Improving Channel Capacity in Bidirectional Cooperative MIMO Relay Network

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ABSTRACT

The paper considers MIMO two-way scheme to optimize the end to end capacity in local wireless mesh network. The basic idea is to perform data transmission via intermediate cooperative nodes and cooperative relay therefore higher throughput can be achieved. Each node is equipped with multiple antennas, and has two time slots one for transmission (Tx) and the other is reception (Rx), which are arranged alternatively in the network. In the conventional SISO network, it takes at least four time slots to accomplish the function of two-way relay. Moreover, cooperative technique is used in order to enhance multiplexing of forward and backward streams.

Keywords

MIMO cooperative relay, bidirectional cooperative, cooperative relay network

Ⅰ. Introduction

Wireless mesh network (WMN) consisting of mesh routers and mesh clients and has been achieving much more attention in recent years due to more demands for WMN applications, such as wireless sensor networks and public wireless access networks, etc.

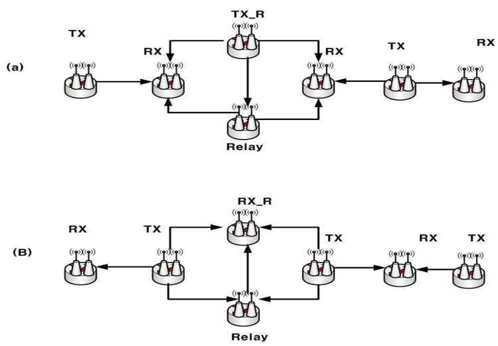
To achieve this, the authors propose a two-way cooperative relay network with every nodes equipped with multiple antennas. Moreover, the multiple antennas must work cooperatively in order to profit virtual MIMO systems.

Among all cooperative communication networks, one of the most important model is relay channel. Network coding is also proposed to support two flows of information (forward and backward) to be simultaneously transported per transmission.

In this way, the proposed method achieves capacity performance near to ideal capacity.

The rest of this paper is as follows .Section II defines system model. SectionIII presents link capacity. SectionIV contains simulation results and discussion. Finally, conclusions are drawn in section V.

II. System model



(a) First time slot
(b) Second time slot

Figure 1.Two way relay cooperative network

At a time slot, for any two nodes adjacent to each other, one node is the transmitter (Tx) and the other is the receiver (Rx).

The Tx node uses its antennas to broadcast transmit signal to its two adjacent Rx nodes.

Each Rx node listens to the two different signals sent from its two adjacent Tx nodes and uses MIMO multiple access algorithm to detect these signals. When it comes to node TX_R or RX_R, as each makes a pair with the relay node, they will enhance the transmitting and receiving respectively.

This technique will enhance the signal power but the position of the relay node should be convenient according to the network extent .It is advisable to put this relay in the center or middle way of the network and it should not be too close to its node pair. This is for avoiding the interference .

A network coding and network decoding are performed to the signals at the Tx node before transmission and at the Rx node after receiving respectively to ensure that the forward and backward information is sent simultaneously at every time slot.

In the next time slot, nodes switch their functions. Tx nodes become Rx node and vice versa.

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,

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

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

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 used in network coding to restrict the transmit power. This results in a shaping loss of $\rho = \frac{1}{2}$ [3].

The receive signal y_i at node i is given by

$$y_i = h_{i,i-1} s_{i-1} + h_{i,i+1} s_{i+1} + n_1 \quad (3)$$

$$= H^{\Lambda_i} s^{\Lambda_i} + n_i \quad (4)$$

$$H_i^{\Lambda} = [h_{i,i-1} h_{i,i+1}] \parallel pos(i,,i+1) - pos(i,,i-1) \parallel^{\gamma} \quad (5)$$

$$s_i^{\Lambda} = [s_{i-1} s_{i+1}]^T \quad (6)$$

Where $h_{i,i-1}$ and $h_{i,i+1} \in c^m$ represent the channel from node i-1 and i+1 respectively.*pos* is the position of the relay node with respect to its pair node. γ =-3.5, is the path loss exponent in wireless environment. n_i is the AWGN noise with zero mean.

