Adaptive Power Allocation in Cooperative Relay Networks

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ABSTRACT

In this paper, we proposed a simple power allocation scheme to maximize network lifetime. To maximize network lifetime, it is important to allocate power fairly among nodes in a network as well as to minimize total transmitted power. In the proposed scheme, the allocated power is proportional to the residual power and also satisfies the required SNR at destination node. In this paper, we calculate power allocation in "amplify and forward" (AF) model. We evaluated the proposed power allocation scheme using extensive simulation and simulation results show that proposed power allocation obtains much longer network lifetime than the equal power allocation.

Keywords

cooperative diversity, relay network, network lifetime, adaptive power allocation

Ⅰ. Introduction

A wireless channel suffers from time-varying fading caused by multi-path propagation and destructive superposition of signals arriving via different paths. Diversity techniques are a widely applied to reduce detrimental effects of multi-path fading. A new class of methods called cooperative communication or cooperative diversity has been proposed to achieve transmit diversity [1]. Relay transmission can be viewed as a good example of cooperative communication, where each node acts both as information sources as well as relays. There are some possible methods, like amplify and forward, decode and forward, coded cooperation, selection relaying, incremental relaying.

In the cooperative relay network, relay selection and power allocation are the important issues to determine the system performance. Especially in the power-constrained network, relay selection and power allocation seriously affect on the power consumption and the network lifetime. Lots of ad-hoc networks are modeled as a power-constrained network and relay node selection and power allocation algorithm should be designed to maximize the network life. In [2], power of source and relay are allocated to maximize the instantaneous received SNR at the destination. In [3], power-aware relay selection strategy is proposed to maximize network lifetime, and power of source and relay are allocated to minimize total transmitted power. However, these papers try to find optimal solutions using complex computations and didn't consider the residual power at stage of power allocation.

In this paper, we proposed a simple power allocation scheme to maximize network lifetime, which exploits the information of residual power of each node. To maximize network lifetime, it is important to allocate power fairly among nodes in a network as well as to minimize total transmitted power. In the proposed power allocation, the allocated power is proportional to the residual power and satisfies the required SNR at destination node.

The rest of the paper is organized as follows. The cooperative 2-hop relay network model is described in section II. In section III, we propose adaptive power allocation schemes for the AF relay protocol. The results are verified by simulations in section IV. In section V, we give the conclusions.

II. Cooperative 2-hop relay network

System model in this paper is a general 2-hop relay network with multiple parallel relay terminals. As shown in Fig. 1, it consists of one source, several relays and one destination.

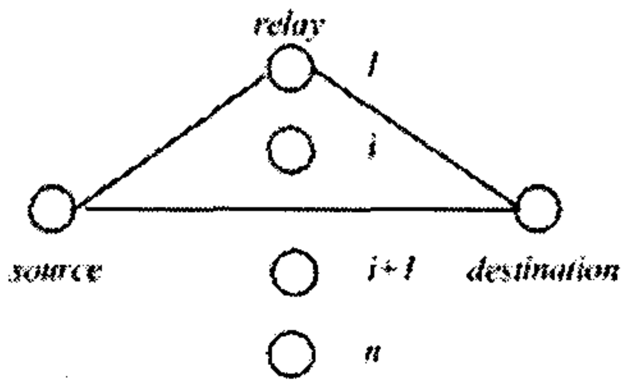

Fig. 1. Cooperative transmission from source to destination using opportunistic relaying

We consider a quasi-static fading channel, for which the fading coefficients are constant We also assume that the fading channels between the source and destination, between the source and each relay, and between each relay and the destination are independent.

Optimal relaying is about selecting the "best" relay from all the possible candidates. [3] have applied this idea to the ad-hoc networks with cooperative diversity, where each user first select the best relay from a set of M available relays and then uses this best relay for cooperation. Distributed method has been proposed in [3] for relay selection in ad-hoc networks. Base on the basic model, we proposed our optimal relaying model in the purpose of meeting the required received signal to noise ratio (SNR) at the destination. At the same time, the residual power of source and relay node is also in our research area.

