Joint Scheduling for Multi-Service in Coordinated Multi-Point OFDMA Networks

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***Abstract*—In this paper, the issues upon user scheduling in the downlink packet transmission for multiple services are addressed for coordinated multi-point (CoMP) OFDMA networks. We consider mixed traffic with voice over IP (VOIP) and best effort (BE) services. In order to improve cell-edge performance and guarantee diverse quality of service (QoS), a utility-based joint scheduling algorithm is proposed, which consists of two steps: ant colony optimization (ACO) based joint user selection and greedy subchannel assignment. We compare the proposed algorithm with the opimal algorithm and the greedy user selection (GUS) based scheme. Via simulation results, we show that the performance of our proposed algorithm well approaches to that of the optimal solution. It is also observed that 95% of BE users are satsified with average cell-edge data rate greater than 200kbps by using either of the two algorithms. Whereas, our proposed algorithm ensures that more than 95% of VoIP users are satisfied with packet drop ratio less than 2%, compared to 78% by the GUS based algorithm.**

***Index Terms*—Ant colony optimization (ACO), coordinated multi-point (CoMP), OFDMA, multiple services, scheduling**

I. Introduction

Future wireless networks are required to satisfy not only high-speed data applications, but also delay-sensitive applications such as voice over IP (VoIP). To support broadband and multimedia services, orthogonal frequency division multiple access (OFDMA) is identified as a leading candidate for future wireless networks [1]. Additionally, full frequency reuse is envisioned to offer high spectrum efficiency in wireless networks to guarantee diverse service requirements. However, intercell interference (ICI) due to the universal reuse of spectral resources can significantly degrade the system performance and quality of service (QoS).

Coordinated Multi-Point (CoMP) joint transmission is proposed as a promising technique to mitigate ICI and improve system spectral efficiency [2]. In CoMP joint transmission systems, coordinated base stations (CBSs) are connected via a high-speed backbone, and ICI is significantly mitigated by applying the signals transmitted from other CBSs to assist the transmission. In order to make the inter-BS communication overhead affordable, user grouping, e.g., serving subsets of terminals with CoMP joint transmission [3], and clustering of BSs, i.e., dividing the network into small clusters of BSs [4], have been considered. Currently, studies on radio resource management (RRM) cooperation for CoMP systems mainly focus on single service networks, assuming full buffer for all the users [4]-[6]. A convex optimization based coordinated subchannel assignment scheme is proposed in [4] for coordinated OFDMA networks with the objective of maximizing total cell-edge utility. The combinatorial optimization problem is then decomposed into independent optimization problems for each subchannel. The approach proposed in [5] reduces the complexity of centralized multi-cell scheduling by exploiting the idea of greedy user selection (GUS), however, at the expense of degradation in the system performance. In [6], a two-phase scheduling method is proposed considering joint transmission, where user grouping is solved via graph theory in the first phase and subchannel allocation is accomplished in the second phase.

Notice that, [4]-[6] assume only single service for all the users in the networks. In [7] multiple services are taken into account for designing the scheduling algorithms with CoMP joint transmission, under the assumption of a flat fading channel. In this paper, the joint scheduling problem is addressed for multi-cell multi-subchannel scenarios. The system is divided into several disjoint clusters, where each cluster performs joint scheduling independently. Users in each cluster are divided into two groups, i.e., VoIP users and best effort (BE) users according to their traffic patterns. Different utility functions are defined for VoIP users and BE users with respect to different individual QoS requirements. The objective is to maximize the total utility in each cluster.

In general, to solve the scheduling problem in multi-cell multi-service OFDMA systems with CoMP joint transmission is computationally intensive, especially when the number of users and subcarriers are large. Ant colony optimization (ACO) has recently attracted growing attention in the studies of complex combinatorial optimization problems in communications networks [8]-[9]. Based on ACO, in this paper a joint user selection scheme is proposed for each subchannel as a first step. Then, subchannel assignment is based on the idea of greedy algorithm. Via simulation results, the proposed algorithm is shown to yield sum utility which well approaches that of the optimal solution, and could achieve better cell-edge performances compared to the GUS based algorithm.

