Energy Efficient Coordinated Multipoint Transmission and Reception Techniques-A Survey

Parkash Chand, Rajarshi Mahapatra & Rishi Prakash
Department of Electronics and Communication Engineering
Graphic Era University, Dehradun

Abstract— Energy efficiency in cellular networks is a growing concern for cellular operators to not only maintain profitability, but also to reduce the overall environment effects. According to technical analysts, the base stations are the most energy intensive part of a typical cellular network. Saving power in base stations is therefore the primary focus in energy efficient operation. The main goal of energy efficiency is for saving and reducing power consumption while guaranteeing QoS. As mobile traffic is increasing, new applications are raising expectations for higher data rates creates heterogeneous Network by introducing low power nodes is an attractive approach to meeting traffic demand, performance and energy efficiency. According to technologist, the energy efficiency of cellular network can be improved at component level, link level and network level. There is lots of literature available on energy efficiency at component level, link level and network level without coordination. The energy efficiency can also be achieved by coordinated transmits and receive at network level, this can be achieved by power saving protocols, energy aware cooperative base station power management, cell zooming, link adaptation and beamforming with CoMP. This attempt will review existing CoMP solutions towards energy efficient architecture and network deployment.

Keywords- Energy efficiency, Network deployment, Heterogeneous network, energy efficient CoMP, power saving.

I. INTRODUCTION

The overlap between mobile and data access services has caused an increasing demand for high data rate wireless communications. In the recent years, availability of low-cost notebooks, tablet computers, smart phones, etc. as well as a wide range of services including web browsing, streaming, and interactive file transfer has resulted a significant rise in the mobile data traffic. With the increased demand of these services, there is need for denser networks. These more compressed small networks have pushed the limits of energy consumption in wireless networks and have some impact on the industry's overall carbon footprint. This results into increasing global green house gas emission. Within ICT, the contribution of mobile communication networks was 64 Megatons of CO_2 in 2002. This may seem a rather small fraction (12% of ICT emissions) but it is expected to grow by a factor of three to 178 Megatons in 2020[1, 2]. The global greenhouse gas emissions from information and communication technology (ICT) are comparable with those of the aviation industry [3]-[7].

It is reported in [8] that the total energy consumed by the infrastructure of cellular wireless networks, wired communication networks, and internet takes up more than 3% of the worldwide electric energy consumption nowadays. A typical 3G base station (BS) uses 500W of input power to produce 40W of RF output power, which will consume more than 50 GWh per year in a network with 12,000 BSs. This causes a large amount of CO_2 emission as well as contributes to the network's operating costs [9]. The latest projections of wireless data rates need additional BSs for next generation (4G) mobile networks (e.g. 3GPP LTE) [10], which increase the energy consumption of the network infrastructure even more. Therefore, energy consumption and CO_2 emissions of the mobile network infrastructure have received more and more attention in the telecommunications sector to lower the CO_2 emission and as well as reduce energy consumption. The European Commission (EC) has reached an agreement to cut green house gas emissions by 20% by 2020 and to improve energy efficiency by 20% [1]. In addition to this worldwide Green touch consortium aims to deliver the architecture, specifications and roadmap to increase network energy efficiency by a factor of 1000 from current levels [11].

In the present scenario, several wireless technologies are available to support user requirement satisfactory. These technologies are varied with different coverage area with different transmit power and support different performance for user. Each of these technologies evolves for a specific purpose and works better in a particular environment. These technologies are diverse in nature and coexist in the same environment to provide ubiquitous network coverage. UEs can connect to any available wireless technologies depending on their requirements. With the increased drive from the industry for a fully connected network, there is a need to design the wireless Heterogeneous Network (HetNet) architecture to interconnect these different wireless technologies. These interworking mechanisms are of prime importance to achieve ubiquitous access and seamless mobility in HetNet environment [12, 13]. As shown in Fig. 1, next generation networks are composed of different types of cells with multiple RATs. In HetNet, UEs can connect to any available neighboring APs, which can operate with different RATs at a given point of time. The selection of EE operating point is a non-trivial task in such a network scenario.

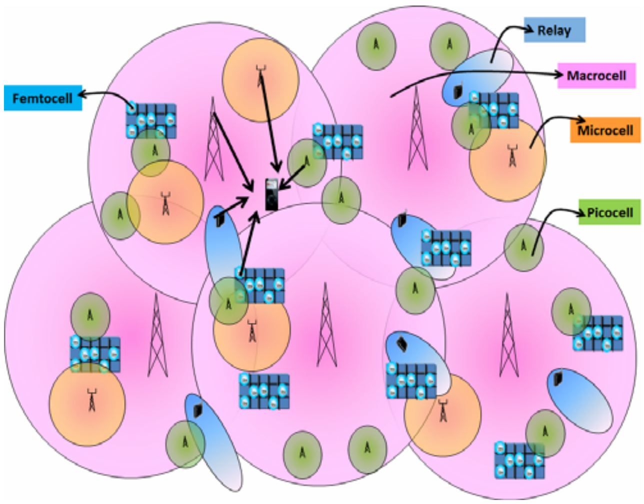

Fig. 1 Heterogeneous network consisting of a mix of macro, micro, pico, femto, and relay base-stations

Since the power consumption of the entire cellular network includes the summation of energy consumed by each BS. Reducing BS number has a direct impact on energy consumption of a cellular network. However, there is direct comparison between the number of low power BSs deploy in a dense area and low density deployment of high power BSs. Low power BS consumes less energy than high macro BSs [14]-[16]. Table I represents the specifications of different elements in HetNet. Networked deployment based on smaller cells such as micro, pico or femto cells is a possible solution using cognitive radio to reduce total power consumption of cellular network [17].

To analysis energy consumption issue, the European Commission has taken initiatives under seventh Framework Program (FP7), such as; "Energy Aware Radio and Network Technologies" (EARTH) [18], "Towards Real Energy-efficient Network Design" (TREND) [19] and "Cognitive Radio and Cooperative strategies for Power saving in multi-standard wireless devices" (C2POWER) [20]. These projects addressed the energy efficiency of mobile communication systems by applying a number technical approaches and committed to the development of a new generation of energy efficient equipment, network architecture and protocols, energy-efficient wireless transmission techniques for reduced transmission power and reduced radiation, cross-layer optimization methods, network management solutions and opportunistic spectrum sharing without causing harmful interference pollution. In such perspective, the Green touch consortium [11] and Mobile VCE [21] focus on achieving the infrastructure energy savings of wireless networks at the system level. The main goal of these projects is to develop innovative algorithms and technologies for green operation of wireless networks. Authors in [22] and [23] show a breakdown of power consumption in a typical cellular network and tell us the possible areas for reducing energy consumption in wireless communications. In [24], the authors have identified four key trade-offs, as energy efficiency (EE) vs spectrum efficiency (SE) [25], EE vs deployment efficiency (DE), bandwidth & power, and delay & power. Energy efficient radio covers all the layers of the protocol stack and various system architectures.

