Call Admission Control Scheme based on Quality of Service (QoS)

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ABSTRACT: *The quality of service (QoS) of several real time multimedia applications has become a crucial research topic. One of the challenges to achieve QoS requirements is to determine how to allocate system bandwidth to various applications with the respect of their QoS requirements. In this paper, we proposed a Call Admission Control scheme based on QoS requirements of different traffic types in mobile WiMAX. Our proposed admission control scheme is suitable for real time applications as it gives more priority to real time service classes. Numerical results show that the proposed CAC scheme could be the better choice for admission control in terms of call blocking probability of the connections and bandwidth utilization of the system.*

Keywords: IEEE 802.16; QoS; Admission control, Bandwidth request, Bandwidth allocation

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1. Introduction

In recent years, real time multimedia services become an important part of Internet traffic and require a guaranteed quality of services. The emerging Broadband Wireless Access (BWA) network is one of the most promising solutions for the last mile BWA to support high data rate, high mobility, and wide coverage at low cost. The most popular implementation of the IEEE 802.16 standard is the Mobile Wireless MAN originally defined by the 802.16e-2005 [1]; amendment that is now in process of being deployed around the world in more than 140 countries by more than 475 operators.

WiMAX is the next step in the mobile technology evolution path; it competes with IEEE 802.11-based WLAN technology, broadband residential Internet technologies such as digital subscriber line and cable and third generation cellular technologies. WiMAX offers numerous advantages, such as improved performance and robustness, end-to-end IP-based network, secure mobility, and broadband speeds for voice, data, and video.

When a subscriber station SS send a request to the base station (BS) with a certain QoS parameters for a new connection, the BS will check whether it can provide the required QoS for that connection. If the request was accepted, the BS verifies whether the QoS of all the ongoing connections can be maintained. Based on this it will take a decision on whether to accept or reject the connection. The process described above is called as CAC mechanism. Thus, CAC restricts the access to the network in order to prevent network congestion or service degradation for already accepted users. The most important concern for providing CAC in wireless networks is to guarantee QoS of connections.

Recent researches in QoS field aimed at providing new bandwidth allocation scheme and new admission control mechanisms. A dynamic bandwidth allocation algorithm called DBA was proposed in [3] and [9]. The scheme in [3] aims to minimize the average queuing delay. In [9], the CAC was proposed for the downlink stream. In [4], authors provided a performance analysis of three types of connections defined in IEEE 802.16 standard (UGS, rtPS and nrtPS). Different levels of priority and blocking probability were assigned to each class of service. An efficient uplink bandwidth request-allocation algorithm for real time services in mobile WiMAX was proposed in [5]. The proposed algorithm aimed to minimize bandwidth wastage without violating QoS requirements. In [6] an adaptive call admission control was proposed. This proposal aims to take advantage of the variability of traffics and to adapt the CAC according to the characteristics of incoming flows. This adaptive CAC was applied to the case of video traffics using measurements done by the BS to guess and classify flows according to the similarities in their behaviors and then adapt the system model parameters that will be used by the CAC. In [7], a dynamic call admission control scheme and bandwidth allocation algorithm was proposed for IEEE 802.16e mobile WiMAX. The relationship between the channel utilization, the dropping and blocking probability versus traffic loads are investigated. The proposed WiMAX scheme supports voice, data and multimedia services with differentiated QoS. In [8], a QoS-aware resource allocation scheme was proposed for IEEE 802.16 fixed WiMAX system operating in TDD mode. It focuses on the performance enhancement of resource allocation. An efficient CAC scheme for IEEE 802.16e Mobile WiMAX that satisfies both bandwidth and delay guarantee to the admitted connections was proposed in [10]. The proposed CAC scheme provides higher priority to Handoff connections. Another CAC for IEEE 802.16 was proposed in [11] considering QoS constraint. It accepts new request for some slot times temporary. In this algorithm, during certain time slots, departure rate for ongoing connections will be decreased and for new connection will increase. After this period, if QoS for ongoing connections and new request is satisfied, new request will be accepted permanently and otherwise it will be rejected.