The rest of the paper is organized as follows. In Section II we briefly describe the system model and formulate the optimization problem. In Section III we introduce the proposed joint scheduling algorithm, involving two steps: ACO

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joint user selection and greedy subchannel assignment. The simulation results are presented in Section IV, and conclustions are given in Section V.

II. System Model and Problem Formulation

A. Clustered CoMP Networks with Multi-Services

We consider the downlink of a cellular OFDMA system, in which CoMP joint transmission is supported. Assume a static clustering technique, where all the base station sectors (BSSs) in the network are divided into a number of disjoint clusters of coordinated BSSs. As in Fig.1), each cluster consists of three neighboring BSSs, and is marked by different color respectively. BSSs within the same cluster are connected to a central unit (CU) through high-speed backbones. According to the long term channel gain, mobile stations (MSs) are divided into two classes, namely cell-center MSs and cell-edge MSs. Only MSs at the cell-edge area are considered in this paper. For simplicity, we assume single antenna for both transmitter and receiver. A spectrum bandwidth B is shared among all the BSSs with universal frequency reuse of 1, and is diveded into K subchannels, each with a bandwidth of $B_{SCH} = B/K$. The maximum transmit power for each BSS is P, which is equally distributed over the subchannels.

Assume each MS has an individual queue to receive its incoming packets, and each CU performs joint scheduling independently according to instantaneous feedback queue information (QI) and channel state information (CSI). The OFDM signaling is time-slotted with the duration of each time slot as T_s. Since joint scheduling is performed independently in each cluster, thus to simplify notation, we focus on a single cluster consisting of a BSS set $\mathcal{N}$ and a cell-edge MS set $\mathcal{M}$, with the cardinality $|\mathcal{N}| = N$, $|\mathcal{M}| = M$ respectively. For any given time slot t, let P_n^k denote the transmit power of BSS n on subchannel k, and $G_{m,n}^k$ denote the channel gain between MS m and BSS n on subchannel k. Suppose each subchannel of a BSS can only be assigned to one MS. $x_{m,n}^k$ indicates whether subchannel k of BSS n is assigned to MS m, and thus we have

$$x_{n,m}^k = \begin{cases} 1, \text{BSS}\, n \text{ transmit to MS}\, m \text{ on subchannel}\, k; \\ 0, \text{otherwise}; \end{cases} \quad (1)$$

subject to $\sum_{m=1}^{M} x_{n,m}^k = 1$. The joint transmission BSS set for MS m on subchannel k can be denoted by $S_m^k = \{n | x_{n,m}^k = 1, n \in \mathcal{N}\}$. Hence, given the power N_0 of the additive white Gaussian noise (AWGN), the signal-to-interference-and-noise ratio (SINR) for MS m on k^{th} subchannel with non-coherent joint transmission is given by

$$\gamma_m^k = \frac{\sum_{n \in \mathcal{N}} P_n^k G_{m,n}^k x_{m,n}^k}{I_m^k + N_0}, \quad (2)$$

where I_m^k is the cochannel ICI on subchannel k for MS m including intra-cluster interference and inter-cluster interference,

$$I_m^k = \sum_{i \in \mathcal{N}} P_i^k G_{m,i}^k \left(\sum_{\substack{s \in \mathcal{M} \\ s \neq m}} x_{s,i}^k \right) + \sum_{j \notin \mathcal{N}} P_j^k G_{m,j}^k. \quad (3)$$

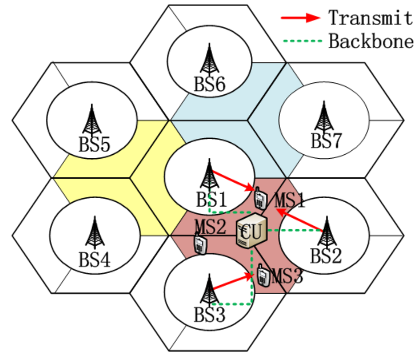

Fig. 1. System model of clustered CoMP networks

Thus the achievable bit rate of MS m on subchannel k is expressed as

$$R_m^k = B_{SCH} \log_2(1 + \beta \gamma_m^k), \quad (4)$$

where β is a constant related to the target bit error rate (BER) given by $\beta = -1.5/\ln(5\,\text{BER})$ [4]. The instantaneous data transmission rate for MS m at time slot t becomes

