Heterogeneous Network Bandwidth Allocation Method based on the Business Characteristics

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Abstract **— To address the demand for different business types and the effectiveness throughput of heterogeneous networks, we study: i) business delay models based on stochastic service system theory, then ii) analyze the effect on: a) the performance of business delay, and b) slot position distribution. The instant messaging service is introduced into service types of heterogeneous networks. A kind of multi-user bandwidth allocation method based on the characteristics of business awareness is proposed and, according to the characteristics of different businesses, we express: i) the uplink frame joint perception, ii) the minimum required bandwidth, iii) downlink bandwidth allocation algorithm (UCDBAA) based on TCBAA to satisfy the bandwidth of multiple users. This can: i) guarantee the transmission of packets less than a certain threshold in probability, thus ii) setting reasonable threshold value and iii) analyzing the effect of the threshold on the stability of the system. The simulation results show that UCDBAA makes more users meet the QoS requirements of the heterogeneous network, and channel utilization is improved under the condition of the lack of bandwidth.**

Keywords - heterogeneous, characteristics of perception, QoS, bandwidth allocation

I. INTRODUCTION

In recent years, the users' demands increase with the continuous development of wireless access technology. people gradually realize that the form that the user only can access a single network causes some problem, such as the needs of users can not meet and some network congests. To address this problems and improve user satisfaction, resources of heterogeneous wireless network should be effective use and multi-mode terminals need to be able to access different networks at the same time. At present the problem of bandwidth resource scarcity of network is increasingly serious. Therefore, bandwidth allocation problem in the heterogeneous wireless network has attracted more and more people's attention and research. Study pointed out that cognitive radio technology is first option[1] to solve the above problems. The introduction of cognitive radio technology in the network becomes a hot spot in recent years.

IEEE802.16 standard is air interface standard for fixed and mobile broadband wireless access systems，which early standards have backward compatibility. The system is the effective solution to solve the wireless channel fading problem under the premise of low-cost. The current IEEE 802.16 system have done the corresponding regulations for the bandwidth requested way of each business type. Users send the bandwidth request to the base station through the uplink, the base station allocates the bandwidth request to the corresponding bandwidth allocation module, in which the user bandwidth allocation information will be produced and sent to the users through the downlink channel depending on the type of business-related QoS parameters and other conditions of the users. In the bandwidth allocation mechanism, there is few specific bandwidth allocation methods which have be presented.

According to the bandwidth allocation mechanism of IEEE802.16 standard. People put forward some corresponding bandwidth allocation method. In order to improve bandwidth utilization, a greedy weighted bandwidth allocation algorithm (GWA) based on weight was proposed according to bandwidth required for different business types [1]. In [2] introduces that uplink transmission scheduling requests (SRs) may be prohibited for a lower priority data flow to make more efficient scheduling achieve. [3] proposes an algorithm for bandwidth allocation that used two phase extra bandwidth allocation policy and compensation strategy according to the service flows' type and state.[4] proposes virtual partitioning resource allocation schemes for best effort and guarantee access with preemption for best effort traffic.[5] proposes an enhance model for performance analysis of an energy saving mechanism in the IEEE 802.16e broadband wireless access (BWA) network.[6] proposes a bandwidth allocation scheme for WiMAX networks using fuzzy logic concepts.[7][8]An efficient dynamic pricing scheme for optimal network resource utilization in Mobile WiMAX network has been developed and validated.[9] developed a context-aware ertPS algorithm which gathers statistics on the numbers of request headers of medium access control layer management messages among various subscriber stations.

The IEEE 802.11n standard defines many new physical and medium access control (MAC) layer enhancements[10] , however, the MAC protocol as the mainstream of the wireless LAN failed to convert physical capacity of ascension to improve throughput[11], Many bandwidth allocation schemes[12-15] have been proposed according to the minimum bandwidth, but given no estimation method of the minimum bandwidth. [16] proposes TCBAA algorithm which can dynamically adjust bandwidth allocation of the real-time access. About the slot allocation of resources, the main research how to distribute the appropriate bandwidth for terminal (timeslot number/frame) to ensure the quality of service (QoS) of the business and delay performance at present. The research of how to distribute the concrete position of the slots in the frame and the influence of the length of frame on the business delay is very few.