In this paper, we propose a call admission control (CAC) scheme for mobile WiMAX network based on the service classes to support differentiated QoS requirement. CAC is one of the ways to guarantee QoS in WiMAX network. However, no specific admission control policy is standardized so that proprietary implementations may be used by equipment vendors.

The remainder of this paper is organized as follows: In section II, we introduce the basic features of WiMAX system based on its QoS architecture and the bandwidth allocation mechanism of IEEE 802.16 MAC layer. In section III, we propose an admission control scheme and a bandwidth allocation mechanism. In section IV, we describe the analytical model. We present the simulation results in section V. Finally, conclusion and future works are given in section VI.

2. Basic Features Of Wimax Network

2.1 QoS architecture of IEEE 802.16 networks

CAC is a key element in the provision of guaranteed QoS in IEEE 802.16 network. CAC is responsible of accepting or rejecting a connection depending on network available resources. A new connection request can be accepted if there are enough free resources to meet the QoS requirements of the new connection without violating the QoS constraints for existing connections. Thus, CAC restricts the access to the network in order to prevent network congestion or service degradation for already accepted users. It can prevent the system from being overloaded. CAC has been characterized as the decision maker for the network as is shown in figure1.

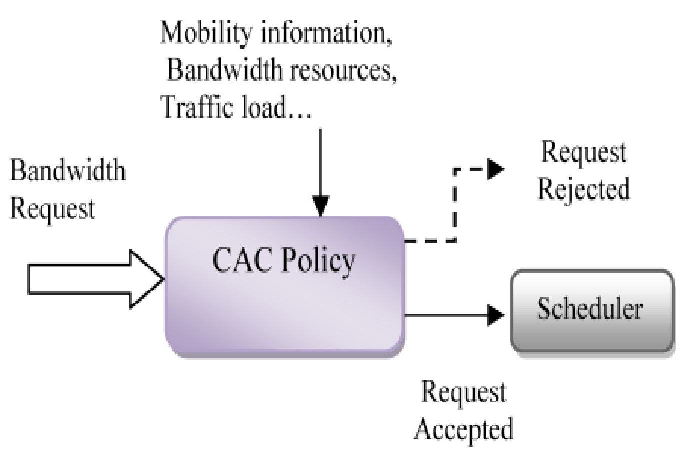

Figure 1. CAC policy process

In this paper, we only consider the PMP mode architecture of IEEE 802.16 BWA networks, where transmission only occurs between a base station (BS) and subscriber stations (SSs) and the BS controls all the communications between BS and SSs.

The connection can be either downlink (from BS to SS) or uplink (from SS to BS) as it is depicted in figure2. In PMP architecture, two modes are defined: Grant-Per-Connection (GPC) and Grant-Per-Subscriber-Station (GPSS). Under GPC, the CAC algorithm considers each individual connection arriving from an SS, while for GPSS each SS manages admission of its own individual connections before sending a single bandwidth (BW) request to the BS.

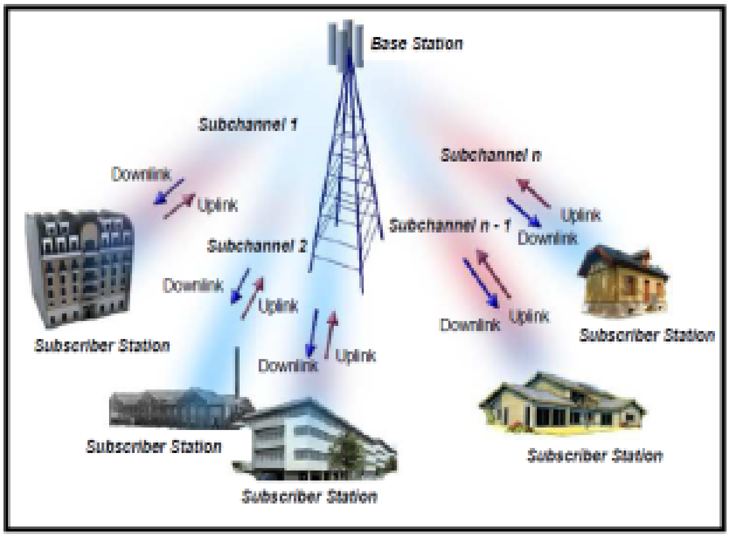

Figure 2. WiMAX PMP network

In order to meet the QoS requirements of multimedia applications, the IEEE 802.16-2004 standard specifies four different scheduling services. Scheduling services represent the data handling mechanisms supported by the MAC scheduler for data transport on a connection. Each connection is associated with a single data service. Each data service is associated with a set of QoS parameters that quantify aspects of its behaviour. These services are described as follows:

