Network MIMO with Decision Tree Classification in Downlink OFDMA Networks

Ling Zhang, Shenghua He, Xiangming Wen, Zheng Wei, Jun Zhao, Zhiqun Hu
Beijing Key Laboratory of Network System Architecture and Convergence
Beijing University of Posts and Telecommunications, Beijing, China
Email: sing19901101@hotmail.com

Abstract—**A coordination strategy among a large cellular MIMO network is presented in this paper. With clustered linear precoding and dynamic frequency reservation techniques, JDFR-BDGMD (Joint Dynamic Frequency Reservation and Block Diagonalization precoding with Geometric Mean Decomposition precoding scheme) greatly mitigates intra-cluster interference as well as inter-cluster interference in the downlink OFDMA networks. Furthermore, the coordination is based on decision tree classification which categorizes users into coordinative users and non-coordinative users. It is noteworthy that we pick a capacity-based subchannel from system available resources for coordinative users. Finally, an equal power allocation algorithm is utilized to distribute power. Simulation results show that our proposed scheme can significantly improve the performance of multi-cell networks.**

I. Introduction

Wireless cellular networks have been facing the explosive demand for wireless data service. In conventional cellular systems, each terminal is served by one Base Station (BS) and resources are dynamically scheduled accordingly. With limited resources, people begin to deploy BSs or other access points more densely which breeds sever inter-cell interference (ICI), which in turn degrades the system performance [1].

Multi-antenna transmission and reception (known as MIMO) is key technique for improving system capacity. In particular, multi-user MIMO (MU-MIMO) boost the sum capacity through joint precoding method [2]. Nevertheless, ICI caused by MIMO systems is severe since each antenna acts as an interference source and it is especially serious for the downlink because complicated interference suppression techniques are not practical for mobiles. The capacity gains promised by MIMO techniques degrade severely in the multi-cell environment [3]. Conventional approaches to mitigate multi-cell interference, such as static frequency reuse, are not efficient enough for MIMO networks [4].

Due to the fast improvement of processing capability at BSs and the increase of the backhaul capacity, coordinated multi-cell MIMO communications with cooperative processing among BSs have become a hot topic in recent years. Much work have been done. From [5], we know that inter-cell scheduling is a practical strategy to reduce interference. In [6], it was shown that one major advantage of inter-cell scheduling compared with conventional frequency reuse is the expanded multiuser diversity gain. The interference reduction is at the expense of a transmission duty cycle, however, and it does not make full use of the available spatial degrees of freedom which encourages us to study more efficient strategy of network MIMO systems. Furthermore, in order to improve the spectrum efficiency of network MIMO systems, we need to select users who need CoMP transmission which we call coordinative users. There are several papers about coordinative user selection. The author in [7] utilizes the geometry law or RSVP (Reference Signal Receiving Power) law to distinguish coordinative users and non-coordinative users while the author in [8] proposes a metric based on user location which groups the users into cluster interior and cluster edge users. Such approaches only rely on SINR or UE location, usually directing a user far away from BS to the need-type, is not accurate and may cause waste, impelling us to explore a more precise method to make the classification. Decision tree, which has a widely application from data mining to economic statistical data processing, has received much attention in intelligent learning recently. In this paper, we introduce decision tree method into wireless communication by classifying users in downlink OFDMA (Orthogonal Frequency Division Multiple Access) networks where we utilize a coordination strategy for network MIMO users.

The remainder of this paper is organized as follows. Section II describes a system model of three clusters, each comprising three cells. Section III then introduces decision tree into our paper to make the user classification. Description of BDGMD precoding method within cluster to mitigate intra-cluster interference is followed. Hereafter, DFR algorithm is presented in detail which focus on reduction of inter-cluster interference. Some simulation results through which we show the superiority of the proposed scheme are followed in section IV. Finally, some conclusions are drawn to summarize the contribution this paper have accomplished in section V and it also gives the direction of future work.

Notations: For a matrix $\mathbf{X}$, $(\mathbf{X})^T$ and $(\mathbf{X})^*$ denotes the transpose and the conjugate transpose of a matrix respectively. For a set $\mathbf{Y}$, we use $|\mathbf{Y}|$ to denotes the cardinality of $\mathbf{Y}$. 'E' means the expectation.

