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Performance analysis of DAS Group Cell scheme aided Downlink Turbo encoded MIMO OFDMA Wireless Communication System

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Abstract— Distributed antennas systems (DAS) transmission has been recognized as one of the spectrally efficient techniques in future cooperative communication based cellular wireless communication systems. In this paper, we have tried to make a comprehensive study on the impact of implementing DAS Group Cell scheme on performance evaluation of downlink Turbo encoded MIMO OFDMA wireless Communication system. With both 4-by-4 transmit and receive antennas and simultaneous transmission of identical signals from three distributed antennas systems of adjacent cells , it is observable from computer simulation study that the system under consideration shows its robustness in retrieving transmitted signal in hostile fading channel.

Index Terms— Distributed Antennas Systems (DAS), Turbo coding, Linear signal detection technique, Bit Error Rate (BER), AWGN and Raleigh fading channels.

1 Introduction

The wireless transmission and networking technologies are the essential components of the mobile communication systems. Due to the recent breakthrough in transmission technologies, cellular communications have entered the era of cooperative communications. The concept of Group Cell architecture was proposed correspondingly by the authors [1, 2]. Distributed antennas systems (DAS) was first introduced to improve the indoor coverage performance of wireless communication systems in 1987[3].The DAS with multiple remote antennas connected to same Base station (BS) is gaining more attention as an effective means for signal quality enhancement, capacity improvement and spatial diversity. A Scenario of Distributed Antenna Systems (DAS) with multiple remot antennas connected to a single Base station (BS) is shown in Fig. 1.

Various types of cooperative communication schemes such as relay, DAS, multicellular coordination, Group Cell, Coordinated Multiple Point transmission and reception (CoMP) have turned the traditional cellular system into a cooperative system. Unlike typical cooperative relay systems for which the available system bandwidth is shared for transmission to user equipment (UE) and for relaying. DAS does not require additional radio resources as remote antennas are typically connected to the BS via optical fibers. Cooperative communications have recently been migrated to one of state-of-the-art features of 3GPP LTE-Advanced (LTE-A).

In such system, base-station (BS) cooperative transmission under CoMP cooperative transmission scheme has been widely recognized as a promising technique to enhance throughput by avoiding intercell interference (ICI), particularly for cell-edge users. With development of physical layer techniques , the data rate of mobile communication services has increased by about 100 times every six to seven years, and it is predicted that in 2020, the required data rate will be 100 to 1000 times as large as the currently served data rate.

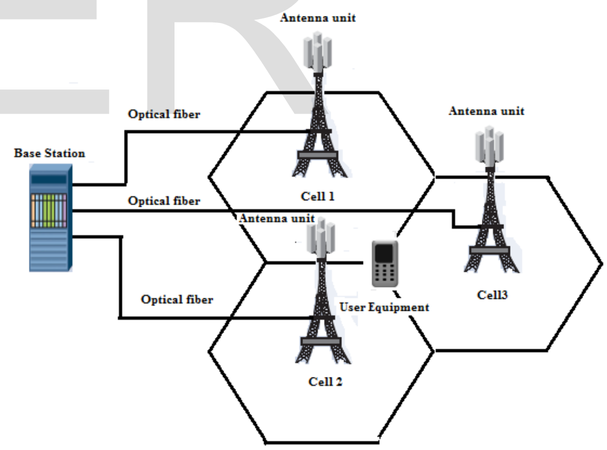

Fig. 1 Scenario of Distributed Antenna Systems (DAS) with multiple remote antennas connected to a single Base Station (BS)

Future mobile communication systems promise to provide very high data rates and mass wireless access services for broad area coverage. It is expected that such cooperative communication based systems will meet up the challenges due to constrained transmit power and complicacy in frequency of handover in high speed mobile environment (350km/h) of traditional cellular systems ; cell edge effect for transmission frequencies higher than 2 GHz [4-6].

