Cross-layer Joint Relay Selection and Power Allocation Scheme for Cooperative Relaying System

Hui Zhi\textsuperscript{1,2}, Mengmeng He\textsuperscript{1,2}, Feiyue Wang\textsuperscript{1,2}, Ziju Huang\textsuperscript{1,2}

\textsuperscript{1}Key Lab of Computing Intelligent and Signal Processing (Ministry of Education), Anhui University, Hefei, China
\textsuperscript{2}College of Electronics and Information Engineering, Anhui University, Hefei, China

*Corresponding author: Hui Zhi, E-mail: zhihui_0902@163.com

Abstract. A novel cross-layer joint relay selection and power allocation (CL-JRSPA) scheme over physical layer and data-link layer is proposed for cooperative relaying system in this paper. Our goal is finding the optimal relay selection and power allocation scheme to maximize system achievable rate when satisfying total transmit power constraint in physical layer and statistical delay quality-of-service (QoS) demand in data-link layer. Using the concept of effective capacity (EC), our goal can be formulated into an optimal joint relay selection and power allocation (JRSPA) problem to maximize the EC when satisfying total transmit power limitation. We first solving optimal power allocation (PA) problem with Lagrange multiplier approach, and then solving optimal relay selection (RS) problem. Simulation results demonstrate that CL-JRSPA scheme gets larger EC than other schemes when satisfying delay QoS demand. In addition, the proposed CL-JRSPA scheme achieves the maximal EC when relay located approximately halfway between source and destination, and EC becomes smaller when the QoS exponent becomes larger.

1. Introduction

As far as we know, multiple-input multiple-output (MIMO) technology can provide space diversity. It is a useful way to combat multipath fading in wireless communications. However, the mobile terminals are small and power limited, so MIMO is difficult to use in mobile terminals. Cooperative relaying can solve this problem. In cooperative relaying system \cite{1-2}, mobile terminals share their own antennas with each other to form space diversity. So cooperative relaying becomes a hot research topic. Researches show that cooperative relaying can effectively increase the system reliability and capacity. In addition, the introduction of relay can expand the coverage range of the network.

There are many researches focus on the resource allocation design and optimization of cooperative relaying, such as relay selection (RS) scheme \cite{3-4}, power allocation (PA) scheme \cite{5}, joint relay selection and power allocation (JRSPA) scheme \cite{6-7}, etc.

However, most of these schemes \cite{1-7} mainly pay attention to the analysis and resource allocation design in physical layer without considering the quality of service (QoS) demands form upper layers. As we know, with the rapid development of wireless communications, QoS demands are very important performance metrics of wireless communications, and delay QoS is an important metric among these metrics. The design only in physical layer (PHL) maybe can’t meet the delay QoS demand in data-link layer (DLL).
However, in the DLL, packet switching needs queuing analysis. Especially, some real-time applications are subject to delay, and require reliable delay QoS guarantee. So the cross-layer analysis and design, which satisfies delay QoS demand, needs to be discussed. Papers [8-9] discuss cross-layer PA schemes for cooperative relaying and two way relaying (TWR) system respectively through introducing the concept of effective capacity (EC). Inspired by [8-9], we consider the cross-layer joint relay selection and power allocation (CL-JRSPA) scheme over PHL and DLL for cooperative relaying system. Although we use the concept of EC to combine PHL with DLL as in [8-9] and we also focus on cross-layer design, our work is very different from [8-9]. Because papers [8-9] are all discuss PA schemes while we focus on JRSPA scheme. Through introducing RS, the JRSPA scheme can achieve higher system performance than PA scheme without system synchronization requirements, so our work is more meaningful. Furthermore, the solving process of optimization problem in our work is totally different form [8-9], and we give the gradient descent method for searching the value of Lagrange multiplier while [8-9] are totally different train of thought. Follows are the contributions of this paper.

(1) To maximize EC, novel CL-JRSPA scheme for cooperative relaying system is proposed, and the optimization problem is solved through first solving optimal PA problem and then solving optimal RS problem.

(2) The proposed CL-JRSPA scheme is compared with other four kinds of schemes. For all these schemes, the influences of delay QoS exponent and relay location on system EC are summarized.

