Cooperative Transmission Strategy for Downlink Distributed Antenna Systems Over Time-Varying Channel

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***Abstract*—The channel state information (CSI) is used to optimise data transmission in time division duplex (TDD) systems, which is obtained at the time of channel estimation. The actual channel of data transmission at downlink time slot is different from the estimated channel due to channel variation in user movement environment. In this paper the impact of different user mobility on TDD downlink multiuser distributed antenna system is investigated. Based on mobility state information (MSI), an autocorrelation based feedback interval technique is proposed and updates CSI and mitigate the performance degradation imposed by the user speed and transmission delay. Cooperative clusters are formed to maximize sum rate and a channel gain based antenna selection and user clustering based on SINR threshold is applied to reduce computational complexity. Numerical results show that the proposed scheme can provide improved sum rate over the non cooperative system and no MSI knowledge. The proposed technique has good performance for wide range of speed and suitable for future wireless communication systems.**

I. INTRODUCTION

The rapid growth of mobile data access requires huge demand for high data rates transmission and extended coverage is required within limited transmit power and bandwidth [1]-[4]. Recent studies have shown that the distributed antenna system (DAS) can extend coverage area, improve spectral efficiency and reduce overall transmit power by reducing the distance between the transmitter and the receiver [5]-[12]. Therefore, the DAS is regarded as a promising system for future mobile communications. In the DAS, a number of remote antenna units (RAUs) are geographically distributed over a cell and controlled by a single central unit (CU) via optical fibre or cable [13], [14]. The RAUs in the DAS are only simple antenna units carrying out radio transmission and reception for the CU [13], [14]. All RAUs have different independent channel characteristics because the signal from RAU to different users experience different large scale fading and different fast fading. Multi-user transmission supported by the DAS causes inter-user interference (IUI), which can be mitigated by using linear precoding like zero forcing (ZF) and minimum mean square error (MMSE) [15]-[18]. However, these beamforming techniques require channel state information (CSI) from all users at the CU.

In a frequency division duplex (FDD) system, the CSI for the CU is provided by separate frequency band, where the user should estimate and quantize the pilot signal. The increasing demand of high data rate is mainly due to the use of multimedia services such as social networking, real-time video and interactive games. These services require asymmetric traffic between uplink and downlink. The asymmetric traffic in FDD system requires extra system bandwidth, whereas time division duplex (TDD) can fit it into any single spectrum by allocating uplink and downlink time slots according to the traffic condition [19], [20]. In TDD system, the CU estimates CSI from the uplink pilot sent by the users at uplink time slot and then uses it via channel reciprocals to generate transmit precoding matrix for downlink transmission at the downlink time slot. However, the CSI obtained by the CU is outdated in practice due to channel variation in user movement environment.

In a practical scenario, every user may have different mobility characteristics. For different mobility users, the DAS is arguably better suitable than small cell. This is because user is always near to one of the RAUs and same signal is transmitted by multiple RAUs which reduces handoffs. When the user moves, the channel from RAU to the user becomes a time varying channel. In this situation, the transmitted signal is subject to the Doppler effect and hence experiences frequency offset. When the mobility speed increases or the transmission delay increases, the correlation between the actual channel and the estimated channel becomes small which severely degrades the performance. For a multi-user system with linear precoding, the outdated CSI mismatch the actual channel and the precoder. In [21], as the channel correlation degrades, the interference increases and the performance of the precoding system degrades to approach the performance of the non-precoding systems. [22], has investigated the effects of imperfect CSI. The performance of the multiuser MIMO system strongly depends on the correlation between the real channel and the estimated CSI at the transmitter. In [23], the multiuser MIMO system is considered in the presence of non-perfect CSI. The authors concluded that only predictable (low mobility) users can be served jointly, where space time coding transmission is allocated to non-predictable (high mobility) users.

The low mobility user implicitly has high channel temporal correlation coefficient and the channel mismatch becomes small within a feedback interval because the channel varies slowly. The feedback interval is the time duration of two uplink time slots where the CU estimates the CSI as shown in Fig. 1. For high mobility user, the feedback interval of the channel will diminish with its user speed. Hence, the channel mismatch becomes large, when the speed is large. The channel mismatch can be reduced by reducing feedback interval.

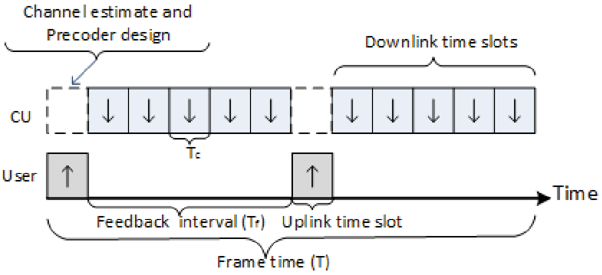

Fig. 1. Illustration of feedback interval.

