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A Novel Approach of LLR based Relay Selection Algorithm for Cooperative Communication

Sudheer Shukla[1], Jaya Dipti Lal[2], S. V. Charhate[3]
[1, 2, 3]Department of Electronics and Telecommunication Engineering
Shri Govindram Seksaria Institute of Technology and Science, Indore (India)

Abstract – **As wireless communication turns out to be more common, the interest for higher rates of data transfer and continuous availability is expanding. Future wireless systems are provisioned to be very heterogeneous and interconnected. Wireless ad hoc networks are rising for an extensive variety of new applications. Moreover, substructure based broadband wireless frameworks are extending to fulfil demand for service quality with abundant coverage. Higher data rates and Quality of Service (QoS) are two major expectations from any wireless technology. This paper is focused towards the relay selection scheme of cooperative diversity network. Log-likelihood Ratio (LLR) based relay selection scheme is applied to cooperative diversity architecture with Cooperative non-regenerative (AF) and regenerative (DF) relying technique. Bit Error Rate (BER) performance is compared in Rayleigh fading environment.**

Keywords – **AF, BER, DF, LLR, QoS.**

I. Introduction

As wireless communication becomes more prevalent, the demand for higher data rates and uninterrupted connectivity is increasing. Future wireless systems are provisioned to be highly heterogeneous and interconnected. On one side, wireless sensor networks are emerging for a wide range of new applications, on the other side; infrastructure based broadband wireless systems are expanding to provide increasing number of services with ubiquitous coverage.

In wireless broadband networks cooperative communication developed as a move up to single hop cellular architecture. As apparent from the present and future standards, there is a developing accord in wireless group on adding multi-hop capacity to these networks. In substructure based wireless networks, empowering multi-hop relaying brings numerous prospects at various network layers. Displacing long and weaker links with short and more grounded links can mitigate the weight on the link budget. Unconventional paths between the users and the base station give strength against multi-path fading and shadowing, and present novel design possibilities for planning and routing.

In physical layer an essential prospect emerges with cooperation; because of the broadcast property of wireless medium, as the information is transmitted to its destination in different hopes, numerous nodes in the region can hear these transmissions. Transmissions from various nodes are normally influenced by various and statistically independent fading. Thus, the last destination of the information can consolidate all the received signals using utilizing conventional combining strategies, for example, Maximal Ratio Combining (MRC) or Selection Combining (SC) and achieve diversity against the destroying properties of fading. [1].

Diversity qualities acquired through multihop transmissions is typically alluded to as cooperative diversity qualities. Diversity is an essential method to expand robustness in contrast to channel fading. Cooperative diversity is a type of spatial diversity which can be acquired without multiple antennas. It is particularly helpful when frequency, time and spatial diversity through various receiving antennas are not practical [2].

Since the source node in the cooperative communication scheme depends on the relay nodes to forward the transmission, relay selection and resource allocation for the relay nodes become important in order to obtain optimal performance of the cooperative communication system. By choosing the right nodes to relay the transmission, the system can achieve higher capacity by using lower resources. The main objective of this paper is to develop a Log-Likelihood Ratio-based Relay Selection Algorithm for Cooperative Communications. The performance of proposed system will be based on BER analysis of Rayleigh fading channel.

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II. Proposed Methodology

LLR Based Relay Selection

Proposed framework contains a two-hop network structure which has one transmitter, one receiver and L number of relays as shown in Figure 1.

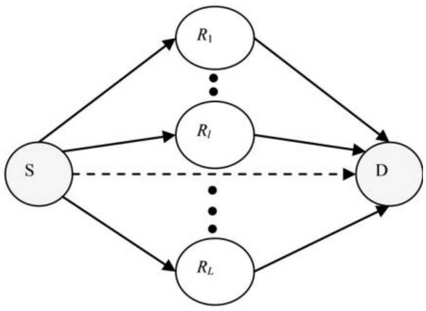

Figure 1: System Model

The transmission, relay and receiver are installed along with single antenna system assuming half duplex transmission. This arrangement contains peer to peer communication between the transmission end and receiver end. The considered noise is additive white Gaussian noise (AWGN).