Work done in this area is reported in [26]. However, power consumption in all level may broadly categories into three level; component level, link level & network level. Several power saving protocols have been proposed to minimize energy consumption [21]-[37], where the authors analyzed the performance of sleep mode technique. The use of sleep mode offer approximately 13-56 % energy savings in the network relative to operation without sleep modes. It is also use to reduce inter-cell interference (ICI). In order to switch off the BSs without affecting the user outage, cell zooming technique has been proposed [38]. It can balance the traffic load and the energy consumption by adaptively adjust the size of the cells according to traffic conditions. Summary of the work [39]-[46] is presented in Table II. Therefore, BS equipment manufacturers have begun to offer a number of eco-friendly and cost-friendly solutions to reduce power demands of BSs and to support off-grid BSs with renewable energy resources.

TABLE I. SPECIFICATIONS OF DIFFERENT ELEMENTS OF HET NET

Type of node	*Table Column Head*		
	Transmit Power	*Coverage*	*Backhaul*
Macro cell	*50 W*	*Few KMs*	*S1 interface*
Microcell	*10 W*	*1 to 3 KMs*	*S2 interface*
Pico cell	*50 mW – 1 W*	*100 m*	*X2 interface*
Femto cell	*15 mW*	*10 m*	*Internet*
Relay	*50 mW – 1 W*	*Few KMs*	*Wireless*

TABLE II. SUMMARY OF WORK DONE

Techniques	**Table Column Head**		
	Work done	*References*	*Comments*
BS Energy	Hardware desugn and power saving	[39]-[41], [45[46]	70% reduction in power
BS Power Mangement	Cell zooming and Self-organizing network	[38]-[42] [45]	30% power saving
Renewable Energy Resource	Sustainable biofuels,Solar energy and Wind energy	[47],[45]	0.355 saving in diesel

This interference affects the average spectral efficiency of the cell. Hence, heterogeneous deployment requires using innovative cell association and inter-celling interference coordination techniques in order to realize the promised capacity and coverage gains. In recent years, mobile communication with multimedia applications are became popular which need to support high data rate transmissions reliably. In [31], authors have considered many advanced

physical layer transmission and reception techniques, such as MIMO, adaptive antenna array, advanced retransmission schemes, carrier aggregation and coordinated multi point (CoMP) transmission and reception technique.
The rest of the paper is organized as follows. Section II presents the fundamental characteristics of CoMP. The different CoMP techniques have been discussed in Sec. III. This section also presents the several challenges in CoMP. Sec IV investigates the several energy efficient techniques in wireless communication using CoMP. Finally, Sec. V concludes our work.

II. Basics Of CoMP

The fundamental principle of CoMP [48]-[50], is to coordinate multiple BSs or antennas located within a certain geographical area. In CoMP, multiple points coordination with each other can make in such a way that the transmission signals from/to other points do not incur serious interference or even can be exploited as a meaningful signal. There are several techniques available for CoMP. Most of the CoMP approaches require some scheduling information regarding the users at the different BSs that must be shared among them. This sharing is very important in low-latency links, such as microwave links, where information need to be exchanged between coordinated nodes within the order of milliseconds. By coordinating and combining signals from multiple antennas, CoMP makes it possible for UEs to enjoy consistent performance and quality when they access and share videos, photos and other high band width services whether they are close to the center of an LTE cell or at its outer edges. CoMP is considered by 3GPP as a tool to improve coverage, cell-edge throughput, and/or system efficiency. Thus, CoMP is a prominent technique in LTE wireless broadband networks as well as other 4G networks to ensure consistent service quality [51].

CoMP transmission is very effective for cell-edge user, where UE's performance has been limited by interferences. User Equipment (UE) at the cell edge is serviced by cells 1, 2 and 3 at the same time. The interference from other cells to UE can be cleared in this way, and the signal quality of cell's edge users can be enhanced. For this to occur, the CSI [52], from all the BSs need to be available at the central unit for pre-coding. This constitutes the centralized joint processing algorithm, where a set of BSs form a cluster of cooperative cells. However, coordinating BSs for coherent joint processing puts tremendous requirements for high speed back-hauling to make available CSI at central unit. Hence, various joint processing schemes [51] are developed to reduce the burden on back hauling. The partial joint processing algorithm [53] is one such scheme, where only a subset of BSs is allowed to transmit based on a threshold. Contrary to centralized joint processing, the pre-coding can be done locally at each BS, which gives rise to distributed joint processing [50] [55]. In the following, we will discuss two types of architecture; centralized and distributed.

A. *Centralized Architecture*

In centralized approach [10][50][56], a central entity gathers channel information from all the UEs, present in the area covered by coordinating BSs. This entity performs user scheduling and signal processing operations such as pre-coding. This operation can be possible when user data are available at all collaborating nodes and tight time synchronization is required among BSs to access them. Figure 2 describes the centralized framework for coordination among different BSs [57]. UEs first estimate the channel related corresponding to the cooperating BSs. The information is feedback to a single cell, which acts as the serving cell of the UE when coordination is being applied. Once the information are gathered, each BS forwards it to the central entity, which eventually decides the scheduling with transmission parameters, and forwards these new information to the BSs. The main challenges of this architecture are related to the associated communication links between central entity and BSs. They must support very-low latency data transmissions. In addition to this, a communication protocols need be designed to support these information exchange.

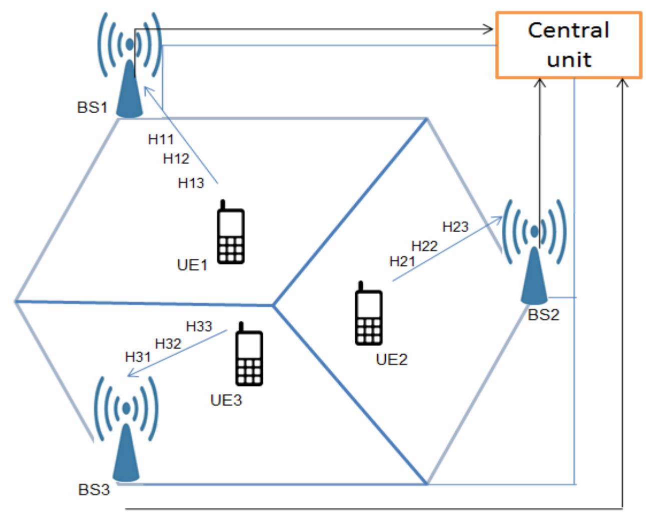

Fig. 2 Centralized CoMP Architecture.

