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Research Article

Analysis of Cooperative Networks Based on WiMAX LDPC Code

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Abstract: This study focus on the performance analysis of Cooperative communication networks based on WiMAX Low Density Parity Check (LDPC) codes. The channel capacity approaching coding technique LDPC having coding gain method Bit Interleave Coded Modulation with Iterative Decoding (BICM-ID) is used. The different fading environment is analyze to counter the challenges in wireless communication and provides solutions for the drawbacks in the multiple input multiple output MIMO technology. The relays are used in Cooperative communications networks to increases the range and link reliability at a lower transmit power because once the signal transmit power loses its strength it's amplify on the relay node and when it suffers from noise it is also decoded at the relay node which increases the link reliability. LDPC with iterative decoding are used to gain BER performance only a small amount of decibel to attain Shannon limit. This performance analysis open the way for WiMAX technology can be used with Cooperative networks by using LDPC codes. The above mention communication system will provides rate, range and reliability at a lower cost, less complexity and lower transmit power.

Keywords: BER, BICM, cooperative network, ID, LDPC, MIMO, Nakagami-m, Rician-K, WiMAX

INTRODUCTION

In the era of innovation, creativity and fast paced development in the field of science and technology, Wireless technology played an important role for providing information to the whole world as global village with no direct visibility. This emerging field has grown at a formidable rate and witnessed spectacular expansion over the last two decades. The OFDM combination with TDMA/FDMA introducing a promising technique is called Orthogonal Frequency Division Multiple Access (OFDMA) (Baek *et al*., 2007). It is considered to be a solution for enhancing the performance of multiple users' broadband wireless access. OFDMA has made it possible for different flavors of wireless broadband systems to attain the such high data traffic to fulfill the quality of service needed for high speed future multimedia applications and videos conferencing (Laroi *et al*., 2004; Liu and Li, 2005) OFDMA drastically combat the ISI by avoiding the multipath phenomena in frequency selective fading channel.

MIMO is the one the best solution for mitigating the channel fading and provide higher capacity to cellular systems. It is commonly accepted that the wireless broadband access will only be possible with the use of increasing number of antennas at the both side of the communication system. The channel capacity will continue to increase proportionally to the use of multiple antennas at the transmitter and receiver side. So a novel system was introduced by designing multiple antennas at both ends of the communication system i.e., the Base Station (BS) and the Mobile Terminal (MT) (Foschini and Gans, 1998). On the other hand, due to smart cell size, low cost and hardware limitations, it is not practical to use more than two antennas array at the MTs. An introduction of new diversity scheme known as cooperative communications is one of manicuring solution for wireless systems for overcoming the above limitations Edited by Fitzek and Katz (2006). It provides an effective approach to gain advantages of spatial diversity with the single antenna device without the acquiring for physical antenna arrays. Under these smart benefits the novel research on cooperative diversity can be found in the revolutionary papers of (Van der Meulen, 1971; Cover and Gamal, 1979) on the information theoretic belongings of the channel having relays. Open cooperation of neighboring relays nodes were proposed in (Sendonaris *et al*., 2003; Dohler, 2003; Laneman *et al*., 2004).

One of the classes of Shannon Limit or a channel capacity approaching Codes is the (LDPC) codes. They are first invented by researcher (Gallager, 1962, 1963). This research was further gernalized in 1990 when researchers began to investigate codes by doing some coding by mapping codes on graphs with iterative decoding methods. LDPC with iterative decoding are