• UGS: The UGS is designed to support real-time service flows that generate fixed-size data packets on a periodic basis, such as T1/E1 and Voice over IP without silence suppression. The service offers fixed-size grants on a real-time periodic basis, which eliminate the overhead and latency of SS requests and assure that grants are available to meet the flow's real-time needs. The BS shall provide Data Grant Burst IEs to the SS at periodic intervals based upon the Maximum Sustained Traffic Rate of the service flow. The size of these grants shall be sufficient to hold the fixed-length data associated with the service flow (with associated generic MAC header and Grant management subheader) but may be larger at the discretion of the BS scheduler. In order for this service to work correctly, the Request/Transmission Policy setting shall be such that the SS is prohibited from using any contention request opportunities for this connection.

• rtPS**:** The rtPS is designed to support real-time service flows that generate variable size data packets on a periodic basis, such as moving pictures experts group (MPEG) video. The service offers real-time, periodic, unicast request opportunities, which meet the flow's real-time needs and allow the SS to specify the size of the desired grant. This service requires more request overhead than UGS, but supports variable grant sizes for optimum data transport efficiency. The BS shall provide periodic unicast request opportunities. In order for this service to work correctly, the Request/Transmission Policy setting shall be such that the SS is prohibited from using any contention request opportunities for that connection. The BS may issue unicast request opportunities as prescribed by this service even if prior requests are currently unfulfilled. This results in the SS using only unicast request opportunities in order to obtain uplink transmission opportunities.

• nrtPS: The nrtPS offers unicast polls on a regular basis, which assures that the service flow receives request opportunities even during network congestion. The BS typically polls nrtPS CIDs (Connection Identifier) on an interval on the order of one second or less. The BS shall provide timely unicast request opportunities. In order for this service to work correctly, the Request/Transmission Policy setting shall be set such that the SS is allowed to use contention request opportunities. This results in the SS using contention request opportunities as well as unicast request opportunities and unsolicited Data Grant Burst Types. All other bits of the Request/Transmission Policy are irrelevant to the fundamental operation of this scheduling service and should be set according to network policy.

BE: The intent of the BE service is to provide efficient service for best effort traffic. In order for this service to work correctly, the Request/Transmission Policy setting shall be set such that the SS is allowed to use contention request opportunities. This results in the SS using contention request opportunities as well as unicast request opportunities and unsolicited Data Grant Burst Types. All other bits of the Request/Transmission Policy are irrelevant to the fundamental operation of this scheduling service and should be set according to network policy.

In addition to these four types of service classes, ertPS is introduced in IEEE 802.16e, an amendment of IEEE 802.16-2004 [2].

2.2 Bandwidth allocation and request mechanisms

IEEE 802.16 MAC is defined as connection-oriented so as to support QoS for scheduling services. All services, including inherently connectionless service (packet service like IPv4, IPv6) are mapped to a connection. Bandwidth is allocated by a request/grant mechanism. Once the connect is admitted into the network, if new packets arrive at the SS, SS sends out the request per connection on the allocated time slots or using contention time slots or by piggybacking on the next transmitted data packet. After BS receives the request, based on the amount of bandwidth requested (granted) so far, the BS uplink scheduler estimates the residual backlog at each uplink connection, and allocates future uplink grants. The bandwidth grant is aggregated into a single grant to the SS and not directly to the requesting connection. Typically, SS uses the bandwidth for the requesting connection, but also can send the higher QoS data or discard the grant and make a new request when the QoS situation at the SS as changed since the last request. The above MAC mechanisms define the actions after connection is admitted into the system and should belong to a part of the packet scheduling.

