Performance Evaluation of a Cooperative OFDM system with implementation of Decode and Forward and Amplify and Forward Relaying Protocols on Text message transmission

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Abstract:

Cooperative diversity is a newly proposed virtual MIMO technology based transmission technique achieving diversity gain through a combination of the relayed signal and the directly transmitted signal. In this paper, we made a comprehensive study to elucidate the performance of a single-relay cooperative OFDM system under Amplify-and-Forward (AAF) and Decode-and-Forward (DAF) relaying strategies on Text message transmission. The bit-interleaved channel encoded system under investigation incorporates four conventional signal combining schemes such as Equal Ratio Combining (ERC) and Fixed Ratio Combining (FRC), Signal to Noise Ratio Combining (SNRC) and Enhanced Signal to Noise Ratio Combining (ESNRC) under BPSK and QPSK digital modulations. In the present study, results of BER simulation in AWGN and Raleigh fading channels shows that the AAF relaying protocol supported cooperative OFDM system outperforms in ERC signal combining scheme as compared to others (FRC, SNRC and ESNRC) under BPSK digital modulation . It has been anticipated from the simulation study that the cooperative OFDM communication system provides diversity gain like MIMO system as compared to single antenna transmission system.

Keywords:

Relaying protocol, Cooperative OFDM system, Signal combining scheme, Bit Error rate, AWGN and Raleigh fading channels.

1. Introduction:

Multiple-Input, Multiple-Output (MIMO) technique constitutes a cost effective approach to high-throughput wireless communications. MIMOs have been accepted as the key building blocks of next-generation wireless communication systems and are capable of supporting significantly higher data rates than the Universal Mobile Telecommunications System (UMTS) and the High-Speed Downlink Packet Access (HSDPA) based 3G networks A MIMO system employs multiple transmitter and receiver antennas for delivering parallel data streams. As the wireless system may not be able to support multiple transmitter antennas due to size, cost and hardware constraint, a class of techniques known as cooperative communication may be considered which allow single-antenna mobiles to reap some of the benefits of MIMO systems. The basic idea is that the users or nodes in a wireless network share their information and

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transmit cooperatively as a virtual antenna array, thus providing diversity without the requirement of additional antennas at each node. Cooperative communications allow users in the system to cooperate by relaying each others' messages to the destination and that creates a virtual MIMO system **[1,2].**

In this present study, Orthogonal frequency division multiplexing (OFDM) based cooperative protocol has been implemented. In broadband wireless communications. OFDM is an effective means to mitigate the intersymbol interference (ISI) and offer high spectral efficiency. OFDM is used in many communications systems such as wireless local area networks (WLANs), wireless personal area networks (WPANs) etc. To improve the performance of OFDM systems, the fundamental concept of cooperative diversity can be applied **[3].** In this paper**,** two relaying protocols and four signal combining techniques have been used. A brief description is given below. [3]

2. Mathematical model:

2.1 Amplify and Forward (AAF) Relaying Protocols

In AAF relaying procol, the signal received by the relay is attenuated and it is needed to be amplified before it is sent up again. In doing so, the noise in the signal is amplified as well, this is the main drawback of this protocol.

The incoming signal is amplified block wise. Assuming that the channel characteristic is estimated perfectly, the gain for the amplification can be calculated as follows.

The power of the incoming OFDM signal is given by

$$E\left[\left|y_r^2\right|\right] = \mathrm{E}\left[\left|\mathrm{h}_{\mathrm{s,r}}\right|^2\right] E\left[\left|x_s\right|^2\right] + E\left[\left|z_{s,r}\right|^2\right]$$

$$= \left|h_{s,r}\right|^2 \xi + 2\sigma_{\mathrm{s,r}}^2 \qquad (1)$$

Where s denotes the sender, r the relay and $\xi = E\left[\left|x_s\right|^2\right]$ denotes the energy of the transmitted signal. To send the data with the same power as the sender did, the relay has to use a gain β which can be expressed as:

$$\beta = \sqrt{\frac{\xi}{\left|\mathrm{h}_{\mathrm{s,r}}\right|^2 \xi + 2\sigma_{\mathrm{s,r}}^2}} \qquad (2)$$

This term has to be calculated for every block and therefore the channel characteristic of every single block needs to be estimated.

