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Bit Error Probability of Cooperative Diversity for M-ary QAM OFDM-based system with Best Relay Selection

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Abstract. Cooperative relay networks in OFDM-based systems have been shown to improve performance in wireless communication systems as a form of spatial diversity, but are not readily available cooperative diversity for M-ary QAM OFDM-based system where the best relay only participates in the relaying. In this paper, we investigate the error rate performance of cooperative Diversity for M-ary QAM OFDM-based system with best-relay selection. The results present bit error probability of M-ary QAM OFDM-based system with best-relay selection for different values of the numbers of relays (M), the numbers of subchannels and modulation scheme. M-ary QAM OFDM-based system with best-relay selection provides higher performance.

Keywords: OFDM, M-ary QAM, cooperative diversity, best relay selection

1. Introduction

Relays are exploited to improve performance in wireless communication systems. The advantages of the cooperative diversity protocols come at the expense of a reduction in the spectral efficiency since the relays must transmit on orthogonal channels in order to avoid interfering between the source node and each other as well. Hence for a regular cooperative diversity network with M relaying nodes, M+1 channels are employed, which incurs a bandwidth penalty. This problem of the inefficient use of the channel resources can be eliminated with the use of the best-relay selection scheme. In such a scheme, the best relay node only is selected to retransmit to the destination. Hence, two channels only are required in this case (regardless of the number of relays). In this paper, we investigate the error rate performance in a multiple path amplify-and-forward relay with best-relay selection network using orthogonal frequency division multiplexing (OFDM) signals. Multiple-relay cooperative diversity in M-ary QAM OFDM-based systems with Best Relay Selection has better performance than the regular cooperative system.

2. System Model

2.1. M-ary QAM OFDM-based system

Fig. 1. shows the system consists of an OFDM-based implementation, with M-ary QAM on each subchannel. This is similar to the configuration used for DMT-based Asymmetric Digital Subscriber Line (ADSL), but with fixed modulation on each subchannel. [1]

The single-carrier system was extended to a multicarrier (multiple subchannels) system by dividing the available bandwidth into N subchannels. The M-ary QAM OFDM system was simulated for M=4, 16, 64 and 256, over N=4, 16, 64 and 256 subchannels respectively. We refer to these combinations of M-ary modulation scheme (used per subchannel) and N subchannels as MQAM-N (e.g. 64QAM-16 is 64-QAM modulation over 16 subchannels).

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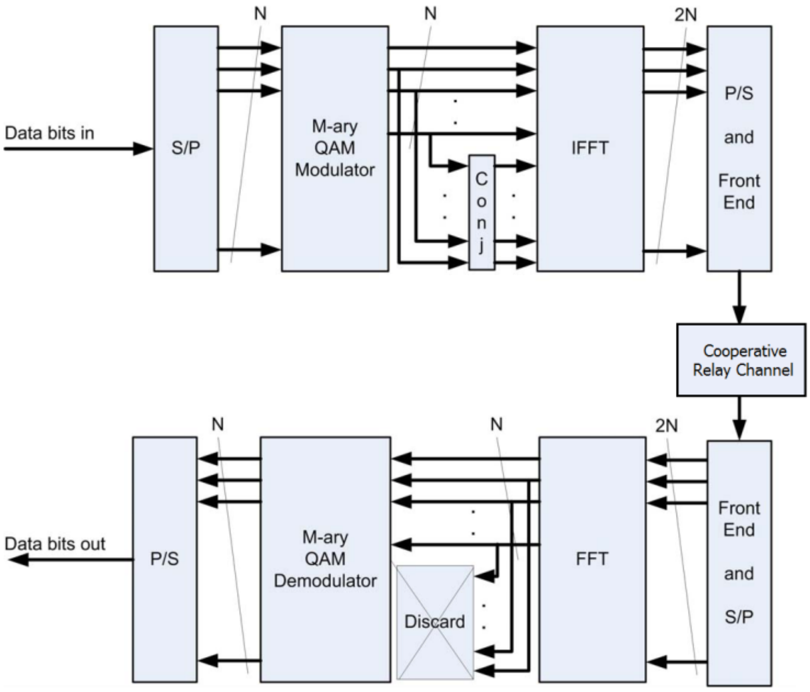

Fig. 1: Illustration of M-ary QAM on OFDM Relay Network System.

