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Performance Evaluation of Resource Allocation Technique for OFDMA WiMAX System

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***Abstract:** Orthogonal frequency division multiple access (OFDMA) has recently attracted vast research attention from both academia and industry and has become part of new standards for broadband wireless communication. In this paper, I addressed the radio resource allocation in the downlink of an OFDMA system and K&H and MPF scheduler algorithm for resource allocation. By comparing the output parameter of both the algorithm get the performance characteristics of OFDMA system. Both scheduling algorithm are based on the quality of service (QoS) requirements of each service flow in terms of BER and data rate. The results show that the algorithms give way fairness among real-time and non real-time service flows as well as guaranteeing their constraint in term of QoS and spectrum efficiency.*

***Index Terms:** Cross-Layer, IEEE802.16e, OFDMA, QoS, Scheduling, WiMAX*

I. INTRODUCTION

There is at present a tough extending technique of the OFDM concept to multiuser communication systems. Best case of this technique is the orthogonal frequency division multiple access (**OFDMA**) technology, which comes from a combination of OFDM with a frequency division multiple access (FDMA). In recent times, it has become part of the emerging IEEE 802.16 standards for wireless communication systems. It is currently attracting vast research topic from academic world and industry for next generation broadband wireless networks.

In OFDMA systems, the subcarriers are disturbed into the equally exclusive subchannels or subbands that are assigned to users for transmission. OFDMA inherits from OFDM the ability to compensate channel distortions in the frequency domain without the need of computationally demanding time domain equalizers. By using a long guard interval between adjacent OFDMA blocks (cyclic prefix) provides intrinsic protection against timing errors at the expense of some reduction in data throughput as a consequence of the extra overhead. Timing accuracy becomes a strict requirement in those applications where the cyclic prefix (CP) is made as short as possible to minimize the overhead. In OFDMA systems, timing and frequency synchronization is accomplished by following a three-step method. The first step is taken during the downlink transmission, when each mobile terminal (MT) performs frequency and timing estimation by taking the advantage of a pilot signal transmitted by the base station (BS). This operation reduces synchronization errors within a reasonable range. And it can be capable by using the same methods available for OFDM systems since the users signals appear at each MT with common frequency and timing errors. The estimated parameters are then exploited by each user not only to detect the downlink data stream. Due to Doppler shifts and propagation delays, the uplink signals arriving at the BS may still be weighed down by residual synchronization errors. The second step of the synchronization process is represented by frequency and timing estimation in the uplink. This operation may be present challenging task, defiantly to the downlink situation; the uplink received waveform is a combination of signals transmitted by different users, each affected by exclusive synchronization errors. According to frequency and timing recovery in the uplink can be categorized as a multiparameter estimation problem in which each user must be separated from the others before starting the synchronization procedure.

IEEE802.16e, the enhanced version of IEEE802.16 standard to support mobility for broadband wireless access with the capability of delivering high data rates over long ranges. This is due to the use of Orthogonal Frequency Division Multiple Access (OFDMA) modulation coupled with many advanced physical (PHY) and Medium Access Control (MAC) features, such as traffic channel termed (subchannel), zone switching between diversity and Adaptive Modulation and Coding (AMC), Multiple-Input Multiple-Output (MIMO) and Advanced Antenna System (AAS).In OFDMA, the total bandwidth is divided into subchannels, each consisting of a set of subcarriers. therefore, multiple data subcarriers are grouped into a subchannel forming subchannelization in both uplink and downlink [4].

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Scheduling is the major component of the MAC layer that helps QoS to different service classes. The scheduler is used to distribute the resources among Mobile Stations (MSs).In OFDMA, the smallest unit for bandwidth allocation is a slot, and scheduler should calculate first the number of slots based on QoS of service classes and then select which slots are suitable for each user. The objective of a scheduler is to minimize power consumption and Bit Error Rate (BER) and to maximize the total throughput.

In this paper, the resource allocation scheme in WIMAX based on OFDMA in both time and frequency domains. Resources are represented by a two-dimensional matrix whose dimensions are subchannels and time symbols. Hence, one subchannel in the frequency domain with one symbol in the time domain forms a slot. Therefore, slots represent the basic allocation unit to which data from higher layer are mapped. This corresponds exactly to the PUSC (Partially Usage Subchannel) and FUSC (Fully Usage Subchannels) modes of the standard. From the performance of the traditional scheduler and mapper in IEEE802.16e, two scheduling and mapping methods are decide for the QoS requirements of each service flows such as data rate and bit error rate (BER). The scheduling determines which service flow to be scheduled first and the mapper assigns the service flows to the remaining slots by not only taking into account the decision of the scheduler but also channel quality information[4].

