Energy-Efficient Optimization Joint User Scheduling and Resource Allocation in OFDMA Relay Networks

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Abstract—**Normally, the existing resource allocation research for orthogonal frequency division multiple access (OFDMA) relay networks directly allocate resources to the users without considering the user scheduling. Different from allocating resources directly for the users, we allocate resources for the packets with a priority queue. For this model of resource allocation, we propose three resource allocation algorithms based on adaptive modulation and coding (AMC) which is discrete and applied in practice system. Energy efficiency is the main optimization goal in this paper. We propose an energy-efficient global optimization (EEGO) algorithm and an energy-efficient maximization greedy (EEMG) algorithm for the purpose of energy-efficient optimization. For comparison, we also propose a spectral-efficient maximization greedy (SEMG) algorithm whose main purpose is spectral-efficient optimization. Moreover, because the three proposed resource allocation algorithms are all based on the packets queue, we also propose a novel packet scheduling scheme in this paper, which considers the relay selection results and the service types. Simulation results show that EEGO has the highest energy efficiency while SEMG has the highest spectral efficiency.**

Keywords—**OFDMA; relay; resource allocation; scheduling; energy-efficient;**

I. INTRODUCTION

In the next-generation wireless communication networks, user scheduling and resources allocation (sub-carrier, bit and power) based on orthogonal frequency division multiple access (OFDMA) have a highly flexibility and is particularly important for the system performance [1]. Relay technology is able to provide high data rate and extends the high data rate coverage to the edge of cell [2][3]. We investigate user scheduling and resource allocation problems extending to the relay-enhanced networks. User scheduling scheme decides which users' packets should be served firstly and resource allocation algorithm decides which sub-carriers, how many bits and how much power should be allocated to the packets to be transmitted.

Recently, [4-9] investigate resource allocation problem in OFDMA relay networks. [4] proposed a sub-carrier-pair based resource allocation scheme for cooperative multi-relay OFDM systems using amplify-and-forward (AF) protocol, and its objective is to maximize the system throughput with individual power constraints. To ensure user fairness with minimal impact on system throughput, [5] provided a comprehensive centralized fairness-aware radio resource management algorithm in OFDM cellular relay networks. The authors in [6] decompose the resource allocation problem into rate control and scheduling problems at the transport and medium access control (MAC)/physical layers respectively, and proposed computationally efficient adaptive scheduling (CEAS) and opportunistic time division multiple access (Opp-TDMA) scheduling schemes in traditional OFDMA networks, whose main goal is to maximize utility which includes spectral efficiency and fairness. Related works about resource allocation directly allocate resources to the users without considering the user scheduling as to simplify the problems [4-9]. Therefore, in this paper we investigate the resource allocation problem jointly with user scheduling. Scheduling scheme transfers user information into packet priority queue, and resource allocation algorithm allocates resources for the data packets in the queue. Compared to allocate resources directly for users, the resource allocation for packets has a transmission priority queue. The algorithms for packets can be divided into two categories. One is the greedy type, which allocates resources packet by packet in the scheduling queue. For each packet the allocation schemes are different in different optimization goals. The other is global optimization, which allocates resources to all packets in the queue according to different optimization goals (throughput maximization, energy minimization, etc.).

Energy saving and green communication have become the focus attention worldwide. Therefore, how to improve energy efficiency is the main optimization goal in this paper. For the purpose of energy-efficient optimization we propose an energy-efficient global optimization (EEGO) algorithm and an energy-efficient maximization greedy (EEMG) algorithm. For comparison, we also propose spectral-efficient maximization greedy (SEMG) algorithm whose main purpose is spectral-efficient optimization. The three proposed resource allocation algorithms all allocate resources (sub-carrier, bit and power) for the data packets and don't disturb the priority of the scheduling queue. Different from using Shannon formula which is continuous theoretical value in related works, all three proposed schemes are all based on Adaptive modulation and coding scheme (AMC) scheme in practice system. Because the three proposed resource allocation algorithms are all based on the packets queue, we also propose a novel packet scheduling scheme for relay-enhanced networks, which considers the relay selection results and the service types.