$$R_m(t) = \sum_{k=1}^{K} R_m^k. \quad (5)$$

Based on different traffic types, the M users in the cluster are classified into two subsets, i.e., BE and VoIP users. We assume full buffer for BE users, with a prescribed minimum average bit rate $\bar{R}_{\min}$. For delay sensitive VoIP services, we consider very bursty and low bit rate, and impose a maximum allowed instantaneous queueing delay $\tau_{\max}$, i.e., $\tau_m(t) \leq \tau_{\max}$, where $\tau_m(t)$ denotes the instantaneous packet delay of user m. The expired packets with latency larger than $\tau_{\max}$ will be dropped at the transmitter. Besides, at the receiver any unsucessfully received packet that fails to be decoded is also discarded. The packet drop ratio should be maintained at an acceptable level to guarantee QoS for VoIP services.

B. Optimization Objective

Let $\mathcal{M}_B$ and $\mathcal{M}_V$ denote the subsets of BE and VoIP users, respectively. According to different QoS requirements of different services, we utilize two different utility functions to represent satisfaction levels for the two different types of users. For a BE user, user's satisfaction increases as the average data rate increases, and thus the utility is defined as a concave and monotonically increasing function of its average data rate, i.e., $U_m(t) = U_{B,m}(\bar{R}_m(t)); \forall m \in \mathcal{M}_B$, where $\bar{R}_m(t)$ is the average data rate of BE user m at time slot t, and is estimated using an exponential filter [4]

$$\bar{R}_m(t) = (1 - \rho_B)\bar{R}_m(t-1) + \rho_B R_m(t). \quad (6)$$

We consider the utility of VoIP users as a monotonically decreasing function of the average delay, i.e., $U_m(t) = U_{V,m}(\bar{\tau}_m(t)); \forall m \in \mathcal{M}_V$, where $\bar{\tau}_m(t)$ is the average delay of VoIP user m at time slot t, and expressed as in [7] by

$$\begin{aligned} \bar{\tau}_m(t) = &(1 - \rho_V)\bar{\tau}_m(t-1) + \rho_V \bar{\alpha}_m^{-1}[Q_m(t-1) \\ &- \min\{R_m(t)T_s, Q_m(t-1)\} + \alpha_m(t-1)], \end{aligned} \quad (7)$$

given that $\bar{\alpha}_m$ denotes the time average arriving bits per slot, $Q_m(t-1)$ is the instantaneous queue size at time slot $t-1$, and

$\alpha_m(t-1)$ denotes the number of instantaneous arriving bits at the end of time slot $t-1$.

Our objective is to maximize sum utility of the MSs in each disjoint cluster. Therefore, the objective function is

$$U(t) = \sum_{m_1\in\mathcal{M}_B} U_{B,m_1}\big(\bar{R}_{m_1}(t)\big) + \sum_{m_2\in\mathcal{M}_V} U_{V,m_2}(\bar{\tau}_{m_2}(t)). \quad (8)$$

Note that $\bar{R}_{m_1}(t-1)$ and $\bar{\tau}_{m_1}(t-1)$ are fixed at time slot t. Using Taylor expansion, (13) can be approximated as [4]

$$\begin{aligned} U(t) = &\sum_{m_1\in\mathcal{M}_B} U'_{B,m_1}\big(\bar{R}_{m_1}(t-1)\big)\bar{R}_{m_1}(t) \\ &+ \sum_{m_2\in\mathcal{M}_V} U'_{V,m_2}(\bar{\tau}_{m_2}(t-1))\bar{\tau}_{m_2}(t). \end{aligned} \quad (9)$$

Control the departure rate so that $R_{m_2}(t)T_s \le Q_{m_2}(t-1)$. Substituted with (6) and (7), thus to maximize (9) is equivalent to maximize

$$\Pi(t) = \sum_{m\in\mathcal{M}} \omega_m R_m(t), \quad (10)$$

where

$$\omega_m = \begin{cases} \rho_B U'_{B,m}\big(\bar{R}_m(t-1)\big), & m\in\mathcal{M}_B; \\ -\rho_V \bar{\alpha}_m^{-1} U'_{V,m}(\bar{\tau}_m(t-1)), & m\in\mathcal{M}_V. \end{cases} \quad (11)$$

Accordingly, the optimization objective turns out to be a linear function in terms of $R_m(t)$.

