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Throughput Enhancement of 2 cell cooperation scheme in a wireless cellular network

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***Abstract*— In this paper ,we are introducing a technique mainly improving cell-edge throughput by coordinating scheduling and signal transmission of multiple BSs. Different from joint transmission (JT), in which the desired signals for a user equipment (UE) are simultaneously transmitted from multiple BSs. In this paper, we use the collaborative MIMO method to implement our idea of cell edge user throughput improvement. Emerging broadband wireless systems, such as those based on IEEE 802.16 m or 3GPP LTE-A, will re-use spectrum in every sector and maximize system spectrum efficiency. In so doing, the spectrum efficiency for cell-edge users is very poor in comparison with the system-wide average, and nomadic users located near the cell edge experience very low throughput. Co-MIMO has the advantages of ICI mitigation and spectral efficiency improvement. Moreover, it provides an acceptable tradeoff between the performance gain and the stringent requirement on the backbone traffic and computational complexity.This paper reviews an integrated package of three techniques, the paper will discuss the performance of each technique, and also show that they can be employed together in a complementary manner to improve cell-edge performance.**

***Keywords*— Spectral efficiency, Data rate, Cell edge user, Capacity.**

I. INTRODUCTION

The number cellular users are increasing more or less exponentially. As per the prediction of International Telecommunication Union (ITU) the global cellular subscriber base will be around 1.5 Billion by the end of year 2010.The expected economic impact of mobile and wireless communications providing improved productivity in business processes and access to information anytime and anywhere is driving the further improvement of communication systems. Traffic over mobile and wireless systems is expected to increase significantly especially for data applications. Data traffic is strongly increasing mainly due to Internet traffic. In order to meet the demands of multirate multimedia communications, next-generation cellular systems must employ advanced algorithms and techniques that not only increase the data rate, but also enable the system to guarantee the quality of service (QoS) desired by the various media classes. However, with scarcity of available radio resources, to achieve a good capacity and Quality of Service (QoS) efficient utilization of channel resources is important. In a conventional cellular network, a terminal receives signals not only from the base station of that cell, but also from other cell base stations. Using a proper frequency reuse, such interference is reduced to a tolerable limit. However, this method of using different frequency bands for different cells will decrease the spectral efficiency. In a full frequency re-use network, this interference degrades the system performance, and thereby reduces network capacity. The techniques currently being investigated for meeting next-generation goals include advanced signal processing, tailoring system components (such as coding, modulation, and detection) specifically for the wireless environment, departing from classic dichotomies (such as between source and channel coding), and using various forms of diversity. By effectively transmitting or processing (semi)independently fading copies of the signal, diversity is a method for directly combating the effects of fading. A new form of spatial diversity is proposed in [3], whereby diversity gains are achieved via the cooperation of in-cell users. This is complicated by the fact that the inter user channel is noisy. It is also complicated by the fact that both partners have information of their own to send. Using Base Station Cooperation, this ability to receive signals from multiple base stations can be utilized as an opportunity to improve the spectral efficiency of the cellular network and achieve higher data rates for cell edge users. Cooperative transmission utilizes the inherent user diversity available in a multi-user environment to provide higher spectral efficiency [1–3]. In [1] and [3], cooperation among active users for the uplink channel in wireless networks is described. The active users under cooperation have its own information to transmit, and therefore, do not simply act as a mobile relay stations. Since the inter-user link is also a noisy channel, there is a possibility that the information received by a user from the other user is corrupted. In [3], coded cooperation is proposed where each user decodes the signal of the other user that needs to be relayed, and will relay only if it is successfully decoded. In case of unsuccessful decoding, the users go to non-cooperative mode. In [2], cooperative strategies like amplify-forward and decode-forward for adhoc or per-to-peer wireless networks are proposed. In [4], it is shown that the downlink efficiency can be improved using Coherent Coordinated transmission (CCT) from multiple base stations. Two types of coordination transmission are proposed, namely, Equal Rate using Zero Forcing and Equal Rate Using Dirty Paper Coding. In Equal Rate using Zero Forcing, the transmission from all base stations intended for a particular user do not interfere with other users. In the Dirty Paper Coding scheme, knowledge of the interference is used at the transmitter for coding. Comparison of different coordination schemes like full coordination, partial coordination and no coordination is presented in [5] for a downlink Multiple Input Multiple Output (MIMO) system in a slow fading channel. In the full coordination scheme, the transmit covariance matrix for all the possible downlink channels between base stations and the users is computed using Dirty Paper Coding by a central coordinator to provide maximum sum throughput, based on the Channel Quality Information (CQI) provided by the base stations. These covariance matrices are then sent to corresponding base stations. However, this entire process adds significant latency. A new partial coordination scheme, where the base stations transmit in Time Division Multiple Access (TDMA) mode is proposed in [7]. In the allotted slot, each base station transmits to its associated users using Space Division Multiple Access (SDMA).Cooperative encoding and scheduling in a Networked MIMO system is discussed in [8], in order to suppress Other Cell Interference (OCI) and thereby achieve maximum capacity in MIMO downlink channel. In [10], it is shown that in a multi-cell environment, using cooperation the overall interference can be reduced only marginally, whereas the interference within the cooperation region is largely reduced. This leads to a question whether it is worth doing cooperation all the time, i.e., whether the performance gains are worth the cost addition in terms of the extra complexity added in the signal processing to perform cooperation. In this paper, we analyze the cooperation scenario in a multi cell environment where the other cell interference is significant. The capacity achieved through cooperation is shared equally among the cell-edge users, i.e., resources are shared fairly among the cooperating users. The transmission rate to each user is determined based on the signal to interference plus noise ratio (SINR). Cooperative transmission by two base stations can improve this SINR by transmitting jointly to one user at a time. However, the increase in terms of throughput may not always be enough to increase the throughput of each of the users. In such a scenario, in this paper, we propose a selective cooperation scheme based on user throughput that provides better capacity than full cooperation. The downlink environment under consideration will not have any interference from users in the same cell. They are properly separated in time, frequency or code such that orthogonality exists. Inter-cell interference is allowed by doing a full frequency re-use in each cell.