In this paper，we choose the WLAN based on IEEE802.11 standards and WiMAX based on IEEE802.16 standards as the representative of heterogeneous networks.[17]proposes a heterogeneous network bandwidth allocation algorithm which combines with routing strategy and regulate the bandwidth of the heterogeneous network to make network load capacity increased.[18]proposes a novel bandwidth utilization optimization technique which realizes the optimization problem using the hybrid genetic algorithm to make bandwidth allocation more efficiently. In[19]an optimal resource allocation scheme is proposed in heterogeneous wireless networks. The scheme makes the users' quality of experience (QoE) maximized. [20]proposes a energy efficient resource allocation algorithm and design parameters to make the overall energy efficiency of the network maximized according to QoS requirements. [21]proposes a jointly optimal power and bandwidth allocation algorithm to make the network utility function maximized and meet the QoS requirements of the users.

MAC protocols in a heterogeneous network, according to its own delivery mechanism, generally can be divided into the following two types. The first type is based on the slot competitive of the bandwidth distribution agreement, the second type is based on the slot allocation scheduling mechanism, the main idea of this kind of agreement is that the time axis is divided into frames. These distribution patterns do not consider the imbalance of node business, according to the priority as much as possible the node has slots during the competition phase, without taking into account the user's own bandwidth requirements, and in the case of insufficient bandwidth, cannot guarantee that most users access the networks.

The above-mentioned bandwidth allocation method focuses on how to allocate bandwidth to meet quality of service requirements can not take into account the minimize delay and maximize throughput, have to sacrifice the validity of throughput in order to meet the needs QoS of users, can not be guaranteed the maximum number of access users under the condition of the bandwidth is insufficient. The method of allocating bandwidth by this paper studies heterogeneous network under limited bandwidth. A bandwidth allocation algorithm (UCDBAA) based on the TCBAA is proposed to solve the problem of allocate bandwidth of heterogeneous network can not guarantee the access number of users is the largest. Bandwidth is cognitived according to the delay of business minimum, and according to the size of the penalty function to dynamically adjust the bandwidth of users. Thus the users' demand for bandwidth and network throughput achieve to the balance. And set the value of the threshold to ensure the stability of the system.

Instant communication service is added in service type to adapt to business changes of the heterogeneous network，the business types are divided into three types which are real-time business, instant communication and non real-time business. The business performance of real-time business and instant communication is analyzed. The simulation results show that the UCDAA increases the total number of users who satisfied the QoS requirements under the premise of guaranteeing the effectiveness of the network throughput

II. THE SYSTEM MODEL

In this paper, we consider the bandwidth assigned by the base station. The base station estimates the minimum rate of the user according to the packet delay and other information on the uplink, then dynamically adjusts the size of the allocation bandwidth for the users on the downlink.

Due to different slot location allocation lead to different slot interval distribution, different service time led to the slot position allocation methods are also different.