This rest of this paper is organized as follows. In section II, system description and assumptions are given. Section III proposes a scheduling scheme, and the detailed description of proposed energy-efficient optimization of resource allocation scheme is given in Section IV. Simulation results are presented in Section V while Section VI concludes the paper.

II. SYSTEM DESCRIPTION AND ASSUMPTIONS

The configuration of relay-enhanced networks can be seen in Fig.1. We use TDD mode, one sub-frame is divided into two time slots. The system transmits data from BS to RS and BS to MS in the first slot while transmits data from RS to MS in the second slot. The two slots in a sub-frame have the same number of symbols. The scheduling and resource allocation model can be seen in Fig.2. We assume that there are K active users and N sub-carriers in a sub-frame. If a user selects one RS to transmit data, we denote by $relay_k$ the RS number selected by user k, where $relay_k \in \Sigma$ and $\Sigma=\{0, 1, 2, \ldots, N_{RS}\}$ denotes the set of the RSs, N_{RS} is the RS number in the cell, 0 denotes the direct transmission mode between BS and the user. The scheduling algorithm transfers user information into packet queue in a scheduling cycle. Then the data packets are assigned different transmission priorities. After scheduling we assume that there are M data packets in the scheduling queue and R_m denotes the bit number of data packet m, where $m=\{1,2,\ldots,M\}$. Resource allocation algorithm assigns a set of sub-carriers to each packet and determines the transmitting power in each sub-carrier and the number of bits to be transmitted through each sub-carrier. In this paper, we focus on the centralized scheduling scheme for OFDMA-based two-hop relay systems. The packets scheduling and resource allocation are both controlled by the BS while the RSs report their channel measurement information to the BS.

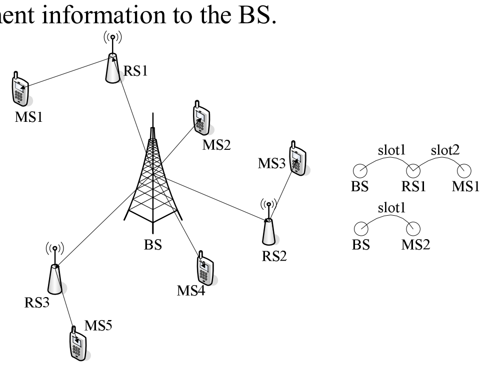

Fig.1. Relay scenario

We denote by $\alpha_{k,n}^2$ the channel gain of the nth sub-carrier as seen by the kth user. We assume that the single-sided noise power spectral density level N_0 is equal to unity for all sub-carriers and is the same for all users. As we take the queue of the data packet to be the object of the resource allocation, to ensure the quality of service (QoS) requirements at the receiving side, the transmission power for the mth data packet in the nth sub-carrier must be satisfied

$$P_{m,n} = \frac{f_m(c_{m,n}) \cdot (N_0 + I_{user_m,n})}{\alpha_{user_m,n}^2} \tag{1}$$

where, $c_{m,n}$ denotes the transmission bit number in the nth sub-carrier as seen by the mth data packet, and $c_{m,n} \in D=\{0, 1, 2, \ldots, L\}$; L is the maximum number of information bits that can be transmitted by each sub-carrier. $f_m(c_{m,n})$ is the required received power in the nth sub-carrier to transmit $c_{m,n}$ bits. AMC is performed in this paper, therefore, $f_m(c_{m,n})$ denotes the lowest signal-to-interference-and-noise radio (SINR) to transmit $c_{m,n}$ bits according to the AMC table. $user_m$ is the user index of the mth data packet. $I_{user_m,n}$ is the interference of the $user_m$th user received from other stations (BSs and RSs) in the nth sub-carrier, and it can be described as

$$I_{user_m,n} = \sum_{j \neq relay_{user_m}}^{N_{BS\_RS}} p_n^j \cdot \alpha_{j,user_m,n}^2 \tag{2}$$

where N_{BS_RS} is the number of BSs and RSs in the system, P_n^j is the transmit power of the jth station in the nth sub-carrier. $\alpha_{j,user_m,n}^2$ is the magnitude of the channel gain of the nth sub-carrier from station j to the $user_m$th user.

