Investigation on Energy Efficiency in HetNet CoMP Architecture

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***Abstract*—The increasing energy consumption driven by striking growths in the number of users and data usage turns out the focal point for mobile operators in fulfilling requirements on cost reduction and environmental impact targets. As a step towards incorporating more energy friendly mobile platforms in future networks, 3GPP LTE-Advanced has adopted coordinated multi-point (CoMP) transmission/reception due to its ability to mitigate and/or coordinate inter-cell interference (ICI). The major CoMP techniques which already existed are joint transmission (JT) and coordinated scheduling/ beamforming (CS/CB). In this paper we propose a novel energy-efficient design (NEED) for heterogeneous network (HetNet) CoMP architecture composing both JT and CS/CB which provides a realistic trade-off for green wireless networks. A feedback based ICI coordination scheme is investigated in terms of different performance metrics (throughput; cell average and cell-edge energy efficiency; radio signaling and backhaul overhead comparison; and power consumption ratio) which eventually helps to reach a decision in favor of the proposed architecture in terms of performance trade-off.**

***Index Terms*—CoMP; Green; HetNet; LTE-Advanced**

I. Introduction

Information and communication technology (ICT) is playing an increasingly important role in global greenhouse gas emissions since the amount of energy consumption for ICT has been increasing dramatically [1]. Therefore, pursuing high energy efficiency (EE) is becoming a mainstream concern in future wireless communications design.

We basically have three technical approaches to improve the energy efficiency without loss in capacity and consuming extra spectrum. 1) Improve the power channel gain such as reducing the access distance and number of obstacles between transmitter and receiver, which can be solved by deploying heterogeneous networks (HetNets) [2]. 2) Reduce the interference, specifically; reducing the co-channel interference in mobile networks, which can be solved by applying coordinated multi-point (CoMP) transmission and reception techniques [3]. 3) Enhanced spectral efficiency promised by MIMO techniques, which can be done by multi-user MIMO (MU-MIMO) [4].

One of the reference scenarios are heterogeneous networks (HetNet) [2], network that consists of a mix of macrocells and low-power nodes such as remote radio head (RRH), picocell, femtocell, relay; where some may be configured with restricted access and some may even lack wired backhaul. HetNet combined with CoMP is now a booming research topic, presenting synergies able to enhance future wireless system bitrates. CoMP scheme is categorized mainly into two types [3]. These are 1) Joint transmission (JT), 2) Coordinated Scheduling / Beamforming (CS/CB).

Early research of MIMO techniques mainly focused on single-user (SU) MIMO, where multiple spatial channels are allocated to a single user and multiple users are served through time-multiplexing. Later attention has been raised on MU-MIMO, where multiple users are served simultaneously in the same frequency band over user-specific spatial channels [5]. In contrast with SU-MIMO, MU-MIMO is adequate of substantially improving spectral efficiency and hence is being considered as a strong candidate for future-generation mobile cellular systems. Although the JT scheme can bring large performance gain to the CoMP system, it also has a range of problems, such as high backhaul requirement for exchanging the channel state information (CSI) and users' data, high computational complexity due to user scheduling and transmit precoding design, and synchronization among all eNBs within the same CoMP cell-sites. By contrast, the CS/CB scheme is capable of lowering the backhaul requirement, due to no requirement of exchanging users' data among eNBs within the CoMP cluster. However this less computational complexity in CS/CB provides much less performance gain in comparison with its counterpart in the JT scheme.

The major issue in case JT-CoMP is used along with MU-MIMO, is the complexity and cost of both user handsets and BSs. Moreover, another issue is the increased signaling overhead between the BSs which make the high capacity backhaul network crucial. As discussed above, the CS/CB downlink schemes are simpler, mainly because the amount of signaling overhead is kept low, as they do not require full CSI information at the transmitter. On the other hand, JT provides a more sophisticated solution with much better results but in practice it can be very complex for the eNBs coordination [6]. Therefore a practical architecture is needed to trade-off between the system complexity and the system performance. A method was envisioned for LTE-A [7] which combines both of JT and CS/CB for homogeneous SISO scenario. We proposed a novel energy efficient architecture (NEED) architecture which covers HetNet CoMP using MU-MIMO as shown in Fig. 1. In this implementation, we take advantage of the benefits of both JT and CS/CB, while keeping signaling overhead low and performance is almost near to JT. In our proposed method JT scheme is used for intra-CoMP where cells belong to same cell/site and CS/CB scheme is used for the inter-CoMP coordination between eNBs in a distributed or semi-centralized way.

