Multiuser Diversity-Aware Autonomous Decentralized TRP Group Selection to Maximize System Throughput in Downlink Distributed MIMO

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***Abstract*—This paper investigates a method for each user equipment (UE) to select its connected transmission reception point (TRP) groups to maximize the system throughput, defined as the generalized average of user throughput, in a downlink distributed MIMO (multi-input multi-output) system. As a realistic assumption, the TRP groups to be selected are pre-determined by the system. We extend our previously reported TRP group selection method, which assumed a static channel environment without fading, to accommodate the multiuser diversity effect obtained from the user scheduling in a fading channel. To consider the multiuser diversity effect during TRP group selection, each TRP group calculates the expected multiuser diversity gain in terms of the achievable throughput gain based on the actual temporal data transmission results of connected users. Each TRP group broadcasts this information, and users calculate the TRP group selection metric using this information. The proposed method achieves autonomous and distributed TRP group selection that adapts to fading environments and maximizes the system throughput. Computer simulations quantitatively demonstrate the effectiveness of the proposed method compared to conventional TRP group selection methods.**

***Keywords*—Distributed MIMO, System throughput, Transmission reception point, TRP group selection, Multiuser diversity**

I. Introduction

Future mobile communication systems such as 5G new radio (NR) [1, 2] and 6G [3, 4] are expected to achieve more uniform and higher throughput across the entire system coverage area to support various use cases that will shape the future of industry and society. For this requirement, network multiple-input multiple-output (MIMO) [5] and coordinated multiple point transmission (CoMP) [6] improve the throughput by eliminating cell boundaries between cooperating base stations. They enable a MIMO transmission utilizing more transmitter and receiver antennas at the network level, thereby increasing the throughput. Furthermore, distributed antenna systems (DASs) [7] and distributed / cell-free MIMO [8-11], in which antennas are distributed throughout the system coverage, are expected to achieve lower required transmission power and higher total throughput compared to MIMO transmission in which many antennas are locally deployed, by reducing the area of insensitivity. Therefore, distributed / cell-free MIMO has been actively studied for application to 5G NR and beyond [1, 3].

In this paper, we consider downlink distributed MIMO, and each of the distributed antennas is denoted as a transmission reception point (TRP) following the notation in NR [1]. In addition, we assume that a group of TRPs, referred to as a TRP group, is preconfigured within the system to enable cooperative data transmission. When TRP groups are predefined by the system, the selection of the TRP group for each user equipment (UE) affects the transmission quality of that UE and other UEs in downlink distributed MIMO. This is because the number of UEs in a TRP group changes when UEs change their connected TRP group. Each TRP only allocates bandwidth to UEs in its group, and when the number of UEs in a TRP group changes, bandwidth must be allocated to the newly connected UEs. This alters the bandwidth allocation for the other UEs, thereby changing the transmission quality of each UE. Therefore, to maximize the system throughput, each UE must consider these effects when selecting the optimal TRP group for connection.

In [11-14], TRP group selection methods based on received signal power were proposed. These methods individually select the TRP group based solely on the received signal power from the TRPs without considering bandwidth allocation or its impact on the throughput of other UEs. To cope with this issue, our group proposed a TRP group selection method to maximize the system throughput, defined as the generalized mean of user throughput with exponent p in [15, 16]. In this method, each UE independently calculates a metric for TRP group selection based on the maximization of the system throughput using supplementary information about the bandwidth allocated to newly connected UEs on the downlink. After that, each UE informs the metric value of the best TRP group with the highest value. Finally, each TRP group determines the UE to be newly connected based on the metrics reported by UEs. By iteratively repeating this process, appropriate TRP group selection for all UEs is achieved through autonomous distributed control. However, the TRP group selection method in [15, 16] assumes a static channel environment without fading variation and cannot utilize the multiuser diversity effect [17, 18] obtained from scheduling that dynamically allocates bandwidth to each UE based on instantaneous fading.

