Bit Error Probability Analysis of Cooperative Relay Selection OFDM Systems Based on SNR Estimation

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Abstract: - Cooperative networking plays an important role in wireless adhoc and sensor networks, in which the information from the source to the destination is relayed by intermediate nodes. In this paper, we propose OFDM-based all subcarrier and per subcarrier basis relay selection schemes. The relay selection is based on average signal to noise ratio (SNR) estimation. Data aided (DA) preamble based MMSE estimator is employed for average SNR calculation. We consider rician fading channel i.e., line of sight (LOS) path exits between source and destination. Data aided (DA) preamble based MMSE estimator is employed for SNR calculation. The relative Bit error rate (BER) performance of both all subcarrier and per subcarrier basis relay selection schemes are derived and compared to conventional amplify and forward (AF) ,decode and forward (DF) relaying. The simulation results demonstrates that per subcarrier basis relay selection scheme gives better BER performance compared to all subcarrier basis relay selection scheme.

Keywords: - OFDM, DA, MMSE, LOS, SNR, BER, AF, DF.

1 Introduction

Cooperative diversity is novel ways to achieve spatial diversity that can be obtained without multiple transmit or receive antennas which extend the coverage of wireless transmitters and increase robustness against channel fading. The 802.16e standard is developed exclusively for both fixed and mobile versions and licensed spectrum is used for pure mobile applications. Mobile WiMAX profiles will cover 5, 7, 8.75, and 10 MHz channel bandwidths for licensed worldwide spectrum allocations in the 2.3 GHz, 2.5 GHz, 3.3 GHz and 3.5 GHz frequency bands. The Mobile WiMAX air interface adopts Orthogonal Frequency Division Multiple Access (OFDMA) which provides large data rates with sufficient robustness to radio channel impairments in non-line-of-sight environments.

In relay-based multi-hop cooperative networking source node transfer's information to the destination with the help of a relay selected from the available nodes and it is important to select a relay among available candidates to maximize cooperation benefits for the user or for the whole system. Among them the two most popular cooperative relaying protocols are amplify and forward (AF) and decode and forward (DF) as in [1]-[4]. Hybrid AF-DF relaying, several relaying protocols and their performances in terms of SER or BEP and outage probabilities are investigated as in [4]-[8]. Selective relaying in OFDM multi hop cooperative networks was proposed in [14] and outage performance with coded OFDM was investigated and demonstrated.

Wireless OFDM systems for coherent detection require estimation of channel parameters in order to form time and phase references for the decisions. These parameters are used to calculate signal power. In order to get the long term estimates the instantaneous SNR estimates are averaged over the whole OFDM band by taking the mean of all the estimate over all the subcarriers as in [9]-[13].The MMSE estimation can both decrease the estimation error and shorten training sequence and apply to any channel environment if the transmitter or receiver know the channel estimates as in [9]-[11]. There are two popular categories of OFDM average SNR estimators: data-aided (DA) estimator and non-data-aided (NDA) also called blind estimator as in [10]-[12] both have their own advantages and disadvantages. In DA estimator a certain portion of data is needed for estimation purpose which reduce bandwidth efficiency whereas NDA estimators derive SNR estimate from unknown information bearing portion of the received signal preserving efficiency at the cost of decreasing performance as in [11]. Additional throughput reduction is avoided by using preamble (several training pilot symbols) for DA estimation and the main idea here is to linearly add a known pilot sequence to the transmitted data sequence and perform joint channel estimation and detection in the receiver. Different types of DA estimators for the purpose of channel estimation are investigated in [11].

Clustering in wireless networks means the aggregation of nodes into groups according to some criteria or features. In this paper we propose two clusters one near to the source, relay in cluster near to source employs AF protocol and cluster near to destination employs DF protocol. Average SNR is calculated at each relay using preamble based DA MMSE estimator and relays from each cluster are selected using all subcarrier basis or per subcarrier basis relay selection schemes and selected relay(s) transmits to destination. BER performances of both selection algorithms are compared.

The paper is organized as follows: In Section II, we describe the system model, Section III describes relay selection schemes and their BER evaluation. In Section IV simulation results are analyzed. Finally, Section V draws some conclusions.