2 Signal Models

We assume that a user unit is receiving data from a Base sta-

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tion with Group Cell based distributed transmitting antennas. The Group Cell is characterized by various adjacent cells that use the same resources to communicate with the user unit. In transmitting section, we consider a binary data stream **d** with elements $d_i \in \{0,1\}$ for i = 0, 1, 2, …, L. The binary data are turbo encoded with its length is M (M=2L). The channel encoded binary data d_{turbo} are interleaved and mapped into digitally modulated symbol vector **X** with its size N depending upon the order of modulation considered. The signal is spatially demultiplexed and processed under implementation of MIMO OFDMA radio interface technology and data modulation in such case is made with utilization of twelve contiguous subcarriers.

If H_1, H_2 and H_3 are considered to be the 4 × 4 channel matrices for the cell 1 to user unit, cell 2 to user unit and cell 3 to user unit and N_1, N_2 and N_3 are the corresponding zero mean circularly symmetric complex Gaussian noise, Xs is the transmitted signal and PL is the path loss, the received signal Y can be written as:

$$Y = H_1 X_s + N_1 - PL1_{linear} + H_2 X_s + N_2 - PL2_{linear} + H_3 X_s + N_3 - PL3_{linear} \qquad (1)$$

where, distance-dependent path-loss, PL in dB equals 128.1 + $37.6\log_{10}(R)$, R is the distance in km from mobile unit to central point of individual cell**[4].** The linear value of path loss, is given by

$$PL_{linear}=10\text{^} \left(-(128.1+37.6\log10(R))/10\right);$$

After estimating path loss, Equation (1) can be written in simplified form as

$$Y_{new} = H\,X_s + N \qquad (2)$$

Assuming equivalent channel matrix,

$$H= H_1+ H_2+ H_3$$

and equivalent complex Gaussian noise, $N= N_1+ N_2+ N_3$. The received signal Y_{new} can be processed to extract transmitted signal using various signal detection schemes.

In Minimum mean square error (MMSE) signal detection scheme, the MMSE weight matrix is given by

$$W_{MMSE} = (H^H H + \sigma_n{}^2 I)^{-1} H^H \qquad (3)$$

and the detected desired signal from the transmitting antenna is given by

$$\tilde{X}_{MMSE} = W_{MMSE} Y_{new} \qquad (4)$$

In Zero-Forcing (ZF) scheme, the ZF weight matrix is given by

$$W_{ZF} = (H^H H)^{-1} H^H \qquad (5)$$

and the detected desired signal from the transmitting antenna is given by**[7]**

$$\tilde{X}_{ZF} = W_{ZF} Y_{new} \qquad (6)$$

In ZF-SIC channel equalization scheme, the channel matrix **H** undergoes QR factorization as

$$H = QR = Q\begin{bmatrix} R_{1,1} & R_{1,2} & R_{1,3} & R_{1,4} \\ 0 & R_{2,2} & R_{2,3} & R_{2,4} \\ 0 & 0 & R_{3,3} & R_{3,4} \\ 0 & 0 & 0 & R_{4,4} \end{bmatrix} \qquad (7)$$

where, Q and R are the unitary and upper triangular matrix respectively. Equation (2) can be rewritten on multiplying by Q^H as

$$X = Q^H Y_{new} = RXs + Q^H N \qquad (8)$$

where, $Q^H N$ is a zero-mean complex Gaussian random vector. Since $Q^H N$ and N have the same statistical properties, $Q^H N$ can be used to denote N. We get Equation (8) as

$$X = RXs + N \qquad (9)$$

$$\Downarrow$$

$$\begin{bmatrix} \mathbf{x_1} \\ \mathbf{x_2} \\ \mathbf{x_3} \\ \mathbf{x_4} \end{bmatrix} = \begin{bmatrix} \mathbf{r_{1,1}} & \mathbf{r_{1,2}} & \mathbf{r_{1,3}} & \mathbf{r_{1,4}} \\ \mathbf{0} & \mathbf{r_{2,2}} & \mathbf{r_{2,3}} & \mathbf{r_{2,4}} \\ \mathbf{0} & \mathbf{0} & \mathbf{r_{3,3}} & \mathbf{r_{3,4}} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{r_{4,4}} \end{bmatrix} \begin{bmatrix} \tilde{\mathbf{x}}_{s1} \\ \tilde{\mathbf{x}}_{s2} \\ \tilde{\mathbf{x}}_{s3} \\ \tilde{\mathbf{x}}_{s4} \end{bmatrix} + \begin{bmatrix} \mathbf{n_1} \\ \mathbf{n_2} \\ \mathbf{n_3} \\ \mathbf{n_4} \end{bmatrix}$$