2. Cross Layer Cooperative Relaying System Model and CL-JRSPA problem

2.1. Cross Layer Cooperative Relaying System model

Consider a cooperative relaying system as shown in Fig.1. There are \( L + 2 \) nodes, one source node \( S \), one destination node \( D \), \( L \) relay nodes \( R_1, R_2, \ldots, R_L \). \( S \) transmits information to \( D \), relays are helpers for \( S \), and they have no information to send. Assumed each node has single antenna. Amplify-and-forward (AF) policy is adopted by relay nodes. Half-duplex mode is adopted by the system. The data arriving at relays are forwarded immediately, and \( S \) has a queue with a constant arrival rate in DLL.

![Figure 1. The cross-layer cooperative relaying system model.](Image)

The channel state information (CSI) from \( S \) to \( R_i \), \( R_i \) to \( D \), \( S \) to \( D \), are \( h_{is} \), \( h_{id} \), \( h_{sd} \) respectively, where \( i \in \{1, 2, \ldots, L\} \). Assume all channels are statistically independent, and all CSIs follow zero-mean circularly symmetric complex Gaussian distribution, such that the channel gain \( \gamma_i = |h_{is}|^2 \), \( \gamma_{id} = |h_{id}|^2 \), \( \gamma_{sd} = |h_{sd}|^2 \) follows exponential distributions with parameter \( \lambda_1, \lambda_2, \lambda_3 \) respectively. At each receiver, additive white Gaussian noise (AWGN) follows independent circularly symmetric complex Gaussian distribution of zero-mean and unit variance. Assume destination node knows all CSI \( h_{is}, h_{id}, h_{sd} \), and relay \( R_i \) knows its own local CSI \( h_{is} \) for \( i \in \{1, 2, \ldots, L\} \), all CSI stays...
the same within each frame but change from one frame to another. \( T_f \) is the duration time of each frame, it contains two equal time slots.

At the first time slot, \( S \) broadcasts its data \( x \) with power \( p_s \) while relays and destination listen. The received information at \( R_i \) (\( i \in \{1, \ldots, L\} \) ), \( D \) during the first time slot are

\[
y_i = \sqrt{p_s h_{si} x + n_i}, \quad y_{d1} = \sqrt{p_s h_{sd} x + n_{d1}}
\]

respectively, where \( n_i \) and \( n_{d1} \) are AWGN at relay \( R_i \) and \( D \) respectively during the first time slot. Here we assume \( E\{x \cdot x^H\} = 1 \). At the second time slot, one relay is chosen among all \( L \) relays according to relay selection (RS) criteria. Assume the \( i \)-th relay (\( R_i \)) is chosen for retransmission. Then \( R_i \) transmits data \( \rho_i y_i \) (i.e., its received information \( y_i \) multiplying an amplification factor \( \rho_i \)) with transmit power \( p_i \) while \( D \) listen. The received information at \( D \) during the second time slot is

\[
y_{d2} = \sqrt{p_i \rho_i (\sqrt{p_s h_{si} x + n_i}) h_{id} + n_{d2}}
\]

where \( n_{d2} \) is AWGN at \( D \) during the second time slot. \( \rho_i = 1/\sqrt{p_s h_{si}} + 1 \) is amplifying factor of relay \( R_i \), so the received signal-to-noise ratio (SNR) for link \( S \rightarrow R_i \rightarrow D \) at \( D \) can be written as

\[
SNR_i = \frac{p_i \rho_i y_{i} y_{i2}}{1 + p_i \rho_i y_{i} + p_i \rho_i y_{i2}}.
\]

Using maximal-ratio combining (MRC), and combining received information of first time slot and second time slot at \( D \), the total received SNR is

\[
SNR_i = p_i \gamma_i + \frac{p_i \rho_i p_i \gamma_i y_{i2}}{1 + p_i \rho_i y_{i} + p_i \rho_i y_{i2}}.
\]

So, when \( R_i \) is chosen for AF relaying, the total achievable rate at \( D \) is

\[
R_{AF} = \frac{T_f B}{2} \log_2 \left( 1 + p_i \rho_i + \frac{p_i \rho_i y_{i} y_{i2}}{1 + p_i \rho_i y_{i} + p_i \rho_i y_{i2}} \right)
\]

where \( B \) is the spectral bandwidth of system.