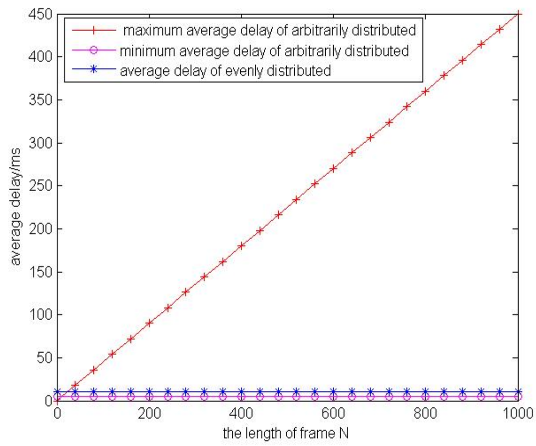

Figure 1 Relationship between delay and frame length

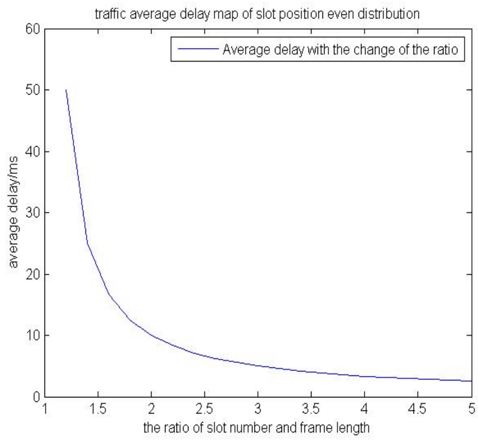

Figure 2 Relationship between average delay slot of position uniform distribution and α

From Figure 1 to Figure 2, it is straightforward that the additional delay is led to due to holiday, The delay of slot position evenly distributed queue is almost the same as the minmum delay of M/G/1/ ∞ system, the business delay is only associated with the ratio of slot number and the frame and has nothing to do with the length of the frame. So this paper uses the slot position even distribution.

A. The minimum rate of uplink

At present the effective method to solve the business with delay requirement is the equivalent bandwidth[22]. Assuming that $D(s)$ denotes packet queuing delay of the sth frame, $D_{\max}$ denotes the maximun queuing delay, $\beta(\mu)$ is used to characterize QoS parameters of the business emergency degree, $\varepsilon_{\max}$ is the probability that the queuing delay of packet exceeds the maximum delay. The state, $p_{k,\mu}$ is the probability of system which has k packets, $p_{0,\mu}$ can be obtained by cognitive, so we can get constraint of transmission delay is smaller, the service rate of the same amount of data need for more. By the [22-24] we can expressed as below.

$$\exp(-\beta(\mu)\mu D_{\max}) \le \varepsilon_{\max} \tag{1}$$

$$\exp(-D_{\max} / E_{\mu}(D(\infty))) \le \varepsilon_{\max} \tag{2}$$

Assumptions that we can get the relationship between $E_{\mu}[D(\infty)]$ and μ passing the business characteristic parameters, which can be satisfied the minimum service rate.

1)Poisson characteristic parameter analysis:

The packet arrival interval is in accordance with typical negative exponential distribution,when we know $D_{\max}$ and $\varepsilon_{\max}$. And the packet arrival rate can be achieved through cognitive, when cognitive time is long, according to the law of large Numbers, which satisfied the minimum service rate of Eq. (3).

$$\mu_{\min} = \hat{\lambda} - \frac{\ln(\varepsilon_{\max})}{2D_{\max}} \tag{3}$$

Assuming that T is the observation time, T can be divided into M equal parts,

$Y_j(j = 1,2,3,\cdots,M)$ denotes the jth arrived data grouping. The estimate of the average arrival rate as follows:

$$\hat{\lambda} = \frac{\sum_{j=1}^{P} Y_j}{T} \tag{4}$$

When the packet length of the sth user is l_i, the minimum service rate of the sth user can be expressed as Eq. (3).

2) The non poisson characteristic parameter analysis:

When the packet arrival interval does not necessarily comply with negative exponential distribution, this arriving interval distribution is unable to function at formula using mathematical. The corresponding relationship between $E_{\mu}[D(\infty)]$ and μ can be get through packet arrival interval on the numerical statistics, the minimum service rate $\mu_{\min}$ is still able to get. Assuming that $\hat{p}_n(t_i)$ is the probability of reaching n data grouping on arbitrary interval t_i. Under the stable

the probability that the number of packet is 1 under the steady state. The probability distribution of System is obtained by repeated iteration under the service rate of μ.

The average waiting delay of packet is

$$E_{\mu}[D(\infty)] = \sum_{k=2}^{n}(k-1)p_{k,\mu} \quad (5)$$

Putting the probability distribution into the Eq.(9) can be concluded that the relationship between $E_{\mu}[D(\infty)]$ and μ. The minimum service rate satisfied QoS can be get from the above statistics method.

