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Enhancing Vertical Sectorization Performance with eICIC in AAS Based LTE-A Deployment

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***Abstract*—Cell densification is a typical means for capacity enhancement in a certain area. A flexible and dynamic way of cell densification can be provided via sectorization by Active Antenna Systems (AAS). By means of flexible beam forming capabilities, sectorization employs new sub-sector(s) reusing the same frequency band. The higher resource gain has to be paid off with more cell borders and cell edge users suffering from inter-sector interference. In this paper work, enhanced Intercell Interference Coordination (eICIC) technique is applied to coordinate the intra-site co-channel interference between the inner/outer sector in Vertical Sectorization (VS). Simulation results have shown that, eICIC brings significant system performance gain by improving the Signal to Interference plus Noise Ratio (SINR) experience of the users close to the inner/outer sector border regions; mainly, the severely affected regions of the outer sector.**

***Index Terms*—eICIC, Vertical Sectorization, AAS**

I. Introduction

Vertical Sectorization (VS) is one of the flexible deployment options supported by features of AAS. VS is realized by splitting the beam covering the conventional sector layout in a vertical domain resulting in two beams representing an inner and outer sector [1], [2]. In case of frequency reuse 1, the new sectors use the same frequency resources doubling the total available radio resources for the area of the conventional sector and, therefore, leading to a better and improved resource share for the users. The particular advantage of VS is the flexibility, i.e. VS can be activated when needed, i.e. more system capacity via a denser cell deployment is applied when and where it is needed [1], [2].

One of the challenges in VS is the increased intra-site inter-sector interference due to the new additional sector introduced after the cell-split. The common approach considered to tackle this interference problem is to apply enough offset in the elevation tilt setting between the inner and outer sector beam in order to minimize the degree of sector overlap while maintaining the desired quality of service and coverage [1]. Apparently, the introduction of a new inner sector creates a new inner/outer sector border which is characterized by high interference in case of frequency reuse 1 operation and users covered in the middle of the conventional sector become cell edge users. The VS model and corresponding interference problem investigation are explained in [1] where the system performance with respect to tilt adjustment is presented as well. Moreover, it can be seen that the VS performance is highly determined by the geographical distribution of the users. VS might be detrimental and should not be activated, if a large number of users lie in the highly interfered region of the inner or the outer sector unless an interference coordination mechanism is able to cope with the aforementioned situation and boosts the VS performance.

In this paper, eICIC technique, which have been widely used in heterogeneous network (HetNet) deployment cases for macro-small cell deployment [3], is adapted here in macro-only deployment scenario to tackle the interference issue between the inner/outer sector for VS. For the reason to be explained in later section, the inner sector is found to be an aggressor interferer to its corresponding outer sector. As a result, the eICIC technique is applied by muting some of the subframes of the inner sector and by using the corresponding protected subframes of the outer sector to schedule severely affected users. Additionally, the adapted eICIC scheduling mechanism is explained and the system performance is analyzed for various level of muting. The benefits and corresponding trade-offs are presented with elaborated system level simulation results.

The paper is organized as follow; in Section-II, problem formulation of using eICIC with VS is presented. Section-III elaborates the resource allocation scheme employed in detail. Performance analysis and discussions are presented in Section-IV and the paper closes with concluding remarks in Section-V.

II. Problem Formulation

Let $c^{(i)}$ refer to a sector c with index i, and i takes value of 0 to refer to the conventional sector, i.e no VS, whereas i is non zero value of 1 and 2 to refer to outer and inner sector, respectively. Consider a user location u inside the conventional sector coverage area whose serving sector is given by $s(u)$, i.e. $s(u) = c^{(i)}$. VS is realized by activating an inner sector with a higher tilt as shown in Figure 1 (a). It is assumed that the inner and outer sector beam have same radiation pattern settings like antenna gain, elevation and azimuth beam width. Moreover, the total power budget available at the site, P_T, is equally allocated to the inner/outer sector, i.e. $P_c^{(1)} = P_c^{(2)} = \frac{P_T}{2}$. When VS is activated, a user at any location u that has been connected to the conventional sector will be connected to either of the sectors depending on the strength of the signal power it receives, $p_{u,c^{(i)}}$. The stronger sector becomes the