### 2.2. CL-JRSPA Problem

Paper [11] introduces effective capacity (EC), and it is defined to be the maximum constant arrival rate of wireless communication system in order to guarantee \( \theta \). The EC is written as follows

\[
C_x(\theta) = -\frac{1}{\theta} \ln \left( E\left[ e^{-\theta x} \right] \right)
\]

where \( \theta \) is the QoS exponent, which means the exponential decaying rate of delay exceed probabilities, and \( \theta > 0 \). Smaller \( \theta \) means looser delay QoS guarantee, and larger \( \theta \) means stricter delay QoS guarantee. \( R \) is the average achievable rate when queue is state. For the cooperative relaying system in this paper, \( R \) is also equal to the achievable rate in expression (3). So the EC is not only related to PHL parameters (such as \( p_s, p_i, \rho_i, y_{i2}, \gamma_i \)), but also related to DLL parameters (such as \( \theta \)). Thus, we can associate PHL with DLL through EC. In addition, the maximization of EC is equivalent to the maximization of achievable rate while satisfying \( \theta \) at source. So we can discuss the cross-layer analysis and design for joint relay selection and power allocation (JRSPA) scheme.

Our goal is selecting the optimal relay \( R_i \) (\( i \in \{1, \ldots, L\} \) ) and finding the optimal power allocation \( p_s, p_i \) to maximize the achievable rate while guaranteeing the total power constraint and the delay QoS requirement. According to the above analyses of EC, we can formulate the JRSPA problem into an optimization problem, i.e.,

\[
\max_{p_s, p_i} \frac{1}{\theta} \ln \left( E_{\gamma_i} \left[ e^{-\theta p_i (v_i)} \right] \right)
\]

\[s.t. \quad E_{\gamma_i} \left[ p_s (v_i) + p_i (v_i) \right] = p, \quad p_s (v_i) \geq 0, \quad p_i (v_i) \geq 0\]
where we use function \( \gamma_i = (\gamma_{i1}, \gamma_{i2}, \gamma_i) \) to describe the instantaneous system CSI when \( R_i \) is chosen, and use \( \nu_i = (\nu_i, \theta) \) to describe the instantaneous system state information. \( E_{\gamma_i}(\cdot) \) means the expectation with respect to \( \gamma_i \) when \( R_i \) is chosen. According to expression (3),
\[
R_{aw}(\nu_i) = \frac{T^2 B}{2} \log \left( 1 + p_i(\nu_i)\gamma_i + \frac{p_i(\nu_i)\gamma_i \nu_i}{1 + p_i(\nu_i)\gamma_i + p_i(\nu_i)\gamma_i} \right).
\]
The total power constraint \( E_{\gamma_i} \left[ p_i(\nu_i) + p_i(\nu_i) \right] = p \) means the expectation of total transmit power is limited to \( p \).

JRSPA in (5) is based on cross-layer parameters, \( \gamma_{i1}, \gamma_{i2}, \gamma_i, \nu_i, \nu_i, \theta \) are PHL parameters, \( \theta \) is DLL parameter. So we refer to the solutions of optimization problem (5) as cross-layer joint relay selection and power allocation (CL-JRSPA) scheme.

3. CL-JRSPA scheme

In order to get the CL-JRSPA scheme, we need to solve the optimization problem (5). So we give the solving process in the following content. But optimization problem (5) is difficult to solve because it is non-convex.

It is found through observation that optimization problem (5) can be equivalent to first optimized over \( \nu_i, \nu_i \), which is the optimal PA problem. And then optimized over \( i \), it is the optimal RS problem. So we study the two steps separately.

The optimal PA problem can be represented as
\[
\max_{p_i, p_i} \frac{-1}{\theta} \ln \left( E_{\gamma_i} \left[ e^{\alpha_{r_a}(\nu_i)} \right] \right)
\]
\[
\text{s.t. } E_{\gamma_i} \left[ p_i(\nu_i) + p_i(\nu_i) \right] = p, p_i(\nu_i) \geq 0, p_i(\nu_i) \geq 0
\]

According to paper [12], EC is a concave function with power allocation factors. So we can get that the EC in (6) is a concave function with \( p_i, p_i \) too. That is to say, problem (6) is a convex optimization problem, and it exists at least one optimal solution.

