Cooperative Multicast Resource Allocation Strategy

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***Abstract*—In this paper we propose a new cooperative video multicast strategy, the so called Coordinated multiple relays (CoMR). This is based on an efficient one–to-many resource sharing technique which exploits the space diversity of the base station to relay to mobile station in a two hop topology. The new scheme showed considerable enhancement of system average throughput and user fairness compared to non cooperative schemes and in addition, from an energy efficiency perspective due mainly to: a) the significant gain in terms of coverage provided by relay deployment, b) the positive superposition of synchronous transmissions at the access stage which boost the received Signal to Interference and Noise Ratios which ultimately allows the use of higher Modulation and Coding Schemes, c) The flexibility of the proposed algorithm to switch from cooperative mode to non cooperative mode according to when the conditions are most beneficial.**

***Keywords*—Cooperative communication, multicast scheduling, two hop network, coordinated transmission, WiMAX, and LTE.**

I. INTRODUCTION

Industry forecasts that mobile data traffic will grow 10-fold between 2011 and 2016, mostly driven by video transmissions [1]. Attending a sports match, concert or other live event is a great experience that people tend to share the same content of photos and/or videos to enhance interactive communities of friends, colleagues and family. With current network infrastructures high incidence of video upload or download from closely packed users in those scenarios can cause serious shortage of network resources which may result in a large number of unsatisfied users.

Multicast strategies can provide reliable solutions to satisfy both user experience and operator infrastructure challenges [2]. Among those one-to-many transmission strategies is the multimedia broadcast and multicast services. These multicast services, already standardized in both the third generation partnership project (3GPP) [3] and IEE802.16m (WiMAX) standards [4], enable one-to-many delivery schemes; "the service will deliver a greatly improved customer experience vs. unicast video delivery", said DeSantis executive director of advanced solutions for Verizon Wireless [5].

However, since subscribers of the same multicast group are distributed at different locations and experience different fading time-varying channels, it remains rather challenging to provide satisfactory video multicast services to all subscribers [6]. In fact, ensuring highest users' satisfaction requires the selection of the lowest supported rate of all multicast group members which corresponds to the group member with the worst channel condition, but still able to decode the data. The latter approach, known in literature by Conserve [6], results in conservative resource utilization and evidently inefficient when the majority subscribers have good channel conditions and able to perform for high rate transmissions; while only a small division of subscribers suffer deep fading.

In the other hand, cooperative communication has shown to be a promising technology that can considerably enhance the user experience by exploring the broadcasting nature of wireless channels and cooperation among numerous users or operator infrastructure nodes. Specifically, the two-hop network together with OFDMA technology brings up several diversity gains (multiuser, channel, and cooperative) and basically larger resource allocation flexibility that can be leveraged through sophisticated scheduling mechanism [2].

A. Related Work

While several scheduling studies [7], [8] were specifically designed for unicast traffic, only modest work has been carried out on scheduling strategies for multicast traffic for two-hop OFDMA relay networks [2] and [9]. Multicasting in two-hop relay networks is considerably different from the conventional cellular multicast [9]. The broadcast benefit of multicast data in relay period (first hop) is drastically decreased on the access period (second hop). In fact, transmission from relays RSs to users MSs on the second hop turn out to be comparable to multiple unicast transmissions requiring more transmission resources where ultimately the same data is designated to all users even if they are associated to different relays [2].

B. Our Contributions

In this work, we propose a two-hop cooperative multicast transmission scheme the so-called Coordinated Multiple Relays (CoMR) which is mainly inspired from both the Coordinated Multipoint (CoMP) transmission concept [10] and the so-called multi-cell Multicast Broadcast Single Frequency Network (MBSFN) transmissions [11]. We also solve the core multicast scheduling problem, which performs the following operations: 1) identify whether relay cooperation is beneficial and dynamically determine whether to activate or disable CoMR on a frame basis; 2) Allocate each downlink (DL) sub-frame to either relay or access transmission; 3) find out both modulation and coding scheme of the first hop transmission (relay period) and similarly the modulation and coding schemes of the second hop (access link). The proposed scheduling procedure is performed by maximizing a cost function which incorporates a tradeoff between users fairness/satisfaction and system throughput.

