

SUMRATE MAXIMIZATION OF TWO WAY RELAY NETWORKS USING COOPERATIVE PROTOCOLS

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Abstract

This paper considers the relay assisted co-operative transmission in wireless networks, Where multiple user pair conduct bidirectional communications via multiple relays based on Orthogonal Frequency Division Multiplexing (OFDM) transmission. The main objective is to improve the overall system performance by maximizing the total throughput. It deals with the joint optimization of channel and relay assignment, subcarrier allocation as well as relay selection. The problem is formulated as a combinatorial optimization problem. It mainly deals with two-way relaying and to make it more governable. It adopted a graph-based approach. Thus the problem is solved optimally in polynomial time by transforming it into Maximum Weighted Bipartite Matching (MWBM) problem. The simulation result shows the comparison of the proposed algorithm and the bench mark along with two relaying protocols. And to evaluate the network total throughput versus transmit power per node and the number of relays.

Index terms : *Two way relaying, Bidirectional Communications, OFDM, subcarrier pairing, Graphical approach.*

1.Introduction

The introduction of relay aided co-operative communication into the existing cellular infrastructure is considered as the most practical improvement under high rate and coverage. In comparison with legacy cellular network relay aided co-operative communication network enjoys relative advantages over coverage efficiency, operation cost capacity and transmission.

Even though the communication is conducted by relay assisted networks, it suffers from loss in spectral efficiency due to the half duplex transmission in practical systems. Recently network coding (via bidirectional transmission mode selection) has demonstrated significant potential for improving network throughput[3]. Thus two way relaying is introduced to improve spectral efficiency in relay

assisted bidirectional communication and it overcomes the half duplex problem when compared to the one way relaying[1] [4]. In this paper, the OFDM based bidirectional transmission the user pair exchange their information with the assistance of the multiple AF and DF relays. Resource allocation has attracted extensive attention recently in a variety of OFDM based relay networks[5]-[10]. For the optimal relay and subcarrier allocation in an OFDMA relay network with multiple sources, multiple relays and a single destination was investigated in [5]. In [7]the problem handles based on dual decomposition method . In [5][7] the works are assumed that the relay assisted two hop transmission employs the same subcarrier for uplink and downlink. This assumption made easy to tackle the problem but it does not fully utilize the channel dynamics. It is then shown in [6],[8]-[9], a better performance can be achieved if subcarrier in the first and second hops are paired according to their channel conditions. In [15], authors are discussed about the separated power allocation and subcarrier pairing in three node two way relaying, where the power allocation is formulated based in water filling method and subcarriers are paired at the relay by a heuristic method. In [10], a three time slot time division duplex transmission protocol is used in OFDMA cellular networks, where it gave the solution by joint optimization framework for the resource allocation. In [8],subcarrier pairing based joint optimization of power allocation, relay selection and subcarrier assignment for single user multi relay co-operative OFDM.

In this work, it consider an OFDM based network where multiple relays help multiple pairs of source nodes to conduct bidirectional communications. The main objective is to maximize the total throughput of the system and it deals with two relaying protocols.The relaying is not always necessary in the relay assisted communication [5]-[10],[15] (i.e. direct link communication) is present in the

network . To make the system realistic we considered a AWGN channel with fading environment.

The rest of this paper is organized as follows: Section II introduces the system model. In section III ,Optimization frame work is explained. In section IV Simulation results and the merit of the proposed Section. Future work is explained in secion VI

2.System model

Inspired by the two way relaying protocols such as Amplitude and Forward (AF) and Decode and Forward (DF). The proposed transmission protocol can easily accommodate different transmission modes in a unified fashion. The two relaying protocol AF or DF can be used in the transmission modes. According to the channel conditions each user pair can select any one of the transmission modes. In direct transmission mode user pair can exchange the information through the subcarriers directly without any use of relays.