To simplify problem (6), we use the high SNR approximation that
\[
1 + p_i(\nu_i)\gamma_i + p_i(\nu_i)\gamma_i + p_i(\nu_i)\gamma_i \approx + p_i(\nu_i)\gamma_i + p_i(\nu_i)\gamma_i.
\]
So we can get
\[
R_{aw}(\nu_i) \approx \frac{T B}{2} \log \left( 1 + p_i(\nu_i)\gamma_i + \frac{p_i(\nu_i)\gamma_i p_i(\nu_i)\gamma_i}{p_i(\nu_i)\gamma_i + p_i(\nu_i)\gamma_i} \right)
\]
\[
(7)
\]
Substituting (7) into (6), and optimal PA problem (6) can be equivalent to the problem (8)
\[
\begin{align*}
\min_{p_i, p_i} & \left\{ E_{\gamma_i} \left[ 1 + p_i(\nu_i)\gamma_i + \frac{p_i(\nu_i)\gamma_i p_i(\nu_i)\gamma_i}{p_i(\nu_i)\gamma_i + p_i(\nu_i)\gamma_i} \right] \right\} \\
\text{s.t. } & E_{\gamma_i} \left[ p_i(\nu_i) + p_i(\nu_i) \right] = p, p_i(\nu_i) \geq 0, p_i(\nu_i) \geq 0
\end{align*}
\]
\[(8)\]
where \( \beta = \frac{\theta TB}{2 \ln 2} \). Using Lagrange multiplier approach to solve problem (8), the Lagrange function is
\[
J = E_{\gamma_i} \left[ 1 + p_i(\nu_i)\gamma_i + \frac{p_i(\nu_i)\gamma_i p_i(\nu_i)\gamma_i}{p_i(\nu_i)\gamma_i + p_i(\nu_i)\gamma_i} \right]^{\beta} + \lambda \left( E_{\gamma_i} \left[ p_i(\nu_i) + p_i(\nu_i) \right] - p \right)
\]
\[(9)\]
where \( \lambda \) is the Lagrange multiplier, and \( \lambda \geq 0 \). According to Karush-Kuhn-Tucker (KKT) conditions, we take the derivatives of the Lagrange function in (9) with respect to \( p_i \) and \( p_i \), respectively, and let the derivatives equal to zero, we can obtain the solution of problem (8), which is given by theorem1.

**Theorem 1** When the relay \( R_i \) is selected, the optimal power allocation policy that solves problem (8) (or problem (6)) is
\[
\begin{align*}
p_{s}(v) &= a_{s} p_{s}(v), \\
p_{r}(v) &= \frac{1}{\eta} \left[ \left( \frac{r_{0}}{y_{s2}} \right) \left( y_{s2} + w_{r} \right) \right]^{\frac{1}{p+1}} - 1
\end{align*}
\]

for \( y_{s2} > y_{s1} \), and
\[
\begin{align*}
p_{s}(v) &= \left( \frac{r_{0}}{y_{r2}} \right)^{\frac{1}{p+1}} - y_{s1}^{\frac{1}{p+1}}, \\
p_{r}(v) &= 0
\end{align*}
\]

for \( y_{s2} \leq y_{s1} \) \( (10) \)

where \( w_{r} = \sqrt{y_{s2} y_{s3} + y_{s2} - y_{r3}} \), \( a_{i} = \frac{y_{s2} (y_{s3} + w_{r})}{y_{s1} (y_{s2} - y_{s1})} \), \( b_{i} = \frac{y_{s2} (y_{s3} + w_{r}) (y_{s2} + w_{r}) + y_{s1} (y_{s2} - y_{s1})}{y_{s1} (y_{s2} - y_{s1})} \), \( r_{0} = \frac{2}{\beta} \).

The gradient descent method for searching the value of \( \lambda \) is given in Algorithm 1.

**Algorithm 1** Gradient descent method for searching the value of \( \lambda \)

Initialization one, \( \lambda = \lambda^{(0)} \), \( j = 0 \)

**Initialization two**, the accumulative sum of total transmit power \( p_{\text{sum}} = 0 \)

**Repeat**
- Randomly generate \( \gamma_{s1}, \gamma_{s2}, \gamma_{s3} \)
- Calculate \( p_{s}, p_{r} \) using expression (10)
- Calculate the accumulative sum of total transmit power \( s_{\text{sum}} = s_{\text{sum}} + p_{s} p_{r} \), return to **Repeat**, and repeat \( N \) times
- Calculate the expectation of total transmit power \( E_{i} (p_{s} + p_{r}) = p_{\text{sum}} / N \)
- Update \( \lambda \) using gradient descent method \( \lambda^{(j+1)} = \lambda^{(j)} - \delta^{(j)} \left( p - E_{i} (p_{s} + p_{r}) \right) \), \( j = j + 1 \), return to **Initialization two**, where \( \delta^{(j)} \) is the step size of \( j \)th step in the gradient descent method.