In this paper, we propose a TRP group selection method that maximizes system throughput while adapting to real environments where instantaneous fading occurs. In such environments, the multiuser diversity effect obtained from scheduling depends on the number of candidate UEs determined by TRP group selection. Therefore, to maximize system throughput, the TRP group selection considering this effect is required. Thus, we extend our previously reported TRP group selection method in [15, 16], which calculates estimated user throughput for each UE by assuming static channels in metric calculation, to consider the multiuser diversity effect obtained from proportional fairness (PF) scheduling at the TRP group level. Specifically, each TRP group calculates the multiuser diversity gain, expressed as the throughput gain per TRP group, based on the scheduling and the actual temporal data transmission results of currently connected UEs. Then, each TRP group broadcasts to UEs this throughput gain in addition to the supplementary information of the conventional method. After that, each UE multiplies the reported multiuser diversity gain by the user throughput normalized by the total allocated bandwidth assuming static channels to predict the throughput that accounts for multiuser diversity effects. As with the conventional method in [15, 16], each UE calculates metrics using the predicted throughput, and the connected TRP groups are updated based on these metrics. By iterating these processes, the proposed method autonomously and distributed achieves connection TRP group selection that maximizes system throughput under instantaneous fading conditions. Computer simulations quantitatively demonstrate the improvement in system throughput achieved by the proposed method compared to conventional methods.

The remainder of this paper is organized as follows. Section II describes the system model. Section III presents the conventional methods, and Sect. IV details the proposed method. Section V evaluates their performance through computer simulations. Finally, Sect. VI concludes the paper.

II. System Model

Let $\mathcal{B}$ and $\mathcal{K}$ be the sets of TRPs and UEs within the system coverage, respectively. The TRPs are spatially distributed and each is connected to the nearest central processing unit (CPU). Multiple CPUs are placed in the system coverage, and the TRPs connected to the same CPU constitute a TRP group that cooperatively transmits data to the UEs connected to that TRP group. Each UE connects to a single TRP group and communicates using a portion of the system bandwidth W allocated by each TRP within the TRP group. Each TRP transmits a separate data stream to the target UE. Let $\mathcal{N}$ denote the set of TRP groups in the system coverage, and let $\mathcal{B}_n$ denote the set of TRPs belonging to TRP group $n \in \mathcal{N}$. The discrete time t denotes the unit assumed to be the TRP group selection of UEs cycles.

The purpose of this paper is to maximize system throughput $U(t)$, which is defined as the generalized mean of the user throughput and expressed as

$$U(t)=\left(\frac{1}{|\mathcal{K}|}\sum_{k\in\mathcal{K}}R_k(t)^p\right)^{\frac{1}{p}}. \tag{1}$$

Here, $R_k(t)$ denotes the throughput of UE $k \in \mathcal{K}$ at time t, and p ($p \le 1$) is the generalized mean index that controls the tradeoff between system efficiency and the fairness among UEs regarding the throughput performance. For best-effort services where spectrum efficiency is essential, p should be set to a large value. While for quality-guaranteed services where fairness among users is critical, p should be set to a small value. When p is 1, 0 (the limit of), −1, and −∞, $U(t)$ is equivalent to the arithmetic mean, the geometric mean, the harmonic mean, and the minimum of user throughput, respectively.

III. Conventional Method

This section describes the conventional TRP group selection method described in [15, 16], which will be evaluated in Sect. 5 along with the proposed method. The conventional method assumes a static environment without fading variation and aims to maximize the system throughput $U(t)$.

Under a static environment, the user throughput $R_k(t)$ is defined as

$$R_k(t)=R_k(t-1)+\frac{1}{T_{\text{avg}}}\left\{\sum_{n\in\mathcal{N}}b_{k,n}(t)\sum_{j\in\mathcal{B}_n}\rho_{k,n,j}^{\text{static}}(t)r_{k,n,j}^{\text{static}}(t)-R_k(t-1)\right\}, \tag{2}$$

where T_{avg} represents the averaging time, and $r_{k,n,j}^{\text{static}}(t)$ denotes the link-level throughput per hertz of UE k connected to TRP j of TRP group n under a static environment. Term $b_{k,n}(t)$ is an indicator if UE k is connected to TRP group n at time t and is defined as

$$b_{k,n}(t)=\begin{cases}1, \text{if UE } k \text{ is connected to TRP group } n \text{ at time } t\\ 0, \qquad\qquad \text{otherwise}\end{cases}$$
$$\sum_{n\in\mathcal{N}}b_{k,n}(t)=1. \tag{3}$$

