Interference Management for Multimedia Femtocell Networks with Coalition Formation Game

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***Abstract*—Recently, the multimedia content delivery has replaced the traditional voice communication as the major source of traffic in wireless networks. The deployment of femtocells is promising in satisfying the requirements of these multimedia applications if the interference among the femtocell access points (FAPs) is well-managed. In this paper, we study the interference management problem of the FAPs in a cooperative multimedia femtocell network. We consider the network setting where the players (i.e., the FAPs) can coordinate their transmissions to reduce the level of interference within a coalition. We first formulate the interference management problem as a coalition formation game in partition form with negative externalities, where the payoff of a player depends on actions of other players in the same coalition and in different coalitions. Based on the solution concept of *recursive core* in coalitional games, we propose an efficient coalition formation algorithm, RECORD, to achieve a final stable coalition structure. Simulation results show that the RECORD algorithm results in a substantially higher flow throughput and aggregate utility than some previously proposed scheduling algorithms.**

I. INTRODUCTION

With a growing demand for mobile data access services, especially the delivery of *multimedia* content, the mobile operators are pressed to increase the system capacity in a cost-effective manner. The idea of *femtocells* was proposed, where small femtocell access points (FAPs) are deployed by the end users or service providers in an indoor environment to improve the coverage and capacity [1], [2]. The operating and capital costs of the service operators are expected to reduce significantly. However, with the deployment of femtocells in some scenarios, the utility of some users may drop below a satisfactory level due to the multi-user *interference*. The issue of efficiently managing the level of interference in femtocell networks remains an open problem. Furthermore, for femtocell networks supporting multimedia services, since the multimedia applications have different quality-of-service (QoS) requirements, the problem of interference management for such femtocell network is challenging.

Different *interference management* techniques have been proposed recently for femtocell networks. Pantisano *et al.* in [3] proposed a framework for macrocell-femtocell cooperation to maximize the utility in terms of throughput and delay. Cheung *et al.* in [4] proposed a resource allocation algorithm to deal with inter-tier and intra-tier interference by considering both open-access and closed-access femtocell networks. Chandrasekhar *et al.* in [5] analyzed the uplink capacity in a shared spectrum two-tier direct sequence code division multiple access (DS-CDMA) femtocell network. An interference avoidance technique based on time hopping code division multiple access (TH-CDMA) physical layer and sectorized receive antenna was proposed. Jo *et al.* in [6] proposed open-loop and closed-loop uplink power control schemes for interference mitigation in femtocell networks. It was shown that the schemes can suppress the interference level below some fixed and adaptive thresholds. In [7], Pantisano *et al.* modeled the spectrum sharing problem in a femtocell network as a coalition formation game in partition form. They proposed a distributed algorithm to partition the network based on the recursive core. Zhang *et al.* in [8] modeled the subchannel and power allocation problem of femtocells as a non-cooperative game and proposed a suboptimal subchannel allocation algorithm and an optimal power allocation algorithm to solve the resource allocation game.

Although the interference management techniques in previous work can improve the network capacity, they may not be suitable for multimedia femtocell networks. For the femtocell networks delivering multimedia content, treating the flows running multimedia applications differently is important, because the satisfaction of each user may not be proportional to the throughput. Simply maximizing the throughput of each flow is not equivalent to maximizing the aggregate utility for the multimedia femtocell networks.

In this paper, we apply the *coalitional game theory* [9], [10] to study the interference management problem in a *cooperative* multimedia femtocell network. Specifically, we consider the scenario where each FAP sets up a video transmission with a femtocell user equipment (FUE) in each femtocell. We assume that the players (i.e., the FAPs) can form *coalitions* and coordinate their transmissions using time division multiple access (TDMA) to reduce the level of interference. For players belonging to different coalitions, concurrent transmissions can occur. Our method can also be applied to orthogonal frequency-division multiple access (OFDMA) systems with modifications.