**Until** \( \lambda^{(j+1)} - \lambda^{(j)} \leq \xi \) (\( \xi \) is a very small constant), end this algorithm.

After solving the optimal PA problem (6), note the maximum of system EC as \( C_{\text{EC}}^{\max} (i) \) when using relay \( R_{i} \), i.e., \( C_{\text{EC}}^{\max} (i) = \max_{(p, p_{r})} - \frac{1}{\eta} \ln \left( E_{i} \left[ e^{-\beta \frac{y_{s3}}{y_{r2}}} \right] \right), \ s.t. \ E_{i} \left[ p_{s}(v) + p_{r}(v) \right] = p, p_{s}(v), p_{r}(v) \geq 0 \).

Thus the problem (5) can be reduced to the optimal RS problem
\[
\max_{i \in \{1, 2, \ldots, L\}} C_{\text{EC}}^{\max}(i) \tag{11}
\]

**4. Simulation results**

Simulations are developed to illustrate the performance of the proposed CL-JRSPA scheme, and the CL-JRSPPA scheme is compared with other four kinds of schemes, i.e., cross-layer power allocation (CL-PA) scheme with a fixed relay (i.e., the solution of problem (6)), cross-layer relay selection (CL-RS) scheme with equal power allocation (i.e., the solution of problem (11) with \( p_{s} = p_{r} = p/2 \) for all \( i \in \{1, 2, \ldots, L\} \), equal power allocation with a fixed relay (EPA-FR) scheme, direct transmission (DT) scheme.

We take the cooperative relaying system model with independent Rayleigh channels, and S transmits 10^4 frames for each Monte-Carlo simulation. Let \( T/B=1 \) in all simulations, the influence of relay location, \( p, \theta \) to EC is considered respectively. In order to search the influence of relay location to EC, let \( d_{s1}, d_{s2}, d_{s3} \) denote the distances between S and \( R_{1}, R_{2}, \) and D, S and D respectively, and \( d_{s3} = 1 \).

In simulations, the distance between relays is supposed to be far less than that between source and destination as in [13], and all relays are set in a straight line between S and D, then we can get that \( d_{s1} = d_{s2} \cdots d_{s3} = d \), \( d_{s3} = d_{s6} \cdots = d_{s9} = 1 - d \), where \( 0 < d < 1 \). As described before, \( \gamma_{s1} = [\beta_{s}]^{\frac{1}{\eta}} \), \( \gamma_{s2} = [\beta_{s}]^{\frac{1}{\eta}} \), \( \gamma_{s3} = [\beta_{s}]^{\frac{1}{\eta}} \) are following exponential distributions with parameter
\( \lambda_0 = d^\alpha, \lambda_2 = (1-d)^\alpha, \lambda_3 = 1 \) separately, where \( \alpha \) is the path loss exponent, we assume \( \alpha=4 \) in simulations.

Fig. 2 shows the EC versus total transmit power \( p \) with \( \theta=1, d=0.75 \). We can see that CL-JRSPA is better than other schemes while satisfying the delay QoS requirement, and the cooperative relaying system with relay brings tremendous improvements on the EC than conventional DT. We can also see that, when compare EC, CL-RS is better than CL-PA, and CL-PA is better than EPA-FR. This means, in order to improve system EC, RS is more effective than PA. In addition, the EC of CL-JRSPA and CL-RS becomes higher while \( L \) (the number of relays) becomes larger.

Fig. 3 shows the influence of relay location to EC. First, considering the comparisons among different schemes, we can get the same results as Fig.2, i.e., the proposed CL-JRSPA can achieve the best EC while DT is worst. Second, we mainly study the influence of relay location to EC. CL-JRSPA, CL-RS and EPA-FR achieve their maximal EC when the relay located approximately halfway between S and D (\( d \approx 0.5 \)), while CL-PA achieve its maximal EC when \( d \) is approximately equal to 0.6. The direct transmission has nothing to do with relay nodes, so its EC keeps to be a constant in spite of the change of \( d \). In addition, the CL-RS with \( L=5 \) is better than CL-JRSPA with \( L=3 \) when \( 0.25 < d < 0.65 \).

![Figure 2. EC versus total transmit power \( p \) with \( \theta=1, d=0.75 \).](image1)

![Figure 3. EC versus \( d \) with \( \theta=1, p=10dB \).](image2)
Fig. 4 shows the influence of $\theta$ to EC. From Fig. 4, we can get that CL-JRSPA can achieve the best EC while DT is worst, CL-RS is better than CL-PA, and CL-PA is better than EPA-FR. It is the same results as in Figs. 2 and 3. The EC of all schemes become smaller when the QoS exponent $\theta$ becomes larger. This conclusion conforms to the description of delay exceed capacity of information theory. Furthermore, if the delay constraints are loose ($\theta \leq 1$), the EC of all schemes have no obvious change. But when $\theta > 1$, the EC of all schemes decrease fast when $\theta$ increases.