The fading channel coefficients from source-to-destination, source-to-ith relay, and ith relay-to-destination links are represented by h_{SD}, h_{SR_i} and h_{R_iD} respectively. Here the channel coefficients are supposed to be autonomous and similarly dispersed flat Rayleigh fading channels. Every transmission is separated into two intervals. For the duration of the initial interval, the transmitter end conducts the signal thorough the relays and as well as to the receiver end. Consequently, the received signal at ith relay terminal from the transmitting end is expressed as:

$$r_{s,r_i} = sh_{SR_i} + n_{SR_i} \quad (1)$$

Where s is the transmitted signal which is supposed to be BPSK signal with amplitudes either $+\sqrt{E_s}$ or $-\sqrt{E_s}$. The received signal at receiver end from the transmitter end in line for to peer to peer communication link is expressed as:

$$r_{SD} = sh_{SD} + n_{SD} \quad (2)$$

Where h_{SD} and h_{SR_i} are the independent complex Gaussian fading channel parameters of the S-D link and S-R link correspondingly with zero mean and variances of $\sigma^2_{h_{SD}}$ and $\sigma^2_{h_{SR_i}}$ respectively. n_{SD} and n_{SR_i} are the additive white Gaussian noise of the S-D link and S-R link with zero mean and variances of $\sigma^2_{h_{SD}}$ and $\sigma^2_{h_{SR_i}}$ respectively.

For the duration of the second interval, each relay resend the signal to the receiver utilizing either DF or AF algorithms which are explained as follows:

Decode and Forward (DF)

For the duration of the second interval in decode and forward technique (DF), the very first step for the relay is demodulation and decoding of the received signal. After completion of first step, each relay encodes again signal data and sends it to the receiver end. The receiver node associates total signals received from all the relays for detection. Consequently the received signal at the receiver from i^{th} relay is expressed by:

$$r_{ri,d} = \hat{s}h_{R_iD} + n_{R_iD} \quad (3)$$

Where $\hat{s}$ is the re-encoded signal at the relay terminals. h_{R_iD} is the independent complex Gaussian fading channel parameter of the R-D link with zero mean and variance of $\sigma^2_{h_{R_iD}}$ and n_{R_iD} is the additive white Gaussian noise of the R-D link with zero mean and variance of $\sigma^2_{n_{R_iD}}$. The destination in DF receives less noisy versions of signal compare to AF.

Amplify and forward protocol (AF)

For the duration of the second interval in amplify and forward protocol (AF), every relay combines its received signal by a gain and forwards the amplified signal to the receiver end. The drawback of this approach is that the noise at the relay will get intensified. Normally, this approach is used when the relays have bounded resources, for example power limitations, processing time or when the source-relay channel is fragile. Thus the received signal at the receiver end from i^{th} relay is expressed as:

$$\begin{aligned} r_{ri,d} &= G_i[r_{s,ri}]h_{R_iD} + n_{R_iD} \\ &= G_i[sh_{SR_i} + n_{SR_i}]h_{R_iD} + n_{R_iD} \\ &= G_i s h_{SR_i}h_{R_iD} + G_i n_{SR_i}h_{R_iD} + n_{R_iD} \quad (4) \end{aligned}$$

Where G_i is the gain of i^{th} relay, expressed by:

$$G_i = \sqrt{\frac{P_s}{P_s|h_{SR_i}|^2 + N_0}} \quad (5)$$

Where P_s the transmitted signal power and N_0 is the power spectral density.

This approach might be suitable for different types of modulation schemes such as QAM, QPSK. For this instance, one has to determine the LLR for the type of respective modulation. Subsequent heading determines the LLR for BPSK modulation.

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Origin of the Proposed Algorithm

For the duration of the initial interval the source transmits the BPSK signal to the relays and to the receiver end utilizing equations (1) and (2). For the duration of the second interval, the relays obtains the transmitted signal from the source, the log-likelihood ratio (LLR) is measured for every relay and expressed by:

$$\Delta = \ln \frac{P\left(r_{s,r_i} | h_{SR_i}, s = +\sqrt{E_S}\right)}{P\left(r_{s,r_i} | h_{SR_i}, s = -\sqrt{E_S}\right)} \quad (6)$$

Where the sign of Δ is the hard decision value and the magnitude signifies the dependability of the hard decision which is utilized to select the most consistent relay for detection.