3. Proposed Bandwidth Allocation Algorithm

The proposed bandwidth allocation scheme determines the amount of bandwidth to be allocated for different services by giving several priorities between them. In fact, there are some points we should take into consideration. As we know, UGS service is designed to support real time applications without silence suppression, ertPS is suitable for real-time VBR traffic and VoIP traffic with silence suppression and rtPS is designed to support real-time service flows that generate variable size data packets on a periodic basis, such as moving pictures experts group (MPEG) video. On the other hand, nrtPS and BE are intended to support non real time applications e.g. File Transfer Protocol (in nrtPS service) or e-mail and web (in BE service). Due to their original QoS requirements, we assign the priorities to calls of UGS, ertPS, rtPS, nrtPS and BE in descending order. A fixed bandwidth is allocated to UGS calls firstly based on their fixed bandwidth requirements. The remaining bandwidth minus the minimum reserved bandwidth for ertPS service is then further allocated to ertPS, rtPS, nrtPS and BE in the priority order. BE service is normally assigned to connections that do not require QoS and thus, it issues its bandwidth request in the contention period. However, the rich media has been more and more applied in the web pages, so the amount of the data needed by BE connections is not small any more. In our scheme, we take into our considerations the BE bandwidth allocation mechanism but with the less priority then other service classes.

We model five service classes and so, we consider five types of classes denoted by c1, c2, c3, c4 and c5 which represent UGS, ertPS, rtPS, nrtPS and BE respectively. We assign priority between service classes as follows: $c_1 > c_2 > c_3 > c_4 > c_5$.

Assumptions:

We consider that the BS service capacity is C, in other words the capacity of WiMAX BS is C Mbps. The BS can provide services for M SSs.

We assume that the arrival of the bandwidth request of class c_1 (resp.c_2, c_3, c_4, c_5) follows a Poisson process with rate $\lambda c1$ (resp.$\lambda c2$, $\lambda c3$, $\lambda c4$, $\lambda c5$). The service times of UGS, ertPS, rtPS, nrtPS and BE are exponentially distributed with mean $1/\mu_1$, $1/\mu_2$, $1/\mu_3$, $1/\mu_4$ and $1/\mu_5$ respectively. The numbers of bandwidth requests for each service classes are: Breq1, Breq2, Breq3, Breq4 and Breq5 with class c_1, c_2, c_3, c_4 and c_5 respectively. The total requested bandwidth is defined by: Breq=Breq1+Breq2+Breq3+ Breq4+ Breq5.

B_{resv} is the reserved amount of bandwidth for ertPS service class. The available bandwidth for each SS is denoted B_{avail} that is mean that The BS can offer the amount of bandwidth equal to ($M*B_{avail}$) which do not exceed the total capacity. Then, due to the given priority between services classes, each SS distributes the allocated bandwidth to each service class. The numbers of allocated bandwidth to different types of service of SS are: Balloc1, Balloc2, Balloc3, Balloc4 and Balloc5 for class c_1, c_2, c_3, c_4 and c_5 respectively. Thus the input parameters of the proposed algorithm are: Breq1, Breq2, Breq3, Breq4 and Breq5 of each SSi; Bavail and Bresv. The output settings are: Balloc1, Balloc2, Balloc3, Balloc4 and Balloc5 of each SS_i.