2 System Model

In this paper we propose a new improved cooperative relay selection scheme for multi-relay mobile adhoc transmission network. The system consists of a single source S, a destination node D with two clusters and each cluster has K relay nodes as shown in Fig. 1 and Fig. 2. All relays in cluster1 (C1) which are near to the S employs amplify and forward (AF) scheme and all relays in cluster 2 (C2) which are far away from S employs decode and forward (DF) scheme. As distance increases noise increases and if we use AF scheme it amplifies signal as well as noise which increases BER, hence we employ DF scheme for C2 relays. First we calculate average SNR at each relay by using preamble based MMSE estimator and relay(s) from each cluster are selected for transmission depending on the relay selection criterion. In this paper we investigate two relay selection criterions: (a) All subcarrier basis relay selection and (b) Per subcarrier basis relay selection.

The system is assumed to be half duplex and each relay employs a single antenna. The cooperation is based on the receiver diversity (RD) protocol i.e., it adopts a two slot transmission protocol as in [16]. In the first time slot the source S broadcasts its information to both the destination and relays. In second time slot, the selected relay(s) transmit the message to the destination.

In the first time slot, the received signals at relay and the destination from source are represented by $y_{SR}(i,k,n)$ and $y_{SD}(n)$ respectively.

$$y_{SR}(i,k,n) = \sqrt{P_S} h_{SR}(i,k,n) x(n) + n_{SR}(i,k,n) \tag{1}$$

$$y_{SD}(n) = \sqrt{P_S} h_{SD}(n) x(n) + n_{SD}(n) \tag{2}$$

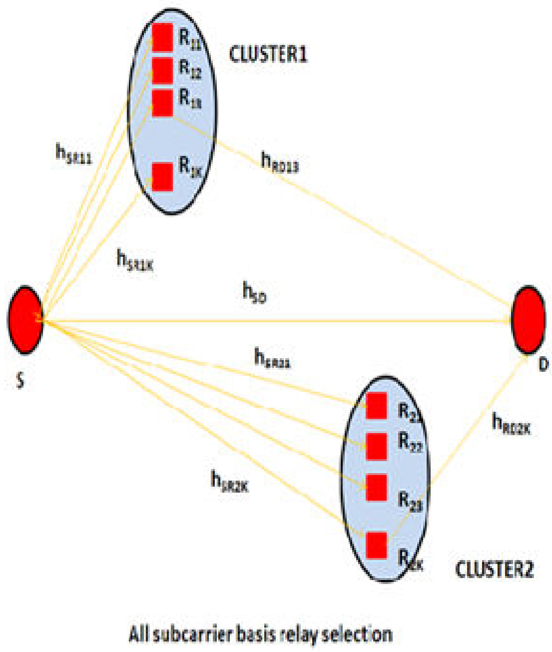

Fig.1 All subcarrier basis relay selection scheme

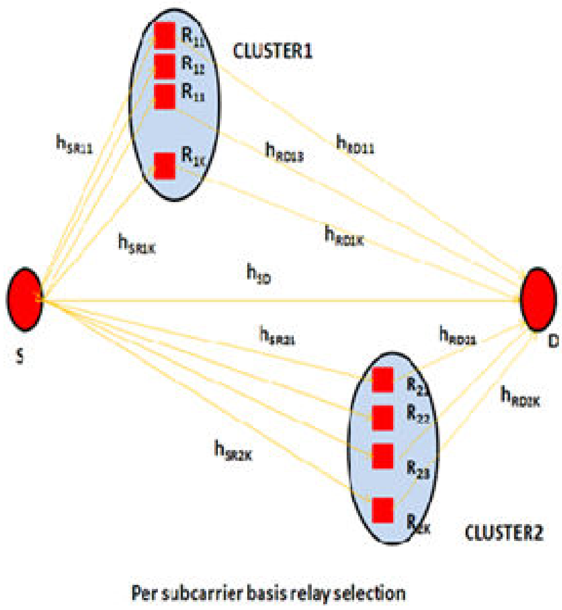

Fig.2 Per subcarrier basis relay selection scheme

where k represents relay number $k = 1$ to K; n represents number of the subcarrier, $n = 1$ to N; N represents total number of subcarriers, and all subcarriers has equal transmit power; i represents cluster number, $i = 1$for AF scheme, $i = 2$ for DF scheme. P_S is the transmit signal power at the source, $h_{SR}(i,k,n)$ and $h_{SD}(n)$ are channel gains between source to relay and source to destination respectively. The noise coefficients $n_{SD}(n)$, $n_{SR}(i,k,n)$ and $n_{RD}(i,k,n)$ represents independent mean and variance N_O respectively.

At destination the corresponding received signal from the relay in second timeslot can be represented as $y_{RD}(i,k,n)$.