C. Problem Formulation

Let $\mathbf{X} = \left[x_{m,n}^k\right]$ be the subchannel assignment matrix. Since $R_m(t)$ is decided by $\mathbf{X}$, substituting (5) we thus formulate the optimization problem in the coordinated OFDMA system as

$$\begin{aligned} &\max_{\mathbf{X}} \sum_{m\in\mathcal{M}}\sum_{k=1}^{K} \omega_m R_m^k, \\ &\text{s.t. } 1) \sum_{k=1}^{K} R_m^k T_s \le Q_m, \forall m\in\mathcal{M}_V, \\ &\quad\; 2) \sum_{m=1}^{M} x_{m,n}^k = 1, \\ &\quad\; 3) \tau_m(t) \le \tau_{\max}, \forall m\in\mathcal{M}_V. \end{aligned} \quad (12)$$

That is, the optimization problem becomes to decide $\mathbf{X}$ such that (11) is maximized, subject to the following constraints 1) the CU does not waste spectrum by serving an empty queue or a queue with less bits than achivable departure rate, 2) each subchannel of a BSS can only be assigned to one MS, and 3) the instantaneous latency of a VoIP packet should be no greater than the maximum allowed delay.

III. Proposed Joint Scheduling Algorithm

The optimization problem presented in (12) is an NP-hard combinatorial problem in this paper. ACO is introduced to solve the problem. ACO was inspired by the way that real ants find the shortest path in search for food. Ants deposit some amount of pheromone on the path to the food. More ants passing a way to the food place, the higher amount of pheromone the path will have, and more attractive that path will become. Based on this idea, ACO is proposed to solve difficult tasks and figure out combinatorial problems [8].

In an ant colony system, a number of edges and vertices make all the possible paths from the nest to the food source. The ants make decision in parallel and asynchronously choose the next edge in all vertices. The optimal solution would be a list of edges and vertices which makes the shortest route between the nest and food. Virtual ants choose their paths using two factors: *visibility* and *trail intensity*. Visibility is what an ant can see, and usually it is considered as the inverse of the edge length. Trail intensity is the pheromone left at each vertex, and also related to the number of ants passing through the edge [9].

Based on the idea of ACO, we propose a two-step joint scheduling algorithm in this section. We firstly model the joint user selection on each subchannel as an ACO problem. Then all the subchannels are allocated for each group of coordinated BSSs by using greedy algorithm.

A. ACO Based Joint User Selection

We model the combinatorial user selection problem on each subchannel into a pseudograph with each vertex representing a BSS in the cluster. A set of ants $\mathcal{A}$ is considered in our ant colony system. A combination of BSS and user utility is denoted by an edge, which is connected to a vertex. Edges are associated with the user utility augment or priority, which indicates how likely an edge will be selected. Hence, it is reasonable to design the visibility as

$$V_{n,m}^k = \begin{cases} \omega_m R_{n,m}^k, & Q_m > 0; \\ 0, & \text{otherwise}; \end{cases} \quad (13)$$

where $R_{n,m}^k$ denotes the data rate transmitted from BSS n to MS m over subchannel k, and is estimated using (4) based on the local SINR approximation considering only inter-cluster interference

$$\gamma_{n,m}^k = \frac{P_n^k G_{m,n}^k x_{m,n}^k}{\sum_{l\notin\mathcal{N}} P_l^k G_{m,l}^k + N_0}. \quad (14)$$

