Performance Analysis of Asymmetric Cooperative Relaying Schemes for SISO Systems

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ABSTRACT
One of the most challenging aspects of wireless communication is the wireless channel which is subjected to fading. Fading leads to deterioration of the signal quality at the receiver. Cooperative relaying is considered to be one of the most versatile techniques to overcome fading. In this paper serial, parallel and opportunistic asymmetric cooperative relaying strategies are studied and comparisons are drawn between the different schemes used. In serial relaying data is transmitted in hops while in parallel relaying two or more relaying nodes transmit simultaneously. Opportunistic relaying on the other hand involves selecting one best relay based on predetermined criteria. The BER performance of the schemes are analyzed in detail and the optimal relaying techniques for different SNR conditions are suggested.

Keywords
cooperative communications, cooperative relaying, serial relaying, parallel relaying, opportunistic relaying.

1. INTRODUCTION
The field of wireless communications faces many design challenges. The wireless environment is ever-changing with varying user location and traffic patterns. Cellular networks are required to meet the ever-increasing user demand. To reap maximum benefits service providers try to accommodate maximum number of users possible with a limited expenditure of resources- channels, bandwidth, power, rate, base stations(BS) and access.

The power of a transmitted signal falls of exponentially with distance as it propagates in the wireless channel. In certain situations users located far away from BSs are unable to establish a reliable link leading to call dropping. These problems can be resolved by deploying a relay node. Relays extend the range of an existing BS and are specifically used in areas that have coverage holes due to shadowing and blockage.

In cases where relay nodes cannot be deployed cooperative relaying proves to be a good strategy. The broadcast nature of wireless is usually considered as a foe and treated as interference. But cooperative relaying exploits this aspect. Potential relay nodes overhear the transmission from the source during the first phase and retransmit the overheard data in the second phase. This relaying of overheard data allows the cell edge users to transmit at higher rates. The cooperating relays may be any device ranging from a mobile user, a femtocell BS or even a fixed relay.

Cooperative relaying was first introduced in [1] and many strategies have been discussed in [2] [3] [4]. The two basic modes of operation are Amplify and Forward (AF) and Decode and Forward (DF). In the former the relay node simply amplifies the overheard signal and transmits it in the second phase. AF relaying suffers from noise amplification. While in the latter the relay node decodes the received signal and retransmits it to the destination. Hard decisions are taken on the received symbols at the relay which may lead to erroneous forwarding of data.

Different schemes have been proposed in literature [3][4][5]. In this paper Multihop/Serial cooperative relaying, Parallel relaying and Opportunistic Relaying (OR) are investigated in detail. Multihop/Serial relaying is mainly used to extend the range of a BS and it involves the use of one or more relays. In Parallel relaying many relay nodes simultaneously transmit the data to the destination. The use of many relays can lead to wastage of spectral resources to overcome this disadvantage opportunistic relaying is employed in many cases [6][7][8]. OR employs only one best relay node from a set of potential candidate relay nodes to transmit data from source to destination.

In this paper the three above mentioned relaying schemes are analysed based on their bit error rate (BER) performance and comparisons are drawn. The BER improvement achieved at different Signal to Noise Ratio (SNR) are quantified and conclusions are drawn on the optimal relaying strategy under different SNR conditions. The rest of this paper is organized as follows-section II deals with system description, section-3 explains the relaying strategies in detail. Section-4 goes on to present the results obtained and the inferences arrived at. Finally section-5 concludes the paper.

2. SYSTEM MODEL
The relaying strategies discussed in the paper are depicted in figures 1,2 and 3.The source and destination nodes are represented by S and D respectively, and all the relay nodes are represented as R1, R2…Rn. The following assumptions are made: 1)Each node has only a single antenna and hence cannot transmit and receive at the same time (SISO, half duplex operation). 2)The channel between source and relay(s), relay(s) and the destination are assumed to be flat Rayleigh fading channels.3) The noise over all channels is additive white gaussian noise (AWGN). 4) all transmissions are orthogonal and each transmission takes place at different time slots. 5) in the case of OR it is assumed that channel quality indication (CQI) is fed back to the transmitter via a noiseless reliable channel.

All relaying nodes operate in the DF mode.The destination performs Maximal Ratio Combining(MRC)[9] to combine transmissions from relay(s) and the source. The relaying strategies are explained in detail in the next section.

3. COOPERATIVE RELAYING SCHEMES

3.1 Multihop/Serial Cooperative Relaying

In figure 1 due to the broadcast nature of wireless environment transmission from the source reaches both the relays (relay2 is further away from relay1) and the destination. The source-destination link is assumed to be highly faded and is represented by a dotted line. It is also assumed that there is no link between relay1 and the destination.