B. *Distributed Architecture*

Apart from the centralized architecture, distributed architecture is another solution to perform coordination that relieves the requirements of a centralized approach [10][58]. It is based on the assumption that schedulers in all BSs are identical and channel information regarding the whole coordinating set can be available to all cooperating nodes. Thus, inter- BS communication links are no longer necessary to perform cooperation. Figure 3 depicts the distributed frame work for coordination among different BSs. With these, this architecture has the great advantage of minimizing the infrastructure and signaling protocol cost associated with these links and the central processing unit, so conventional systems need not undergo major changes. The UE estimates the channel from all the coordinated BSs in the same way as in the centralized approach. The estimates are then sent back to all cooperating BSs and the scheduling is independently performed in each of them. Since the schedulers are identically designed, the same input parameters produce same output decisions and therefore, same UEs are selected in the entire BS cluster. Further, the drawback of this scheme is the handling of errors on the different feedback links. The same UE reports its channel conditions to all the BSs in the set but the wireless links to the different nodes might be different and can affect the system performance. The above CoMP architectures use different approaches to enhance network performances. In the following section, we will discuss them briefly.

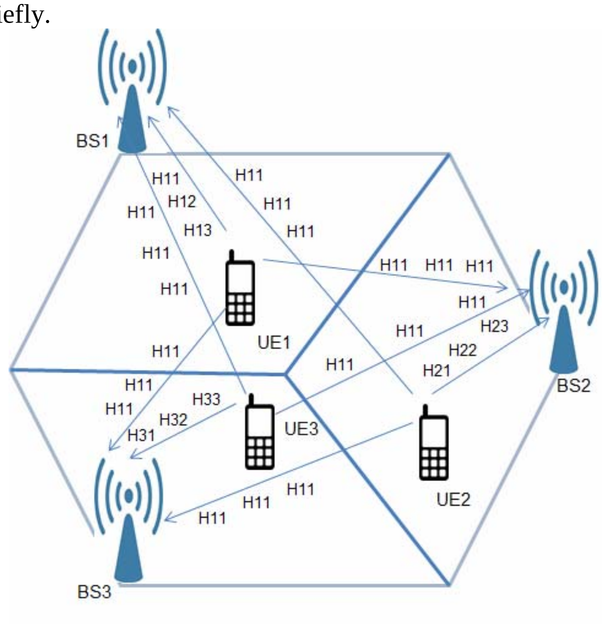

FIG.3 Distributed CoMP Architecture.

III. DIFFERENT COMP TECHNIQUES

Independent of distributed or a centralized architecture, different approaches at different levels of coordination have been proposed in literature [51]-[67]. CoMP, proposed in LTE-A, includes various possible coordinating schemes among BSs. They typically have different requirements in terms of measurements, signaling, and back-haul, where as usual the most advanced approaches are achieving the best performance. Furthermore, the 3GPP technical report [61] extends two major approaches for further advancements of physical layer which are namely CoMP for down link and uplink [63].

A. Down link Transmission

1) *Joint Processing*: In joint processing (JP), data intended for a particular UE is jointly transmitted from multiple BSs [51], to improve the received signal quality and cancel interference. JP is divided into two subcategories; Joint transmission (JT) and fast cell selection (Dynamic cell selection -DCS). Although data are indeed transmitted from several sites, the JT scheme does it simultaneously while the DCS uses a fast cell selection approach and only one of them transmits data at a time. Figure 5 shows a simplified scheme of both techniques. In both cases user data need to be shared among base stations so a very fast link interconnecting them is required, although the complexity of the signal processing is higher in the joint transmission scheme. The simplest form of cooperative transmission is simulcast from several transmission points, similar to what normally is referred to as macro diversity. This improves the total transmitted power and is typically applicable to cell edge users.

2) Dynamic network reconfiguration and coordinated Scheduling/beamforming:

A very simple form of CoMP would be dynamic network reconfiguration and management [61]-[62]. The easiest reconfiguration scheme envisaged is of turning on/off the remote units in the CoMP system, according to network planning or traffic constraints. When needed, the planner could easily turn on/off a remote unit in order to upgrade/downgrade the overall coverage and/or capacity in the area. Furthermore, based on traffic requirements, the network characteristics can be adapted. The dynamic coordinated scheduling is another form of CoMP. In this case, the transmission points coordinate their schedulers to avoid interference. The coordination takes place on fast time scale, which means that the fast fading can be followed. In coordinated beamforming, the beams activation at different transmission points are need to be coordinated to minimize the probability of beam collision or minimize the inter-beam interference. Hence, the term coordinated beamforming as shown in Figure 4. The main advantages of these schemes over joint transmission are that the requirements of coordination links and the back-haul are much reduced. This is due to that, only information of the activated beams and/or scheduling decisions are need to be coordinated, and the user data do not need to be made available at the coordinated transmission points, since there is only one serving transmission point for individual user.

B. Uplink Transmission

In uplink, the CoMP scheme [51] [67] aims to increase cell edge user throughput, which received the signal transmitted by geographically separated multiple UEs. These points are the set of coordinating BSs assigned to each UE. The UE does not need to concern of receiving nodes and it's processing. There are two methods of CoMP for uplink; dynamic network reconfiguration & coordinated scheduling, and coherent joint processing.

1) Dynamic network reconfiguration & coordinated scheduling:

It is same as the down link. For example, a rather simple form of CoMP on the uplink is dynamic coordinated scheduling, meaning that the scheduling of UEs are coordinated among the different transmission/reception points in such a way that the interference among them is minimized [59].

2) Coherent joint processing:

The advanced form of CoMP for uplink transmission is coherent joint processing [59]. It is coherently combine and process received signals at different reception points. The main benefit of this processing is that the energy collected at several reception points, can be used for advanced combining algorithms in the receive processing to cancel interference. However, this approach puts high requirements on the coordination links, since the received signals need to be exchanged among the receptor points

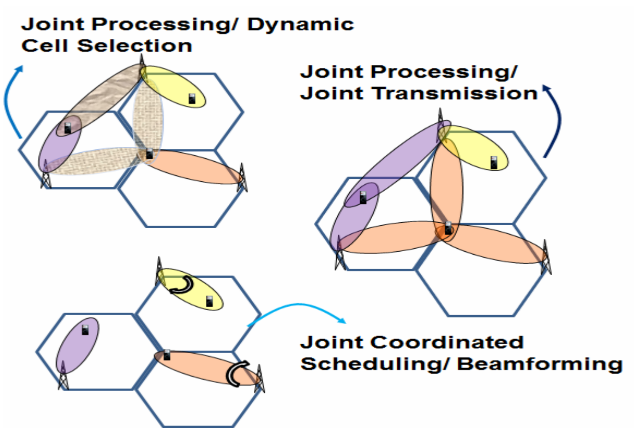

Fig.4 Different approaches of COMP.