The paper organization is as follow. Section II gives a brief description of the system architecture, section III gives the fundamental description of the downlink system while Section IV presents in detail the basic resource allocation in IEEE 802.16e. Section V describes the comparisons of algorithms. Section VI ends the paper with our conclusion.

II. SYSTEM ARCHITECTURE

A Base Station (BS) serves S *MSs* in a cell at a particular time. The BS controls the transmission in both communication directions. All packets from higher layers are classified in the BS into Service Flows (SFs), each with different QoS requirements. A service flow is a unidirectional flow of packets with a set of QoS parameters and it is identified by a Service Flow Identifier (SFID). The QoS parameters could contain traffic priority, maximum sustained traffic rate, maximum burst rate, minimum tolerable rate, scheduling type, Automatic Repeat Request (ARQ) type, maximum delay, etc. The base station is responsible for issuing the SFID and mapping it to Connection Identifiers (CIDs)[4]. IEEE802.16e defines five types of SFs, three classes are designed for real-time applications while the others are designed for non real-time applications such as UGS (Unsolicited Grant Ser-vice), rtPS (real-time Polling Service), ertPS (Extended rtPS), nrtPS (non real-time Polling Service) and BE (Best Effort).

In IEEE802.16e, after classifying higher layer data into SFs and scheduling by the MAC layer, they are mapped into OFDMA slots by a mapper. The definition of an OFDMA slot depends on the mode of permutation of subcarriers in an OFDMA subchannel. In WiMAX, the subcarriers form a subchannel can either be adjacent to each other or distributed throughout the frequency band, depending on the subcarrier permutation mode. A distributed subcarrier permutation such as Partial Usage of SubCarriers (PUSC) and Full Usage of SubCarriers (FUSC) provides better frequency diversity. But an adjacent subcarrier distribution such as AMC mode is more popular for beamforming and allows the system to take advantage of multiuser diversity. Here he AMC mode permutation is used.

III. FUNDAMENTALS OF OFDMA DOWNLINK

Subcarrier Allocation Strategies, the OFDMA downlink is essentially equivalent to an OFDM system. Assume that the BS communicates with S users by exploiting N available subcarriers. The latter are evenly divided into P subchannels, each consisting of Q=N/P subcarriers. Consider the situation in which different subchannels are assigned to distinct users, even if more subchannels may be allocated to the same user depending on its requested data rate. Since the maximum number of users that the system can simultaneously support is limited to P, where assume S < P.

The subcarriers are numbered from n= 0 to n = N - 1, while the subcarriers of the pth subchannel have indexes in the set Im. Three possible methods are illustrated in Figure1 to distribute subcarriers among dynamic users [5]. For illustration N=16 and S = P = 4 as system parameters. In the subband carrier assignment scheme (CAS) of Fig. 1(a), each subchannel is composed by a group of Q adjacent subcarriers. The main disadvantage of this is that it does not develop the frequency diversity offered by the multipath channel. A viable solution to this problem is obtained by adopting the interleaved CAS shown in Fig. 1(b), where the subcarriers of each user are uniformly spaced over the signal bandwidth at a distance d from each other. Even if this method can fully exploit the channel frequency diversity, the current drift in OFDMA favors a more flexible allocation strategy where users can select the best subcarriers that are currently available. This scheme is called generalized CAS and its basic concept is shown in Fig. 1(c). Since there is no hard organization between subcarriers and users, the generalized CAS allows dynamic resource allocation and provides more flexibility than subband or interleaved CAS [5].

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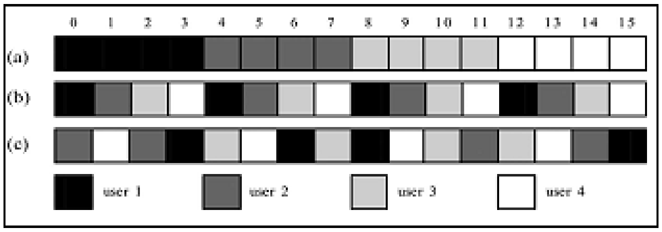

Figure1.Subcarrier assignment scheme (a) Subband CAS,(b) interleaved CAS,(c) generalized CAS.

