Experimental evaluation on uplink MU-MIMO using high-density distributed antennas selection

Sho Yoshida[1], Kentaro Nishimori[1], Tomoki Murakami[2], Koichi Ishihara[2], Yasushi Takatori[2],
and Masato Mizoguchi[2]

1, Graduate School of Science and Technology, Niigata University
Ikarashi 2-nocho 8050, Nishi-ku Niigata, 950-2181 Japan
2, Nippon Telegraph and Telephone Corporation NTT
Access Network Service Systems Laboratories
1-1 Hikarinooka, Yokosuka, Kanagawa, 239-0847 Japan

Abstract - **Multi-user MIMO (MU-MIMO) realizes a high channel capacity with a little limited number of antennas at user terminals. On the other hand, MU-MIMO needs a channel state information to obtain the transmit weight of beam forming. The distributed antenna system (DAS), which switches the high density arranged antennas according to user distribution in indoor environment, has been proposed. In this paper, we obtain the channel state information in an actual indoor environment. The paper shows that the SNR, eigenvalues and channel capacity can be improved compared to centralized antenna system by selecting antenna with highest SNR from limited area. We verify that the proposed antenna selection is effective from points of view on both the simplification of antenna selection and improvement on channel capacity.**

Index Terms — **Multi-user MIMO, distributed antenna system, antenna selection, channel capacity, zero forcing**

1. Introduction

The growing popularity of smart phones and wireless LANs has set the demand for achieving broadband wireless transmission within a limited frequency band. Multiuser MIMO (MU-MIMO) systems have recently attracted much attention as a technology that enhances the total system capacity by generating a large virtual MIMO channel between a base station (BS) and multiple user terminals (UTs) [1][2].

To further enhance the ability of MU-MIMO, MU-MIMO in distributed antenna system (DAS) has been proposed in many researchers (for example, in [3] [4]). It is widely known that MU-MIMO in DAS achieves not only higher received power at each user but also higher special diversity than that in centralized antenna system (CAS).

In this paper, we evaluate the effectiveness of DAS in an actual indoor propagation environment. To reduce the overhead by using channel state information (CSI) in DAS [5], we propose a new antenna selection where antenna is selected by dividing several groups in DAS and selecting antenna with highest signal to noise power ratio (SNR) from each group. The SNR, eigenvalues, and channel capacity enhancement with DAS with the proposed antenna selection is verified by using the CSI in an actual indoor propagation environment
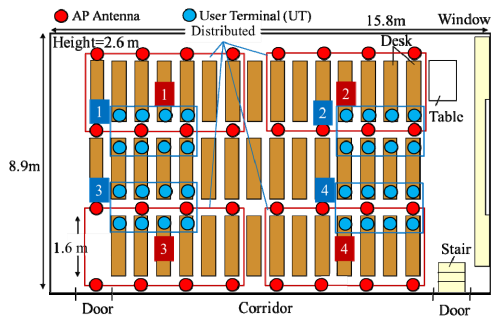
2. Measurement environment

Fig. 1(a) and (b) show measurement environment for CAS and DAS. Carrier frequency and bandwidth are 2.6 GHz and 6 kHz, respectively. Modulation scheme is minimum shift keying (MSK). Transmission power is 20 dBm. The transmitters and receivers are connected with UT and AP antennas, respectively and uplink CSI between UT and AP antennas is measured. The heights of AP and UT antennas are 2.3 and 0.7 m, respectively. Patch and sleeve antennas are used for AP and UT antennas, respectively. As shown in Fig. 1(a), the number of AP antennas is 4 and the number of UTs is 32. As shown in Fig. 1(b), the number of AP antennas is 32 and the number of UTs is 32.

One user is selected in turn from each group (1 to 4 for UT in Fig. 1(a) and (b)) and four users are totally selected for each trial. 4096 trial is totally employed for UTs' combination. Moreover, single antenna is selected from each group (1, 2, 3 and 4 at the AP in Fig. 1(b)): totally four AP antennas are selected in Fig. 1(b). Therefore, uplink 4x4 MU-MIMO transmission is evaluated in Fig. 1(a) and (b). The noise power is determined so that average received power versus the noise power, i.e., SNR is 20 dB when considering DAS.

When considering DAS in Fig. 1(b), two types of antenna selection are evaluated. One is random antenna selection from each group (DAS (R)). Another method is that the antenna with the highest SNR is selected from each group (DAS (H)).
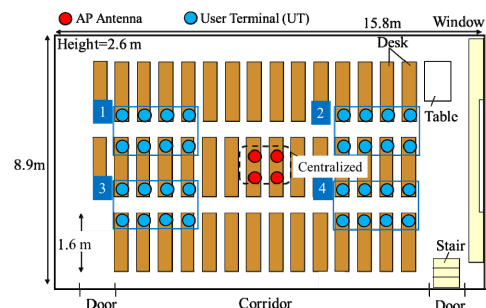
(a)   Measurement environment of CAS

(b) Measurement environment of DAS

Fig.1 Measurement environment of CAS and DAS

3. Channel capacity comparison between CAS and DAS

Fig. 2 shows the cumulative density function (CDF) of SNR. As can be seen in Fig. 2, the SNR by DAS (R) cannot be improved. On the other hand, 7 to 8 dB SNR improvement is obtained by selecting antenna with highest SNR for each region compared to CAS.