The rest of the paper is organized as follows: Section 2 describes the system model, signal to interference noise ratio (SINR) and user throughput with and without cooperation. Section 3 describes the SINR for different modes of Cooperation considered in this paper. Section 4 presents the cooperation selection algorithm and an example for UMTS. Section 5 presents the simulation results and conclusions are presented in section 6.

II. SYSTEM MODEL

The basic system model and transmission protocol is as shown in Figure 1 and Figure 2 respectively. Base stations BS1 and BS2 are the candidates for cooperation, to transmit signals to mobile terminals MS1 and MS2. For BS1, BS2 is one of the interfering base stations among the total 12 base stations in a re-use1 network. More than one base station can be involved in cooperation, but for simplicity we are considering only two stations to form a coalition. The signals from the serving BS and from the neighbour BS arrives at the terminal at the same time, i.e., received signal by the terminal from the two base stations are frame synchronized.

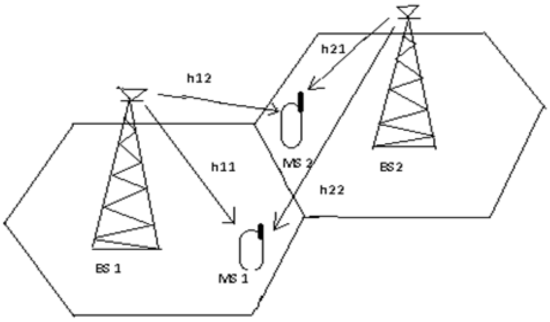


Fig 1.System model

MS1	MS2	MS1	MS2
MS1	MS2	MS1	MS2
Frame 1 for BS 2 transmission		Frame 2 for BS 1 transmission	

The frame duration in which the BS1 transmits to MS1 is divided into two sub-frames, where the first sub-frame is used for signal transmission to MS1 and the second one to MS2. Similarly, BS2, which is under cooperation with BS1, transmits in the same sequence of BS1.

A. System Equation

The received signals at MS1 and MS2 is y1 and y2, and is given by system equation (1), where hij is the channel between terminal i and BS j. x1 is transmit signal of BS1 and x2 is that of BS2.zi is the total interference received by MS i due to transmissions from all the base stations other than the one under cooperation (in this case BS2) and ni is the additive white Gaussian noise.

$$\begin{bmatrix} y1 \\ y2 \end{bmatrix} = \begin{bmatrix} h11 & h12 \\ h21 & h22 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \end{bmatrix} + \begin{bmatrix} z1 \\ z2 \end{bmatrix} + \begin{bmatrix} n1 \\ n2 \end{bmatrix}$$

(1)

B. No Cooperation

Under normal operation that is when there is no cooperative transmission i.e. the signal is received only from home base station, the signal to interference noise ratio (SINRnc) in the downlink for MS1 is given by equation 2.

$$\mathrm{SINR}_{nc} = \frac{|h_{11}|^2 E\{X_1^2\}}{\sigma_n^2 + \sum_{k=2}^{12} |h_{1k}|^2 E\{X_i^2\}} \qquad (2)$$

where hij represents the channel between the terminal i and base station j, E {Xi2} is the average transmit power of Base Station i, and σ n2 is noise variance.