We present our protocols simplest. When transmitting the RTS packet, the source adds some self-information in it, including its residual power level P_{rs}, so that all the potential relays can share this information. When receiving the RTS packet, not only each potential relay but also the destination actively measure the local channel conditions. The destination gets the ICSI of the source-destination link, i.e.h_{sd}, and broadcasts this measurement in the CTS packet. Having the knowledge of h_{sd} will help the source decide whether cooperation is beneficial, and also can help each potential relay i to do the optimal power allocation when combined with their own measurements, i.e. h_{sr} and h_{rd} . After system select a best relay node that transmitting the signal as a cooperative transmitting. Relay node and source performs the optimal power allocation to meet required received signal to noise ratio (SNR) at the destination, at the same time, considering the residual power of the source and relay node.

The source first broadcasts the information to both the destination and relays. The received signals at the relay node and the destination, at time k, are denoted by $y_{sr}(k)$ and $y_{sd}(k)$, respectively.

$$y_{sr}(k) = h_{sr}s(k) + n_{sr}(k) \tag{1}$$

$$y_{sd}(k) = h_{sd}s(k) + n_{sd}(k) \tag{2}$$

Where h_{sr} and h_{sd} are the fading coefficient between source and relay, and source and destination, respectively. n_{sr} and $n_{sd}$are zero mean complex Gaussian variable with variance of σ_N^2 . Let $x_r(k)$ be the reconstructed signal upon receiving $y_{sr}(k)$ at relay node. The corresponding received signal at destination from relay node can describe by

$$y_{rd}(k) = h_{rd}x_r(k) + n_{rd}(k) \tag{3}$$

The signals received at the destination, transmitted from the source and relays, given in equations (2) and (3), are the combined as follows,

$$\begin{aligned} & w_1 y_{sd}(k-\tau) + w_2 y_{rd}(k) \\ & = w_1(h_{sd}s(k-\tau) + n_{sd}(k-\tau)) + w_2(h_{rd}x_r(k) + n_{rd}(k)) \\ & = w_1(h_{sd}s(k-\tau) + n_{sd}(k-\tau)) + w_2(h_{rd}(h_{sr}s(k) + n_{sr}(k)) + n_{rd}(k)) \end{aligned} \tag{4}$$

where w_1 and w_2 are the combination coefficients.

III. Adaptive Power Allocation

we show a simple power allocation expression to prolong the whole network life.

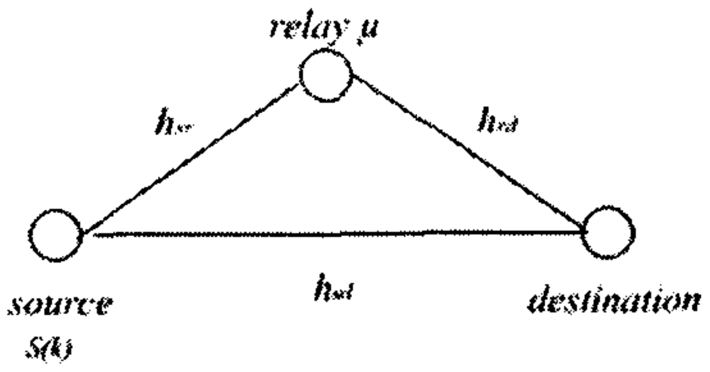

Fig. 2. AF model

To extend network life, transmitted power is determined by residual power and required SNR at destination. We calculate the allocated power for the AF model in Fig. 2. At relay and destination node, the received signals from the source are

$$y_{sr}(k) = h_{sr}s(k) + n_{sr}(k) \tag{5}$$

$$y_{sd} = h_{sd}s(k) + n_{sd}(k) \tag{6}$$

The transmitted power at source node is denoted by P_s, and the transmitted power at relay node is defined by the amplified signal power and can be obtained by

$$P_r = \mu^2 |h_{sr}|^2 P_s \tag{7}$$

Where μ is an amplification factor. The received signal at the destination from relay a node is

$$y_{rd}(k) = h_{rd}\mu(h_{sr}s(k-\tau) + n_{sr}(k-\tau)) + n_{rd}(k) \tag{8}$$

Substituting (8) into (4) and combining the signals, we can get

$$\begin{aligned} & w_1 y_{sd}(k-\tau) + w_2 y_{rd}(k) \\ & = w_1(h_{sd}s(k-\tau) + n_{sd}(k-\tau)) + w_2(h_{rd}\mu(h_{sr}s(k-\tau) + n_{sr}(k-\tau)) + n_{rd}(k)) \end{aligned} \tag{9}$$

The SNR at the destination node denoted by SNR_{AF} and can be written as

$$SNR_{AF} = \frac{p_s |h_{sd}w_1 + \mu h_{rd}h_{sr}w_2|^2}{\sigma_N^2(|w_1|^2 + |w_2|^2(|\mu h_{rd}|^2 + 1))} \tag{10}$$