2.1 For AF Scheme (at C1)

Cluster1 employs AF scheme, therefore $i = 1$ for AF scheme.

$$y_{RD_{AF}}(i,k,n) = \beta(i,k,n)h_{RD}(i,k,n)y_{SR}(i,k,n) + n_{RD}(i,k,n) \quad (3)$$

where $h_{RD}(i,k,n)$ is channel gain between relay to destination and $\beta(i,k,n)$ is amplification factor at the AF relay.

$$\beta(i,k,n) = \sqrt{\frac{P_R}{|h_{SR}(i,k,n)|^2 P_S + N_O}} \quad (4)$$

where P_R is the received signal power at the AF relay.

2.2 For DF Scheme (at C2)

Cluster2 employs DF scheme, therefore $i = 2$ for DF scheme.

$$y_{RD_{DF}}(i,k,n) = \sqrt{\widehat{P_R}}\, h_{RD}(i,k,n)\widehat{x(n)} + n_{RD}(i,k,n) \quad (5)$$

where $\widehat{P_R}$ is the received estimated signal power at the DF relay.

3 Relay Selection Criteria

The two different relay selection criterions are proposed and are explained below:

3.1 All Subcarrier Basis Relay Selection

In this scheme only one relay is selected at each cluster to forward the entire OFDM block so that all the subcarriers traverse the same path. The average SNR of all subcarriers is calculated at each relay using MMSE estimator from each cluster one relay which is having maximum average SNR for all subcarrier is selected for transmission as shown in Fig.1.

Let $\gamma_{avMMSE}(i,k)$ is the average SNR of all subcarriers at each relay calculated using MMSE estimator given in [6, 7].Where $\hat{S}_{MMSE}(i,k)$ and $\widehat{W}_{MMSE}(i,k)$are the MMSE estimates of the signal power and noise power.

$$\gamma_{avMMSE}(i,k) = \frac{\hat{S}_{MMSE}(i,k)}{\widehat{W}_{MMSE}(i,k)} \quad (6)$$

$$\hat{S}_{MMSE}(i,k) = \left|\frac{1}{N}\sum_{n=0}^{N-1} y_{SR}(i,k,n)x(n)^*\right|^2 \quad (7)$$

$$\widehat{W}_{MMSE}(i,k) = \frac{1}{N}\sum_{n=0}^{N-1}|y_{SR}(i,k,n)|^2 - \hat{S}_{MMSE}(i,k) \quad (8)$$

From each cluster one relay having max $\gamma_{avMMSE}(i,k)$ is selected and used to forward entire OFDM block, $\gamma_{max}(i)$ represents maximum average SNR for the cluster i.

$$\gamma_{max}(i) = \max_k \gamma_{avMMSE}(i,k) \quad (9)$$

Let $R_{sel}(i,k)$ represents relay selection factor for all subcarrier basis relay selection.

$$R_{sel}(i,k) = \begin{cases} 1, & if\ \gamma_{avMMSE}(i,k) = \gamma_{max}(i) \\ 0, & otherwise \end{cases} \quad (10)$$

Selected relay is represented by k_{sel} and is given by

$$k_{sel} = k \ \text{ if } R_{sel}(i,k) = 1\ for\ k = 1\ to\ K \quad (11)$$

The MRC combiner output for this scheme is given by

$$y_{D_{MRC}}(n) = \frac{\sqrt{P_S}}{n_{SD}(n)} w_{SD}(n)y_{SD}(n) + \sqrt{P_S}\, w_{RD\_AF}(1,k_{sel},n)y_{RD\_AF}(1,k_{sel},n) + \frac{\sqrt{\widehat{P_R}}}{n_{RD}(2,k_{sel},n)} w_{RD\_DF}(2,k_{sel},n)y_{RD\_DF}(2,k_{sel},n) \quad (12)$$

where

$$w_{SD}(n) = h^*{}_{SD}(n) \quad (13)$$

$$w_{RD\_DF}(2,k,n) = h^*{}_{RD}(2,k,n) \quad (14)$$

$$W_{RD\_AF}(1,k,n) = \frac{h_{SR}^*(1,k,n)h_{RD}^*(1,k,n)\beta(1,k,n)}{|h_{RD}|^2\beta^2(1,k,n)n_{SR}(1,k,n)+n_{RD}(1,k,n)} \quad (15)$$