The capacity (or throughput) for terminal MS1 in bits/sec/Hz under no cooperation can derived from the Shannon Capacity as given by equation (3)

Cnc = log2 (1+bSINRnc) (3)

where, b is determined by the SNR gap between the practical coding scheme and the theoretical limit.

C. Cooperation

When terminal MS1 is in coope*ration with BS1 and BS2,* SINRcoop, SINR of the downlink channel will depend on the type of cooperation scheme. The detail of different ways of combining the signal is described in the next section.

The capacity (or throughput) for terminal MS1 under cooperation n bits/sec/Hz will be

$$Ccoop= \alpha \log2 (1+bSINRcoop) \quad (4)$$

The factor α in eq. 3.4 defines the proportion of resource sharing among the terminals under cooperation. In our system, considering resource fairness, the value for α is 1/2.

D. Cooperation Selection

Under the resource fairness constraint, the users in the serving cell and the neighbor cell who decided to cooperate for an SINR improvement will share the available resource (time, frequency or code) between them equally. Therefore, the individual user throughput is 1/2 of the actual capacity of the cooperative transmission as in (4).

Considering b = 1 in the capacity expressions (3) and (4), for a low SINR regime, as $\log(1 + x) \approx x$, for the user capacity in "Cooperation mode" to be at least equal to what the same user could achieve under "No cooperation", the SINR in the former must be twice of the latter, i.e., should be ≥ 3 dB. The exact expression for the capacity (or user throughput) for cooperative scheme with resource constraint, to perform better than normal transmission, i.e., Ccoop > Cnc is shown below:

$$1/2 \log (1+bSINRcoop) > \log (1 + b\, SINRnc)$$
$$1+ b\, SINRcoop > (1 + b\, SINRnc)2$$
$$1+ b\, SINRcoop > 1 + b2\, SINR2nc + 2bSINRnc$$
$$SINRcoop > b\, SINR2nc + 2SINRnc \quad (5)$$

From the expression (5), for low SINR regime, our earlier approximation is valid. However, in the high SINR regime, the relationship between the two SINR is not linear, rather it is exponential. Even though, the SINR under cooperation (SINRcoop) is always better than the normal SINR (SINRnc), the user throughput of former is not always better than the latter. Hence, it is worthwhile, for the user to decide whether to perform cooperation in the downlink channel.

A brief description of the selection algorithm is given in Algorithm 1. This selection algorithm is of low complexity as it is approximation of the exact expression presented in (5) with b = 1. The user decides on cooperation with the measurements of its own channel and the nearest neighbor. The decision is informed to the base station of the serving cell. The serving station informs the neighbor station whether to do cooperation or not with a single bit information based on the input from the user.

III. SIMULATION AND RESULTS

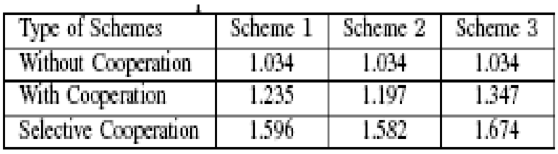
All A 19 cell full re-use multi-cell environment is simulated based on Monte Carlo methods to analyze the performance of user capacity and SINR for three transmission scenarios namely, i) Without Cooperation, ii) With Cooperation and iii) Selective Cooperation. Selective Cooperation is a hybrid scheme, where cooperative transmission is performed only if the (4) is greater than (3) as described in algorithm 1. A cellular network of radius 500m, operating at 1800 MHz with one cell edge user per cell is considered for simulations. The channel gains for both signal and interference are based on COST-231 path loss model [9] including fading and lognormal shadowing. The correction factors for the path loss model are that of metropolitan/urban areas. The shadowing component is a Gaussian random variable with zero mean and 10 dB of standard deviation. Fading component is an iid random variable with zero mean and unit variance. The transmission power of each base station (at the antenna) is 2W (33 dBm). The superposition of signals for cooperation is performed in three different ways as mentioned in section 3.