The above SNR can be maximized by taking partial derivatives relative to w_1 and w_2 as [4]

$$w_1 = \frac{\sqrt{P_s}h_{sd}^*}{\sigma_N^2} \qquad w_2 = \frac{\mu\sqrt{P_s}h_{rd}^* h_{sr}^*}{(\mu^2|h_{rd}|^2 + 1)\sigma_N^2} \tag{11}$$

By substituting (11) into (10), SNR$_{AF}$ can be expressed as

$$SNR_{AF} = \left(|h_{sd}|^2 + \frac{\mu^2|h_{rd}h_{sr}|^2}{\mu^2|h_{rd}|^2 + 1}\right)\frac{P_s}{\sigma_N^2} \tag{12}$$

When the received SNR is equal to required SNR, we can get the minimum transmitted power

$$SNR_{AF} = \left(|h_{sd}|^2 + \frac{\mu^2|h_{rd}h_{sr}|^2}{\mu^2|h_{rd}|^2 + 1}\right)\frac{P_s}{\sigma_N^2} = SNR_{req} \tag{13}$$

Where SNR$_{req}$ is the minimum signal to noise ratio over which the destination can decode received signal without error. To extend network life, transmitted power should be proportional to the residual power, and get the relationship among the residual power and transmitted power of source and relay.

$$\frac{P_s}{P_{rs}} = \frac{P_r}{P_{rr}} = \frac{\mu^2(|h_{sr}|^2 P_s + \sigma_N^2)}{P_{rr}} \tag{14}$$

Where P_{rs} and P_{rr} are the residual power of source and relay node, respectively. From (13) and (14), we can get the transmitted power of source and relay node.

$$\mu^2 = \frac{P_s P_{rr}}{P_{rs}(|h_{sr}|^2 P_s + \sigma_N^2)} \tag{15}$$

$$P_s = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \tag{16}$$

Where

$$a = P_{rr}|h_{sd}|^2|h_{rd}|^2 + P_{rs}|h_{sr}|^2|h_{sd}|^2 + P_{rr}|h_{rd}h_{sr}|^2$$

$$b = P_{rs}|h_{sd}|^2\sigma_N^2 - P_{rr}|h_{rd}|^2\sigma_N^2 SNR_{req} - P_{rs}|h_{sr}|^2\sigma_N^2 SNR_{req}$$

$$c = -P_{rs}\left(\sigma_N^2\right)^2 SNR_{req} \tag{17}$$

IV. Simulation Results

Through a simulation, we evaluate the proposed power allocation policy on a Rayleigh fading channel, and compared the performance of proposed power allocation with that of equal power allocation. We randomly scattered nodes in a network area in which any nodes can transmit and receive data using cooperative relay node. At every transmission, source, relay and destination node are randomly selected and the transmitted powers of source and relay are calculated. We assumed that every transmission takes same time duration. For the performance evaluation, we defined the network life as the time when the network has more than one node of which residual power is under 10% of maximum charged power. The network lifetime is normalized by the time duration of transmission.

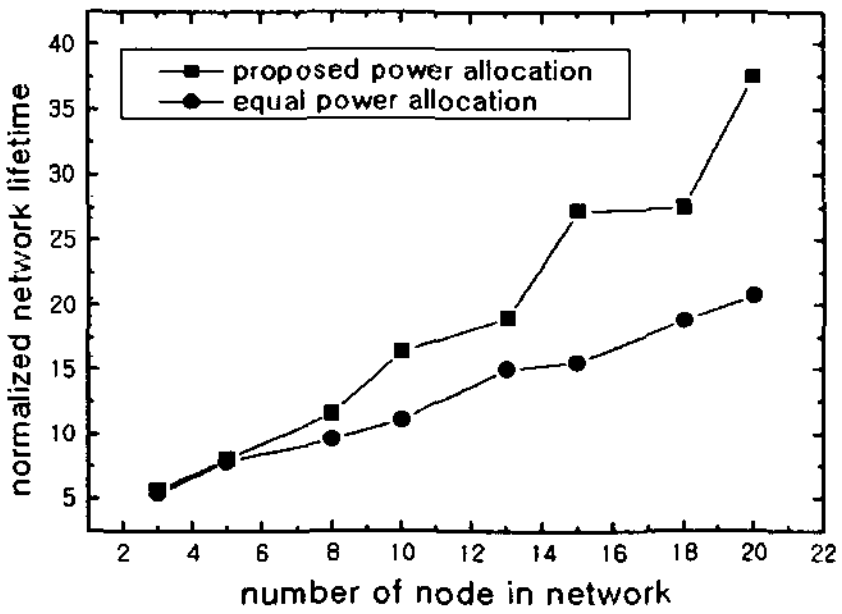

Fig. 3. Normalized network lifetime between proposed power allocation and equal power allocation in AF model