II. System Model

We consider a system of C clusters, each including adjacent B BSs as in Fig. 1. Block fading model is assumed so that the channel is static over one scheduling interval, but varies from

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TABLE I: SYSTEM PARAMETERS

Symbol	Description
P	the maximum transmit power at each BS
B	number of BSs in each cluster
C	number of clusters we consider
B_b	the *b-th* BS in cluster c
$\mathbf{I_b}$	set of active users in B_b
$\mathbf{I'_b}$	set of coordinative users in B_b
$\mathbf{K}$	$\mathbf{K} = \bigcup_{b=1}^{B} \mathbf{I'_b}$
l	length of data symbol for user, $l \leq N_r$
N_t	number of antennas at each BS
N_r	number of antennas at each mobile
N	number of subchannels at each BS

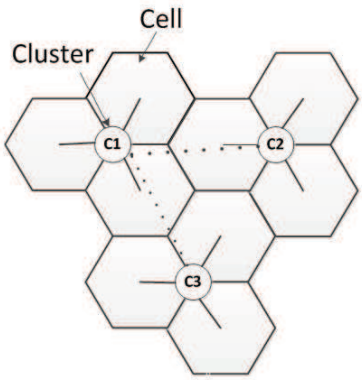

Fig. 1: System model. $B = 3$, $C = 3$. Node "c" in each cluster is virtual controller, which means coordination within each cluster. The dashed line among controllers in neighboring clusters denotes the inter-cluster interference.

interval to interval. The system parameters used in this paper are summarized in Table I. We consider a cellular network, where we do cooperations among BSs in the same cluster which greatly mitigates intra-cluster interference. Cluster co-operation is more practical than global cooperation since it significantly reduces information exchange. In addition, DFR presented in next sector is used to reduce interference from other adjacent clusters which is destructive.

To efficiently accommodate all the users, we group them into two types according to certain criterion: coordinative users and non-coordinative users. Without loss of generality, we consider the cluster c. And we denote $\mathbf{K}$ as the set of active coordinative users in cluster c. To accommodate both types of users simultaneously and make coordinative users be free from non-coordinative user interference, we need allocate some resources to coordinative users exclusively. Since system's affordability is limited that only several coordinative users can be served simultaneously. We denote K_{max} as the maximum number of supportable coordinative users on one subchannel and suppose $\mathbf{K} \leq K_{\max}$. Therefore, we just need to give one subchannel to coordinative users and the left to the other type. Several assumptions are made to ensure the system requirements for clustered coordination based on a cluster scale, which is much lower than that for global coordination, especially in a large network.

Hypothesis 1: The BSs within a cluster have perfect Channel State Information (CSI) of all the users in this cluster, and perfect CSI of the edge users in the neighboring clusters.

Hypothesis 2: The BSs within the same cluster can fully share CSI and user data. The BSs in different clusters can exchange traffic information, such as the number of active users and user locations.

The $N_r \times 1$ received signal vector at user k, $k \in \mathbf{K}$, in cluster c is as follow:

$$\mathbf{y_k^{(c)}} = \underbrace{\sum_{b=1}^{B} \mathbf{H_k^{(c,b)}} \mathbf{T_k^{(c,b)}} \mathbf{x_k^{(c)}}}_{desired\ signal} + \underbrace{\sum_{b=1}^{B} \mathbf{H_k^{(c,b)}} \sum_{i=1,i\neq k}^{\mathbf{K}} \mathbf{T_i^{(c,b)}} \mathbf{x_i^{(c)}}}_{\mathrm{intra}-cluster\ \mathrm{inter}ference} + \underbrace{\sum_{c'=1,c'\neq c}^{C} \sum_{b'=1}^{B} \mathbf{H_k^{(c',b')}} \sum_{j=1}^{\mathbf{K^{(c')}}} \mathbf{T_j^{(c',b')}} \mathbf{x_j^{(c')}}}_{\mathrm{inter}-cluster\ \mathrm{inter}ference} + \mathbf{n_k^{(c)}}, \tag{1}$$

