A Dynamic Admission Control for IEEE802.16e Wireless Network

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Abstract

The grunt/request mechanism in IEEE 802.16e MAC provides different Quality of Service (QoS) for different service flows, wherein the call admission control(CAC) comparing the network resource available in the system with requirement of the QoS of the connection to decide if a connection can be admitted is an important stage to guarantee the QoS of each connection. Aiming at the current CAC's shortcoming of lower utilization of network resource and incomplete guarantee of QoS due to a static, constant and identical network resource for each connection, a dynamic resource allocation based admission control is proposed in this paper. In order to realize the dynamic admission control, a user-oriented based connection-oriented resource allocation is investigated at first in this paper. The novel CAC works together with such adaptive resource allocation based on OFDMA, where the resource is distributed to each connection according to the priority of the connection and channel condition of the user subjected to the connection's QoS and the admission decision is made by satisfaction to requirement of QoS , so the QoS of the connection is guaranteed, meanwhile, the utilization of network source can be maximized. The simulation results reveal that the number of the user admitted with the novel strategy and the utilization of the network resource is much larger than that with traditional algorithm.

Keywords: *QoS support, user-oriented resource allocation, connection-oriented resource allocation, , number of the user; utilization of network resource.*

1. Introduction

Not only providing high capacity and long distance coverage but also QoS guarantee for telecom-level service in internet by a connection-oriented MAC protocol, where the grunt/request mechanism provides different Quality of Service (QoS) for different service flows, EEE802.16e wireless network is having received extent research. Call admission control(CAC) is used to decide if a new arrived call or an old call with changed QoS should be admitted based on the network resource obtained by it in each connection creation, which satisfy the requirement of QoS and simultaneously make the utilization of network resources optimal. However, the algorithm for CAC is not specified in IEEE802.16e standard, so it attracts people's attention. A simple admission control is adopted by using the Minimum Reserved traffic rate in [1], due to that the connection having the lowest priority be admitted earliest, the QoS of these connections will not be guaranteed. A CAC algorithm which supply the highest priority to UGS to get adequate bandwidth and simultaneously maximize the utilization of bandwidth with borrowing criteria where the resource of the lower-priority connection is borrowed by that with the higher-priority is proposed in [2].Both above are strategy based on flow rate for every connection. Alternatively, the policy based on the number of users being admitted is proposed in [3]. A defect of all these mentioned above is that a constant and identical rate provided by network to each user or connection in admission control algorithm is assumed. In fact, the channel of linked user or connection is different with each other and the link adapting technology corresponding to channel led to the different capacity and furthermore the adapting resource allocation matching the capacity, resulting in the difference and time-varying of the network resource obtained by each user or connection. So the current admission control algorithm which assume constant and identical bits rate for each connection will make the resource of the user or connection in good channel redundant and that of those in bad channel deficiency such that the QoS can not be guaranteed. Due to the fact mentioned above, establishing a dynamic resource allocation based CAC which take the channel condition and the corresponding resource allocation into consideration is necessary. Such method combines the physical condition with information space of internet intelligently, which reveal the integration trend of the physical space and information and is the key

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component of the pervasive computing.

Orthogonal frequency division multiple access (OFDMA) is adopted by IEEE802.16e as access technology. In OFDMA, the set of subchannels are shared by multiple users, named multiuser diversity that enable each user to select the best channel and optimized bit and power allocation algorithm for maximizing the utilization of network resource, which brings new opportunities for the allocation of resource among multiple user. Meanwhile, admitting new call by adaptive resource rather than average resource is significantly important. So resource allocation plays very important role in CAC of IEEE802.16e wireless network. Some adaptive resource allocation based on OFDMA have been discussed in[4][5][6][7] ,in which the main method is assigning the subcarrrier to the user by the greedy algorithm and allocating the bits and power by waterfilling approach so as to optimize the system. However, all these are user-oriented based on OFDMA but not connection-oriented, which results in an inefficacy when it is used in connection-oriented CAC of IEEEE802.16e.So a novel connection-oriented adaptive resource allocation based on OFDMA is proposed at first in this paper.

The remainder of this paper is organized as follows. In section Ⅱ , the QoS support in IEEE802.16e wireless network is narrated. In sectionⅢ, a connection-oriented adaptive resource allocation algorithm is discussed which take the fairness between the users and the priority of service flow into consideration. In section Ⅳ, a dynamic CAC strategy is investigated. Some numeric results is shown in sectionⅤ, which indicates the improvement of the performance of the novel strategy. In section Ⅵ,we conclude our work.