According to [1], the BER expression for M-ary QAM OFDM is:

For M=4 (QPSK):

$$P_e = \frac{1}{2} erfc\left(\sqrt{\frac{(2^{\sqrt{N}}-1)}{2^{\sqrt{N-1}}} \cdot \frac{E_b}{N_0}}\right) \tag{1}$$

For M=16, 64, 256,…:

$$P_e = \frac{\sqrt{M}-1}{\sqrt{M}\log_2\sqrt{M}} erfc\left(\sqrt{\frac{(2^{\sqrt{N}}-1)}{2^{\sqrt{N-1}}} \cdot \frac{3.\log_2 M.E_b}{2(M-1).N_0}}\right) \tag{2}$$

2.2. Multiple-Relay Cooperative Diversity Systems with Best Relay Selection System

Fig. 2 shows a source node (S) communicates with the destination (D) through the direct link and the indirect link (through the best relay). This best-relay selection scheme allows the destination to get two copies of the source signal. The first one is from the source (direct link). The channel coefficients between the source S and the ith relay R_i (h_i), between R_i and $D(g_i)$ and between S and D(f) are flat Rayleigh fading coefficients. In addition, h_i, g_j, and f are mutually-independent and nonidentical for all i and j. We also assume here, without any loss of generality that additive white Gaussian noise (AWGN) terms of all links have zero mean and equal variance N_0.

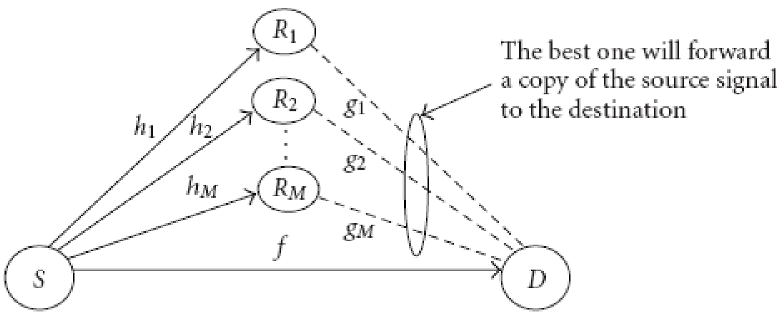

Fig. 2. Illustration of the cooperative diversity network with the best-relay selection scheme

Assuming that the relaying gain equals $\sqrt{1/\left(E_s h_i^2 + N_o\right)}$ [6] (to keep the relay power within its constraints, especially when the fading coefficient (hi) is low), where Es is the transmitted signal energy of the source, it is straightforward to show that the end-to-end SNR of the indirect link S →R_i→D can be written as

$$\gamma_{S\to R_i \to D} = \frac{\gamma_{h_i}\gamma_{g_i}}{\gamma_{h_i} + \gamma_{g_i} + 1} \quad (3)$$

Where $\gamma_{h_i} = h_i^2 E_s / N_o$ is the instantaneous SNR of the source signal at R_i and $\gamma_{gi} = g_i^2 E_s / N_o$ is the instantaneous SNR of the relayed signal (by R_i) at D, where E_i is the signal transmitted energy of the relay. The best relay will be selected as the one that achieves the highest end-to-end SNR of the indirect link. Then assuming that maximum ratio combining (MRC) technique is employed at the destination node, the total SNR at the destination node can be written as

$$\gamma_{tot} = \gamma_f + \max_i\left(\frac{\gamma_{h_i}\gamma_{g_i}}{\gamma_{h_i} + \gamma_{g_i} + 1}\right) \quad (4)$$

where $\gamma_f = f^2 E_s / N_o$ is the instantaneous SNR between S and D. In order to use the total SNR in the outage and error performance calculations, (3) should be expressed in a more mathematically tractable form. To achieve it, we proposed in [7] a tight upper bound for $\gamma_{S\to R_i \to D}$, given by

$$\gamma_{S\to R_i \to D} \le \gamma_i = \min\left(\gamma_{h_i}\gamma_{g_i}\right) \quad (5)$$

The PDF of γ_i can be expressed in terms of the average SNR $\overline{\gamma_{h_i}} = \mathbf{E}\left(h_i^2\right)E_s / N_o$ and $\overline{\gamma_{gi}} = \mathbf{E}\left(g_i^2\right)E_s / N_o$ (where $\mathbf{E}(\bullet)$ is the statistical average operator) as $f_{\gamma_i}(\gamma) = \left(1/\overline{\gamma}_i\right)e^{\gamma/\overline{\gamma}_i}$ where $\overline{\gamma}_i = \overline{\gamma}_{h_i}\overline{\gamma}_{gi} / \left(\overline{\gamma}_{h_i} + \overline{\gamma}_{gi}\right)$. Using the value of, we can rewrite the total SNR in (4) as

$$\gamma_{tot} \le \gamma_f + \gamma_b \quad (6)$$

where $\gamma_b \le \min(\gamma_i) = \max_i\left(\min\left(\gamma_{h_i}\gamma_{g_i}\right)\right)$. This approximation of the end-to-end SNR in (6) is analytically more tractable than the exact value in (4)

3. Simulation Result

We used an amplify and forward cooperative diversity system where a source node communicates with a destination node directly and indirectly.