A. Related Work

The Third Generation Partnership Project (3GPP) community has already taken steps towards reducing the energy consumption in future emerging networking technologies (e.g. Long Term Evolution (LTE)-Advanced [8]) by proposing new energy efficient networking topologies, deployment strategies and modulation technologies. In [9] the authors investigated the energy efficiency of heterogeneous network and also took into account the effects of cell size on cell energy efficiency by introducing a new concept of area energy efficiency. In [10], the energy efficiency of multi-cell cellular networks with co-channel interference is inquired. MIMO is not considered in both works mentioned above. The study in [11] has investigated energy efficiency based on SU-MIMO techniques both in slow-fading and fast-fading channels. But it does not provide any impetus in MU-MIMO scenario. None of the prior research works considers MU-MIMO and coordination between transmission points let alone HetNet scenario. However, there is a little or no study analyzing the impact of HetNet CoMP using MU-MIMO on the energy efficiency of cellular networks. To the best of the authors' knowledge this is the first attempt which covers HetNet CoMP using MIMO to investigate energy efficiency.

B. Contributions

The objective of this research work is to design a novel wireless architecture utilizing multiple antenna techniques in HetNet CoMP which provides best trade-off for different CoMP techniques including the proposed one.

- Propose a novel MU-MIMO HetNet CoMP architecture combining both JT and CS/CB.
- Devise feedback based inter-cell interference (ICI) coordination technique.
- Investigate the influences on different performance aspects (throughput; cell average and cell-edge energy efficiency; radio signaling and backhaul overhead; and power consumption ratio).

C. Paper Organization

The rest of the paper is organized as follows: Section II explains the system model; section III provides the proposed novel energy-efficient architecture; section IV describes the simulation results followed by conclusions in section V.

II. System Model

We consider a MU-MIMO HetNet CoMP (MHC) system. A MHC system composed of several MHC cell-sites. Each MHC cell-site consists of one macro eNB and several low power RRHs based on LTE technology. Our MHC system is composed of C CoMP-cells, indicated by $C = \{1, 2, ..., c, ..., C\}$, where a MHC cell-site comprises one centralized point eNB (indicated by E_c i.e., the eNB of the MHC c) with R (indicated by $R = \{1, 2, ..., r, ..., R\}$) number of RRHs, serving U user equipments (UEs) which are uniformly distributed over its coverage area. We should keep in mind that both eNB and RRH are termed as T number of transmission points, indicated by $T = \{1, 2, ..., t, ..., T\}$, i.e., $E_c \in T$ and $r \in T$. Therefore, one MHC cell-site contains transmission signal from both eNB and RRH as well. Furthermore, each transmitter in a MHC cell-site is assumed to have M transmit antennas in order to support U users with N receive antennas per user.

For the MU-MIMO HetNet-CoMP system, interference is classified as intra-MHC and inter-MHC interference. The former is created where multiple users are served simultaneously in the same frequency band over user-specific spatial channel [5], i.e., considered as multi-user interference (MUI). The latter originates from transmission points of other MHC cell-sites and is unknown to the eNBs, but can be estimated; i.e., considered as ICI. In both cases, the available information about interference can be used to perform adaptive resource allocation. The CoMP system can be seen as a distributed MU-MIMO system using eNBs and RRHs as a distributed antenna array [4]. In the following we provide SINR calculation for JT, CS/CB.