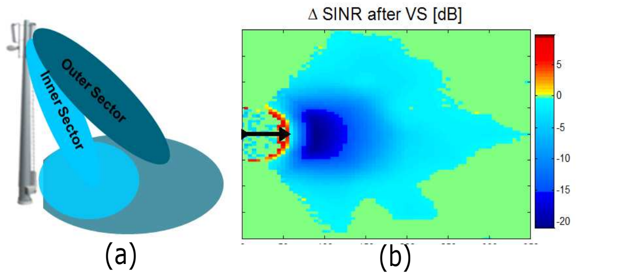

Fig. 1. Vertical Sectorization and $\Delta SINR$ map

dominant and serving one, i.e. $s(u) = \underset{c^{(i)}}{\operatorname{argmax}} \{p_{u,c^{(i)}}\}$, where $i \in \{1, 2\}$.

Assume that VS is activated at one conventional sector. The ratio of the power received by a user located at u from the inner and the outer sector is given by $k(u)$, i.e. $k(u) = \frac{p_{u,c^{(2)}}}{p_{u,c^{(1)}}}$ and the corresponding SINR, in linear scale, of the user while being served by sector $c^{(i)}$ is given by $\gamma_{u,c^{(i)}}$ and $\gamma'_{u,c^{(i)}}$, before and after VS, respectively. Accordingly, a relationship between $\gamma_{u,c^{(i)}}$ and $\gamma'_{u,c^{(i)}}$ can be derived by including the effect of inter-sector interference as shown in Equation III-B. The detail of the derivation can be found in [1].

$$\gamma'_{u,c^{(1)}} = \frac{\gamma_{u,c^{(0)}}}{1 + k(u) \cdot \gamma_{u,c^{(0)}}}, \quad \gamma_{u,c^{(2)}} = \frac{k(u) \cdot \gamma_{u,c^{(0)}}}{1 + \gamma_{u,c^{(0)}}} \tag{1}$$

Thus, the change in the SINR, $\Delta SINR(u)$, can be expressed in dB scale as:

$$\Delta SINR(u) = \begin{cases} -10 \cdot \log_{10}\left(1 + k(u) \cdot \gamma_{u,c^{(0)}}\right), & s(u) = c^{(1)} \\ -10 \cdot \log_{10}\left(\frac{1+\gamma_{u,c^{(0)}}}{k(u)}\right), & s(u) = c^{(2)} \end{cases} \tag{2}$$

Here, the SINR loss gets much worse for user locations that are closer to the inner/outer border, i.e. when $k(u)$ approaches to 1. Figure 1 demonstrates the corresponding SINR change map for exemplary scenario described in [1] where up to 15 dB SINR loss has been reported in the critical area. Despite such SINR loss, the over all expected system gain of VS comes from the gain in the radio resource share achieved due to the freedom to reuse the whole system bandwidth independently within the inner and outer sector. Due to the fact that VS leads to smaller inner sector and wider outer sector coverage area, assuming uniform geographical user distribution, there will be plenty of resource share gain per user at the inner sector to compensate the SINR loss. On the other hand, this share becomes relatively much lower for the outer sector users not even enough to compensate the SINR loss for the users in the severely affected area. Therefore, the VS performance is highly limited by the inner/outer inter-sector interference. Moreover, the problem becomes more critical in non-homogeneous traffic distribution case when there is a traffic hotspot situation in the deep interference region.

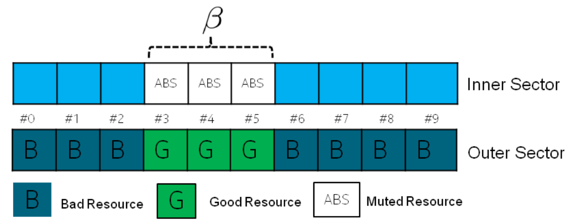

Fig. 2. LTE Radio Frame: eICIC Based Subframe Types

III. eICIC enabled Resource Allocation for VS

A. Resource Type and User Classification

In this study, eICIC is applied by muting the inner-sector's data transmission during some subframes to create a better interference situation for the corresponding subframe of the outer sector. The muted sub-frames at the inner-sector are also known as Almost Blank Sub-frames (ABS) [3] as they are almost totally muted but only reference signal transmissions are there. Figure 2 depicts the LTE radio frame structure for inner and outer sector where β fraction of subframes are muted from the inner sector. This leads to two types of radio subframes at the corresponding outer sector based on their interference experience with respect to the inner sector. Accordingly, the outer sector's subframe(s) during which inner is muted is (are) in a better interference condition, hence, is (are) called Good-SINR (G) subframe(s) whereas the the remaining ones in which the inner sector is transmitting are called Bad-SINR (B) subframes.

