MIMO Two-way Cooperative Relay to Improve End to End Capacity in Non-equidistant Topology

Christine Niyizamwiyitira* · 강철규* · 오창헌*

*한국기술교육대학교 전기전자공학과

Christine Niyizamwiyitira*, Chul-Gyu Kang* and Chang-Heon OH*

*Korea University of Technology and Education, Department of Electrical and Electronics Engineering

E-mail : nchristine8@gmail.com

ABSTRACT

This paper proposes MIMO two-way cooperative relay scheme to optimize the end to end capacity in wireless multi-hop mesh network. The basic idea is to perform data transmission via multi-hop relay nodes, in equidistant topology, this method is quite efficient. However, on one hand this topology is very rare in practical situation, on the other hand, in real practical situation where the topology is most likely non equidistant, the end to end capacity significantly degrades due to bottleneck link caused by uneven SNR. Moreover, the end to end capacity degrades at high SNR due to overreach interference from far nodes existing in multi-hop relay networks. In this paper, MIMO two-way cooperative relay in the region of non equidistant nodes is found efficient to improve the end to end capacity. The proposed scheme is validated using numerical simulation.

Keywords

MIMO cooperative two way relay, end to end capacity, cooperative multi-hop relay network

I. INTRODUCTION

With the rapid advancement of the internet and wireless access technologies, increasing the system capacity becomes one of the key goals in the wireless system design. Multiple-Input Multiple-Output (MIMO) emerged recently a strong candidate to increase the system capacity. It has now been widely recognized that by deploying multiple antennas at both the transmit and receive ends of a point-to-point link, one can exploit spatial diversity for increasing data rates without wasting bandwidth and power resources[1],[2]. MIMO cooperative relay, as an efficient solution for ubiquitous coverage, has the potential to become a key technology for future wireless communication systems. The combination of cooperative MIMO and relaying technology would provide an excellent information service with high data rates and ubiquitous coverage. To avoid inter-flow interference, array beamforming is used in the MIMO two way multi-hop relay network[3], network coding is also used to support two flows of information (forward and backward) to be simultaneously transported per transmission. Section II presents the system model, section III presents link capacity. Section IV gives simulation. Finally, conclusions are drawn in section V.

II. SYSTEM MODEL

2.1 MIMO TWO WAY RELAY NETWORK

As figure 1 shows, at a time slot, for any two nodes adjacent to each other, one node is the transmitter and the other is the receiver .

We assume absence of hidden and exposed node problem as well as knowledge of at least two next hops. The node weight on node i is calculated as follows: transmit signal s_{i-1} and s_{i+1} at node $i-1$and $i+1$ in time slot n is coded using network coding as follows,

$$s_{i-1} = F^n s_{i-1} + B^n s_{i-1} \mod q \ . \tag{1}$$

$$s_{i+1} = F^n s_{i+1} + B^n s_{i+1} \mod q \ . \tag{2}$$

Where $F^n s_{i-1}$ and $F^n s_{i+1}$ are the forwarded signal to node $i-1$ and $i+1$ respectively,

$B^n s_{i-1}$ and $B^n s_{i+1}$ are the backward signal to node $i-1$ and $i+1$ and q denotes the lattice size. The receive signal y_i at node i is given by

$$y_i = h_{i,i-1}s_{i-1} + h_{i,i+1}s_{i+1} + n_1. \quad (3)$$
$$= H^{\Lambda i} S^{\Lambda i} + n_i$$
$$H_i^{\Lambda} = [h_{i,i-1}h_{i,i+1}] \parallel pos(i,,i+1) - pos(i,,i-1) \parallel^{\gamma}. \quad (4)$$
$$s_i^{\Lambda} = [s_{i-1}s_{i+1}]^T. \quad (5)$$

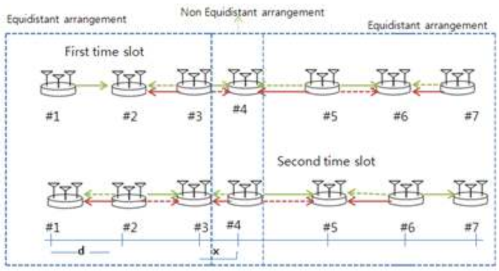

Figure 1. Non equidistant topology.