In this paper, the spectral efficiency of downlink multiuser DAS is studied under constraints on per-antenna power and per-user signal to interference plus noise ratio (SINR) considering different speed range. To improve the system throughput, the CSI feedback interval reduction technique is proposed. The proposed technique divides users into several groups based on mobility state information (MSI). The MSI of the user can be speed or acceleration information. We assume that the speed of the user is perfectly known at the CU. To achieve a maximum sum rate within a group, all users should be jointly served. However, in the DAS, the sum rate mainly depends on the channel between RAU and user whose channel gain is high, which means less propagation loss. Based on this observation, we consider antenna selection of RAUs and interference based user clustering. The user clustering is done within the same group. This divides the original problem into multiple cluster based problems. When the system transmits the signal simultaneously using the same frequency, the inter-group inter-cluster interference will occur and limits the average sum rate of the system. To improve the average sum rate of the system, we propose a cooperative clustering based cooperative strategy. Each cluster serves a subset of users of own group and has a set of users of the other group to coordinate interference. The strategy consists of full intra-cluster coordination.

II. SYSTEM MODEL

Consider a single cell downlink environment which consists of N_t RAUs and K users, as shown in Fig. 2. Each user is equipped with a single antenna. The users are uniformly distributed within a cell. We assume that $N_t \geq K$, the CU perfectly estimates the CSI of all users at the uplink transmit slot and the MSI of the user is also perfectly known at the CU. Let $\mathcal{K}$ is the user set, i.e., $\mathcal{K} \in \{1, \cdots, k, \cdots, K\}$ and $\mathcal{N}$ is the RAU set, i.e., $\mathcal{N} \in \{1, \cdots, j, \cdots, N_t\}$. Under these assumptions, the received signal for k-th user at time t is $y^k \in \mathbb{C}^{1\times 1}$ and is given by:

$$y^k(t) = \mathbf{h}^k(t)\mathbf{W}(t-\tau)\sqrt{\mathbf{P}(t-\tau)}\mathbf{s}(t-\tau) + n_k(t)$$

$$\begin{aligned} y^k(t) &= \mathbf{h}^k(t)\mathbf{w}_k(t-\tau)\sqrt{p_k(t-\tau)}s_k(t-\tau) \\ &+ \mathbf{h}^k(t)\sum_{\substack{i\in K\\ i\neq k}} \mathbf{w}_i(t-\tau)\sqrt{p_i(t-\tau)}s_i(t-\tau) + n_k(t) \end{aligned} \tag{1}$$

where $\mathbf{h}^k \in \mathbb{C}^{1\times N_t}$ is a time-varying channel vector, $\mathbf{W} \in \mathbb{C}^{N_t\times K}$ denotes the precoding matrix whose j-th row and k-th column is $w_{j,k}$, $\mathbf{P} \in \mathbb{C}^{K\times K}$ be diagonal matrix of power normalization factor of each RAU, $\mathbf{s} \in \mathbb{C}^{K\times 1}$ is a transmit symbol vector where s_k is a transmit symbol of user k with $E\{|s_k|^2\} = 1$ and n_k is the additive Gaussian noise (AWGN) as $\mathcal{CN}(0, \sigma_k^2)$. The $(1, j)$-th element of the channel vector $\mathbf{h}^{\mathbf{k}}(t)$ represent the channel from RAU j to user k at time t, i.e, $h_{k,j}$. The channel $h_{k,j}(t)$ consists of path loss and Rayleigh fading and is given as:

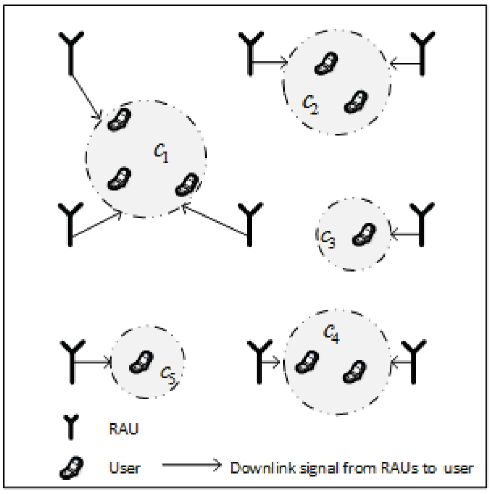

Fig. 2. DAS architecture in cell.