We formulate the problem of interference management as a *coalition formation game* in partition form [10] with *negative externalities*. In fact, negative externality is a term used to describe the cost incurred by the sharing of the common resources [11]. In our work, due to the interference among different coalitions, obtaining the optimal coalition structure in this coalition formation game is difficult even by a centralized approach. In this way, we apply the solution concept of *recursive core* [12], [13] to analyze the choice of each FUE in joining a coalition. The REcursive CORe Discovery (RECORD) algorithm is proposed based on the recursive core to obtain a stable final partition. In summary, the main contributions of the paper are three-fold:

- We formulate the interference management problem in a multimedia femtocell network as a coalition formation game in partition form with the goal of maximizing the network utility.
- We propose the RECORD algorithm to obtain the recursive core of the coalition formation game.
- Simulation results show that the RECORD algorithm achieves a higher average flow throughput and aggregate utility than the non-cooperative scheme and a recently proposed interference management scheme in [7].

The rest of the paper is organized as follows. In Section II, the system model is presented. We formulate the coalition structure formation problem in Section III, and propose the RECORD algorithm based on the recursive core in Section III-A. Simulation results are presented in Section IV, followed by the concluding remarks in Section V.

II. SYSTEM MODEL

As shown in Fig. 1, we consider a femtocell network in a building with N FAPs installed. The femtocell network is within the range of a *macrocell* base station (BS). Each FAP is connected to the cellular operator network through an Internet protocol (IP) backhaul [1]. The FUEs are receiving video content from the FAPs. We let $\mathcal{N} = \{1, \ldots, N\}$ be the set of communication links. We let S_i and R_i be the transmitter and receiver of link $i \in \mathcal{N}$, respectively. Thus, (S_i, R_i) form a transmitter/receiver pair of link $i \in \mathcal{N}$.

In the channel model, we consider path loss and large-scale fading in determining the average link quality and thus the link data rate. With *concurrent* transmissions, the transmission rate of each link is constrained by the summation of mutual interference from the other links. Given the transmission power P_i of transmitter S_i, the received signal power can be expressed as $P_i \kappa G_{i,i} d_{i,i}^{-\gamma}$, where $G_{j,i}$ represents the fading gain of the channel with transmitter S_j and receiver R_i. κ is the constant scaling factor corresponding to the reference path loss, $d_{j,i}$ is the distance between S_j and R_i, and γ is the path loss exponent. The received signal to interference plus noise ratio (SINR) of the i-th FUE can be written as

$$\mathrm{SINR}_i = \frac{P_i \kappa G_{i,i} d_{i,i}^{-\gamma}}{N_0 + I_0 + \sum_{j \neq i} P_j \kappa G_{j,i} d_{j,i}^{-\gamma}}, \qquad (1)$$

where N_0 is the background noise power. $I_0 = P_0 \kappa G_{0,i} d_{0,i}^{-\gamma}$ is the received interference power from macrocell BS, where P_0 is the transmission power of the macrocell BS, $d_{0,i}$ represents the distance between the macrocell BS and the receiver R_i. Since the distance from the macrocell BS to each FUE in the building is roughly the same, we let d_0 be the distance between the macrocell BS and a FUE, and use it to calculate the interference I_0 for all the receivers. $G_{0,i}$ represents the fading gain of the channel from macrocell BS to receiver R_i. For the downlink scenario we consider, only the macrocell BS but not the macrocell users will generate interferences to FUEs. We assume that link i can achieve a transmission rate r_i according to the Shannon capacity estimation, which is given by