2.2 NON-EQUIDISTANT TOPOLOGY

From figure 1, node 4 is far from node 5, it means that much more power is needed to communicate between node 4 and 5; hence the slow link is henceforth referred to as the bottleneck link. In this paper, we consider $x+d/d=1.5$. To overcome this problem, MIMO two way cooperative relay is proposed by choosing two close nodes to cooperatively relay their neighbors. Initially, node 2 receives the forward signal from node 1 as figure 2 shows; simultaneously node 2 receives backward signal of weigh $w_{tB_{spe}}$ from cooperative relay nodes 3 and 4 (see figure 3). The cooperative transmission of nodes 3 and 4 towards node 2 is

$$H_r = w^{T*}[h_{23}h24]. \quad (6)$$
$$w_{tB_{spe}} = pnv(H_r). \quad (7)$$

Through array beamforming using SVD technique, we get temporary transmitted backward weight towards node 2 and received forward weight on node 5. $w_{tB_{spe-tmp}}$ and $w_{rF_{spe-temp}}$.

$$[U,S,V] = svd(H_r^H H_r). \quad (8)$$
$$w_{tB_{spe-tmp}} = V. \quad (9)$$

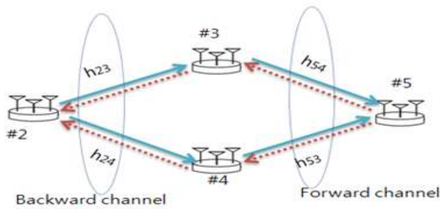

Figure 2. Two way cooperative relay.

$$H_s = [h_{53}h_{54}]w_{tB_{spe}}. \quad (10)$$
$$[U,S,V] = svd(H_s H_s^H). \quad (11)$$
$$w_{rF_{spe=tmp}} = V. \quad (12)$$

On the pair cooperative nodes denoted by *spe* we have

$$H_r = w_{rF_{spe-tmp}}[h_{53}h_{54}]w_{rB_{spe-tmp}}. \quad (13)$$
$$[U,S,V] = svd[H_r]. \quad (14)$$

the forward received weight on node 5

$$w_{rF_5} = w_{rF_{spe-tmp}}U. \quad (15)$$

and the transmitted forward weight on *spe :*

$$w_{tF_{spe}} = w_{tB_{spe-tmp}}V. \quad (16)$$

Finally, the total transmitted weight on spe :

$$w_{t_{spe}} = [w_{tF_{spe}} w_{tB_{spe}}]. \quad (17)$$

The received backward weight on node 5 is

$$[U,S,V] = svd(H_s H_s^H). \quad (18)$$
$$w_{rB_5} = V. \quad (19)$$

The total received weight on node 5 is

$$w_{t_5} = [w_{tF_5} w_{tB_5}]. \quad (20)$$

In the second time slot,

$$w_{rB_{spe}} = conj(w_{tF_{spe}}). \quad (21)$$
$$w_{rF_{spe}} = conj(w_{tB_{spe}}). \quad (22)$$
$$w_{tF_5} = conj(w_{rB_5}). \quad (23)$$
$$w_{tB_5} = conj(w_{rF_5}). \quad (24)$$

From node 5 until 7, the processing of the weight calculation is given in [4].

III. END TO END CAPACITY

In relay network, end to end capacity is important to evaluate the performance.

$$c_{f_1} = \log_2\left(1 + \frac{snr \parallel w_{rF1}^T H_{j,i} w_{tF1} \parallel^2 diag(\sqrt{p_{nt}})}{snr(i_f) + n_i}\right). \quad (25)$$

$$c_{b_1} = \log_2\left(1 + \frac{snr \parallel w_{rB1}^T H_{j,i} w_{tB1} \parallel^2 diag(\sqrt{p_{nt}})}{snr(i_f) + n_i}\right). \quad (26)$$

$$c_{f_2} = \log_2\left(1 + \frac{snr \parallel w_{rF2}^T H_{j,i} w_{tF2} \parallel^2 diag(\sqrt{p_{nt}})}{snr(i_f) + n_i}\right). \quad (27)$$

$$c_{b_2} = \log_2\left(1 + \frac{snr \parallel w_{rB2}^T H_{j,i} w_{tB2} \parallel^2 diag(\sqrt{p_{nt}})}{snr(i_f) + n_i}\right). \quad (28)$$