2.QoS support in IEEE802.16e wireless network

IEEE802.16e standard defines a connection-oriented MAC protocol and each connection created between the Subscriber stations (SS) and Base Station (BS) is identified by a 16 bit connection identifier (CID). The QoS scheme is in fig.1.The bandwidth allocation is done based on two ways:(i) Grant Per Connection (GPC),in which bandwidth is assigned to each connection, and (ii) Grant Per Subscriber Station (GPSS), in which SS re-distributes the transmission slots allotted by the BS to its all connections.

The IEE802.16 standard provides mechanism to support QoS, defining four types of service flows with different QoS requirements for each. 1) Unsolicited Grant Service (UGS) is designed to support real-time service flows that generate fixed size packets on periodic basis, such as TI, El and VoIP without silence suppression. The BS allocates fix size granting to the UGS at periodic intervals without any explicit request from the SS, which eliminates the overhead and the latency of bandwidth requests so as to meet the real time requirement of UGS service. 2) Real Time Polling Service (rtPS) is designed to support real-time service flows that generate variable size data packets on a periodic basis, such as MPEG video. The BS provides periodic dedicated request opportunities for SS to meet flow's real-time demands. In order for the service to work appropriately, the SS is allowed to use only unicast request issued by BS for connection and is prohibited from using any other contention request opportunities. 3) Non-Real Time Polling Service (nrtPS) is introduced for non-real-time flows which require variable size data granting on a regular basis, such as high bandwidth FTP. The nrtPS is almost the same as the rtPS except that connections may utilize random access transmit opportunities for sending bandwidth request.4) Best Effort Service (BES) is designed to support best effort traffic such as email and offers no QoS guarantee. The SS is allowed to use contention request opportunities as well as unicast request opportunities for BE service flow.The interval of unicast request opportunities should be longer than the nrtPS and the availability of dedicated opportunities is subject to the network load.

The four different class connection are the base for resource allocation and admission control.

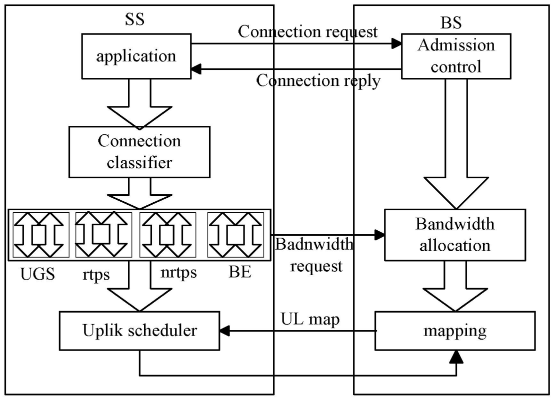

Fig.1 QoS architecture of IEEE802.16e

The current admission control algorithm is described in (1)(2).

$$N_{\max} = \frac{FD - OH_1 - OH_2}{FD * 8M\frac{\lambda}{R} + K * STG} \quad (1)$$

$$\sum_{i=1}^{N} R_c(i) + R_c(N+1) \le R_{TC} \quad (2)$$

In (1),the biggest number users available is computed, where *FD* is the frame duration and *M* is the packet size of the application in bytes. OH_1, OH_2 are the overhead of *UL* and *DL*, respectively. *K* is the number of stations active in the IEEE802.16e system. *STG* is the Station

Transition Gap. λ is the arrival rate of data and R is the bits rate provided by physical layer. In (2), how a new call is admitted is described, where $Rc(i)$ is the mean resource required for i th call, R_{TC} is the total resources available in the IEEE802.16e system. From (1) and (2), we can see that the bits rate, or named resource required, is assumed constant for all connection or user in admission control procession, which make the utilization of network resource lower due to not adapting to channel condition thus led to no guarantee for QoS of connection.

3.Connection-oriented adaptive resource allocation

Connection-oriented adaptive resource allocation is designed for QoS guarantee supported by connection defined in IEEE802.16e. In order to realize such a design, the user-oriented resource allocation should be taken into consideration at first, where it is assumed that each user can fairly obtain the network resource, such as subcarrier, power, bits rate and so on, according to the proportion of their required bits rate. Based on this, the resource assigned to each user will be allocated to its different class service flow according to the priority of different class connection.