C. Challenges in CoMP

Due to propagation loss, fading etc, cell edge UEs is suffered worse than other UEs. CoMP techniques can provide a solution to counteract this problem. Simultaneously, it is also necessary to estimate accurate CSI of channel to enable proper CoMP technique. During CSI estimation, the reference signals transmitted from far BSs may be interfered by reference signals and data transmissions from nearer BSs. This problem can be solved by assigning orthogonal resource blocks (RBs) for reference signals, transmitted by cooperative BSs, and these resources can not be used for data transmission. This result in loss of data throughput and can be minimized by sparse transmission of CSI reference signals (CSI-RS) in time/frequency. Furthermore, the gain achieved due to CoMP can be compensating the loss of throughput in data transmission. In addition to this, other factors, such as delay, synchronization, CSI availability and feedbacks play a impact on the performance of CoMP. Work done in CoMP is summarized in Table III.

The above methods are used to improve the system performances using Comp. However, one of the main challenges in CoMP transmission is Energy consumption. In CoMP, several BSs are coordinated among each other to improve network performance. In this process several information need to be exchanged amongst, additional synchronization techniques, processing algorithms need to be used. In addition to this, several frequencies, time slots are assigning to serve a particular UE All these factors consume energy/power. Thus, in CoMP, energy/power consumption is an important issue. The following section provides the detailed literature survey on the energy efficient CoMP in heterogeneous network.

TABLE III. USAGE OF COMP

Techniques	**Table Column Head**	
	Work done	***References***
Interfernce Mitigation	Dirty paper coding,Joint processing and CS/CB schemes	[49],[57]-[66]
Network deployment	CoMP in wireless networks	[17],[66]-[67]
Performance enhancement	a) Adaptive CoMP b) Gain in spectral efficiency and system capacity	a)[52] b)[17], [60], [64] [52], [68], [34], [28]

IV. ENERGY-EFFICIENT COMP TECHNIQUES IN HETEROGENEOUS NETWORK

Energy consumption of network depends on cell size, deployment scenario, traffic distribution, user requirements and environments (ranging from dense urban to rural areas). With a mix of different BSs with different cell sizes have deployed recently for 4G mobile communication systems to increase user & system performances. These deployments can increase energy consumption. However, energy efficiency of the network/ system can measure with several metric. In a simplest form, it is performance per unit energy consumption. Several measures have been considered to enhance energy efficiency. In heterogeneous environment, cooperative transmission from several base stations to one UE can enhance EE of network [34].This section provides detailed survey on EE of coordinated transmission in heterogeneous network in the following.

A. Energy Efficient cell edge user

BSs usually have lower energy efficiency in serving the users at the cell edge than in serving the users at the center of the cell. This is not only because cell edge users are far away from BSs and require more transmission power, but also because cell edge users experience more interference from neighboring cells. Multi-cell cooperation can improve energy efficiency for cell edge communications [35]. In this paper closed-form approximation of the DMIMO capacity has been utilized for assessing both the channel and bit-per-joule capacities of the idealized CoMP system. Results have indicated that multi- BS cooperation is efficient when the link quality between the BSs and UEs is weak, e.g. cell-edge communication. Therefore, cooperative processing power should be kept low for CoMP to provide energy efficiency gain.

B. Coordinated Scheduling/Coordinated Beamforming CoMP

A BS forms radio beams to enhance the signal strength of its serving users while forming null steering toward users in its neighboring cells. BS1 forms the radio beam toward its associated user; user1 to increase the user's receiving signal strength. On the other hand, in order to reduce the interference to user2 who is served by a neighboring BS, BS1 forms the null steering toward user2. BS2 executes the same operation as BS1. Therefore, through cooperative beam forming, the signal to- noise ratio (SNR) of both user1 and user2 is enhanced. Thus, less transmission power is required for BSs to serve the cell edge users, and the energy efficiency of cell edge communications is increased.

C. Joint Transmission CoMP:

Joint transmission exploits the cooperation among neighboring BSs to transmit the same information to individual users located at the cell edge [68]. Due to joint transmission, cell edge users experience higher receiving signal strength and lower interference, hence requiring less transmission power from both BSs. Thus, joint transmission improves the energy efficiency of the cell edge communications. The paper investigated energy consumption impacts of JT-CoMP deployments in heterogeneous LTE-Advanced networks. Results obtained using macro base station cooperation show significant improvements in cell-edge rates and almost 80% reduction in energy consumption per delivered bit compared to a baseline single-point network.

D. Coordinated Cell Swich off

The main idea is that when BS is in sleep mode, radio parts of the transceiver can be de-activate for energy saving. A coordinated sleep schedule has been proposed for BS transceivers on LTE Re-8 and LTE Re-10 to get the full benefit from the ICI reduction [69]. The authors in [70] have analyzed the energy saving performance by turning off certain BSs with average outage constraint for three typical cooperation schemes: single BS transmission, BS cooperation and wireless relaying. The authors also investigate the effect on traffic intensity and network density due to energy saving performance. Based on the typical parameters setting, calculation results show that traffic intensity can be divided into three classes: coverage-limited region, energy-efficient region, and capacity-limited region. The coverage-limited region prefers off line fixed algorithms, while dynamic online algorithms are more suitable for the energy-efficient region. As BS density goes higher, the energy efficient region becomes larger. However, the traffic load region where the cooperation schemes bring benefits becomes smaller. The sleep mode-based scheduling also been used to improve EE of network [64]. This work takes advantage of coordination among neighboring base stations for ICI reduction. The proposed coordinating sleep scheduling algorithm improves EE by 13%, leading to an overall reduction of energy consumption of up to 83% with respect to non sleep mode.

Network cooperation can also play an important part for energy saving [34]. This work considered the overlapping coverage from different networks, the proposed to achieve energy saving without increasing the transmission power. It relies on the cooperation among different networks to save energy on two scales. On a large scale, networks with overlapped coverage alternately switch on and off their BSs according to the long term fluctuations in the traffic load. On a small scale, each active BS switches on and off its channels according to the short term fluctuations in the traffic load. The work in [71] presented an optimal resource on-off switching framework that adapts to the fluctuations in the traffic load and maximizes the amount of energy saving under service quality constraints, in a cooperative networking environment [72]. In this paper, authors analyzed an alternative way of improving the cell switch off schemes for further energy saving enhancements using CoMP transmission technique and proved the advantages in terms of energy efficiency. The sensitivity of the CoMP scheme to channel estimation errors in dynamic channels lead to incorrect CSI feedbacks. Imperfect downlink channel estimations and the unnecessary CoMP set degree increases lead to energy inefficiency in the cellular systems in terms of bits/Joule.

