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A NOVEL TRANSMISSION TECHNIQUE FOR INTERFERENCE MANAGEMENT AND MITIGATION IN 3GPP LTE-ADVANCED

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ABSTRACT

In order to achieve improved cell edge throughput in LTE-Advanced, CoMP technology is introduced to support high data rates over wider bandwidths. Coordination of control of data and channel interference is important to maintain the uplink and downlink coverage to enhance channel performance. CoMP is a new class of transmission scheme for the interference reduction and can have significant effect in terms of improving cell edge user throughput, coverage in the 4G mobile networks. This proposed article presents a coordination technique among multiple cell sites of improving the cell edge user throughput and compares different CoMP joint processing schemes. In this paper author presents a CoMP scheme where Joint Transmission is applied in the downlink of a LTE heterogeneous network structure for the purpose of interference cancellation. The technical challenges for both uplink and downlink are also addressed. Simulation results indicate that the proposed method gives an effective control of ICI and improves cell edge user throughput.

Keywords- *CoMP , CS/CB, LTE-A, JT, ICI.*

I. INTRODUCTION

In recent years, multi cell-processing is proposed as a promising method to suppress ICI (Inter-Cell Interference) through coordination among multiple base stations. The industry's first live field tests of Coordinated Multipoint Transmission and Reception (CoMP), a new technology based on network MIMO were conducted in Berlin in October 2009.

LTE-Advanced (LTE-A) is currently predicted to release-10 to support higher data rates, peak data rates up to 1 Giga bit per second (Gbps) in the DL (Downlink) and 500 Mega bit per second (Mbps) in the UP (Uplink). The mobile data traffic has been recently surged due to the availability of affordable notebooks, tablet computers, smart phones with web-oriented user interfaces. In today's interference-limited cellular systems, interference management has already become the central task to achieve spectrally efficient communications and novel deployments like heterogeneous networks are needed to provide the required capacity. The performance and quality of these systems can be improved by cooperation between the sectors or different sites, with this interference can be exploited and significant gains can be achieved for both the uplink and downlink. LTE-A uses Multiple Input and Multiple outputs (MIMO)-(OFDM) Orthogonal Frequency Division Multiplexing to achieve improved spectral efficiency within one cell. However, the real-world implementation of CoMP is linked with major challenges such as multi-cell synchronization and multi-cell channel estimation, backhaul traffic, synchronization and feedback design. These activities have been carried out by a powerful consortium consisting of universities, chip manufacturers, equipment vendors, and network operators. Coordinating the base stations can result in great capacity improvement in the downlink can be considered as a promising approach to improve coverage at high data rates, as well as overall system performance for 3GPP LTE-A.

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In this article the purpose for CoMP based on the system requirements, and actual CoMP transmission and reception schemes for LTE-A is presented. The necessity for CoMP transmission and reception to satisfy the system requirements in terms of capacity and cell edge user throughput is explained in section II. UL CoMP can take advantage of multiple receptions to significantly improve link performance and its challenges are described in section III. Dynamic coordination among multiple cells improves cell edge throughput with coordinated beam forming and joint processing schemes detailed in section IV. Section V gives how new CoMP Joint processing technique used at the receiver to mitigate interference to overcome implementation challenges. The superior performance attained by the proposed scheme as opposed to the conventional system in terms of cell average and cell throughput which has been demonstrated in the simulation results shown in section 6 finally section 7 provides conclusion for this paper. [1-8]

2. ADVANCED COORDINATED MULTI-POINT TRANSMISSION/RECEPTION

CoMP is a technology which sends and receives signals from multiple sectors to a given UE (User Equipment) with coordinating transmission among multiple cells. The power of the desired signal can be increased, and interference from other cells can be reduced. COMP is deployed in semi distributed system with centralized functionality and allocates resources to satisfy the QoS (Quality of Service) requirements

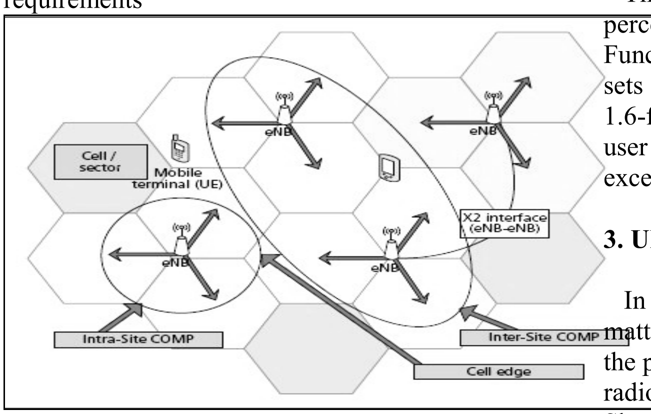

Figure 1. Base Station Cooperation: Intersite & Intrasite Comp

of the UEs. In 3GPP (Third Generation Partnership Project) the same spectrum resources are used in all sectors and also at between cell edges where signals from multiple base stations are having similar signal power in the DL.