We define the channel matrix from transmission point t within MHC c to user u as $\mathbf{H}^u_{c,t}$, then a concatenated channel $\mathbf{H}^u_{c,:}$ can be formed as [12]

$$\mathbf{H}^u_{c,:} = [\mathbf{H}^u_{c,1}, \mathbf{H}^u_{c,2}, \ldots, \mathbf{H}^u_{c,T}]. \quad (1)$$

A. SINR calculation for Joint Transmission

Then the received signal at user u can be expressed as

$$y^u_c = \underbrace{\mathbf{H}^u_{c,:}\mathbf{F}^u_{c,:}x^u_c}_{\textbf{Desired signal}} + \underbrace{\mathbf{H}^u_{c,:}\sum_{l\in\Theta_c, l\neq u}\mathbf{F}^l_{c,:}x^l_c}_{\textbf{MUI}} + \underbrace{\sum_{i\in\Theta_{c'}, c'\neq c}\mathbf{H}^u_{c',:}\mathbf{F}^i_{c',:}x^i_{c'}}_{\textbf{ICI}} + \mathbf{n}^u_c \quad (2)$$

where $\mathbf{F}^u_{c,:}$ and x^u_c are the beamforming (precoding) matrix and the data transmitted from MHC c to user u respectively; and Θ_c is the set of transmit precoder associated with MHC c, and $\mathbf{n}^u_c$ the receiver noise with AWGN elements, each with variance σ^2_n. When perfect CSI is not available at the eNB, the MUI in equation (2) can be reformed as [12]

$$\mathbf{H}^u_{c,:}\sum_{l\in\Theta_c, l\neq u}\mathbf{F}^l_{c,:}x^l_c = \sum_{l\in\Theta_c, l\neq u}\left(\sum_{t=1}^{T}\mathbf{H}^u_{c,t}\mathbf{F}^l_{c,t}\right)x^l_c. \quad (3)$$

The main channel measurement considered is the signal-to-interference-plus-noise-ratio (SINR) of the UEs in the system. In order to determine whether a transmission has been successful, the SINR measured for a given path is employed to determine the packet error rate (PER) for the block of data sent on each PRB. The SINR $\Gamma^u_c(\mathbf{JT})$ perceived by a UE u of the MHC cell-site c can be expressed as

$$\Gamma^u_c(\mathbf{JT}) = \frac{\left\|\mathbf{H}^u_{c,:}\mathbf{F}^u_{c,:}\right\|^2 p^u_c}{\sum_{l\in\Theta_c, l\neq u}\left\|\sum_{t=1}^{T}\mathbf{H}^u_{c,t}\mathbf{F}^l_{c,t}\right\|^2 p^l_c + \sum_{i\in\Theta_{c'}, c'\neq c}\left\|\mathbf{H}^u_{c',:}\mathbf{F}^i_{c',:}\right\|^2 p^i_{c'} + \sigma^2_n} \quad (4)$$

B. SNR calculation for CS/CB

In CS/CB scheme, CoMP eNBs within a MHC only share their scheduling information. Therefore, only one transmission point is used to transmit data after coordination. Denote user u's transmit precoder applied at transmission point of MHCs

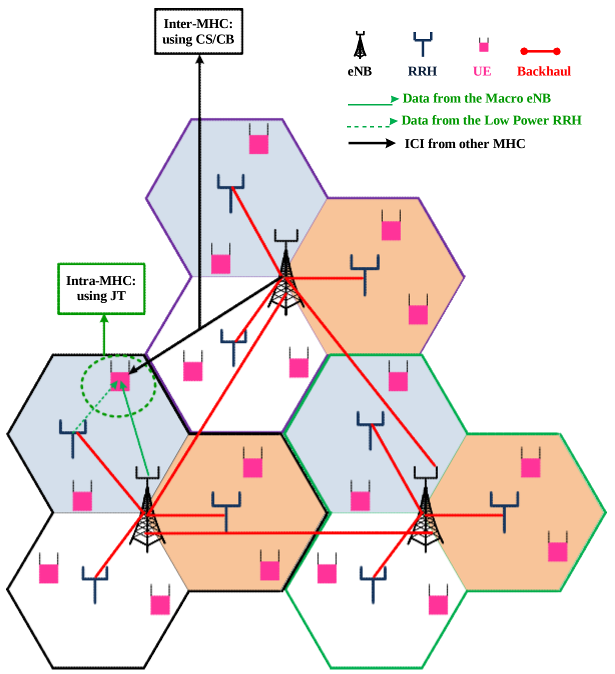

Fig. 1. Proposed NEED architecture

as $\mathbf{F}^u_{c,t}$, then the signal received at user u can be written as (5), where Φ_c is the set of transmit precoder associated with the MCH c, and $\Phi = \cup\Phi_c$ is the union set of Φ_c [12]. From (5), it can be observed that MUI for a user only depends on other users within the same cell rather than all other users within the whole MHC cell-site. Then the received signal at user u can be expressed as