IV. ALGORITHMS FOR DOWNLINK OFDMA

In downlink OFDMA the multiuser traffic over time varying channel is shown in figure 2[3].In order to beat frequency selective fading causing inter-symbol interference, the bandwidth of each sub-carrier is chosen to be smaller than the coherence bandwidth of the channel, so it is sensible to assume that base station transmits data over *N* parallel, independent channels to *K* mobile user terminals, each of which requires certain QoS guarantees [6].

In this algorithm, each OFDM sub-carrier *n*, as perceived by user *k*, is subject to flat Rayleigh fading, path loss and shadowing with channel gains $\alpha_{k,n}$. The signals whose single-sided noise power spectral density level *N0* is considered equal to unity (i.e. *N0*=1), for all sub-carriers and is the same for all users. The Base Station (BS) has a knowledge of the Channel State Information (CSI) i.e. $\alpha_{k,n}$, and the channel is variable so that the proposed allocation algorithm convergence within the channel coherence time. In addition assume that for packet transmission, and the packets designed to different mobile users are put into separate queues as shown in Figure 2 [3].

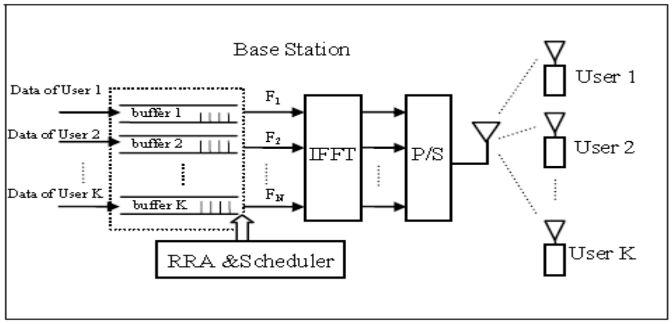

Figure 2: Multi-user OFDMA downlink architecture

Let $C_{k,n}$ denote the numbers of bits assigned to the *k*th user on the *n*th sub-carrier in one OFDM symbol, so $C_{k,n}$ must be integer in the set D= {0, 1, 2, M}. In OFDMA, one user is allowed in a sub-carrier of an OFDM symbol, it follows that for each n, if $C_{k,n} \neq 0$, $C_{k,n} = 0$ for all $k \neq k'$.

Define $\rho_{k,n}$ as the indicator of allocating the *n*th sub-carrier to the *k*th user, where, $\rho_{k,n} = 1$ when the *n*th sub-carrier is assigned to the *k*th user, otherwise $\rho_{k,n} = 0$.

The required QoS of the *k*th user is describe by its minimum data rate requirement equal to *Rk* bits per OFDM symbol, target bit error rate *BERk* and time delay constraints *τk* in OFDM symbol [3].

The transmission power for allocating the *n*th sub-carrier of the *k*th user is given following equation:

$$P_{k,n} = \frac{g_k(C_{k,n}BER_k)}{\alpha_{k,n}^{2}} .....(i)$$

Where $g_k(C_{k,n}BER_k)$ is the received power with unity channel gain for reception of bits per symbol, and it depends on the target BER of the *k*th user. $C_{k,n}$ is the function of the target *BERk*, the transmit power $P_{k,n}$ and channel gains $\alpha_{k,n}$. That is

$$C_{k,n} = f\left(BER_k \alpha_{k,n} P_{k,n}\right) ....(ii)$$

A. *JOINT K&H and MPF algorithm*

K&H/MPF algorithm is with the aim of a capacity gain to maximum throughput can be achieved and fairness among users. The algorithm is developed by the sub-carriers are allocated to maximize the throughput without considering the target rates and time delay constraints.
The sub-carrier allocation is adjusted by MPF scheduler to satisfy the target rates and delay constraints.

1) $C_{k,n}$ is defined as a current channel information and target BER requirements in given OFDM symbol by assign power to each sub-carrier is equal.

$$C_{k,n} = f\left(BER_k \alpha_{k,n} P_{k,n}\right) ....(1)$$

2) The sub-carriers for each user are allocated according to formula (ii). That is selecting the user k^* to transmit data in each sub-carrier.

$$k^* = \arg \max_{k \in \{k=1,2,...k\}} C_{k,n}$$

When the *n*th sub-carrier is assigned to the *k*th user, $\rho_{k,n} = 1$, otherwise $\rho_{k,n} = 0$.