The determination of $\{b_{k,n}(t)\}$ corresponds to the selection of the TRP group. $\rho_{k,n,j}^{\text{static}}(t)$ is the bandwidth allocated by TRP j to UE k in static environments. To maximize $U(t)$ assuming static environments, the optimal bandwidth allocation for UE $k \in \mathcal{K}_n(t)$, a UE set connected to TRP group n at time t, is determined using (4).

$$\rho_{k,n,j}^{\text{static}}(t)=\max\left\{\mu_{n,j}(t)\{r_{k,n,j}^{\text{static}}(t)\}^{\frac{p}{1-p}}-\frac{\sum_{j'\in\mathcal{B}_n\setminus\{j\}}\rho_{k,n,j'}^{\text{static}}(t)r_{k,n,j'}^{\text{static}}(t)}{r_{k,n,j}^{\text{static}}(t)},0\right\}, \tag{4}$$

where the Lagrange multiplier $\mu_{n,j}(t)$ is calculated so that the total allocated bandwidth equals the system bandwidth W. In (4), the optimal bandwidth allocation to UEs within the TRP group is achieved by switching sequentially among the TRPs within the TRP group and repeatedly calculating $\rho_{k,n,j}^{\text{static}}(t)$ and $\mu_{n,j}(t)$ for all connected UEs.

Next, the conventional method considers the determination of $\{b_{k,n}(t)\}$ to maximize $U(t)$. From the Taylor expansion of $U(t)$ examined in [15,16], the metric that each UE should calculate for the determination of $\{b_{k,n}(t)\}$ to maximize $U(t)$ is given by

$$M_{k,n}(t)=\frac{1}{R_k(t-1)^{1-p}}\left[\hat{R}_{k,n}(t)-R_k(t-1)\right], \tag{5}$$

where $\hat{R}_{k,n}(t)$ is the predicted user throughput assuming that UE k connects to TRP group n at time t. In the static channels, $\hat{R}_{k,n}(t)$ is expressed as the product of the allocated bandwidth and the link throughput. Therefore, each UE k calculates the predicted bandwidth allocation based on the reported supplementary information $\mu_{n,j}(t-1)$ and its own measured $r_{k,n,j}^{\text{static}}(t)$ by equation (6).

$$\tilde{\rho}_{k,n,j}^{\text{static}}(t)=\max\left\{\mu_{n,j}(t-1)\{r_{k,n,j}^{\text{static}}(t)\}^{\frac{p}{1-p}}-\frac{\sum_{j'\in\mathcal{B}_n\setminus\{j\}}\rho_{k,n,j'}^{\text{static}}(t)r_{k,n,j'}^{\text{static}}(t)}{r_{k,n,j}^{\text{static}}(t)},0\right\}. \tag{6}$$

However, if the predicted bandwidth is directly used, the total allocated bandwidth, which includes the bandwidth allocated to the newly connected UE, exceeds W. Thus, the final prediction $\hat{\rho}_{k,n,j}^{\text{static}}(t)$ is obtained by normalizing $\tilde{\rho}_{k,n,j}^{\text{static}}(t)$ as follows

$$\hat{\rho}_{k,n,j}^{\text{static}}(t)=\frac{W}{\tilde{\rho}_{k,n,j}^{\text{static}}(t)+W}\tilde{\rho}_{k,n,j}^{\text{static}}(t). \tag{7}$$

After calculating the metric $M_{k,n}(t)$ for all TRP groups, each UE reports the metric corresponding to the TRP group that provides the maximum positive value as a handover request. Each TRP group then selects one UE with the highest reported metric for new connection at time t. By repeating the above process, the TRP group selection of all UEs that maximizes $U(t)$ is achieved in an autonomous decentralized process.

IV. Proposed Method

This section describes the proposed TRP group selection method for maximizing system throughput under a fading environment.