$$h_{k,j}(t) = d_{k,j}^{\frac{-\alpha}{2}}(t)\cdot \tilde{h}_{k,j}(t) \tag{2}$$

where $d_{k,j}^{\frac{-\alpha}{2}}(t)$ denotes the propagation path loss with path loss exponent α due to distance $d_{k,j}$ between user k and RAU j at time t, $\tilde{h}_{k,j}(t)$ is channel fading from RAU j to user k at time t and is independently and identically distributed. The $\tilde{h}_{k,j}(t)$ is a Rayleigh fading and modelled as Jakes fading model [24] where N_0 scatters arrive at moving user with uniformly distributed arrival angles α_n, such that scatter n experiences a Doppler shift $\omega_n = \frac{2\pi f_c v}{c}\cos\alpha_n$ where f_c is the carrier frequency, v is the user speed, c is the speed of light. The received channel is given as

$$\tilde{h}_{k,j}(t) = \sqrt{\frac{2}{N_0}}\sum_{n=1}^{N_0}\mathbf{A}_j(n)[\cos(\beta_n) + i\sin(\beta_n)]\cos(\omega_n t + \theta_n) \tag{3}$$

where $\mathbf{A}_j(n)$ is an orthogonal vector of Walsh-Hadamard codewords to generate multiple uncorrelated waveforms at moving user, $\beta_n = \frac{\pi n}{N_0}$ is a phase and gives zero correlation between the real and imaginary parts of $h_{k,i}(t)$, θ_n is oscillator phase. The arrival angles $\alpha_n = 2\pi(n - 0.5)/N$ and $N_0 = N/4$.

The received SINR of user k at time t is given by

$$\mathrm{SINR}_k(t) = \frac{p_k(t-\tau)|\mathbf{h}^k(t)\mathbf{w}_k(t-\tau)|^2}{\sigma^2 + \sum_{\substack{i\in\mathcal{K}\\ i\neq k}} p_i(t-\tau)|\mathbf{h}^k(t)\mathbf{w}_i(t-\tau)|^2} \tag{4}$$

The achievable user rate (R_k) at time t is

$$\mathrm{R}_k(t) = \log_2(1 + \mathrm{SINR}_k(t)), \quad \forall k \in \mathcal{K} \tag{5}$$

The system sum rate (R) at time t is then written as

$$R(t) = \sum_{k\in\mathcal{K}} R_k(t) = \sum_{k\in\mathcal{K}} \log_2(1 + \mathrm{SINR}_k(t)) \tag{6}$$

In DAS, all RAUs are geographically separated and have individual power amplifier and transceiver architectures. So the per antenna power constraint becomes practically relevant, then the total power constraint. We formulate the sum rate maximization problem at time $t-\tau$ as follows:

$$\max_{\{\mathbf{w}_k\}} \sum_{k=1}^{K} \log_2(1 + \mathrm{SINR}_k(\mathbf{w}_k)) \tag{7a}$$

$$\text{s.t } \max_{j} \sum_{k=1}^{K} \left[\mathbf{w}_k p_k \mathbf{w}_k^H\right]_{j,j} \le \frac{P_t}{N_t} \tag{7b}$$

$$\mathrm{SINR}_k(\mathbf{w}_k) \ge \gamma_k \ \ \forall k \tag{7c}$$

where P_t is a total transmit power, γ_k is target SINR of user k , (7b) is a per antenna power constraint and (7c) is quality of service (QoS) constraint.

In the TDD system, the CU estimates the CSI at the uplink transmit slot and then uses it via channel reciprocals to generate transmit precoder for downlink transmission. There exists a delay τ from the instant when CSI is obtained for downlink transmission. Therefore, the CU designed the precoding based on the estimated channel, which is obtained at time $t-\tau$. Zero-forcing precoding is considered which completely eliminates interference and transforms the SINR of each user into SNR. For zero delay ($\tau = 0$), the actual channel and the estimated channel is an ideal, i.e., perfect CSI. With perfect CSI, $\mathbf{h}_k(t)\mathbf{w}_i(t) = 0 \ \forall k \neq i$ as a result the desired user symbol is perfectly obtained due to elimination inter-user interference. For a non-zero delay ($\tau \neq 0$), the CSI is imperfect and $\mathbf{h}_k(t)\mathbf{w}_i(t-\tau) \neq 0$. Due to this mismatch, the desired user symbol is interfered with the other user symbols due to the presence inter-user interference (IUI). The second term of (1) is the IUI or residual interference.

The problem (7) may be infeasible as (7b) and (7c) give the upper and lower bounds of the transmit power respectively. Assigning all RAUs to all the users may increase infeasibility because it increases the dimension of channel matrix. This gives us a motivation of antenna selection. The problem (7) is difficult to solve directly due to i) non-convex cost function and constraint and ii) the computational complexity of designing a large precoding matrix. The cost function and constraint can relax to the convex. However, the result may not reduce the computational complexity of optimization. Therefore, sub optimization needs to be established. One possible approach is to decompose into multiple problems by antenna selection and user clustering to reduce the computational complexity.