3.1 User-oriented proportional resource allocation based on OFDMA

The block diagram for the downlink of a typical OFDMA system is shown in Fig2. The OFDM symbol is transmitted through a slowly time-varying, frequency-selective Rayleigh channel with a bandwidth B. It is assumed that each user experiences independent fading. We use the following notation:

- K is the set of users, $K = \{1, 2, 3 \cdots K\}$.
- N is the set of all subchannels, $N = \{1, 2, 3 \cdots N\}$.
- $c_{k,n}$ is the nth subchannel usage index for user k. $c_{k,n} = 1$ if and only if subcarrier n is assigned to user k.
- P_{tot} is an allocated power to the user k in subchannel n.
- $g_{k,n}$ is the channel gain of user k in subcarrier n and the corresponding subcarrier signal-to-noise ratio (SNR) is thus denoted as $h_{k,n} = g_{k,n}^2 / \sigma^2$ and the kth user's received SNR on subcarrier n is $\gamma_{k,n} = h_{k,n} p_{k,n}$.
- M is the level of M-level MQAM used on subcarrier to modulate the bits on it.
- R_k is bit rate of the $k\,th$ user on total subcarriers denoted as: $R_k = \frac{B}{N}\sum_{n=1}^{N} c_{k,n} r_{k,n}$ (3)

In order that the BER constraints be met, the effective SNR has to be adjusted accordingly. The BER of a square M-level QAM with Gray bit mapping as a function of received SNR $\gamma_{k,n}$ and number of bits $r_{k,n}$ can be approximated to (4) within 1 dB for $r_{k,n} \geq 4$ and $BER \leq 10^{-3}$ as [10]:

$$BER_{MQAM}(\gamma_{k,n}) \approx 0.2\exp[\frac{-1.6\gamma_{k,n}}{2^{r_{k,n}} - 1}] \quad (4)$$

so $$r_{k,n} = \log_2(1 + \frac{\gamma_{k,n}}{\Gamma}) = \log_2(1 + p_{k,n} H_{k,n}) \quad (5)$$

where $\Gamma = -\ln(5BER)/1.6$ and $H_{k,n} = h_{k,n}/\Gamma$ .Our objective is to maximize the total data rate over all users subject to power and BER as well as each user's rate constrained. The problem can be formulated as (6)(7):

$$\max_{c_{k,n}, p_{k,n}} \frac{B}{N}\sum_{k=1}^{K}\sum_{n=1}^{N} c_{k,n}\log_2(1 + p_{k,n}H_{k,n}) \quad (6)$$

$$\text{subject to: } \begin{cases} C1: c_{k,n} \in \{0,1\}\forall k,n \\ C2: p_{k,n} \geq 0 \forall k,n \\ C3: \sum_{k=1}^{K} c_{k,n} = 1 \forall n \\ C4: \sum_{k=1}^{K}\sum_{n=1}^{N} c_{k,n}p_{k,n} \leq P_{tot} \\ C5: R_i : R_j = \phi_i : \phi_j \forall i,j \in \{1,\cdots K\}, i \neq j \end{cases} \quad (7)$$

At the same time, for C5,we compute the R_k according to : $R_k = r_{ugs} + r_{rtps} + r_{nrtps}$ (8)

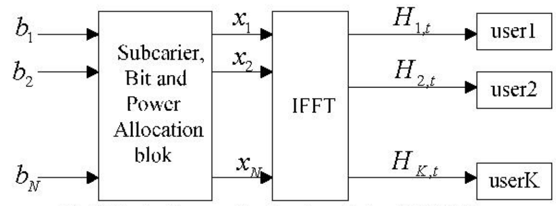

Fig.2 block diagram for the downlink of OFDMA

Combining(3)(6)(7),we can find the solution for this problem. But this is an NP-hard combinatorial optimization problem with non-liner constraints. Finding the solution to it is very complex and impractical. [4] give a simple iterative method as follows.

3.1.1.Computing the number of subcarrier per user

According to [4], the proportion of subcarriers assigned to each user is approximately the same as their eventual rates after power allocation , so

$$N_1 : N_2 : \cdots : N_K = \Phi_1 : \Phi_2 : \cdots : \Phi_K \;,\; N_k = \lfloor \Phi_k N \rfloor \quad (9)$$

$N^* = N - \sum_{k=1}^{K} N_k$ (10) is the unallocated subcarrier.