Compared to the static channel assumption of the conventional method, a fading channel requires dynamic bandwidth allocation to account for varying channel conditions over time. In this case, the bandwidth allocation is based on PF scheduling [19, 20]. When the discrete time τ is assumed to be the unit of the scheduling cycles, PF scheduling allocates the bandwidth of each frequency block to UE k that maximizes the following metric

$$\frac{\sum_{n\in\mathcal{N}} b_{k,n}(t) r_{k,n,j}^{\text{dynamic}}(\tau,f)}{R_k(t-1)^{1-p}}. \tag{8}$$

This is the link throughput of frequency block f at time τ, $r_{k,n,j}^{\text{dynamic}}(\tau,f)$, normalized by the user throughput at time t−1. In equation (8), p ($p \le 1$) is a parameter that determines the tradeoff between system efficiency and fairness among UEs, which is the same parameter as p in equation (1). When p = 1, 0, −1, −∞, respectively, the norms become total rate maximization, proportional fairness, transmission delay minimization, and minimum rate maximization. In fading environments, this PF scheduling dynamically allocates bandwidth to UEs within the TRP group, thereby the predicted bandwidth under a static environment in equation (6) can significantly differ from the actual allocated bandwidth. Furthermore, the link throughput under PF scheduling tends to increase compared to static environments due to the multiuser diversity effect. This multiuser diversity effect depends on the number of candidate UEs for scheduling determined by TRP group selection. Thus, the design of metrics that account for multiuser diversity effects is required to achieve more appropriate TRP group selection in fading environments.

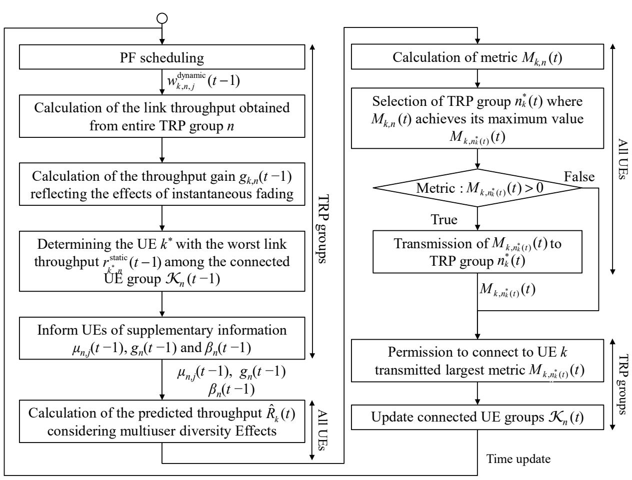

Fig. 1. Flow of the proposed method.

Next, we describe the proposed TRP group selection method for each UE. Fig. 1 summarizes the flow of the proposed method. The proposed method extends the TRP group selection process in [15, 16] by considering the effect of PF scheduling and aims to maximize system throughput under instantaneous fading environments. The proposed method utilizes the metric defined in equation (5) of the conventional method. However, in fading environments, each UE needs to consider the multiuser diversity effect obtained from PF scheduling when calculating the predicted user throughput $\hat{R}_{k,n}(t)$. However, each UE can calculate only the link throughput equivalent to a static channel based on the average signal-to-interference-plus-noise ratio (SINR) and the currently allocated bandwidth. To account for multiuser diversity effects, supplementary information from the target TRP group is required. Therefore, the throughput gain obtained from PF scheduling is calculated as the throughput increase rate compared to the static channels based on the communication status of the currently connected UEs. By multiplying this throughput gain and the user throughput normalized by the total allocated bandwidth assuming static channels, the proposed method calculates a predicted user throughput considering the multiuser diversity gain. The following describes the calculation of the throughput gain.

To calculate the throughput gain accurately, the proposed method utilizes the allocated bandwidth $w_{k,n,j}^{\text{dynamic}}(t-1)$ obtained from each TRP j through PF scheduling at time t−1 as the predicted value for a newly connecting UE at time t and the information for metric calculation. Furthermore, $r_{k,n,j}^{\text{dynamic}}(t)$ denotes the link-level throughput per hertz of UE k connected to TRP j of TRP group n in a fading environment. The values of $w_{k,n,j}^{\text{dynamic}}(t-1)$ and $r_{k,n,j}^{\text{dynamic}}(t)$, measured at 1 ms scheduling intervals, are averaged over each TRP group during the 500 ms TRP group selection cycle before they are utilized.

