Interference Performance Analysis in COMP for Downlink System

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Abstract: In the cellular communication system, the co-channel interference (CCI) deteriorates the users' performance seriously. Since in the Coordinated Multiple Point (COMP) technology every cell can utilize the all physical resource blocks (RB) instead of part of them, therefore CCI is more seriously than other schemes. This paper talks about the sources and features of downlink CCI in COMP, and proposes a network scheme that can deal with the question. Through simulation, the paper obtains a suitable coordinated region and proves the scheme is feasible and meaningful.

I. INTRODUCTION

Next generation mobile communications systems expect to communicate at a high spectral efficiency. Single base station (BS) with multiple antennas or other absence of coordinated technologies can improve the transmitted data rate, but have no way to ameliorate the performance of use equipment (UE) near the cell edge. Furthermore many approaches, such as beamforming and multiplexing, are not good enough in universality. On the contrary, coordinated multi-point (COMP) joint processing or joint transmission not only can improve the performance of UEs near the cell edge, but also it doesn't need UE change too much. Hence, it is a promising option. To make the UEs near cell edge performance better, COMP acquire high ration of signal to interference and noise (SINR) by adopting several BSs separated in position jointed transmitting the same signal to single UE. It is possible for COMP to implement goals of improving spectral efficiency, lowering costs, improving service, making use of new spectrum and better integration with other open standards.

Using unitary frequency to communicate in different regions simultaneously is an important technology to improve the frequency efficiency. At the same time, it causes the co-channel interference (CCI). CCI is generally regarded as one of the factors that limit the capacity and the transmission performance in wireless communications. Reference [15]-[17] introduce some approaches about dealing with the CCI in LTE. There are three main methods for CCI mitigation: CCI randomization, CCI cancellation and CCI coordination (or avoidance). Every approach has some advantages. But unfortunately the benefits of each of these schemes are mutually exclusive. Of the three, CCI coordination is most often used in the 3GPP LTE system, since CCI randomization does not decrease interferences and CCI cancellation only eliminates dominant interference, as in [14]. In COMP, all the cells can utilize the all physical resource blocks (RB) instead of part of them. CCI in COMP systems is very serious and inevitable, especially for UE at the cell edge regions. In wireless communication, the statistical characterization of desired signal and interference involves mainly two propagation effects: the small-scale fading, caused mainly by multipath in the local area, and the large-scale fading, mainly induced by random attenuators of the local area. Generally accepted, the local mean signal is modeled as a lognormal random variable, as in [11]-[13]. In other words, if expressed in decibel unit, the mean signal follows the normal distribution. Reference [7] and [8] pay much attention on the narrow band CCI, and [9] based coordination in cluster, proposed one way to avoid interference. To use the RB in system effectively, wireless network needs to be coved seamlessly and the interference between UEs using the same RB be little enough. This paper is mainly about the features of CCI and proposes a way to reduce the effect of CCI.

The rest of the paper is organized as follows: In section II, we describe coordinated strategy and the signal model. Section III illustrates some simulation results, followed by the conclusions in section IV.

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II. COODINIATION STRATEGY AND SIGNAL MODEL

When analyzing the performance of a cellular system, it is very important to accurately model the effects of the radio propagation on the received signal, since those effects are very often the major reasons of system performance degradation. If the desired UE location is known, the distances to all potential interfering base stations can be easily determined based on the network geometry, and hence a probabilistic based estimate of the SINR. Generally the received is divided into two parts, one is signal and the other is noise. In other words, the interference belongs to noise. In fact, noise has much difference with interference, especially the strong interference. Hence, in this paper, we separate the strong interference from others. The weak interference is classified into the noise. Note that in COMP, the sources of signal may be more than one. In other words, the system has multiple signals, multiple interference and noise.

In the system, we utilize a hexagonal cell layout comprising 19 base stations (BS). All the BSs outfit with omni-directional antennas. In analysis presented in this paper, we assume that the small-scale fading effects are averaged out and only shadowing and path loss are taken into consideration. At the same time, the small-scale effects fading can be easily incorporated in further analysis. We divided the cells into three sets, the first includes all the coordinated cells (called C), and the second includes cells with strong interference source (called I), and the third includes other cells, which are regarded as noise.