3.1.2. Subcarrier assignment

We maximize the overall capacity while maintain rough proportionality by a modified greedy algorithm.

(a).let $c_{k,n}=0, \forall k \in \{1,\cdots,K\} and \forall n \in \{1,\cdots,N\}$

$R_k=0, \forall k \in \{1,\cdots,K\}$, $p=P_{tot}/N$, $\mathbb{N}=\{1,2,\cdots,N\}$

(b)for *k=1 to K*

$$n^*=\arg\max_{n\in\mathbb{N}}|H_{k,n}|, N_k=N_k-1; \mathbb{N}=\mathbb{N}\setminus n^*$$

$$c_{k,n^*}=1, R_k=R_k+\frac{B}{N}\log_2(1+pH_{k,n})$$

(c) while $(N-\sum_{k=1}^{K}N_k)>N^*$

$$\mathrm{K}=\{1,2,\cdots,K\},\quad k^*=\arg\min_{k\in\mathrm{K}}(R_k/\Phi_k)$$

$$n^*=\arg\max_{n\in\mathbb{N}}|H_{k^*,n}|$$

if $N_{k^*}>0$,

$$c_{k^*,n^*}=1,\quad N_{k^*}=N_{k^*}-1, \mathbb{N}=\mathbb{N}\setminus n^*$$

$$R_{k^*}=R_{k^*}+\frac{B}{N}\log_2(1+pH_{k^*,n^*})$$

(d) $\mathrm{K}=\{1,2,\cdots,K\}$

for *n=1 to* N^*

$$k^*=\arg\max_{k\in\mathrm{K}}|H_{k,n}|, c_{k^*,n}=1$$

$$R_{k^*}=R_{k^*}+\frac{B}{N}\log_2(1+pH_{k^*,n}), \mathrm{K}=\mathrm{K}\setminus\{k\}$$

Alternatively, all the remained subcarrier in (d) can be left for future user.

3.1.3..Power and bits allocation

Power allocation is according to waterfill principle.We adopt the method in [4]:

For each user: $P_1=(P_{tot}-\sum_{k=2}^{K}\frac{b_k}{a_{kk}})/(1-\sum_{k=2}^{K}\frac{1}{a_{kk}})$

$$P_k=(b_k-P_1)/a_{kk} \qquad \forall k=2,\cdots,K$$

For each subcarrier: $P_{k,1}=\frac{P_K-V_k}{N_k}$

$$P_{k,n}=P_{k,1}+\frac{H_{k,n}-H_{k,1}}{H_{k,n}H_{k,1}}, r_{k,n}=\frac{B}{N}\log_2(1+p_{k,n}H_{k,n})$$

where $V_k=\sum_{k=2}^{N_k}\frac{H_{k,n}-H_{k,1}}{H_{k,n}H_{k,1}}, W_k=(\prod_{k=2}^{K}\frac{H_{k,n}}{H_{k,1}})^{\frac{1}{N_k}}$,

$$a_{k,k}=-\frac{N_1}{N_k}\frac{H_{k,1}W_k}{H_{1,1}W_1}$$

$$b_k=\frac{N_1}{H_{1,1}}(W_k-W_1+\frac{H_{1,1}V_1W_1}{N_1}-\frac{H_{k,1}V_kW_k}{N_k})$$

3.2.Connection-oriented resource allocation based on user-oriented algorithm

The basic idea is to allocate the resources, which include the assigned subcarrier and the bit rate on it belongs to any user, to each connection of each user according to the different priority of different service flow. Due to independence among the user, any one can be selected as example. It is assumed that the set subcarrier $\mathbb{N}_1$ is assigned to the user k_1 with four different priority connection, named UGS, rtps, nrtps and BE,whose priority decrease successively. We still adopt greedy algorithm to allocate the subcarrier with designed bits rate among the connections again. Letting $r_{UGS}, r_{rtps}, r_{nrtps}, r_{BE}$ denote the corresponding connection's bits rate, the allocation step is as follows:

(1) let $r_{ugs}=r_{rtps}=r_{nrtps}=r_{BE}=0$ at first and the maximum is $R_{UGS}, R_{rtps}, R_{nrtps}, R_{BE}$, $\mathbb{N}_1=\{1,2,\cdots,N_1\}$ and it is a subset of set N, with the assumption that the number n of $\mathbb{N}_1$ map the same value in set N. $c_{k,n,UGS}, c_{k,n,rtps}, c_{k,n,nrtps}, c_{k,n,BE}$ is the subcarrier occupation indicator for each connection.