3) r_k is determine for all user using the following formula, which is the total numbers of bits transmitted by each user in current OFDM symbol.

$$r_k = \sum_{n=1}^{N} C_{k,n} \rho_{k,n}, \forall k \in \{1, 2, ..k\} \ldots(2)$$

4) Update the average data rate of user *k* one by one by this equation.

$$\overline{R_k} = \left(1 - \frac{1}{\tau_k}\right)\overline{R_k} + \frac{1}{\tau_k} r_k \forall k \in \{1, 2, ..k\} \ldots(3)$$

5) R_k is the target data rate of each user, has been approached by average rate $\overline{R_k}$.

For user k, if $\left|\overline{R_k} - R_k\right| / R_k \leq \delta$, consider the user's rate requirement has been definite; if $\left|\overline{R_k} - R_k\right| / R_k > \delta$, it indicates the user's average data rate is high that the sub-carriers belonging to them to be reallocated to the users whose $\left|\overline{R_k} - R_k\right| / R_k > \delta$.Here δ is an adjustable parameter. For inconvenience, denoted the users $\left|\overline{R_k} - R_k\right| / R_k > \delta$ as k', and the sub-carrier owned by the users whose $\left|\overline{R_k} - R_k\right| / R_k > \delta$ as n'.

6) Reallocate the sub-carriers marked as n' among the users marked as k' employing MPF scheduler.

That is selecting the user k^* to transmit data for each sub-carrier n'.

$$K^* = \arg \max_{k \in \{k=1,2,\ldots k\}} \frac{C_{k,n}}{\overline{R_k} / R_k}$$

Where, R_k is initial value at the beginning of the current OFDM symbol.

7) Modify the r_k and R_k according to step 3) and step 4) for all users denoted as k'.

The K&H/MPF algorithm is carried out on an OFDM symbol by symbol, until all QoS constrains are satisfied [6].

B. A SERVICE FLOWS RESOURCE ALLOCATION MODEL BASED ON FREQUENCY-TIME DOMAIN

By using adaptive modulation and coding (AMC), the maximum number of bits per symbol per Hz, that subcarrier k for user m can transmit per unit time during a symbol t is denoted by $r_m[k, t]$ and expressed as a function of SNR and target BER [4].

$$r_m[k, t] = \Delta B \, \Delta T \left[\log_2\left(1 + \alpha \gamma_m[k, t]\right)\right] \ldots..(a)$$

Where ΔB and ΔT are the frequency bandwidth and symbol length of one slot and $\gamma_m[k, t]$ is the instantaneous SNR at symbol t for subcarrier k corresponding to user m. so, modification of the Shannon capacity equation can be applied to practical forward error correction scheme:

$$r_m[k, t] = \min\left(\log_2\left(1 + \frac{\alpha \gamma_m[k, t]}{\delta}\right), S^{\max}\right) \ldots.(b)$$

Where Smax is the highest supported data rate in the system and δ is a parameter to bridge the gap between Shannon capacity and practical forward error correction scheme. Note that α is a constant BER, $\alpha = -1.5/\ln \text{Pber}$, where Pber is the target BER. The calculated spectral efficiency (capacity) using Convolutional code at BER of 10^{-5} is depicted .Define $\rho_m[k, t]$ to be the slot assignment indicator for the mth user, then $\rho_m[k, t] = 1$ indicates that the slot is allocated to the user and $\rho_m[k, t] = 0$ when the slot is not allocated [4]. Assume that F is the time length of an OFDM frame, then the mth user's achievable data rate (bps) for one frame is

$$R_m = \frac{1}{F} \sum_{t=1}^{T} \sum_{k=1}^{K} r_m[k, t] \rho_m[k, t] \ldots.(c)$$

So the overall throughput for one frame is

$$Thr = \frac{1}{F} \sum_{t=1}^{T} \sum_{k=1}^{K} \sum_{m=1}^{M} r_m[k, t] \rho_m[k, t] \ldots(d)$$

The algorithm aim is to maximize total system throughput while achieving fairness among the heterogeneous service flows by using their QoS requirements such as maximum sustained traffic rate and minimum reserved traffic rate. Since UGS service flow has a fixed size grant on a real-time basis, so its maximum sustained traffic rate should be equal to its minimum reserved traffic rate, while the data rate for rtPS, ertPS, nrtPS and BE is bounded by the maximum sustained traffic rate and the minimum reserved traffic rate. Thus the constrained optimization problem to be solved is then

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$$\max_{r_m[k,t]\rho_m[k,t]} \sum_{t=1}^{T}\sum_{k=1}^{K}\sum_{m=1}^{M} r_m[k,t]\rho_m[k,t] \ldots\text{(e)}$$

Subject to;

$$R_m \geq C_{max} \forall SFi \in UGS$$

$$C_{min} \leq R_m \leq C_{max} \forall SFi \in \{ertPS, rtPS, nrtPS, BE\}$$

If $\rho_m[k,t]=1$, then $\rho'_m[k,t]=0 \forall m \neq m'$

Where C_{min} and C_{max} denote minimum reserved traffic rate and maximum sustained traffic rate for these service flows.