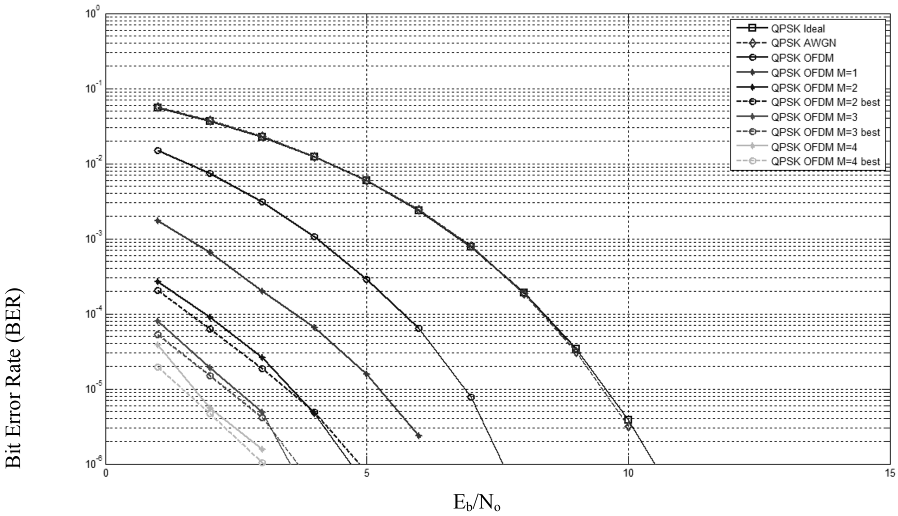

Fig. 3: Comparison of the best-relay selection schema and the regular cooperative diversity

Fig. 3. , We simulated BER versus SNR for QPSK OFDM into 16 subchannels with the best-relay selection. Fig. 3. compares BER performance of the best-relay selection schema and the regular cooperative diversity for different values of the numbers of relays(M). At BER=10^{-5}, QPSK-16 will require a E_b / N_o= 9.5

dB., QPSK-16 for numbers of relays (M) equal 1 will require a E_b / N_o= 6.9 dB., QPSK-16 for numbers of relays (M) equal 2 will require a E_b / N_o= 3.47 dB., QPSK-16 for numbers of relays (M) equal 2 with best-relay selection will require a E_b / N_o= 3.18 dB., QPSK-16 for numbers of relays (M) equal 3 will require a E_b / N_o= 2.5 dB., QPSK-16 for numbers of relays (M) equal 3 with best-relay selection will require a E_b / N_o= 2.05 dB., QPSK-16 for numbers of relays (M) equal 4 will require a E_b / N_o= 1.77 dB., QPSK-16 for numbers of relays (M) equal 4 with best-relay selection will require a E_b / N_o= 1.29 dB. The best-relay selection which numbers of relays (M) equal 2 provides a performance improvement of nearly 0.29 dB. The best-relay selection which numbers of relays (M) equal 3 provides a performance improvement of nearly 0.45 dB. The best-relay selection which numbers of relays (M) equal 4 provides a performance improvement of nearly 0.48 dB.