2.2. Decode and Forward (DAF) Relaying Protocol

In DAF relaying protocol,the source node transmits its own information both to the destination node and the relay node at the same time. The relay node decodes it, and forward to the destination node. The advantage of decode-and-forward is that if the information contains errors, the error can be corrected in the relay and the error message could not be sent to the destination node. The received signal's quality can be greatly improved. However, in the DAF protocol, as the relay node needs to decode the received signal from source node and forward to the destination node, it will increase the complexity of relay and cost.

2.3 Signal combining techniques

2.3.1. Equal Ratio Combining (ERC)

In Equal Ratio Combining,the incoming signals are just added up before the symbols are detected. It is to be noted here that we need to know the information of the phase shift of the signal occured due to multipath fading. The received signal in ERC is given by

$$y_d[n] = y_{s,d}[n] \cdot e^{-\angle h_{s,d}[n]} + y_{r,d}[n] \cdot e^{-\angle h_{r,d}[n]} \quad (3)$$

The parameters $y_{s,d}[n]$ and $y_{r,d}[n]$ denote the incoming signal from the sender and the relay.

2.3.2. Fixed Ratio Combining (FRC)

In Fixed Ratio Combining, the incoming signals are weighted with a constant ratio. Its optimal value is approximated by assigning different values in simulation to get an idea on its properly selected value. The received signal in FRC is given by

$$y_d[n] = d_{s,d} \cdot y_{s,d}[n] \cdot e^{-\angle h_{s,d}[n]} + d_{r,d} \cdot y_{r,d}[n] \cdot e^{-\angle h_{r,d}[n]} \quad (4)$$

2.3.3. Signal to Noise Ratio Combining (SNRC)

In Signal to Noise Ratio Combining, a much better performance can be achieved when the current state of different channel is known precisely.. An often used value to characterize the quality of a link is the SNR which is used to weight the received signals. The received signal in SNRC is given by

$$y_d[n] = SNR_{s,d} \cdot y_{s,d}[n] \cdot e^{-\angle h_{s,d}[n]} + SNR_{r,d} \cdot y_{r,d}[n] \cdot e^{-\angle h_{r,d}[n]} \quad (5)$$

The estimation of the SNR of a multi-hop link using AAF or a direct link can be performed by sending a known symbol sequence in every block. This sequence is used to estimate the phase shift as well. If the multi-hop link is using a DAF protocol the receiver can only see the channel quality of the last hop. It is assumed that the relay sends some additional information about the quality of the unseen hops to the destination, so the SNR of the multi-hop link can be estimated. Whatever protocol is used, an additional sequence needs to be sent to estimate the channel quality. This results in a certain loss of bandwidth [4].

2.3.4 Enhanced Signal to Noise Ratio Combining (ESNRC)

In Enhanced Signal to Noise Ratio Combining, an incoming signal is neglected in case of other incoming signal have a much better quality. If the channels have more or less the same channel quality, the incoming signals are rationed equally. We can fix the SNR value of the channel for which this decision can be made. In this simulation study, a SNR value of 10 dB has been fixed up. The signal received at the destination can be expressed as

$$y_d[n] = \begin{cases} y_{s,d}[n] & \dfrac{SNR_{s,d}}{SNR_{s,r,d}} > 10 \\ y_{s,d}[n] + y_{s,r,d}[n] & 0.1 \le \dfrac{SNR_{s,d}}{SNR_{s,r,d}} \le 10 \\ y_{s,r,d}[n] & \dfrac{SNR_{s,d}}{SNR_{s,r,d}} < 0.1 \end{cases} \qquad (6)$$

Where, $SNR_{s,d}$ and $SNR_{s,r,d}$ are the sender to destination channel (direct channel) and the sender-relay-destination channel (relay channel) SNR values respectively[5]

3. Communication system model

The block diagram of the simulated Cooperative OFDM system is shown in Figure 1. It consists of three major units such as sender, relay and destination. In sender unit, a text message is used as input information source. .