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used to gain BER performance only a small amount of decibel to attain Shannon limit. This invention of LDPC codes makes them strong competitors with turbo codes for controlling the error where there is high reliability is desired in many communication and digital storage system. There are some advantages of LDPC over the turbo codes. To achieve a better BER performance they do not need a long interleaver and have better performance of block error. Their error floor occurs at very lower BER values. Their decoding is not based on the Trellis. With the introduction LDPC codes, k number of information bits are firstly encoded to n create code bits by $r = n-k$ number of parity check bits. The LDPC codes are based on a H (parity check matrix) having a size of $(n-k) \times n$ that is extended from the H_b (binary base matrix) of size $r_b \times n_b$, whereas $n = z \, . \, n_b$ and $r = z. \, r_b$. The size of the base matrix n_b is an integer that is equal to 24 and t increasing from z to $24 \leq z \leq 96$. From these integers values we can figure out the minimal length of code where $n_{min} = 24.24 = 576$ bits and the maximum length of code where $n_{max} = 24 \, .96 = 2304$ bits. In total there are having five different base matrices (Forney Jr., 1991), one base matric for rate 1/2 codes, two different base matrices for rate 2/3 codes and two different base matrices for rate 3/4 codes. The base matrix having entries p (i, j) are either '-1' signifying a replacement with a z×z all-zero matrix or integers p (i, j) ≥0 signifying a replacement with a $z \times z$ having permutation matrix. The permutation matrix will be circular right shift on p (i, j) points. From this an entry p $(i, j) = 0$ must be substituted by a $z \times z$ identity matrix. For decoding algorithm it can be apply a certainty transmission decoder using the sum-product algorithm (David and MacKay, 1999).

The introduction of coded modulation scheme in cooperative networks provides high spectral efficiency which includes Block Coded Modulation (BCM) (Imai and Hirakawa, 1977) and the Trellis Coded Modulation (TCM) (Ungerboeck, 1982). Coded modulation schemes offer large coding gains while they are having good algebraic structures which permit a simple encoding and decoding process (Forney Jr., 1991). On the other hand, there are two drawbacks that limit the application of TCM and BCM. Both schemes transmit effectively over Additive White Gaussian Noise (AWGN) channels but there is performance degradation in fading channels (Schlegel and Costello, 1989; Zehavi, 1992). In order to enhance the performance of digital transmission over the fading channels, the introduction of Bit-Interleaved Coded Modulation (BICM) (Caire *et al*., 1998). This introduces time diversity by inserting bit interleaving between the encoding and modulation to attaining high spectral efficiency. Coded modulation schemes is mostly use signal constellation shaping methods, like shell mapping and trellis shaping (Wachsmann *et al*., 1999). As another shaping method, the introduction of partially overlapped signal sets (Tran *et al*., 2008).

METHODOLOGY

System model: The system model WiMAX LDPC based on cooperative network is shown in Fig. 1. The different steps involve in the transmission over different fading environment and the functional blocks that comprises of source, transmitter, channel, signal combiner and receiver.

Transmitter: In the transmitter the random data from the source is which firstly coded using WiMAX standard based LDPC encoder. For enhancement in digital transmission over the fading channels, the use of Bit-Interleaved Coded Modulation (BICM) introduces the time diversity by using a bit interleaver between the encoder and modulator.

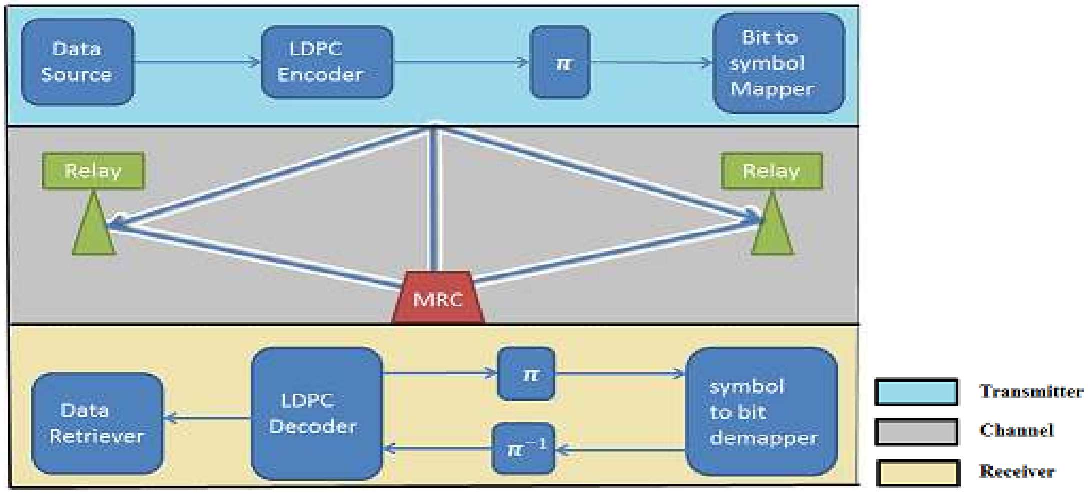

Fig.1: WiMAX LDPC BICM-ID based cooperative system model

Relay network: In relay network there are two phases. In phase 1, the source point sends information to the destination and the relay points. The incoming received signals y_{SD} and y_{SR} at the destination and the relay points, individually, can be mathematically written as:

$$y_{SD} = \sqrt{P_1} h_{SD} x + \eta_{SD} \tag{1}$$

$$y_{SR} = \sqrt{P_1} h_{SR} x + \eta_{SR} \tag{2}$$

where, P_1 is the power of transmitted signal at the source, x is the information of transmitted symbol, $\eta_{S,D}$ and $\eta_{S,R}$ are corresponding additive noise having variance N_0 at the destination and relay points, individually. In Eq. (1) and (2), h_{SD} and h_{SR} are the corresponding channel coefficients from the source to the destination and the relay points, individually.

In phase 2, now the relay points can co-operate the source point by advancing or retransmitting the information to the destination point. The relay operation mode can be amplify-And-Forward (AF) or Decode-and Forward (DF). For an AF mode, the relay point amplifies the incoming received signal and the sends it to the destination point having transmitted power P_2. In this case, the incoming received signal at the destination point in phase 2 is specified as:

$$y_{RD} = \frac{\sqrt{p_2}}{\sqrt{p_1 |h_{SR}|^2 + N_o}} h_{RD} y_{SR} + \eta_{RD} = \frac{\sqrt{p_1 p_2}}{\sqrt{p_1 |h_{SR}|^2 + N_o}} h_{RD} y_{SR} + \eta'_{RD} \tag{3}$$

where,

h_{RD} : The fading channel coefficient from the relay point to the destination point

η_{RD} : An channel additive noise term:

$$\eta'_{RD} = y_{RD} = \frac{\sqrt{p_2}}{\sqrt{p_1 |h_{SR}|^2 + N_o}} h_{RD} y_{SR} + \eta_{RD} \tag{4}$$

Having variance $\left(\frac{P_1 |h_{R,D}|^2}{P_1 |h_{S,R}|^2 + N_0} + 1\right) N_0$.

In phase 2, for DF relaying mode, however, if the relay point is correctly able decode the transmitted symbol, then it moves the decoded symbol to the destination point with power P_2; otherwise, it does not forward. The received signal at the destination point in phase 2 in this case can be mathematically modeled as:

$$y_{RD} = \sqrt{\widetilde{P}_1} h_{RD} x + \eta_{RD} \tag{5}$$

where, $\widetilde{P_2} = P_2$ if the relay point correctly decodes the transmitted symbol, otherwise $\widetilde{P_2} = 0$. AF relaying modes lead to low computation complexity relay point transceivers and consumes lower power because it only amplify instead of decoding. Another pro of AF relaying mode is that they are transparent to adaptive modulation techniques, which may be active by the source point. However, as Eq. (4) shows, AF relaying mode also forwards noise to the destination point.

Receiver: The receiver function is ultimately the reverse operation as the transmitter. Once the data bits have been demapped, it goes into the decoder block and finally retrieved the data.

Transmission protocol: The TDMA based two times slot relaying method is used (Nabar *et al*., 2004).

Time slot 1: The incoming received data at the D station in time slot 1 is given as:

$$y_{SD} = \sqrt{E_{SD}} h_{SD} x + \eta_{SD} \tag{6}$$

where, E_{SD} is the transmitted data signal energy and x is the signal of transmitted data. n_{SD} is additive white Gaussian noise at D station, i.e., $n_{SD} \sim \mathcal{CN}(0,1)$. The received data signal at the R station in time slot 1 is given by:

$$y_{SR} = \sqrt{E_{SR}} h_{SR} x + \eta_{SR} \tag{7}$$

where, $n_{SR} \sim \mathcal{CN}(0,1)$ additive white Gaussian noise at a R station.