Fig.1. illustrates the situation, the desired signal comes from central cell and cells in the set C ,but cells in set I are the mainly sources of CCI which are the strong interference. The signal model is given as follow:

$$y_k = \underbrace{\sum_{c=1}^{C} H_k{}^c x_k^c}_{desired\_signal} + \underbrace{\sum_{i=1}^{I} H_k{}^i x_i{}^i}_{strong-interference} + n_k$$

Where the $H_k{}^c$ and $H_k{}^i$ denote the channel matrix of desire signal and interference respectively, and the x_k^c and x_k^i denote the signal and interference respectively, n_k is the additive white Gaussian nose at user k.

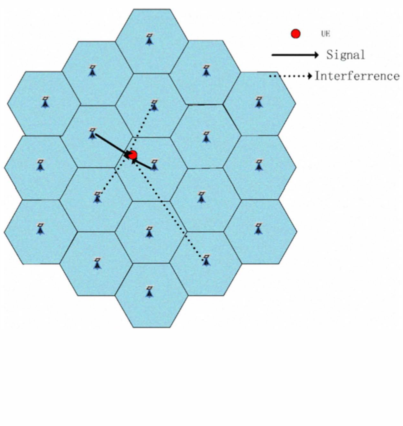

Fig.1. the network structure and model of signal and interference

In the old communication system, CCI was avoided by using different frequency in the adjoined cells. Since path loss is a function of propagation distance, the reuse distance D is an important parameter in determining average inter-cell interference power. It is mainly decided by the number of intermediate cells between the two cells using the same channel. Frequency reuse of 1（D=R）provides the best throughput for users in the cell-center experiencing higher SINR while reuse of more than 1(D<R) provides the highest throughput for the cell-edge users experiencing low SINR. Given a particular average SINR for a performance level, we can obtain the corresponding minimum reuse distance that meets the target performance, as in [14]. In another words, it is possible to ensure the performance target provided that enough reuse distance. In other words, it is not necessary to coordinate in all over the region. In this paper, we define several circles whose radiuses is r. In these circles (the yellow part), UE communicate only with one BS, while out of these

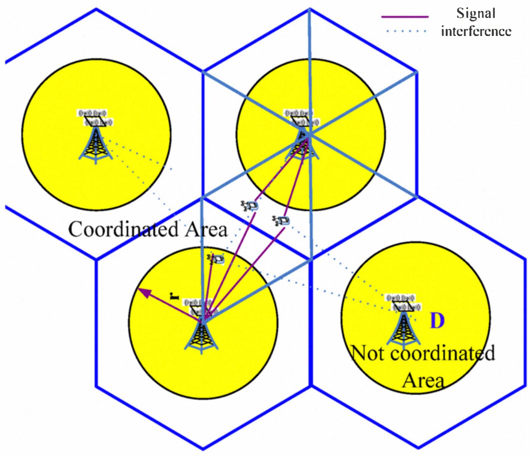

Fig.2. the distribution of the coordinated region. the white part is coordinated region and yellow is not.

circles (the white part), several BSs transmit data to the UE simultaneously and coherently. The strategy not only can engage the performance target, but also improve the effectiveness of frequency. It is a perfect tradeoff between the fairness and effectiveness. Whether UE lies in the coordinated area or not is illustrated in Fig.2.

The effects of cells in set I on the UE can be regarded as the independent and identically distributed (i.i.d.) and they follow the lognormal distribution. Assumption there are N cells in the set I. then the local effect of the ith CCI can model as followed. $X_i = m_{X_i} + \chi_i$

Where m_{X_i} represents the mean power of the ith CCI, and χ_i represents a zero-mean normally distributed random variable in decibel unit, with standard deviation σ_{X_i}, also in decibel unit, due to the shadowing caused by large obstacles. The summation of All the CCI also follows the lognormal distribution, since they are not coherent. We can get the noise distribution through matching the first and the second moments. Under the reasonable assumption that the individual interference I_i add incoherently, the total effect is modeled as the sum of N lognormal distributed signals. $I = \sum_{i=1}^{I} I_i$

Since the sum I is lognormal distributed, $X = 10\log_{10} I$ follows normal distribution. We can compute the mean value m_x and standard deviation σ_X by means of Wilkinson's method [13].