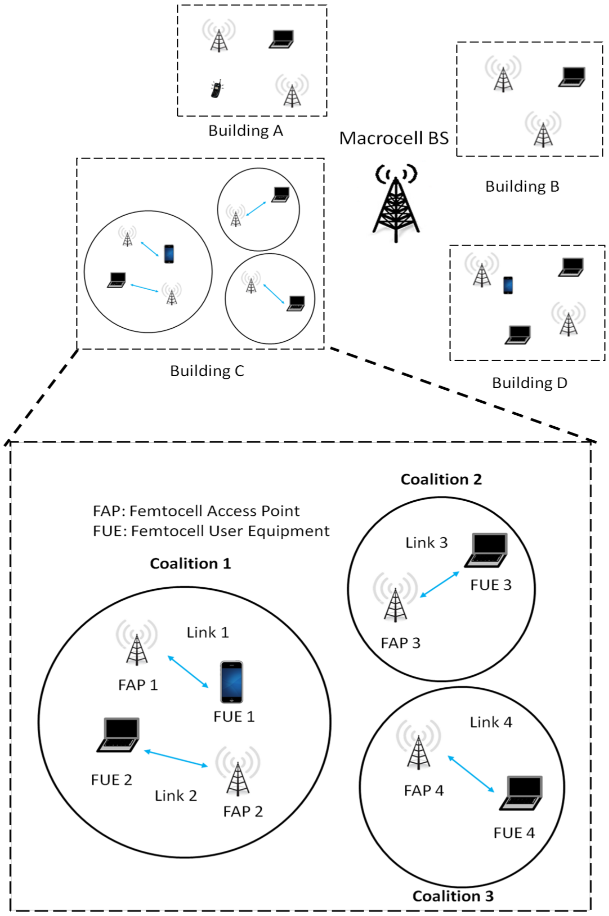

Fig. 1. An illustration of our system model. (a) The upper part of the figure shows a wireless cellular network, where some femtocells are deployed in buildings within the range of a macrocell BS. (b) The lower part of the figure shows a multimedia femtocell network with four active FAP/FUE links transmitting videos. Due to the high level of interference, they form *coalitions* and coordinate their transmissions. This paper aims to study this coalition formation problem for interference management in a multimedia femtocell network.

$$r_i = \eta W \log_2(1 + \mathrm{SINR}_i), \qquad (2)$$

where W is the transmission bandwidth, and $\eta \in (0, 1)$ is a coefficient describing the efficiency of the transceiver design. Using (1) and (2), the data rate r_i of link i in a *non-cooperative* scheme can be written as

$$r_i = \eta W \log_2\left(1 + \frac{P_i \kappa G_{i,i} d_{i,i}^{-\gamma}}{N_0 + I_0 + \sum_{j \neq i} P_j \kappa G_{j,i} d_{j,i}^{-\gamma}}\right). \qquad (3)$$

For each FUE $i \in \mathcal{N}$, we use nondecreasing utility functions to model the level of satisfaction that it experiences when it attains a certain data rate. The average data rate for different

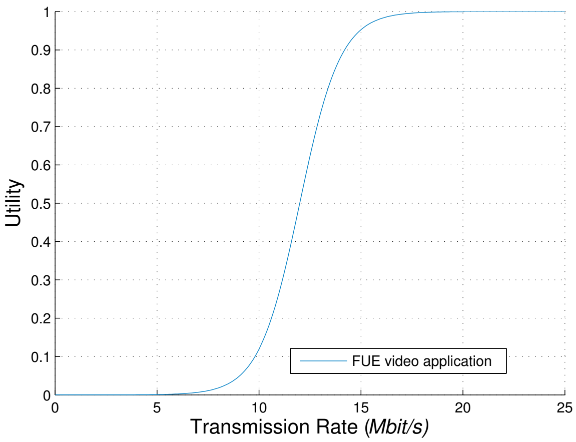

Fig. 2. Utility functions for the FUE video traffic.

videos depends on the video resolution, frame rate, and codec used [14], [15]. In this paper, we consider a high-definition (HD) video format which is widely used on the newest mobile devices, which include iPhone 5 and Samsung Galaxy S3. We consider that the video has 1080p HD quality, (i.e., with the resolution of 1920×1080 pixels), achieving a frame rate of 30 frames/second, and uses H.264 as codec. The video format requires a bit-rate of 15 Mbit/s to support full 1080p HD video quality, bit-rate between 8 $\sim$ 15 Mbit/s can support a video quality in between 720p and 1080p. We use the logistic sigmoid function as shown in Fig. 2 to model the utility of the video traffic by carefully tuning the parameters [16], That is,

$$U_i(r_i) = (a_i + b_i e^{-k_i(r_i - c_i)})^{-1} - (a_i + b_i e^{k_i c_i})^{-1}, \tag{4}$$

where the data rate r_i is defined in (3). The coefficients a_i, b_i, k_i and c_i are the parameters used to discribe the amplitude, slope, and central point of the sigmoid function, which can be determined by the traffic characteristics of the i-th FUE.

To manage the level of interference due to simultaneous transmissions, we consider a setting where the links can form *coalitions*. Since each femtocell FAP is connected to a broadband gateway, the control messages among the links can be exchanged through the IP backhaul.