(2)for *n=1 to* N_1

$$n^*=\arg\max_{n\in\mathbb{N}_1}|H_{k_1,n}|$$

if $r_{UGS}(t)<R_{UGS}(t)$

$c_{k_1,n^*,UGS}=1$,

$N_{k_1,UGS}=N_{k_1,UGS}+1, \mathbb{N}_1=\mathbb{N}_1\setminus n^*$

$r_{UGS}=r_{UGS}+r_{k_1,n}$

else if $r_{rtps}(t)<R_{rtps}(t)$

$c_{k_1,n^*,rtps}=1$, $N_{k_1,rtps}=N_{k_1,rtps}+1$,

$\mathbb{N}_1=\mathbb{N}_1\setminus n^*$

$r_{UGS}=r_{UGS}+r_{k_1,n^*}$

else if $r_{nrtps}(t)<R_{nrtps}(t)$

$c_{k_1,n^*,nrtps}=1$, $N_{k_1,nrtps}=N_{k_1,nrtps}+1$,

$\mathbb{N}_1=\mathbb{N}_1\setminus n^*$

$r_{nrtps}=r_{nrtps}+r_{k_1,n^*}$

else

$c_{k_1,n^*,BE}=1$, $N_{k_1,BE}=N_{k_1,BE}+1$,

$\mathbb{N}_1=\mathbb{N}_1\setminus n^*$

$r_{BE}=r_{BE}+r_{k_1,n^*}$

4.A dynamic admission control strategy

We proposed a dynamic resource allocation based admission control strategy working with the adaptive resource allocation based on OFDMA. At first, the maximum number of calls supported by IEEE 802.16e system is modified as:

$$N_{\max} = \frac{FD - OH_1 - OH_2}{(\frac{\lambda_{UGS}}{r_{UGS}^{avr}} + \frac{\lambda_{rtps}}{r_{rtps}^{avr}} + \frac{\lambda_{nrtps}}{r_{nrtps}^{avr}} + \frac{\lambda_{BE}}{r_{BE}^{avr}})FD * 8M + K * STG} \quad (11)$$

where, FD , OH_1, OH_2 , K , STG are designed as above. $\lambda_{ugs}, \lambda_{rtps}, \lambda_{nrtps}, \lambda_{BE}$ are the arrival rate for *UGS, rtps, nrtps* and *BE* connection, respectively, and $r_{UGS}^{avr}, r_{rtps}^{avr}, r_{nrtps}^{avr}, r_{BE}^{avr}$ is corresponding average bits rate. The average bits rate can be predicted by the least mean square error method such as $r_i^{avr}(m) = \sum_{n=1}^{m-1} \omega_n r_i^{avr}(m-n)$,where $r_i^{avr}(m)$ is the average rate of the *i*th connection at the *m*th time, ω_n is the weight coefficient obtained by principle of orthogonal projection.

Whenever a new call or connection with modified QoS arrive, the BS determined whither it is a new user at first. If it is, there is two ways to process it. The one is that the new user together with the registered user re-distribute the network resource as mentioned in Ⅲ.1 , such as subcarrier and bite rate. At this time, if there is not enough resource to support all user, it is supposed to satisfy the QoS of registered user while reject the new call. The other way is that the new user can only obtain the remained subcarrier after the registered user. The following step is to distribute the resource among the different connection of the same user according to priority by greedy algorithm mentioned in Ⅲ.2. In order to guarantee the QoS of UGS connection, the subcarrier and corresponding bits assigned to it should be kept invariant. The admission criterion is shown in (15) and (16). When there is not enough resource to support all connections, it is supposed to support the UGS ,rtps and nrtps connection having already existed in system , which mean that the resource for BE of registered connection will be borrowed by the new connection with higher priority.

If the new call is only a new connection of the registered user, the resource is re-distributed among the different connection of the same user according to priority by greedy algorithm mentioned in Ⅲ.2.The admission criterion is shown in (12) and (13).When there is not enough resource to support all connections, it is supposed to support the UGS and rtps connection which have already exist in system at first.