$$y^u_c = \underbrace{\mathbf{H}^u_{c,t}\mathbf{F}^u_{c,t}x^u_c}_{\text{Desired signal}} + \underbrace{\sum_{l\in\Phi_t, l\neq u} \mathbf{H}^u_{c,t}\mathbf{F}^l_{c,t}x^l_c}_{\text{MUI}} + \underbrace{\sum_{c^t\in\Phi, t\neq j}\sum_{i\neq u\in c^t} \mathbf{H}^u_{c^t,j}\mathbf{F}^i_{c^t,j}x^i_{c^t}}_{\text{ICI}} + n^u_c \tag{5}$$

Then the SINR Γ^u_c(**CS/CB**) perceived by a UE u of the MHC cell-site c can be expressed as

$$\Gamma^u_c(\textbf{CS/CB}) = \frac{\|\mathbf{H}^u_{c,t}\mathbf{F}^u_{c,t}\|^2 p^u_c}{\sum_{l\in\Phi_t, l\neq u}\|\mathbf{H}^u_{c,t}\mathbf{F}^l_{c,t}\|^2 p^l_c + \sum_{c^t\in\Phi, t\neq j}\sum_{i\neq u\in c^t}\|\mathbf{H}^u_{c^t,j}\mathbf{F}^i_{c^t,j}\|^2 p^i_{c^t} + \sigma^2_n}. \tag{6}$$

III. Novel Energy Efficient Design (NEED) Architecture with ICI Technique

In this section we describe the proposed NEED HetNet CoMP architecture incorporating JT and CS/CB techniques. Figure 1 demonstrates the vivid picture of the NEED architecture.

A. SINR Calculation for NEED

The intra-MHC part consists desired signaling and MUI is calculated by JT and the inter-MHC part consists the ICI which is calculated using CS/CB. Then the received signal at user u can be expressed as

$$y^u_c = \underbrace{\mathbf{H}^u_{c,:}\mathbf{F}^u_{c,:}x^u_c}_{\text{Desired signal}} + \underbrace{\sum_{l\in\Theta_c, l\neq u}\mathbf{H}^u_{c,:}\mathbf{F}^l_{c,:}x^l_c}_{\text{MUI}} + \underbrace{\sum_{c^t\in\Phi, t\neq j}\sum_{i\neq u\in c^t}\mathbf{H}^u_{c^t,j}\mathbf{F}^i_{c^t,j}x^i_{c^t}}_{\text{ICI}} + n^u_c \tag{7}$$

Then the SINR Γ^u_c(**NEED**) perceived by a UE u of the MHC cell-site c can be expressed as

$$\Gamma^u_c(\textbf{NEED}) = \frac{\|\mathbf{H}^u_{c,:}\mathbf{F}^u_{c,:}\|^2 p^u_c}{\sum_{l\in\Theta_c, l\neq u}\sum_{t=1}^{T}\|\mathbf{H}^u_{c,t}\mathbf{F}^l_{c,t}\|^2 p^l_c + \sum_{c^t\in\Phi, t\neq j}\sum_{i\neq u\in c^t}\|\mathbf{H}^u_{c^t,j}\mathbf{F}^i_{c^t,j}\|^2 p^i_{c^t} + \sigma^2_n} \tag{8}$$

B. Feedback based inter-cell interference(ICI) Coordination

There are two types of interference we come across in the transmission methods. Those are the MUI and the ICI. Specifically, upon utilizing users' CSI, the eNB can design dedicated precoder to sufficiently suppress MUI based on a range of principles, such as zero-forcing (ZF), minimum mean-square-error (MMSE) [5, 13]. Hence the SINR formula in (8) can be reformed as

$$\Gamma^u_c(\textbf{NEED}) = \frac{\|\mathbf{H}^u_{c,:}\mathbf{F}^u_{c,:}\|^2 p^u_c}{\sum_{c^t\in\Phi, t\neq j}\sum_{i\neq u\in c^t}\|\mathbf{H}^u_{c^t,j}\mathbf{F}^i_{c^t,j}\|^2 p^i_{c^t} + \sigma^2_n} \tag{9}$$

These ways of MUI suppression also apply to both JT and CS/CB.

