

Coordinated Multi-Point Algorithms in Pico Based Heterogeneous Networks

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Abstract— This paper considers Down-Link (DL) Coordinated Multi-Point (CoMP) transmission/reception techniques within Heterogeneous Networks (HetNets) which are comprised of Macro Stations (MSs) and Pico Stations (PSs). CoMP schemes based on Joint Processing/Joint Transmission (JP/JT) and transmit Zero Forcing (ZF) algorithms are evaluated using a static System-Level Simulator (SLS). Performance comparisons against the enhanced Inter-Cell-Interference-Coordination (eICIC) scheme for different Range Expansion (RE) bias values are presented.

Keywords— Heterogeneous Networks, Coordinated Multi-Point, Interference Mitigation, LTE/LTE-Advanced, Macro Zero Forcing, Inter-Cell Interference

I. INTRODUCTION

With the continuous increase in demand over wireless cellular services, and finite bandwidth resources, HetNets have evolved as cost-effective means of improving network capacity in future wireless systems compared to traditional Macro-Only networks[1]. In a HetNet configuration, low power stations, such as PSs, are deployed throughout the network in order to leverage average cell performance[2]. Further, application of RE bias allows MS off-loading to PSs yielding increase in MS capacity[3]. However, Inter-Cell Interference (ICI) remains a primary cause of performance degradation[4]. To combat such interference effects, advanced interference mitigation techniques, such as CoMP, have been introduced in wireless systems currently under standardization, such as LTE-Advanced. A study item on CoMP has been initiated in LTE-Advanced to investigate potential performance gains and PHY layer specifications[5]. Figure 1 depicts an interference scenario in a Pico based HetNet.

In CoMP based schemes, CoMP serving stations coordinate transmission using multiple antennae aiming to

improve User Equipment (UE) received signal strength, and minimize ICI from neighboring stations[6].

In this paper, we evaluate DL interference mitigation algorithms based on CoMP schemes using a static SLS. Average and Cell-Edge (CE) performance is compared to the enhanced Inter-Cell Interference Coordination (eICIC) scheme for different RE bias values. We consider a HetNet deployment scenario based on the LTE-Advanced CoMP study item scenario 4. In section II, descriptions of the interference mitigation schemes are described. In section III, simulation settings are presented, followed by results in section IV.

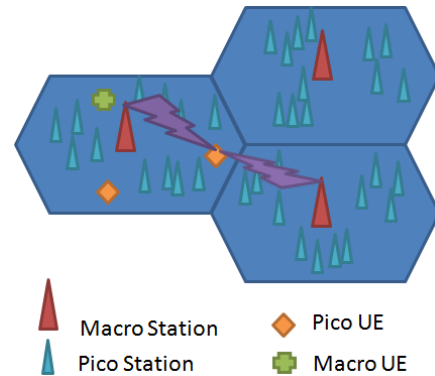


Figure 1. Neighboring MSs causing interference at a PS UE

II. SCHEMES

In the CoMP schemes presented below, Resource Blocks (RBs), assuming reuse-1, are divided by a ratio r defining a CoMP zone, while the remaining $1-r$ of the RBs define a non-CoMP zone. CoMP UEs are determined as r percent of UEs with the weakest SINR. The schemes are defined as:

- 1) **JP**: In this joint processing scheme, CoMP UEs are served by jointly receiving the same data from the

MS and the four PSs in their respective serving sectors. The CoMP-zone RBs are divided equally among the CoMP UEs, and each CoMP UE is served individually at a given time. In the non-CoMP zone, non-CoMP UEs are served normally (receiving interference from all stations).