where $\mathbf{x_k^{(c)}}$ is the $l \times 1$ transmitted vector for user k in cluster c. Denote $\bar{\mathbf{x}}^{(c)} = [\mathbf{x_1^{(c)*}}, \mathbf{x_2^{(c)*}}, ..., \mathbf{x_K^{(c)*}}]^*$. The covariance matrix for $\bar{\mathbf{x}}^{(c)}$ is denoted as $\mathbf{Q}^{(c)} = E[\bar{\mathbf{x}}^{(c)}\bar{\mathbf{x}}^{(c)*}]$. $\mathbf{H_k^{(c,b)}}$ is the $N_r \times N_t$ channel matrix from BS_b in cluster c to user k. $\mathbf{T_k^{(c,b)}}$ is the $N_r \times l$ precoding matrix . $\mathbf{n_k^{(c)}}$ is the additive white Gaussian noise at user k in cluster c, with zero mean and variance $E(\mathbf{n_k^{(c)}}\mathbf{n_k^{(c)*}}) = \delta_n^2 \mathbf{I_{N_r}}$. Because the network MIMO system can be seen as a super BS with separate distributed antennas, the signal model can be rewritten as:

$$\mathbf{y_k^{(c)}} = \mathbf{H_k^{(c)}} \sum_{i=1}^{\mathbf{K}} \mathbf{T_i^{(c)}} \mathbf{x_i^{(c)}} + \mathbf{n_k^{(c)}} + \sum_{c'=1,c'\neq c}^{C} \mathbf{H_k^{(c')}} \sum_{\mathbf{j=1}}^{\mathbf{K^{(c')}}} \mathbf{T_j^{(c')}} \mathbf{x_j^{(c')}} \tag{2}$$

where $\mathbf{H_k^{(c)}} = [\mathbf{H_k^{(c,1)}}, \mathbf{H_k^{(c,2)}}, ..., \mathbf{H_k^{(c,B)}}]$ is the $N_r \times N_t B$ aggregate channel transfer matrix from the super BS to user k, and $\mathbf{T_k^{(c)}} = [\mathbf{T_k^{(c,1)*}}, \mathbf{T_k^{(c,2)*}}, ..., \mathbf{T_k^{(c,B)*}}]^*$ is the aggregate transmit precoder for user k over all BSs in cluster c. Unlike traditional downlink with co-located MIMO channels, the channel gains from any two antennas at different BSs are guaranteed to be independent.

Denote $\mathbf{z_k^{(c)}} = \mathbf{n_k^c} + \sum_{c'=1,c'\neq c}^{C} \mathbf{H_k^{(c')}} \sum_{j=1}^{\mathbf{K^{(c')}}} \mathbf{T_j^{(c')}} \mathbf{x_j^{(c')}}$ as sum of the noise and interference from other clusters, the covariance matrix of which is

$$\mathbf{R_k^{(c)}} = \delta_n^2 \mathbf{I_{N_r}} + \sum_{c'=1,c'\neq c}^{C} \sum_{j=1}^{\mathbf{K^{(c')}}} \mathbf{H_k^{(c')}} \mathbf{T_j^{(c')}} \mathbf{Q_j^{(c')}} \mathbf{T_j^{(c')*}} \mathbf{H_k^{(c')*}} \tag{3}$$

III. Cooperation scheme Based on Decision Tree

A. Decision Tree Classification

Decision tree is a flow-chart like structure in which internal node represents test on an attribute and each branch represents outcome of test while each leaf node represents class label. The model of decision tree is demonstrated in Fig. 2.

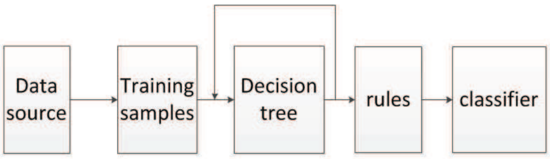

Fig. 2: The process of using a decision tree

Assuming that groups of samples are obtained and we denote them with T. Our paper is a two-type classification, denoting by C_0 the coordinative users and C_1 the non-coordinative users. Utilizing the training data, we create a proper decision tree which we use to judge user types in real communication. C4.5 algorithm is a classical decision tree building method proposed by Quinlan. It uses information gain ratio rather than information gain to select testing attributes. What's more, C4.5 will pruning a tree structure in the process of making decision tree and it is suitable to discrete attributes [9].

