Wireless Evolution
Toward 5G Mobile Communications Network

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Abstract: Maximizing the spectrum and energy efficiencies is required for the 5th generation (5G) mobile communications network. One promising approach is to adopt a small-cell structured network. The massive multi-input multi-output (MIMO) transmission can effectively form a large number of user-centric small-cells. In this paper, a recent advance in the distributed massive MIMO toward 5G network is presented.

1. Introduction

Mobile communications network has now evolved into the 4th generation (4G) [1]. Recently, the development of 5G network is on-going worldwide [2]. Maximizing the area spectrum efficiency (ASE) and the energy efficiency (EE) is required for 5G network. One promising approach is to adopt a small-cell structured network. Reducing the base station (BS) coverage area (i.e., small-cell) enables the same frequency to be reused more densely in the same service area and accordingly, the ASE can be improved. The short distance communication lowers the transmit signal power significantly, thereby the EE can be improved. However, frequent handover may happen even if a user is walking, thereby increasing the control signal traffic. To avoid frequent handover, the multi-input multi-output (MIMO) can be utilized. The massive MIMO effectively forms a large number of user-centric small cells. It can be classified into distributed massive MIMO [3] and centralized massive MIMO [4]. The former replaces the handover with distributed antenna selection and the latter with beam selection. This paper presents recent advances in the distributed massive MIMO using cooperative distributed antenna signal transmission (CDAT) technique.

2. Distributed massive MIMO using CDAT technique

A possible advantage of using distributed massive MIMO over centralized massive MIMO is its capability of alleviating problems arising from the shadowing loss. The conceptual structure of distributed massive MIMO is illustrated in Fig. 1. Each distributed antenna is connected to the macro-cell BS (MBS) by optical fiber link. Each MBS performs the radio signal processing required for signal transmission and reception using CDAT technique (i.e., single-user space-time block coded transmit diversity (STBC-TD) and multi-user spatial multiplexing called MMSE-SVD) [4]. A predetermined number of distributed antennas near a user equipment (UE) are selected to form a user-centric small-cell and to perform CDAT.

In 5G network, the signal bandwidth wider than 100MHz may be used. Since such a broadband channel is severely frequency-selective, a powerful equalization technique like frequency-domain equalization (FDE) is needed. FDE requires accurate channel state information (CSI). When using time division duplex (TDD), the CSI estimated during uplink reception can be reused for the downlink transmission. Therefore, FDE for both uplink reception and downlink transmission can be done at MBS. A simplified transmitter/receiver structure of SC uplink CDAT is illustrated in Fig. 2.

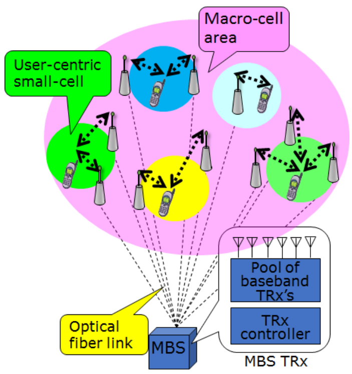

Fig. 1. Conceptual structure of distributed massive MIMO.

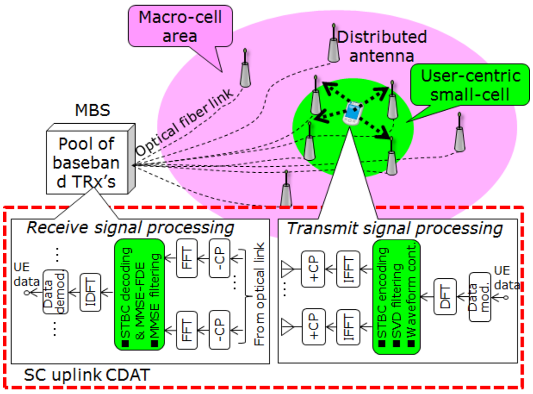

Fig. 2. SC uplink CDAT transmitter/receiver structure.

The uplink user throughput was examined by computer simulation. It is assumed that the MBS area of interest is surrounded by 6 adjacent MBS areas. As an initial study, only 7 antennas are deployed uniformly in each MBS area, while 2 UEs, each equipped with 2 antennas, are randomly located. 4 distributed antennas are selected for up/downlink transmissions using CDAT technique. Multi-access scheme for single-user STBC-TD is frequency-division multiple access (FDMA); the system band consisting of 128 subcarriers is divided to 2 subcarrier-blocks, each block being assigned to each UE. On the other hand, for multi-user MMSE-SVD, the system band is shared by 2 UEs. A frequency-selective fading channel having 16-path uniform power delay profile (PDP) is assumed as well as a log-normally distributed shadowing loss with standard deviation of 7 dB and a path loss with path loss exponent of 3.5. The channel is assumed to be a Nakagami-Rice fading channel with K=10dB when the distance between distributed antenna and UE is shorter than the radius of distributed antenna coverage area.

The spatial distribution of the uplink user throughput obtained by computer simulation is illustrated in Fig. 3. It can be clearly seen that the distributed massive MIMO using CDAT technique provides high throughput over nearly entire MBS area, while the centralized massive MIMO provides high throughput only near the center of MBS area. It is also seen that the single-user STBC-TD can provide higher throughput than multi-user MMSE-SVD near the edge of BS area, where the uplink signal received at MBS is weak and is thus strongly affected by the CCI from UEs in surrounding MBS areas.

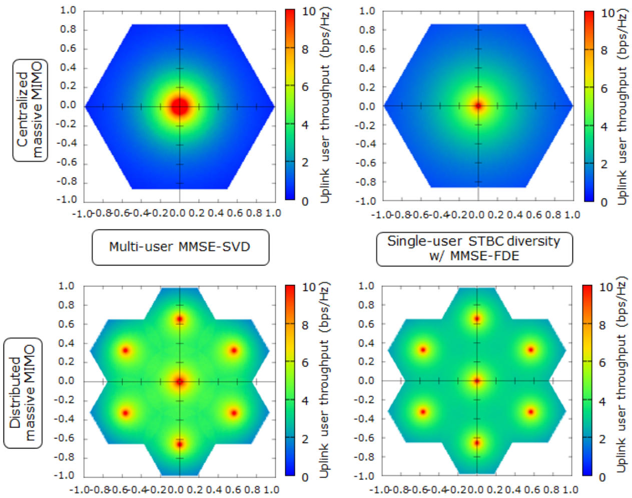

Fig. 3. Spatial distribution of uplink user throughput over an MBS area.

3. Radio-optical convergence for a new C-RAN

Our future research topic is the realization of a new centralized radio access network (C-RAN) which virtually and flexibly deploys a number of virtual TRx's over the macro-cell area. Fully coherent optical transmission technology plays an important role. It can directly transmit, without A/D and D/A conversion and without optical-radio frequency conversion, the baseband in-phase/quadrature-phase (I/Q) signal waveforms from an MBS to mobile users vice versa via distributed antennas [5]. This is the real radio-optical convergence.

4. Conclusion

In this paper, the recent advance in distributed massive MIMO using CDAT technique for 5G network was presented. Also presented was the future research topic. Higher deployment cost is expected in distributed massive MIMO since spatially distributed antennas need to be connected by optical fiber links. In practical situation, user distribution and propagation environment are quite dynamic and complicated. A hybrid (distributed-centralized) massive MIMO may be considered as a practical solution for balancing user throughput maximization and system deployment cost.

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4. References

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