II. SYSTEM MODEL

We consider a two-hop WiMAX relay network fully compliant to IEEE 802.16m [4] similar to systems used in numerous existing researches [2] and [12]. On this work only the two-hop network is addressed. The main air interface parameters of the adopted system are summarized in Table 1 [4]. The schematic of basic frame structure is shown in Fig. 1 where each 5 ms radio frame consists of 5 sub-frames allocated to DL and 3 sub-frames allocated to UL. The cyclic prefix fraction chosen is 1/8 instead of 1/16 to reduce of interference incidence during synchronous transmission of relays within the same sector [11]. We assume the chosen CP is sufficient to ensure symbol level synchronization for a constructive superposition of coordinated transmitted signals from different relays of the same sector. We also assume the allocation of DL sub-frames to either relay or access zone is dynamically updated at each one frame slot. The number of sub-frames allocated to each zone is determined by the proposed scheduler described on the next section. The latter requires extra overhead to indicate the sub-frames allocation scheme to the destination and intermediate nodes.

The proposed model for the two-hop WiMAX multicast network consists of one BS and N_{RS} RSs and N_{MS} subscribers. The relaying scenarios considered on this study are the Above Roff-Top (ART) scheme with 2 RSs or Below Roof-Top (BRT) scenario with 6 RSs [4]. ART and BRT configuration parameters are described in [4]. An MS can be associated either with the BS or with one of the RSs. For sub-channelization we consider the distributed permutations (DP) for OFDMA subcarriers grouping. On the latter a channel quality index (CQI) for each resource unit is provided.

Fig. 1 demonstrates the two phases of the proposed coordinated multiple relays multicast transmission methodology. In the first phase, the BS broadcasts/multicasts the modulated and encoded signal based on the scheduled modulation and coding schemes (MOD_1 and COD_1) to all MSs and RSs during the allocated sub-frames for the first relay hop (on this example 2 sub-frames allocated for the relay phase).

Users and relays with sufficient channel conditions can receive and successfully decode the data and store it for the next hop. On this example, as shown in Fig. 1, only MS_1, MS_2, MS_6 and RS_1 RS_3 and RS_4 have successfully decoded the data.

TABLE 1 IEEE 802.16M SLS OFDMA AIR INTERFACE PARAMETERS

Parameter	**Value**
Carrier frequency	2.5 GHz
Total bandwidth	10 MHz
Number of points FFT	1024
Sampling frequency	11.2 MHz
Subcarrier spacing	10.9375 kHz
symbol duration -CP	91.43 us
Cyclic prefix fraction	1/8
symbol duration +CP	102.86 us for CP=1/8
Frame length	5 ms
Number of OFDMA symbols in frame	47
Ratio of DL to UL	29 : 18 sym/ 5 : 3 sub-frames
Ratio of relay to access	29 : 0 or 24 : 5 or 18 : 11 or 12 : 17 or 6 : 23

The BS also transmits MAP messages which contain the sub-frames allocation and the list of relays scheduled for the coordinated transmission on the second hop and corresponding modulation and coding schemes (MOD_2 and COD_2). This will introduce extra moderate overhead which is not considered in this work. On the second phase (access hop), the BS and scheduled RSs perform synchronous transmission by transmitting the same signal using the same data, modulation and coding schemes (MOD_2 and COD_2) in a coordinated fashion. While we consider a simple coordinated strategy by ensuring synchronous transmission and choosing an appropriate cyclic prefix (CP) to reduce the probability of destructive superposition, our scheduling solutions are equally applicable to other sophisticated cooperation strategies such as used with MIMO, e.g. the Alamouti scheme [9].

The synchronous transmission with appropriate CP will maximize the probability of positive joint reception of the multiple copies sent by different nodes of the same signal. The latter will result in an increase of the SINR of the majority of the MSs during the second stage transmission which means enhanced coverage with more users capable to decode the transmitted signal during the second stage.