The SINR of an outer sector user while being scheduled in the G or in the B subframe, denoted by $\gamma'^{g}_{u,c^{(1)}}$ and $\gamma'^{b}_{u,c^{(1)}}$, respectively, depends on the level of interference they experience from the inner sector which depends on its location relative to the inner/outer sector border, which is clearly demonstrated with the $\Delta SINR$ in Figure 1. Accordingly, the outer sector users can be classified as sensitive and non-sensitive, denoted by s and ns, respectively. Hence, the eICIC system gain can be achieved by scheduling the sensitive users on the good radio subframe. The sensitivity level of an outer sector user, located at u, is given by Γ_u. It is defined as the ratio of the achieved throughput per a single Physical Resource Block (PRB) in G to that in B subframe, i.e. $\tau^{g}_{u,c^{(1)}}$ and $\tau^{b}_{u,c^{(1)}}$, respectively, whereas the throughput per PRB for inner sector users is given by $\tau_{u,c^{(2)}}$.

$$\Gamma_u = \frac{\tau^{g}_{u,c^{(1)}}}{\tau^{b}_{u,c^{(1)}}} = \frac{f(\gamma'^{g}_{u,c^{(1)}})}{f(\gamma'^{b}_{u,c^{(1)}})} \geq 1 \tag{3}$$

where $f(\cdot)$ is a mapping function used to calculate the achieved throughput value from the SINR.

B. Resource Allocation

Assuming the total radio resource per sector is given by M, and $\beta_{c^{(2)}}$ is the fraction of muted resources at the inner sector, the total effective radio resource available for scheduling at the inner sector is given by $M^{eff}_{c^{(2)}} = M \cdot (1 - \beta_{c^{(2)}})$ whereas at the outer sector $M^{eff}_{c^{(1)}} = M$. Moreover, $M^{eff}_{c^{(1)}}$ is composed of good, M^g, and bad, M^b, resources determined by the configured $\beta_{c^{(2)}}$ at the inner sector:

$$M^g = \beta_{c^{(2)}} \cdot M^{eff}_{c^{(1)}}, \quad M^b = (1 - \beta_{c^{(2)}}) \cdot M^{eff}_{c^{(1)}} \tag{4}$$

Assume that the total number of users connected to inner and outer sectors are given by N_I and N_O, respectively. N_O consists of the sensitive, N_s, and non-sensitive, N_{ns}, users which are classified upon scheduling by setting a sensitivity level threshold, Γ^{th}_u, yielding efficient resource partitioning while maximizing performance. Assume $\alpha_{u^t,c^{(1)}}$ is the fraction of resource allocated to an outer sector user of type t located at u whereas $\alpha_{u,c^{(2)}}$ is the resource fraction assigned to an inner sector user. Apparently, the outer sector's user can be scheduled within resources from the G and B subframes and this fraction is given by $\delta^g_{u^t}$ and $\delta^b_{u^t}$, respectively. Consequently, the allocated resource shares at each sectors satisfy the following relationships:

Outer Sector:

$$\begin{gathered}\alpha_{u^t,c^{(1)}} = \delta^g_{u^t} + \delta^b_{u^t}, \quad t \in \{s, ns\} \\ \text{where: } \sum \alpha_{u^s,c^{(1)}} + \sum \alpha_{u^{ns},c^{(1)}} = 1\end{gathered} \tag{5}$$

$$\sum \delta^g_{u^t} = \beta_{c^{(2)}}, \quad \sum \delta^b_{u^t} = 1 - \beta_{c^{(2)}} \tag{6}$$