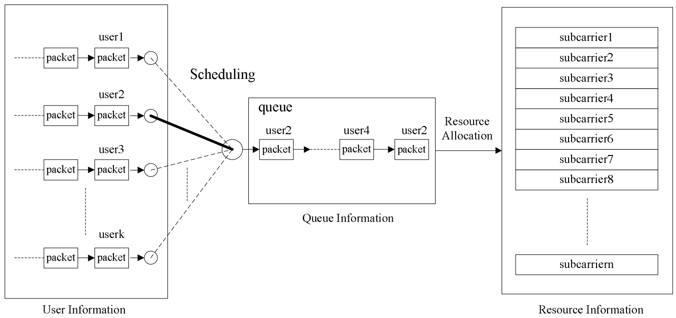

Fig.2. System model

In relay-enhanced networks, the system assigns sub-carriers for the users in the BS to RS link and BS to MS link in the first slot, and assigns sub-carriers for the users in the RS to MS link in the second slot. At the BS side, for the direct transmission users the power consumption is equal to the power from BS to the user, for the relaying transmission users the power consumption is equal to the power from BS to the RS user selected. Therefore, the power consumption $P_{m,n}^0$ at the BS side can be denoted as,

$$P_{m,n}^0 = \begin{cases} \dfrac{f_m(c_{m,n}) \cdot (N_0 + I_{user_m,n})}{\alpha_{user_m,n}^2} & relay_{user_m} = 0 \\ \dfrac{f_m(c_{m,n}) \cdot (N_0 + I_{user_m,n})}{\alpha_{0 \to relay_{user_m},n}^2} & relay_{user_m} \neq 0 \end{cases} \tag{3}$$

where $\alpha_{0 \to relay_{user_m},n}^2$ denotes the channel gain of the nth sub-carrier from BS to the $relay_{user_m}$ th RS.

On the RS side, the system needs to allocate sub-carriers resource in the second slot, for the ith RS,

$$P_{m,n}^i = \begin{cases} \dfrac{f_m(c_{m,n}) \cdot (N_0 + I_{user_m,n})}{\alpha_{i \to MS,user_m,n}^2}, & relay_{user_m} = i \\ 0, & relay_{user_m} \neq i \end{cases} \tag{4}$$

The optimization problem with the objective to minimize the sum power P_T can be formulated as,

$$\min P_T = \min_{\rho_{m,n}} \sum_{n=1}^{N}\sum_{m=1}^{M} \rho_{m,n} \cdot \frac{f_m(c_{m,n}) \cdot (N_0 + I_{user_m,n})}{\alpha^2_{user_m,n}} \tag{5a}$$

subject to

$$\sum_{m=1}^{M} \rho_{m,n} = 1, \quad \forall n \in \{1,2,...,N\} \tag{5b}$$

$$R_m = \sum_{n=1}^{N} \rho_{m,n} c_{m,n}, \quad \forall m \in \{1,2,...,M\} \tag{5c}$$

where $\rho_{m,n} \in [0,1]$ and $\rho_{m,n}=1$ denotes that the nth sub-carrier is assigned to the mth packet. (10b) denotes that we don't allow more than one packet to share one sub-carrier. (10c) is the rate constraint.

III. Scheduling Scheme

The scheduling scheme transfers users information into packets queue. Scheduling is not only to ensure the fairness, but also to maximize system throughput as much as possible. Proportional fair (PF) is a compromise consideration between user fairness and system capacity. In this paper we assume that BS can obtain users' instant channel information through channel estimation and measurement.

With the increasing demand of wireless communication rate, the user's service type is not restricted to traditional voice. Let's take WiMAX as an example, which supports four types of service with different QoS requirement. Unsolicited Grant Service (UGS) has the strictest real-time requirement, which should be given the highest priority. The Real-time Polling Service (rtPS) supports real-time data streams consisting of variable-size data packets, while it should be provided periodic request opportunities. Non-real-time Polling Service (nrtPS) supports delay-tolerant data streams consisting of variable-sized data packets. According to the specification, the real-time requirement for rtPS is much stricter than that for nrtPS. Best Effort (BE) service supports data streams without strict QoS requirement [10]. In this paper we define a priority factor to distinguish four types of service.

