2013 IEEE 27th International Conference on Advanced Information Networking and Applications

Wireless Fair Intelligent Admission Control - WFIAC

Fatima Furqan
INEXT Centre for Innovation in IT Services and Applications
University of Technology, Sydney
Fatima.furqan@student.uts.edu.au

Doan B. Hoang
INEXT Centre for Innovation in IT Services and Applications
University of Technology, Sydney
Doan.Hoang@uts.edu.au

Abstract — **In next generation wireless networks like WiMAX, a dynamic Call Admission Control (CAC) plays an important role to ensure Quality of Service (QoS) of existing users and to efficiently utilize network resources. We propose a predictive CAC namely Wireless Fair Intelligent Admission Control (WFIAC) that admits or rejects a new incoming connection base on resource availability and load in the network. The proposed CAC works in conjunction to a load control module namely WiMAX Fair Intelligent Congestion Control (WFICC) to determine load in network. The proposed CAC is based on bandwidth borrowing and degradation of over provisioned connections in order to minimize blocking probability and to maximize resource utilization in the network. Once the network load reduces, WFICC upgrades the bandwidth allocated to connections that have data to send. So, WFIAC along with WFICC ensures the network operates around a target operating point to guarantee QoS to end users.**

A detailed and comprehensive simulation is performed in ns-2 to show the efficiency of the proposed CAC scheme in terms of blocking probability of different service classes and QoS provisioning to existing connections when the network is in congested and non congested state.

Keywords: Admission Control, Quality of Service (QoS), Throughput, Delay, blocking probability.

I. INTRODUCTION

The IEEE 802.16 series of standards aim to provide Broadband Wireless Access (BWA) over a long distance with guaranteed Quality of Service (QoS) in terms of low delay/jitter, low loss, and adequate bandwidth to different types of traffic. To ensure the QoS of different traffic types, WiMAX Standard has defined 5 different Class of Services (CoSs), namely Unsolicited Grant Service (UGS), Extended Real Time Polling Service (ertPS), Real time polling service (rtPS), Non Real time polling service (nrtPS) and Best Effort (BE).

In IEEE 802.16, there are two types of stations namely Base Station (BS) and Subscriber Station (SS). Each SS can serve multiple users who have access to network. Both BS and SSs are fixed, but inside the SS, users can be either static or mobile. WiMAX architecture supports communication in two modes, Point to Multipoint (PMP) and Mesh mode. In PMP mode, base station makes allocations to SSs either in Grant Per connection (GPC) or Grant per subscriber Station (GPSS) mode. In Grant Per connection (GPC) mode bandwidth is granted explicitly to each connection, while in Grant per subscriber Station (GPSS) all connections from the same SS are treated as single unit and bandwidth is allocated to a SS by the BS [1]. So in GPSS mode the scheduler at the SS need to be intelligent.

The IEEE 802.16-2005 standard [2] defines specific QoS parameters for each class of service but it does not provide mechanisms to ensure QoS of the connections of different CoSs. The Admission Control (AC) mechanism is not specified by the standard and is left as an open research area. AC plays a crucial role in admitting connections of different traffic types with different QoS constraints and priorities. An efficient AC ensures QoS provisioning to new and existing connections in the network. IEEE 802.16 is a connection oriented MAC and any MS before sending the data establishes a logical connection with the BS by sending a Dynamic Service Addition (DSA) request that contains all the QoS parameters of the incoming connection. AC module admits/ rejects a new connection based on the QoS requirements of incoming connection and the QoS constraints of existing connections.

The authors in [1] suggested a CAC scheme based on thresholds. CAC scheme that reserves resources for high priority UGS CoS only in busy hours is proposed in [3]. To prioritize handoff connections authors in [4] proposed to reserve adaptive temporal channel bandwidth instead of fixed guard channels. CAC schemes proposed in [1], [3] and [4] accept an incoming connection only if sufficient resources are available in network. To provide service differentiation in fixed WiMAX, a CAC scheme based on degradation is proposed in [5] and CAC schemes based on both bandwidth reservation and degradation are proposed in [6], [7], [8] and [9]. To prioritize handoff connections in mobile WiMAX, a degradation based strategy is proposed in [10] and [11] and a CAC scheme that uses a combination of bandwidth reservation and a degradation based strategy is proposed in [12].

In literature all CAC schemes that are based on degradation strategy to admit a new / handoff connection use a fixed size degradation step. Same size degradation step is applied on connections of all CoSs without taking into account priority of different CoSs. The rationale behind the selection of the degradation step size is also not discussed.

In this paper we propose a new intelligent Admission Control, WFIAC, at the BS for GPC mode. To provide priority to connections of different CoSs, our proposed AC is based on a degradation strategy. In this paper we introduce a variable size degradation step that is based on available slots for the uplink in the network. A degradation step of variable size is proposed to ensure the service differentiation is maintained when degradation is applied on connections of different CoSs. Another important feature of our admission control is that it

1550-445X/13 $26.00 © 2013 IEEE
DOI 10.1109/AINA.2013.29

takes into account the current status of the network load by working in conjunction with a congestion control module. The network is considered congested if the queue at the base station output buffer is above the target operating point [13]. If the network is heavily loaded and WFIAC is informed that WFICC [13] is not be able to manage the load of network by degrading the connections of lower priority CoSs then WFIAC rejects the incoming connection even if enough resources are available in network in order to maintain the QoS of existing connections in terms of delay and throughput.