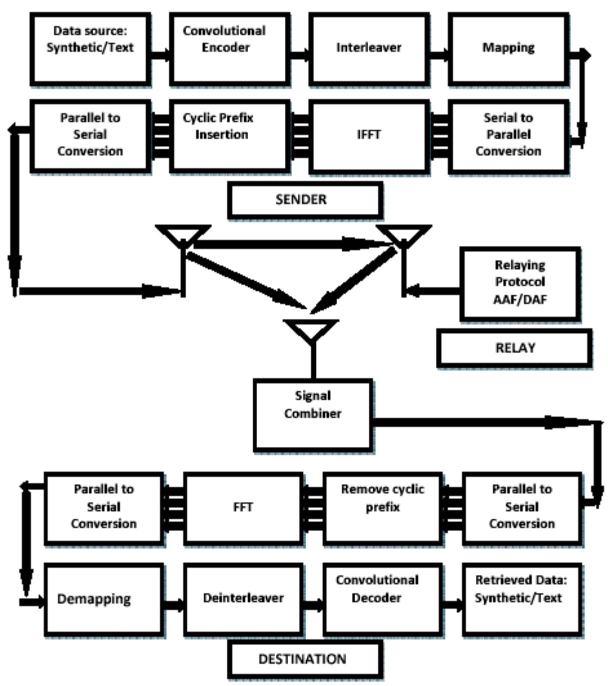

Figure 1: Block diagram of a
Cooperative OFDM wireless Communication System

The input information source in binary bit form is applied to the ½-rated Convolutional encoder and interleaved[6]. The convolutionally encoded interleaved bits are modulated digitally by binary phase shift keying (BPSK)/ Quadrature phase shift keying (QPSK). The symbols are then fed into OFDM modulator which performs an IFFT on each OFDM block of length 256 symbols/ sub carriers followed by a parallel to serial conversion A cyclic prefix (CP) of length Lcp containing a copy of the last Lcp samples of the parallel to serial converted output of the 256-point IFFT is then prepended. The CP is essentially a guard interval which serves to eliminate interference between OFDM symbols. However, the resulting OFDM symbols of length 256+ Lcp are lunched from the transmit antenna. At destination, the receiver receives two signals, one directly transmitted from sender and another one via relay. In relay unit, it receives transmitted signal from sender, it process the signal under any one of the two relaying protocols and retransmits. In destination, the two signals are combined using various combining techniques and the transmitted signal from sender with its increased strength as compared to noise signal is retrieved. The retrieved signal processed through the different sections of OFDM demodulator, is demapped, deinterleaved and convolutionally decoded to recover the transmitted Text message.

4. Results and discussion

The present simulation based study has been made for cooperative OFDM system in consideration with various parameters presented in Table 1.

Table 1: Summary of the simulated model parameters

No. of bits used for text message	**1197**
Channel Coding	**½-rated Convolutional Encoder**
Modulation	**BPSK and QPSK**
OFDM Block size	**256 symbols**
Relaying Protocols	**Amplify and Forward(AAF) and Decode and Forward(DAF)**
Signal Combining Scheme	**Equal ratio combining(ERC), Fixed ratio(FRC), Signal to noise ratio combing(SNRC) and Enhanced Signal to noise ratio combing (ESNRC)**
CP length	**26 symbols**
Channel	**AWGN and Rayleigh**
Signal to noise ratio,SNR	**0 to10 dB**

In Figure 2, it is quite noticeable that the system outperforms in AAF relaying protocol with ERC signal combining and BPSK digital modulation schemes as compared to its worst system performance in DAF relaying protocol with ERC signal combining and QPSK digital modulation schemes. For a typically assumed SNR value of 2 dB, the corresponding BERs are 0.00013 and 0.00040 respectively viz. the system performance is improved by 4.88 dB.

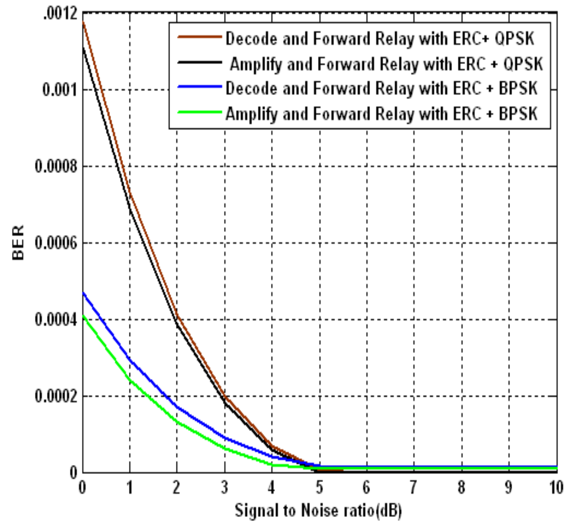

Figure 2: Bit error rate of the Cooperative OFDM system under implementation of DAF and AAF relaying protocols and ERC signal combining scheme in BPSK and QPSK digital modulations

In Figure 3, the AAF relaying protocol based cooperative OFDM system again confirms its suitability for showing enhanced performance under working with ERC and BPSK schemes.

