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Transceiver Design in OFDMA-based Distributed Wireless Powered Communication Networks

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1. Introduction

Wireless powered communication networks (WPCNs) are suitable for small communication devices operating on low power consumption and have been the subject of much research for the sustainable deployment of IoT networks. The WPCN experiences the doubly near-far problem [1]; devices far from a hybrid access point (HAP) collect less power and require more power for communication. To overcome the near-far problem, distributed WPCN is known to be effective because the antennas of HAP are geographically distributed, and the distance between antennas and devices can be reduced. Previous studies on distributed WPCNs assumed single-carrier transmissions [2] and cannot be applied to multi-carrier transmissions. In this paper, we propose a transceiver design method that maximizes the sum rate in an orthogonal frequency division multiple access (OFDMA)-based distributed WPCN.

2. System Model and Transceiver Design

We consider a distributed WPCN consisting of L single-antenna distributed antennas (DAs) connected to a central processing unit (CPU) and K single-antenna IoT users employing OFDMA with N subcarriers. In the wireless energy transmission phase, each user harvests energy from the signals broadcasted by DAs with a beamforming (BF) vector $\mathbf{v} = [\mathbf{v}_1^T \ \cdots \ \mathbf{v}_L^T]^T \in \mathbb{C}^{LN\times 1}$ for a time duration of $\tau_0 \in [0,1]$. In the wireless information transmission phase, each user transmits information data using the harvested energy and the allocated subcarriers for the remaining duration of $1-\tau_0$. At the CPU, we employ the maximum ratio combining to detect the data from the signal received by DAs.

We consider the following sum rate maximization problem to design the optimal time fraction τ_0, BF vector $\mathbf{v}$, subcarrier allocation variable $q_{n,k}$, and power allocation variable $\rho_{n,k}$:

$$\max_{\substack{\tau_0,\{q_{n,k}\},\\ \mathbf{v},\{\rho_{n,k}\}}} \quad (1-\tau_0)\sum_{n=1}^{N}\sum_{k=1}^{K} q_{n,k}\log_2\left(1+\rho_{n,k}\gamma_{n,k}\right), \quad (1)$$

$$\text{s. t.} \quad (1-\tau_0)\sum_{k=1}^{K}\sum_{n=1}^{N} q_{n,k}\rho_{n,k} = \eta\tau_0\sum_{k=1}^{K}\left|\mathbf{v}^H\mathbf{g}_k\right|^2, \quad (2)$$

$$\|\mathbf{v}_l\|^2 = \frac{P_{\max}}{L}, \sum_{k=1}^{K} q_{n,k} = 1, \sum_{n=1}^{N} q_{n,k} = \frac{N}{K}, \quad (3)$$

$$q_{n,k}\in\{0,1\},\ \rho_{n,k}\ge 0,\ 0\le\tau_0\le 1, \quad (4)$$

where $\mathbf{g}_{n,k}$ is the channel coefficient between DAs and the kth user on the nth subcarrier, $\mathbf{g}_k$ is a vector stacking $\{\mathbf{g}_{n,k}\}$, $\gamma_{n,k} \triangleq N\|\mathbf{g}_{n,k}\|^2/B\sigma_z^2$, σ_z^2 is the noise spectral density, B is bandwidth, η is the energy conversion efficiency, and $P_{\max}$ is total transmit power budget at the DAs. We impose practical per-antenna power constraints. To solve the problem, we divide it into subproblems for each variable and solve them alternately.

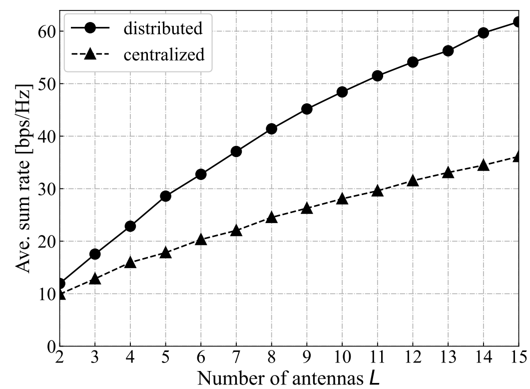

Fig. 1 Comparison of distributed and centralized WPCN.

3. Simulation Result

We compare the proposed distributed WPCN with a centralized WPCN. We set $N = 16$, $K = 2$, $B = 1.0$ MHz, $\eta = 0.6$, $P_{\max} = 30$ dBm, $\sigma_z^2 = -110$ dBm/Hz. Users are randomly generated within a circle with a radius of 50 m centered on the coordinate origin, and the lth DA is placed at $(25\cos\{(2\pi l+\pi)/L\}, 25\sin\{(2\pi l+\pi)/L\})$ on a circle with a radius of 25 m centered on the coordinate origin. We ran 10^4 simulation trials. Figure 1 shows the average sum rate performance. The performance of the distributed WPCN improves as the number of antennas increases and is superior to that of the centralized one.

4. Conclusion

We proposed an OFDMA-based distributed WPCN system and showed its superiority to the centralized counterpart.

References

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