The total received SNR at the destination for all subcarrier scheme can be denoted as

$$\gamma_t = \sum_{n=1}^{N}[\gamma_D(n) + \gamma_{AF}(1,k_{sel},n) + \gamma_{DF}(2,k_{sel},n)] \quad (16)$$

where

$$\gamma_D(n) = \frac{h_{SD}^2(n)P_S}{n_{SD}(n)} \quad (17)$$

$$\gamma_{AF}(1,k,n) = \frac{\frac{P_S h_{SR}^2(1,k,n)}{n_{SR}(1,k,n)} \cdot \frac{P_R h_{RD}^2(1,k,n)}{n_{RD}(1,k,n)}}{\frac{P_S h_{SR}^2(1,k,n)}{n_{SR}(1,k,n)} + \frac{P_R h_{RD}^2(1,k,n)}{n_{RD}(1,k,n)} + 1} \quad (18)$$

$$\gamma_{DF}(2,k,n) = \frac{\widehat{P_R} h_{RD}^2(2,k,n)}{n_{RD}(2,k,n)} \quad (19)$$

3.2 Per Subcarrier Basis Relay Selection

In this scheme at each cluster the relay selection is performed in a per-sub carrier manner. Per each subcarrier n the relay with the highest received SNR i.e., $\gamma_{max}(i,n)$ is selected. At each cluster different relays might be selected for different subcarriers as shown in Fig.2. Here the number of relays selected may be less than or equal to N.

Let the SNR per subcarrier at each relay is calculated by using MMSE estimator and is represented as $\gamma_{MMSE}(i,k,n)$. For each cluster, relay having maximum $\gamma_{MMSE}(i,k,n)$ is selected for each n^{th} subcarrier for transmission.

$$\gamma_{MMSE}(i,k,n) = \frac{\hat{S}_{MMSE}(i,k,n)}{\widehat{W}_{MMSE}(i,k,n)} \quad (20)$$

$$\hat{S}_{MMSE}(i,k,n) = |Y_{SR}(i,k,n)x(n)^*|^2 \quad (21)$$

$$\widehat{W}_{MMSE}(i,k,n) = |Y_{SR}(i,k,n)|^2 - \hat{S}_{MMSE}(i,k,n) \quad (22)$$

From each cluster, relay having $\max_k \gamma_{MMSE}(i,k,n)$ is selected for n^{th} subcarrier transmission; the max. SNR for n^{th}subcarrier is represented by $\gamma_{max}(i,n)$ and are given by

$$\gamma_{max}(i,n) = \max_k \gamma_{MMSE}(i,k,n) \quad (23)$$

Let $R_{sel}(i,k,N)$ represents relay selection factor for per subcarrier basis selection criterion then

$$R_{sel}(i,k,n) = \begin{cases} 1, & if\ \gamma_{MMSE}(i,k,n) = \gamma_{max}(i,n) \\ 0, & otherwise \end{cases} \quad (24)$$

MRC output for per subcarrier relay selection scheme is given by

$$y_{D_{MRC}}(n) = \frac{\sqrt{P_S}}{n_{SD}(n)} w_{SD}(n) y_{SD}(n) + \sum_{k=1}^{K}[\sqrt{P_S} R_{sel}(1,k,n) w_{RD_{AF}}(1,k,n) y_{RD_{AF}}(1,k,n) + \frac{\sqrt{P_R}}{n_{RD}(2,k,n)} R_{sel}(2,k,n) w_{RD\_DF}(2,k,n) y_{RD\_DF}(2,k,n) \quad (25)$$

For this scheme, the total received SNR at the destination is given by

$$\gamma_t = \sum_{n=1}^{N}\{\gamma_D(n) + \sum_{k=1}^{K}[R_{sel}(1,k,n)\gamma_{AF}(1,k,n) + R_{sel}(2,k,n)\gamma_{DF}(2,k,n)]\} \quad (26)$$

Bit error probability P_e [15] for M=16, 64, 256 … is given by

$$P_e = \frac{\sqrt{M}-1}{\sqrt{M}\, log_2\sqrt{M}} erfc \sqrt{\frac{\left(2^{\sqrt{N}}-1\right)}{2^{\sqrt{N-1}}} \cdot \frac{3.log_2 M.E_b}{2(M-1).N_o}} \quad (27)$$

4 SIMULATION RESULTS

In this paper, the relay selection based cooperative system for mobile adhoc network is implemented as per 802.16e standards. IEEE 802.16e defines multiple physical layers for different applications. Here the air interface uses OFDM techniques and the simulation parameters are shown in Table 1. We consider rician fading channel between source and destination, 10MHz channel bandwidth, FFT size 1024, cluster formation is considered as in [18] and the cluster near to the source is considered for AF relay selection and cluster near to destination for DF.

In this Section, the performances of the proposed relay selection schemes for OFDM systems based on SNR estimation are evaluated. In Fig. 3 and Fig. 4 we plot the bit error rate of the all subcarrier basis relay selection scheme and per subcarrier basis relay selection scheme as a function of the SNR. The performance of both relay selection schemes are analyzed and compared.