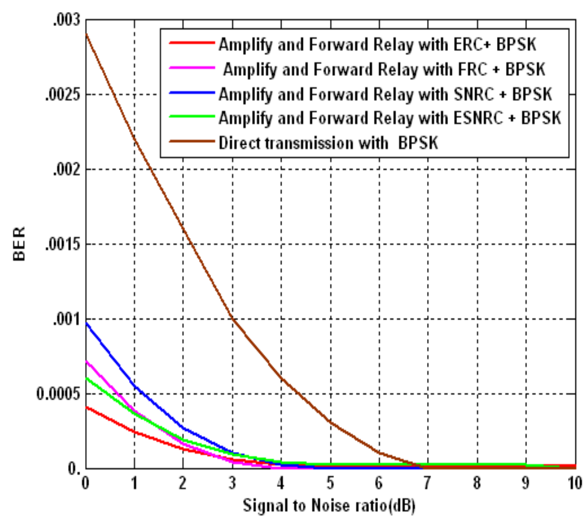

Figure 3: Bit error rate of the Cooperative OFDM system under implementation of DAF and AAF relaying protocols and four signal combining schemes with comparison to BPSK digital modulation based direct transmission

On comparison with direct transmission, the system provides benefits of virtual MIMO technology through cooperative diversity. As a typically assumed SNR value of 2dB, the system performance is enhanced by 10.91 dB (BER values: 0.00013 and 0.00160) relative to direct transmission. In Figure 4, better system performance is achieved in case of AAF, ERC and BPSK schemes. In case of direct transmission with QPSK, the system shows worst performance.

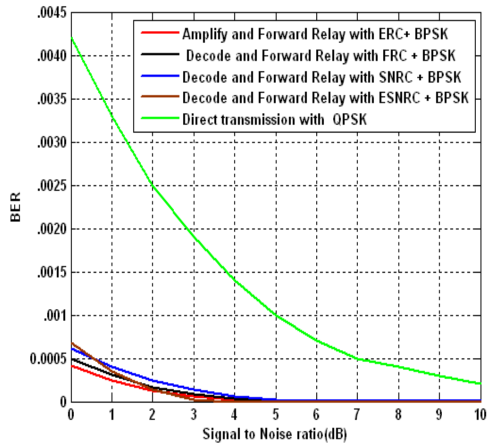

Figure 4: Bit error rate of the Cooperative OFDM system under implementation of DAF and AAF relaying protocols and four signal combining schemes with comparison to QPSK digital modulation based direct transmission

In Figure 5, the effect of relative distance between sender, relay and destination on estimated BERs has been shown. In case of maintaining identical distance between three ports, the system shows satisfactory performance.

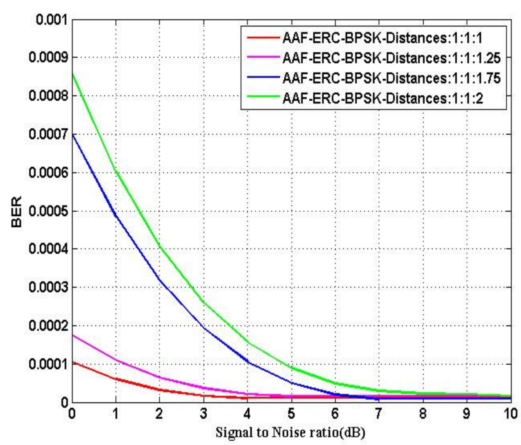

Figure 5: Effect of varying the distance between Relay and Destination keeping the distance between the Sender and Destination and the distance between the Sender and Relay fixed for AAF relaying protocol With ERC and BPSK.

In Figure 6, the transmitted and retrieved text message at different SNR values have been shown. The retrieved message is contaminated with noise at low SNR values (red marked). At 4dB SNR, the retrieved message is found to be noise free.