the detected desired signal $\tilde{\boldsymbol{X}}\boldsymbol{s}$ from the four transmitting antennas can written on neglecting noise term from Equation (9) as

$$\left.\begin{aligned} \tilde{\mathbf{x}}_{s4} &= \frac{\mathbf{x}_4}{\mathbf{r}_{4,4}} \\ \tilde{\mathbf{x}}_{s3} &= \frac{(\mathbf{x}_3 - \mathbf{r}_{3,4}\tilde{\mathbf{x}}_{s4})}{\mathbf{r}_{3,3}} \\ \tilde{\mathbf{x}}_{s2} &= \frac{(\mathbf{x}_2 - \mathbf{r}_{2,3}\tilde{\mathbf{x}}_{s3} - \mathbf{r}_{2,4}\tilde{\mathbf{x}}_{s4})}{\mathbf{r}_{2,2}} \\ \tilde{\mathbf{x}}_{s1} &= \frac{(\mathbf{x}_1 - \mathbf{r}_{1,2}\tilde{\mathbf{x}}_{s2} - \mathbf{r}_{1,3}\tilde{\mathbf{x}}_{s3} - \mathbf{r}_{1,4}\tilde{\mathbf{x}}_{s4})}{\mathbf{r}_{1,1}} \end{aligned}\right\} \quad (10)$$

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In MMSE-SIC Scheme, the received signal, channel matrix and noise are extended

$$H_{ex} = \left[H^T \sqrt{\frac{\sigma^2{}_n}{\sigma^2{}_s}} I \right]^T, \; Y_{ex} = \left[Y_{new}{}^T \quad 0^T \right] \text{ and}$$

$$N_{ex} = \left[N^T - \sqrt{\frac{N_0}{E_s}} X_s^T \right]^T \qquad (11)$$

Where, $\frac{\sigma^2{}_n}{\sigma^2{}_s}$ is the ratio of average noise power to average signal power (1/SNR). On QR factorization of extended channel matrix, H_{ex}, we get

$$H_{ex} = Q_{ex}.R_{ex} \qquad (12)$$

Where, Q_{ex} and R_{ex} represent a unitary matrix and an upper triangular matrix respectively. We assume that Y, H, N, Q and R are replaced by Y_{ex}, H_{ex}, N_{ex}, Q_{ex} and R_{ex} respectively and correspondingly the resulting system takes the following form

$$x_{ex} = Q_{ex}^H.Y_{ex}$$
$$= R_{ex}.X_s + Q_{ex}^H.N_{ex} \qquad (13)$$

Neglecting noise term in Equation (13) and using matrix inversion scheme, the transmitted signal can be detected [8].

3 Evaluation Results and Discussion

In this section, achievable BER performance of the 4 x 4 downlink distributed antennas system (DAS) aided Cooperative wireless Communication system based on the parameters presented in Table 1 has been evaluated and discussed. Results presented in terms of signal to noise ratio (SNR) and bit error rate (BER) are obtained by the computer simulation programs written in MATLAB12. In our study, we assume a MIMO fading channel with its channel state information (CSI) available at the transmitter side and consider the bandwidth of the wireless channel wider as compared to transmitted signal bandwidth to neglect Doppler frequency effect.