To reduce the impact of residual interference on the system sum rate, the users are divided into a number of groups based on a speed. Each group contains a set of users which has similar speed range. In the DAS, the user experiences different channels from RAUs due to different path loss. This motivates us to consider antenna selection among RAUs and select users by user clustering. This will reduce the system computational complexity while designing precoding matrix. All clusters are served simultaneously using the same frequency resource and suffer from inter cluster interference (ICI). The ICI can be reduced by coordinating the cluster based on the particular needs of a given user. Therefore, each cluster basically cooperates with its non-negligible neighbours. The design of the cooperative user clustering is given in Section III. Let $\mathcal{C}_c$ is the index set of users for the c-th cluster, $\sum_{c=1}^{C} |\mathcal{C}_c| = K$ and $k \cup \mathcal{C}_c$. The RAU of cluster c is denoted RAU_c and $\mathcal{N}_c$ is a subset of RAUs which serves $\mathcal{C}_c$. The received signal $y_c^k(t)$ for k-th user of the c-th cluster at time t, which is expressed as:

$$\begin{aligned} y_c^k(t) &= \mathbf{h}_{c,c}^k(t)\mathbf{W}_c(t-\tau)\sqrt{\mathbf{P}_c(t-\tau)}\mathbf{s}_c(t-\tau) \\ &\quad + \sum_{\substack{j\in C \\ j\neq c}} \mathbf{h}_{c,j}^k(t)\mathbf{W}_j(t-\tau)\sqrt{\mathbf{P}_j(t-\tau)}\mathbf{s}_j(t-\tau) + n_c^k(t) \\ &= \mathbf{h}_{c,c}^k(t)\mathbf{w}_{k,c}(t-\tau)\sqrt{p_k(t-\tau)}s_k(t-\tau) \\ &\quad + \mathbf{h}_{c,c}^k(t) \sum_{\substack{i\in c \\ i\neq k}} \mathbf{w}_{i,c}(t-\tau)\sqrt{p_i(t-\tau)}s_i(t-\tau) \\ &\quad + \sum_{\substack{j\in C \\ j\neq c}} \mathbf{h}_{c,j}^k(t)\mathbf{W}_j(t-\tau)\sqrt{\mathbf{P}_j(t-\tau)}\mathbf{s}_j(t-\tau) + n_c^k(t) \end{aligned} \tag{8}$$

where $\mathbf{h}_{c,c}^k \in \mathbb{C}^{1\times|\mathcal{N}_c|}$ is a channel vector from RAU_c to the k-th user of the c-th cluster, $\mathbf{W}_c \in \mathbb{C}^{|\mathcal{N}_c|\times|\mathcal{C}_c|}$ denotes the precoding matrix for the c-th cluster whose j-th row and k-th column is $w_{j,k}$, $\mathbf{h}_{c,j}^k$ is interfering channel from RAU_j to k-th user of c-th cluster. $\mathbf{P}_c \in \mathbb{C}^{|\mathcal{C}_c|\times|\mathcal{C}_c|}$ be diagonal matrix of power normalization factor of each RAU. We assumed same power normalization factor p for every RAU lies in the same cluster of the group. The achievable rate for the k-th user of the c-th cluster at time t is

$$R_{k,c}(t) = \log_2(1 + \mathrm{SINR}_{k,c}(t)) \tag{9}$$

where

$$\mathrm{SINR}_{k,c}(t) = \frac{p_k(t-\tau)|\mathbf{h}_{c,c}^k(t)\mathbf{w}_{k,c}(t-\tau)|^2}{\sigma^2 + \mathrm{I}_{\text{intra}} + \mathrm{I}_{\text{inter}}} \tag{10}$$

where $\mathrm{I}_{\text{intra}} = \sum_{i\neq k} p_i(t-\tau)|\mathbf{h}_{c,c}^k(t)\mathbf{w}_{i,c}(t-\tau)|^2$ $\mathrm{I}_{\text{inter}} = \sum_{j\notin c} |\mathbf{h}_{c,j}^k(t)\mathbf{W}_j(t-\tau)\sqrt{\mathbf{P}_j(t-\tau)}|^2$.

In order to maximize the cluster sum rate, we consider the cooperative clustering. The joint cooperation RAU selection and user clustering gives sub-problem formulation that maximizes the sum rate at time $t-\tau$ and gives as:

$$\max_{\{\mathbf{w}_{k,c}\}} \sum_{k=1}^{K} \log_2\left(1 + \mathrm{SINR}_{k,c}\left(\mathbf{w}_{k,c}\right)\right) \tag{11a}$$

$$\text{s.t } \max_{j} \sum_{k=1}^{K} \left[\mathbf{w}_{k,c} p_k \mathbf{w}_{k,c}^H\right]_{j,j} \le \frac{P_t}{N_t} \tag{11b}$$

$$\mathrm{SINR}_k\left(\mathbf{w}_{k,c}\right) \ge \gamma_k \ \ \forall k \tag{11c}$$

III. COOPERATIVE CLUSTER FORMATION

The cooperative cluster is formed to serve the set of users $\mathcal{C}_c$ while considering the non-negligible interference. The cooperation cluster formation consists of an antenna selection (phase one) and user clustering (phase two) algorithms. We assign the user to the RAU based on the channel gain. Then, the pair of user-RAU is selected to form cluster based on cluster SINR threshold where the obtained SINR of user is less than the cluster SINR threshold (γ_0). The cluster formation is done after the channel estimation at the uplink transmit slot.