E. Enable more BSs to enetr into sleep Mode

As discussed in the previous subsection, CoMP transmission (e.g., joint transmission) enhances the receiving SNR of cell edge users, implying that BSs are able to cover a larger area with the same transmission power. Therefore, under low traffic demands, adopting the CoMP transmission can reduce the number of BSs required to cover an area, thus improving the energy efficiency of cellular networks [73]. As presented earlier, traffic-intensity-aware multi cell cooperation enables BSs with low traffic demands to go into sleep mode to save energy. The users in the off cells will be served by their active neighboring cells. However, due to the limitation of BSs' maximal transmission power, a few BSs should stay awake to provide coverage in the area. By applying CoMP transmission, the number of required active BSs can be further reduced. The inner circle of BS 1 is the original coverage area, while the outer circle indicates the coverage area after cooperation with its neighboring BS, BS 3. The additional coverage area is achieved by multi cell cooperation. Under the condition of lower traffic demands, if there is no cooperation among BSs, three BSs have to stay awake to cover the whole area. However, if multi cell cooperation is enabled, BS 1 and BS 3 can provide services to the users in the area by applying cooperative transmission; thus, BS 2 can be switched into sleep mode. Therefore, the total energy consumption of cellular networks is reduced.

F. Network Self organiging Techniques

SON can save energy by power ON/OFF of BSs by meeting the network objective [74, 75]. This BS activation, deactivation algorithm achieves network level energy saving. These algorithm uses coordination among network elements and coverage information to appropriate activation and deactivation of BSs.

G. Distributed Space Time Coding

Distributed space time coding [35, 76] explores the spatial diversity of both the relay nodes and the mobile users to combat multi-path fading, and can be applied to improve the spectral and energy efficiency of cell edge users. The distributed space-time coding scheme consists of two phases. In the first phase, the BS broadcasts a data packet to its destination and the potential relays. In the second phase, the potential relays that can decode the data packet cooperatively transmit the decoded data packet to the destination using a suitable space time code. By exploring spatial diversity, distributed spaced time coded cooperative transmission improves the diversity gain of cellular networks. However, the multiplexing gain of the wireless system may be sacrificed [77]. The authors proposed an opportunistic distributed space-time coding (ODSTC) scheme to increase the multiplexing gain. Taking advantage of DSTC cooperative transmission, the spectral efficiency is increased. As a result, fewer transmissions are required in order to transmit a given number of data packets. Therefore, the energy efficiency of the cellular networks is enhanced.

H. Energy Efficiency via Cooperative Relaying

User cooperation in relay [78] has been shown that not only it increase the data rates but also the system is more robust, but increased rate of one user comes at the price of energy consumed by other user acting as a relay. Taking advantage of cognitive radio techniques, cooperation can be exploited between a primary cell and a secondary cell. The secondary BS cooperatively relays the signal from the primary BS to the primary user. The primary user combines the signals from both the primary and secondary BSs to decode the information. To stimulate cooperative relaying, the primary BS grants the secondary BS some spectrum that can be utilized for communications between the secondary BS and secondary users.

By cooperating with secondary BSs, the transmission power required from primary BSs to serve the cell edge users is reduced. Therefore, the cooperative relay scheme reduces the power consumption of primary BSs [79]. However, due to the time-varying wireless channels, the scheduling delay involved in the relaying process may increase the outage probability. The authors in [80] showed that the outage probability caused by the scheduling delay can be alleviated by optimizing the transmission power of the network nodes. Further, the limited battery life time of mobile users in a mobile network leads to selfish users who do not have incentive to cooperate. The authors in [81] investigated the user cooperation from the EE perspective using game-theoretic approach. With this approach, an incentive will be given to users in order to act as relays when they are idle, and it is shown that user cooperation has the potential of simultaneously improving both users' bits-per energy efficiency under different channel conditions [82]. Furthermore, at MAC and routing level, persistent relay carrier sensing multiple access (PRSMA) MAC protocol scheme uses distributed cooperative automatic retransmission request (C-ARQ) scheme. In [83]-[84], it has been shown that the PRCSMA with C-ARQ provides higher EE than non cooperative ARQ schemes.

I. Beamforming Techniques

Beamforming uses multiple antennas to control the direction of a wave front by appropriately weighting the magnitude and phase of individual antenna signals (transmit beamforming). Beamforming improve transmission to users at the far reaches of cell coverage and provide better coverage to specific areas along the cell edge of cells. Because every single antenna in the array makes a contribution to the steered signals, an array gain (also called beamforming gain) is achieved. Receive beamforming makes it possible to determine the direction that the wave front will arrive (direction of arrival, or DOA). It is also possible to suppress selected interfering signals by applying a beam pattern null in the direction of the interfering signal and therefore, increase energy efficiency. The energy consumption for a general class of cooperative beamforming based transmission schemes has been analyzed [85]. The authors have considered the relay selection rules. Further, the cooperative communication scheme reduces energy consumption compared to non-cooperative schemes and cooperative schemes that use either a single relay or all available relays; energy savings up to 16% was achieved.

J. Link Adaptation

In this paper [86] a subset of base stations participate in the cooperative link adaptation and cooperative decoding for a single UE are considered, in which case, the other UEs' signals intended to the other base stations in the network interfere with the single UE's uplink signals, and hence the CSI experienced during the actual transmission is different from the CSI used for link adaptation. According to the analysis, they found that the maximum energy efficiency of the link adaptation controller is achieved when no rate back-off is employed, when a certain condition is satisfied.

Furthermore, in order to see benefits of multi-user uplink transmissions for energy efficiency, they in cite analyzed the optimal energy efficiency of a link adaptation method and a CoMP reception scheme of multiple UEs' uplink transmissions in a cellular network, where all the base stations participate in the cooperative decoding. The optimal power allocation gives similar intuition as water-filling in parallel channels, that is, it is need to assign more power to a better-quality channel, to achieve the maximum energy efficiency. They also provided a simulation result showing that two user spatial division- multiple-access transmissions achieves larger maximum energy efficiency than single user transmissions in the same cellular network.

K. Interfernce Reduction Techniques

In a heterogeneous network, a mobile may connect to a closer low power BS even though the received power from a macro BS could be higher. With HetNet deployment in same spectrum, users can experience severe inter-cell interference (ICI). This ICI can cause significant performance loss to the users, especially to cell edge users when all frequency channels are fully reused [87]. It is necessary to mitigate the ICI to support a full frequency reuse operation to improve the performance of the user at cell edge. In [88], the performance of CoMP scheme over Rayleigh fading channel for down link has been analyzed. The CoMP scheme gives better error performance over conventional non-cooperative. Further, cooperation among BSs can turn harmful ICI into useful signals, allowing power gain which may improve the EE.