Proposed Bandwidth Allocation Algorithm:

```
For i=1:M
 if B_avail ≥ Breq
 Balloc_k = Breq_k , k=1,2,3,4,5
 else
 B_remaind = B_avail – Breq1 – B_resv
 Balloc1=Breq1
 if Breq2d ≤ B_resv
   Balloc2=B_resv
   if B_remaind ≥  Breq3
          Balloc3=Breq3
          if (B_remaind- breq3)≥ Breq4
             Balloc4= Breq4
             Balloc5= B_remaind-Balloc3-Balloc4
         else
            Balloc4=B_remaind - Breq3
            Balloc5=0
   else
       Balloc3=B_remaind
       Balloc4=0
       Balloc5=0
  else
   if (Breq2-B_resv) ≥  B_remaind
      Balloc2=B_remaind+B_resv
   Balloc3=0
   Balloc4=0
  Balloc5=0
 else
  Balloc2=Breq2
  if (B_remaind-Breq2)≥ Breq3
     Balloc3=Breq3
     if (Bremaind-Breq2-Breq3)≥ Breq4
        Balloc4=Breq4
        Balloc5= B_remaind-Breq2-Breq3-Breq4
     else
        Balloc4= Bremaind-Breq2-Breq3
        Balloc5=0
  else
    Balloc3=Bremaind-Breq2
    Balloc4=0
    Balloc5=0
  end
  end
  end
  end
  end
```

The proposed algorithm collects the BW requests from each SS and compares the available resources to these BW requests; if there is enough BW to satisfy the requested BW of the SS so BW requests are accepted and BW allocated will be equal to the requested one. Otherwise, some BW requests will be rejected and the available BW is shared between different services classes by respect to the priority described previously.

4. Analytical Model

We have presented our CAC and bandwidth allocation algorithm in the previous section. In this section, we propose a mathematical model based on the Continuous Time Markov Chain in order to determine QoS parameters (call blocking probability and Bandwidth Utilization).Markov Chain is adopted to analyze the problem; we use the Continuous Time Markov Chain. Each Markov Chain state is represented by five parameters (i, j, k, l, m).

i, j, k, l, m are the number of UGS, ertPS, rtPS, nrtPS and BE connections admitted into the network respectively. The state space of the Markov Chain is obtained based on our proposed scheme. We suppose that the steady state probability of the state s= (i, j, k, l, m) is represented by $\pi\,(i, j, k, l, m)$. The state space S for our model is obtained by the following equation:

$$S = \{s = (i, j, k, l, m) \mid$$

$$i.B_{balloc1} + j.B_{balloc2} + k.B_{balloc3} + l.B_{balloc4} + m.B_{balloc5} \leq C\}$$

From a state *s= (i, j, k, l, m)*, a transition occurs when a new request for connection admission is accepted at the BS or an ongoing connection term n figure 3.

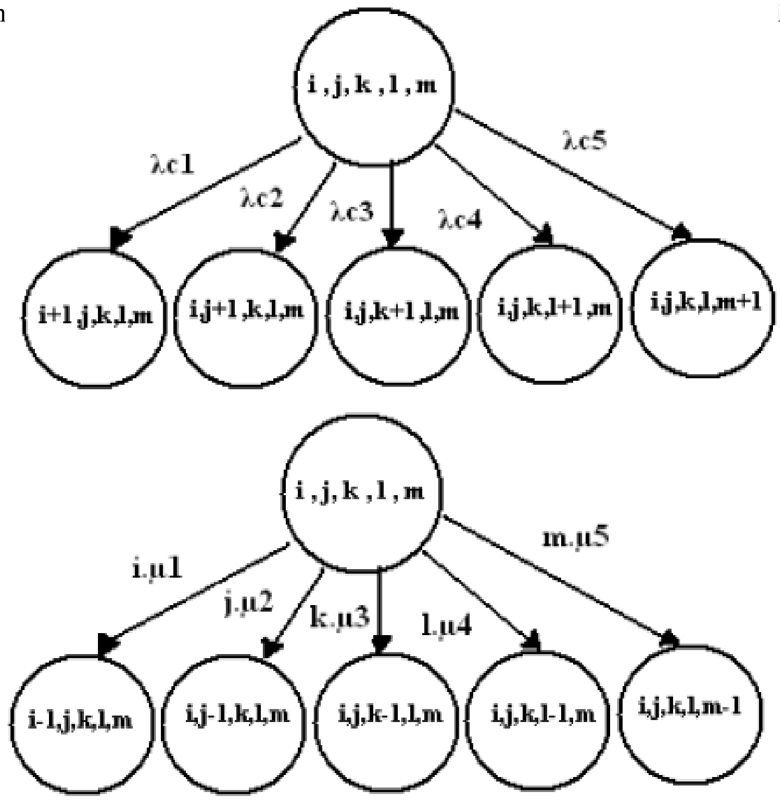

Figure 3. The Continuous Time Markov Chain

The state balance equation for a given state s is obtained by the following equation:

$$(\lambda\mathbf{c1}.Q(i+1,j,k,l,m)+\lambda\mathbf{c2}.Q(i,j+1,k,l,m)+\lambda\mathbf{c3}.Q(i,j,k+1,l,m)+$$
$$\lambda\mathbf{c4}.Q(i,j,k,l+1,m)+\lambda\mathbf{c5}.Q(i,j,k,l,m+1)+i.\mu_1 Q(i-1,j,k,l,m)+$$
$$j.\mu_2.Q(i,j-1,k,l,m)+k.\mu_3.Q(i,j,k-1,l,m)+l.\mu_4.Q(i,j,k,l-1,m)+$$
$$m.\mu_5.Q(i,j,k,l,m-1))\,\pi(i,j,k,l,m)=0$$

$$Q(i,j,k,l,m)=\begin{cases}1, & (i,j,k,l,m)\in \boldsymbol{S}\\ 0, & \text{otherwise}\end{cases}$$

The steady state probabilities of all states in S can be obtained by solving the above equation. The resolution of this equation is done with the normalized condition:

$$\sum_{s \in S} \pi(i, j, k, l, m) = 1$$

From the steady state probabilities, we calculate the QoS parameters: call blocking probability and Bandwidth Utilization.

4.1 Call Blocking Probability:

- $CBP\text{-}UGS = \sum_{s \in S_1} \pi(i, j, k, l, m)$ where

$S_1 = \{s = (i, j, k, l, m) \mid$

$(i+1).B_{balloc1} + j.B_{balloc2} + k.B_{balloc3} + l.B_{balloc4} + m.B_{balloc5} > C\}$

- $CBP\text{-}ertPS = \sum_{s \in S_1} \pi(i, j, k, l, m)$ where

$S_1 = \{s = (i, j, k, l, m) \mid$

$i.B_{balloc1} + (j+1).B_{balloc2} + k.B_{balloc3} + l.B_{balloc4} + m.B_{balloc5} > C\}$

- $CBP\text{-}rtPS = \sum_{s \in S_1} \pi(i, j, k, l, m)$ where

$S_1 = \{s = (i, j, k, l, m) \mid$

$i.B_{balloc1} + j.B_{balloc2} + (k+1).B_{balloc3} + l.B_{balloc4} + m.B_{balloc5} > C\}$

- $CBP\text{-}nrtPS = \sum_{s \in S_1} \pi(i, j, k, l, m)$ where

$S_1 = \{s = (i, j, k, l, m) \mid$

$i.B_{balloc1} + j.B_{balloc2} + k.B_{balloc3} + (l+1).B_{balloc4} + m.B_{balloc5} > C\}$

- $CBP\text{-}BE = \sum_{s \in S_1} \pi(i, j, k, l, m)$ where

$S_1 = \{s = (i, j, k, l, m) \mid$

$i.B_{balloc1} + j.B_{balloc2} + k.B_{balloc3} + l.B_{balloc4} + (m+1).B_{balloc5} > C\}$

4.2 Bandwidth Utilization:

$$BU = \sum_{s \in S} (i.B_{balloc1} + j.B_{balloc2} + k.B_{balloc3} + l.B_{balloc4} + m.B_{balloc5}) \pi(i, j, k, l, m)/C$$

5. Simulation Results

We considered the simulation scenarios with multiple types of traffic per SS, to evaluate different features of the standard. The simulations are carried out on MATLAB. In our proposed scheme, each service class has its constraint: UGS with mean data rate of 512kbps, ertPS, rtPS and nrtPS with mean data rate of 1Mbps and BE with mean data rate of 300 Kbps. The total bandwidth capacity of the BS is set as 70Mbps.