A. Antenna Selection

Antenna selection is done at the CU based on the estimated channel. At the uplink transmit slot, the CU estimates channel for all users from all RAUs. Let N_k be a predetermined number of RAUs that are supposed to be assigned to user k. At each stage, the CU assigns the RAU j to the user k based on the strongest channel gain of the estimated channel, given by

$$j = \arg\max_{j \in \mathcal{N},\ k \in \mathcal{K}} |h_{k,j}(t)|^2 \tag{12}$$

then the user k and the RAU j will be removed from allocation procedure. This procedure is repeated until all users are assigned to the RAUs.

B. User Clustering

Each user has own mobility speeds. We assume that the MSI is perfectly known at the CU. Based on user speed (v), the users are classified into groups as follows:

$$\begin{array}{ll} 0 \leq \text{speed} \leq v_1 & \text{Low mobility} \\ v_1 < \text{speed} \leq v_2 & \text{Medium mobility} \\ v_2 < \text{speed} \leq v_3 & \text{High mobility} \end{array} \tag{13}$$

After the antenna selection, each group selects the first user k and its associated RAU which has the highest channel gain. The next user i is chosen from the remaining unselected pairs and compute the SINR. The SINR is calculated under the assumption of maximum power transmission and maximum ratio combining [15] and given as:

$$\gamma_{k,i} = \min\left\{ \frac{\sum_{j \in |\mathcal{N}_k|} |h_{k,j}|^2 P_j}{\sigma^2 + \sum_{\tilde{j} \in |\mathcal{N}_i|} |h_{k\tilde{j}}|^2 P_{\tilde{j}}}, \frac{\sum_{j' \in |\mathcal{N}_i|} |h_{ij'}|^2 P_{\tilde{j}}}{\sigma^2 + \sum_{j \in |\mathcal{N}_k|} |h_{ij}|^2 P_j} \right\} \tag{14}$$

where $|\mathcal{N}_k|$ is a set of RAUs to serve the user k. If the minimum SINR between the selected user and the chosen user ($\gamma_{k,i}$) is less or equal to γ_0, i.e., $(\gamma_{k,i}) \leq \gamma_0$, then the chosen user is added to the cluster. This process is repeated until all the pairs of user-RAU are assigned to the cluster.

The performance of the system is severely degraded by inter-group-inter-cluster interference, which is uncoordinated. In the uncoordinated case, if the SINR of two interfering users of the neighbouring clusters are smaller than the cluster SINR threshold, then the neighbouring clusters are merged and form a cooperative cluster.

To satisfy QoS constraint (11c), We proposed an iterative antenna selection algorithm. In the iterative antenna selection algorithm, the RAU is assigned to those users of the cluster whose SINR is less than target SINR, i.e., $\text{SINR}_k \geq \gamma_k$. The iterative process is repeating until all the users of the cluster satisfy the QoS constraint.

IV. FEEDBACK INTERVAL ALLOCATION

This subsection describes a feedback time slot allocation for the cluster to minimize the channel mismatch error. Fig. 1 shows the feedback model and the frame structure of the TDD system. We assume that the channel matrix is not changing during a time slot (with length T_c). For simplicity, we assume there are N (an integer) time slots in a time frame, i.e., $T = NT_c$ and first time slot is always use for uplink pilot.

When the mobility speed increases or the transmission delay increases, the channel mismatch occurs which severely degrades the performance. This motivates us to calculate the feedback interval of the mobility user based on the autocorrelation of the channel. The autocorrelation, $R(\tau)$, of the channel is equal to the zeroth order Bessel function of the first kind, $J_0(.)$, as,

$$R(\tau) = J_0(2\pi f_d \tau) \tag{15}$$

where f_d is the maximum Doppler shift and τ is a delay, i.e., $\tau = nT_c$, $n = \{1, \cdots, \cdots, N\}$. As mentioned above, a long feedback interval limits the system performance. In order to overcome the problem, we introduce a minimum autocorrelation coefficient ρ_o. Therefore, when $R(\tau) < \rho_o$, nT_c becomes next consequent uplink time slot. The feedback interval (T_f) of the user becomes,

$$T_f = (n-1)T_c, \text{ where } n = \{1, \cdots, \cdots, N\} \tag{16}$$

Let N_u and N_d be number of uplink/feedback time slots and number of downlink time slots respectively, which are given as:

$$N_u = \frac{NT_c}{T_f} \text{ and } N_d = N - N_u \tag{17}$$

Let T_u be uplink/feedback time slot of time frame T and given as:

$$T_u = 1 + (m-1)\frac{N}{N_u}, \text{ where } m = \{1, \cdots, \cdots, N_u\} \tag{18}$$

In the cooperative clustering, each cluster may have user with different range of mobility to cancel the inter-group interference. Therefore, the feedback time slot of the cooperative cluster is allocated based on the fastest mobility user, to minimize the mismatch error of the high mobility user.