On the other hand, the desired signals enter into receiver coherently. The summation of all the coordinated signals is equal the effect that one signal is zoomed in or out. As a result, its mean value can be expressed as followed.

$$m_S = \sum_{j \in I} \alpha_j m_j = \alpha m$$

Where α_j and m_j are the jth signal's coefficient and mean value respectively, m_s represents the overall mean value. Assumption that the small-scale effect has been offset by interweave and coding. Then the mean value m_s is mainly related to the distance between the BS and UE. In a similar way, the standard deviation of desire signal is also received coherently. It can be expressed as followed. $\sigma_S = \alpha\sigma$

Where σ_S represents the overall deviation. Definition that r, l_c *and* l_i represents the distance between UE to the central BS, to coordinated BS and to CCI BS respectively. Often, the SINR is used as a measure of the radio link quality, which means that system level simulations must include the calculation of the received SINR. Assumption that the power of all BS are equal, named p_0. And the antenna gain is 0 dB. Then the SINR is given as

$$\text{SINR} = \frac{C}{I} = \frac{p_0 (r^2 + \sum_{c=1}^{C} l_c^2)^{\gamma/2}}{\sum_{i=1}^{I} p_0 l_i^\gamma} = \frac{(r^2 + \sum_{c=1}^{C} l_c^2)^{\gamma/2}}{\sum_{i=1}^{I} l_i^\gamma}$$

Where C represents the coordinated set and I represents the interference set. γ represents the path loss index. Now suppose the target performance is $SINR_0$, if the channel realization satisfy $SINR < SINR_0$, then whatever approaches used by the transmitter, the performance cannot be satisfied the system required. The system is said to be in outage, expressed in decibel unit, the outage probability is

Where μ_c, μ_i represents the mean value of desired signal and the interference respectively, σ_c, σ_i represents the standard deviations of the signal and interference respectively, and Λ_{th} represents the target signal threshold.

Outage capacity is the largest possible rate of transmission.

$$p_{out} = P(SINR_0 > SINR)$$
$$= \int_0^{\text{SINR}_0} \frac{1}{\sqrt{2\pi\sigma_{\text{SINR}}}} \exp\left(\frac{-(\text{x-m}_{\text{SINR}})^2}{2\sigma_{\text{SINR}}}\right) \text{dx}$$
$$= 1 - Q\left(\frac{\mu_c - \mu_i - \Lambda_{th}}{\sqrt{\sigma_c^2 + \sigma_i^2}}\right)$$

When with many UE, the sum data rate of outage is expressed as

$$R = \sum_{k=1}^{K} (1 - p_{out}) \log_2(1 + SINR)$$

Where K represents the number of UE in every cell. Suppose that the UEs are randomly distributed within the cells. For a given radius of coordinated r, if the data rate is deprived through only one BS instead of several multiple BSs, then the rate is more effective. To illustrate the situation, we define an effective rate as $R_{ef} = R / B$. Where the R represents the data rate, and B represents the number BS take part in coordination. It is clearly that with the B increasing, R_{ef} represents monotonous decreases. With a fixed R, if the r is small, then too many edge UEs lie in the coordinated region. As a result, the edge UEs' performance is better but they consume more resource of the system. In other words, it is more fairness for the edge UEs but the throughout of the system is low. Alternatively, if the d is large, it is difficult to ensure high performance for the edge UEs. To get a reasonable tradeoff between the fairness and the total throughput, we propose to use a function *f(r)* to evaluate the effect of *r* upon R and the R_{ef}. The function f(r) is define as

$$f(\mathrm{r}) = \frac{R + R_{sum}}{2}$$

Simulation result of f(r) for $\mathrm{r} \in (0,\mathrm{R})$ is shown in the Fig.3, with R=1km, K=10, 1000 iterations, and target SINR at the cell edge is 18dB. From the result, we can get a conclusion that the maximum value of f(r) is achieved around 0.3R, which is a reasonable choice.

