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A PRIORITIZATION SCHEME FOR INTEGRATED VOICE/DATA TRAFFIC FOR PREEMPTIVE HANDOFF CALLS IN CELLULAR MOBILE NETWORKS

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ABSTRACT*:* Call admission control is a key element in the provision of guaranteed quality of service in wireless networks. In this paper, we proposed a call admission control (CAC) scheme that deals with two types of traffic classes: voice and data respectively. These traffic classes are further divided into new/handoff voice calls and data calls. A call admission control scheme for wireless mobile communication networks is presented that works on threshold based guard channel technique. The proposed scheme assumes two different threshold values one for data calls and another one for new voice calls with a finite capacity buffer used to store data calls when the number of busy channels reaches at a certain threshold for data calls and block new voice calls when the number of busy channels reaches at another threshold for new voice calls, the rest of the channels will be available for handoff calls only. Pre-emptive technique is used to admit handoff calls when free channels are not available. This technique will significantly decrease the handoff call blocking probability. We propose an analytical model to calculate the key performance measures, and thoroughly investigate the system performance under a variety of system parameters.

Keywords: Call Admission Control, Threshold, QoS, Buffer, Pre-emptive.

1. Introduction

Mobile wireless communications is, by any measure, the fastest growing segment of the communications industry. As such, it has captured the attention of the media and the imagination of the public. Based on cellular systems mobile wireless communication networks have experienced exponential growth over the last decade and there are currently about two billion users worldwide. Indeed, mobile phones have become a critical business tool and part of everyday life in most developed countries, and they are rapidly supplanting antiquated wired systems in many developing countries. The explosive growth of mobile wireless communication networks coupled with the proliferation of laptop and palmtop computers suggests a bright future for mobile wireless communication networks, both as stand-alone systems and as part of the larger networking infrastructure. However, many technical challenges remain in designing robust wireless networks that deliver the performance necessary to support various types of traffics.

One of the main issues in wireless mobile communication networks is the implementation of call admission control. Call Admission Control is defined by a set of actions to determine if the incoming call request can be accepted or rejected. Based on the call admission control scheme's mechanism, the condition for accepting an incoming call request is depends on the availability of sufficient resources to guarantee the Quality of Service (QoS) without affecting the existing calls. In a wireless mobile network, based on cellular architecture, the main cell level QoS parameters are: new call blocking and handoff call dropping. As the dropping of on-going calls are less desirable than the blocking of new incoming calls, therefore a good CAC scheme has to balance the call blocking and call dropping in order to provide a desired QoS requirement.

Many call admission control schemes were developed by researchers in the past. Guerin [1] presented that the guard channel schemes proves effective for providing the necessary QoS guarantee in terms of both call termination and call blocking probabilities. A threshold based guard channel policy for single traffic type illustrated by Ramjee et al. [2]. In this policy, three methods are described to optimize a linear objective function of the new and handoff call blocking probability. The policy allocates some guard channels only for handoff calls, new calls are blocked when the number of busy channels exceeds a given threshold. The number of guard channels depends on the required values of the new and handoff call blocking probabilities. Haung et al. [3] proposed an analytical model to investigate the performance of an integrated voice/data mobile network with finite data buffer in terms of voice-call blocking probability, data loss probability, and mean data delay. The model is based on the movable-boundary scheme that dynamically adjusts the number of channels for voice and data traffic. With the movable boundary scheme, the bandwidth can be utilized efficiently while satisfying the QoS requirements for voice and data traffic. Fang and Zhang [4] investigate the call admission control strategies for the wireless networks, when average channel holding times for new calls and handoff calls are significantly different, the traditional one-dimensional Markov chain model may not be suitable; two-dimensional Markov chain theory must be applied. They also proposed a new approximation approach to reduce the computational complexity and performed much better than the traditional approach. Zaim [5] derives a Markov Model to calculate new call and hand-off call blocking probabilities in LEO satellite networks carrying voice calls. The model is used to define blocking conditions for new and hand-off calls. The satellite constellation is treated as a group of M/M/K/K queues affecting each other with a set of constraints. Wang et al. [6] propose a new CAC scheme for a code division multiple access (CDMA) wireless cellular network supporting heterogeneous self-similar data traffic. In addition to ensuring transmission accuracy at the bit level, the CAC scheme guarantees service requirements at both the call level and the packet level. Mahmoud and Al Qahtani [7] studied the performance analysis of call admission control (CAC) schemes in multi-traffic mobile wireless networks. Different schemes have been analysed under different configurations. Madan et al. [8] proposed a new handoff technique by combining the MAHO and GC techniques. In the proposed technique, the MT reports back not only the RSSI and the BER but the number of free channels that are available for the handoff traffic as well. This will ensure that a handed-off call has acceptable signal quality as well as a free available channel. A queuing analytical framework for these admission control schemes is presented by Bouchti et al. [9] considering OFDMA-based transmission at the physical layer. Then, based on the queuing model, both the connection-level and the packet-level performances are studied and compared with their analogues in the case without CAC. The connection arrival is modelled by a Poisson process and the packet arrival for a connection by a Markov Modulated Poisson Process (MMPP).Call Admission Control (CAC) schemes viz., throughput (TP) based CAC and dynamic partitioning (DP) CAC with service differentiation for WLAN coupled to 3G networks have been analyzed by Kokila et al. [10].