V. SIMULATION RESULTS

We consider a TDD downlink MU-DAS system. We assume that the users have different mobility and its speed range is 0 to 15 m/s. We assume that the MSI is perfectly known at the CU. We assume that user speed is random between 0m/s to 15m/s. In the antenna selection, the number of RAUs assigns to user is one. Table I summarizes the MU-DAS system parameters.

TABLE I
SIMULATION PARAMETERS

Parameter Settings	Value
Cell Model	square grid1 km^2
Carrier Frequency	2 GHz
Number of RAUs	400
Intra RAU distance	50 m
Number of users	2 to 12
Users distribution	Uniform
Min dist. between RAU and user	5 m
Path loss exponent	3
Number of scatterers	64
Radio frame duration	10 ms
Time slot duration	0.1 ms
Total transmit power (P_t)	46 dBm
Noise power	-104 dBm
User speed range	0 m/s to 15 m/s
Cluster SINR threshold	20 dB
User target SINR	50 dB
Minimum autocorrelation	0.8

The users are classified into four groups based on its speed as follows:

$0 \leq \text{speed} \leq 2 \quad (\text{m/s})$ Low mobility
$2 < \text{speed} \leq 4 \quad (\text{m/s})$ Medium mobility
$4 < \text{speed} \leq 9 \quad (\text{m/s})$ Moderate mobility
$9 < \text{speed} \leq 15 \quad (\text{m/s})$ High mobility

Assuming the minimum autocorrelation coefficient $\rho_o = 0.8$, the number feedback time slots N_u and the number of downlink time slots N_d is calculated based on (17). Fig.3 illustrates the feedback interval of different mobility users as a function of time delay. The $R(\tau)$ of user with speed above 2m/s has always been higher than ρ_o. When users speed increase or transmission delay increases, the $R(\tau)$ become less than ρ_o. So, the next time slot becomes uplink time slot. For simplicity, we assume that there are equal number of M (an integer) time slot in each feedback interval, i.e., $T_f = MT_c$ and $M < N$. Therefore, the $R(\tau)$ of user with speed 4m/s becomes high when transmission delay is 5.1ms, i.e., $T_f = 50$ms, $M = 50$. Table II summarizes the uplink/feedback and downlink parameters for performance evaluation.

TABLE II
FEEDBACK PARAMETERS

Speed (m/s)	N_u	N_d	T_u
0 - 2	1	99	1^{st}
2 - 4	2	98	$1^{st}, 51^{st}$
4 - 9	5	95	$1^{st}, 21^{st}, 41^{st}, 61^{st}, 81^{st}$
9 - 15	10	90	$1^{st}, 11^{st}, 21^{st}, 31^{st}, 41^{st},$ $51^{st}, 61^{st}, 71^{st}, 81^{st}, 91^{st}$

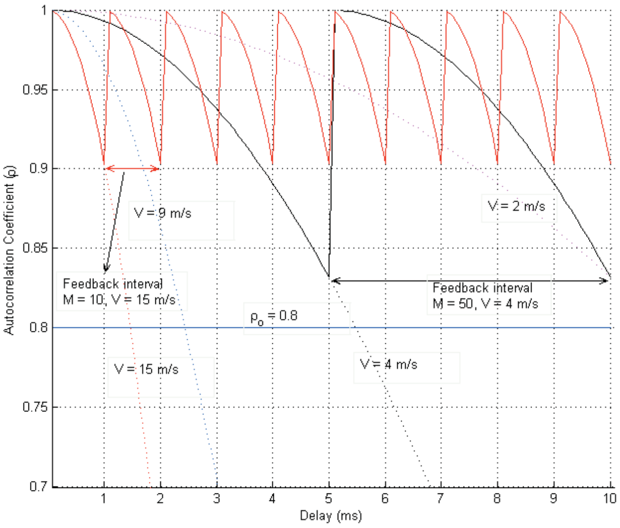

Fig. 3. Illustration of feedback interval of different mobility users where minimum autocorrelation coefficient is 0.8.