The paper is organized as follows. Section II presents related work. Proposed CAC scheme is discussed in section III. Section IV discusses the simulation setup and simulation results are given in section V. Finally, conclusion is given in section VI.

II. RELATED WORKS

To provide satisfactory QoS [1] proposed a dynamic call admission control and a QoS aware bandwidth allocation algorithm (QABAA) for Point to Multipoint (PMP), last mile access. Dynamic call admission control namely Quadra-Threshold bandwidth Reservation (QTBR) is based on class of service and uses thresholds G1, G2, G3 and G4 for four classes of service UGS, rtPS, nrtPS and BE respectively, where G1>G2>G3>G4. QABAA is triggered when the blocking and dropping probability increases predefined thresholds to reduce the bandwidth allocated to existing connections and is applied only to rtPS, nrtPS and BE. To apply the proposed schemes in [1], system effectively needs to define CAC thresholds and blocking and dropping probabilities thresholds. The paper also did not consider delay requirements of connections.

In the approach proposed in [3] the bandwidth for the UGS class is reserved only under busy hours condition, when the arrival rate of UGS connections exceed a specified threshold. The proposed scheme is based on bandwidth reservation concept and is executed under busy hour condition. Under these conditions, when a UGS connection request arrives and the bandwidth (BW_T) is sufficient to deal with the connection demand then accept the connection. The remaining bandwidth ($BW_T – BW_R$) is provided to rtPS and nrtPS traffic as UGS connections enjoy a higher priority. While BE connections are always accepted as they don't have any QoS requirements.

To handle handoff connections an Adaptive Connection admission control (CAC) and packet scheduling over an OFDMA PHY layer was proposed in [4]. The proposed CAC applies in GPSS mode. Handoff connections are given priority by reserving an adaptive temporal channel bandwidth based on most recent requests. When the network is moderately loaded, the proposed dynamic guard channel scheme performed better than the fixed guard channel scheme in terms of new connection blocking, handoff dropping probability and resource utilization.

Authors in [6] proposed a dynamic CAC scheme for fixed WiMAX network. The proposed scheme is based on reservation and degradation. VOIP is classified as UGS traffic and is given top priority, resources are reserved for these connections. To reduce the blocking probability of rtPS and nrtPS connections, the proposed CAC scheme reduces/degrades the bandwidth of only over provisioned nrtPS connections. The step size of degradation is assigned a fixed value of 32kbps.

To provide service differentiation and to maximize system revenue, authors in [7] proposed a CAC scheme that exclusively reserves bandwidth for connections of high priority CoS like UGS and rtPS. On the arrival of UGS, rtPS and nrtPS connections, if resources are not sufficient then a degradation is applied to connections of nrtPS and BE CoSs only. The paper did not discuss the step size of degradation.

Authors in [11] proposed a CAC scheme that admits new connection only if the system has enough resources. With handover connections, if resources are not sufficient then the proposed scheme apply degradation on existing connections of low and same priority CoS. The degradation process reduces the bandwidth of a connection to its minimum reserve rate. The degradation is not equally applied on all connections of a CoS that can lead to unfairness in network.

For handover connections, authors in [14] applied a guard channel scheme. Additionally when resources are not enough then for handoff and new connections, bandwidth borrowing is applied on connections of lower and same priority CoS to minimize blocking and dropping probability. The paper did not apply step wise degradation but it reduces the bandwidth of a connection to its minimum reserve rate.

Authors in [5] proposed a CAC based on degradation. The proposed CAC degrade the bandwidth of all nrtPS connections to their minimum reserve rate as in [14], if the request of high priority CoS like UGS and rtPS come and resources are not adequate in network. The scheme also proposed to upgrade the nrtPS connections when the network is lightly loaded.

A Call Admission Control that satisfies both bandwidth and delay requirements to admitted connections was proposed in [10]. For new and handoff UGS and rtPS connections, if enough bandwidth is not available in the network then a bandwidth degradation process is applied to nrtPS connections. If requested bandwidth is still not satisfied then only for handoff UGS and rtPS connections degradation is applied on the admitted rtPS connections. The step size of degradation is assigned a fixed value of 256 and is same for each CoS. After allocating the bandwidth, the delay requirements of the rtPS connections is investigated. A new connection is rejected if it effects the delay requirements of existing rtPS connections.

To avoid starvation a CAC scheme that uses a combination of thresholds and degradation was proposed in [8]. The proposed mechanism defines threshold for each CoS. To minimize the connection blocking probability, if resources are not sufficient in the system, degradation is applied on connections of lower priority, same priority and even high priority CoS only if connections of respective CoSs are using bandwidth above their respective thresholds. Proposed degradation process leads to unfairness among connections of a CoS as to steal resources from a CoS above its threshold, degradation is applied only on some connections of respective CoS. Additionally the paper did not clearly define the degradation step.

Authors in [9] proposed a CAC scheme that defines a priority table and degradation groups based on the priority and precedence values in the Connection ID (CID) field. The scheme define threshold for each CoS as in [8], and if a CoS is above its threshold then any incoming connection of that respective CoS is marked as downgraded flow that can be preempted when the network is congested.

A proactive resource reservation scheme was proposed in [15]. In the proposed scheme the resource reservation module accepts/rejects an incoming connection based on the congestion notification sent by the traffic prediction module. Traffic prediction module based on the current QoS states and the QoS demand of incoming connection estimates the future condition of network in terms of stability and load.

In this paper we propose an admission control scheme that admits connections based on both resource availability and estimated network load with the aim to maintain the QoS of existing connection in terms of delay and throughput. The proposed CAC estimates the expected rate for each CoS (ER_{CoS}) based on the resource availability.