B. Downlink bandwidth allocation method

In order to make the limited bandwidth resources to meet the needs of more users QoS demand, the service rate can be distributed to maximize each frame transmission business successfully under the condition that allocated bandwidth is less than the total bandwidth and service rate is no more than the overall service rate. Assuming that $B_{is}(s)$ denotes the successful amount of data of the ith user of the sth frame that the transmission delay is not greater than $D_{\max}$, $B_{if}(s)$ denotes the successful amount of data of the ith user of the sth frame that the transmission delay is greater than $D_{\max}$, $\varepsilon_{\max}B_i(s)$ denotes the greatest amount of data transmission failure that the ith user can withstand, According to the following cases:

(1) we invoke the remaining bandwidth for all users when the bandwidth can meet the QoS requirements of all users.

(2) we invoke the algorithm to search out the optimal group of users,when the remaining bandwidth is insufficient to meet the minimum bandwidth requirement. Eliminate the user whose packet is long to maximize the access number.

In order to adjust the bandwidth dynamically, the objective function is given as

$$J(s) = \sum_{i=1}^{M}(B_{is}(s) + p_i(g_i(s))g_i^2(s)), i \in I \quad (6)$$

Define the error function

$$g_i(s) = B_{if}(s) - \varepsilon_{\max}B_i(s) \quad (7)$$

Define the punishment function

$$p_i(g_i(s)) = \begin{cases} 0 & g_i(s) \le 0 \\ K & g_i(s) > 0 \end{cases} \quad (8)$$

$$\text{s.t.} \quad \sum_{i=1}^{M} f_i(s) \le f_S \quad (9)$$

Where I is the number of users in the user group.

By the objective function formula shows the following two cases:

$B_{if}(s) < \varepsilon_{\max}B_i(s)$, the error function $g_i(s) \le 0$,the distribution service rate of the ith user meet the QoS requirements, the punishment function is zero.

(2)At that time $B_{if}(s) > \varepsilon_{\max}B_i(s)$, the error function $g_i(s) > 0$,the distribution service rate of the ith user do not meet the QoS requirements, the punishment function is K.

Analysising the value of K impacts on the business performance. Assuming that the total number of N = 80. The number of real-time business and the number of non real-time business is 50% each. The size of the value of K impacts on business performance is expressed as Figure 1.

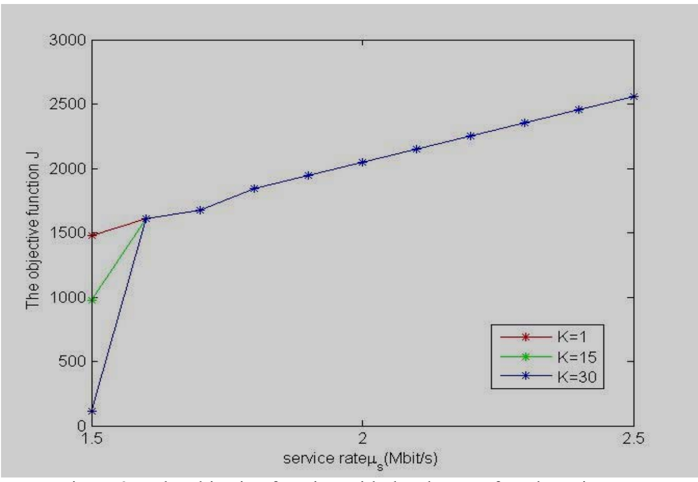

Figure 3 The objective function with the change of total service rate

The objective function drops fastest when the total service rate is insufficient when k is equal to 30. The objective function gradually decreases with the reduction of service rate when the value of K becomes smaller by the large. The value of K becomes smaller, the rate of decline becomes slower and the lower of the sensitivity to demand of the service rate becomes smaller. But that the value of K is too large will cause system dramatic changes in the system, selecting the value of K reasonably is conducive to the stability of the system.

