

A Review on Cooperative Communication with Relay

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Abstract: Cooperative communication is one of the fastest growing areas of research. It is likely to be a key enabling technology for efficient spectrum use in future. Cooperation not only leads to improve data rate but also results in a system that is more robust to variations in the channel parameters. Relay selection scheme for cooperative communication aims to achieve full cooperative diversity gain while maintaining spectral and energy efficiencies. Relays receive and retransmit the signal between two base stations. Infrastructure of relay does not need wired connection to network, thereby, offering reduction in operator's backhaul costs. A relay facilitates an alternate channel for flow of duplicate information corrupted by any kind of error. In this paper we have studied the role of relay towards benefits in cooperative communication under increased relay requirements, and derived exact expression for the outage probability of various DF protocol. We have verified the results using MATLAB simulation which are in full conformity with our analysis.

Keywords- Cooperative Communication, outage probability, Relay, Wireless network.

1. Introduction

The next generation wireless systems are supposed to handle high data rate as well as large coverage area. It should consume less power and utilize bandwidth efficiently. At the same time, the mobile terminals must be simple, cheap, and smaller in size. In wireless environment, the quality of received signal level degrades due to path-loss and shadowing from various obstacles in propagation path. In addition to this, signal quality suffers from fading due to constructive and destructive interferences of multipath components which makes it difficult for the receiver to extract the message correctly.

In cooperative wireless networks, it is often the case that multiple sources and multiple relays cooperate to transmit their data to destination. A relay facilitates an alternate channel for flow of duplicate information corrupted by any kind of error. In this paper we have studied the role of relay towards benefits in cooperative communication under increased relay requirements and derived exact expression for the outage probability of various DF protocol. We have verified all these result using MATLAB simulation.

For the cooperative systems, selecting an appropriate relay node is of prime importance. This paper also elaborates the different relay selection techniques to select an appropriate relay to reduce transmission power and to improve overall performance of the wireless network.

2. COOPERATIVE COMMUNICATION

The basic idea of cooperative communication is proposed in the pioneering paper [1]. Later, Laneman et al.[2] have studied the mutual information and outage probability between a pair of nodes using cooperative communication under both AF (amplify-and-forward) and DF (decode-and forward) modes. Based on their fundamental work, cooperative communication has been extensively studied from the perspectives of both physical layer and network layer. We summarize the most relevant work in the following categories: energy efficiency, relay assignment, and time-spectrum allocation in cooperative communications.

Cooperative relaying has been adapted as an effective strategy to improve network capacity and link reliability in emerging standards.

In cooperative links, the message sent by the source arrives at destination through diverse path: one directly from the active (source) node others through relay node.

3. COOPERATIVE TRANSMISSION PROTOCOLS

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I. Amplify and Forward Method

As shown in fig 1, In the Amplify and Forward method. Laneman and Wornell first proposed amplify-and-forward as a cooperative signalling scheme[4] Amplify-and-forward is conceptually the most simple of the cooperative signalling method, In this method, each user receives a noisy version of the signal transmitted by its partner; the user then amplifies and retransmits this noisy signal.

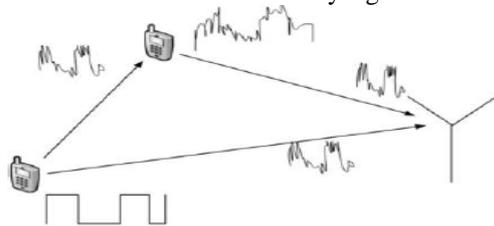


Fig 1: Amplify and Forward method [4].

The destination will combine the information sent by the user and partner and will make a final decision on the transmitted symbols. Although the noise of the partner is amplified, the destination still receives two independently-faded versions of the signal and is thus able to make better decisions for the transmitted symbols. A potential challenge in this scheme is that sampling, amplifying, and retransmitting analog values may be technologically non-trivial. Nevertheless, amplify-and-forward is a simple method that lends itself to analysis, and therefore has been very useful in furthering the understanding of cooperative communication system. The high SNR and outage probability P_{AF}^{out} : approximated as, [5],

$$P_{AF}^{out} := Pr[I_{AF} < R] \approx \left(\frac{1}{2\sigma_{sd}^2} \frac{\sigma_{sr}^2 + \sigma_{rd}^2}{\sigma_{sr}^2 \sigma_{rd}^2} \right) \left(\frac{2^{2R} - 1}{SNR} \right)^2$$

where, σ is the r.m.s. value of received voltage signal before envelope detection

II. Decode and Forward Method

The first work proposing a detect-and-forward protocol for user cooperation was by Sendonaris, Erkip, and Aazhang [6]. Nowadays, a wireless transmission is very seldom analogue and the relay has enough computing power, so Detect and Forward is most often the preferred method to process the data in the relay as shown in fig. 2. The received signal is first decoded and then re-encoded. Hence, there is no amplified noise in the sent signal, as is the case using Amplify and Forward protocol. There are two main implementations of such a system. The relay can decode the original message completely.