To provide priority to connections of high priority CoSs, resources are borrowed from connections of lower priority CoSs. To maintain the priority of connections of high priority CoSs during degradation, a variable size degradation step is defined as a function of slots in the network that allows different amount of degradation to be applied on connections of different CoSs.

III. Proposed Scheme.

In this section we describe our proposed WFIAC. In this scheme for simplicity we assume the connections of same CoS have the same QoS parameters namely MRTR, MSTR, delay and jitter. Furthermore we also assume that all users in the cell use the same Modulation and Coding scheme (MCS). The terminology used in this paper is given below.

C : Total amount of bandwidth available at the BS for uplink in terms of slots.
C_{used} : Total number of slots in use.
S_{CAP}: Slot Capacity in bytes.
C_{REQ}: Slots requested by an incoming connection and is equal to $MSTR_{UGS}/S_{CAP}$ for UGS and ER_{CoS}/S_{CAP} for rtPS, nrtPS and BE CoSs.
C_{rem} : C_{REQ} - (C – C_{used}).
C_0: (C_{used}-C_{REQ})Target total number of slots in use after WFIAC.
B_{UGS}: MSTR of UGS.
B^{min}_{rtPS}, B^{min}_{nrtPS}: MRTR of rtPS and nrtPS respectively.
B^{max}_{rtPS}, B^{max}_{nrtPS}: MSTR of rtPS and nrtPS respectively.
ER_{UGS}, CC_ER_{UGS}: Expected rate (in bytes) of UGS maintained by WFIAC and WFICC respectively.
ER_{rtPS}, CC_ER_{rtPS}: Expected rate (in bytes) of rtPS maintained by WFIAC and WFICC respectively.
ER_{nrtPS}, CC_ER_{nrtPS}: Expected rate (in bytes) of nrtPS maintained by WFIAC and WFICC respectively.
ER_{BE} : Expected rate of BE.
Q_{len} : Current Queue length at base station output buffer.
Q_0 : Target Queue length.
f(Q) : function of Queue use in WFICC.
f(S): function of slots use in WFIAC.
N_{UGS} , N_{rtPS} , N_{nrtPS} : Number of connections already admitted for UGS, rtPS and nrtPS CoS respectively.

A. *Congestion Control (CC) :*

We proposed a congestion control (CC) scheme namely WFICC in [13] that defines a target operating point (Q_0) and dynamically maintains the network traffic around the target operating point so that the queue at the BS output buffer neither reaches to its maximum capacity nor becomes empty ensuring link is never idle unnecessarily. WFICC is a robust congestion control algorithm [16] and is always operational whether the network is above or below the target point.

1) *Queue Control Function f(Q)*

WFICC employs an efficient function of queue size called queue control function (f(Q)). The queue control function expresses the degree of network congestion that a base station can tolerate. The f(Q) is defined as in the following equation.

$$f(Q) = \begin{cases} \frac{(Bufferlen-Qlen)}{(Bufferlen-Q0)}, & if\ Q_0 \leq Qlen \\ \frac{(\alpha-1)*(Q_0-Q_{len})}{Q_0}+1, & if\ Q_0 \geq Qlen \\ 1, & if\ Qlen = 0 \end{cases} \tag{1}$$

Where Bufferlen is the total size of output buffer at the base station and α can be considered as an oversell factor when the network is underutilized. Qlen is the actual queue length at the output base station buffer and Q_0 is the target operating point. During the congested state, when queue length is more than the target operating point (Qlen > Q_0), the function value is less than 1 to discourage incoming traffic and vice versa.

2) *Estimation of Expected Rate of Each Class of Service (CC_ER_{CoS}):*

In order to keep the queue length around the target operating point, WFICC estimates the current bandwidth allocated to each CoS, and then calculates the expected rate for each CoS (CC_ER_{CoS}) using the queue control function. To estimate the current bandwidth allocated to each CoS, WFICC uses a variable named MACR, but one for each CoS ($MACR_{CoS}$).

The main aim of WFICC is to calculate the explicit rate, which reflects how much traffic could be handled by a base station. The Mean explicit rate is defined as follows.

$$CC\_ER_{CoS} = MACR_{CoS} * f(Q) \tag{2}$$

WFICC estimates the degree of congestion in the network by calculating the function of queue (f(Q)). If value of f(Q) is less than 1, indicating there is congestion in the network, WFICC reduces the bandwidth allocated to all connections corresponding the BE CoS, then connections corresponding the next priorities class nrtPS and finally rtPS CoS. Unless f(Q) is above 1, WFICC can reduce the bandwidth allocated to BE connections until it reaches to zero, but for nrtPS and rtPS CoS, it cannot degrade below MRTR per frame of respective CoS. If f(Q) is greater than 1, indicating network is operating below its target level, WFICC raises the bandwidth share to all connections corresponding the rtPS, then nrtPS and finally BE CoS. WFICC cant not increase the bandwidth share of any service flow beyond the MSTR per frame of the respective CoS.

