Large Scale Massive MIMO Field Trial for 5G Mobile Communications System

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Abstract – **Higher spectrum efficiency is a target of the 5th generation (5G) mobile communications system. Massive MIMO is considered as one of important technologies for that purpose. Under the practical conditions that the number of antennas on user equipment (UE) is limited, multi-user MIMO (MU-MIMO) is a probable use scenario of Massive MIMO. Furthermore, massive connectivity is another important target, and MU-MIMO under high UE correlations could occur in the massive connectivity scenarios. By taking these targets and scenarios into account, Huawei and NTT DOCOMO have conducted a large scale field trial to evaluate the feasibility of massive MIMO, especially the performance of linear, non-linear, and hybrid precoding MU-MIMO schemes.**

Index Terms — **Massive MIMO, MU-MIMO, 5G, Trial**

1. Introduction

The 5th generation (5G) mobile communications system targets three scenarios; enhanced mobile broadband (eMBB), massive machine type communications (mMTC), and ultra-reliable and low-latency communications (URLLC) [1]. Massive MIMO is considered as a key technology especially for higher spectrum efficiency for eMBB and more connections with user equipments (UEs) for mMTC. However, more connections in eMBB or mMTC can cause more inter-UE interference. Hence, the efficient MU-MIMO precoding schemes for Massive MIMO needs to be investigated.

Zero-forcing (ZF) [2] is a widely used linear precoding scheme for multi-user transmissions. However, when the number of UEs increases and the resultant UE correlation gets higher, performance loss occurs with ZF. In theory, the non-linear dirty paper coding scheme (DPC) can eliminate the inter-user interference with more computational complexity. Tomlinson-Harashima precoding (THP) [3] is a practical procedure for DPC but has not been widely used still due to its computational complexity. Considering that the hardware processing capability is being enhanced, and the scenarios of 5G requires more inter-user interference suppression capability, we conducted the large scale MU-MIMO field trial with massive MIMO base station (BS).

The rest of this paper is organized as follows. Section 2 describes the system configurations and the environment of the field trial. Section 3 elaborates the basic concept of evaluated MU-MIMO precoding schemes. The trial results and discussions are described in Section 4. Section 5 concludes this paper.

2. System Configurations

The trial system is implemented in 2.3GHz band based on the LTE Advanced specification with some enhancement for higher order MU-MIMO. The system is TDD and uses DL/UL configuration 1. The channel estimation for DL transmission is based on the UL sounding signal by exploiting the channel reciprocity.

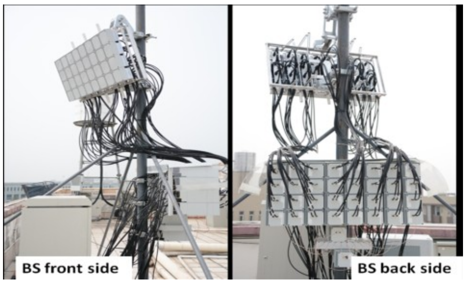

Fig. 1. 5G prototype base station

The BS with 64T64R shown in Fig. 1 is located on the rooftop of 25 meters height building, and 24 UEs with their antenna height of about 1 meter are deployed in front.

Fig. 2. Deployment scenarios of UEs

Fig. 2 shows the UE deployment where each UE is deployed under one umbrella. In order to evaluate the MU-MIMO schemes under different UE correlations, two UE deployment scenarios are introduced here. The adjacent UE distance is shorter than 2 meters in very close scenario and longer than 3.6 meters in distant scenario.

3. MU-MIMO Schemes

For the field trial, three types of the MU-MIMO precoding schemes were implemented and evaluated.

(1) Linear precoding; Eigen Zero Forcing (EZF)

For generating ZF precoder, singular value decomposition (SVD) is applied to the channel matrix and the right singular vector corresponding to the maximum singular value is used as the equivalent channel because the number of streams to each UE is limited and it can limit the signal subspace [4].