$P\left(r_{s,r_i} | h_{SR_i}, s = +\sqrt{E_S}\right)$ and

$P\left(r_{s,r_i} | h_{SR_i}, s = -\sqrt{E_S}\right)$ are the probability density function (pdf) of the observation at the relays given the transmitted signal and channel. Utilizing equation (1) and deliberate that the additive noise is AWGN and the channel is complex, then these probability density functions might be expressed as:

$$P\left(s = +\sqrt{E_S} | h_{SR_i}, r_{s,r_i}\right) = \frac{1}{2\pi\sigma^2} e^{\frac{-\left|\left(r_{s,r_i} - h_{SR_i}\sqrt{E_S}\right)\right|^2}{\sigma^2}} \quad (7)$$

$$P\left(s = -\sqrt{E_S} | h_{SR_i}, r_{s,r_i}\right) = \frac{1}{2\pi\sigma^2} e^{\frac{-\left|\left(r_{s,r_i} + h_{SR_i}\sqrt{E_S}\right)\right|^2}{\sigma^2}} \quad (8)$$

Putting values of equation (7) and (8) into (6), the LLR simplified as:

$$\Delta = \left|r_{s,r_i}\right|^2 + 2\sqrt{E_S} Re\{r_{s,r_i} h^*_{SR_i}\} + \left|h_{SR_i}\sqrt{E_S}\right|^2 - \left|r_{s,r_i}\right|^2 + 2\sqrt{E_S} Re\{r_{s,r_i} h^*_{SR_i}\} - \left|h_{SR_i}\sqrt{E_S}\right|^2 \quad (9)$$

Then, the magnitude of LLR $|\Delta|$ in its simplest form might be expressed as:

$$|\Delta| = \frac{4\sqrt{E_S}}{\sigma^2} \left|Re\{r_{s,r_i} h^*_{SR_i}\}\right| \quad (10)$$

Where $Re\{.\}$ signifies the real part, $(.)^*$ signifies the complex conjugate and $|.|$ signifies the magnitude of the equation.

III. Simulation And Results

The performance of proposed algorithms has been studied by means of MATLAB simulation.

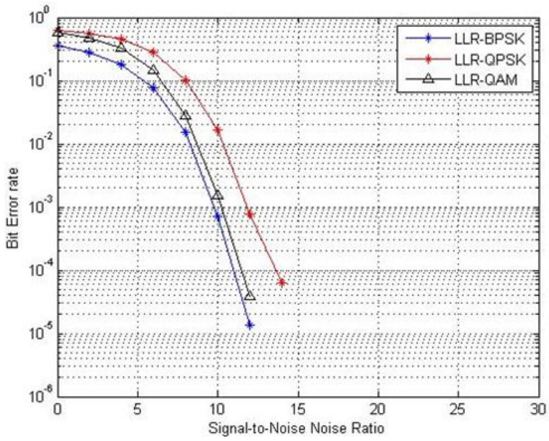

Figure 2: Comparison of BER performance for LLR relay selection scheme for different modulation techniques

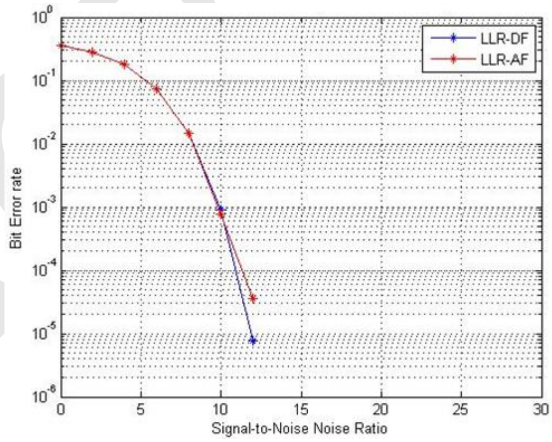

Figure 3: Comparison of BER performance for LLR relay selection scheme for different relaying techniques

IV. Conclusion

LLR based relay selection scheme is applied to the adopted system architecture. To evaluate system performance Rayleigh fading scenario has been considered. Simulation results on the basis of Bit-Error-Rate vs. Signal-to-noise Ratio has been presented. It was found that the LLR based relay selection in cooperative diversity improves system performance by 4 dB.

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