Mutiple sectors of one base station can cooperate in intrasite CoMP, where as intersite CoMP involves multiple enBs as shown in figure 1. On the downlink, simultaneously connected UE are orthogonalized in the frequency domain where as in uplink they are orthogonalized in frequency domain as well as in code domain using cyclic shift and block spreading. It is possible to apply fractional frequency reuse control method which assigns different frequency ranges for cell-edge UE to control interference between cells semi-statically. The implementation of intra-cell/inter-cell orthogonalization on the uplink and downlink to meet the requirements of capacity and cell-edge user throughput.

LTE-A achieves much higher levels of system performance than Release8 to satisfy the increasing future traffic demand. System requirements focusing on physical layer given in [1][10]. The peak spectrum efficiency achieved by using four-stream or single-stream transmission with 64-quadrature amplitude modulation (QAM) and by a combination of BSs (Base stations) and high-class UE with a larger number of antennas. The transmission bandwidth of LTE-A compared to Rel-8, extending around 100 MHz, by maintaing maximum of eight antennas in the downlink and four antennas in uplink, the target values of peak data rate and peak spectrum efficiency will be achieved.

The cell edge user throughput is defined as the 5 percent value in the CDF (Cumulative Distribution Function) of the user throughput assuming 10 UE sets with a full buffer per cell. In LTE-A, 1.4 to 1.6-fold improvements in capacity and cell edge user throughput are expected from Release 8 LTE except for increasing the number of antennas. [8]

3. UPLINK-COMP

In CoMP reception uplink is an implementation matter and does not require a significant change in the physical layer
radio interface, the PUSCH (Physical Uplink Shared Channel) is received at multiple cells. In this case MRC (Maximal Ratio Combining) is used at multiple RREs, and the CoMP reception with IRC (Interference Rejection Combining) with coordinated scheduling, multiple UE sets transmit the PUSCH simultaneously using the same RB (Resource Block). However received weights are

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generated that the received SINR (Signal-to Interference-plus-Noise power Ratio) after combining at the central eNB is maximized in CoMP reception with IRC.

The MMSE (Minimum Mean Squared Error) or (ZF) zero Forcing algorithms are typically used to combine, the received PUSCHs at multiple cell sites. One UE set transmits the PUSCH using a Resource Block based on the coordinated scheduling among cells in CoMP reception with coordinated scheduling improves the cell-edge user throughput due to the increase in the received signal power.

Uplink CoMP schemes categorized as Interference aware detection and joint multicell scheduling with link adaptation. In former case all the enBs estimates the link to interfering user terminals so no cooperation needed between cell sites to calculate receiver filter performance. Where as in later case the received signals are preprocessed before information exchange among enBs. Hence better performance would be attained even with less CoMP gain.

The main idea of CoMP is when an UE is in the cell-edge region, it may be able to receive signal from multiple cell sites and the UEs transmission may be received at multiple cell sites. The dependence of the user rate distribution on the number of rings of neighbours with which each base station is coordinated, as well as signal to noise ratio distribution in the network, results in the possibility of increasing cell edge user rates almost tenfold, doubling the overall system throughput in high-SNR conditions. The UL interference prediction is to perform link adaptation based on SINR value occurs during data transmissions.

The performance gains with intrasite cooperation obtained up to 25 percent gain with respect to baseline cell edge throughput due to UL receivers with Channel State Information (CSI). For the UL, the signal can be received by multiple cell sites; the system can take advantage of this multiple reception to significantly improve the link performance.

A. The following are the key challenges of UL CoMP in LTE

1) Clustering: The static or dynamic cooperating eNBs needed for suitable clustering for cooperation among sites.

2) Synchronisation: The inter carrier interference and inter symbol interference can be avoided if cooperating eNBs synchronized in frequency and time. More advanced equalization may be required to reduce propagation delays of different UEs due to limited distance between cooperating base stations.

3) Channel estimation: Estimation of channel require large number of orthogonal UL pilot sequences but due to additional piolet efforts the CoMP gains are out-weighted.