In our proposed WFIAC when a new connection request comes with C_{REQ}, WFIAC checks resources availability. To calculate the available resources WFIAC module obtains the expected rate of each CoS maintained by the WFICC module denoted as CC_ER_{CoS} and then update the expected rate for each CoS (ER_{CoS}) maintained by it (WFIAC) as follows.

$$ER_{CoS} = \min(CC\_ER_{CoS}, ER_{CoS}) \tag{3}$$

Where CoS represents rtPS, nrtPS and BE. The aim is to assign the incoming connection of a particular CoS the same rate as used by the existing connections of respective CoS. Actual current resource utilization in network in terms of slots used (C_{used}) is calculated as follows.

$$C_{used}=ceil(ER_{UGS}/S_{CAP})*N_{UGS}+ceil(ER_{rtPS}/S_{CAP})*N_{rtPS}+ceil(ER_{nrtPS}/S_{CAP})*N_{nrtPS}+ceil(ER_{BE}/S_{CAP})*N_{BE} \tag{4}$$

Where ER_{CoS} is in bytes so we divide it by the slot capacity (S_{CAP}) to obtain the number of slots used by a connection of a particular CoS. If the system has sufficient available resources ($C- C_{used}$) then the WFIAC updates the Qlen based on the data rate assigned to the incoming connection, otherwise step wise degradation is applied on all connections of lower priority CoSs for the remaining slots (C_{rem}).

The step size of degradation used by WFIAC is similar to the step size used by WFICC. Step size of WFICC is a function of Qlen as shown in Eq. 1, the step size of proposed WFIAC is a function of slots and is as follows.

$$f(S) = \frac{C - C_{used}}{C_0} * S_{CAP} \quad (5)$$

Where $C_0 = C_{used}-C_{rem}$ is the target number of used slot after degradation process is complete. So f(S) degrades bandwidth/expected rate of all connections of a CoS equal to a fraction of a slot at a time. The proposed step size maintains the priority of connections of different CoSs. As when degradation is applied on connections of lower priority CoS, number of used slots C_{used} decrease and the value of degradation step will also decrease resulting in less degradation applied on connections of high priority CoSs.

If requested resources are still not obtained even after the degradation process is complete, the requested connection is rejected, otherwise WFIAC updates the current Qlen and the ER of each CoS based on the degradation applied and estimates the load in the network. If the network is in congestion state indicated by the queue length at BS then the WFIAC will reject the connection otherwise it will accept the connection.

At Wimax Base Station Admission Control (AC) for each DSA Request.

1. Initialization
   a. Obtain ER for each CoS (ER_{CoS}) from WFICC namely CC_ER_{rtPS}, CC_ER_{nrtPS} and CC_ER_{BE}.
   b. Update ER of each CoS (ER_{CoS}) as in Eq. 3.
   c. Calculate C_{used} using Eq. 4.
   d. $C_{REQ}= ER_{CoS}/S_{CAP}$ // Slots Requested
2. If $C_{REQ} < (C-C_{used})$ // Found Enough Resources
   Go to step 3.
   Else
   $C_{rem}= C_{REQ}-C$
   Step wise degrade all connections of low priority CoSs.
   If $C_{REQ} < (C-C_{used})$ // Found enough Slots after degradation
   Go to step 3.
   Else
   Reject Connection Request.
3. Calculate f(Q) using Eq. 1. // Check for load
4. If f(Q) > 1 //Indicate network is underutilized.
   Accept Connection Request.
   Else If f(Q) <1 // Load in network
   If $\sum_{i=0}^{j}\sum_{n=0}^{N_{CoS}} ER_{CoS} - MRTR_{CoS} > MRTR_{REQ\_CoS}$ // i= CoSs lower than the priority of requesting connection CoS.
   Accept Connection
   Else
   Reject Connection

B. *Description of CAC*

To provide service differentiation in the network WFIAC degradation process deals connection of each CoS in a different manner as discussed below.

1) *UGS connection*

When the BS receives a DSA for UGS connection with the bandwidth request of B_{UGS}, the admission control module checks the availability of resources. The connection request is honoured if the system has sufficient available resources otherwise step wise degradation is applied on the over provisioned connections of lower priority CoSs for the remaining slots (C_{rem}). For UGS connections step wise degradation is first applied on all BE connections. If after degrading the BE connections resources are still not sufficient then step wise degradation is applied on all connections of next priority nrtPS CoS until enough resources are obtained or their expected rate reduces to $MRTR_{nrtPS}$. If still enough resources cannot be obtained then connections of next higher priority rtPS CoS are step wise degraded until either enough resources are obtained or their expected rate reduces to $MRTR_{rtPS.}$

The connection request is rejected if adequate resources are not obtained after the degradation process otherwise WFIAC using the new expected rate of each CoS after degradation, updates Qlen and checks for the load in network. For a UGS connection, network is in load if following statement is true.

If f(Q)<1

$$\text{If } \sum_{n=0}^{N_{BE}} ER_{BE} - 0 + \sum_{n=0}^{N_{nrtPS}} ER_{nrtPS} - MRTR_{nrtPS} + \sum_{n=0}^{N_{rtPS}} ER_{rtPS} - MRTR_{rtPS} < B_{UGS} \quad (6)$$

The above statement shows that f(Q) is less than 1 indicating that the network is in congestion state and also sum of the rate above the minimum rate of all connections of lower priority CoSs is less than the bandwidth requested by the incoming connection, indicating that WFICC will not be able to manage the load introduced by the incoming connection even after degrading the lower priority connections. So the AC will not accept the connection to maintain the QoS of existing connections.

2) *rtPS connection*

When the BS receives a DSA for rtPS connection with the bandwidth request of B_{rtPS}^{max} and B_{rtPS}^{min} , the admission control module assign the incoming connection the value of ER_{rtPS} as calculated in Eq.3. The aim is to assign the incoming connection the same rate as used by existing connections of the rtPS CoS. The requested connection is honoured if the system has sufficient available resources otherwise step wise degradation is applied on the over provisioned connections of lower priority CoS for remaining slots (C_{rem}). For rtPS connections step wise degradation is applied first on all BE connections. If after degrading the BE connections resources are still not adequate, the step wise degradation is then applied on all the connections of next priorities nrtPS CoS until enough resources are obtained or their expected rate reduces to $MRTR_{nrtPS}$.