Transmission time allocation within a coalition is based on a superframe structure. Each superframe begins with a period for network synchronization, control message broadcast and coalition formation. The remaining time of the superframe is the channel allocation time for contention-free data transmission. We assume that within each coalition, a scheduler is used for scheduling the transmissions in the coalition such that only one link in each coalition is allowed to transmit at a given time. For simplicity, we assume that all the links in the coalition have an equal share of the transmission time. Therefore, each FUE is not interfered by the FAPs in the same coalition. However, the data rate of each link is still influenced by the interference from the simultaneously transmitting links in other coalitions.

The problem of how coalitions should be formed to maximize the aggregate network utility in the network is difficult to solve in general. In the next section, we will apply coalition formation game to study this interference management problem.

III. Coalition Formation For Interference Management in Multimedia Femtocell Networks

We formulate the problem of coalition formation for interference management in a multimedia femtocell network as a coalition formation game. The RECORD algorithm is proposed for coalition formation based on the *recursive core*, which results in a *stable* final partition.

Using the terminology of coalitional game theory, we refer to the set of links $\mathcal{N} = \{1, \ldots, N\}$ as the set of *players*. Moreover, we refer to the set of players $\mathcal{S} \subseteq \mathcal{N}$ that coordinates their transmissions using TDMA as a *coalition*. Let $\mathcal{A}(\mathcal{K})$ be the set of *partition* or *coalition structure* [10] of set $\mathcal{K} \subseteq \mathcal{N}$. That is, for a partition $\pi \in \mathcal{A}(\mathcal{K})$, we have $\cup_{\mathcal{S}\in\pi}\mathcal{S} = \mathcal{K}$ and $\hat{\mathcal{S}} \cap \tilde{\mathcal{S}} = \emptyset, \forall \hat{\mathcal{S}}, \tilde{\mathcal{S}} \in \pi$ with $\hat{\mathcal{S}} \neq \tilde{\mathcal{S}}$. As an example, for $\mathcal{K} = \{1,2,3\}$, $\pi \in \mathcal{A}(\mathcal{K})$ can be one of the following five coalition structures: $\{\{1\},\{2\},\{3\}\}$, $\{\{1\},\{2,3\}\}$, $\{\{2\},\{1,3\}\}$, $\{\{3\},\{1,2\}\}$, and $\{\{1,2,3\}\}$.

Given a partition π, we consider the *worst-case* interference experienced by player $i \in \mathcal{S}$ from other coalitions $\mathcal{W} \in \pi \setminus \mathcal{S}$, which is given by

$$I_i(\mathcal{S}, \pi) = \sum_{\mathcal{W}\in\pi\setminus\mathcal{S}} \max_{j\in\mathcal{W}} P_j \kappa G_{j,i} d_{j,i}^{-\gamma}. \tag{5}$$

Notice that due to the use of TDMA within each coalition, we only consider the interference from one particular player that generates the highest level of interference to player $i \in \mathcal{S}$ in each coalition $\mathcal{W} \in \pi \setminus \mathcal{S}$.

We define the *value* or *payoff* of player $i \in \mathcal{S}$ as the utility of link i, which is given by

$$\begin{aligned} &v_i(\mathcal{S}, \pi) \\ &= \left(a_i + b_i e^{-k_i\left(\frac{1}{S}\eta W \log_2\left(1 + \frac{P_i \kappa G_{i,i} d_{i,i}^{-\gamma}}{N_0 + I_0 + I_i(\mathcal{S},\pi)}\right) - c_i\right)}\right)^{-1} \\ &\quad - (a_i + b_i e^{k_i c_i})^{-1}, \end{aligned} \tag{6}$$

where S is the number of players in coalition $\mathcal{S}$ with $S = |\mathcal{S}|$. Note that the transmission time in each channel allocation time is fairly divided by all the S players in coalition $\mathcal{S}$. Moreover, for any coalition $\mathcal{S} \subseteq \mathcal{N}$, the payoff of every player in the coalition depends on the overall structure π of the network, i.e., on the players in $\mathcal{S}$ as well as on the players in $\mathcal{N} \setminus \mathcal{S}$.