Inner Sector:

$$\sum \alpha_{u,c^{(2)}} = 1 - \beta_{c^{(2)}} \tag{7}$$

A proportional fair (PF) scheduler is considered to assign the resources in such a way that the sum of throughput utility of all users, $\mathbb{U}_{c^{(i)}}$, is maximized at each sector where the throughout utility of a user is defined as $\log(TP_u)$ [3] [4]. As a result, at the inner sector all the available resources will be shared equally among the N_I users, hence, $\alpha_{u,c^{(2)}} = \frac{1}{N_I}$. At the outer sector, since there are two types of resources as well as two types of users, the resource allocation assumes grouping the same types of users, $\{u^s\}$ and $\{u^{ns}\}$, and sharing the good and bad resources between the two user groups with the group resource share of μ^k_t, $k \in \{g, b\}$ & $t \in \{s, ns\}$, and μ^k_t is shared equally among the users in the same group:

$$\begin{aligned}\delta^g_{u^s} &= \frac{\mu^g_s}{N_s}, \ \delta^g_{u^{ns}} = \frac{\mu^g_{ns}}{N_{ns}}, \quad \text{where: } \ \mu^g_s + \mu^g_{ns} = \beta_{c^{(2)}} \\ \delta^b_{u^s} &= \frac{\mu^b_s}{N_s}, \ \delta^b_{u^{ns}} = \frac{\mu^b_{ns}}{N_{ns}}, \quad \text{where: } \ \mu^b_s + \mu^b_{ns} = 1 - \beta_{c^{(2)}}\end{aligned} \tag{8}$$

In general, the $\delta^g_{u^t}$ and $\delta^b_{u^t}$ values depend on N_s and N_{ns} which in turn are determined by the optimal Γ^{thr}_u value, $\Gamma^{thr(opt)}_u$. $\Gamma^{thr(opt)}_u$ is selected by the outer sector upon scheduling to accommodate the most sensitive users that can benefit the most from the available $\beta_{c^{(2)}}$ of good resources while maximizing $\mathbb{U}_{c^{(1)}}$.

$$N_s = \sum_{\substack{\{u|s(u)=c^{(1)} \wedge \\ \Gamma_u > \Gamma^{thr}_u\}}} 1, \implies N_{ns} = N_O - N_s \tag{9}$$

Since the Γ_u values depend on the geographical distribution of the users in the outer sector's coverage area, $\Gamma^{thr(opt)}_u$ can not be easily determined and this makes the resource allocation optimization problem more complex.

The employed sum of throughput utility defined at each sector is given by:

$$\begin{aligned}\mathbb{U}_{c^{(1)}} = & \sum^{N_s}_{\{u^s:s(u^s)=c^{(1)}\}} \log\left(M^{eff}_{c^{(1)}} \cdot (\delta^g_{u^s} \cdot \tau^g_{u^s,c^{(1)}} + \delta^b_{u^s} \cdot \tau^g_{u^s,c^{(1)}})\right) \\ & + \sum^{N_{ns}}_{\{u^{ns}:s(u^{ns})=c^{(1)}\}} \log\left(M^{eff}_{c^{(1)}} \cdot (\delta^g_{u^{ns}} \cdot \tau^g_{u^{ns},c^{(1)}} + \delta^b_{u^{ns}} \cdot \tau^g_{u^{ns},c^{(1)}})\right) \\ \mathbb{U}_{c^{(2)}} = & \sum^{N_I}_{\{u:s(u)=c^{(2)}\}} \log\left(M^{eff}_{c^{(2)}} \cdot \alpha_{u,c^{(2)}} \cdot \tau_{u,c^{(2)}}\right)\end{aligned} \tag{10}$$

This can be rewritten as:

$$\begin{aligned}\mathbb{U}_{c^{(1)}} = & \sum^{N_s}_{\{u:s(u)=c^{(1)}\}} \log\left(M \cdot \left(\frac{\mu^g_s \cdot \tau^g_{u^s,c^{(1)}} + \mu^b_s \cdot \tau^g_{u^s,c^{(1)}}}{N_s}\right)\right) \\ & + \sum^{N_{ns}}_{\{u:s(u)=c^{(1)}\}} \log\left(M \cdot \left(\frac{\mu^g_{ns} \cdot \tau^g_{u^{ns},c^{(1)}} + \mu^b_{ns} \cdot \tau^g_{u^{ns},c^{(1)}}}{N_{ns}}\right)\right) \\ \mathbb{U}_{c^{(2)}} = & \sum^{N_I}_{\{u:s(u)=c^{(2)}\}} \log\left(M \cdot \frac{(1 - \mu^g_s - \mu^g_{ns})}{N_I} \cdot \tau_{u,c^{(2)}}\right)\end{aligned} \tag{11}$$