Fig. 3 shows the CDF of first and fourth eigenvalues (λ_1 and λ_4) by CAS and DAS (H). When we compare the eigenvalues at CDF = 50 %, λ_1 by DAS (H) increases about 7 dB in comparison with λ_1 by CAS. Surprisingly, λ_4 by DAS (H) increases about 20 dB in comparison with λ_4 by CAS. Because each antenna is spatially located at a distance in DAS (H), not only SNR but also spatial correlation can be improved by this method.
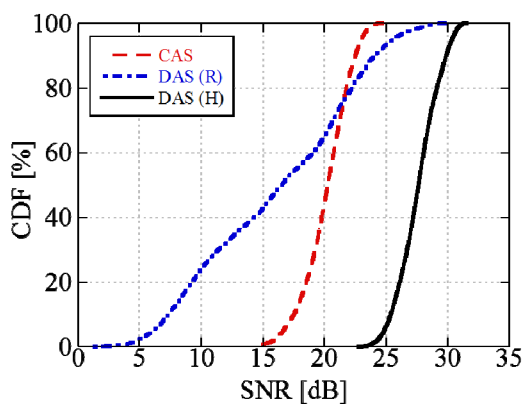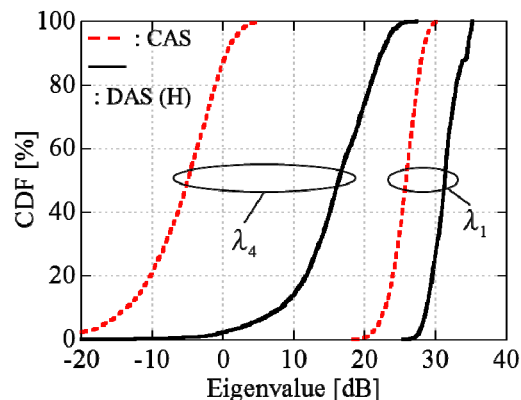

Fig. 2 CDF of SNR (CAS, DAS (R) and DAS (H)).

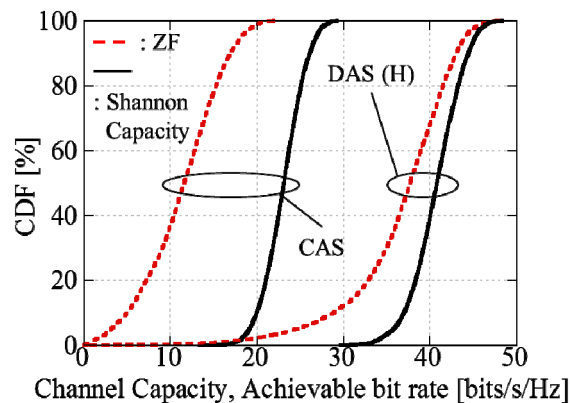Fig. 3 CDF of 1st and 4th eigenvalues (CAS and DAS (H)).

Fig. 4 Shannon capacity and achievable bit rate (CAS and DAS (H)).

Fig. 4 shows the CDF by Shannon capacity and achievable bit rate by CAS and DAS (H). When considering a realistic signal processing, a linear decoding such as zero forcing (ZF) is essential for MU-MIMO transmission. In this paper, the ZF is adopted as an actual decoding algorithm at the AP.

As can be seen in Fig. 4, both Shannon capacity and achievable bit rate by ZF by DAS (H) can be greatly improved compared to those by CAS. Because both SNR and spatial correlation characteristics can be improved by DAS (H), improvement of the achievable bit rate by ZF is much larger than that of Shannon capacity when considering DAS (H). It is shown that DAS with the antenna selection with highest SNR for a certain separated area has great advantage which realizes a simple decoding algorithm such as ZF.

4. Conclusion

In this paper, a new antenna selection has been proposed where antenna is selected by dividing several groups and selecting antenna with the highest SNR from each group in DAS. The CSI is measured when considering CAS and DAS in an actual propagation environment. It is shown that DAS with the antenna selection with highest SNR for a certain separated area has great advantage. In particular, we verified that the achievable bit rate of ZF by DAS with the proposed method is improved compared to that by CAS.

References

[1] Q. H. Spencer, C. B. Peel, A. L. Swindlehurst, and M. Haardt, ``An introduction to the multi-user MIMO downlink, '' IEEE Signal Processing Magazine, vol. 42, no. 10, pp. 60-67, Oct. 2004.

[2] D. Gesbert, M. Kountouris, R. W. Heath Jr. , C. B. Chae, and T. Salzer, ``Shifting the MIMO Paradigm, '' IEEE Signal Processing Magazine, vol. 24, no. 5, pp. 36-46, Sep. 2007.

[3] R.W. Heath Jr et al., "Multiuser MIMO in distributed antenna systems with out-of-cell interference," IEEE Transactions on Signal Processing, vol.59, no.10, pp.4885-4899, Oct. 2011.

[4] D. Samardzija et al. "An experimental downlink multiuser MIMO system with distributed and coherently-coordinated transmit antennas," in Proc. IEEE International Conference on Communications, pp.5365-5370, June 2007.

[5] T. Hiraguri and K. Nishimori, "Survey of transmission methods and efficiency using MIMO technologies for wireless LAN systems," IEICE Trans. Common. Vol.E98-B, No.7, pp.1250-1267, July 2015.