Using linear decoding algorithm, $\widetilde{s_i^{\Lambda}}$ can be estimated as,

$$\widetilde{s_i^{\Lambda}} = s_i^{\Lambda} = [\widetilde{s_{i-1}} \widetilde{s_{i+1}}]^T = w y_i \quad . \quad (7)$$

$w = pnv(H_i^{\Lambda^H})$:pseudo inverse of the channel for zero forcing decoder.

III. End to End Capacity Calculation

$$c_{f_1} = \log_2\left(1 + \frac{snr \parallel w_{rF1}^T H_{nr,nt} w_{tF1} \parallel^2 dig(\sqrt{p_{nt}})}{snr(i_f) + n_i}\right) \quad (8)$$

$$c_{b_1} = \log_2\left(1 + \frac{snr \parallel w_{rB1}^T H_{nr,nt} w_{tB1} \parallel^2 dig(\sqrt{p_{nt}})}{snr(i_f) + n_i}\right) \quad (9)$$

$$c_{f_2} = \log_2\left(1 + \frac{snr \parallel w_{rF2}^T H_{nr,nt} w_{tF2} \parallel^2 dig(\sqrt{p_{nt}})}{snr(i_f) + n_i}\right)$$

$$c_{b_2} = \log_2\left(1 + \frac{snr \parallel w_{rB2}^T H_{nr,nt} w_{tB2} \parallel^2 dig(\sqrt{p_{nt}})}{snr(i_f) + n_i}\right) \quad (10)$$

Where c_{f1} and c_{b_1} are the forward and backward signal in the first time slot.

c_{f_2} and c_{b_2} are forward and backward signal in the second time slot.

w_r: received node's weight

w_t: transmitted node's weight

$H_{nr,nt}$ is the channel between transmit node *nr* and receiver node *nt*, H is of NM dimension with N as transmit antennas ,and M receive antenna

$diag(\sqrt{P_{nt}})$ is the diagonal of the transmit power.

nt: transmit node, nr: receiver antenna.

snr: signal noise ratio

i_f interfering signal power

$$C_{e2e} = \frac{\min(mean(c_{f_1} \bigcup c_{f_2})) + \min(mean(c_{b_1} \bigcup c_{b_2}))}{2} \quad (11)$$

IV. Simulation and Discussion

The system considers a wireless mesh network of 7 locally located nodes. The parameters used are as following: cooperative

MIMO 3x3, one relay node which makes a pair with another node.

if relay node is of n order, its pair node should be of n-1 or n+2 order, the weight of each node depends on its neighbors node whether transmitting or receiving. The tool used to simulate is Matlab.

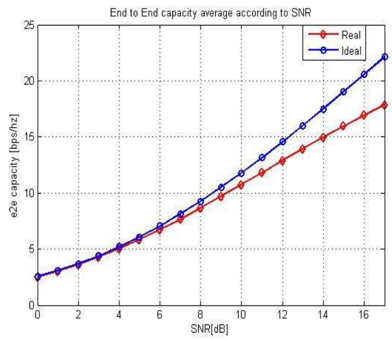


Figure 2. Average end to end capacity per flow with respect to SNR.

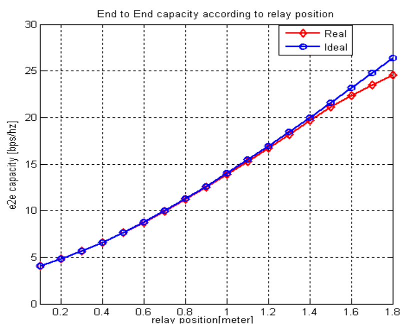


Figure 3. Average end to end capacity per flow with respect to position.

As the figure shows, the average of the end to end capacity per flow taken from different relay position is getting high as the signal noise ratio is increasing.

The ideal capacity is the one expected without interference and noise whereas the real capacity is the one actual capacity when the system considers the interference and noise.

Figure 3 shows the average end to end capacity per flow with respect to average distance of the relay node position according to the pair node.

From this graph, we realize that as the relay position is getting high as the end to end capacity is performing better. This means that relay position is important and the latter should be placed to the distance not close to its pair node.

After comparing ,the ideal and real capacity we find out that this method improve the end to end .

V. CONCLUSION

In this paper we proposed two way relay cooperative combined with MIMO in mesh network, through simulation results we realize that the proposed technique provides a significant gain of end to end capacity which is quite equals to the ideal capacity.

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