III. SIMULATION ASSUMTION AND RESULTS

In this section, the performance of the proposed coordinated strategy is shown via simulation. We set either transmitted of received antenna is only one, the standard deviation of shadowing is 8dB, the path loss exponent is 4, and the cell radius is 1km. Other stated, UEs is uniformly distributed in every cell, the interference-free SINR at the cell edge is 18dB, Overlooking the small-scale fading.

The Fig.4 illustrates the probability of outage, from it we can find that the performance of strategy absence of coordination much worse than other two. And the coordinated strategies in all regions and in part of the region only have little difference when SINR is over 18dB. The maximum difference between the two coordinated strategies is not more than 10%, which takes place when SINR is too low to take place.

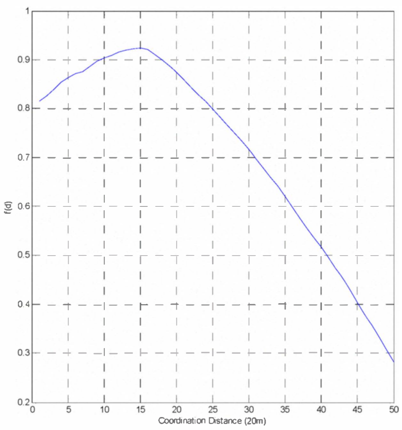

Fig.3. the relationship between the *f(d)*and the coordinated distance

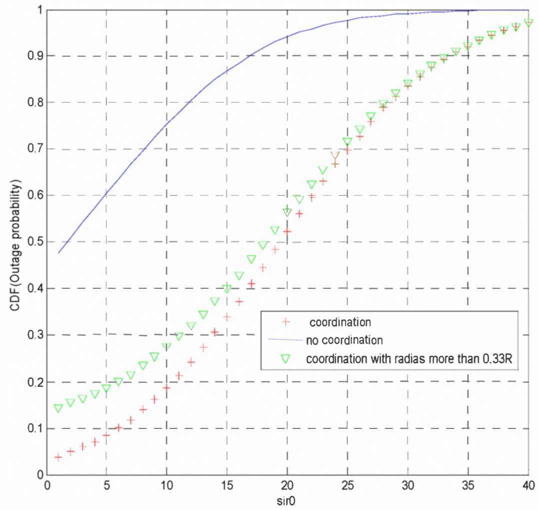

Fig.4. the outage probability comparison of different coordinated strategy

The Fig.5 illustrates the outage capacity of the three strategies. A similar result appears once again. The capacity of with coordination is much higher than absence. The two strategies have little difference in performance.

Although the performance of coordination in entire region has higher performance than in part region, its high performance depends on occupying much more resource of the system. Its effectiveness of frequency is low. Therefore this strategy is not advisable.

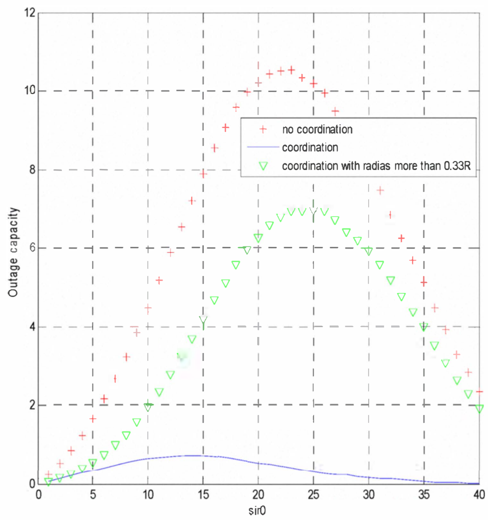

Fig.5. the outage capacity comparison of different coordinated strategy

IV. CONCLUSSION

It has been observed that although both the two coordinated strategies achieve higher cell-edge throughput, coordination in entire region suffers seriously in terms of sector throughput. On the contrary, the proposed schemes not only achieve higher mean throughput but also show improvement in frequency effectiveness compared to other strategy. It is a reasonable choice.

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