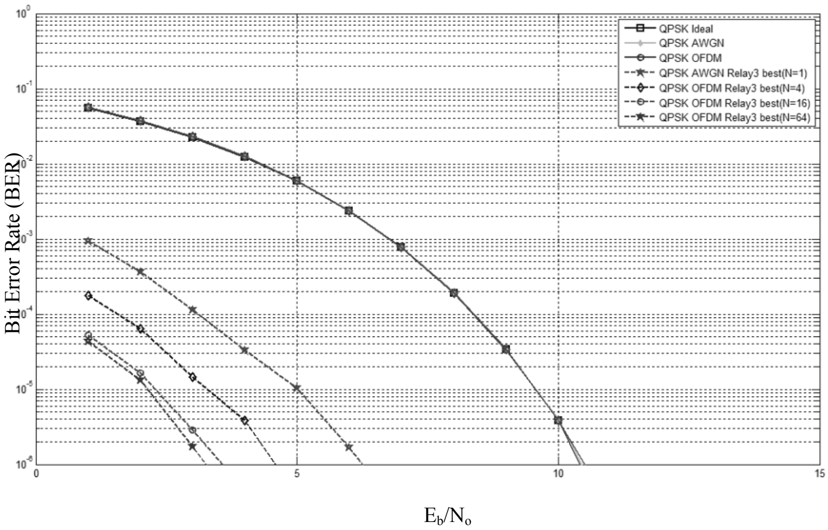

Fig. 4: Comparison of the best-relay selection schema for different values of the numbers of subchannels

Fig. 4. , We simulated BER versus SNR for QPSK OFDM with the best-relay selection for numbers of relays (M) equal 3. Fig. 4. compares BER performance of the best-relay selection schema for different values of the numbers of subchannels. At BER=10^{-5}, A single carrier will require a E_b / N_o= 5 dB. By subdividing the single carrier into 4 subchannels will require a E_b / N_o= 3.27 dB. By subdividing the single carrier into 16 subchannels will require a E_b / N_o= 2.09 dB. By subdividing the single carrier into 64 subchannels will require a E_b / N_o= 1.93 dB. Subdividing the available bandwidth thus provides a performance improvement of nearly 2.7-3.1 dB.

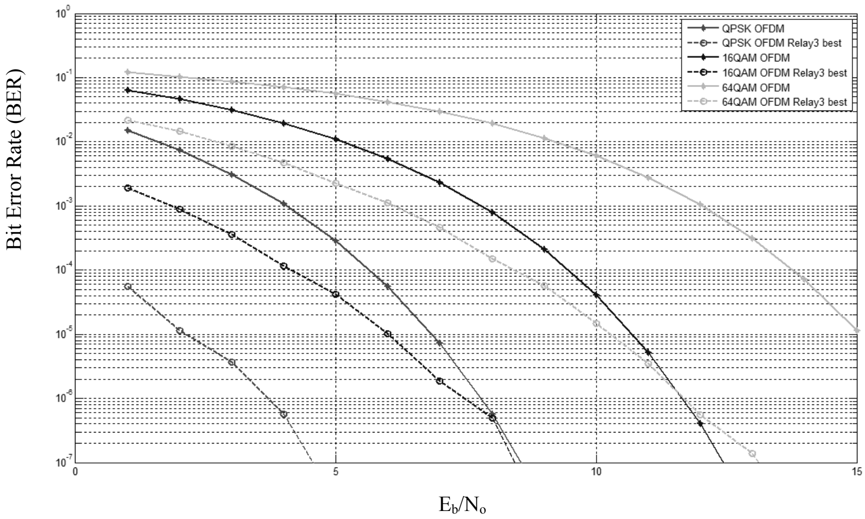

Fig. 5: Comparison of the best-relay selection schema for M-ary QAM OFDM-based system

Fig. 5. , We simulated BER versus SNR for M-ary OFDM into 16 subchannels with the best-relay selection for numbers of relays (M) equal 3. Fig. 5. compares BER performance of M-ary QAM OFDM-

based and with the best-relay selection schema. At BER=10^{-5}, 4QAM-16 will require a E_b / N_o= 6.9 dB. 4QAM-16 with the best-relay selection will require a E_b / N_o= 2.05 dB. 16QAM-16 will require a E_b / N_o= 10.7 dB. 16QAM-16 with the best-relay selection will require a E_b / N_o= 6 dB. 64QAM-16 will require a E_b / N_o= 15 dB. 64QAM-16 with the best-relay selection will require a E_b / N_o= 10.2 dB. The cooperative diversity with best-relay selection provides a performance improvement of nearly 4.7 dB.

4. Conclusion

The results show M-ary QAM OFDM-based system with Best Relay Selection the best-relays selection cooperative has BER better than the regular cooperative diversity. It was found that the performance gain between M-ary QAM OFDM-based system with Best Relay Selection the best-relays selection cooperative and the regular cooperative diversity (irrespective of modulation scheme used) was about 0.29-0.45 dB. When we change modulation scheme for higher capacity, we can increase number of subchannel and use cooperative diversity with best-relay selection for higher performance.

In this paper, we investigate only amplify and forward cooperative diversity system in the multiple path. For example, decode and forward, the single path can be considered.

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