Based on the averaged $w_{k,n,j}^{\text{dynamic}}(t-1)$ and $r_{k,n,j}^{\text{dynamic}}(t)$, the proposed method calculates the throughput of UE k, normalized by the total bandwidth allocated by TRP group n, as follows

$$r_{k,n}^{\text{dynamic}}(t-1) = \frac{\sum_{j\in\mathcal{B}_n} w_{k,n,j}^{\text{dynamic}}(t-1) r_{k,n,j}^{\text{dynamic}}(t-1)}{\sum_{j\in\mathcal{B}_n} w_{k,n,j}^{\text{dynamic}}(t-1)}, \tag{9}$$

$$r_{k,n}^{\text{static}}(t-1) = \frac{\sum_{j\in\mathcal{B}_n} \rho_{k,n,j}^{\text{static}}(t-1) r_{k,n,j}^{\text{static}}(t-1)}{\sum_{j\in\mathcal{B}_n} \rho_{k,n,j}^{\text{static}}(t-1)}. \tag{10}$$

To account for the multiuser diversity effect under fading channels, the link throughput gain is defined as

$$g_{k,n}(t-1) = \frac{r_{k,n}^{\text{dynamic}}(t-1)}{r_{k,n}^{\text{static}}(t-1)}. \tag{11}$$

The UEs that repeatedly update the connected TRP group are likely to be located at the edge of the TRP group. Therefore, for each TRP group n, the UE k_n^* with the minimum $r_{k,n}^{\text{static}}(t)$ received from the entire TRP group within $\mathcal{K}_n(t-1)$ is identified.

Then, each TRP group n broadcasts supplementary information of $\mu_{n,j}(t-1)$, $g_n(t-1)$, $\beta_n(t-1)$ to UEs for calculating the estimated link throughput. Here, $g_n(t-1)$ corresponds to the link throughput gain $g_{k_n^*,n}(t-1)$ of UE k_n^*, and $\beta_n(t-1)$ corresponds to the sum of the bandwidth $w_{k_n^*,n,j}^{\text{dynamic}}(t-1)$, normalized in the same manner as in equation (7).

After the broadcast, UE k calculates its predicted link throughput when connected to TRP group n at time t, as follows

$$\hat{r}_{k,n}^{\text{dynamic}}(t) = g_n(t-1) \frac{\sum_{j\in\mathcal{B}_n} \hat{\rho}_{k,n,j}^{\text{static}}(t) r_{k,n,j}^{\text{static}}(t)}{\sum_{j\in\mathcal{B}_n} \hat{\rho}_{k,n,j}^{\text{static}}(t)}. \tag{12}$$

Based on this predicted link throughput and $\beta_n(t-1)$, UE k calculates the predicted user throughput using equation (13).

$$\hat{R}_{k,n}(t) = \beta_n(t-1)\hat{r}_{k,n}(t). \quad (13)$$

By applying the predicted throughput in equation (13) to equation (5), TRP group selection considering multiuser diversity effects is achieved. Using the metric in equation (5), by repeating the selected TRP group selection in the same manner as conventional method in [15, 16], the TRP group selection of all UEs that maximizes $U(t)$ under fading conditions is achieved in an autonomous decentralized process.

In the proposed method, each TRP group needs to broadcast supplementary information in the downlink to enable each UE to estimate its own throughput. However, this additional downlink overhead is sufficiently small, since each TRP group broadcasts only a few scalars every TRP group update interval, such as 500 ms. Moreover, the feedback of the metric in the uplink is practical, as similar procedures are already adopted in real systems such as 5G NR. Therefore, the signaling overhead introduced by the proposed method is applicable to large-scale networks.

V. Numerical Results

Table I gives the simulation parameters. The CPUs, TRPs, and UEs are placed randomly within a wrap-around 2 × 2-km^2 system coverage area based on the Poisson point process (PPP). The CPU density M and UE density K per km^2 are parameterized in the following evaluation. TRP density is set to 10 per km^2. Each TRP is connected to the CPU with the minimum distance to itself. The numbers of TRP and UE antennas are set to 10 and 1, respectively. TRPs perform beamforming equivalent to maximum ratio transmission (MRT) using closely located transmitter antennas and independently transmit data streams. The system bandwidth is 9 MHz, and the transmit signal power per TRP is set to 30 dBm. The distance-dependent path loss and log-normal shadowing based on the parameters listed in Table I are simulated as a propagation channel model [21]. The UE receiver noise power density is set to −165 dBm/Hz. The PF scheduling interval and the TRP group update interval were set to 1 ms and 500 ms, respectively. The initial configuration of the TRP group selection process in the proposed method was based on the conventional method in [15, 16]. In addition to the proposed method, the conventional method in [15, 16] and the path loss-based method in [11-14], where each UE selects the TRP with the highest path gain and then connects to its TRP group, are evaluated for comparison.