In this paper, we propose a dual threshold guard channel based call admission control scheme to deal with two types of traffic classes, voice and data, which is further subdivided into following three categories:

- data calls(new/handoff)
- new voice calls
- handoff voice calls

The threshold is applied for the distinct type of input traffic to achieve high quality of service. As the data calls are delay insensitive, we add the capability of buffering the data calls when the number of occupied channels reaches at a certain threshold T_1. The new voice calls can be accepted until the number of occupied channels reaches at another thresholdT_2andrest of the free channels are available for handoff calls. The handoff voice calls has given priority over new voice calls and data calls as handoff calls are more sensitive. The performance of the call admission control scheme is analysed by applying pre-emption technique for prioritization of handoff calls over data calls and new voice calls respectively. The CAC scheme performance is evaluated on the following QoS metrics:

- Blocking probability of data calls

- Blocking probability of new voice calls
- Dropping probability of handoff voice calls

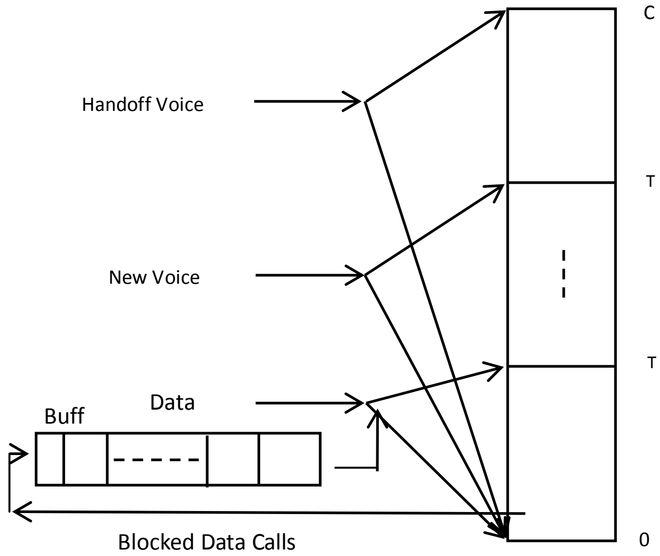

Figure 1: System Model of the Proposed CAC Scheme

The rest of the paper is organized as follows. In section-2 the proposed call admission control scheme is described using the system model, CAC algorithm and System flowchart. In section-3 an analytical model of the proposed CAC is presented.

Numerical results and performance analysis of algorithm is presented in Section-4. Section-5summarizes the inferences arrived from the analytical results in conclusion.

2. *Call Admission Control Scheme*

A good Call admission control scheme should provide different QoS guaranteed for different traffic types, while at the same time fully utilize the resources available in the wireless mobile communication networks. In the proposed call admission control scheme, a cell can have maximum number of C channels. Two threshold values T_1 and T_2 divided these C channels into three distinct regions as shown in figure 1. All types of traffic i.e. data calls, new voice calls and handoff voice calls are accepted when the number of occupied channels are less than T_1. When the number of occupied channels reaches over threshold T_1, a buffer of the finite capacity Kis used to store data calls until half of the buffer capacity is occupied, otherwise data calls will be blocked, the rest of the buffer capacity is used later. The new voice calls will be accepted until the number of occupied channels reaches another threshold T_2. However, handoff voice call will be admitted according to the following conditions:

- If the number of busy channels is less than total number of channels available.
- If all the channels are busy and some channels are occupied by ongoing data calls then any one of the ongoing data calls is added to the buffer, if the buffer is not completely full and the released channel will be assigned to handoff voice call, otherwise, the handoff voice call will be dropped. This method is known as preemptive method.
- If there is no ongoing data calls available then handoff voice call will be dropped.

