Linear Interference Cancellation Method for Relay Systems

Won-Seok Lee, Myoung-Jin Kim, Jung-In Baik, Hyoung-Kyu Song[1)]
uT Communication Research Institute
Sejong University
412, CHOONGMU-GWAN, 98 GUNJA-DONG, GWANGJIN-GU
SEOUL, REPUBLIC of KOREA
scu008@nate.com, windingkey@naver.com, bji0309@sdc.sejong.ac.kr, songhk@sejong.ac.kr[1)]

Abstract: - High mobile data traffic has been an important issue in wireless communication. In metropolitan areas that the data traffic is much higher than other areas, heterogeneous network (HetNet) is used to meet the traffic demand. The HetNet has several low power base stations (BS) or remote radio heads (RRH) in a macro cell coverage and sometimes coordinates the low power transmission points to improve system performance. This paper proposes linear interference cancellation method for relay system using the coordinated multipoint. In existing schemes, the cancellation is performed at a destination node but proposed method performs the cancellation at relay nodes to reduce the complexity of detection algorithm for the destination node. Simulation results show that proposed method achieves better BER performance than the existing full interference cancellation (FIC) method.

Key-Words: - CoMP, CS, IRI, MIMO detection, ZF

1 Introduction

High mobile data traffic has been an important issue in wireless communication. In most cities where population density is high, this traffic requirement is a serious problem. To solve this problem, small cells are used within a city macro cell network. This network which are called heterogeneous network (HetNet) has low power base stations (BS) or remote radio heads (RRHs) to implement the network. In the HetNet, the small power transmission points are coordinated to form virtual multiple-input and multiple-output (MIMO) system which provides improvements for data rate and reliability. In [1], coordinated multipoint (CoMP) methods and scenarios using these CoMP techniques are presented. Fig. 1 shows coordinated scheduling (CS) which is one of CoMP schemes. In this paper, this CS is used to implement a two-path relay system. Fig. 2 shows the two-path relay system which does not have direct link between a source node and a destination node. In the two-path relay system, the source node transmits data to the two relay nodes alternately. Then these relay nodes transmit the received data to the destination node. This system overcomes bandwidth loss by applying this alternating transmission but this transmission method makes interference problem between the relay nodes. To apply this system successfully, the inter-relay interference (IRI) must be handled.

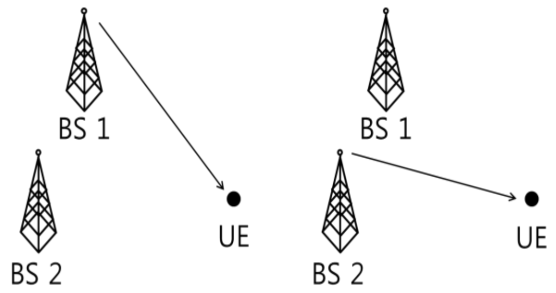

Fig.1 Coordinated scheduling system

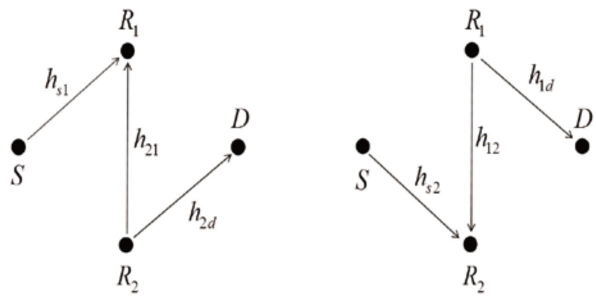

Fig.2 Two-path relay system using CS

2 System Model

The system model is shown in Fig.2. S is a source node, R_1 and R_2 are wireless relay nodes, h_{s1} and h_{s2} mean channel coefficients from the source node to the relay nodes, h_{12} and h_{21} mean channel coefficients between the relay nodes, h_{1d} and h_{2d} mean channel coefficients from the relay nodes to

1) Corresponding author

the destination node. In this system, the Source node S transmits data to the relay node R_1 and R_2 alternately. If R_1 receives data from the source node S, another relay node R_2 transmits previously received data from S to the destination node. Since the transmissions occur simultaneously, R_1 receives undesired data from R_2. These received data by the relay nodes R_1 and R_2 are represented as follows,

$$y_1(n) = h_{s1}x(k) + h_{21}y_2(m-1) + w_1(n), \qquad (1)$$

$$y_2(m) = h_{s2}x(k+1) + h_{12}y_1(n) + w_2(m). \qquad (2)$$

where n and m are indices for received data y_1 and y_2, k is an index for the transmitted data from the source, w_1 and w_2 are noise at the relay node R_1 and R_2. In (1) and (2), the $y_1$and y_2 terms of right-hand side are the IRI. If the IRI terms are not cancelled, the detection performance of the system decreases severely. IRI cancellation method must be applied. In [4] and [5], amplify-and-forward (AF) method and IRI cancellation at the destination node are used. In AF method, the received data by the relay nodes are amplified. The amplified data are expressed as

