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간섭이 존재하는 양방향 중계네트워크에서의 사용자 선택을 통한 불능확률 분석

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Outage Probability Analysis for a Two-Way Relay Network with User Selection in the Presence of Interference

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요 약

본 논문에서는 다수의 간섭자로부터의 간섭 신호가 존재할 때 양방향 중계 네트워크의 불능 확률을 분석하였다. 양방향 중계 네트워크에서 한사용자는 다른 선택된 사용자와 세 단계로 통신한다. 제안된 네트워크에서 사용자 선택 기준을 제시하였으며 불능 확률을 수식적으로 유도하였다. 컴퓨터 모의 실험을 통해 제안된 분석과 모의실험이 잘 일치함을 확인하였으며 유저 수와 간섭자의 수의 불능 확률에의 영향을 보였다.

Abstract

This paper analyzes the outage performance of a two-way relay network in the presence of interference from multiple interferers. We investigate a two-way relay network where a single user communicates with a selected other user via a relay during three phases. We propose a user selection scheme and analyze an outage probability. Numerical results verify our analysis by comparison with computer simulation and show effects of the number of users and the number of interferers on its the outage probability.

Keyword : Two-way, relay, outage probability, interference

Ⅰ.Introduction

In a wireless network, relay communication improves reliability and coverage [1]-[3]. Recently, there have been growing interests of two-way relay networks in order to improve spectral efficiency. In practical environment, the performances of relay networks are degraded by interference [4]-[5]. However, Furthermore, the performance analysis of

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multiuser two-way relay network in the presence of interference has not been investigated.

In this paper, we investigate a multiuser two-way relay network where both the users and the relay receive interfering signals from multiple interferers and time-division-broadcast protocol is used. In our model, a multiuser diversity is exploited by user selection which the relay selects a user based on signal-to-interference-plus-noise-ratio (SINR). The analysis is verified by the simulation.

This paper is organized as follows. We describe the system model in section II, and analyze the outage probability in section III. Numerical results are shown in section IV and conclusion is given in section V.

Notation : $f_X(\cdot)$ denotes the probability density function (PDF) of a random variable X. The complex normal distribution with mean a and variance b is denoted by $CN(a,b)$ and the gamma distribution with a shape parameter c and a scale parameter d is denoted by $G(c,d)$.

Ⅱ. System Model

Consider a multiuser two-way decode-and-forward relay network which consists of multiple users A, B_1, B_2, $\cdots$, B_K, and a relay R as shown in Fig. 1. The user A communicates with one among B_1, B_2, $\cdots$, B_K via the relay R during three phases. Suppose that each terminal has a single antenna and operates in a half-duplex mode. Assume that each terminal is impaired by multiple interferers and each interferer has transmit power P_I. Assume that each terminal is also impaired by the additive white Gaussian noise (AWGN) with zero mean and unit variance. Assume that there is no direct link between the user A and the user B_k.

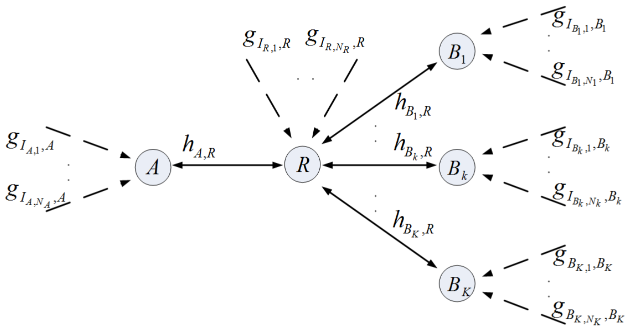

그림 1. 다중 간섭이 존재하는 다중 유저 양방향 복호 후 전송 릴레이 네트워크 시스템 모델

Fig. 1. System model of a multiuser two-way DF relay network having multiple interferers

Assume that each channel from a terminal to another terminal and other each channel from an interferer to a terminal are independent. Assume that each channel is reciprocal and has Rayleigh quasi-static fading such that the channel coefficients remain unchanged during three phases. Let $h_{a,R} \sim CN(0,\Omega_{a,R})$ denote the independent channel coefficient from the user a to the relay R, $a \in A, B_k$. Let $g_{I_{A,i},A} \sim CN(0,\Omega_{I_{A,i},A})$, $g_{I_{R,j},R} \sim CN(0,\Omega_{I_{R,j},R})$, and $g_{I_{B_m,i},B_k} \sim CN(0,\Omega_{I_{B_k,m},B_k})$ denote the independent channel coefficient from i-th interferer affecting the user A to the user A, from j-th interferer affecting the relay R to the relay R, and from m-th interferer affecting the user B_k to the user B_k, respectively.