4) Complexity: All the techniques have been performed in CoMP-LTE are OFDMA in uplink and SC-FDMA in downlink. If SC-FDMA used in Rel-8 equalization would become more complex.

5) Backhaul: Especially for adaptive centralized or decentralized cooperation needed source coding schemes which are very essential for backhaul compression.

4. DOWNLINK- COMP

In 3GPP LTE-A, downlink CoMP transmission can be accomplished by dynamic coordination among multiple geographically separated transmission points, including two main schemes which are CBF (Coordinated Beam Forming) and JP (Joint Processing). In CoMP transmission, the related control channels including the physical downlink control channel (PDCCH) are transmitted only from the serving cell regardless of the transmission scheme. The capacity requirement is much higher for the JT scheme where the data has to be delivered to all eNBs than for the CS/CB where only serving cell transmits.

A. Coordinated scheduling and beam forming

Coordinated Scheduling/Beam forming (CS/CB) implies that the involved eNBs coordinate the access to the resource blocks in a way that the interference will be avoided. For CBF mode, data to single UE is instantaneously transmitted from one of the transmission points same as in case of non-CoMP transmission and set of users will be selected, so that the transmitter beams are constructed to reduce the interference to other neighbouring users while increasing the served user's signal strength. However, precoding at each base station to achieve beam forming may be coordinated to improve the sum throughput and reduce interference.

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In this CS/CB, transmit beam forming weights for each UE reduce the unnecessary interference to other UE scheduled within the coordinated cells. Only one eNB that transmits data to the UE, although different eNBs may share control information. With this SINR will be improved. The downlink CoMP transmission mainly contributes to improving the cell edge user throughput with MIMO multiplexing, multiuser MIMO techniques were proposed to improve the capacity.

B. Joint processing and transmission

In Joint Processing several cooperating base stations transmitting to one single UE interference can be avoided by having the cooperating eNBs form their transmit signals in a way that interfering signals will cancel each other at the UE. For joint transmission, two methods are being studied. One is non-coherent transmission which uses soft-combining reception of the OFDM signal and where as coherent transmission does precoding between cells and uses in-phase combining at the receiver.

JP is further categorized into JT and DCS (Dynamic Cell Selection) operating RB of the PDSCH is transmitted from multiple cells associated with a UE specific demodulation reference signal (US-RS) among coordinated cells.

JT is achieved by codebook-based precoding to reduce feedback signal overhead. The best precoding matrixes for intercell site coordination are selected in addition to the individual selection of the best precoding matrix at each cell site so that the received SINR is maximized at a UE set among the predetermined precoding matrix candidates.

A UE set feeds back a CQI (Channel Quality Indicator) based on the combined received SINR to the serving cell, and then an RB is dynamically assigned to the UE by fast scheduling at the central BS because the transmission power resources of multiple cell sites can be used through coherent transmissions, the cell edge user throughput is improved significantly.

C. Following are the challenges in DL CoMP in next generation mobile networks:

- Integration of CoMP into higher layers with reduced cost of eNB synchronization and efficient feedback compression techniques required to reduce feedback delays during data transmissions.
- Efficient multi-user selection and flexible networking needed to handle outer interference within the cluster behind CoMP.
- Flexible formation of cooperation clusters need to be implemented in large scale networks.

5. INTERFERENCE MANAGEMENT IN DOWNLINK COMP

In this proposed scheme, joint transmission is applied to CoMP in the down link of a LTE heterogeneous network to mitigate interference to a maximum extent by retransmitting the signal by Pico-cell jointly with Macro cell. This approach is mostly focussed on the users of the low power nodes (Pico cells).

In this algorithm, JT scheme is performed for all active mobile stations served by Pico-cells independently. [10]. The down link signal of the dominant interfering macro cell received by the Pico-cell a user is calculated by retransmitting signal from Pico-cell. JT-algorithm is performed in every sub frame TTI (Transmit Time Interval), and in every subcarrier independently.

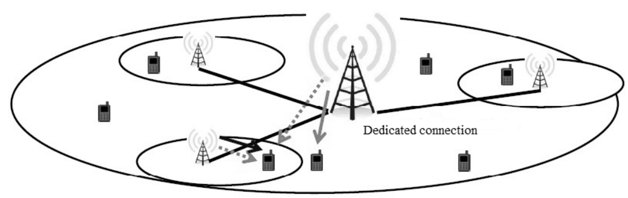

Figure 2. Inter-Cell Interference Received By Pico Cell Users From Macro Enodeb And Re-Transmitted By The Pico Enodeb For Cancellation.