However, in addition to the aforementioned MUI, cellular system may suffer from ICI, which cannot be suppressed individually within a single cell. Specifically, in comparison with cell-center users, cell-edge users tend to have lower received signal strength and are therefore more vulnerable to ICI. For our scenario, to minimize the ICI we devise ICI reduction technique using coordination through limited feedback [14, 15]. The algorithm of the envisioned MHC scenario for interference coordination is listed as follows in Algorithm 1 [14].

Algorithm 1 ICI Coordination Algorithm

1: Estimate the aggregated channel (macro-cell eNB and RRH) from the serving MHC for each UE.
2: Estimate the aggregated channel (macro-cell eNB and RRH) from the interfering MHC for each UE.
3: Each UE receives (physical downlink shared channel- PDSCH) the feedback information for interfering channel. The feedback information contains given in the following:
   a. Precoding matrix indicator (PMI) and channel quality indicator (CQI) for the serving cell.
   b. Reference PMI from the interfering MHCs,
4: Calculate the PMI which cause less interference from the interfering MHCs.
5: Each UE receives the minimum PMI calculation which is used for performance enhancement:
   a. That means, improvement of SINR while using the recommended set of PMIs at the interfering MHCs.
6: Each UE sends back the information, which is fed back to serving MHC as well as interfering MHCs.
7: Finally, Serving MHC and the interfering MHCs select respective PMI to serve their aimed users.

A pictorial presentation is given in the following, for example, using 2 MHCs (MHC_1 and MHC_2) as shown in Fig. 2. Each MHC contains their respective macro-eNB and RRH to coordinate ICI to minimize ICI impact. For instance, MHC_1 is the serving MHC and MHC_2 is the interfering MHC which causes ICI. We consider the serving channel from MHC_1 (aggregated channel from eNB_1 and RRH_{MHC_1}) is $\mathbf{H}_1$ and the interfering channel from MHC_2 (aggregated channel from eNB_2 and RRH_{MHC_2}) is $\mathbf{H}_2$ for UE_1. We also denote PMIs $\mathbf{F}_1$ and $\mathbf{F}_2$ for eNB_1 and eNB_2 respectively. $\mathbf{F}_1$ is calculated using $\mathbf{H}_1$ and $\mathbf{F}_2$ is calculated for minimizing the ICI for UE_1 as $\mathbf{F}_2$ is the interfering PMI.

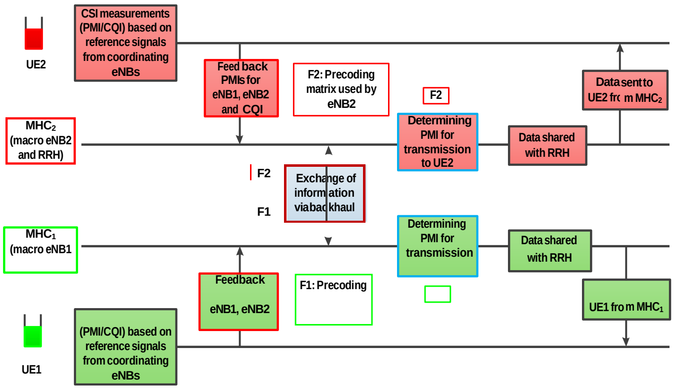

Fig. 2. ICI coordination for proposed MU-MIMO HetNet-CoMP architecture

IV. Simulations and Discussion

This section represents system level simulation (SLS) results

Monte Carlo simulation is used where the users are randomly distributed over the geographical area. Full-queue traffic model is used for all the users, which means they always have information ready to be transmitted. The effect of channel delay on the cell throughput will be examined. The key parameters of the simulated system are set according to the LTE Standard [3]. Implementation is explained in [16] in details. For SLS purposes, we consider a LTE-A cellular system consisting of 19 MHC cell sites, with six MHC cell-sites in the first tier and twelve MHC cell-sites in the second tier, surrounding the central MHC cell-site. Due to simplicity all the simulation results are collected from the central MHC cell-site, with the other MHC-cell sites serving as interfering sites since the system is fully loaded. A wrap-around model is used to avoid border effects .