The value of each coalition $\mathcal{S}$ is defined as the sum of the values of all the players in the coalition, which is given by

$$v_{\mathcal{S}}(\pi) = \sum_{i\in\mathcal{S}} v_i(\mathcal{S}, \pi). \tag{7}$$

The value of a partition π is defined as the sum of the values of all the coalitions $\mathcal{S} \in \pi$, which is given by

$$v(\pi) = \sum_{\mathcal{S}\in\pi} v_{\mathcal{S}}(\pi) = \sum_{\mathcal{S}\in\pi}\sum_{i\in\mathcal{S}} v_i(\mathcal{S}, \pi). \tag{8}$$

The interference management problem for multimedia femtocell networks can be modeled as a $(\mathcal{N}, v)$ *coalition formation game* in *partition form* [10]. Due to the *negative externalities* [11] from the inter-dependent interference among different coalitions, any coalition of players is affected by the behavior of players in other distinct coalitions in the network.

The goal of the $(\mathcal{N}, v)$ coalition formation game is to find the optimal partition $\pi^* \in \mathcal{A}(\mathcal{N})$ that maximizes $v(\pi)$. That is,

$$\pi^* = \underset{\pi \in \mathcal{A}(\mathcal{N})}{\arg\max}\, v(\pi). \tag{9}$$

Since $(\mathcal{N}, v)$ is not a superadditive game, the grand coalition is usually not the optimal partition. To obtain the optimal partition π^*, a *centralized approach* can be used, which involves iterating over all the possible partitions $\mathcal{A}(\mathcal{N})$ in problem (9). The number of iterations required is equal to the *Bell number* [11], [17], where the k^{th} Bell number represents the number of partitions in a set with k elements. As an example, the first ten Bell numbers are $1, 2, 5, 15, 52, 203, 877, 4140, 21147, 115975$. Since the number of possible partitions in $\mathcal{A}(\mathcal{N})$ grows exponentially with the total number of players N in the system, finding the optimal partition π^* is computationally complex for dense networks, and is thus *impractical*. In the next section, we propose an algorithm for coalition formation based on the recursive core.

A. Recursive Core Discovery (RECORD) Algorithm

We apply the solution concept of *recursive core* in coalitional game theory to address the coalition formation problem with externalities. For $\mathcal{K} = \{1, \ldots, k\} \subseteq \mathcal{N}$, a recursive core of a game $(\mathcal{K}, v)$ is an *outcome* [12] that consists of two components: the partition $\pi \in \mathcal{A}(\mathcal{K})$ and the corresponding payoff $v_i(\mathcal{S}, \pi)$ of each player $i \in \mathcal{K}$.

The recursive core is defined by *recursions* in a total of N iterations. Let $\pi^{(k)*}$ be the partition formed in the k^{th} iteration for the game $(\mathcal{K}, v)$. In the $k + 1^{\text{th}}$ iteration, we consider the game $(\mathcal{K} \cup \{k + 1\}, v)$, where player $k + 1$ decides to either join a coalition in $\pi^{(k)*}$ or form a new coalition to maximize the value of the new partition.

We propose the RECORD algorithm based on the recursive core for coalition formation in Algorithm 1. It allows each player to decide to which coalition it should join in order to maximize the value of the partition. In the first iteration (line 2), we consider the trivial game $(\{1\}, v)$, where the optimal partition is $\{\{1\}\}$. We then include the players one by one into the system in each iteration (line 3). In the k^{th} iteration, different possible coalition structure $\pi^{(k)}$ is considered (line 6), where player k either joins a coalition $\mathcal{S} \in \pi^{(k-1)*}$ formed in the previous iteration or forms a new coalition (when $\mathcal{S} = \emptyset$) (lines 4 and 6). As an example, in the second iteration where $k = 2$, player 2 can either join the coalition $\{1\}$ (i.e., the partition $\pi^{(2)} = \big\{\{1, 2\}\big\}$ is formed in line 6) or form a new coalition $\{2\}$ (i.e., the partition $\pi^{(2)} = \big\{\{1\}, \{2\}\big\}$ is formed in line 6). The partition $\pi^{(k)}$ that results in the largest $v(\pi^{(k)})$ so far is recorded in lines 8 to 10. After N iterations, the recursive core is obtained in line 13. The players belonging to the same coalition then coordinate their transmissions using TDMA based on the final partition $\pi^{(N)*}$ (line 14).

