전력 제한된 무선 애드혹 네트워크에서의 적응적 전력할당기법

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Adaptive Power allocation inenergy-constrained wireless ad-hoc networks

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요 약

Amplify and forward (AF)와 decode and forward (DF) 의 두 가지 모드에 대하여 네트워크의 네트워크 수명을 극대화할 수 있는 단순한 구조의 전력할당 방식을 제안한다. 네트워크 수명을 극대화하기 위해서는 전송전력을 최소화하는 것뿐만 아니라 전력을 네트워크의 모든 노드에게 균등하게 할당하는 것이 중요하다. 제안된 전력할당기법에서 송신전력은 노드의 잔여전력에 비례하고 목적지 노드에서 요구되는 수신 SNR을 만족하도록 할당된다. 본 논문에서는 AF와 DF의 두 가지 모드에 대하여 할당전력을 계산하였고 시뮬레이션을 통하여 그 성능을 분석하였다. 시뮬레이션 결과 제안된 전력할당 방식은 균등할당방식에 비하여 네트워크 수명을 크게 증가시킬 수 있었다.

ABSTRACT

We proposed a simple power allocation scheme to maximize network lifetime for "amplify and forward (AF)" and "decode and forward (DF)". 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 model of AF and DF. 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.

키워드

Index terms－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. Transmit diversity generally requires more than one antenna at the transmitter. However, many wireless devices are limited by size or hardware complexity to one antenna. A new class of methods called cooperative communication or cooperative diversityhas been proposed that enables signal antenna and

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접수일자 : 2007. 9. 18

generate a virtual multiple-antenna transmitter that allows them to achieve transmit diversity [1]. Relay transmission can be viewed as a good example of cooperative communication. In a cooperative relay network, each node acts both as information sources as well as relays. The source sends information to the relays. The relays amplify or detect the received signals and then forward them to the destination. At the destination, by properly combining the received signals from the source and relays, a distributed diversity can be achieved. There are some possible methods, like amplify and forward, decode and forward, coded cooperation, selection relaying, incremental relaying [2], [3], and [4].

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 [5], power of source and relay are allocated to maximize the instantaneous received SNR at the destination. In [6], 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. The proposed power allocation exploits the informationof 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 and DF relay protocols, respectively. 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 one relay and one destination.

We consider a quasi-static fading channel, for which the fading coefficients are constant within one transmission block, but change independently from one block to another. 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.

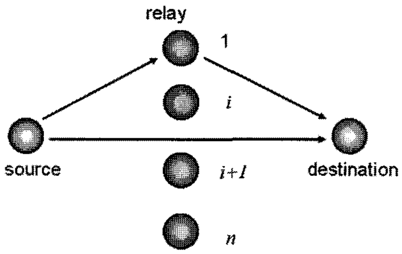

그림 1. 협업통신을 이용한 2홉 릴레이 네트워크
Fig. 1 2-hop relay network with cooperative transmission

Optimal relaying is about selecting the "best" relay from all the possible candidates. [6] 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 [6] for relay selection in ad-hoc networks, which is based on local measurements of the instantaneous channel conditions and requires no knowledge of the global topology information.

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.

The main idea of our strategies can be divided into two pares. In sensor network, the optimal power allocation between the source and each potential relay only meet the required received signal to noise ration (SNR) at the destination. At the same time, we consider the residual power of source and relay nodes.

In this part, 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 ration (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 . Upon receiving signals from the source, each relay detects and reconstructs the received signals. 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

In this section, we consider two relay model such as amplify and forward (AF) and decode and forward (DF). For those relay models, we show a simple power allocation expression to prolong the whole network life. To extend network life, transmitted power is determined by residual power and required SNR at destination.

A: Amplify and forward (AF) model

In this sub-section, we calculate the allocated power for the AF model in Fig. 2.