Then the probability of selecting an edge to a vertex is given by [9]

$$p_{n,m}^k = \frac{[T_{n,m}^k]^\alpha \cdot [V_{n,m}^k]^\beta}{\sum_{m=1}^{M} [T_{n,m}^k]^\alpha \cdot [V_{n,m}^k]^\beta}, \quad (15)$$

where $T_{n,m}^k$ is the trail intensity of MS m receiving service from BSS n over subchannel k, and is initially set to 1. Trail intensity shows the popularity of an edge. Hence, the trail intensity is updated in each iteration by

$$T_{n,m}^k(l+1) = \xi T_{n,m}^k(l) + \Delta T_{n,m}^k, \quad (16)$$

where $0 < \xi < 1$ is the pheromone evaporation parameter, and $\Delta T_{n,m}^k$ is calculated by

$$\begin{aligned} &\Delta T_{n,m}^{k,a} = \begin{cases} \kappa/L_a, & a^{\text{th}} \text{ ant select } m \text{ to vertex } n; \\ 0, & \text{otherwise}; \end{cases} \\ &\Delta T_{n,m}^k = \sum_{a\in\mathcal{A}} \Delta T_{n,m}^{k,a}, \end{aligned} \quad (17)$$

given that κ is a constant, and L_a^k is the tour length of a^{th} ant which corresponds to the total utility augment subject to the rate control constraint 1) in (12)

$$\begin{aligned} &\Delta L_{n,m}^{k,a} = \begin{cases} \omega_m R_{n,m}^k, & R_{n,m}^k T_s \le Q_m, m\in\mathcal{M}_V; \\ 0, & \text{otherwise}; \end{cases} \\ &L_a^k = \sum_{n=1}^{N} \Delta L_{n,m}^{k,a}, \end{aligned} \quad (18)$$

By substituting (13) into (15), we can see that a user with empty data queue will never get served, which makes sure that the spectrum is not wasted serving a empty queue.

B. Greedy Subchannel Assignment

After performing ACO joint user selection on each subchannel, the queue size of each VoIP user requires adjustment such that the spectrum is not wasted serving a VoIP user redundantly. Hence, the queue size estimate of VoIP user m after multi-cell scheduling on subchannel k is updated successively as

$$\hat{Q}_m^{(k)} = \hat{Q}_m^{(k-1)} - R_m^k T_s \sum_{n=1}^{N} x_{m,n}^k,\ m \in \mathcal{M}_V. \qquad (19)$$

In turn, the visibilities and user priorities should be reassigned according to $\hat{Q}_m^{(k)}$ on the remaining available subchannels. The proposed joint scheduling algorithm is presented in Algorithm 1.

C. Computational Complexity

A number of ants as well as iterations are in need for ACO joint user selection to improve the quality of solutions and acquire a final solution for joint scheduling. Therefore, the computational complexity of the proposed ACO joint user selection strategy could be much greater than the GUS scheme proposed in [5]. However, the ACO joint user selection can be implemented in parallel on multi-processors, which makes it an efficient algorithm for practical use. As long as there is a constant positive lower bound for the pheromone, ACO algorithm has been proved to be able to converge to the optimal solution [10], though the time for convergence is not given. Hence, considering simulation feasibility, the number of iterations can be predefined. It is shown that ACO based scheduling strategy can still achieve better performances than other suboptimal algorithms even without convergence [11].

IV. Simulation Results

The simulation is conducted in a multi-cell OFDMA network with cell radius of 500 m. The total bandwidth is 3 MHz with the carrier frequency of 2 GHz and 15 parallel subchannels. The network is divided into multiple static disjoint clusters, with each cluster consisting of three adjacent BSSs. The propagation model takes into account path loss and fast fading, with the path loss as $L(d) = 128.1 + 37.6 \log_{10} d$ in dB [4], where d is the distance in km. A number of users are uniformly allocated with 50% of VoIP users and 50% of BE users in the cell-edge area, where the long term channel gain is assumed under the threshold -100 dB. The target BER for data transmission is prescribed as 10^{-5}. In the step of ACO joint user selection, 20 iterations are run in total with 10 ants used per iteration [8]. α and β are both set to 1, and the evaporation coefficient ξ and constant κ are set to 0.9 and 1 respectively as in [11]. Inter-cluster interference is taken into account. 1000 independent trials are evaluated by Monte-Carlo simulation under various numbers of cell-edge users per cluster.