BER verses SNR for all subcarrier basis relay selection scheme was plotted in Fig.3 by using (16) and (27). It was observed that combined relaying protocol gives better performance compared to AF and DF schemes alone. BER verses SNR for per subcarrier basis relay selection scheme was calculated using (26) and (27) and was plotted in Fig. 4. It was observed from Fig. 3 and Fig. 4 that for a given SNR value per subcarrier basis relay scheme provides better BER performance than all subcarrier basis relay selection.

Table 1 Simulation Parameters

Parameter	Value
BW: Channel bandwidth	10MHz
N_{FFT} : Size of FFT	1024
Fs=n.BW: Sampling frequency	11.2MHz
Npilot : Number of Pilot Subcarriers	120
N used :Number of user Subcarriers	720
Null subcarriers	184
n:Sampling factor	28/25
$\Delta_F = F_S/N_{FFT}$:Subcarrier Frequency Spacing	10.9375 KHz
$T_b = 1/\Delta_F$:Useful symbol time	91.42 µs
T_g:Guard time	11.4 µs (1/8)or 22.855 µs(1/4)
$G = T_g/T_b$:Guard period ratio	1/8 or 1/4
$T_s = T_g + T_b$Over all symbol time	102.8 µs (1/8) or 114.2 µs(1/4)
Number of OFDM symbols in 5ms frame	48

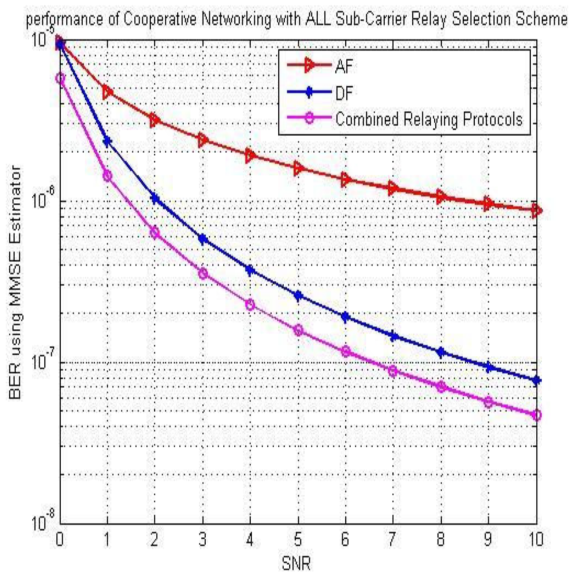

Fig.3 BER Vs SNR for all sub-carrier relay selection scheme

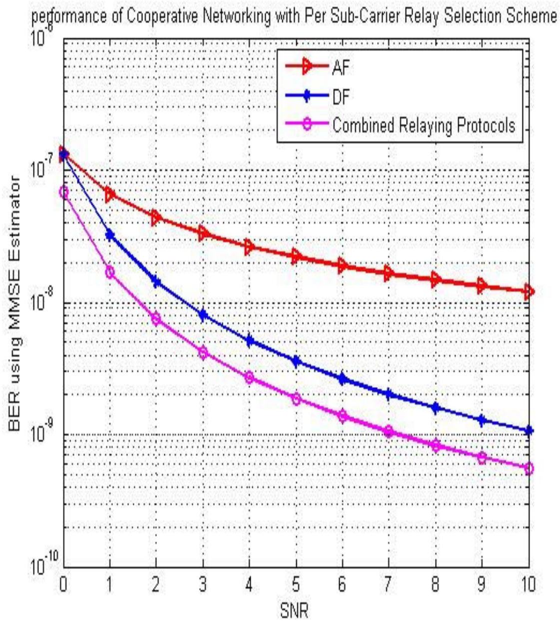

Fig.4 BER Vs SNR for per sub-carrier relay selection scheme

5 CONCLUSIONS

In this work, Cooperative diversity strategies in Mobile systems are employed with both AF and DF relaying. Depending on the geographical location of the cluster, the relaying protocol is employed. Rician fading with both LOS and NLOS conditions are considered because of mobile scattering environment. All subcarrier and per subcarrier Data aided (DA) estimation are analyzed at both the clusters. The average MMSE-SNR estimation is considered and evaluated because of its simplicity in calculation. The simulation results demonstrated the performance comparison between per subcarrier and all subcarrier relay selection schemes. Furthermore, the multipath signals coming from different relays are combined with Maximum ratio combiner. From the simulation results, it is observed that the BER performance of per subcarrier is better than all subcarrier relay selection strategy.

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