In relay-enhanced networks, we should consider the impact of relay forwarding for scheduling. Without losing generality, this paper doesn't involve relay selection algorithm, and we assume that the system has already perform the relay selection. The relayed users have more serious time delay problem than the direct users, which should be taken into the scheduling queue as early as possible in order to reduce the packet lose rate and to ensure fairness. The detailed scheduling scheme is operated as follows.

1) Scheduling for UGS Packets

UGS is given the highest priority, it should be scheduled firstly. Considering the PF, it is a compromise scheme between user fairness and system capacity. In each frame scheduling cycle, the PF scheduling algorithm selects the user whose current C/I and the average transmission rate in the previous period is the largest to access into the scheduling queue. As we consider the impact of relay forwarding, the user to be scheduled can be redefined by

$$k^* = \arg\max_k \left\{ \frac{C_k(t)}{\overline{R_k(t)}} \cdot \tau_k \right\} \tag{6}$$

where,

$$C_k(t) = \begin{cases} C_k^{BS\to MS}(t), & direct\ user \\ \min\left\{C_k^{BS\to RS}(t), C_k^{RS\to MS}(t)\right\}, & relay\ user \end{cases} \tag{7}$$

$\overline{R_k(t)}$ is updated based on

$$\overline{R_k(t)} = \left(1 - \frac{1}{T_w}\right)\overline{R_k(t-1)} + \frac{1}{T_w} C_k(t) \tag{8}$$

and T_w is a constant which determines the effective memory of the throughput averaging window; τ_k denotes the relay weighting factor, because the system tends to schedule relay users priority, therefore,

$$0 < \tau_{direct} < 1 < \tau_{relay}$$

2) Scheduling for other Packets

For other packets, we denote by β_k the service factor to distinguish different types of service. As the real-time requirement of rtPS packets is stricter than that of nrtPS packets, and the QoS requirement is relatively low and there is no delay requirement for BE packets, therefore,

$$\beta_{BE} < \beta_{nrtPS} < \beta_{rtPS}$$

The user k selected to be scheduled preferentially can be acquired as

$$k^* = \arg\max_k \left\{ \frac{C_k(t)}{\overline{R_k(t)}} \cdot \tau_k \cdot \beta_k \right\} \tag{9}$$

The proposed scheduling scheme is: in each frame scheduling cycle, schedule the UGS packets first until all UGS packets are scheduled, then schedule other packets.

IV. Energy-efficient Optimization of Resource Allocation

Resource allocation algorithm assigns a set of sub-carriers to each packet in the scheduling queue, and determines the transmitting power in each sub-carrier and the number of bits to be transmitted through each sub-carrier. In this paper, we take sub-carrier as the basic unit of resource allocation, while each sub-carrier could be allocated to different packets, but could not be shared by more than one packet. The resource allocation algorithms we proposed are based on the scheduling queue information, and we allocate resources for the packets, not directly for the users. As packets in the scheduling queue have different priorities, we should not disrupt the priority in resource allocation. Based on this basic principle, we propose three algorithms to allocate resources to packets.

A. Energy-efficient global optimization

We consider the solution for optimization problem (5) in this sub-suction. As we describe in the section II, $I_{user_m,n}$ and $\alpha^2_{user_m,n}$ are constants that can be precalculated, but $c_{m,n} \in D=\{0, 1, 2, \ldots, L\}$ is a discrete variable, and $f_m(c_{m,n}) \in \{0, f_m(1), \ldots, f_m(L)\}$.