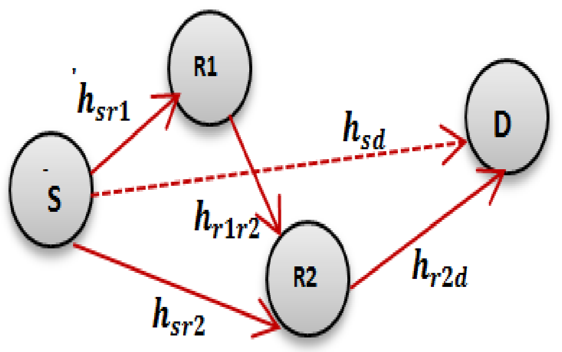

Fig. 1. Multihop/Serial Cooperative Relaying

In phase 1, the source broadcasts its information to the destination and the two relay nodes. In phase 2, the first relay helps the source by amplifying the source signal and sending it to the second relay. In phase 3, the second relay applies MRC on the two received signals from the previous two phases and forwards the MRC signal to the destination. Finally, the destination applies an MRC on the signals that it receives from all phases and jointly detects the information from the source.

3.2 Parallel Cooperative Relaying

In figure 2 the parallel relaying scheme is presented. In phase 1 the source transmits the data which is received by the destination and relays. The relays then decode and forward the data simultaneously to destination in the second phase. Thus in a single hop all the relays process the data for transmission. Parallel relaying is an advantage in a heavy multipath fading environment. Parallel cooperative relaying allows several independently faded signals to reach the destination thereby providing both power gain and diversity gain. In terms of resource utilization it is not preferred as many channels are required.

3.3 Opportunistic Relaying

Figure 3 depicts OR. It differs from other schemes in the fact that only one best relay is chosen for transmission. The selection criteria may vary [6][7][8]. In this paper the relay with best received SNR is chosen to forward the data. In phase1 the source transmits a test transmission, all the relays feedback the received SNR to the transmitter. In phase 2 the transmitter identifies the relay with best received SNR and transmits data. In phase 3 the relay identified by the source forwards the data to the destination. This scheme is suited for applications where resources are limited.

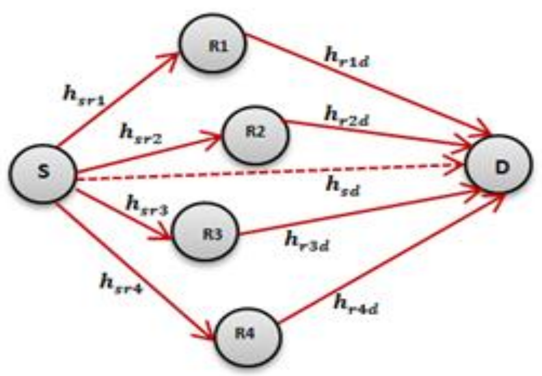

Fig. 2. Parallel Cooperative Relaying

4. SIMULATION ANALYSIS

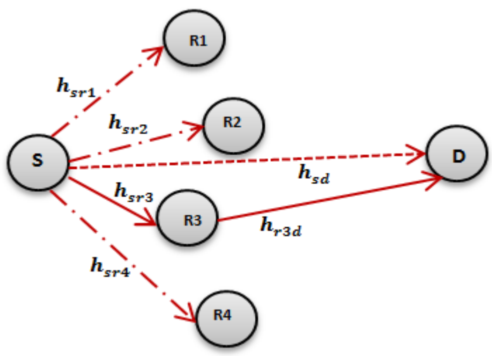

Fig. 3. Opportunistic Cooperative Relaying

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4.1 Simulation Procedure

The following steps describe the simulation.

- Number of bits, SNR are defined in the program.
- The data generated is modulated using Quadrature Phase Shift Keying (QPSK) modulation technique.
- The modulated data is then subjected to Rayleigh fading and AWGN is added .
- At the relay node the received signal (after being subjected to Rayleigh fading and AWGN) is decoded (hard decisions are made) and forwarded to the destination.
- The signal forwarded to the destination is again subjected to Rayleigh fading and AWGN
- At the destination maximal ratio combining is implemented to combine signal from source as well as the relay node(s).
- Number of bits in error are calculated by comparing the resultant combined and decoded data with the originally transmitted data.

- The whole procedure is customized for serial, parallel and opportunistic asymmetric cooperative systems and comparisons are drawn.