Algorithm 1 *REcursive CORe Discovery (RECORD) for Coalition Formation in Femtocell Networks*

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1:  Input: Parameters $P_i$, $a_i$, $b_i$, $c_i$, $k_i$, $\forall i \in \mathcal{N}$, $N$,
        $d_{i,j}, G_{i,j} \forall j, i \in \mathcal{N}, j \neq i$, $N_0$, $\gamma$, $\kappa$, $b$, $d_0$, $G_0$, and $P_0$
2:  Set $\pi^{(1)*} := \{\{1\}\}$
3:  for $k = 2$ to $N$ do
4:      for $\mathcal{S} \in \pi^{(k-1)*} \cup \emptyset$ do
5:          Set $\sigma := -\infty$
6:          Set $\pi^{(k)} := (\pi^{(k-1)*} \backslash \mathcal{S}) \cup (\mathcal{S} \cup \{k\})$
7:          Calculate $v(\pi^{(k)})$ using (8)
8:          If $v(\pi^{(k)}) > \sigma$
9:              Set $\pi^{(k)*} := \pi^{(k)}$
10:         end if
11:     end for
12: end for
13: Output: (Recursive Core) The output lies in recursive
        core of game $(\mathcal{S}, v)$ consisting of both the final partition
        $\pi^{(N)*}$ and the value $v_i(\mathcal{S}, \pi^{(N)*})$ of each player $i \in \mathcal{N}$
        using (7)
14: Inner Coalition Scheduling: Within each coalition $\mathcal{S} \in$
        $\pi^{(N)*}$, TDMA is performed
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IV. PERFORMANCE EVALUATION

In this section, we first compare the performance between the RECORD algorithm and the optimal partition in (9) by using exhaustive search. We then evaluate the performance of the RECORD algorithm by comparing it with the non-cooperative scheme, and the modified recursive core (MRC) scheme in [7]. Moreover, the average flow throughput and aggregate system utility of the RECORD algorithm under different settings are studied.

For the exhaustive search approach, we determine all the possible partitions of a set and record the optimal partition that results in the maximal aggregate utility. For the non-cooperative scheme, the links do not cooperate and the partition $\big\{\{1\}, \ldots, \{N\}\big\}$ is chosen. All the links transmit concurrently during the channel allocation time, and the data rate r_i of link i is given by (3). The system payoff of the non-cooperative scheme is

$$\begin{aligned} v_{nc} &= \\ &\sum_{i \in \mathcal{N}} \left(a_i + b_i e^{-k_i \left(\eta W \log_2 \left(1 + \frac{P_i \kappa G_{i,i} d_{i,i}^{-\gamma}}{N_0 + I_0 + \sum_{j \neq i} P_j \kappa G_{j,i} d_{j,i}^{-\gamma}} \right) - c_i \right)} \right)^{-1} \\ &- \sum_{i \in \mathcal{N}} \left(a_i + b_i e^{k_i c_i} \right)^{-1}. \end{aligned} \tag{10}$$

Different from MRC scheme in [7], the proposed RECORD algorithm aims to maximize the aggregate system utility. In addition, our RECORD algorithm further improves the

TABLE I
SIMULATION PARAMETERS

Parameter	**Value**
Bandwidth W	20 MHz
Noise power spectral density N_0/W	-174 dBm/Hz
FUE transmission power P	20 dBm
BS transmission power P_0	5 W
FAP coverage radius r	15 m
Distance between BS and FUE d_0	1000 m
Scaling factor κ	3.6012×10^{-5}
Path loss exponent γ	2
Building size l	100 m

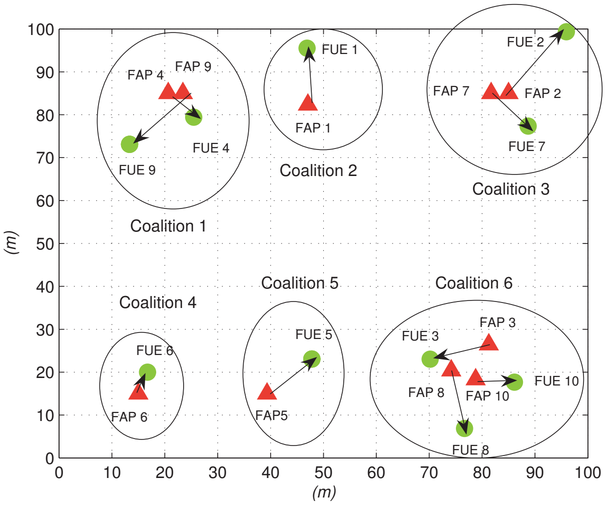

Fig. 3. Snapshot of coalition formation in a femtocell network with video applications for $N = 10$ and $l = 100$ m. The triangles and circles represent the FAPs and FUEs in the femtocell network, respectively.

performance compared to MRC scheme for the femtocells with multimedia content delivery.