In this admission control scheme, the handoff voice calls gets highest priority over new voice calls and data calls, while the data calls receives the lowest as the data traffic can tolerate certain degree of delay, while voice calls cannot. On the other hand, the buffering of data requests can lead to a relative data blocking probability. The algorithm of the proposed CAC is given below:

Algorithm:

Vol.2 Issue.2, Pg.: 142-152
February 2014

```
INCALL = new incoming call
if (INCALL = Data_Call)
{
        if (number of busy channels < T1)
        {
                admit INCALL;
        }
        else
        {
                if (number of calls in buffer < K/2)
                {
                        add INCALL to buffer;
                }

                else
                {
                        block the INCALL;
                }
        }
}
else if (INCALL = New_Voice_Call)
{
        if (number of busy channels < T2)
        {
                admit INCALL;
        }
        else
        {
                block the INCALL;
        }
}
else if (INCALL = Handoff_Voice_Call)
{
        if (number of busy channels < C)
        {
                admit INCALL;
        }
        else
        {
                if (there is any ongoing Data_Call)
                {
                if (number of calls in buffer < K)
                {
                        released the channel from ongoing Data_Call and assign that channel to
                INCALL;addData_Call to buffer;
                }
                else
                {
                        drop the INCALL;
                }
                }
                else
                {
                        drop the INCALL;
                }
        }
```

}

The system flowchart is shown in figure 2.

1. Analytical Model

In this paper, we consider a homogeneous wireless network where all the cells have same number of channels and the arrival rate is same for all types of calls. The arrival of data calls, new voice calls and handoff voice calls follows the Poisson distribution with the arrival rate of λ_d, λ_{nv}, and λ_{hv} respectively. Here, the new data calls and handoff data calls are not distinguished as data calls can tolerate some degree of service degradation. Therefore, the total arrival rate of data call is denoted by λ_d and the total arrival rate of voice calls is $\lambda_v = \lambda_{nv} + \lambda_{hv}$. The call duration times or call holding times of all types of calls are exponentially distributed with the average call duration times for data calls, new voice calls and handoff calls is denoted by $\frac{1}{\mu_d}$, $\frac{1}{\mu_{nv}}$, and $\frac{1}{\mu_{hv}}$ respectively. The total average call duration time for voice calls and data calls is given by $\frac{1}{\mu_v} = \frac{1}{\mu_{nv} + \mu_{hv}}$ and $\frac{1}{\mu_d}$ respectively. The traffic intensity of data calls, new voice calls and handoff calls is given by $\rho_d = \frac{1}{\mu_d}$, $\rho_{nv} = \frac{1}{\mu_{nv}}$, and $\rho_{hv} = \frac{1}{\mu_{hv}}$ respectively. From the literature it has been observed that, as the traffic intensity of particular type of call increases the blocking probability of that type of calls is also increases. We also assume that the service time for all types of calls is normalized to unity, as there is no effect of this normalizing process on traffic intensity.