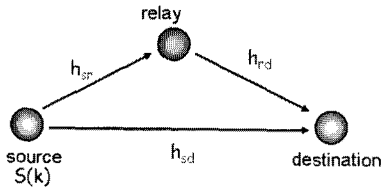

그림 2. AF 모델
Fig. 2 AF model

At relay and destination node, the received signals from the source are

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

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

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

$$P_r = \mu^2 |h_{sr}|^2 P_s \qquad (7)$$

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

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

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

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

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

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

The above SNR can be maximized by taking partial derivatives relative to w_1 and w_1, and their optimal values can be calculated as [7]

$$w_1 = \frac{\sqrt{P_s}\,h_{sd}^*}{\sigma_N^2}$$

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

By substituting (11) into (10), SNR_{AF} can be expressed as

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

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

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

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

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

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.

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

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

Where

$$\begin{aligned} a &= P_{rr}|h_{sd}|^2|h_{rd}|^2 + P_{rs}|h_{sr}|^2|h_{sd}|^2 + P_{rr}|h_{rd}h_{sr}|^2 \\ b &= P_{rs}|h_{sd}|^2\sigma_N^2 - P_{rr}|h_{rd}|^2\sigma_N^2 SNR_{req} - P_{rs}|h_{sr}|^2\sigma_N^2 SNR_{req} \\ c &= -P_{rs}(\sigma_N^2)^2 SNR_{req} \end{aligned} \qquad (17)$$

B: Decode and forward (DF) model

In this sub-section, we calculate the allocated power for the DF model in Fig. 2. Let s(k) be the transmitted signal from the source at time k. The corresponding received signals at the relay and destination, at time k, are denoted by $y_{sr}(k)$ and $y_{sd}(k)$.

$$y_{sr}(k) = h_{sr}s_1(k) + n_{sr}(k) \tag{18}$$

$$y_{sd}(k) = h_{sd}s_1(k) + n_{sd}(k) \tag{19}$$

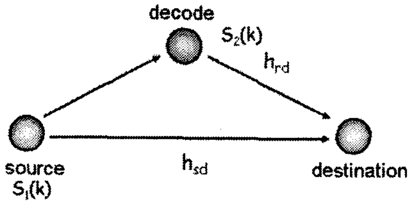

그림 3. DF 모델
Fig. 3. DF model

In the relay network, generally the distance between relay and source is shorter than the distance between source and destination, and so we model the wireless link between source and destination as an error free channel.

Let $s_2(k)$ be the regenerated signal from the $s_1(k)$ and the received signal at the destination can be written as

$$y_{rd} = h_{rd}s_2(k) + n_{rd}(k) \tag{20}$$

Similar to the AF, we combine Eqs. (19) and (20) as follows,

$$w_1 y_{sd}(k) + w_2 y_{rd}(k) \tag{21}$$

The optimum weighting coefficients w_1 and w_2 can be calculated as,

$$w_1 = \frac{\sqrt{P_1}h_{sd}^*}{\sigma_N^2} \tag{22}$$

$$w_2 = \frac{\sqrt{P_2}h_{rd}^*}{\sigma_N^2} \tag{23}$$

Where P_1 and P_2 are the power of the source and relay node, respectively.

The received SNR, denoted by SNR_{DF}, can be calculated as

$$SNR_{DF} = \frac{P_1|w_1h_{sd}|^2 + P_2|w_2h_{rd}|^2}{\sigma_N^2(|w_1|^2 + |w_2|^2)} \tag{24}$$

Transmitted power is controlled to satisfy the required SNR at destination.

$$SNR_{DF} = \frac{P_1|w_1h_{sd}|^2 + P_2|w_2h_{rd}|^2}{\sigma_N^2(|w_1|^2 + |w_2|^2)} = SNR_{req} \tag{25}$$

Using the same manner with AF model, transmitted power is set to be proportional to the residual power

$$\frac{P_1}{P_{rs}} = \frac{P_2}{P_{rr}} \tag{26}$$

From (25) and (26), we can get the transmitted power of source and relay node.

$$P_1 = \frac{P_{rs}SNR_{req}\sigma_N^2(|w_1|^2 + |w_2|^2)}{P_{rs}|w_1h_{sd}|^2 + P_{rr}|w_2h_{rd}|^2} \tag{27}$$

$$P_2 = \frac{P_{rr}SNR_{req}\sigma_N^2(|w_1|^2 + |w_2|^2)}{P_{rs}|w_1h_{sd}|^2 + P_{rr}|w_2h_{rd}|^2} \tag{28}$$

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.