We pluck four attributes of a service, SINR, LOCATION, PACKET LOSS, DELAY, which may indicate the Quality of Service (QoS) most. Let A_{k0} and A_{kM} denote the minimum and maximum value of A_k respectively. M is a proper value acquired by simulations. A_k is the *k-th* attribute of updated A. T_i means the number of samples in interval $[A_{k(i-1)}, A_{ki}]$. C_{0i} and C_{1i} mean the number of C_0 type and C_1 type in T_i respectively. Denote the information entropy of samples as $I(T)$ and it can be calculated as follow:

$$I(T) = -\frac{|P|}{|T|}\log_2\frac{|P|}{|T|} - \frac{|Q|}{|T|}\log_2\frac{|Q|}{|T|} \tag{4}$$

where P and Q stand for the set of C_0 and C_1 in T respectively. Applying C4.5 algorithm to our target problem, we form a combined algorithm that can be stated as Algorithm 1.

In conclusion, given training samples, we first make a decision tree as Algorithm 1 goes. And then UEs feed back four attributes to their own server BS to classify users by the decision tree which we have modeled previously. After that we can get $\mathbf{K}$, $\mathbf{I'_b}$ in section II.

B. Cooperation Schemes

We firstly explain the BDGMD precoding in cluster c. To guarantee a intra-interference free received signal $\mathbf{y_k^{(c)}}$ in equation (1), the following condition must be fulfilled:

$$\mathbf{H_{k'}^{(c,b)}}\mathbf{T_k^{(c,b)}} = 0, (\forall k' \neq k) \tag{5}$$

Let $\mathbf{\bar{H}_k^{(c,b)}} = [\mathbf{H_1^{(c,b)*}}, \mathbf{H_1^{(c,b)*}}, ..., \mathbf{H_{k-1}^{(c,b)*}}, \mathbf{H_{k+1}^{(c,b)*}}, ..., \mathbf{H_K^{(c,b)*}}]^*$ denotes other coordinative users' subchannel gain matrix. Make $\tilde{N}_k^{(c,b)} = rank(\mathbf{\bar{H}_k^{(c,b)}})$ and decompose $\mathbf{\bar{H}_k^{(c,b)}}$, we get:

$$\mathbf{\bar{H}_k^{(c,b)}} = \mathbf{\tilde{U}_k^{(c,b)}}\mathbf{\tilde{\Lambda}_s^{(c,b)}}[\mathbf{\tilde{V}_k^{(c,b,1)}}\mathbf{\tilde{V}_k^{(c,b,0)}}]^* \tag{6}$$

where $\mathbf{\tilde{U}_k^{(c,b)}}$ and $\mathbf{\tilde{\Lambda}_k^{(c,b)}}$ represents left singular matrix and diagonal matrix of the singular value respectively. $\mathbf{\tilde{V}_k^{(c,b,1)}}$

Algorithm 1: User Classification Combined With C4.5

Obtain samples
A={SINR, LOCATION, PACKET LOSS, DELAY}
While $A \neq \Phi$
  For $k \leq |A|$
    Split $[A_{k0}, A_{kM}]$ into M subinterval uniformly by A_{k_i}, (i=1,2,...,M-1).
    $Entropy(A_k) = -\sum_{i=1}^{M-1}\frac{|T_i|}{|T|} \times (\frac{|C_{0i}|}{|T_i|}\log_2\frac{|C_{0i}|}{|T_i|} + \frac{|C_{1i}|}{|T_i|}\log_2\frac{|C_{1i}|}{|T_i|})$
    $Gain(A_k) = I(T) - Entropy(A_k)$
    $Gainratio(A_k) = \frac{Gain(A_k)}{\sum_{i=1}^{M-1}\frac{|T_i|}{|T|}\log_2\frac{|T_i|}{|T|}}$
  End for
  Select A_j that has the maximum information gain ratio as testing attribute
  $A = A - Aj$
End while
Draw rules from the decision tree, construct a training pattern.