In the first phase, the user A transmits its signal x_A with transmit power P_A to the relay R. The received signal at the relay R is given by

$$y_R^{(1)} = \sqrt{P_A} h_{A,R} x_A + \sqrt{P_I} \sum_{m=1}^{N_R} g_{I_{R,m},R} x_{I_{R,m}}^{(1)} + n_R^{(1)}$$

where $x_{I_{R,m}}^{(1)}$ is transmitted signal from the m-th interferer affecting the relay R in the first phase, $n_R^{(1)}$ is the AWGN at the relay R in the first phase, and N_R is the number of interferers affecting the relay R.

In the second phase, the user B_k transmits its signal x_{B_k} with transmit power P_{B_k} to the relay R. The received signal at the relay R is given by

$$y_R^{(2)} = \sqrt{P_{B_k}} h_{B_k,R} x_{B_k} + \sqrt{P_I} \sum_{m=1}^{N_R} g_{I_{R,m},R} x_{R,m}^{(2)} + n_R^{(2)}$$

where $x_{I_{R,m}}^{(2)}$ is transmitted signal from the m-th interferer affecting the relay R in the second phase, and $n_R^{(2)}$ is the AWGN at the relay R in the second phase.

In the third phase, the relay R broadcasts its signal $x_R = x_A \oplus x_{B_k}$ with power P_R where $\oplus$ is the XOR operation. The received signals at the user A and the user B_k are given by

$$y_A = \sqrt{P_R} h_{A,R} x_R + \sqrt{P_I} \sum_{i=1}^{N_A} g_{I_{A,i},A} x_{I_{A,i},A} + n_A$$

and

$$y_{B_k} = \sqrt{P_R} h_{B_k,R} x_R + \sqrt{P_I} \sum_{j=1}^{N_k} g_{I_{B_k,j},B_k} x_{I_{B_k,j},B_k} + n_{B_k}$$

respectively, where $x_{I_{A,i},A}$ and x_{I_{j,N_k},B_k} are transmitted signal from the i-th interferer affecting the user A and the j-th interferer affecting the user B_k, respectively, n_A and n_{B_k} are the AWGN at the user A and the user B_k, respectively, and N_A and N_k are the number of interferers affecting the user A and the user B_k, respectively.

The SINR at the relay R in the first phase and the second phase are given by

$$\gamma_{A,R} = \frac{P_A |h_{A,R}|^2}{1 + \sum_{m=1}^{N_R} P_I |g_{I_{R,m},R}|^2}$$

and

$$\gamma_{B_k,R} = \frac{P_{B_k} |h_{B_k,R}|^2}{1 + \sum_{m=1}^{N_R} P_I |g_{I_{R,m},R}|^2},$$

respectively.

The SINRs at the user A and the user B_k in the third phase are given by

$$\gamma_{R,A} = \frac{P_R |h_{A,R}|^2}{1 + \sum_{i=1}^{N_A} P_I |g_{I_{A,i},A}|^2}$$

and

$$\gamma_{R,B_k} = \frac{P_R |h_{B_k,R}|^2}{1 + \sum_{j=1}^{N_k} P_I |g_{I_{B_k,j},B_k}|^2},$$

respectively.

Assume that perfect channel state information is available at the relay R aiming to find one user B_{k^*} who has maximum SINR γ_{R,B_k}. Let D denote the set of users whose signals are decoded successfully at the relay R in the second phase. The relay R selects the user which has the largest SINR among the users in the set D, that is,

$$B_{k^*} = \arg\max_{k \in D} \gamma_{R,B_k}.$$

III. Outage Probability

For simplicity, assume that $P_{B_k} = P_B$, $N_k = N_B$, and $\Omega_{B_k,R} = \Omega_{B,R} \quad \forall k,$ $\Omega_{I_{B_k,i},B_k} = \Omega_{I_B,B} \quad \forall i,k$, and $\Omega_{I_{A,i},A} = \Omega_{I_A,A}$, $\forall i$, $\Omega_{I_{R,m},R} = \Omega_{I_R,R} \quad \forall m$.

