Linear Interference Cancellation Method for Relay Systems

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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.

2 System Model
The system model is shown in Fig.2. S is a source node, R1 and R2 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
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,

$$y_1(n) = h_{s_1}x(k) + h_{s_2}y_2(m-1) + w_1(n),$$

$$y_2(m) = h_{s_2}x(k+1) + h_{s_1}y_1(n) + w_2(m).$$

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 (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

$$y_d(k) = h_{s_1} \beta_1 y_1(n) + w_d(k),$$

$$y_d(k+1) = h_{s_2} \beta_2 y_2(m) + w_d(k+1).$$

In (3) and (4), $\beta_1$ and $\beta_2$ are amplifying factors. Theses amplifying factors are calculated as follows,

$$\beta_1 = \sqrt{\frac{P_1}{P_1|h_{s_1}|^2 + P_2|h_{s_2}|^2 + \sigma^2}},$$

$$\beta_2 = \sqrt{\frac{P_2}{P_1|h_{s_1}|^2 + P_2|h_{s_2}|^2 + \sigma^2}}.$$  

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,
\( h_{ab}^n \) 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,

\[
H^\dagger = (H^H H)\, H^H. \tag{12}
\]

\( H^H \) 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,

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

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

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.

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

\[
\text{loss}_{ab} = \sqrt{Pd_{ab}^{-\alpha}} \cdot 10^{\omega/10}. \tag{15}
\]
\( P \) is transmission power, \( \gamma \) is path loss exponent (which is set to 3) and \( \varphi \) 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.

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