In this system model, all nodes are subject to their own individual peak power constraint and therefore , the transmit power is assumed to be fixed and uniformly distributed among all subcarriers..Let $N=\{1,2,\dots,N\}$ denote the set of subcarriers, $M=\{1,2,\dots,M\}$ denote the set of relays and $K=\{1,2,\dots,K\}$ denote the set user pairs. The two way communication takes place in two phases in the fig (1).First phase, is known as (MAC) multiple access phase, here all the K pairs of users concurrently transmit the signals to the relay nodes. In second phase transmit the signals from relay nodes to source nodes known as (BC) broad cast phase. It received the signal from source and amplify it and then forwards to the 2K destinations. In both the phases user pair and relay are operating on non-overlapping subcarriers to avoid inter relay interference. The signal is received on one subcarrier, say n, then the first phase will be forwarded on subcarrier n' may not be the same as n. This is known as subcarrier pairing or tone permutation [8] [16].

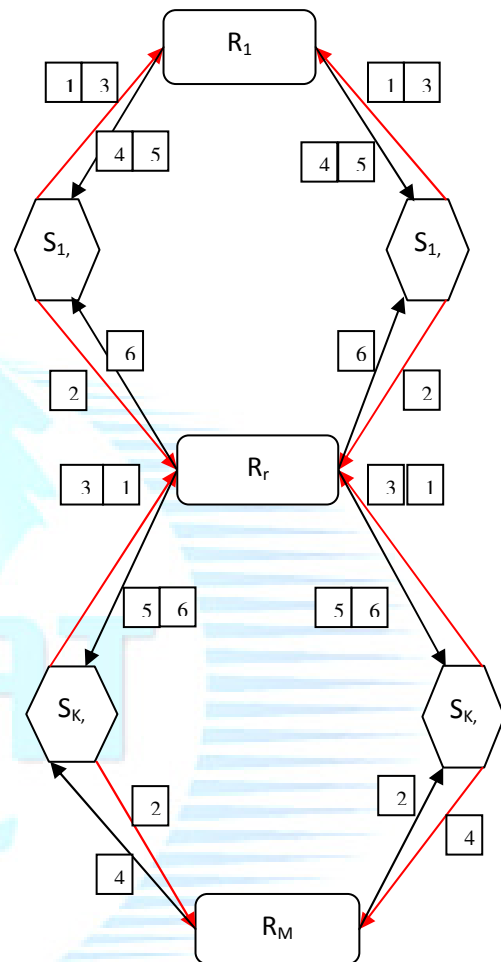


Fig 1.System model

3.Optimization framework

In this section the optimization framework is explained detailed the system model with two relaying protocols AF and DF. The subcarriers are n and n' in the first and second phase respectively. If the user pair k is assigned with subcarrier n and sends signals to relay r in the first phase, the relay r then broadcasts the amplified received signals on subcarrier n' in the second phase by the AF relay protocol. Thus by the DF relay protocol, the relay broadcasts the received signal by decoding it on the subcarrier n' in the second phase

Direct Transmission: In this mode, both phase use direct transmission. The achievable rate pair is easily obtained as

$$R_{MAC} = \frac{1}{2} C(\gamma_{k1k2}^{nn'}) \quad \dots \quad (1)$$

$$R_{BC} = \frac{1}{2} C(\gamma_{k2k1}^{n,n'}) \quad \text{--- (2)}$$

where $C(x) = \log(1+x)$ and γ_{ij} denotes signal to noise ratio(SNR) from node i to node j and assuming that all the nodes have the unit noise variance.

One way relaying: In this mode, relaying strategies is used for the transmission. Currently, many relay strategies are proposed. Among them, the two popular and practical ones are known as AF and DF. Thus focus on AF and DF throughout this paper. Then, write the achievable rate pair for direct phase, and combine together for MAC Phase and BC phase as

$$R_D = \frac{1}{2} C(\gamma_{k1k2}) \quad \text{--- (3)}$$

$$\left. \begin{aligned} R_{k,r}^{n,n'} &= \frac{1}{2} C\left(\frac{\gamma_{k2}^{n'}\gamma_{k1}^n}{1+\gamma_{k2}^{n'}+\gamma_{k1}^n}\right) \text{ for AF} \\ R_{k,r}^{n,n'} &= \frac{1}{2} \min\{C(\gamma_{k2r}^n)C(\gamma_{rk1}^{n'})\} \text{ for DF} \end{aligned} \right\} \quad \text{--- (4)}$$

