Power Allocation based Hybrid Multihop Relaying Protocol for Sensor Networks

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Abstract. In this paper, Hybrid relay systems are comprised of Amplify-and-Forward (AF), Decode-and-Forward (DF) and DeModulate-and-Forward (DMF) together in cooperative networks. We propose adaptive relay schemes based on Channel State Information (CSI) of the received Signal-to-Noise Ratio (SNR) at the Relay Node (RN). We select the relay protocol adaptively, on the basis of Power Allocation (PA) constraint, or the SNR value at previous hop. We improve multihop performance of the relay system, by using PA allocation. As the power in terms of sensors is very crucial, we focus as it is an important aspect. The simulation results show that the performance of the novel hybrid sensor relay protocol improves the conventional hybrid system.

Keywords: AF, DF, DMF, Hybrid, PA, Sensors

1 Introduction

In this paper, we propose a novel hybrid relay technique using AF, DF and DMF using novel relay selection based on the threshold of CSI. Secondly, we propose a novel algorithm based on the power allocation in low channel quality of multihop sensor network due to interference between the Ubiquitous Sensor Network (USN) application and heterogeneous (WiFi, Bluetooth, etc.). Simulation result shows that the proposed scheme with novel power allocation considerably improves the performance.

The rest of the paper is organized as follows: section 2 describes the system model, section 3 explains the proposed criteria for hybrid relay with different protocol schemes, and the novel hybrid power allocation scheme, and section 4 shows simulation results and analysis. Finally, conclusions are drawn in section 5.
2 System Model

Fig. 1 shows an overall system model. There is one source, one destination and N relays. So this system is called a hybrid sensor relay in a multihop system. A 3-hop relay system is considered. The overall communication system uses two time slots to transfer data. In the first time slot, the source broadcasts the signal to relays. In the second time slot, the selected relays retransmit the signal to the destination. The relays that are selected in AF mode amplify the received signal and forward it. The relays that are selected in DF mode decode the received signal and re-encode the estimated data. Similarly, the relay selected for the DMF, adaptively demodulate the received signal and forwards it. In the paper, nomenclature we consider source as eNB, relay as Relay Node (RN) and Destination as User Equipment (UE).

All links are orthogonal rayleigh fading channels where $h_{S-R}$ and $h_{R-D}$ are independent and circularly symmetric complex Gaussian random variables with $CN(0,\sigma_{S-R}^2)$ and $CN(0,\sigma_{R-D}^2)$ respectively. From now on, we assume that $\sigma_{S-R}$ and $\sigma_{R-D}$ are normalized to 1. The additive noise is a white Gaussian random variable with zero-mean and unit-variance.

![Fig. 1. System Model of Hybrid Multihop Sensor Relay](image)

In figure 1, we describe the system model of the multihop environment. It is a multistage relay system, which shows various RN scenarios. All the RNs possess 3 kinds of relay protocols, as shown AF, DF and DMF. The sensor node is selected on the base of the power constraint. The system selects the AF, DF and DMF protocols on the threshold of the CSI as per Table 1

3 Power Allocation in Hybrid Sensor Relays

On using all relay protocols together on each node, we observe much better performance, as per the SNR of the CSI and using the threshold for each relay protocol, as given in Table 1.

Table 1. Sensor Relay Protocol Selection Criteria.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>SNR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\gamma=\mathbf{-10-4}$ dB</td>
</tr>
<tr>
<td>Tx-Rx</td>
<td>DMF</td>
</tr>
</tbody>
</table>
At the first transmission, the eNB sends a block ‘L’ of dimension Tx1 with a unit norm of sensor nodes. The received signal to the kth RN is given by:

\[ r_k = \sqrt{P_0} h_k L + N \]  

(1)

where, \( h_k \) is the channel coefficient between the sensor node and the transmitter, and white Gaussian noise is given by \( N \), with the transmit power as \( P_0 \).

The new signal transmitted by the kth sensor node is signal block ‘S’, transmitted from the RN in the second phase, and is termed as:

\[ s_k = \frac{P_k}{\sqrt{P_0 h_k L}} r_k W_k \]  

(2)

where, \( W_k \), \( 1 < k < r \), \( r \) is a set of k relays and \( W_k \) is the channel matrix of each sensor node, considering the \( P_k \) as the transmit power assigned to the kth sensor node as,

\[ \sum_{k=1}^{R} P_k = P_f \]  

(3)

The transmit power of each relay is controlled by the receiver using the power control strategy, under the assumption that the feedback channel is reliable. When the received signals from all the sensor nodes are coherent at the symbol level and the signal at the receive nodes are coherent at the symbol level, the signal at the receive node is given by:

\[ y = \sum_{k=1}^{R} \frac{P_k h_k L}{\sqrt{P_0 h_k L}} s + \sum_{k=1}^{R} \frac{P_k h_k L}{\sqrt{P_0 h_k L}} W_k + N \]  

(4)

The second term shows the addition of a noise factor, which is not negligible. We consider the participation of the 3 relays in cooperation guarantees the performance, that if the total transmission power is optimally allocated. The power of the whole relay network averaged over random relay channel matrices is given by:

\[ P_{\text{overall}} = \frac{\sum_{k=1}^{R} P_k h_k L}{1 + \sum_{k=1}^{R} P_k h_k L} = \sum_{k=1}^{R} P_k \]  

(5)

where, \( P_k \) is the overall relay power value allocated to the kth sensor node.

### 4 Simulation Results

Table 2 shows the simulation parameters are based on 3GPP LTE-Advanced 20 MHz Bandwidth.

Fig. 2 shows the power allocation for each sensor relay protocol independently. The relay protocols are selected that is based on the threshold based on CSI of Table 1, but the channel gain performance is improved, using the power constraint of the received symbol power at each RN. The power allocation considerably improves the performance of the system, including the basic relay protocols, including the important protocol for the hybrid sensor relay. The simulation results clearly state that relay protocols show independent improved performance, in the case of AF, DF and DMF BER, with SNR performance as 14.5 dB in the case of AF, 13 dB for DF, and considerable improvement in DMF protocol of 7 dB. Also, the major point of improvement in the hybrid sensor relays is considered at 2 dB.
Table 2. Simulation parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier Frequency</td>
<td>2 GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>20 MHz</td>
</tr>
<tr>
<td>Subcarrier spacing</td>
<td>15 KHz</td>
</tr>
<tr>
<td>Occupied Subcarriers</td>
<td>(1200 + 10 \times \text{DC subcarrier}) = 1201)</td>
</tr>
<tr>
<td>CP size (samples)</td>
<td>512 (Extended CP)</td>
</tr>
<tr>
<td>No. of OFDM Symbols/subframe</td>
<td>12 (Extended CP)</td>
</tr>
<tr>
<td>Channel</td>
<td>EPA, EVA, ETU</td>
</tr>
<tr>
<td>Modulation Scheme</td>
<td>QPSK, 16 QAM</td>
</tr>
<tr>
<td>Noise</td>
<td>AWGN</td>
</tr>
<tr>
<td>Relay Node (RN)</td>
<td>3</td>
</tr>
<tr>
<td>Relaying Protocol</td>
<td>AF, DF, DMF, Hybrid</td>
</tr>
</tbody>
</table>

Fig. 2. Performances of novel hybrid multihop sensor relay with power allocation.

5 Conclusions

The novel hybrid relay protocol, when implemented with a power allocation threshold, improves the performance of the conventional relay system. We concluded that the performance of the conventional relay can be increased, using the power allocation technique proposed in the paper, certainly for multihop sensor networks. We expect that the proposed scheme configures a more efficient sensor environment.
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References