Fig. 3. shows the normalized network lifetime according to the number of node in AF model. As the number of node increase, each node has less chance to participate in the transmission and increase network lifetime. Proposed power allocation scheme has longer network lifetime than the equal power allocation scheme. Especially, in the larger number of node, proposed power allocation scheme has much higher network lifetime.

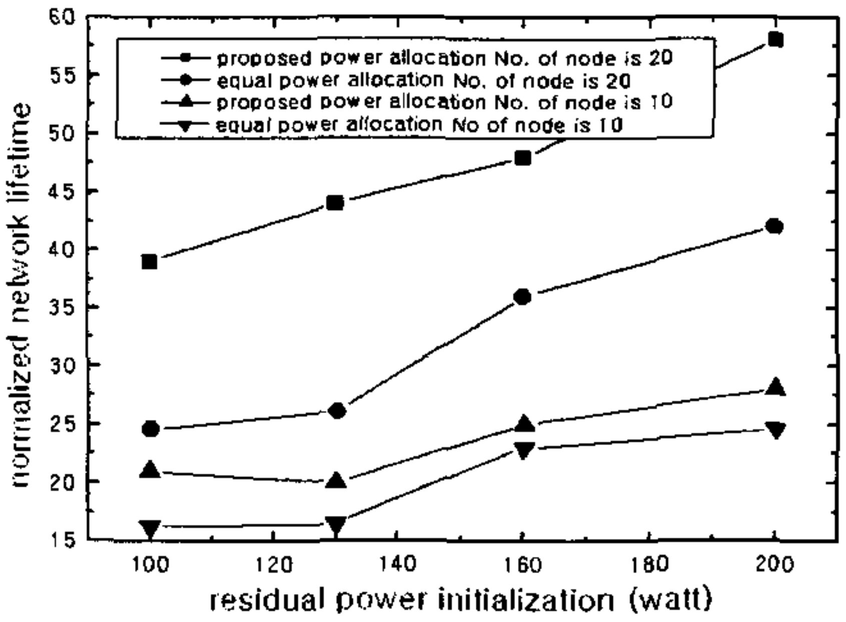

Fig. 4. According to different residual power initialization, the normalized network lifetime between proposed power allocation and equal power allocation in AF model

From Fig. 4, we can get that normalized network lifetime value of proposed power allocation according to the different residual power initialization in AF model. We assume that there are two conditions (10 nodes and 20 nodes) in network, as the number of node increase, each node increase network lifetime. Proposed power allocation scheme has longer network lifetime than the equal power allocation scheme.

V. CONCLUSION

In this paper, we proposed a simple power allocation scheme to maximize network lifetime. We show how to calculate the allocated power to be proportional to the residual power and satisfy the required SNR at the destination. Simulation results show that proposed power allocation obtains much longer network lifetime than the equal power allocation. Especially, as the number of nodes in a network increases, proposed power allocation has much longer network lifetime than the equal power allocation. So our power allocation methods are effective in optimizing the system performance, reducing the network power consumption, and prolong the network lifetime.

References

[1] Aria Nosratinia, todd E. Hunter, and Ahmadreza Hedayat, "Cooperative communication in wireless networks," *IEEE Communications Magazine*, pp. 74-80, Oct. 2004.

[2] Yonghui Li, Branka Vucetic, and Mischa Dohler, "distributed adaptive power allocation for wireless relay networks," *IEEE Transactions on Wireless Communications*, vol. 6, no. 3, pp. 948-958, Mar 2007.

[3] Yan chen, Guanding Yu, Peiliang Qiu and Zhaoyang Zhang, "Power-aware cooperative relay selection strategies in wireless ad hoc networks," *The 17th Annual IEEE international symposium on personal, Indoor and mobile radio communications (PIMRC'06)*, 2006.

[4] J. N. Laneman and G. W. Wornell, "Energy-efficient antenna sharing and relaying for wireless networks," *Proc. IEEE WCNC*, 2000, pp. 7-12.