The amount of muted resources at the inner sector, $\beta_{c^{(2)}}$, should lead to an overall system performance gain over both inner and outer sector, hence, a combined throughput utility, $\mathbb{U} = \mathbb{U}_{c^{(1)}} + \mathbb{U}_{c^{(2)}}$, is used to determine the optimal $\beta_{c^{(2)}}$ configuration:

$$\underset{\{\mu^g_s,\mu^g_{ns},\mu^b_s,\mu^b_{ns}\}}{\operatorname{argmax}} \mathbb{U}\Big|_{\Gamma^{thr}_u = \Gamma^{thr(opt)}_u}, \implies \beta_{c^{(2)}} = \mu^g_s + \mu^g_{ns} \tag{12}$$

$\Gamma^{thr(opt)}_u$ is evaluated, here, iteratively from range of Γ^{thr}_u values, $\{1 < \Gamma^{thr}_u < \Gamma^{thr(max)}_u\}$ maximizing the target throughput utility where $\Gamma^{thr(max)}_u$ and the granularity step size could be tuned accordingly.

Once $\beta_{c^{(2)}}$ is known or in the case of a fixed $\beta_{c^{(2)}}$ configuration, the resource allocation at the outer sector is done with the following optimization criteria:

$$\underset{\{\mu^g_s,\mu^g_{ns},\mu^b_s,\mu^b_{ns}\}}{\operatorname{argmax}} \mathbb{U}_{c^{(1)}}\Big|_{\Gamma^{thr}_u = \Gamma^{thr(opt)}_u} \tag{13}$$

C. System model

AAS-based LTE-A deployment is assumed with 7 tri-sectored fixed sites consisting of 21 conventional sectors. A macro sector layout is considered and an Inter-Site Distance (ISD) of 1732 m is assumed, as defined by the 3rd Generation Partnership Project (3GPP). VS is activated at all sectors and 16 users are dropped over the conventional sector area and a fullbuffer traffic situation is considered. Other system model and parameter settings are found in Table I.

TABLE I
SYSTEM PARAMETERS AND SETTINGS

System Model and Parameter Settings		
Description	Parameter	Value
Site	# Site Height [m]	7 Tri-sectored Antenna =30, UE = 1.5
SectorPower	Inner/Outer Sector	26/26 dBm/PRB
Antenna	Gain[dBi] Φ_{3dB} /Θ_{3dB} Inner/outer Tilt	14 70°/10° 13°/6°
Propagation	Pathloss Shadowing Std.	$128.1{+}37.6{\cdot}\log_{10}(r_{km})$ 8 dB
Traffic	Type	Full Buffer

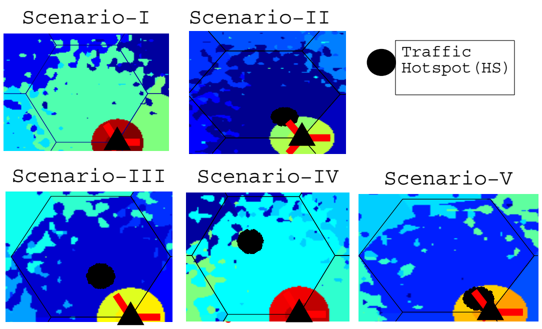

Fig. 3. VS Scenarios for Various Traffic User distribution

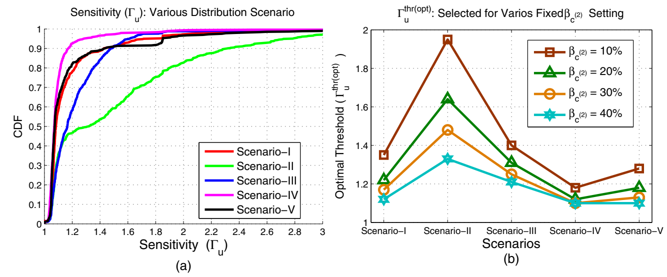

Fig. 4. (a) Sensitivity of users; (b) Selected $\Gamma_u^{thr(opt)}$ for different $\beta_{c(2)}$

