S \end{cases} \quad (7)$$

With the normalization constraint we have,

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

$$P(0) = \left[\sum_{k=0}^{P_1-1}\frac{(P_1\rho)^k}{k!} + \frac{(P_1\rho)^{P_1}}{P_1!}\left(\frac{1-\rho^{Q_S+1}}{1-\rho}\right)\right]^{-1} \quad (8)$$

Where $\rho = \frac{\lambda_S}{P_1\mu}$

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

$$B_S = \frac{(P_1\rho)^{P_1}\rho^{Q_S}}{P_1!} * \frac{1}{\sum_{k=0}^{P_1-1}\frac{(P_1\rho)^k}{k!} + \frac{(P_1\rho)^{P_1}}{P_1!}\left(\frac{1-\rho^{Q_S+1}}{1-\rho}\right)} \quad (9)$$

Similarly from Figure 6 and Figure 7, the CBP of gold and platinum user class denoted by B_G and B_P can be written as

$$B_G = \frac{(P_2\rho)^{P_2}\rho^{Q_G}}{P_2!} * \frac{1}{\sum_{k=0}^{P_2-1}\frac{(P_2\rho)^k}{k!} + \frac{(P_2\rho)^{P_2}}{P_2!}\left(\frac{1-\rho^{Q_G+1}}{1-\rho}\right)} \quad (10)$$

Where $\rho = \frac{\lambda_G}{P_2\mu}$

$$B_P = \frac{(P_3\rho)^{P_3}\rho^{Q_P}}{P_3!} * \frac{1}{\sum_{k=0}^{P_3-1}\frac{(P_3\rho)^k}{k!} + \frac{(P_3\rho)^{P_1}}{P_3!}\left(\frac{1-\rho^{Q_P+1}}{1-\rho}\right)} \quad (11)$$

Where $\rho = \frac{\lambda_P}{P_3\mu}$

5. SIMULATION RESULTS

The channel partitioning model is simulated using matlab. Simulation study is carried out by assuming that the total number of virtual channels available in the system is 30 which are partitioned into three disjoint classes in the ratio of 1:2:3. With this partitioning ClassS users have access to 5 channels, ClassG users have access to 10 channels and high priority ClassP users have access to 15 channels i.e. $P_1=5$, $P_2=10$ and $P_3=15$. 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 $\lambda/P_1\mu$ for ClassS users, $\lambda/P_2\mu$ for ClassG users and $\lambda/P_3\mu$ for ClassP users.

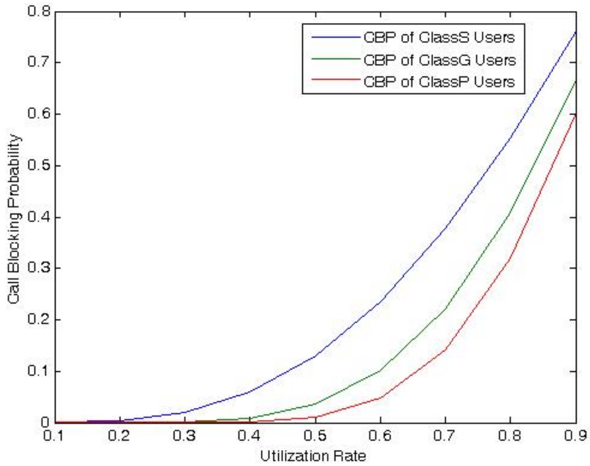

Figure 8: Utilization Rate VS CBP for all classes of users with Infinite Queue Size

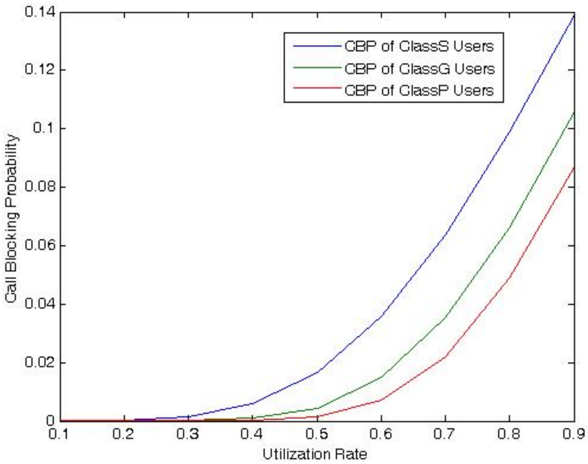

Figure 9: Utilization Rate VS CBP for all classes of users with Queue Size = 2

The simulations were carried out by varying the utilization rate for all classes of users under three scenarios. In the first scenario the queue size was assumed to be infinite and Figure 8 is the graph of utilization rate versus CBP for all the three classes of users. In the second scenario the queue size was assume to be finite and equal to 2 for all the three classes and Figure 9 is the graph of utilization rate versus CBP for all the three classes of users. The graphs of both Figure 8 and Figure 9 clearly indicate that as the utilization rate increases the CBP also increases for all the three class of users. Also the CBP of high priority user class is very low when compared to that of low priority user classes. In the third scenario for each class of users the queue size was varied along with the utilization rate. Figure 10, Figure 11 and Figure 12 are the graphs of utilization rate versus CBP for ClassS, ClassG and ClassP users respectively. These graphs clearly indicate that as the queue size is increased the CBP gets lower for all the three classes of users.