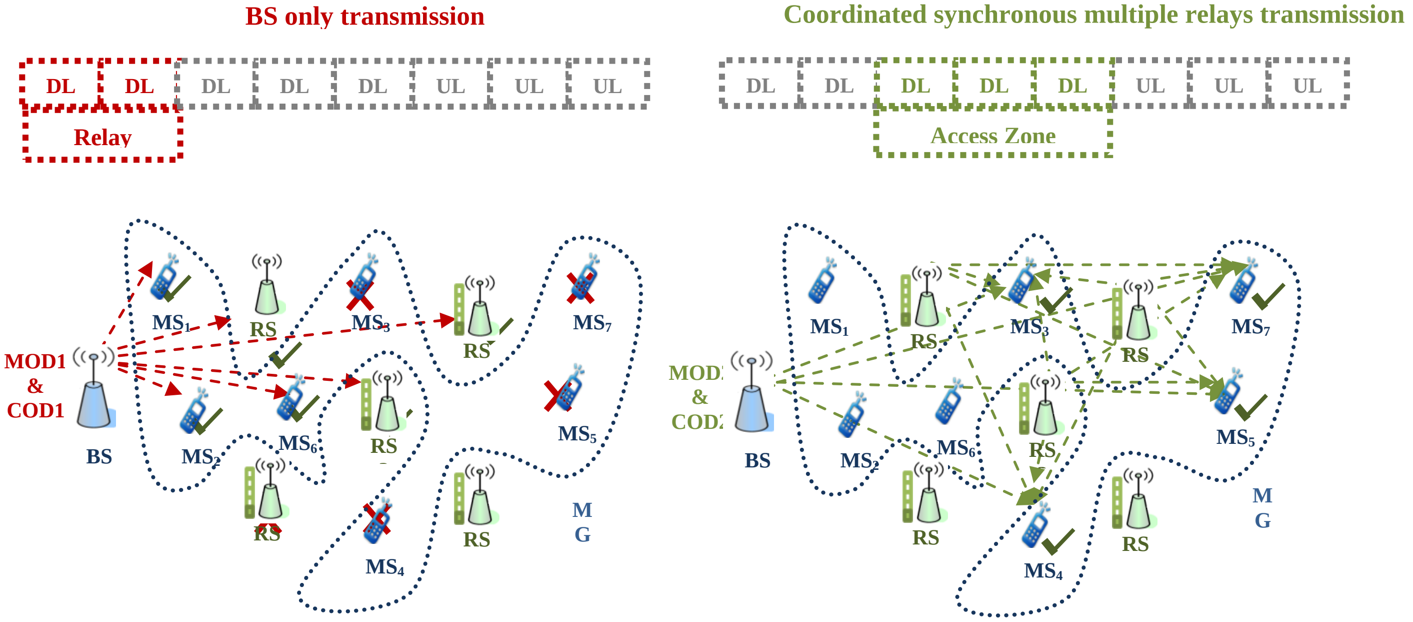

Fig. 1. The Two Phases of the Coordinated Multiple Relays Transmission for 3C scenario

Cooperative multicasting using relays is not always beneficial since using relays enhances the system coverage but since data need to be transmitted to relays beforehand during relaying phase there will be loss on the spectral efficiency compared to the non cooperative multicasting where all sub-frames are allocated to one transmission session. So the first question the scheduler needs to answer is whether cooperative multicasting is beneficial? On the next section we present the proposed scheduling methodology for the coordinated multiple relays transmission on which we will try to answer the latter question.

III. RESOURCE ALLOCATION ALGORITHM

On this section we derive a new scheduling algorithm tailored for the proposed CoMR transmission by taking into consideration the two transmission phases. We focus on the DL multicast problem where the DL sub-frames are divided into an access zone and a relay zone. For CoMR, the dedicated bandwidth for the multicast session is fully exploited on both phases and the scheduler has no bandwidth allocation task to perform. Instead, the BS should make the following scheduling decisions at the beginning of each frame: a) decide whether relay assistance is beneficial and activate cooperative transmission accordingly, b) allocate the appropriate number of DL sub-frames to the relay phase and to the access phase, c) identify the set of RSs to be activated during coordinated transmission of the second phase, d) determine the modulation mode (MOD_1) and the coding scheme (COD_1) of the first hop transmission (relay period) within allocated sub-frames and full dedicated BW, e) establish the corresponding modulation mode (MOD_2) and coding scheme (COD_2) of the second hop (access phase) within allocated sub-frames and full dedicated BW.