Where c_f and c_b are the forward and backward signal.

$$C_{e2e} = \frac{\min(mean(c_{f_1} \bigcup c_{f_2})) + \min(mean(c_{b_1} \bigcup c_{b_2}))}{2}. \quad (29)$$

IV. SIMULATION AND ANALYSIS

The number of antennas per node is 3. The path loss exponent is 3.5. In equidistant topology, 4th node is located in the middle of 3rd and 5th nodes. For non-equidistant topology, 4th node is located at a certain point between 3rd and 5th nodes. The tool used for simulation is Matlab 7.8.0 .

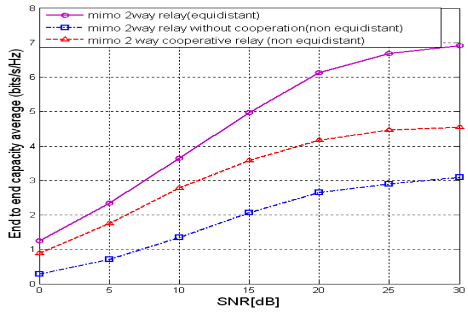

Figure 3. End to end capacity analysis in MIMO two way relay network.

On figure 3, the average end to end capacity of MIMO two-way is drawn against SNR. The performance of non equidistant topology without two way cooperative relay severely degrades, since it suffers from far interference from 4th node. The introduction of MIMO two way cooperative relay between node 3 and 4 as figure4 shows, improves the performance even better than the equidistant topology, especially, in high SNR. Figure4 shows the performance against 4th node position with the average SNR of 5, 10, 20 and 30[dB], with same SNR, the average end to end capacity is almost same in all positions of 4th node.

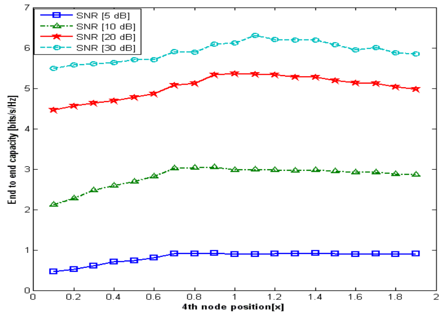

Figure 4. End to end capacity with respect to 4th position with two way cooperative relay scheme

V. CONCLUSION

In this paper, we introduced MIMO two-way cooperative relay scheme in the non- equidistant topology. This scheme can combat the problem of interference from far nodes in non-equidistant topology. By comparing the SNR of all links and boosting of the capacity of the bottleneck for the non equidistant nodes, the end to end capacity is dramatically improved even better than in the equidistant topology. Thus the proposed scheme is effective for non equidistant topology.

REFERENCES

[1] I. E. Teltar, “Capacity of multi-antenna gaussian channels,”*European Trans. Tel*, vol. 10, pp. 585-595, Nov./Dec. 1999.

[2] G. J. Foschini and M. J. Gans, “On limits of wireless communications in a fading environment when using multiple antennas,”wireless personal comm, pp. 311-335, 1998.

[3] I. F. Akyildiz and X. Wang, “A survey on wireless mesh networks,” IEEE Commun. Mag., vol. 43, no. 9, pp. 523-530, Sep. 2005.

[4] K. Sakaguchi and F. Ono, “Multiple access interference cancellation and link multiplexing for MIMO mesh network,” in Proc. IEEE Inter. Conf. Comp. Commun. Networks (ICCCN07), Hawaii, USA, Aug. 2007.

[5] R. Zhang, Y. Chang and C. Choy, “Optimal beamforming for two-Way multi-antenna relay channel with analogue network coding,” IEEE Journal on selected areas in comm., vol. 27, no. 5, June 2009.