Therefore (5) can't be solved as integer programming (IP). A new indicator variable $\gamma_{k,n,c}$ is defined as follows:

$$\gamma_{m,n,c} = \begin{cases} 1, & if\ \rho_{m,n} = 1\ and\ c_{m,n} = c \\ 0, & otherwise \end{cases} \tag{10}$$

For all $c \in \{0, 1, 2, \ldots, L\}$, $f_m(c_{m,n})$ is rewritten as

$$f_m(c_{m,n}) = \sum_{c=0}^{L} \gamma_{m,n,c} f_m(c) \tag{11}$$

The indicators $\rho_{k,n}$ and $\gamma_{k,n,c}$ are related as follows:

$$\rho_{m,n} = \sum_{c=0}^{L} \gamma_{m,n,c} \tag{12}$$

And it also can be seen that

$$\gamma_{m,n,c} \cdot \rho_{m,n} = \gamma_{m,n,c} \tag{13}$$

Therefore, (5) can be rewritten as

$$\min P_T = \min_{\gamma_{m,n,c}} \sum_{n=1}^{N} \sum_{m=1}^{M} \sum_{c=0}^{L} \gamma_{m,n,c} \cdot \frac{f_m(c) \cdot (N_0 + I_{user_m,n})}{\alpha^2_{user_m,n}} \tag{14a}$$

subject to

$$R_m = \sum_{n=1}^{N} \sum_{c=0}^{L} \gamma_{m,n,c} \cdot c, \quad \forall m \in \{1, 2, \ldots, M\} \tag{14b}$$

$$\sum_{m=1}^{M} \sum_{c=0}^{L} \gamma_{m,n,c} = 1, \quad \forall n \in \{1, 2, \ldots, N\} \tag{14c}$$

Thus, the optimization problem can be solved by IP when treating $\gamma_{m,n,c}$ as variables[11]. $\gamma_{m,n,c}$=1 denotes that the nth sub-carrier is assigned to the mth packet and allocated c bits data. The power $P_{m,n}$ can be calculated as follows,

$$P_{m,n} = \frac{f_m(c) \cdot (N_0 + I_{user_m,n})}{\alpha^2_{user_m,n}} \tag{15}$$

$\gamma_{m,n,c}$=0 denotes that the nth sub-carrier is not assigned to the mth packet and $P_{m,n}$=0.

If the number of the users is large and the system resources are not sufficient, it is possible that (14) does not have any feasible solution because of the obtained P_T is larger than P_{max}. In this case, we reduce the number of packets one by one until (14) is feasible, the remaining packets in the queue can be transmitted in the next cycle of resource allocation. And energy-efficient (EE) maximization is equivalent to spectral-efficient (SE) maximization in this case because of P_T is approximately equal to P_{max}.

B. Energy-efficient Maximization Greedy

In this section we propose an EE maximization greedy (EEMG) resource allocation algorithm for the packets, which allocates sub-carriers and power to each packet in the queue one by one, and for each packet the criteria is to maximize EE of the packet. Since each packet can obtain EE maximization resource allocation, there will be EE improvement in this scheme and its complexity is low. The obvious lack of EEMG is that the total throughput is lower than that of EEGO. For the mth packet, the proposed scheme allocates resources as follows:

$$\min \sum_{n=1}^{N_{remain}} \sum_{c=0}^{L} \eta_{n,c} \frac{f_m(c) \cdot (N_0 + I_{user_m,n})}{\alpha^2_{user_m,n}} \tag{16a}$$

subject to

$$\sum_{c=0}^{L} \eta_{n,c} = 1, \quad \forall n \in \{1, 2, \ldots, N_{remain}\} \tag{16b}$$

$$R_m = \sum_{n=1}^{N_{remain}} \sum_{c=0}^{L} \eta_{n,c} \cdot c \tag{16c}$$

where $\eta_{n,c} \in \{0,1\}$ and $\eta_{n,c}$=1 denotes that there are c bits allocated in the nth sub-carrier, N_{remain} is the number of available sub-carriers.

EEMG allocates resources one packet by one packet using (16) until there are no sub-carriers available or no packets in the queue.