V. CONCLUSION AND FURUTE WORK

This paper addresses the energy efficiency of cellular communication systems, which is becoming a major concern for network operators to not only reduce the operational costs, but also to reduce their environmental effects. We reviewed few techniques for saving power consumption and improve energy efficiency in architecture and network deployment by using Energy efficient CoMP. There are still many technical challenges for base station architecture redesign, heterogeneous network deployment, radio resource management and CoMP architecture etc. that need to be addressed for energy efficiency. Further, a few work has been done on energy efficient joint transmission scheduling, coordinated beamforming and link adaptation.

REFERENCES

[1] Climate change, "Commission welcomes final adoption of Europe's climate and energy package," *EC press release*, Dec.2008.

[2] O. Blume,D.Zeller and U. Barth,"Approaches to Energy Efficient Wireless Access Networks," 4th International Symposium on Communications, Control and Signal Processing (ISCCSP), 3-5 March 2010.

[3] Postnote, "ICT and CO2 emissions," Number 319 Parliamentary Office of Science and Technology, December 2008.

[4] 3GPP TR 32.826,"Telecommunication management; Study on Energy Savings Management (ESM)," *(Release 10)*, Mar 2010. Available: http://www.3gpp.org/ftp/Specs/html-info/32826.html, Accessed on 14th Aug,2012.

[5] ITU-T Focus Group on Future Networks (FG FN), FG-FN OD- 66, Draft Deliverable on, "Overview of Energy Saving of Networks," October 2010. Available: http://www.itu.int/dms pub/itut/ oth/3A/05/T3A050000660001MSWE.doc, Accessed on 20th,Aug 2012

[6] M.A. Imran *et. al.* ,"Energy efficiency analysis of the reference systems, areas of improvements and target breakdown," *Deliverable D2.3,WP2 EARTH,2010*

[7] D. Tipper,A. Rezgui,P.Krishnamurthy and P.Pacharintanakul,"Dimming Cellular Networks," *IEEE GLOBECOM '10,Miami,Florida,USA*,Dec.2010

[8] G.Fettweis and Z.Ernesto et. al. ,"ICT energy consumption-trends and challenges," Proc. 11th Int. Symp. Wireless Personal Multimedia Commun. (WPMC'08) Lapland, Finland,, Sept. 2008.

[9] X.Wang,V.Vasilakos and Y.Liu,"Survey of Green Mobile Networks: Opportunities and Challenges," *Springer Science- Business Media, Mobile Netw Appl, LLC* , 2011.

[10] I.J.Akyildiz et al.,"The evaluation to 4G cellular system:LTE - Advanced, ", *Communication*,2010

[11] "Green Touch Initiative," http:// www.greentouch.org ,Accessed on 22nd Sep.,2012

[12] R. Ferrus,O.Sallent and R.Agusti "Interworking in Heterogeneous Wireless Networks: Comprehensive Framework and Future Trends," *IEEE Wireless Communications*, vol. 17, no. 2, pp. 22-31, April 2010.

[13] A. Ghosh *et al.*, "LTE-advanced: next-generation wireless broadband technology," *IEEE Wireless Communications*, vol. 17, no. 3, pp. 10-22, June 2010.

[14] O. Ozel and E.U.Biyikoglu., "Network-wide energy efficiency in wireless networks with multiple access points ," *Trans Emerging Tel Tech.doi:10.1002/ett.2543*,2012

[15] J. Hoydis and M.Debbah.,"Green small cell," *IEEE VT magazine*, march 2011.

[16] A. Damnjanovic *et. al.*, "A Survey on 3GPP Heterogeneous Networks," *IEEE Wireless Communications*, June 2011

[17] R. Mahapatra, A. D. Domenico, R. Gupta and E. C. Strinati, "Energy-efficient green framework of future heterogeneous wireless network," Computer Network, Elsevier, vol. 57, no. 6, pp. 1518-1528, April 2013.

[18] EARTH, "Energy Aware Radio and NeTwork TecHnologies "*https://www.ict-earth.eu/*.Accessed on 30th Sep., 2012

[19] TREND "Towards Real Energy-efficient Network Design,"*http://www.fp7-trend.eu/*.Accessed on 4TH Oct., 2012

[20] C2POWER, "Cognitive Radio and Cooperative strategies for Power saving in multi-standard wireless devices" *http://www.ict-c2power.eu/*.Accessed on 10th Oct., 2012

[21] C.Han *et al.,* "Green radio: radio techniques to enable energy efficient wireless networks," *IEEE Communication Mag., Vol.49,no. 6,pp.46-54*,June.2011.

[22] Z.Zhou, S.Zhou, J.Cui and S.Cu.,"energy-efficient cooperative communication based on power control and selective relay in wireless sensor networks," *Wireless Communications, IEEE*,2008.

[23] S.Mishra et. al .,"energy efficiency in AD HOC network," International Journal of Ad hoc, Sensor and Ubiquitous Computing (IJASUC) Vol.2, No.1, March 2011.

[24] Chen Yan,S.Zhang,S.Xu and G.Y.Li.,"Fundamental trade-offs on green wireless networks, "*IEEE Communications Magazine, vol. 49, no. 6, pp. 3037*,2011.

[25] M.Deruyck,W.Joseph and L.Martens,"Power consumption model for macrocell and microcell base stations," *Trans Emerging Tel Tech.doi:10.1002/ett.2565*,2012

[26] C.E.Jones,K.M.Sivalingam,P.Agarwal and J.C.Chen,"A survey of Energy efficeicnt network protocols for wireless Networks," *wireless Networks 7,343-358*, 2001.

[27] I.ASharaf, B.Federio and Lester Ho ,"Sleep mode techniques for small cell deployments," *IEEE Communication Magazine* Aug.2011.

[28] I. Ashraf,*F.B0ccardi andL.Ho.*,"Power Savings in Small Cell Deployments via Sleep Mode Techniques," *IEEE Communications Magazine*, August 2011.

[29] I. Ashraf,Lester Ho and Holgar cla.,"Improving Energy Efficiency of Femtocell Base Stations Via User Activity Detection," *Proc. of IEEE WCNC'10, pp.1-5*,April 18-21, 2010.

[30] Eunsung Oh,Bhasker K. and Z. Niu.,"Toward Dynamic Energy-Efficient Operation of Cellular Network Infrastructure," *IEEE Communications Magazine*, 2011

[31] M.Zeinali and L.Sifan,"MIMO, Coordinated Multiple Point Transmission and Reception, and Carrier Aggregation Techniques in LTE-Advanced Mobile Systems," ,Dec 2011

[32] L. M. Correia *et. al.*, "Challenges and Enabling technologies for Energy aware Mobile Radio Networks," *IEEE Communications Mag.Nov.*,2010

[33] L.R.Zhao *et. al.*, "Energy saving scheme in radio access networks via compressive sensing -based traffic load prediction," *Trans Emerging Tel Tech.doi:10.1002/ett.2583*,2012

[34] M. Ismail and W.Zhuang,"Network Cooperation for Energy Saving in Green Radio Communications," *IEEE Wireless Communications*, Oct. 2011.