The resulting assignments of the relay phase of the current frame and the access phase of the next frame are designated by the BS to the RSs and MSs through a small control region in the frame called the MAP. The MAP comes after the preamble in the frame and is transmitted at the lowest modulation and coding schemes [11]. The adopted WiMAX system can support three modulation modes namely QPSK, 16QAM and 64QAM and four coding rates 1/2, 2/3, 3/4, and 5/6.

Table 2 summarizes all 12 possible Modulation Coding Schemes (MCS) that can be scheduled. The scheduler is restricted to pick up only one of those schemes at each phase.

TABLE 2 IEEE 802.16M MODULATION AND CODING SCHEMES

MCS	MOD	COD	MCS	MOD	COD
1	QPSK	1/2	7	16QAM	3/4
2	QPSK	2/3	8	16QAM	5/6
3	QPSK	3/4	9	64QAM	1/2
4	QPSK	5/6	10	64QAM	2/3
5	16QAM	1/2	11	64QAM	3/4
6	16QAM	2/3	12	64QAM	5/6

In order to incorporate the option of non cooperative mode (relays disabled) we introduce a fifth mode 5-0 in addition to cooperative four possible relay-access sub-frames allocation (SBFA) modes (4-1, 3-2, 2-3, and 1-4), as can be seen in Table 3. The mode 5-0 corresponds to the case where all 5 sub-frames are allocated to the relay phase and no sub-frame is allocated to the access period. The mode 0-5 (0 sub-frames for relay phase and 5 sub-frames for access period) is not a valid option in our transmission model. The inclusion of non cooperative mode simplifies the formulation of the scheduling algorithm as the main objective of scheduling now can be narrowed to maximize one cost function M.

TABLE 3 THE FIVE POSSIBLE RELAY-ACCESS SUB-FRAMES ALLOCATION OF SAMSUNG'S COMR STRATEGY

SBFA mode	Relay zone	Access zone
1	**5** 🟥🟥🟥🟥🟥	**0**
2	**4** 🟥🟥🟥🟥	🟩 **1**
3	**3** 🟥🟥🟥	🟩🟩 **2**
4	**2** 🟥🟥	🟩🟩🟩 **3**
5	**1** 🟥	🟩🟩🟩🟩 **4**

One of the main challenges on designing the scheduler is to how to maximize both throughput and fairness among users and strikes a good balance between the two metrics. To overcome this dilemma we propose a tuneable cost function which consists of a weighted product of two components. The first component represents the expected total throughput delivered to all subscribers during the scheduled time frame:

$$\mathrm{M_R} = \sum_m R_{MS}^m \tag{1}$$

$\mathrm{R_{MS}^m}$ is the expected throughput of user $m \in \mathrm{N_{MS}}$, $\mathrm{N_{MS}}$ is the total number of users of the multicast group. The second part which symbolizes the scheduler fairness is quantified by Jain's fairness index [13]:

$$\mathrm{M_F} = \frac{\left(\sum_m R_{MS}^m\right)^2}{N_{MS}\sum_m \left(R_{MS}^m\right)^2} \tag{2}$$

The Jain's index is a well accepted metric by network engineering community which determines the fairness of the scheduling mechanism and whether users are receiving a fair share of system resources [13]. The index ranges from $\frac{1}{\mathrm{N_{MS}}}$ for the most unfair allocation to 1 for the fairest scheduling on which all users have the same scheduled rates.

The proposed cost function to be maximized is the weighted product of $\mathrm{M_R}$ and $\mathrm{M_F}$ that can be given by:

$$\mathrm{M} = \left(\sum_m R_{MS}^m\right)\left(\frac{\left(\sum_m R_{MS}^m\right)^2}{N_{MS}\sum_m \left(R_{MS}^m\right)^2}\right)^{\alpha} \tag{3}$$

α is a tunable factor which identifies the balance between throughput and fairness. High values of α promote fairer scheduling against maximizing the throughput and vice versa. Calculating $\mathrm{R_{MS}^m}$ at each phase mainly depends on three parameters: a) selected SBFA mode k, b)the MCS mode $\mathrm{s_R}$of the relay phase, and c) the MCS mode $\mathrm{s_A}$ of the access phase. The main objective now is to identify the three parameters k^{max}, ${s_R}^{max}$ and ${s_A}^{max}$ which maximises $\mathrm{M}(k, s_R, s_A)$:

$$\{k^{max}, {s_R}^{max}, {s_A}^{max}\} = \arg\left(\max_{k, s_R, s_A}\left(\mathrm{M}(k, s_R, s_A)\right)\right) \tag{4}$$