$$y_d(k) = h_{1d}\beta_1 y_1(n) + w_d(k), \qquad (3)$$

$$y_d(k+1) = h_{2d}\beta_2 y_2(m) + w_d(k+1). \qquad (4)$$

In (3) and (4), β_1 and β_2 are amplifying factors. Theses amplifying factors are calculated as follows,

$$\beta_1 = \sqrt{\frac{P_1}{P_s|h_{s1}|^2 + P_2|h_{21}|^2 + \sigma^2}}, \qquad (5)$$

$$\beta_2 = \sqrt{\frac{P_2}{P_s|h_{s2}|^2 + P_2|h_{12}|^2 + \sigma^2}}. \qquad (6)$$

P_s is a transmission power of the source node, P_1 and P_2 are constraints of transmission power for the relay node R_1 and R_2, σ is variance of the noise at the relay nodes. By using (1), (2), (5) and (6), (3) and (4) are represented as follows,

$$\begin{aligned} y_d(k) = {} & h_{1d}\beta_1 h_{s1}x(k) + h_{1d}\beta_1\beta_2 h_{21}y_2(m-1) \\ & + h_{1d}\beta_1 w_1(n) + w_d(k), \end{aligned} \qquad (7)$$

$$\begin{aligned} y_d(k+1) = {} & h_{2d}\beta_2 h_{s2}x(k+1) + h_{2d}\beta_2\beta_1 h_{12}y_1(n) \\ & + h_{2d}\beta_2 w_2(n) + w_d(k+1). \end{aligned} \qquad (8)$$

In (7) and (8), the second terms are IRI and can be expressed by (3) and (4). Therefore, these terms are cancelled at the destination node using previously received data in [5]. The IRI cancellation of [4] and [5] uses AF method. The implementation of AF method is simple but the destination node need all channel information from the source node to the destination node to detect the transmitted data. This requirement for channel information and IRI cancellation algorithm increase the complexity of the destination node. Since most destination nodes are mobile devices which run many applications, the increase of complexity is unacceptable.

3 Proposed Method

The existing methods cancel the IRI at the destination node but proposed method cancels the IRI at the relay nodes to reduce implementation complexity of the destination node. Proposed method increases complexity of the relay nodes. In system model of proposed method, however, the relay nodes are small power base stations. Therefore, the increase of complexity is acceptable than the case of the destination node.

3.1 New System Model

In the existing system model, the relay nodes can not cancel the IRI since each relay node has one antenna. To cancel the IRI, each relay node need two antennas at least. In new system model of proposed method, the relay nodes use two antennas when receive data from the source node. The new system model is multiple-input multiple-output model by using additional antennas at the relay nodes. Fig.3 shows the new system model. H_1 and H_2 are difference between existing system model and new system model. The H_1 and H_2 mean channel matrices from the source node to the relay nodes. These channel matrices are represented as follows,

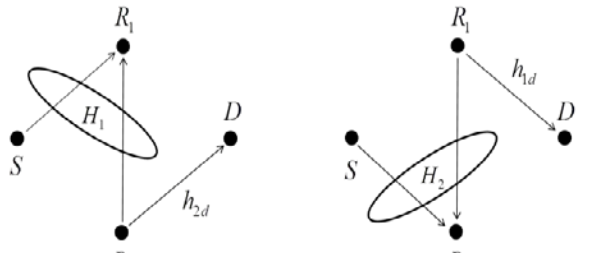

Fig.3 A new system model for proposed method

$$H_1 = \begin{pmatrix} h_{s1}^1 & h_{21}^1 \\ h_{s1}^2 & h_{21}^2 \end{pmatrix}, \qquad (10)$$

$$H_2 = \begin{pmatrix} h_{s2}^1 & h_{12}^1 \\ h_{s2}^2 & h_{12}^2 \end{pmatrix}. \qquad (11)$$

h_{ab}^n means channel coefficient from a node *a* to the *n*-th antenna of the node *b*.

3.2 Interference Cancellation Method

Since the new system model is MIMO system model, the MIMO detection methods can be used to cancel the IRI. Nonlinear detection methods have better performance than linear detection methods but nonlinear detection methods have high complexity of calculation. Since nonlinear methods increase the processing time at the relay nodes, proposed method uses simple linear detection method. Zero forcing (ZF) is one of MIMO linear detection methods. This method uses a pseudo inverse matrix of a channel matrix to cancel unwanted elements. The pseudo inverse matrix is calculated as follows,

$$H^{\dagger 1} = (H^H H)^{-} H^H. \qquad (12)$$

H^H means Hermitian matrix of H and H^{-1} means inverse matrix of H. The pseudo inverse matrix H is applied to detect desired data $\hat{X}$ as follows,

$$\hat{X} = H_1^{\dagger} H_1 \begin{pmatrix} x(k) \\ y_2(m) \end{pmatrix}, \qquad (13)$$

$$\hat{X} = H_2^{\dagger} H_2 \begin{pmatrix} x(k+1) \\ y_1(n) \end{pmatrix}. \qquad (14)$$

The first element of $\hat{X}$ is the desired data from the source node. After the detection is performed, the first element is transmitted from the relay nodes to the destination node.