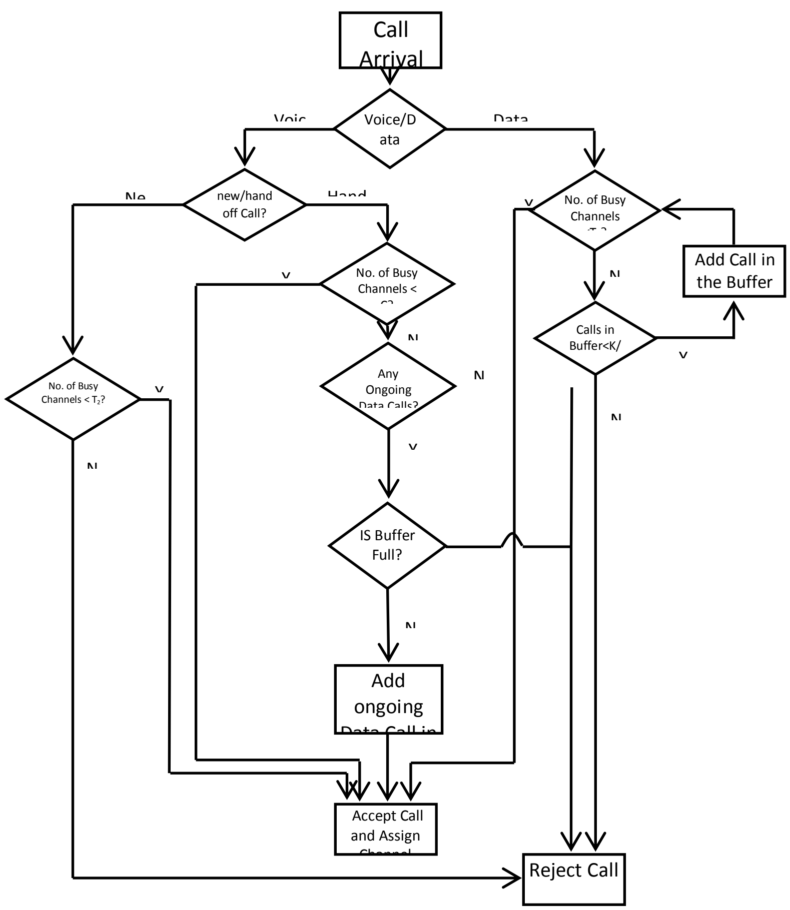

Figure-2: System Flow Chart

Vol.2 Issue.2, Pg.: 142-152
February 2014

In this paper, the proposed call admission control scheme can be modeled as the three dimensional Markov chain. Let $P_{i,j,k}$ be the steady state probability that there are i voice calls, j data calls in the system, and k data calls in the buffer. The maximum capacity of the buffer is K. The steady-state balance equation of the proposed CAC is given below.

Case 1: If $i + j = 0$, then

$$(\lambda_v + \lambda_d)P_{0,0,0} = \mu_v P_{1,0,0} + \mu_d P_{0,1,0}.$$

……………….(1)

Case 2: If $0 < i + j < T_1$, then

$$(\lambda_v + \lambda_d + i\mu_v + j\mu_d)P_{i,j,k} = (i+1)\mu_v P_{i+1,j,0} + (j+1)\mu_d P_{i,j+1,0} + \lambda_v P_{i-1,j,0} + \lambda_d P_{i,j-1,0}$$

……………… (2)

Case 3: If $i + j = T_1$ and $k = 0$, then

$$(\lambda_v + \lambda_d + i\mu_v + j\mu_d)P_{i,j,0} = (i+1)\mu_v P_{i+1,j-1,1} + (j+1)\mu_d P_{i,j+1,0} + (i+1)\mu_v P_{i+1,j,0} + j\mu_d P_{i,j,1} + \lambda_v P_{i-1,j,0} + \lambda_d P_{i,j-1,0}$$

(3)

Case 4: If $i + j = T_1$ and $0 < k < K/2$, then

$$(\lambda_v + \lambda_d + i\mu_v + j\mu_d)P_{i,j,k} = (i+1)\mu_v P_{i+1,j-1,k+1} + (j+1)\mu_d P_{i,j+1,k} + (i+1)\mu_v P_{i+1,j,k} + j\mu_d P_{i,j,k+1} + \lambda_v P_{i-1,j,k} + \lambda_d P_{i,j-1,k}$$

…………….. (4)

Case 5: If $i + j = T_1$ and $k = K/2$, then

$$(\lambda_v + \lambda_d + i\mu_v + j\mu_d)P_{i,j,K/2} = (i+1)\mu_v P_{i+1,j-1,k} + (j+1)\mu_d P_{i,j+1,k} + (i+1)\mu_v P_{i+1,j,k} + j\mu_d P_{i,j,k+1} + \lambda_v P_{i-1,j,k} + \lambda_d P_{i,j-1,k}$$

………….. (5)

Case 6: If $T_1 < i + j < T_2$, then

$$(\lambda_v + \lambda_d + i\mu_v + j\mu_d)P_{i,j,k} = (i+1)\mu_v P_{i+1,j-1,k} + (j+1)\mu_d P_{i,j+1,k} + \lambda_v P_{i-1,j,k} + \lambda_d P_{i,j,k-1}$$

………….. (6)