Time slot 2: While in the second time slot, the relay station normalizes the received data signal and then sends again to the D station. MRC at the D station is come first by noise normalization. After the noise normalization, the received data signal through the R station in time slot 2 is given as:

$$y_{RD} = \frac{1}{\omega} \sqrt{\frac{E_{RD} E_{SR}}{E_{SR} |h_{SR}|^2 + 1}} h_{RD} h_{SR} x + \eta_{RD} \tag{8}$$

where,

$$\omega = \sqrt{\frac{E_{RD} |h_{RD}|^2}{E_{SR} + N_0} + 1}$$

ω is noise normalization factor for a R station path, $n_{rd} \sim \mathcal{CN}(0,1)$. E_{rd} is the R station transmitted data signal energy. Two independent signals are received at D in the second time slot. The received data signal at D station can be written as:

$$Y = Hx + N$$

where, Y^T= (y_{SR} and y_{SD}), the channel gain is represented as H^T= (A B) and N^T= (n_{SR} n_{RD}), A = $\sqrt{E_{SD} h_{SD}}$:

$$B = \frac{1}{\omega} \sqrt{\frac{E_{SR} E_{RD}}{E_{SR} |h_{xy}|^2 + 1}}$$

Superscript T denotes the transpose of the matrix and h_{xy} is the path gain through X ⟶Y link.

Channel model: The communication over a wireless fading channel the retrieved output signal cannot be correctly modeled as a copy of the transmitted input signal that is degraded by random additive Gaussian noise. The signal fading is affected by the time-varying characteristics of the different fading environment. So, the rapid amplitude fluctuations produced in the signal by scattering of different obstacles in the transmitted environment that produces a multipath transmission. In this study it is assumed that wireless fading channels will be same over the period of two timeslots i.e., flat fading coefficients. In this system model, we analyze the cooperative system over Rician-k and Nakagami-m fading channels. It is also assumed that Channel State Information (CSI) and perfect synchronization and are present at the receiver of system, hsd is the path gain coefficient through S⟶D link and |hsd| follows Rician-k and Nakagami-m distributions.

Rician model: In a wireless communication system, if there is one strong LOS signal component typically to the NLOS multipath channels, the incoming signal will have a Rician distribution. The multipath components become superimposed on the LOS strong channel. As the strong component gets weaker, there exhibit fluctuation in the composite signal starts to that follows Rayleigh distribution. Therefore, when the strong component no longer remains stronger, the Rician distribution becomes into Rayleigh distribution. The Rician distribution mathematical model is given by the following relation:

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{\left(r^2+A^2\right)}{2\sigma^2} I_o\left(\frac{Ar}{\sigma^2}\right)}, \qquad \left(for A \geq 0, r \geq 0\right)$$

(9)

Nakagami model: Nakagami-m besides Rician and Rayleigh is a refined statistical model for envelop detection of a fading model. The channel pdf of signal amplitude introduced to mobile fading have been recommended Nakagami match. Therefore it delivers more flexibility and provides better accuracy to model fading channel's characteristics. The mathematical model is given by the following relation:

$$p(\alpha) = \frac{2m^m \alpha^{2m-1}}{\sigma^2} \exp\left(-\frac{m\alpha^2}{\Omega}\right), \ \alpha \geq 0 \qquad (10)$$

where, as m is the shaping factor, which values start from ½ to infinity. Ω is given by:

$$\Omega = E(\alpha^2)$$

The SNR value per symbol γ is scattered according to gamma distribution given by:

$$p(\gamma) = \frac{m^m \gamma^{2m-1}}{\bar{\gamma}\Gamma(m)} \exp\left(-\frac{m\gamma}{\bar{\gamma}}\right), \ \gamma \geq 0 \qquad (11)$$