Two way relaying : This is the 3-step two-way relaying, where transmits signals from a source pair $S_{1,1}$ to relay R1 in the MAC phase ,and $S_{1,2}$ transmits its signals to relay R1, then relay mixes the received signals and broadcasts it to both user pairs $S_{1,1}$ and $S_{1,2}$ as second phase BC. Depending on if AF or DF issued, the achievable rate pairs are presented separately. The achievable sum rate of user pair k over subcarrier pair (n, n') with the assistance of AF relay for the system model can be expressed as

$$R_{k,r}^{n,n'} = \frac{1}{2} C\left(\frac{\gamma_{k1r}^n\gamma_{rk2}^{n'}}{1+\gamma_{rk2}^{n'}+\gamma_{k1r}^n}\right) + \frac{1}{2} C\left(\frac{\gamma_{k2r}^{n'}\gamma_{rk1}^n}{1+\gamma_{k1r}^n+\gamma_{k2r}^{n'}}\right)$$

Thus the achievable sum rate of user pair k over subcarrier pair (n, n') with the assistance of DF relay for the system model can be expressed as

$$R_{k,r}^{n,n'} = \frac{1}{2} \min\{C(\gamma_{k1r}^n)C(\gamma_{rk2}^{n'})C(\gamma_{k2r}^{n'})\} + \frac{1}{2} \min\{C(\gamma_{k2r}^{n'})C(\gamma_{rk1}^n)C(\gamma_{rk2}^n)\} \quad \text{--- (6)}$$

Let us consider the set of binary variables $\rho_{k,r}^{n,n'} = \{0,1\}$ for all k,r,n,n, Where $\rho_{k,r}^{n,n'} = 1$ means that subcarrier n in the first phase is paired with subcarrier n' in the second phase assisted by relay r for user pair k, else $\rho_{k,r}^{n,n'} = 0$ otherwise. As assumed above, each subcarrier can be assigned to one user pair and one relay, in the first and second phases, respectively to avoid interferences. Therefore, $\{\rho_{k,r}^{n,n'}\}$ must satisfy the constraints.

The main objective is to maximize the system total throughput by optimally pairing subcarriers in the two phases and selecting the best relays and the best paired subcarriers for each user pair. Mathematically, this can be formulated as (P1):

$$\begin{aligned} \text{P1 : } & \max \sum_{k \in K} \sum_{r \in M} \sum_{n \in N} \sum_{n' \in N} R_{k,r}^{n,n'} \rho_{k,r}^{n,n'} \\ & \text{s.t. (2), (3).} \end{aligned} \quad \text{--- (7)}$$

Note that it can be easily modify the objective function in P1 to weighted sum of all user rates without affecting the algorithm design if fairness is considered.

4.Results discussion

Consider a two-dimensional plane of node locations shown in Fig.3, where the source nodes and relay nodes are randomly but uniformly distributed in the corresponding square regions. The path loss model is adopted in [6], where the path loss exponent is set to 4 and the standard deviation of Log-normal shadowing is set to 5.8 dB. The small-scale fading is modeled by multi-path Rayleigh fading process, where the power delay profile is exponentially decaying with maximum delay spread of 5 μ s and maximum Doppler spread of 5 Hz. A total of 2000 independent channel realizations were generated, each associated with a different node locations. The number of subcarriers is $N = 32$. All sources have the same maximum power constraints, so do all relays and they satisfy $P_r = P_{k1} + 3\text{dB} = P_{k2} + 3\text{dB}$ (per-subcarrier) for all r and k.