In our simulation setting, we consider that N FAPs are randomly placed in a square region with dimensions $l \times l$ m^2. The coverage range of each FAP is a circle with radius equal to 15 m. For each FAP, we assume that one FUE is currently engaged in a downlink communication with the FAP at a given time. Unless stated otherwise, we adopt the simulation parameters from a typical femtocell setting [3], which are summarized in Table I. The utility function for the video traffic is as in (4) with parameters $a_i = 1; b_i = 1; k_i = 1; c_i = 12$ based on the FUE video format described in section II. Using MATLAB as our simulation tool, we repeat the experiment 2000 times using Monte Carlo simulation for each number of flows, and calculate the average value of the performance metrics over different network topologies. The performance of the algorithms are fairly compared under the same network configuration.

For our proposed RECORD algorithm, we first present a sample coalition formation for a femtocell network deployed within a $100 \times 100\, m^2$ square region with ten FAP/FUE links. Fig. 3 shows the coalition formation result of a multimedia femtocell network with FUEs receiving video content from the FAPs. The triangles and circles represent the FAPs and FUEs in the femtocell network, respectively. Due to the high level of interference among links 2 and 7; links 3, 8 and 10; links 4 and 9; three different coalitions are formed.

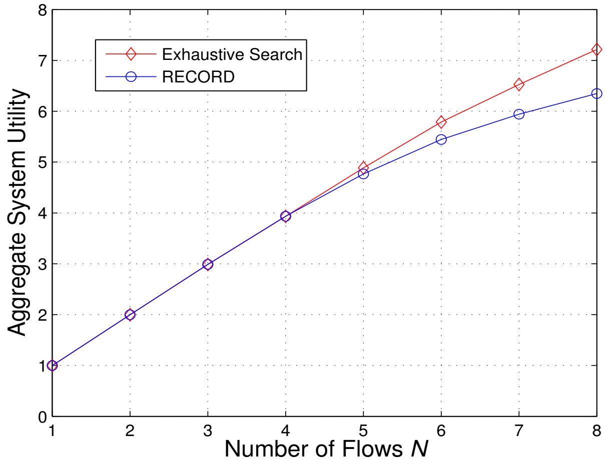

Fig. 4. Comparison between RECORD algorithm and exhaustive search.

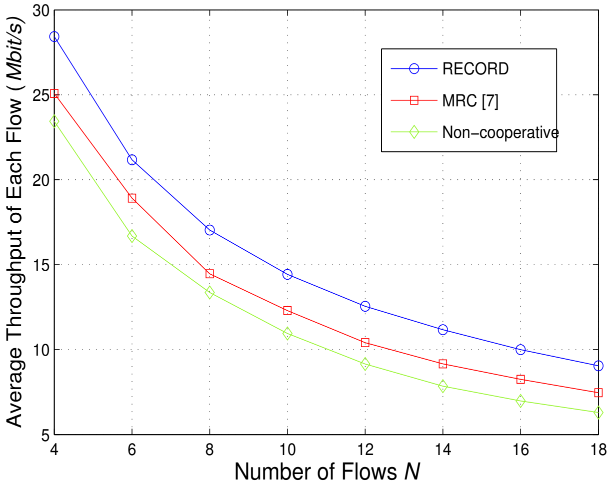

Fig. 5. Average flow throughput versus the number of flows N.

We then compare the performance between the optimal partition in (9) by using exhaustive search and our proposed RECORD algorithm. Fig. 4 shows the aggregate system utility results. Note that since the computational complexity for exhaustive search, which determines the optimal partition of a set, increases exponentially with the number of FAPs, we present the results for up to eight FAPs in the network. The results show that the proposed RECORD algorithm achieves a near-optimal performance when the number of flows N is small. In a femtocell network with 8 flows, the RECORD algorithm achieves 90% of the aggregate utility of the exhaustive search approach with a much lower computational complexity.