Figure 3 shows the cumulative distribution function (CDF) concerning the cell-site throughput of different coordinated transmission schemes along with the uncoordinated MU-MIMO transmission (in the Fig. W/o-Coord. means no co-ordination). Cell-site throughput is defined as the ratio of the number of bits transmitted in one cell-site over the time required to transmit them. For large capacity system the unit can be Kbps, Mbps and so on. From Fig. 3, we have the following observations – the JT scheme is capable of outperforming all its counter-parts. Compared with JT, NEED architecture

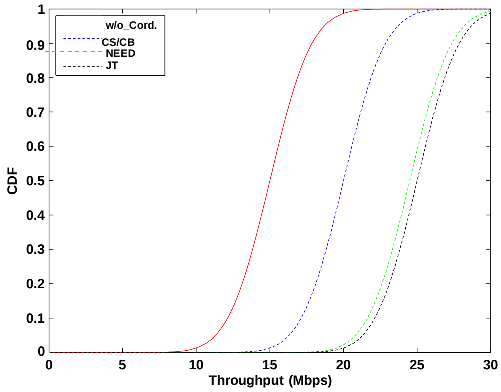

Fig. 3. Capacity CDF of different CoMP schemes

performs slightly worse (4%) than JT. The ICI minimizing technique discussed above employed by the NEED make the performance gap very narrow between JT and NEED.

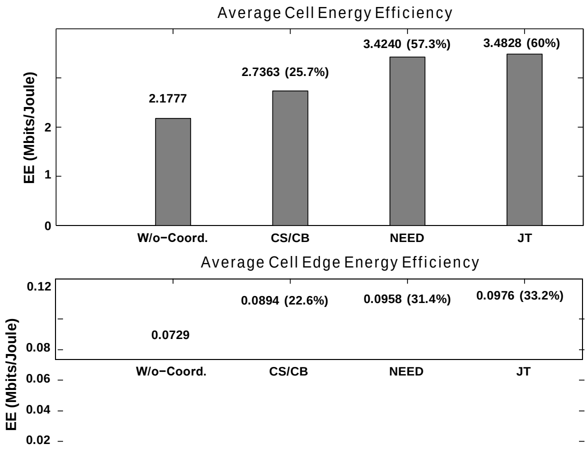

Fig. 4. Energy Efficiency of different CoMP schemes

Energy Efficiency (EE) is usually defined in bits per joule, as in [17]. More elaborately,

$$EE = \frac{Data\,rate}{Power} = \frac{bits/Second}{Watt} = \frac{bits}{Second \times Watt} = bits/Joule \tag{10}$$

To demonstrate the EE gain compared to different transmission techniques, the following performance metric is employed, called Relative EE gain (unit: percentage):

$$EE_{gain}(\%) = \left(\frac{EE_C - EE_B}{EE_B}\right) \times 100 = \left(\frac{EE_C}{EE_B} - 1\right) \times 100, \tag{11}$$

where EE_C is the energy efficiency of the compared technique and EE_B is the energy efficiency of the technique which is used as a benchmark to find out the relative gain. Figure 4 depicts the average and cell edge EE for uncoordinated MU-MIMO and different downlink CoMP transmission schemes. It can be seen that CS/CB, NEED and JT schemes can obtain an EE gain of 25%, 57.3% and 60% respectively with respect to uncoordinated MU-MIMO at cell average. And also CS/CB, NEED and JT schemes can obtain an EE gain of 22.6%, 31.4% and 33.2% respectively with respect to uncoordinated MU-MIMO at cell edge. From Fig. 4, we have the following observations: JT scheme can achieve the best performance in terms of EE in both cell center and cell edge for intra- and inter-MHC transmissions. The cell-edge EE is improved in NEED, compared with its cell average EE in terms of gain difference from JT. That means the gain difference in cell average and cell edge is 2.7% and 1.8%.

