Inter-symbol Interference Suppression Scheme Employing Periodic Signals in Network MIMO-OFDM Systems

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Abstract - **This paper proposes an inter-symbol interference (ISI) suppression scheme employing periodic signals for network MIMO-OFDM systems. Network MIMO-OFDM suffers from the ISI due to long time difference of arrival (TDOA) among the users especially in large cells. In the proposed scheme, the periodic signals generated by only the even-numbered sub-carriers is adopted for suppressing the ISI and the appropriate transmission mode is chosen between the traditional non-periodic and periodic signals based on the theoretical BER obtained by means of correlation operation. The proposed approach makes the most of the useful properties that a certain ISI-affected user does not interfere at all with the other users, which enables us to make the countermeasure individually. The effectiveness of the proposed method is demonstrated in comparison with the traditional non-periodic transmission by means of computer simulations.**

Index Terms — **Network MIMO-OFDM, inter-symbol interference, interference suppression, periodic signal, theoretical approach.**

1. Introduction

In recent years, the rapid spread of smartphones and tablet devices makes traffic explosively increase, which strengthens demand for high speed and large capacity in mobile communication systems [1]. Network MIMO can be seen as a promising technique for achieving high system capacity because the ICI is effectively suppressed by coordinated multipoint (CoMP) [2]. Moreover, the combination of network MIMO with OFDM makes it possible to realize high transmission rate while retaining high system capacity [3], [4]. In network MIMO-OFDM, the adoption of MU-MIMO is considered as an attractive approach because advanced signal processing is not required at the MS [4]. Considering the installation of network MIMO-OFDM in practical mobile systems, the influence of TDOA on the transmission performance is crucial issue because TDOA in excess of the guard interval (GI) causes the ISI, which becomes severe problem especially in large cells.

In this paper, we propose an ISI suppression scheme employing periodic signals for network MIMO systems. Taking advantage of the fact that TDOA of all users can be easily obtained from the CSI, the proposed scheme adopts the periodic signals enabling the GI extension [5] for the users with ISI while traditional OFDM transmission is conducted in ISI-free users. Moreover, this appropriate transmission mode is chosen based on the theoretical BER obtained by means of correlation operation. The proposed approach is inspired from interesting properties that a certain ISI-affected user does not interfere with the other users at all, which enables us to make the countermeasure in each user. The effectiveness of the proposed method is demonstrated in comparison with the traditional non-periodic transmission by means of computer simulations.

2. Proposed Scheme

Figure 1 shows the impact of network MIMO on OFDM waveforms. As shown in Fig. 1, the maximum delay time differs depending on the position of MS, which causes large TDOA especially in large cells [3], [4]. Especially in MS #3, since TDOA is found to be larger than the GI, the BER performance is significantly degraded. To cope with this problem, we adopt the periodic signals generated by only the even-numbered sub-carriers. The proposed approach makes use of the useful property that a certain ISI-affected user does not interfere at all with the other users, which enables us to makes the countermeasure individually. Moreover, the periodic signals make it possible to virtually extend the GI without any change of symbol synchronization [5]. Figure 2 shows the concept of the proposed scheme. As shown in Fig. 2, the appropriate transmission mode is chosen between traditional non-periodic and periodic signals based on the theoretical BER calculated at the BS. In the proposed scheme, the theoretical BER is calculated by means of the correlation operation between the desired and ISI-affected signals. Here, the ISI-affected signals are generated by the convolution of the precoded signal and the impulse response originally obtained from the CSI.

The cross-correlation between the desired signal and the ISI-affected signal is given by

$$\alpha_m = \frac{E[x_m^*(t)x'_m(t)]}{\sqrt{E[|x_m(t)|^2]E[|x'_m(t)|^2]}}, \qquad (1)$$

where $x_m(t)$ and $x'_m(t)$ are the desired signal and the ISI-affected signal, respectively. By using the result of the cross correlation operation in (1), the desired signal power P_{Dm} and the ISI power P_{Im} are calculated as

$$P_{Dm} = |\alpha_m|^2 \cdot R_m(0), \tag{2}$$

$$P_{Im} = R_m(0) - P_{Dm} = (1 - |\alpha_m|^2) \cdot R_m(0), \tag{3}$$

where $R_m(0)$ is the autocorrelation of $x'_m(t)$, which corresponds to the received signal power. Considering the effect of noise enhancement in each sub-carrier, the ISI power P_{Imk} and the noise power P_{Nmk} are represented by