C. Spectral-efficient Maximization Greedy

We also propose a spectral-efficient (SE) maximization greedy (SEMG) resource allocation algorithm in order to the comparison, which allocates resources to each packet in the queue one by one, and for each packet the criteria is to maximize SE of the packet. In OFDMA-based systems, the unit of resource allocation is the sub-carrier, so if we want to maximize SE we should minimize the number of sub-carriers used for each packet. Firstly we calculate the least number of sub-carriers to transmit one packet using the size of the packet, and then determine which sub-carriers should be allocated. The least number of sub-carriers to transmit the mth packet can be calculated as

$$N_m = \left\lceil \frac{R_m}{r_m} \right\rceil \tag{17}$$

where, r_m is the number of information bits that can be transmitted in the center sub-carrier with the maximum transmit power according to the $user_m$th user's channel quality, $\lceil x \rceil$ denotes the smallest integer greater than x. Then we select N_m sub-carriers for the mth packet. As the number of sub-carriers assigned to the mth packet is determined, the SE of the packet is determined accordingly. Therefore we can take EE as the criteria to select N_m sub-carriers, which can be described as,

$$\min \sum_{n=1}^{N_{remain}} \sum_{c=0}^{L} \eta_{n,c} \frac{f_m(c) \cdot (N_0 + I_{user_m,n})}{\alpha^2_{user_m,n}} \tag{18a}$$

subject to

$$\sum_{c=0}^{L} \eta_{n,c} = 1, \quad \forall n \in \{1, 2, \ldots, N_{remain}\} \tag{18b}$$

$$R_m = \sum_{n=1}^{N_{remain}} \sum_{c=0}^{L} \eta_{n,c} \cdot c \tag{18c}$$

$$N_m = \sum_{n=1}^{N_{remain}} \sum_{c=0}^{L} \eta_{n,c} \tag{18d}$$

(18d) denotes that the number of sub-carriers selected for the mth packet is N_m.

The detailed three proposed algorithms of resource allocation can be seen in TABLE I.

TABLE I. THREE PROPOSED RESOURCE ALLOCATION ALGORITHMS

Algorithm 1 Energy-efficient global optimization (EEGO)
allocate resources for all M packets using (14).
While ($P_T > P_{max}$)
$M = M - 1$
allocate resources for all M packets using (14).
End while.
Algorithm 2 Energy-efficient maximization greedy (EEMG)
For $j = 1 : M$
allocate resources using (16).
End for.
Algorithm 3 Spectral-efficient maximization greedy (SEMG)
For $j = 1 : M$
compute N_m in (17).
allocate resources using (18).
End for.

V. SIMULATION RESULTS

In this section, we validate the proposed energy-efficient optimization joint user scheduling and resource allocation in OFDMA-based cellular relay networks and compare the performance of different scheduling schemes and different resource allocation schemes respectively. The AMC set in terms of modulation and code rate and the simulation parameters are listed in Table II and Table III respectively.

We take the traffic models in the Next Generation Mobile Networks (NGMN) Radio Access Performance Evaluation Methodology [12]. UGS, rtPS, nrtPS, and BE take VoIP, Video Streaming, Web Browsing/HTTP, and FTP models respectively. The delay limits for UGS, rpPS, nrtPS and BE are 50, 250, 1000, and 10000 ms respectively, while the percentage of the four types users are 40%, 30%, 20% and 10% respectively.

TABLE II. ADPTIVE MODULATION AND CODING SCHEME (AMC)

ID	1	2	3	4	5	6
Modulation	QPSK		16QAM		64QAM	
Code Rate	1/2	3/4	1/2	3/4	2/3	3/4
Bits/RE	1	1.5	2	3	4	4.5
SINR (dB)	5.0	8.0	10.5	14.0	18.0	20.0

We compare the PF and Round robin (RR) with the proposed scheduling scheme. Fig.3 shows the system throughput comparison of RR, PF and proposed schemes. Abscissa denotes user arrival rate which follows Poisson distribution and λ=1 denotes one thousand users arrival in a second. From the figure we can see that the throughput of three kinds of algorithms increases with the user arrival rate. When the number of arrival users is less, there is a little difference among three kinds of algorithms because the system has enough resources to be allocated. As users arrival rate continues to increase, the system resources are gradually not sufficient, while the system throughput of proposed scheduling scheme is the largest and that of RR is the least. This is because the proposed scheduling scheme considers the relay selection results and the service types.