The connection request is rejected if enough resources are not obtained after the degradation is complete otherwise WFIAC using the new expected rate of each CoS after degradation, updates Qlen and checks for the load in network. For an rtPS connection, network is in load if following statement is true.

If f(Q)<1

$$\text{If } \sum_{n=0}^{N_{BE}} ER_{BE} - 0 + \sum_{n=0}^{N_{nrtPS}} ER_{nrtPS} - MRTR_{nrtPS} < MRTR_{rtPS} \quad (7)$$

The above statement shows that the f(Q) is less than 1 indicating that network is in congestion state and also sum of the rate above the minimum rate of all the connections of lower priority CoSs is less than the minimum reserve rate of the incoming connection, indicating that WFICC will not be able to manage the load introduced by the incoming connection even after degrading the low priority connections. So the WFIAC will not accept the connection to maintain the QoS of existing connections. For rtPS connection WFICC can degrade the rate above the minimum reserve rate ($MRTR_{rtPS}$) so WFIAC is only validating load for $MRTR_{rtPS}$ that WFICC is not allowed to degrade.

3) *nrtPS connection*

When the BS receives a DSA for nrtPS connection with the bandwidth request of B_{nrtPS}^{min} and B_{nrtPS}^{min} , admission control module assigns the incoming connection the value of ER_{nrtPS} as calculated in Eq.3. The aim is to assign the incoming connection the same rate as used by existing connections of the nrtPS CoS. The requested connection is honoured if the system has sufficient available resources otherwise step wise degradation is applied on the connections of lower priority CoS for remaining slots (C_{rem}). For nrtPS connections, the step wise degradation is applied on all BE connections. The connection request is rejected if enough resources are not obtained after the degradation process is complete otherwise the AC module using the new expected rate of each CoS after degradation, updates Qlen and checks for the load in network. For a nrtPS connection, network is in a congested state if following statement is true.

If f(Q)<1

$$\text{If } \sum_{n=0}^{N_{BE}} ER_{BE} - 0 < MRTR_{nrtPS} \quad (8)$$

The above statement shows that the f(Q) is less than 1 indicating that network is in congestion state and also sum of the rate above the minimum rate of all connections of lower priority CoSs is less than the MRTR requested by the incoming connection, indicating that WFICC will not be able to manage the load introduced by the incoming connection even after degrading the lower priority COS connections. So WFIAC will not accept the connection to maintain the QoS of existing connections.

4) *BE connection*

When the BS receives a DSA for BE connection with the bandwidth request of B_{BE}, the admission control module always admits the connection as it does not need QoS guarnatee. After allocating resources to connecions of high priority CoS, remaining free slots are equally shared among all the BE connections so ER_{BE} connections is calculated as follow.

$$ER_{BE} = \text{Remaining free slots}/N_{BE} \quad (9)$$

IV. Simulation Setup

The overall goal of the simulation is to investigate the effectiveness of the proposed WFIAC scheme in terms of blocking probability of incoming connections and the guaranteed QoS of existing connections in the network in terms of throughput and delay. The simulations have been performed in ns-2 [17] using the WiMAX module for OFDMA by WiMAX forum and NIST [18] namely ns2-wimax-awg.

In the current simulation setup, WiMAX SSs are connected to a WiMAX BS in IEEE 802.16 PMP mode. The BS is connected to a sink node to reflect the actual deployment of the WiMAX network. The Link capacity between sink node and base station is initially set at 1.4 Mbps and the target Queue length (Q_0) is set at 1/4 of the total buffer capacity of 1.2 Mbps. In the simulation 5 ms frame duration is assumed, the ratio of downlink to uplink is set at 7:3. The Modulation and Coding scheme (MCS) QPSK-3/4 with slot capacity of 9 bytes is assumed for all the nodes.

UGS service flows are dynamically added to handle VOIP traffic. For the video traffic, rtPS flows are added and nrtPS flows are created for the FTP traffic.

The arrival rate of rtPS and nrtPS follows a Poisson distribution with an average rate of 1 connection per second. The arrival rate of UGS is a Poisson distribution with an average rate that is increased from 1 connection per second to 7 connections per second. The data rate used by connections of each CoS is as follows

TABLE I QoS PARAMETERS

Service	**Rate**
B_{UGS}	64 kbps
B_{rtPS}^{max} , B_{nrtPS}^{max}	256 kbps
B_{rtPS}^{min} , B_{nrtPS}^{min}	88 kbps

V. Smulation Results

This section presents and discusses the results of our simulations to show the effectiveness of our proposed WFIAC. First we show the comparison of WFIAC in terms of connection blocking probability of UGS and non UGS (rtPS and nrtPS) connections with a strict admission Control (SAC) that admits the incoming connection only if enough resources are available in the network.

Later, we present the investigation of the effect of load estimation performed by WFIAC on the QoS of existing connections in terms of throughput and delay when the network is congested as indicated by the queue length at the base station output buffer. As BE CoS does not have any MRTR or delay requirements so results for BE CoS have not been shown in the following section.