As a performance benchmark, the fixed subcarrier pairing scheme is considered. From the references [3], [5] let the signals are transmitted by the user pair on one subcarrier in the MAC phase is forwarded on the same subcarrier by a

relay in the BC phase, i.e., $\pi(n) = n$, rather than seeking the optimal subcarrier pairing. Then the problem reduces to selecting the optimal user pair and relay for each subcarrier for throughput maximization. From the Fig (3) the performance of the proposed algorithm is compared with benchmark along with AF protocol and from the Fig (4) the performance is compared along with DF Protocol.

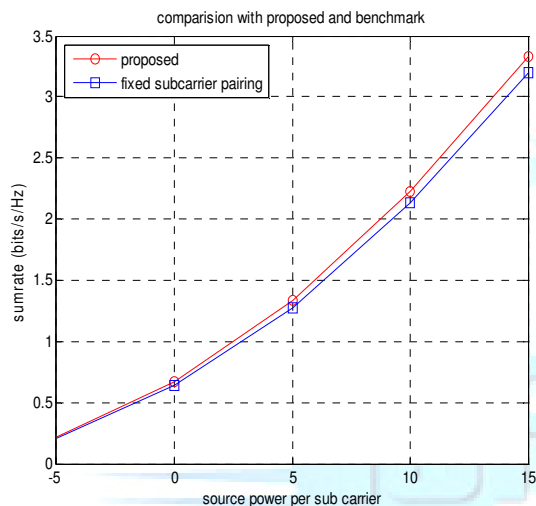


Fig. 3. Performance comparison of the proposed algorithm and the benchmark along with AF protocol.

From the figure 4 and figure 5 proposed algorithms is compared with the bench mark algorithm for amplified and forward cooperative communication network protocol. From above results we prove that the variable subcarrier is better than the fixed subcarrier assignment and the sum rate is improved from the previous system.

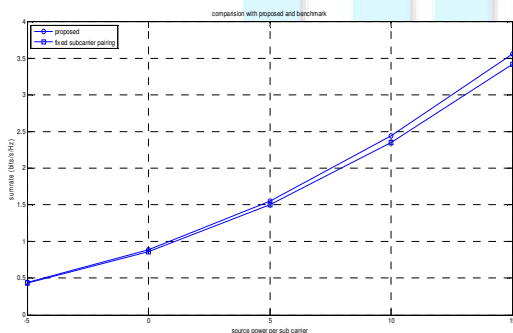


Fig 4. Proposed algorithm with DF protocol

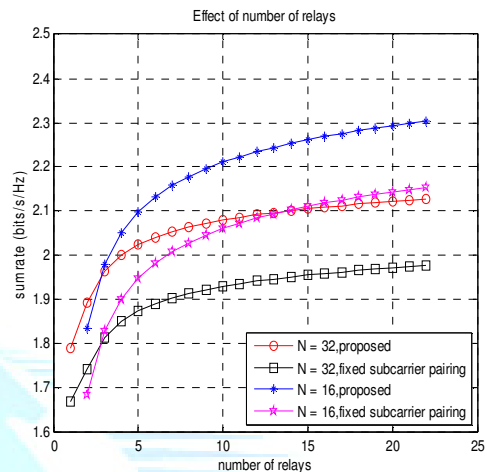


Fig 5. Effects of number of relays

Fig.5 illustrates the total throughput when there are $K=5$ user pairs and $M=4$ relays in the network. The proposed optimal channel and relay assignment is observed with adaptive subcarrier pairing achieves 8 ~10% improvement in total throughput over the scheme with fixed subcarrier pairing.

5. Conclusion and future work

In this work, it was investigated that the joint optimization of subcarrier-pairing based subcarrier assignment and relay selection for multi-relay multi-pair two-way relay OFDM networks with AF and DF relaying protocol. The problem was formulated as a combinatorial optimization problem. We proposed a bipartite matching approach to solve the problem optimally in polynomial time.. The results are shown for the use of different number of subcarriers. The difference between proposed and fixed scheme are shown using graphs. With the change in number of subcarriers, get the relation between the numbers of relays used to that of throughput. This similar problem based on more advanced regenerative two-way relay strategies and with different combining methods can be considered in the future works.