TABLE III. SIMULATION PARAMETERS

Parameter		Assumption
Number of cells		19
Number of RSs per cell		3
Number of sub-carriers per cell		64
Number of REs per sub-carrier		14
Bandwidth of sub-carrier		15 KHz
Carrier frequency		3.5 GHz
Cell-to-cell distance		1.5 Km
BS-RS distance (r)		3/8 of cell-to-cell distance
BS maximum transmission power		46 dBm
RS maximum transmission power		38 dBm
Path-Loss	BS-RS link	Recommendation ITU-R M.1225
	BS-MS and RS-MS link	IEEE 802.16j EVM Type D
Lognormal Shadowing	BS-RS link	3.4 dB
	BS-MS and RS-MS link	8 dB

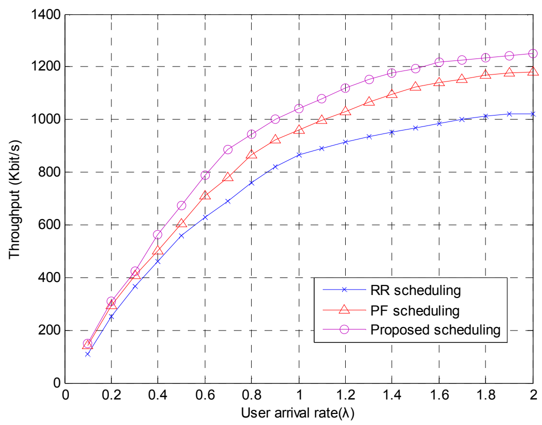

Fig.3. System throughput in different scheduling schemes

Fig.4 shows the energy efficiency of different resource allocation algorithms with the number of packets in the queue. As can be seen from the figure, the energy efficiency drops with the number of packets. The reason is that when the number of packets is less, the system has enough sub-carriers and power for the packets to select, the opportunity of selecting high energy efficiency resource allocation is great. However, with the packets increase, there are more packets competing for system resources, thus some packets can't be satisfied for its high energy efficiency requirement and have to select low energy efficiency sub-carriers. As can be seen from the figure, EEGO is with the highest energy efficiency and SEMG is with the lowest. We can also see the spectral efficiency of different resource allocation schemes from Fig.5. Spectrum efficiency is the total transmission data rate divided by the sub-carriers bandwidth which has been used. As the number of sub-carriers consuming of SEMG are the least, SEMG has the highest spectral efficiency, while EEGO still has higher spectral efficiency than EEMG.