IV. RESULTS AND DISCUSSIONS

In this investigation, homogeneous and non-homogeneous traffic distribution situations are considered. For the non-homogeneous case, a traffic hot-spot (HS) containing 50% of the user traffic from the conventional sector area is positioned depending on the scenario at different sensitivity locations, as depicted in Figure 1. These scenarios with corresponding user distributions are illustrated in Figure 3 showing the inner/outer sector coverage maps and the traffic HS depicted as black dot. The remaining 50% user traffic is uniformly distributed in the background. The sensitivity against interference of each user is evaluated per scenario along with the optimal threshold decided to classify the users during scheduling. The determination of the optimal muting value, $\beta_{c(2)}$, and the corresponding system performance gain achieved with VS+eICIC over the VS-Only deployment (without eICIC) is explained in the following sub-sections.

A. User Sensitivity and Optimal Threshold

The severity of the co-channel interference resulting from inner sector activation on the corresponding outer sector depends on how many of its users are located in the critical sensitive area. Sensitivity values of the outer sector users are shown in Figure 4 (a). Accordingly, the most critical situations can be seen in Scenario-II where the inner/outer sector border is lying over HS users' location region. In this case, over 50% of the outer sector users are reporting a significant sensitivity level while over 20% of them are critically interfered experiencing more than 50% degradation in their TP performance over a single PRB. On the other hand, in Scenario-IV, the HS users are located farther in the non-sensitive area that the inner-sector interference problem is not a critical issue. In Scenario-I and Scenario-V case, the outer sector users are uniformly distributed, hence, they exhibit the same sensitivity distribution pattern.

As explained earlier, the scheduler then decides on the optimal $\Gamma_u^{thr(opt)}$ level to select as many users as possible, based on their sensitivity level, to be scheduled in the available good resources while maximizing the sector performance . This is demonstrated using different non-optimal muting setting value of $\{10\%, 20\%, 30\%, 40\%\}$. For each scenarios, it can be observed that the $\Gamma_u^{thr(opt)}$ value gets smaller and smaller as the $\beta_{c(2)}$ value is increasing to include more and more users in the sensitive user group. It can be also noted from Figure 4 (b) that, the $\Gamma_u^{thr(opt)}$ is highly dependent on the users distribution and their reported sensitivity values. Hence, the selected $\Gamma_u^{thr(opt)}$ value in Scenario-II is much higher than the others as it is the most critical use case scenario for VS where many of its users are highly impacted. In Scenario-IV, increasing the $\beta_{c(2)}$ doesn't cause a significant change on the $\Gamma_u^{thr(opt)}$, this is due to the relatively much less number of users presence in the highly sensitive area as most of the users are located farther experiencing more or less similar interference conditions. Hence, scheduler decides closely the same $\Gamma_u^{thr(opt)}$ values as those users' sensitivity can not be discriminated, unless high $\beta_{c(2)}$ value is set. This will be illustrated in the next section.

B. Optimal Muting Value ($\beta_{c(2)}$)

The optimal $\beta_{c(2)}$ which yields maximized system performance should be adapted as per the traffic distribution. Generally, muting inner sectors sub-frame is acceptable if the inner sector is not too heavy loaded and has spare resources. At the same time, there should be also users classified as sensitive at the corresponding outer sector which can benefit from the muting. Therefore, the sum of user throughput utility maximization over the aggregated inner plus outer sector has been employed to determine the $\beta_{c(2)}$ for each scenarios and different $\beta_{c(2)}$ values are obtained as depicted in Figure 5 (a). For the homogeneous traffic distribution case, in Scenario-I, the inner-sector is willing to mute more resources and $\beta_{c(2)} = 40\%$ is found to be optimal. In Scenario-II, despite the critical location of the HS, part of the HS users are