Although the JT scheme can bring more performance gain to the MHC system, it also has a range of problems, such as high signaling (radio signaling) overhead and backhaul requirement. Signaling overhead is quantified by the number of channel frequency response fed back by the UEs [18]. Consider $\xi(t_s)$ be the set of all channel frequency response in time slot t_s. With T transmitters and U users there are a total of $|\xi(t_s)| = (T \cdot M) \cdot (U \cdot N)$ frequency responses. In each time slot a subset $\beta(t_s) \subseteq \xi(t_s)$ is fed back. The instantaneous feedback load is denoted as $\lambda(t_s) = |\beta(t_s)|$ in each slot. Eventually we obtain the average number of frequency responses fed back per UE of the system is expressed as

$$\Lambda(\%) = \left(\frac{1}{U} \mathrm{E}_{t_s}\{\lambda(t_s)\} \right) \times 100 \tag{12}$$

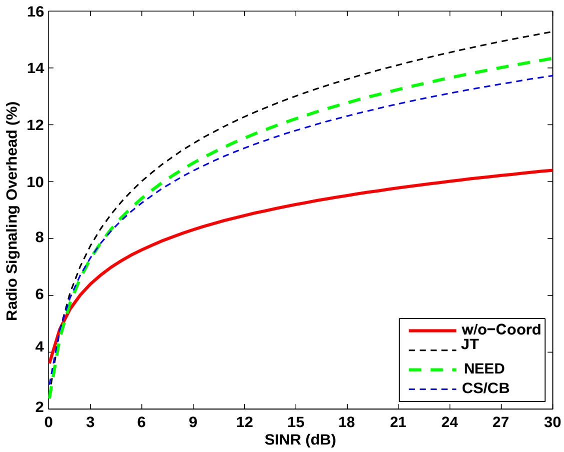

Fig. 5. Radio signaling overhead comparison of different HetNet CoMP

Figure 5 demonstrates the average signaling overhead (in percentage) for different HetNet CoMP techniques as a function of system SINR. It can be clearly seen that the value of radio signaling overhead increases in the high SINR regime. JT demonstrates the highest signaling overhead among the all HetNet CoMP techniques due to their intra- and inter-MHC JT technique. On the contrary NEED provides less signaling overhead than JT but more than CS/CB thanks to intra-MHC JT and inter-MHC CS/CB. The signaling overhead comparison is not that significant to provide a clear distinction among the techniques. To deduce the final decision in favor of the proposed HetNet CoMP technique backhaul overhead comparison is needed to exhibit.

Backhaul overhead is produced for exchanging the CSI and users' data and end up with high computational complexity due to user scheduling and transmit precoding design, and synchronization among all eNBs within the same MHC cell-site. In comparison with JT scheme, each MHC in the NEED scheme only serve its associated users upon designing its transmitter precoder to reduce its ICI to other MHCs. The NEED scheme is capable of lowering the backhaul requirement, due to no requirement of exchanging users' data among transmission between the MHC cell-site. The backhaul overhead is the average number of user data streams transmitted per transmitter per time slot. This is determined by the number of zero elements of the precoding / beamforming matrix $\mathbf{F}^u_{c,t}$. The number of transmitted streams per transmitter while coordinating transmitter both for intra- and inter-MHC case give an idea of backhaul usage [18]. We consider, $\zeta(t_s)$ be the number of zero elements of the beamforming matrix during slot t_s. The average number of transmitted data streams to calculate backhaul overhead per transmitter is

$$\Sigma(\%) = \left((T \cdot M) - \frac{1}{T \cdot M} \mathrm{E}_{t_s}\zeta(t_s) \right) \times 100 \tag{13}$$