This requires a lot of computing time but has numerous advantages. If the source message contains an error correcting code, received bit errors might be corrected at the relay station. Or, if there is no such code implemented a checksum allows the relay to detect if the received signal contains errors. Depending on the implementation, an erroneous message might not be sent to the destination. But it is not always possible to fully decode the source message. The additional delay caused to fully decode and process the message is not acceptable, the relay might not have enough computing capacity or the source message could be coded to protect sensitive data. In such a case, the incoming signal is just decoded and re-encoded symbol by symbol. Thus, neither an error correction can be performed nor a checksum calculated.

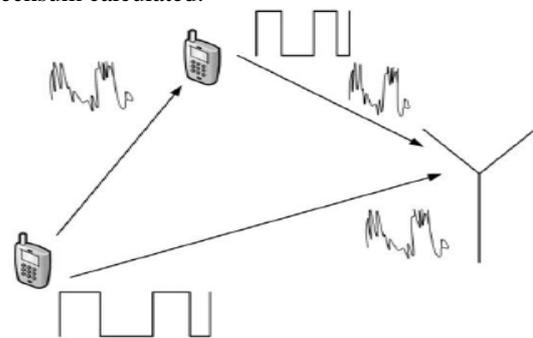


Fig 2: Decode and Forward Method [7].

The outage probability for repetition-coded DF can be calculated according to

$$P_{DF}^{out} := Pr[I_{DF} < R] \\ = Pr \left[|h_{sr}|^2 < \frac{2^{2R} - 1}{SNR} \right] + Pr \left[|h_{sr}|^2 \geq \frac{2^{2R} - 1}{SNR} \right] Pr \left[|h_{sd}|^2 + |h_{rd}|^2 < \frac{2^{2R} - 1}{SNR} \right]$$

Where, h_{sr}, h_{sd}, h_{rd} is channel gain

However, for the purpose of improving the accuracy we calculate the exact value by

$$P_{DF}^{out} = 1 - e^{-(2^{2R}-1)/(\sigma_{sr}^2 SNR)} + e^{-(2^{2R}-1)/(\sigma_{sr}^2 SNR)} P_{SD+RD}^{out}$$

4. RELAY SELECTION ANALYSIS

In relay selection analysis, all relays are assumed to perform in time division multiple accesses and routed as orthogonal signals. With all relay participation, the available power is equally divided between 'M' relays. We are assuming that the ideal maximum ratio combining (MRC) has been used in the relay node (RN) and destination node(DN). Hence the SNR at the destination node is the instantaneous sum of that all relay nodes. The best relay selection method is represented in the Fig 3. The instantaneous SNR is represented as,

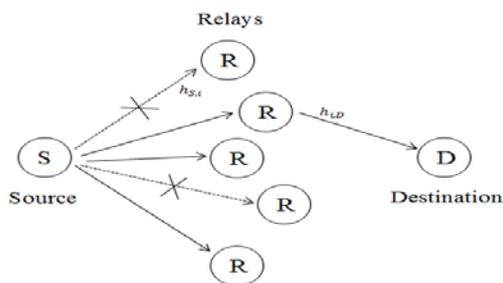


Fig 3: System model for best relay cooperative Scheme [8]

The instantaneous end to end SNR at the destination node can be written as in (Laneman 2004)

$$\gamma_i = \gamma_{s,D} + \sum_{i=1}^m \frac{\gamma_{s,i} \gamma_{i,D}}{1 + \gamma_{s,i} + \gamma_{i,D}}$$

$$\gamma_{s,i} = |h_{s,i}|^2 \frac{E_s}{N_0}$$

$$\gamma_{i,d} = |h_{i,d}|^2 \frac{E_s}{N_0}$$

$$\gamma_{s,D} = |h_{s,D}|^2 \frac{E_s}{N_0}$$

Where, $\gamma_{s,i}, \gamma_{i,d}, \gamma_{s,D}$, and are the instantaneous signal to noise ratio of source to relay, source to destination and relay to the destination link respectively. Here the best relay selection algorithm is proposed, which will select the best relay path at which signal can attain maximum SNR. During the first hop, source node has transmitted the information to the best selected relay based on the instantaneous SNR and in the second hop the destination node will select the appropriate number of relays among the selected relay set. The first step is related to identify the weakest path among the relay, which will determine the number of relays required for acquiring promising data rate in the cooperative communication. The best relay selection criteria is given on the basis of SNR as

$$\xi_i = \max_{i \in A} \{\xi_i\} = \max_{i \in A} \{\min(\gamma_{s,i}, \gamma_{i,D})\}$$