Unlike the non cooperative multicast scheme there is an extra cost on the system overhead mainly on the uplink load where two sets of MS channel quality indexes $(CQI_{R,m}^{MS}\}$ and $\{CQI_{A,m}^{MS})$and one set of RS channel feedback $\{CQI_{R,r}^{RS}\}$are required. $The\ CQI_{R,m}^{MS}$ corresponds to the quality index of BS-

MS$_m$ channel obtained throughout the previous relay transmission. On the other hand, $CQI_{A,m}^{MS}$ is a representative index of a group of channels which include all RS-MS$_m$ and BS-MS involved on the coordinated transmission process of the previous access phase. $CQI_{R,r}^{RS}$ is the quality index of the BS-RS$_r$ channel of the previous relay transmission. The BS needs also to save the previous list of scheduled relays RS_{SCH}^{prev} in order to update $CQI_{A,m}^{MS}$ according to the up to date list of scheduled relays RS_{SCH}. To perform the latter operation a set $SINR_{r,m}^{RS\rightarrow MS}$ of average values of SINRs of all possible RS-MS links is required. The latter can be obtained by performing a short training transmission at the start of the call. Whenever the list of scheduled relays is altered compared to previous scheduling slot, the $CQI_{A,m}^{MS}$ is no longer a good representative index. The average impact of disabled relays RS$_{r-}$ need to be subtracted using the $SINR_{r^-,m}^{RS\rightarrow MS}$ values and the effect of new scheduled relays RS$_{r+}$ need to be added following the below equation:

$$CQI_{A,m}^{MS} = \min\left(\varepsilon > 0, CQI_{A,m}^{MS} - \sum_{r^-} SINR_{r^-,m}^{RS\rightarrow MS} + \sum_{r^+} SINR_{r^+,m}^{RS\rightarrow MS}\right) \quad (5)$$

$$\forall r^- \in RS_{SCH}^{prev} \,\&\, r^- \notin RS_{SCH} \text{ and } \forall r^+ \notin RS_{SCH}^{prev} \,\&\, r^- \in RS_{SCH}$$

The minimum is introduced to make sure no negative dB values of $CQI_{A,m}^{MS}$ are produced. The main steps of the scheduling algorithm of CoMR are explicitly summarized below. For every configuration $(\mathrm{k}, s_\mathrm{R}, s_\mathrm{A})$ the calculation of the expected throughputs $\mathrm{R}_{\mathrm{R,MS}}^{\mathrm{m}}$ and $\mathrm{R}_{\mathrm{A,MS}}^{\mathrm{m}}$ of user m during relay phase and access transmission are calculated using the $CQI_{R,m}^{MS}$ and the updated $CQI_{A,m}^{MS}$ respectively. The process of calculating the expected throughput is as follows: 1) since a distributed permutations (DP) sub-channelization is adopted each CQI is represented by NRU multi-state CQI values across all resource units (NRU is the number of resource units). 2) A compression procedure on which the set of CQIs is mapped to one effective value CQIeff using the symbol level mutual information look up table (LUT), LUT maintained by the system, for the corresponding modulation scheme (for more details on the compression procedure the reader may refer to [4]). The left plots in Fig. 2 sketch the three look up tables which correspond to the three supported modulation schemes where symbol level mutual information are depicted versus CQIs. The effective index CQI$_{\mathrm{eff}}$ is then mapped to the corresponding code word error rate CWER through a mapping procedure. The latter uses another set of LUT which corresponds to both the modulation and coding scheme adopted and represent the dependency of the CWER with CQI values.

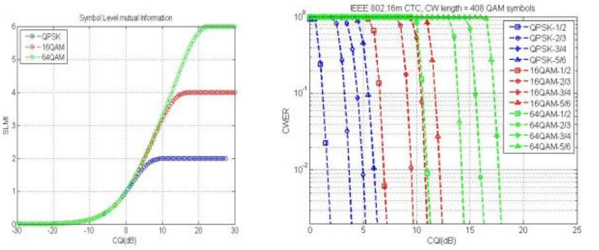

Fig. 2. left) The symbol level mutual information versus CQIs in dB for different modulation schemes used in Samsung SLS right) The CWER versus CQI of all possible MCS for code word length ≥408 QAM symbols for Convolutional Turbo Code (CTC).