4.2 Simulation Results

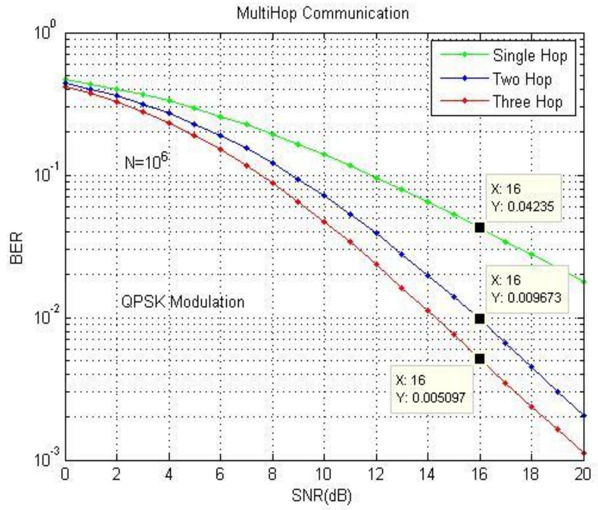

Fig. 4. Multihop/Serial Cooperative Relaying

Figure 4 shows the BER performance of Multi-Hop Relaying with One, Two and Three hops corresponding to the use of no relay, one relay and two relays used in series. More the number of hops better the performance. The graph shows that at 16 dB SNR there is a 3.267% BER improvement achieved between One and Two hop relaying and a BER improvement of 3.725% between One and Three hop relaying.

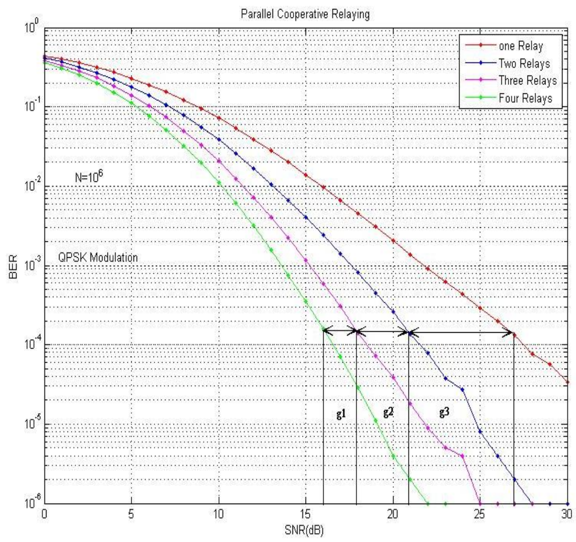

Fig. 5. Parallel Cooperative Relaying

Figure 5 shows the BER performance of Parallel Relaying with One, Two, Three and Four relays. It is found that gain increases with the increase in number of relays. The SNR gains g1, g2 and g3 shown in the Figure 3.20 correspond to 2.1dB, 3dB and 5dB respectively. Where g3 corresponds to the SNR gain between one and two relays used in parallel, g2 corresponds to SNR gain between two relays and three relays used in parallel and g1 corresponds to three relays and four relays used in parallel. It can be observed that the SNR gain improvement decreases with increase in the number of relays.

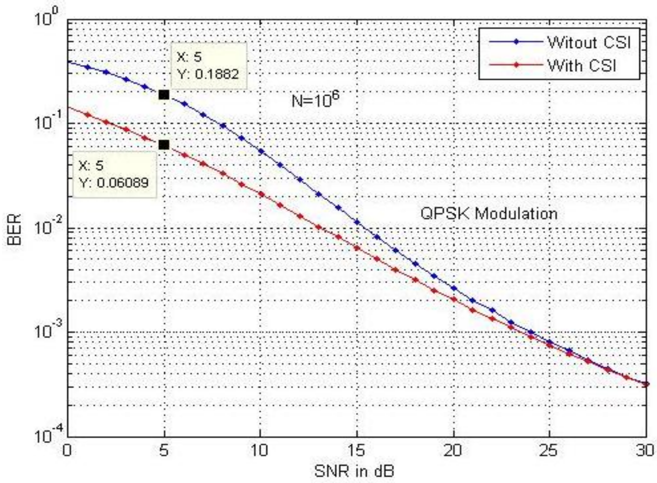

Fig. 6. Opportunistic Cooperative Relaying

Figure 6 shows the BER performance of Opportunistic Relaying (OR) with CSI and relaying without CSI. It can be observed that at low SNRs – OR performs better, this is due to the fact that at low SNRs having CSI at the transmitter enables it to adapt transmissions to current channel conditions, which is crucial for achieving reliable communication. However at higher SNRs the channel conditions are good and having CSI has no impact on the BER performance this is shown by the convergence of the two curves at high SNRs. The graph shows that there is a 12.7% BER improvement achieved at 5 dB SNR with Opportunistic Relaying.