The amount of fluctuations occurs in Nakagami-m distribution is determined by:

$$AF_m = \frac{1}{m}, \ m \geq 1/2 \qquad (12)$$

The amount of fluctuation can range from value 0 to 5 as the value of m can increase or decrease. When the value of m is infinity and the amount of fluctuation is 0, then the channel Nakagami-m converges to a channel AWGN which is non-fading.
Nakagami in 1960:

$$f\left(\left|h_{xy}\right|\right) = \left(\frac{m}{E\left|h_{xy}\right|^2}\right) m^2 \frac{\left|h_{xy}\right|^{2m-1}}{\Gamma(m)} \exp\left(\frac{-m\left|h_{xy}\right|^2}{E\left|h_{xy}\right|^2}\right) \qquad (13)$$

where, τ (.) is a gamma function and E (.) is the expectation operator and h_{xy} is the fading magnitude of link X⟶Y. Hence $\alpha_{SD} = |h_{SD}|^2$, $\alpha_{RD} = |h_{RD}|^2$ and, $\alpha_{SR} = |h_{SR}|^2$ are gamma distributed random variables given by:

$$f\left(\left|h_{xy}\right|\right) = \frac{2m^m \alpha_{xy}^{m-1}}{\Gamma(m)} \exp\left(-m\alpha_{xy}\right) \qquad (14)$$

For Nakagami fading factor, m = 1 and m = (K+1) 2/ (2K+1) (where K is the Rice factor), the channel coefficients follows Rayleigh and Rician distribution, respectively.

RESULTS AND DISCUSSION

In this section scenario based simulation is performed by considering performance analysis of LDPC BICM-ID system with different code rates, Nakagami-m and Rician-K fading channels with single and multiple relays by varying the positions of the relays under path loss effect. The detail discussion and results has been provided by considering the attributes containing parameter setting or values given in Table 1 of the WiMAX LDPC based cooperative network system. The simulation has been performed on Intel (R) Core (TM) i5-3210M CPU @2.50 GHz, 4 GB of RAM and running with MATLAB version 2012a.

Scenario I: performance analysis of LDPC BICM-ID system with different coding rates: In Fig. 2 multiple relays performance is better than the single relay. The Multiple relay provides Lower BER value at a low SNR value than the single relay its means if the increase the number of relays the performance will also increase. Same is case that 1/2 coding rate provides

Table 1: Parameters setting/values for WiMAX LDPC codes

Parameters	Values/setting
Channel coding	LDPC
Coding rate	1/2, 2/3, 5/6
Modulation scheme	BPSK, QPSK, M-QAM
Frame size	2304
Channel	Rician, rayleigh, nakagami
No of relays	Two
Relaying mode	AF
Relaying protocol	Two time slot
Access method	TDMA
Signal combining scheme	MRC
No of iterations	5
SNR	0 to 6 dB