Fig. 2 right) shows all possible 12 LUT plots used to perform the mapping procedure on our scenario. Note that the code word length used here is 408 since all resource units are exploited on both transmission, for smaller lengths different set of LUTs need to be used [14]. After calculating the expected throughputs $R_{R,MS}^{m}$ *and* $R_{A,MS}^{m}$ for each MS at the relay and access phases only the maximum throughput $R_{MS}^{m} = \max(R_{R,MS}^{m}, R_{A,MS}^{m})$ of each user is maintained. This is because the data transmitted on the two phases are correlated. Finally, the cost function to be maximized for each configuration can be calculated where configuration parameters which correspond to the cost function maximum can be identified after scanning all possible configurations. Below is a summary of the proposed multicast scheduler.

Algorithm 1: Multicast scheduler algorithm - CoMR

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Inputs:
$\{CQI_{R,r}^{RS}, \forall r \in N_{RS}\}$
$\{CQI_{R,m}^{MS}, \forall m \in N_{MS}\}$
$\{CQI_{A,m}^{MS}, \forall m \in N_{MS}\}$
$RS_{SCH}^{prev} = \{r, R_{R,RS}^{r,prev} > 0, r \in N_{RS}\}$
$\{SINR_{r,m}^{RS\rightarrow MS}, \forall m \in N_{MS} \text{ and } \forall r \in N_{RS}\}$
$SBFR = \{1,2,\dots,5\}$
$MCS = \{1,2,\dots,12\}$
for $k \in SBFR$
    mode $k$: sub-frames allocation for both relay and access zones
    for $s_R \in MCS$
        Calculate $R_{R,MS}^{m}(CQI_{R,m}^{MS}\ k, s_R)$ and $R_{R,RS}^{r}(CQI_{R,r}^{RS}, k, s_R)\ \forall m, r$
        Identify scheduled relays; $RS_{SCH} = \{r, R_{R,RS}^{r} > 0, r \in N_{RS}\}$
        Update Relay buffers $Q_{RS_r}, \forall r \in RS_{SCH}$
        for $s_A \in MCS$
            update
            $CQI_{A,m}^{MS} = \min(\varepsilon > 0, CQI_{A,m}^{MS} - \sum_{r^-} SINR_{r^-,m}^{RS\rightarrow MS} + \sum_{r^+} SINR_{r^+,m}^{RS\rightarrow MS})$,
            $\forall r^- \in RS_{SCH}^{prev} \,\&\, r^- \notin RS_{SCH}$ and $\forall r^+ \notin RS_{SCH}^{prev} \,\&\, r^- \in RS_{SCH}$
            Calculate $R_{A,MS}^{m}(CQI_{A,m}^{MS}\ k, s_A, Q_{RS})\ \forall m$
            $R_{MS}^{m} = \max(R_{R,MS}^{m}, R_{A,MS}^{m}), \forall m$
            Calculate scheduling metric
            $\mathrm{M}(k, s_R, s_A) = (\sum_m R_{MS}^{m}) \left(\frac{(\sum_m R_{MS}^{m})^2}{N_{MS} \sum_m (R_{MS}^{m})^2}\right)^{\alpha}$
        end for
    end for
end for
Determine scheduling parameters $\{k^{max}, {s_R}^{max}, {s_A}^{max}\} = \arg(\max_{k,s_R,s_A}(\mathrm{M}(k, s_R, s_A))$
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IV. SIMULATION RESULTS

On this section we evaluate the performance of the proposed cooperative multicast scheduling for CoMR in terms of fairness, throughput and energy efficiency for different scenarios. For this purpose we utilize the WiMAX IEEE802.16m system level simulator SLS which supports ART and BRT relaying and multicasting capabilities. The network topology adopted is a 19 hexagonal OFDMA based cell layout where each cell is divided into three sectors. Each sector is associated to one macro BS. MS are uniformly distributed within the cell, while RSs are deployed based on either ART scenario, two relays per sector, or BRT where 6 relays are distributed per sector. Each MS is associated to either BS or RS based on the maximum average SNR value. The feedback from the MS (through RS) and RS is assumed to be made available to the BS through standard feedback procedures in DP mode.