comprises the first $\tilde{N}_k^{(c,b)}$ right singular vectors while $\mathbf{\tilde{V}_k^{(c,b,0)}}$ comprises the last $(3N_t - \tilde{N}_k^{(c,b)})$ right singular vectors which consists of a set of orthogonal basis. Let $\mathbf{T_k^{(c,b)}} = \mathbf{\tilde{V}_k^{(c,b,0)}}\mathbf{D_k^{(c,b)}}$, then $\mathbf{y_k^{(c)}}$ can be simplified as follow:

$$\mathbf{y_k^{(c)}} = \mathbf{H_{eff,k}^{(c,b)}}\mathbf{D_k^{(c,b)}}\mathbf{x_k^{(c)}} + \mathbf{z_k^{(c)}} \tag{7}$$

where $\mathbf{H_{eff,k}^{(c,b)}} = \mathbf{H_k^{(c,b)}}\mathbf{\tilde{V}_k^{(c,b,0)}}$ is the effective channel gain matrix. To cancel the difference of subchannel gain caused by SVD, we replace it with GMD by making $\mathbf{H_{eff,k}^{(c,b)}} = \mathbf{Q_k^{(c,b)}}\mathbf{R_k^{(c,b)}}\mathbf{P_k^{(c,b)*}}$, where $\mathbf{Q_k^{(c,b)}}$ and $\mathbf{P_k^{(c,b)}}$ are unitary matrix, $\mathbf{R_k^{(c,b)}}$ is real upper triangular matrix with equal diagonal elements r_{kk}.Then, we properly choose $\mathbf{Q_k^{(c,b)}}$ and $\mathbf{P_k^{(c,b)}}$ to maximize r_{kk} [10]. And r_{kk} can be written as follow:

$$r_{kk} = (\prod_{m'=1}^{M'}\delta_{m'})^{1/M'}, 1 \leq m' \leq M' \tag{8}$$

$\delta_{m'}$ is $\mathbf{H_{eff,k}^{(c,b)}}$'s *m-th* nonzero singular value and $M' = rank(\mathbf{H_{eff,k}^{(c,b)}})$. Let $\mathbf{D_k^{(c,b)}} = \mathbf{P_k^{(c,b)}}(\mathbf{E_k^{(c,b)}})^{1/2}$. $\mathbf{E_k^{(c,b)}}$ is a diagonal matrix with its elements indicating the power allocated to each link for user k. (7) can be rewritten as (9):

$$\begin{aligned}\mathbf{y_k^{(c)}} &= \mathbf{Q_k^{(c,b)}}\mathbf{R_k^{(c,b)}}\mathbf{P_k^{(c,b)*}}\mathbf{P_k^{(c,b)}}(\mathbf{E_k^{(c,b)}})^{1/2}\mathbf{x_k^{(c)}} + \mathbf{z_k^{(c)}} \\ &= \mathbf{Q_k^{(c,b)}}\mathbf{R_k^{(c,b)}}(\mathbf{E_k^{(c,b)}})^{1/2}\mathbf{x_k^{(c)}} + \mathbf{z_k^{(c)}}\end{aligned} \tag{9}$$

Next, we use DFR algorithm to dynamically allocate subchannels to coordinative users in order to reduce inter-cluster interference. Denote $C_{(1)}^{(f,n)}$ as coordinative users' capacity in cluster c_f when CoMP transmission was conducted on subchannel n and when intra-cluster interference is eliminated. Then, if we decodes at mobile by multiplying with $\mathbf{R_k^{(c,b)*}}\mathbf{Q_k^{(c,b)*}}(\mathbf{E_k^{(c,b)}})^{1/2}$ and with equal power allocation in each link, network MIMO cluster coordinative user capacity $C_{(1)}^{(f,n)}$ can be calculated as (10):

$$C_{(1)}^{(f,n)} = \sum_{k \in \mathbf{K}} M' \log(1 + \frac{P'}{M'|\mathbf{K}|\delta_n^2} r_{kk}^2) \tag{10}$$

where P' is the sum power allocated to the cluster. And in this paper we just consider it is $3P/N$. DFR is as Algorithm 2 shows.