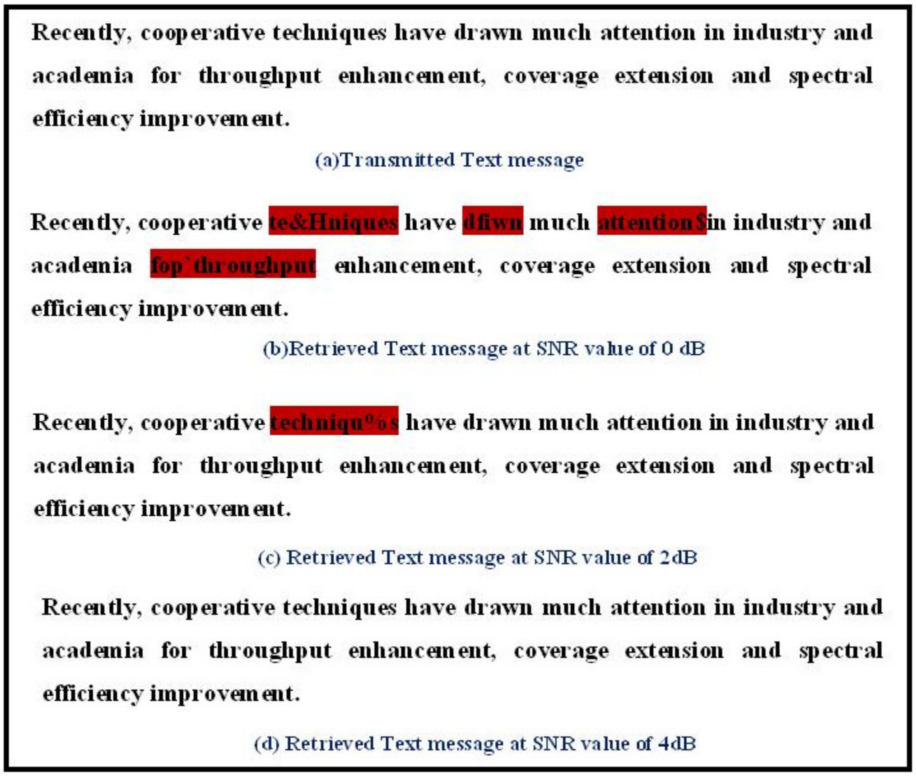

Figure 6: Transmitted and Retrieved text messages for the Cooperative OFDM wireless communication system under implementation of Amplify and Forward Relaying protocol with Equal Ratio combining and BPSK

5. Conclusions

On the basis of results obtained in the present simulation, it may be concluded that the effect error of the in channel can be overcome simply using Convolutional encoder and block interleaver. The Performance of the considered wireless communication system is better in AAF relaying protocol with ERC scheme than DAF protocol. Specifically, the system shows better performances with identical distances between Sender, Relay and Destination in both cases. It is also seen that the Quadrature Phase shift keying based Cooperative OFDM communication system shows unique performance in proper identification and retrieval of transmitted text message. Therefore, it is possible to transmit the text message with lower value of the transmitted power and it can lossless reproduce the transmitted text message at the receiving ends via possible relay station.

References:

[1] Lajos Hanzo, Yosef (Jos) Akhtman, Li Wang and Ming Jiang : MIMO-OFDM for LTE, Wi-Fi and WiMAX, John Wiley and Sons Ltd, United Kingdom, 2011

[2] Aria Nosratinia, Todd E. Hunter and Ahmadreza Hedayat : Cooperative Communication in Wireless Networks, IEEE Communications Magazine, pp.74-80,2004

[3] W. Pam Siriwongpairat , Ahmed K. Sadek, and K. J. Ray Liu: Cooperative communications Protocol for Multiuser OFDM Networks, IEEE Transactions On Wireless Communications, vol .7(7), pp. 2430-2435, 2008

[4] Leng Zhi-juan , Cheng En , Sun Hai-xin, Zhu Qing-kun , Chen Vi-long: The Research Of The Cooperative OFDM System, 2nd International IEEE Conference on Industrial Mechatronics and Automation (ICIMA),:pp.582-585,2010 DOI: 10.1109/ICINDMA.2010.5538239

[5] Laneman, J. N., Tse ,D. N. C., and Wornell ,G. W., 2004:Cooperative diversity in wireless networks: efficient protocols and outage behavior, IEEE Transactions on Information . Theory, 50(12):pp3062–3080. INSPEC Accession Number**:** 8208822, DOI: 10.1109/TIT.2004.838089

[6]. Goldsmith, Andrea, 2005: Wireless Communications, First Edition, Cambridge University Press, United Kingdom

Related Work:

[1] M. Mowrin Hossain, Shaikh Enayet Ullah "Performance Evaluation of a Cooperative OFDM system with implementation of DAF and AAF Relaying Protocols on Color Image Transmission", International Journal of Information Technology Convergence and Services (IJITCS), ISSN 2231- 153X (Online) ; 2231- 1939 (Print),June 2011,Volume 1,Number 3.

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