- 2) **JP Limited:** In this joint processing scheme, in the CoMP zone, CoMP UEs are served by jointly receiving the same data from the MS and one PS only in its respective sector. The CoMP zone RBs are divided equally among the CoMP UEs, and each UE is served alone. In the non-CoMP zone, non-CoMP UEs are served normally (receiving interference from all stations).
- 3) **JP/ZF:** In this joint processing ZF scheme, in each sector, all CoMP UEs are served by jointly receiving the same data from the MS and four PSs, in the CoMP zone, in a Multi-User Zero-Forcing scheme (MUZF). The CoMP zone RBs are divided equally among the CoMP UEs. In the non-CoMP zone, the non-CoMP UEs are served normally (receiving interference from all stations).
- 4) **JP/ZF Limited:** In this joint processing ZF scheme, in each sector, all CoMP UEs are served jointly in the CoMP zone, receiving the same data from the MS and one PS in a MUZF. The CoMP-zone RBs are divided equally among the CoMP UEs. In the non-CoMP zone, the non-CoMP UEs are served normally (receiving interference from all stations).
- 5) **Macro-ZF:** For every PS, $r/4$ percent of associated UEs with weakest SINR are determined as eligible for CoMP. The closest MS transmission is nulled in the direction of the weakest PS UEs for $r/4$ percent of the RBs. The Macro UEs are not scheduled over these RBs. The rest of the PS UEs experience normal interference in the remaining $(1-r/4)$ percent of the RBs. Macro UEs experience all-interference mode in the remaining $(1-r)$ of the RBs.
- 6) **Macro-Pico-ZF (5 Set):** For every PS, r percent of its associated UEs with the weakest SINR are determined as eligible for CoMP. The MS and three PSs remain silent over r percent towards each CoMP user, during which MS UEs are not scheduled. The rest of the PS UEs experience all-interference mode in the remaining $(1-r)$ of the RBs. Macro UEs experience all-interference mode in the remaining $(1-r)$ of the RBs.
- 7) **eICIC:** In the eICIC scheme, which will also be denoted as the Macro-Free Zone (MFZ) scheme in the rest of this paper, MSs stay silent r percent of the

RBs, and hence the Pico UEs receive no interference from the MSs.

III. SIMULATIONS

Simulations are performed with a network deployment based on LTE-Advanced scenario 4(b). The SLS assumes 19-cells, 10 users per sector, and 10 Monte-Carlo drops. A 4x1 Rayleigh DL fading MISO channel is assumed. Each cell contains one MS and four PSs per sector. PSs are deployed randomly within its sector. Two-thirds of the UE stations are clustered around the PSs, and one-third are random uniformly distributed. RE bias is selected to be either 0 or 10 dB. CoMP zone ratio values are varied between 0 and 1 to investigate the CoMP zone ratio effect on algorithm performance. Table 1 shows the percentage UE associations with MSs and PSs versus RE bias values. Table 2 shows the simulation parameter settings.

TABLE 1. UE ASSOCIATIONS VERSUS BIAS

Bias(dB)	MS Percentage UE Associations	PS Percentage UE Associations
0	24.173	75.827
10	9.445	90.555

TABLE 2. SIMULATION PARAMETERS

Parameter		Value
Center frequency		2 GHz
Bandwidth		10 MHz
Cell layout		19 macro-cells 3 cells per Macro-cell 4 PS-cells per cell
Macro-cell ISD		500 m
Minimum distance between PSs		40 m
Minimum distance between MSs and PSs		75 m
Minimum distance between Macro-UE and Macro-cell		35 m
Minimum distance between PS-UE and PS		10 m
Total Tx power	MS	46 dBm
	PS	30 dBm
Antenna pattern	MS	3D pattern defined in TR 36.814 with antenna down tilt 12 degrees
	PS	2D pattern, Omnidirectional.
Antenna gain	MS	17 dBi
	PS	5 dBi
Transmission point antenna height	MS	25 m
	PS	10 m
Path loss	MS-cell-to-UE	ITU UMa with 25 m Tx antenna height
	PS-cell-to-UE	ITU UMi with 10 m Tx antenna height
Shadowing standard deviation	MS-cell-to-UE	ITU UMa
	PS-cell-to-UE	ITU UMi
UE height		1.5 m
UE noise figure		9 dB
Feeder loss		0 dB