[35] F. Heliot,M.A.Imran and R.Tafazolli.,"Energy Efficiency Analysis of Idealized Coordinated Multi-Point Communication System," *TIEEE VTC-Spring '11, Budapest, Hungary*,May,2011

[36] M.Sawahashi *et. al.*, "Coordinated Multipoint Transmission/ Reception Techniques for LTE-Advanced(Coordinated and Distributed MIMO),"*IEEE Wireless Commun., vol. 17, no. 3,pp 26-34*,June,2010

[37] S.Morosi,P.Piunti and E.D.Re.,"Sleep mode managment in cellular networks: a traffic based technique enabling energy saving," *Trans Emerging Tel Tech.doi:10.1002/ett.2621*,2013

[38] Z. Niu,Y.Wu,J.Gong and Z.Yang*et*,"Cell zooming for cost-efficient green cellular networks," *IEEE Communications Magazine, vol.48, no.11, pp.74-79*, November 2010

[39] L.M.Correia *et. al.* ,"Challenges and enabling technologies for energy aware mobile radio networks," *IEEE Communications Magazine, vol.48, no.11,pp.66-72*,November 2010.

[40] L.Saker,S.E Elayoubi and T.Chahed ,"Minimizing Energy Consumption via Sleep Mode in Green Base Station," IEEE Wireless Communications and Networking Conference (WCNC),pp.1-6,April 2010.

[41] P. Kolios,V.Friderikos and K.Papadaki,"Switching off low utilization base stations via store carry and forward relaying," *Personal, Indoor and Mobile Radio Communications Workshops (PIMRC Workshops)*, IEEE 21st International Symposium,2010

[42] L. Ewe and H.Bakker,"Base station distributed handover optimization in LTE self-organizing networks," *Personal Indoor and Mobile Radio Communications (PIMRC)*,IEEE 22nd International Symposium,2011.

[43] Bi-annual Report, November 2010,"Green Power for Mobile ," *Available: http://www.gsm.org/documents/GPM Bi- Annual Report June 10.pdf*, Accessed on 25th Sep.,2012

[44] "green power for mobile," http://www.gsmworld.com/ourwork/mobile *planet/green power for mobile*, Accessed on 28Th Sep.,2012

[45] C. R. Murthy and Dr. C.Kavitha,"A survey of Green Base Stations in Cellular Networks," IRACT-International Journal of Computer Networks and Wireless Communications (IJCNWC),ISSN:2250-3501, Vol.2, No.2,April 2012.

[46] A. A. Abdulkafi *et. al.*, "Energy Efficiency of Heterogeneous Cellular Networks: A Review," *Journal of Applied Sciences 12(14: 1418- 1431)*, 2012.

[47] F. Zhang and S. T. Chanson, "Improving communication energy efficiency in wireless networks powered by renewable energy sources," *IEEE Trans. Veh.Technololgy.,* vol. 54, no. 6, Nov. 2005.

[48] 3GPP R1-110461, "Bseline schemes and focus of CoMP studies," *Eriction,ST-Eriction, TSG-RANWG1 no. 63bis*,Jan. 2011

[49] Y.Song L. Cai, K. Wu and H. Yang.,"Collaborative MIMO,Alcatel-lucent, Contribution to IEEE 802.16m-07/244 r1," *ICIEIS 2011, Part III, CCIS 253*,,November 2007

[50] M. Bengtsson *et. al.*, "CELTIC/CP5-026 WINNER+,D1.4 intial report on advanced multiple antenna systems, Tech. Rep," *ICIEIS 2011, Part III, CCIS 253*,January 2009

[51] D.M.G.Estevez,I.FAkyildiz andE.C.E.Reyes,"The Evolution to 4G Cellular Systems: LTE Advanced," *Physical Communication, vol. 3, no. 4, pp. 217 - 244*, 2010.

[52] Yun Rui *et. al.* , "Achievable Rates of Coordinated Multi-Point Transmission Schemes under Imperfect CSI," *IEEE ICC 2011 proceedings*, 2011.

[53] T. R. Lakshmana1,C.Botella and T.Svensson,"Partial joint processing with efficient backhauling using particle swarm optimization," *EURASIP Journal on Wireless Communications and Networking*, 2012.

[54] P.Marsch and G.P Fettweis,"Coordinated Multi-Point Mobile Communications *From theory to practice,* 1st ed, University Press, Cambridge, United Kingdom 2011.

[55] W. Wang,Z.Zhang andA.Huang.,"Spectrum Aggregation: Overview and Challenges in Network Protocols and Algorithms ," *ISSN 1943-3581,Vol. 2, No. 1*.,2010.

[56] S. Brueck,L.Zhao,J.Giese andM.A.Amin,"Centralized Scheduling for Joint- Transmission Coordinated Multi-Point in LTE-Advanced" *IProc. ITG/IEEE Wksp. Smart Antennas '10, Bremen, Germany,* Feb. 23-24, 2010

[57] Motorola, "R1-090793 coordinated multi-point transmission-coordinated beamforming/precoding results, Tech.Rep ," February 2009.

[58] C. Hoymann,L.Falconetti and R.Gupta.,"Distributed Uplink Signal Processing of Cooperating Base Stations based on IQ Sample Exchange," *Proc. IEEE ICC '09, Dresden, Germany, June 14-18*, 2009

[59] LG, "R1-101355: System Level Performance with CoMP JT," *LG Electronics Inc.*, February 2010.

[60] "Coordinated Multi-Point Transmission in LTE-Advanced Downlink-Test System ," Deutsche Telekom and Fraunhofer Institute for Communications, Heinrich-Hertz Institute (HHI), Press Report, July 2009.

[61] 3GPP TR 36.814-900, "3rd Generation Partnership Project; Technical Specification Group Radio Access Network, " *Further Advancements for EUTRA Physical Layer Aspects (Release 9)*, March 2010.

[62] M. Boldi *et. al.* , "D1.8 Intermediate Report on CoMP (Coordinated Multi-Point) and Relaying in the Framework of CoMP," *CELTIC CP5-026 WINNER+,* November 2009.