Algorithm 2: DFR

```
For f = 1, f ≤ 3, f + +
    C_(1)^(f) = 0, n ∈ N' = {1, 2, .., N}
    For n = 1, n ∈ N', n + +
     Calculate C_(1)^(f,n) by equation (10)
        If C_1^(f,n) ≻ C_1^(f)
          m_f = n
        End if
    End for
  Select m_f as the subchannel of coordinative users in
  cluster c_f, N' = N'/n.
End for
```

DFR actually is a resource reservation scheme and its selection of subchannels is based on coordinative user capacity. If joined by BDGMD (called JDFR-BDGMD), it significantly contribute to system capacity. DFR is scheduled at every interval, and the allocated subchannel varies with the alteration of channel state and active user.

We would like to conclude that as a large number of users in each cluster fight for the available limited resources, it is necessary to schedule transmission for a subset of users selected by a performance criterion: decision tree classification. We utilize BDGMD to mitigate intra-cluster interference. Meanwhile, DFR is adopted to reduce inter-cluster interference for coordinative user. Sum rate optimal scheduling algorithm in [11] can be used to schedule non-coordinative users which will be left to future work. Additionally, resource allocation algorithm in [12] and [13] can be introduced to this paper.

IV. Simulation Results

A. Decision Tree Simulations

We utilize a group of data tested by other objects in our laboratory as in Table II which evaluates the Quality of Service according to several attribute parameters. If a service is good enough to a user, it was defined as '1.0'. Otherwise, it was '0.0'. Here we declare that '0.0' means C_0 type while '1.0' means C_1 type.

Then we use Table II to build a decision tree classifier by Weka 7.0. And the result is as Figure 3 shows (label 'yes' means C_1 type and label 'no' means C_0 type). A set of rules become obvious from the built decision tree which we would like to exploit to classify users. Here we can see that only two attributes are selected and this is reasonable since SINR and DELAY are decisive for users' experience of certain service (such as real time transmission video) while others have less sound effects for wireless (video) users. The number after labels is the quantity of samples classified to that type and '17.0/1.0' means that there is one sample being judged wrongly. According to this tree, we easily distinguish coordinative users from others.

TABLE II: Training Data

No.	SINR (dB)	DELAY (ms)	PACKET LOSS	LOCATION (km)	CLASS
1	22.9416	9.6274	0.0556	699.3316	0.0
2	20.8948	6.3867	0.0571	800.4586	0.0
3	22.6839	5.8296	0.0945	598.1755	1.0
4	21.4041	6.1457	0.0504	699.6659	0.0
5	22.0786	9.2789	0.1721	700.0761	0.0
6	22.3403	7.3147	0.0383	700.0474	1.0
...	....				
28	22.8927	5.5716	0.0612	600.2993	1.0
29	19.7783	11.1725	0.0705	901.0142	0.0
30	25.5531	5.1537	0.0441	499.1056	1.0

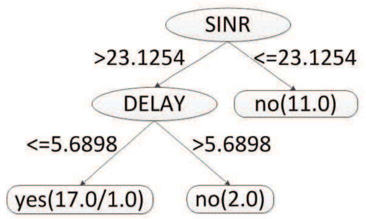

Fig. 3: Built decision tree

B. System Performance Simulations

We let $N_t = 4$, $N_r = 2$ and $N = 10$. The cell radius is 1 Km. Following [14], we model the base-band fading channel linking the BS_b to the user k on subchannel n as:

$$\mathbf{H}_{\mathbf{k}}^{(\mathbf{c},\mathbf{b})}(\mathbf{n}) = \left(\frac{200}{d_k^{(c,b)}(n)} \right)^{3.5} \mathbf{L}_{\mathbf{k}}^{(\mathbf{c},\mathbf{b})}(\mathbf{n}) \bar{\mathbf{h}}_{\mathbf{k}}^{(\mathbf{c},\mathbf{b})}(\mathbf{n}) \tag{11}$$

where $\left(\frac{200}{d_k^{(c,b)}(n)} \right)^{3.5}$ represents the path loss factor, $d_k^{(c,b)}(n)$ represents the distance from BS_b to user k, the index of path loss is 3.5. $10\log_{10}\mathbf{L}_{\mathbf{k}}^{(\mathbf{c},\mathbf{b})}(\mathbf{n})$ is a real Gaussian random variable with zero mean and standard deviation 1 accounting for large-scale Log-Normal shadowing. $\bar{\mathbf{h}}_{\mathbf{k}}^{(\mathbf{c},\mathbf{b})}(\mathbf{n}) \sim CN(0, \mathbf{I}_{\mathbf{N_t}})$ is a circularly symmetric comlex Gaussian random vector accounting for Rayleigh fast fading. $P = 40dB$ and the $\delta_n^2 = -20dB$.