IV. RESULTS

Figures 2(a-d) show total and CE performance of the JP, JP Limited, JP/ZF, JP/ZF Limited and the MFZ schemes, for RE bias values 0 and 10 dB respectively. The performance curves are compared to two additional metrics which are the all-interference and the orthogonal interference. The all-interference metric reflects the network performance without application of interference mitigation schemes. Orthogonal interference assumes orthogonal transmission between MSs and PSs. From the figures, it is observed that JP CE performance outperforms MFZ at 0 dB RE bias and exceeds orthogonal interference, with a peak performance at a CoMP zone ratio of 0.3. At the same CoMP zone ratio value, the total average cell performance of the MFZ scheme is modestly higher. In contrast, at a RE bias value of 10 dB, the MFZ outperforms all algorithms for both total average and CE performance. Figures 3(a-d) show total and CE performance of the Macro-ZF scheme for RE bias values 0 and 10 dB respectively. From the figures, it is evident that the MFZ outperforms Macro-ZF for both total and CE performance regardless of RE bias value or CoMP zone ratio r . The degradation in the Macro-ZF performance is explained by the scheme's inability to mitigate interference from neighboring, and occasionally distant, stations and the resource division amongst CoMP users. Figures 4(a-d) show total and CE performance of the Macro-Pico-ZF scheme for RE bias values 0 and 10 dB respectively. From the figures, a marginal gain is observed in total average cell and CE performance of the MPZF scheme at RE bias value of 10 dB compared to the MZF scheme. However, the MFZ yields highest overall performance.

V. CONCLUSIONS

In this paper we presented CoMP schemes based on Joint-Processing/Joint-Transmission (JP/JT), Macro Zero-Forcing (MZF), and Macro-Pico Zero-Forcing (MPZF). From the results, CoMP schemes based on JP/JT demonstrate CE improvements over baseline and eICIC at low RE bias values, exhibiting a peak CE performance at $r = 0.3$, while eICIC outperforms JP/JT, both total and CE throughput, at a bias value of 10 dB. CoMP algorithms based on MZF and MPZF yield improvements over baseline, but remain inferior to MFZ at all RE bias values, and CoMP zone ratios.

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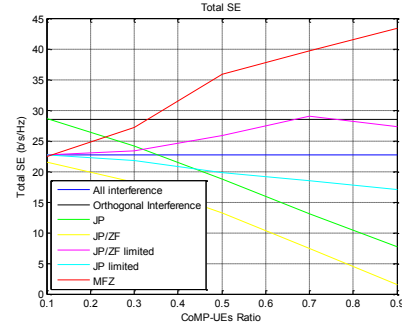