Defining K is the stability of the system when the value of K is different.

$$\delta_K = \sum \frac{J_{\mu_{S(n+1)}} - J_{\mu_{Sn}}}{J_{\mu_{Sn}}} * 100 \quad (10)$$

The value of the objective function is $J_{\mu_{S(n+1)}}$ when the service rate is $\mu_{S(n+1)}$; The value of the objective function is $J_{\mu_{Sn}}$ when the service rate is μ_{Sn}. It can be seen that system is relatively stable when K = 1、K = 15 and K = 30. Setting a threshold value δ_n <0.2.

III. THE REALIZATION OF THE ALGORITHM OF UCDBAA

Step 1:Input: all the user's business packet concurrency
Step 2:Output: Allocate bandwidth to users
Step 3:Initialize: obtain initial values
Step 4:Perception minimum bandwidth of the user on the uplink
(1)Cognitive arrival rate of each user's business.
(2)According to the arrival rate of the business and the limited delay cognitive the minimum bandwidth which can meet the users.
Step 5:Allocation of bandwidth and dynamic adjustment on the dawnlink
1. If the threshold is greater than 0.2, making an error.
2. If the threshold is smaller than 0.2, dynamically adjusting the size of the bandwidth
1.If the total bandwidth can meet the bandwidth requirements of all users. Allocated the remaining bandwidth to the optimal user. The objective function J_{u_i} derivatives with respect to u_i, selecting the use of the largest derivative and allocating the bandwidth. The allocation of bandwidth is

$$\Delta\mu = \alpha\, i^* \big/ \lambda_i l_i \exp(-2(\mu_i - \lambda_i) D_{i,\max} \quad (11)$$

Where α is a parameter, iterativing in turn, finished until all the remaining bandwidth is allocated.
2.If the total bandwidth can't meet the demand requirements of all the users, The objective function J_{u_i} derivatives with respect to u_i, selecting the user of the smallest derivative and allocating the bandwidth. The allocation of bandwidth can be expressed as Eq. (11). Iterativing in turn, finished until all the remaining bandwidth is allocated.
3.

IV. PERFORMANCE ANALYSIS

The essence of UCDBAA algorithm is the smallest service rate for each user, this paper choose the frame combination on the uplink, through business characteristic parameters percept the user's minimum service rate. Then the service rate of each user is optimized with the gradient direction of $J(s)$. Increasing the service rate maximize the addition of the objective function $J(s)$ When the total service rate is sufficient. Decreasing the service rate minimize the reduction of the objective function $J(s)$ when the service rate is insufficient. The service rate of the initial allocation ensure the objective function $J(s)$ maximum. Finally after many iterations can ensure the objective function $J(s)$ maximum. Known from the analysis of the throughput:

The amount of transmission success

$$B_{is}(s) = \lambda_i l_i s(1-\varepsilon_i) \quad (12)$$

The amount of transmission failure

$$B_{if}(s) = \lambda_i l_i s \varepsilon_i \quad (13)$$

The objective function is as follow:

$$J(s) = \sum_{i=1}^{M} (\lambda_i l_i s(1-\varepsilon_i) - p_i(g_i(s))(\lambda_i l_i s\varepsilon_i - \varepsilon_{\max}(\lambda_i l_i s(1-\varepsilon_i))^2) \quad (14)$$

Divided into three of the following discussion:
1.When the sum of the minimum bandwidth of all users is equal to the total bandwidth, as a result of the K value is large enough, so we can get the optimal solution, the allocated bandwidth of each user is equal to the minimum bandwidth of the user.
2.When the sum of the minimum bandwidth of all users is less than the total bandwidth, bandwidth can meet all the user's QoS requirements, selecting a user to increase service rate at this time, the probability ε_i that any of users' delay exceed the maximum delay is less than the $\varepsilon_{i,\max}$ of the user.

$$g_i(s) = B_{if}(s) - \varepsilon_{\max} B_i(s) < 0 \Leftrightarrow p_i(g_i(s)) = 0 \quad (15)$$

The objective function is as follow:

$$J(s) = \sum_{i=1}^{M} (\lambda_i l_i s(1-\varepsilon_i) \approx \sum_{i=1}^{M} \lambda_i l_i s(1-\exp(-2(\mu_i - \lambda_i) D_{i,\max}) \quad (16)$$