$$P_{Imk} = g_k^{\ 2} / \left(\sum_{k=0}^{N-1} g_k^{\ 2} \right) \cdot P_{Im}, \tag{4}$$

$$P_{Nmk} = g_k^{\ 2} \cdot 2\sigma_n^{\ 2}, \tag{5}$$

where g_k denotes the power normalization factor, and N and σ_n^2 are the number of sub-carriers and the noise variance, respectively. In consequence, the instantaneous SINR $\gamma_m(k)$ is given by

$$\gamma_m(k) = \frac{P_{Dm}/N}{P_{Imk} + P_{Nmk}}. \tag{6}$$

By substituting (6) into a complimentary error function for QPSK or 16QAM, the theoretical BER at the m-th MS can be calculated, which is utilized for the transmission mode selection in the proposed scheme.

3. Numerical Results

Figure 3 shows the performance comparison, in terms of the BER versus the average CNR, between the proposed and traditional non-periodic scheme, where the number of sub-carriers and the MIMO antenna configuration are set to be $N = 64$ and 8 × 8, respectively. In Fig. 3, 2-bit transmission is assumed and hence, QPSK and 16QAM are applied to the traditional non-periodic and periodic modes, respectively. Moreover, only the 8th MS is assumed to be affected by the ISI and the others are in the ISI-free condition. It is found from Fig. 3 (b) that the proposed scheme successfully eliminates the error floor which appears in the traditional transmission. In addition, it can be seen from Fig. 3 (a) that the proposed scheme provides better BER than the non-periodic transmission. This is because the proposed scheme can precisely choose the appropriate transmission mode regardless of the ISI-free condition.

4. Conclusion

This paper has proposed the ISI suppression scheme employing periodic signals for network MIMO-OFDM systems. In the proposed method, the periodic signal transmission is adopted for the ISI-affected users taking advantage of the useful property that the ISI of a certain user does not interfere at all with the other users. Moreover, the appropriate transmission mode including the traditional non-periodic transmission is chosen based the theoretical BER obtained by the correlation operation. Computer simulation results showed that the proposed scheme perfectly eliminates the error floor of the ISI-affected user, which implies that the ISI due to large TDOA in network MIMO can be suppressed individually by the use of the periodic signals.

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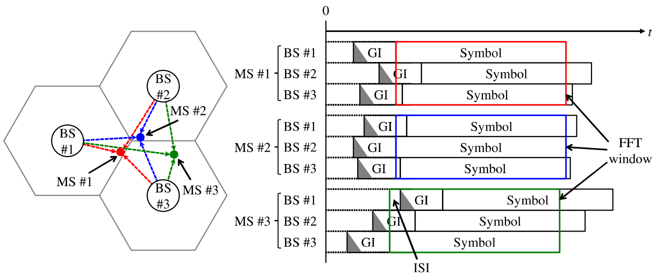


Fig. 1. Impact of ISI on network MIMO-OFDM.

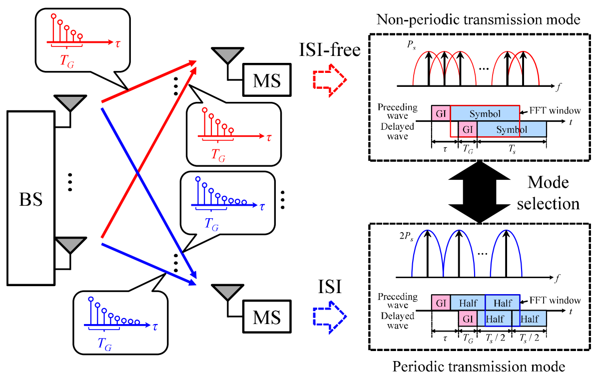
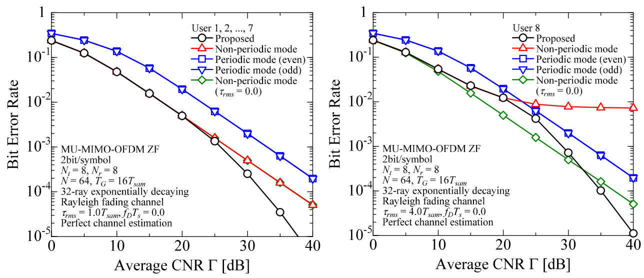


Fig. 2. Concept of proposed scheme.



(a) User 1, 2, ..., 7 (b) User 8

Fig. 3. BER performance versus average CNR (8 × 8).