Applying Heterogeneous Cooperative Relay Network Based Cooperative Relay Node Selection and PSO Algorithm

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Abstract. In this paper a novel scheme of cooperative networks depending on the number and locations of relays in the network. The effect of relay number and locations are investigated by considering energy optimization. First selects the optimal relay from a set of available relays and then uses this “optimal” relay for cooperation between the source and the destination. The simulation-based performance analysis confirms that the cooperative relaying scheme has an advantage of diversity gain thus improving the bit error ratio performance. The simulation results demonstrate that the proposed cooperative relay node selection algorithm can improve performances by achieving the cooperative gain.

Introduction

Cooperative relaying is a promising technique for multihop wireless networks to exploit spatial diversity. In addition, using relays in cooperative wireless networks can potentially lead to significant capacity increases, which is a critical task of network planning and deployment to achieve an efficient and scalable network design.

Many researches focus on fundamental relaying problems of determining who should be relays for whom and how to perform resource allocation for these relaying schemes jointly with routing such that the system performance. While most previous relay placement related studies only consider data forwarding through traditional multi-hop relaying [89,90]. Network coding extends store-and-forward-based routing solutions and allows intermediate relay nodes to code over the incoming packets. Since the received signals at the relay nodes are a superposition of transmitted signals, the simple amplify-and-forward (AF) scheme is a form of network coding at the signal level.

Although relay problem remains unsolved in terms of the optimal communication scheme, the studies above have taken significant steps in quantifying the performance gains obtained from cooperation. However, research in this subject has been mainly concentrated on information theoretic considerations, and only a few studies have focused on the system level performance of cooperation such as, in which Mergen et al study the problem of cooperative broadcast under a single-source single-destination setup with multiple levels of cooperation, where the broadcast performance is quantified by finding a signal decoding threshold above which a message is propagated in the network. Nabar et al further evaluate the performance of cooperative schemes in the case of single source, single relay, and single destination and prove that full diversity can be obtained. In Sankaranarayanan, Kramer and Mandayam further consider the case where multiple sources send their message to a relay, and the relay either simply forwards the data or first decodes and then forwards.

Related Work

The capacity region for the relay channel with \( M \) relays is not known to date. However, Gastpar and Vetterli have obtained upper and lower bounds on the capacity scaling under Gaussian noise and show that these bounds meet in the limit of large number of nodes. The existing work on the resource allocation has been done in terms of optimal energy, location, and joint energy-location for the system resource. Analysis and optimization of wireless systems using different scheduling policies were conducted.
System Model
In our wireless network, communication between a source and a destination terminal is facilitated by direct graph $G = (V, L)$, where $V$ is the set of nodes and $L$ is the set of directed links. There is a link between a pair of nodes if the communication link can be established between them. With utilizing the cooperative technique in the heterogeneous relay nodes, the high transmission data rate and the extended coverage can be sufficed, which will achieve the performances of seamless convergence between the heterogeneous wireless access networks. The number $n \geq 0$ of the relays which can successfully decode the received symbol is a random variable, and $n$ has a special distribution such as Poisson distribution, normal distribution, and so on.

Cooperative Scheme
Under the proposed scheme, The multihop cooperative relaying networks. Signals transmitted by the different relay station are delayed copies of the same signal. The received signal at the destination is demodulated using estimation method. The source station transmits the data streams $s(k)$. where $h_{R1D}$, $h_{R2D}$ represent complex channel coefficients between the destination station and the relay stations $R_1$, $R_2$, respectively. $E_{R1}^t$, $E_{R1}^t$, $E_{R2}^t$ denote the transmission power of $R_1$, $R_2$, respectively.

It means that each relay station retransmits the received packet only if it is correctly decoded. The transmission power and noise performance of each station are assumed to be equal. The relay route and timing synchronization are assumed to be established in advance.

Let the transmission power for direct transmission on link $(i, j)$ be $P_d(i, j)$, and the total interference at the receiving side of this link be $N_0(i, j)$. Then, the achieved rate $(b/s/Hz)$ for direct transmission is

$$r_d(i, j) = \log_2 \left(1 + g(i, j)P_d(i, j) \right)$$

(1)

The achieved data rate at relay node $k$ in the first time slot and at node $j$ in the second time slot after using maximum ratio combining are given, respectively, by

$$r_r(i, j) = \log_2 \left(1 + g(j, k)P_d(i, j) \right)$$

$$r_c(i, j) = \log_2 \left(1 + g(j, k)P_d(i, j) + g(k, j)P_{c(i,j)}(k, j) \right)$$

(2)

Note that for relaying to be useful, the achieved rate at relay node $k$ must be higher than that due to direct transmission. Let the maximum achievable data rate on link $(i, j)$ be $r(i, j)$. This achievable rate on each link depends on the transmission power, link gain, and the transmission strategy, the achievable transmission rate on link $(i,j)$ for different transmission strategies can be written as

$$r(i, j) = \begin{cases} r_d(i, j) & \text{for direct transmission} \\ r_r(i, j) = r_c(i, j) & \text{for cooperative transmission} \end{cases}$$

(3)