For a single user

$$\max \lambda_i l_i (1-\exp(-2(\mu_i - \lambda) D_{i,\max}) = \min \lambda_i l_i \exp(-2(\mu_i - \lambda) D_{i,\max}) \quad (17)$$

$$\frac{\partial \lambda_i l_i \exp(-2(\mu_i - \lambda) D_{i,\max})}{\partial \mu_i} < 0 \qquad (18)$$

The user of transmission failure is shrinking with the increase of service rate for the formula(18) is less than 0. The increase of the throughput decreases .After the distribution of the minimum rate has been finished, selecting the optimal user to increase the service rate.

The optimal user

$$i^* = \arg\min \frac{\partial \lambda_i l_i \exp(-2(\mu_i - \lambda_i) D_{i,\max})}{\partial \mu_i} \qquad (19)$$

The optimal step length can be expressed as Eq. (15), the service rate of the i-th user increases with the gradient direction of the objective function $J(s)$. So it still can ensure that the objective function $J(s)$ is a maximum.

3.When the sum of the minimum bandwidth is greater than the total bandwidth, bandwidth can not satisfy all user's QoS requirements, selecting a user to decrease service rate at this time, the service rate of the user can not meet the requirement of the user.

$$g_i(s) = B_{if}(s) - \varepsilon_{\max} B_i(s) > 0 \Leftrightarrow p_i(g_i(s)) = K \qquad (20)$$

The objective function

$$J(s) = \sum_{i=1}^{M} (\lambda_i l_i s(1-\varepsilon_i) - K(\lambda_i l_i s(\varepsilon_i - \varepsilon_{i,\max} + \varepsilon_i \varepsilon_{i,\max}))^2) \qquad (21)$$

To make the objective function is the largest

$$\max J(s) \Leftrightarrow \min(K\lambda_i l_i \varepsilon_i^2 + \lambda_i l_i \varepsilon_i) \qquad (22)$$

Simultaneously, the optimal user can be expressed as Eq. (19). The optimal step length can be expressed as Eq. (11). The minimum service rate of the initial allocation for the user can guarantee the maximum of $J(s)$, decreasing service rate in the gradient direction can still guarantee the maximization of the $J(s)$ for the shortage of the overall service rate, it can guarantee maximum of $J(s)$ through repeated iteration.

V. SIMULATION ANALYSIS

In this section, we make the simulation for UCDBAA algorithm using the matlab simulation software.The current service rate model of satisfied the QoS are mainly fixed allocation model(FA)and maximum throughout allocation model(MTA). We do the simulation based on the two mode for comparison with real-time business and non real-time business.The simulation parameters such as Table I.

Table I business parameters

business types	Packet length/bit	λ $packet/s$	$D_{\max}$ $/ms$	$\varepsilon_{\max}$
real-time business	300	10	150	0.1
Instant messaging business	2000	15	200	0.08

The total number of the users is *N*, the real-time business number of the users is N_1, the non real-time business number of the users is N_2, the overall service rate is 1.2 Mbit/s. When the total number of the users is fixed for 100 people, we analysis non real-time business accounts for the proportion of the effects of the number of users who meet the QoS and throughput.

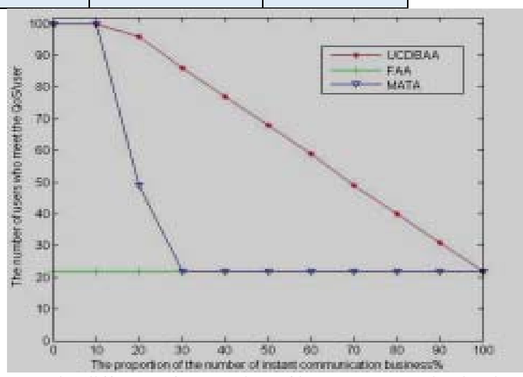

Figure 4 The different of proportion of instant communication business affects on the number of users who meet the QoS