Our observation from simulation revealed that with probability 0.45, the user throughput without cooperation (3) is better than (4) for α = 1/2. Since, cooperation in a multi-cellular environment with full resource fairness is advantageous only half the time, it is better to do a hybrid transmission of both normal operation and cooperation that can give a better user throughput. Average throughput and SINR for cell edge user for different cooperative schemes is shown in Table I and II. Averaging is done over 105 frames for each combination of cooperative scheme and selection of cooperation. The observed values from the simulation given in the table, clearly shows the advantage of selective cooperation over full cooperation. Even though, the average SINR of Scheme 2 with cooperation is same as Scheme 1 with Selective cooperation, the capacity of the latter is better than the former. User throughput captured over 1000 frames for scheme 1 for full cooperation and selective cooperation is shown in Fig. 3. Throughput captured for first hundred frames is captured and shown in Fig.4, which depicts the fact that there are crossovers in user throughput for with and without cooperation. Hence, selective cooperation is a better option to get maximum throughput.

A. Algorithm 1 Cooperation Selection

```
Get channel measurement of the serving DL and nearest DL
Calculate the SINR under normal operation(SINRnc)
Calculate the SINR under cooperative transmission (SINRcoop)
case: Low SINR regime
for SINRnc <= 0 do
    if SINRcoop > 2 * SINRnc then
        Base stations goes to Cooperative Transmission State
    else
        Normal Transmission
    end if
end for
case: High SINR regime
for SINRnc _>=0 do
    if SINRcoop > SINR2 nc then
        Base stations goes to Cooperative Transmission State
    else
        Normal Transmission
    end if
end for
```

TABLE I
AVERAGE THROUGHPUT FOR CELL EDGE USER



Type of Schemes	Scheme 1	Scheme 2	Scheme 3
Without Cooperation	1.034	1.034	1.034
With Cooperation	1.235	1.197	1.347
Selective Cooperation	1.596	1.582	1.674

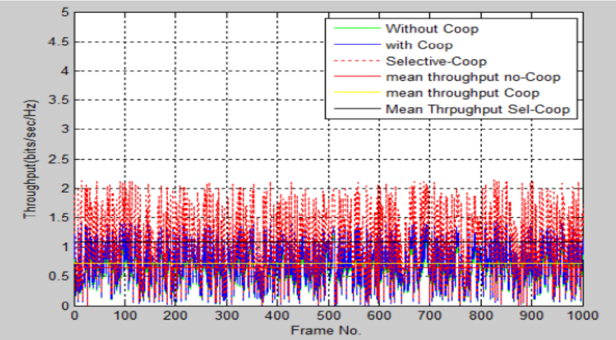


Fig. 3: User Throughput Comparison for Various Operations in Scheme

TABLE I
SINR OF CELL EDGE USER(DB) FOR DIFFERENT COOPERATION SCHEME

Type of Schemes	Scheme 1	Scheme 2	Scheme 3
Without Cooperation	-7.50	-7.50	-7.50
With Cooperation	3.52	2.79	4.70
Selective Cooperation	2.79	2.58	3.88

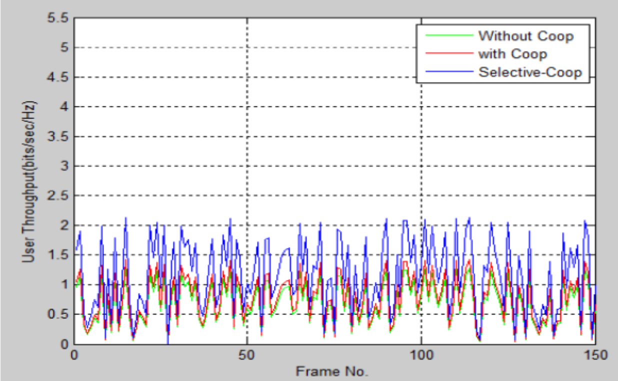


Fig.4: Snapshot of User Throughput for Various Operations in Scheme 1

IV. CONCLUSIONS

In this paper, we presented simulation analysis of downlink cooperation in a multi-cell cellular network. In resource airness cooperation, the user capacity of a cell-edge user is not always better than normal transmission. The simulation results show that for almost half the time user capacity with cooperation is poorer than the capacity with normal operation. By doing a selective cooperation, both capacity and SINR is improved. The throughput improvement is about 33.3% from full cooperation to selective cooperation for same SINR.

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