Proposed Algorithm
For this problem, the source rates $S_i$ are assumed to be fixed and the optimization problem, in essence, is the joint routing, relay selection and power allocation in a multihop wireless network. The goals are to find optimal transmission strategy for each link (i.e., either direct or cooperative transmission), the optimal power allocation for the chosen strategy, and the link flow to route data generated by source nodes to the corresponding destination node. This is a cross-layer design problem for both physical layer (i.e., relay selection, power allocation) and network layer (i.e., routing of traffic flows). The problem can be stated as follows:
minimize \[ \sum_{i,j \in L} P(i, j) \]

subject to

\[ \sum_{j \in \partial(i)} x(i, j) - \sum_{j \in \partial(i)} x(i, j) = S_i, i \in V \]

\[ x(i, j) \leq r(i, j), (i, j) \in L \]

\[ x \geq 0, P_{\min} \leq P \leq P_{\max} \]

Where \( \leq, \geq \) denote component-wise inequalities, \( x \) is the vector of link flows, \( P_{\min} (P_{\max}) \) denotes the lower (upper) limit for the power vector with element \( P_{\min}(i, j) (P_{\max}(i, j)) \) being the minimum (maximum) allowed power to transmit or relay packets on link \((i, j)\). We assume that this problem is feasible. The feasibility is assumed to be maintained by an appropriate admission control algorithm.

PSO has been successfully used to perform a wide range of optimization problems. Each particle in the swarm represents a multicast tree. The population of permutation-based chromosomes \( \{C_p = [c_p^1, \ldots, c_p^N], p = 1, \ldots, P\} \) is initialized by employing a hybrid of random and deterministic approaches, where \( P \) is known as the population size. In order to produce the deterministic solution, the MPM algorithm is run first and the corresponding node subsequently added to the broadcast tree is recorded into a node sequence, which serves as the deterministic population for the proposed PSO approach. Based on the node sequence, the construction of the broadcast tree can be carried out using PSO algorithm as follows:

Input: source node \( s \) and chromosome \( C_p = [c_p^1, \ldots, c_p^N] \);

Output: broadcast tree \( T \) and the corresponding consumption power \( PT \). For clarity, the flow of these operations is illustrated in Figure 1.

1) Initialize \( PT = 0 \), mark the source node \( s \) in the permutation \( ep \) to avoid the subsequent selections;

2) Obtain the first unmarked node \( z \) in permutation \( ep \), construct a link between source nodes \( s \) and \( z \), and assign the required power \( p_{sz} \) to the source node;

3) Check all the remaining unmarked nodes in the permutation to see if any other node is already covered by the above transmission between nodes \( s \) and \( z \), mark those nodes to avoid the subsequent selections;

4) Go through the unmarked node \( z' \) in permutation sequentially. Employ the rules of the minimum power multicafe algorithm to add node \( z' \) to the existing tree and assign a power \( p_{sz'} \) to the corresponding source node (assuming it is \( s' \));

5) Check all the remaining unmarked nodes in the permutation to see if any other node is covered by the above transmission between nodes \( s' \) and \( z' \), mark those nodes to avoid subsequent selections;

6) If not end of permutation, go to 5;

7) Calculate \( PT \) by eq.(5), and form a Multicast tree \( T \) in which all constructed links correspond to the edges in \( T \).

**Numerical Analysis and Simulation Results**

In this section, present numerical results based on the proposed analytical framework and compare them with the simulation results by consider the effect of relay locations and numbers with in three scenarios:

First scenario: the convergence of the simulation and proposed algorithm are evaluated by assume that all relay nodes located as shown in Figure 1;

Second scenario: the performance gain of with difference location and fix no. of relays are verified.

Third scenario: the performance gain of with Fix location and different no. of relays are verified.

First scenario: To show the convergence of the proposed algorithms, a wireless network with 25 relays distributed in an area of 200m \( \times \) 200m. Two topologies was proposed namely, grid and random topology (Figure 1). For the both topology, Figure 1a shows total 25 nodes fix at four corners.
and one node at the center of the area; and Figure 1b shows total 25 nodes fix as follows 20 nodes are positioned randomly with 5 nodes in each area of 100m × 100m and power limits on each link \((i, j)\) are \(P_{\text{min}}(i, j) = 0\) mW, \(P_{\text{max}}(i, j) = 50\) mW for transmissions from both source nodes and relay nodes.

![Figure 1. Distribution Topology 25 relays and routing path from a source relay to the destination node](image1)

(a) Grid topology b) Random topology.

The total power consumed versus the source rate for both the network topologies with and without cooperative diversity implementation is shown in Figure 2. For the random topology actually requires a bit higher power consumption than the grid topology for these particular source-sink pairs. This performance gain is achieved without sacrificing the distributed nature of the proposed algorithm because only local information is needed to search for the best relay together with the optimal power allocation.

![Figure 2. Total power consumption same source rate with grid and random](image2)

Second scenario: the wireless network performance of ten cases with 20 relays and different allocation are verified.

**Summary**

By applying heterogeneous cooperative relay network based cooperative relay node selection and PSO algorithm can successfully decode the received symbol is a random variable. The theoretical optimization model and proposed algorithm are not only available for the heterogeneous relay based wireless networks, but efficient for the homogeneous relay based wireless networks. Numerical results based on the proposed analysis provide design guidelines for optimal relaying that they can improve the system performance dramatically.
References