References

- [1] Boris Rankov and Armin Wittneben "Spectral Efficient Protocols for Half-Duplex Fading Relay Channels" *IEEE Journal On Selected Areas In Communications*, Vol. 25, No. 2, pp 379-389, February 2007
- [2] Eun-Hee Shin and Dongwoo Kim, "On the Capacity Growth of Opportunistic Single-Relay Selection Using Quality-Based Feedback in Fixed-Gain Amplify-and-Forward Relaying" *IEEE Communications Letters*, Vol. 13, No. 11, pp.835-837, November 2009.
- [3] R. Ahlswede, N. Cai, S.-Y. R. Li, and R. Yeung, "Network information flow," *IEEE Trans. Inf. Theory*, vol. 46, no. 4, pp. 1204-1216, July 2000.
- [4] S. J. Kim, P. Mitran, and V. Tarokh, "Performance bounds for bidirectional coded cooperation protocols," *IEEE Trans. Inf. Theory*, vol. 54, no. 11, pp. 5253-5241, Aug. 2008.
- [5] Guoqing Li, and Hui Liu "Resource Allocation for OFDMA Relay Networks With Fairness Constraints" *IEEE Journal on selected Areas in Communications*, vol. 24, no. 11, pp. 2061-2069, November 2006.
- [6] Ingmar Hammerström and Armin Wittneben "Power Allocation Schemes for Amplify-and-Forward MIMO-OFDM Relay Links" *IEEE Transactions On Wireless Communications*, Vol. 6, No. 8, pp.328-339, August 2007.
- [7] Truman Chiu-Yam Ng and Wei Yu "Joint Optimization of Relay Strategies and Resource Allocations in Cooperative Cellular Networks" *IEEE Journal on Selected Areas Communication* Vol. 25, no. 2, pp.328-339, Feb 2007.
- [8] Wenbing Dang, Meixia Tao, Hua Mu, and Jianwei Huang "Subcarrier-Pair Based Resource Allocation for Cooperative Multi-Relay OFDM Systems" *IEEE Transactions On Wireless Communications*, Vol. 9, No. 5, pp. 1640-1649, May 2010.
- [9] Yong Li, Wenbo Wang, Jia Kong, and Mugen Peng "Subcarrier Pairing for Amplify-and-Forward and Decode-and-Forward OFDM Relay Links" *IEEE Communications Letters*, Vol. 13, No. 4, pp. 209-211, April 2009.
- [10] Yuan Liu, Meixia Tao, Bin Li, and Hui Shen "Optimization Framework and Graph-Based Approach for Relay-Assisted Bidirectional OFDMA Cellular Networks" *IEEE Transactions On Wireless Communications*, Vol. 9, No. 11, pp.3490-3500, November 2010.
- [11] Vinko Erceg, Larry J. Greenstein, Sony Y. Tjandra, Seth R. Parkoff, Ajay Gupta, Boris Kulic, Arthur A. Julius, and Renee Bianchi "An Empirically Based Path Loss Model for Wireless Channels in Suburban Environments" *IEEE Journal On Selected Areas In Communications*, Vol. 17, No. 7, pp.1205-1211, July 1999.
- [12] Yong-Up Jang, Eui-Rim Jeong, and Yong H. Lee, "A Two-Step Approach to Power Allocation for OFDM Signals Over Two-Way Amplify-and-Forward Relay" *IEEE Transaction Signal process*, Vol 58, no .4, pp.2426-2430, Apr 2010.
- [13] D.West, "Introduction to Graph Theory", Prentice Hall, 2001.
- [14] X.J.Zhang and Y.Gong, "Adaptive power allocation in two-way amplify and forward relay networks: in *proc, 2009 IEEE ICC*.
- [15] C.K.Ho, R.Zhang and Y.C.Liang, "Two -way relaying ove OFDM: Optimized tone permutation and power allocation," in *proc.2008 IEEE ICC*,pp.3908-3912
- [16] I.Hammerstrom and A.Wittneben, "On the optimal power allocation for nonregenerative OFDM relay links", in *proc. IEEE ICC, June 2006*, pp. 4463-4468.