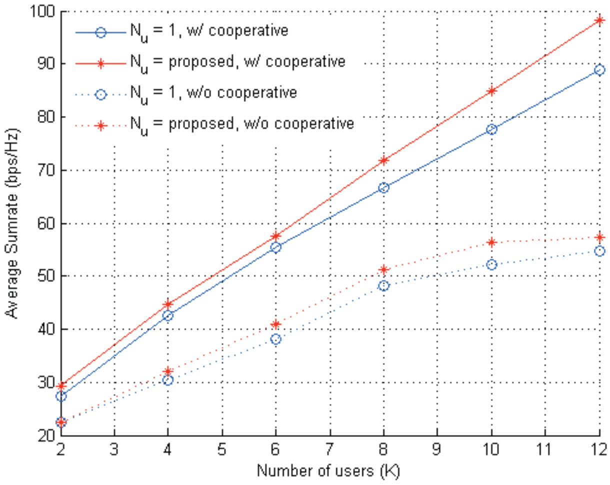

Fig. 4. Illustration of Average sum rate of different users mobility with and without cooperative clustering where clustering threshold is 20dB and user target SINR 50 dB at feedback time slot.

In Fig. 4 illustrates the average sum rate for the DAS with and without cooperative clustering; the performance of the proposed feedback interval technique is also compared with a system with number of feedback interval is one ($N_u = 1$) in this figure. Clearly the DAS with cooperative clustering outperforms the system without cooperative clustering due to joint processing of the signal which cancels intergroup-inter-cluster interference. The residual interference and the noise is the only limiting factor. Within the non-cooperative clustering, the average sum rate with and without proposed feedback interval is similar. This is because the SINR is mainly affected by the inter-group-inter-cluster interference and limits the system sum rate. It is also observed that in cooperative clustering, the system employing the proposed feedback interval technique outperforms the system with number of feedback interval is one ($N_u = 1$). This is because at every feedback time slot of the proposed feedback interval technique, the CSI is updated as shown in Fig.3 and the residual interference reduces, and noise becomes the only limiting factor to performance.

Fig. 5 illustrates the average sum rate the DAS with and without MSI. The performance of the proposed feedback interval technique is also compared with a system with number of feedback interval is one ($N_u = 1$). It is observed that when the number of feedback interval is one, the DAS without MSI outperforms the system with MSI. This is because the knowledge of MSI increases the number of users in a cooperative cluster and decreases the number of clusters. This consequently increases the number of RAUs in the cluster. Due to the increment of RAUs, the per antenna power constraint becomes more strict, i.e., if one of the RAUs transmit power exceeded the constraint, then the transmit power of all RAUs of the cluster is

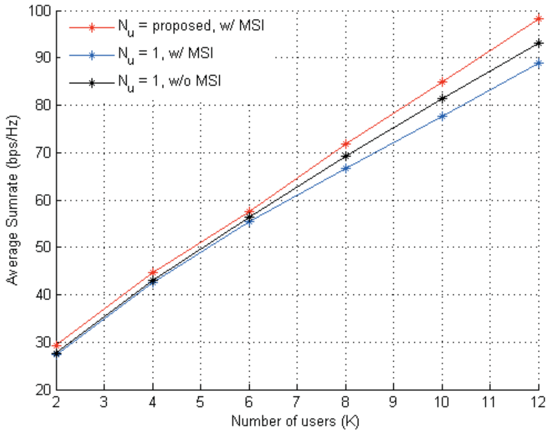

Fig. 5. Illustration of Average sum rate of different users mobility with and without MSI where cooperative clustering is formed.

normalized. However, the proposed feedback interval technique with knowledge of MSI outperforms the system without MSI. This is because the CSI is updated at every feedback time slot and the residual interference is reduced.

VI. CONCLUSION

This paper has studied the sum rate of TDD downlink MU-DAS with the consideration of different user speed. A feedback interval reduction technique based on an autocorrelation of the channel is proposed to minimize the channel mismatch error. Using MSI knowledge, user are divided into multiple groups to implement the proposed feedback interval technique. The system computational complexity is reduced by channel gain based antenna selection and SINR threshold based user clustering. To maximize the sum rate, we have proposed the cooperative clustering. The numerical results have shown that the proposed technique can maximize the system sum rate over a time varying channel in MU-DAS.

REFERENCES

[1] H. Zhu, ”Radio resource allocation for OFDMA systems in high speed environments,” IEEE Journal on Selected Areas in Communications, vol. 30, pp. 748-759, May 2012.

[2] H. Zhu and J. Wang, ”Chunk-based resource allocation in OFDMA systems - Part I: chunk allocation,” IEEE Transactions on Communications, vol. 57, no. 9, pp. 2734-2744, Sept. 2009.

[3] H. Zhu and J. Wang, ”Chunk-based resource allocation in OFDMA systems - Part II: joint chunk, power and bit allocation,” IEEE Transactions on Communications, vol. 60, no. 2, pp. 499-509, Feb. 2012.

[4] H. Zhu and J. Wang, ”Performance analysis of chunk-based resource allocation in multi-cell OFDMA systems,” IEEE Journal on Selected Areas in Communications, vol. 32, no. 2, pp. 367-375, February 2014.