A. *Blocking Probability (BP)*

Blocking probability is calculated as follow.

$$BP = \frac{Total\ Number\ of\ Connections\ Rejected}{Total\ Number\ of\ Connection\ Requests}$$

Fig.1 and Fig. 2 show the blocking probability (BP) of UGS and non UGS connections for the networks both in congested (CON) and non congested (NCON) states respectively. To simulate light congestion (LCON) and high congestion (HCON) in the network the link capacity between BS and sink node is reduced from 1.4 Mbps to 1.1 Mbps and to .9 Mbps respectively.

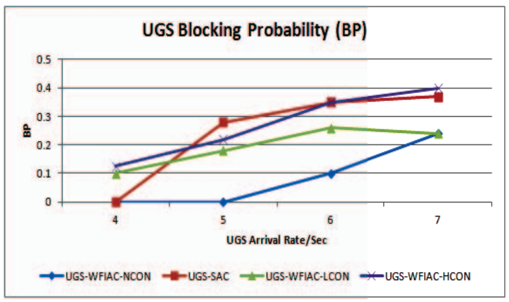

Figure 1. BP of UGS connections in light congestion

Results show the BP of UGS's starting with arrival rate of 4 connections per seconds as at this rate BP for UGS is already zero. As Strict AC (SAC) admits connection only if enough resources are available to meet the request of incoming connection and does not consider load in the network so BP of UGS connections with SAC scheme is highest and is same for congested and non congested scenarios as shown in Fig.1. Fig.1 shows when the network is in non congested state (NCON), the BP of UGS is lowest with WFIAC scheme. When the network is lightly congested and queue length grows above the target operating point, WFIAC admits less number of connections to maintain the QoS of existing connections so BP of UGS increases with WFIAC scheme (WFIAC-LCON) but it is still less than the BP of UGS with SAC scheme as shown in Fig. 1.

Fig. 1 also shows the BP of UGS when the network is highly congested. As the arrival rate of UGS connections increases, the BP of connections with WFIAC scheme (WFIAC-HCON) increases and exceeds the BP of UGS connections with SAC scheme as shown in Fig.1 as in heavy load WFIAC rejects more incoming connections to maintain the QoS of already admitted connections in the network.

Combined BP of non UGS (rtPS and nrtPS) connections is shown in Fig. 2. Fig. 2 shows that for non UGS connections BP is highest with strict AC (SAC). To accommodate rtPS connections WFIAC can degrade connections of nrtPS CoS so with WFIAC in non congested (NCON) scenario the BP of non UGS is lower as compare to SAC scheme.

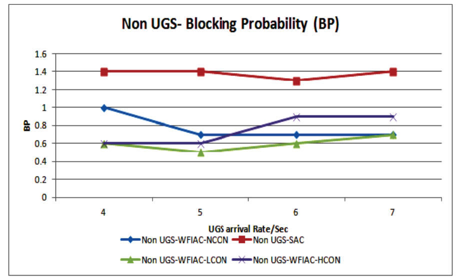

Figure2. BP of non UGS connections

Fig. 2 shows in non congested scenario (NCON) when the arrival rate of UGS increases, the BP of non-UGS connections decreases as when UGS connections arrival rate increases then to accommodate more UGS connections degradation is applied on non-UGS connections (both nrtPS and rtPS) so the current resource utilization of non UGS connections reduces and is maintained by WFIAC as new reduced expected rate of the respective non UGS CoS. So, now new incoming connections of non UGS CoSs can be admitted with new reduced expected rate even when limited resources are available in the network. Fig. 2 shows that when the network is lightly congested (LCON) then the BP of non-UGS reduces even more as when the network is in load state WFICC in order to control load degrades the bandwidth allocated to non-UGS connections, so the current resource utilization of non UGS connections reduces even when UGS arrival rate is low. As soon as the arrival rate of UGS increases then BP of non UGS in light congested (LCON) scenario even becomes equal to the BP of non UGS in non congested (NCON) scenario.

Fig. 2 also shows when the network is highly congested (HCON) and the arrival rate of UGS increases, the BP of non UGS connections with WFIAC scheme increases and exceeds the BP of non UGS connections with WFIAC in not congested (WFIAC-NCON) scenario as in heavy load WFIAC rejects more incoming connections even with relatively reduced expected rate to maintain the QoS of existing connections.

B. *Effect of Load Estimation on QoS*

To show the effect of load estimation on the QoS of existing connections simulation is performed with link capacity of .9 Mbps, rtPS and nrtPS arrival rate of 1 connection per second and for UGS the arrival rate is 7 connections per second.

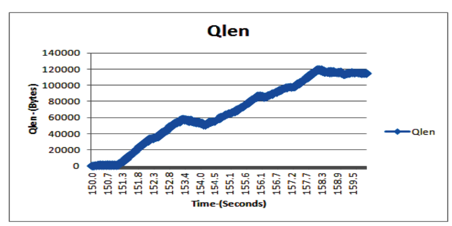

Figure 3. Qlen without load estimation

Fig.3 shows when the network is congested indicated by the queue length of the BS output buffer that goes beyond the target operating point, if further connections are admitted in the network by WFIAC only on the base of resource availability without taking into account the current load in the network then the queue length at the base station output buffer increases to the maximum buffer limit.

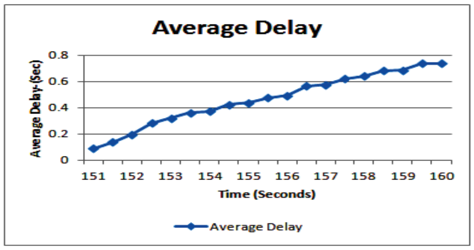

Figure 4. Average Delay without load estimation

Fig. 4 shows the effect of increasing queue length on the average delay of all the connections in the network. Fig. 4 shows that when the network is congested, the output buffer at the base station overflows and this results in an increase in the packet average delay for all network connections.