Case 7: If $i + j = T_2$, then

Vol.2 Issue.2, Pg.: 142-152
February 2014

$$(\lambda_{hv} + \lambda_d + i\mu_v + j\mu_d)P_{i,j,k} = (i+1)\mu_v P_{i+1,j,k} + (j+1)\mu_d P_{i,j+1,k} + \lambda_v P_{i-1,j,k} + \lambda_d P_{i,j,k-1}$$

………….. (7)

Case 8: If $T_2 < i + j < C$, then

$$(\lambda_{hv} + \lambda_d + i\mu_v + j\mu_d)P_{i,j,k} = (i+1)\mu_v P_{i+1,j,k} + (j+1)\mu_d P_{i,j+1,k} + \lambda_{hv} P_{i-1,j,k} + \lambda_d P_{i,j-1,k}$$

………….. (8)

Case 9: If $i + j = C$ and $k = K/2$, then

$$(\lambda_{hv} + \lambda_d + i\mu_v + j\mu_d)P_{i,j,K/2} = (i+1)\mu_v P_{i+1,j-1,k} + (j+1)\mu_d P_{i,j+1,k} + (i+1)\mu_v P_{i+1,j,k} + j\mu_d P_{i,j,k+1} + \lambda_{hv} P_{i-1,j,k} + \lambda_d P_{i,j-1,k}$$

………….. (9)

Case 10: If $i + j = C$ and $K/2 < k < K$, then

$$(\lambda_{hv} + \lambda_d + i\mu_v + j\mu_d)P_{i,j,k} = (i+1)\mu_v P_{i+1,j-1,k+1} + (j+1)\mu_d P_{i,j+1,k} + (i+1)\mu_v P_{i+1,j,k} + j\mu_d P_{i,j,k+1} + \lambda_{hv} P_{i-1,j,k} + \lambda_d P_{i,j-1,k}$$

………….. (10)

Case 11: If $i = C,\ j = 0$ and $k = K$, then

$$(\lambda_{hv} + i\mu_v + j\mu_d)P_{i,j,k} = \lambda_{hv} P_{i-1,j,k} + \lambda_d P_{i,j,k-1}$$

………….. (11)

After obtaining the steady state transition equations for each state in the Markov chain, we can solve the linear equation together with the normalizing condition in equation (12) by using LU factorization.

$$\sum_{i+j\geq 0}^{C} \sum_{k\geq 0}^{K} P_{i,j,k} = 1 \quad \text{……….. (12)}$$

After obtaining all the steady state probabilities $P_{i,j,k}$, the data call blocking probability P_{db}, the new voice call blocking probability P_{nvb}, the handoff call blocking probability P_{hvd} and the average buffer capacity $\bar{B}$ can be derived as below:

$$P_{db} = \sum_{i+j\geq T_1}^{C} \sum_{k\geq 0}^{K/2} P_{i,j,k} \quad \text{……….. (13)}$$

$$P_{nvb} = \sum_{i+j\geq T_2}^{C} \sum_{k\geq 0}^{K/2} P_{i,j,k} \quad \text{……….. (14)}$$

$$P_{hvd} = \sum_{i+j=C} \sum_{k\geq 0}^{K} P_{i,j,k} \quad \text{……….. (15)}$$

$$\bar{B} = \sum_{i+j\geq T_1}^{C} \sum_{k=K} k P_{i,j,k} \quad \text{……….. (16)}$$

Vol.2 Issue.2, Pg.: 142-152
February 2014

1. Numerical Results and Discussion

In this section the numerical results is demonstrated the performance of call admission control scheme for different values of voice call arrival rate λ_v, and data call arrival rate λ_d. The accuracy of our analysis is checked using an event driven simulation. The following system characteristics are assumed. The total number of channels C in a cell is set to be 50, the voice call arrival rate $\lambda_v$can range from 0.05 to 0.30, the data call arrival rate $\lambda_d$can be range from 0.02 to 0.09, while the average call duration times are set for data calls$\mu_d = 0.0001$, new voice calls $\mu_v = 0.001$, and handoff calls $\mu_{hv} = 0.01$.