All the variable in this algorithm considered as index k=1 to 100, for the operation of k_{th} subframe and the subcarrier should be indicated as 's' as from 1 to N_{sc}. The number of transmitting antennas at eNB given as N_t, and at UE antenna is N_r, $w^p = (w_1^p, w_2^p .... w_{Nr}^p)$ is the UE receiver weight, H is the wireless channel matrix of order $N_t \times N_r$ of corresponding eNB and UE, and $N_t \times 1$ is the vector of transmitting precoding weight s^m. The interfering signal received by a Pico-UE from its dominant interfering Macro eNB is,

$$n_s^m = w^p H^{mp} s^m x$$

Where w^p is the received weights of pico cell user, H^{mp} is the channel matrix describes radio

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channel from the macro enB to the Pico-cell UE. The received Macro UE data signal n^{pm} is retransmitted by pico eNB at the same time can be formulated as,

$$n^{pm} = \left(w_1^p w_2^p\right)\begin{pmatrix} h_{1,1}^{pp} & h_{1,2}^{pp} \\ h_{2,1}^{pp} & h_{2,2}^{pp} \end{pmatrix}\begin{pmatrix} s_1^{pm} \\ s_2^{pm} \end{pmatrix}$$

The Serving Pico retransmit a phase and a power level aligned version of the main interference, the goal of serving Pico eNB is to atleast partly cancel main Macro cell interference to fulfil the three optimization steps, which are optimization of phase, power fraction between ports of transmitter and power fraction between Pico-UE and retransmitted version of the interfering signal due to Macro eNB. The Pico-cell UEs do not always receive the highest macro cell interference from the macro cell, whose hexagon covers serving Pico-cell shown in figure 2.

The eNB power is fixed for macro base station but power of Pico varies between two values under given simulating conditions. In order to analyse the results of changing transmitted power Pico-eNB in the performance proposal joint transmission algorithm different scenarios for different power of Pico base stations have been created. SINR for Pico UE is,

$$SINR = \frac{|n^p|^2}{I_0 + \sigma_N^2 + \left(n^m - n^{pm}\right)^2}$$

The throughput of the system is calculated by mutual information based mapping of resource blocks SINRs to the number of bit to be transmitted. The performance of joint transmission algorithm is influenced by the deployment of different NSI (NSI=I_0) models and these are expected to provide best results with NSI perfect knowledge. The received SINR and the throughput for Pico-cell UEs used for evaluation of CDF. In order to show the power distribution of the retransmitted signal, power ratios will be given for different network scenarios [5] [7], CDFs of average SINR of the Pico-cell UE plotted in figure 5. The cell throughput and cell edge user throughput can be evaluated by combining link-level and system-level simulations. In the link-level simulations the average BLER (Block Error Rate) of each modulation against effective SINR is measured over one TTI, where as in system-level simulations by adding random errors between the measured SINR and the BLER performance, cell throughput and cell edge user throughput are calculated. The models and assumptions of LTE-A given in [5] [7] for both link and system level simulations.

A new CoMP joint transmission technique is presented in this paper to manage interference and to investigate the feasibility of coherent transmission for intra and intersite CoMP in real-world scenarios. With this significant gains and spectrum efficiency will be improved. A distributed implementation of joint transmission in DL has been demonstrated with synchronized base stations and cell specific pilots. It was also observed that the interference situation experienced at a terminal is indeed critical at the cell-edge if both eNB signals received equally strong. Once the downlink CoMP is switched ON high data rates can be achieved in both cells simultaneously due to mutual interference cancellation. Moreover outage probability observed at the cell edge in the interference limited case can be reduced. As per enabling features and simulation parameters given in[8][12] corresponding throughput variations in a two cell scenario given in figure 6 have been shown that CoMP gains are significant for simple interference scenarios and with that the implementation challenges can be overcome.

6. SIMULATION RESULTS

The CoMP transmission schemes employing JT and CS have achieved the highest cell throughput for transmission scheme corresponds to the full load case with an activity factor of one where as for fractional loaded cases with activity factors obtained for lower cell throughput values.