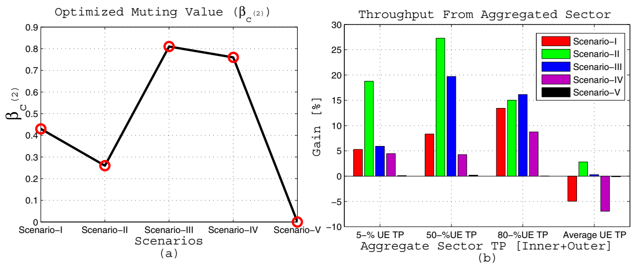

Fig. 5. (a) Optimal Muting Value ($\beta_{c^{(2)}}$), (b) Performance gain of VS+eICIC

also connected the inner sector, as a result, the optimal $\beta_{c^{(2)}}$ value is reasonably lower than what has been obtained in Scenario-I, $\beta_{c^{(2)}} \approx 30\%$. In Scenario-III and Scenario-IV, the outer sector is highly loaded due to the presence of the HS traffic condition while the corresponding inner-sectors are lightly loaded resulting in rather high $\beta_{c^{(2)}}$, $> 50\%$. In such cases, activating the inner sector is introducing more interference rather than taking away load from the outer sector. Interestingly, the optimal $\beta_{c^{(2)}}$ value found for Scenario-V is close to zero, $\beta_{c^{(2)}} \approx 0$. This is attributed to the fact that a traffic HS which has 50% of the conventional sector load, is located inside the inner-sector coverage, and some of the users are even close to the critical border area. The inner sector is now highly loaded and it can not afford to mute resources as its resources can be fully utilized. At the same time, there are relatively less number of users located in the critically interfered area due to the homogeneity of the traffic distribution in the outer sector.

C. Throughput Performance

In this subsection, the throughput performance has been analyzed by comparing the traditional VS scenario, i.e. without eICIC, with the VS+eICIC scenario assuming that the optimal $\beta_{c^{(2)}}$ found before is known and configured. The user throughput statistics are taken from the aggregate sector (Inner+outer), i.e. complete conventional sector area. The throughput statistics at a different CDF percentile levels, $\{5\%$-ile, 50%-ile, 80%-ile$\}$, and average user throughput values are used as measure of performance metrics, and the achieved performance gain is shown in Figure 5.

In all the defined scenarios, except Scenario-V, eICIC can provide a significant performance gain for the higher throughput CDF percentiles over the VS-Only case. Accordingly, a marginal gain of around 5% has been recorded, for Scenario-I and Scenario-III, for the cell-edge users whose performance is reflected by the 5%-ile level of the CDF. In Scenario-II, however, a significant gain of more than 15% is achieved at the 5%-ile level as the severely affected HS users at the inner/outer sector border are benefiting a lot from the eICIC. Moreover, substantial throughput gains have been achieved at the higher percentiles, especially, for Scenario-II and Scenario-III case where there are HS traffic situations at the most interference sensitive area. Thus, more than 25% and 15% of TP gain is obtained at the 50%-ile level for Scenario-II and Scenario-III, respectively, and 15% gain at the 80%-ile level, in both cases. For Scenario-IV case, however, since the HS is located far in the non-sensitive location, the achieved gain is not very high, yet about 5% gain is recorded at both the 5%-ile and 50%-ile level, and about 10% at 80%-ile level.

It is interesting to see that except for Scenario-II the average TP performance has always shown degradation. This is due to the fact that the average TP performance of the entire aggregate sector with VS is dominated by the substantial throughput gain of the inner sector users resulting from the large resource share the users are getting. While applying eICIC, however, this extra resource share is eaten up from muting to help the poor users in the sensitive area and to bring a balanced system performance at the overall sector layout. This is the trade-off of enabling eICIC over the traditional VS and it can be seen that the average performance degradation level is marginal.

V. Conclusion

In this paper, the inter-sector co-channel interference issue between the inner/outer sectors resulting from VS has been thoroughly investigated for various traffic distribution scenarios. eICIC technique that mutes transmission on some of the inner sectors radio sub-frames has been employed. The muting in combination with a coordinated scheduling of the critically affected outer sector users tackles the problem and provides them a better SINR condition. System level simulation results have shown that the throughput performance of the users located in the interference critical area is significantly improved by applying eICIC based scheduling. The proposed technique brings substantial overall system performance gain by not only maximizing the aggregate sector throughput level but also maintaining a balance of the system performance in the inner and outer sector. It has been also demonstrated that it is possible to determine the optimal muting factor for the inner-sector depending on the actual traffic distribution. This information can be further exploited to decide on whether to enable or disable the eICIC feature at all.

The eICIC feature can be dynamically enabled/disabled and the corresponding muting value can be adapted automatically in a self-organized manner. The Self Organizing Network (SON) mechanism to autonomously control dynamic vertical sectorization as well as eICIC is left as an outlook.

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