C. Algorithm

In order to solve equation (e), an adaptive slot allocation with multiple types of service flows, where the users are classified according to their service flows characteristic. So, prioritize the UGS service flow over all the other types by allocating first the best slots for UGS as described below:

1) Calculate the achievable data rate Rm by using equation (c) for all service flows in the system according to channel information and target BER requirements.

2) Allocate the best slots to all the UGS in the system one by one, until the maximum sustained traffic rate is achieved for all of them. so,

$$UGS_m = \arg\max R_m$$

Note that when a slot is allocated, the $\rho_m[k,t]$ will be set to one, otherwise $\rho_m[k,t]=0$.

3) Allocate the residual slots with the $\rho_m[k,t]=0$ to the remaining service flows.

4) Initiate the unsatisfied users from the rtPS, ertPS, nrtPS and BE.

5) Reallocate the slots to guarantee the minimum reserved traffic C_{min} for all rtPS, ertPS, nrtPS and BE. If this reallocation does not lead to a violation of minimum reserved data rate for the satisfied service flows, i.e., $R_m - r_m[k,t] \geq C_{min}$, then the reallocation will continue until all the service flows are satisfied [4].

V. DISCUSSION ON RESULTS

To evaluate the performance of K&H algorithm, simulation is performed by system architecture described in section IV. In this system consider a cell which radius is 500m, and the users are distributed within the cell independently and uniformly. The path loss is considered as a zero-mean Gaussian variable in the logarithmic scale responsible for shadowing with a standard deviation 8dB, and the path loss exponent is 4.

In radio resource allocation (K&H) algorithm using different equation for achieving maximum throughput in OFDMA WiMAX System when throughput is based the maximum power constraint of target BER rate and Channel Gain and number of bits transmitted per subcarrier or user shown in figure3[3] and figure 5.Also, assume that the target rate and target bit error rate for data user are equal to 64bits/OFDM symbol and1.0e-4, respectively and for voice user and the target rate and target bit error rate for data user are equal to 8bits/OFDM symbol and1.0e-2.In the simulation, an OFDMA downlink system with 128 sub-carriers is considered. By performing this on MATLAB, the results are getting as shown in figure 5.

In radio resource allocation algorithm using different service flows, in which the Spectrum Efficiency is higher in WiMAX when number of users is increased. In these two algorithm the target BER rate of the subcarrier ant the number of bits transmitted per user has been taken as a main performance parameter for comparison and its having different parameters are taken for calculations of target BER rate, maximum power constraint ,channel gain.

In both the algorithm, the BER rate is taken with respect to user requirement or data requirement of each user or subcarrier In service flow based algorithm, multiuser diversity provides significant improvement in overall system capacity and throughput, since a slot at any given time is allocated to the user with the highest SNR/capacity in that slot shown in figure 4[4].

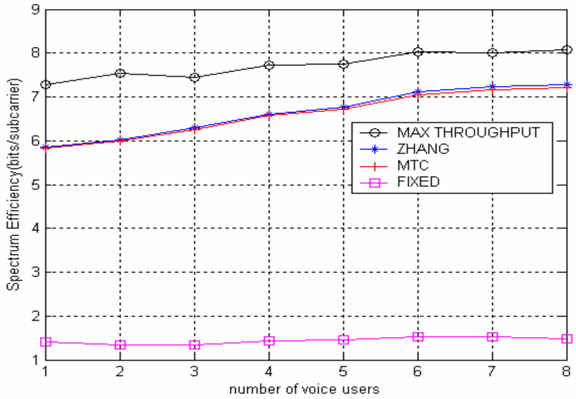

Figure 3: Spectrum efficiency versus the number of voice users when SNR/OFDM symbol =12dB [3]