In downlink, the 2×2 antenna configuration has the throughput values of 12Mb/s and cell edge user throughput approximately 58 and 40% compared to single cell transmission by applying JS, CS. The cell edge user throughput for single cell transmission for 4×2 configuration is further improved by 35 and 30% using JT&JS with high precoding gain. In uplink the cell edge throughput is function of the cell throughput with 1×2 and 1×4 antenna configurations. The performance of CoMP reception schemes employing MMSE CoMP, ZF combining and MRC with coordinated scheduling plotted with single cell reception as a reference. When the cell throughput of 8Mb/s is achieved with a two Rx antenna configuration the cell user throughput is increased as shown in figures 3 and 4 by 56, 39 and 16% in

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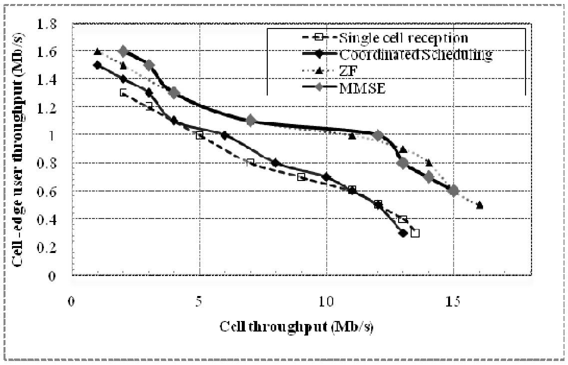

Figure 3. Cell-Edge User Throughput In Uplink (1×4).

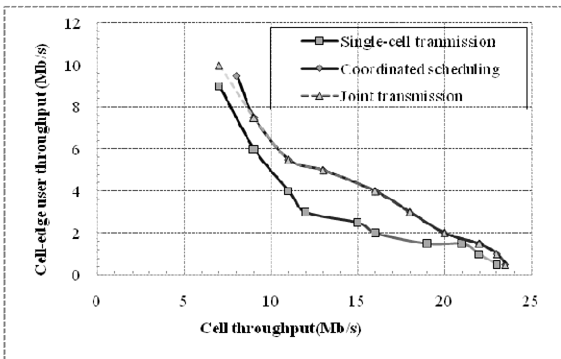

Figure 4. Cell-Edge User Throughput In Downlink (4×2).

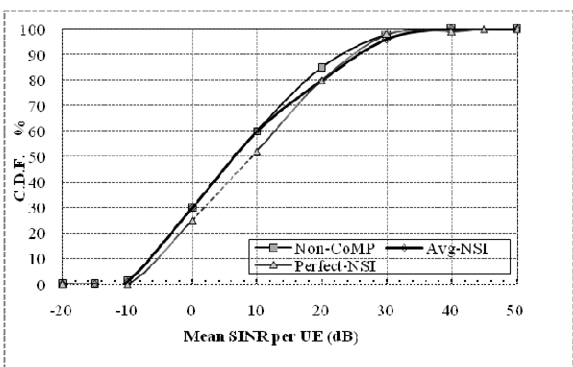

Figure 5. Cdfs Of Average SINR Of The Pico-Cell UE.

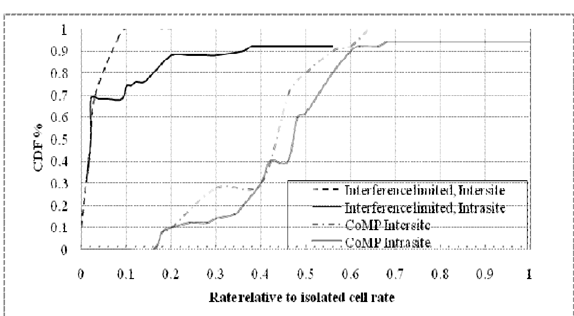

Figure 6. Measured Throughput With External Interference Relative To The Isolated Cells.

CoMP MMSE, ZF schemes compared to single cell reception especially for fractional loaded cases. [11] Finally it can concluded that the CoMP reception scheme with MMSE or ZF combining achieves higher cell throughput in full load case, and CoMP reception with MMSE(ZF) combining increases cell throughput in a full load case by 20 (10) and 23 (18)% with 2 or 4 antenna configurations. This increasing of throughput due to increasing of antennas.

7. CONCLUSION

This paper provides an overview of system requirements applied to CoMP system for LTE-A. The system level simulations have been shown that CoMP transmission in DL and reception in UL are effective for improving cell edge throughput. In this paper the authors presented a joint transmission scheme for the downlink of LTE-A for heterogeneous network and also concluded that an interference cancellation algorithm in downlink significantly improves the
received signals SINR values of the user terminals.

In future works, a new CoMP system needs to be adopted for an algorithm based tight base station synchronization or distributed power allocations need to be designed with that system. The further improvements require evaluation of channel estimation errors, feedback quantization, delay imperfections and interference cancellation for more Macro eNBs.

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