Where $A = \{1, 2, \dots, M\}$ and the system will maximize the minimum SNR of relay and attain suitable communication path. Based on the SNR value, system will select the suitable number of RN for the energy efficient relaying scheme. Fig 4 shows the best relay selection algorithm, where a suitable number of relays select and route the signal. The system capacity C_{best} for different number of relay channels is given as [9]

$$C_{best} = \frac{1}{2} \log_2 \left[1 + \gamma_{s,D} \max \frac{\gamma_{s,i} \gamma_{i,D}}{1 + \gamma_{s,i} + \gamma_{i,D}} \right]$$

The outage probability of best relay selection scheme can be expressed as

$$P_{outbest} = \Pr \left(\gamma_{s,D} + \max_i \frac{\gamma_{s,i} \gamma_{i,D}}{1 + \gamma_{s,i} + \gamma_{i,D}} < \gamma_{th} \right)$$

We have studied the outage probability of Rayleigh fading channel using DF relay by selection combiner technique The pdf function is given as,

$$P_{out} = \left[\prod_{i=1}^n \left\{ \min(\gamma_{sr_i}, \gamma_{r_i,d}) \right\} \right]^n$$

Where, n is number of relay

$$P_{out} = \min(\gamma_{sr}, \gamma_{rd})^n$$

The CDF function of above equation given as

$$= \left[1 - \max(\gamma_{sr}, \gamma_{rd}) \right]^n$$

Outage probability of Rayleigh fading channel is

$$P_{out} = \exp \left(-\frac{\gamma_{th}}{\gamma} \right)$$

The cumulative function of above probability function are given as

$$P_{out} = 1 - \exp \left(-\frac{\gamma_{th}}{\gamma} \right)$$

Hence the outage probability for Rayleigh fading channel from source to relay and relay to destination using selection combiner are given as

$$P_{out} = \left[1 - \left\{ \exp \left(-\frac{\gamma_{th}}{\gamma_{sr}} \right) \right\} \times \left\{ \exp \left(-\frac{\gamma_{th}}{\gamma_{rd}} \right) \right\} \right]^n$$

5. RESULT

As shown in fig.4 we have calculated when only 1 relay is used, SNR at 4dB and 5dB the outage probability is 0.9505 and 0.9093 respectively, and when n= 2 relays are used then for SNR at 4db and 5db the outage probability is formed to be 0.9029 and 0.8268 respectively.

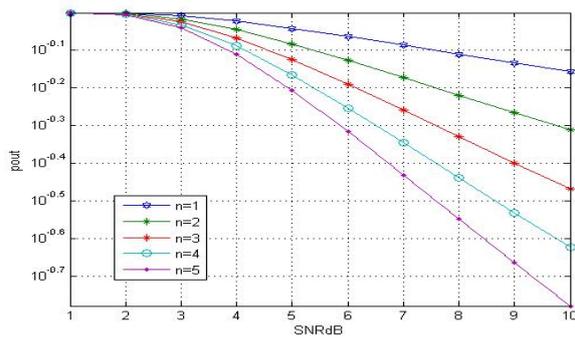


Figure 4: outage probability versus SNR

In fig. 5, we can see that, when number of relay only 1 threshold SNR 3db and 4db the outage probability is 0.8647 and 0.9305 respectively, however when n=2 relays are used in cooperative communication then for threshold SNR 3db and 4db the outage probability is formed to be 0.7476 and 0.8659 respectively.

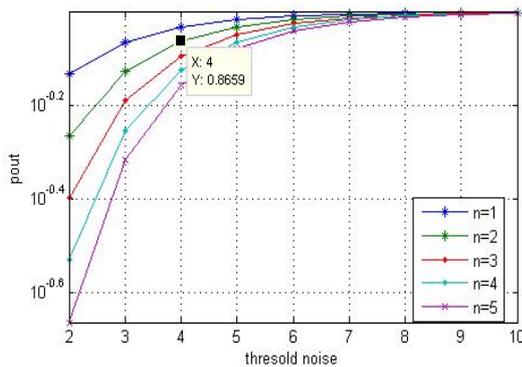


Figure 5: Outage probability versus threshold SNR

In this paper we have derived outage probability of Rayleigh fading channels using DF relay by selection combiner technique. The proposed technique shows that as we increase the number of relays the outage probability will increase. The simulation result using MATLAB shows much better increase in outage probability with an increase in number of relays and it also verifies outage probability analysis with DF relay.

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