Performance of the call admission control scheme under different voice call arrival rates are shown in the figures 3 to 5. For different values of arrival rate of voice callsλ_v=0.05 to 0.30, we assume that$T_1 = 20$, $T_2 = 35$, $\lambda_d = 0.03$ and buffer capacity varies from K=2 to 20. Figure-3 show that the handoff voice call dropping probability $P_{hvd}$is affected by the pre-emptive technique as it depends on the buffer capacity. It is observed that as the arrival rate of voice calls increases the handoff voice call dropping probability increases slightly but as the buffer capacity increases there is a significant decrease in P_{hvd}.From the figure-4 it is clear that the new voice call blocking P_{nvb}increases with the increase in buffer capacity as new voice calls do not depends on the buffer capacity and it is observed that as the voice call arrival rate increases the new voice call blocking probability P_{nvb} is also increases. Observing the figure-5, it is clear that the as the buffer capacity increases the data calls blocking probability decreases since more data calls can be buffered and wait for service when the number of occupied channels is greater or equal to threshold T_1. It is also clear that with the increase in arrival rate of voice calls more data calls will be queued in the buffer and will enter the system for service immediately, if there is a channel becomes available.

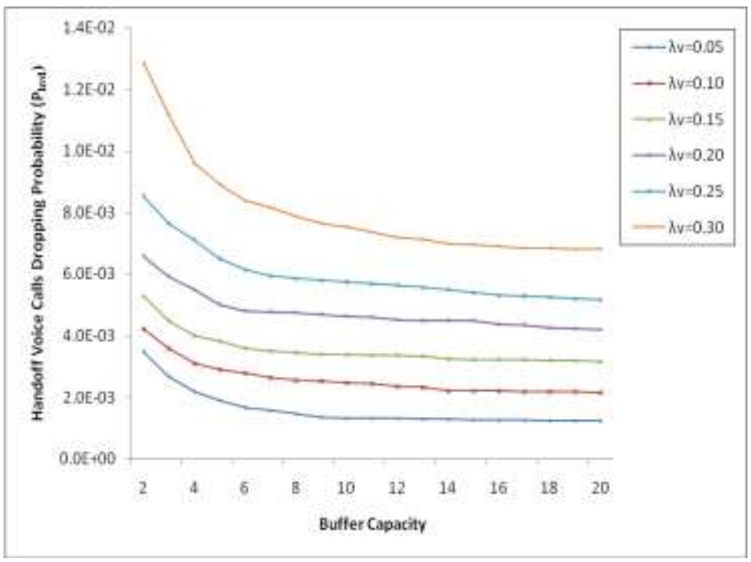

Figure-3: The handoff voice call dropping probability P_{hvd} for different values of λ_v

Vol.2 Issue.2, Pg.: 142-152
February 2014

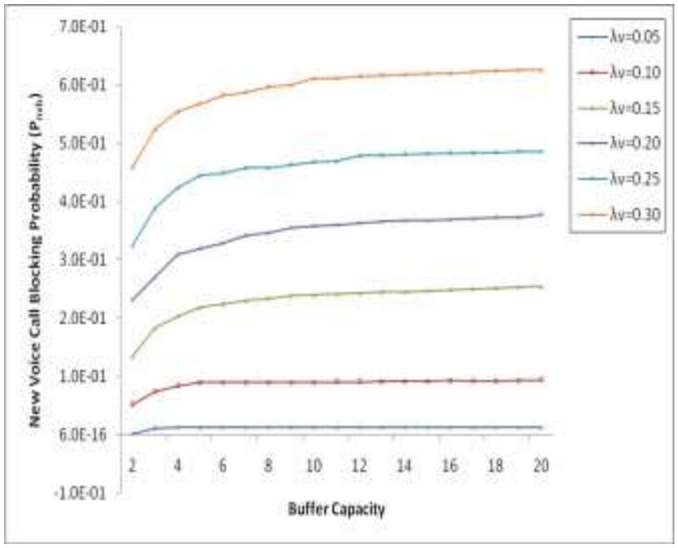

Figure-4: The new voice call blocking probability P_{nvb} for different values of λ_v