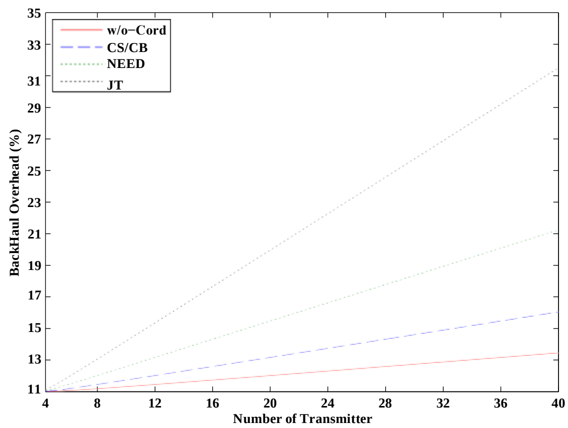

Fig. 6. Backhaul overhead comparison of different HetNet CoMP

Figure 6 demonstrates the backhaul overhead comparison (in percentage) of different transmission techniques in umber of transmitter. As expected JT shows high backhaul overhead compared to other techniques. CS/CB shows less overhead than NEED since it does not need exchanging data signals in intra-MHC and inter-MHC. Only scheduling and signaling information needs to be exchanged. In the case of NEED data exchanging is needed in intra-MHC since it is used JT scheme but not needed in the inter-MHC case (coordinated scheduling information needed between MHCs). Therefore NEED provides less overhead than JT but higher than CS/CB. Uncoordinated MU-MIMO technique has least overhead due to no signaling information exchange between the MHCs. NEED shows 6% more overhead than CS/CB whereas JT has 12% more overhead than NEED. Since JT has to exchange data signaling overhead both intra- and inter-MCH, hence the increase rate of backhaul overhead is quite high compare to NEED where data signaling needs to be exchange only in the intra-MHC case not in the inter-MHC. The trend shows us the more the transmitter involved in the coordination the more backhaul overhead is increasing for every technique.

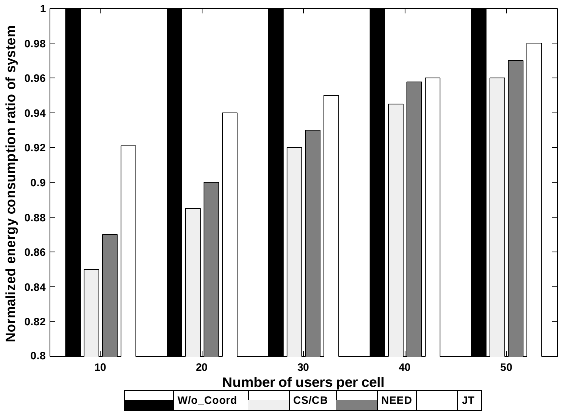

Fig. 7. Energy consumption ratio of the different techniques.

Figure 7 describes the comparison of ratio of power consumption for uncoordinated, CS/CB, NEED and JT under different cell load conditions. It can be concluded that, compared to full reuse case, proposed strategy in this paper has a better performance with lower power consumption except from CS/CB. This demonstrates the efficiency and necessity of coordinated power allocation. Note that larger size of coordination provides higher power efficiency. Besides, the power consumption increases as the users' number increases.

Based on the above discussion as illustrated by the SLS, it can be concluded that our architecture NEED provides best trade-off between performance gain and overhead (both signaling and backhaul) for future complex energy efficient green communication network. Our architecture does not provide best performance in every cases but it shows optimum performance to make a pragmatic solution for highly complexed coordinated scenario. EE in NEED can be little worse than JT but considering the fact for making a realistic implementation JT is too much computationally complex for higher backhaul requirement, if not improbable. The power consumption ratio of CS/CB can be less than NEED, but on the contrary it shows very poor system performance in terms of EE and throughput.

V. Conclusions

In this paper, a novel MU-MIMO HetNet CoMP system architecture termed as NEED is investigated. Gains in terms of the energy efficiency index are analyzed for different CoMP techniques. We also provide relative gain in terms of energy efficiency and overhead comparison (both for radio signaling and backhaul) with respect to other techniques to show the feasibility of NEED. JT provides us more EE whereas CS/CB provides less overhead. But neither of those shows a performance as a pragmatic solution due to overhead complexity (in the case of JT) and system performance (in the case of CS/CB). Therefore a trade-off exists between these two. The proposed NEED architecture provides the best trade-off for realistic implementation as the operator point-of-view is concerned.

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