Algorithm 1 Proposed Joint Scheduling Algorithm

Initialize $P_n^k = P/K, \forall n \in \mathcal{N}$; $\hat{Q}_m^{(1)} = Q_m(t-1), m \in \mathcal{M}_V$; $R_m^k = 0, \forall m \in \mathcal{M}, \forall k \in \mathcal{K} = \{1, 2, ..., K\}$
for $k = 1$ to K **do**
Step1: ACO based coordinated scheduling
  Initialize $T_{n,m}^k = 1$, $\Delta T_{n,m}^k = 0$, $\forall m \in \mathcal{M}, \forall n \in \mathcal{N}$
  Calculate $V_{n,m}^k$, and $p_{n,m}^k$, $\forall m \in \mathcal{M}, \forall n \in \mathcal{N}$
  for $l = 1$ to the number of iterations **do**
    for all $a \in \mathcal{A}$ **do**
      for $n = 1$ to N **do**
        Select an edge m to visit a new vertex n with probability of $p_{n,m}^k$
        Update $\Delta T_{n,m}^k$ according to selected m and n
      end for
    end for
    Save the best solution so far
    Update $T_{n,m}^k$, and $p_{n,m}^k$, $\forall m \in \mathcal{M}, \forall n \in \mathcal{N}$
  end for
Step2: Greedy subchannel assignment
  Assign the subchannel k according to the best solution
  Update $\hat{Q}_m^{(k)}$, $\forall m \in \mathcal{M}$
end for

Barrier Function is used to model the utility function for BE users [12]

$$U_{B,m_1}(\bar{R}_{m_1}) = \ln(\bar{R}_{m_1}) + (1 - e^{-\varphi(\bar{R}_{m_1} - \bar{R}_{\min})}), \qquad (20)$$

where $\bar{R}_{\min}$ denotes the minimum target bit rate, assumed to be 200 Kbps. φ determines how aggressively the utility increases when $\bar{R}_{m_1}$ approaches $\bar{R}_{\min}$, and is set to 0.02. For the VoIP users, we model the voice traffic by an ON/OFF data arrival process with packet inter-arrival time of 10 ms. The full-rate voice frame size is 160 bits in ON period, and no transmit data otherwise. The maximum queuing delay $\tau_{\max}$ is 25 ms, and the required maximum packet drop ratio δ_{m_2} is 2%. A packet experiencing delay larger than $\tau_{\max}$ will be discarded. Hence, the utility function for the VoIP users is defined as

$$U_{V,m_2}(\bar{\tau}_{m_2}) = -\frac{\log_{10} \delta_{m_2}}{2\tau_{\max}} \left(\tau_{\max}^2 - \bar{\tau}_{m_2}^2\right), 0 < \delta_{m_2} < 1. \qquad (21)$$

In fact, the marginal function of (21) turns out to be the modified-largest-weighted-delay-first (M-LWDF) utility [7].

To evaluate the performance of the proposed joint scheduling algorithm (shortly written as ACO), a two-step GUS based algorithm (referred as GUS) is given for comparison. In GUS algorithm, we firstly apply greedy user selection on each subchannel. Then the subchannel assignment is performed in the same way as the second step of our proposed algorithm. The performance of optimal user selection by exhaustive search (referred as Optimal) is also evaluated for purpose of comparison. Considering simulation feasibility, only the cases with small number of users are simulated for the Optimal algorithm.