We consider the following main simulation parameters: number of users per multicast group ranging from 10 to 100 users. We also assume only one multicast group is assigned to each BS where all available resource units RUs (BW) are allocated to this session. The number of transmission iterations is 50 repeated over three different deployment snapshots. The scheduling algorithms are evaluated per frame, where the main metrics are the average throughput per user or per BS in Mb/s, the Jain’s Fairness, and the average energy efficiency of the system in J/b. The tunable parameter α of the scheduler cost function varies from 0 to 10. The Multicast scheduling scheme denoted as Conserve is used for comparison, where the BS selects a conservative rate such as maximizing the number of satisfied members without RSs assistance.

A. *Evaluation of the CoMR Scheduling Algorithm*

In this experiment we evaluate the performance of the proposed scheduling algorithm for CoMR. Two cooperative topologies are implemented: the ART based, where two relays are deployed to assist the cooperative multicasting, we refer to this scheme by CoMR ART, and the CoMRT BRT with 6 relays engaged to perform the coordinated transmission. The non cooperative multicasting Conserve is also implemented for benchmarking.

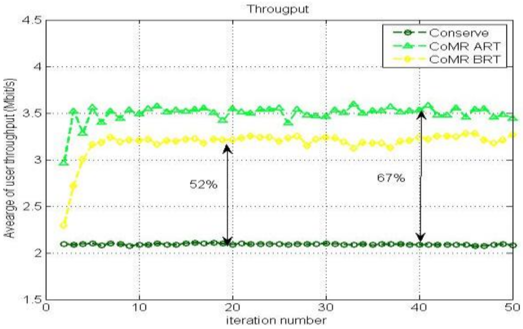

Fig. 3. User Average throughput in Mb/s of three multicast strategies: non cooperative (Conserve), ART Coordinated Multiple Relays and BRT Coordinated Multiple Relays

Fig. 3 shows the profile of the average throughput in Mb/s per user through frame iteration progress of the three schemes Conserve, CoMR ART and CoMR BRT. The number of subscribers per group is 40 and the scheduler tuneable factor α=0. As can be seen both CoMR ART and BRT have shown considerable improvements more than 50% compared to Conserve. The latter is mainly due to: a) the significant gain in terms of coverage provided by relays deployment, the positive superposition of synchronous transmissions at the access stage which boost the received SINRs which ultimately allows the use of higher MCS schemes, and c) the flexibility of the proposed algorithm to switch from cooperative mode to non cooperative mode according to when the conditions are most favorable. We can also distinguish that CoMR ART produced higher average throughput compared to CoMR BRT despite the fact that more relays are deployed on the latter. This is mainly due to the nature of relay stations used on both schemes. In ART the stations are deployed above the roof with LOS links with BS, better visibility to users and with much higher power transmission (36dBm) compared to the below roof deployment which have weaker links with BS and limited access to users on the sector due to lower power transmission of the BRT station (27dB). Now, since relays deployment come with an extra energy consumption cost, especially if multiple relays are activated to perform the same transmission. The question now is: despite the throughput enhancement are we gaining in terms of energy efficiency?

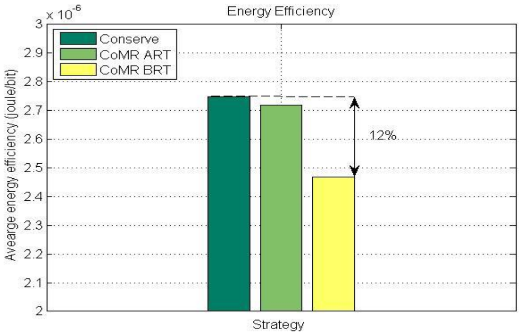

Fig. 4. Average energy efficiency of the three multicast strategies in joule per bit

Fig. 4 demonstrates the energy efficiency of the above experiment of the three schemes. The power consumption model used is described in [15]. As can be seen the CoMR BRT still showing improvement in terms energy efficiency by around 12% compared to Conserve, where CoMR ART only showed minor improvement. This is mainly due to the much lower power consumption of BRT stations compared to ART. In fact, the proposed cost function can be easily modified to incorporate the energy efficiency instead of throughput, by adopting the same way the throughput and fairness are combined, on which non efficient (minimal enhancement in terms of throughput) relays may not be activated during the access phase. The latter procedure would save more power and consequently improves further the average energy efficiency of the system.