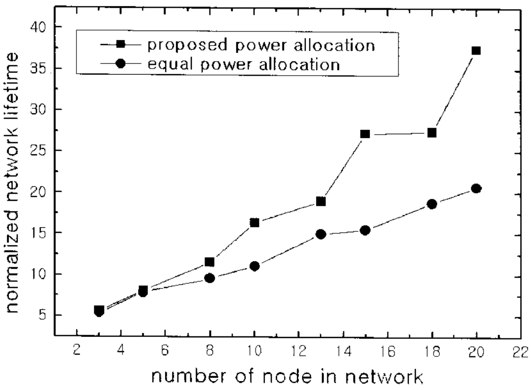

그림 4. AF모델에서의 정규화된 네트워크 lifetime
Fig. 4. Normalized network lifetime in AF model

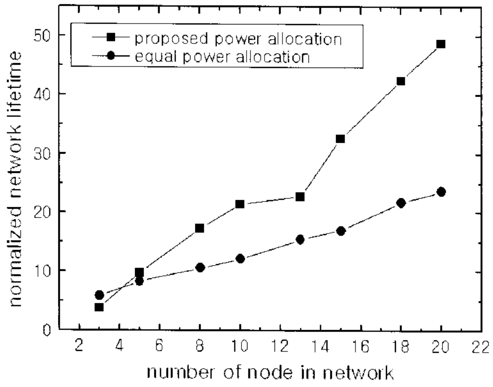

그림 5. DF모델에서 정규화된 네트워크 lifetime
Fig. 5. Normalized network lifetime in DF model

Fig. 4 and Fig. 5shows the normalized network life time according to the number of node in AF model and DF 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.

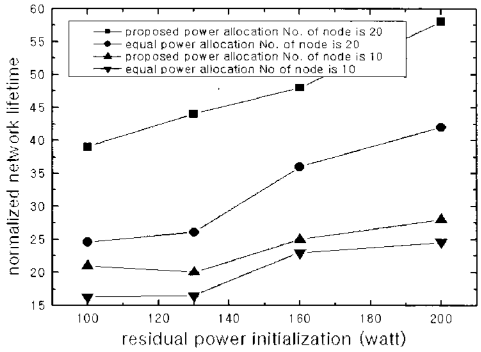

그림 6. AF모델에서 서로 다른 잔여 전력에 따른 정규화된 네트워크 lifetime
Fig. 6. The normalized network lifetime according to different residual power initialization in AF model

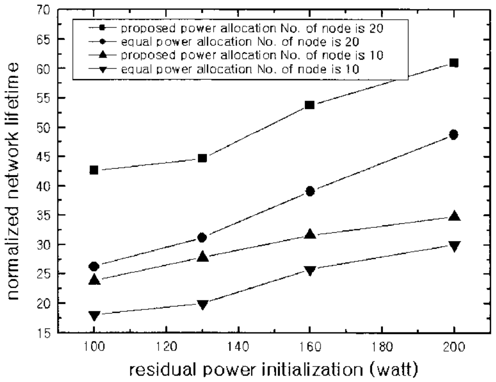

그림 7. DF 모델에서 서로 다른 잔여 전력에 따른 정규화된 네트워크 lifetime
Fig. 7. The normalized network lifetime according to different residual power initialization in DF model

From Fig. 6, Fig. 7, we can get that normalized network lifetime value of proposed power allocation according to the different residual power initialization in AF model and DF 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 allocationscheme 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.

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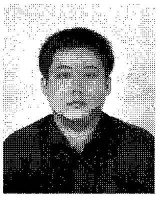
저자소개



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