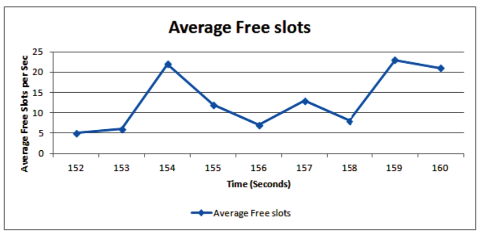

Figure 5. Average Free Slots without load estimation

Fig. 5 shows the average number of free slots in the network. In the current scenario if an incoming connection request comes through DSA, WFIAC admits the connection if enough resources are available or obtained after degrading connections of lower priority CoS without load estimation at the BS output buffer, so overall the average number of free slots is low except the peaks that exist due to departure of connections.

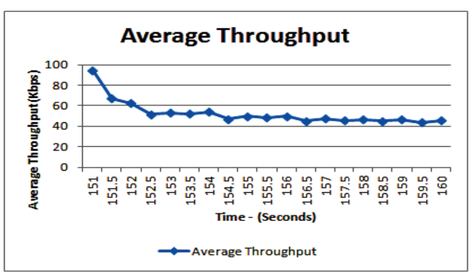

Figure 6. Average Throughput without load estimation

Fig. 6 shows the effect of increasing queue length on the average throughput of all the connections in the network. As the queue length at the base station output buffer starts increasing the average delay of all connections starts increasing and results in decreasing average throughput of the network even though maximum resources (in terms of slots) are utilized to send user's data as shown in Fig. 5.

So if the admission control admits connection only on the basis of resource availability without taking into account the network load status, the QoS of existing connections degrade in terms of delay and throughput as shown in Fig. 4 and Fig .6.

The results below are shown for the scenario when WFIAC admits connections based on both the resource availability and the network load estimation.

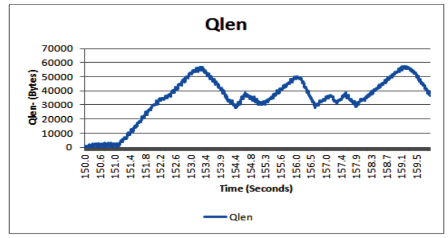

Figure 7. Qlen with load estimation

Fig. 7 shows the queue length at the base station output buffer when WFIAC admits/rejects incoming connection based on available resources and also on the estimation of load in network. Fig. 7 shows that when the queue length rises above the target operating point, WFIAC admits connections only if it estimates that WFICC will be able to manage the load introduced by the incoming connection by degrading the connections of lower priority CoSs, otherwise it rejects the connection. Once the load in the network stabilizes its operation below or at the target operating point, WFIAC again starts admitting the connections. So in Fig. 7 the queue length is around the target operating point.

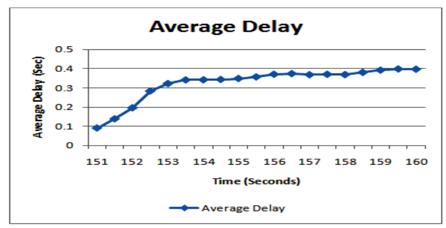

Figure 8. Average Delay with load estimation

Fig. 8 shows when the traffic in the network increases the average delay at the base station output buffer also increases. Initially as there is less amount of data in the queue, so the delay is small. As the transmission starts the data in the queue builds up resulting in an increase in the delay. Fig. 8 shows that when the queue length increases beyond the target operating point, the average delay of connections increases but as soon as the queue length reduces and remains around the target operating point the average delay becomes stable.

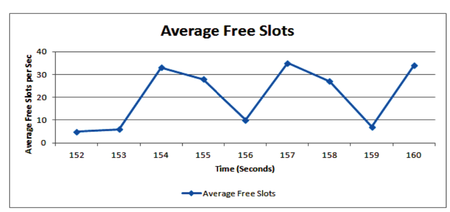

Figure 9. Average Free Slots with load estimation

Fig. 9 shows the average number of free slots in the network. In the current scenario if an incoming connection request comes and resources are available in the network then WFIAC admits the connection only if it estimates the incoming connection will not degrade the minimum QoS level of existing connections, so the average number of free slots is overall a value larger than the scenario when WFIAC admits connection without load estimation as shown in Fig. 5.

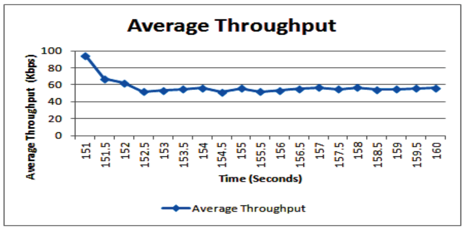

Figure 10. Average Throughput with load estimation

Fig. 10 shows that when the congestion in the network increases average throughput of all the connections in the network decreases. Fig.10 shows that when the queue length increases above the target operating point, the throughput starts reducing which can be contributed to the increasing delay as shown in Fig. 8 but as soon as the queue length reduces and remains around the target operating point the throughput becomes stable. So even if the average number of free slots is higher as shown in Fig. 9 the overall average throughput of network is better than the scenario when the network admits connections without load estimation as shown in Fig. 6.

So when WFIAC admits/rejects incoming connections based on the load estimation in the network, it can maintain the queue length at the base station output buffer around the target operating point and this results in lower blocking probability, smaller average delay, stable and slightly better average throughput for all connections in network as shown in Fig. 8 and Fig. 10.