TABLE I. Simulation Parameters

System coverage		Wraparound 2 km × 2 km
Number of antennas per TRP		10
Number of antennas per UE		1
Node density	CPU	$M = 1 \sim 5$ per km^2
	TRP	10 per km^2
	UE	$K = 5 \sim 35$ per km^2
System bandwidth		9 MHz
Frequency block		0.18 MHz
Maximum transmission power		30 dBm per TRP
Distance-dependent path loss		114.1+37.6log$_{10}$(d), d: kilometers
Shadowing		Lognormal shadowing with standard deviation of 8 dB and inter-site correlation of 0.5
Receiver noise power density		−165 dBm/Hz
Instantaneous fading		6-path Rayleigh fading with a delay spread of 1 μs
Scheduling interval		1 ms
TRP group selection update interval		500 ms
Index of generalized mean		$p = -20 \sim 1$

Fig. 2 shows the various system throughputs as a function of p used in the proposed method when M and K are set to 2 and 20, respectively. The horizontal axis represents the value of p set in the procedure of the proposed method, while the vertical axis represents the system throughput obtained by applying the generalized mean to user throughputs based on (1). The evaluated system throughput levels of arithmetic mean, geometric mean, harmonic mean, and worst-user throughput correspond to the value of $U(t)$ in (1) when p is set to 1, 0, −1, and −∞, respectively. As the procedural parameter p on the horizontal axis varies, the system throughput defined by each parameter p changes differently. Fig. 2 shows the arithmetic mean user throughput is maximized when p used in the proposed method is set to 1. Similarly, the geometric mean, harmonic mean, and worst-user throughput achieve their maximum values when p is set to 0, −1, and a sufficiently small value, such as −10. Therefore, the proposed TRP selection method maximizes the system throughput using the same p defined in the system throughput in (1). Consequently, the proposed method can contribute to various requirements of operators and service policy.

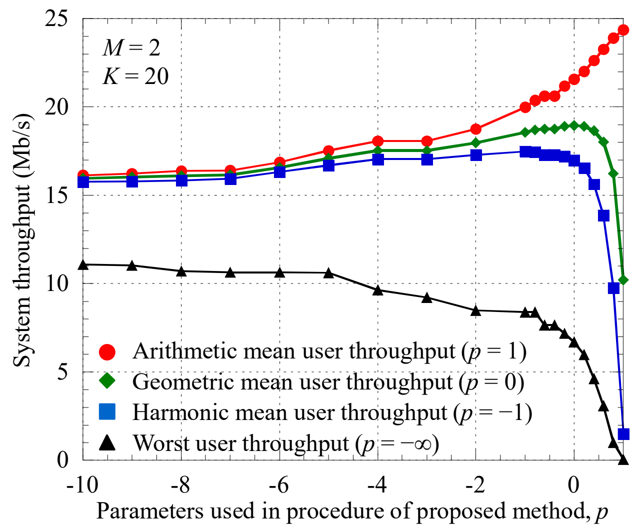

Fig. 2. Various system throughput levels as a function of p used in the proposed method.

Fig. 3 shows the cumulative distribution of user throughput when p is set to −20 to prioritize fairness among UEs. Parameters M and K are set to 2 and 20. The proposed method exhibits slightly lower user throughput than the two conventional methods in high cumulative probability regions where the probability exceeds 0.57. However, this method improves the user throughput in regions with a cumulative probability of 0.57 or less. The two conventional methods select TRP groups based on received signal power or bandwidth allocation assuming static channels, and do not consider the effect of scheduling in instantaneous fading environments. In such cases, UEs with low throughput have difficulty connecting to TRP groups where they can benefit from the multiuser diversity effect obtained from PF scheduling. In contrast, the proposed method selects TRP groups using a metric that considers the multiuser diversity effect. This provides UEs with deteriorating channel conditions connection to TRP groups, where they take advantage of better channel conditions through PF scheduling. Consequently, compared to conventional methods assuming static environments, the proposed method improves user throughput particularly in low cumulative probability regions.