Let R_k be bits rate obtained by user k from the system. If there are n_1 *UGS* connection and n_2 *rtps* connection as well as n_3 *nrtps*, the following formula must be satisfied:

$$\sum_{i=1}^{n_1} r_{i,UGS} + \sum_{i=1}^{n_2} r_{i,rtps} + \sum_{i=1}^{n_3} r_{i,nrtps} \le R_k \quad (12)$$

$$r_{i,class} \ge R_{i,class} \quad (13)$$

Where class can be UGS, rtps and nrtps, $r_{i,class}$ is instantaneous bits rate and $R_{i,class}$ is the corresponding requirement of QoS. The process of admission control is shown in fig3.

5. Numerical Results

In our simulation, we assume that the new connection's arrival obeys the Poisson distribution .For each user, the total arrival rate is λ_{total} , and the arrival rate for UGS, rtps, nrtps are $\lambda_{UGS} = \lambda_{total}/3$, $\lambda_{rtps} = \lambda_{total}/6$ and $\lambda_{nrtps} = \lambda_{total}/2$,respectively. For convenience, we assumed each user has the same service quantity with 42bits/s and $\lambda_{total} = 1$.

An OFDM with 512 subcariers is adopted to base the admission control working together with the adaptive resource allocation. The wireless channel quality of each connection remains constant per frame, but is allowed to vary from frame to frame. For each user, the multipath include four discriminable paths composed of 11 indiscriminable paths based on Jakes' model. AMC is implemented on a frame-by-frame basis Perfect channel state information (CSI) is available at the receiver relying on training-based channel estimation. The corresponding transmission mode selection is fed back to the transmitter without error and latency. The transmission mode based on convolution code cascaded with CRC-16 error detection is shown in table Ⅰ.

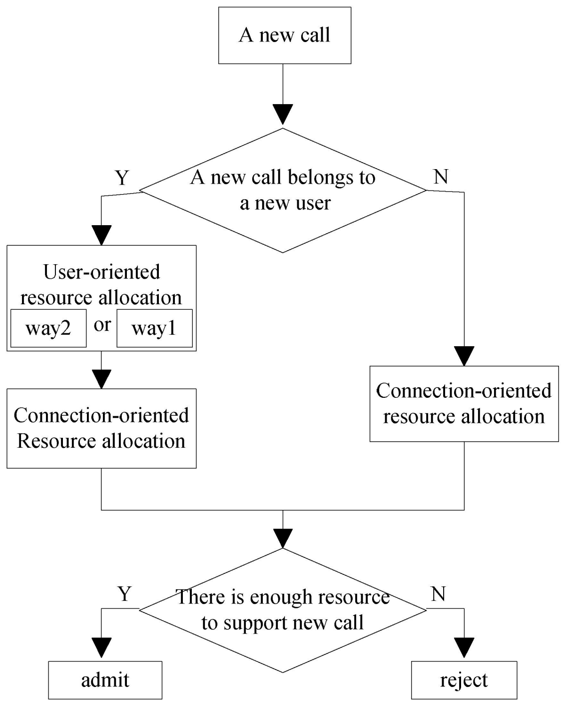

Fig.3 dynamic admission control procession

Table Ⅰ MCS and corresponding thresholds

	Mode1	Mode2	Mode3	Mode4	Mode5	Mode6
调制	BPSK	QPSK	QPSK	16QAM	16QAM	64QAM

码率	1/2	1/2	3/4	9/16	3/4	3/4
效率	0.50	1.00	1.50	2.25	3.00	4.50
γ_{pn}	-1.5331	1.0942	3.9722	7.7021	10.2488	15.9784

The adaptive resource allocation strategy mentioned in section3 and the dynamic admission algorithm control mentioned in section 4 are adopted in our simulation.Fig.4 compares the maximum number of user admitted by system with different signal noise ratio(SNR),which shows that the number increase with the increased SNR in dynamic admission control while lower increment in traditional admission control where the transmission mode is decided by the average SNR resulting in the lower bits rate for all connection.Fig.5 compares the bits rate for BE connection between the two different strategy when the resource requirement for UGS,rtps and nrtps connection is satisfied and invariant, which shows that the bits rate for BE connection in our dynamic system is much larger than that in traditional system.