Firstly, in order to evaluate the performance of the proposed bandwidth allocation algorithm, we compute the call blocking probability (CBP) under different service classes. Figure 4 shows the call blocking probability of different type of services: UGS, ertPS, rtPS, nrtPS and BE. The call blocking probability of different type of services increases as the number of SSs increases. The call blocking probability of BE traffic increases more rapidly, the following is nrtPS traffic then rtPS, ertPS and finally UGS. This is because in our proposed bandwidth allocation algorithm, the bandwidth is allocated by BS to different services according to their different priorities.

Secondly, to evaluate our proposed bandwidth allocation algorithm, we create another bandwidth allocation algorithm which is based on First in First out (FIFO) strategy. In the FIFO bandwidth allocation algorithm, the IEEE 802.16 BS allocates bandwidth to SSs based on first come first serve policy; whereby the bandwidth requests of each SS are attended to in the order that they arrived without consideration of different type of services. In our bandwidth allocation algorithm, the IEEE 802.16 BS allocates bandwidth for different type of services of each SS based on the proposed BW algorithm respecting the priority between different traffic types.

Figure 5, 6 and 7 show respectively a comparison between the UGS, ertPS and rtPS blocking probability in FIFO algorithm and in our proposed algorithm. Figure 8 shows the comparison between bandwidth utilization of our algorithm and the FIFO algorithm. It is clear that bandwidth utilization is improved by our proposed scheme. We notice, through this comparison, that our proposed scheme is suitable for real time applications as it reduce the rate loss of requested bandwidth more than the FIFO algorithm.

Consequently our proposed bandwidth allocation algorithm seems be is a competent method as it gives an important results. It is evaluated and validated with an analytical process using MATLAB and it gives a performance improvement for call blocking probability and bandwidth utilization more than the FIFO strategy.