5. Conclusion
A CL-JRSPA problem for cooperative relaying system is studied. Our goal is finding the optimal relay selection and power allocation to maximize the achievable rate when satisfying total transmit power constraint in PHL and statistical delay quality-of-service (QoS) demand in DLL. Then, this problem is formulated into an optimization problem of JRSPA to maximize the EC under total transmit power limitation. The optimization problem is solved through first solving optimal PA problem, and then solving optimal RS problem. In simulations, the proposed CL-JRSPA is compared with CL-RS, CL-PA, EPA-FR and DT schemes, and a few important conclusions are made. First, the proposed CL-JRSPA can always get better EC than the other schemes while satisfying delay QoS demand. Second, proposed CL-JRSPA achieves its maximal effective capacity when the relay located approximately halfway between source and destination. Third, EC becomes smaller when the QoS exponent becomes larger.

In this paper, the algorithm and simulation implementations of CL-JRSPA scheme are given, there is no theoretical analysis result of system EC. So the theoretical analysis will be focused in our future work.

Acknowledgments
This work is supported by the Natural Science Foundation of Anhui Province (1508085QF125), the College Natural Science Research Project of Anhui Province (KJ2016A042), the Startup Research Foundation of Anhui University.

References
[1] M. S. Alam, F. Labeau, G. Kaddoum, Performance analysis of DF cooperative relaying over bursty impulsive noise channel, IEEE Transactions on Communications, vol. 64, no. 7, 2016, pp. 2848-2859.
[2] M. Xu, F. Ji, M. Wen, W. Duan, Novel receiver design for the cooperative relaying system with non-orthogonal multiple access, IEEE Communications Letters, vol. 20, no. 8, 2016, pp. 1679-1682.
[3] A. A. M. Siddig, M. F. M. Salleh, Balancing buffer-aided relay selection for cooperative relaying systems, IEEE Transactions on Vehicular Technology, vol. 66, no. 9, 2017, 8276-8290.

[4] S. Lin, K. Liu, Relay selection for cooperative relaying networks with small buffers, IEEE Transactions on Vehicular Technology, vol. 65, no. 8, 2016, pp. 6562-6572.

[5] T. Q. Duong, T. M. Hoang, C. Kundu, et al., Optimal power allocation for multiuser secure communication in cooperative relaying networks, IEEE Wireless Communications Letters, vol. 5, no. 5, 2016, pp. 516-519.

[6] L. Liu, C. Hua, C. Chen, X. Guan, Semidistributed relay selection and power allocation for outage minimization in cooperative relaying networks, IEEE Transactions on Vehicular Technology, vol. 66, no. 1, 2017, pp. 295-305.

[7] C. Wang, J. Chen, Power allocation and relay selection for AF cooperative relay systems with imperfect channel estimation, IEEE Transactions on Vehicular Technology, vol. 65, no. 9, 2016, pp. 7809-7813.

[8] T. Jia, X. Zhang, Cross-layer resource allocation over wireless relay networks for quality of service provisioning. IEEE Journal on Selected Areas in Communications, vol. 25, no. 4, 2007, pp. 645-656.

[9] C. Lin, Y. Liu, M. Tao, Cross-layer optimization of two-way relaying for statistical QoS guarantees. IEEE Journal on Selected Areas in Communications, vol. 31, no. 8, 2013, pp. 1583-1596.

[10] Y. Zhao, R. Adve, and T. J. Lim, Improving amplify-and-forward relay networks: optimal power allocation versus selection, IEEE Trans. Wireless Commun., vol. 6, no. 8, 2007, pp. 3114-3123.

[11] D. Wu, R. Negi, Effective capacity: a wireless link model for support of quality of service, IEEE Trans. Wireless Commun., vol. 2, no. 4, 2003, pp. 630-643.

[12] Q. Du, X. Zhang, QoS-driven power control for downlink multiuser communications over parallel fading channels in wireless networks, Proc. IEEE/ACM International Conference on Heterogeneous Networking for Quality, Reliability, Security and Robustness. Vancouver, British Columbia, Canada, Aug. 14-17, 2007.

[13] H. Zhi, L. Yang, H. Zhu, Outage probability and ergodic capacity analysis for two-way relaying system with different relay selection protocols, Wireless Personal Communications, vol. 72, no. 4, 2013, pp. 2047-2067.