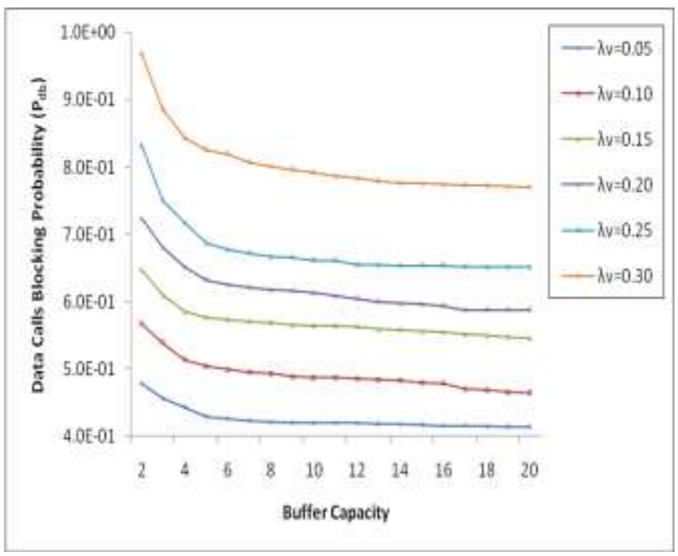

Figure-5: The data call blocking probability P_{db} for different values of λ_v

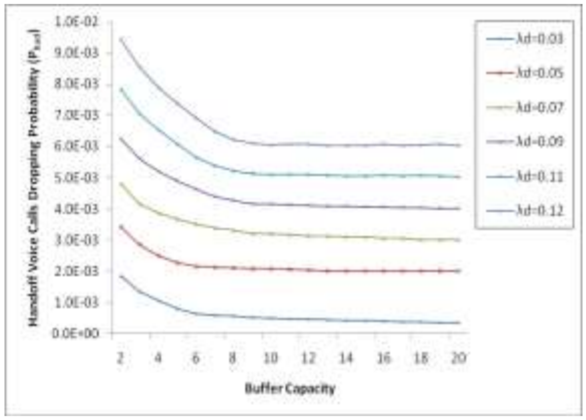

Figure-6: The handoff voice call dropping probability P_{hvd} for different values of λ_d

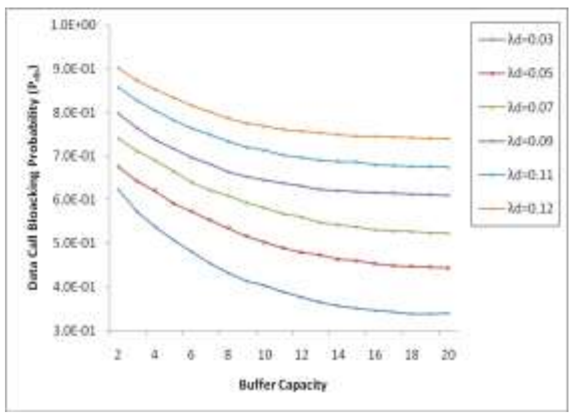

Figure-7: The data call blocking probability P_{db} for different values of λ_d

Performance of the proposed call admission control scheme under different data call arrival rates are shown in the figures 6 to 7. For different values of arrival rate of data calls λ_d=0.03 to 0.12, we assume that $T_1 = 20$, $T_2 = 35$, $\lambda_v = 0.05$ and buffer capacity varies from K=2 to 20. Figure-6 shows that the handoff voice call dropping probability P_{hvd} decreases with the increase of buffer capacity and data call arrival rate λ_d. This is because, the increase in data call arrival rate implies that there are significant number of channels will be occupied by the data calls and therefore more channels are available for the handoff voice calls to be pre-empted over the data calls, when all the channels in the cell will be busy. Similarly, as the buffer capacity increases, more space is available for on-going data calls to be buffered and release the occupied channel for the handoff voice calls and hence the handoff voice call dropping probability decreases. In figure-7 it is obvious that with the increase in buffer capacity and data call arrival rate λ_d the data call blocking probability P_{db} decreases significantly.

5, Conclusion

In this paper, we present a call admission control scheme that applies preemptive technique to prioritize handoff voice calls over new voice calls and data calls in a wireless mobile communication network. The performance of CAC scheme is analyzed with three dimensional Markov process, and an event driven simulation is developed to validate the accuracy of our analysis. From the results obtained from the analysis, we observe that the proposed

CAC scheme provide a better QoS for different traffic types. The buffering of data calls benefits the data users and data call blocking probability decreases with the increase in buffer capacity. Preemptive technique used in CAC decrease the handoff dropping probability significantly and guarantees the better QoS for handoff voice calls. However, proper selection of buffer capacity and threshold values in the proposed call admission control scheme may optimize the performance of the system and obtain good Quality of Service (QoS) for different types of traffics.

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