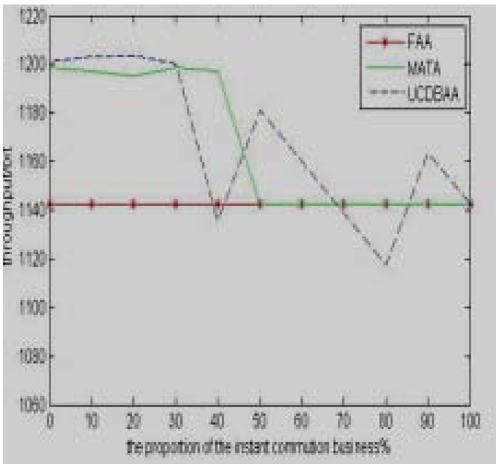

Figure 5 The different of the proportion of the number of users of instant communication business affects on throughput

It can be seen when the overall service rate is fixed, the service rate of the user is always fixed by Figure 4. For fixed allocation algorithm, the maximum bandwidth is assigned to meet the requirements of all users. No matter how much the instant communication business is the proportion of users, the number of users to meet the QoS is unchanged. For maximum throughput algorithm, Objective function of the system make the throughput maximized. When the proportion of instant communication business is larger, it need more bandwidth to meet the service rate of instant communication business, the users of instant communication business take up a lot of bandwidth, the remaining bandwidth meets the user of real-time business, so the number of the users of satisfied the QoS decreases. When the total bandwidth do not satisfy bandwidth requirements of all users, UCDBAA algorithm in this paper adjusts to maximize users who meet the QoS dynamically by $K\max\{0,\varepsilon_i-\varepsilon_{\max}\}$.

We show that the throughput of fixed allocation algorithm do not change with the increase of the proportion of instant communication business in Figure 5. The throughput of maximum throughput allocation algorithm declines with the increase of instant communication business. The throughput of UCDBAA algorithm is just less than the throughput of maximum throughput allocation algorithm in the proportion of instant communication business between 30% and 50%. The loss of the throughput exchanges to the maximum of the users who meet the requirement of QoS within this interval. The throughput of UCDBAA algorithm is higher than the maximum throughput allocation algorithm in other proportion.

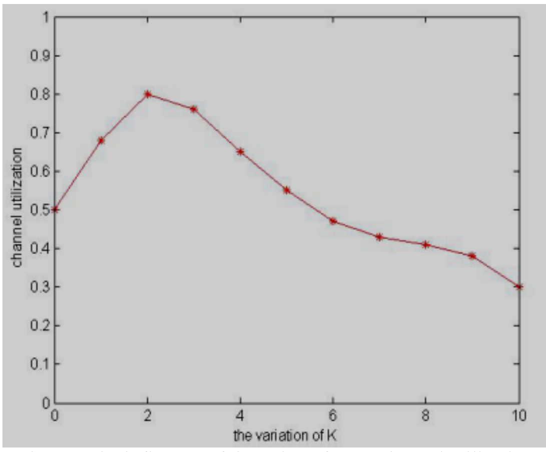

Figure 6 the influence of the value of K on channel utilization

It can be seen that the value of channel utilization rate is the lagest when the value of K is two. The channel utilization become smaller under the condition that the K value is higher . The channel utilization rate of system is low because the stability of the K in system is reduced. So the value of K is not suitable for too much in order to improve the utilization rate of system.

VI. CONCLUSIONS

This paper presents a multi-user uplink and downlink bandwidth allocation method based on TCBAA allocation algorithm. The key of the algorithm is perceiving joint business features of real-time traffic business and instant communication real-time business. The establishment of the uplink perception and downlink allocation model saves slots of heterogeneous network. Distribution to the position of the slots is discussed. We designs the objective function to dynamically adjust the size of the bandwidth allocation for the user . Analysis the influence of the value of K on channel utilization. The simulation experiments show that UCDBAA allocation algorithm can achieve more users accessing in the heterogeneous network than the fixed allocation algorithm and the maximum throughput algorithm under the condition of the lack of the bandwidth.

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