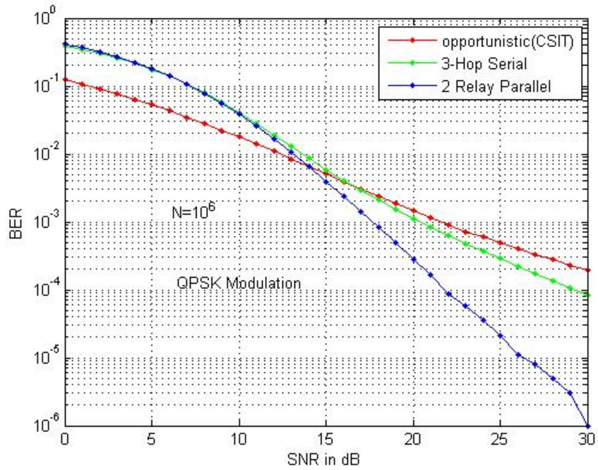

Fig. 7. Comparison of Cooperative Relaying schemes

Figure 7 shows the Comparison of Opportunistic, Parallel and Multi-Hop Cooperative Relaying. It can be inferred that at low SNRs the OR performs the best till 14dB SNR. This is due to the availability of CSI at the transmitter which enables it to adaptively vary the transmissions to the current channel conditions. Parallel relaying with two relays performs better than multi-hop with two relays due to the fact that it provides three independently faded signals (relay1-destination, relay2-destination, direct) at the receiver while only two independently faded signals are available for the Multi-Hop case (relay2-destination and direct), it is also important to note that OR uses only one relay.

5. CONCLUSIONS

In a cooperative cellular communication system two or more active users in a network share their antennas and jointly transmit their messages, either simultaneously or at different times to obtain greater reliability and efficiency than they could obtain individually. Through cooperation both terminals are able to simultaneously increase their reliabilities even when they are connected via low quality links, or when one terminal has a much better link than the other. In this paper the several relaying schemes for cooperative communication are presented. The effect of adding hops (relays) between transmitter and receiver and using several relays to transmit simultaneously in a parallel approach has also been simulated. Opportunistic relaying was one of schemes studied and simulated. Simulations were carried out to compare the BER performance of these systems. It can be inferred that under low SNRs OR performs best and is suited for resource conservation. Parallel cooperative relaying scheme performs best at moderate and high SNRs as it provides many independently faded paths. Multihop /Serial cooperative relaying achieves only power gain hence suited for range extension. In future a fuzzy logic can be implemented that will monitor the channel state and select the best possible scheme to implement under the observed conditions allowing optimal performance.

6. REFERENCES

[1] Sendonaris, Andrew, Elza Erkip, and Behnaam Aazhang. "User cooperation diversity. Part I. System description." Communications, IEEE Transactions on51.11 (2003): 1927-1938.

[2] Laneman, J. Nicholas, and Gregory W. Wornell. "Distributed space-time-coded protocols for exploiting cooperative diversity in wireless networks." Information Theory, IEEE Transactions on 49.10 (2003): 2415-2425

[3] Laneman, J. Nicholas, David NC Tse, and Gregory W. Wornell. "Cooperative diversity in wireless networks: Efficient protocols and outage behavior."Information Theory, IEEE Transactions on 50.12 (2004): 3062-3080

[4] K. J. Ray Liu, Ahmed K. Sadek , Weifeng Su, and Andres Kwasinski "Cooperative Communications and Networking" Cambridge University Press 2009.

[5] Su Weifeng, and Xin Liu. "On optimum selection relaying protocols in cooperative wireless networks." Communications, IEEE Transactions on 58.1 (2010): 52-57.

[6] Zimmermann, Ernesto, Patrick Herhold, and Gerhard Fettweis. "On the performance of cooperative diversity protocols in practical wireless systems."Vehicular Technology Conference, 2003. VTC 2003-Fall. 2003 IEEE 58th. Vol. 4. IEEE, 2003.

[7] Bletsas, Aggelos, et al. "A simple cooperative diversity method based on network path selection." Selected Areas in Communications, IEEE Journal on24.3 (2006): 659-672.

[8] Zhiguo Ding, Yu Gong, T. Ratnarajah, and Colin F. N. Cowan, "On the Performance of Opportunistic Cooperative Wireless Networks," IEEE Trans. Commun, vol. 56, no. 8, , pp.1236–1240, Aug. 2008

[9] Rappaport, Theodore S. Wireless communications: Principles and practice. Vol. 2. New Jersey: Prentice Hall PTR, 1996.