Figure 2(a). Total Average SE, Bias 0 dB

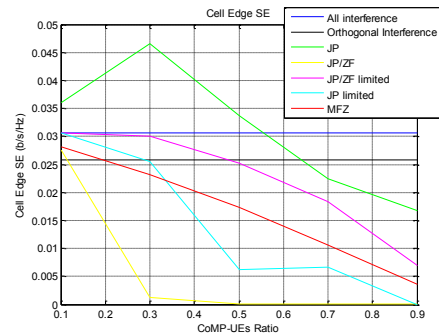


Figure 2(b). Cell-Edge SE, Bias 0 dB

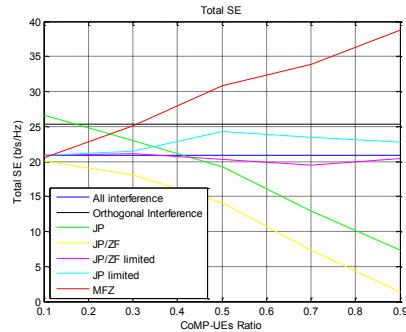


Figure 2(c). Total Average SE, Bias 10 dB

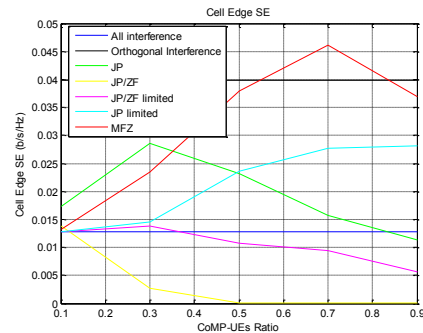


Figure 2(d). Cell-Edge SE, Bias 10 dB

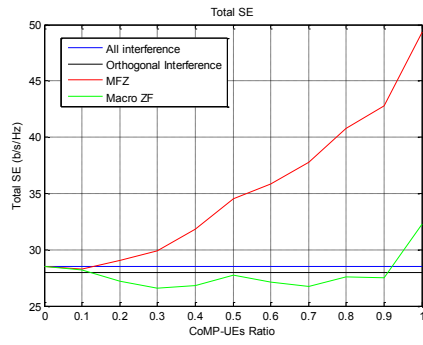


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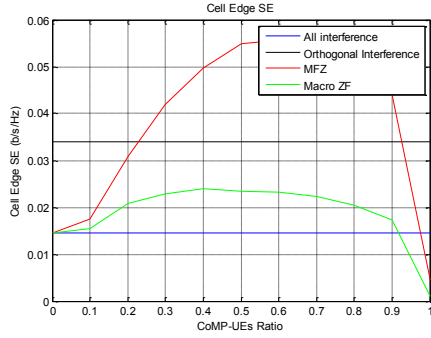


Figure 3(b). Cell-Edge SE, Bias 0 dB

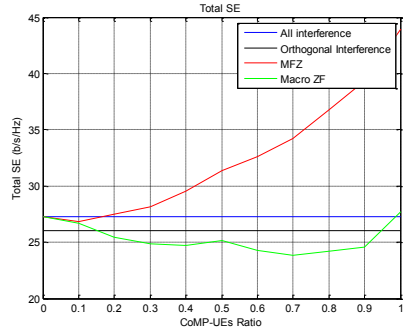


Figure 3(c). Total Average SE, Bias 10 dB

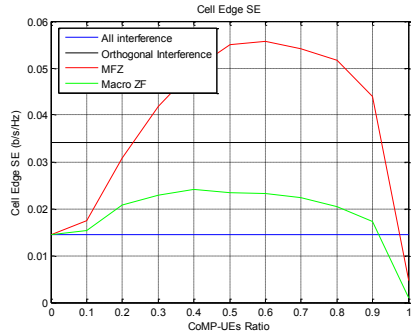


Figure 3(d). Cell-Edge SE, Bias 10 dB

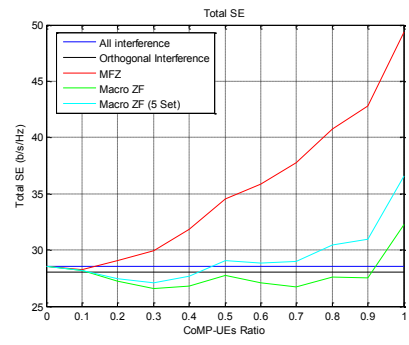


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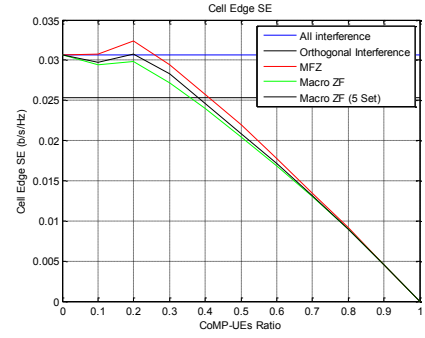


Figure 4(b). Cell-Edge SE, Bias 0 dB

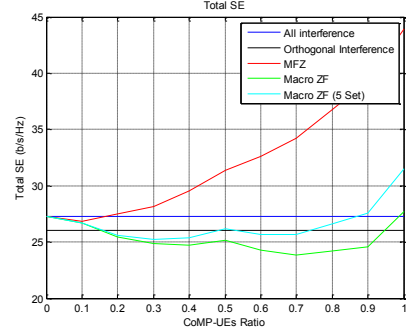


Figure 4(c). Total Average SE, Bias 10 dB

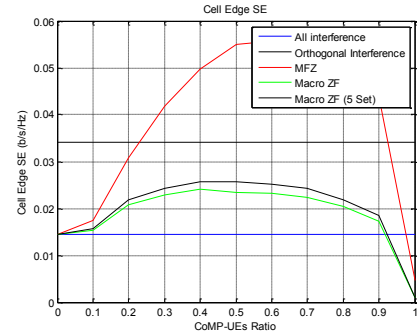


Figure 4(d). Cell-Edge SE, Bias 10 dB