(2) Non-linear precoding: THP

THP scheme utilizes modulo operation to suppress the transmission power increase caused by the DPC processing [3]. In this trial, modulo adaptation method, which adaptively selects the better one from the power normalization and the modulo operation, has been implemented on THP [5].

(3) Hybrid precoding: Hybrid

Hybrid precoding scheme, which selects EZF and THP based on the UE channel correlation was implemented. EZF is applied to generate precoder for low correlation UEs, and THP is applied by avoiding the low correlation UEs signal subspace to generate precoder for high correlation UEs [6].

4. Performance Results and Discussions

The cell throughput is averaged over 1 second including all subframes. The spectrum efficiency is calculated for 4 downlink subfarmes within 10 subframes.

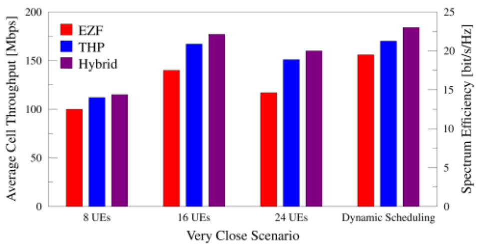

Fig. 3. Spectrum efficiency for very close scenario

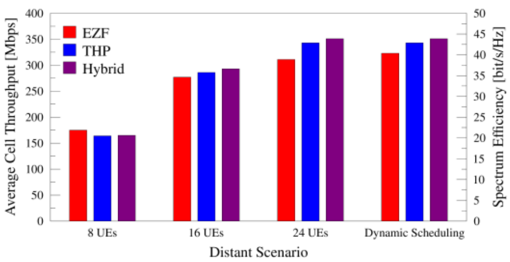

Fig. 4. Spectrum efficiency for distant scenario

Fig. 3 and 4 show the performance result of different schemes in different deployment scenarios. The number of co-scheduled UEs for MU-MIMO is fixed to 8, 16, and 24. With dynamic scheduling, the co-scheduled UEs are dynamically selected from all 24 UEs.

In very close scenario in Fig. 3, THP has performance gains over EZF in all scheduling cases, which shows the advantage of THP under high UE correlation. The gain increases as the number of UE increases because the UE correlation also increases. Hybrid scheme has larger gains than THP, which are 15%, 26%, and 37% over EZF with 8, 16, and 24 co-scheduled UEs, respectively. This shows the benefit of the hybrid scheme, which takes the advantage of lower processing latency in EZF, and better inter-user interference cancelation capability of THP. With the lower processing latency, the measured channel used for the precoder calculation is more accurate in EZF than in THP.

In distant scenario in Fig. 4, the hybrid scheme achieves the highest spectrum efficiency in the whole trial, which is 43.9 bit/s/Hz per cell. However, THP and hybrid schemes have smaller gains over EZF than those in very close scenario due to lower UE correlation. Because the UE correlation is especially low in case of 8 UEs in distant scenario, the longer processing time of THP due to its higher computational complexity causes lower channel estimation accuracy, and the resultant performance loss compared to EZF. According to the trial result, however, there would be a room for improvement on how the hybrid scheme selects EZF and THP.

5. Conclusion

Through the large scale massive MIMO field trial, we investigated the performance of different MU-MIMO schemes in different UE deployment scenarios for 5G mobile communications system.

The highest spectrum efficiency in the whole trial is 43.9 bit/s/Hz per cell, which shows the importance of massive MIMO for higher spectrum efficiency and its feasibility for the use in the real radio propagation environment. In addition, different MU-MIMO precoding schemes such as EZF, THP and their hybrid scheme were evaluated. It shows that THP, which has not been widely used due to its complexity so far, has a clear gain over EZF especially when UEs distances are very close, and the number of UEs is large. Furthermore, it shows that the hybrid scheme brings the benefit of its flexibility on selecting EZF and THP in order to take both of their advantages in practical systems.

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