The probability that the cardinality of the set D is l is given by

$$\Pr\{|D| = l\} = \binom{k}{l} \Pr\{\gamma_{B_k,R} \ge \gamma_{th}\}^l \times (1 - \Pr\{\gamma_{B_k,R} \ge \gamma_{th}\})^{K-l}.$$

where $\binom{k}{l} = \frac{K!}{(K-l)!l!}$.

Outage event occurs if $\gamma_{A,R}$, $\gamma_{B_k,R}$, $\gamma_{R,A}$, or γ_{R,B_k} is less than a target SINR threshold γ_{th}. The outage probability is given by

$$P_{out} = 1 - \sum_{l=1}^{K} \Pr\left\{ \frac{P_R X}{1+V} > \gamma_{th} \cap \max_{k \in D} \frac{P_R Y_k}{1+W_k} > \gamma_{th} \cap \frac{P_A X}{1+Z} > \gamma_{th} \cap |D| = l \right\}$$

where

$$X=|h_{A,R}|^2,\ Y_k=|h_{B_k,R}|^2,\ Z=\sum_{m=1}^{N_R}P_I\,|g_{I_{R,m},R}|^2,\ V=\sum_{i=1}^{N_A}P_I\,|g_{I_{A,i},A}|^2,$$

and $W_k=\sum_{j=1}^{N_B}P_I\,|g_{I_{B_k,j},B_k}|^2$ and the random variables $Z\sim G(N_R,P_I\Omega_{I_R,R})$, $V\sim G(N_A,P_I\Omega_{I_A,A})$, and $W_k\sim G(N_B,P_I\Omega_{I_B,B})$ are Gamma random variables.

Ⅳ. Numerical Results

In this section, numerical results verify our analysis by comparison with computer simulation where we suppose that A, R, and B_k have same transmit power P and the target SINR threshold γ_{th} is 7 dB.

Fig. 2 shows the outage probability versus the transmit power for the number of interferers, $N=2$ and various the number of users, K. In this figure, the interference transmit power is fixed at 0 dBm. It is shown that the outage probability decreases as the transmit power increases. It is shown that outage probability when $K=2$ is lower than that when $K=1$. It is also shown that the outage probability when $K=4$ is slightly lower than that when $K=2$ in the low transmit power, and is almost same with that when $K=2$ in the high transmit power which implies that the outage probability is less affected by the number of multiple users K as K is bigger than 2. This is because the outage performance mainly depends on the link between the user A and the relay R as the transmit power increases.

Ⅴ. Conclusion

In this paper, we consider the multiuser two-way DF relay network where a single user communicates with a selected other user via a relay. We propose a user selection criterion and derive expression of outage probability. Considering the user selection, SINR at the relay in the second phase is just used for the decoding set composition and SINR at the one user who is included in the decoding set in the third phase is used for final user selection. Analysis is verified by computer simulation.

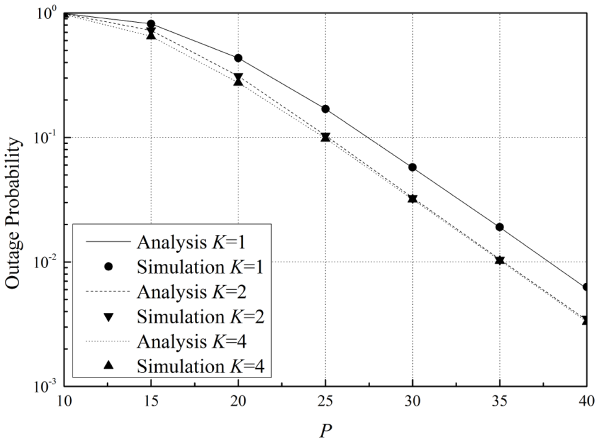

그림 2. K 가 바뀔 때의 P 에 대한 불능확률. $N=2$

Fig. 2. Outage probability versus P for various K. $N=2$.

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