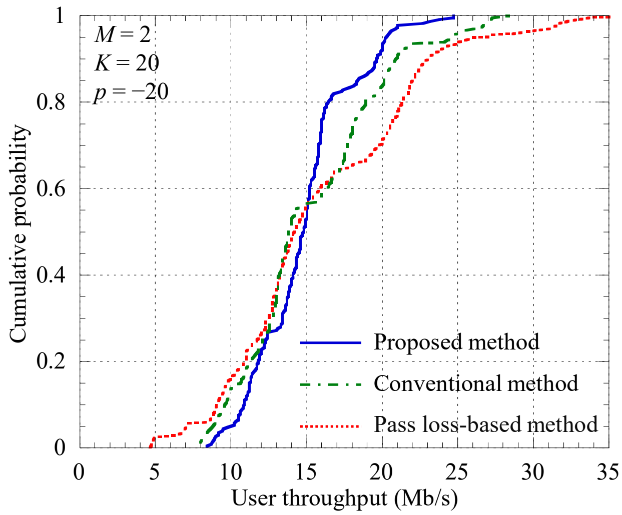

Fig. 3. Cumulative distribution of user throughput.

Fig. 4 shows the system throughput as a function of the UE density K when M is set to 2. The parameter p is evaluated at 0 and −10. The proposed method and the conventional method significantly improve the system throughput compared to the path loss-based method as the UE density increases, regardless of the value of p. This is because both the conventional method and the proposed method perform TRP group selection considering the allocated bandwidth, which effectively prevents excessive concentration of connections to specific TRP groups, and this effect becomes more effective with higher UE density. Next, when comparing the conventional method and the proposed method, the improvement in the system throughput increases as the UE density decreases regardless of p. This is because a decrease in the number of UEs increases the bandwidth allocated to each UE, resulting in a more effective multiuser diversity effect from PF scheduling. Consequently, since the proposed method accounts for this effect in the metric for TRP group selection, it outperforms the conventional method, which does not consider PF scheduling.

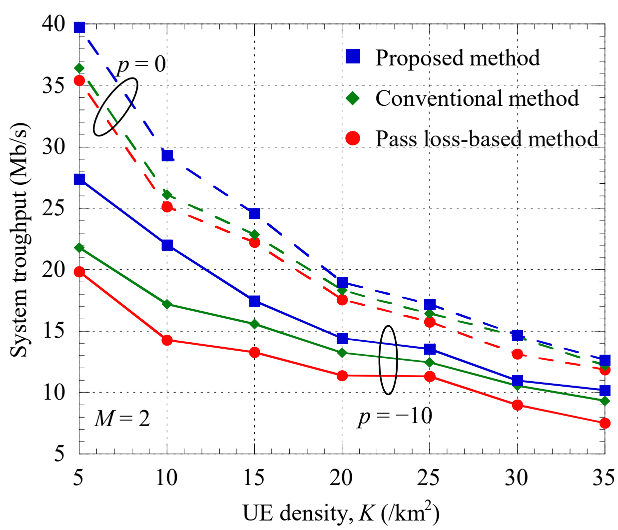

Fig. 4. System throughput as a function of UE density K.

Fig. 5 shows the system throughput as a function of the CPU density M where K is set to 20. Both the proposed method and the conventional method achieve a greater improvement as the CPU density increases, *i.e.* as the number of TRP groups in the system increases, regardless of the value of p. This is because, in the path loss-based method, each UE selects TRP groups to be connected based solely on received signal power, which may lead to an increase in TRP groups with no connected UEs. This causes wasted bandwidth, thereby reducing overall system throughput. In contrast, the proposed and conventional methods appropriately update the selection of TRP groups to increase the number of TRPs connected to UEs. This reduces the waste of system bandwidth caused by unused TRPs and achieves a greater improvement when the CPU density is high. Fig. 5 also demonstrates that the performance gap between the proposed method and the conventional method in [15, 16] increases when the CPU density is low. This is because, when the CPU density is low and the numbers of UEs and TRPs within each group are relatively high, the number of candidate channel conditions between TRPs and UEs considered in PF scheduling increases and the multiuser diversity effect becomes more significant. Since the proposed method accounts for this effect in the TRP group selection metric, it outperforms the conventional method, which does not consider PF scheduling.