4 Simulation Results

In this section, the Full interference cancellation (FIC) of [5] and proposed method are compared. Fig.4 shows distance assumption of the simulation. The distance between the source node and the relay nodes is normalized to 4. The direct link from the source node to the destination node is ignored. The other distances are normalized to 1.

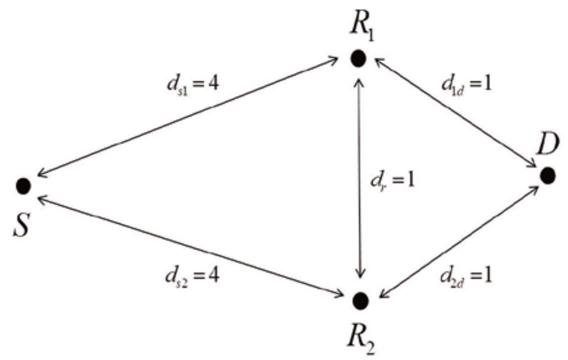

Fig.4 A distance assumption for new system model

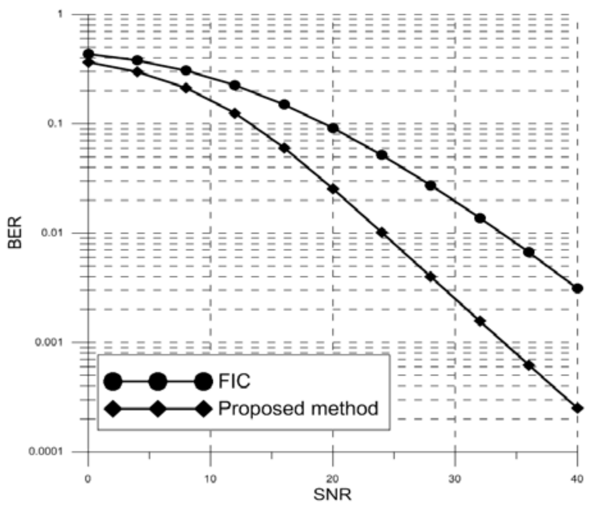

Fig. 4 BER performance for FIC and Proposed method

The path loss according to the distance assumption is expressed as follows,

$$loss_{ab} = \sqrt{P d_{ab}^{-\gamma} 10^{\varphi/10}}. \qquad (15)$$

P is transmission power, γ is path loss exponent (which is set to 3) and φ is log-normal shadowing factor (which is set as a normal variable with zero mean and standard deviation of 8 dB). The modulation scheme is quadrature phase shift keying (QPSK) and the orthogonal frequency division multiplexing (OFDM) scheme is used to transmit the modulated symbols. The number of OFDM subcarriers is 128. Fig.4 shows the bit error rate (BER) performance for FIC of [5] and proposed method. In the result, it is shown that the proposed method has better performance than the FIC method. The difference of two curves increases as the SNR becomes high value.

5 Conclusion

This paper proposes IRI cancellation using relays. The existing FIC method used IRI cancellation algorithm at the destination node. Proposed method performs the IRI cancellation at the relay nodes to reduce the complexity of the destination node. The simulation result shows that the performance of proposed method is better than the FIC method.

Acknowledgment

This work was supported by Institute for Information & communications Technology Promotion(IITP) grant funded by the Korea government(MSIP) (No.B0126-15-1076, Development of non-powered technology combined with ambient RF energy harvesting and Backscatter data transfer)

References:

[1] J.Lee et al., “Coordinated Multipoint Transmission and Reception in LTE-Advanced Systems,” *IEEE Commun. Mag.*, Vol.50, No.11, 2012, pp.44-55.

[2] K.R.Kim, D.H.Ha and H.K.Song, “Performance Improvement Technique with Cooperative Relay in Cellular System,” *IEICE Trans. Commun.*, Vol.E98-A, No.6, 2015, pp.1339-1342.

[3] S.J.Yu, H.W.Jang, H.K.Song, “Hybrid MIMO Cooperative Scheme for Improved Throughput in Wireless OFDM Systems,” *Wireless personal Commun.*, Vol.83, No.3, 2015, pp.1945-1953

[4] B.Rankov and A.N.Wittneben, “Spectral Efficient Protocols for Half-Duplex Fading Relay Channels,” *IEEE J. Sel. Areas Commun.*, Vol.25, No.2, 2007, pp.379-389

[5] C.Luo, Y.Gong and F.Zheng, “Full Interference Cancellation for Two-Path Relay Cooperative Networks,” *IEEE Trans. Veh. Technol.*, Vol.60, No.1, 2011, pp.343-347.