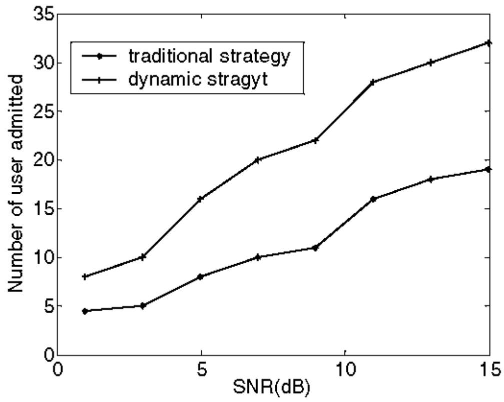

Fig.4 number of the user admitted

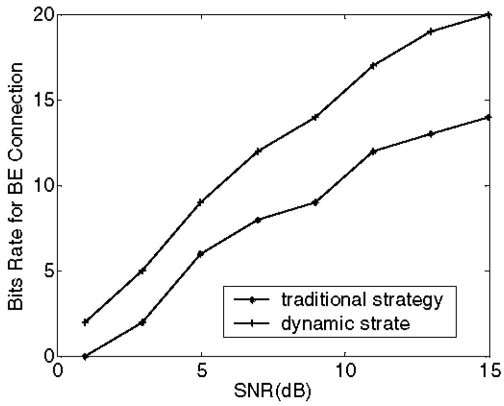

Fig.5 bits rate for BE connection

6.Conclusion

A novel dynamic admission control is proposed in this paper. Unlike the traditional CAC with lower utilization of network resource and incomplete guarantee of QoS due to a static, constant and identical network resource for each connection being assumed, the novel CAC works together with the adaptive resource allocation based on OFDMA, wherein the resource is distributed to each connection according to the priority of the connection and channel condition of the user subjected to the connection's QoS and the admission decision is made by that if the QoS be satisfied, so the QoS of the connection can be guaranteed and simultaneously the utilization of network source maximized. At the same time, a connection-oriented resource allocation based on a user-oriented is investigated in this paper. We believe that the work presented in this paper is the first step of our research on CAC of IEEE802.16e wireless MAN. Some work ,such as multiple QoS parameters combination for one connection and adaptive resource allocation subjected to this combination as well as corresponding admission decision , is very important in CAC. We are planning to investigate these issues in our future work.

Refrence

[1] Chen Jianfeng, Jiao Wenhua, Wang Hongxi," A Service Flow Management Strategy for IEEE 802.16 Broadband Wireless Access Systems in TDD Mode" [C],*Int Conf Communications 2005. Piscataway,NJ: IEEE Press*, 2005:3422-3426.

[2] Wang Haitang, Liwei, A grawal D P, "Dynamic Admission Control and QoS for 802.16 Wireless MAN "[C],*Wireless Telecommunication Symposium.Piscataway, .2005, NJ:IEEE Press*, 2005: 60-66.

[3] J. Jackson ,Juliet Roy, V. Vaidehi, S.Srikanth, "Always Best-Connected QoS Integration Model for the WLAN, WiMAX Heterogeneous Network"[C], *First International Conference on Industrial and Information Systems,* ICIIS 2006,p361-366

[4]Ian C, Wong, Zukang Shen, Brian L. Evans and Jeffrey G. Andrews, "A Low Complexity Algorithm for Proportional Resource Allocation in OFDMA Systems"[C], *2004 IEEE [Workshop on Signal Processing Systems Design and Implementation, Proceedings*, 2004, p 1-6

[5]Sameh Najeh, Hichem Besbest, Ammar Boualleguet," Greedy Algorithm for Dynamic Resource Allocation in Downlink of OFDMA System"[C], *2nd International Symposium on Wireless Communications Systems 2005, ISWCS 2005 - Conference Proceedings,* 2005, p 475-479

[6] Mustafa Ergen, Sinem Coleri, Pravin Varaiya, "QoS Aware Adaptive Resource Allocation Techniques for Fair Scheduling in OFDMA Based Broadband Wireless Access Systems", *IEEE Trans. on Broadcasting*, 2003, 12,p36-370

[7]Cheong Yui Wong, Roger S. Cheng, "Multiuser OFDM with Adaptive Subcarrier,Bit, and Power Allocation"[J], *IEEE Journal on Selected Areas in Comm.*,1999,10,p1747-1758

[8] IEEE Std 802. 16-2004. *IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Fixed Broadband W ireless Access System s [S]. Piscataway, NJ:IEEE,* 2004