In order to illustrate the excellent performance of the proposed scheme with decision tree, we compare it with the following systems:

- Multi-cell JDFR-BDGMD without decision tree classification: This system utilize the same cooperation scheme, but it classify users by mobile location solely.

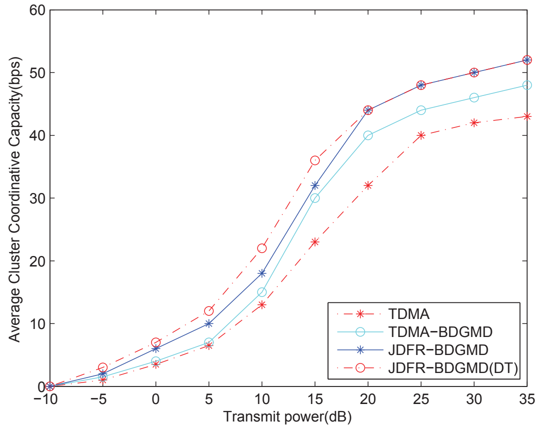

Fig. 4: Average cluster capacity for different systems, with $C = 3, B = 3$.

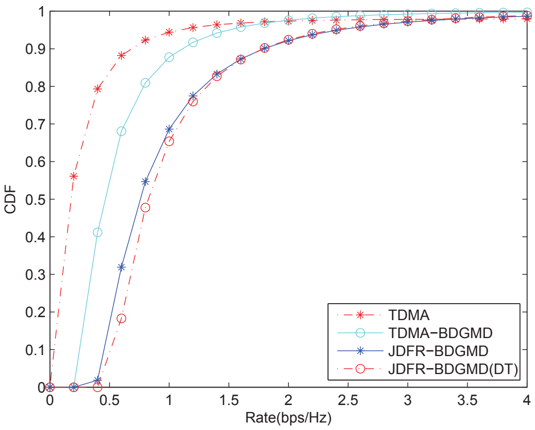

Fig. 5: CDF of the rates for users.

- TDMA with Intercell Scheduling (TDMA): Neighboring BSs cooperatively schedule their transmissions, and only one BS is active to serve one user at each time.
- Intercell Scheduling with BDGMD (TDMA-BDGMD): Compared to TDMA with inter-cell scheduling only, this technique allows one BS to serve multiple users at each time slot with BDGMD.

In Fig. 4, 'JDFR-BDGMD (DT)' denotes the proposed scheme while 'JDFR-BDGMD' denotes the same cooperation without decision tree classification. 'TDMA' denotes inter-cell scheduling scheme and 'TDMA-BDGMD' denotes the inter-cell scheduling with BDGMD precoding. Here we distribute 30 users per cell. We can see that two JDFR-BDGMD schemes have the better performance than the others. And it occurs to us that when the transmit power is under 20dB, decision tree provide considerable gain than that without decision tree. This is because only when transmit power is low, users need to be further judged by DELAY (see the built tree) which make decision tree more accurate to classify users. The fact that TDMA with BDGMD precoding prevail over TDMA inter-cell scheduling show the superiority of BDGMD. Fig. 5 shows the CDF of user rate. We can see that the rate with 60% outage for JDFR-BDGMD (DT) is 0.7bps/Hz, for JDFR-BDGMD is 0.6bps/Hz, for TDMA-BDGMD is 0.5bps/Hz and for TDMA is 0.2bps/Hz.

V. Conclusion

We presented a cooperation scheme which take both inter-cluster and intra-cluster interference into account. Meanwhile, an accurate decision tree algorithm is used to classify users. We firstly get a group of training data to built a decision tree under the present communication conditions and then collect all the needed attribute parameters of the users and make a classification. Moreover,we make a dynamic frequency reservation algorithm to cast aside inter-cluster interference which greatly benefit coordinative users at the edge of clusters. By BDGMD precoding, intra-cluster interference is canceled for coordinative users.

VI. Acknowledgement

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