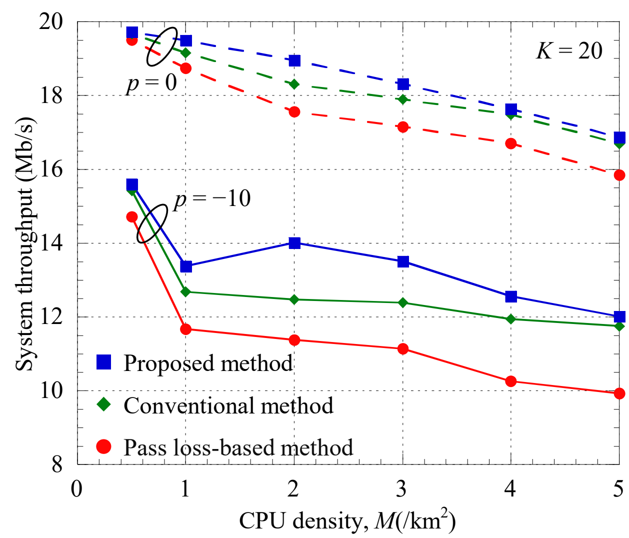

Fig. 5. System throughput as a function of CPU density M.

Finally, Fig. 6 shows the system throughput of the proposed method and two conventional methods at each generalized mean index p when M and K are set to 2 and 20, respectively. This figure demonstrates that the proposed method improves system throughput compared to the two conventional methods when p is set to 0, −1, −20. For p is set to 1, although the proposed method achieves slightly higher throughput than the path loss-based method, it exhibits almost no difference compared to the conventional method in [15, 16]. This is because, when maximizing the arithmetic mean user throughput, all bandwidth is allocated to UEs with the best channel conditions. As a result, the multiuser diversity effect for UEs with poor channel conditions is not reflected, and the system throughput becomes close to that of the conventional method assuming a static environment. On the other hand, as p decreases, the improvement achieved by the proposed method becomes more significant. This is because smaller p values emphasize fairness, prompting UEs to connect to TRP groups that allow them to effectively exploit the multiuser diversity effect achieved by PF scheduling. These results suggest that the proposed method performs better when fairness is prioritized by the system.

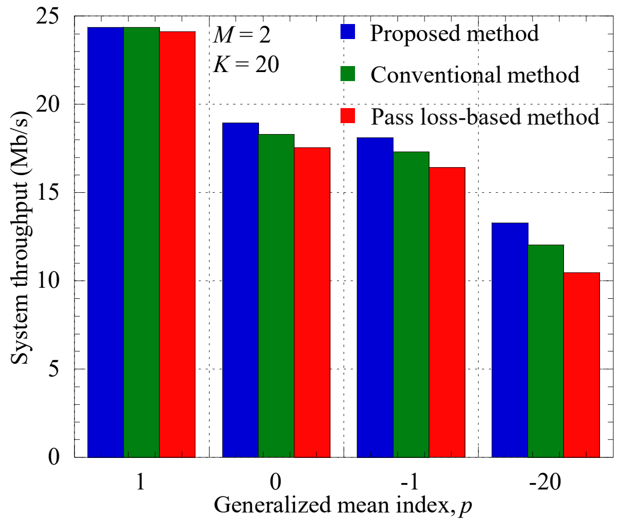

Fig. 6. Various system throughputs as a function of p.

VI. Conclusion

We proposed an autonomous decentralized TRP group selection method in downlink distributed MIMO systems that maximizes system throughput by utilizing the multiuser diversity effect obtained from PF scheduling. In the proposed method, each TRP group calculates the throughput gain based on past PF scheduling results and broadcasts this gain along with allocated bandwidth for newly connected UEs as supplementary information. Each UE calculates a metric using the user throughput predicted based on this information and its own channel conditions and feeds back the metric value to the TRP group with the highest value. Finally, each TRP group determines the newly connected UE according to the reported metrics. By periodically repeating this process, the proposed method autonomously realizes a TRP group selection that maximizes system throughput under fading channels. Computer simulations confirmed that the proposed method improves system throughput compared to the path loss-based method and the conventional method assuming static channels. In particular, the improvement becomes more significant when the generalized mean index p is small, *i.e.*, fairness is prioritized, thereby contributing to the performance enhancement of UEs with low throughput.

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