In Fig. 5, we plot the average flow throughput versus the number of flows N from 4 to 18. Results show that when the number of flows increases, the average flow throughput reduces due to the multi-user interference. However, the proposed RECORD algorithm outperforms the MRC and non-cooperative schemes. In a femtocell network with 18 flows, the average flow throughput of our RECORD algorithm is higher than the MRC and non-cooperative schemes by 21% and 44%, respectively.

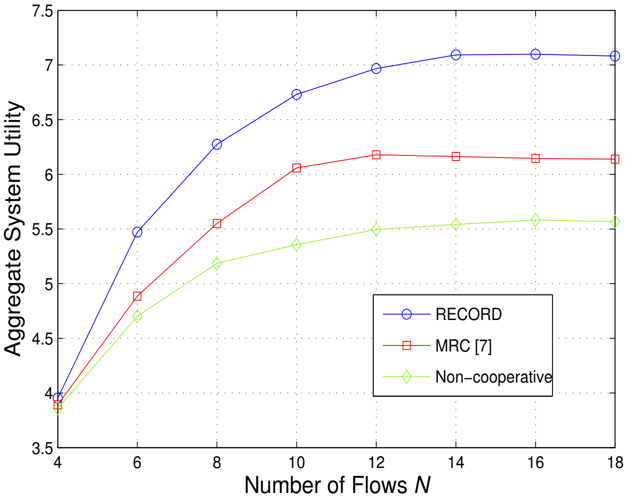

Fig. 6. Aggregate system utility versus the number of flows N.

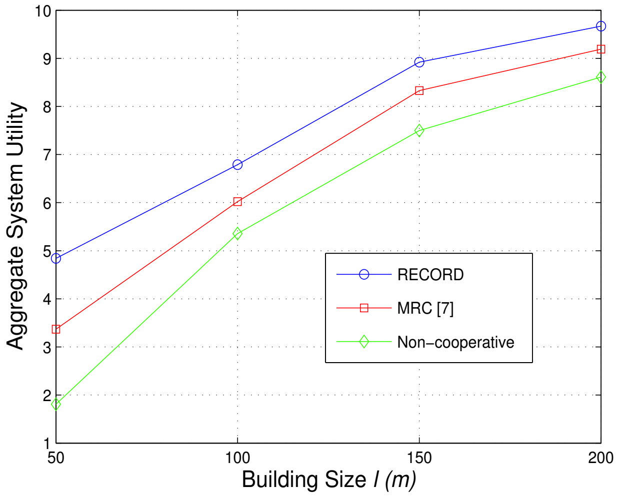

Fig. 7. Aggregate system utility versus the building size l for $N = 10$.

In Fig. 6, we compare the aggregate system utility of the RECORD, MRC, and non-cooperative schemes. Simulation results show that the aggregate utility saturates when $N \geq 14$. This is due to the fact that the increased multi-user interference degrades of utility of each flow. More flows will not increase the aggregate utility further. The RECORD algorithm achieves the highest system utility among the three schemes. In a femtocell network with 18 flows, our RECORD algorithm outperforms the MRC and non-cooperative schemes by 17% and 27%, respectively.

In Fig. 7, we plot the aggregate system utility against different building sizes l when the number of flows N is equal to 10. Simulation results show that when the building size increases, the aggregate system utility increases for all the schemes. This is due to the fact that an increased in l reduces the interference, which increases the aggregate utility.

V. CONCLUSION

In this paper, we studied the interference management problem in multimedia femtocell networks for aggregate network utility enhancement. We formulated it as a coalition formation game with externalities, which models the interactions and cooperations among the communication links between the femtocell access points and the femtocell user equipments. An efficient REcursive CORe Discovery (RECORD) algorithm was proposed based on the recursive core in coalitional game theory. Simulation results showed that a substantial improvement of the aggregate network utility is achieved over the modified recursive core (MRC) scheme in [7], and the non-cooperative scheme. For future work, we will consider a general system model with multiple active users in each femtocell. We will also consider generalizing the proposed RECORD algorithm for the OFDMA femtocell systems.

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