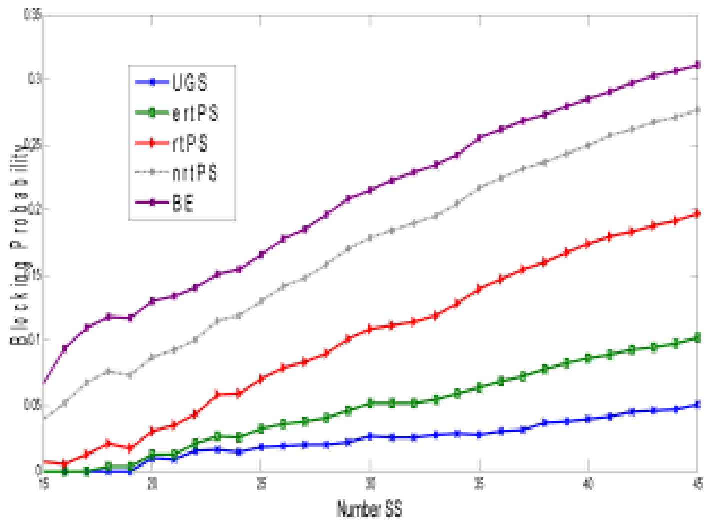

Figure 4. CBP under different service classes

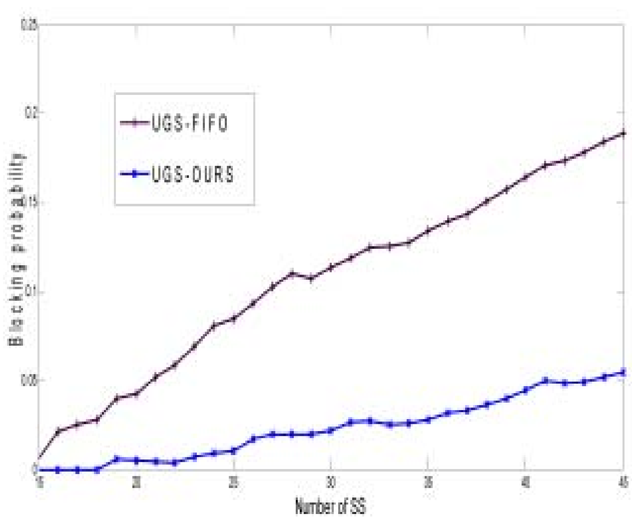

Figure 5. UGS blocking probability for different algorithms

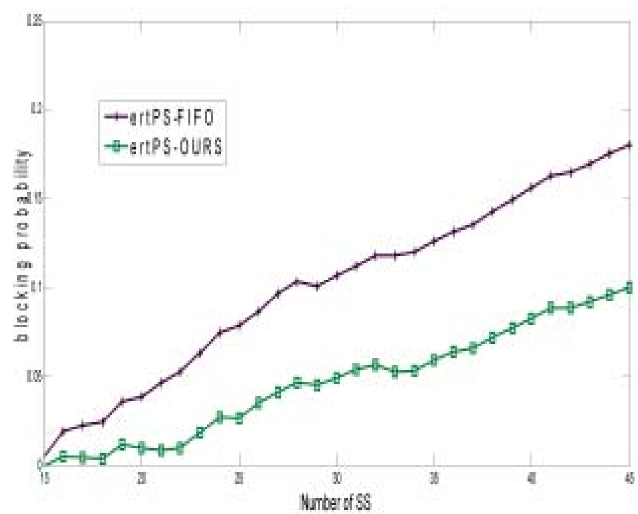

Figure 6.ertPS blocking probability for different algorithms

6. Conclusion And Future Works

In this paper, we proposed a bandwidth allocation algorithm based on QoS requirements of different traffic types in mobile

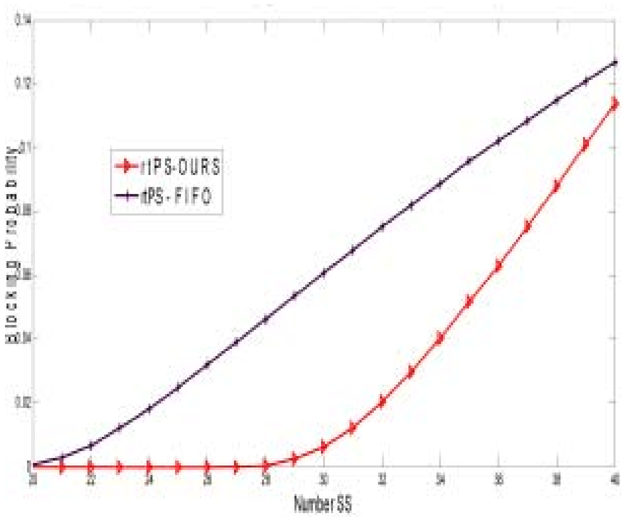

Figure 7. rtPS blocking probability for different algorithms

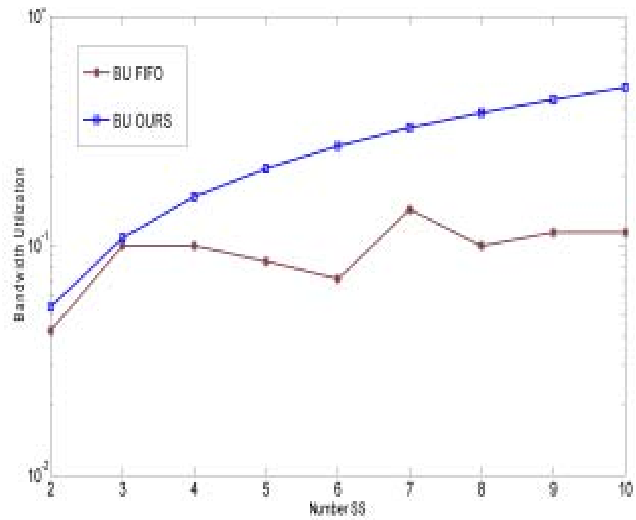

Figure 8. Bandwidth Utilization for different algorithms

WiMAX. Our proposed admission control scheme is suitable for real time applications as it gives more priority to real time service classes. An analytical model was developed to evaluate the performance of the CAC schemes. From the numerical results we can conclude that the proposed CAC scheme could be the better choice for admission control in Mobile WiMAX in terms of call blocking probability of different types of connections and the bandwidth utilization of the system.

Further research will focus on a simulation of another admission control schemes and scheduling policy employed in WiMAX networks with fixed and mobile technologies.

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