Table 1

Summary of the simulated model parameters

No. of Bits	8448
Type of Cooperative technique used	Distributed antennas systems (DAS)
Antenna configuration	4 by 4
No. of adjacent cells in Group	3
Data Modulation	QPSK, QAM, 16PSK, 16QAM, 64QAM
Receiver signal detection algorithm	MMSE,ZF,MMSE-SIC,ZF-SIC
Channel Coding	Turbo
Cell radius	500 m or 0.5km
Carrier frequency	3.5GHz

It is quite noticeable that the BER curves depicted in Fig. 2 through Fig. 5 are clearly indicative of showing distinguishable difference between system performance under various channel detection and digital modulation schemes. In all cases, the simulated system shows worst performance in higher order digital modulation (64-QAM). In Fig. 2, it is observable that the DAS based Turbo encoded Cooperative wireless Communication system exhibits better bit error rate (BER) performance with deployment of ZF channel detection scheme in QAM digital modulation as compared to QPSK, 16-PSK, 16-QAM and 64-QAM. In Fig. 2, it is also seen that at a typically target 1%(10^{-2}) BER, the ZF linear equalizer in QPSK and 16QAM require approximately 1.2 dB and 5.3 dB higher SNR values as compared to QAM respectively. At a typically assumed 4 dB SNR value, the estimated BERs are 0.0942 and 0.1584 and 0.3690 in case of QAM, QPSK and 64QAM which imply system performance of 2.2570 dB and 5.2975 dB in QAM as compared to QPSK and 64QAM respectively. With MMSE signal detection scheme, the simulated system is found to have BER values of 0.0774 and 0.2267 for QAM and QPSK (Fig. 3) which is indicative of a system performance improvement of 4.6671 dB. In Fig. 3, it is observable that at the targeted 1% BER, the MMSE linear equalizer in QPSK requires approximately 3.2 dB higher SNR value as compared to QAM.
In Fig. 4, it is noticeable that with MMSE-SIC signal detection scheme, the estimated BER values at 4dB SNR are 0.1792 and 0.3759 for QAM and 64-QAM which provides a system performance enhancement of 3.2173 dB. In low SNR region, it is observed that the performance gap for QAM and QPSK reduces with increase in SNR value. In Fig. 5, a quite remarkable scenario is observed for QAM and QPSK under deployment of ZF-SIC signal detection scheme. In low SNR region, performance gap reduces with increase in SNR values and in higher SNR region, the system performance is not well differentiable from each other. At 4 dB SNR, the simulated system achieves a performance improvement of merely 2.7509 dB in QAM as compared to 64QAM (BERs: 0.1941 and 0.3657). Graphical illustrations presented in Fig. 6 justifies the suitability of implementing QAM digital modulation and MMSE signal detection scheme in pursuing satisfactory performance of the DAS Group Cell scheme aided downlink Turbo encoded MIMO OFDMA wireless Communication system.

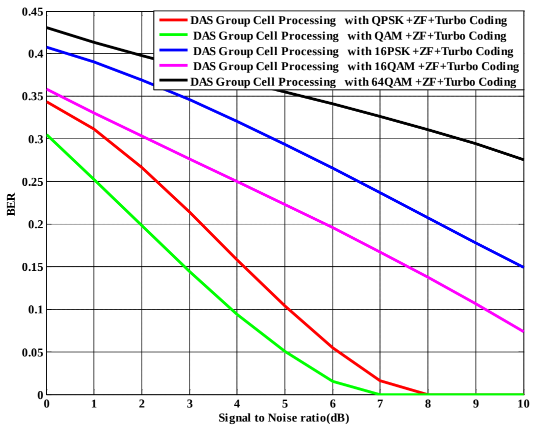

Fig. 2 BER performance comparison of downlink DAS Group Cell processing scheme aided MIMO OFDMA wireless communication system with adaptation of ZF Channel Equalization and various digital modulation schemes