The cell-edge sum utilities of the three algorithms are plotted in Fig.2a). It shows that both ACO and GUS algorithm yield a sum utility very close to Optimal algorithm, however, with much lower complexity. For a better observation, the

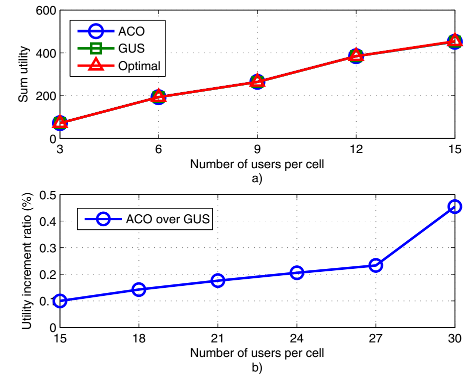

Fig. 2. a) Cell-edge sum utility b) Cell-edge sum utility increment ratio of ACO over GUS

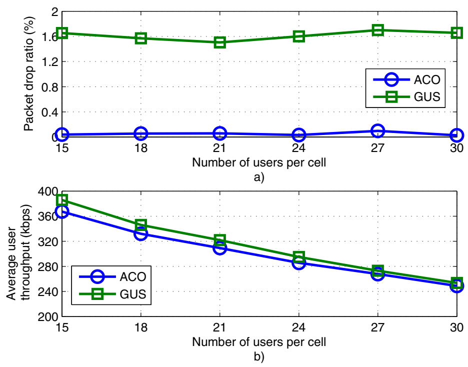

Fig. 3. a) Cell-edge packet drop ratio of VoIP users b) Cell-edge average user throughput of BE users

sum utility increment ratio of ACO over GUS instead of sum utilities, is plotted in Fig.2b) in the cases when the number of cell-edge users is greater than 15. It shows that ACO yields higher cell-edge sum utility than GUS. The utility increment is small but it increases as the number of cell-edge users increases. Accordingly, we also plot in Fig.3 the VoIP packet drop ratio and average user throughput of BE users in the cases when the number of users is larger than 15.

Fig.3a) shows the VoIP packet drop ratio of the two algorithms. We can see that the two algorithms both achieve low packet drop ratio and satisfy the prescribed QoS requirement, but by contrast, ACO outperforms GUS by achieving much lower packet drop ratio. The average user throughputs of cell-edge BE users are plotted in Fig.3b). It shows that average user throughput decreases as the number of cell-edge users increases. QoS is satisfied in all the cases for both ACO and GUS, with GUS achieving higher average user throughput than ACO. However, when traffic gets heavier, the cell-edge average user throughput of ACO approaches to that of GUS.

The user satisfaction ratio, i.e., the ratios of the numbers of QoS-satisfied users to the total number of cell-edge users of the two algorithms, are also plotted for both BE and VoIP users in Fig.4. In the plotting, we illustrate that more than 95% of the BE users are satisfied utilizing either ACO or GUS when the number of cell-edge users is within 27. For VoIP users, more than 95% of the users are satisfied for all the cases by exploiting ACO. However, using GUS only about 78% of the cell-edge users are satisfied. Hence, we can conclude that ACO yields higher sum utility at the cell-edge area, and in turn

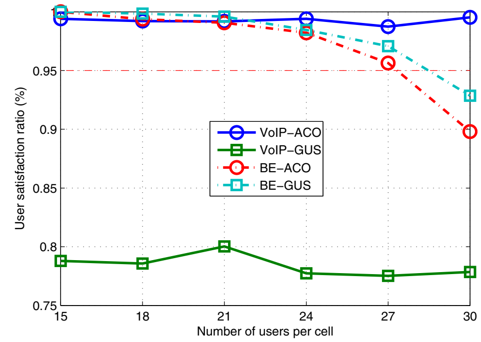

Fig. 4. Cell-edge user satisfaction ratio

achieves better performance in balancing average throughput of BE users and packet drop ratio of VoIP users.

V. Conclusion

In this paper, we focus on the downlink of multi-cluster CoMP OFDMA networks with multiple types of traffic patterns and diverse provisioning QoS requirements. A two-step joint scheduling scheme is proposed to address the utility-based combinatorial optimization problem of joint scheduling in the network. By multi-cluster system level simulation, our proposed algorithm is shown to well approximates the optimal solution in terms of sum utility. Compared to the greedy user selection based algorithm, we demonstrate that the proposed joint scheduling algorithm yields higher sum utility, and achieves better performances in balancing average throughput of BE users and packet drop ratio of VoIP users at the cell-edge area with large number of users.

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