VI. CONCLUSION

In this paper we presented an intelligent admission control scheme namely WFIAC. By using different network scenarios we presented an evaluation of the performance of proposed WFIAC scheme through simulation. The results showed that when network is lightly loaded, WFIAC performs extremely well in terms of lower blocking probability and preserving the QoS provisioning to existing connections. When the network is congested there is a tradeoff between blocking probability of UGS connections and QoS of existing connections. As WFIAC ensures the QoS of existing connections in terms of bandwidth and delay guarantee by rejecting the incoming connections until the queue length at the base station output buffer reduces to the target operating point. As soon as the queue length reaches the target operating point, the WFIAC starts admitting the connections. The results also showed that when the network is lightly loaded, higher bandwidth is allocated to existing connections that cause the extra allocation increase the efficiency of the network, yet the network is kept stable around the target operating point. So our proposed AC is well suited to the network that wants to ensure the QoS of existing connections in terms of throughput and delay.

REFERENCES

[1] H. Y. Tung, K. F. Tsang, L. T. Lee, and K. T. Ko, "QoS for Mobile WiMAX Networks: Call Admission Control and Bandwidth Allocation," in *Consumer Communications and Networking Conference, 2008. CCNC 2008. 5th IEEE*, 2008, pp. 576-580.

[2] Ieee 802.16-2005, "Part 16 : Air interface for Fixed and Mobile Broadband Wireless Access Sytems," *IEEE Standard for local and Metropolitan Area Networks,* October 2004.

[3] A. Antonopoulos and C. Verikoukis, "Traffic-Aware Connection Admission Control Scheme for Broadband Mobile Systems," *Communications Letters, IEEE,* vol. 14, pp. 719-721, 2010.

[4] S. B. Chaudhry and R. K. Guha, "Adaptive Connection Admission Control and Packet Scheduling for QoS Provisioning in Mobile WiMAX," in *Signal Processing and Communications, 2007. ICSPC 2007. IEEE International Conference on*, 2007, pp. 1355-1358.

[5] S. Murawwat, S. Aslam, and F. Saleemi, "Urgency and Proficiency Based Packet Scheduling & CAC Method for IEEE 802.16," in *Wireless Communications, Networking and Mobile Computing, 2009. WiCom '09. 5th International Conference on*, 2009, pp. 1-4.

[6] H. Wang, W. Li, and D. P. Agrawal, "Dynamic admission control and QoS for 802.16 wireless MAN," in *Wireless Telecommunications Symposium, 2005*, 2005, pp. 60-66.

[7] Hou Fen, Ho Pin-Han, and Shen Xuemin, "WLC17-1: Performance Analysis of a Reservation Based Connection Admission Scheme in 802.16 Networks," in *Global Telecommunications Conference, 2006. GLOBECOM '06. IEEE*, 2006, pp. 1-5.

[8] Jiang Chi-Hong and Tsai Tzu-Chieh, "Token bucket based CAC and packet scheduling for IEEE 802.16 broadband wireless access networks," in *Consumer Communications and Networking Conference, 2006. CCNC 2006. 3rd IEEE*, 2006, pp. 183-187.

[9] Luo Sida, Li Zhishu, Hu Jian, Liu Tao, and Cai Biao, "A Policy-Based CAC Scheme for Fixed WiMAX System," in *Communication Software and Networks, 2009. ICCSN '09. International Conference on*, 2009, pp. 376-379.

[10] S. Kalikivayi, I. S. Misra, and K. Saha, "Bandwidth and Delay Guaranteed Call Admission Control Scheme for QOS Provisioning in IEEE 802.16e Mobile WiMAX," in *Global Telecommunications Conference, 2008. IEEE GLOBECOM 2008. IEEE*, 2008, pp. 1-6.

[11] Wang Liping, Liu Fuqiang, Ji Yusheng, and Ruangchaijatupon Nararat, "Admission Control for Non-preprovisioned Service Flow in Wireless Metropolitan Area Networks," in *Universal Multiservice Networks, 2007. ECUMN '07. Fourth European Conference on*, 2007, pp. 243-249.

[12] S. Chandra and A. Sahoo, "An Efficient Call Admission Control for IEEE 802.16 Networks," in *Local & Metropolitan Area Networks, 2007. LANMAN 2007. 15th IEEE Workshop on*, 2007, pp. 188-193.

[13] Doan B. Hoang Fatima Furqan, "WFICC: A New Mechanism for Provision of QoS and Congestion Control in WiMAX," *IEEE Consumer Communication and Networking Conference, Jan, 2013.* .

[14] Ge Yin and Kuo Geng-Sheng, "An Efficient Admission Control Scheme for Adaptive Multimedia Services in IEEE 802.16e Networks," in *Vehicular Technology Conference, 2006. VTC-2006 Fall. 2006 IEEE 64th*, 2006, pp. 1-5.

[15] A. Ukil and J. Sen, "Proactive resource reservation in next-generation wireless networks," in *Communications (NCC), 2010 National Conference on*, 2010, pp. 1-5.

[16] Fatima Furqan and Doan B. Hoang, "Wireless Fair Intelligent Congestion Control - A QoS performance evaluation," *Parallel and Distributed Computing, Applications and Technologies,* Dec, 2012.

[17] The network simulator ns-2 http://www.isi.esu/nsnam/ns.

[18] WiMAX- ns2 http://code.google.com/p/ns2-wimax-awg/source/checkout.