[5] H. Zhu, ”On frequency reuse in cooperative distributed antenna systems”, IEEE Communications Magazine, vol. 50, no. 4, pp.85-89, April 2012.

[6] H. Zhu, S. Karachontzitis and D. Toumpakaris, ”Low-complexity resource allocation and its application to distributed antenna systems,” IEEE Wireless Communications Magazine, vol. 17, no. 3, pp. 44-50, June, 2010.

[7] H. Zhu, B. Xia and Z. Tan, ”Performance analysis of Alamouti transmit diversity with QAM in imperfect channel estimation,” IEEE Journal on Selected Areas in Communications, vol. 29, no. 6, pp. 1242-1248, June, 2011.

[8] H. Osman, H. Zhu, D. Toumpakaris, and J. Wang, ”Achievable rate evaluation of in-building distributed antenna systems,” IEEE Transactions on Wireless Communications, vol. 12, no. 7, pp. 3510-3521, July 2013.

[9] T. Alade, H. Zhu, and J. Wang, ”Uplink spectral efficiency analysis of in-building distributed antenna systems,” IEEE Transactions on Wireless Communications, vol. 14, no. 7, pp. 4063-4074, July 2015.

[10] X. You, et al, ”Cell edge performance of cellular mobile systems,” *IEEE J. Sel. Areas Commun.,* vol. 29, no. 6, pp. 1139-1150, Jun. 2011.

[11] H. Zhu, ”Performance comparison between distributed antenna and microcellular systems,” *IEEE J. Sel. Areas in Commun.,* vol. 29, no. 6, pp. 1151-1163, Jun. 2011.

[12] L. Dai, ”A comparative study on uplink sum capacity with co-located and distributed antennas,” *IEEE J. Sel. Areas Commun.,* vol. 29, no. 6, pp. 1200-1213, Jun. 2011.

[13] J. Wang, H. Zhu and N. J. Gomes, ”Distributed antenna aystems for mobile communications in high speed trains,” *IEEE J. Sel. Areas in Commun.,* vol. 30, no. 4, pp. 675-683, April 2012.

[14] H. Zhu and J. Wang, ”Radio resource allocation in multiuser distributed antenna systems,” *IEEE J. Sel. Areas in Commun.,* vol. 31, no. 10, pp. 2058-2066, Oct. 2013.

[15] J. Joung, Y. K. Chia and S. Sun, ”Energy-efficient, large-scale distributed-antenna system (L-DAS) for multiple users,” *IEEE J. Sel. Top. Sign. Proces.,* vol. 8, no. 5, pp. 954-965, Oct. 2014.

[16] A. Wiesel, Y. C. Eldar and S. Shami, ”Zero-Forcing precoding and generalized inverses,” *IEEE Trans. Signal Processing,* vol. 56, no. 9, pp. 4409-4418, Sept. 2008.

[17] C. Xing, S. Ma, and Y. Zhou, Matrix-monotonic optimization for MIMO systems, *CoRR*, vol. abs/1312.1766, 2013.

[18] B, Bandemer, M, Haardt and S, Visuri, ”Linear MMSE Multi-User MIMO Downlink Precoding for Users with Multiple Antennas,” *Personal, Indoor and Mobile Radio Communications,* pp. 1-5, Sept. 2006.

[19] I. Sohn, K. B. Lee and Y. S. Choi, ”Comparison of decentralized time slot allocation strategies for asymmetric traffic in TDD systems,” *IEEE Trans. Wireless Commun.,* vol. 8, no. 6, pp 2990-3003, Jun. 2009.

[20] P. Komulainen, A. Tolli and M. Juntti, ”Effective CSI signaling and decentralized beam coordination in TDD multi-cell MIMO systems,” *IEEE Trans. Sign. Proces.,* vol. 61, no. 9, May 2013.

[21] S. Pandula and B-P. Paris, ”Performance analysis of MIMO receivers under imperfect CSIT,” *IEEE Inform. Sciences and Systems,* pp. 107-112, Mar. 2007.

[22] G. Primolevo, O. Simeone and U. Spagnolini, ”Effects of imperfect channel state information on the capacity of broadcast OSDMA-MIMO systems,” *IEEE Workshop on Sig. Proc. Advances in Wireless Commun.,* pp. 546-550, Jul. 2004.

[23] H. Shirani-Mehr, G. Caire and M. J. Neely, ”MIMO downlink scheduling with non-perfect channel state knowledge,” *IEEE Trans. Commun.,* vol. 58, no. 7, pp. 2055-2066, Jul. 2010.

[24] P. Dent, G. E. Bottomley and T. Croft, ”Jakes fading model revisited,” *IEEE Electron. lett.,* vol.29, no.13, pp. 1162-1163, Jun. 1993.