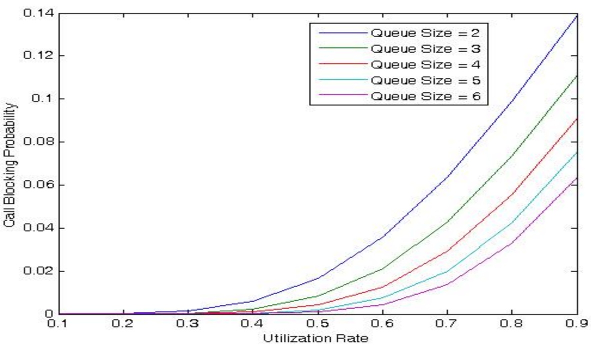

Figure 10: Utilization Rate VS CBP for ClassS users with different Queue Size

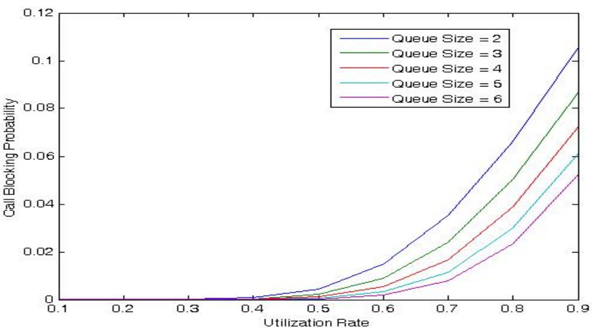

Figure 11: Utilization Rate VS CBP for ClassG users with different Queue Size

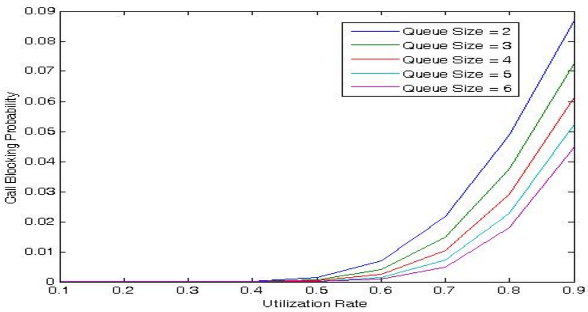

Figure 12: Utilization Rate VS CBP for ClassP users with different Queue Size

6. CONCLUSION

In this paper, we have proposed channel partitioning with queuing model for user class based CAC in NGWN. Equations for CBP are derived for all class of users. Equations (3) to (6) represent the CBP of ClassS, ClassG and ClassP users respectively for infinite queue size. Equations (9) to (11) represent the CBP of ClassS, ClassG and ClassP users respectively for finite queue size. The simulation results are optimistic and clearly indicate that high priority user classes have very low CBP when compared to low priority user classes in both cases of finite and infinite queue size. From the users point of view the proposed model brings more delightness to users as they can choose their class based on their QoS requirements. Finally from the point of network service providers the proposed model is expected to bring more revenue by having more number of users along with guaranteeing the agreed upon QoS to its users.

7. REFERENCES

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8. AUTHORS PROFILE

Mahesh G received Bachelor of Engineering degree in Computer Science and Engineering and, MTech in Computer Science and Engineering from Visvesvaraya Technological University, Belgaum and pursuing Doctoral degree in Visvesvaraya Technological University, Belgaum. He is currently working with Information Science and Engineering department, Acharya Institute of Technology, Bangalore – 560090, Karnataka, INDIA.

Dr. Gowrishankar received Bachelor of Engineering degree in Computer Science and Engineering from Mysore University, ME in Computer Science and Engineering from Visvesvaraya Technological University, Belgaum and PhD from Visvesvaraya Technological University, Belgaum. He is currently working with Computer Science and Engineering department, B.M. Sreenivasaiah College of Engineering, Bangalore – 560019, Karnataka, INDIA.

Dr. RameshBabu H S received Bachelor of Engineering degree in Computer Science and Engineering from Bangalore University, MS in Software Systems from BITS Pilani, and PhD from Visvesvaraya Technological University, Belgaum. He is currently working with Information Science and Engineering department, Acharya Institute of Technology, Bangalore– 560090, Karnataka, INDIA.