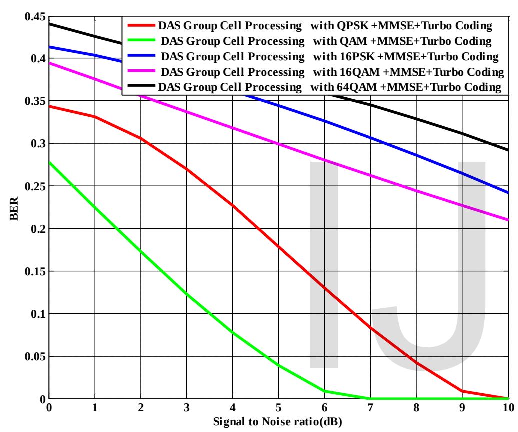

Fig. 3 BER performance comparison of downlink DAS Group Cell processing scheme aided MIMO OFDMA wireless communication system with adaptation of MMSE Channel Equalization and various digital modulation schemes

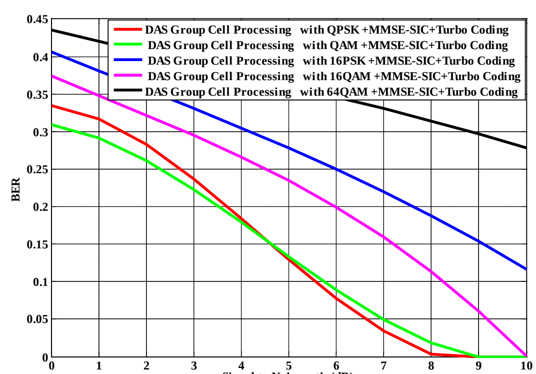

Fig. 4 BER performance comparison of downlink DAS Group Cell processing scheme aided MIMO OFDMA wireless communication system with adaptation of MMSE-SIC Channel Equalization and various digital modulation schemes

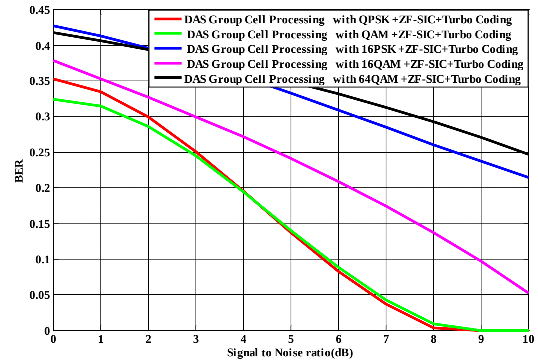

Fig. 5 BER performance comparison of downlink DAS Group Cell processing scheme aided MIMO OFDMA wireless communication system with adaptation of ZF-SIC Channel Equalization and various digital modulation schemes

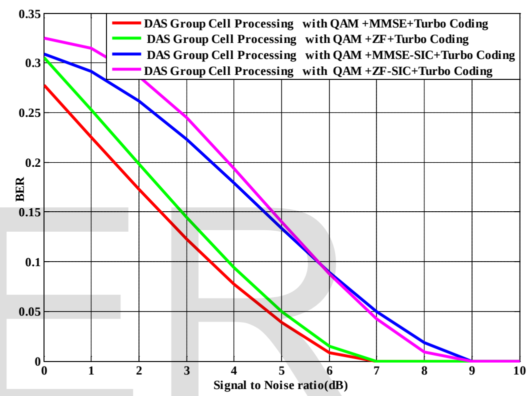

Fig. 6 BER performance comparison of downlink DAS Group Cell processing scheme aided MIMO OFDMA wireless communication system with adaptation of QAM digital modulation and various Channel Equalization schemes

4 Conclusions

With development of physical layer techniques, the data rates of mobile communication services are increasing. Cooperative communication has already been accepted as state-of-the-art feature of 4G LTE-Advanced system. Cooperative Relay technologies are expected to be implemented extensively in future generation robust and reliable wireless networks. In this paper, we have presented a new co-operative scheme with deployment of DAS Group Cells on performance assessment of Turbo encoded MIMO OFDMA wireless Communication system. . In context of system performance under scenario of various digital modulations and signal detection schemes, it can be concluded that the DAS Group Cell configuration based Turbo encoded MIMO OFDMA wireless communication system provides robust and satisfactory performance with MMSE signal detection and QAM digital modulation.

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