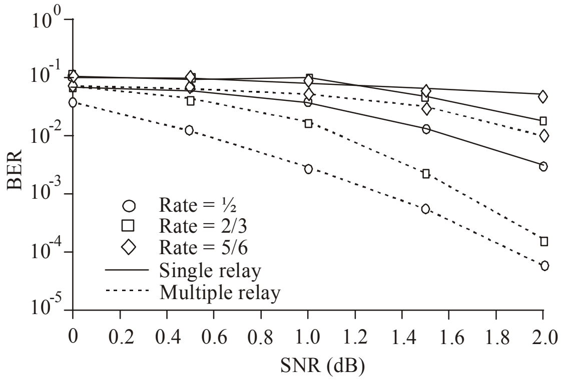

Fig. 2: Simulated BER for different coding rates

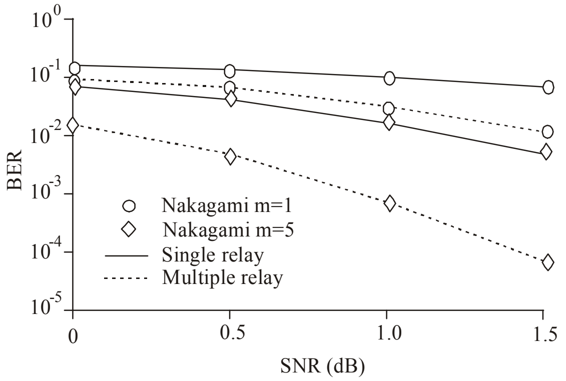

Fig. 3: Simulated BER for Nakagami-m fading channel

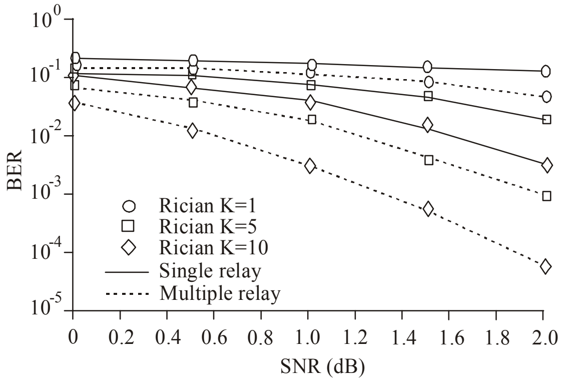

Fig. 4: Simulated BER over Rician-K fading channel

lower BER at value at a low SNR value than the 2/3 and 5/6. Code rate 1/2 with multiple relay performance is the best which provides reliable communication with BER of 10^{-4} at very low value of a SNR nearly equal 1.9 dB on the other hand code rate 5/6 is provides very poor performance with single relay.

Scenario II: performance analysis of LDPC BICM-ID system over Nakagami-m fading channel: In this simulation result performance analysis is based on fading channel Nakagami-m distribution. From the simulation results shown in Fig. 3 as the value of the m increases from 1 to 5 the system provides the lower BER value at lower SNR value. The performance of m = 5 is much better than m = 1. In the same way the performance of multiple relay provides lower BER value at Lower SNR value than single relay in both the cases m = 1 and m = 5. In this simulation result Nakagami-m = 5 distribution with the multiple relay is the best performance result with the value of BER of 10^{-4} is achieved at very low value of 1.4 dB of SNR which is very efficient for reliable communication.

Scenario III: BER analysis of LDPC BICM-ID system over Rician-K fading channel: In this simulation result performance analysis for the fading channel Rician-K. Here three different value of K is taken with single and multiple relay to analyze the performance evaluation. From the Fig. 4 the value of factor K increase from 1 to 10 for both the single and multiple relay the system provides Lower BER value at Lower SNR value. The value of Rician K = 10 provides better performance than value of Rician K = 1 and K = 5 for both the single and multiple relay. In simulation results multiple relay performance is better than single relay for all value of K. In this simulation result Rician K = 10 with the multiple relay is the best result with the value of BER of 10^{-4} is achieved at very low value of 1.4 dB of SNR which is very efficient for reliable communication.

Scenario-IV: BER analysis by varying the position of relays under pathloss effect: In this simulation the performance analysis under pathloss effect is consider. In this simulation scenario the distances of the relays from the source to destination is varied. Here three cases are considered first both the relays are 1/4 of distance from the destination. Secondly both the relays are place at Center. Finally one relay is place at the 3/4 of the destination and other is place at the center. From the Fig. 5 the performance of relays place equally at the center is better than other two position of the Relay. It provides lower BER values at lower values of the SNR. So placing relays at equally distances from source to the destination provides better communication used in the Cooperative networks.

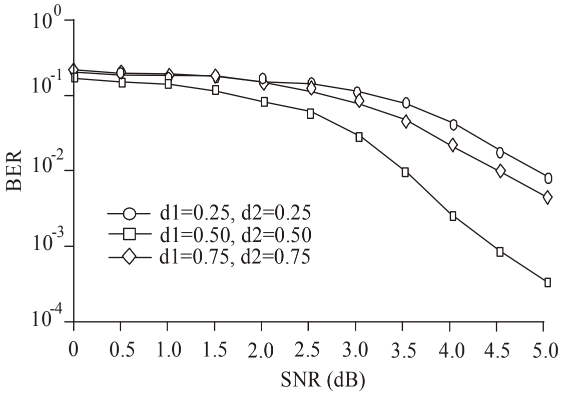

Fig. 5: Simulated BER by varying the position of relays

CONCLUSION

In this study, cooperative communication system with AF mode two time slot TDMA based transmission protocols has been investigated with BILDPCM-ID based system over Rician-K and Nakagami-m fading channel. It is clear from simulation results that by increasing the value of m, K in Nakagami and Rician fading distribution increases the performance of system respectively and moving from single relay to multi-relay network performance of system also increases. The results also shows that the system with 1/2 code rate obtained 1-2 dB gain over 2/3 code rate. If relays are equally place from source to destination the performance of the system increases. Future work is required to perform the mathematical modeling of this system so that further performance and analysis of the model could be done.

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