B. *Impact of number of users*

To explore the impact of denser population on the performance of the proposed methodology we carried out a similar experience to the above experiment for different population sizes ranging from 10 to 100 for α=0. Fig. 5 demonstrates the evolution of the average throughput per BS in Mb/s while the size of the multicast group increases. As can be seen in Fig. 5 both CoMR ART and CoMR BRT showed throughput gain compared to non cooperative strategy for all populations. Even though higher throughput delivered for larger groups but the gain is approximately around the same percentage 60~67% for ART compared to Conserve.

C. *Impact of tuneable parameter α*

On the third experiment we evaluate the impact of the cost function weighting factor α on the scheduler performance.

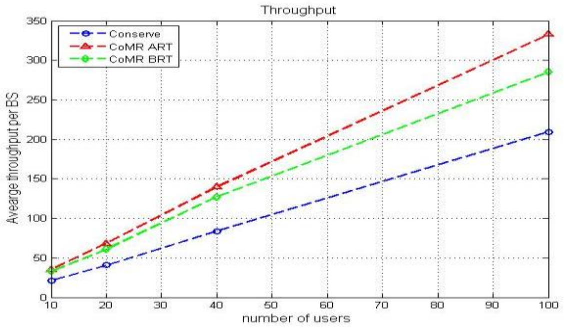

Fig. 5. Base station average throughput of the three strategies versus the number of multicast group users

The number of users per group is fixed to 40 members for four different values of αϵ{0,2,5,10}. Fig. 6 represents the accumulative distributed function (CDF) of the Jain's Fairness per BS of Conserve and CoMR BRT for the four different values of α. As can be observed in Fig. 6, the CoMR BRT for α=10 showed by a considerable enhancement of the scheduler fairness and users satisfaction. Indeed the cumulative distribution function of Jain's fairness index for higher values marginally outperformed Conserve and CoMR with lower values.

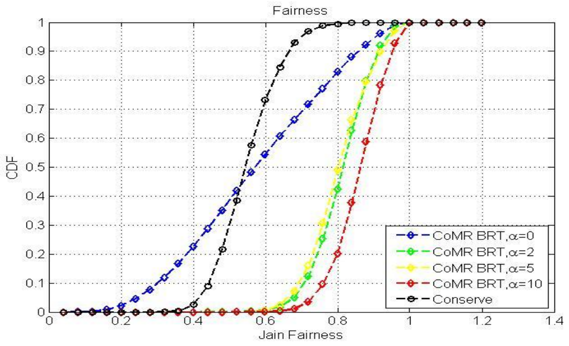

Fig. 6. The cumulative distribution function of Jain Fairness factor of the non cooperative scheme and CoMR BRT (for different values of α)

V. CONCLUSION & PERSPECTIVES

In this work, we addressed the problem of multicast scheduling in two-hop OFDMA relay network for close community cooperation. We proposed a new two-hop multicast transmission scheme CoMR on which a set of relays scheduled to coordinate with base station for a synchronous transmission in the access phase. We also designed a tuneable scheduling algorithm at the core of the video multicast strategy to address the trade-off between maximizing the system average throughput and the scheduler fairness/user satisfaction. The new scheme implemented and tested through an IEEE 802.16m system level simulator for both ART and BRT relaying scenarios. The new scheme showed considerable enhancement of not only system average throughput and fairness compared to non cooperative scheme but also from energy efficiency perspectives. The impact of varying the multicast group population and the scheduler weighting factor have been also addressed where the flexibility of the proposed cost function to produce the desired balance between maximizing the throughput and ensuring maximum fairness has been demonstrated. For future work, it would be interesting to explore how multilayer transmission can be incorporated into CoMR. It would be also interesting to investigate the adjustment of the proposed scheduler to support the technology of scalable video coding (SVC) specified in the H.264 standard as used for the real-time video multicast services.

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