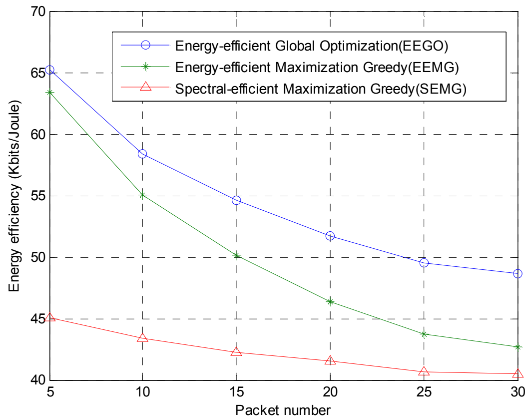

Fig.4. Energy efficiency in different resource allocation algorithms

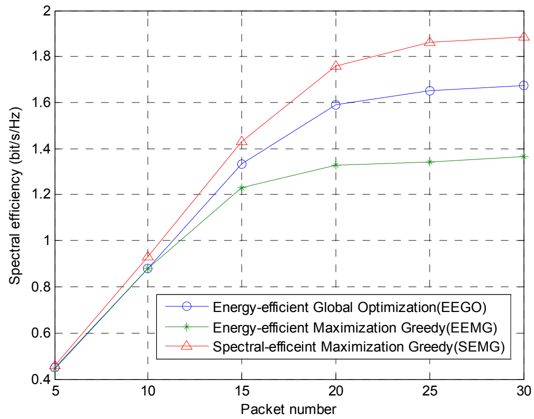

Fig.5. Spectral efficiency in different resource allocation algorithms

VI. CONCLUTIONS

In this paper, we investigate energy-efficient optimization joint user scheduling and resource allocation in OFDMA-based cellular relay networks. Different from allocating resources for the users, we allocate resources for the packets which have a priority queue. For this model of resource allocation, we propose three resource allocation algorithms based on adaptive modulation and coding (AMC) which is discrete and applied in practice system. For the energy efficiency optimization, we propose EEGO and EEMG. For comparison, the SEMG is also proposed which is a spectral-efficiency oriented. Simulation results show that EEGO has the highest energy efficiency while SEMG has the highest spectral efficiency. Because the three proposed resource allocation algorithms are all based on the packets queue, we also propose a novel user scheduling scheme in this paper, which considering the relay selection results and the service types. Simulation results show that the system throughput of proposed scheduling scheme is larger than that of PF.

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REFERENCES

[1] H. Sampath, S. Talwar, J. Tellado, V. Erceg, and A. Paulraj, “A Fourth-generation MIMO-OFDM Broadband Wireless System: Design, Performance, and Field Trial Results ,” IEEE Communications Magazine, Vol.40, pp.143-149, September 2002.

[2] R. Pabst, B. Walke, D. Schultz, P. Herhold, H. Yanikomeroglu, S. Mukherjee, H. Viswanathan, M. Lott, W. Zirwas, M. Dohler, H. Aghvami, D. Falconer, and G. Fettweis, “Relay-based deployment concepts for wireless and mobile broadband cellular radio,” IEEE Communications Magazine, Vol.42, pp.80-89, September 2004.

[3] M. Salem, A. Adinoyi, H. Yanikomeroglu, Young-Doo Kim, “Opportunities and Challenges in OFDMA-Based Cellular Relay Networks: A Radio Resource Management Perspective,” IEEE Transactions on Vehicular Technology, Vol.59, pp.2496-2510, May 2010.

[4] W. Dang, M. Tao, H. Mu, and J. Huang, “Subcarrier-Pair Based Resource Allocation for Cooperative Multi-Relay OFDM Systems,” IEEE Transactions on Wireless Communications, Vol.9, pp.1640-1649, May 2010.

[5] M. Salem, A. Adinoyi, M. Rahman, H. Yanikomeroglu, D. Falconer, and Young-Doo Kim, “Fairness-Aware Radio Resource Management in Downlink OFDMA Cellular Relay Networks,” IEEE Transactions on Wireless Communications, Vol.9, pp.1628-1639, May 2010.

[6] M. Fathi, H. Taheri, “Utility-based resource allocation in orthogonal frequency division multiple access networks,” The Institution of Engineering and Technology, Vol.4, pp.1463-1470, December 2010.

[7] Y. Liang, V. Veeravalli, and H. Poor, “Resource Allocation for Wireless Fading Relay Channels: Max-Min Solution,” IEEE Transactions on Information Theory, Vol.53, pp.3432-3453, October 2007.

[8] D. Wang, Z. Li, and X. Wang, “Joint Optimal Subcarrier and Power Allocation for Wireless Cooperative Networks Over OFDM Fading Channels,“ IEEE Transactions on Vehicular Technology, Vol.61, pp.249-257, January 2012.

[9] J. Joung, and S. Sun, “Power Efficient Resource Allocation for Downlink OFDMA Relay Cellular Networks,” IEEE Transactions on Signal Processing, Vol.60, pp.2447-2459. May 2012.

[10] Y. Huang, X. Fang, and Y. Zhao, “An Energy Saving Scheduling Scheme for OFDMA Two-hop Relay Systems,” IEICE Transactions on Fundamentals of Electronics Communications and Computer Sciences, Vol.E94-A, pp.2320-2326, November 2010.

[11] I. Kim, I.S. Park, and Y.H. Lee, “Use of Linear Programming for Dynamic Subcarrier and Bit Allocation in Multiuser OFDM,” IEEE Transactions on Vehicular Technology, Vol.55, pp.1195-1207, July 2006.

[12] R. Lrmer, “Next Generation Mobile Networks Radio Access Performance Evalution Methodology,” June 2007.