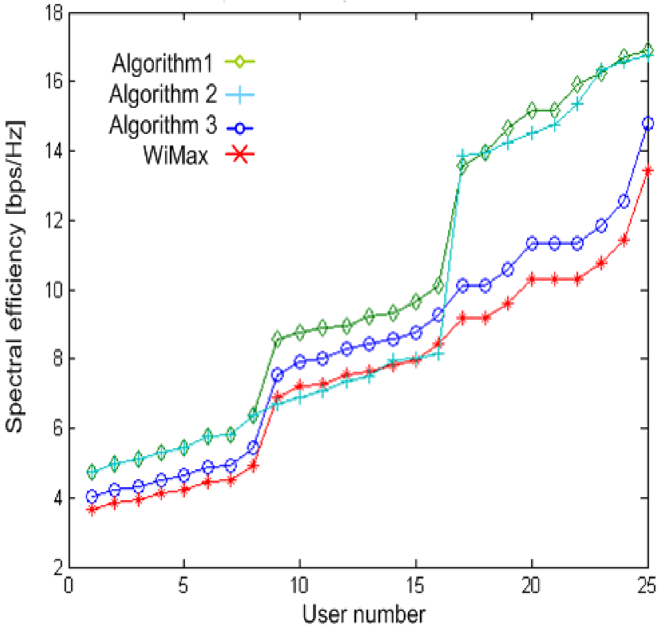

Figure 4: Spectral efficiency comparison versus number of users [4]

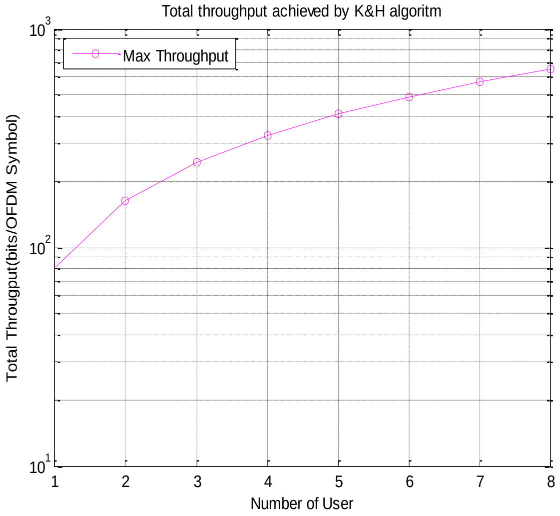

Figure 5.Total throughput achieved by K&H algorithm verses number of users

VI. CONCLUSION

This research area is attracting considerable attention and significant efforts are underway to develop new schemes with improved performance. Resource allocation techniques for downlink transmissions can directly be taken from the vast literature devoted to multi-user OFDMA.

In this paper, the general comparison of OFDMA concept with different algorithm used for subcarrier allocation. From the BER point of view the algorithms having different throughput and efficiency. As it will improve by means of computer simulations, the application of OFDMA is not always straightforward and there exist certain scenarios, typically for high BER, where OFDMA can perform better. This is a special relevance of the upcoming next evolution of WIMAX where OFDMA receives special interest even in the downlink of the cellular systems [5].

REFERENCES

1. http://www.wimaxforum.org
2. Ronak Farhadi, Vahid Tabataba Vakili, Shahriar Shirvani Moghaddam,"*A Novel Cross-Layer Scheduling Algorithm for OFDMA-Based WiMAX Networks",* Int. J. Communications, Network and System Sciences, 2011, 4, 98-103.
3. X. N. Zhu, J. H. Huo, S. Zhao, Z. M. Zeng and W. Ding, "An Adaptive Resource Allocation Scheme in OFDMA Based Multiservice WiMAX Systems," *Proceedings of* 10*th International Conferenece on Advanced Communication Technology*, Phoenix Park, 17-20 February 2008, Vol. 1, pp. 593-597.
4. T.Ali-Yahiya, A.-L. Beylot and G. Pujolle, "Radio Resource Allocation in Mobile WiMAX Networks Using Service Flows," *Proceedings of IEEE* 18*th International Symposium on Personal, Indoor and Mobile Radio Com- munications*, Athens, 3-7 September 2007, pp. 1-5.
5. M Morelli, C.-C., JayKuo,and M.O. Pun, "*Synchronization techniques for orthogonal frequency division multiple access (OFDMA): a tutorial review*," Proceedings of the IEEE Vol. 95, No. 7, July 2007.
6. Lu Yanhui, Wang Chunming, Yin Changchuan, and Yue Guangxin,"*Downlink Scheduling and Radio Resource Allocation in Adaptive OFDMA Wireless Communication Systems for User-Individual QoS*", International Journal of Electrical and Electronics Engineering 3:2 2009.

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