[63] A. Tetsushi,Y.Kishiyama,Y.Kakura and D.Imamura,"Radio Interface technologies for Cooperative Transmission in 3GPP LTE-Advanced," *IEEE TRANS. COMMUN., VOL.E94- B,NO.12*, Dec. 2011

[64] M.K.Karakayali, G.J.Foschini and R.A Valenzuela.,"Network coordination for spectrally efficient communications in cellular systems," *Wireless Communications, IEEE, vol. 13, no. 4, pp. 56-61,* August 2006

[65] R. Irmer *et. al.*, "Coordinated multipoint: concepts, performance and field trial results," *IEEE Commun. Mag. 49(2), 102-111,* 2011.

[66] D. Lee *et. al.*, "Coordinated Multipoint Transmission and Reception in LTE-Advanced: Deployment Scenarios and Operational Challenges," *IEEE Communications Magazine*, February 2012.

[67] L.Qiang,S.Fang,Y.Yang and Z.Pan.,"User Pairing Transmission Scheme in Uplink Coordinated Multi-point Reception," *2nd International conference on future computer and communication*, May 2010.

[68] C.Kirallah,D.Vakobratovic and J.Thompson," On Energy efficiency of joint transmission coordinated multi-point in LTE-Advanced," *International ITG workshop on smart antenna(WSA)*, 2012.

[69] 3GPP TS 36.300 V8.8.0, "Technical Specification Group Radio Access Network (E-UTRA) and (EUTRAN);(Release 8),March 2009.

[70] 3GPP TS 36.300 version 10.5.0, "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN);(Release 10), 2011

[71] C.Dongxu,S.Zhou,C.Zhang and Z.Nui.,"Energy Saving Performance Comparison of Coordinated Multi-Point Transmission and Wireless Relaying," *IEEE Globecom 2010 proceedings*,2010.

[72] G.Cilli,H.Yanikomeroglu and F.R.Yu,"Cell switch off technique Combined with coordinated multi-point(CoMP)Transmission for energy efficiency in beyound-LTE cellular networks," *IEEE ICC12 workshop on Green Communication and networking)*,2012.

[73] M.Herlich and H.Karl,"Reducing Power Consumption of Mobile Access Networks with Cooperation," *2nd Int'l. Conf. Energy-Efficient Computing and Networking, New York City*, May, 2011.

[74] K. Samdanis,D.kutschar, and M. Brunner.,"Self-organized energy efficient cellular networks," *Proc. of IEEE PIMRC'10,pp.1665-1670, 2010*

[75] T.Han and N.Ansari,"On Green cellular networks via multicell cooperation," *IEEE wireless communication*,Feb.,2013.

[76] Y.Zou,Y.D.Yau and B.Zheng, "Opportunistic Distributed Space-Time Coding for Decode-and-Forward Cooperation Systems," *IEEE Trans. Signal Proc., vol. 60, no. 4,pp 1766-81*,Apr. 2012.

[77] Q. Zhang,J.Jia andJ.Zhang.,"Cooperative Relay to Improve Diversity in Cognitive Radio Networks," *IEEE Commun. Mag., vol. 47, pp. 111-117*,Feb. 2009.

[78] SK. Jayaweera,M.Bkassiny andK.A.Avery.,"Asymmetric Cooperative Communications based Spectrum Leasing Via Auctions in Cognitive Radio Networks," *IEEE Trans. Wireless Commun., vol. 10, no. 8, pp. 2716-24*,Aug. 2011.

[79] L. Fan,X.Lei,P.Fan and R.Q.Hu,"Outage Probability Analysis and Power Allocation for Two-Way Relay Networks with User Selection and Outdated Channel State Information," *IEEE Commun. Letters, vol. 16, no. 5, pp. 638- 41*,May. 2012.

[80] H. Ding *et. al.*, "Energy-Efficient and Low- Complexity Schemes for Uplink Cognitive Cellular Networks," *IEEE Communications Letters, vol. 14, no. 12, pp. 1101-1103*,2010.

[81] E.Yaacoub *et. al.*, "A utility minimization approach for energy-aware cooperative content distribution with fairness constraints," *Trans Emerging Tel Tech.doi:10.1002/ett.1546*,2012

[82] J.A.Zrate, E.Kartsakli,Ch. Verikoukis and L.Alons,"Persistent RCSMA: A MAC Protocol for a Distributed Cooperative ARQ Scheme in Wireless Networks," " *EURASIP Journal on Advances in Signal Processing, vol. 2008, pp. 1-14*, 2008.

[83] O. Duval *et. al.*, "Subcarrier selection and power allocation for amplify and- forward relaying over OFDM links," *IEEE Trans. on Wireless Commun., vol.9, no.4, pp.1293-1297*,April 2010.

[84] H.W. Tseng *et. al.*," Performance analysis with coordination among base stations for next generation communication ," *Progress In Electromagnetics Research B, Vol. 36, 5367* , 2012

[85] Y.H.Nam, L.Liu,G.Miao and C.J.Zhang,"Link adaptation for energy-efficient uplink coordinated multi-point receptions," *EURASIP Journal on Wireless Communications and Networking*, 2011

[86] D. Lopez *et. al.*, "Enhanced Inter-Cell Interference Coordination Challenges in Heterogeneous Networks," *in IEEE Wireless Communications, No. 9*,June 2011

[87] A.A. Manaf*et. al.*" Inter-cell interference management and coordination in CoMP Systems,"*ICIEIS2011, part III, CCIS 253, PP.-654-665*,2011

[88] T. Chen,H.Kim and Y.Yang," Energy efficiency metrics for green wireless communications," 2010 International Conference on Wireless Communications and Signal Processing (WCSP), pp.1-6, 21-23 , Oct. 2010.

AUTHORS PROFILE

Parkash Chand is currently pursuing his PhD in ECE, Graphic Era University,Dehradun. He received his B. Tech and M.Tech from REC, Hamirpur, Himachal Pradesh and REC, Kurukshetra, Haryana in 1996 and 1999 respectively.

Rajarshi Mahapatra received his Ph.D in Electronics and Communication Engineering from IIT Kharagpur. Recently, he has completed his Postdoc in CEA-LETI, France. In his postdoc research, he was engaged in FP7 Call4 BeFEMTO and Greentouch. He is associate with as Professor to the Dept. of ECE, Graphic Era University, Dehradun. He has served as a member of TPC for several national and international conferences and peer-reviewed journals in the area of wireless network. He has published about 20 peer reviewed paper in several international journals and conferences. His current research interests include cognitive radio, dynamic spectrum access, energy consumption in wireless networks and optical access networks.

Rishi Prakash received the his Ph.D. thesis from the Department of Electronics and Computer Engineering, Indian Institute of Technology Roorkee. He is current working as Assistant Professor in the Dept. of ECE, Graphic Era University, Dehradun. His research interests are soil moisture study with SAR data, SAR and optical data fusion to retrieve soil parameters, study of soil parameters in bistatic domain and wireless communication.